THE ROLE OF TRIBUTARY GROUND WATER IN IRRIGATED CROP PRODUCTION IN THE SOUTH PLATTE BASIN: RESULTS FROM A SURVEY

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ABSTRACT

The Role of Tributary Ground Water In Irrigated Crop Production in the South Platte Basin: Results from a Survey

When a drought appeared to be developing in northeastern Colorado in 1989, a survey of farmers using water from the South Platte stream-aquifer system was designed to learn how farmers adapted to limited irrigation water supplies, with particular emphasis on the role of ground water. The survey was planned to provide estimates of the volume of surface and ground water used for irrigation in 1989, to seek information on how farmers used ground water in adapting to drought, and to determine whether ground water use was increasing over time. Secondary objectives included learning the extent of leasing (temporary surface water transfers) among water right owners to meet local temporary needs and estimating the perceived adequacy of existing water sources.

Although late summer rains in 1989 eased concerns over drought, the study was carried out as planned during the autumn of 1989. The most complete available list of commercial farmers was one that represented federal farm program participants. A mail survey was planned, but a mailed pretest questionnaire failed to yield accurate and complete information. Telephone methods were used to interview 198 farmers in seven counties in the basin, providing much improved response rates and more accurate and complete results. Farms irrigating fewer than 25 acres were excluded from the sample because of their limited commercial importance. When the data were analyzed, we found that the sampling procedure did not obtain an adequate representation of large farms (defined here as those irrigating over 1000 acres), mainly because the corporate entities registered for federal farm programs often were not listed or could not be identified in telephone directories.

Survey results confirm that wells drawing from the South Platte tributary aquifer supply a large proportion (about 35 percent for those surveyed) of irrigation water applied, augmenting irrigation capacity and increasing agricultural productivity, and reducing farmers' dependence on fluctuating surface water supplies. (The reliance on ground water was found to increase with farm size which, given the under-representation of very large farms in the sample, suggests that the actual use of ground water may be even higher than our results indicate.) Leasing provides additional flexibility to the South Platte water distribution system, although at only 6 percent of total surface water diversions, it is considerably less significant than ground water. Surface water leasing is most common in the Front Range counties where urban water right ownership is increasing, and wells are less common. Conversely, wells are more frequently found in the counties farther downriver where surface water is relatively scarce. Small farms typically depend more on surface water than large farms.

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I. INTRODUCTION

Background

The South Platte River originates on the east side of the Rocky Mountains of central and northern Colorado and flows northeast to Nebraska to meet the North Platte. About 80 percent of the South Platte Basin's 24,300 square miles are located in Colorado. The South Platte River serves the most important urban and agricultural areas in Colorado. About two-thirds of the state's population lives in the basin. Native surface water supplies average over 1.4 million acre-feet (maf) per year, supplemented by some 0.4 maf of water imported from the western slope. On the average, approximately 0.4 maf flows out of Colorado to Nebraska.

Linked to the South Platte River is an important ground water resource. An unconfined alluvial aquifer along the river and its tributaries, consisting of unconsolidated deposits hydraulically connected (tributary) to the river, provides water to small rural public supply systems and large amounts of supplemental water to irrigators. Official data do not separate the irrigation wells in the tributary aquifer from all high capacity wells in the basin, so there are apparently no specific official records of the number of large capacity irrigation wells in the basin. Informal estimates by the Colorado Division of Water Resources indicate that over 8,000 irrigation wells are currently withdrawing from the tributary aquifer.

The alluvial aquifer is recharged by excess surface irrigation water applications, by precipitation, and from leakage from reservoirs and ditches. The stream and aquifer maintain a hydrologic balance; water flowing from stream to aquifer or from aquifer to stream, depending on the relative water levels. With an estimated storage capacity of nearly nine maf (Hurr et al., 1975), the South Platte tributary aquifer represents a water resource many times larger than the human-made surface water storage developed in the basin over the past century.

Economic and population growth continue to increase the demand for urban water supplies in northeastern Colorado. Given the difficulties in developing additional traditional storage projects, attention turns to alternative methods of accommodating both continuing agricultural needs and population growth. Rural-to-urban water rights transfers and conservation by users are the most frequently discussed alternative approaches. In previous studies of non-traditional alternatives, Young et al. (1990) examined the effects of rural-to-urban market transfers of water, while Michelsen and Young (1993) examined the possibility of dry-year options for meeting urban water needs.

The aquifer tributary to the South Platte River is another potentially significant contributor to water supplies in northeastern Colorado. With its extensive storage capacity, it could serve as a buffer reservoir to be drawn upon during periods when rainfall and surface water supplies are limited. MacDonnell (1986) discussed the evolution of legal institutions governing the interrelated stream-aquifer system in the South Platte Basin. Young et al. (1990) showed (via a hydrologic-economic simulation model of the Henderson-Kersey reach of the South Platte stream-aquifer system) that it would be possible in the short term to replace 30,000 to 40,000 acre feet of surface water by pumping, without causing major adverse effects on either the aquifer or on streamflows. Based on a sampling of pumps chosen for a hydrologic investigation conducted by the U.S. Geological Survey, Hurr et al. (1975) estimated that during 1961-70, an annual average 566,000 acre-feet was pumped from the tributary aquifer for crop irrigation. This compares to their estimate of an average 981,000 acre-feet of surface water diverted annually from the South Platte system for irrigation during 1947-70. Based on these two estimates, ground water supplied approximately 36 percent of the water withdrawn by irrigators in the South Platte River Basin during the 1961-70 period.

As noted above, the South Platte River and its tributary aquifer represent a single hydraulic system. The flow of water through the South Platte stream-aquifer depends on natural conditions (weather and aquifer storage capacity) and man-made structures (reservoirs, ditches and wells). Crop irrigation diverts surface and ground water from natural channels, distributing it over a wide area. A part of the applied water (some 50-70 percent) transpires through crops or evaporates from fields, and the remainder seeps into the underlying aquifer. Water reaching the tributary aquifer eventually returns to natural channels, most of which becomes available throughout the summer. Increases in ground water use from the thousands of new wells installed mainly during the 1950s and 1960s indirectly reduces water supplies of downstream surface water users.

Updated information on how farmers actually use the conjunctive stream-aquifer system will be valuable for devising policies to further utilize the aquifer. Every year ditch companies and ground water augmentation organizations estimate the volume of water used by irrigators in northeastern Colorado. Ditch companies estimate the volume of surface water diverted from the South Platte River and from reservoirs and canals supplying their ditches. Ground water augmentation organizations estimate the ground water pumped from the South Platte tributary aquifer. Ditch companies own and maintain canals, distributing surface water according to their members' expressed needs and water right claims. They play a complex role of allocating surface water from rivers, reservoirs, and, to some extent, field runoff and ditch leakage as water moves through the South Platte tributary aquifer.

