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Estimated Stream Depletion In the Nebraska Platte Basin Due to New Irrigated Land Developed after July 1, 1997

by

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Stream depletion by wells: *Reduction in streamflow due to pumping wells. Stream depletion may be due to either direct depletion of the stream or interception of groundwater that is moving toward the stream. The latter is more common in Nebraska. Steam depletion can occur across stream basin boundaries. Stream depletion also can occur across groundwater divides.*

Introduction

In March 2006, the Nebraska Department of Natural Resources (NDNR) and the Cooperative Hydrology Study (COHYST) entered into an agreement to estimate the effects on streamflows in the Platte River basin of pumpage for irrigated land developed after July 1, 1997. The analysis was for a 40-year period beginning with the irrigation season that started May 1, 1998. The analysis was to determine "when and where new streamflow depletions would occur." To address the "where" part of the analysis, the area was subdivided into six sub-areas: Wyoming line to Kingsley Dam, Kingsley Dam to Tri-County Supply Canal diversion, Tri-County Supply Canal diversion to Lexington, Lexington to U.S. Highway 183, U.S. Highway 183 to Chapman, and Chapman to Columbus (fig. 1).

The analysis was limited to the streams in the Platte River system, including the North Platte and South Platte Rivers, and its baseflow tributaries. Baseflow tributaries flow essentially year-round because of groundwater discharge to them. Lodgepole Creek was included only upstream as far as it flowed in 1998. Pumpkin Creek was included only upstream as far as it flowed in 1998. The analysis extended beyond the surface-water divide of the Platte River system because changes in the groundwater system beyond the divide can still affect surface water in the Platte River system. A second analysis was performed using a smaller area closer to the Platte River to provide a perspective on how the distance from the stream of the new irrigated land impacts streamflow depletions in this area over time.

The analysis was done using groundwater flow models, as revised following COHYST Peer Review by Eagle Resources. The Peer Review was conducted from December 2004 through September 2005. After Peer Review, the COHYST Technical Committee evaluated the review and summarized the comments into 52 items, many of which suggested model revisions or enhancements. The Technical Committee grouped the 52 items into priorities and recommend to the COHYST Sponsors that the high priority items related to the models be completed before the models were used for analysis. All high priority items were completed on the models, as well as some lower priority items, before this analysis was done.

Groundwater Models

Groundwater flow models covering three overlapping areas were used in this analysis (fig. 1). The Western Model Unit covers the area upstream from Kingsley Dam in central Keith County and goes 6 miles into Wyoming. The western model was used to estimate effects for Wyoming line to Kingsley Dam. The Central Model Unit covers the area from eastern Garden County to central Dawson County. The central model was used to estimate effects for Kingsley Dam to Tri-County Supply Canal diversion and Tri-County Supply Canal diversion to Lexington. The Eastern Model Unit covers the area from western Dawson County to eastern Platte County. The eastern model was used to estimate effects for Lexington to U.S. Highway 183, U.S. Highway 183 to Chapman, and Chapman to Columbus. All three models had cell sizes of 160 acres. The western model had a single layer. The central and eastern models had six and five layers respectively, although fewer layers actually exist in most areas. Model documentations for the models used in this analysis are being finalized and will be placed on the COHYST Internet site in the future.

Simulated water levels on April 30, 1998, were the starting water levels in the models used in this analysis. The models simulated two stress periods per year, an irrigation season (May through September) and a non-irrigation season (October through April). Although the latter period is called the non-irrigation season, some irrigation on small grains and alfalfa was simulated during this period. Pumpage and recharge were held constant within a stress period but were varied between stress periods. Pumpage also was varied on a year-by-year basis through the irrigation season beginning May 1, 2005; after that year, annual pumpage was held constant. Simulation time steps were essentially monthly with the irrigation season simulated in 5 time steps and the non-irrigation season simulated in 7 time steps. The models simulated 40 years, from May 1, 1998, to May 1, 2038. As will be discussed in the Net Irrigation Requirements section, 1997 meteorological data were used for all 40 years of the simulation. Overall, 1997 was slightly dryer than the 1895-1998 average (-0.47 inches) with the range of 1997 deviation from average being +0.76 inches (Climate Division 1) to -1.98 inches (Climate Division 6).

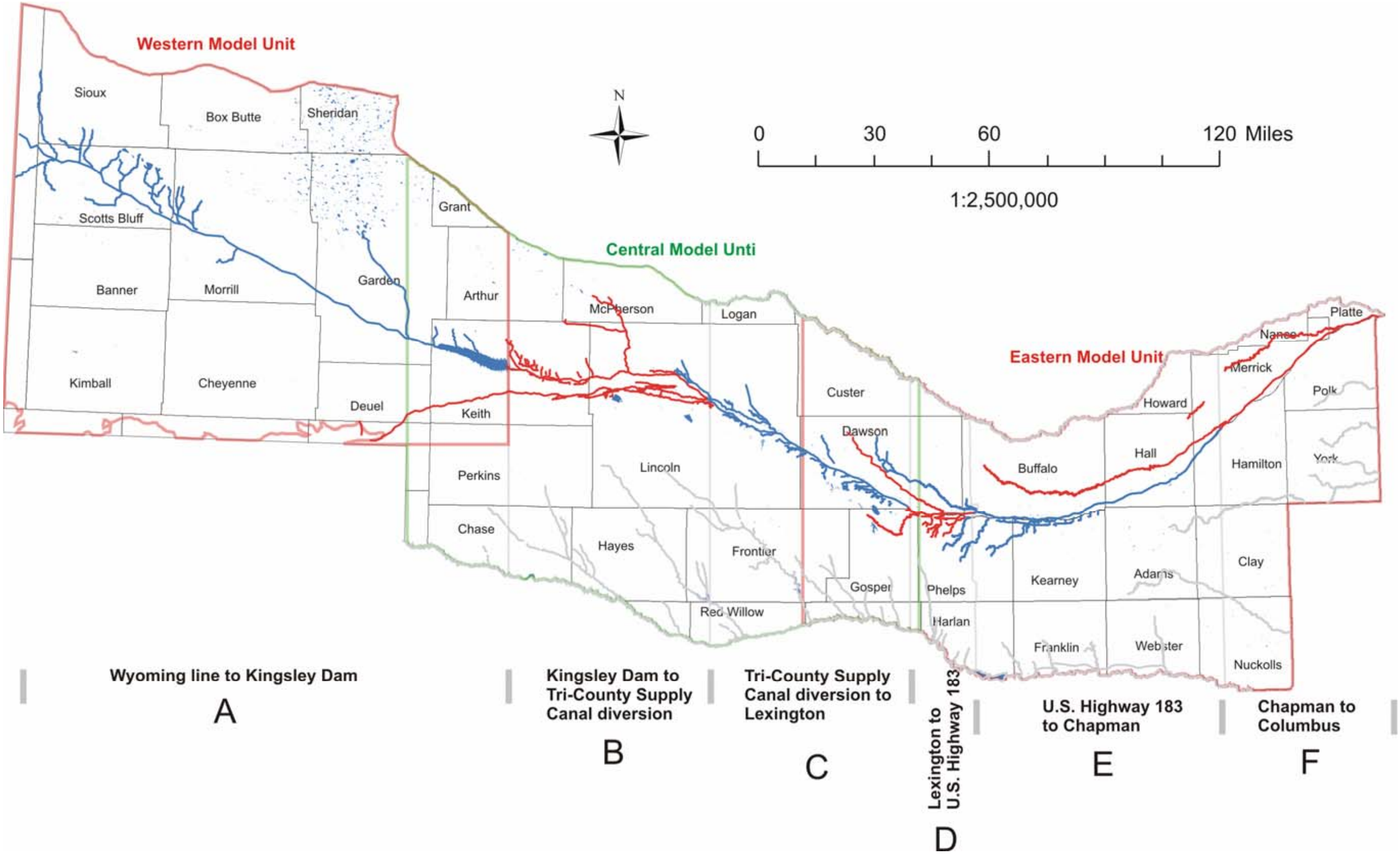


Figure 1. Cooperative Hydrology Study (COHYST) Model Units and the six sub-areas used in the analysis of streamflow depletion to the Platte River system due to groundwater-irrigated lands developed between July 1, 1997, and June 30, 2006. Note that streams are grouped by the sub-area in which they reach the Platte River, including the North Platte River and South Platte River.

Changes in Irrigated Land

The first task was to estimate new irrigated land developed after July 1, 1997. This was done by computing changes in irrigated land use from the 1997 land-use map (Dappen and Tooze, 2001), the 2001 land-use map (Dappen and Merchant, 2003), and the 2005 land-use map (Dappen and others, 2006). These three reports on land use were developed using Landsat remote sensing imagery, Farm Service Administration field data, and ground truth data collected by the Natural Resources Districts. The reports include an assessment of the accuracy of the data which was used to generate the maps. The 2001 and 2005 land-use maps also contain an assessment of the irrigation layer alone. The 1997, 2001, and 2005 land-use maps contained polygons showing irrigated lands. For 1997 and 2001, the polygons were registered to each other based on the centroids of the polygons. This registration resulted in small shifts, principally on center pivots. The 1997 polygons were then subtracted from the 2001 polygons in a geographical sense to produce polygons that indicated an increase in irrigated land between 1997 and 2001 (gained irrigated land). In a similar manner, the 2001 polygons were subtracted from the 1997 polygons to produce polygons that indicated a decrease in irrigated land between 1997 and 2001 (lost irrigated land). Polygons with areas less than 1 acre were removed because they were unlikely to represent real gains or losses in irrigated lands. Polygons whose centroids fell within a surface-water irrigation district were deleted because these were assumed to be only temporarily gained or lost irrigated land. Because these polygons were deleted, gained or lost irrigated land really means gained or lost ***groundwater irrigated land*** throughout this report.

Many of the remaining polygons consisted of two concentric circles or parts of circles with a thin strip between them indicating either an increase or a decrease in irrigated land. These concentric circle polygons were due to imperfect field boundaries and are called *edge effects* here. The area of each 1997 to 2001 gained or lost irrigated land polygon was divided by its perimeter. For a 120 acre pivot, the ratio of area divided by perimeter is 645. For a 120 acre rectangle that is 1,320 feet by 3,960 feet, the ratio of area divided by perimeter is 495. Edge effect polygons have much smaller ratios. Analysis indicated that deleting those 1997 to 2001 gained or lost irrigated land polygons with ratios of less than 100 removed most of the edge effect fields without removing real fields. The remaining polygons were deemed a map of estimated gained or lost irrigated land after July 1, 1997, and before June 30, 2001 (fig. 2).

A similar process was used for 2001 to 2005, although these maps generally used the same field boundaries so edge effects were less pronounced for 2001 to 2005. As with 1997 to 2001, polygons with areas less than 1 acre were discarded as were polygons with area to perimeter ratios of less than 100. The remaining polygons were deemed a map of estimated gained or lost irrigated land after July 1, 2001, and before June 30, 2005 (fig. 2). Table 1 summarizes the gained and lost irrigated land by county for 1997 to 2001 and 2001 to 2005. The table also lists 1997 to 2005 net gained irrigated land. For 1997 to 2001, there was a net gain of approximately 204,000 irrigated acres. For 2001 to 2005, there was a net gain of approximately 304,000 irrigated acres. For 1997 to 2005, there was a net gain of approximately 508,000 irrigated acres. Table 2 summarizes the gained and lost irrigated land by Natural Resources District.

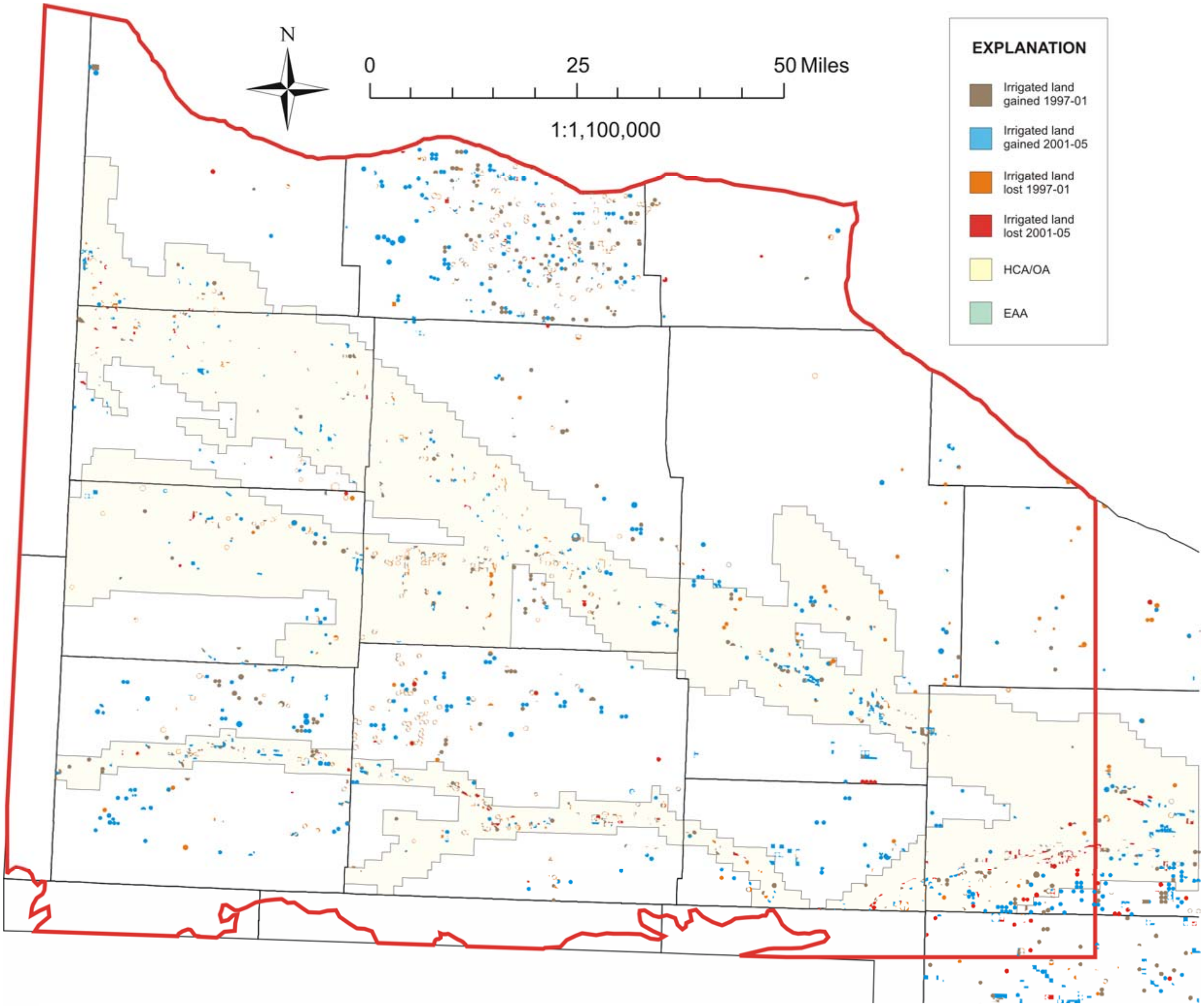


Figure 2. Groundwater-irrigated land developed between July 1, 1997, and June 30, 2001, and between July 1, 2001, and June 30, 2005, and the Hydrologically Connected Area for the Overappropriated Basin (HCA/OA), and the Eastern Analysis Area (EAA). Western Model Unit.

