Global Warming and the American Economy

A Regional Assessment of Climate Change Impacts

Edited by

Robert Mendelsohn

Edwin Weyerhaeuser Davis Professor, School of Forestry and Environmental Studies, Yale University

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Contents

5. Water resources: Economic analysis

Brian Hurd and Megan Harrod

INTRODUCTION

Water systems may be economically vulnerable to changes in global climate. The indicators of climate change – including higher temperatures, new patterns of precipitation, changes in evaporation rates and changes in the frequency and intensity of droughts and storms – can have important consequences for water users and the institutions that regulate water supply and demand. Analyses of climate change impacts on water supply and use have evolved from projections of runoff changes to methods that link physical and water management models. Early studies used statistical models to relate climate (temperature and precipitation) to runoff at the river basin scale level (for example, Stockton and Boggess 1979, Revelle and Waggoner 1983). Nemec and Schaake (1982) improved on these approaches by calibrating a physical runoff model and projecting the effects of climate changes on runoff. Other researchers (for example, Gleick 1987, Lettenmaier *et al.* 1993) helped advance the state of the art in hydrologic modeling and raised interesting issues about how climate change might influence competition for water. These studies, however, did not grapple directly with allocation issues in a quantitative fashion. This assessment aims to provide researchers and policy makers with a more in-depth analysis of specific regional impacts from climate change.

Our assessment is based on four watershed optimization models that simulate major regional economic and physical attributes of water resource supply and use. The four US watersheds simulated are the Colorado, Missouri, Delaware and Apalachicola–Flint–Chattahoochee. These were selected on the basis of regional and national significance, diversity of climate, geography and water use patterns. They are broadly representative of the diverse range of water resources and climates across the United States. Results from these four models are extrapolated to remaining US watersheds. Hydrologic changes were estimated only for the four modeled watersheds. The regional results are extrapolations from these four watersheds and should be viewed as only a rough gauge of the sensitivity of regional water resources to climate change.

Ideally, one would want to examine a representative set of watersheds in each region, but limited resources prevented this more thorough approach.

MODEL OVERVIEW

The watershed models simulate economic factors in relation to the physical characteristics of water use and supply within the watershed. The models view the watershed from the perspective of an overall manager who can distribute and manage water supplies to generate the greatest economic value. These models treat water as a commodity and assume that water can be traded across both space and time, to the extent allowed by physical conditions such as reservoirs and water delivery systems. The models do not consider changing water infrastructure, building or removing dams and canals; they do consider how climate might change both runoff and the demand for water. By weighing the economic tradeoffs between alternative water uses, the models determine the most efficient allocation and storage of water given the watershed's economic and physical characteristics, and a given sequence and spatial pattern of runoff. A seasonal time-step simulates the inflow and movement of water throughout the watershed.

The models embody efficient adaptation. As runoff changes in each scenario, it is assumed that water is reallocated to its highest use. Current water distribution systems are not this efficient, so it is reasonable to question whether this adaptation will take place. Encouraging public institutions to manage water more efficiently is an important adaptation to climate change.

A sequence of simulated runoff data is the primary input to the water allocation models. These data characterize changes in mean climatic conditions, primarily changes in average temperature and average precipitation rates. The runoff sequence is calibrated off a 38-year historical record (1949–87) and simulates changes in average water use and allocations. The models assume that the water administrator is aware of not only this year's runoff but also all future runoff as well (that is, the model has perfect foresight). In this assessment, we hold the current water infrastructure fixed. For example, the models do not consider removing or adding dams or canals. They do, however, allow agricultural irrigation demand to change.

Thus, our analysis examines how known changes in long-term levels and timing of water resources affect efficient water allocations. The models do not take into account uncertainty surrounding existing or future runoff. We assume that the water manager can look forward with perfect foresight and make the best possible decisions given what is coming. The impact estimates may be underestimated because they do not include uncertainty. Nonetheless, the models are well suited to investigate large-scale and long-term effects of prescribed changes in the water system. The models, however, are not suitable for simulating day-to-day management or short-run system needs, both of which must be responsive to the current state of the system and expectations of short-run changes in demand and supply.

Two additional climate change scenarios not included in the previous study are reported here, +1.5°C, 0 per cent change in precipitation and +2.5°C, 0 per cent precipitation. Furthermore, the analysis drops the scenarios hypothesizing a 10 per cent decrease in precipitation under each of the temperature changes. Readers with interest in the details of the analytic methods and models should see Hurd *et al.* (1999a).

REGIONAL SCOPE

Our current focus is on the potential impacts to each of seven regions. Table 5.1 lists the regions, the associated US water resource regions and the modeled

Table 5.1 Regional definitions and pairing of modeled river basins to US water resource regions

Region	*Approximate US water resource region*	*Model proxy*
Northeast	New England	Delaware River
	Mid-Atlantic	
Midwest	Upper Mississippi	Missouri River
	Great Lakes	Delaware River
	Ohio	
Northern Plains	Missouri	Missouri River
	Souris–Red–Rainy	
Northwest	Pacific Northwest	Missouri River
Southeast	South Atlantic	Appalachicola–Flint–Chattahoochee Rivers
	Tennessee	
	Lower Mississippi	
Southern Plains	Arkansas–White–Red	Missouri River
	Texas–Gulf	
Southwest	Rio Grande	Colorado River
	Upper Colorado	
	Lower Colorado	
	Great Basin	
	California	

