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Impacts on Irrigated Agriculture of Changes in Electricity Costs Resulting from Western Area Power Administration's Power Marketing Alternatives

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Impacts on Irrigated Agriculture of Changes in Electricity Costs Resulting from Western Area Power Administration's Power Marketing Alternatives

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FOREWORD

This report is one of a series of technical memorandums prepared to support an environmental impact statement (EIS) on power marketing prepared by Argonne National Laboratory for the U.S. Department of Energy's Western Area Power Administration (Western). Western markets electricity produced at hydroelectric facilities operated by the Bureau of Reclamation. The facilities are known collectively as the Salt Lake City Area Integrated Projects (SLCA/IP) and include dams equipped for power generation on the Colorado, Green, Gunnison, and Rio Grande rivers and on Plateau Creek in the states of Arizona, Colorado, New Mexico, Utah, and Wyoming.

Western proposes to establish a level of commitment (sales) of long-term firm electrical capacity and energy from the SLCA/IP hydroelectric power plants; the impacts of this proposed action are evaluated in the EIS. Of the SLCA/IP facilities, only the Glen Canyon Dam, Flaming Gorge Dam, and Aspinall Unit (which includes Blue Mesa, Morrow Point, and Crystal dams) are influenced by Western's power scheduling and transmission decisions. For this reason, the impacts of hydropower operations at these three facilities were examined in the EIS.

The technical memorandums present detailed findings of studies conducted by Argonne National Laboratory specifically for the EIS. These studies are summarized in the EIS, and the results were used to assess environmental impacts related to alternative commitment levels. Technical memorandums were prepared on a number of socioeconomic and natural resource topics. Staff members of Argonne National Laboratory's Decision and Information Sciences Division and Environmental Assessment Division prepared these technical memorandums and the EIS as part of a joint effort managed by the Environmental Assessment Division.

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IMPACTS ON IRRIGATED AGRICULTURE OF CHANGES IN ELECTRICITY COSTS RESULTING FROM WESTERN AREA POWER ADMINISTRATION'S POWER MARKETING ALTERNATIVES

by

B.K. Edwards, S.J. Flaim, R.E. Howitt, and S.C. Palmer

ABSTRACT

Irrigation is a major factor in the growth of U.S. agricultural productivity, especially in western states, which account for more than 85% of the nation's irrigated acreage. In some of these states, almost all cropland is irrigated, and nearly 50% of the irrigation is done with electrically powered pumps. Therefore, even small increases in the cost of electricity could have a disproportionate impact on irrigated agriculture. This technical memorandum examines the impacts that could result from proposed changes in the power marketing programs of the Western Area Power Administration's Salt Lake City Area Office. The changes could increase the cost of power to all Western customers, including rural municipalities and irrigation districts that rely on inexpensive federal power to pump water. The impacts are assessed by translating changes in Western's wholesale power rate into changes in the cost of pumping water as an input for agricultural production. Farmers can adapt to higher electricity prices in many ways, such as (1) using different pumping fuels, (2) adding workers and increasing management to irrigate more efficiently, and (3) growing more drought-tolerant crops. This study projects several responses, including using less groundwater and planting fewer water-intensive crops. The study finds that when dependence on Western's power is high, the cost of power can have a major effect on energy use, agricultural practices, and the distribution of planted acreage. The biggest percentage changes in farm income would occur (1) in Nevada and Utah (however, all projected changes are less than 2% of the baseline) and (2) under the marketing alternatives that represent the lowest capacity and energy offer considered in Western's Electric Power Marketing Environmental Impact Statement. The aggregate impact on farm incomes and the value of total farm production would be much smaller than that suggested by the changes in water use and planted acreage, which can be quite large.

1 INTRODUCTION

Marketing strategies and allocation criteria were developed during the 1980s by the Salt Lake City Area Office (SLCAO) of Western Area Power Administration (Western). The purpose was to integrate power generating operations and contractual obligations of the four main hydroelectric projects under Western's control. The resulting post-1989 marketing and allocation criteria established terms under which Western would allocate long-term firm sales of electricity to power customers. Because the development of the post-1989 marketing criteria led to a number of legal, environmental, and political concerns, a number of alternative power generation and dam operation scenarios were also developed. Each alternative represents a combination of possible dam operation and power generation options Western is considering to increase power revenues while continuing commitments made to power customers. Western's Electric Power Marketing Environmental Impact Statement (EIS) evaluates the impacts of proposed changes in the level of capacity and energy offered to Western's customers under each alternative. Western's customer utilities affected by the proposed changes are located in a six-state region in the western United States, an area that includes rural communities where the principal economic activity is agriculture.

In 1987, although irrigated cropland accounted for only about 15% of harvested cropland in the United States, it accounted for nearly 38% of the total value of crops produced. Irrigated farms are larger and more capital-intensive than nonirrigated farms and have higher average yields. Irrigated farms, on average, have more than twice as much capital invested — and consequently debt to service — than typical nonirrigated farms. Irrigated cropland has increased across the entire United States since World War II and has been a substantial factor in increasing agricultural productivity. The western United States accounts for about 85% of all irrigated acreage. Virtually all harvested cropland in Arizona and Nevada is irrigated.

A substantial portion of total irrigated acreage in Western's SLCAO service area is irrigated with electrically powered pumps. In Arizona, approximately 45% of total irrigated cropland is electrically pumped. Moreover, many of Western's customers in Arizona are irrigation districts that purchase electricity primarily for pumping water. For the other states in the SLCAO service region, the share of total irrigated acres is somewhat smaller, but it is still highly significant when compared with national averages. On a local basis, the irrigation districts studied in this technical memorandum may receive more than 90% of their total electricity supply from Western.

Because Western's wholesale rate is statutorily limited to cost recovery for cumulative investments in federal water projects, the customer's cost for this power has historically been well below market rates. For example, in 1992, the average cost of Western's SLCAO power was $0.015 per kilowatt-hour (kWh), compared with a regional average retail price of $0.06/kWh. This difference in electricity costs has led to a higher investment in electrically powered irrigation pumps and equipment than would have occurred under a market-pricing mechanism.

Because Western's customers depend heavily on pumped irrigation, especially electrically powered pumping, any increase in Western's electricity prices could result in disproportionate impacts to agriculture. With higher-than-average farm investments, higher debt service, and fixed capital equipment in the short term, large adjustments in farming practices could result from relatively small changes in Western's power marketing programs.

This technical memorandum summarizes previous findings from studies that have examined the effects of energy price increases on the viability of irrigated agriculture in the western United States. It characterizes the potential responses by irrigators to an increase in the price of energy. This report also details the data sets, analysis, and conclusions of Argonne National Laboratory's modeling of the relationship between electricity prices and agricultural output.

Impacts on agriculture were determined by translating the change in Western's wholesale rate into changes in the costs of pumping water for individual customer utilities. For cooperatives and irrigation districts that rely heavily on Western power, changes in the level of commitment correspond to proportionate increases in the purchased power. These purchases can be quite expensive, especially during the summer months, when irrigation timing is critical and air-conditioning demand is high. However, even small changes in electric power costs can result in substantial adjustments in farming practices: reduced water consumption, increased use of other inputs, and switches to drought-resistant crops.

Marginally profitable crops such as barley would not be produced in several states if electric pumping costs were to increase by the amounts indicated in the EIS. On a local basis, the adjustments to these higher costs could be larger than the state-level analysis indicates. The state-level analysis combines the higher-cost impacts on cooperatives and irrigation districts with the lower-cost impacts on utilities having a low reliance on Western power; the resulting composite average understates impacts on high-reliance customers and overstates impacts on low-reliance customers.

The results summarized in Section 6 indicate that as electricity prices increase, rather large adjustments in groundwater usage and acreage planted are made. However, impacts to farm-level incomes are proportionately less than these adjustments indicate. The computed results in the study suggest that farm-level incomes remain relatively stable and within 2% of baseline projections. The reason is that farmers are highly responsive and adaptable to changes in input costs.

Section 2 of this report summarizes data on irrigated agriculture in Western's SLCAO service area. Section 3 is an overview of irrigators' responses to increasing energy prices and reviews some past studies of this subject. Section 4 presents the methods for analysis. Baseline agricultural conditions are summarized in Section 5. Section 6 contains a summary of state-level results, and Section 7 contains a summary of results for subregions within each state.

2 IRRIGATED AGRICULTURE IN THE SERVICE AREA OF WESTERN'S SALT LAKE CITY AREA OFFICE

2.1 BACKGROUND

Western's SLCAO provides firm electric service in all or part of six states: Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. In 1987, almost all harvested cropland in Arizona and Nevada was irrigated, for a total of 1.4 million acres. In Arizona, Nevada, Colorado, and New Mexico, nearly 40% of all irrigated cropland was irrigated with electric pumps. About two-thirds of all cropland in Utah and Wyoming was irrigated, but a much smaller proportion was pump irrigated; therefore, irrigated agriculture in these states was less dependent on electricity. Electrically pumped irrigation accounted for more than one-half of all pump-irrigated acreage in each state and accounted for an average of 80% of all pump-irrigated acreage in the six-state service area. Clearly, when pumping is required, electricity is the fuel of choice. Table 1 summarizes the data on harvested cropland in the six-state service area in 1987 and identifies the proportions of irrigated, pump-irrigated, and electric-pump-irrigated acreage. The last column identifies the percentage of harvested cropland that was irrigated by electric pumps in each state and in the entire region.

In Western's SLCAO service area, about 60% of all harvested cropland was irrigated. In Arizona and Nevada, almost all cropland was irrigated — 859,732 and 534,067 acres, respectively. In Utah, 77% of harvested cropland was irrigated (829,732 acres), and in New Mexico and Wyoming, about two-thirds (606,344 and 1,132,266 acres, respectively) was irrigated. Colorado was the least irrigation-intensive state, with only 44% of its harvested cropland irrigated. Even though a lower percentage of its harvested cropland was irrigated, about 2.4 million acres in Colorado was irrigated. In total, nearly 6.4 million acres of harvested cropland in the SLCAO service area was irrigated.

TABLE 1 Harvested and Irrigated Cropland in Six States in 1987

State	Harvested Cropland (10^3 acres)	Percent of Harvested Cropland That Is Irrigated	Percent of Irrigation Done by Pumps	Percent of Pumping That Is Electrically Powered	Percent of Harvested Cropland Irrigated by Electric Pumps
Arizona	865.8	99.3	54.2	83.5	44.9
Colorado	5,522.2	44.2	59.2	85.8	22.4
Nevada	526.1	99.6	43.7	90.2	39.3
New Mexico	989.2	61.3	79.3	56.5	27.4
Utah	1,076.9	77.0	35.6	78.6	21.5
Wyoming	1,717.0	65.9	20.1	81.9	10.8
Total	10,697.2	59.8	49.2	80.3	23.6

Source: Bajwa et al. (1992).

Of the 6.4 million acres of irrigated cropland in the study area, nearly one-half is irrigated by using on-farm, pumped, sprinkler irrigation. Electricity is the most common source of energy used to pump and distribute water, with 80% of all pumped irrigation being powered by electricity. In Colorado, one-half of the irrigated cropland is irrigated by electrically powered pumps (1,239,603 acres). In Arizona (388,748 acres) and New Mexico (271,946 acres), about 45% of all irrigated cropland is irrigated by electrically powered pumps. In Nevada, 206,565 acres (39%) of all irrigated farmland is irrigated with electrical pumps. In Utah about 28%, and in Wyoming, about 17% of irrigated cropland is irrigated by electrically powered pumps.

2.2 DEMOGRAPHIC CHARACTERISTICS OF AGRICULTURE

Farm populations and farming employment have always been difficult to measure, since many workers are seasonal laborers and many farmers have nonfarm jobs that provide primary or supplemental family income. Family members, especially older children, often work part time or full time during summer months. Despite these definitional problems, it is generally recognized that the number of farms, total farm populations, and farming employment have been falling for decades. The total U.S. farm population decreased from about 10 million persons in 1970 to 4.6 million persons by 1990, a drop of 53%. During the same period, farm employment, including self-employed and unpaid workers, decreased from about 4.5 million to 2.9 million persons, a decline of 36%.

Data on the number of farms, their total acreage, and the average farm size in the six-state SLCAO service area in 1991 are summarized in Table 2. Average farm sizes in the six-state area were from 2 to nearly 10 times the national average. Arizona had the largest average farm size (4,500 acres), and Nevada, New Mexico, and Wyoming had average farm sizes of more than 3,200 acres. In aggregate terms, the six-state region accounted for about 4% of the number of all U.S. farms and about 18% of the U.S. total farm acreage.

2.3 ECONOMIC CHARACTERISTICS OF AGRICULTURE

Agriculture is an important, if modest, contributor to overall economic activity in Western's SLCAO service area. As shown in Table 3, in 1984, farm-level earnings ($1.2 billion) were 1.3% of total earnings for all sectors of the economy ($93.8 billion). This figure does not include farm-related spending for equipment, materials, and purchased goods and services used in agriculture, food processing, or retailing, nor does it include the multiplier effects that this primary industry has on other economic activity in each state. Furthermore, agriculture is the primary industry in most rural areas in these states, and economic activity in cities overshadows the importance of agriculture in most urban areas.

State comparisons reveal that 0.5-1.9% of total state earnings came from agriculture. An average for the six-state region is 1.3%, with the farm sector being most dominant in Colorado and least dominant in Nevada (0.5%).

TABLE 2 Number and Acreage of Farms in Six States in 1991

State	Farms (10^3)	Acreage (10^6)	Acres per Farm
Total U.S.	2,105	983	467
Arizona	8	36	4,500
Colorado	27	33	1,262
Nevada	3	9	3,560
New Mexico	14	44	3,281
Utah	13	11	850
Wyoming	9	35	3,867
SLCAO (% of U.S.)	4	18	

Source: U.S. Bureau of the Census (1992).

TABLE 3 Agricultural Earnings in Six States in 1984

State	Total Earnings by All Sectors (10^6 \$)	Farm Earnings (10^6 \$)	Farm Earnings (%)
Arizona	24,889	333.2	1.34
Colorado	32,860	626.3	1.91
Nevada	9,012	49.7	0.55
New Mexico	10,412	109.6	1.05
Utah	12,063	87.3	0.72
Wyoming	4,545	21.4	0.47
Total	93,783	1,227.5	1.31

Source: USDA (1991).

Table 4 summarizes farm assets, debt, and income by state in 1990. For the entire United States, farming assets reached nearly $1 trillion in 1990, with about $145 billion in debt, which resulted in an asset/debt ratio of 14.6. Gross farm incomes were $195 billion, and net farm incomes were about $51 billion.

Asset/debt ratios showed wide variation across the six-state SLCAO region, ranging from a low of 7.1 in Nevada to a high of 17 in Colorado. The regional average asset/debt ratio was about 77% of that of the entire United States in 1990. Although the region accounts for about 6% of total U.S. farming assets, farm debt and gross and net farm incomes were proportionately lower than the U.S. average. Farming in five of the six states (i.e., excluding Colorado) was more heavily leveraged and had fewer assets to cover debt responsibilities.

TABLE 4 Farm Assets, Debt, and Income in Six States in 1990

States	Assets (10^6 $)	Debt (10^6 $)	Asset/ Debt Ratio	Gross Income (10^6 $)	Net Income (10^6 $)
Total U.S.	997,935	145,067	14.6	195,123	50,832
Arizona	11,529	1,443	12.5	2,039	582
Colorado	19,467	3,011	17.0	4,785	873
Nevada	3,742	267	7.1	341	87
New Mexico	12,541	1,031	8.2	1,641	337
Utah	6,343	698	11.0	883	240
Wyoming	7,512	822	11.7	857	120
SLCAO (% of U.S.)	6.1	5.0	77.1	5.4	4.4

Source: U.S. Bureau of the Census (1992).

Consequently, changes in Western's power marketing programs could have larger effects on farming operations in this region (with higher debts, interest payments, and lower assets) than in other farming regions in the United States.

Table 5 presents a summary of total marketed farm products and revenues from crops, livestock, and government payments by state for 1990. Although the value of marketed livestock and livestock products was about 11% larger than the value of all crops marketed in the United States in 1990, the value of livestock in the SLCAO six-state region was of much greater importance — about 79% larger than the value of the crops marketed in this region. Hence, field crops and irrigated field crops are of relatively less importance in this region than they are in the United States as a whole.

Government payments to farmers ranged from a low of $5 million in Nevada to $237 million in Colorado. Although the six-state region accounts for about 5.6% of total U.S. marketed farm products, it receives only 4.5% of government payments to agriculture. This lower level of government support indicates that farmers in this region absorb a higher degree of risk than do farmers in other regions of the United States.

2.4 ENERGY USE AND COSTS FOR IRRIGATED AGRICULTURE

For the purposes of the analyses that follow, irrigation is accomplished in one of two ways: by gravity systems that use surface water or by pump systems that withdraw water from subsurface aquifers (Mapp and Dobbins 1977; Lacewell and Collins 1986). Using groundwater as a water source requires over 25 times more energy than using surface water sources (Harman 1986). For irrigated agriculture in western states, about 60% of the total amount of water consumed comes from surface water sources (rivers and impoundments) and about 40% from groundwater supplies. In 1980, about 25.6 million acres of cropland was irrigated from groundwater sources. In 1975, about 56 million acre-feet (acre-ft) of water was applied to agricultural cropland in these western states. On the basis of the assumption that

TABLE 5 Marketed Farm Products and Government Payments in Six States in 1990 (10^6 $)

State	Total	Crops	Livestock and Livestock Products	Government Payments
Total U.S.	169,987	80,364	89,623	9,298
Arizona	1,865	1,046	819	43
Colorado	4,213	1,184	3,029	237
Nevada	333	115	218	5
New Mexico	1,529	483	1,046	64
Utah	755	179	576	35
Wyoming	767	157	610	31
SLCAO (% of U.S.)	5.6	3.9	7.0	4.5

Source: U.S. Bureau of the Census (1992).

the total amounts of irrigated acreage and acre-feet of applications remained about the same during the late 1970s, an average of about 2.2 acre-ft of water was applied for every acre planted during that period.

