7. Water Budget

A water budget is an accounting of the input and output volumes of water for the different components of the hydrologic cycle and for a specified hydrologic system. The hydrologic cycle is a continuous set of processes through which water evaporates from the oceans to the atmosphere, falls on the land, and eventually flows back to the oceans. The part of the hydrologic cycle that is of most relevance to water planning is the fate of precipitation, which will partition to the following components:

- Some precipitation that falls on land seeps (infiltrates) into the ground to become soil moisture, part of which is taken up by plant roots and returned to the atmosphere through the process of transpiration. It is difficult to separate this transpiration from evaporation off land surfaces, so they are typically combined into a single term known as evapotranspiration.

- Precipitation that is not intercepted or infiltrated flows across the land surface and through channels, from which it may be diverted for various consumptive uses or used to fill reservoirs, where it is stored until used or evaporated.

- When soil moisture storage capacity is exceeded, recharge to groundwater occurs. Groundwater may reside in storage until withdrawn from a well or, where physical conditions allow, it may discharge into springs, streams or lakes or flow to other groundwater basins.

The hydrologic cycle is thus a complex movement of water through several subsystems. A hydrologic budget is a quantification of the amounts of water moving in and out of a specified subsystem of the overall hydrologic cycle.

For a given region, the overall hydrologic budget can be expressed by the following equation (Viessman and Lewis, 1996):

$$P - R - G - E - T = \Delta S$$

Where P = precipitation

R = surface runoff

G = groundwater flow to and from other basins

E = evaporation

T = transpiration

ΔS = change in aquifer storage

Except for precipitation, subsets of these parameters apply differently to budgets computed above or below the surface. For example, losses to infiltration from the surface are realized as an input to the subsurface (groundwater) system, and losses from subsurface discharges are sometimes realized as an input to the surface system. It is therefore convenient to view surface water systems and groundwater systems as separate, interconnected subsystems of the hydrologic cycle.

The Northeast New Mexico Water Planning Region covers a very large area based on political (county line) boundaries and contains two major stream systems that supply water to the region (the Dry Cimarron and Canadian Rivers [Figure 5-6]) and all or parts of eight declared groundwater basins (Figure 4-1). Groundwater budgets were developed for each county, and surface water budgets were prepared for the Dry Cimarron and Canadian Rivers.

Although the water budgets presented in this section provide a broad overview of the supply and demand in each of these surface water systems and groundwater basins, they should not be used as an indicator of availability of supply to meet demand in individual localities, as that ability depends on water rights, infrastructure, and proximity to surface water and/or groundwater supplies.

7.1 Surface Water Budget

Surface water budgets were prepared for the two principal perennial streams in the planning region: the Dry Cimarron and Canadian Rivers. The water budget for the Dry Cimarron River represents the reach from the gage near Guy (Figure 5-7) to the state line with Oklahoma. The

Canadian River water budget is for the reach from Conchas Reservoir, located just west of the planning region, to the gage near Logan (below Ute Dam) (Figure 5-7).

7.1.1 Surface Water Budget Terms and Methodologies

Surface water budget analyses rely heavily on estimates of components instead of actual measurements. Although precipitation and streamflow are measurable water sources, they are typically measured at only a few locations. Evaporation, evapotranspiration by plants, infiltration, return flows, and spring and seep discharges are generally not measured directly and are therefore estimated. Consequently, the surface water budget calculations presented here have a high degree of uncertainty and should be used with caution.

7.1.1.1 Inflow Components

Inflow sources for surface water include surface inflow, spring or stream gain, and return flow from municipal and irrigation uses.

The main component of ***surface inflow*** for the Northeast Region water budget is the amount of surface water that flows into the planning region. Runoff from rain and snowmelt provides surface inflow to a stream. This is the volume of water that flows into streams from the precipitation that has not been intercepted or evapotranspired by vegetation. The estimated average annual precipitation volume for the entire planning region is 9,830,000 acre-feet (based on the precipitation contours in Figures A-4a and A-4b in Appendix A), but the vast majority of this inflow does not become streamflow, due to evapotranspiration and other factors. Non-riparian evapotranspiration, which is likely the largest output component of the water budget, can exceed 90 percent of precipitation in some watersheds (Brooks et al., 1991), and measurements in the Los Alamos, New Mexico area indicated that non-riparian evapotranspiration losses in that area were between 75 and 87 percent of total precipitation (Gray, 1997). In addition, about 10 to 20 percent of precipitation is intercepted such that it wets and adheres to aboveground objects (generally vegetation) and is subsequently returned to the atmosphere through evaporation. Because of the uncertainties in quantifying precipitation, evapotranspiration, and interception, an alternative method commonly used to characterize surface inflow is to rely on gaged streamflow data.

Accordingly, the surface inflow component for the Northeast Region water budgets was based on gaged stream discharge data and gaged diversions for the Arch Hurley Conservancy District from the two main drainages in the planning region:

- There are two gages on the Dry Cimarron River, both of which are inactive. The Dry Cimarron River near Guy gage was used for inflow because it is located further upstream than the Dry Cimarron River near Folsom gage and is more representative of flows that enter the region upstream of irrigation diversions. Also, the period of record for the Dry Cimarron River near Guy is 30 years (1943-1973), compared to only four years (1928-1932) for the Dry Cimarron near Folsom gage.

- For the Canadian River, inflow was estimated as the median diversions for Arch Hurley from 1975 through 2005 plus median or minimum (for the median or drought budget) discharges to the main stem of the Canadian River from Conchas Reservoir (estimated by USBR) for 1975 through 2000 and the median or minimum streamflow at the Ute Creek Near Logan gage from 1975 through 2000.

Although the diversions from Conchas Reservoir are used in the Northeast Region, the reservoir is located outside (upstream) of the planning region; accordingly, inflow to Conchas Reservoir and the reservoir evaporation from Conchas Reservoir are not included in the water budget. Also, the diversions from Conchas Reservoir for Bell Ranch (about 2,000 ac-ft/yr) are not included in the water budget, as those diversions are not used in the Northeast Region. However, the Arch Hurley diversions, although occurring outside of the planning region, are used in the planning region and the return flow to the groundwater from these diversions is an important component of the Northeast Region groundwater budgets.

Spring/stream gain is inflow from springs and seeps and surface runoff from ungaged tributaries. Spring/stream gain in the water budgets for the Northeast Region are estimated in the balance of the water budget and therefore reflect both water that is discharged from the aquifer and inflow from ungaged tributaries. Although the overall High Plains aquifer is known to be in hydraulic connection with the major river systems in its eight-state area (Dennehy et al., 2002), in the planning region, the Ogallala aquifer is disconnected from the Dry Cimarron and

Canadian Rivers and it therefore does not discharge to these streams. The Entrada sandstone is estimated to have discharged 700 ac-ft/yr before groundwater development began (Trauger and Bushman, 1964), and although this number has likely been reduced due to groundwater production, the pre-development estimate has been used in the surface water budgets. The large amount of irrigation return flow to the groundwater (estimated as 68,000 ac-ft/yr) in Quay County from the Arch Hurley diversions may ultimately return to the Canadian River.

To balance the surface water budget on the Canadian and Dry Cimarron Rivers for median conditions, stream gains of 50,000 ac-ft/yr and 2,300 ac-ft/yr, respectively, were added from an unknown component. This could be streamflow from ungaged tributaries or groundwater contribution.

For some uses, a portion of the diverted flow is not consumptively used and returns to a waterbody; the returned water is called ***return flow***. Return flow from irrigation with surface water is assumed to return directly to the stream in the Dry Cimarron River Basin. In the Canadian River Basin, return flow was assumed to go to groundwater, but again, this water may ultimately return to the Canadian River.

7.1.1.2 Outflow Components

Outflows are comprised of surface water depletions due to diversions, evapotranspiration, open water evaporation, and flow past the New Mexico state line. Stream loss into the groundwater, the amount of water that is lost from a stream that recharges the aquifer, is typically included in water budget outflow components; however, there are no literature values that quantify stream loss in the Northeast Region, and so outflow from surface to groundwater was not estimated.

The only ***diversions*** from surface water in the entire planning region are for irrigation and livestock use. According to Wilson et al. (2003), no surface water was used for public supply, domestic, commercial, industrial, mining or power in the planning region in the year 2000. The amount of water diverted for irrigation has been estimated as follows:

- The majority of the irrigation diversions are from the Arch Hurley Conservancy District, where 41,000 acres of irrigable land are supplied from Conchas Reservoir, as authorized in 1954 (USBR, 2006). The median diversion from Conchas Reservoir, diverted through the unlined Conchas and Hudson Canals, was 72,500 ac-ft/yr from 1975 to 2005 (USBR, 2006) or 81,200 ac-ft/yr from 1947 to 2003 (*Quay County Forty Year Water Plan* [Barnes, 2004]).

- Other surface water diversions in the region include irrigation from the Dry Cimarron River and Tramperos Creek in Union County. A total of 2,575 acres are irrigated with surface water from the Dry Cimarron and another 350 acres are irrigated from Tramperos Creek (Wilson et al., 2003). Total surface water withdrawals were 6,385 ac-ft in 1999 (Wilson et al., 2003), an estimated 70 percent of which are lost in conveyance to the farm. As discussed in Section 4.7.2, the Dry Cimarron Decree defines 11,205 ac-ft/yr of surface water rights in Union County; thus, potential withdrawals could be higher if sufficient water were available.

No surface water is used for irrigation in Harding, Curry or Roosevelt Counties.

Stream loss into the groundwater is the amount of water that is lost from a stream that recharges the aquifer. No literature values that quantify stream loss for the Northeast Region are available. Consequently, no outflow from surface water to groundwater was estimated. To balance the surface water budgets on the Canadian River in Quay County and the Dry Cimarron River in Union County, a net loss from groundwater to surface water was estimated. The streams may be losing in some reaches and gaining in others, but the net change in surface water budgets based on the unknown components (i.e., spring flow and ungaged tributary flows) is positive.

Evapotranspiration is the amount of water lost from plants through transpiration and evaporation from water, soil, and other surfaces. Evapotranspiration data specific to the Northeast Region were not available; therefore, an average annual evapotranspiration rate was estimated for the region after reviewing values available for other areas:

- A study done for the Rio Grande Basin near Albuquerque using data from 1990 through 1991 quantified evapotranspiration ranges of 0.15 to 4.70 millimeters per day (mm/day) for grass-covered areas and 0.13 to 6.40 mm/day for bare ground (Thorn, 1995).