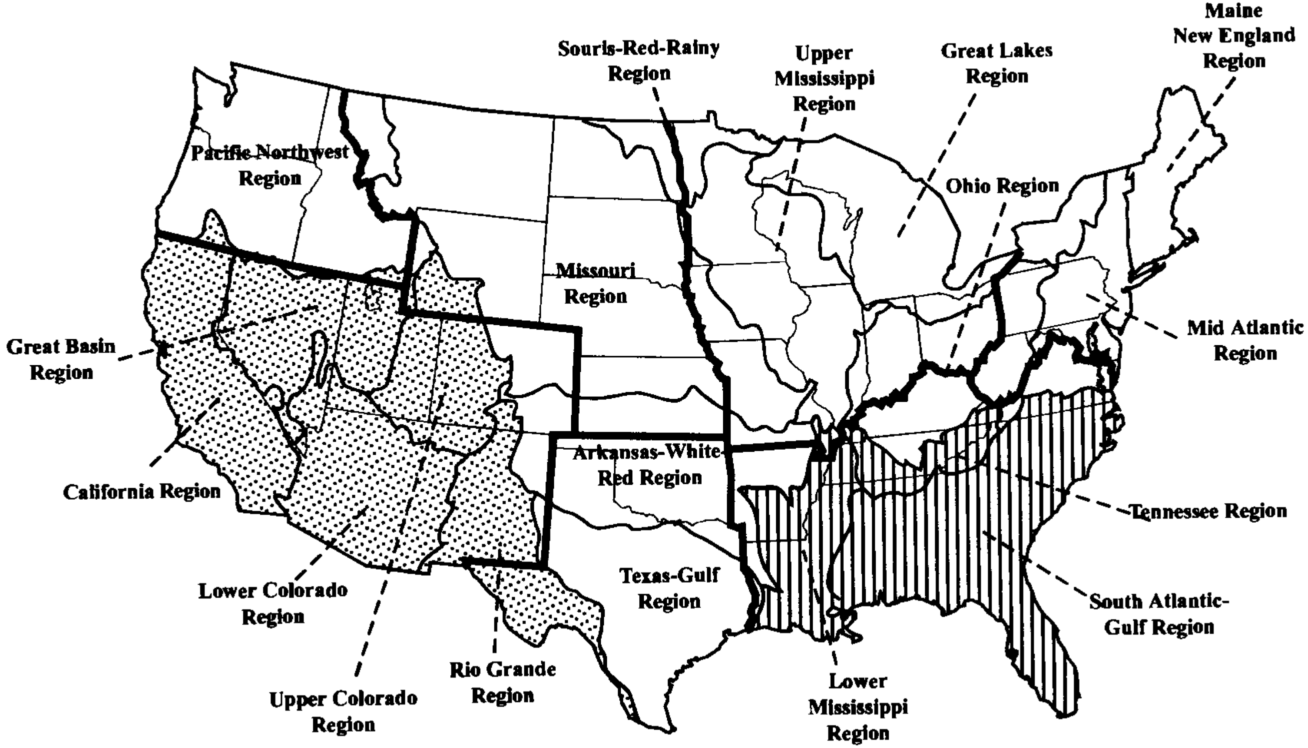

Figure 5.1 *Spacial association and aggregations for the regional water assessment. Shading indicates which watersheds are associated with each one of the four watershed models (see Table 5.1).*

watersheds assumed to approximate for each of the extrapolated regions. Figure 5.1 also illustrates the regions and model associations. We emphasize that characterizing regional water resources by using a proxy model from another region is an important limitation of this analysis. Caution should be used in interpreting the results for those regions where no rivers were explicitly modeled (Northwest, Midwest and Southern Plains).

SCENARIOS AND MODEL ASSUMPTIONS

The watershed models are based on scenarios of socioeconomic change through 2060 (baseline) and climate change in 2060. Water supply and demand conditions are estimated for 2060, both with and without climate change.

Baseline assumptions

The baseline scenario assumes no change in climate and projects water demands in 2060, taking into account factors such as historical trends in population, income and water use. These historical data suggest that water demand in the energy and municipal sectors has been growing over time, whereas irrigation demand has been relatively constant. The growth of water demand by thermal energy producers has been considerably less than the growth of demand by municipal users. In addition, we hypothesized that future growth in electricity demand will be increasingly met by technologies that are less water intensive (for example, solar, gas turbines, dry cooling). Based on these historical trends, demand for water in 2060 is estimated to increase 23 per cent and 10.2 per cent (0.3 per cent and 0.14 per cent annually) from 1990 levels for the municipal and thermal energy sectors, respectively.

Irrigation demand has been relatively constant over the last 20 years, partly because there have been few new federal irrigation projects. Projections of irrigation demand assume that no significant new federal water supply projects will be built, and that changes in irrigation technology will offset increases in the demand for irrigation water. That is, the overall demand for irrigation water is assumed to remain constant at current levels under baseline climate conditions.

Water demand under climate change

Demand for water may be sensitive to climate change. Greater rates of evaporation and evapotranspiration in plants will increase the irrigation requirements of a variety of uses, most notably for agriculture but also for some municipal uses such as lawns, gardens, parks and golf courses. In estimating climate-induced changes in water demand, we focus on the agriculture sector because of its overall scale and critical linkage to climate and water resources. Changes in the water demands of other sectors such as municipal and industrial are plausible, but lacking clear empirical measures on the sensitivity of water demand to temperature changes in these sectors, we conservatively assumed no climate sensitivity in these sectors.

In assessing the effect of climate change on agricultural water demand, we used the research results reported by Peterson and Keller (1990) to estimate changes in regional irrigation demand. These estimates do not take into account the potential water savings from increased water use efficiency of some plants in response to increased CO_2, so therefore we may overstate the impacts to agriculture.

DATA AND METHODS

The watershed models are used to measure changes in economic welfare that are driven by changes in hydrologic conditions and water demand caused by climate change. Hydrologic runoff data were developed for this study by Dr. Dennis Lettenmaier (University of Washington) and Dr. Eric Wood (Princeton University). These data describe how the level and timing of runoff are estimated to change as a result of climate change. The baseline is calibrated to historical runoff between 1949 and 1987, and runoff changes under each climate change scenario are estimated by adjusting the historical sequence to account for changes in average annual temperature and percentage changes in precipitation. These data are the principal driving force affecting water supply within the watershed models.

The watershed models are dynamic, nonlinear optimization models sometimes referred to as spatial equilibrium models. The model objective is to allocate available water supplies to competing economic uses across space and time to maximize the total value of water within the watershed within physical, economic and institutional constraints. The models also assume 'perfect foresight', which means that the optimization occurs with full knowledge and anticipation of future runoff and system changes. This assumption is common to long-run optimization models, and implies that adjustments and responses in water use to climate changes are made more efficiently and more certainly than they might otherwise be (that is, the estimated welfare effects are likely to be understated). Economic welfare for consumptive uses is defined by consumer and producer surplus, and is measured by the underlying demand and supply relationships (the benefits and costs). Valuation of nonconsumptive uses such as hydropower is based on reservoir and river flows and is measured by the market value of electricity produced. The models are constrained by runoff, physical and institutional features governing water flow, distribution, storage and water exports. Parameters for the models' objective and constraint functions are based on available data on water use, prices and other information from a variety of both primary and secondary sources, including the US Geological Survey (USGS), local water utilities and agricultural extension agents. Details on the models can be found in Hurd *et al.* (1999a).

To extend our analysis beyond the four modeled watersheds, data on water supply and use were developed for each of the 18 USGS water resource regions in the coterminous United States. Baseline data on water use were obtained from the USGS (Solley *et al.* 1993) by region and by sector. These data identified current water allocations in each of the regions, which are aggregated to form the baseline data for the seven regions of this study according to Table 5.1.

To assess how climate change might affect water use and welfare in each of these regions, we developed a spreadsheet model to analyze potential changes in regional water use using the allocation response and welfare changes estimated in the four modeled watersheds. Changes in sector water use, for example, are estimated by scaling the baseline regional water use for that sector (based on Solley *et al.* 1993) by the estimated change in sector allocation from the modeled result from the reference watershed model. This scaling procedure is described further in the discussion of the welfare changes in the next section. Note that in developing these regional estimates, the regional water use data from Solley *et al.* were not adjusted for changes in baseline use and allocation. Since this analysis focuses on relative climate change impacts, not the impacts of baseline changes, and since we account for baseline changes within each watershed model, it is more important to account for the relative changes in water use and the economic consequences of these changes rather than absolute levels of regional water use.