Relative to other uses of energy in agricultural production, irrigation accounts for about 20% of total energy consumption, placing third behind field machinery (30%) and farm transportation (25%) (Gopalakrishnan 1987). The most common types of fuel used to power irrigation pumps, in decreasing order of importance, are electricity, diesel fuel, gasoline, natural gas, and liquefied petroleum gas (LPG). In Western's SLCAO service area, more than 80% of all pump-irrigated cropland is irrigated by electrical pumps. In 1975, the cost of energy for irrigation in the United States was less than $500 million. By 1983, that cost had risen to nearly $2 billion. This increase in pumping costs was accompanied by an increase in irrigated acreage of only 17% during the same period (Sloggett 1986).

On the basis of limited information, the cost for electricity accounts for from 11% to more than 40% of total variable costs, depending on the type of crop and the state in which it is grown. In Arizona, about 35% of the total variable costs for barley production is accounted for by the cost for electricity to pump water. The cost for electricity accounts for about 25% of the total variable costs for alfalfa production in Arizona.

Irrigation is extremely important to agriculture in the six-state SLCAO service area, and most of the pumped irrigation in these areas is powered by electricity. Agriculture in this region has proportionately higher debt service and lower government support than it does in the rest of the United States. Therefore, agriculture was identified as a special area to be studied in order to examine the impacts of higher electricity prices that could result from changes in Western's power marketing programs.

3 RESPONSES OF IRRIGATORS TO INCREASING ENERGY PRICES

3.1 INTRODUCTION

The impacts of higher energy prices on irrigated agriculture have been the subject of intense investigation for 20 years (see Adams et al. 1977; Mapp and Dobbias 1977; Sloggett and Mapp 1984; Chancellor and Johnston 1986; Whittlesey and Herrell 1987; Majoro 1990). This literature is applicable to the increases in costs that farmers could experience as a result of Western's proposed changes in its electric power marketing programs.

Increases in pumping costs can be the result of increasing energy prices or declining water supplies that reduce irrigation well yields, increase the distance that water must be lifted to the surface, and increase the costs of irrigated crop production (Warren et al. 1982). Regardless of the cause of increasing irrigation costs, farmers can respond in a variety of ways. Mapp (1988) found that increasing pumping costs could substantially shorten the period over which many producers find irrigation economically feasible. Although adjustments due to declining groundwater levels are generally gradual, when they are combined with increasing energy prices, the effects can be most severe. The areas with the deepest pump lifts will be the first ones to be affected by higher pumping costs (Lacewell and Collins 1986). Other studies (Whittlesey and Herrell 1978) indicate that farms with irrigation wells with pump lifts of 400-600 feet (ft) already faced possible conversion to dryland farming under the 1986 electric rates in western states. Other farms with wells requiring more than 400 ft of lift would be able to continue to operate but would only be able to cover their variable costs. The authors also conclude that electricity costs greater than $0.04/kWh may cause farms with pump lifts of less than 400 ft to abandon irrigation.

The possible responses to rising energy costs depend on numerous factors. First, the nature of the response can vary depending on the time horizon under consideration. In the short run, irrigators' responses to rising energy costs are limited by fixity of the capital stock. Irrigation equipment represents a substantial investment, and certain types of equipment are limited to the amount and type of application. For example, if pumping costs were to increase rapidly, farmers might adjust by reducing their total water application and by applying water at night when evaporation losses are lower. However, because the equipment is sized to provide a specific application rate, farmers might be limited to the amount of water that could be pumped during these periods. Other types of short-run responses could include the use of more fertilizer or pesticides instead of water to reduce plant stress and increase viability.

Over the longer term, farmers' responses to higher electricity costs could include switching to more drought-tolerant crops and crop varieties. Irrigators' responses could include purchasing more energy-efficient and water-efficient equipment and developing and implementing conservation and water management schemes. If electricity costs were to increase enough, farmers might switch to other fuel types (diesel, etc.), to dryland production, or even from cropland to pasture land.

As an example of the large changes in farming practices that might occur in response to rising energy costs, the 1972-1975 increase in natural gas prices of 450% in the Trans-Pecos region of Texas contributed to the decline in cotton acreage from more than 200,000 to 20,000 acres — a tenfold decrease (Lacewell and Collins 1986). Such large adjustments, while not representative of all responses that could occur, do illustrate the magnitude of adjustments that could occur.

A number of factors can affect the magnitude of responses caused by increasing energy costs. In addition to local or regional economic conditions, certain physical and technological factors can influence the magnitude and type of response: the height of the pump lift, type of equipment, operating pressure of the equipment, or depletion of local aquifers.

In general, the particular mix of production factors that farmers choose when responding to higher energy prices most often involves the substitution of one input for another. Energy has been found to be substitutable with other factors of production (Gopalakrishnan 1987). In the western United States, energy and farm capital have the highest cross elasticities of substitution, followed by energy for labor and, to a lesser extent, energy for land. On the basis of data from all 17 western states, the estimated cross-elasticity of energy and capital suggests that a 10% increase in the price of energy would result in a 3.2% increase in the use of capital. Energy and other nonenergy inputs do not seem to be complementary. Studies on energy's own price elasticity of demand indicate that a 10% increase in the price of energy would reduce agricultural energy consumption by 8.5% (Gopalakrishnan and Yanagida 1986; Gopalakrishnan et al. 1989).

An increase in the cost of pumping water for irrigation, with all other things being equal, could reduce the level of net returns to management and labor associated with irrigated crop production. Whether these higher costs for pumping water would induce substitution away from irrigated agriculture would depend, in part, on the cost of switching to an alternative, less energy intensive technology relative to the change in energy prices. Higher energy prices can induce shifts from high to moderate levels of irrigation with more intensive irrigation management and control. Water conservation measures can have the effect of increasing irrigation efficiency without reducing net returns.

A more severe effect of increasing energy prices occurs when the marginal net benefits of irrigation become zero. In this situation, net returns to management and labor are maximized by shifting from irrigated to dryland crop production. The most severe effect of increasing energy prices would result in abandonment of farming altogether. The actual impacts of an increase in the costs of pumping water for irrigation would largely depend on the magnitude of the increase and the regional economic conditions at the time.

3.2 CONSERVATION AND MANAGEMENT RESPONSES

As the cost to pump water increases as crop prices are held constant, there is an economic incentive to apply less water per acre to the cropland (Lacewell and Collins 1986).

> The largest potential savings of energy use in irrigation can be obtained by reducing the quantity of water pumped, and any reductions in water pumped will yield a corresponding reduction in energy consumption even if no other changes are made in the irrigation system or pumping plant (Gilley, Heerman, and Stetson, as cited in Lacewell and Collins 1986).

Water conservation irrigation technologies and water management practices significantly increase agricultural irrigation efficiency (by 10-30%) and reduce direct energy requirements for crops (Schaible et al. 1991). Modeling studies have shown sizable ratios between the shadow prices for energy and the current cost of supplies, implying that farmers are not using energy at the point of maximum profitability, at which marginal costs equal the marginal value product of energy (Chancellor and Johnston 1986). The authors further note that if farmers irrigated more efficiently by using improved management or technology, these savings might offset an increase in input costs. This finding is consistent with the Gopalakrishnan (1987) finding that between 1974 and 1978, a decrease in energy intensity occurred despite an increase in the energy requirements for crop production.

Irrigation system studies have addressed the techniques of irrigation scheduling, deficit irrigation, and peak-load management as a means to respond to physical or monetary restrictions on water or energy availability (Wade 1986). Irrigation scheduling is designed to apply water at certain optimal times in a crop's development. The goal is to produce near maximum crop yield by an efficient application of water when the plant is most sensitive to water stress. Many crops grown in the West, including wheat, sorghum, corn, and cotton, can be irrigated with improved timing and application rates to achieve increased water use efficiency and energy use efficiency (Harman 1986). Harman found that one seasonal water application to sorghum, properly timed, can improve efficiency from 25% to more than 500%.

With a technique called deficit irrigation, water is purposely held below levels that would produce maximum yields. The result of this management practice is to lower both total revenues and costs, but net economic returns can be increased if energy or water costs are very high. Other practices, such as irrigating alternative furrows and reducing the length of the run, can increase energy use efficiency by 20%, especially on coarse, textured soils (Harman 1986).

Peak-load management involves scheduling irrigation applications during off-peak power-demand periods in the early morning and late evening and at night. This practice can reduce the total cost of producing that power, and these savings can be passed through to farmers. A recent study indicates that a 21-48% reduction in the price of electricity would be necessary to generate net returns equal to the returns to irrigators who irrigated during off-peak hours (Bosch et al. 1986). Hence, peak-load management has a good chance of offsetting increases in the price of electricity, if these savings to the utilities that generate off-peak power are shared with irrigators. By combining water management with peak-load management, the energy costs to irrigators could be reduced by up to 20% yet have no effect on crop yields, at least under certain circumstances (Harman 1986).

3.3 CROPPING PRACTICES

Farmers may also respond to higher pumping costs for irrigation by switching to higher-yielding crop varieties or drought-resistant varieties. The planting of crops that use less water is expected to increase when irrigation costs increase. Recently, substantial shifts from corn, an intensive water-use crop, to wheat and sorghum have occurred in some regions experiencing higher irrigation costs (Mapp 1988). This response is important in some states, such as Arizona and Nevada, where almost all cropland is irrigated and farmers cannot switch to dryland production techniques. Colorado, Wyoming, and New Mexico are showing an increasing trend to grow wheat and not plant corn because of the expense and limited availability of water.

As pumping costs increase through time, a gradual shift from irrigated to dryland farming occurs (Mapp and Dobbins 1977). The benefits of irrigation can be defined as the growth in profit to a producer who uses irrigation compared with the profit of a producer who does not use irrigation. When irrigation costs rise, the benefits of irrigation fall; they can fall so low that farmers stop irrigating. Hence, as power costs increase, the percentage of irrigated land that will be converted to dryland use will increase as well. In 1982, a study by Young (as cited in Lacewell and Collins 1986) analyzed the marginal value of irrigation and found it to be $10-15 per acre-foot in the intermountain valley region of the upper Colorado River and Snake River basin, $20-25 per acre-foot in the desert Southwest, and $44-45 per acre-foot in the Ogallala groundwater region of the High Plains. These findings suggest that the benefits of irrigation are regional in nature (Lacewell and Collins 1986). Small but positive shadow values that represent the marginal value of water in irrigation indicate that there are insufficient flows and price levels to irrigate all land; thus, it is economically advantageous for some farmers to dryland farm (Keith et al. 1989).

3.4 SUMMARY OF ADAPTIVE RESPONSES TO HIGHER IRRIGATION COSTS

When the price of energy rises, causing the costs of pump irrigation to increase, farmers' responses must take into account much more than the additional increase in energy expenditures. Innovations, alternative irrigation systems, and changes in cropping strategies, when considered for widespread adoption, are all subject to economic, environmental, and institutional factors (Harman 1986). Economic parameters include the investment cost, operating cost, and eventual payoff of innovations. They may present a situation in which a long-term solution would allow an individual to continue farming, but a short-term solution would only allow a farmer to stop farming altogether. Farm abandonments are viewed as a serious problem in the West. A price increase for Western's power customers could cause farmers to make some or all of their farmland idle.

4 METHOD OF ANALYSIS

4.1 INTRODUCTION

Marketing strategies and allocation criteria were developed during the 1980s by SLCAO to integrate power generating operations and contractual obligations of the four main hydroelectric projects under Western's control. The resulting post-1989 marketing and allocation criteria established terms under which Western would allocate long-term firm sales of electricity to power customers. Because the development of the post-1989 marketing criteria led to a number of legal, environmental, and political concerns, a number of alternative power generation and dam operation scenarios were also developed. Each alternative represents a combination of possible dam operation and power generation options Western is considering to increase power revenues while continuing commitments made to power customers.

The alternatives under consideration include a No Action Alternative that represents a continuation of the pre-1989 power marketing criteria, an alternative that reflects the post-1989 marketing plan, and five additional alternatives that reflect different commitment levels. Each alternative represents a combination of different power supply and dam operation options. Table 6 outlines the main characteristics of each alternative.

The levels of long-term energy being considered in the Western Electric Power Marketing EIS could change the cost of electricity to Western's utility customers and their industrial, commercial, and residential end-users. Because many of these end-users are farmers, these changes could affect the cost and amount of electricity used in agriculture. In the six-state region examined in the EIS, nearly 80% of all irrigation pumps are electrically powered. The emphasis of this technical memorandum is to examine the potential impacts of higher electricity costs on farmers — in particular, on how they respond to these changes in electricity costs.

A change in the cost of electricity to farmers will change the relative costs of growing crops in the region and stimulate a series of adjustments. Because the main use of electricity in farming is to pump irrigation water, a change in the cost of power to farmers will shift the comparative advantage against irrigated production, particularly for crops that use a relatively large amount of water. Some adjustment in the acreage of crops grown in the region will occur. The increase in electricity prices will also induce further shifts away from pumps powered by electricity to those powered by diesel or natural gas where feasible. In addition, a shift away from using groundwater for irrigation and toward using surface water will occur where surface water is available.

In effect, changing electricity costs will trigger changes in the relative costs and net returns per acre of irrigated crops, which will, in turn, induce changes in cropping patterns and the use of other inputs.

TABLE 6 Electric Power Marketing EIS Commitment Level Alternatives and Supply Options

Alternative	Description	Supply Option	Dam Operation	Capacity Commitment (MW)	Energy Commitment (GWh)
No Action	Moderate capacity and high energy (the 1978 marketing program commitment level)	A B C	Full flexibility Low fluctuation Steady flow	1,291	5,700
1	High capacity and high energy (post-1989 commitment level)	A B C	Full flexibility Low fluctuation Steady flow	1,449	6,156
2	High capacity and low energy	A B C	Full flexibility Low fluctuation Steady flow	1,450	3,300
3	Moderate capacity and moderate energy	A B C	Full flexibility Low fluctuation Steady flow	1,225	4,000
4	Low capacity and low energy	A B C	Full flexibility Low fluctuation Steady flow	550	3,300
5	Low capacity and high energy	A B C	Full flexibility Low fluctuation Steady flow	625	5,475
6	Moderate capacity and moderate energy	A B C	Full flexibility Low fluctuation Steady flow	1,000	4,750

This analysis focuses on estimating the impacts that result from substitution in three main dimensions of agricultural production, as follows:

1. Substitution between irrigated and nonirrigated methods of producing the same crop. Many of the states in the study have crops that are grown by both methods in the base year, and changes in the cost of pumping irrigation water will change the proportion of crops that are grown by dryland and irrigated methods.

2. Substitution among the types of crops grown in the farming region. A given region has a distribution of soils that are suitable for particular crops. The range of soil types results in a range of yields and consequently a range of economic returns per acre. Given that variable costs do not vary greatly over different soil types in a region, the change in yield by soil type can differ by as much as 25% above or below the

average yield. These yield changes make a dramatic difference in the returns to land and management. Aggregate empirical evidence gathered when water availability changed during recent droughts suggests that changing the proportions of crops grown is the major method used by crop farmers to adjust to changes in the cost and availability of irrigation water.

3. Substitution among the variable inputs per acre used to grow a given irrigated crop will also occur as a response to higher electricity prices. Economic theory and practice show that as one input becomes relatively more expensive, profit-maximizing producers tend to use it less and use less expensive inputs more. The most obvious example for this study is the substitution between electricity and other energy sources to pump groundwater for irrigation.

These three types of substitution are modeled in three different but interacting ways in the regional agricultural production model. Substitution between irrigated and nonirrigated production of a given crop is treated as a change in the production method. Separate production functions are calibrated for dryland and irrigated production since they have different input sets and production intensities (see Figures A.1 and A.2 in Appendix A). The regional restrictions on land availability in the model allow irrigated land areas to revert to producing dryland crops but do not allow irrigated areas to expand. This latter constraint is defined to reflect the irrationality of an irrigation cost increase being able to induce additional capital expenditure to expand the amount of irrigated land.

Changes in the acreage data for producing a given crop because of changes in the soil type available to grow it are reflected in a quadratic cost function that is defined as being separate from the production function. The justification for this separate approach is that production data are available only on the basis of measured average yields and levels of input use for the crop and region, which reflect typical soil types for that crop. However, the farmer makes an adjustment at the margin on the basis of the marginal soil type used for growing that crop. Economic theory shows that the principle of "equal marginal returns to land" will hold across all crops for profit-maximizing farmers. However, given a fixed land area with heterogenous soils, the same profit-maximizing farmer will also follow Ricardo's principle by allocating the best soil types to grow the most profitable crops. This practice leads to the usual situation reflected in the available data, in which more profitable crops have higher average returns to land and some other inputs. Another explanation for this observed situation assumes constant land quality and sharply decreasing returns to scale for the most profitable crops. Given the lack of evidence of strong diseconomies of scale in farming and the well-documented evidence that crop yields vary over different soils, the explanation of heterogenous land quality and constant returns to scale production functions for a given soil type is preferred. Because the available data reflect average regional production technology, a production function is calibrated to these data. A quadratic soil variability cost function is then calibrated for each regional crop, on the basis of equal marginal conditions and the average yield. The soil variability cost is deducted from the average revenue function in the objective function. In this way, the production model is calibrated to the base-year average data, and it also satisfies the marginal input conditions over a wide range of average crop profitabilities. As the costs of productive inputs or constraints on their availability are changed, the number of acres of a crop that is grown will expand or contract up and down the profit gradient, driven by changes in the comparative advantage of the crop in a specific region.