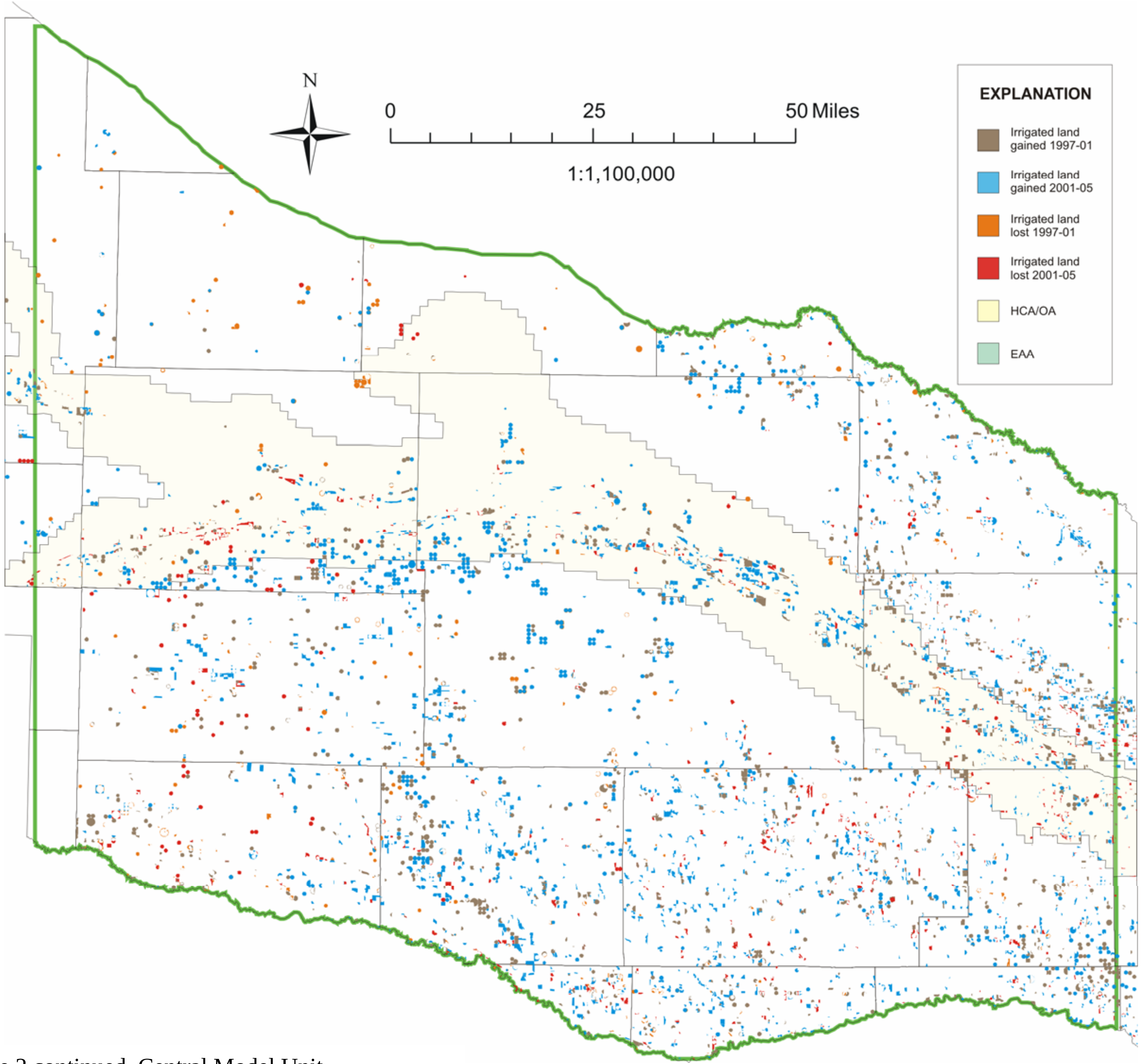


Figure 2 continued. Central Model Unit.

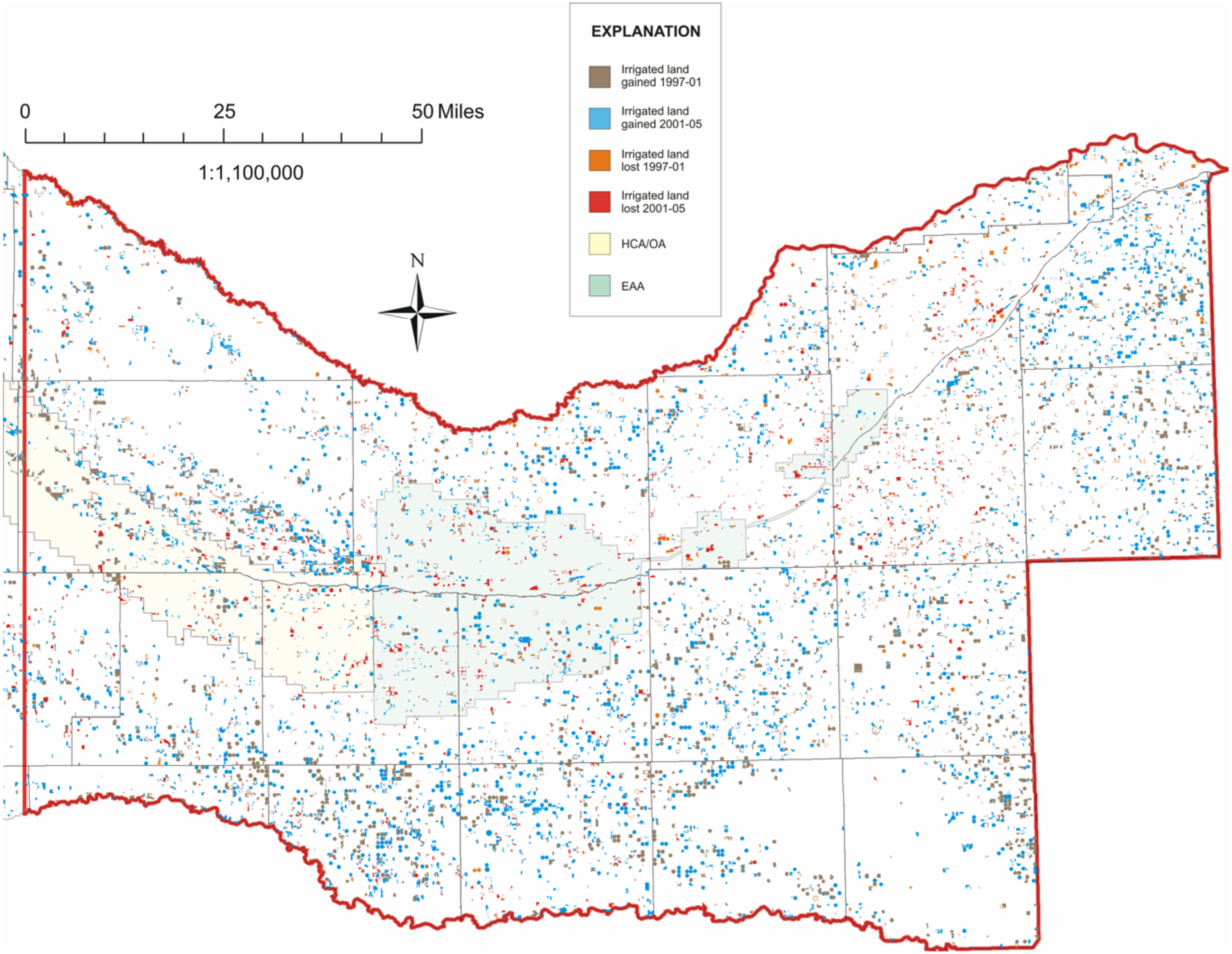


Figure 2 continued. Eastern Model Area.

Table 1. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005 by county. Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 10 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the COHYST part of the county and is from Dappen and Tooze (2001). New wells are for that part of the county within the COHYST area.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Adams	360,900	100	184,670	14,050	1,530	12,520	16,570	770	15,800	28,320	243
Arthur	459,400	90	11,650	310	2,150	-1,840	880	210	680	-1,160	3
Banner	477,300	100	26,860	1,400	1,720	-310	2,780	370	2,410	2,100	22
Box Butte	689,400	64	110,640	10,040	2,290	7,750	11,250	1,130	10,120	17,870	105
Buffalo	623,800	88	208,400	7,910	2,710	5,190	16,690	6,790	9,910	15,100	206
Butler	376,400	0	0	50	0	50	30	0	30	80	0
Chase	574,300	68	120,950	6,130	2,800	3,330	4,850	3,540	1,310	4,640	2
Cheyenne	765,200	100	54,600	4,570	3,840	730	6,770	1,580	5,200	5,930	55
Clay	366,900	100	190,940	13,280	1,510	11,770	9,660	1,430	8,230	20,000	152
Custer	1,647,600	24	48,980	6,660	1,920	4,730	7,580	1,110	6,470	11,200	44
Dawson	652,000	100	155,130	23,010	1,430	21,580	23,110	4,900	18,200	39,780	294
Deuel	281,900	100	18,990	850	1,160	-310	3,160	700	2,450	2,140	23
Franklin	368,700	79	74,050	10,190	990	9,190	15,470	2,360	13,110	22,300	104
Frontier	627,000	100	54,300	13,460	1,060	12,400	19,260	6,300	12,960	25,360	28
Furnas	461,100	22	11,350	4,370	120	4,250	3,630	560	3,070	7,320	78
Garden	1,107,100	99	27,990	3,240	3,880	-640	6,480	680	5,800	5,160	41
Gosper	296,000	100	68,140	7,060	1,280	5,780	8,360	2,490	5,870	11,650	115
Grant	500,900	17	490	0	390	-390	350	0	350	-40	0
Hall	353,200	100	205,270	4,460	3,480	980	7,850	4,110	3,740	4,720	201
Hamilton	349,700	100	239,240	9,160	2,560	6,600	7,360	4,650	2,710	9,310	99
Harlan	367,400	68	48,970	14,560	700	13,860	15,920	1,460	14,450	28,310	100
Hayes	456,400	96	44,250	12,910	2,190	10,720	18,980	2,700	16,270	26,990	132
Hitchcock	459,800	14	7,230	1,170	470	700	3,310	1,160	2,150	2,850	4
Howard	368,200	30	39,380	1,720	1,800	-80	3,720	770	2,950	2,870	59
Kearney	330,200	100	173,760	6,300	1,230	5,080	12,810	4,040	8,770	13,850	231
Keith	709,800	100	82,410	8,270	2,830	5,440	17,780	5,500	12,280	17,720	178

Table 1 continued.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Kimball	609,100	100	30,200	4,060	2,600	1,460	7,550	340	7,210	8,670	40
Lincoln	1,647,100	100	184,470	18,710	6,340	12,370	39,520	3,890	35,640	48,010	350
Logan	365,300	75	14,680	1,840	650	1,190	3,130	110	3,030	4,220	32
McPherson	550,000	55	8,630	250	1,500	-1,250	510	940	-440	-1,690	1
Merrick	316,200	99	179,530	4,260	4,590	-330	5,580	2,590	2,990	2,660	255
Morrill	914,500	100	61,820	5,860	3,470	2,390	4,530	590	3,950	6,340	130
Nance	286,600	24	19,100	1,670	440	1,230	1,530	80	1,450	2,680	49
Nuckolls	368,600	96	35,640	9,970	580	9,390	8,160	130	8,020	17,410	107
Perkins	565,600	100	131,240	6,150	2,500	3,640	8,460	2,840	5,610	9,250	4
Phelps	345,900	100	157,530	3,900	740	3,160	9,090	4,600	4,500	7,660	270
Platte	438,100	13	23,060	740	1,300	-560	1,570	130	1,440	880	37
Polk	282,100	100	135,660	10,370	2,820	7,550	19,090	720	18,370	25,920	125
Red Willow	459,500	38	21,040	3,620	1,170	2,460	5,580	1,080	4,510	6,970	26
Scotts Bluff	476,800	100	7,190	1,110	810	300	1,920	700	1,220	1,520	104
Sheridan	1,580,200	16	2,900	430	370	60	230	240	-10	50	0
Sioux	1,322,600	38	5,830	890	770	130	1,300	680	620	750	30
Webster	368,000	81	35,240	9,420	360	9,060	8,800	330	8,460	17,520	129
York	368,400	100	230,890	14,420	1,350	13,070	12,630	880	11,750	24,820	183
TOTAL	**25,295,200**	**74**	**3,493,290**	**282,780**	**78,380**	**204,400**	**383,780**	**80,170**	**303,610**	**508,010**	**4,391**

Table 2. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005 by Natural Resources District. Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 100 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the COHYST part of the Natural Resources District and is from Dappen and Tooze (2001). New wells are for that part of the Natural Resources District within the COHYST area.