- A study done at the Sevilleta National Wildlife Refuge (NWR) near Socorro using data from three summer monsoon seasons (2000, 2001, and 2002) quantified an evapotranspiration range of 0.5 to 4.0 mm/day (Kurc and Small, 2004). The Sevilleta NWR study looked both at grassland (black grama) with 60 percent cover and shrubland (creosote bush) with 30 percent cover, and the resulting evapotranspiration range covered both vegetation types.

- Bawazir et al. (2000) measured an evapotranspiration rate of 1,315 mm/yr (4.31 ft/yr) in a dense salt cedar thicket in the Rio Grande Basin near Socorro in 1999. In this study, the salt cedar canopy transpired 10 percent of its annual total by April 17, 95 percent by November 1, and the remaining 15 percent during the 6-month leafless period (Bawazir et al., 2000). These results indicate that, while the bulk of evapotranspiration occurs in the summer months, transpiration does not shut completely off during the rest of the year.

- McDonnell et al. (2004) have collected evapotranspiration data using three-dimensional eddy covariance towers at 12 sites in the Middle Rio Grande over multiple years. These sites include flooding and non-flooding cottonwood and salt cedar communities. Summary data indicate that in 2002 evapotranspiration rates averaged 860 millimeters per season (mm/season) (2.82 ft/yr) at the cottonwood non-flooding sites, 990 mm/season (3.25 ft/yr) at the cottonwood flooding sites, 780 mm/season (2.56 ft/yr) at the salt cedar non-flooding sites, and 990 mm/season (3.25 ft/yr) at the salt cedar flooding sites (McDonnell et al., 2004). This research also indicates that evapotranspiration rates are greatest when daily low temperatures are between 10°C and 17°C (50°F and 62.6°F) (McDonnell et al., 2004).

For the Northeast Region surface water budgets, evapotranspiration was estimated for riparian reaches only because, as discussed in Section 7.1.1.1, the budgets do not include precipitation and evapotranspiration in upland areas that don't contribute surface inflow to the Canadian or Dry Cimarron Rivers. To develop the budgets, evapotranspiration ranges presented by Thorn (1995) and Kurc and Small (2004) were converted to feet and multiplied over a full year to yield ranges of 0.18 to 5.63 ft/yr for grass-covered areas and 0.16 to 7.66 ft/yr for bare ground (after Thorn, 1995) and 0.60 to 4.79 ft/yr for Sevilleta NWR (after Kurc and Small, 2004). These ranges were averaged to yield evapotranspiration values of 2.91 ft/yr for grass-covered areas, 3.91 ft/yr for bare ground, and 2.70 ft/yr for ungrazed shrub and grassland. These averages are likely overestimates of actual evapotranspiration, as they assume that the daily estimates that are presented in these papers represent accurate ranges for full years.

An average evapotranspiration rate of 3.56 ft/yr was calculated for the planning region assuming that riparian area vegetation can be described by a breakdown of 30 percent salt cedar, 5 percent cottonwood, 5 percent ungrazed shrub and grassland, 20 percent grassland, and 40 percent bare ground. The Bawazir et al. (2000) salt cedar and McDonnell et al. (2004) flooded salt cedar evapotranspiration rates were averaged together for use in this conglomerate.

For the Canadian River Basin, the average evapotranspiration rate of 3.56 ft/yr was multiplied by the total area of hydric soils adjacent to perennial and intermittent streams for the median scenario water budget and perennial streams only for the drought scenario water budget. There are 3,350 acres of hydric soils adjacent to intermittent streams and 2,400 acres of hydric soils adjacent to perennial stream valleys (measured using GIS) in the Canadian River Basin. Based on these acreages, a total of approximately 20,000 ac-ft/yr is lost to evapotranspiration in the Canadian River Basin (Section 7.1.2). The total applied to the water budget for the Canadian River was the amount of evapotranspiration above the gage near Logan, which is 8,965 ac-ft/yr under median conditions and 8,422 ac-ft/yr under drought conditions.

No hydric soils were identified in the Dry Cimarron Basin. To estimate riparian evapotranspiration in this basin, the length of the stream (39 miles) times an assumed width of 20 feet was multiplied times the evaporation rate of 3.56 ft/yr to obtain an evapotranspiration rate of 337 ac-ft/yr.

Open water evaporation within the planning region includes evaporation from lakes, ponds, and perennial streams. Approximately 11,000 acres in lakes and ponds and 570 perennial river miles were measured (using GIS) in the Canadian River Basin, and approximately 400 acres of lakes and ponds and 100 perennial river miles were measured in the Dry Cimarron River Basin. Open water evaporation was estimated for the Dry Cimarron by making assumptions on perennial stream widths and by multiplying pan evaporation rates from Capulin National Monument times the area of open water times 0.7 (to correct for the difference between evaporation rates measured in a pan and those that would occur in a large lake). The reservoir evaporation for Ute Reservoir as reported by Wilson et al. (2003) was used in the Canadian River water budget.

Surface outflow from the planning region was based on gaged stream flow below irrigation diversions. The outflow on the Dry Cimarron River was based on a gage in Oklahoma (where the name changes to the Cimarron River) near Kenton, approximately 2 miles east of the state line. Median streamflow measured at that gage from 1975 through 2003 was 5,300 ac-ft/yr. The outflow for the Canadian River was set at the gage at Logan, which is downstream of all surface water diversions from the Canadian River in the Northeast Region. The median flow at that gage from 1975 to 2004 was 14,500 ac-ft/yr.

7.1.2 Summary of Surface Water Budgets

Surface water budgets were prepared for the Dry Cimarron and Canadian River Basins for the reaches where water is diverted. For each of these two basins, two annual water budgets were prepared, one reflecting a median water supply year and the other, a drought year.

7.1.2.1 Median Surface Water Budget

The median annual surface water budget results for the Dry Cimarron and Canadian River Basins are presented in Tables 7-1 and 7-2, respectively. The surface inflows reflect the median annual water yield for the period of record at each of the gages used (Section 7.1.1.1):

Table 7-1. Dry Cimarron Water Budget for Median Conditions

Component of Flow	Annual Flow (ac-ft/yr)
Surface water inflows	
Stream inflow from gaged flow [a]	7,307
Stream gain from unknown [b]	2,300
Irrigation return flow [c]	3,141
Stream gain from ungaged tributaries	Not estimated
Total inflows	12,748
Surface water depletions and outflows	
Commercial [c]	0
Domestic [c]	0
Industrial [c]	0
Irrigation [d]	5,809
Livestock [c,e]	59
Mining [c]	0
Power [c]	0
Public water supply [c]	0
Riparian ET [f]	337
Open water evaporation [g]	1,264
Stream loss to groundwater	Not estimated
Surface outflow (to Oklahoma) [h]	5,308
Total outflows	12,777
Balance	–29

[a] Median water yield at the Dry Cimarron River near Guy gage 1943 to 1973

[b] Balance of groundwater budget

[c] Wilson et al., 2003 (2000 data)

[d] Estimated irrigation return flow in 1999 (Wilson et al., 2003)

[e] Assuming that 2/3 of Union County livestock depletions are in the Canadian River Basin and the other 1/3 are in the Dry Cimarron Basin.

[f] Length of perennial reach times width of 20 feet times ET rate of 3.56 ft/yr

[g] Using pan evaporation value for Capulin National Monument and area of open water bodies along the Dry Cimarron River

[h] Median water yield at the Cimarron River near Kenton, Oklahoma gage 1975-2003

Table 7-2. Canadian River Water Budget for Median Conditions

Component of Flow	Annual Flow (ac-ft/yr)
Surface water inflows	
Stream inflow to Arch Hurley Canal [a]	72,748
Stream inflow from Ute Creek [b]	5,391
Releases from Conchas Reservoir to main stem [c]	3,373
Stream gain from Unknown [d]	49,500
Stream gain from Entrada sandstone discharge [e]	700
Total inflows	131,712
Surface water depletions and outflows	
Commercial [f]	0
Domestic [f]	0
Industrial [f]	0
Irrigation [f]	72,748
Livestock [f,g]	86
Mining [f]	0
Power [f]	0
Public water supply [f]	0
Riparian ET [h]	8,965
Open water evaporation (includes reservoirs) [i]	35,346
Stream loss to groundwater	Not estimated
Surface outflow (to Texas) [j]	14,519
Total outflows	131,664
Balance	48

[a] Median Arch Hurley diversion 1975 to 2000

[b] Median water yield at the Ute Creek near Logan gage 1975 to 2000

[c] Median water yield in Canadian main stem 1975 to 2000

[d] Estimate from balance of surface water budget, may be irrigation return flow from Arch Hurley or ungaged tributaries

[e] Trauger and Bushman, 1964

[f] Wilson et al., 2003 (2000 data for everything except irrigation, which is median irrigation for Arch Hurley, 1975-2000)

[g] Assuming that 2/3 of Union County livestock depletions are in the Canadian River Basin and the other 1/3 are in the Dry Cimarron Basin.

[h] Hydric soils from perennial reaches only plus ET from stream area.

[i] Wilson et al., 2003 for Ute Reservoir

[j] Median water yield at the Canadian at Logan gage 1975 to 2000

7.1.2.2 Representative Drought Year Surface Water Budget

Annual surface water budget results for a representative drought year are presented in Tables 7-3 and 7-4. Inflows for the drought year water budgets reflect the water yields from minimum flows on record at each of the gages (Section 7.1.1.1). Outflows reflect surface water depletions reported by the OSE (Wilson et al., 2003) and the USACE (2005) and minimum flows observed in the gaged streams during their periods of record.

- Inflow to the Dry Cimarron was based on the minimum flow, observed in 1970, at the gage near Guy.

- Outflow on the Dry Cimarron was based on the minimum flow, observed in 1993, at the Cimarron River gage near Kenton, Oklahoma.

- Inflow to the Canadian River was based on the minimum flows to the main stem (zero in many years) and at the Ute Creek near Logan gage (observed in 1974). Arch Hurley diversions in 2002 were used for the minimum inflow to Arch Hurley (although it has been as low as zero, in 2003).

- Outflow from the Canadian River was based on the minimum flow, observed in 1963, at the gage near Logan.

