

HELTON & WILLIAMSEN, P.C.
CONSULTING ENGINEERS IN WATER RESOURCES
384 INVERNESS PARKWAY, SUITE 144
ENGLEWOOD, COLORADO 80112-5822
PHONE (303) 792-2161
FAX (303) 792-2165

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MEMORANDUM

TO: Ken Knox – Colorado Division of Water Resources

FROM: Jim Slattery and Randy Hendrix - Helton & Williamsen, P.C.
Dr. Willem A. Schreuder - Principia Mathematica

SUBJECT: 2005 Irrigated Acreage Analysis – Republican River Basin in Colorado

This memorandum documents the procedure to refine the pumping estimates in Colorado by identifying the specific location of the irrigated fields for the 2005 irrigation season using aerial photography. For the 1940 through 2004 period Colorado calculated the irrigation pumping in Colorado utilizing the information from the county's assessor records for irrigated acreage. The county assessors identified the irrigated acreage by county wide totals for sprinkler and flood irrigation. Using these county wide totals and county crop statistics total pumping was estimated for each county. Pumping was then distributed to each grid cell in the MODFLOW model based on the well locations and permitted acreage associated with each well.

Colorado developed a more refined procedure for estimating the well pumping for 2005 by using 2005 aerial photography to identify the location of the irrigated fields. Pumping was estimated for each field based on the county crop statistics, county climate data, and the type of pumping associated with the parcel (flood or sprinkler). The pumping was then assigned to the irrigation well located closest to the irrigated parcel.

Aerial photography for 2005 was obtained from the United States Department of Agriculture's Aerial Photography Field Office (APFO) as part of its National Agricultural Imagery Program (NAIP). Utilizing the 2005 NAIP photographs within a Geographic Information System (GIS) program, individual irrigated parcels were identified. The aerial photography analysis resulted in approximately 1% more irrigated acreage than the 2005 county assessor information for the basin as a whole.

METHODOLOGY

In analyzing the irrigated acreage using the 2005 NAIP aerial photographs several other sources of information were used to determine whether a field should be classified as irrigated in 2005. These sources included the 2004 NAIP aerial photographs, county assessor information, well commissioner field visits, and a tasseled cap analysis of 2001 satellite images. In performing the tasseled cap analysis of the 2001 satellite images, a supervised classification of irrigated versus non-irrigated on a composite of three 2001 satellite images taken during the irrigation season was performed using ERDAS Imagine software. Training and testing sets were developed from approximately 450 fields that were ground truthed in 2001. The overall accuracy assessment of the supervised classification was 76.6 percent.

The county assessor records indicate that center pivot sprinkler irrigation account for approximately 95 percent of all irrigation within the basin. Therefore, the vast majority of the irrigable fields are easily identified from the circular pattern seen in the NAIP aerial photographs.

As shown in Figure 1, the following steps were utilized in this analysis:

1. If a parcel was identified as being part of the Environmental Quality Incentives Program (EQIP) or Conservation Reserve Program (CRP) in 2005 by the Republican River Water Conservation District then the parcel was identified as not irrigated.
2. All surface water irrigated acreage was identified based on field visits and water commissioner information.
3. An inspection of the 2005 NAIP photograph was utilized to determine if the field was irrigated by a center pivot. If the field was not irrigated by a center pivot then the following steps were used to check if the field was flood irrigated.
 - a. The 2005 aerial photograph was visually inspected to determine if the parcel was green with an irrigation well located near the parcel. If neither of these conditions were true then the parcel was identified as not irrigated.
 - b. If the parameters from the previous step were true, information from the county assessor for that parcel was used to confirm that the field was flood irrigated.

