Bear River Basin

From: Bear River Basin Planning Team

Subject: **APPENDIX G - Crop Consumptive Use**

Date: December 12, 2000

Introduction

This memorandum describes the approach and results obtained under Task 2A, Agricultural Use. The determination of potential crop evapotranspiration (ET) requires climate, acreage, and crop type information. The determination of actual crop consumptive use requires knowledge of actual water supply available to meet the crop ET demand. The following subtasks were performed to determine monthly crop consumptive use in the Bear River basin for the study period 1971 through 1998:

1. Climate Data Collection. Monthly temperature and precipitation data were collected for climate stations in the basin for the study period. Missing records were filled using appropriate methodologies.
2. Crop Consumptive Use Methodology. Previous estimates of crop consumptive use in the Bear River basin were investigated to determine the appropriate methods for this study.
3. Irrigated Acreage. Basin wide mapping of irrigated lands was obtained.
4. Key Ditch Systems and Diversion Data Collection. A subset of total irrigation ditch systems was chosen to analyze in more detail. Monthly diversion records for these ditch systems were digitized for the study period.
5. Crop Type and Irrigation Practices. Meetings were held with local water administrators and users to determine crop types, irrigation practices, and use of supplemental supplies.
6. Irrigated Land-Diversion Association. An inventory of water rights was completed for irrigated parcels for use in associating irrigated lands with river headgate diversion records.
7. Irrigation Water Requirements. Irrigation water requirements were determined for irrigated lands in the basin.
8. Water Supply-Limited Consumptive Use. Water-supply limited consumptive use was determined by comparing irrigation water requirements with water made available to the crops.

Several terms used in this memorandum have been broadly used in other studies. The definitions used in this study are consistent with the American Society of Civil Engineers Manuals and Reports on Engineering Practice No. 70. They are simply stated as follows:

Evapotranspiration The total amount of water that would be used for crop growth if provided with an ample water supply. Also called potential consumptive use.

Effective Precipitation The portion of precipitation falling during the crop-growing season that is available to meet the evapotranspiration requirements of the crop.

Irrigation Water Requirement The amount of water required from surface or ground water diversions to meet crop consumptive needs. Calculated as evapotranspiration less effective precipitation.

Supply-Limited Consumptive Use The amount of water actually used by the crop, limited by water availability. Also called depletion.

In general, agricultural consumptive use is presented based on the basin division outlined in the Bear River Compact. The upper division consists of the Bear River Basin and its tributaries in Wyoming upstream of Pixley Dam. This includes the area above Woodruff Narrows Reservoir plus the areas in Wyoming just downstream of Woodruff Narrows Reservoir and to Pixley Dam. The central division consists of the Bear River Basin and its tributaries in Wyoming from Pixley Dam to the Idaho border. The lower division boundary does not include portions of Wyoming.

Approach and Results - Climate Data Collection

The Bear River basin climate stations in the upper and central division were reviewed to determine the appropriate stations for use in the consumptive use analysis. There are three stations with long term records in Wyoming near the towns of Evanston, Sage, and Border. There are also two climate stations located just outside the basin in Afton and Kemmerer. Table 1 summarizes the climate station elevations in feet above mean sea level, periods of record, and missing average monthly temperature and total monthly precipitation values for the study period 1971 through 1999.

Table 1
Climate Station Summary

Station ID	Station Name	Station Elevation	Station Record	Missing Monthly Records 1971-1999	
				Temperature	Precipitation
480027	Afton	6155	1957-1999	22	19
480915	Border	6120	1902-1993	Not applicable	Not applicable
483100	Evanston	6860	1898-1999	20	19
485105	Kemmerer	6954	1948-1999	23	28
487955	Sage	6321	1948-1999	47	70

Source: National Oceanic and Atmospheric Administration (NOAA). Temperature is in degrees Fahrenheit, precipitation is in inches.

The Border gage was not used in any further evaluation because the station does not cover the entire study period. As shown in Figure 1, average monthly temperature does not vary significantly across the southwestern area of Wyoming. Figure 2 shows that, with the exception of the Afton climate station in the Snake River basin, total monthly precipitation also does not vary significantly across the southwestern area of Wyoming. The Evanston climate station was chosen to use in the consumptive use analysis for irrigated acreage in the upper division and the Sage climate station was chosen for the central division and lands in the upper division below Woodruff Narrows Reservoir for the following reasons:

- The stations have records that cover the length of our study period
- The stations have relatively few missing data months
- The stations are in the Bear River basin
- The stations are close in proximity and elevation to the majority of irrigated acreage in the two divisions

Figure 1
Average Monthly Temperature - 1971 through 1999

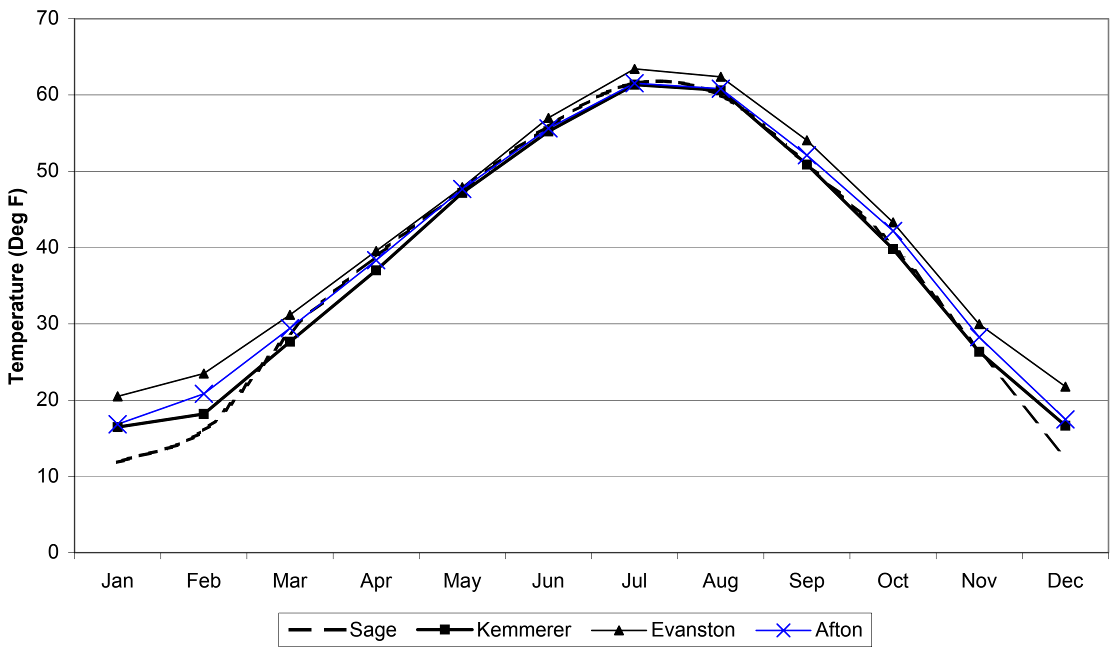
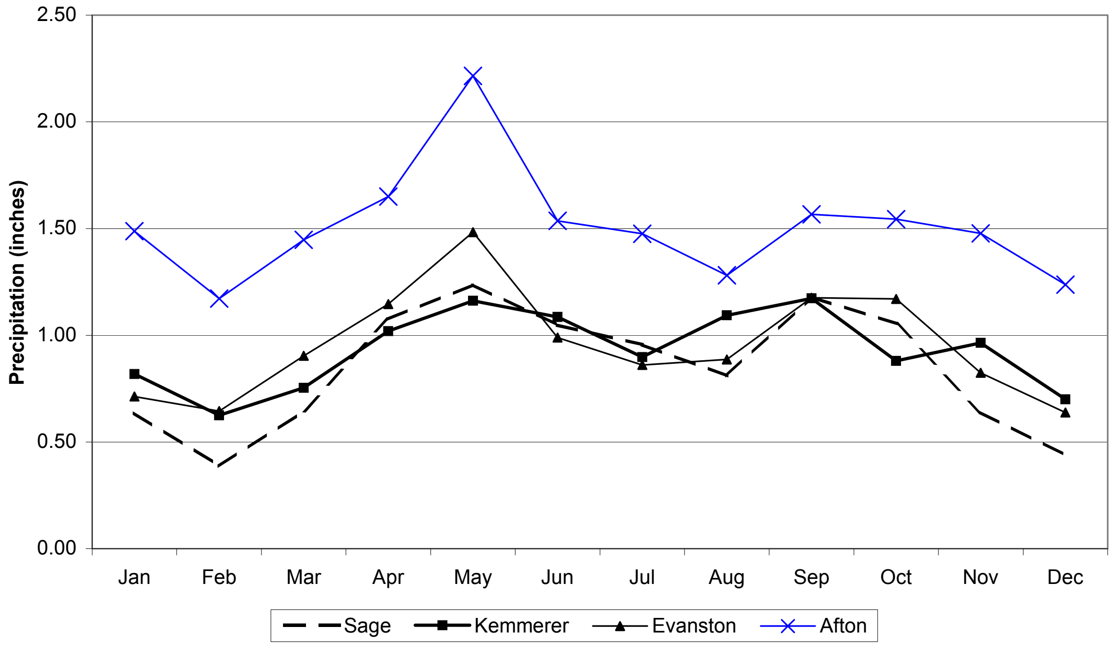