Substitution among the variable inputs used to grow a particular crop in a region depends on the production function specified and the degree of substitution allowed by the specification. The production function used in this study is called the constant elasticity of substitution (CES) production function. The precise mathematical form is shown in Appendix A. To summarize, this mathematical form allows inputs to the production process to be substituted to improve economic efficiency, with all inputs in a particular group assumed to be substituted at the same rate. This assumption is realistic for closely related groups of inputs, but is not reasonable to impose across all inputs to irrigated production. For example, it is reasonable to assume that different ways of pumping and supplying water to a crop are equally substitutable. In this model, three sources of water — surface water, groundwater pumped with electricity, and groundwater pumped with other fuels — are specified to be equally substitutable (Figure A.2). However, the ability to substitute nitrogen for irrigation water would be expected to be very different. Accordingly, nitrogen is put in a separate input group, with similar inputs such as pesticides or capital equipment for cultivation.

Each group has its own CES production function whose parameters are calibrated against the cost, production, and input use data used in the model. The calibration procedure follows an approach used in national general equilibrium models, by which the parameters are obtained by solving a consistent set of equations obtained from the total output condition and the necessary conditions for optimizing behavior. The three subgroups (nests) for irrigated crop production (shown in Figure A.2) are likewise linked by a three-input CES production function calibrated against the aggregate values for each nest and a different elasticity-of-substitution parameter.

Using these three types of response to changed input prices avoids the rigidity inherent in the usual linear optimization approaches, which restrict inputs so they are used in fixed proportions. The regional agricultural production is modeled as an aggregate unit, which can be defined as a state or substate unit. When aggregated on a state level, the model objective function maximizes the net income from the sector, subject to technological possibilities and constraints on resource availability.

4.2 PRODUCTION FUNCTION SPECIFICATION

The production function is the mathematical linkage in the model between input use by farmers and resulting production. In the model, a separate production function is calibrated for each crop and region where it is grown (Just et al. 1983). These production functions reproduce the base-year production but also reflect the profit-maximizing reactions of the farm sector when it is faced with changes in input prices, such as increased power costs.

The main avenue of farmer response to changes in prices is to change the mix of crops grown. The production model specifies that farmers can grow a selection of seven crops in most areas (barley, corn grain, corn silage, cotton, hay, sorghum, and wheat). Some areas are not able to grow certain crops; for example, growing cotton is restricted to the southern states in the region.

A second way of responding to changed power costs is to produce crops without using irrigation water. Accordingly, the model allows for two alternative dryland and irrigated production practices in many regions. In some regions, however, a dry climate combined with the water requirements of a crop prevent that crop from being grown. For example, nonirrigated production of hay is not possible in the drier southern regions.

The third avenue of adjustment is to change the input mix used for a particular acre of crop production. Irrigated crop production is specified to have seven inputs. They are broken down into three groups (or nests): land, variable inputs, and water inputs, as shown in Figure A.2.

Land is represented by a single input, but the quality of the land is characterized in a crop yield function that reduces the productivity per unit of land as the amount of land in a given crop is increased. Variable inputs are broken down into capital inputs, chemical inputs, and other variable inputs (such as fuel, labor, transport, and harvesting costs). The variable input group has a separate level of substitutability that can be defined over a range, from perfectly substitutable inputs (such as water of the same quality from two different sources) to those inputs with a low level of substitutability for technical reasons (such as harvesters and fertilizers).

The value of the elasticity of substitution is defined from zero to infinity. The greater the ability to substitute an input, the higher the elasticity of substitution. For example, the traditional linear programming models have a fixed proportion technology specified, which is equivalent to an elasticity of substitution of zero. At the other extreme, elasticities approaching infinity indicate a nearly perfect ability to substitute inputs. In technical terms, the elasticity of substitution measures the curvature of the isoquant in terms of two inputs (where production is held constant). The CES production function specified in this model is defined to hold the elasticity of substitution constant over the full range of input proportions. Thus, while the substitutability between two inputs (the curvature of the isoquant) is defined from prior econometric studies, it is assumed to hold constant over the whole range. A precise explanation of the elasticity of substitution and the mathematical definition of the CES production function are contained in Appendix A.

4.3 EMPIRICAL MODELING METHODS

The empirical approach used in this study was determined to a great extent by the data available and the structural constraints on crop production in the areas covered in the EIS. The data available were based on the 1990 crop year and collected by the departments of agriculture in the states concerned. Data on crop water use and sources were also obtained from the U.S. Department of Agriculture (USDA) publication, *Farm and Ranch Irrigation Survey* (USDA 1988). The data are detailed in Section 5. The problem facing the empirical model builder is that the data on yields, costs, and returns reflect the average values for a particular crop and region, but the crop acreage allocation data reflect the marginal decisions of farmers who have detailed local knowledge about the marginal yields of the soils available in a given area.

However, an analysis such as this has to be able to reflect comparatively subtle changes in regional comparative advantage to measure the effects of changes in electricity price to farmers. The projected changes in the power costs are in the range of 10%. Since electric power is an important but not dominant part of the cost of crop production in these regions, the marginal adjustments are unlikely to be large changes in regional crop production but rather a series of slight adjustments on the several margins mentioned earlier. A successful modeling approach has to be able to infer the marginal conditions from the observed marginal crop allocations and the average data.

The empirical approach uses a two-stage approach and follows Howitt (1991a,b). The conventional empirical approach in applied production economic analysis is to estimate a general flexible-form production function from the available time series or cross section data by using a dual specification. This approach has some serious drawbacks for the present analysis and database that prevent it from being used. The main problem is a lack of time series data on a regional basis. Data on a cross section of six states for most crops are available, but assuming identical conditions over the states and trying to estimate a cross-section production function would be meaningless because of the wide differences in regional conditions and the small number in the cross section. Accordingly, calibrating six different production functions for each regional crop was felt to more accurately reflect the regional changes in farmers' responses and adjustments to increased electricity prices.

The first stage uses a linear program with particular calibration constraints on the crop acreage to generate two essential sets of empirical values. The first set of values consists of the shadow values of the fixed but allocatable resources that are constraining in a given region during the base year. The second set consists of the dual values on the calibration constraints. These dual values are not zero for those crops for which the resource constraints are not binding.

Howitt (1991a,b) show that these dual values measure the difference between average and marginal value products, which is attributed to changing land quality across the regional acreage grown. These two sets of values provide the required data to specify "share equations," from which one can calculate the production function coefficients that reproduce the base-year resource use and output, when optimized in the nonlinear CES production model. The dual values from the calibration constraints are also combined with the data on average yields and base-year acreages to calculate the quadratic yield heterogeneity function that calibrates the cropland allocations. To reiterate, the production function is based on the average yield and input cost data, but the observed land allocations are based on the marginal profitability of the crop in question.

Given the parameters for each regional, crop-specific CES function and the quadratic land variability cost function, the regional production model can be specified as a nonlinear optimization problem by maximizing the nonlinear profit function for each area, subject to the regional constraints on farming inputs. A mathematical representation of the production model is shown in Appendix A. The resulting model will accurately reproduce base-year production and resource use yet still be able to respond to changed electricity input prices by substitution in the three ways outlined at the start of this section: (1) changing from irrigated to dryland production, (2) changing the proportions of crops grown in a region, or (3) following some land and substituting among the variable inputs used to produce the irrigated crop.

5 DATA AND BASELINE DEVELOPMENT

5.1 INTRODUCTION

The analysis of the impacts of changes in electricity rates was undertaken at two geographic scales — the state level and the substate level. The analysis of impacts on agricultural activity might have been based at the individual farm level or on the service territories of individual Western customer utilities. However, to generally understand how farmers respond to changes in the farm economy, and therefore better facilitate decision making, the analysis of the impact of changes in electricity rates used an economic model that assesses impacts at a more aggregated geographic level than the individual farm or utility service district. Therefore, the analysis modeled the impacts of each alternative and supply option at the state level, with additional information presented at the substate level for five county groupings. These groupings were likely to show the largest impacts of power marketing alternatives on agricultural activity.

The analysis at the state level estimated impacts in each of the six states in Western's SLCAO service territory (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming). The analysis at the substate level estimated impacts in five regions that represent groupings of individual counties within the six-state area. These counties were chosen on the basis of the proportion of county incomes produced by agriculture and on the reliance of Western customer utilities in these counties on Western power. County reliance levels were calculated according to the methodology described in (Allison et al. 1995). Counties included in the substate analysis are shown in Table 7.

5.2 DATA SOURCES

For both levels of analysis, primary cropping data were obtained from the individual state departments of agriculture and their annual publications containing agricultural statistics (Arizona Agricultural Statistics Service 1991; New Mexico State University 1991;

TABLE 7 Counties Included in the Substate Analysis

Subregion	County	State	Income from Agriculture (%)	Reliance on Western for Electricity (%)
1	Wayne, Piute	Utah	29.4	56.5
2	Costilla, Saguache	Colo.	24.3	49.4
3	Phillips, Sedgewick, Washington, Yuma	Colo.	51.3	39.8
4	Cheyenne, Kit Carson, Lincoln	Colo.	34.8	39.8
5	Baca, Kiowa, Prowers	Colo.	66.8	9.8

Colorado Agricultural Statistics Service 1991; Nevada Agricultural Statistics Service 1991; University of Nevada 1991; Utah Department of Agriculture 1991; Wyoming Agricultural Statistics Service 1991). Typically, these statistics included data on acreage for each crop (by cropping practice), yields per acre, and output of each crop. In addition, these publications included prices for each crop (usually an average of monthly prices for the year). For all states and substate regions, primary input was taken for the year 1990. Cost data obtained from the USDA included unit costs for land, capital, chemistry, and other inputs. Water use data obtained from the *Farm and Ranch Irrigation Survey* (USDA 1988) included the amount of water used (in acre-feet per acre of land), water requirements for each crop, and a breakdown of groundwater pumps by fuel source. Information on water requirements (acre-feet per acre) were available on a state-by-state basis for each crop. Data on energy use for pumping, which indicates how many acres were pump-irrigated by energy source, were available at the state level but not the individual crop level. Consequently, shares of groundwater pumping by each energy source were assumed to remain constant for all crops. Finally, crop price projections were obtained from the Food and Agricultural Policy Research Institute (FAPRI); these included forecasts of prices to the year 2000.

The analysis was performed for four individual years (1993, 1995, 2000, and 2008). To construct the baseline for the analysis, FAPRI national-level acreage projections for each crop produced were used. To obtain state-level projections of acreage, individual state-level acreages for each crop were taken as a percentage of the national-level acreage allocations for 1990, and individual state shares were assumed to remain constant for the years 1993, 1995, 2000, and 2008. As a result, no significant changes in the composition of acreage between crops (other than those that are reflected in the national acreage data) were assumed to occur within individual states from 1993 until 2008. Individual crop price projections were also obtained from the USDA. Since these projections extended only to the year 2001, additional projections to the year 2008 were made by applying the projected average rate of growth over the 1990-2001 period to subsequent years to extend the price projections to the year 2008.

5.3 BASELINE STATE-LEVEL ANALYSIS

The baseline projection includes acreage for each crop and divides this acreage by cropping practice. Irrigated acreage is further divided by water source (i.e., between surface water and groundwater). Groundwater acreage is further divided between electrically pumped groundwater and water pumped by using other energy sources. The other energy sources include natural gas, diesel, gasoline and gasohol, and propane and butane. For the analysis, electrically pumped acreage that used these other energy sources was aggregated into one "other" category. To convert acreage into water use, information on acre-feet of water required for each crop were used; acreage for each crop was multiplied by the acre-feet of water per acre of land requirement. Implicit in this approach are two assumptions. The first is that the water requirements for each crop are independent of the source of water used. The second assumption is that the water requirements of each crop do not change over the course of the analysis (i.e., from 1990 through 2008).

This second assumption is consistent with a broader assumption that the state of agricultural technology is fixed throughout the time horizon of this study. This assumption encompasses the following suppositions: yields (output per acre harvested) do not change over time; the efficiency of irrigated agriculture does not change (i.e., pump efficiency will not change); and the efficiency of other inputs such as fertilizer or capital do not improve and thus do not improve yields or reduce the water requirements of each crop.

In addition to assuming there will be no technical change, it is necessary to assume there will be no dramatic changes in the consumption patterns of the crops (i.e., there are no changes in the composition of the demand for food that would require changes in the composition of crops and, as a result, changes in the distribution of acreage across crops). In effect, the baseline is constructed on the basis of the assumption that the existing state-level composition of crops will remain at its 1990 configuration.

Tables B.1 through B.6 in Appendix B summarize data on acreage and output under the baseline for each crop in each of the six states. These tables include data on acreage and output by cropping practice and irrigated acreage and output by surface water and groundwater. When the entire six-state region is considered, the split between electrically pumped groundwater and groundwater pumped by other energy sources is about 80% for electrically powered pumps and 20% for pumps powered by other sources.

5.4 BASELINE SUBSTATE-LEVEL ANALYSIS

The state-level analysis examines how an entire state's agricultural sector would be affected by changing electricity costs resulting from alternative hydroelectric marketing programs. However, the distribution of Western's power sales across counties is not uniform. For the six-state region as a whole, Western power sales account for less than 20% of the total power sold. However, some counties rely on Western for electricity to a larger degree than suggested by the statewide averages. Moreover, many of the local economies in each state are not agricultural to any significant degree. For the six-state region as a whole, agricultural net income makes up about 1-2% of the total. However, some counties in each of the six states depend on agriculture to a much larger degree than indicated in statewide averages of the share of total income accounted for by agriculture. As a result, the effects of alternative hydropower marketing programs could be larger for counties or groups of contiguous counties than the state-by-state analysis would suggest. To account for the potential of disproportionate county-level impacts, an analysis at the county level was performed.

The construction of the baseline and actual analysis at the county level were similar to those of the state-level analysis. The principal exception was that the county-level shares of national acreage for each crop were used to calculate baseline acreage levels for each county. Acreage estimates for the baseline for each of the five regions were then constructed by aggregating acreage across each of the counties that defined each region. County-level acreage and production data were available from the same state-level agricultural publications that were used to construct the state-level analysis.

The counties that made up the five regions were selected according to one of two criteria. Either the county had to depend on agriculture for at least 25% of its total economic activity (measured by county income) or the county had to depend on Western for at least 25% of the electricity used by the agricultural sector.[1] Finally, individual counties that were geographically contiguous were aggregated into the five regions analyzed. Table 7 lists the counties included in each region.

Tables B.7 through B.11 summarize data on acreage and output under the baseline for each crop in each of the five substate regions. These tables include data on acreage and output by cropping practice and irrigated acreage and output by surface water and groundwater.

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[1] The criteria for electricity used by the agricultural sector were based on electricity used by all sectors except commercial, industrial, and residential end-users. As a result, this measure will probably overstate the dependence of the agricultural sector on Western for electricity. For example, all recreational uses of electricity are included in this classification.

6 STATE-LEVEL RESULTS

The focus of this analysis has been on seven crops grown under dryland and irrigated cropping practices. As such, this analysis does not capture the full extent of agricultural impacts in each state. The seven crops analyzed in this report do not represent all agricultural activity in the six states. However, other crops (such as peanuts and chili peppers) that are grown in each state do not represent large proportions of state agricultural activity. Moreover, other kinds of agricultural activity are not analyzed; these include livestock farming, greenhouse nursery farming, and fruit crops. These other activities are substantial in some of the six states. As a result, this analysis represents an underestimate of the full potential impacts of the hydropower marketing program alternatives under consideration in Western's Electric Power Marketing EIS. It does, however, include an assessment of the major crops and potential impacts of electricity price increases in the region.

The alternatives under consideration include a No Action Alternative that represents a continuation of the pre-1989 power marketing criteria (NA), an alternative that reflects the post-1989 marketing plant (Alternative 1), and five additional alternatives that reflect different commitment levels (Alternatives 2-6). Each alternative represents a combination of different power supply and dam operation options. The No Action Alternative with full flexibility of dam operations (NA-A) represents baseline conditions.

For the agricultural activity considered in this report, results indicate that the impact of each of these alternatives on statewide agricultural net income would be fairly small. Overall, results indicate losses in agricultural income that range from about zero to less than 2%, in terms of deviations from baseline state net agricultural income. The largest impacts tend to occur (1) under alternatives that show larger percentage increases in electricity costs to the farming sector and (2) in states that are more dependent on Western for electricity; impacts also tend to be larger (for a given percentage change in electricity costs) in states that have few alternatives in terms of both irrigated crops and dryland cropping practices. With respect to the last point, results suggest that states with substantial dryland acreage have an additional option by which some of the impacts from higher electricity costs can be mitigated.

In addition, the statewide impacts reflect substantial substitution among crops, cropping practices, and inputs. Higher electrical irrigation costs typically reduce net income to farmers who grow the crops that depend most on water — in particular, electrically pumped groundwater — and they can also result in higher net income to farmers who grow dryland crops and crops that are less dependent on groundwater. The impacts on net state agricultural income reflect crop and input substitution by farmers responding to these higher electricity costs; when taken at the aggregated state level, the impacts represent the net effects of this process of substitution. For most irrigated crops, the strongest impacts occur in groundwater use. The reduction in use of electrically pumped groundwater is often accompanied by an increase in use of nonelectrically pumped groundwater and surface water.