Ground water augmentation organizations, funded by pump operators, are responsible for ensuring adequate water to higher priority surface water right owners. They estimate the volume of ground water pumped from members' wells as a basis for allocating water, ditch maintenance, and operating costs. Groundwater Appropriators of the South Platte (GASP) and the Central Colorado Water Conservancy District (Central) are the primary ground water augmentation organizations in the South Platte Basin. GASP and Central purchase and lease water rights and authorize release of water from reservoirs and pumping fields to senior right owners who put "calls on the river" when the senior's surface water supplies are inadequate. Most of the water released by GASP and Central to senior water right holders is far downstream from where wells are located and drawdown occurs.

Unfortunately, most of the data collected by these organizations is unavailable to the public or to researchers. The augmentation organizations and ditch companies we contacted while designing the survey declined to reveal their members' historical water use, except in highly aggregated form. It is therefore difficult to find up-to-date answers to such questions as how much water from the stream-aquifer system is used by irrigators in individual reaches of the basin. When a drought appeared to be developing in early 1989, it also appeared useful to learn how drawing on ground water and entering into temporary lease arrangements would help farmers respond to water shortages. We therefore undertook to conduct a survey of farms to learn more about the role of ground water and water right leasing for irrigation in the basin.

Objectives of Study

The specific purpose of the study reported here was to better understand surface and ground water use by the agricultural sector in the Colorado's South Platte Basin, and to learn how farmers responded to limited water supplies. Our primary interest was in the role of tributary ground water in irrigated crop production in the South Platte Basin. We aimed to document the significance of the South Platte tributary aquifer in meeting the water needs of northeastern Colorado irrigators, and to determine whether farmers are increasing their use of the aquifer to supplement limited surface water supplies. Matters of secondary interest were how short-term leasing was used to meet temporary water needs, and what proportion of farmers experienced water shortages and felt threatened by growing urban demands.

The purpose of the survey was to estimate population parameters for a number of variables, including 1) acres irrigated, 2) use of surface water rights, 3) distribution of irrigation wells, 4) volume of surface and ground water used, 5) number of acres irrigable and actually irrigated by wells, and 6) extent of temporary water leasing transactions. Another goal was to determine how farmers use ground water and leasing to cope with inadequate surface water supplies. The study area falls within seven counties in the non-mountainous parts of the basin in northeastern Colorado, including four counties along the Northern Front Range (Adams, Boulder, Larimer and Weld; henceforth designated in this report as the Front Range) and three counties farther downriver in the lower South Platte Basin (Logan, Morgan and Sedgwick; henceforth designated as the Lower South Platte).

A year such as 1989 is not entirely appropriate for describing long term water needs in northeastern Colorado. However, 1989 is quite suitable for determining how farmers use ground water and water leasing to cope with limited surface water supplies. "All indications at the beginning of the summer months were that Colorado was in the grip of a severe drought," reported the September, 1989 edition of *Stream Lines*, a monthly newsletter published by the Colorado Division of Water Resources. The rainfall at the beginning of the 1989 cropping season was unusually low for an already semiarid northeastern Colorado. (In a typical season, about half the average annual 14 inches of precipitation falls during April-June). In July, 1989, many of the weather stations in the South Platte Basin measured accumulated rainfall at about half its meager normal level. In some areas farmers irrigated their fields before planting because of insufficient rain and spring runoff to germinate the seed corn planted in April and the pinto beans planted in mid to late May. After the dry spring and early summer, fields throughout the basin quickly dried. Most disturbing, calls on the river began in June, a month earlier than usual, as some water right holders ran short of ditch water and exercised their claims by requiring that upstream ditch users cease diversions and pump operators provide supplemental surface water. However, despite widespread early indications of drought, the weather turned unusually wet by late July, and total accumulated rainfall in the 1989 cropping season was above average. Although the ample late summer rains in 1989 eased the worry over drought, the study plan was carried out.

II. SURVEY METHODS

Initial Steps in Planning

There are no recently published data on the specific details of ground water use and water leasing activities by irrigators in the South Platte Basin. Our survey undertook to determine the sources, volumes, and uses of irrigation water used in the area. (We were interested only in irrigation wells. Ground water use for households, farmsteads and livestock were omitted.) The following description of survey methods tells how the survey was designed, tested, and conducted. Farmers were expected to respond to survey questions by citing data from their own records, ditch company annual reports, and GASP and Central invoices.

Initially, a mail survey was planned. (Limited budget and researcher time precluded the most desirable personal interview approach). With assistance from colleagues in the Department of Agricultural and Resource Economics and the Department of Statistics at Colorado State University (CSU), we designed a written questionnaire and formulated a sampling plan.

Questionnaire Pretest Procedures

Next, we developed a pretest procedure to refine our approach. Agricultural agents of the CSU Cooperative Extension Service in each of the seven counties in the study area evaluated an initial draft of the mail survey questionnaire, and we incorporated their suggestions into the survey. Extension agents in four counties then identified 40 irrigators likely to cooperate in a pilot survey. To this group, we mailed draft questionnaires, cover letters explaining the purpose of the survey, and pre-addressed, stamped envelopes.

However, only three irrigators responded, and these few responses were incomplete, inaccurate, or both. To learn why our questionnaire was not successful, we contacted non-respondents by telephone. These telephone interviews successfully gathered data where the mail survey had failed. This approach was more convenient for farmer respondents and demonstrated significant advantages in completeness and accuracy over the postal approach. Telephone surveys were less expensive, yielded higher response rates and lower sampling bias, and enabled interviewers to adapt to respondents' terminology, to determine the reliability of responses and to quickly eliminate unqualified respondents. [See Dillman (1978) and Fowler (1993) for recommended procedures for conducting surveys, including sampling, questionnaire design, interviewing techniques and data recording. Lavrakas (1987) specifically addresses telephone surveys. Salant and Dillman (1994) provide a more recent and readily comprehensible authority.)

Details of Survey Methods

The sampling procedure was designed with the guidance of the Statistics Laboratory at Colorado State University. A sample of approximately 30 respondents per county was randomly selected to enable researchers to identify statistically significant differences in irrigation practices between farms of different size categories in the Front Range and the Lower South Platte. (Larimer and Boulder Counties were grouped together for purposes of the study.)

The sample population was composed of participants in federal farm programs, which we believe is the most complete sample frame available for our purposes. Names were randomly selected from lists provided by the Agricultural Stabilization and

Conservation Service (ASCS) county offices. When selected farmers could not be contacted by telephone (i.e., telephone numbers could not be found or farmers were unavailable for the original call and two callbacks) or when farmers refused to answer survey questions, new names were randomly selected from ASCS lists. To qualify as a respondent, a farmer must have irrigated at least 25 acres of crops in 1989 and used irrigation water from the South Platte, its tributaries, and/or its tributary aquifer. We intentionally excluded irrigators relying on ground water from the Ogallala-High Plains Aquifer, because those water users typically rely completely on that source and do not draw from the South Platte tributary aquifer. We believe the exclusion of non-participants in the farm program and those irrigating less than 25 acres, most of whom were probably hobby and truck garden farmers, did not seriously bias results.

The survey was conducted between January - March, 1990. The senior author of this report, P. Kingsley Bash, and another graduate student in the Department of Agricultural and Resource Economics at CSU conducted the telephone interviews. Calls took place mostly in the evenings for the convenience of both interviewers and respondents. Respondents were assured of anonymity. Interviewers followed a checklist of questions adapted from the initial questionnaire.