Natural Resources District	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Central Platte	2,136,500	100	812,800	46,000	13,600	32,400	63,200	19,400	43,800	74,500	1,032
Little Blue	1,538,100	57	294,900	33,400	2,600	30,800	29,300	1,200	28,000	58,900	395
Lower Loup	5,092,000	11	128,000	9,400	5,600	3,900	14,400	2,100	12,300	16,100	168
Lower Republican	1,587,100	60	163,300	35,900	2,200	33,600	42,300	4,700	37,600	71,200	412
Middle Republican	2,428,100	71	192,700	35,600	6,700	28,800	53,400	12,100	41,400	71,900	243
North Platte	3,307,000	99	128,800	12,100	10,600	1,500	16,700	2,900	13,800	15,300	323
South Platte	1,661,000	100	103,800	9,500	7,600	1,900	17,500	2,600	14,900	16,700	118
Tri-Basin	971,700	100	399,400	17,300	3,200	14,000	30,300	11,100	19,100	33,200	616
Twin Platte	2,736,300	93	215,700	21,600	10,400	11,200	51,600	9,300	42,300	53,500	477
Upper Big Blue	1,830,900	58	670,800	36,800	6,200	30,600	36,500	6,600	29,900	60,500	461
Upper Loup	4,299,800	6	16,400	2,000	1,600	500	3,600	300	3,300	3,800	32
Upper Niobrara White	4,175,700	21	114,400	10,800	2,700	8,200	11,800	1,500	10,300	18,500	109
Upper Republican	1,730,500	55	252,200	12,300	5,300	7,000	13,300	6,400	6,900	13,900	6
TOTAL	**33,494,700**	**53**	**3,493,300**	**282,800**	**78,400**	**204,400**	**383,800**	**80,200**	**303,600**	**508,000**	**4,391**

Annual Irrigated Land Changes

Land use maps were available for 1997, 2001, and 2005. Between those years, the registered well database from the NDNR was used to scale the gained or lost irrigated land. All irrigation wells not specifically indicated as replacement wells with a completion date on or after July 1, 1997, were selected and the cumulative number of new irrigation wells was calculated for each Model Unit. Some of these wells were used to irrigate new land and some were used to irrigate existing irrigated land. The database does not include information to distinguish between new and existing irrigated land. The number of new registered wells was summed for July 1 through June 30 of the following year (table 3). For example, for the Western Model Unit, 59 new wells were registered from July 1, 1997, through June 30, 1998. This represented approximately 26 percent of the new registered wells for the area through June 30, 2001, so the gained or lost irrigated land for the model period that started May 1, 1998, was assumed to be approximately 26 percent of the gained or lost irrigated land for 2001. Similarly, for July 1, 1998, through June 30, 1999, an additional 49 new wells were added, so the cumulative effect was approximately 48 percent of the gained or lost irrigated land for 2001. A similar process was used for subsequent years.

The 2001 gained irrigated land was as shown in brown on figure 2 and the 2001 lost irrigated land was as shown in orange. This land was retained as gained or lost to irrigation to May 1, 2038, unless the 2001 and 2005 irrigated land maps indicated otherwise (fig. 2). The process of estimating gains or losses in irrigated land began anew with the differences between the 2001 and 2005 land use maps. The 2005 gained irrigated land is shown in cyan on figure 2 and the lost irrigated land is shown as red. The 2002, 2003, and 2004 gained or lost irrigated land was interpolated between 2001 and 2005 using the registered well database as described above.

Gained or lost irrigated land was held constant beginning May 1, 2006, so the analysis does not project gained or lost irrigated land after that date. The assumption of no new net irrigated land after that date is reasonable because most of the area has been designated as Fully Appropriated or Overappropriated, which prohibits expansion of irrigated land.

Scaling gained or lost irrigated land between land-use map dates means that irrigated land gained or lost for other years was assumed to be near gained or lost irrigated land between land use map dates. This assumption seems reasonable and information to do otherwise was not available.

Table 3. Well registration data used to interpolate between 1997 and 2001 or between 2001 and 2005. The three Model Units sum to more than the COHYST area because of model overlap. The * indicates that counting new wells starts over July 1, 2001.

Year ending June 20	Number of new irrigation wells registered	Cumulative number of new wells	Ratio of cumulative new wells to 2001 or 2005	Ration applied to year ending May 1
Western Model Unit				
1998	59	59	0.265	1999
1999	49	108	0.484	2000
2000	58	166	0.744	2001
2001	57	223	1.000	2002
2002	89	* 89	0.228	2003
2003	198	287	0.736	2004
2004	98	385	0.987	2005
2005	5	390	1.000	2006-38
Central Model Unit				
1998	170	170	0.398	1999
1999	76	246	0.576	2000
2000	65	311	0.728	2001
2001	116	427	1.000	2002
2002	170	* 170	0.215	2003
2003	264	434	0.548	2004
2004	279	713	0.900	2005
2005	79	792	1.000	2006-38
Eastern Model Unit				
1998	336	336	0.342	1999
1999	180	516	0.524	2000
2000	220	736	0.748	2001
2001	248	984	1.000	2002
2002	299	* 299	0.146	2003
2003	621	920	0.449	2004
2004	615	1,535	0.750	2005
2005	513	2,048	1.000	2006-38
Entire COHYST Area				
1998	503	503	0.339	1999
1999	279	782	0.528	2000
2000	321	1,103	0.744	2001
2001	379	1,482	1.000	2002
2002	506	* 506	0.179	2003
2003	937	1,443	0.511	2004
2004	841	2,284	0.808	2005
2005	542	2,826	1.000	2006-38

Net Irrigation Requirements

The next step was to determine the average net irrigation requirements for the irrigation seasons beginning May 1 of 1997, 2001, and 2005. The 1997-98 CropSim net irrigation requirement for each crop, reduced by 10 percent, was combined with the 1997-98 land-use map for each Model Unit to compute the area weighted average 1997-98 net irrigation requirement for each Model Unit. The 10 percent reduction accounted for less-than-ideal crops in the real world, because real-world crops are less healthy, do not always receive all the nutrients and water they would like, are stressed by insects and other pests, and thus consume less water. Table 4 shows the 1997-98 net irrigation requirements for each Model Unit; table 5 shows the 2001-02 net irrigation requirements; and table 6 shows the 2005-06 net irrigation requirements. Because the net irrigation requirements represent an area weighted average of all crops and because corn is the dominant crop in all areas, its net irrigation requirement dominates the average.

The differences in net irrigation requirements shown in tables 4-6 were solely a function of differences in crop mix because 1997 meteorological conditions were used in all calculations. For example, soybeans became a larger part of the crop mix between 1997 and 2001 and corn became a smaller part (although still dominant). Because soybeans use less water than corn, the 2001 net irrigation requirement was smaller than the 1997 net irrigation requirement. The seasonal net irrigation requirements for 1998-99 through 2000-01 were linear interpolations of the net irrigation requirement for 1997-98 and 2001-02 and the seasonal net irrigation requirements for 2002-03 through 2004-05 were linear interpolations of the 2001-02 and 2005-06 net irrigation requirements. The 2005-06 seasonal net irrigation requirements were used after 2005.

Net Pumpage

The final step was to multiply gained or lost irrigated land (fig. 2) by net irrigation requirements (tables 4-6) for each year to get net pumpage due to increased or decreased irrigated land for that year. Most of this net pumpage occurred during the May through September period, but some net pumpage occurred on alfalfa and small grains during the October through April period. By the sign convention used in the groundwater flow models, net pumpage due to increased irrigated land was negative and net pumpage due to decreased irrigated land was positive. Table 5 shows the sum of net pumpage due to increased and decreased irrigated land for 2001-02 for each Model Unit using the opposite sign convention. Table 6 shows the sum of net pumpage due to increased and decreased irrigated land for 2005-06 for each Model Unit.

Table 4. 1997-98 net irrigation requirement for each Model Unit. Differences between annual and seasonal numbers are due to rounding. Net irrigation requirement occurs in the non-irrigation season because of alfalfa and wheat.

Area	1997-98 net irrigation requirement, irrigation season (inches)	1997-98 net irrigation requirement, non-irrigation season (inches)	1997-98 net irrigation requirement, annual (inches)
Western Model Unit	15.06	0.87	15.94
Central Model Unit	11.40	0.03	11.43
Eastern Model Unit	7.79	0.01	7.80

Table 5. 2001-02 net irrigation requirement and net pumpage due to gained or lost irrigated land for each Model Unit. Differences between annual and seasonal net irrigation requirement area are due to rounding. Note that net pumpage cannot be summed to get total because of model overlap. Net irrigation requirement occurs in the non-irrigation season because of alfalfa and wheat.

Area	2001-02 net irrigation requirement, irrigation season (inches)	2001-02 net irrigation requirement, non-irrigation season (inches)	2001-02 net irrigation requirement, annual (inches)	2001-02 new net pumpage, annual (acre-feet)
Western Model Unit	14.14	0.86	15.00	16,900
Central Model Unit	9.24	0.02	9.26	60,700
Eastern Model Unit	7.68	0.01	7.70	94,100

Table 6. 2005-06 net irrigation requirement and net pumpage due to gained or lost irrigated land for each Model Unit. Differences between annual and seasonal net irrigation requirement area are due to rounding. Note that net pumpage cannot be summed to get total because of model overlap. Net irrigation requirement occurs in the non-irrigation season because of alfalfa and wheat.

Area	2005-06 net irrigation requirement, irrigation season (inches)	2005-06 net irrigation requirement, non-irrigation season (inches)	2005-06 net irrigation requirement, annual (inches)	2005-06 new net pumpage, annual (acre-feet)
Western Model Unit	14.78	0.91	15.69	71,500
Central Model Unit	7.20	0.18	7.38	135,400
Eastern Model Unit	7.71	0.01	7.72	205,100

Modeling Procedures

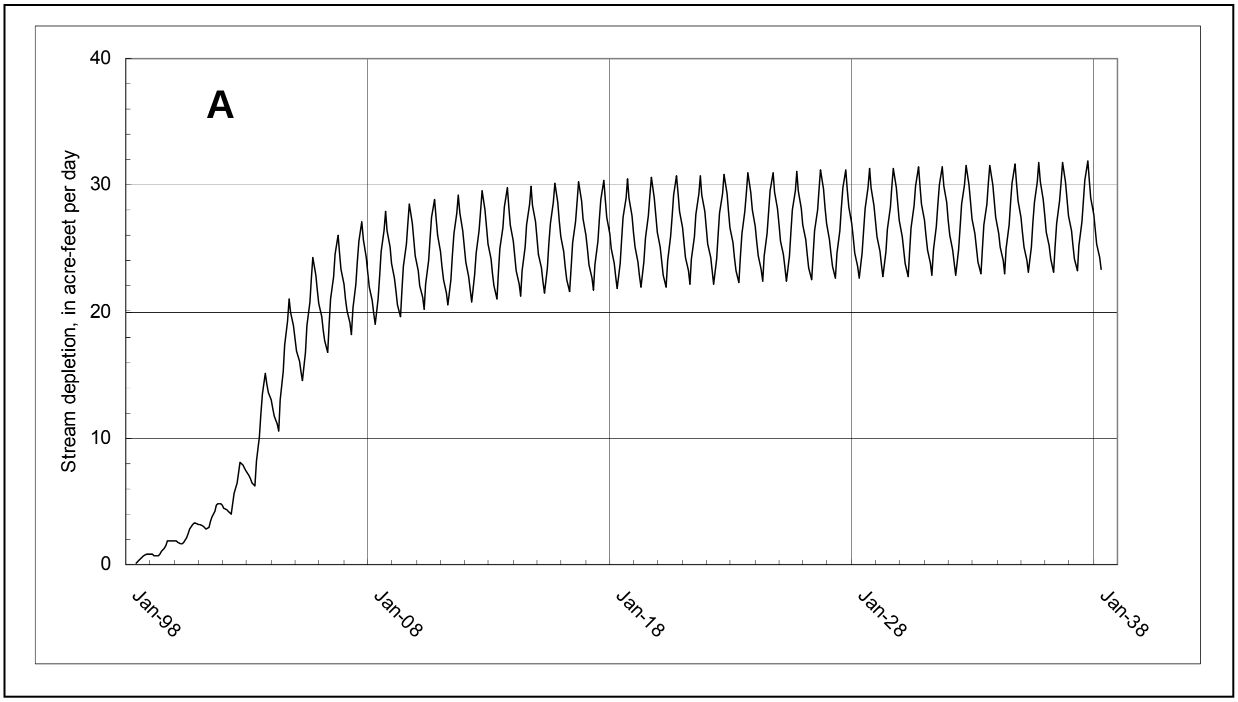
The models were first run for 40 years without any new net pumpage to establish a baseline case. These models produced cumulative water budgets for each month of each year. The models were then run for 40 years with the new net pumpage added to the models and these models also produced cumulative water budgets for each month. The difference between the two water budgets on any given date is the effect of the new net pumpage on the hydrologic system.

Results – Part I

Figure 3 shows the monthly stream depletion due to new net pumpage after July 1, 1997, for each area. For Wyoming line to Kingsley Dam, stream depletion due to gained or lost irrigated land after July 1, 1997, was 27.1 acre-feet per day on October 1, 2007, and was 18.9 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land was 29.7 acre-feet per day on October 1, 2013, and was 21.3 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 89,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 31.9 acre-feet per day on October 1, 2037, and was 23.3 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigated land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 0.6 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 328,000 acre-feet.

For Kingsley Dam to Tri-County Supply Canal diversion, stream depletion due to gained or lost irrigated land after July 1, 1997, was 32.9 acre-feet per day on October 1, 2007, and was 14.6 acre-feet per day on May 1, 2008 (fig. 3). Stream depletion due to gained or lost irrigated land was 38.8 acre-feet per day on October 1, 2013, and was 20.5 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 102,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 49.5 acre-feet per day on October 1, 2037, and was 31.5 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 3.1 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 422,000 acre-feet.