- Reservoir evaporation from Ute Reservoir (Wilson et al., 2003) applied to the median water budget was used in the drought budget also. However, if the water level in the reservoir is much lower, the evaporation rate could be lower as well.

- Riparian evapotranspiration was estimated based on GIS coverage and available data for riparian evapotranspiration rates in New Mexico. This value may decrease in a drought year due to plants shutting down or dying back from lack of available water; however, available data are insufficient to accurately estimate drought year riparian evapotranspiration.

Table 7-3. Dry Cimarron Water Budget for Drought Conditions

Component of Flow	Annual Flow (ac-ft/yr)
Surface water inflows	
Stream inflow from gaged flow [a]	2,151
Stream gain from unknown [b]	2,300
Irrigation return flow [c]	925
Stream gain from ungaged tributaries	Not estimated
Total inflows	5,376
Surface water depletions and outflows	
Commercial [c]	0
Domestic [c]	0
Industrial [c]	0
Irrigation [c, d]	5,809
Livestock [c, d]	59
Mining [c]	0
Power [c]	0
Public water supply [c]	0
Riparian ET [e]	337
Open water evaporation [f]	1,264
Stream loss to groundwater	Not estimated
Surface outflow (to Oklahoma) [g]	384
Total outflows	7,853
Balance	–2,478

[a] Minimum flow recorded between 1943 and 1973 (in 1970) at the Dry Cimarron River near Guy gage

[b] Same numbers as for average conditions, as discharge from groundwater will not lessen in short-term drought.

[c] Proportion of gaged inflow that results in return flow, based on Wilson et al. (2003)

[d] Same numbers as for average conditions, as demand will remain the same even if there is not adequate supply.

[e] The length of the Dry Cimarron times width of 20 feet times 3.56 ft/yr evapotranspiration

[f] Same numbers as for average conditions, as the amount of evaporation will depend on the surface area, so may actually be less than in average conditions.

[g] Minimum flow recorded between 1975 and 2003 (in 1993) on the Cimarron River near Kenton, Oklahoma

Table 7-4. Canadian River Water Budget for Drought Conditions

Component of Flow	Annual Flow (ac-ft/yr)
Surface water inflows	
Stream inflow to Arch Hurley Canal [a]	15,500
Stream inflow from Ute Creek [b]	152
Releases from Conchas Reservoir to main stem [c]	0
Stream gain from unknown [d]	49,500
Stream gain from Entrada sandstone discharge [e]	700
Total inflows	65,852
Surface water depletions and outflows	
Commercial [f]	0
Domestic [f]	0
Industrial [f]	0
Irrigation [a]	72,748
Livestock [f]	86
Mining [f]	0
Power [f]	0
Public water supply [f]	0
Riparian ET [g]	8,422
Open water evaporation (Ute reservoir) [h]	35,346
Stream loss to groundwater	Not estimated
Surface outflow (to Texas) [i]	927
Total outflows	117,529
Balance	–51,677

[a] Arch Hurley diversions (2002)

[b] Minimum flow recorded between 1960 and 2004 (in 1974) at the Ute Creek near Logan gage

[c] Minimum flow recorded between 1991 and 2005 (in multiple years) at the Canadian below Conchas Reservoir gage

[d] Same numbers as for average conditions, as discharge from groundwater will not lessen in short-term drought.

[e] Trauger and Bushman, 1964

[f] Wilson et al, 2003 (2000 data)

[g] Using hydric soil area for perennial streams only

[h] Using the same numbers as for average conditions, as the amount of evaporation will depend on the surface area, so may actually be less than in average conditions.

[i] Minimum flow recorded between 1960 and 2004 (in 1963) at the Canadian at Logan gage

Outflows were not reduced to reflect a decrease in demand during drought, as demand is not expected to decrease as a result of a reduction in supply.

7.1.3 Discussion of Surface Water Budgets

The water budgets summarized in Tables 7-1 through 7-4 are highly uncertain given the lack of gage data and water level elevation information in the vicinity of the streams. However, these budgets do indicate the order of magnitude of the supply and demands and help to highlight where data gaps exist.

7.1.3.1 Dry Cimarron River Basin

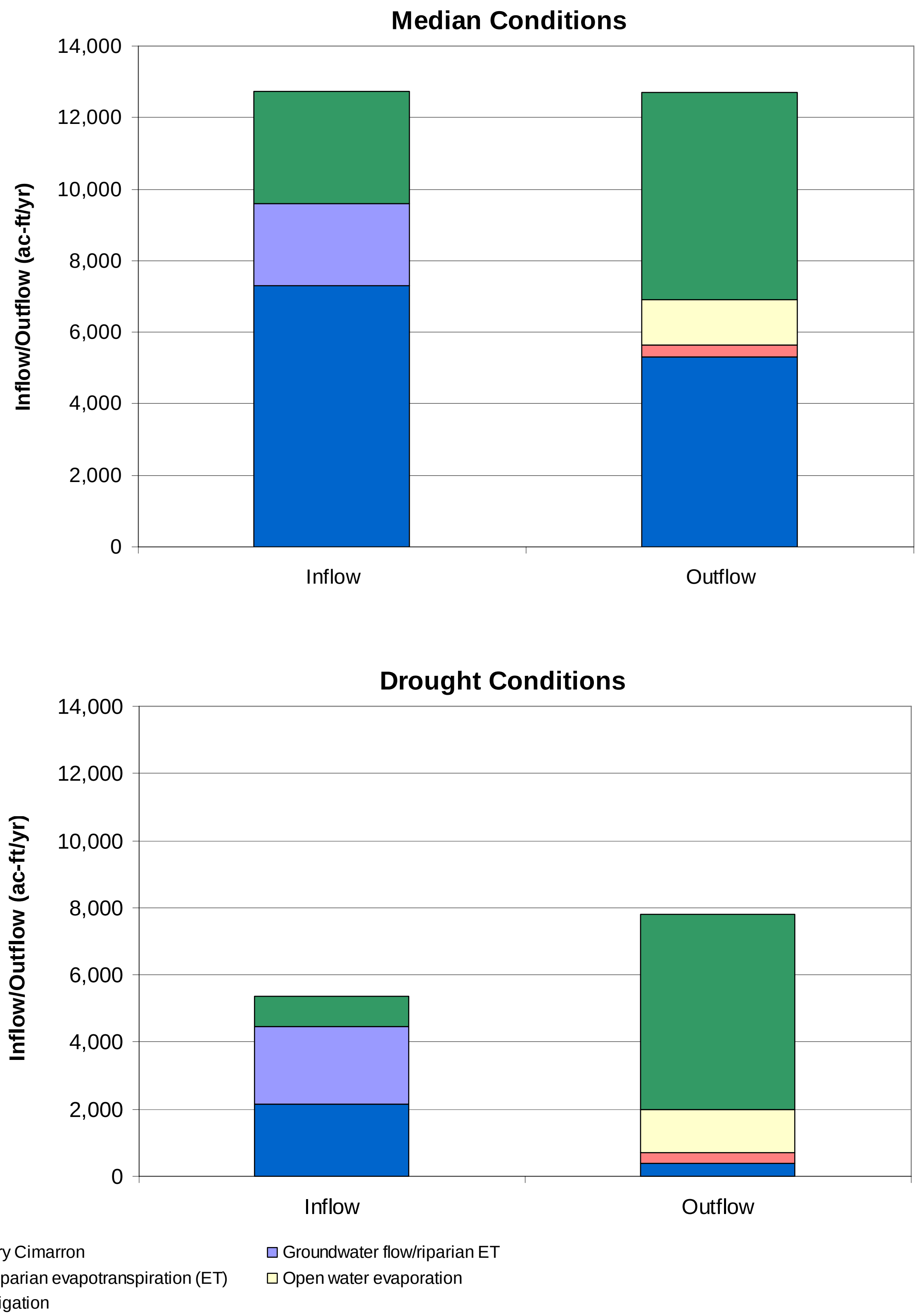
Tables 7-1 and 7-3 detail the water budget components to the degree that they can be determined with the limited data available. Figure 7-1 shows the balance of the surface water budget on the Dry Cimarron River between the gage near Guy and the State line, under both median and drought conditions.

7.1.3.2 Canadian River Basin

Tables 7-2 and 7-4 and Figure 7-2 show the water budgets under median and drought conditions for the Canadian River. Under median conditions the inflows approximately equal outflows; however, under drought conditions the supply is about 51,000 acre-feet short of median historical supply and closer to 80,000 acre-feet short of meeting full supply demands. The water budgets should be used with caution for the Canadian River, particularly because part of the supply (inflow) is based on the median diversions by Arch Hurley of 72,500 ac-ft/yr. The actual ideal demand for Arch Hurley is more than 100,000 ac-ft/yr.

7.2 Groundwater Budget

Historically, groundwater has provided most of the water supply needs throughout the planning region. While the demands on groundwater have been estimated by the OSE (Wilson et al., 2003), the natural components of flow are not well understood. DBS&A has calculated recharge for each county, but little else is known. Although the groundwater budgets are incomplete, they do clarify areas in which data are needed.



NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Dry Cimarron (Near Guy to State Line)
Water Budget

Daniel B. Stephens & Associates, Inc.
3/20/07

Figure 7-1

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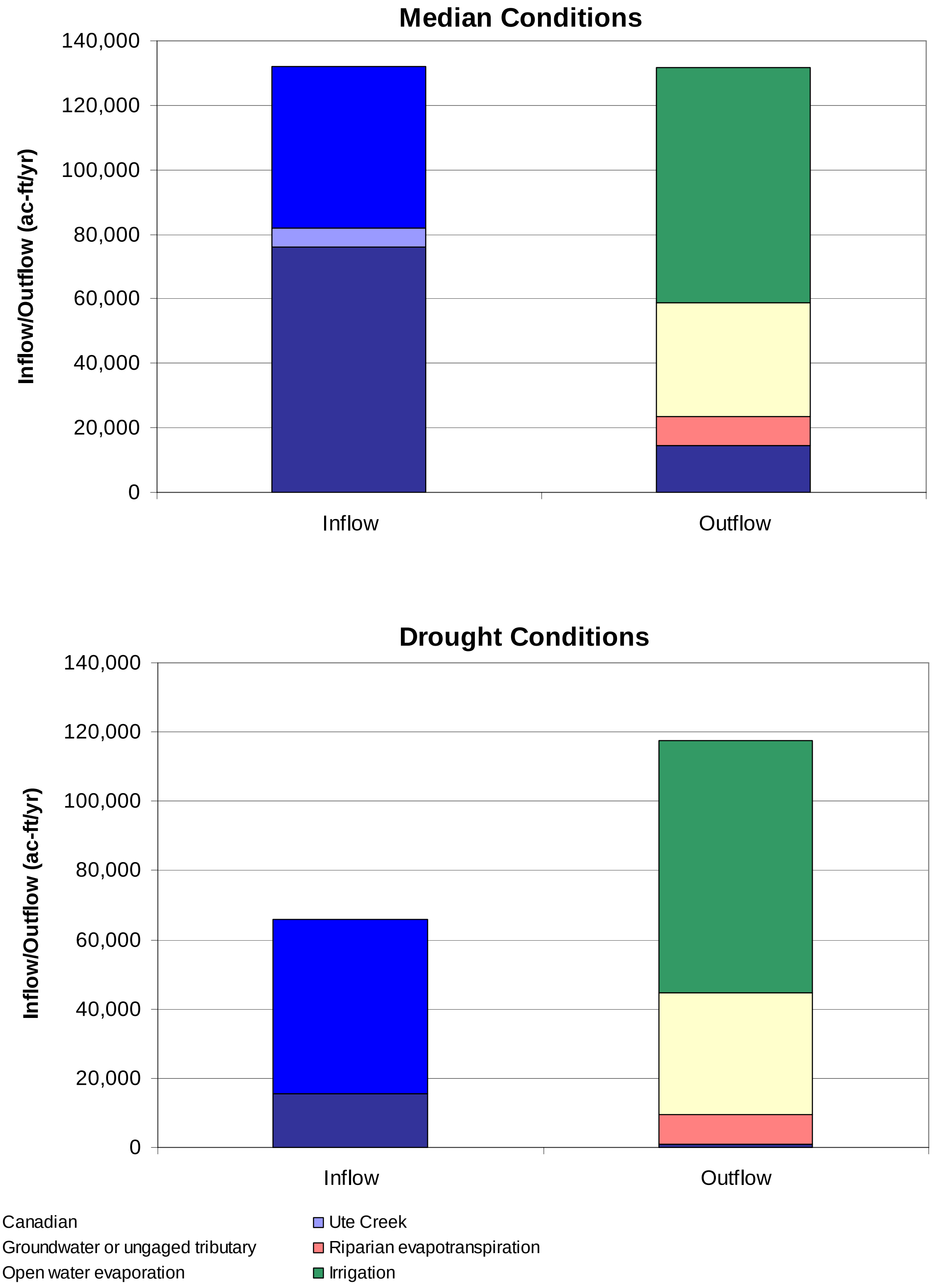

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NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Canadian River (Conchas Reservoir to Below Ute Reservoir) Water Budget

Daniel B. Stephens & Associates, Inc.

3/20/07

Figure 7-2

Groundwater budgets can be developed more accurately for individual systems with hydrologic boundaries as compared to basins with subsurface groundwater flow between basins. The number of water-bearing geologic formations in the planning region and the scarcity of knowledge about their interactions further complicate the development of the Northeast Region groundwater budgets.

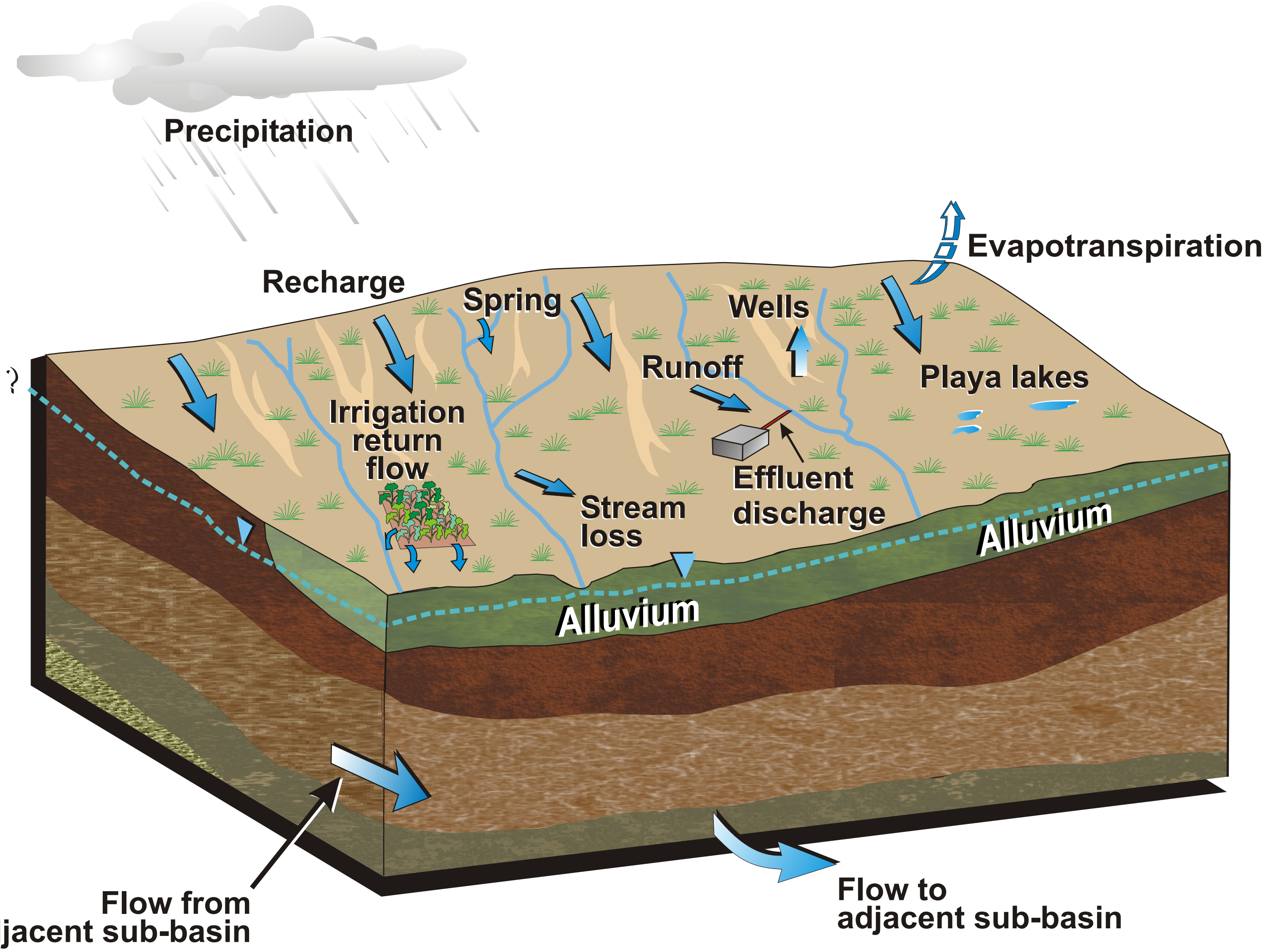
7.2.1 Groundwater Budget Terms and Methodology

The groundwater budget components (Figure 7-3) consist of the inflow components of recharge, stream loss, sub-flow from adjacent basins, and return flow from municipal, commercial, domestic, industrial, mining, power, livestock, and irrigation uses. The outflow components consist of pumping from municipal, commercial, domestic, irrigation, industrial, livestock, mining, and power generation wells, evapotranspiration, springs, and sub-flow to other basins.

A groundwater budget is the balance between inflow and outflow:

- If the total inflow and outflow components are equal, groundwater levels will not rise or fall.
- If outflow is greater than the inflow, groundwater levels will decline and the volume of water in storage will decrease.
- If inflow is greater than outflow, groundwater levels will rise and the volume of water in storage will increase.

In other words, where the change in storage is negative, water levels in the basin are dropping and where the value is positive, water levels are rising. It is possible for water levels to be dropping in one location and rising in another within the same basin. Where the water budget components are poorly understood, the difference between inflow and outflow components may be a result of error in the knowledge of the basin rather than an indication of changes in groundwater storage. The procedures used to estimate the inflow and outflow components for the Northeast Region groundwater budgets are discussed in Sections 7.2.1.1 and 7.2.1.2.



Not to Scale

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NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Water Budget Components

Figure 7-3

7.2.1.1 Inflow Components

Recharge consists of the addition of water to an aquifer by infiltration, either directly into the aquifer or indirectly by way of another rock formation. Recharge estimated here is the average natural recharge from precipitation that infiltrates to the water table. Artificial recharge, which occurs from irrigation, septic tank leach fields, and wastewater treatment plant discharge are treated as the separate water budget component of return flow. Using the method described in Section 5.3.3, recharge for the groundwater basins within the planning region was estimated to be approximately 247,000 ac-ft/yr or 2.5 percent of precipitation.

Stream loss represents recharge to the aquifer by seepage from streams. Stream losses vary from day to day and year to year depending on the amount of precipitation. Establishing the average annual losses to groundwater in a losing reach requires records from stream gaging stations in appropriate locations with sufficient periods of record, and the Northeast Region does not have an adequate number of gaging stations to establish the amount of surface water lost to recharge. In addition, there are no literature values that quantify stream loss for the region, and so outflow from surface water to groundwater has not been estimated. However, to balance the surface water budgets on the Canadian River in Quay County and the Dry Cimarron River in Union County, a net loss from groundwater to surface water was estimated. The streams may be losing in some reaches and gaining in others, but the net change in surface water budgets based on the unknown inflows (comprised of spring flow and ungaged tributary flows) is positive.

Sub-flow from adjacent basins is the water that flows across basin boundaries underground. In general, groundwater is flowing southeast in the planning region. OSE administrative groundwater basins (Figure 4-1) are not formation- or aquifer-specific, and literature discusses groundwater interaction based on formations, not state-set boundaries; therefore, sub-flow for the Northeast Region water budget was analyzed for the geologic basins in the planning region.

Water is known to move between the Ogallala and other High Plains formations, although the Ogallala is the only High Plains formation that occurs in New Mexico (Dutton et al., 2001b). In New Mexico, however, the Ogallala is hydraulically connected to other non-High Plains basins:

- The Dakota-Purgatoire (Cretaceous) and Morrison-Exeter (Jurassic) aquifers are hydraulically connected to the Ogallala aquifer, providing recharge from upward leakage (Kilmer, 1987).

