

Appendix G3
Irrigated Agriculture Water Use
Estimation Methods

Crop Consumptive Use (HRC1)

This appendix describes the Blaney-Criddle method (Blaney and Criddle, 1950, 1962) used to compute crop consumptive water use. The Blaney-Criddle method was used to determine consumptive use for crops grown in the planning region. The method uses mean monthly air temperatures (t) in degrees Fahrenheit, monthly percentage of annual daylight hours (p) based on the latitude of the area under study, seasonal consumptive use coefficients (K), and length of growing season to estimate the total consumptive use (U).

$$U=Kf$$

Where, $f = t * p / 100$. Once a value is obtained for U it is necessary to account for effective rainfall (R_e). R_e values can be obtained by following a methodology developed by the US Bureau of Reclamation (USBR). The USBR method expresses effective rainfall as a percentage of the total monthly rainfall and for each one-inch increment in rainfall there is a corresponding decrease in the percentage of effective rainfall. The USBR effective rainfall can be calculated using the equations in Table G3-1:

Table G3-1. USBR effective rainfall

Monthly Rainfall (R) (in)	Effective Rainfall (R_e) (in)
$R \leq 1$	$R_e = 0.95 R$
$1 < R \leq 2$	$R_e = 0.95 + 0.90 (R-1)$
$2 < R \leq 3$	$R_e = 1.85 + 0.82 (R-2)$
$3 < R \leq 4$	$R_e = 2.67 + 0.65 (R-3)$
$4 < R \leq 5$	$R_e = 3.32 + 0.45 (R-4)$
$5 < R \leq 6$	$R_e = 3.77 + 0.25 (R-5)$
$R > 6$	$R_e = 4.02 + 0.05 (R-6)$

Once values for U and R_e have been obtained, R_e should be subtracted from U to obtain the consumptive use value that will be used to determine total water demand. The $U-R_e$ should be converted to feet and multiplied by the acreage of crop to obtain a value for the total crop consumption in acre-feet. The values obtained in this way do not account for any incidental depletions or irrigation efficiency factors.

Cropping acreages were obtained as described in Section 6.1, mean monthly air temperature and mean monthly precipitation were obtained from Kunkel (1984), monthly percentage of daylight hours were obtained from Table B4 in Blaney and Hanson (1965), and crop-specific consumption coefficients and growing seasons were obtained from Table 6 and Table B5 in Blaney and Hanson (1965).

The spreadsheets used for these calculations follow: Table G3-2 Values for calculation of crop specific consumptive use (U), Table G3-3 Crop Acreages, and Table G3-4 Total water crop consumption.

Table G3-2. Values for calculation of crop specific consumptive use.

Socorro						Socorro						
Month	t	p	f	prec	Re	Crop	Growing Season	K FF	K not FF	U	U - R (in)	U - R (ft)
January	37.00	7.10	2.63	0.40	0.38	Wheat	9/15 - 6/25	0.70	0.35	36.10	27.79	2.32
February	42.40	6.91	2.93	0.40	0.38	Alfalfa Hay	4/14 - 10/29	0.85	0.50	45.00	36.69	3.06
March	49.20	8.36	4.11	0.31	0.29	All Other Hay	4/14 - 10/29	0.75	0.50	40.62	32.31	2.69
April	57.40	8.80	5.05	0.38	0.36	Corn	5/15 - 9/25	0.75		32.87	24.56	2.05
May	65.40	9.72	6.36	0.56	0.53	Chile	4/20 - 10/15	0.70		30.68	22.37	1.86
June	74.30	9.70	7.21	0.59	0.56	Sorghum	5/15 - 10/4	0.70		30.68	22.37	1.86
July	78.10	9.88	7.72	1.35	1.27	Vegetables		0.70		30.68	22.37	1.86
August	76.00	9.33	7.09	1.59	1.48	Orchards	4/14 - 10/29	0.65	0.40	34.68	26.38	2.20
September	69.30	8.36	5.79	1.47	1.37							
October	58.40	7.90	4.61	0.92	0.87							
November	45.40	7.02	3.19	0.32	0.30							
December	38.00	6.92	2.63	0.53	0.50							
Total					8.31							
Sierra						Sierra						
Month	t	p	f	prec	Re	Crop	Growing Season	K FF	K not FF	U	U - R	U - R (ft)
January	40.70	7.15	2.91	0.30	0.29	Wheat	9/15 - 6/25	0.70	0.35	39.91	31.67	2.64
February	44.90	6.94	3.12	0.27	0.26	Alfalfa Hay	3/31 - 11/4	0.85	0.50	49.13	40.89	3.41
March	50.70	8.36	4.24	0.26	0.25	All Other Hay	3/31 - 11/4	0.75	0.50	43.87	35.63	2.97
April	59.10	8.78	5.19	0.22	0.21	Corn	5/15 - 9/25	0.75		39.43	31.19	2.60
May	67.50	9.68	6.53	0.42	0.40	Chile	4/15 - 10/15	0.70		36.80	28.57	2.38
June	77.20	9.64	7.44	0.78	0.74	Sorghum	5/15 - 10/4	0.70		36.80	28.57	2.38
July	79.40	9.83	7.81	1.51	1.41	Pecans	3/31 - 11/4	0.90	0.40	50.87	42.63	3.55
August	76.90	9.31	7.16	1.64	1.53	Onions	2/15 - 8/15	0.65	0.40	37.72	29.49	2.46
September	71.20	8.34	5.94	1.57	1.46	Cotton	4/15 - 11/4	0.62	0.40	36.15	27.91	2.33
October	60.90	7.92	4.82	0.97	0.92	Vegetables		0.70		36.80	28.57	2.38
November	48.80	7.06	3.45	0.37	0.35	Orchards	3/31 - 11/4	0.65	0.40	37.72	29.49	2.46
December	40.80	6.99	2.85	0.45	0.43							
Total					8.24							