Completed interviews were obtained from 198 irrigators. The response rate for completed interviews was 80 percent of the eligible farmers contacted. Approximately 25 respondents provided what were judged to be inadequate or unreliable information, and these responses were discarded. Only eight farmers refused to answer the survey questions. Seven of these farmers, nevertheless, reported their total irrigated acreage.

The distribution of farm sizes of those farmers who refused to answer survey questions was similar to the distribution found in the general sample, thus avoiding a source of sample bias.

Once the interviews were completed and we turned to analysis of the responses, we recognized a serious problem with the survey. Census data indicate that farms with more than 1,000 irrigated acres make up about 38 percent of the irrigated farm acreage. However, farms with over 1,000 irrigated acres made up only 4 percent of the farms actually interviewed, even though they accounted for a larger percentage of the acres in our sample. We had been unable to find telephone numbers for many farms in the ASCS lists, a disproportionate number of whom turned out to be larger farms. Incorporated family farms may be registered under their corporate name with the ASCS but not have a listed telephone under that name. Given our resource limitations, we could not find a way to go back and locate additional observations to complete our subsample of large farms. The small number of respondents with large farms introduces a significant potential error [of the type called "coverage error" in survey research textbooks (Salant and Dillman, 1994)], and made our findings on large farm irrigation practices less reliable than desired. Responses from large farms were included in the "All Farms" category, but were not reported separately.

Estimating the quantity of water received by farmers proved difficult. Most irrigators reported the number of ditch company shares they owned, but did not accurately recall the volume of surface water they actually received. Subsequent interviews with their ditch companies (described in more detail in the next paragraph) provided estimates of the volume of surface water diverted per ditch company share.

In order to improve our estimates of surface water supplied with various priority rights, we subsequently contacted as many of the ditch companies identified by survey respondents to be serving them along the South Platte in Colorado as we could locate. Most of the remaining (about 15 percent) ditch companies designated by farmers were apparently not legal entities. Some were abbreviations or local nicknames for ditch companies we were able to identify. Others were the names of local ditches, rather than ditch companies. The ditch companies we contacted supplied approximately 95 percent of the surface water used by all survey respondents. They provided estimates of the total number of shares owned by members, and the number of acre-feet diverted from lakes, rivers and reservoirs per share. They did not estimate the volume of water delivered to individual farmers' headgates. The diverted volume may have exceeded the delivered volume by 10-25 percent, due to conveyance losses. It is likely that this source of estimate error was largely offset by another source of error. Previous CSU studies indicate that pump operators without flow meters tended to overestimate the flow rates and efficiency of wells and pumping equipment (Longenbaugh, 1979). Irrigators thereby overstate the volume of ground water pumped and underestimate the proportion of surface water used. On the other hand, conveyance losses were ignored when estimating surface water diversions, thereby overestimating the proportion of surface water used. These two sources of estimate error are opposite in effect and are likely approximately equal in magnitude, so the estimated average proportions of surface and ground water used are believed to be indicative of typical field conditions.

Limitations of the Approach

In addition to the sampling limitations discussed above, we noted several other limitations to our procedures. Despite pretesting, some of the survey questions contained terminology confusing to respondents. For example, almost all farmers characterized their surface water rights as "Senior," implying a long-standing high-priority legal claim to a specified proportion of available surface water. Because everyone in a prior appropriation system cannot have senior rights, apparently some respondents either misunderstand the water rights system, or they measured water supply reliability in other terms. Perhaps they did not measure water supply reliability because they saw no immediate threat to their water supplies. Perhaps they had reliable measures of water supply reliability, but they did not know how it compared with those of other farmers. Water right priority status was not subject to frequent manipulation by farmers. Urban areas frequently purchase water rights to increase their water portfolio's priority and security, but farmers rely more heavily on temporary water leasing. Farmers rarely buy and sell permanent rights and seldom switch ditch companies to increase their priority right status. For many farmers, water right priority status may change from year to year. Farmers frequently reported owning shares in several companies, each of which distributed water according to its own unique priority status. Even if the priority status of each water source were clearly defined, the overall status of a farmer's water rights can change from year-to-year as ditch companies supply different proportions of surface water each year. In practice, water right priority strictly determined neither the absolute or relative volume of water delivered. Some ditch companies in the Front Range, for example, had unlimited "free water" during spring runoff regardless of priority rights. Perhaps most significantly, it was our impression that ditch companies often cooperated informally in subordinating water right seniority to improve water distribution efficiency.

Moreover, despite survey pretesting, some of our questions did not anticipate the breadth of potential responses. For example, farmers were asked the cost and volume of water they leased. We assumed the term "water leasing" would cover all manner of water transfers between farmers and between farmers and urban water right holders. Eventually, however, one respondent reported receiving "surface water loans." Perhaps other farmers receiving surface water loans, gifts, or trades reported these cashless transfers as leases, thereby overestimating the volume of water actually leased. It is also possible that cashless water transfers went unreported. Cashless water transfers possibly occur frequently as neighboring farms, preferring barter and reciprocity to formal contracts and even taxable income, find ways to coordinate water use.

Respondents frequently answered survey questions imprecisely. A primary cause of imprecision was recall error. Six or more months had elapsed between the irrigation decisions of the summer of 1989 and the survey in early 1990. Second, few farmers used water measurement instruments like water meters. Indirect measurements based on flow and duration estimates compounded recall error. Nearly all respondents provided detailed data and estimates, and most reported the number of surface water rights they owned and also estimated the flow rates of their pumps. Most farmers recalled their 1989 irrigation schedules and knew the approximate dates and durations of irrigation. Several knew the number of acre-feet of surface water delivered per share of water rights. Few knew how many acre-feet they applied to crops. This information frequently had to be derived indirectly using imprecise estimates. In addition, respondents often rounded to the nearest ten, hundred or thousand unit and used estimates in calculations, which compounded the imprecision. Cross-referencing of responses increased both the response rates and reduced the degree of estimate error. For example, interviewers first asked farmers how many acre-feet of water they used, and subsequently asked the same question in terms of flow rates, frequency and duration of irrigation, and number of ditch company shares. When cross-referencing revealed discrepancies, interviewers could identify the source of error and attempt to reconcile the conflicting responses.

III. RESULTS

Our findings are summarized in four tables. Table 1 presents the overall results of all 198 responses, subdivided by regions (Front Range and Lower South Platte Basin). Tables 2 and 3 show responses of small and medium farms, also subdivided by region. (Recall the limited response obtained from the large farm sector; accordingly, those results are not reported separately). Table 4 presents the overall results of all 198 responses, subdivided by county.

In extrapolating the sample to the population, non-numerical responses, including those regarding the adequacy of water supplies and the existence of irrigation wells and ditches, were weighted by the number of farms in the population. Numerical answers, including the number of wells used per farm and the number of irrigated acres per well used, were weighted by the number of irrigated acres in the population subsample.

Summary of Findings from the Entire Sample

Table 1 displays the findings for the entire survey of activities in 1989 of South Platte Basin farms irrigating more than 25 acres, and also shows results divided by subregion. U.S. Census data show that in 1987, there were about 3,900 farms irrigating 773,000 acres in the seven-county study region.