- The Ogallala aquifer is considered to be hydrologically continuous with Cretaceous aquifers where it is present in Union and Harding Counties, but in areas to the south in Quay, Curry, Roosevelt and Lea Counties where these aquifers are absent, the Ogallala is instead in contact with the Chinle and Redonda formations (Triassic), which are less permeable and separate Ogallala water from the saline deeper water (Wilson, 1998).

- A hydraulic connection also appears to exist locally between the Ogallala Formation and the Dockum Group (Triassic); however, flow can go either way, depending on local geology (Nativ, 1988).

- Upward movement of water from Permian rocks into the Ogallala Formation is also suspected to occur along the Eastern Caprock Escarpment (Nativ, 1988), on the eastern edge of the aquifer.

Assumptions made in modeling studies regarding sub-flow from or to the Ogallala aquifer include:

- Modeling done for the Panhandle planning area treated northwest Union County as a no-flow boundary, because that area is the highest upgradient side of the High Plains aquifer. The authors assumed that there was no inflow to the aquifer from adjacent formations in this area (Dutton et al., 2001a).

- The western boundary for USGS RASA modeling of the Central High Plains aquifer (Section 5.3.3.2.1) was defined by the extent of the High Plains aquifer and was also treated as a zero-flow boundary (Luckey and Becker, 1999).

- As a part of the USGS RASA modeling (Section 5.3.3.2.1), interactions between aquifers were estimated and tested in the model; however, the model was insensitive to these exchanges because their volumes were so small. Interaction between the High Plains aquifer and the underlying aquifers was assumed to be negligible for the RASA modeling, and the base of the High Plains aquifer was simulated as an impermeable boundary (Luckey et al., 1986).

In summary, these and other studies that discuss the direction of flow between aquifers agree that the amount of water flowing between aquifers is small. In addition, the amount of flow between aquifers is assumed to be much less than the amount of groundwater that is withdrawn. Accordingly, this term was estimated to be zero in the Northeast Region water budgets.

As discussed in Section 7.1.1.1, ***return flow*** is that portion of flow diverted for some uses that is not consumptively used and returns to a waterbody. The Northeast Region water budgets include OSE estimates of return flow to groundwater from municipal and irrigation uses (Wilson et al., 2003):

- The OSE estimates assume that 50 percent of unmetered municipal/industrial uses are returned to the groundwater system. This is a very general estimate for water budgeting purposes. Specific return flow analyses are required by OSE for individual water rights applications. To be consistent with OSE practice, no return flow was estimated from domestic well diversions.

- The estimates of irrigation return flow are based on a combination of conveyance losses and estimated irrigation efficiencies, which differ from basin to basin but range in the planning region from 45 percent for flood irrigation to 85 percent for drip irrigation. For example, an irrigation water right of 1,000 acre-feet with a system conveyance efficiency of 60 percent and an on-farm efficiency of 70 percent will lose 400 acre-feet before it reaches the farm and 30 percent of the remaining 600 acre-feet (180 acre-feet), for a total return flow of 580 acre-feet. For the Northeast Region water budgets, all return flow from irrigation with groundwater diversions is assumed to return to groundwater. The conveyance system includes 140.5 miles of the Conchas and Hudson Canals, which deliver water to 172 miles of distribution system. Of the amount of water diverted

(108,400 acre-feet in 1999, according to Wilson et al. [2003]), more than 57 percent (61,800 acre-feet) is lost to seepage in the conveyance to the farms and 40 percent of the water (18,576 acre-feet) that reaches the farms returns to groundwater. Thus only 27,624 acre-feet, or 25.6 percent of the water diverted, is consumptively used by the crops. Diversions and conveyance efficiencies have varied from year to year; however, for consistency in approach, the estimates provided by Wilson et al. (2003) have been used for developing the water budgets for each county.

7.2.1.2 Outflow Components

The estimates of ***well diversions*** for municipal, domestic, commercial, irrigation, industrial, livestock, mining, and power uses were all obtained from the OSE water use report for 2000 (Wilson et al., 2003), as described in Section 6.1. Based on this report, the primary groundwater budget output components for the Northeast Region are (values are from Table 6-1):

- In the year 2000, all of the domestic water supply (diversions and depletions of 1,250 acre-feet) and all of the public water supply (depletions of 8,970 acre-feet) were supplied from groundwater. Together, these two uses made up 2.6 percent of total estimated groundwater depletions.

- Also in 2000, groundwater supplied 11,930 acre-feet, or 95.5 percent, of the total livestock needs. This amount was equivalent to 3.1 percent of the total estimated groundwater depletions.

- Irrigation accounted for 79 percent of all groundwater depletions in the planning region in 2000. Groundwater supplied 80 percent of all irrigation depletions.

- Together commercial, industrial, mining, and power accounted for less than 1 percent of total estimated groundwater depletions in 2000. Groundwater supplied 100 percent of all commercial, industrial, mining, and power depletions in 2000.

The ***evapotranspiration*** component of the water budget is the discharge of groundwater through the roots of trees or other vegetation that taps the aquifer directly; groundwater evapotranspiration therefore occurs only where the depth to water is shallow. Groundwater discharge to evapotranspiration can be estimated for areas with a depth to groundwater of 20 feet or less, based on the fact that phreatophyte trees typically have rooting depths of about 33 feet (Bouwer, 1978) and phreatophyte shrubs commonly root to a depth of 10 feet. A depth to groundwater map for the planning region was developed by WRRI (Figures A-7a and A-7b in Appendix A), but available data are not sufficient to identify the 20-foot depth-to-water contour. Groundwater discharge due to evapotranspiration in the planning region was estimated to be zero because groundwater is generally deep and evapotranspiration from groundwater is therefore unlikely to be a significant water budget component in the Northeast Region.

Discharge to springs and streams occurs where the groundwater level intersects the ground surface or the elevation of a stream. Discharge to springs can either be directly measured, where a spring issues at a single location, or can be estimated in the same way that stream losses are estimated, by evaluating the water budget on a stream system using stream gages. There are not enough stream gages to evaluate actual losses and gains in the planning region and discharge to springs and streams was thus not estimated for these water budgets. However, to balance the surface water budgets for median years on the Canadian and Dry Cimarron Rivers, a stream gain was assumed to originate from groundwater (although it could be due to ungaged tributaries). An estimated 2,300 ac-ft/yr was estimated to discharge from groundwater to the Dry Cimarron and 50,000 ac-ft/yr was estimated to discharge to the Canadian River.

Sub-flow out of a basin is the water that flows underground out of a basin boundary. In general, groundwater is flowing southeast in the planning region, and as four of the five counties in the region border Texas, the majority of sub-flow out of the Northeast Region flows into Texas. Any groundwater flowing out of Harding County flows into Union and Quay Counties before flowing on to Texas. Northern Union County also shares a border with Oklahoma for approximately 35 miles, and the groundwater flow direction in that area is toward Oklahoma.

Literature discussing groundwater flow between New Mexico and Texas (in terms of geologic formations rather than OSE-declared groundwater basins) focuses primarily on the Southern High Plains aquifer in Quay, Curry, Roosevelt, and Lea Counties; however, numerical estimates of flow have been made only for Curry and Roosevelt Counties. It has been established that groundwater development within 5 miles of the state line has a measurable effect on groundwater conditions in both states (Chudnoff, 1998), but modeling done by the OSE indicates that the observed reduction in saturated thickness in New Mexico is primarily due to New Mexico well withdrawals (Chudnoff and Logan, 1995).

Hydraulic gradient has increased because of drawdown in Texas; however, the total flow across the state line has actually decreased because of the reduction in saturated thickness (Chudnoff, 1998). Additional OSE modeling shows that while flow across the New Mexico-Texas state line in the Curry County and Portales groundwater basins (equivalent to all of Curry County and approximately one-third of Roosevelt County) was 36,000 ac-ft/yr for the period of 1915 to 1950, it had decreased to 14,000 ac-ft/yr in 1990 (Musharrafieh and Logan, 1999). Chudnoff has estimated that the annual flow rate across the New Mexico-Texas state line in all of Curry and Roosevelt Counties has decreased from an estimated 53,000 acre-feet in 1956 to 34,000 acre-feet in 1991 (Chudnoff, 1998).

The High Plains aquifer straddles the New Mexico-Texas state line for approximately 80 percent of the Northeast Region, and Curry and Roosevelt Counties account for approximately 50 percent of this total. Assuming that 34,000 ac-ft/yr of water crosses the state line in these two counties (Chudnoff, 1998) and that groundwater is flowing at the same rate in the Central and Southern High Plains aquifers, the total amount of groundwater crossing the state line is estimated to be 54,400 ac-ft/yr. Curry and Roosevelt Counties account for approximately 46 and 54 percent of the border for the two-county area, respectively. Dividing the 34,000 ac-ft/yr between these two counties based on these percentages yields a total of 15,640 ac-ft/yr crossing into Texas from Curry County and 18,360 ac-ft/yr from Roosevelt County. Groundwater in the portion of Quay County within the Southern High Plains aquifer area drains into Curry County before leaving New Mexico and so is accounted for in the Curry County estimate. The remaining 20,400 ac-ft/yr is estimated to cross the state line in the Central High Plains, with 17,000 ac-ft/yr estimated from Union County and 3,400 ac-ft/yr estimated from

Quay County, based on aquifer presence along the state line. These county estimates have been used in the groundwater budgets.

7.2.2 Summary of Basin Groundwater Budgets

Table 7-5 summarizes the groundwater budgets for the five counties in the planning region. The inflows and outflows (OSE groundwater withdrawal and return flow data) for 2000 (Wilson et al., 2003) were used in the development of these budgets. In addition, recharge was estimated as described in Section 5.3.3, and flow between basins, sub-flow out of basins, and spring and stream gain were estimated based on a literature review, as described in Section 7.2.1.

Comparison of the total inflows to outflows (Figure 7-4) shows that in Union County the inflows are close to the outflow, indicating that the groundwater system may be in a state of dynamic equilibrium. Water level hydrographs (Appendix D3) confirm this. In Harding and Quay Counties, inflows appear to exceed the outflows, which would mean that either some component of outflow has not been quantified or water levels may be rising. In Quay County, irrigation return flows from the Arch Hurley Conservancy District appear to be recharging the aquifer. The Southern Ogallala GAM (DBS&A, 2003, Figure 65) shows that water levels in Quay County have risen up to 25 feet since predevelopment. Conversely, in Curry and Roosevelt Counties, groundwater withdrawals far exceed inflow and water level decline rates confirm that the Ogallala aquifer is being mined.