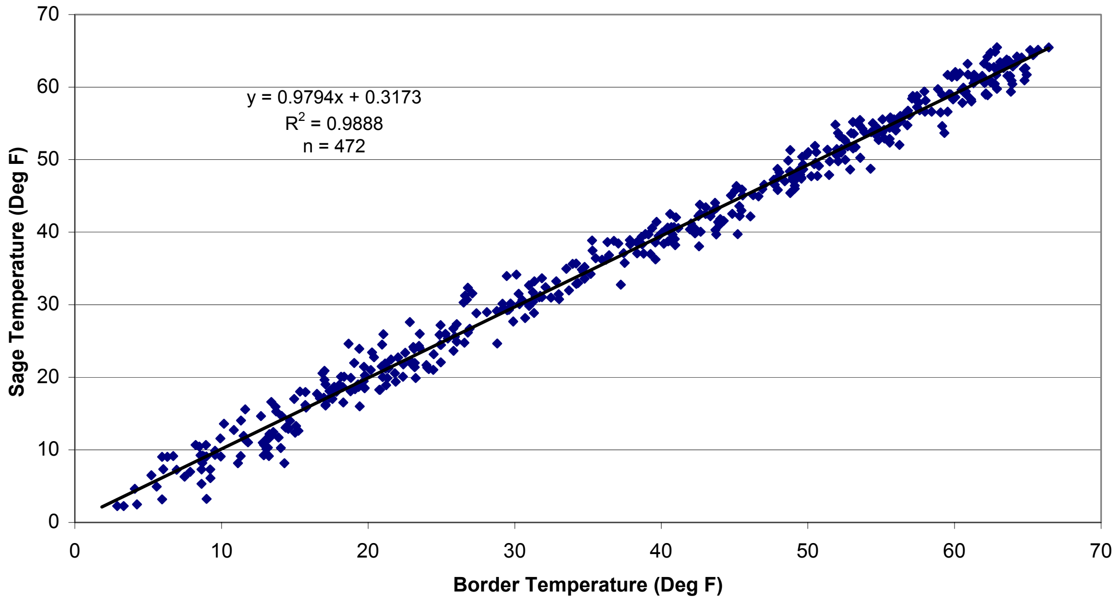
Figure 2
Total Monthly Precipitation - 1971 through 1999



To determine historic consumptive use estimates for the entire study period, it was necessary to fill in missing temperature and precipitation data. The closest climate stations to the Evanston station are Sage and Woodruff, Utah. Both of these stations are missing the same monthly measurements that the Evanston gage is missing. There are relatively few missing temperature and precipitation values for the Evanston climate station; therefore, both missing temperature and precipitation were filled with long-term monthly averages for the station.

The Sage climate station is close in elevation and proximity to the Border station. The Border station and the Sage station have 472 overlapping average temperature values, and 43 of the 47 missing measurements at Sage are available at Border. As shown in Figure 3, there is an excellent correlation between the two stations, therefore, the Border station was used to estimate the missing monthly temperature values at Sage. Four of the missing temperature values at the Sage station did not overlap with the Border station. For these months, the average monthly value for the entire period of record was used to fill the gaps.

Figure 3
Sage Average Monthly Temperature vs Border Average Monthly Temperature



Total monthly precipitation at Sage station was compared to precipitation at the other four stations reviewed in the analysis. Clear relationships were not found. Therefore, missing precipitation values for the Sage station were filled with the long-term monthly average of the measured data.

Approach and Results - Crop Consumptive Use Methodology

Blaney-Criddle approaches to determining crop evapotranspiration (ET) are widely used due to limited climate data requirements. Blaney-Criddle methods require average monthly temperature and total monthly precipitation, whereas other methods may require daily parameters including temperature, precipitation, wind speed, vapor pressure, and solar radiation.

One of the most widely used Blaney-Criddle approach is the Soil Conservation Service (SCS) method, published in Irrigation Water Requirements Technical Release No. 21 (TR-21) by the Soil Conservation Service, April 1967 revised September 1970. This methodology can be adapted to better represent known local conditions by calibrating the climatic coefficient (k_t) and the crop coefficients (k_c) so empirically calculated ET estimates represent measured ET. This procedure was followed in a cooperative project sponsored by the Bear River Commission in the published Duty of Water Under the Bear River Compact: Field Verification of Empirical Methods for Estimating Depletion - Research Report 125, January 31, 1989, Robert W. Hill, et al (Research Report 125).

The SCS Modified Blaney-Criddle equation is as follows:

$$ET = k_c \times k_t (t \times p/100)$$

where

ET = monthly consumptive use, inches
k_c = monthly crop growth stage coefficient
k_t = climatic coefficient = 0.0173t - 0.314
t = mean monthly temperature (oF)
p = percentage of daylight hours of the year occurring during the month

A local climatic coefficient (k_t) was developed for Research Report 125 to represent the entire Bear River Basin region. Monthly crop coefficients (k_c) were calibrated for Research Report 125 for several locations in the basin so that ET estimated using the SCS Modified Blaney-Criddle approach represented measured ET values in those areas. Calibrated crop coefficients developed near the climate stations of Evanston, Woodruff, and Border are believed to best represent our study area. Therefore, the crop coefficients for these three sites were averaged to represent an appropriate set of crop coefficients for the analysis.