More than half (some 55 percent) of the farm operators we contacted reported that they used irrigation wells. (As noted earlier, all subsequent reference to wells will be to wells used for field irrigation; we omit consideration of wells for household and farmstead water supply or for livestock watering.) Ground water provided an estimated 35 percent of the irrigation water used on sample farms in the South Platte Basin in 1989, and surface water sources (including water delivered by ditches from both streams and reservoirs)

Table 1 Survey Results Regarding Irrigation Management in the South Platte Basin: All Irrigated Farms With at Least 25 Irrigated Acres (total and by region), 1989.

	Front Range	High Plains	Total Basin
GENERAL			
Irrigated Acres[a]	521,000	252,000	773,000
Farms with Irrigation	2,922	962	3,884
GROUND WATER			
Proportion of Irrigation Water from Ground Water	31.0%	49.0%	35.0%
Proportion of Farms with Irrigation Wells	50.0%	75.0%	55.0%
Average # of Wells Used per Farm with Wells[b]	4.1	4.5	4.3
	(0.4)	(0.4)	(0.3)
Average # of Irrigated Acres per Well Used[b]	80.0	130.0	102.0
	(17.0)	(25.0)	(16.0)
Acreage Potentially Irrigated by Wells	30.0%	31.0%	30.0%
SURFACE WATER			
Proportion of Irrigation Water from Surface Water	69.0%	51.0%	65.0%
Proportion of Farms Leasing-In	32.0%	20.0%	27.0%
Proportion of Surface Water Leased-In	7.0%	5.0%	6.0%
OTHER			
Farms with Water Deficit in 1989	33.0%	33.0%	33.0%
Farmers Feeling Threatened by Growing Urban Water Demand	83.0%	53.0%	70.0%

[a] 1987 Census of Agriculture
[b] Standard errors are given in parentheses.

provided the remaining 65 percent. On average, there are 4.3 irrigation wells per farm with wells. (These data imply a total of about 8,800 irrigation wells drawing from the tributary aquifer in the basin, which is quite similar to the "8,000 +" wells informally estimated by the State Division of Water Resources.) Respondents reported an average of 102 irrigated acres per well used.

Because the water right in Colorado is a legal property right, short-term leases or rentals of irrigation water supplies can be readily negotiated between prospective purchasers and sellers of water. Other than standard contract law, no special regulations govern leasing of water. The terms (price, quantity, timing) of a lease can be set out in formal written documents, although verbal agreements are also employed. Municipal water agencies in the Front Range typically own water rights in excess of current needs. These agencies are frequently willing to make water temporarily available to farmers via some sort of lease or rental agreement.

It is customary to refer to the lessor (selling side of a lease agreement) as “leasing-out” and to the lessee (buying side of a lease) as “leasing-in.” Lease agreements can apply to transactions ranging from one single irrigation event to renting water supplies for an entire irrigation season.

We asked farmers if they leased-in water rights during the study year. Leasing-in of water was frequently reported by respondents, although this practice is less extensively employed and less important to overall water supply than to ground water. About 27 percent of the irrigated farms reported leasing-in water from other farmers or from urban holders of water rights in 1989. However, only 6 percent of surface water used was leased, making this source of adjustment to shortages much less significant than ground water.

Farmers in the basin expressed some concern over their water situation and outlook for the future. One-third indicated experiencing some degree of water deficit during 1989. A much larger proportion (78 percent) reported feeling threatened by growing urban water demands.

Contrasting the Front Range and Lower Basin Region Responses

We turn next to a discussion of the overall sample results, subdivided according to geographic area, also from Table 1. The Front Range counties of Adams, Boulder, Larimer and Weld contained approximately 521,000 irrigated acres on some 2,900 farms in the South Platte Basin (from Census data shown in Table 1). These counties accounted for about 75 percent of the irrigated farms but represented only about 68 percent of the irrigated acres.

Respondents reported that ground water provided 31 percent of the irrigation water from the South Platte tributary aquifer used in the sampled Front Range counties (Adams, Boulder, Larimer, Weld) in 1989. On average, approximately 50 percent of the farms in the Front Range had irrigation wells, with an average 4.1 wells per farm. A typical Front Range farm had 80 irrigated acres per well. If surface water were inadequate due to drought or other causes, about 30 percent of the irrigated area could have been adequately irrigated using only wells. The average number of irrigated acres per well is higher in the Lower South Platte Basin (130 acres) than in the Front Range (80 acres). In both regions, the number of wells on farms using ground water was approximately equal - an average 4.5 wells per irrigated farm.

Approximately one-third (32 percent) of the Front Range irrigated farms reported that they leased-in irrigation water, receiving an average 7 percent of their surface water from other water right owners. Lower Basin farmers were less likely to report leasing water, with only 20 percent reporting this practice. However, 5 percent of water supplies were leased-in. Front Range farms in the sample relied less on ground water than did farms in the Lower Basin, but reported a slightly higher incidence of leasing.

The proportion of responding Front Range area farmers reporting irrigation water deficits during the 1989 season (32 percent) was similar to that of the Lower Basin, (34 percent). Farmers from the relatively densely populated counties in the Front Range, however, were much more likely to express concern over threats from growing urban demand; some 83 percent responded positively to that question, compared to only 53 percent in the Lower Basin.

Despite the larger irrigated acreage per well in the Lower South Platte Basin, farmers in both regions estimated that if surface water were suddenly to become unavailable due to drought or other causes, about 30 percent of the irrigated area could have been adequately irrigated temporarily using only wells. This indicates either that wells in the Lower South Platte Basin are of larger capacity, or that topography or geohydrology is more limiting to ground water distribution in the Front Range than in the Lower South Platte Basin.

Ground water provided 49 percent of the irrigation water from the South Platte stream-aquifer system in the Lower South Platte Basin counties in 1989. A larger proportion of farms had wells, and a smaller proportion of farmers leased surface water than in Front Range counties. On average, approximately 75 percent of the farms in the Lower South Platte Basin had irrigation wells, with an average 4.5 wells per farm. A typical farm had 130 irrigated acres per well. Approximately 20 percent of the farms leased water from other water users, receiving an average 5 percent of their surface water from leasing.

Water Use Patterns by Size of Farms

Turning now to Tables 2 and 3, we discuss basin-wide results classified by number of acres irrigated. "Small farms" were defined as farms having 25-299 irrigated acres, and "medium farms" were defined as farms having 300-1000 irrigated acres. Approximately 62 percent of the total irrigated acreage was on small and medium farms with 25-1000 irrigated acres (Tables 2 and 3). The largest farms (over 1000 acres), representing 38 percent of acres, are not discussed here due to the insufficient number of observations.

Considering the basin as a whole, small farms depended somewhat more on surface water and were less likely to have wells than were medium farms. Approximately 50 percent of the small farms had wells, with an average 2.7 wells per farm, as compared to 71 percent of medium farms, with an average 4.9 wells per farm with wells. Medium farms reported that 40 percent of their water was supplied from ground water, while small farms indicated only 25 percent. Small farms with wells also had more irrigated acres per well than larger farms, irrigating an average 131 irrigated acres per well. Medium farms irrigated an average 80 acres per well.