Brown (1999) underscores the key critical issues in estimating baseline changes in water use. He estimates baseline changes in regional water use by sector out to 2040 based on estimated changes in population, income and recent trends. Such an analysis requires assumptions regarding future water supplies such that if water use in one sector grows, reductions may be needed in other sectors, particularly in dry regions. His analysis shows that the greatest changes are estimated for domestic and public use, which, he expects, will closely follow population growth trends. He estimated the increase in national domestic water use between 1995 and 2040 to be about 42 per cent; the estimated municipal and industrial demand increase used in the watershed models (not the extrapolated regions) over this time period is about 15 per cent. He also estimated slight increases for thermoelectric and industrial use over this period of 9 per cent and 6 per cent, respectively, and a decrease in irrigation of 3 per cent. Following Brown (1999), we assume that domestic and public sector use is highly price inelastic and, therefore, unresponsive to changes in price. Our watershed model results, as shown in Hurd *et al.* (1999a) and here, suggest that there are likely to be only very small changes in domestic water use as a result of runoff and climate change, although there could be significant changes in water costs.

Economic welfare in this study measures the net value associated with the provision and use of water. Like other commodities, water can be used in a variety of ways to generate economic value: in producing goods and services that are exchanged in markets, by direct consumption of domestic water users, and in producing nonmarket services such as water pollution control, flood control and ecosystem support. Through market exchanges and allocation changes, water supplies can be directed toward those uses with the greatest economic potential. Thus, the economic damages from climate change could be reduced by lessening consumption in sectors where the marginal economic contribution is least. Institutional changes that facilitate such transfers, such as water banks, can contribute significantly during times of intense water supply stress.

Regional welfare estimates are derived by assessing the market value of changes for each sector and region as a result of runoff and demand changes. Conceptually for consumptive sectors, the net change in economic welfare (consumer and producer surplus) is measured by the change in the area below the water demand curve net of marginal water supply costs.

In this model, we assume linear demands in each sector. Figure 5.2 illustrates this by showing the net demand for water, or the willingness to pay for water in excess of its marginal supply costs (net demand equals demand price minus marginal supply cost). Another way to interpret this is to view the premium above the marginal supply cost as the market opportunity cost of the water in serving other users elsewhere in the system or in delaying use to the future. In the figure, baseline equilibrium is given by point *E*, at which the price and water use are given by points *A* and *G*, respectively. If, under climate change, water scarcity increases, a new equilibrium emerges at point *C*, where price moves up from *A* to *B* and water use declines from *G* to *F*. As a result of this change, net economic welfare falls by the change in area under the net demand curve, shown by the area *CEGF*. In notation, the economic welfare measure for each sector in each region is defined as:

$$\Delta R_{ij} = (P_{ij_0} \cdot \Delta W_{ij}) + \frac{1}{2}(P_{ij_0} \cdot \Delta W_{ij})$$

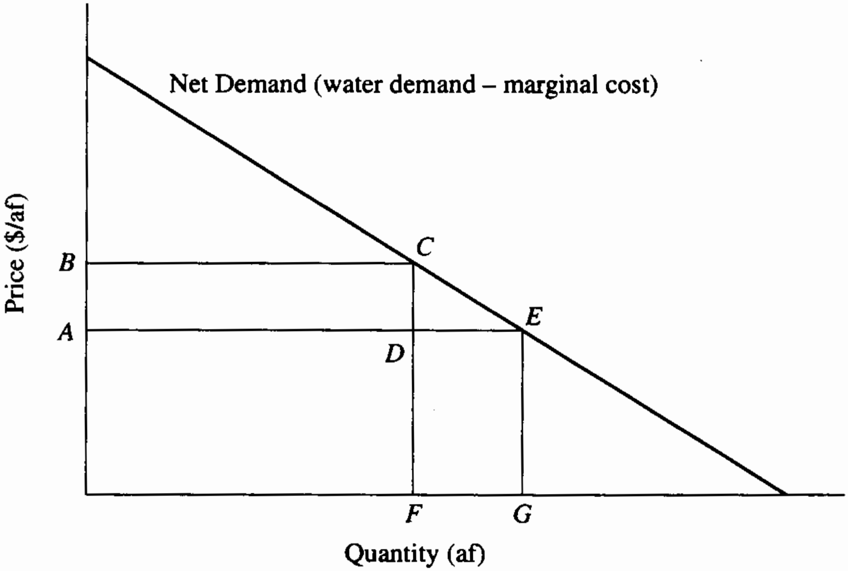

Figure 5.2 Demand for water consumption

where ΔR_{ij} is the change in welfare in sector i and region j. The variable P_{ij_0} is the baseline net marginal value of water estimated in the proxy regional model j_0 (point A in Figure 5.2), and W_{ij} is the baseline water use for sector i and region j (based on estimates from Solley *et al.* 1993). The variable ΔW_{ij} is the change in water withdrawal by sector i in region j (the change in quantity, G minus F), and is estimated by the baseline water use patterns in region $j(W_{ij})$, the simulated changes in sector water use in the modeled region j_0, and relative runoff changes between paired region j and modeled region j_0, given as:

$$\Delta W_{ij} = W_{ij}(1+\%\Delta W_{ij_0}),$$

where W_{ij_0} is the efficient water withdrawal to sector i determined in basin model j_0. This term, therefore, assumes that changes in water use patterns are proportional across paired regions and sectors. We also recognize the difference between withdrawals and consumptive use, and that efficient use depends on equalizing the marginal value across consumptive uses, after accounting for return flows. However, consistent data on consumptive use were not available. If average return flow rates are approximately the same within a given sector across regions, then no particular bias is introduced.

This analysis accounts for differences in river volumes across regions; however, it assumes that the response of water users to price and runoff changes (within each economic sector) is the same between the modeled regions and paired regions. It assumes, for example, that agricultural water use in the upper Mississippi region has the same demand elasticity as agricultural water use in the Missouri region.

This approach assumes that the value of water in a modeled region is largely similar to those in the extrapolated regions. This assumption may be more valid for estimating national level impacts, as in the previous study, and could produce some misleading results for some regional estimates. For example, water use in the Pacific Northwest, and in particular in the Columbia basin, is constrained in ways that are very different from those in the Missouri basin, which we use as a model proxy. Instream values associated with salmon are the most striking difference. The water needs of salmon require adjustments in the management of reservoirs and in the timing and volume of offstream withdrawals. These adjustments, therefore, could raise the instream value of water within the Columbia system in comparison to the Missouri, and thus underestimate the magnitude of economic impacts in this study. Therefore, extreme caution in interpreting these results is advised.

RESULTS

Estimated changes in water resource services are driven by shifts in both water supply and demand. As a primary indicator of the direction and magnitude of changes in service levels, modeled changes in annual average runoff (Lettenmaier and Wood 1995) are a useful measure to compare against the estimated changes in welfare and water use. As described earlier, runoff changes are an input into the watershed models and become a driver for redistributing water resources across time and space. The four runoff datasets are summarized in Table 5.2 for each modeled watershed and climate change scenario.