Farmers typically respond to higher costs of electrical pumping by reducing their use of electrically pumped groundwater, increasing their use of nonelectrically pumped groundwater, and increasing their use of surface water. The composition of crops across different plots of acreage (irrigated and dryland) reflect a farmer's response to higher costs for electrically pumped groundwater. In effect, the farmer is allocating more water-intensive crops away from electricity-intensive water sources (including surface water, irrigated land, and dryland).

However, in some cases, such substitution is not possible, either because dryland farming is infeasible or because the cost changes under consideration are not large enough to dramatically alter the basic composition of farming in each state. For example, cotton production in Arizona is irrigated, and despite some movement away from electrically pumped irrigated acreage, this cotton production remains irrigated under all the alternatives under consideration. In other instances, the composition of a state's agricultural production tends to favor some crops, and this pattern does not change under any of the alternatives. For example, states that traditionally grow a substantial amount of wheat continue to do so, although some reductions occur under some of the alternatives.

6.1 RESULTS FOR ARIZONA

The largest impacts for Arizona occur under Alternatives 4C and 5C. Under these alternatives, electricity costs change by about the same percentage: from 3.99% in 2008 to 5.03% in 1993 under Alternative 4C, and from 3.78% in 2008 to 5.07% in 1993 under Alternative 5C. The electricity cost increases are somewhat smaller under Alternatives 4A and 4B than either 4C or 5C, and are much smaller under Alternatives NA-B, NA-C, 2A, 2B, 2C, 5A, and 5B. Table 8 indicates the range of percentage increases in electricity costs under each marketing alternative for Arizona.

On average, the electricity cost changes range from a minimum of 0.36% (under Alternative NA-B) to a maximum of 4.52% (under Alternative 4C). The results of the analysis for Arizona, and other states as well, grow in proportion to the electricity cost increases. As a result, the size of the impacts increases proportionally to the percentage cost increase in electricity input into the model. As a result, the remainder of this section focuses on the results of those alternatives that predict larger percentage increases in electricity. Qualitatively (i.e., in terms of the nature and direction of the impacts), the results are similar across all alternatives.

Under Alternative 4C, the largest percentage reductions in crop net revenues occur in 1993. In that year, net revenues fall by $1.79 million, or about 0.78% of the total. The largest share of this loss in net income occurs for cotton, which loses nearly $1.2 million. The only other crops that contribute significantly to these losses are hay, which loses just more than $450,000, and wheat, which loses just more than $122,000. For all irrigated crops, use of electrically pumped groundwater falls by just more than 54,000 acre-ft, which represents a reduction of about 3.3% of total use of electrically pumped groundwater. There is a very slight increase in use of nonelectrically pumped groundwater and a somewhat larger increase

TABLE 8 Summary of Electricity Cost Changes for Arizona (percent deviation from NA-A, the No Action baseline; all deviations are positive)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.30	2008	0.36	0.42	1993
NA-C	2.41	2008	2.89	3.30	1993
2A	1.55	2008	1.94	2.20	2001
2B	2.18	2008	2.71	3.02	1993
2C	3.11	2008	3.83	4.31	1993
4A	3.11	2008	3.45	3.79	1993
4B	3.33	2008	3.71	4.09	1993
4C	3.99	2008	4.52	5.03	1993
5A	2.34	2008	2.76	3.08	1993
5B	2.97	2008	3.52	3.95	1993
5C	3.78	2008	4.50	5.07	1993

in use of surface water. Overall, the net reduction in use of groundwater is just less than 54,000 acre-ft, or about 2.7% of the total. An additional 2,278 acre-ft of surface water is used under this alternative.

The results under Alternative 5C are similar to those described above. Crop net income falls by $1.8 million, or about 0.8% of the total. As occurs under Alternative 4C, most of this loss is a result of the loss in cotton net income, which totals nearly $1.2 million. Hay net income falls by nearly $459,000, or about 1.6% of total hay net income. Wheat income falls by just more than $123,000, or about 0.9% of total wheat income. Changes in input use are similar to those that occurred under Alternative 4C. Use of electrically pumped groundwater falls by 42,753 acre-ft (about 2.6% of the total), while use of nonelectrically pumped groundwater increases by 263 acre-ft (0.08% of the total). Use of surface water increases by 2,056 acre-ft (0.1% of the total).

6.2 RESULTS FOR COLORADO

The largest cost increases occur under Alternatives NA-C and 5C, in which electricity prices are higher than baseline electricity prices by an average of 3.9% and 4.1%, respectively, over the 1993-2008 period. Under both alternatives, the cost increases are fairly constant over the time horizon. For Alternative NA-C, they are at their highest (in percentage terms) in 1993 and then decline gradually throughout the rest of the period of analysis. The electricity cost increases under Alternative 5C exhibit slightly different behavior, increasing gradually until reaching their peak in 1999. After dropping slightly in 2000, they gradually increase until 2008. Table 9 summarizes how electricity costs to the agricultural sector deviate from the baseline under the 11 alternatives and supply options.

TABLE 9 Summary of Electricity Cost Changes for Colorado (percent deviation from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.38	2008	0.46	0.52	1993
NA-C	3.42	2008	3.85	4.23	1993
2A	-2.02	1998	-1.76	-1.32	2008
2B	-0.90	1996	-0.36	0.02	2008
2C	1.39	1996	1.93	2.31	2000
4A	-1.49	1996	-1.07	-0.54	2008
4B	-0.96	1996	-0.55	-0.03	1995
4C	0.46	1996	1.13	1.62	2008
5A	-0.47	2000	0.11	0.72	1995
5B	1.08	2000	1.77	2.30	1999
5C	3.29	2000	4.11	4.95	1999

The largest impacts for Colorado occur under Alternatives NA-C and 5C. Under Alternative NA-C, the largest impacts on net revenue occur in 1993, when net income from the crops under consideration in this analysis falls by 0.6%. This percentage reduction represents a loss of about $2.0 million in net revenues. Under Alternative 5C, the largest percentage impacts occur in 2008, when crop net income falls by 0.63%, or about $1.75 million.

Under Alternative NA-C, irrigated corn grain and hay account for most of the loss in net revenue. Net profits to irrigated corn grain fall by just more than $1.0 million, or about one-half of the total loss. Net profits to irrigated hay fall by $935,000, accounting for most of the remaining losses to state net income. Net profits to the other irrigated crops (barley, corn silage, sorghum, and wheat) also fall, but these crops represent small shares of total agricultural activity. In terms of output, the losses to irrigated corn translate into a reduction of about 1.8 million bushels (about 1.4% of the total), while hay output declines by 16,590 tons (about 0.5% of the total).

The reduction in net profits under Alternative NA-C can be further divided by cropping practice. For all irrigated crops, net income falls by $2.3 million. For dryland crops, net income rises by $355,838. Most of this increase in dryland net income is attributed to increases in dryland wheat, which gains about $275,000 in net revenue. In percentage terms, this amount represents a small (just under 0.3%) increase in net income. This gain in dryland wheat profits comes from an additional 72,855 bushels of output. In effect, under this alternative, dryland wheat is substituted for irrigated corn grain and hay.

In terms of input use, under this alternative, 9,648 irrigated acres (about 0.4% of the total) is switched to dryland cropping. Use of electrically pumped groundwater falls by 70,890 acre-ft, or about 3.3%. Since yields to dryland crops are generally lower than yields to equivalent irrigated crops, total output falls, despite this substitution. A smaller decrease in use of nonelectrically pumped groundwater (about 0.44%) amounts to a reduction of about 1,578 acre-ft. Use of surface water declines as well, but by just under 0.3% of the total, or 5,714 acre-ft.

The results under Alternative 5C are similar both qualitatively and quantitatively. More than $2.7 million of the total loss of slightly more than $3.0 million in net income that occurs in 2008 is accounted for by corn grain and hay, with each of these crops sharing equally in the loss. In percentage terms, hay loses just under 2.0% of net income, while corn grain loses about 1.5%. The remaining irrigated crops account for the remainder of the loss in net income. Some of this loss is made up by gains to dryland cropping, but these gains total just more than $262,000, or about 0.11% of total dryland net revenues. Under this alternative, dryland hay makes up most of the difference, gaining $240,400 in net revenue. In terms of input use, under Alternative 5C, about 17,134 acres of irrigated cropland is switched to dryland cropping. Use of electrically pumped groundwater declines by 85,284 acre-ft, or about 3.6%. Use of nonelectrically pumped groundwater and surface water also decline, but by a much smaller percentage (0.5% and 0.6%, respectively).

6.3 RESULTS FOR NEVADA

The increases in electricity costs to Nevada farmers are generally smaller than those that occur to either Arizona or Colorado farmers. The largest average price increases occur under Alternatives 4B, 4C, and 5C, ranging from 2.2-2.5% above the baseline. The largest percentage increases in electricity costs under Alternatives 4B and 4C occur in 2008, while under Alterative 5C, the largest percentage deviation from baseline occurs in 1993. Table 10 summarizes how electricity costs deviate from the baseline under the 11 alternatives.

In terms of net income to farming, the largest percentage impacts occur under Alternatives 4B, 4C, and 5C, all of which occur in 2008. Under Alternative 4B, net income to farming falls by 2.1% in 2008. Under Alternative 4C, net income falls below the baseline by 2.3%. Finally, under Alternative 5C, net income falls below the baseline by 1.95%. Despite what appear to be relatively larger percentage reductions, these net income reductions still represent fairly small losses in dollar terms when compared with those that occur in Arizona and Colorado. Under Alternative 4B, net income to farming falls by $345,781, while under Alternative 4C, net income falls by $373,657. Alternative 5C shows similar impacts, with net income to farming falling by a slightly smaller amount — $317,114.

Under all three alternatives, irrigated hay accounts for most of the losses. Losses to irrigated hay range from $308,250 under Alternative 5C to $363,200 under Alternative 4C. The other irrigated crops in Nevada (barley and wheat) also show losses, but these losses are smaller, in both absolute and relative terms, than the losses to irrigated hay.

TABLE 10 Summary of Electricity Cost Changes for Nevada (percent deviation from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.07	2008	0.08	0.10	1993-1994
NA-C	0.54	2008	0.60	0.71	1993
2A	-0.33	1993	-0.28	-0.24	2008
2B	-0.29	2008	-0.21	-0.12	1993
2C	0.18	1996-2008	0.18	0.20	1993
4A	1.88	1997-1998	1.95	2.03	1993, 2008
4B	2.10	1993	2.25	2.37	2008
4C	2.32	1993	2.46	2.57	2008
5A	1.71	1998-1999	1.77	1.89	1993
5B	1.89	1998-1999	1.95	2.10	1993
5C	2.12	1998-1999	2.18	2.38	1993

6.4 RESULTS FOR NEW MEXICO

The increases in electricity costs are small for New Mexico under all alternatives. On average, they range from the 0.07% under Alternative 2A to 0.49% under Alternative 5C. The largest deviation from the baseline occurs in 1999 under Alternative 5C. Table 11 summarizes the percentage deviations in electricity costs from the baseline.

Under Alternative 5C, net profits fall in 1993 by about $81,175, or about 0.07%. Most of this reduction in net income is accounted for by irrigated hay, which loses $53,660. In terms of net profits to irrigated hay, this loss represents a reduction of 0.11% below the baseline. The remaining irrigated crops (barley, corn grain and silage, cotton, sorghum, and wheat) also lose net income under this alternative, but these losses are slight. Some of the loss in net income is made up by gains to dryland sorghum and wheat; net profits to these crops increase by $12,120.

6.5 RESULTS FOR UTAH

The largest percentage increases in electricity costs occur under Alternatives 4A, 4B, and 4C, by 12.2%, 12.7%, and 13.5%, respectively. However, these cost increases do not reflect the pattern that occurs over the 1993-2008 period under these alternatives. Through the year 2005, electricity prices deviate from the baseline by no more than 7.3% under Alternative 4A in 2004, 7.8% under Alternative 4B in 2004, and 8.6% under Alternative 4C in 1994. While these deviations represent large percentage deviations from the baseline, when compared with those that occur in the other states, they are more reflective of the general pattern of electricity cost deviations that occur in the years before the 2006-2008 period. Table 12 summarizes how electricity costs deviate from the baseline under the

TABLE 11 Summary of Electricity Cost Changes for New Mexico (percent deviation from NA-A, the No Action baseline; all deviations are positive)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.07	2008	0.08	0.08	1993-2007
NA-C	0.33	2008	0.38	0.40	1993-1999
2A	0.04	1994, 1995	0.07	0.10	1999
2B	0.17	1995, 1996	0.18	0.23	1999
2C	0.29	2008	0.30	0.35	1999
4A	0.17	1995, 1996	0.20	0.34	1993
4B	0.22	1994-1996	0.24	0.39	1999
4C	0.36	2008	0.39	0.55	1999
5A	0.24	2008	0.28	0.45	2008
5B	0.31	2008	0.38	0.55	1999
5C	0.41	2008	0.49	0.68	1999

TABLE 12 Summary of Electricity Cost Changes for Utah (percent deviation from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.33	2008	0.40	0.49	1993
NA-C	2.36	2008	2.81	3.27	1994-1997
2A	-0.68	1998	0.41	2.05	2008
2B	-0.01	2005	1.22	2.65	2008
2C	1.24	2005	2.58	3.89	2008
4A	4.81	1998	6.98	12.22	2008
4B	5.32	1998	7.44	12.67	2008
4C	6.27	1998	8.36	13.47	2008
5A	0.39	2005	2.66	4.22	1993
5B	1.19	2005	3.54	5.21	1993
5C	2.30	2005	4.79	6.58	1993

11 alternatives for the state of Utah. Because the percentage deviations in electricity costs that occur in 2000 are more typical of the general pattern of cost increases that occur in other years, this discussion focuses on the impacts that occur under Alternatives 4A, 4B, and 4C in the year 2000 rather than in 2008.

Under Alternative 4A, net profits to farming fall by $486,489 in the year 2000. This decline represents a reduction of about 0.7% below the baseline for that year. In 2000, under Alternative 5B, net income to farming falls by $527,225, or about 0.7% below the baseline; under Alternative 4C, net profits fall by $602,441, or 0.77% below the baseline.

Under Alternative 4A, irrigated hay absorbs the largest losses in net income; hay net income falls by $446,840, or about 0.77%. Other irrigated crops that experience losses under this alternative include barley, corn grain, corn silage, and wheat. The two dryland crops in Utah — barley and wheat — make up for some of the losses in net income. Dryland barley gains about $25,000 in net income, or 8.3% of the total, and dryland wheat gains nearly $30,000 in net income, or about 0.4% of the total. The larger percentage gain for barley is probably a result of the fact that it is a less water-intensive crop than the others. In terms of input use under Alternative 4A, about 1,732 acres of irrigated land are switched to dryland cropping. Use of electrically pumped groundwater falls by 19,764 acre-ft, or more than 4.0% of the total. Use of nonelectrically pumped groundwater and surface water both decline, by a combined amount of 1,135.5 acre-ft.

Agricultural activity exhibits similar behavior under Alternative 4B. Irrigated agricultural net income falls by $712,635 in 2000. Dryland net profits increase by $59,337. Irrigated hay and corn silage account for most of the losses under this alternative — a combined loss of $585,391 in net revenue. Irrigated barley and corn grain together lose about $106,714 of the remainder. As occurred under Alternative 4A, gains to dryland barley and wheat offset some of these losses, but together they make up only about $59,337 of the losses. In terms of input use under this alternative, 1,873 acres of irrigated land is switched to dryland farming. Use of electrically pumped groundwater falls by 21,378 acre-ft, or about 4.3%, while use of nonelectrically pumped groundwater and surface water together declines by 1,227 acre-ft.

The losses in net income that occur under Alternative 4C represent 1.0% of total net agricultural income, or $814,091. Dryland profits increase, in percentage terms, by nearly the same magnitude but make up only $67,591 of the losses to net state income. Corn silage and hay together account for most of the loss, with net income to these crops falling below the baseline by $668,772 in 2000. In percentage terms, corn grain absorbs the largest reduction — 4.0% below baseline net revenues, while losses to hay represent a reduction of 0.9 below the baseline. Under this alternative, 2,134 acres of irrigated land is switched to dryland farming. Use of electrically pumped groundwater declines by 24,338 acre-ft. Use of nonelectrically irrigated groundwater and surface water together declines by 1,397 acre-ft.

6.6 RESULTS FOR WYOMING

With the exception of Alternatives NA-C and 5C, the average deviations from baseline in Wyoming are small. For Alternative NA-C, the largest deviation from baseline occurs; it happens in 1993, when electricity costs rise above the baseline by 4.1%. Under Alternative 5C, prices reach their greatest deviation from baseline in 1995, at 3.6% above the baseline. Under both alternatives, electricity costs deviate from the baseline more in earlier years, with the difference falling gradually throughout the remainder of the 1993-2008 period. Table 13 summarizes how electricity costs deviate from the baseline for all alternatives and supply options.

In Wyoming, even when electricity costs deviate the most, the impacts on agriculture are small. Under Alternative NA-C, in 1993, net income to the crops examined in this study deviates by 0.3%, or $348,811. This loss represents the combination of losses to irrigated agriculture of $431,356 offset by gains to dryland farming of $82,545. Irrigated hay bears most of this loss, falling below the baseline in 1993 by $250,520. Other irrigated crops that fall below the baseline are barley at $46,691, corn grain at $55,709, and corn silage at $61,467. Losses to irrigated wheat are even smaller, dropping below the baseline by $2,866 in 1990. The gains to dryland farming are distributed approximately equally among barley, hay, and wheat. Under this alternative, 2,088 irrigated acres is taken out of irrigation and used for dryland farming. Use of electrically pumped groundwater falls by 12,814 acre-ft. Use of nonelectrically pumped groundwater and surface water falls by a combined 1,697 acre-ft.