Leasing was more common among medium farms than among small farms. Only 22 percent of small farms leased irrigation water, amounting to an average 3 percent of their surface water supplies, while 35 percent of medium farms leased 9 percent of their surface water. Farms without wells appeared to compensate by increasing leasing.

Front Range Area

We now discuss responses by farm size for the two subregions. In general, in the Front Range, a smaller proportion of farms had wells and a higher proportion of farms leased surface water than in the Lower South Platte Basin. Lower South Platte Basin farms using surface or ground water from the South Platte tributary aquifer typically were larger than farms in the Front Range. Only about 51 percent of irrigated acres in the three Lower South Platte Basin counties was on farms with 25-1000 irrigated acres.

About 46 percent of the Front Range small farms reported wells, with an average 2.8 wells per farm. These small farms had an average 99 irrigated acres per well. Small farms pumped less of their water (approximately 23 percent) than medium farms (approximately 37 percent). Only 25 percent of the small farms leased water from other water users, supplying an average 3 percent of surface water from other water users.

The larger farms in the Front Range sample were more likely to have irrigation wells, more wells per farm, and fewer irrigated acres per well. Approximately 68 percent of the medium farms had wells, with an average 4.8 wells per farm. These farms had an average 61 irrigated acres per well. Medium farms pumped approximately 37 percent of their irrigation water. About 42 percent of medium farms leased surface water from other water users, receiving 10 percent of surface water in this fashion.

Table 2 Survey Results Regarding Irrigation Management in the South Platte Basin: Small Irrigated Farms With 25-299 Irrigated Acres (by region), 1989.

	Front Range	High Plains	Total Basin
GENERAL			
Irrigated Acres[a]	128,894	30,220	159,114
Farms with Irrigation	1,727	304	2,031
GROUND WATER			
Proportion of Irrigation Water from Ground Water	23.0%	48.0%	25.0%
Proportion of Farms with Irrigation Wells	46.0%	5.0%	50.0%
Average # of Wells Used per Farm with Wells[b]	2.8 (0.2)	2.6 (0.2)	2.7 (0.2)
Average # of Irrigated Acres per Well Used[b]	99.0 (24.0)	182.0 (49.0)	131.0 (31.0)
Acreage Potentially Irrigated by Wells	40.0%	44.0%	41.0%
SURFACE WATER			
Proportion of Irrigation Water from Surface Water	77.0%	52.0%	75.0%
Proportion of Farms Leasing-In	25.0%	18.0%	22.0%
Proportion of Surface Water Leased-In	3.0%	4.0%	3.0%
OTHER			
Farms with Water Deficit in 1989	26.0%	32.0%	27.0%
Farmers Feeling Threatened by Growing Urban Water Demand	84.0%	55.0%	80.0%

[a] 1987 Census of Agriculture
[b] Standard errors are given in parentheses.

Table 3 Survey Results Regarding Irrigation Management in the South Platte Basin: Medium Irrigated Farms With 300-1000 Irrigated Acres (total and by region), 1989.

	Front Range	High Plains	Total
GENERAL			
Irrigated Acres[a]	224,674	98,194	322,868
Farms with Irrigation	389	223	611
GROUND WATER			
Proportion of Irrigation Water from Ground Water	37.0%	49.0%	40.0%
Proportion of Farms with Irrigation Wells	68.0%	76.0%	71.0%
Average # of Wells Used per Farm with Wells[b]	4.8 (0.4)	4.9 (0.5)	4.9 (0.3)
Average # of Irrigated Acres per Well Used[b]	61.0 (12.0)	96.0 (114.0)	80.0 (9.0)
Acreage Potentially Irrigated by Wells	47.0%	66.0%	53.0%
SURFACE WATER			
Proportion of Irrigation Water from Surface Water	63.0%	51.0%	60.0%
Proportion of Farms Leasing-In	42.0%	25.0%	35.0%
Proportion of Surface Water Leased-In	10.0%	5.0%	9.0%
OTHER			
Farms with Water Deficit in 1989	36.0%	37.0%	36.0%
Farmers Feeling Threatened by Growing Urban Water Demand	81.0%	51.0%	70.0%

[a] 1987 Census of Agriculture
[b] Standard errors are given in parentheses.

Lower South Platte Basin

About 75 percent of the Lower Basin small farms had wells, with an average 2.6 wells per farm. These farms had an average 82 irrigated acres per well. If surface water were inadequate due to drought or other causes, about 44 percent of the irrigated area on small farms could have been adequately irrigated using only wells. Only 18 percent of the small farms leased water from other water users, accounting for an average 4 percent of their surface water.

Water leasing was somewhat more common among medium farms than among small farms in the Lower Basin. Approximately 76 percent of the medium farms had wells, with an average 4.9 wells per farm. These farms reported an average 96 irrigated acres per well. If surface water supplies were inadequate due to drought or other causes, about two-thirds (66 percent) of the irrigated area on medium farms could have been adequately irrigated temporarily using only wells. Approximately 25 percent of the irrigated farms reported that they leased irrigation water, receiving an average 5 percent of their surface water from other water right owners.

Responses by Individual County

The survey sample size (less than 30 per county) was insufficient to draw heavily reliable conclusions at the county level. However, it appeared that the likelihood of irrigation wells varied greatly between the Front Range and Northern Plains regions, and between the counties within each region. Along the Front Range in Boulder and Larimer counties, ground water supplied just 16 percent of the irrigation water used in 1989, much less than the regional average. Conversely, the Larimer/ Boulder Counties combination showed the largest proportion involved in leasing-in of water: 59 percent. Larimer and Boulder Counties reported leasing 14 percent of surface water supplies. The differences in ground water between Larimer-Boulder Counties and the rest of the area are likely due in part to a less extensive aquifer resource in those counties, and leasing-in is probably facilitated in northern Front Range cities having excess inventories of water rights who lease some back to farmers when not needed. In Weld County, ground water supplied 34 percent of the irrigation water. In Adams County, which extends farther east from the mountains and is partially outside the main stem of the South Platte River, ground water provided 69 percent of irrigation water (Table 4). Leasing water was less frequently reported for both Weld and Adams Counties.

In the Lower South Platte Basin, Logan County respondents reported that ground water provided approximately 32 percent of their irrigation water in 1989, which is roughly equivalent to the proportion in Weld County. In contrast, neighboring Sedgwick and Morgan Counties relied more heavily on ground water. Sedgwick County pumped approximately 57 percent of its irrigation water. Much of the irrigated land in Morgan County that is supplied by the South Platte tributary aquifer extends some distance from the river, and almost two-thirds (64 percent) of the irrigation water was pumped. Approximately 20-24 percent of the irrigated acres in Adams, Boulder, Larimer and Logan Counties could have been irrigated using only ground water, compared to 32-37 percent in Weld, Morgan and Sedgwick Counties.

Table 4 Survey Results Regarding Irrigation Management in the South Platte Basin: Farms with 25 or more Irrigated Acres, by County, 1989.