More information on the amount of evapotranspiration, stream losses and gains, and sub-flow in and out of each basin is needed to obtain a better understanding of actual water budgets. Return flow estimates could be improved by measuring surface diversions and canal losses. Greater coverage of groundwater level monitoring throughout the planning region would allow the development of detailed water level maps, which could help define the flow regimes in each basin and lead to a better understanding of groundwater resources in the planning region.

Table 7-5. Groundwater Budgets for the Northeast Region

County	Annual Flow (ac-ft/yr)				
	Union	Harding	Quay	Curry	Roosevelt
Inflow [a]					
Recharge	88,200	24,300	49,200	46,700	38,500
Return flow commercial	0	0	0	4	0
Return flow domestic	0	0	0	0	0
Return flow industrial	0	0	0	0	0
Return flow irrigation [b]	9,843	487	68,151	38,003	21,318
Return flow livestock	0	0	0	0	0
Return flow mining	0	0	0	0	0
Return flow power	0	0	0	0	0
Return flow public water supply	292	42	917	4,054	1,503
Total Inflow	98,300	24,800	118,300	88,800	61,300
Outflow					
Commercial	8	0	11	232	141
Domestic	176	51	335	529	161
Industrial	0	0	0	0	0
Irrigation	77,185	3,654	6,546	195,886	148,714
Livestock	1,591	363	792	4,626	4,560
Mining	0	0	0	0	0
Power	0	0	0	0	17
Public water supply	585	84	2,172	8,417	4,525
Springs/stream gain [c]	2,300	0	49,500	0	0
Springs/stream gain [d]	0	0	700	0	0
Sub-flow out to adjacent counties [e]	17,000	0	3,400	15,640	18,360
Total outflow	98,845	4,152	63,455	225,330	176,477
Balance	–500	20,600	54,800	–136,500	–115,200

Source: Wilson et al., 2003 (unless otherwise noted)

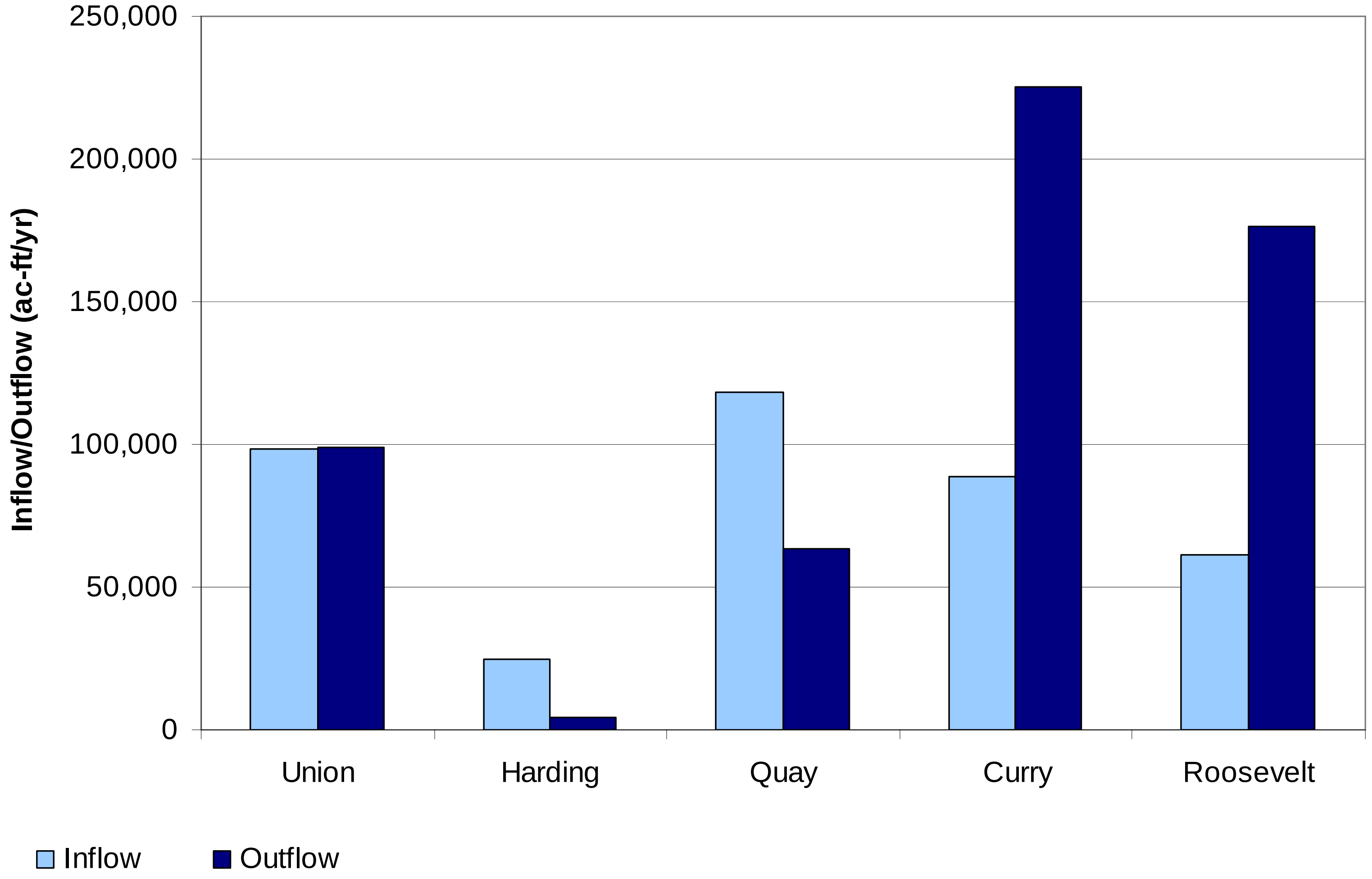
[a] Does not include stream loss and inflow from adjacent counties, as these terms were not estimated.

[b] Return flow from irrigation in Quay County includes 85% of the canal seepage from Conchas and Hudson Canals and the distribution system and return flow from the farms. Canal seepage is 57.3% and on-farm return flow is 35 to 40% for surface water diversions and 15 to 35% for groundwater diversions minus incidental depletions.

[c] To balance the surface water budget, gains of 50,000 and 2,300 acre-feet were estimated to the Canadian and Dry Cimarron, respectively; this is probably irrigation return flow eventually returning to the rivers. Some of outflow to the Canadian River could be accounted for in Harding County, as the Canadian River marks the western boundary of Harding County.

[d] The Entrada aquifer is in Quay County.

[e] Based on 1991 estimate by Chudnoff, 1998.



NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Groundwater Budget Components by County

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Figure 7-4

7.3 Comparison of Supply and Demand Projections

To determine the Northeast Region's practical ability to meet future water demand, DBS&A compared the projected water supply for each county (Table 7-6), based on the information provided in Section 5, to the projected demands outlined in Section 6.3. The projected supply was determined based on estimates of the lifetime of existing supplies. In Union County, the extent of the groundwater resource is not as well understood as it is in Curry and Roosevelt Counties, but some areas in all three counties are experiencing dramatic water level declines. In Curry and Roosevelt counties, numerous USGS-monitored wells are completed to the bottom of the Ogallala aquifer, and therefore, it is relatively straightforward to predict the decline in the water table. By assuming that the declines will continue at the same rate, the year when the well will go dry can be estimated. In Union County, the depth of the aquifer is assumed to be the depth of the wells, but it is possible that the wells could be deepened into the Entrada Formation. In Union County, the projected groundwater supply was reduced in proportion to the reduction in saturated thickness. In Curry and Roosevelt Counties, the projected supply was reduced to be equivalent to the total recharge to the aquifer in the two counties.

As detailed in Sections 7.3.1 through 7.3.5, while the supply for Harding County should be adequate to meet future needs (Figure 7-5), the projected groundwater supplies for Union, Curry, and Roosevelt Counties, which are diminishing at a rapid rate, are inadequate to meet projected demands (Figure 7-5). In Quay County, which relies largely on surface water supplies, groundwater supplies are adequate to meet demands on that resource, but while surface water supplies are adequate in wet years, during years with lower water supplies water years, there may be shortfalls in meeting agricultural demands of the Arch Hurley Conservancy District.

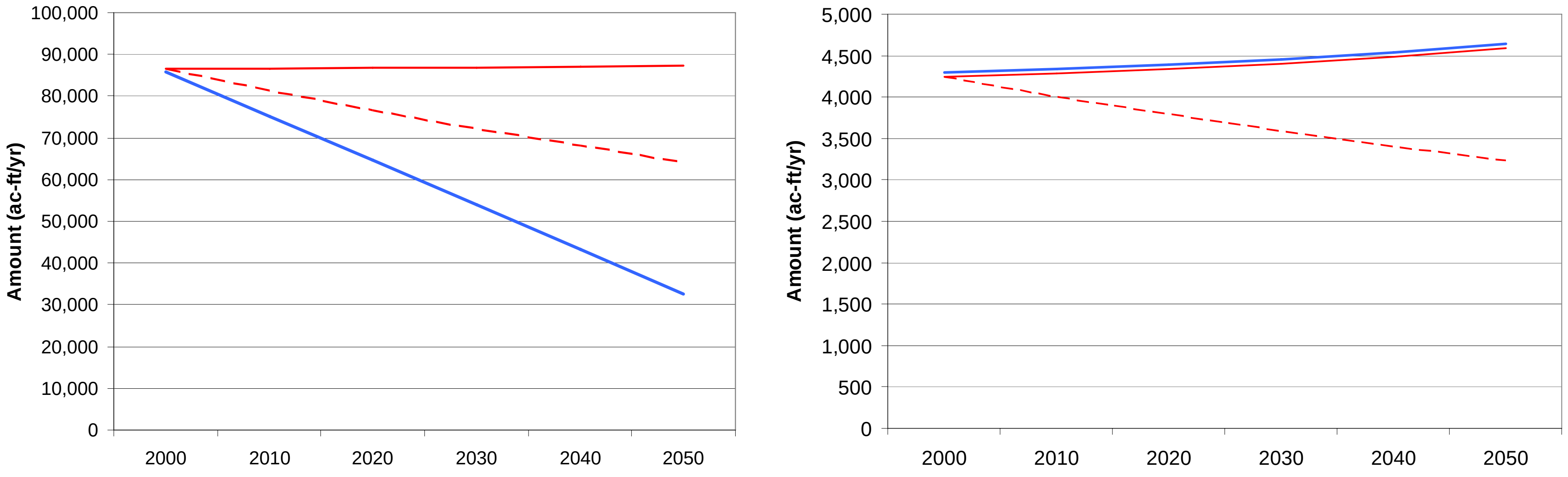
7.3.1 Union County

The projected surface water and groundwater supplies for Union County will not be sufficient to meet projected demands (Figure 7-5). There is a deficit of surface water supplies along the Dry Cimarron River during drought years (Section 7.1.3.1), and while groundwater levels in some areas in Union County are increasing, other areas, primarily in southeastern Union County, are experiencing declining aquifer levels (Section 5.3.5).