TABLE 13 Summary of Electricity Cost Changes for Wyoming (percent deviation from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.54	2008	0.58	0.63	1993
NA-C	3.78	2008	3.93	4.09	1993
2A	-1.83	1996	-1.48	-0.89	2008
2B	-0.49	1996	-0.03	0.82	2008
2C	1.55	1993	2.01	2.51	2008
4A	-1.55	1996	-1.09	-0.39	2008
4B	-1.07	1996	-0.61	0.08	2008
4C	0.51	1996	0.96	1.58	2008
5A	-0.68	2003	-0.34	0.42	1995
5B	0.76	2003	1.07	1.81	1995
5C	2.75	1996	3.03	3.64	1995

The results under Alternative 5C are similar to those that occur under Alternative NA-C. Net income falls by $322,232 in 1995, or 0.3% below the baseline for that year. Some of the losses to agricultural income are offset by gains to dryland agriculture, but this offset amounts to just $63,786. Under this alternative, 1,529 acres of irrigated land is switched to dryland farming, and use of electrically pumped groundwater falls by 10,890 acre-ft, or 2.6% below the baseline. Use of nonelectrically pumped groundwater and surface water falls by a combined amount of 797 acre-ft.

7 SUBSTATE-LEVEL RESULTS

The results for individual regions tend to be more varied than the results for states discussed in Section 6. The reason is that the variability in electricity cost changes is much greater. For some of the alternatives, percentage deviations from the baseline in electricity costs are lower than those that occur at the state level. The reason is that local costs for electricity are higher than the state average cost. For example, for Alternative NA-B, region 3 (Phillips, Sedgewick, Washington, and Yuma counties, Colorado) is the only substate region that exhibits cost changes that approach those that occur on the state level. The deviations in electricity costs for region 3 usually exceed those that occur in the other regions under all alternatives. However, the most pronounced deviations from baseline occur under Alternatives 5 and 6 (all supply options) for region 1. For the remaining alternatives and regions, the magnitudes of the deviations from the baseline are similar to those that occur at the state level.

7.1 RESULTS FOR REGION 1 (WAYNE AND PIUTE COUNTIES, UTAH)

Region 1 shows the greatest variability in electricity cost changes under the alternatives and supply options. Alternatives 4 and 5 (all supply options) show the largest deviations from the baseline of the entire analysis. Electricity costs deviate from the baseline by as much as much as 27% under Alternatives 4C and 5C. In Table 14, electricity costs changes from the baseline under all alternatives and supply options are summarized for this region.

Under Alternative 4C in 1993, net farm income falls 5.7% below the baseline, or by $109,660. Virtually all of these losses occur in irrigated hay, which falls below the baseline by $106,744. Because hay is the principal crop in this region, hay is the only crop affected to this degree under this alternative. Dryland cropping does not occur in this region, so there are no offsetting gains to alternative dryland crops. Use of electrically pumped groundwater falls by 3,377 acre-ft. There is a very slight increase in the use of nonelectrically pumped groundwater and surface water.

The results under Alternative 5C are similar in magnitude to those that occur under Alternative 4C. Net farm crop income falls by $112,033, or 5.9% relative to the baseline. Again, irrigated hay losses account for virtually all of this loss, namely $109,049 in 1993. The remaining losses to farm income are accounted for by barley, which falls $2,984 below the baseline. Use of electrically pumped groundwater falls by 3,443 acre-ft (about 15.5% of the total), while use of nonelectrically pumped groundwater increases by just 6.9 acre-ft. Use of surface water also shows a slight increase, rising 33 acre-ft above the baseline in 1993.

TABLE 14 Summary of Electricity Cost Changes for Region 1 (percent deviations from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.39	2008	0.63	1.02	1993
NA-C	3.26	2008	5.21	8.24	1993
2A	-3.81	1993	-2.28	-1.30	2008
2B	-1.68	2000-2001	-1.61	-1.43	1993
2C	1.10	2008	1.56	2.26	1993
4A	12.21	2008	16.77	23.42	1993
4B	14.10	2008	19.11	24.23	1993
4C	15.26	2008	20.93	26.77	1993
5A	10.79	2008	15.23	21.78	1993
5B	11.79	2008	16.82	24.21	1993
5C	13.08	2008	18.88	27.40	1993

7.2 RESULTS FOR REGION 2 (COSTILLA AND SAGUACHE COUNTIES, COLORADO)

For region 2, the alternatives that exhibit any significant deviation from the baseline are 5B and 5C, which deviate by an average of 4.1% and 5.9%, respectively. The largest deviations in electricity occur in 1999 for Alternative 5B (6.2%) and in 2008 for Alternative 5C (9.04%). The next highest deviations from baseline occur under Alternative 5A; they average 2.7% throughout the 1993-2008 period. Table 15 summarizes the deviations in electricity costs from baseline for region 2.

Alternative 5B experiences the largest losses in net income in 1995, when net income falls below the baseline by $113,292, or 0.92% relative to the total. Most of these losses occur in irrigated hay, which loses $101,907, accounting for more than 90% of total state losses in net income. Irrigated barley and wheat losses account for the remainder. The results under Alternative 5B are similar both qualitatively and quantitatively.

7.3 RESULTS FOR REGION 3 (PHILLIPS, SEDGEWICK, WASHINGTON, AND YUMA COUNTIES, COLORADO)

Alternatives NA-C and 5C show the largest percentage deviations from baseline electricity costs. Deviations average 10.9% under Alternative NA-C and 10.0% under Alternative 5C. The maximum deviations for an individual year also occur under these alternatives. Alternatives 2C and 5B also show large deviations for individual years, but the average deviations under these alternatives are on the same order as those of other alternatives. Table 16 summarizes electricity costs changes from the baseline for this region under the alternatives and supply options.

TABLE 15 Summary of Electricity Cost Changes for Region 2 (percent deviations from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.14	2008	0.17	0.18	1993-1998
NA-C	1.17	2008	1.37	1.48	1997
2A	-2.94	2008	-1.34	-0.45	2000
2B	-2.46	2008	-0.77	0.14	2000
2C	-1.77	2008	0.06	1.03	1993
4A	-1.29	2008	-0.44	0.23	2000
4B	-0.55	2008	0.27	0.96	2000
4C	0.93	2007	1.29	1.63	2001
5A	1.04	2000	2.74	4.33	1999
5B	1.58	2000	4.08	6.18	1999
5C	2.29	2000	5.87	9.04	2008

TABLE 16 Summary of Electricity Cost Changes for Region 3 (percent deviations from NA-A, the No Action baseline; all deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	1.28	2008	4.82	8.29	1993
NA-C	6.64	2008	10.85	15.00	1993
2A	-0.48	2008	1.35	4.38	1993
2B	1.86	2008	3.88	6.81	1993
2C	5.80	2008	7.94	10.27	1993
4A	-0.03	2008	2.14	6.23	1993
4B	0.79	2008	3.02	7.08	1993
4C	3.46	2008	5.94	9.74	1993
5A	0.64	2008	3.52	8.10	1993
5B	3.02	2008	6.20	10.46	1993
5C	6.77	2008	10.03	13.56	1993

Under Alternative NA-C, net profits fall $1.4 million below the baseline in 1993, representing a loss of about 1.6% of total income. For irrigated crops, the losses to net income are 3.6% of total income, or about $1.7 million. Gains to dryland cropping offset some of this loss — on the order of $286,126. The crop that bears most of this loss in state income is corn grain, which loses $1.4 million, or 3.5% of the total for that crop. Losses to corn silage and hay are also fairly large, together amounting to $163,195. For irrigated corn silage, these losses amount to 16.5% of net income for that crop, while hay's share of the loss amounts to 3.9% of net income. The gains to dryland cropping occur mostly through barley, hay, and wheat, with the latter accounting for most of the offset to the losses that occur in irrigated crops, or about $230,810. In terms of input use, 5,071 acres of irrigated land are switched to dryland farming, which represents about 1.3% of total irrigated acreage. Use of electrically pumped groundwater falls by 41,459 acre-ft, or 9.9% of the total. Use of nonelectrically pumped groundwater and surface water also drop, but to a much smaller degree.

Under Alternative 5C, the results are similar, showing a loss of just less than $1.3 million in 1993, or about 1.5% of total net income. As occurs under Alternative NA-C, some of the losses are offset by gains to dryland cropping, but this offset is small, amounting to $259,667. Corn grain bears the bulk of these losses, on the order of $1.3 million. Irrigated corn silage, hay, sorghum, and wheat make up the remainder of the losses. Gains to dryland cropping make up some of these losses, with dryland wheat representing most of the offset, or $209,420. Use of electrically pumped groundwater in 1993 drops by 9%, or 37,860 acre-ft. Use of nonelectrically pumped groundwater and surface water falls as well, but to a much smaller degree.

7.4 RESULTS FOR REGION 4 (CHEYENNE, KIT CARSON, AND LINCOLN COUNTIES, COLORADO)

Alternatives NA-C and 5C exhibit the largest average deviations from the baseline, as well as the largest deviations from baseline for an individual year. Table 17 summarizes how electricity costs deviate from the baseline under the marketing alternatives and supply options.

Under Alternative NA-C, net profits show the largest deviation from the baseline in 1993, with $192,444 in losses. In percentage terms, this loss represents a reduction of 0.6% of total net income. Losses to irrigated agriculture amount to $243,181, or about 2.3% of the total. In this region, income from dryland cropping is larger than that from irrigated cropping; it accounts for more than two-thirds of the region's total net income. However, dryland cropping only barely makes up the losses that occur to irrigated agriculture; by $50,736. Losses to irrigated corn grain and wheat account for most of the losses to irrigated agriculture; together, they amount to $171,180 in 1993. Wheat, the principal dryland crop in this region, accounts for virtually all of the offset to these losses. Under this alternative, 1,369 irrigated acres are switched to dryland farming. Use of electrically irrigated groundwater falls by 6,736 acre-ft, or about 4.6% of the total. Use of nonelectrically irrigated groundwater and surface water declines by a combined total of 997 acre-ft.

The results under Alternative 5C are similar to those that occur under Alternative NA-C. In terms of percentage deviations from baseline, the largest impacts to net income occur in 1995, when income falls below the baseline by 0.5%, or $195,890. This loss represents a combined loss to irrigated agriculture of $238,568 and gain to dryland farming of $42,678. Irrigated corn grain bears most of the losses to irrigated agriculture, accounting for $147,060 of the total loss in income. Gains to dryland wheat, although small

TABLE 17 Summary of Electricity Cost Changes for Region 4 (percent deviations from NA-A, the No Action baseline; deviations are positive unless preceded by a minus sign)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.47	2008	0.56	0.62	1993
NA-C	4.59	2008	5.08	5.50	1993
2A	-2.62	1996	-2.36	-2.10	2008
2B	-0.71	1996	-0.47	-0.23	2000
2C	2.19	1996	2.52	2.96	2000
4A	-2.21	1996	-1.75	-0.89	1995
4B	-1.55	1996	-1.09	-0.22	1995
4C	0.77	1996	1.35	1.99	2008
5A	-0.32	1996	0.46	1.52	2008
5B	1.87	1996	2.88	4.35	2008
5C	4.69	1993	6.29	8.59	2008

in percentage terms (0.18%), offset about $38,450 of the loss. Use of electrically pumped groundwater falls by 6,308 acre-ft, or about 4.3% of the total. As occurs under Alternative NA-C, use of both nonelectrically pumped groundwater and surface water is slightly reduced.

7.5 RESULTS FOR REGION 5 (BACA, KIOWA, AND PROWERS COUNTIES, COLORADO)

For this region, no alternatives have deviations from baseline that are significantly larger than those of any other alternative. Alternative 2C shows the largest average deviation from the baseline, exceeding the baseline by 4.0% throughout the 1993-2008 period. Table 18 summarizes how electricity costs deviate from the baseline under the marketing alternatives and supply options.

Under Alternative 2C, the largest percentage deviations from the baseline occur in the year 2000, when net income falls below the baseline by $86,031, or about 0.17% of the total. Most of this loss is accounted for by losses to irrigated agriculture, which amount to $96,659, with a slight offset in dryland cropping making up the difference. As occurs in region 4, dryland cropping dominates irrigated agriculture, accounting for more than two-thirds of net agricultural income for this region. Losses to irrigated agriculture are distributed somewhat more equally across crops in this region than they are in the other regions. Corn grain loses $33,914 in net income, or 1.6% of the total; hay loses $33,543, or 0.4% of the total; and sorghum loses $15,567, or about 0.3% of the total. Gains to dryland wheat account for virtually all of the offset from dryland cropping, but these gains represent only 0.04% of total dryland wheat net income. Use of electrically pumped groundwater falls by 2,716 acre-ft, or about 3.1% of the total. Use of nonelectrically pumped groundwater and surface water fall by a combined 282 acre-ft.

TABLE 18 Summary of Electricity Cost Changes for Region 5 (percent deviations from NA-A, the No Action baseline; all deviations are positive)

Alternative	Minimum (%)	Year of Minimum	Average (%)	Maximum (%)	Year of Maximum
NA-B	0.20	2008	0.26	0.32	1993
NA-C	1.70	2008	2.15	2.55	1993
2A	1.90	2008	2.43	2.65	2000
2B	2.24	2008	3.03	3.36	1995
2C	3.02	2008	4.02	4.50	1994
4A	2.03	2008	2.41	2.57	2000
4B	2.20	2008	2.63	2.82	1996
4C	3.33	2008	3.56	3.69	1997
5A	0.61	1993	1.13	1.61	2008
5B	1.39	1993	2.09	2.85	2008
5C	2.40	1993	3.34	4.45	2008

8 SUMMARY AND CONCLUSIONS

The results of the analysis discussed in this report show that changes in electricity rates arising from Western's various power marketing alternatives result in only small percentage changes in electricity costs in the majority of the area in which Western power is sold. Within this area, farmers adjust to changes in electricity costs in a number of ways, substituting between different inputs and crops within the agricultural production system.

The results discussed in sections 6 and 7 show that even when changes in the cost of electric power are very small (down to a fraction of a percent), the model can respond; responses are in the form of small and subtle changes that result in some substitutions of crops and inputs and some minor changes in net farm income. The model was run on a state-level basis to generally understand the nature of adjustments in the farm economy and on a substate, regional basis to assess the magnitude of impacts in areas where impacts were expected to be the largest.

Across states, the effect of a given increase in power costs on net farm income differed widely. For example, in Arizona, electricity prices increased more than in the other states. However, the resulting loss in net farm income was only about 0.8%. In contrast, in Nevada, the same scenarios resulted in lower price increases, of 2.2-2.5%. The impact on net farm income was greater, however; income was reduced much more than it was in Arizona, with losses of 2.1-2.3%.

Regional differences were pronounced. The aggregate state-level analysis masked some of the changes in power cost because of averaging over the state, and it possibly overestimated the ability of farmers to substitute other methods of production. In many substate regions, the average percentage increase in power cost was substantially higher than it was on a statewide basis. For example, a comparison of Table 12 for the state of Utah and Table 14 for region 1 in Utah shows that under all scenarios, the increase in power costs was greater for region 1 in Utah than for Utah as a whole. The ability to model agricultural production on a state or substate level is important when the variability of the impact and the end-user's ability to adapt to increased prices differ widely. Because of these regional differences, an aggregate cross-section model would have overestimated the production changes and income loss in regions with high potential for substitution and underestimated these effects in areas with a very limited ability to substitute alternative inputs and production practices.

The substitution of dryland production practices for irrigated cropping is pronounced in some states and almost absent in others. The state-level results exhibit a range. Measured in dollar terms, the percentage of reduced irrigated production that is compensated for by dryland production ranges from zero in three states — Arizona, Nevada, and New Mexico — to 6% in Utah, 15% in Colorado, and 19% in Wyoming. Given the fact that productivity per acre is lower for dryland production, the percentage of substitution in cropping area is much greater than the financial offset. Arid states cannot substitute dryland practices; areas with higher rainfall and a substantial dryland cropping system can substitute land, although at a cost in productivity and profit.

TABLE 19 Net Farm Income Impacts of an Electricity Price Increase (% reduction in income for 1% increase in electricity price)

Arizona	0.172
Colorado	0.574
Nevada	0.935
New Mexico	0.143
Utah	0.110
Wyoming	0.076

The ability to substitute among alternative sources of water also varies across the states. In most states, the ability to substitute surface water or an alternative pumping technology was very limited. Only in Arizona was substitution among water sources noticeable, with use of surface water and diesel-pumped groundwater offsetting 8% of the reduction in use of groundwater pumped by electricity. This low level of fuel substitution probably reflects the short-run costs of changing pumping equipment. In the longer run, the substitution of diesel fuel or natural gas for electricity to pump groundwater would probably occur more often.

A convenient measure of the effect of an electricity price change on the aggregate regional farm economy is to calculate the percentage reduction in net farm income caused by a 1% increase in electricity cost. A value of 0.5 would mean that for every 1% increase in electricity price, regional net farm income would be reduced by 0.5%. The results for the six states in the study are shown in Table 19.