1 acre-foot per day = 0.504 cubic feet per second
226 gallons per minute



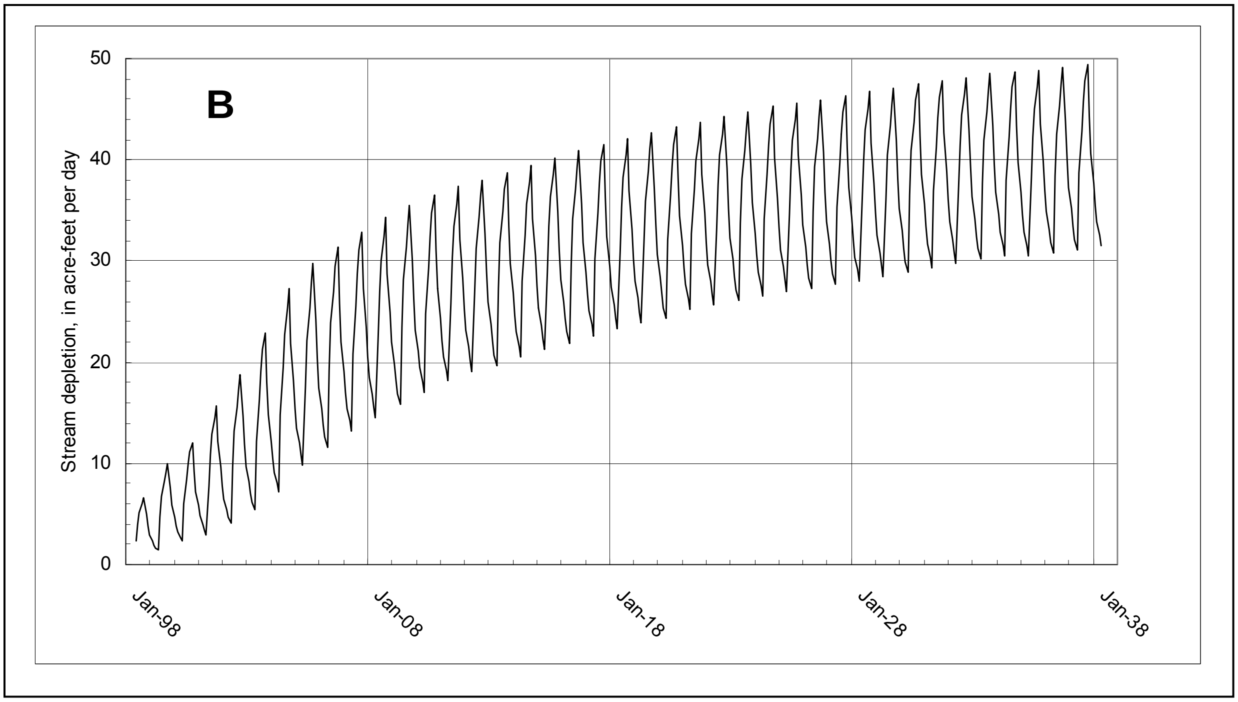
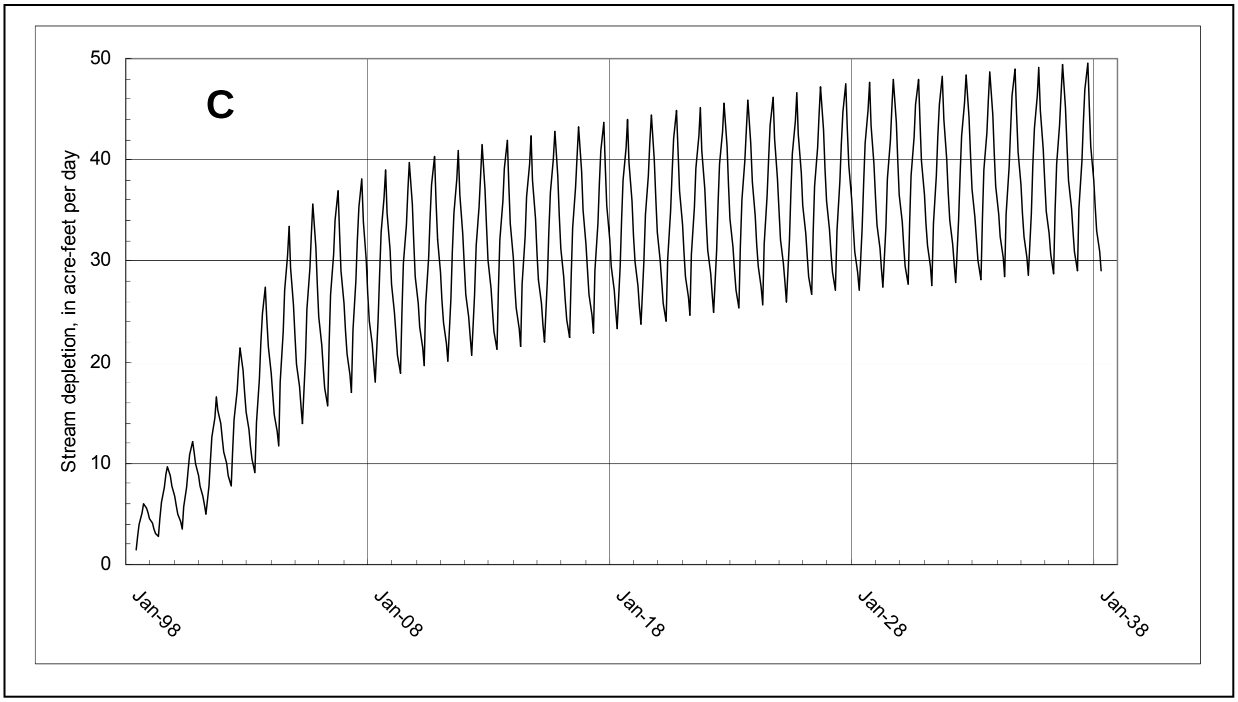
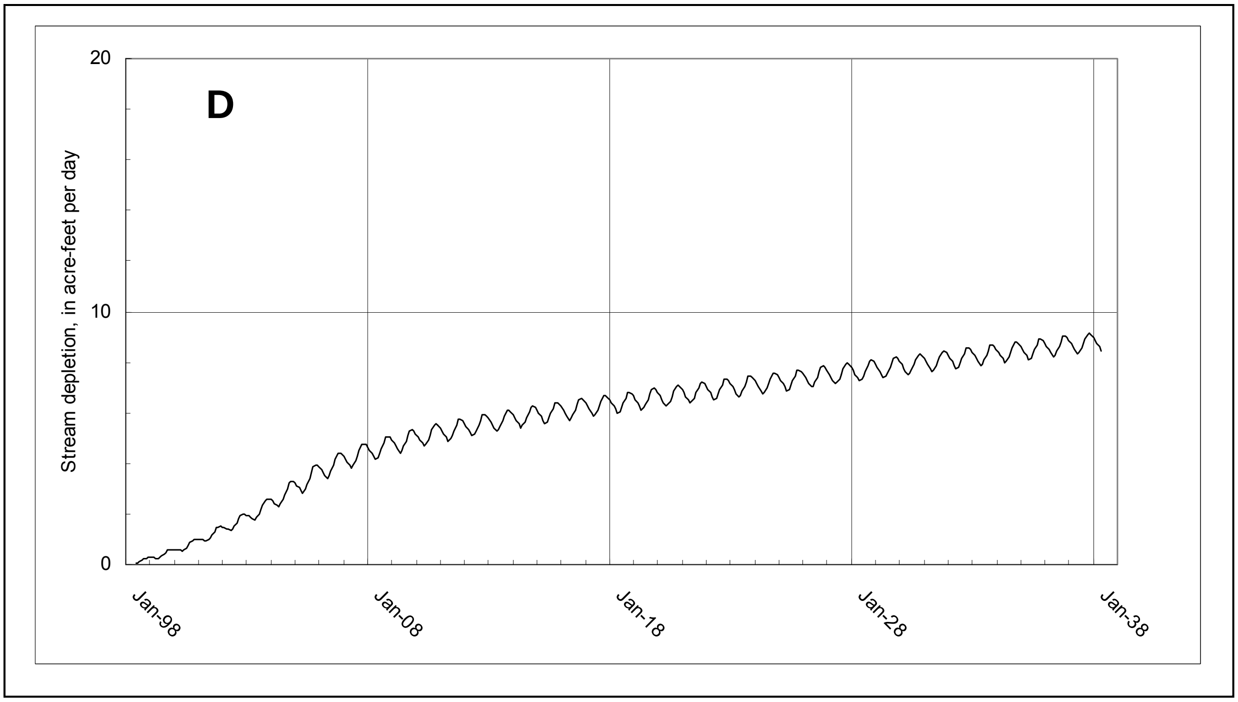


Figure 3. Monthly stream depletion to the Platte River system due to groundwater-irrigated lands gained or lost between July 1, 1997, and June 30, 2006, for each area. A) Wyoming line to Kingsley Dam; B) Kingsley Dam to Tri-County Supply Canal diversion; C) Tri-County Supply Canal diversion to Lexington; D) Lexington to U.S. Highway 183; E) U.S. Highway 183 to Chapman; and F) Chapman to Columbus.





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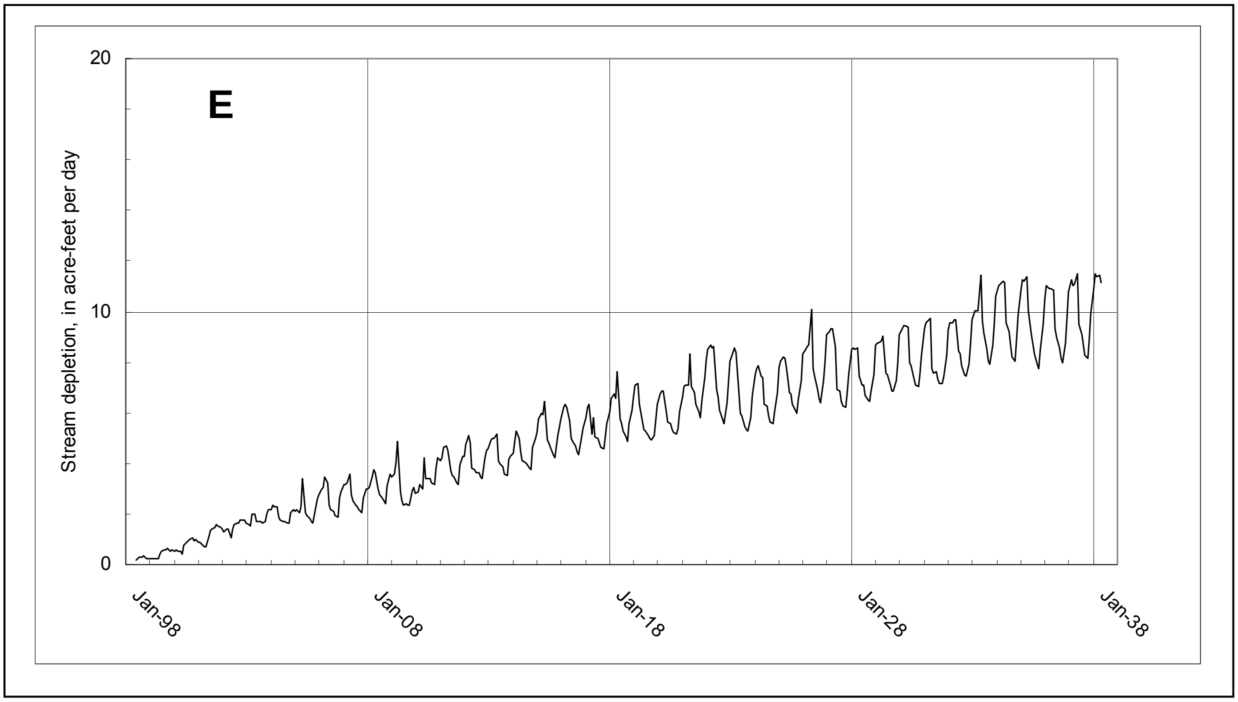