Table 7-6. Projected Surface and Groundwater Supply by County

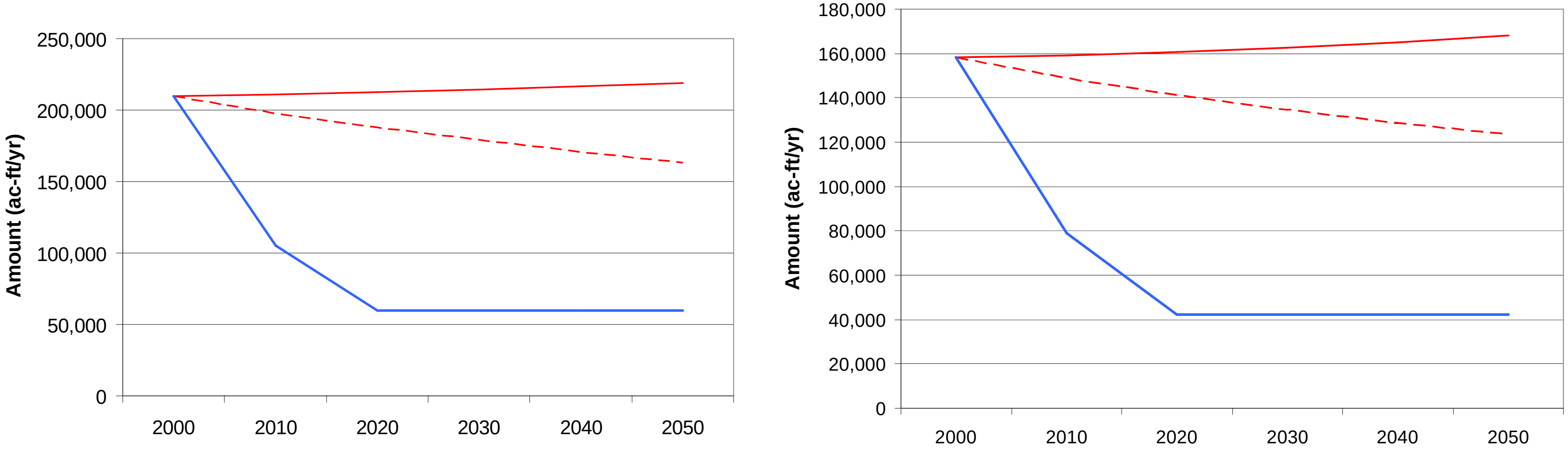
Supply Source	Projected Supply (ac-ft/yr)						Explanation
	2000	2010	2020	2030	2040	2050	
Union							
Surface water	6,346	6,346	6,346	6,346	6,346	6,346	Median in Dry Cimarron + evaporation from Clayton lake that is not included in the surface water budget for the Dry Cimarron River
Groundwater	79,545	68,886	58,227	47,568	36,909	26,250	Based on water level monitoring, which indicates declining water levels in vicinity of most pumping, saturated thickness will be reduced to 33% by 2050.
Total	85,891	75,232	64,573	53,914	43,255	32,596	
Harding							
Surface water	90	90	90	90	90	90	Livestock supply
Groundwater	4,152	4,197	4,246	4,310	4,394	4,504	Water levels and water budget indicate stable supply
Total	4,292	4,337	4,386	4,450	4,534	4,644	Added 50 for graphing
Quay							
Surface water	72,834	72,834	72,834	72,834	72,834	72,834	Median to Arch Hurley + livestock use of surface water
Groundwater	9,855	9,855	9,855	9,855	9,855	9,855	Water levels and water budget indicate stable supply
Total	82,690	82,690	82,690	82,690	82,690	82,690	
Curry							
Surface water	140	140	13,107	13,107	13,107	13,107	Livestock supply + Ute Reservoir deliveries
Groundwater	209,690	104,845	46,657	46,657	46,657	46,657	Reduced supply to equal recharge amount
Total	209,830	104,985	59,764	59,764	59,764	59,764	
Roosevelt							
Surface water	70	70	3,553	3,553	3,553	3,553	Livestock use of surface water + Ute Reservoir deliveries
Groundwater	158,117	79,059	38,546	38,546	38,546	38,546	Reduced supply to equal recharge amount
Total	158,187	79,128	42,099	42,099	42,099	42,099	

Note: Projections are based on existing supplies and do not include development of potential new supplies.



Union County

Harding County



Curry County

Roosevelt County

Figure 7-5

NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Projected Diversions vs. Groundwater Supply

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Table 7-7 shows the calculated lifetime of the Dakota Formation in southeastern Union County in several USGS-monitored wells, and Figure 7-6 illustrates the water level decline in one of those wells. Based on the current trends in water level decline, which average about 2.5 ft/yr, some wells could go dry as soon as 2027 (Table 7-7). The average time until the wells go dry is estimated to be about 76 years. If the depth of these monitored wells represents the extent of the Dakota and Ogallala formations in this area, the productivity of the aquifer, as indicated by well yields, is likely to decline. By the year 2050 the remaining aquifer thickness in these wells will range from 0 to 58 percent and will average 33 percent of the current saturated thickness. To reflect the potential drop in yield, the supply in 2050 (Table 7-7) has been reduced to 33 percent of the original diversions for agriculture in Union County, 93 percent of which are diverted in the vicinity of Clayton.

A detailed groundwater model of this area would assist in predicting the potential yield of the aquifer. While recharge to Union County is almost 90,000 ac-ft/yr and the water budget does not indicate a major decrease in the amount of water in storage, the pumping is concentrated in a relatively small area and is clearly not being recharged at a sufficient rate to offset water level declines in the vicinity of the target pumping centers. To continue current pumping levels, other groundwater resources in the County should therefore be explored.

7.3.2 Harding County

The total diversions in Harding County were less than 5,000 ac-ft/yr in 2000 and are not projected to increase significantly, even under the high water use projection. Recharge to the groundwater in Harding County is estimated to be 24,000 ac-ft/yr, with only 4,100 ac-ft/yr estimated to discharge across the State line to Texas. Water levels are thus increasing in Harding County, suggesting that regionally the groundwater supply should be sufficient to meet the projected demands (Figure 7-5). However, even though overall supply may be adequate, individual users and water systems need to evaluate the long-term capacity of their wells.

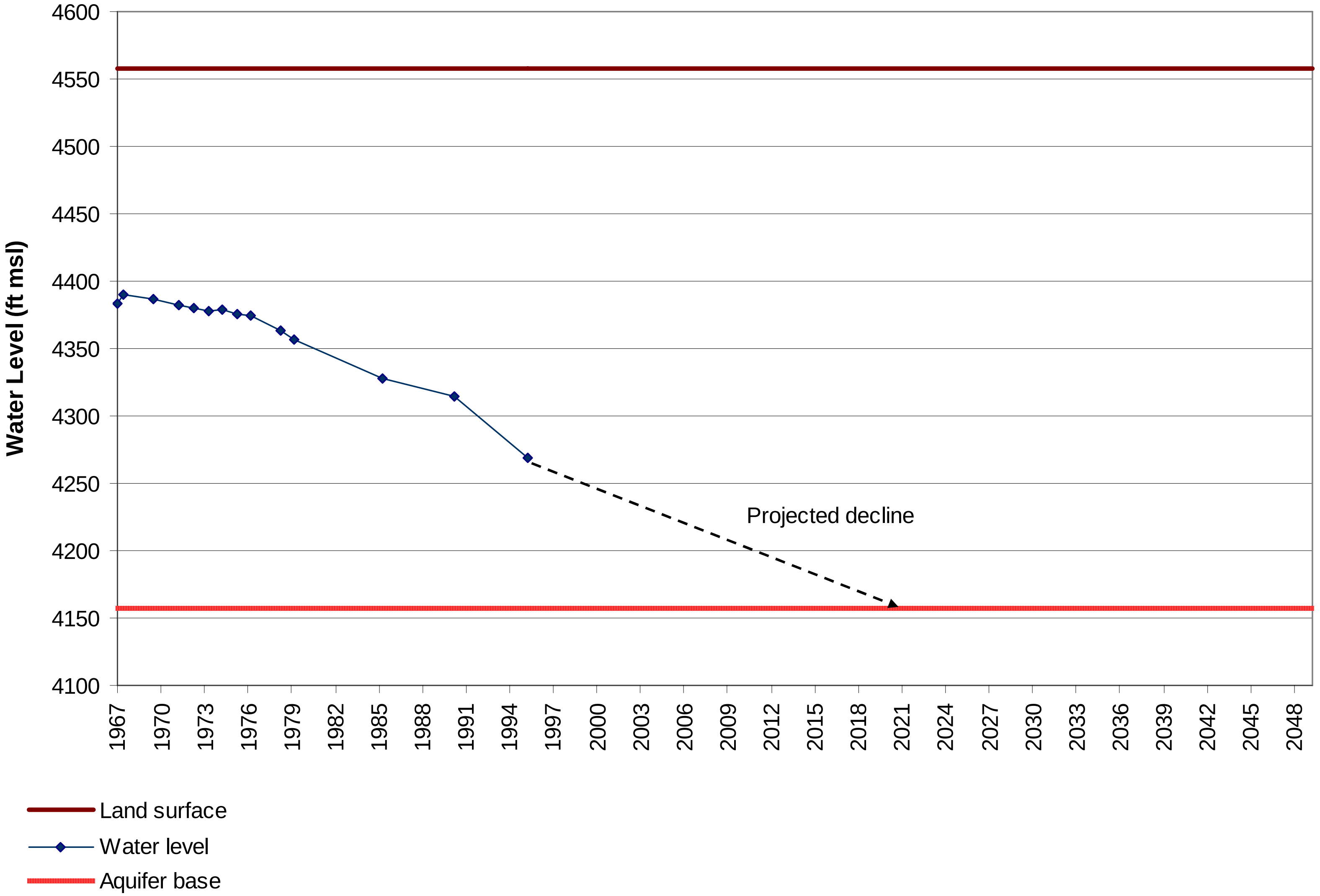
7.3.3 Quay County

Sufficient groundwater supplies are available to meet the projected demands for uses other than agriculture in the county. Quay County and the communities of Logan, San Jon, and Tucumcari also have a total of 7,550 ac-ft/yr reserved in Ute Reservoir to meet municipal water demands.