Research Report 125 provides an approach that is, presumably, acceptable to all three compact States, therefore appropriate to use in the Bear River Plan. Therefore, the SCS Blaney-Criddle method was used to estimate potential evapotranspiration with the following parameters put forth in Research Report 125:

- Calibrated climatic coefficient, k_t, was used
- Calibrated crop coefficients, k_c, were used

In addition, irrigation water requirements were determined by estimating effective precipitation to be 80% of growing season rainfall, instead of using the SCS effective rainfall method. This was done to be consistent with the approach used in Research Report 125.

Blaney-Criddle estimated ET, using the averaged calibrated crop coefficients from Research Report 125 and the crop coefficients recommended in TR-21, were determined for both alfalfa and irrigated meadow (pasture) using the Evanston climate station and the Sage climate station precipitation and temperature data. Many Blaney-Criddle models are available to easily calculate estimates using the SCS Blaney-Criddel aproach. For this study, a public domain model, developed by Leonard Rice Engineers staff for the State of Colorado, was used. The StateCU model is available of the Colorado CDSS Web Site at http://cdss.state.co.us.

Figure 4 shows the average monthly ET for irrigated meadow for the period 1971 through 1990 at the Evanston climate station. Figure 5 shows the average monthly ET for alfalfa for the period 1971 through 1990 at the Sage climate station. For both crop types, the total annual ET estimates using local parameters are around 25 percent higher, with the increase seen in the spring and early summer months.

Figure 4
Average Potential ET Estimate Comparison (1971 through 1990)
Irrigated Meadow (Pasture) at the Evanston Climate Station

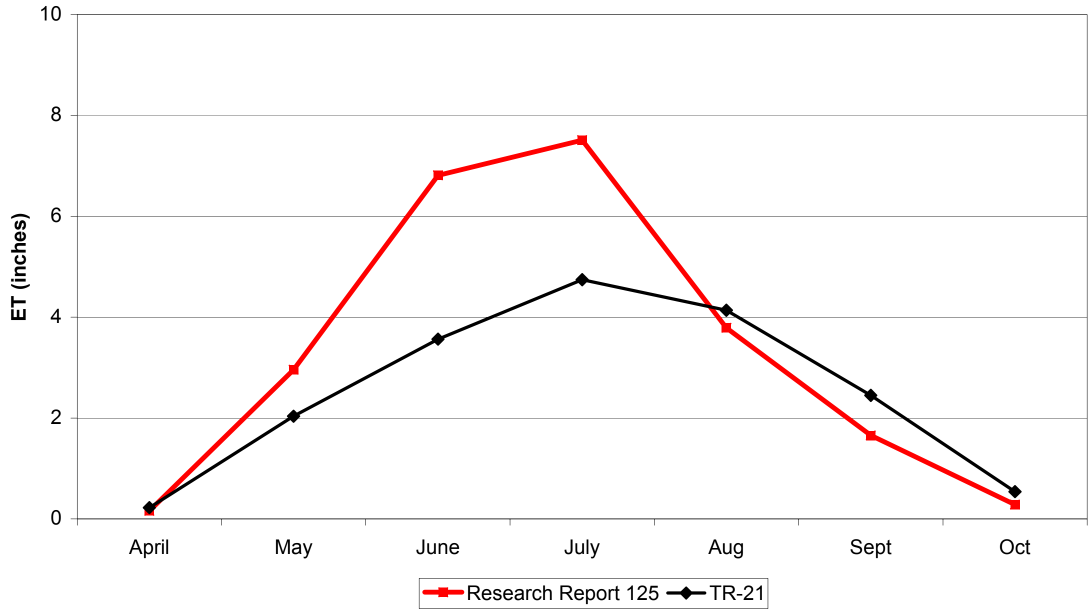


Figure 5
Average Potential ET Estimate Comparison (1971 through 1990)
Alfalfa at the Sage Climate Station

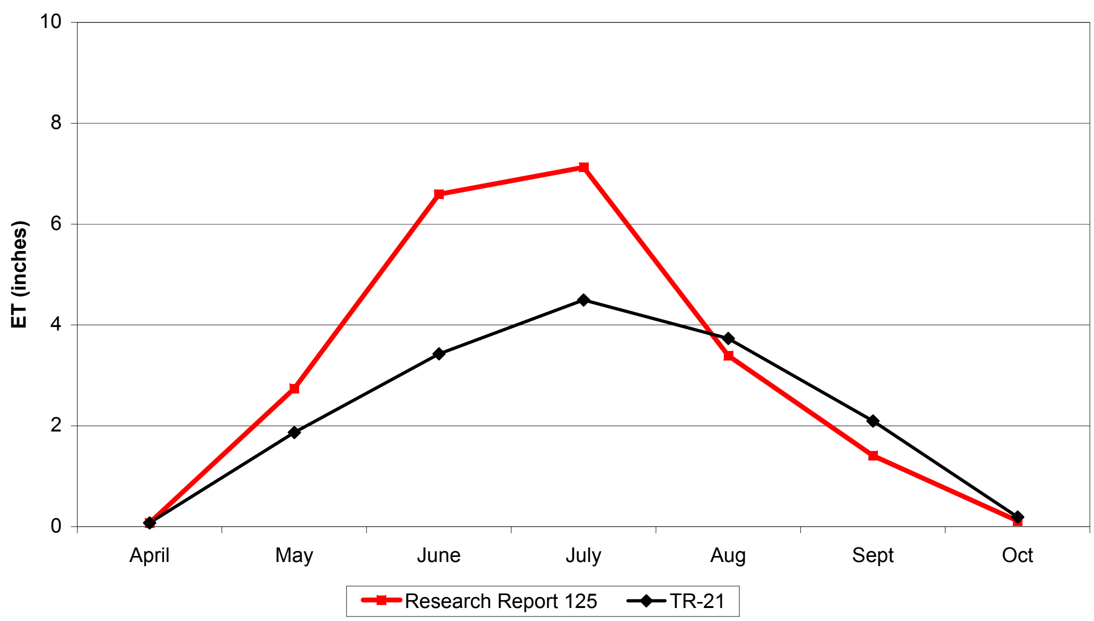


Table 2 shows Blaney-Criddle TR-21 crop coefficients and the averaged crop coefficients recommended for use in determining the historic crop consumptive use in the Bear River Basin, Wyoming. Crop coefficients are shown for both pasture and alfalfa. The growing season in the Bear River Basin in Wyoming generally extends from mid April through mid October. The differences shown in Table 2, TR-21 coefficients higher early and late in the growing season and calibrated coefficients higher during the summer months, are similar to calibrated coefficients in other higher elevation basins in the Western U.S.