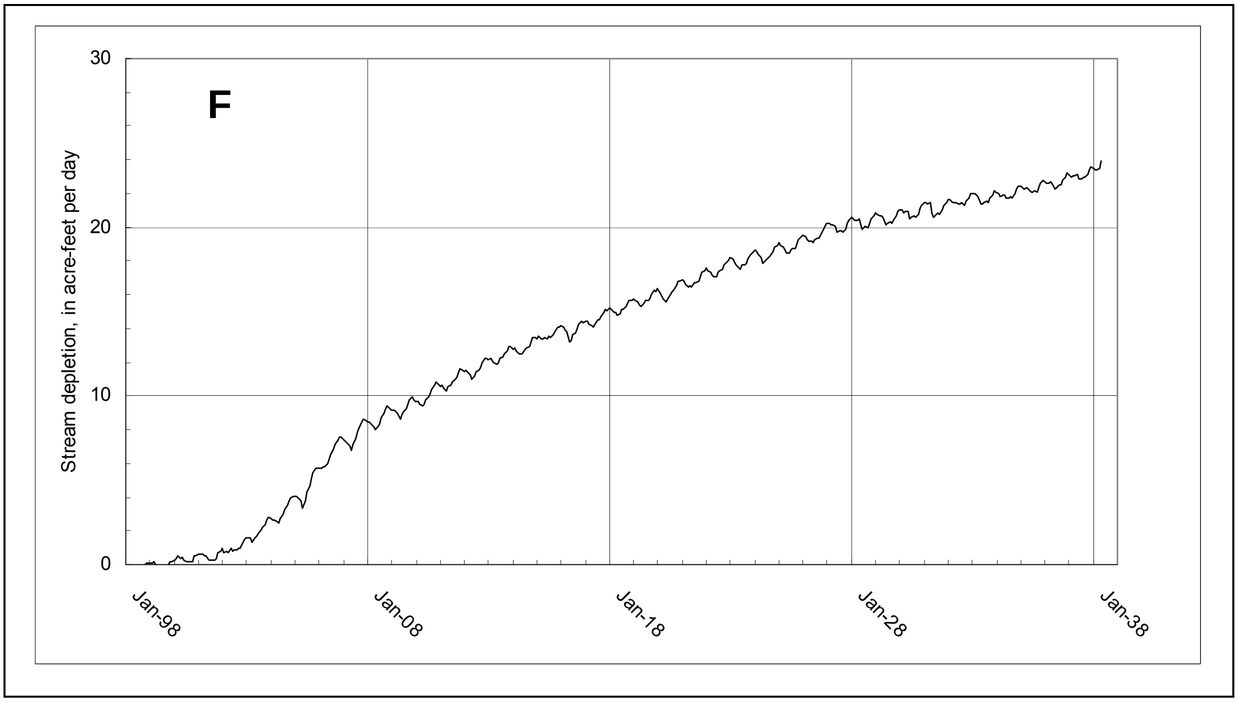

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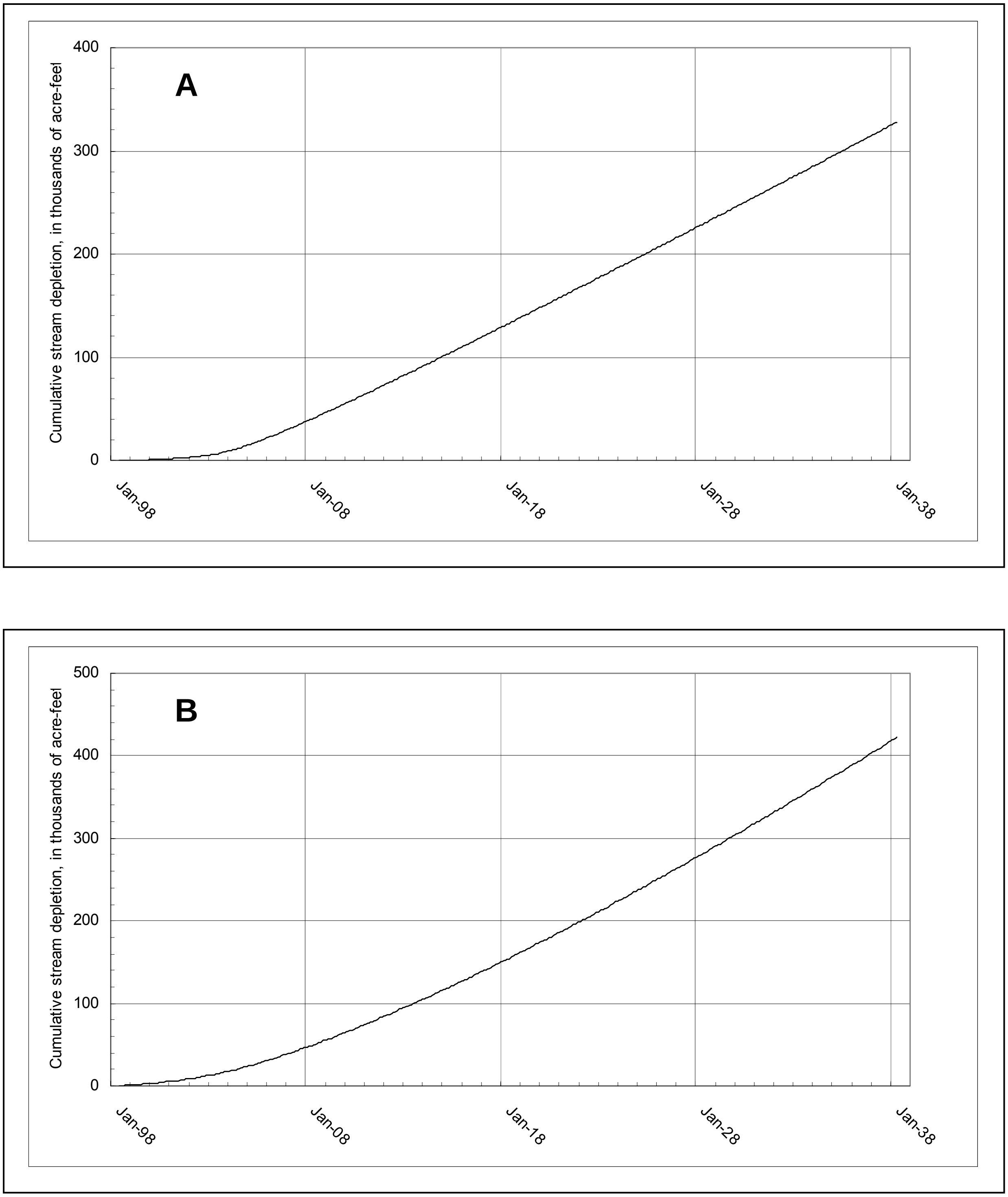
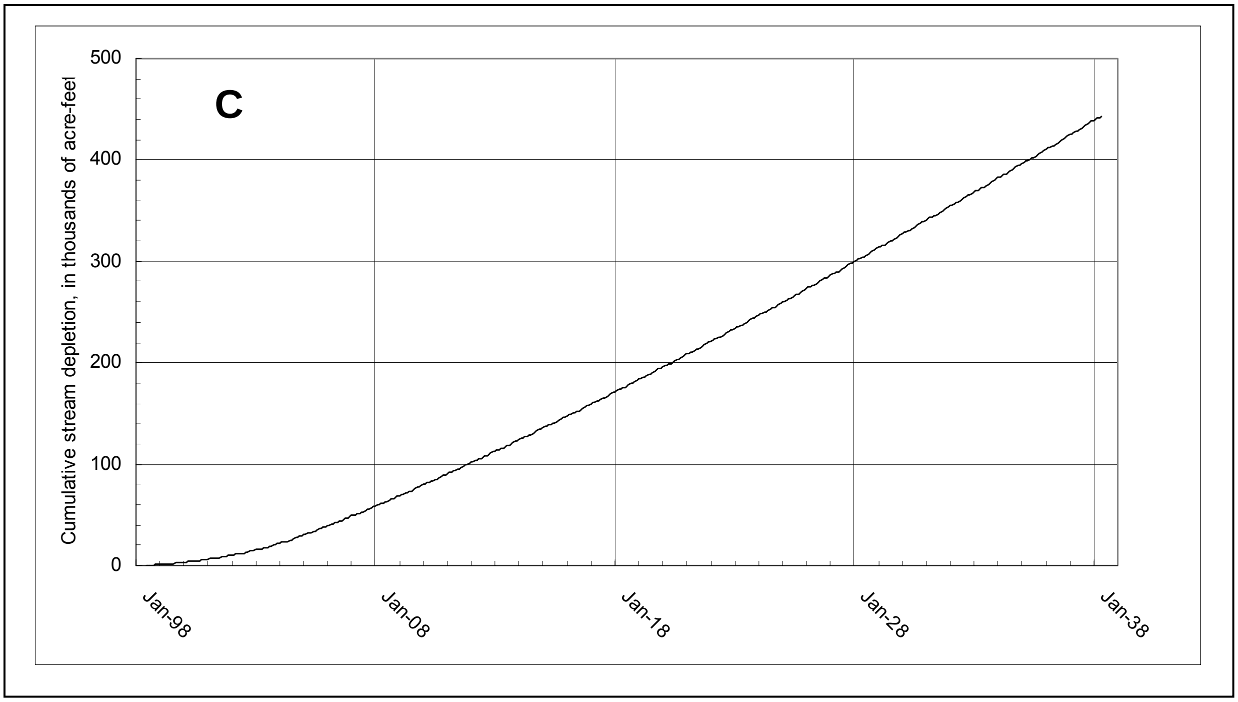


Figure 4. Cumulative stream depletion to the Platte River system due to groundwater-irrigated lands gained or lost between July 1, 1997, and June 30, 2006, for each area. A) Wyoming line to Kingsley Dam; B) Kingsley Dam to Tri-County Supply Canal diversion; C) Tri-County Supply Canal diversion to Lexington; D) Lexington to U.S Highway 183; E) U.S. Highway 183 to Chapman; and F) Chapman to Columbus.



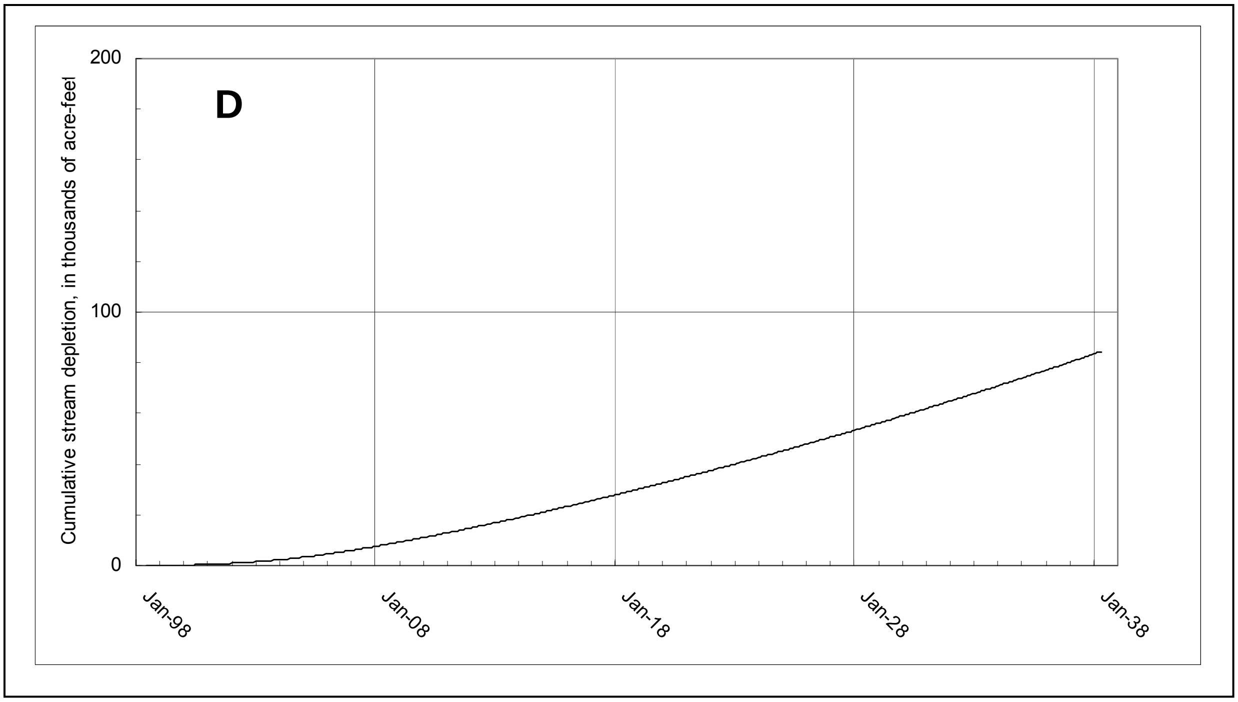
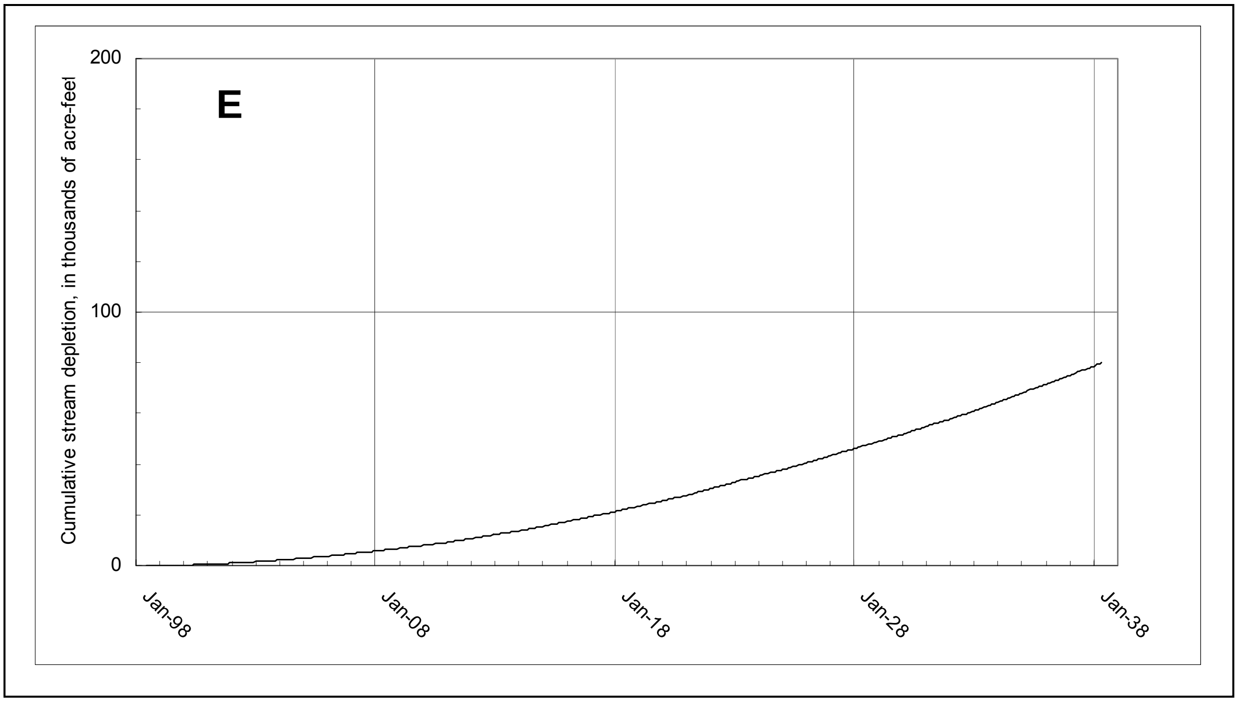


Figure 4 continued.



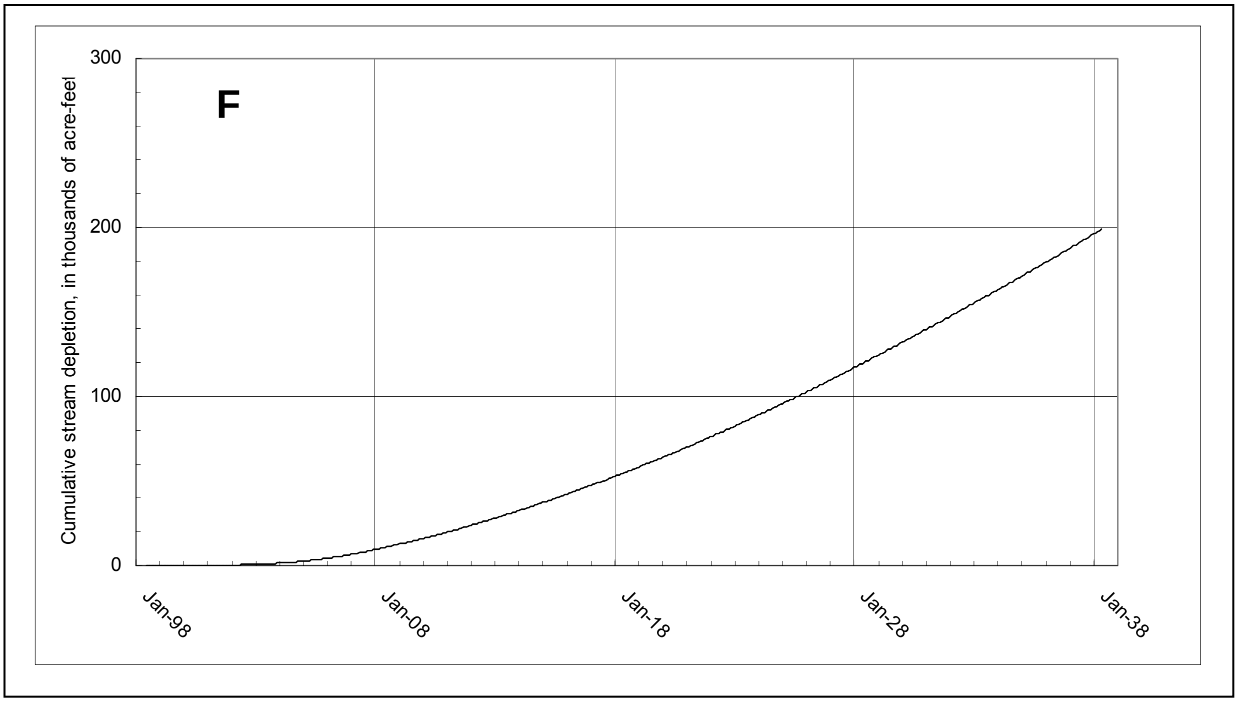


Figure 4 continued.