Table 7-7. Estimated Aquifer Lifetime Based on Dakota and Ogallala Formation Monitored Wells in the Vicinity of Sedan, Union County

Well Designation	Water Level Monitoring Dates		Water Level (ft msl)		Change (feet)	No. of Years	Rate (ft/yr)	Land Surface Datum (ft msl)	Well Depth (ft)	Aquifer Bottom [a] (ft msl)	Remaining Saturated Thickness (ft)	Remaining Aquifer Life (years [b])	Year of Total Aquifer Depletion
	First	Last	First	Last									
360837103090701	03/16/1971	03/09/2004	4446	4379	–67	33	–2.0	4605	390	4215	165	82	2086
360910103051301	01/19/1972	01/24/1996	4382	4269	–113	24	–4.7	4558	400	4158	111	23	2027
361041103033601	03/17/1971	02/14/2001	4393	4289	–104	30	–3.5	4556	380	4176	113	33	2037
361121103044001	01/09/1972	02/14/2001	4402	4344	–58	29	–2.0	4611	405	4206	138	68	2072
361227103070601	03/24/1971	02/14/2001	4467	4427	–40	30	–1.3	4676	405	4271	156	116	2120
361319103023901	04/08/1970	02/14/2001	4444	4374	–70	31	–2.3	4571	386	4185	189	84	2088
371021103060701	04/08/1970	01/25/1996	4430	4382	–48	27	–1.8	4611	455	4156	226	128	2132
Average							–2.5				157	76	

[a] Calculated by assuming that wells are completed to the bottom of the aquifer.
[b] Years after last water level measurement



NORTHEAST NEW MEXICO REGIONAL WATER PLAN

Dakota Formation Water Level Decline

USGS Well 360910103051301

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Figure 7-6

As discussed below, however, surface water supplies are often insufficient to meet agricultural demands.

The largest water diversions in Quay County are by the AHCD, which in wet years (e.g., 1999) has diverted almost 120,000 acre-feet of water. The surface water demand for the Arch Hurley Conservancy District varies widely: while Arch Hurley has diverted almost 120,000 acre-feet in some years (e.g., 1999), in one recent year (2003), no water was available for diversion. However, the median supply to AHCD is 72,500 ac-ft/yr, based on Conchas Reservoir outflow from 1975 through 2005. Table 7-8 shows the range in projected demands, which vary depending on the number of acres irrigated and variations in off-farm efficiencies. With a median supply of 72,500 ac-ft/yr and a demand ranging from 90,000 to well over 100,000 ac-ft/yr, the supply is insufficient to meet the demands in many years.

Currently, off-farm irrigation conveyance through the more than 300 miles of canals and ditches from Conchas Reservoir to the farms in the AHCD results in a loss ranging from 37 to 60 percent and averaging 49 percent of the water diverted (off-farm efficiency of 51 percent) (Barnes, 2004). On-farm efficiencies are estimated to be 60 percent (Wilson et al., 2003). An improvement in irrigation efficiencies from the current level of 32 percent to 45 percent (shown as the goal on Table 7-8) for the combined off-farm and on-farm efficiencies would result in sufficient supply for the 33,000 irrigated acres 80 percent of the time based on the period of record from 1947 through 2005. Such an improvement would require a concerted effort to reduce losses through ditch lining and on farm efficiency improvements (Section 8.3).

Table 7-8. Arch-Hurley Conservancy District Irrigation Efficiency

Variable	Acres Irrigated [a]	CIR [b] (ac-ft/ac/yr)	Irrigation Efficiency (%)		Project Efficiency (%)	Diversion Demand (ac-ft/yr)
			Off-farm [a]	On Farm [b]		
Median	33,000	0.861	52.9	60.0	31.7	89,600
Maximum	37,688	0.861	40.5	60.0	24.3	133,500
Minimum	33,000	0.861	63.0	60.0	37.8	75,100
Goal [c]	33,000	0.861	70.0	65.0	45.0	62,400

[a] Source: Barnes, 2004
[b] Source: Wilson et al., 2003
[c] Based on improved delivery efficiencies

CIR = Consumptive irrigation requirement
ac-ft/ac/yr = Acre-feet per acre per year
ac-ft/yr = Acre-feet per year

7.3.4 Curry County

As shown in the groundwater budgets discussed in Section 7.2, Curry County is depleting the aquifer at the rate of about 137,000 ac-ft/yr. The GAM model predicts that the yield of the Southern Ogallala will diminish rapidly, and some of the model cells in Curry County are already dry (DBS&A, 2003).

To project the future supply, water level declines in the Ogallala aquifer were analyzed to predict the lifetime of the aquifer. Figure 7-5 illustrates historical water level declines in two monitored wells in the vicinity of Clovis and the projected decline in those wells if pumping continues at its current rate. In both wells, the water level is projected to drop to the bottom of the Ogallala aquifer in less than 15 years. Table 7-8 shows the projected decline for these and four other wells located in southeast Curry County, where most of the pumping is occurring. The average rate of decline is 2.5 ft/yr and the average lifetime of the wells is until 2020. In reality, the yield of the production wells will diminish before the wells go completely dry.

For the purposes of comparing the future supply of groundwater in Curry County to the projected demand (Figure 7-5), the available groundwater was assumed to be reduced to 46,600 ac-ft/yr by 2020, an amount equal to the recharge rate to the groundwater. Because recharge to the aquifer may not, in reality, be immediately available to the pumping centers, this is the most optimistic outlook for the groundwater supply. This approach is also optimistic in that it assumes that the amount of water flowing across the Stateline to Texas would diminish to zero from a current estimate of 15,640 ac-ft/yr (in other words, it assumes that New Mexico will be pumping all the available water). The amount of surface water was assumed to increase by 12,967 ac-ft/yr to account for the water supply from Ute Reservoir for Curry County and the communities of Clovis, Grady, Melrose, and Texico.

7.3.5 Roosevelt County

Like Curry County, Roosevelt County relies almost entirely on groundwater and is depleting the Ogallala aquifer at a rate of 115,000 ac-ft /yr. Table 7-9 summarizes estimated lifetimes for several USGS-monitored wells in the northeast quadrant of Roosevelt County, where the

Table 7-9. Estimated Aquifer Lifetime Based on Ogallala Aquifer Monitored Wells in Curry County

Well Designation	Water Level Monitoring Dates		Water Level (ft msl)		Change (feet)	No. of Years	Rate (ft/yr)	Aquifer Bottom (ft msl)	Remaining Saturated Thickness (ft)	Remaining Aquifer Life (years [a])	Year of Total Aquifer Depletion
	First	Last	First	Last							
342502103083301	01/12/1977	01/06/1998	3941.4	3917.7	–23.7	21	–1.1	3860	58	51	2049
341836103052001	01/28/1972	10/05/2005	3954.8	3807.2	–147.6	33	–4.5	3750	57	13	2018
342006103134201	01/06/1970	02/22/2005	4006.5	3857.0	–149.5	35	–4.3	3800	57	13	2018
342744103055701	01/06/1979	02/22/2003	3918.0	3903.1	–14.9	24	–0.6	3860	43	69	2067
342729103103801	01/08/1970	02/29/2004	3983.2	3945.2	–38.0	34	–1.1	3915	30	27	2025
342211103053901	01/06/1970	03/22/2005	3943.4	3829.3	–114.0	35	–3.3	3800	29	9	2014
Average							–2.5		46	18	

[a] Years after last water level measurement

Table 7-10. Estimated Aquifer Lifetime Based on Ogallala Aquifer Monitored Wells in Roosevelt County

Well Designation	Water Level Monitoring Dates		Water Level (ft msl)		Change (feet)	No. of Years	Rate (ft/yr)	Aquifer Bottom (ft msl)	Remaining Saturated Thickness (ft)	Remaining Aquifer Life (years [a])	Year of Total Aquifer Depletion
	First	Last	First	Last							
341143103032101	01/27/1972	01/07/1998	3939.2	3854.3	–85.0	26	–3.3	3775	79	24	2022
341419103053501	01/06/1975	02/17/2005	3968.5	3875.8	–92.7	30	–3.1	3800	76	25	2030
340641103093702	10/09/1979	01/22/1997	3865.2	3859.3	–5.9	18	–0.3	3800	59	182	2179
341016103084801	01/13/1977	02/20/1997	3978.9	3906.7	–72.2	20	–3.6	3850	57	16	2013
340553103063001	01/07/1970	01/22/1997	3874.5	3846.1	–28.4	27	–1.1	3800	46	44	2041
341042103074501	03/09/1972	01/09/1997	3974.0	3889.9	–84.0	25	–3.4	3875	15	4	2001
Average							–2.5		55	23	

[a] Years after last water level measurement

majority of pumping is occurring. The average rate of decline in these wells is 2.5 ft/yr with an average remaining saturated thickness of about 55 feet, which is projected to last about 20 more years.

To compare the future supply of groundwater in Roosevelt County to the projected demand (Figure 7-5), the amount of groundwater was reduced to 38,500 ac-ft/yr, the amount of recharge to the aquifer. Because recharge to the aquifer may not, in reality, be immediately available to the pumping centers, this provides the most optimistic outlook for the groundwater supply. This approach is also optimistic in that it assumes that the 18,400 acre-feet of water that flows to Texas each year from Roosevelt County would diminish to zero. The amount of surface water was increased to 3,483 ac-ft/yr to account for the Ute Reservoir pipeline that will supply public water to Roosevelt County and the communities of Portales and Elida.