	Adams	Boulder Larimer	Weld	Logan	Morgan	Sedgwick
GENERAL						
Irrigated Acres[a]	30,000	117,000	374,000	94,000	119,000	39,000
Farms with Irrigation	225	967	1,730	356	489	117
GROUND WATER						
Proportion of Irrigation Water from Ground Water	69.0%	16.0%	34.0%	32.0%	64.0%	57.0%
Proportion of Farms with Irrigation Wells	86.0%	34.0%	54.0%	52.0%	88.0%	92.0%
Average # of Wells Used per Farm with Wells[b]	4.5	4.3	3.8	4.1	4.2	5.8
	(4.3)	(10.5)	(5.5)	(6.7)	(4.1)	(3.9)
Average # of Irrigated Acres per Well Used[b]	93.0	85.0	76.0	87.0	182.0	103.0
	(36.0)	(200.0)	(39.0)	(91.0)	(162.0)	(17.0)
Acreage Potentially Irrigated by Wells	26.0%	20.0%	33.0%	24.0%	37.0%	32.0%
SURFACE WATER						
Proportion of Irrigation Water from Surface Water	31.0%	84.0%	66.0%	68.0%	36.0%	43.0%
Proportion of Farms Leasing-In	16.0%	59.0%	21.0%	12.0%	24.0%	23.0%
Proportion of Surface Water Leased-In	3.0%	14.0%	4.0%	5.0%	4.0%	4.0%
OTHER						
Farms with Water Deficit in 1989	41.0%	39.0%	28.0%	30.0%	38.0%	23.0%
Farmers Feeling Threatened by Growing Urban Water Demand	41.0%	79.0%	87.0%	67.0%	50.0%	31.0%

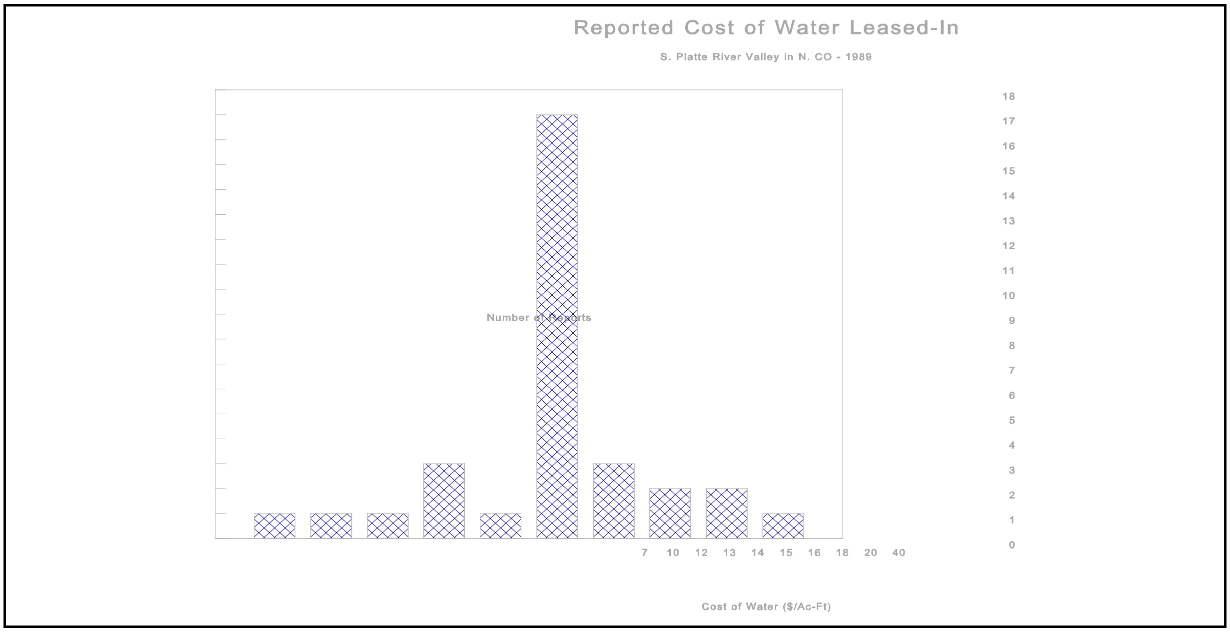
[a] 1987 Census of Agriculture
[b] Standard errors are given in parentheses

Nature of Leasing Market and Costs of Leasing

We requested information on the costs of leasing from the respondents. Due to the limited number of responses, these data are not reported by area or size of farm in the Tables discussed above.

The water leasing markets used by farmers and urban water users in the South Platte Basin are largely informal. Water transactions are coordinated by ditch companies that post notices of water rights for lease or for sale. Water brokers or traders also play a role, setting up a portion of the water leases and sales between farmers and public institutions that manage water supplies for local towns and reservoirs.

The cash water market appears to be characterized by a form of reciprocity agreement. Many of the farmers who leased-in water paid a price approximating the owner's ditch company service and maintenance assessment costs, (i.e., the lessees paid only the cash costs incurred by the lessors). This is reflected in the relative uniformity of water lease prices - mostly from $13-15 per acre foot (see Figure 1). The absence of a premium over the owner's annual costs indicates that water was not particularly scarce in the year of the survey. (Only 34 respondents reported the price charged or paid for leased water, so the water lease prices we observed should be generalized to the region with appropriate caution).


Reported Cost of Water Leased-In
S. Platte River Valley in N. CO - 1989
Number of Reports
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
7
10
12
13
14
15
16
18
20
40
Cost of Water ($/Ac-Ft)

V. SUMMARY AND CONCLUDING REMARKS

A survey of farmers using water to irrigate from the South Platte stream-aquifer system in northeastern Colorado was designed to learn how farmers in Colorado's most important agricultural region adapted to limited water supplies, with particular emphasis on the role of ground water. The survey was prompted by evidence that a drought appeared to be developing in northeastern Colorado in 1989. Specifically, the survey sought estimates of 1) the volume of surface and ground water used for irrigation in 1989, with special reference to how ground water was used to cope with drought; 2) the extent of leasing (temporary surface water transfers) among water right owners to meet local and temporary needs; and 3) the perceived adequacy of existing water sources. Although late summer rains in 1989 alleviated concerns about drought, the study plan nevertheless was carried out. A mail survey was planned, but a mailed pretest questionnaire yielded a less than 10 percent response rate and failed to provide accurate and complete information. Telephone methods, which provided improved results, were used to contact 198 farmers in seven counties in the basin. A major limitation of the sample was the inability to locate and obtain an adequate representation of very large farms (those irrigating in excess of 1,000 acres.)

The experience reported here illustrates both the strengths and limitations of survey research to determine farm management practices. After testing and rejecting the mail survey approach, we turned to a telephone interview procedure to obtain useful results on the amount of ground water used, the limited practice of temporary leasing and the respondents' perceptions regarding water needs and future competition for water. Few selected respondents (less than 4 percent) refused to participate, but more than 10 percent of the interviews were subsequently discarded because of inadequate or inconsistent responses. Recall error was a problem, partly because of the several-month interval between the summer irrigation season and the period when the interviews were conducted the following winter. However, contacting farmers and obtaining agreement to participate was easier during the off-season than during the summer and autumn peak production periods. The major limitation of our results was the finding that few large farms were included in our sample frame. Budget and time limitations made it impossible to locate and interview representatives of the larger farm classification. The resulting inaccuracy can be attributed more to inadequate implementation and limited resources than to the survey technique itself.