Table 2
TR-21 and Calibrated Crop Coefficients (K_c)

Day of the Year	Alfalfa Crop Coefficients		Pasture Crop Coefficients	
	TR-21	Calibrated	TR-21	Calibrated
April 15	0.990	0.347	0.855	0.463
May 1	1.045	0.930	0.880	0.868
May 15	1.090	1.513	0.900	1.273
June 1	1.120	1.637	0.915	1.515
June 15	1.135	1.760	0.920	1.757
July 1	1.130	1.405	0.925	1.612
July 15	1.115	1.050	0.925	1.467
August 1	1.090	1.105	0.915	1.147
August 15	1.065	1.160	0.905	0.827
September 1	1.030	0.848	0.890	0.710
September 15	0.990	0.537	0.870	0.593
October 1	0.950	0.502	0.840	0.483
October 15	0.905	0.467	0.795	0.373

Sources: Irrigation Water Requirements, Technical Release No 21, SCS, 1967
Duty of Water Under the Bear River Compact: Field Verification of Empirical Methods for Estimating Depletion - Research Report 125, Robert Hill et al, 1989

Approach and Results - Irrigated Acreage

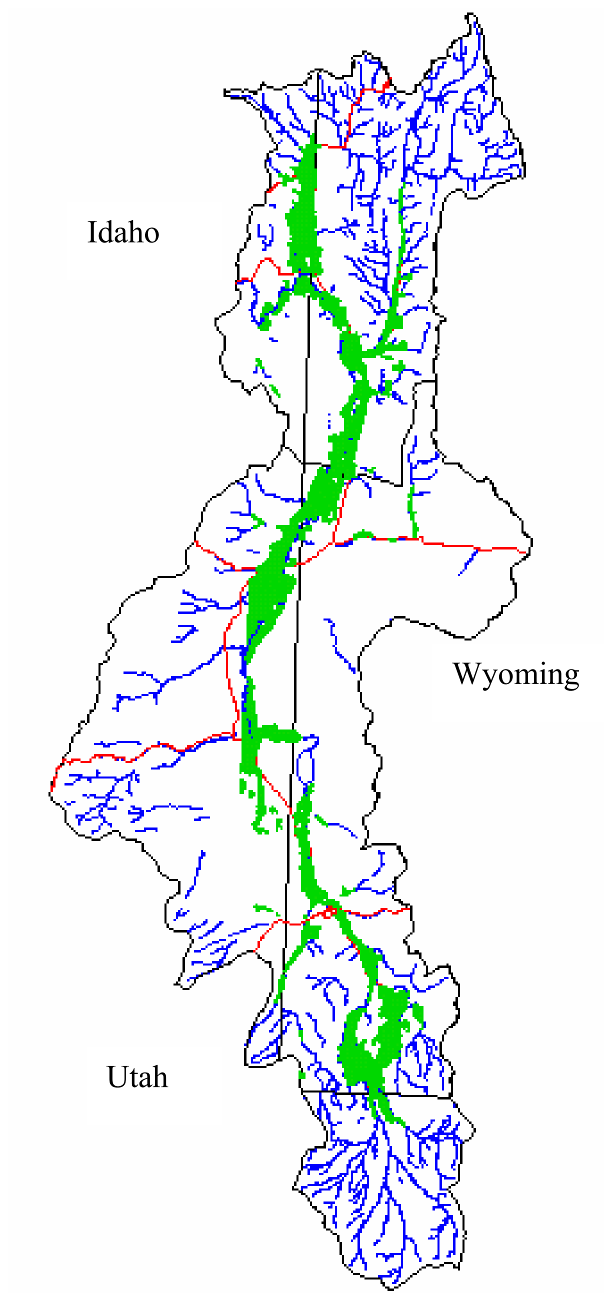
Irrigated acreage estimates for the Bear River basin were developed for the WWDC during the 1998 feasibility study by States West Engineering. Table 3 shows the breakdown of irrigated acreage in the basin. Figure 6 shows the location of irrigated acreage in the basin.

Table 3
Irrigated Acreage in the Bear River Basin, Wyoming

Location	Irrigated Acreage (acres)
Upper Division	40,400
Central Division	23,500
Total Bear River Basin	63,900

Wyoming Agricultural Statistics, reported each year by county, were perused to determine how acreage has changed over the study period. County agricultural statistics generally report cash crops only, therefore are not a good indicator of actual acreage in the Bear River basin. A large majority of the acreage is irrigated meadow that is either used for grazing or hayed for on-farm use. However, information from local water users indicates that irrigated lands have been fairly consistent through the period 1971 through 1998. Since 1971, water rights for approximately 2,900 additional acres have been permitted in the basin, representing less than 5 percent of the total acreage. Based on this information, a constant acreage was used in the consumptive use analysis.

Figure 6
Location of Irrigated Acreage in the Bear River Basin



Approach and Results - Key Ditch Systems and Diversion Data Collection

Although there are over 100 diversions for irrigation in the Bear River basin in Wyoming, approximately 75 percent of the irrigated acreage are served by 36 larger diversion structures. These 36 "key" ditch systems are modeled individually, both in the consumptive use analysis and in the surface water simulation model. The 36 ditch systems were chosen based on a cutoff minimum diversion capacity of 9 cfs, plus input from the local water administrators. In general, less than 9 cfs ditch systems were considered key if they are important to the compact or state administration, for instance if they have high priority water rights, or they receive supplemental water from one of the three larger reservoirs; Whitney, Sulphur Creek, or Woodruff Narrows.

Table 4 shows the key ditch systems for the upper division in upstream to downstream order. All the key ditch systems in the upper division divert from the mainstem Bear River. In addition, the average annual diversions for the period 1971 through 1999 are shown.

Table 4
Upper Division Key Ditch Systems

Key Ditch System	Average Annual Diversion (acre-feet)
Hilliard East Fork	2,860
Lannon and Lone Mountain	3,320
Hilliard West Side	4,310
Bear Canal	8,960
Crown and Pine Grove	4,210
McGraw (and Big Bend)	4,440
Lewis	1,250
Myers No 2	1,100
Myers No 1	870
Myers Irrigation	930
Booth	2,620
Anel	1,420
Evanston Water Supply	1,140
Evanston Water Ditch	3,450
Rocky Mountain Blythe	2,380
John Sims	2,780
SP Ramsey	2,720
Chapman	18,040
Morris Brothers	780
Tunnel	2,880
Francis Lee	6,550
Bear River Canal	9,230
Pixley Dam	7,555
BQ Dam	12,081

Table 5 shows the key ditch systems for the central division in upstream to downstream order by source. In addition, the average annual diversions for the period 1971 through 1999 are shown.

Table 5
Central Division Key Ditch Systems

Key Ditch System	Source	Average Annual Diversion (acre-feet)
Quinn Bourne	Smiths Fork	1,350
Button Flat	Smiths Fork	640
Emelle	Smiths Fork	2,260
Cooper	Smiths Fork	1,190
Covey	Smiths Fork, Bruner Creek, Spring Creek	16,380
VH Canal	Pine Creek	2,740
Goodell	Pine Creek	1,650
Whites Water	Smiths Fork	5,460
S. Branch Irrigating	North Channel Smiths Fork	3,900
Alonzo F. Sights	Bear River	2,990
Oscar E. Snyder	Bear River	4,040
Cook Brothers	Bear River	8,020

Clarence Kemp walked the river and major tributaries with the local water administrators for both the upper and central division. The headgate location of the key ditch systems was determined, using a hand-held GPS unit, and photographs were taken documenting the condition of the structures. Detailed operating memoranda were developed for each of these systems, and are provided separate from this memorandum.

Diversions are measured or observed throughout the irrigation season by the local water administrators, as required by the Bear River Compact. Complete daily diversion records in Wyoming were obtained for the key ditch systems from the Compact Administrator for 1971 through 1999; therefore no data filling was required. The most current years were provided in digital form. Paper copies were provided for the earlier years and digitized as part of this study. Because our study is being performed using a monthly consumptive use model, and a monthly river simulation model, only average monthly rates, in cfs, and total monthly volumes, in acre-feet, were digitized. Tables showing diversion records for the key ditch systems are provided with the operating memoranda described above.