The summary statistics in Table 19 show that the effects of electricity price changes on net farm income vary widely among states. In some states, much of the effect of the price increases can be adjusted for by substitution of crops or inputs; in other states, the potential for substitution and adjustment is limited, and the crops that are irrigated by electric pumps are financially more important to the regional farm economy. Wyoming, with its well-established, dryland grain-growing economy and its lower-valued, irrigated crop production, has the ability to offset most of the impacts from higher electric power costs. At the other extreme, Nevada, with its arid climate and complete absence of dryland cropping, has limited opportunities for substituting other technologies. In addition, Nevada, unlike Arizona, has no sources of surface water to substitute for the groundwater. Other states range between these two extremes of an almost 1/1 percentage effect in Nevada to a ratio of less than 0.1/1 in Wyoming.

The results of these analyses indicate that at the state level, the effect of changes in Western's power marketing programs is not large. However, this result occurs because the percentage increases in power costs are not large when they are averaged on a statewide basis and when they occur over a long period. The difference in the impact on net income is largely a result of differences in the ability of farmers to substitute crops and inputs to minimize the reduction in income. In contrast, at the substate level, effects can be larger. Areas within the six-state region that are more dependent on irrigated agriculture are more likely to be adversely affected by changes in Western's rates. In these areas, the power increases are greater, and the effects on net farm income are consequently more severe.

Some regions and farming operations could be adversely affected by changes in Western's power marketing programs. Decision makers should consider these potential adverse affects when evaluating future marketing programs.

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APPENDIX A:

ELASTICITY OF SUBSTITUTION

APPENDIX A: ELASTICITY OF SUBSTITUTION

A.1 INTRODUCTION

The elasticity of substitution measures the percentage change in the factor ratio divided by the percentage change in the marginal rate of technical substitution. To illustrate this relationship, consider the following production function, where output is assumed to be a function of two inputs, x_1 and x_2:

$$y = f\,(\,x_1,\,x_2\,)\quad .$$

Totally differentiating this equation yields the following:

$$dy = \frac{\partial f}{\partial x_1}\,dx_1 + \frac{\partial f}{\partial x_2}\,dx_2\quad .$$

The marginal rate of substitution between two inputs is defined along an isoquant, which assumes that output is held constant. Setting $dy = 0$ and rearranging terms yield the marginal rate of technical substitution between inputs x_1 and x_2:

$$\frac{dx_2}{dx_1} = -\,\frac{\partial f/\partial x_1}{\partial f/\partial x_2} = -\,\frac{MP_{x_1}}{MP_{x_2}} = MRTS_{1,2}\quad ,$$

where MP_{xj} is the marginal product of x_j (j = 1, 2), and $MRTS_{1,2}$ is the marginal rate of technical substitution between inputs x_1 and x_2. The elasticity of substitution is then defined as:

$$\sigma = \frac{\dfrac{\Delta\,(x_2/x_1)}{(x_2/x_1)}}{\dfrac{\Delta\,MRTS_{1,2}}{MRTS_{1,2}}}\quad .$$

The marginal rate of technical substitution measures the slope of an isoquant at a particular input combination; the elasticity of substitution measures the curvature of an isoquant. A constant elasticity of substitution (CES) production function assumes that the elasticity of substitution is constant. For the two factors of production, x_1 and x_2, that are used to produce output y, the CES production function takes the following form:

$$y = A\,[\beta_1\,x_1^{\eta} + \beta_2\,x_2^{\eta}]^{\frac{1}{\eta}}\quad ,$$

where $\eta = (1 - \sigma)/\sigma$ when σ equals the elasticity of substitution as defined above. The CES specification has the advantage of being general enough to admit many types of production functions, depending on the value of the elasticity of substitution.

The analysis specifies that production is characterized by nested CES production functions. In other words, each "input" in the production function is assumed to be generated by its own CES production function. The CES production functions are separated for each cropping practice, one for integrated production and the other for dryland production.

For dryland cropping, production is assumed to be a function of acreage, capital, chemistry, and other inputs. These inputs are grouped into two nests. The first nest is the acreage input. The second is for capital, chemistry, and other inputs. The nests for dryland production are illustrated in Figure A.1.

The nested CES production function for dryland crop i is given by the following:

$$y_i = C_i \left\{ \beta_{i,land}\, x_{i,land}^{\eta_t} + \beta_{i,var} \left[A_{i,var} \sum_{j=1}^{J} (\beta_{ij}\, x_{ij}^{\eta_{iv}})^{\gamma_{iv}}\right]^{\eta_t} \right\}^{\gamma_t} ,$$

where:

y_i = output of crop i,

C_i = top nest scale parameter for crop i,

$\beta_{i,land}$ = top nest share parameter for land input for crop i,

$\beta_{i,var}$ = top nest share parameter for variable inputs for crop i,

$A_{i,var}$ = sub nest scale parameter for variable inputs and crop i,

$x_{i,land}$ = amount of acreage allocated to crop i,

x_{ij} = amount of input j allocated to crop i,

η_t = $1/(1 - s_t)$ with s_t = top-level substitution elasticity,

η_{iv} = $1/(1 - s_{iv})$ with s_{iv} = variable input substitution elasticity,

γ_{iv} = $1/\eta_{iv}$, and

γ_t = $1/\eta_t$.

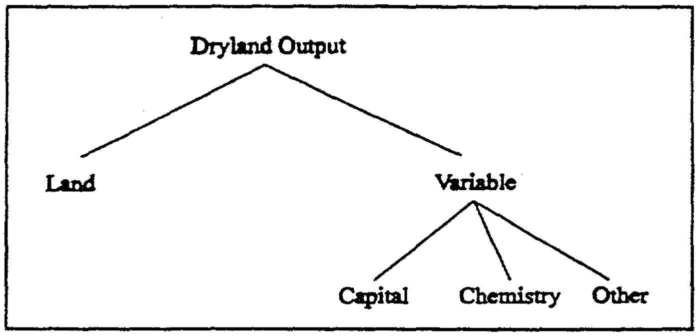

FIGURE A.1 Nests for Dryland Production

For irrigated production, there are three nests. The first and second nests are similar to those specified for dryland production, namely, land and variable inputs. For irrigated production, a third nest is introduced for the water input. For this nest, there are three possible water inputs (surface water, electrically pumped groundwater, and groundwater pumped by using other energy sources). The nests for irrigated production are illustrated in Figure A.2. Irrigated production for crop i is given by the following equation:

$$y_i = C_i \left\{ \beta_{i,land}\, x_{i,land}^{\eta_t} + \beta_{i,var}\, [A_{i,var} \sum_{j=1}^{J} (\beta_{ij}\, x_{ij}^{\eta_{iv}})^{\gamma_{iv}}]^{\eta_t} + \beta_{i,water} \right.$$
$$\left. [A_{i,water} \sum_{r=1}^{R} (\beta_{ij}\, x_{ij}^{\eta_{iv}})^{\gamma_{iv}}]^{\eta_t} \right\}^{\gamma_t} ,$$

where:

$\beta_{i,water}$ = top nest share parameter for water inputs for crop i,

$A_{i,water}$ = sub nest scale parameter for water inputs for crop i,

x_{ir} = amount of water input r applied to crop i,

η_{ir} = $1/(1 - s_{ir})$ with s_{ir} = water input substitution elasticity, and

γ_{ir} = $1 / \eta_{ir}$.

A.2 POSITIVE PROGRAMMING CALIBRATED MODELS

A.2.1 First-Stage Constrained Linear Model

The first stage of the positive mathematical programming (PMP) approach is to solve the following linear programming problem:

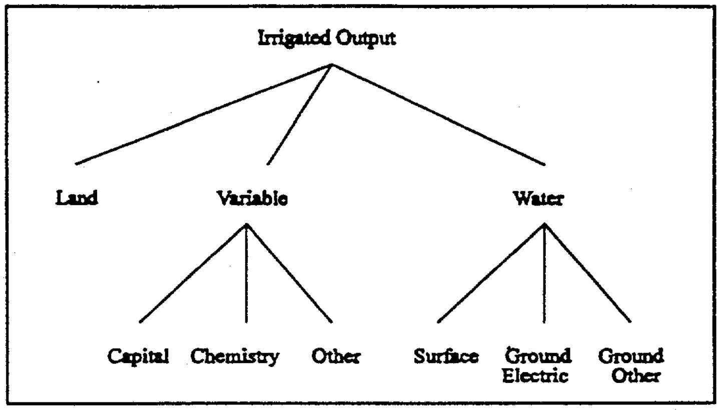

FIGURE A.2 Nests for Irrigated Production

$$\max \Pi = \sum_{i=1}^{I} p_i\, y_i - c_i\, \hat{x}_i \quad ,$$

subject to the following constraints:

- Resource constraints (for all crops):

$$\sum_{i=1}^{I} \sum_{j=1}^{J} \frac{x_{ij}}{x_{i,land}}\, \hat{x}_i \leq \sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij}$$

- Water constraints (for irrigated crops):

$$\sum_{i=1}^{I} \sum_{r=1}^{R} \frac{x_{ir}}{x_{i,land}}\, \hat{x}_i \leq \sum_{i=1}^{I} \sum_{r=1}^{R} x_{ir}$$

- PMP calibration constraints (for all crops):

$$\hat{x}_i \leq x_{i,land} + \varepsilon \quad \text{for net profits} > 0$$

$$\hat{x}_i \geq x_{i,land} - \varepsilon \quad \text{for net profits} < 0$$

For the objective function and constraints, the following definitions apply:

p_i = price of crop i,

y_i = output of crop i,

c_i = linearized cost per acre of land,

$\hat{x}_i$ = acreage allocated to crop i, and

ε = perturbation for land input.

A.2.2 Second-Stage Nonlinear Programming Problem

The second-stage nonlinear programming problem is the following (for irrigated production:

$$\max \Pi = \sum_{i=1}^{I} p_i \, C_i \Big\{ \beta_{i,land} \, x_{i,land}^{\eta_t} + \beta_{i,var} \, [A_{i,var} \sum_{j=1}^{J} (\beta_{ij} \, x_{ij}^{\eta_{iv}})^{\gamma_{iv}}]^{\eta_t}$$
$$+ \beta_{i,water} \, [A_{i,water} \sum_{r=1}^{R} (\beta_{ir} \, x_{ir}^{\eta_{ir}})^{\gamma_{ir}}]^{\eta_t} \Big\}^{\gamma_t}$$
$$- \sum_{i=1}^{I} \sum_{j_1=1}^{J_1} [\alpha_i \, x_{ij_1} + 0.5 \, \gamma_i \, x_{ij_1}^2] - \sum_{i=1}^{I} \sum_{j_2=1}^{J_2} c_{ij_2} \, x_{ij_2}$$

subject to:

$$\sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij} \le \sum_{i=1}^{I} \hat{x}_i \, .$$

For this optimization problem, the vector of variable inputs has been partitioned into two sets. The first, J_1, represents the land input (acreage) allocated to each crop. The second, J_2, represents the variable inputs (capital, chemistry, other) for both cropping practices; for irrigated production, it includes surface water and groundwater. The parameters used to convert the linear cost function used in the first stage to a nonlinear cost function, namely α_i and γ_i, have been calculated from the results of the first stage by using methods described in Section 4.3.

APPENDIX B:

ACREAGE AND OUTPUT DATA FOR VARIOUS CROPS FOR FIVE YEARS, BY STATE AND REGION

TABLE B.1 Acreage and Output Baseline for Arizona Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	15,000	14,800	15,400	17,800	26,232
Dryland acreage	0	0	0	0	0
Irrigated acreage	15,000	14,800	15,400	17,800	26,232
Surface water acreage	7,553	7,452	7,754	8,963	13,208
Groundwater acreage	7,447	7,348	7,646	8,837	13,023
Total output (bushels)	1,575,000	1,554,000	1,617,000	1,869,000	2,754,309
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	1,575,000	1,554,000	1,617,000	1,869,000	2,754,309
Surface water output (bushels)	793,063	782,489	814,211	941,101	1,386,883
Groundwater output (bushels)	781,937	771,511	802,789	927,899	1,367,426
Corn grain					
Total acreage	7,000	7,073	7,261	7,428	7,773
Dryland acreage	0	0	0	0	0
Irrigated acreage	7,000	7,073	7,261	7,428	7,773
Surface water acreage	2,162	2,184	2,242	2,294	2,400
Groundwater acreage	4,838	4,889	5,019	5,134	5,373
Total output (bushels)	1,120,000	1,131,701	1,161,791	1,188,537	1,243,743
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	1,120,000	1,131,701	1,161,791	1,188,537	1,243,743
Surface water output (bushels)	345,855	349,468	358,760	367,019	384,067
Groundwater output (bushels)	774,145	782,233	803,031	821,518	859,676
Corn Silage					
Total acreage	8,000	8,093	8,192	8,709	10,355
Dryland acreage	0	0	0	0	0
Irrigated acreage	8,000	8,093	8,192	8,709	10,355
Surface water acreage	2,470	2,499	2,530	2,689	3,198
Groundwater acreage	5,530	5,594	5,662	6,020	7,158
Total output (tons)	216,000	218,511	221,183	235,144	279,590
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	216,000	218,511	221,183	235,144	279,590
Surface water output (tons)	66,701	67,476	68,301	72,612	86,337
Groundwater output (tons)	149,299	151,035	152,882	162,532	193,253

TABLE B.1 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Cotton					
Total acreage	472,000	521,896	507,008	528,737	552,557
Dryland acreage	0	0	0	0	0
Irrigated acreage	472,000	521,896	507,008	528,737	552,557
Surface water acreage	237,667	262,791	255,295	266,236	278,230
Groundwater acreage	234,333	259,105	251,713	262,501	274,327
Total output (bales)	1,005,000	1,111,240	1,079,540	1,125,806	1,176,526
Dryland output (bales)	0	0	0	0	0
Irrigated output (bales)	1,005,000	1,111,240	1,079,540	1,125,806	1,176,526
Surface water output (bales)	506,050	559,545	543,583	566,879	592,418
Groundwater output (bales)	498,950	551,695	535,957	558,926	584,107
Hay					
Total acreage	195,000	197,541	198,176	205,163	211,271
Dryland acreage	0	0	0	0	0
Irrigated acreage	195,000	197,541	198,176	205,163	211,271
Surface water acreage	98,189	99,468	99,788	103,306	106,382
Groundwater acreage	96,811	98,073	98,388	101,857	104,889
Total output (tons)	1,421,000	1,439,515	1,444,143	1,495,059	1,539,571
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	1,421,000	1,439,515	1,444,143	1,495,059	1,539,571
Surface water output (tons)	715,519	724,842	727,172	752,810	775,223
Groundwater output (tons)	705,481	714,673	716,971	742,249	764,348
Sorghum					
Total acreage	1,000	1,011	1,055	1,132	1,152
Dryland acreage	0	0	0	0	0
Irrigated acreage	1,000	1,011	1,055	1,132	1,152
Surface water acreage	504	509	531	570	580
Groundwater acreage	496	502	524	562	572
Total output (bushels)	60,714	61,381	64,050	68,720	69,933
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	60,714	61,381	64,050	68,720	69,933
Surface water output (bushels)	30,571	30,907	32,251	34,603	35,214
Groundwater output (bushels)	30,143	30,474	31,799	34,117	34,720

TABLE B.1 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Wheat					
Total acreage	98,000	90,505	86,404	96,444	99,690
Dryland acreage	0	0	0	0	0
Irrigated acreage	98,000	90,505	86,404	96,444	99,690
Surface water acreage	49,346	45,572	43,507	48,563	50,197
Groundwater acreage	48,654	44,933	42,897	47,882	49,493
Total output (bushels)	9,266,000	8,557,345	8,169,590	9,118,921	9,425,760
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	9,266,000	8,557,345	8,169,590	9,118,921	9,425,760
Surface water output (bushels)	4,665,728	4,308,897	4,113,650	4,591,668	4,746,172
Groundwater output (bushels)	4,600,272	4,248,448	4,055,940	4,527,252	4,679,588

TABLE B.2 Acreage and Output Baseline for Colorado Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	150,000	148,000	154,000	178,000	196,736
Dryland acreage	24,000	23,680	24,640	28,480	31,478
Irrigated acreage	126,000	124,320	129,360	149,520	165,259
Surface water acreage	69,223	68,300	71,069	82,145	90,792
Groundwater acreage	56,777	56,020	58,291	67,375	74,467
Total output (bushels)	12,000,000	11,840,000	12,320,000	14,240,000	15,738,911
Dryland output (bushels)	650,000	641,333	667,333	771,333	852,524
Irrigated output (bushels)	11,350,000	11,198,667	11,652,667	13,468,667	14,886,386
Surface water output (bushels)	6,235,587	6,152,446	6,401,870	7,399,564	8,178,446
Groundwater output (bushels)	5,114,413	5,046,220	5,250,797	6,069,103	6,707,940
Corn grain					
Total acreage	830,000	838,672	860,970	880,791	922,016
Dryland acreage	26,000	26,272	26,970	27,591	28,882
Irrigated acreage	804,000	812,400	834,000	853,200	893,134
Surface water acreage	248,274	250,868	257,538	263,467	275,799
Groundwater acreage	555,726	561,532	576,462	589,733	617,335
Total output (bushels)	128,650,000	129,994,104	133,450,373	136,522,612	142,912,529
Dryland output (bushels)	1,500,000	1,515,672	1,555,970	1,591,791	1,666,295
Irrigated output (bushels)	127,150,000	128,478,433	131,894,403	134,930,821	141,246,235
Surface water output (bushels)	39,263,809	39,674,028	40,728,876	41,666,520	43,616,714
Groundwater output (bushels)	87,886,191	88,804,405	91,165,527	93,264,301	97,629,521
Corn silage					
Total acreage	117,000	118,360	119,808	127,370	137,479
Dryland acreage	3,665	3,708	3,753	3,990	4,307
Irrigated acreage	113,335	114,653	116,055	123,380	133,172
Surface water acreage	34,998	35,405	35,838	38,100	41,123
Groundwater acreage	78,337	79,248	80,217	85,280	92,049
Total output (tons)	2,633,000	2,663,613	2,696,185	2,866,360	3,093,854
Dryland output (tons)	30,700	31,057	31,436	33,420	36,073
Irrigated output (tons)	2,602,300	2,632,557	2,664,749	2,832,940	3,057,781
Surface water output (tons)	803,588	812,931	822,872	874,809	944,240
Groundwater output (tons)	1,798,712	1,819,625	1,841,877	1,958,130	2,113,541