Table G3-3. Crop acreages from NMDA Agricultural Statistics (Normal Type) and USDA Census of Agriculture (Bold Type).

Socorro											
Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Wheat		354		200	200		200		209	200	
Alfalfa Hay		9733		13000	13000	14000	10000	11600	12931	13070	12000
All Other Hay		1741		900	1800	1900	1767	1500		930	2000
Corn		393		1200	1000	1200	1050	900	1446	1446	
Chile	300	600	550	400	300	250	350	400	200	400	300
Sorghum								400			
Vegetables		554					356		120	100	
Orchards		362					32			30	
Other				5540	4940	3890	7485	6440	6435	7725	
Sum Total Acres	300	13737	550	15700	16300	17350	13755	14800	14906	16176	14300
Total GW Acres					1310	1310	1310	1310			
Total SW Acres					3330	3330	3330	3330			
Total Combined Acres					16600	16600	16600	16600			
Total Irr Acres				21240	21240	21240	21240	21240			
Sierra											
Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Wheat				700	600	500	300		300		
Alfalfa Hay		1659		2800	3800	4300	4500	4500	2900	5000	6000
All Other Hay		116		200	100	200	120	100		100	100
Corn		190		1000	900	400	600	850	730	1000	1000
Chile	2000	1500	1750	1000	850	800	900	850	1500	700	700
Sorghum								100			
Pecans		185					259		380		
Onions		230		400	450	350	400	500	600	900	900
Cotton		37						200	110	100	
Vegetables		1520					1033		50		
Orchards		1375					506		30		
Other				5300	4700	4850	2782	4300	1623		
Sum Total Acres	2000	6812	1750	6100	6700	6550	8618	7100	6600	7800	8700
Total GW Acres					2940	2940	2940	2940			
Total SW Acres					3050	3050	3050	3050			
Total Combined Acres					5410	5410	5410	5410			
Total Irr Acres				11400	11400	11400	11400	11400			

Table G3-4. Total water crop consumption.

Socorro											
Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Wheat		819.87		463.21	463.21		463.21		484.05	463.21	0.00
Alfalfa Hay		29,758.45		39,747.24	39,747.24	42,804.72	30,574.80	35,466.77	39,536.27	39,961.26	36,689.76
All Other Hay		4,687.18		2,423.01	4,846.02	5,115.25	4,757.18	4,038.35	0.00	2,503.78	5,384.47
Corn		804.45		2,456.35	2,046.96	2,456.35	2,149.31	1,842.26	2,959.90	2,959.90	0.00
Chile	559.30	1,118.60	1,025.39	745.73	559.30	466.08	652.52	745.73	372.87	745.73	559.30
Sorghum								745.73	0.00	0.00	0.00
Vegetables		1,032.84						663.70	223.7204	186.4337	0.00
Orchards		795.65						70.33	0	65.93807	0.00
Other				14,914.98	13,299.64	10,472.80	20,151.38	17,338.00	17,324.53	20,797.52	0.00
Total				60,750.53	60,962.37	61,315.20	58,748.39	60,910.89	60,901.35	67,683.77	42,633.53
Total GW Acres					1310	1310	1310	1310			
Total SW Acres					3330	3330	3330	3330			
Total Combined Acres					16600	16600	16600	16600			
Total Irr Acres				21240	21240	21240	21240	21240			
Sierra											
Crop	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Wheat				1,847.62	1,583.68	1,319.73	791.84		791.84	0.00	0.00
Alfalfa Hay		5,653.24		9,541.34	12,948.96	14,652.77	15,334.29	15,334.29	9,882.10	17,038.10	20,445.73
All Other Hay		344.46		593.90	296.95	593.90	356.34	296.95	0.00	296.95	296.95
Corn		493.92		2,599.58	2,339.62	1,039.83	1,559.75	2,209.64	1,897.69	2,599.58	2,599.58
Chile	4,761.04	3,570.78	4,165.91	2,380.52	2,023.44	1,904.42	2,142.47	2,023.44	3,570.78	1,666.36	1,666.36
Sorghum								238.05	0.00	0.00	0.00
Pecans		657.25					920.15		1,350.03	0.00	0.00
Onions		565.20		982.96	1,105.83	860.09	982.96	1,228.70	1,474.44	2,211.65	2,211.65
Cotton		86.06						465.19	255.86	232.60	0.00
Vegetables		3,618.39					2,459.08		119.03	0.00	0
Orchards		3,378.92					1,243.44		73.72	0.00	0
Other				15,738.34	13,956.65	14,402.07	8,261.15	12,768.85	4,819.50	0.00	0.00
Total				33,684.27	34,255.12	34,772.81	34,051.46	34,565.12	24,234.97	24,045.25	27,220.27
Total GW Acres					2940	2940	2940	2940			
Total SW Acres					3050	3050	3050	3050			
Total Combined Acres					5410	5410	5410	5410			
Total Irr Acres				11400	11400	11400	11400	11400			