With only two small exceptions for the Apalachicola–Flint–Chattahoochee, the estimated hydrologic changes simulated by Lettenmaier and Wood (1995) for each modeled watershed show the same change in direction in annual runoff, either increases or decreases, in response to a given climate change scenario. Thus, the differences across the regions tend to be differences in the estimated magnitude of the response to climate change. With respect to the estimated magnitude, there also appears to be a tendency for the absolute magnitudes to be greater in the western watersheds than in the eastern watersheds, particularly in the drier scenarios.

These observed trends suggest that extrapolations of the direction and range of estimated hydrologic changes from the modeled watersheds to other

Table 5.2 Summary of estimated percentage changes in annual runoff for the modeled watersheds

Scenario	*Appalachicola–Flint–Chattahoochee*	*Delaware*	*Missouri*	*Colorado*
Baseline[a]	24,363 (kaf/yr)	13,660 (kaf/yr)	56,651 (kaf/yr)	17,058 (kaf/yr)
2.5°C, +7% precipitation	0.26	–4.08	–9.07	–4.17
5.0°C, +7% precipitation	–12.43	–22.27	–30.61	–22.38
1.5°C, +7% precipitation	5.07	2.72	1.04	3.97
2.5°C, +15% precipitation	13.70	9.87	9.13	14.13
5.0°C, +15% precipitation	0.51	–8.73	–15.52	–6.92
1.5°C, +15% precipitation	18.69	16.83	20.50	23.49
5.0°C, 0% precipitation	–23.53	–33.87	–42.39	–34.70
1.5°C, 0% precipitation	–6.68	–9.51	–14.79	–11.81
2.5°C, 0% precipitation	–11.32	–16.19	–23.77	–18.89

Note: a Baseline figures in this row are reported as absolute annual runoff.

Source: Lettenmaier and Woods 1995.

'similar' regions may not be grossly inconsistent with the results that might have been generated by simulating hydrologic changes in each watershed specifically. Even for the Northwest, which is the most different from its hypothesized proxy, the Missouri, there is likely to be a similar change in the direction of runoff changes, although the magnitude is not well characterized.

Given these simulated changes in runoff and climate-shifted changes in agricultural water demand, we find a wide range of changes in water resource services and welfare across regions and scenarios. Figure 5.3 illustrates the range of total welfare changes across the regions and scenarios.

At the national level, the total estimated annual impacts range from –$10.6 billion to +$2.5 billion for the 5.0°C, +0 per cent precipitation and 1.5°C, +15 per cent precipitation scenarios, respectively. In contrast, Frederick and Schwarz (1999) recently estimated for the US National Assessment that the total cost to water resource under the relatively severe Canadian Climate

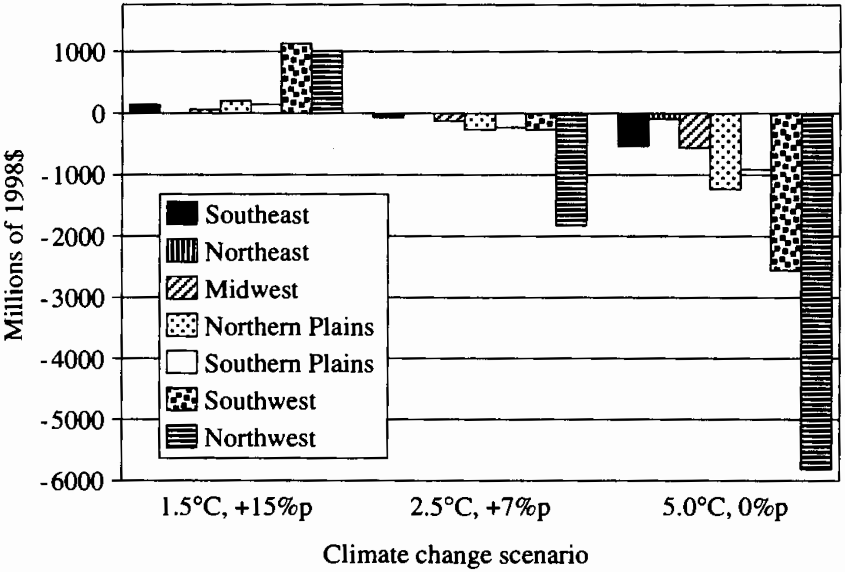

Figure 5.3 Summary of changes in the regional welfare of water resources for selected climate change scenarios

Model would range between $105 and $251 billion annually. Under that scenario, average temperature for the United States rises by 2.1°C and average precipitation declines by 4 per cent. Their analysis is based on the assumption that runoff in a number of basins in the southeastern and south-central United States will decline by up to 92 per cent (in the Texas–Gulf region), whereas our study estimates that it will decline by only 42 per cent in the Missouri watershed. In addition, their analysis includes several nonmarket effects that are not examined in this regional study, including the costs of increased conservation and the valuation of impacts to freshwater ecosystems as a result of diminished instream flows. This accounts for 53 per cent of their estimated impact under their efficient management scenario. Under this scenario, they estimate the costs of developing new supplies to meet projected demands at $45 billion annually. They also estimate the losses to agriculture at $3.2 billion, which is very close to the $3.0 billion we estimate as the impact to agriculture.

It is difficult to compare the results from these two studies because they differ significantly in their approaches and scope. The Frederick and Schwarz study includes nonmarket effects that are outside the scope of this study. We do not consider changes in infrastructure, neither the costs nor the benefits of building new dams or canals, whereas Frederick and Schwarz do allow for these activities (albeit at a very high cost of $1,000 per acre foot) to meet nonirrigated offstream use requirements.

Looking at the aggregated welfare changes across sectors, the western United States, including both regions of the Great Plains, is much more responsive to changes in runoff and climate, with the Northwest demonstrating the greatest variability. In the Northwest, estimated welfare changes range between –43 per cent and +7.5 per cent for the 5.0°C, +0 per cent precipitation and 1.5°C, +15 per cent precipitation scenarios, respectively. This is followed by the Southwest, with a range of –16 per cent and +7 per cent. In contrast, the eastern watersheds show little responsiveness to runoff changes. Of the eastern watersheds, the Southeast shows the greatest variability, ranging between –2.4 per cent and +0.7 per cent. We strongly emphasize that these estimates do not take changes in flood frequency or severity into account, which our watershed level analysis showed could be a major concern in the eastern United States, and in particular in the Southeast.

Underlying the differences in welfare changes across regions is the extent of agricultural irrigation and hydropower production. With respect to agriculture, it is interesting to contrast the relative share of water use to the share of value. As a share of the total value of water resource services, agriculture in the western United States accounts for 18 per cent in the Southern Plains, 37 per cent in the Northern Plains, 27 per cent in the Northwest and 34 per cent in the Southwest. However, in terms of water withdrawals, agriculture accounts for 49 per cent in the Southern Plains, 67 per cent in the Northern Plains, 89 per cent in the Northwest and 84 per cent in the Southwest. In the eastern United States, agriculture's share is only 6 per cent in the Southeast and less than 1 per cent in the Northeast and Midwest. The high agricultural water use in the western United States is a key feature of US water use. Because agriculture tends to place the lowest value on water of the major users, efficiency requires that agriculture be the first user to give up water when runoff declines. The model consequently requires agriculture to give up the biggest share of water when water gets scarce. If society did not permit other users to buy water from agriculture, the welfare impacts of reduced runoff would increase.