TABLE B.2 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	1,550,000	1,570,195	1,575,244	1,630,782	1,679,835
Dryland acreage	350,000	354,560	355,700	368,241	379,318
Irrigated acreage	1,200,000	1,215,635	1,219,544	1,262,541	1,300,517
Surface water acreage	659,269	667,859	670,006	693,628	714,492
Groundwater acreage	540,731	547,776	549,538	568,912	586,025
Total output (tons)	3,805,000	3,854,577	3,866,971	4,003,306	4,123,724
Dryland output (tons)	440,000	445,733	447,166	462,932	476,856
Irrigated output (tons)	3,365,000	3,408,844	3,419,805	3,540,375	3,646,867
Surface water output (tons)	1,848,701	1,872,788	1,878,810	1,945,050	2,003,556
Groundwater output (tons)	1,516,299	1,536,056	1,540,995	1,595,325	1,643,311
Sorghum					
Total acreage	220,000	222,418	232,088	249,011	253,406
Dryland acreage	156,000	157,714	164,571	176,571	179,688
Irrigated acreage	64,000	64,703	67,516	72,440	73,718
Surface water acreage	35,161	35,547	37,093	39,798	40,500
Groundwater acreage	28,839	29,156	30,424	32,642	33,218
Total output (bushels)	10,340,000	10,453,626	10,908,132	11,703,516	11,910,101
Dryland output (bushels)	5,490,000	5,550,330	5,791,648	6,213,956	6,323,642
Irrigated output (bushels)	4,850,000	4,903,297	5,116,484	5,489,560	5,586,459
Surface water output (bushels)	2,664,546	2,693,827	2,810,950	3,015,915	3,069,150
Groundwater output (bushels)	2,185,454	2,209,470	2,305,534	2,473,646	2,517,309
Wheat					
Total acreage	2,590,000	2,391,919	2,283,535	2,548,889	2,548,700
Dryland acreage	2,408,500	2,224,300	2,123,512	2,370,270	2,370,094
Irrigated acreage	181,500	167,619	160,024	178,619	178,606
Surface water acreage	99,714	92,088	87,916	98,132	98,124
Groundwater acreage	81,786	75,531	72,108	80,487	80,481
Total output (bushels)	86,950,000	80,300,144	76,661,544	85,569,841	85,563,488
Dryland output (bushels)	75,910,000	70,104,473	66,927,864	74,705,079	74,699,533
Irrigated output (bushels)	11,040,000	10,195,671	9,733,680	10,864,762	10,863,955
Surface water output (bushels)	6,065,276	5,601,410	5,347,596	5,969,002	5,968,559
Groundwater output (bushels)	4,974,724	4,594,261	4,386,084	4,895,760	4,895,396

TABLE B.3 Acreage and Output Baseline for Nevada Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	9,000	8,880	9,240	10,680	11,801
Dryland acreage	0	0	0	0	0
Irrigated acreage	9,000	8,880	9,240	10,680	11,801
Surface water acreage	4,303	4,245	4,417	5,106	5,642
Groundwater acreage	4,697	4,635	4,823	5,574	6,160
Total output (bushels)	675,000	666,000	693,000	801,000	885,097
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	675,000	666,000	693,000	801,000	885,097
Surface water output (bushels)	322,694	318,392	331,299	382,930	423,134
Groundwater output (bushels)	352,306	347,608	361,701	418,070	461,963
Hay					
Total acreage	490,000	496,384	497,980	515,537	531,045
Dryland acreage	0	0	0	0	0
Irrigated acreage	490,000	496,384	497,980	515,537	531,045
Surface water acreage	234,252	237,304	238,067	246,461	253,874
Groundwater acreage	255,748	259,080	259,913	269,077	277,170
Total output (tons)	1,359,000	1,376,707	1,381,134	1,429,827	1,472,836
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	1,359,000	1,376,707	1,381,134	1,429,827	1,472,836
Surface water output (tons)	649,691	658,156	660,272	683,551	704,112
Groundwater output (tons)	709,309	718,551	720,861	746,276	768,724
Wheat					
Total acreage	14,000	12,929	12,343	13,778	13,777
Dryland acreage	0	0	0	0	0
Irrigated acreage	14,000	12,929	12,343	13,778	13,777
Surface water acreage	6,693	6,181	5,901	6,587	6,586
Groundwater acreage	7,307	6,748	6,442	7,191	7,191
Total output (bushels)	980,000	905,051	864,040	964,444	964,373
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	980,000	905,051	864,040	964,444	964,373
Surface water output (bushels)	468,504	432,673	413,068	461,068	461,033
Groundwater output (bushels)	511,496	472,377	450,972	503,377	503,339

TABLE B.4 Acreage and Output Baseline for New Mexico Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	8,000	7,893	8,213	9,493	10,490
Dryland acreage	0	0	0	0	0
Irrigated acreage	8,000	7,893	8,213	9,493	10,490
Surface water acreage	2,470	2,437	2,536	2,932	3,239
Groundwater acreage	5,530	5,456	5,677	6,562	7,251
Total output (bushels)	600,000	592,000	616,000	712,000	786,753
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	600,000	592,000	616,000	712,000	786,753
Surface water output (bushels)	185,279	182,809	190,220	219,865	242,949
Groundwater output (bushels)	414,721	409,191	425,780	492,135	543,804
Corn grain					
Total acreage	55,000	55,575	57,052	58,366	61,097
Dryland acreage	0	0	0	0	0
Irrigated acreage	55,000	55,575	57,052	58,366	61,097
Surface water acreage	16,984	17,161	17,618	18,023	18,867
Groundwater acreage	38,016	38,413	39,435	40,342	42,231
Total output (bushels)	7,975,000	8,058,321	8,272,575	8,463,022	8,859,133
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	7,975,000	8,058,321	8,272,575	8,463,022	8,859,133
Surface water output (bushels)	2,462,673	2,488,402	2,554,564	2,613,374	2,735,692
Groundwater output (bushels)	5,512,327	5,569,918	5,718,011	5,849,648	6,123,440
Corn silage					
Total acreage	27,000	27,314	27,648	29,393	31,726
Dryland acreage	0	0	0	0	0
Irrigated acreage	27,000	27,314	27,648	29,393	31,726
Surface water acreage	8,338	8,435	8,538	9,077	9,797
Groundwater acreage	18,662	18,879	19,110	20,316	21,929
Total output (tons)	513,000	518,964	525,311	558,467	602,790
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	513,000	518,964	525,311	558,467	602,790
Surface water output (tons)	158,414	160,256	162,215	172,454	186,141
Groundwater output (tons)	354,586	358,709	363,095	386,013	416,649

TABLE B.4 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Cotton					
Total acreage	81,300	89,894	87,330	91,073	95,205
Dryland acreage	0	0	0	0	0
Irrigated acreage	81,300	89,894	87,330	91,073	95,205
Surface water acreage	25,105	27,759	26,967	28,123	29,399
Groundwater acreage	56,195	62,135	60,363	62,949	65,806
Total output (bales)	119,500	132,133	128,363	133,864	139,939
Dryland output (bales)	0	0	0	0	0
Irrigated output (bales)	119,500	132,133	128,363	133,864	139,939
Surface water output (bales)	36,901	40,802	39,638	41,337	43,213
Groundwater output (bales)	82,599	91,330	88,725	92,527	96,726
Hay					
Total acreage	320,000	324,169	325,212	336,678	346,805
Dryland acreage	0	0	0	0	0
Irrigated acreage	320,000	324,169	325,212	336,678	346,805
Surface water acreage	98,816	100,103	100,425	103,966	107,093
Groundwater acreage	221,184	224,066	224,787	232,712	239,712
Total output (tons)	1,376,000	1,393,928	1,398,410	1,447,713	1,491,260
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	1,376,000	1,393,928	1,398,410	1,447,713	1,491,260
Surface water output (tons)	424,908	430,444	431,828	447,053	460,500
Groundwater output (tons)	951,092	963,484	966,583	1,000,661	1,030,760
Sorghum					
Total acreage	42,100	42,563	44,413	47,652	52,012
Dryland acreage	6,652	6,725	7,017	7,529	8,218
Irrigated acreage	35,448	35,838	37,396	40,123	43,794
Surface water acreage	10,946	11,067	11,548	12,390	13,524
Groundwater acreage	24,502	24,771	25,848	27,733	30,270
Total output (bushels)	2,736,500	2,766,571	2,886,857	3,097,357	3,380,773
Dryland output (bushels)	143,814	145,394	151,715	162,778	177,673
Irrigated output (bushels)	2,592,686	2,621,177	2,735,142	2,934,579	3,203,101
Surface water output (bushels)	800,619	809,417	844,609	906,195	989,115
Groundwater output (bushels)	1,792,067	1,811,760	1,890,532	2,028,384	2,213,986

TABLE B.4 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Wheat					
Total acreage	325,000	300,144	286,544	319,841	319,818
Dryland acreage	219,000	202,251	193,087	215,524	215,508
Irrigated acreage	106,000	97,893	93,457	104,317	104,310
Surface water acreage	32,733	30,229	28,860	32,213	32,211
Groundwater acreage	73,267	67,664	64,598	72,104	72,099
Total output (bushels)	8,125,000	7,503,608	7,163,600	7,996,032	7,995,438
Dryland output (bushels)	3,466,000	3,200,924	3,055,882	3,410,984	3,410,731
Irrigated output (bushels)	4,659,000	4,302,684	4,107,719	4,585,048	4,584,707
Surface water output (bushels)	1,438,695	1,328,665	1,268,460	1,415,859	1,415,754
Groundwater output (bushels)	3,220,305	2,974,019	2,839,259	3,169,189	3,168,954

TABLE B.5 Acreage and Output Baseline for Utah Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	105,000	103,600	107,800	124,600	137,682
Dryland acreage	13,000	12,827	13,347	15,427	17,046
Irrigated acreage	92,000	90,773	94,453	109,173	120,635
Surface water acreage	66,527	65,640	68,301	78,945	87,233
Groundwater acreage	25,473	25,134	26,153	30,228	33,402
Total output (bushels)	8,505,000	8,391,600	8,731,800	10,092,600	11,152,224
Dryland output (bushels)	409,000	403,547	419,907	485,347	536,303
Irrigated output (bushels)	8,096,000	7,988,053	8,311,893	9,607,253	10,615,921
Surface water output (bushels)	5,854,351	5,776,293	6,010,467	6,947,163	7,676,547
Groundwater output (bushels)	2,241,649	2,211,760	2,301,426	2,660,090	2,939,374
Corn grain					
Total acreage	19,000	19,199	19,709	20,163	21,106
Dryland acreage	0	0	0	0	0
Irrigated acreage	19,000	19,199	19,709	20,163	21,106
Surface water acreage	5,867	5,928	6,086	6,226	6,518
Groundwater acreage	13,133	13,270	13,623	13,936	14,589
Total output (bushels)	2,660,000	2,687,791	2,759,254	2,822,776	2,954,896
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	2,660,000	2,687,791	2,759,254	2,822,776	2,954,896
Surface water output (bushels)	821,406	829,988	852,055	871,671	912,469
Groundwater output (bushels)	1,838,594	1,857,804	1,907,199	1,951,105	2,042,426
Corn silage					
Total acreage	45,000	45,523	46,080	48,988	52,876
Dryland acreage	0	0	0	0	0
Irrigated acreage	45,000	45,523	46,080	48,988	52,876
Surface water acreage	13,896	14,058	14,229	15,128	16,328
Groundwater acreage	31,104	31,466	31,850	33,861	36,548
Total output (tons)	923,000	933,731	945,150	1,004,805	1,084,553
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	923,000	933,731	945,150	1,004,805	1,084,553
Surface water output (tons)	285,022	288,335	291,861	310,283	334,909
Groundwater output (tons)	637,978	645,396	653,288	694,522	749,644

TABLE B.5 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	625,000	633,143	635,179	657,573	677,353
Dryland acreage	0	0	0	0	0
Irrigated acreage	625,000	633,143	635,179	657,573	677,353
Surface water acreage	451,948	457,836	459,309	475,502	489,805
Groundwater acreage	173,052	175,307	175,871	182,071	187,548
Total output (tons)	2,123,000	2,150,661	2,157,577	2,233,645	2,300,832
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	2,123,000	2,150,661	2,157,577	2,233,645	2,300,832
Surface water output (tons)	1,535,176	1,555,179	1,560,179	1,615,185	1,663,769
Groundwater output (tons)	587,824	595,483	597,397	618,460	637,062
Wheat					
Total acreage	176,000	162,540	155,175	173,206	173,193
Dryland acreage	120,000	110,823	105,801	118,095	118,086
Irrigated acreage	56,000	51,717	49,374	55,111	55,107
Surface water acreage	40,495	37,398	35,703	39,852	39,849
Groundwater acreage	15,505	14,320	13,671	15,259	15,258
Total output (bushels)	7,170,000	6,621,645	6,321,602	7,056,190	7,055,667
Dryland output (bushels)	2,675,000	2,470,418	2,358,478	2,632,540	2,632,344
Irrigated output (bushels)	4,495,000	4,151,227	3,963,124	4,423,651	4,423,322
Surface water output (bushels)	3,250,408	3,001,820	2,865,800	3,198,815	3,198,577
Groundwater output (bushels)	1,244,592	1,149,406	1,097,324	1,224,836	1,224,745

TABLE B.6 Acreage and Output Baseline for Wyoming Crops

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	125,000	123,333	128,333	148,333	163,947
Dryland acreage	15,500	15,293	15,913	18,393	20,329
Irrigated acreage	109,500	108,040	112,420	129,940	143,618
Surface water acreage	86,410	85,258	88,715	102,540	113,334
Groundwater acreage	23,090	22,782	23,705	27,400	30,284
Total output (bushels)	9,250,000	9,126,667	9,496,667	10,976,667	12,132,077
Dryland output (bushels)	513,000	506,160	526,680	608,760	672,838
Irrigated output (bushels)	8,737,000	8,620,507	8,969,987	10,367,907	11,459,239
Surface water output (bushels)	6,894,677	6,802,748	7,078,535	8,181,683	9,042,892
Groundwater output (bushels)	1,842,323	1,817,759	1,891,452	2,186,224	2,416,347
Corn grain					
Total acreage	50,000	50,522	51,866	53,060	55,543
Dryland acreage		0	0	0	0
Irrigated acreage	50,000	50,522	51,86	53,060	55,543
Surface water acreage	15,440	15,601	16,016	16,385	17,152
Groundwater acreage	34,560	34,921	35,850	36,675	38,391
Total output (bushels)	6,000,000	6,062,687	6,223,881	6,367,164	6,665,178
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	6,000,000	6,062,687	6,223,881	6,367,164	6,665,178
Surface water output (bushels)	1,852,795	1,872,152	1,921,929	1,966,175	2,058,201
Groundwater output (bushels)	4,147,205	4,190,534	4,301,952	4,400,989	4,606,977
Corn silage					
Total acreage	39,000	39,453	39,936	42,457	45,826
Dryland acreage	0	0	0	0	0
Irrigated acreage	39,000	39,453	39,936	42,457	45,826
Surface water acreage	12,043	12,183	12,332	13,111	14,151
Groundwater acreage	26,957	27,270	27,604	29,346	31,675
Total output (tons)	741,000	749,615	758,782	806,674	870,697
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	741,000	749,615	758,782	806,674	870,697
Surface water output (tons)	228,820	231,481	234,311	249,100	268,871
Groundwater output (tons)	512,180	518,135	524,471	557,574	601,827

TABLE B.6 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	1,160,000	1,175,114	1,178,893	1,220,456	1,257,167
Dryland acreage	273,000	276,557	277,446	287,228	295,868
Irrigated acreage	887,000	898,557	901,446	933,228	961,299
Surface water acreage	699,963	709,083	711,363	736,443	758,595
Groundwater acreage	187,037	189,474	190,083	196,785	202,704
Total output (tons)	2,076,000	2,103,049	2,109,811	2,184,195	2,249,895
Dryland output (tons)	251,000	254,270	255,088	264,081	272,025
Irrigated output (tons)	1,825,000	1,848,779	1,854,723	1,920,114	1,977,870
Surface water output (tons)	1,440,172	1,458,937	1,463,628	1,515,230	1,560,808
Groundwater output (tons)	384,828	389,842	391,095	404,884	417,063
Wheat					
Total acreage	211,000	194,863	186,033	207,651	207,635
Dryland acreage	198,900	183,688	175,365	195,743	195,728
Irrigated acreage	12,100	11,175	10,668	11,908	11,907
Surface water acreage	9,549	8,818	8,419	9,397	9,396
Groundwater acreage	2,551	2,356	2,250	2,511	2,511
Total output (bushels)	6,113,000	5,645,483	5,389,672	6,015,968	6,015,522
Dryland output (bushels)	5,431,000	5,015,642	4,788,371	5,344,794	5,344,397
Irrigated output (bushels)	682,000	629,841	601,302	671,175	671,125
Surface water output (bushels)	538,190	497,030	474,508	529,648	529,608
Groundwater output (bushels)	143,810	132,811	126,793	141,527	141,516