Turning to our empirical findings, our sample results indicated that ground water provided about 35% of the irrigation water used by respondents in the South Platte Basin in 1989. This is remarkably similar to the estimate of 36 percent reported by Hurr et al. (1975) for their study area during the period 1961-70. However, there are several reasons for believing that the close correspondence between the two estimates must be partly due to chance. Our study included Larimer and Boulder Counties along the Northern Front Range (irrigated primarily from the Cache la Poudre and Big Thompson Rivers and St. Vrain Creek), and Adams, Weld, Morgan, Logan and Sedgwick Counties. Hurr et al. considered only the South Platte mainstem and excluded those first two counties. Because of variation in snowpack, precipitation, and river flows, the proportion of ground water use fluctuates several percentage points from year-to-year. Moreover, the evidence suggests that the larger farms inadequately represented in our sample used more ground water than did the average respondent. Therefore, we might speculate that our estimate represents somewhat of an understatement of the more recent role of ground water. Our sample estimates suggest a total of approximately 8,800 irrigation wells, a number not much larger than the 8,000+ wells informally estimated by the Colorado Division of Water Resources to be drawing from the South Platte tributary aquifer. Regionally, pumping capacity exceeds current ground water needs, although water supplies are reported as insufficient on many individual farms.

Wells improve agricultural productivity in the South Platte Basin by increasing the flexibility, capacity, and number of sites of water extraction. Instead of relying exclusively on networks of storage reservoirs and ditches to supply surface water during droughts, farmers draw on ground water to augment or, if necessary, replace surface water supplies. Even if surface water supplies were completely eliminated, farmers estimate that in the short term, wells could adequately irrigate approximately 30 percent of the current irrigated acreage. Ground water thus provides an effective buffer from drought. Because the aquifer is recharged each year by irrigation return flows, and from the river and its tributaries during periods of high runoff, ground water also helps meet growing water demands from urban areas.

An informal surface water leasing market also improves water distribution efficiency and provides another buffer against drought. Farmers and urban water supply agencies with excess surface and ground water capacity lease surface water rights to farmers with inadequate water. When farmers anticipate drought, they can increase water leasing and use a larger proportion of their ground water capacity. Also, to some degree, ground water is available to replace surface water leased to farms and urban areas. The larger the pumping capacity, the greater the capability of leasing and the greater the flexibility and efficiency of water distribution.

In competitive water markets with unrestricted leasing between urban and rural water users, farmers could lease surface water to cities during drought years when surface water is expensive, substituting less expensive ground water to irrigate crops. Following the drought, surface water supplies would again become abundant and the price of surface water would decline to former levels, making it less expensive than ground water. Farmers could use their surface water rights instead of pumping, which would allow aquifers to recharge.

Our respondents perceived that urban water needs will soon dominate irrigated agriculture in northeastern Colorado. However, this perception likely overstates the reality of the situation. While almost 80 percent of the farmers interviewed felt threatened by growing urban water demands, only one-third reported experiencing any water deficit in 1989. Some portions of the region have more wells and, thus, a greater flexibility and ability to withstand drought than others. Farms in the Front Range area have proportionately fewer wells, but appear to compensate somewhat by increased water leasing. Large farms are likely to be able to adapt to tight water supplies better than small farms because large farms have more wells with fewer irrigated acres per well and greater pumping capacity. The smaller proportion of farmers on large farms who reported experiencing a period of water deficiency in 1989 and feeling threatened by growing water demand from urban areas indicates the importance of wells in increasing water security.

Ground water use reduces the effects of drought at a relatively low cost, compared to the capital expenditures required to obtain additional reservoir capacity. Water planning institutions need to recognize ground water as a strategic resource to be considered when determining water regulation policies and evaluating new surface water projects. Changes in pumping capacity and improved well distribution may increase the value of ground water, particularly during droughts, while ground water augmentation organizations protect senior water right owners from the effects of new wells.

In summary, the survey findings confirm the continued significance of the South Platte tributary aquifer in meeting the irrigation water needs of northeastern Colorado. Farmers are extensively using the aquifer to supplement limited surface water supplies. Leasing of water rights increases productivity of limited water by redistributing excess conjunctive stream-aquifer capacity to farms with both temporary and persistent inadequate water supplies. Irrigators in the Lower South Platte Basin are more likely to have wells and to have more wells than those irrigators in the Front Range. Water leasing activities are concentrated along the Front Range where they tend to be most needed to accommodate growing urban water demands. Peak urban demands might be met without reducing irrigated acreage if the large amount of water stored in aquifers, together with leasing of water, can efficiently supplement the surface water supplies.

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APPENDIX

SURVEY QUESTIONNAIRE

SOUTH PLATTE BASIN IRRIGATION WATER USE STUDY
TELEPHONE QUESTIONNAIRE

A. **(Name of Respondent)**

B. **(Telephone Number)**

C. **(County)**

D. **(Name of Interviewer)**

E. **(Date of Interview)**

1. **HELLO, MY NAME IS**
I AM A GRADUATE STUDENT AT COLORADO STATE UNIVERSITY CONDUCTING A SURVEY ON IRRIGATION PRACTICES. COULD I ASK YOU A FEW QUESTIONS ABOUT YOUR FARM?

(If "NO" or "Other can answer better ... " arrange time for subsequent call and terminate.)

Callback time and date:

2. **ARE YOU THE PRIMARY OPERATOR OF THE FARM? _____ (yes/no)**

(If "No," ask name and telephone number of primary operator.

3. **DID YOU IRRIGATE AT LEAST 25 ACRES OF CROPS IN 1989? ____ (yes/no)**

4. **WHAT IS THE SOURCE OF YOUR IRRIGATION WATER? (S. PLATTE RIVER, TRIBUTARY OF S. PLATTE, WELL IN THE S. PLATTE TRIBUTARY AQUIFER OR FROM A MOUNTAIN RESERVOIR? ____ (yes/no)**

(If "No" to any question, thank respondent and terminate.
If "Yes" to all questions above, ask Q.5-8 to complete Table 1 below.)

4.2 **ARE YOUR SURFACE WATER RIGHTS ADEQUATE FOR YOUR IRRIGATION NEEDS? _____ (yes/no)**

4.2A **IF NOT, HOW DO YOU DEAL WITH IT?**
Can't do anything
Lease water in
Operate wells
Drill wells

5. **WHAT CROPS DID YOU IRRIGATE IN 1989?**

(Ask Q.6-7 for each crop cited.)

6. **HOW MANY ACRES OF EACH CROP DID YOU IRRIGATE?**

Table 1

Crop	Total Irrigated Acres	Gravity Irrigated Acres	Sprinkler Irrigated Acres
________	________	________	
________	________	________	________
________	________	________	
________	________	________	________
________	________	________	________
________	________	________	
________	________	________	________
Total	________	________	________

(Add irrigated acres to get total.)