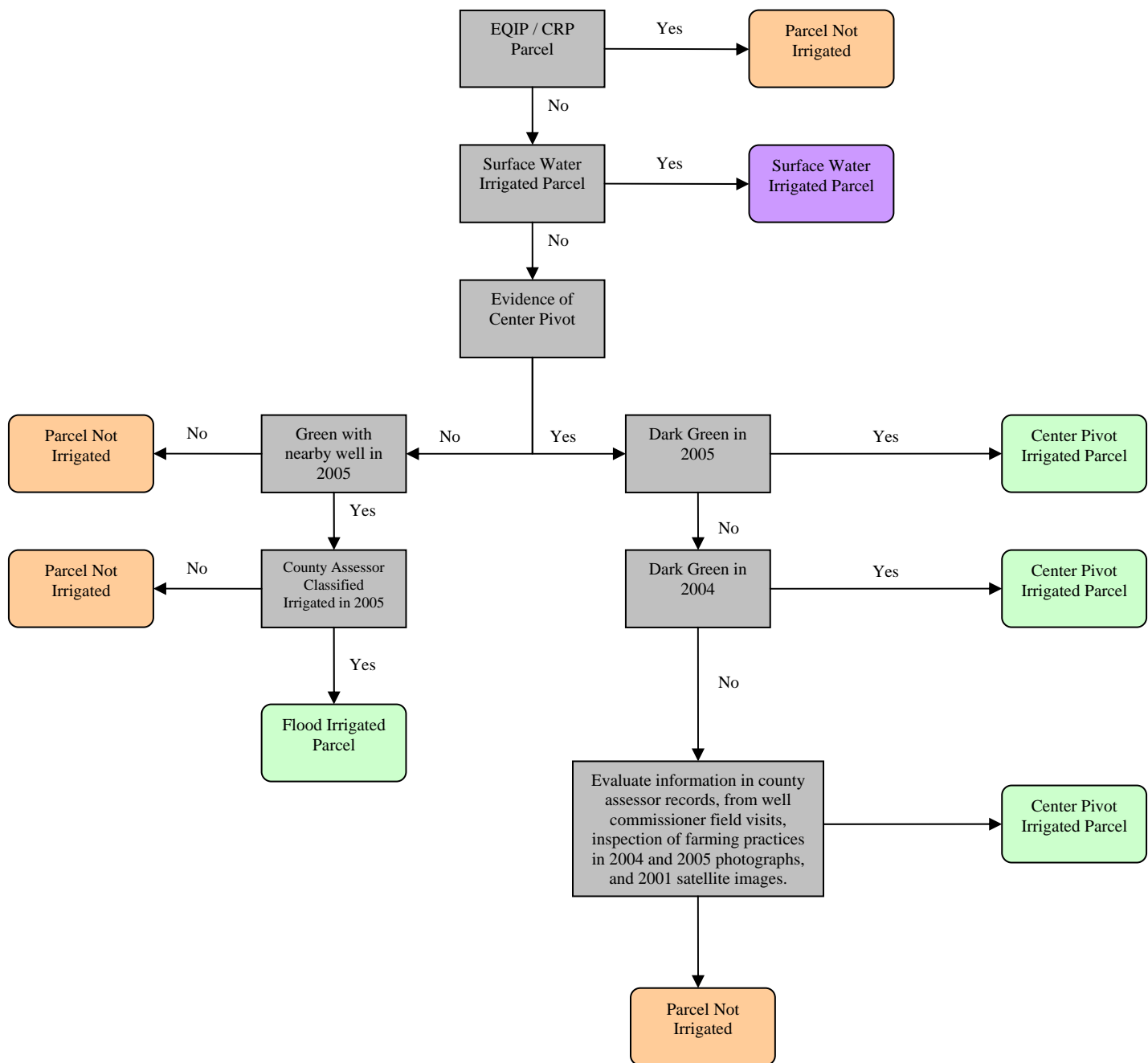
4. If the parcel was determined to be irrigated by a center pivot then the following steps were utilized to determine if the parcel was irrigated in 2005:
 - a. Visual inspection of the 2005 aerial photograph to determine if the parcel was green in 2005. If this condition was true then the field was identified as sprinkler irrigated in 2005.
 - b. Visual inspection of the 2004 aerial photograph to determine if the parcel was green in 2004 to account for possible crop rotation practices. If this condition was true then the parcel was identified as sprinkler irrigated in 2005.
 - c. If a parcel was not identified as irrigated in either of the previous two steps then engineering judgment was used to determine if the parcel was irrigated in 2005. In evaluating the parcel the following information was used: 1) data from county assessor's records, 2) well commissioner field visits, 3) inspection of farming practices shown in the 2004 and 2005 aerial photographs, and 4) indication of irrigation utilizing a tasseled cap analysis of satellite imagery during the 2001 irrigation season.

The acreage of each parcel was determined utilizing ArcGIS. The acreage was summed for each county and compared to the 2005 county assessor information. The following table is the results of that comparison.