Hydropower makes a much larger contribution to water-derived welfare in the West than in the rest of the country. Hydropower's contribution to water derived welfare is 19 per cent in the Southwest and 52 per cent in the Northwest. In the rest of the country, hydropower accounts for only 7 to 8 per cent of welfare.

Even under the central scenario (2.5°C, +7 per cent precipitation), water users in the West experience relatively greater changes from existing water use patterns. Under this scenario they could experience higher water costs, resulting in 6 to 10 per cent reductions in agricultural use, and a consequent

1.3 to 3.9 per cent loss in agricultural welfare; however, total welfare losses range between only 0.6 per cent and 2.2 per cent under this scenario.

Under the scenarios where average runoff declines, water costs rise as competition between users increases. These higher costs generally cut across sectors and locations within a watershed, and result in the migration of water from lower valued economic uses into higher valued ones that can better absorb the higher costs. The general regional results underscore the scale and economic importance of agricultural irrigation and hydropower generation in western water use, and the high sensitivity of these sectors to runoff changes. The result is a strong east–west dichotomy of potential impacts (ignoring flooding and water quality issues).

REVIEW OF REGIONAL IMPACTS

Absent a detailed analysis of hydrologic changes in each of the regions, the regional results are best understood as a sensitivity analysis using hypothetical runoff changes.

Northeast

Water use in the heavily populated Northeast is dominated by municipal and industrial uses (M&I) and thermoelectric power, with 33 per cent and 65 per cent of total stream withdrawals, respectively, and agriculture accounts for 2 per cent (Solley *et al.* 1993). Most of the thermoelectric energy withdrawals are returned to the system; less than 10 per cent is consumed as evaporation in cooling processes. The impacts in the Northeast, which are based on the extrapolated hydrologic changes from the Delaware watershed, are summarized in Table A5.1. (All tabular results across regions and scenarios can be found in Tables A5.1–A5.7 at the end of the chapter.) The total welfare changes in the Northeast are relatively small, ranging between –0.7 per cent and +0.03 per cent. Agricultural users may be affected the most, on a percentage basis; their small share of total water use, however, does not contribute much to the overall regional welfare. Thermoelectric users may experience the greatest welfare changes, estimated to range between –$58 million and +$1.2 million (out of $3.6 billion in baseline welfare). The potential for changes in flood risk is highlighted in Hurd *et al.* (1999b): several watersheds throughout the region have large populations living within the 500-year floodplain. Source water protection and the maintenance of water quality for domestic users are other potential concerns.

Midwest

The assessment for the Midwest, summarized in Table A5.2, is based on results from both the Delaware and the Missouri watershed results. As with the eastern watersheds, the estimated total welfare changes are relatively small, between –1.7 per cent and +0.2 per cent. Irrigated agriculture is potentially the most sensitive to these changes, with withdrawal changes between –33 per cent and +9 per cent and welfare changes between –$21 million and +$3.9 million. However, as a share of regional economic loss, changes in hydropower production may have the greatest regional impact, with welfare changes between –$318 million and +$47 million. Thermoelectric generators may also be affected, with welfare changes between –14 per cent and +2 per cent, or –$189 million and +$3.9 million.

Northern Plains

In contrast to the previous regions, irrigation dominates water use in the Northern Plains, accounting for about 67 per cent of total withdrawals, followed by thermoelectric water use with about 27 per cent. Based on the estimates for the Missouri watershed, summarized in Table A5.3, total welfare changes may range from –16 per cent to +1 per cent. Changes in agricultural withdrawals range between –54 per cent and +14 per cent (a welfare change of between –$778 million and +$13.5 million annually). Hydropower welfare changes range between –$411 million and +$72 million (–67 per cent and +12 per cent). The Northern Plains may also be vulnerable to climate change as a result of relatively high rates of groundwater overdraft, high runoff variability and high levels of streamflow withdrawals relative to streamflow (Hurd *et al.* 1999b). Also, flooding, a significant concern for many communities in the region, is not reflected in these estimates.

Northwest

The Northwest region appears to be the most sensitive to changes in water use under climate change because of its intensive use of water. Irrigation is the dominant water use in the Northwest, accounting for over 85 to 90 per cent of withdrawals. Instream water uses are also vital to the region as a major source of electric power and in support of important recreation and ecosystem services (for example, salmon). This is the most difficult region to extrapolate to, because there are key differences between water use in this region and water use in the Missouri basin, which is the basis for the extrapolated results. The results, summarized in Table A5.4, indicate that total welfare changes range between –21 per cent and +14 per cent, and are primarily distributed between agriculture and hydropower. Losses to both sectors under the more extreme runoff changes are considerable, approaching –$995 million and –$4,655 million for agriculture and hydropower, respectively. Flooding in the western portion of the region could become a greater concern.

Southeast

The findings for the Southeast, summarized in Table A5.5, are based on extrapolating the analysis of changes in the Appalachicola–Flint–Chattahoochee watershed. Ignoring the effects of flooding and water quality changes, the impacts to total welfare in this region range between –2.4 per cent and +0.75 per cent. The relatively low share of runoff that is withdrawn for use accounts for this small range in estimated impacts. Hurd *et al.* (1999b) further underscore this point by examining the ratio of streamflow to withdrawals under current climate and conclude that this region is relatively less vulnerable to changes in runoff. Increased irrigation demand is likely to draw a greater share of available water under climate change. Much of the Southeast is relatively vulnerable to flooding under current climate (Hurd *et al.* 1999b), and changes that bring greater precipitation and runoff, and possibly greater storm intensity, could exacerbate the negative impacts of climate change.

Southern Plains

The Southern Plains span the Texas–Gulf region and the Arkansas–White–Red region. The dominant water use is agricultural irrigation, followed by thermoelectric and M&I uses. Based on the Missouri watershed results, total welfare is estimated to range between –10 per cent and +2 per cent, and total withdrawals to range between –27 per cent and +7 per cent. Key findings are summarized in Table A5.6. Agriculture is potentially the most affected sector, with estimated withdrawal changes ranging between –54 per cent and +14 per cent. The welfare effects for agriculture are significant, with a loss of $428 million (–28 per cent) estimated for a +5°C increase and no change in precipitation. Under this scenario, hydropower losses are estimated at –$450 million (–68 per cent).

Southwest

This region comprises a variety of climatic zones, from water-rich areas in Northern California to extreme deserts in the Lower Colorado, Great Basin and Rio Grande areas. Agricultural irrigation dominates water use, exceeding 80 per cent. The results, summarized in Table A5.7, are based on those from the Colorado watershed model and indicate that total welfare changes range between –16 per cent and +7 per cent, suggesting that this region is very sensitive to changes in runoff, with hydropower and agriculture the most affected sectors. Welfare changes in agricultural range from –$986 million (–18 per cent) to +$321 million (+6 per cent). Hydropower value is estimated to change between –$1,217 million and +$783 million.