Approach and Results - Crop Type and Irrigation Practices

Crop ET requirements and irrigation methods can vary by crop type. Interviews were held with the local water administrators and individual water users to determine crop types for the key ditch systems and to gain an understanding of local irrigation practices. As shown in Table 6, most of the acreage in the basin is irrigated pasture.

Table 6
Crop Types as Percent of Irrigated Acreage

Location	Pasture	Alfalfa
Upper Division	99 %	1 %
Central Division	86 %	14 %
Total Bear River Basin	92 %	8 %

Most of the Upper Division applies surface water to satisfy crop ET requirements using flood irrigation techniques. The only exceptions in the Upper Division are the Cornelison Pump, which diverts water from Sulphur Creek to a center pivot sprinkler serving a quarter section (~160 acres), and the SP Ramsey ditch, which applies diversions through a sprinkler to approximately 80 acres. Sprinkler irrigation is more prevalent in the Central Division. Hand line, side-roll and center pivot sprinkler systems are used. Table 7 shows the percent of lands flood irrigated versus sprinkler irrigated for the major ditches in the Central Division.

Table 7
Flood versus Sprinkler Irrigated Lands for Major Ditches in the Central Division

Ditch Name	Percent Sprinkler Irrigated	Percent Flood Irrigated
Quinn Bourne	0 %	100 %
Button Flat	0 %	100 %
Emelle	100 %	0 %
Cooper	0 %	100 %
Covey	30 %	70 %
VH	100 %	0 %
Goodell	100 %	0 %
Whites Water	40 %	60 %
S. Branch Irr.	60 %	40 %
Alonzo Sights	40 %	60 %
Oscar Snyder	0 %	100 %
Cook Brothers	0 %	100 %

Irrigation in both the Upper and Central Divisions generally begins in mid-May and continues into September. In dry years, irrigation in the central division is more likely to end earlier than irrigation in the upper division; the upper division has access to storage in Whitney Reservoir, Sulphur Creek Reservoir, and Woodruff Narrows Reservoir. There are no major storage reservoirs in the central division in Wyoming.

Approach and Results - Irrigated Land/Diversion Association

In order to determine the actual consumptive use in a basin, it is necessary to associate water supply with crop consumptive demand. As discussed above, irrigated acreage in the basin was developed under a previous contract. As part of the Bear River basin study, water rights have been mapped to irrigated parcels identified in the GIS irrigated acreage coverage. Each water right permit contains point of diversion information, including water source and name of diverting structure. In addition, the water rights define the amount of acreage allowed to be irrigated under the permit, up to 70 acres per 1 cfs.

The irrigated parcel mapping was prepared in a general fashion, without an attempt to create a one-to-one relationship between water rights and irrigated acreage. Therefore, analyses were required to match water rights with their associated irrigated acreage so diversion records could be compared to the irrigation water requirements. In most cases, more than one water right serves an irrigated parcel. In addition, many water rights are tied to more than one parcel. In data terms, the irrigated acreage and water right GIS data tables display a many-to-many relationship.

Water rights were tied to irrigated acreage parcels based on the following general procedure:

1. Link the point of diversion GIS coverage to the water rights coverage.
2. Link the water rights coverage to the irrigated acreage coverage.
3. Identify key structures in the point of diversion theme. Through the links, identify the irrigated parcels that have a water right for that structure.
4. Account for acreage identified, based on the water rights permitted acreage, for land tied to key structures. Next look to other water rights (senior to junior) to account for remaining irrigated acreage.
5. Group acreage not assigned to key structures into aggregates.

This process was iterative in nature, since key structure water rights were associated with the same irrigated parcels as other key water rights. Therefore, this procedure did not lend itself to automation and was performed interactively by using the GIS linking capabilities and engineering judgement. This procedure resulted in the following information, required to complete the supply-limited consumptive use analysis.

- Total acreage in the basin, by diversion or diversion aggregate, for use in determining total basin irrigation water requirement
- Acreage with a one-to-one correspondence between diversions and acreage, for use in estimating supply-limited consumptive use

Only many-to-many water rights and irrigated acreage associations were found in the Upper Division. However, there are unique lands served by both Myers #1 and Myers Irrigation diversions that are not served by other diversions. Two unique associations between water rights and irrigated acreage were found in the Central Division - Quinn Bourne, and VH Canal.

Table 8 shows the estimated acreage in the basin assigned to individual diversion structures or aggregate groups of diversion structures.

Table 8
Acreage Assigned by Diversion

Diversion Name	Estimated Acreage
Hilliard East Fork	2447
Lannon and Lone Mountain	3247
Hilliard West Side	2319
Bear Canal	3654
Crown and Pine Grove	2274
McGraw (and Big Bend)	128
Lewis	850
Aggregate Lands on Bear River above Confluence with Mill Creek	2218
Myers No 2	543
Myers No 1 and Myers Irrigation Combined	377
Booth	1177
Anel	133
Evanston Water Supply	110
Aggregate Lands on Bear River between Mill Creek and Sulphur Creek	413
Aggregate Lands on Sulphur Creek Above Reservoir	1016
Aggregate Lands on Sulphur Creek Below Reservoir	175
Evanston Water Ditch	941
Rocky Mountain Blythe	519
John Simms	485
SP Ramsey (also called Adin Brown)	730
Aggregate Lands on Yellow Creek	2464
Aggregate Lands on Bear River between Sulphur and Yellow Creeks	583
Chapman	1533
Morris Brothers	983
Aggregate Lands on Bear River btw Yellow Crk and Woodruff Narrows	262
Tunnel	609
Francis Lee	101
Bear River Canal	171
BQ Dam	6483
Pixley Dam	3187
Aggregate Lands on Twin Creek	1360
Aggregate Lands on Bear River between Twin Fork and Smiths Fork	1573
Quinn Bourne	315
Button Flat	266
Emelle	960
Cooper	410
Covey	6290
VH Canal	754
Goodell	342
Whites Water	2542
S. Branch Irrigating	822
Aggregate Lands on Smiths Fork	2849
Aggregate Lands on Bear River below Smiths Fork	1394
Alonzo F. Sights	1062
Oscar E. Snyder	558
Cook Brothers	349
Aggregate Lands on Raymond Creek	1940
Bear River Basin in Wyoming Total Irrigated Acreage	63918

During the analysis to associate acreage with diversion structures, wells permitted for irrigation were also tied to irrigated lands and to ditch systems. The following diversions or aggregate diversions were determined to have supplemental ground water:

- Aggregate Lands on Yellow Creek
- Aggregate Lands on Twin Creek
- Aggregate Lands on Bear River between Twin Creek and Smith's Fork
- Covey Canal
- Aggregate Lands on Smiths Fork
- Alonzo F. Sights Ditch
- Aggregate Lands on Raymond Creek