Irrigation District Acreage and Water Use Estimates (HRC2)

To provide an additional independent check on OSE published estimates for agricultural water use, we directly contacted and surveyed all irrigation districts, acequia associations, and ditch associations in the planning region. From each of these entities, we were able to acquire sufficient information to permit an independent estimate of irrigated acreage. These estimated acreages were then utilized to compute IRR diversion and consumptive use demands using default per-acre values consistent with OSE standards. Table G3-5 lists all of the irrigation systems in the planning region, their estimated irrigated acreages, and their estimated diversion and consumptive use (CU) demands.

The La Joya Acequia Association in Socorro County, and the Animas Ditch Association, the Cuchillo Valley Water Users Association, and the Elephant Butte Irrigation District (EBID) in Sierra County provided direct estimates of irrigated acreage in their service areas. For the other entities listed in Table G3-5, we needed to employ a variety of approaches to estimate irrigated acreages as described below.

All of the ditch associations in Sierra County allocate water to members based on permission to divert the entire ditch flow for a specified number of hours. Summing the permitted hours of all ditch members provides a total “rotation time” for the ditch system. Table G3-5 also lists the rotation time for each ditch association, as well as the average estimated flow rate where it is available. By multiplying a typical ditch flow rate by the rotation time and assuming 2.25 inches of water is applied in each irrigation application¹, we can estimate the quantity of irrigated acreage. This acreage estimation approach was suitable only for those ditches where flow rate information was available: the Monticello Community Ditch and the Palomas Creek Ditch (the ditch commissioners interviewed indicated that the flow rate shown in Table G3-5 represented a “typical” rate in an “average” year, but that rates actually vary significantly). For the San Miguel Ditch, only the rotation time was available. To estimate acreage for the San Miguel Ditch Association, we simply multiplied the rotation time by the average of the acreage: rotation-time ratios for the Cuchillo, Monticello, and Palomas Creek ditches.

For the Middle Rio Grande Conservancy District (MRGCD), we employed two approaches to estimate the irrigated acreage, both of which utilized information provided to us by MRGCD. One method used MRGCD assessment billing records, and the other employed MRGCD diversion and return flow records. The MRGCD generates the revenues required for district administration and maintenance by charging an assessment to water users based on the amount of acreage irrigated. MRGCD provided us with the acreage in Socorro County used for the assessment billing. It is important to note that the acreage subject to assessment does not include land that has had its water rights severed. Nonetheless, much of the land in Socorro County that has had its water rights severed remains undeveloped and irrigable for crop production, and in fact is actually being irrigated using leased water rights. We therefore wished to develop an estimate of irrigable acreage that accounted for such lands. The irrigable acreage was computed

¹ The estimate of 2.25 inches applied per irrigation is based on information provided by Mr. Gene Adkins, NRCS soil and water specialist with the Sierra County USDA service office. Mr. Adkins indicated that in general, the Sierra county ditch associations operate on a “deficit irrigation” basis by applying sub-optimal irrigation quantities due to the constraints associated with the “hourly allocation” of their right to use ditch waters.

using MRGCD average diversion and delivery records (Grogan, MRGCD, 2000, pers. comm.) and assuming a farm delivery allotment of 3.4 ac-ft/acre. From this information, we were able to estimate the amount of MRGCD-irrigable acreage in Socorro County as presented in Table G3-5.