SUMMARY AND CONCLUSIONS

By extending the previous analysis to focus on regional changes, this research highlights the importance of considering regional differences in assessing water resource impacts and adaptation potential. Comparisons can be drawn between these results and those of previous regional assessments such as Gleick (1990) and Hurd *et al.* (1999b). Consistent with the results from these studies, which indicate the relative vulnerability of the western United States under current climate conditions, this assessment further underscores the potential impacts as climate changes in these regions.

The study finds especially that western watersheds have a high probability of experiencing runoff reductions from climate change. These reductions would cause significant impacts to agriculture in the West. The important hydropower resources of the West would also be sensitive to these runoff reductions. To adapt to these adverse circumstances, regional economic forces must use water more efficiently by maintaining supplies to high valued users and taking the water away from low valued users. Agriculture will tend to lose the largest share of water because many of the lowest valued uses for water are in agriculture. Although this study makes some reasonable predictions about water impacts across regions in the United States, the extrapolated regional estimates remain highly uncertain. Additional watershed studies need to be conducted in each region to reduce this uncertainty. Flooding remains a large uncertainty that is not well accounted for by examining changes in mean climate conditions and regional extrapolations. Flooding may be a more widespread concern than runoff reductions, because every region needs to be wary of increases in flood conditions.

It needs to be restated here that the regional assessments presented in this chapter concern only market effects. Many important nonmarket impacts to water resources, such as impacts on water quality and other instream uses, are not measured here. In a national analysis, Hurd *et al.* (1999b) point to a number of indicators of vulnerability related to consumptive and instream water use, including flooding, and a more comprehensive regional approach might incorporate some of these indicators in estimating the effects of climate change and regional adaptation. For example, water quality measures such as dissolved oxygen can indicate how well a water body can support aquatic ecosystems suitable for providing valued habitat and recreation. It is important to remember that climate change could have adverse and significant impacts on the quality of life and recreation in sensitive regions. For example, the Southeast may be very sensitive to increases in precipitation rates, which could exacerbate flooding; and semi-arid regions may find altered streamflows are insufficient to meet both consumptive uses and minimum flow requirements for ecosystems.

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Table A5.1 *Simulated effect of climate change on the welfare of water users in the Northeast (millions 1998 USD)*

Climate change scenario	% change in runoff	*Total welfare*			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		Change in welfare ($)	
			Absolute	Percent.		Absolute	Percent.		Absolute	Percent.		Total	Percent.	Total	Percent.
Baseline[a]	216,763 (kaf/yr)	28,966 (kaf/yr)	12,941		484 (kaf/yr)	44		12,128 (kaf/yr)	8,147		16,354 (kaf/yr)	3,738		1,012	
1.5°C, 0%P[b]	-9.51	-0.64	-3.7	-0.028	-3.00	-0.3	-0.592	-0.20	-0.3	-0.004	-0.90	-3.1	-0.08	0.0	0.00
2.5°C, 0%P	-16.19	-1.41	-9.5	-0.073	-7.50	-0.7	-1.590	-0.50	-0.7	-0.009	-1.90	-8.0	-0.21	0.0	0.00
5.0°C, 0%P	-33.87	-5.12	-89.5	-0.691	-8.16	-1.0	-2.309	-1.96	-3.2	-0.039	-7.38	-60.0	-1.60	-5.0	-2.50
1.5°C, 7%P	2.72	0.00	-0.0	0.000	0.00	0.0	0.000	0.01	0.0	0.000	-0.01	-0.0	-0.00	0.0	0.00
2.5°C, 7%P	-4.08	-0.42	-2.5	-0.019	-2.72	-0.2	-0.521	-0.14	-0.4	-0.005	-0.57	-1.8	-0.05	0.0	0.00
5.0°C, 7%P	-22.27	-2.59	-21.8	-0.169	-12.93	-1.4	-3.108	-0.89	-1.4	-0.017	-3.54	-19.1	-0.51	0.0	0.00
1.5°C, 15%P	16.83	0.42	1.7	0.013	3.40	0.2	0.569	0.18	0.3	0.003	0.52	1.2	0.03	0.0	0.00
2.5°C, 15%P	9.87	0.17	0.7	0.006	1.36	0.1	0.237	0.08	0.1	0.001	0.19	0.5	0.01	0.0	0.00
5.0°C, 15%P	-8.73	-1.03	-6.4	-0.050	-5.44	-0.5	-1.091	-0.33	-0.5	-0.006	-1.42	-5.5	-0.15	0.0	0.00

Notes:
Negative values indicate baseline damages.

a. Figures in this row are baseline estimates presented in absolute unit terms.
b. P = precipitation.

Table A5.2 Simulated effect of climate change on the welfare of water users in the Midwest (millions 1998 USD)

Climate change scenario	% change in runoff		*Total welfare*			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
			% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		Change in welfare ($)	
				Absolute	Percent.		Absolute	Percent.		Absolute	Percent.		Total	Percent.	Total	Percent.
Baseline[a]	378,255 (kaf/yr)		93,649 (kaf/yr)	32,826		1,392 (kaf/yr)	134		21,463 (kaf/yr)	14,397		70,793 (kaf/yr)	16,043		2,251	
	West[b]	East[b]														
1.5°C, 0%P[c]	−14.79	−9.51	−0.67	−119.9	−0.365	−7.25	−3.9	−2.923	−0.18	−0.4	−0.003	−0.0069	−10.0	−0.063	−105.5	−4.69
2.5°C, 0%P	−23.77	−16.19	−1.44	−201.0	−0.6	−16.1	−9.1	−6.9	−0.44	−1.1	−0.01	−1.46	−25.1	−0.2	−166.0	−7.6
5.0°C, 0%P	−42.39	−33.87	−5.36	−548.8	−1.672	−32.52	−22.2	−16.53	−1.77	−4.9	−0.034	−0.0591	−194.9	−1.215	−326.7	−14.51
1.5°C, 7%P	1.04	2.72	−0.01	−29.5	−0.090	0.62	0.4	0.257	0.00	0.0	0.000	−0.0002	−0.2	−0.001	−29.7	−1.32
2.5°C, 7%P	−9.07	−4.08	−0.46	−108.0	−0.329	−6.10	−3.2	−2.405	−0.13	−0.7	−0.005	−0.0045	−5.9	−0.037	−98.2	−4.36
5.0°C, 7%P	−30.61	−22.27	−2.92	−342.7	−1.044	−31.52	−19.9	−14.81	−0.86	−2.2	−0.015	−0.0299	−63.3	−0.395	−257.3	−11.43
1.5°C, 15%P	20.50	16.83	0.46	57.2	0.174	9.18	4.0	2.938	0.15	0.4	0.003	0.0039	4.0	0.025	48.9	2.17
2.5°C, 15%P	9.13	9.87	0.16	−8.8	−0.027	2.62	1.2	0.900	0.06	0.2	0.001	0.0014	1.6	0.010	−11.8	−0.52
5.0°C, 15%P	−15.52	−8.73	−1.19	−210.3	−0.641	−17.20	−10.5	−7.782	−0.32	−0.8	−0.005	−0.0114	−17.7	−0.110	−181.4	−8.06

Notes:
Negative values indicate baseline damages.

a. Figures in this row are baseline estimates presented in absolute unit terms.

b. Runoff for two halves of the Great Lakes region reported separately because the region is modeled by two different watershed models, Delaware and Missouri. Land in the East (Delaware) basin comprises 61% (779,770 km^2) of the region's total area; land in the West (Missouri) basin comprises 39% (489,827 km^2) of the region's total area.

c. P = precipitation.