Table 1 – Comparison of 2005 Assessor and Aerial Photograph Irrigated Acreage
(both figures reduced for estimated EQIP, CREP, and surface water irrigated acres)

Year	County (or portion of County in the Republican River Basin study area)								Total
	Kit Cheyenne	Carson	Lincoln	Logan	Phillips	Sedgwick	Washington	Yuma	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2005 Assessor Data									
Sprinkler	10,354	149,546	1,080	5,002	62,155	22,463	31,253	257,182	539,035
Flood	1,024	11,256	402	102	5,331	458	5,258	8,228	32,059
Total	11,378	160,803	1,482	5,104	67,486	22,921	36,511	265,409	571,094
2005 Aerial Photography Estimated from GIS Coverage									
Sprinkler	10,242	155,163	2,367	5,841	68,670	23,282	37,310	268,982	571,858
Flood	102	1,893	0	0	2,262	584	0	1,254	6,095
Total	10,344	157,057	2,367	5,841	70,932	23,866	37,310	270,236	577,953

Figure 1
Republican River Basin Irrigated Acreage in 2005



As Table 1 indicates the overall difference between the irrigated acreage summarized by the county assessors and the evaluation using 2005 aerial photography is approximately 1 percent.

ASSIGN IRRIGATED ACREAGE TO WELL

A GIS layer of irrigated acreage and irrigation well location were spatially joined to assign each irrigated parcel to a well. A tool within ArcGIS will spatially join attributes from one layer to the information from a second layer. The option of using the attributes from the closest well to the parcel was used with this spatial joining tool. If a well was within a parcel it was considered the closest to that irrigated parcel.

The amount of sprinkler and flood irrigated acreage was summarized for each well within the model. This information was used to determine the location of pumping in the MODFLOW model.

IRRIGATION PUMPING WITHIN GROUND WATER MODEL

Once the amount of flood irrigated acres and the amount of center pivot irrigated acreage was determined for each well, the amount of pumping and associated groundwater recharge was estimated for each well. This was estimated using the following formulas to estimate the pumping and recharge rates (units of acre-ft/acre):

$$\begin{aligned}\text{Pumping Sprinkler} &= \text{Deficit} * \text{NetCIR} / \text{SprinklerFarmEfficiency} \\ \text{Pumping Flood} &= \text{Deficit} * \text{NetCIR} / \text{FloodFarmEfficiency}\end{aligned}$$

$$\begin{aligned}\text{ReturnSprinkler} &= \text{DeepPercPercentSprinkler} * \text{PumpingSprinkler} \\ \text{ReturnFlood} &= \text{DeepPercPercentFlood} * \text{PumpingFlood}\end{aligned}$$

Where:

DEFICIT = The amount of pumping as a percentage of the theoretical Net CIR amount. This value is used to adjust the Net CIR to represent the deficit irrigation employed based on the 150 change cases in the basin (75%).

SprinklerFarmEfficiency = Irrigation efficiency for sprinkler irrigation (80%)
FloodFarmEfficiency = Irrigation efficiency for flood irrigation (65%)

NETCIR = Net crop irrigation requirement by County after accounting for effective precipitation and gain in soil moisture from winter and spring precipitation estimated using the same procedure previously utilized by Colorado.

DeepPercPercentSprinkler = Percent of applied sprinkler irrigation that returns to the groundwater system by deep percolation (17%).

DeepPercPercentFlood = Percent of applied flood irrigation that returns to the groundwater system by deep percolation of the applied water (30%).

For each individual irrigation well in the well database, the calculation is then (units of ac-ft):

Pumping = PumpingSprinkler * AcresSprinkler + PumpingFlood * AcresFlood

Returns = ReturnSprinkler * AcresSprinkler + ReturnFlood * AcresFlood

Acres = AcresSprinkler + AcresFlood

The Pumping, Returns and Acres are assigned to model cells corresponding to the location of the well. Note that for most wells, either AcresSprinkler or AcresFlood is zero. In isolated cases, some wells irrigate both flood and sprinkler acres.

SUMMARY

The irrigated acreage in the Colorado portion of the Republican River basin was determined to be 577,953 acres using 2005 aerial photograph and other supplementary sources of data. The aerial photography analysis resulted in approximately 1% more irrigated acreage than the 2005 county assessor information for the basin as a whole. The location of the irrigated parcels determined from the aerial photography was used to refine the location of the pumping within the basin.