Approach and Results - Irrigation Water Requirements

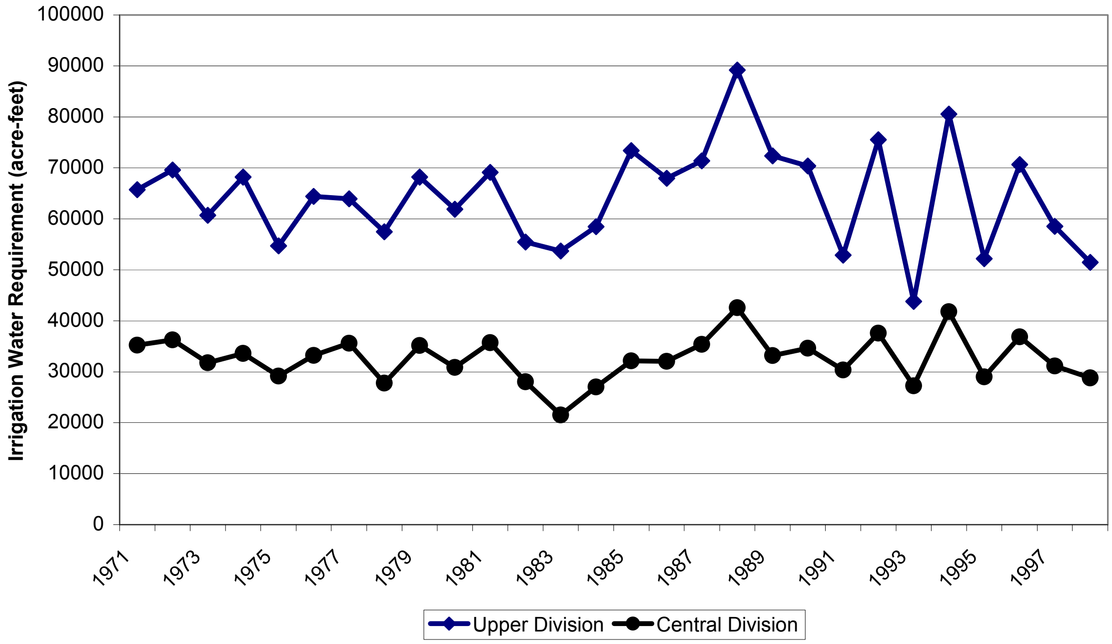
As discussed in the *Crop Consumptive Use Methodology* section, monthly crop consumptive use was determined using the SCS Blaney-Criddle approach outlined in TR-21, with locally calibrated crop coefficients. The monthly effective precipitation was subtracted from the crop consumptive use to estimate irrigation water requirement.

A Blaney-Criddle computer model, developed by staff at Leonard Rice Engineers, was used to automate the calculation process. Inputs to the model include annual irrigated acreage and corresponding crop types (estimated to be constant from 1971 through 1998), calibrated crop coefficients, and monthly temperature and precipitation records (monthly from 1971 through 1998). Table 9 provides the average irrigation water requirements for the Bear River basin in Wyoming for the Upper and Central Divisions. Figure 7 shows the annual irrigation water requirements for 1971 through 1998.

Table 9
Average Irrigation Water Requirements (IWR)
1971 through 1998

Location	IWR (acre-feet)
Upper Division	64,300
Central Division	32,600
Total Bear River Basin	96,900

Figure 7
Annual Crop Irrigation Water Requirement - 1971 through 1998



Approach - Water-Supply Limited Consumptive Use

Irrigation water requirement is an estimate of the amount of water crops would use if they had a full supply. However, in the arid west most farming operations by necessity grow crops with less than a full supply. Water-supply limited consumptive use is the amount of water actually used by the crop. In the Bear River Basin in Wyoming, there are five measurable sources of agricultural supply:

- Supply from precipitation (subtracted from crop potential ET to estimate irrigation water requirement)
- Supply from the river via direct diversion rights
- Supply from excess diverted water stored in the soil root zone layer
- Supplemental supply from reservoir storage
- Supplemental supply from wells

Another indication of well-watered versus limited water conditions is crop yield. However, because much of the irrigated meadow in the Bear River Basin is used for grazing or hayed for on-farm use, consistent yield information is not available.

A farm budget/soil moisture mass-balance approach can be used to estimate supply-limited consumptive use. The StateCU Blaney-Criddle program used in the irrigation water requirement analysis has a farm budget/soil moisture routine that operates based on the procedure outlined in Figure 8.

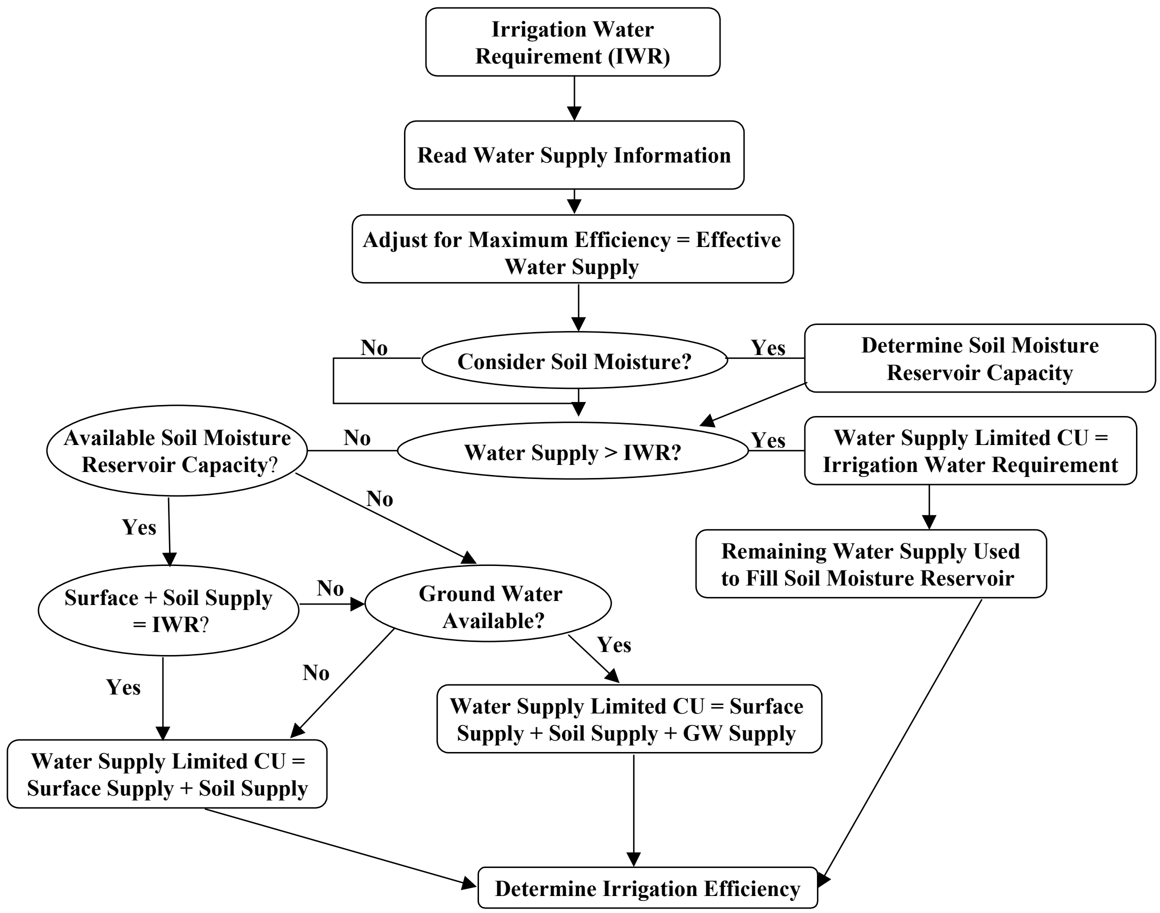


Figure 8
Farm Budget/Soil Moisture Accounting Procedure

The following general procedure was followed to estimate the supply-limited consumptive use and agricultural ground water use in the Bear River basin in Wyoming:

1. Determine the water supply-limited consumptive use for acreage with a unique relationship between diversions and acreage (index structures).
2. Determine the percent shortage for each month in the study period by dividing the water supply-limited consumptive use by the irrigation water requirement.
3. Estimate supply-limited consumptive use for the remaining acreage in the basin based on the percent shortage seen for the "index" structures.
4. Assume that structures with permitted supplemental ground water receive a full supply, up to their maximum permitted amount. Determine ground water use for irrigation based on this estimate.