Table A5.3 Simulated effect of climate change on the welfare of water users in the Northern Plains (millions 1998 USD)

		Total welfare			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
			Change in welfare ($)			Change in welfare ($)			Change in welfare ($)			Change in welfare ($)		Change in welfare ($)	
Climate change scenario	% change in runoff	% change in with-drawals	Absolute	Percent.	% change in with-drawals	Absolute	Percent.	% change in with-drawals	Absolute	Percent.	% change in with-drawals	Total	Percent.	Total	Percent.
Baseline[a]	167,219 (kaf/yr)	42,297 (kaf/yr)	7,781		28,378 (kaf/yr)	2,884		2,689 (kaf/yr)	1,793		11,231 (kaf/yr)	2,482		622	
1.5°C, 0%P[b]	–14.79	–7.41	–295.8	–3.802	–11.00	–137.2	–4.756	–0.10	0.0	–0.001	–0.10	–0.0	–0.001	–158.6	–25.501
2.5°C, 0%P	–23.77	–15.90	–561.0	–7.40	–23.6	–311.0	–11.10	–0.20	–0.0	–0.000	–0.20	–0.1	–0.000	–249.0	–41.20
5.0°C, 0%P	–42.39	–36.74	–1223.6	–15.725	–53.97	–799.4	–27.715	–0.94	–0.2	–0.011	–1.77	–1.9	–0.076	–422.1	–67.87
1.5°C, 7%P	1.04	0.77	–31.4	–0.403	1.17	13.3	0.459	–0.04	0.0	0.000	–0.05	–0.0	–0.001	–44.6	–7.17
2.5°C, 7%P	–9.07	–6.13	–259.8	–3.338	–9.08	–112.1	–3.887	–0.10	0.0	–0.002	–0.10	–0.0	–0.001	–147.6	–23.72
5.0°C, 7%P	–30.61	–32.55	–1081.1	–13.893	–47.88	–692.8	–24.020	–0.75	–0.2	–0.009	–1.40	–1.3	–0.051	–386.8	–62.20
1.5°C, 15%P	20.50	9.58	212.0	2.724	14.27	138.5	4.802	0.04	0.0	0.000	0.02	0.0	0.000	73.5	11.81
2.5°C, 15%P	9.13	2.49	23.3	0.299	3.72	41.0	1.421	–0.01	0.0	0.000	–0.03	–0.0	0.000	–17.7	–2.84
5.0°C, 15%P	–15.52	–18.60	–649.1	–8.342	–27.55	–376.2	–13.044	–0.27	–0.1	–0.003	–0.37	–0.2	–0.006	–272.7	–43.84

Notes:
Negative values indicate baseline damages.
a. Figures in this row are baseline estimates presented in absolute unit terms.
b. P = precipitation

Table A5.4 Simulated effect of climate change on the welfare of water users in the Northwest (millions 1998 USD)

		Total welfare			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
Climate change scenario	% change in runoff	% change in withdrawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in withdrawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in withdrawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in withdrawals	Change in welfare ($) Total	Change in welfare ($) Percent.	Change in welfare ($) Total	Change in welfare ($) Percent.
Baseline[a]	238,800 (kaf/yr)	40,704 (kaf/yr)	13,493		36,315 (kaf/yr)	3,691		3,991 (kaf/yr)	2,661		398 (kaf/yr)	88		7,054	
1.5°C, 0%P[b]	–14.79	–9.82	–1974.3	–14.63	–11.00	–175.5	–4.75	–0.10	0.0	–0.001	–0.10	–0.0	–0.001	–1798.8	–25.50
2.5°C, 0%P	–23.77	–21.08	–3221.0	–24.50	–23.60	–398.0	–11.10	–0.20	–0.1	–0.002	–0.20	–0.0	–0.00	–2823.0	–41.10
5.0°C, 0%P	–42.39	–48.26	–5811.2	–43.06	–53.97	–1023.0	–27.715	–0.94	–0.3	–0.011	–1.77	–0.1	–0.076	–4787.9	–67.87
1.5°C, 7%P	1.04	1.04	–489.2	–3.62	1.17	17.0	0.45	–0.04	0.0	0.000	–0.05	0.0	–0.001	–506.2	–7.17
2.5°C, 7%P	–9.07	–8.11	–1817.3	–13.46	–9.08	–143.5	–3.88	–0.10	–0.1	–0.002	–0.10	–0.0	–0.001	–1673.8	–23.72
5.0°C, 7%P	–30.61	–42.81	–5274.6	–39.09	–47.88	–886.6	–24.02	–0.75	–0.2	–0.009	–1.40	–0.0	–0.051	–4387.7	–62.20
1.5°C, 15%P	20.50	12.73	1010.4	7.48	14.27	177.2	4.80	0.04	0.0	0.000	0.02	0.0	0.000	833.1	11.81
2.5°C, 15%P	9.13	3.32	–148.3	–1.09	3.72	52.4	1.42	–0.01	0.0	0.000	–0.03	0.0	0.000	–200.7	–2.84
5.0°C, 15%P	–15.52	–24.61	–3574.2	–26.48	–27.55	–481.5	–13.04	–0.27	–0.1	–0.003	–0.37	–0.0	–0.006	–3092.6	–43.84

Notes:
Negative values indicate baseline damages.
a. Figures in this row are baseline estimates presented in absolute unit terms.
b. P = precipitation.

Table A5.5 *Simulated effect of climate change on the welfare of water users in the Southeast (millions 1998 USD)*