TABLE B.7 Acreage and Output Baseline for Region 1 (Wayne and Piute Counties, Utah)

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	1,200	1,184	1,232	1,424	1,574
Dryland acreage	0	0	0	0	0
Irrigated acreage	1,200	1,184	1,232	1,424	1,574
Surface water acreage	604	596	620	717	793
Groundwater acreage	596	588	612	707	781
Total output (bushels)	106,000	104,587	108,827	125,787	139,027
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	106,000	104,587	108,827	125,787	139,027
Surface water output (bushels)	53,374	52,663	54,798	63,338	70,005
Groundwater output (bushels)	52,626	51,924	54,029	62,449	69,022
Hay					
Total acreage	22,500	22,793	22,866	23,673	24,377
Dryland acreage	0	0	0	0	0
Irrigated acreage	22,500	22,793	22,866	23,673	24,377
Surface water acreage	11,329	11,477	11,514	11,920	12,275
Groundwater acreage	11,171	11,316	11,352	11,753	12,103
Total output (tons)	71,100	72,026	72,258	74,806	77,033
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	71,100	72,026	72,258	74,806	77,033
Surface water output (tons)	35,801	36,268	36,384	37,667	38,788
Groundwater output (tons)	35,299	35,759	35,874	37,139	38,244

TABLE B.8 Acreage and Output Baseline for Region 2 (Costilla and Saguache Counties, Colorado)

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	28,000	27,627	28,747	33,227	36,724
Dryland acreage	0	0	0	0	0
Irrigated acreage	28,000	27,627	28,747	33,227	36,724
Surface water acreage	15,383	15,178	15,793	18,254	20,176
Groundwater acreage	12,617	12,449	12,954	14,972	16,548
Total output (bushels)	2,580,000	2,545,600	2,648,800	3,061,600	3,383,866
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	2,580,000	2,545,600	2,648,800	3,061,600	3,383,866
Surface water output (bushels)	1,417,429	1,398,530	1,455,227	1,682,015	1,859,065
Groundwater output (bushels)	1,162,571	1,147,070	1,193,573	1,379,585	1,524,801
Hay					
Total acreage	77,000	78,003	78,254	81,013	83,425
Dryland acreage	3,000	3,039	3,049	3,156	3,250
Irrigated acreage	74,000	74,964	75,205	77,857	80,175
Surface water acreage	40,655	41,185	41,317	42,774	44,047
Groundwater acreage	33,345	33,780	33,888	35,083	36,127
Total output (tons)	179,800	182,143	182,728	189,171	194,803
Dryland output (tons)	4,800	4,863	4,878	5,050	5,201
Irrigated output (tons)	175,000	177,280	177,850	184,121	189,602
Surface water output (tons)	96,143	97,396	97,709	101,154	104,166
Groundwater output (tons)	78,857	79,884	80,141	82,966	85,437
Wheat					
Total acreage	12,200	11,267	10,756	12,006	12,410
Dryland acreage	0	0	0	0	0
Irrigated acreage	12,200	11,267	10,756	12,006	12,410
Surface water acreage	6,703	6,190	5,909	6,596	6,818
Groundwater acreage	5,497	5,077	4,847	5,410	5,592
Total output (bushels)	1,037,000	957,691	914,296	1,020,540	1,054,879
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	1,037,000	957,691	914,296	1,020,540	1,054,879
Surface water output (bushels)	569,718	526,147	502,306	560,675	579,541
Groundwater output (bushels)	467,282	431,544	411,990	459,864	475,338

TABLE B.9 Acreage and Output Baseline for Region 3 (Phillips, Sedgewick, Washington, and Yuma Counties, Colorado)

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	5,600	5,525	5,749	6,645	7,345
Dryland acreage	4,600	4,539	4,723	5,459	6,033
Irrigated acreage	1,000	987	1,027	1,187	1,312
Surface water acreage	478	472	491	567	627
Groundwater acreage	522	515	536	619	685
Total output (bushels)	169,000	166,747	173,507	200,547	221,656
Dryland output (bushels)	144,000	142,080	147,840	170,880	188,867
Irrigated output (bushels)	25,000	24,667	25,667	29,667	32,789
Surface water output (bushels)	11,952	11,792	12,270	14,183	15,675
Groundwater output (bushels)	13,048	12,874	13,396	15,484	17,114
Corn grain					
Dryland acreage	19,500	19,704	20,228	20,693	21,654
Irrigated acreage	322,500	325,869	334,534	342,235	358,131
Surface water acreage	99,588	100,628	103,304	105,682	110,591
Groundwater acreage	222,912	225,241	231,230	236,553	247,541
Total output (bushels)	54,085,000	54,650,067	56,103,097	57,394,679	60,060,588
Dryland output (bushels)	1,145,000	1,156,963	1,187,724	1,215,067	1,271,505
Irrigated output (bushels)	52,940,000	53,493,104	54,915,373	56,179,612	58,789,082
Surface water output (bushels)	16,347,826	16,518,624	16,957,819	17,348,215	18,154,017
Groundwater output (bushels)	36,592,174	36,974,481	37,957,554	38,831,397	40,635,065
Corn silage					
Total acreage	12,500	12,645	12,800	13,608	14,382
Dryland acreage	791	800	810	861	910
Irrigated acreage	11,709	11,846	11,990	12,747	13,473
Surface water acreage	3,616	3,658	3,703	3,936	4,160
Groundwater acreage	8,094	8,188	8,288	8,811	9,312
Total output (tons)	272,000	275,162	278,527	296,107	312,957
Dryland output (tons)	6,330	6,404	6,482	6,891	7,283
Irrigated output (tons)	265,670	268,759	272,045	289,216	305,674
Surface water output (tons)	82,039	82,992	84,007	89,310	94,392
Groundwater output (tons)	183,631	185,766	188,038	199,906	211,282

TABLE B.9 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	67,200	68,076	68,294	70,702	72,807
Dryland acreage	37,600	38,090	38,212	39,560	40,737
Irrigated acreage	29,600	29,986	30,082	31,143	32,070
Surface water acreage	14,151	14,335	14,381	14,888	15,332
Groundwater acreage	15,449	15,651	15,701	16,254	16,738
Total output (tons)	198,200	200,782	201,428	208,529	214,738
Dryland output (tons)	65,200	66,050	66,262	68,598	70,640
Irrigated output (tons)	133,000	134,732	135,166	139,931	144,097
Surface water output (tons)	63,583	64,411	64,618	66,896	68,888
Groundwater output (tons)	69,417	70,322	70,548	73,035	75,210
Sorghum					
Total acreage	14,700	14,862	15,508	16,638	16,932
Dryland acreage	11,900	12,031	12,554	13,469	13,707
Irrigated acreage	2,800	2,831	2,954	3,169	3,225
Surface water acreage	1,339	1,353	1,412	1,515	1,542
Groundwater acreage	1,461	1,477	1,542	1,654	1,683
Total output (bushels)	601,000	607,604	634,022	680,253	692,260
Dryland output (bushels)	438,000	442,813	462,066	495,758	504,509
Irrigated output (bushels)	163,000	164,791	171,956	184,495	187,751
Surface water output (bushels)	77,925	78,781	82,206	88,200	89,757
Groundwater output (bushels)	85,075	86,010	89,750	96,294	97,994
Wheat					
Total acreage	633,300	584,866	558,364	623,248	644,219
Dryland acreage	611,700	564,918	539,320	601,990	622,247
Irrigated acreage	21,600	19,948	19,044	21,257	21,972
Surface water acreage	10,326	9,536	9,104	10,162	10,504
Groundwater acreage	11,274	10,412	9,940	11,095	11,468
Total output (bushels)	23,184,000	21,410,909	20,440,727	22,816,000	23,583,726
Dryland output (bushels)	21,979,000	20,298,066	19,378,310	21,630,127	22,357,950
Irrigated output (bushels)	1,205,000	1,112,843	1,062,417	1,185,873	1,225,776
Surface water output (bushels)	576,069	532,012	507,905	566,925	586,001
Groundwater output (bushels)	628,931	580,831	554,512	618,948	639,775

TABLE B.10 Acreage and Output Baseline for Region 4 (Cheyenne, Kit Carson, and Lincoln Counties, Colorado)

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	2,700	2,664	2,772	3,204	3,541
Dryland acreage	1,200	1,184	1,232	1,424	1,574
Irrigated acreage	1,500	1,480	1,540	1,780	1,967
Surface water acreage	463	457	476	550	608
Groundwater acreage	1,037	1,023	1,064	1,230	1,360
Total output (bushels)	110,000	108,533	112,933	130,533	144,273
Dryland output (bushels)	38,000	37,493	39,013	45,093	49,840
Irrigated output (bushels)	72,000	71,040	73,920	85,440	94,433
Surface water output (bushels)	22,234	21,937	22,826	26,384	29,161
Groundwater output (bushels)	49,766	49,103	51,094	59,056	65,272
Corn grain					
Total acreage	75,700	76,491	78,525	80,332	84,064
Dryland acreage	1,000	1,010	1,037	1,061	1,110
Irrigated acreage	74,700	75,480	77,487	79,271	82,953
Surface water acreage	23,067	23,308	23,928	24,479	25,616
Groundwater acreage	51,633	52,172	53,559	54,792	57,337
Total output (bushels)	11,802,000	11,925,304	12,242,373	12,524,212	13,105,945
Dryland output (bushels)	55,000	55,575	57,052	58,366	61,077
Irrigated output (bushels)	11,747,000	11,869,730	12,185,321	12,465,846	13,044,869
Surface water output (bushels)	3,627,463	3,665,362	3,762,816	3,849,442	4,028,244
Groundwater output (bushels)	8,119,537	8,204,368	8,422,504	8,616,404	9,016,625
Corn silage					
Total acreage	7,300	7,385	7,475	7,947	8,399
Dryland acreage	96	97	98	104	110
Irrigated acreage	7,204	7,288	7,377	7,843	8,289
Surface water acreage	2,225	2,251	2,278	2,422	2,560
Groundwater acreage	4,980	5,038	5,099	5,421	5,730
Total output (tons)	133,700	135,254	136,908	145,550	153,832
Dryland output (tons)	635	642	650	691	731
Irrigated output (tons)	133,065	134,612	136,258	144,859	153,102
Surface water output (tons)	41,090	41,568	42,076	44,732	47,278
Groundwater output (tons)	91,975	93,044	94,182	100,126	105,824

TABLE B.10 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	69,800	70,709	70,937	73,438	75,624
Dryland acreage	55,200	55,919	56,099	58,077	59,806
Irrigated acreage	14,600	14,790	14,838	15,361	15,818
Surface water acreage	4,508	4,567	4,582	4,743	4,885
Groundwater acreage	10,092	10,223	10,256	10,617	10,934
Total output (tons)	125,300	126,933	127,341	131,830	135,755
Dryland output (tons)	77,700	78,712	78,965	81,750	84,183
Irrigated output (tons)	47,600	48,220	48,375	50,081	51,572
Surface water output (tons)	14,699	14,890	14,938	15,465	15,925
Groundwater output (tons)	32,901	33,330	33,437	34,616	35,647
Sorghum					
Total acreage	26,100	26,387	27,534	29,542	30,063
Dryland acreage	20,300	20,523	21,415	22,977	23,383
Irrigated acreage	5,800	5,864	6,119	6,565	6,681
Surface water acreage	1,791	1,811	1,889	2,027	2,063
Groundwater acreage	4,009	4,053	4,229	4,538	4,618
Total output (bushels)	1,087,000	1,098,945	1,146,725	1,230,341	1,252,058
Dryland output (bushels)	690,000	697,582	727,912	780,989	794,775
Irrigated output (bushels)	397,000	401,363	418,813	449,352	457,283
Surface water output (bushels)	122,593	123,940	129,329	138,759	141,209
Groundwater output (bushels)	274,407	277,422	289,484	310,592	316,075
Wheat					
Total acreage	629,000	580,895	554,573	619,016	639,845
Dryland acreage	587,500	542,569	517,983	578,175	597,629
Irrigated acreage	41,500	38,326	36,589	40,841	42,216
Surface water acreage	12,815	11,835	11,299	12,612	13,036
Groundwater acreage	28,685	26,491	25,291	28,230	29,179
Total output (bushels)	22,369,000	20,658,240	19,722,163	22,013,937	22,754,675
Dryland output (bushels)	20,250,000	18,701,299	17,853,896	19,928,571	20,599,140
Irrigated output (bushels)	2,119,000	1,956,941	1,868,267	2,085,365	2,155,535
Surface water output (bushels)	654,345	604,302	576,919	643,959	665,627
Groundwater output (bushels)	1,464,655	1,352,639	1,291,348	1,441,406	1,489,907

TABLE B.11 Acreage and Output Baseline for Region 5 (Baca, Kiowa, and Prowers Counties, Colorado)

Crop Statistics	1990	1993	1995	2000	2008
Barley					
Total acreage	9,500	9,373	9,753	11,273	12,460
Dryland acreage	4,300	4,243	4,415	5,103	5,640
Irrigated acreage	5,200	5,131	5,339	6,171	6,820
Surface water acreage	3,760	3,710	3,860	4,462	4,932
Groundwater acreage	1,440	1,421	1,478	1,709	1,888
Total output (bushels)	555,000	547,600	569,800	658,600	727,925
Dryland output (bushels)	92,000	90,773	94,453	109,173	120,665
Irrigated output (bushels)	463,000	456,827	475,347	549,427	607,260
Surface water output (bushels)	334,803	330,339	343,731	397,299	439,119
Groundwater output (bushels)	128,197	126,488	131,616	152,127	168,140
Corn grain					
Total acreage	20,800	21,017	21,576	22,073	23,098
Dryland acreage	0	0	0	0	0
Irrigated acreage	20,800	21,017	21,576	22,073	23,098
Surface water acreage	6,423	6,490	6,663	6,816	7,133
Groundwater acreage	14,377	14,527	14,913	15,257	15,965
Total output (bushels)	2,879,000	2,909,079	2,986,425	3,055,178	3,197,087
Dryland output (bushels)	0	0	0	0	0
Irrigated output (bushels)	2,879,000	2,909,079	2,986,425	3,055,178	3,197,087
Surface water output (bushels)	889,033	898,321	922,206	943,436	987,258
Groundwater output (bushels)	1,989,967	2,010,758	2,064,220	2,111,741	2,209,829
Corn silage					
Total acreage	3,200	3,237	3,277	3,484	3,682
Dryland acreage	0	0	0	0	0
Irrigated acreage	3,200	3,237	3,277	3,484	3,682
Surface water acreage	988	1,000	1,012	1,076	1,137
Groundwater acreage	2,212	2,238	2,265	2,408	2,545
Total output (tons)	55,000	55,639	56,320	59,875	63,282
Dryland output (tons)	0	0	0	0	0
Irrigated output (tons)	55,000	55,639	56,320	59,875	63,282
Surface water output (tons)	16,984	17,181	17,392	18,489	19,541
Groundwater output (tons)	38,016	38,458	38,928	41,385	43,740

TABLE B.11 (Cont.)

Crop Statistics	1990	1993	1995	2000	2008
Hay					
Total acreage	75,600	76,585	76,831	79,540	81,908
Dryland acreage	22,000	22,287	22,358	23,147	23,836
Irrigated acreage	53,600	54,298	54,473	56,393	58,072
Surface water acreage	38,759	39,264	39,390	40,779	41,993
Groundwater acreage	14,841	15,034	15,083	15,614	16,079
Total output (tons)	264,700	268,149	269,011	278,495	286,787
Dryland output (tons)	26,800	27,149	27,236	28,197	29,036
Irrigated output (tons)	237,900	241,000	241,775	250,299	257,751
Surface water output (tons)	172,029	174,271	174,831	180,995	186,384
Groundwater output (tons)	65,871	66,729	66,943	69,304	71,367
Sorghum					
Total acreage	154,200	155,895	162,673	174,534	177,615
Dryland acreage	115,800	117,073	122,163	131,070	133,384
Irrigated acreage	38,400	38,822	40,510	43,464	44,231
Surface water acreage	27,768	28,073	29,293	31,429	31,984
Groundwater acreage	10,632	10,749	11,217	12,034	12,247
Total output (bushels)	7,037,000	7,114,330	7,423,648	7,964,956	8,105,549
Dryland output (bushels)	4,087,000	4,131,912	4,311,560	4,625,945	4,707,600
Irrigated output (bushels)	2,950,000	2,982,418	3,112,088	3,339,011	3,397,950
Surface water output (bushels)	2,133,194	2,156,635	2,250,402	2,414,494	2,457,113
Groundwater output (bushels)	816,806	825,782	861,686	924,517	940,836
Wheat					
Total acreage	500,200	461,945	441,013	492,260	508,824
Dryland acreage	458,200	423,157	403,983	450,927	466,100
Irrigated acreage	42,000	38,788	37,030	41,333	42,724
Surface water acreage	30,371	28,048	26,777	29,889	30,895
Groundwater acreage	11,629	10,740	10,253	11,445	11,830
Total output (bushels)	15,937,000	14,718,153	14,051,237	15,684,032	16,211,777
Dryland output (bushels)	13,602,000	12,561,732	11,992,528	13,386,095	13,836,519
Irrigated output (bushels)	2,335,000	2,156,421	2,058,709	2,297,937	2,375,259
Surface water output (bushels)	1,688,477	1,559,344	1,488,686	1,661,676	1,717,589
Groundwater output (bushels)	646,523	597,078	570,023	636,261	657,670