As shown in Figure 7, the determination of water-supply limited consumptive use requires records or estimates of the following:

- Monthly diversion records associated with irrigated acreage
- Maximum conveyance and application efficiencies per ditch system
- Soil moisture holding capability associated with irrigated acreage
- Availability of supplemental ground water

<u>Diversions for Index Structures.</u> The structures identified as having a unique relationship between diversions and acreage were used as index structures to estimate the overall basin water supply-limited consumptive use. Monthly shortages for the study period for the Myers #1 and Myers Irrigation Ditch combined diversions were estimated to represent shortages seen in the Upper Division. Their combined water rights represent the water right priorities seen in the Upper Division. Almost the entire Upper Division irrigates meadow, so the crop types are consistent between the index structures and structures to be estimated. In addition, nearly all the Upper Division acreage above Woodruff Narrows has access to supplemental water from a combination of Whitney and Sulphur Creek Reservoirs. The Upper Division acreage downstream of Woodruff Narrows shares in supplemental water from Woodruff Narrows Reservoir.

The monthly shortages for Quinn Bourne and VH Canal were averaged and estimated to be representative of shortages seen in the Central Division. Again, the water rights for these two ditches represent the water right priorities seen in the Central Division, and the crop types are consistent with crop types seen throughout the Central Division. There are no major reservoirs in the Central Division. Neither Quinn Bourne nor VH Canal has permits for supplemental ground water.

<u>Maximum Conveyance and Application Efficiencies.</u> Diversion records provide the amount of water diverted at the river headgate. However, only a portion of the headgate diversion is actually available to satisfy crop consumptive use requirements. The unused portion of the headgate diversion is either lost en route to the farm (conveyance loss) or lost during crop application (application or on-farm loss). Conveyance and application efficiencies were estimated in the *Spreadsheet Modeling Support - Efficiencies and Return Flow Patterns* memorandum developed for this study. The efficiencies estimated for the index structures are in the middle range of efficiencies estimated for structures in the basin.

<u>Soil Moisture Holding Capability.</u> The Bear River Basin hydrograph, like most basins in the west, show the peak flow in late spring or early summer coinciding with snowmelt runoff. However, the peak crop demand generally occurs in mid summer, corresponding with more hours of sunlight and warmer temperatures. The practice of applying more water to the land in early spring, when water is available, than the crops actually need is extremely common. Much of this excess supply is stored in the soil root zone and can be used by the crops to continue growing after the surface water supply is exhausted. Depending on the soil characteristics, up to a month of additional growing capabilities is

common. Water stored in the soil root zone is the cause for the "dry-up" period after irrigation ends and prior to harvesting.

Research Report 125 estimated the usable capacity for soil moisture near Randolph UT to be 10 inches, with a corresponding root depth of 6.0 feet. The StateCU Farm Budget/Soil Moisture Accounting procedure requires soil moisture holding capacity input in inches per inch of root depth, allowing the program to account for varying root depth during the growing season and varying root depths by crop. Randolph UT is on the Bear River near Wyoming and was estimated to be representative of soils seen in both the Upper and Central Divisions. Therefore, 0.1389 inches per inch was used to estimate the soil ability to store excess water. If an average root depth of 3-feet is used, this provides a soil "reservoir" capable of holding over 25,000 acre-feet of moisture under the 63,900 acres of irrigated land in the basin.

(63,900 acres) x (0.1389 inches/inch) x (3 feet) = 26,627 acre-feet

Availability of Supplemental Ground Water. Structures that are permitted for supplemental ground water are identified in the Irrigated *Land/Diversion Association* section.

Results - Water-Supply Limited Consumptive Use

The StateCU model was used to automate the Farm Budget/Soil Moisture Accounting procedure for the index structures. The shortages were applied on a monthly basis to other structures within the same Division, as discussed above. Only structures with supplemental ground water were estimated to have a full supply.

Ground Water Use Estimates. Ground water consumptive use was estimated to be the difference between irrigation water requirement and surface water supply-limited consumptive use for those structures with ground water permits. The amount of ground water pumped to meet the deficit demand for these structures is dependent on the application method. More losses are incurred using flood irrigation techniques than sprinkler techniques; therefore more ground water must be pumped to meet the same demand. Table 10 shows the average ground water consumptive use and corresponding pumping estimated by structure, for the study period.

Table 10
Average Ground Water Consumptive Use and Pumping Estimates (1971-1998)

Structure	Ground Water CU (acre-feet)	Average Application Efficiency	Ground Water Pumping
Aggregate Lands on Yellow Creek	120	60 %	200
Aggregate Lands on Twin Creek	200	80 %	250
Aggregate Lands on Bear River between Twin Creek and Smith's Fork	200	80 %	250
Covey Canal	680	80 %	850
Aggregate Lands on Smiths Fork	360	80 %	450
Alonzo F. Sights Ditch	120	80 %	150
Aggregate Lands on Raymond Creek	240	80 %	300
Basin Total	1,920	n/a	2,450

Table 11 shows the average annual irrigation water requirement, water supply-limited consumptive use, and percent shortage estimated for the Upper and Central Divisions. The supply-limited consumptive use includes consumptive use of both surface and ground water sources.

Table 11
Average Annual Crop Consumptive Use Estimates
1971 through 1998

Location	IWR (acre-feet)	Supply-Limited CU (acre-feet)	Percent Shortage
Upper Division	64,300	62,600	2.6 %
Central Division	32,600	31,600	3.1 %
Total Bear River Basin	96,900	94,200	2.8 %

Figures 9 and 10 show the annual irrigation water requirement, consumptive use of surface water, and consumptive use of ground water in the Upper and Central Division for 1971 through 1998.