Climate change scenario	% change in runoff	*Total welfare*			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		% change in with-drawals	Change in welfare ($)		Change in welfare ($)	
			Absolute	Percent.		Absolute	Percent.		Absolute	Percent.		Total	Percent.	Total	Percent.
Baseline[a]	634,165 (kaf/yr)	67,842 (kaf/yr)	21,766		15,097 (kaf/yr)	1,254		16,440 (kaf/yr)	10,875		36,304 (kaf/yr)	8,057		1,581	
1.5°C, 0%P[b]	–14.79	–0.33	–141.1	–0.64	–0.90	–0.2	–0.016	–0.10	0.0	0.000	–0.20	–0.4	–0.004	–140.5	–8.88
2.5°C, 0%P	–23.77	–0.60	–202.9	–0.93	–1.40	–0.4	–0.029	–0.10	0.0	0.000	–0.50	–1.1	–0.014	–201.4	–12.74
5.0°C, 0%P	–42.39	2.78	–529.2	–2.43	16.73	7.8	0.620	–0.30	–0.2	–0.002	–1.63	–7.0	–0.087	–529.8	–33.51
1.5°C, 7%P	1.04	–0.02	3.4	0.01	–0.12	0.0	–0.002	0.00	0.0	0.000	0.01	0.0	0.000	3.4	0.21
2.5°C, 7%P	–9.07	–0.27	–46.1	–0.21	–0.82	–0.2	–0.013	–0.03	0.0	0.000	–0.15	–0.3	–0.003	–45.7	–2.89
5.0°C, 7%P	–30.61	–0.82	–337.8	–1.55	–1.65	–0.5	–0.036	–0.12	0.0	0.000	–0.79	–2.2	–0.027	–335.1	–21.19
1.5°C, 15%P	20.50	0.14	154.2	0.70	0.12	0.0	0.001	0.03	0.0	0.000	0.19	0.2	0.003	154.0	9.74
2.5°C,15%P	9.13	0.06	106.8	0.49	0.00	0.0	0.000	0.01	0.0	0.000	0.11	0.1	0.002	106.6	6.74
5.0°C, 15%P	–15.52	–0.60	–140.1	–0.64	–1.65	–0.4	–0.034	–0.08	0.0	0.000	–0.41	–0.9	–0.011	–138.8	–8.77

Notes:

Negative values indicate baseline damages.

a. Figures in this row are baseline estimates presented in absolute unit terms.

b. P = precipitation.

Table A5.6 Simulated effect of climate change on the welfare of water users in the Southern Plains (millions 1998 USD)

		Total welfare			*Agriculture*			*M&I*			*Thermoelectric*			*Hydropower*	
Climate change scenario	% change in runoff	% change in with-drawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in with-drawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in with-drawals	Change in welfare ($) Absolute	Change in welfare ($) Percent.	% change in with-drawals	Change in welfare ($) Total	Change in welfare ($) Percent.	Change in welfare ($) Total	Change in welfare ($) Percent.
Baseline[a]	239,833 (kaf/yr)	32,369 (kaf/yr)	8,786		15,688 (kaf/yr)	1,594		6,331 (kaf/yr)	4,221		10,350 (kaf/yr)	2,288		683	
1.5°C, 0%P	−14.79	−5.38	−250.1	−2.84	−11.00	−75.8	−4.756	−0.10	0.0	−0.001	−0.10	−0.0	−0.001	−174.2	−25.50
2.5°C, 0%P	−23.77	−11.54	−458.2	−5.21	−23.60	−177.0	−11.098	−0.20	−0.1	−0.002	−0.20	−0.1	−0.003	−281.1	−41.14
5.0°C, 0%P	−42.39	−26.90	−907.9	−10.33	−53.97	−441.9	−27.715	−0.94	−0.5	−0.011	−1.77	−1.7	−0.076	−463.7	−67.87
1.5°C, 7% P	1.04	0.54	−41.7	−0.47	1.17	7.3	0.459	−0.04	0.0	0.000	−0.05	−0.0	−0.001	−49.0	−7.17
2.5°C, 7% P	−9.07	−4.45	−224.2	−2.55	−9.08	−62.0	−3.887	−0.10	−0.1	−0.002	−0.10	−0.0	−0.001	−162.1	−23.72
5.0°C, 7% P	−30.61	−23.80	−809.5	−9.21	−47.88	−383.0	−24.020	−0.75	−0.4	−0.009	−1.40	−1.2	−0.051	−425.0	−62.20
1.5°C, 15% P	20.50	6.93	157.3	1.79	14.27	76.6	4.802	0.04	0.0	0.000	0.02	0.0	0.000	80.7	11.81
2.5°C, 15% P	9.13	1.79	3.2	0.03	3.72	22.7	1.421	−0.01	0.0	0.000	−0.03	−0.0	0.000	−19.4	−2.84
5.0°C, 15% P	−15.52	−13.52	−507.8	−5.77	−27.55	−208.0	−13.044	−0.27	−0.1	−0.003	−0.37	−0.1	−0.006	−299.5	−43.84

Note:

Negative values indicate baseline damages.

a. Figures in this row are baseline estimates presented in absolute unit terms.

b. P = precipitation.

Table A5.7 Simulated effect of climate change on the welfare of water users in the Southwest (millions 1998 USD)

Climate change scenario	% change in runoff	*Total welfare* % change in withdrawals	*Total welfare* Change in welfare ($) Absolute	*Total welfare* Change in welfare ($) Percent.	*Agriculture* % change in withdrawals	*Agriculture* Change in welfare ($) Absolute	*Agriculture* Change in welfare ($) Percent.	*M&I* % change in withdrawals	*M&I* Change in welfare ($) Absolute	*M&I* Change in welfare ($) Percent.	*Thermoelectric* % change in withdrawals	*Thermoelectric* Change in welfare ($) Total	*Thermoelectric* Change in welfare ($) Percent.	*Hydropower* Change in welfare ($) Total	*Hydropower* Change in welfare ($) Percent.
Baseline[a]	152,988 (kaf/yr)	71,077 (kaf/yr)	15,949		59,625 (kaf/yr)	5,467		10,801 (kaf/yr)	7,339		651 (kaf/yr)	173		2,970	
1.5°C, 0%P	−14.79	11.12	134.7	0.84	13.20	133.7	2.44	0.30	0.6	0.009	0.60	0.351	0.20	0.0	0.00
2.5°C, 0%P	−23.77	5.89	−116.5	−0.73	7.00	75.1	1.37	0.10	0.2	0.003	0.20	0.118	0.06	−191.9	−6.46
5.0°C, 0%P	−42.39	−42.27	−2547.0	−15.96	−47.22	−1013.3	−18.53	−14.36	−33.8	−0.461	−52.29	−249.152	−144.20	−1250.7	−42.11
1.5°C, 7%P	1.04	4.97	177.8	1.11	5.92	63.7	1.16	0.07	0.1	0.002	0.15	0.086	0.05	113.9	3.83
2.5°C, 7%P	−9.07	−5.21	−264.0	−1.65	−6.16	−72.4	−1.32	−0.25	−1.1	−0.015	−0.59	−0.351	−0.20	−190.1	−6.40
5.0°C, 7%P	−30.61	−27.62	−1373.5	−8.61	−32.53	−505.2	−9.24	−1.81	−3.9	−0.053	−6.10	−4.086	−2.36	−860.4	−28.97
1.5°C, 15%P	20.50	29.40	1137.9	7.13	34.95	330.9	6.05	0.48	1.0	0.014	1.22	0.706	0.40	805.3	27.11
2.5°C. 15%P	9.13	17.69	669.3	4.19	21.02	210.7	3.85	0.30	0.6	0.009	0.78	0.456	0.26	457.4	15.40
5.0°C, 15%P	−15.52	−8.64	−446.2	−2.79	−10.21	−124.4	−2.27	−0.39	−0.8	−0.011	−0.93	−0.559	−0.32	−320.4	−10.78

Notes:

Negative values indicate baseline damages.

a. Figures in this row are baseline estimates presented in absolute unit terms.

b. P = precipitation.