Given that these irrigated (and irrigable) acreages are not disaggregated by crop types, we were unable to develop an irrigation water demand using an approach that employs crop-specific CU requirements. Rather, we simply employed a representative consumptive use requirement for all irrigated lands in each of the districts. In most cases we employed a crop CU demand of 2.1 ac-ft/acre and a diversion demand of roughly 4.9 ac-ft/acre, consistent with the CU and diversion demand model presented by the OSE (Wilson and Lucero, 1997; Fig. 4.1). For EBID, on the other hand, we were told by Mr. Mike Riley (EBID's representative in the Lower Rio Grande Regional Water Planning effort) that EBID historically uses on average 3.0 ac-ft/acre for crop CU; this value was thus applied for the EBID irrigated acreage in Sierra county.

It is interesting to note that these CU and diversion demand values reflect sufficient water supplies to meet all crop CU, deep percolation, and incidental loss demands. As mentioned previously, the ditch associations in Sierra County generally practice deficit irrigation, being unable to deliver sufficient water to meet all CU and other depletion needs. To estimate the amount of water actually delivered to the ditch association fields (in an typical year), we simply multiplied the assumed 2.25 inches of water per irrigation by the acreage and the number of irrigation rotations in an 8-month (March through October) growing season. This estimate of average annual ditch association water delivery is also presented in Table G3-5, which shows that in most cases the water deliveries barely (and in some cases don't) meet the crop CU requirements.

Table G3-5. Independent irrigated agriculture calculations based on phone interviews with irrigation districts and acequia/ditch associations (HRC2).

<i>Irr. Distr. Name</i>	<i>County</i>	<i>Irrigable Acreage</i>	<i>Irrigated Acreage</i>	<i>Flow Rate (cfs)</i>	<i>Total Hours in Rotation</i>	<i>Diversion Demand (ac-ft/yr)</i>	<i>CU Demand (ac-ft/yr)</i>	<i>Practical Avg Delivery (ac-ft/yr)</i>
<i>Sierra County</i>								
Animas Ditch Assoc.	Sierra	150	150	NA	292	748.2	314.4	563
Cuchillo Valley Water Users Assoc.	¹ Sierra	472	472	NA	524	2,359.1	991.2	989
Elephant Butte Irrigation District	² Sierra	2,972	2,972	³ NA	NA	21,220.1	8,916.0	21,220
Monticello Comm. Ditch Assoc.	Sierra	595	595	3.00	450	2,974.0	1,249.6	1,452
Palomas Creek Ditch Assoc.	Sierra	737	737	2.79	600	3,681.4	1,546.8	1,348
San Miguel Ditch Assoc.	Sierra	465	465	NA	404	2,322.6	975.9	1,263
Misc. Surface diversions	⁴ Sierra	200	200	NA	NA	999.6	420.0	1,000
Misc. lands irrigated by GW only	⁵ Sierra	2,740	2,740	NA	NA	9,590.0	5,754.0	9,590
	<i>Sierra Co. Totals</i>	<u>8,330</u>	<u>8,330</u>			<u>43,895</u>	<u>20,168</u>	
<i>Socorro County</i>								
La Joya Acequia Assoc.	Socorro	1,700	588	NA	NA	2,938.8	1,234.8	2,939
MRGCD	Socorro	25,732	23,881	⁶ NA	⁷ NA	119,356.9	50,150.0	111,005
	<i>Socorro Co. Totals</i>	<u>27,432</u>	<u>24,469</u>			<u>122,296</u>	<u>51,385</u>	
PLANNING REGION TOTAL			32,799			166,191	71,553	

...Acreage for ditch associations estimated assuming: (a) 2.25 inches of water per irrigation (for ditches with flow rate data), or (b) linear scaling based on Cuchillo Water User Association acreage data

...For diversion and consumptive use demands, use representative consumptive irrigation requirement of 2.1 af/ac for planning region(except EBID 3 af/ac), and estimate on-farm and off-farm non-CU depletions based on Wilson and Lucero (1997, Fig. 4.1).

1. Cropped in permanent pasture, orchard, alfalfa; a lot of water lost in creek for 12 miles from diversion dam, 22 miles of ditches
2. Historic CU allotment has been ~3af/acre (according to Mike Riley, EBID)
3. Estimate of 2,972 acres was obtained from Mike Riley of EBID; an alternative estimate of 4,000 was obtained based on map areas
4. Includes Lake Valley (Berenda Creek) and diversion between San Miguel and Palomas Ditch Assoc.
5. Estimate based on 1997 NMDA Ag Statistics published value for acreage irrigated by GW only
6. Estimate based on MRGCD-supplied values (MRGCD, June 30, 2000) for diversions and consumptive use, pro-rated based on map areas; an alternative estimate is anticipated to be available from MRGCD based on satellite photos by February 2000 (Doug Stretch, MRGCD, personal comm., Dec. 2000)
7. From MRGCD assessment billing and water bank records, plus estimated acreage in crop production at Bosque del Apache NWR.