Figure 9
Upper Division Annual Crop Requirements and Use - 1971 through 1998

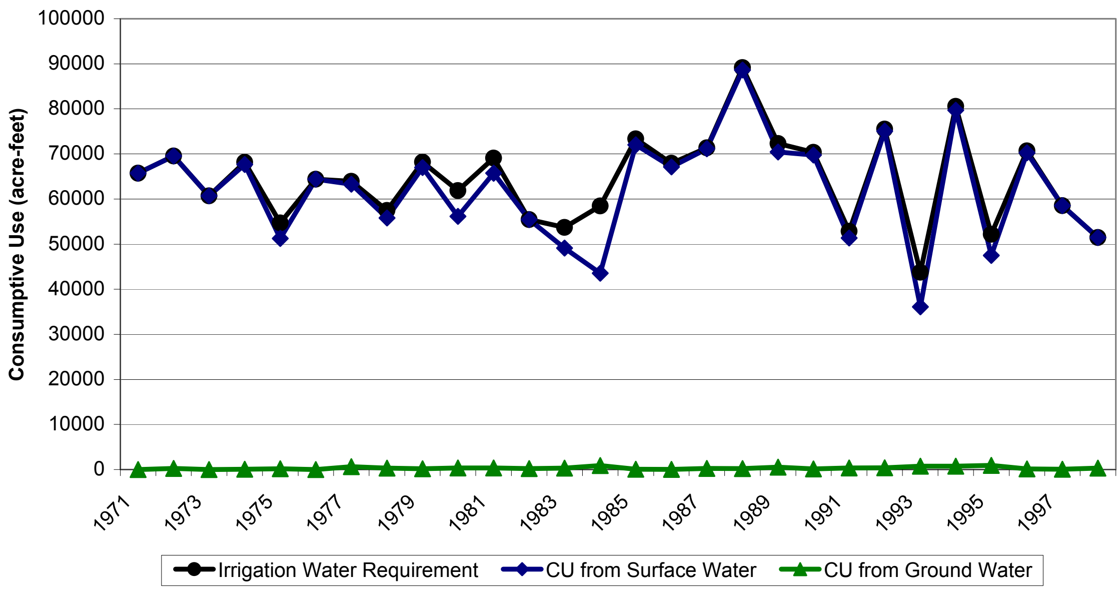
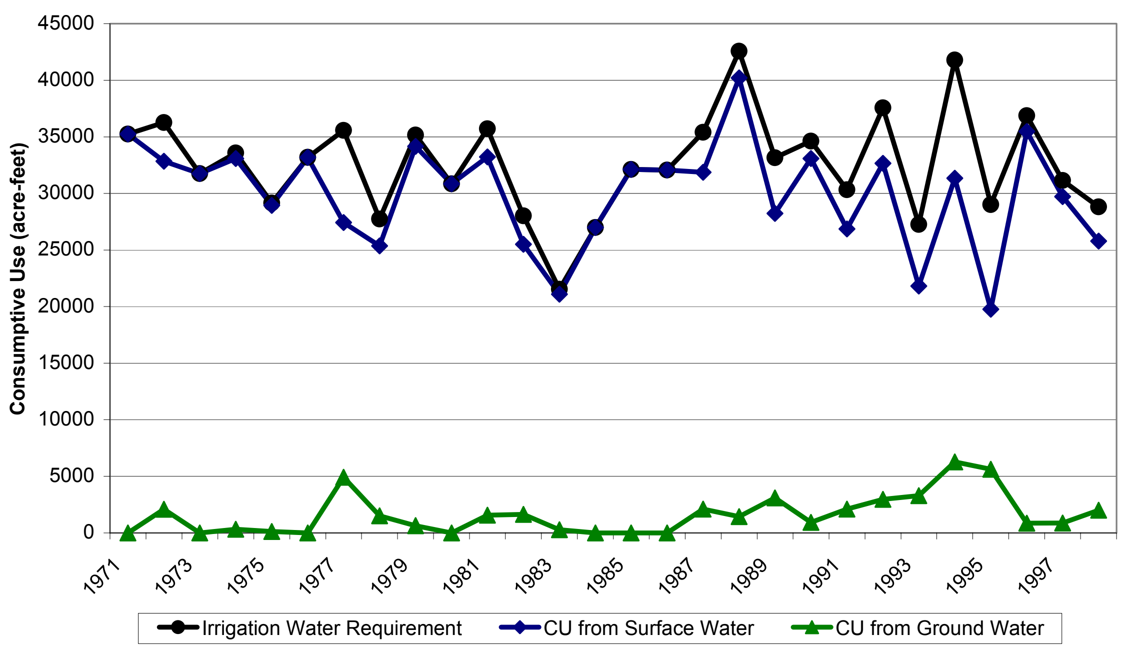


Figure 10
Central Division Annual Crop Requirements and Use - 1971 through 1998



Summary and Conclusions

The Bear River Basin in Wyoming generally has a reliable source of water for irrigation. The three larger reservoirs in the Upper Division allow demand to be satisfied except in the driest years. Supplement ground water, although not widely permitted, helps relieve some of the shortages seen in the Central Division. Figure 11 shows the average annual crop consumptive use for the Upper and Central Divisions from 1971 through 1998. Figure 12 shows the average annual crop consumptive use by supply for 1971 through 1998 for the entire Bear River basin in Wyoming.

Figure 11
Average Annual Supply-Limited Consumptive Use by Division
1971 through 1998

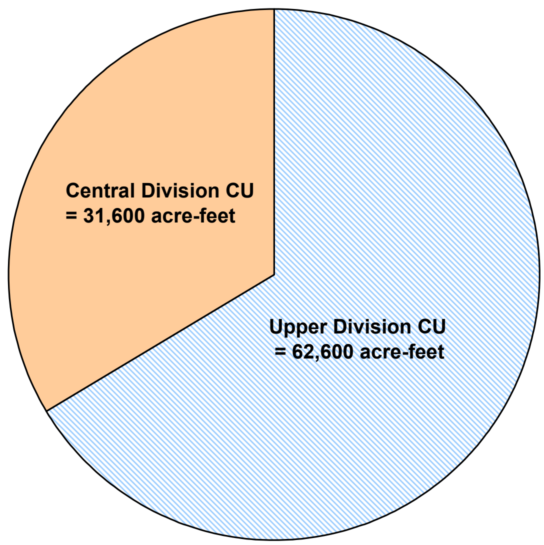
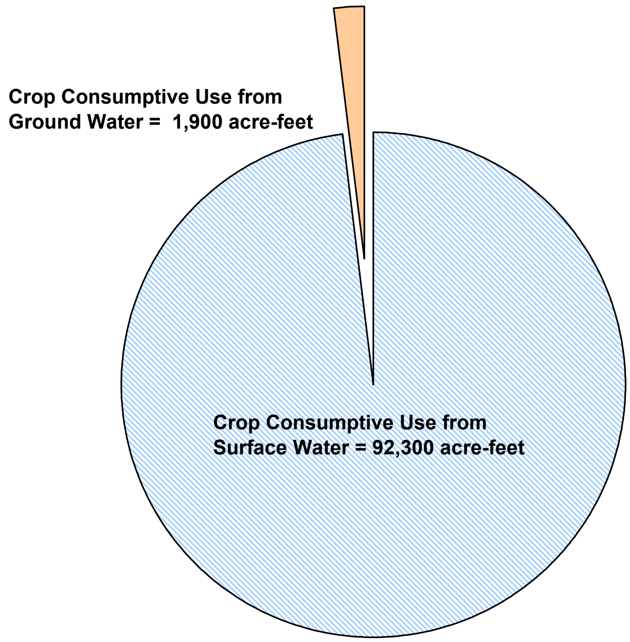


Figure 12
Total Basin Average Annual Supply-Limited Consumptive Use by Source - 1971 through 1998



Comments and Concerns

The method of determining supply-limited consumptive use based on index structures can be improved upon if more detailed mapping of water rights to irrigated lands is undertaken in the future. In addition, more detailed soil analysis and conveyance loss studies may also provide better estimates. However, based on discussions with local water users and water administrators, the estimates prepared in the memorandum are considered an accurate representation of the crop water use.

Estimating ground water consumptive use using the method described in this memorandum is common engineering practice in lieu of better information. However, often farmers sprinkler irrigating from wells will use their ground water as their primary source. This method of estimating ground water use likely underestimates the actual pumping for irrigation use. However, ground water use for irrigation continues to be a small percentage of the water used to meet crop demands.

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