For Tri-County Supply Canal diversion to Lexington, stream depletion due to gained or lost irrigated land after July 1, 1997, was 38.1 acre-feet per day on October 1, 2007, and was 18.0 acre-feet per day on May 1, 2008 (fig. 3). Stream depletion due to gained or lost irrigated land was 41.9 acre-feet per day on October 1, 2013, and was 21.6 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 121,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 49.6 acre-feet per day on October 1, 2037, and was 29.1 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 2.1 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 442,000 acre-feet.

For Lexington to U.S. Highway 183, stream depletion due to gained or lost irrigated land after July 1, 1997, was 4.7 acre-feet per day on October 1, 2007, and was 4.1 acre-feet per day on May 1, 2008 (fig. 3). Stream depletion due to gained or lost irrigated land was 6.1 acre-feet per day on October 1, 2013, and was 5.4 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 18,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 9.1 acre-feet per day on October 1, 2037, and was 8.5 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 1.2 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 84,000 acre-feet.

For U.S. Highway 183 to Chapman, stream depletion exhibits some apparent noise. This noise is thought to be due to numerical instability in techniques used to solve the groundwater flow equations. The overall trend of the results is thought to be reasonable, but the noise obscures some of the details. An effort was made to reduce or eliminate this noise, and the curve shown in figure 3 is the result of that effort. Stream depletion due to gained or lost irrigated land after July 1, 1997, was 2.0 acre-feet per day on October 1, 2007, and was 3.6 acre-feet per day on May 1, 2008 (fig. 3). Stream depletion due to gained or lost irrigated land was 3.5 acre-feet per day on October 1, 2013, and was 4.5 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 13,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 8.1 acre-feet per day on October 1, 2037, and was 11.2 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the general trend of the data was 1.9 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 80,000 acre-feet.

For Chapman to Columbus, stream depletion due to gained or lost irrigated land after July 1, 1997, was 8.4 acre-feet per day on October 1, 2007, and was 8.0 acre-feet per day on May 1, 2008 (fig. 3). Stream depletion due to gained or lost irrigated land was 12.7 acre-feet per day on October 1, 2013, and was 12.5 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 31,000 acre-feet (fig. 4). Stream depletion due to gained or lost irrigated land was 23.2 acre-feet per day on October 1, 2037, and was 23.9 acre-feet per day on May 1, 2038. Figure 3 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the general trend of the data was 3.3 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 199,000 acre-feet.

For Wyoming line to Columbus, stream depletion due to gained or lost irrigated land after July 1, 1997, was 113 acre-feet per day on October 1, 2007, and was 67 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land was 133 acre-feet per day on October 1, 2013, and was 86 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land through October 1, 2013 was 370,000 acre-feet. Stream depletion due to gained or lost irrigated land was 171 acre-feet per day on October 1, 2037, and was 128 acre-feet per day on May 1, 2038. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 1,560,000 acre-feet.

Table 7 shows stream depletions for each area due to gained or lost groundwater-irrigated land after 1997 for other dates. The dates in table 7 were chosen for convenience to correspond to dates consistent with the Platte River Recovery Implementation Program that Nebraska may choose to participate in.

Table 7. Stream depletion to Platte River system due to groundwater-irrigated lands gained or lost between July 1, 1997, and June 30, 2006, for each area.

Date	Stream depletion (acre-feet/day)	Cumulative steam depletion (thousands of acre-feet)
Wyoming line to Kingsley Dam **A**		
Oct. 1, 2001	4.7	2
May 1, 2002	4.0	3
Oct. 1, 2007	27.1	35
May 1, 2008	18.9	40
Oct. 1, 2013	29.7	89
May 1, 2014	21.3	94
Oct. 1, 2020	30.7	155
May 1, 2021	22.2	160
Oct. 1, 2037	31.9	322
May 1, 2038	23.3	328
Kingsley Dam to Tri-County Supply Canal **B**		
Oct. 1, 2001	15.7	8
May 1, 2002	4.1	9
Oct. 1, 2007	32.9	45
May 1, 2008	14.6	49
Oct. 1, 2013	38.8	102
May 1, 2014	20.5	108
Oct. 1, 2020	43.2	183
May 1, 2021	25.2	189
Oct. 1, 2037	49.5	414
May 1, 2038	31.5	422
Tri-County Supply Canal to Lexington **C**		
Oct. 1, 2001	16.6	9
May 1, 2002	7.8	11
Oct. 1, 2007	38.1	56
May 1, 2008	18.0	61
Oct. 1, 2013	41.9	121
May 1, 2014	21.6	127
Oct. 1, 2020	44.8	205
May 1, 2021	24.7	211
Oct. 1, 2037	49.6	434
May 1, 2038	29.1	442
Lexington to U.S. Highway 183 **D**		
Oct. 1, 2001	1.4	1
May 1, 2002	1.4	1
Oct. 1, 2007	4.7	7
May 1, 2008	4.1	8
Oct. 1, 2013	6.1	18
May 1, 2014	5.4	30
Oct. 1, 2020	7.1	34
May 1, 2021	6.4	36
Oct. 1, 2037	9.1	83
May 1, 2038	8.5	84

Date	Stream depletion (acre-feet/day)	Cumulative steam depletion (thousands of acre-feet)
U.S. Highway 183 to Chapman **E**		
Oct. 1, 2001	1.6	1
May 1, 2002	1.1	1
Oct. 1, 2007	2.0	5
May 1, 2008	3.6	6
Oct. 1, 2013	3.5	13
May 1, 2014	4.5	14
Oct. 1, 2020	5.2	27
May 1, 2021	8.3	29
Oct. 1, 2037	8.1	78
May 1, 2038	11.2	80
Chapman to Columbus **F**		
Oct. 1, 2001	0.3	0
May 1, 2002	1.0	1
Oct. 1, 2007	8.4	9
May 1, 2008	8.0	11
Oct. 1, 2013	12.7	31
May 1, 2014	12.5	34
Oct. 1, 2020	16.5	68
May 1, 2021	16.5	72
Oct. 1, 2037	23.2	194
May 1, 2038	23.9	199
TOTAL		
Oct. 1, 2001	40	20
May 1, 2002	19	30
Oct. 1, 2007	113	160
May 1, 2008	67	180
Oct. 1, 2013	133	370
May 1, 2014	86	410
Oct. 1, 2020	148	670
May 1, 2021	103	700
Oct. 1, 2037	171	1,530
May 1, 2038	128	1,560

Results – Part II

The NDNR also asked for an analysis of only that gained or lost irrigated land within the Hydrologically Connected Area for the Overappropriated Basin (HCA/OA) (fig. 2). The purpose of this analysis was to provide technical information regarding the impacts on streamflow from new uses of groundwater from these areas and should not be interpreted as a policy by either the NDNR or the COHYST Sponsors. The HCA/OA starts at the Wyoming state line and ends at U.S. Highway 183. Downstream of U.S. Highway 183, NDNR asked for a similar analysis for the area bounded by the 10 percent stream depletion in 50 years lines downstream to Chapman. The area bounded by the 10 percent stream depletion in 50 years was determined by the NDNR with assistance from several agencies, including the Central Platte Natural Resources District and the Upper Big Blue Natural Resources District. In the Tri-Basin and Upper Big Blue Natural Resources Districts, this line was used when the reach was determined to be Fully Appropriated. The 10 percent in 50 years lines do not exactly meet the HCA/OA, so a north-south line was used to connect them. The polygon formed by the10 percent in 50 years lines, the eastern end of the Fully Appropriated Area, and the north-south line on the west is termed the Eastern Analysis Area (EAA) in this report. The EAA has no legal standing under Nebraska law and is used only to aid in understanding the source of stream depletion.

The second analysis was done exactly the same way as the first analysis, except that net pumpage on gained or lost irrigated land after July 1, 1997, was set to zero outside of the HCA/OA and EAA. For 1997 to 2001, there was a net gain of 28,400 irrigated acres inside the HCA/OA and EAA. For 2001 to 2005, there was a net gain of 43,590 irrigated acres inside the HCA/OA and EAA. For 1997 to 2005, there was a net gain of 72,000 irrigated acres inside the HCA/OA and EAA. Table 8 summarizes the gained and lost irrigated acres inside the HCA/OA and EAA by county for 1997 to 2001 and 2001 to 2005. The table also lists the 1997 to 2005 net gained irrigated land inside the HCA/OA and EAA. Table 9 summarizes the gained and lost irrigated acres inside the HCA/OA and EAA by Natural Resources District.

The same baseline case was used in both analyses. In the second analysis, the groundwater flow models were run for 40 years beginning on May 1, 1998, with net pumpage on gained or lost irrigated land inside the HCA/OA and the EAA. These models produced cumulative water budgets at the end of each month. The difference between the baseline water budget and the second analysis water budget on any given date is the effects of the gained or lost net pumpage inside the HCA/OA and the EAA on the hydrologic system.

Results of the second analysis are presented in a similar manner as was done in the first analysis. Figure 5 shows the monthly stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and the EAA for each area. Table 10 shows stream depletions for each area due to gained or lost irrigated land after 1997 inside the same areas for other dates. Graphs of cumulative stream depletion are not presented because they are similar to those in figure 3, although they end at different values. The ending values can be determined from table 10.

Table 8. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005 inside the HCA/OA and EAA by county. Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 10 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the HCA/OA and EAA and is from Dappen and Tooze (2001). New wells are for that part of the county within the HCA/OA and EAA areas.

County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells in HCA/OA and EAA
				Gained	Lost	Net	Gained	Lost	Net		
Adams	360,900	100	0	0	0	0	0	0	0	0	0
Arthur	459,400	90	0	0	0	0	0	0	0	0	0
Banner	477,300	100	21,220	1,110	1,400	-290	2,170	250	1,910	1,620	19
Box Butte	689,400	64	0	0	0	0	0	0	0	0	0
Buffalo	623,800	88	89,050	1,770	600	1,170	4,700	4,620	80	1,260	74
Butler	376,400	0	0	0	0	0	0	0	0	0	0
Chase	574,300	68	0	0	0	0	0	0	0	0	0
Cheyenne	765,200	100	17,430	1,750	1,820	-80	1,650	960	690	610	14
Clay	366,900	100	0	0	0	0	0	0	0	0	0
Custer	1,647,600	24	0	0	0	0	0	0	0	0	0
Dawson	652,000	100	50,300	9,180	180	9,000	7,290	2,270	5,030	14,020	99
Deuel	281,900	100	11,730	780	590	180	550	700	-150	30	8
Franklin	368,700	79	0	0	0	0	0	0	0	0	0
Frontier	627,000	100	270	690	0	690	0	70	-70	610	0
Furnas	461,100	22	0	0	0	0	0	0	0	0	0
Garden	1,107,100	99	15,410	2,910	1,990	920	4,070	100	3,980	4,890	31
Gosper	296,000	100	22,630	1,250	280	970	1,460	1,380	80	1,050	29
Grant	500,900	17	0	0	0	0	0	0	0	0	0
Hall	353,200	100	18,630	730	550	180	630	1,460	-830	-650	21
Hamilton	349,700	100	3,550	190	10	180	40	60	-10	160	3
Harlan	367,400	68	0	0	0	0	0	0	0	0	0
Hayes	456,400	96	0	0	0	0	0	0	0	0	0
Hitchcock	459,800	14	0	0	0	0	0	0	0	0	0
Howard	368,200	30	0	0	0	0	0	0	0	0	0
Kearney	330,200	100	71,470	2,310	960	1,350	5,420	2,240	3,190	4,540	120

Table 8 continued.

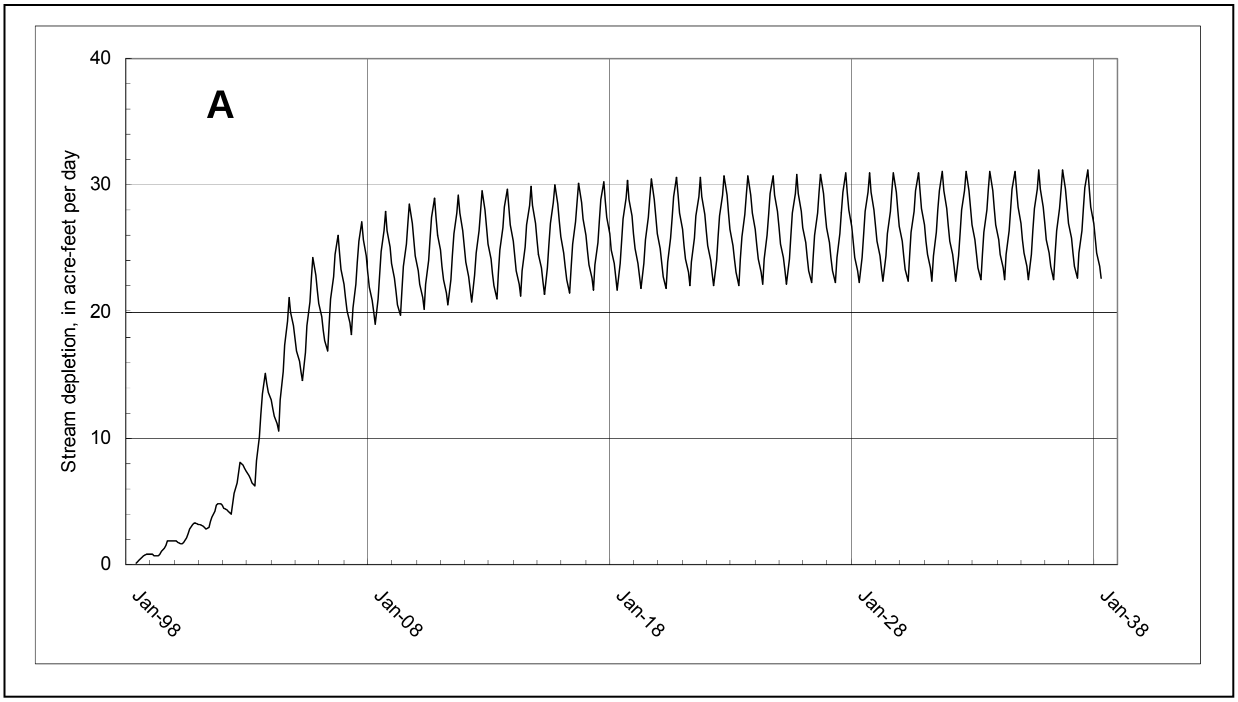
County	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells in HCA/OA and EAA
				Gained	Lost	Net	Gained	Lost	Net		
Keith	709,800	100	57,720	6,040	2,020	4,020	10,450	4,470	5,980	10,010	109
Kimball	609,100	100	13,220	1,640	900	740	1,610	300	1,310	2,050	13
Lincoln	1,647,100	100	58,200	9,250	2,410	6,840	20,080	2,500	17,580	24,420	185
Logan	365,300	75	0	0	0	0	0	0	0	0	0
McPherson	550,000	55	2,890	50	20	30	0	240	-240	-210	0
Merrick	316,200	99	11,260	220	130	90	360	60	300	390	19
Morrill	914,500	100	41,410	3,690	3,220	460	3,070	360	2,710	3,170	112
Nance	286,600	24	0	0	0	0	0	0	0	0	0
Nuckolls	368,600	96	0	0	0	0	0	0	0	0	0
Perkins	565,600	100	0	0	0	0	0	0	0	0	0
Phelps	345,900	100	94,750	2,070	460	1,610	4,490	4,180	310	1,920	221
Platte	438,100	13	0	0	0	0	0	0	0	0	0
Polk	282,100	100	0	0	0	0	0	0	0	0	0
Red Willow	459,500	38	0	0	0	0	0	0	0	0	0
Scotts Bluff	476,800	100	4,980	1,090	540	550	1,490	450	1,040	1,590	103
Sheridan	1,580,200	16	0	0	0	0	0	0	0	0	0
Sioux	1,322,600	38	3,910	460	680	-230	920	200	710	490	25
Webster	368,000	81	0	0	0	0	0	0	0	0	0
York	368,400	100	0	0	0	0	0	0	0	0	0
TOTAL	**25,295,200**	**74**	**610,040**	**47,170**	**18,770**	**28,400**	**70,460**	**26,870**	**43,590**	**72,000**	**1,205**

Table 9. Gained and lost groundwater irrigated land for July 1, 1997, through June 30, 2001, and July 1, 2001, through June 30, 2005 inside the HCA/OA and EAA by Natural Resources District. Net columns may not be the same as the difference between Gained and Lost columns because the numbers were rounded to the nearest 100 acres. Likewise, Total row may not be the same as the sum of the shown numbers because of rounding. 1997 irrigated acres represents groundwater irrigated acres in the COHYST part of Natural Resources District that is in the HCA/OA and EAA and is from Dappen and Tooze (2001). New wells are for that part of the Natural Resources District within the HCA/OA and EAA areas.