7. SO, DID YOU HAVE A TOTAL OF _______ ACRES UNDER IRRIGATION IN 1989? ____ (yes/no) (If "No" repeat Q.6-8.)

8. DID YOU USE GRAVITY OR SPRINKLER IRRIGATION?

(Ask Q.9-10 to complete Table 2.)

9. DID YOU USE SURFACE WATER RIGHTS FOR IRRIGATION? ____ (yes/no) (If "No," skip to Q.14)

10. HOW MANY ACRE-FEET OF SURFACE WATER DID YOU USE FOR IRRIGATION IN 1989 _______ (acre-feet)

11. HOW MANY SHARES OF SURFACE WATER RIGHTS DID YOU SEE, AND WHICH DITCH OR RESERVOIR COMPANIES OWN THE WATER?

12. WERE THESE DIRECT FLOW RIGHTS OR RESERVOIR STORAGE RIGHTS?

Table 2

	Acre-feet	Name of Ditch/Reservoir Company	Total	Shares of Direct Flow Rights	Reservoir/ Storage Rights
	_______	_______________	____	__________	___________
	_______				
	_______				
Total	_______	_______________			

13. WOULD YOU CHARACTERIZE YOUR WATER RIGHT SHARES AS "SENIOR," "INTERMEDIATE" OR "JUNIOR?" _______ (priority)

14. DO YOU HAVE IRRIGATION WELLS? _______ (wells) (If "NONE," skip to Q.23)

15. HOW MANY OF THESE WELLS DID YOU OPERATE IN 1989? (Ask Q.16-17 to complete Table 3.) _______ wells operated

15.2 HOW MANY TOTAL ACRES DID YOU IRRIGATE USING ONLY WELL WATER? _______ (Acres)

15.3 HOW MANY TOTAL ACRES DID YOU IRRIGATE USING ONLY SURFACE WATER?_______ (Acres)

16. CAN YOU ESTIMATE THE NUMBER OF ACRE-FEET PUMPED FROM EACH WELL IN 1989 (If "No" skip to Q.18)

17. WHAT IS THE SOURCE OF ENERGY FOR EACH WELL?

Table 3

	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
Estim. Acre-feet	____	____	____	____	____	____	____	____	____	
Energy Source	____	____	____	____	____	____	____	____		

(If respondent completes Table 3, skip to Q.22)
If respondent cannot complete Table 3, ask Q.18-21 and complete Table 4.)

18. WHAT IS THE ESTIMATED ACTUAL - NOT "RATED" - PUMPING RATE, IN GALLONS PER MINUTE, FOR EACH WELL?

19. APPROXIMATELY HOW MANY DAYS DID YOU PUMP EACH WELL IN 1989?

20. ON AVERAGE, HOW MANY HOURS PER DAY DID YOU PUMP EACH WELL IN 1989?

21. WHAT IS THE SOURCE OF ENERGY FOR EACH WELL?

Table 4

	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6	Well 7	Well 8	Well 9	Well 10
Gallons/Minute	____	____	____	____	____	____	____	________		
Days of Pumping in 1989:	____	____	____	____	____	____	____	________		
Avg. hrs/day of Pump Operation	____	____	____	____	____	____	____	________		
Energy Source	___	____	____	____	____	____	____	________		

22. IF SURFACE WATER WAS INADEQUATE DUE TO DROUGHT OR OTHER CAUSES, HOW MANY ACRES COULD YOU IRRIGATE USING ONLY WELLS? _____ (acres)

22.2 IF, DUE TO DROUGHT OR SOME OTHER CAUSE, YOUR SURFACE WATER WAS ONLY 50% OF NORMAL, HOW WOULD YOU EXPECT TO DEAL WITH IT?

Pump wells more
Lease water in
Nothing I can do

(NOW WE GET TO THE LAST SECTION OF THE QUESTIONNAIRE.)

23. DO YOU FEEL THAT YOUR FUTURE WATER SUPPLY IS THREATENED BY GROWING WATER DEMAND FROM URBAN AREAS? _ (yes/no)

24. WAS YOUR WATER SUPPLY EVER DEFICIENT FOR YOUR CROP? ____ (yes/no)

25. DID YOU LEASE ANY IRRIGATION WATER FROM OTHER WATER USERS IN 1989? ____ (yes/no)
(If "No" skip to Q.30. If "Yes," ask Q.26-29 to complete Table 5.)

26. HOW MANY ACRE-FEET DID YOU LEASE?

27. HOW MANY SHARES DID YOU LEASE?

28. WHAT DITCH OR RESERVOIR COMPANIES OWN THESE SHARES?

29. DID YOU LEASE THEM FROM FARMERS, WATER BROKERS, CITY GOVERNMENTS, OR WHOM?

Table 5

	Number of Acre-feet	OR	Number of Shares	Ditch/reservoir Company
Other Farmers:	______		______	
Water Brokers:	______		______	______________________________
Cities/Other:	______		______	______________________________
Real Estate Devlprs:	______		______	
Total	______		______	

29.2 HOW MUCH DID YOU PAY PER ACRE-FOOT OF WATER LEASED FROM OTHER WATER USERS? $ _____ /Ac-Ft

29.3 WHAT WAS THE ASSESSED COST PER ACRE-FOOT OF THE WATER YOU LEASED FROM OTHERS? $ _____ /Ac-Ft

30. DID YOU LEASE WATER TO OTHER WATER USERS IN 1989? _____ (yes/no) (If "No", skip to Q.35)

31. HOW MANY ACRE-FEET DID YOU LEASE OUT?

32. HOW MANY SHARES DID YOU LEASE OUT?

33. WHAT DITCH OR RESERVOIR COMPANIES OWN THESE SHARES?

34. DID YOU LEASE THEM TO FARMERS, WATER BROKERS, CITY GOVERNMENTS, OR WHOM?

Table 6

	Number of Acre-feet	OR	Number of Shares	Ditch/reservoir Company
Other Farmers:	______________	_______		
Water Brokers:	______________	_______		
Cities/Other:	______________	_______		
Total	______________	_______		

34.2 HOW MUCH DID YOU PAY PER ACRE-FOOT OF WATER LEASED TO OTHER WATER USERS? $ ______ /Ac-Ft

34.3 WHAT WAS THE ASSESSED COST PER ACRE-FOOT OF THE WATER YOU LEASED TO OTHERS? $ ______ /Ac-Ft

35. DURING THE PERIOD 1980 TO 1988, HOW MANY YEARS DID YOU LEASE WATER FROM OTHER WATER USERS? ______ (years)

36. DURING THE PERIOD 1980 TO 1988, HOW MANY YEARS DID YOU LEASE WATER TO OTHER WATER USERS? ______ (years)

37. WAS 1989 A TYPICAL YEAR FOR WATER USE ON YOUR FARM? ______ (yes/no) (If "Yes" skip to Q.37)

38. WHY WASN'T IT A TYPICAL YEAR?

(Terminate) THAT'S THE LAST OF MY QUESTIONS. I APPRECIATE YOUR HELP, AND ENJOYED TALKING WITH YOU.