Natural Resources District	Area (acres)	Percent in COHYST	1997 irrigated acres	1997 to 2001 groundwater acres			2001 to 2005 groundwater acres			1997-05 net groundwater acres	1997-05 new wells
				Gained	Lost	Net	Gained	Lost	Net		
Central Platte	2,136,500	100	169,500	12,300	1,500	10,800	13,000	8,500	4,500	15,300	213
Little Blue	1,538,100	57	0	0	0	0	0	0	0	0	0
Lower Loup	5,092,000	11	0	0	0	0	0	0	0	0	0
Lower Republican	1,587,100	60	0	0	0	0	0	0	0	0	0
Middle Republican	2,428,100	71	0	0	0	0	0	0	0	0	0
North Platte	3,307,000	99	86,900	9,200	7,600	1,600	11,600	1,700	9,900	11,500	290
South Platte	1,661,000	100	42,400	4,200	3,300	800	3,800	2,000	1,800	2,600	35
Tri-Basin	971,700	100	188,900	5,600	1,700	3,900	11,400	7,400	4,000	7,900	370
Twin Platte	2,736,300	93	118,800	15,400	4,500	10,900	30,500	7,200	23,400	34,300	294
Upper Big Blue	1,830,900	58	3,500	100	0	100	0	100	0	100	3
Upper Loup	4,299,800	6	0	0	0	0	0	0	0	0	0
Upper Niobrara White	4,175,700	21	0	0	0	0	0	0	0	0	0
Upper Republican	1,730,500	55	0	0	0	0	0	0	0	0	0
TOTAL	**33,494,700**	**53**	**610,000**	**46,800**	**18,700**	**28,100**	**70,300**	**26,800**	**43,600**	**71,600**	**1,205**

For Wyoming line to Kingsley Dam, stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 27.1 acre-feet per day on October 1, 2007, and was 19.0 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 29.7 acre-feet per day on October 1, 2013, and was 21.2 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 89,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 31.2 acre-feet per day on October 1, 2037, and was 22.6 acre-feet per day on May 1, 2038. Figure 5 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 0.3 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 325,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA was 99 percent of cumulative steam depletion with new net pumpage everywhere.

For Kingsley Dam to Tri-County Supply Canal diversion, stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 31.9 acre-feet per day on October 1, 2007, and was 13.3 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 35.7 acre-feet per day on October 1, 2013, and was 16.8 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 97,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 39.4 acre-feet per day on October 1, 2037, and was 20.7 acre-feet per day on May 1, 2038. Figure 5 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 0.6 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 350,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA was 83 percent of cumulative steam depletion with new net pumpage everywhere.



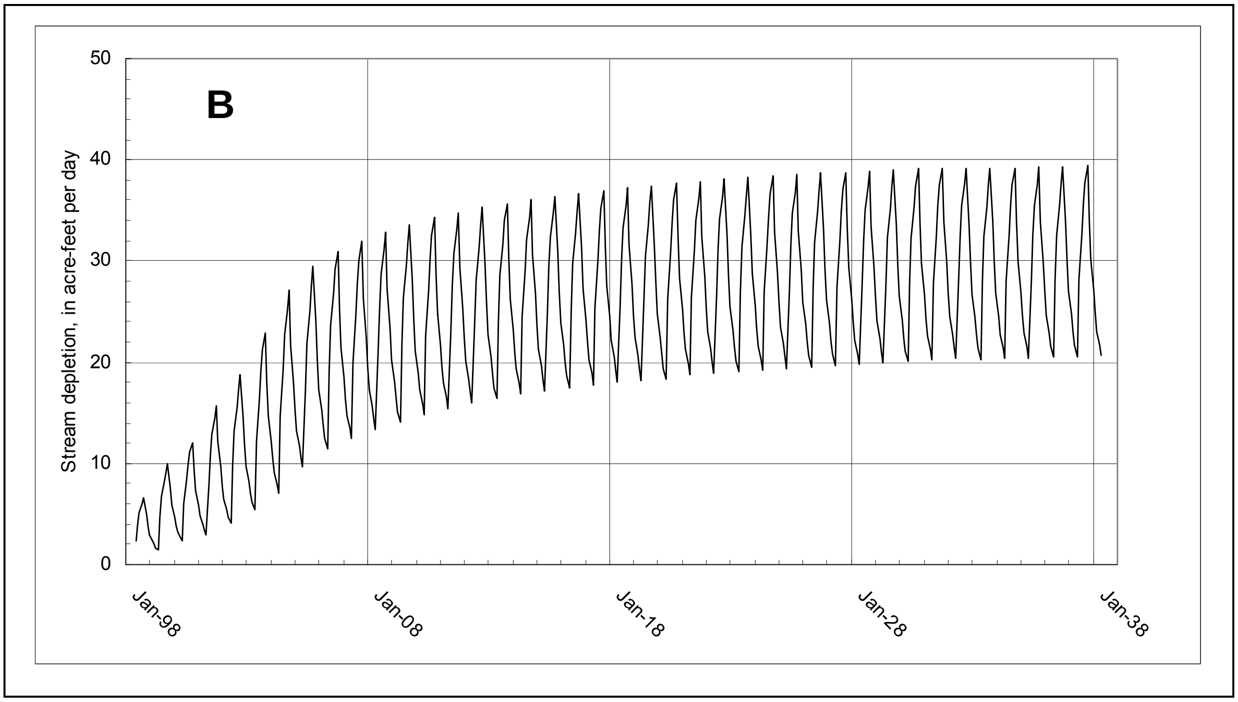
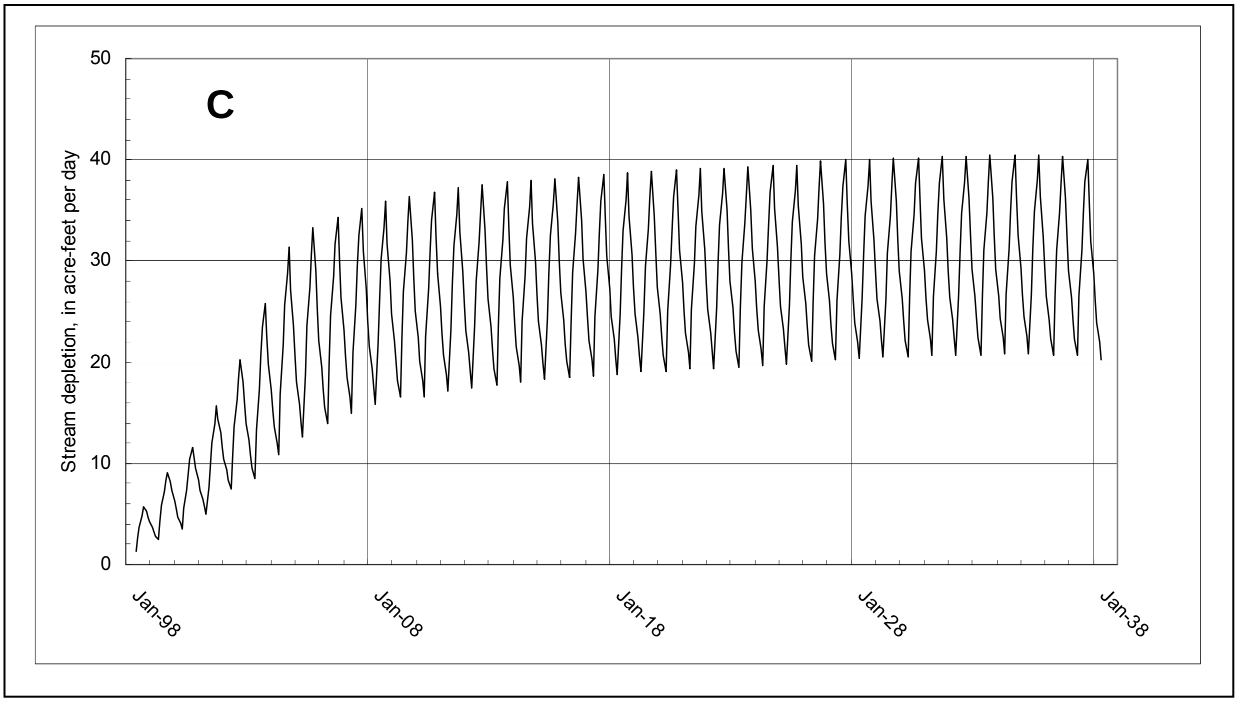


Figure 5. Monthly stream depletion to the Platte River system due to groundwater-irrigated lands developed between July 1, 1997, and June 30, 2006, inside the HCA/OA and EAA for each area. A) Wyoming line to Kingsley Dam; B) Kingsley Dam to Tri-County Supply Canal; C) Tri-County Supply Canal to Lexington; D) Lexington to U.S. Highway 183; and E) U.S. Highway 183 to Chapman.



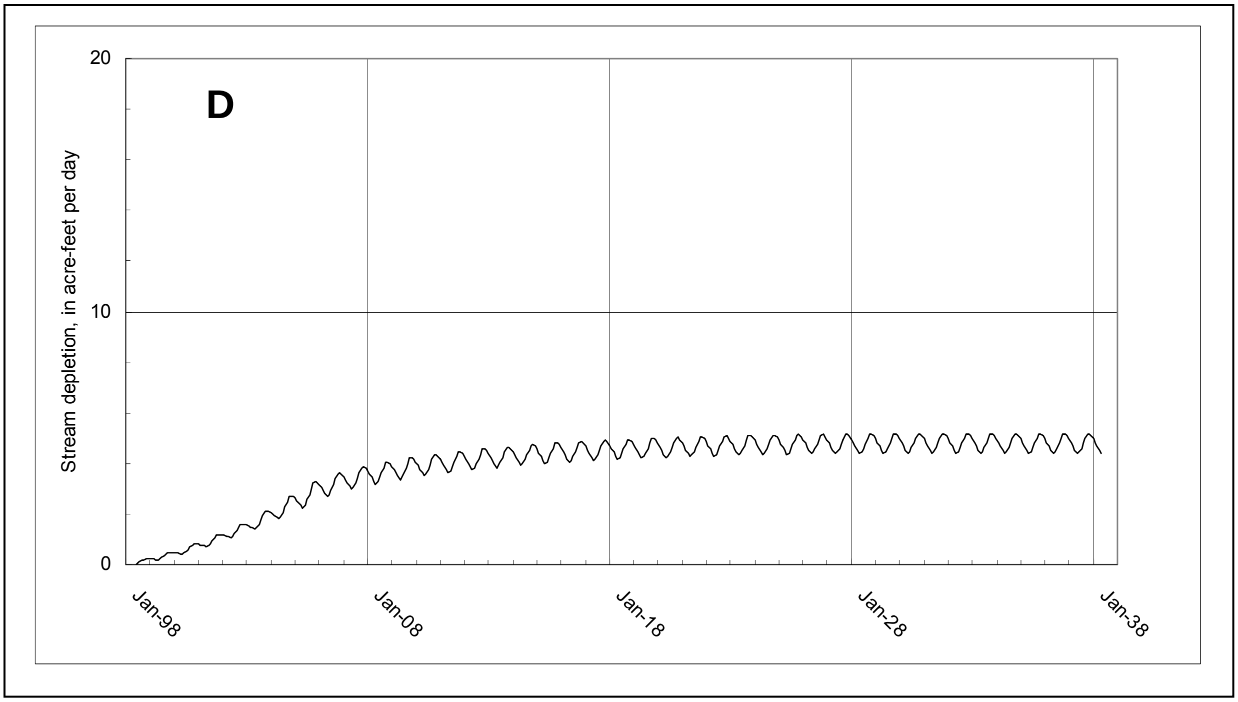


Figure 5 continued.

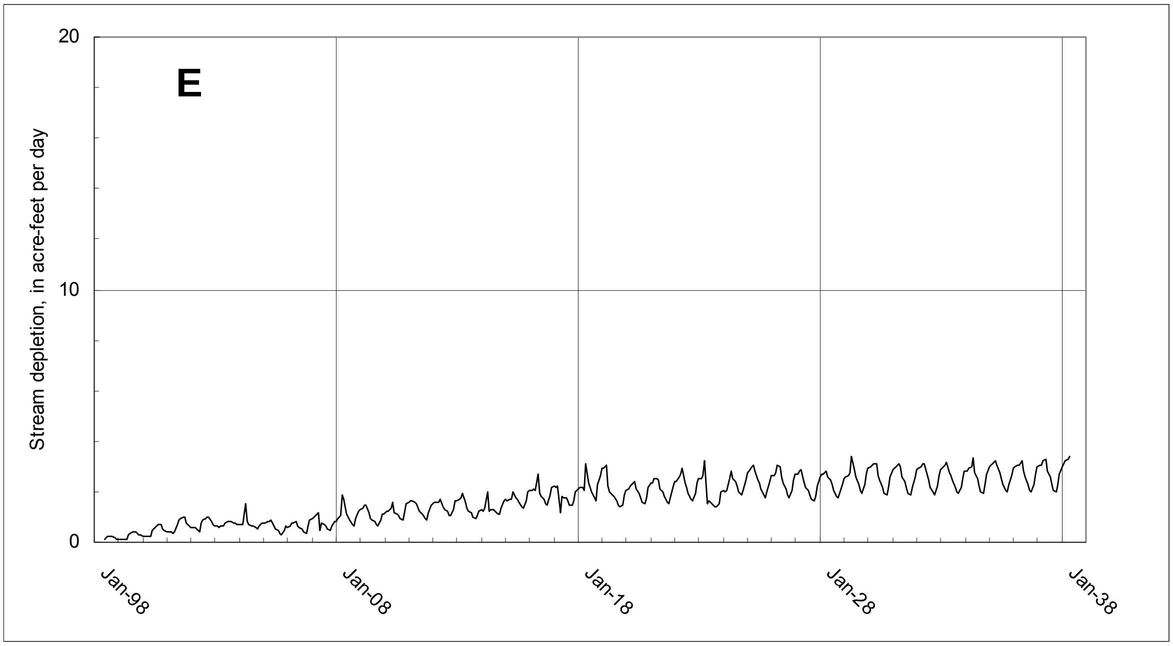


Figure 5 continued.

Table 10. Stream depletion to Platte River basin streams due to groundwater-irrigated lands gained or lost between July 1, 1997, and June 30, 2006, inside the HCA/OA and EAA for each area.

Date	Stream depletion (acre-feet/day)	Cumulative steam depletion (thousands of acre-feet)
Wyoming line to Kingsley Dam **A**		
Oct. 1, 2001	4.7	2
May 1, 2002	4.0	3
Oct. 1, 2007	27.1	35
May 1, 2008	19.0	40
Oct. 1, 2013	29.7	89
May 1, 2014	21.2	94
Oct. 1, 2020	30.6	155
May 1, 2021	22.1	160
Oct. 1, 2037	31.2	320
May 1, 2038	22.6	325
Kingsley Dam to Tri-County Supply Canal **B**		
Oct. 1, 2001	15.7	8
May 1, 2002	4.1	9
Oct. 1, 2007	31.9	44
May 1, 2008	13.3	48
Oct. 1, 2013	37.7	97
May 1, 2014	16.8	102
Oct. 1, 2020	37.7	166
May 1, 2021	18.8	171
Oct. 1, 2037	39.4	345
May 1, 2038	20.7	350
Tri-County Supply Canal to Lexington **C**		
Oct. 1, 2001	15.7	8
May 1, 2002	7.5	11
Oct. 1, 2007	35.2	52
May 1, 2008	15.9	56
Oct. 1, 2013	37.8	110
May 1, 2014	18.1	115
Oct. 1, 2020	38.9	182
May 1, 2021	19.4	187
Oct. 1, 2037	40.1	366
May 1, 2038	20.3	372
Lexington to U.S. Highway 183 **D**		
Oct. 1, 2001	1.2	1
May 1, 2002	1.1	1
Oct. 1, 2007	3.8	6
May 1, 2008	3.2	6
Oct. 1, 2013	4.6	14
May 1, 2014	3.9	15
Oct. 1, 2020	5.0	26
May 1, 2021	4.3	27
Oct. 1, 2037	5.2	56
May 1, 2038	4.4	57

Date	Stream depletion (acre-feet/day)	Cumulative steam depletion (thousands of acre-feet)
U.S. Highway 183 to Chapman **E**		
Oct. 1, 2001	1.0	0
May 1, 2002	0.4	1
Oct. 1, 2007	0.5	2
May 1, 2008	1.7	2
Oct. 1, 2013	1.0	5
May 1, 2014	1.2	5
Oct. 1, 2020	1.5	9
May 1, 2021	2.4	10
Oct. 1, 2037	2.0	25
May 1, 2038	3.4	25
TOTAL to Chapman		
Oct. 1, 2001	38	20
May 1, 2002	17	30
Oct. 1, 2007	98	140
May 1, 2008	53	150
Oct. 1, 2013	111	310
May 1, 2014	61	330
Oct. 1, 2020	114	540
May 1, 2021	67	560
Oct. 1, 2037	118	1,110
May 1, 2038	71	1,130

For Tri-County Supply Canal diversion to Lexington, stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 35.2 acre-feet per day on October 1, 2007, and was 15.9 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 37.8 acre-feet per day on October 1, 2013, and was 18.1 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 110,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 40.1 acre-feet per day on October 1, 2037, and was 20.3 acre-feet per day on May 1, 2038. Figure 5 indicates that stream depletion due to gained or lost irrigated land continued to increase, even late in the 40-year period. This increase indicates that the hydrologic system had not yet come into equilibrium with gained or lost irrigate land between 1997 and 2005. The rise in stream depletion was over the last decade of the simulation based on the peaks was 0.1 acre-feet per day. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 372,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA was 84 percent of cumulative steam depletion with new net pumpage everywhere.

For Lexington to U.S. Highway 183, stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 3.8 acre-feet per day on October 1, 2007, and was 3.2 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 4.6 acre-feet per day on October 1, 2013, and was 3.9 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 14,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 5.2 acre-feet per day on October 1, 2037, and was 4.4 acre-feet per day on May 1, 2038. Figure 5 indicates that stream depletion due to gained or lost irrigated land generally stabilized by late in the 40-year period. This indicates that the hydrologic system had come into equilibrium with gained or lost irrigate land inside the HCA/OA and EAA between 1997 and 2005. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 57,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA was 68 percent of cumulative steam depletion with new net pumpage everywhere.

For U.S. Highway 183 to Chapman, stream depletion exhibits some apparent noise. This noise is thought to be due to numerical instability in techniques used to solve the groundwater flow equations. The overall trend of the results is thought to be reasonable, but the noise obscures some of the details. An effort was made to reduce or eliminate this noise, and the curve shown in figure 5 is the result of that effort. Stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 0.5 acre-feet per day on October 1, 2007, and was 1.7 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 1.0 acre-feet per day on October 1, 2013, and was 1.2 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 5,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 2.0 acre-feet per day on October 1, 2037, and was 3.4 acre-feet per day on May 1, 2038. Figure 5 contains too much noise to determine definitively if the hydrologic system had come into equilibrium with gained and lost irrigated land between 1997 and 2005, although it appears that stream depletion may still be rising. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 25,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA was 31 percent of cumulative steam depletion with new net pumpage everywhere.

For Wyoming line to Chapman, stream depletion due to gained or lost irrigated land after July 1, 1997, inside the HCA/OA and EAA was 98 acre-feet per day on October 1, 2007, and was 53 acre-feet per day on May 1, 2008. Stream depletion due to gained or lost irrigated land in the same area was 111 acre-feet per day on October 1, 2013, and was 61 acre-feet per day on May 1, 2014. Cumulative stream depletion due to gained or lost irrigated land in the same area through October 1, 2013 was 310,000 acre-feet. Stream depletion due to gained or lost irrigated land in the same area was 118 acre-feet per day on October 1, 2037, and was 71 acre-feet per day on May 1, 2038. Cumulative stream depletion due to gained or lost irrigated land through May 1, 2038, was 1,130,000 acre-feet. Cumulative stream depletion for the 40 years with new net pumpage only inside the HCA/OA and EAA for Wyoming line to Chapman was 82 percent of cumulative steam depletion with new net pumpage everywhere, with the percentage being higher upstream and lower downstream.

The second analysis was not performed for Chapman to Columbus because the Eastern Analysis Area did not extend beyond Chapman. If at a later date the Eastern Analysis Area is extended to Columbus, the second analysis could be performed for Chapman to Columbus.

Net gained irrigated land inside the HCA/OA and EAA for 1997 to 2005 was 72,000 acres (table 8), whereas for the entire COHYST area, it was 508,010 acres (table 1). Net gained irrigated land inside the HCA/OA and EAA was only 14 percent of the net gained everywhere. However, the stream depletions from gained and lost irrigated land inside the HCA/OA and EAA accounted for 31 percent (U.S. Highway 183 to Chapman) to 99 percent (Wyoming line to Kingsley Dam) of all new depletions by the end of the period of analysis and averaged 82 percent. By comparing tables 7 and 10 upstream from Chapman, it can be seen that 89 percent of all new depletions are from inside the HCA/OA and EAA by May 1, 2008. These new depletions decreased to 88 percent of all new depletions by May 1, 2014, and decreased to 82 percent of all new depletions by May 1, 2038. However new depletions due to gained or lost irrigated lands inside the HCA/OA and EAA are rising less near the end of analysis as compared to new depletions due to gained or lost irrigated land everywhere. For Wyoming line to Kingsley Dam, the rise in the last decade of the analysis was 0.3 acre-feet per day due to gained or lost irrigated lands inside the HCA/OA and EAA compared to 0.6 acre-feet per day due to gained and lost irrigated land everywhere. For Tri-County Supply Canal diversion to Lexington, the rise in the last decade of the analysis was 0.1 acre-feet per day due to gained or lost irrigated lands inside the HCA/OA and EAA compared to 2.1 acre-feet per day due to gained and lost irrigated land everywhere. For Lexington to U.S. Highway 183, new depletions due to gained or lost irrigated lands inside the HCA/OA and EAA had stabilized in the last decade of the analysis, whereas it rose 1.2 acre-feet per day for gained or lost irrigated land everywhere.

Limitations and Comments

Model calibration indicated that cultivated land, both dryland and irrigated land, enhances recharge from precipitation. This extra recharge was not added to new irrigated land developed after July 1, 1997, in this analysis due to time constraints, so this analysis somewhat over estimates stream depletion due to gained and lost irrigated land.

This analysis is very dependent on the estimates of gained or lost irrigated land and net pumpage. Any errors in the estimates of gained or lost net pumpage would translate to a proportional error in stream depletion due to irrigated land gained or lost after July 1, 1997. An assessment of the accuracy of the data was provided in the reports which were used to provide mapped land uses for 1997 (Dappen and Tooze, 2001), 2001 (Dappen and Merchant, 2003), and 2005 (Dappen and others, 2006). These mapped irrigated lands were compared to county assessor tax data, Farm Service Administration data, and Census of Agriculture data for 20 counties that are completely in the COHYST area (table 11). The sum of the mapped irrigated lands in the 20 counties tended to be slightly larger than that of the tax data, ranging from +2.6 percent difference for 2005 to +3.9 percent difference for 2001. The tax data indicated an increase in irrigated land between 1997 and 2005 in the 20 counties of 296,000 acres whereas the mapped increase was 285,000 acres. The sum of the mapped irrigated lands in the 20 counties tended to be slightly larger than the Census of Agriculture for 1997 (+5.0 percent) and 2001 (+4.6 percent). The census actually occurred in 2002, so a lineal interpolation was done between 1997 and 2002. Census data were not available for 2005. Census data indicated an increase in irrigated land between 1997 and 2001 in the 20 counties of 122,000 acres whereas the mapped increase was 117,000 acres. Farm Service Administration data was compared to mapped irrigated land for 2001 and 2005. The mapped irrigated land was –0.1 percent different from Farm Service Administration data for 2001 and was +0.5 percent different for 2005. Farm Service Administration data indicated an increase in irrigated land between 2001 and 2005 in the 20 counties was 149,000 acres whereas the mapped increase was 168,000. These other data indicate that estimates of gained or lost irrigated land after 1997 are reasonable.

This analysis used 1997 meteorological conditions for the entire 40 years. While 1997 was near an average year in terms of meteorological conditions, it was somewhat wetter in the west and somewhat dryer in the east. Meteorological conditions directly affect net pumpage, so net pumpage under normal conditions could be larger in the west and smaller in the east. The analysis did not capture the natural wet and dry meteorological conditions. While the long-term trends in this analysis are consistent with normal meteorological conditions, wet and dry cycles would impose additional variation on simulated stream depletion. If average future meteorological conditions are much different from 1997 conditions, the current analysis must be adjusted accordingly.

Table 11. Irrigated land for 20 counties completely within the COHYST area. **Mapped** is from Dappen and Tooze (2001), Dappen and Merchant (2003), and Dappen and others (2006). **Tax** is from county assessor data. **Census** is from Census of Agriculture data (interpolated for 2001). **FSA** is from Farm Service Administration data. Differences between years were computed before rounding the acres to the nearest 1000.

	1997 acres	2001 acres	2005 acres	2005 − 1997
Mapped	2,894,000	3,011,000	3,179,000	285,000
Tax	2,801,000	2,897,000	3,097,000	296,000
Census	2,756,000	2,879,000	Not available	Not available
FSA	Not available	3,015,000	3,164,000	Not available
Map/Tax	1.033	1.039	1.026	
Map/Census	1.050	1.046	Not available	
Map/FSA	Not	0.999	1.005	

The calibrated model used for the Western Model Unit had 464 dry cells at the start of the analysis, particularly in Pumpkin Creek valley and it tributary valleys. Dry cells in the model are inactive, meaning that these cells have no pumpage from or recharge to them and water cannot move through these cells. Additional cells were simulated as going dry during this analysis, primarily cells in Pumpkin Creek valley, its tributary valleys, and parts of Lodgepole Creek valley, including its tributary valley Sidney Draw. In the baseline condition, 126 cells went dry during the simulation. In the added pumpage condition, 195 cells went dry during the simulation. Because steam depletion is determined as the difference between the two simulations, only the difference of 69 cells should affect the analysis. This difference in dry cells had a small effect on the analysis.

The results of this analysis are probably affected by evapotranspiration of groundwater, particularly downstream of U.S. Highway 183. Evapotranspiration is simulated in the model in areas where the groundwater is near land surface or in areas of riparian vegetation near large rivers and streams. In some areas, gained or lost net pumpage reduced or increased the amount of evapotranspiration instead of depleting the stream. Stream depletion results are directly affected by the evapotranspiration data used in the model, so any errors in evapotranspiration inputs would cause proportional errors in stream depletion results.

The results of this analysis are more reliable in earlier time and less reliable in later time. This is partly due to dry cells occurring as the simulation progressed. More importantly, there is an accumulation of errors in gained or lost net pumpage estimates and an accumulation of other model errors as the simulations progress.

Errata Sheet

December 5, 2006: Original edition

January 9, 2007: Table 9, Kearney County, changed column 4 from 0 to 71,470 and changed column 5 from 71470 to 2,310.