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# Climate Change and Freshwater Resources

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Earth's climate is warming. This is the unequivocal conclusion of climate scientists. Despite the complexities of climatology, certain consistent trends emerge with implications for water availability: as the world gets warmer, it will experience increased regional variability in precipitation, with more frequent heavy precipitation events and more susceptibility to drought. These simple facts will have a profound impact on freshwater resources throughout the United States, as the warmer climate will reduce available water supplies and increase water demand. Unfortunately, current water law and policy are not up to the new challenges of climate change and resulting pressures on freshwater resources. To adapt to climate change, water law and policy will need to embrace fundamental reforms that emphasize water conservation and more efficient and environmentally sound allocation at the local, regional, and national scales.

The warming of Earth is evident in average global air and ocean temperatures. Polar snow and ice are melting, and the average sea level around the globe is rising. Earth is warming faster than at any time during the twentieth century. Global mean surface temperatures rose 1.33° Fahrenheit (F) (0.74° Celsius (C)) between 1906 and 2005. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 237 (2007) [hereinafter IPCC WORKING GROUP I REPORT]. But during the past fifty years, the rate of global warming has nearly doubled, and eleven of the last twelve years rank among the twelve warmest years on record since 1850. *Id.* Over the next two decades, global warming is forecast to be about 0.4°F (0.2°C) per decade. During the twenty-first century, the best estimates are that average global temperatures will increase 3.2° to 7.2°F (1.8° to 4.0°C), and it is expected that warming in most of North America will be even more intense. *Id.* at 850. Summer temperatures in the American Southwest are expected to rise more quickly than the North American average, while Alaska and northern Canada could warm as much as 18°F (10°C). *Id.* at 889.

One effect of rising temperatures is the atmosphere's increased capacity to hold moisture. For every 1.8°F (1°C) increase in temperature, the water-holding capacity of the atmosphere rises 7 percent. *Id.*, "Frequently Asked Questions" at 13. Increased moisture in the atmosphere will lead to more intense precipitation events, even when regions' annual total amount of precipitation is slightly reduced. In a phrase, when it rains it will pour, but when it does not, you might be looking at a drought.

Climate change is expected to lead to reductions in water supply in most regions in the United States. Scientists predict significant loss of snowpack in the western mountains, a critically important source of natural water storage for California and other western states. As sea levels rise, salt water will intrude on surface freshwater supplies and aquifers on the Pacific, Atlantic, and Gulf coasts. Even the Great Lakes region, which has over 90 percent of the available surface freshwater in the United States, will experience water-supply impacts from climate change. Groundwater supplies are also vulnerable to climate change, as evapotranspiration losses (the loss of water to the air through evaporation and plant transpiration) will drastically reduce aquifer recharge and storage. Expected increases in water demand due to higher temperatures will compound the problem of how to meet increased demand from population growth and economic development. New, widespread conservation and allocation policies will be essential to meet this challenge.

## *How Climate Change Will Affect Regional Water Supplies*

A brief review of how climate change will affect regional water supplies demonstrates the pressures and challenges the country will face. The southwestern United States will become even more arid during the twenty-first century as the subtropical dry zone expands poleward. Over the next century, temperatures in the West are expected to rise 3.6–9°F (2–5° C). Philip W. Mote, et al., *Declining Mountain Snowpack in Western North America*, 86 BULL. AMER. METEOR. SOC. 39, 48 (2005). As mentioned, increased temperatures increase the water-holding capacity of the atmosphere, and warmer air has higher saturation humidity than cooler air. In very wet areas, such as over oceans, where there is adequate moisture, added heat is "used up" primarily by evaporation, so it moistens the air instead of warming it. But in already dry areas, such as the western and southwestern United States, there is little moisture to soften the impact of added heat. As a result, in these areas the added heat from global warming will go primarily to increasing temperature. As relative humidity decreases these areas will receive even less precipitation.

With the generally hotter climates in the West and

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Southwest, those regions will be particularly affected by reduced snowpack in the mountains. The loss of snowpack will reduce the availability of water for California and the other Colorado River basin states (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming). Historically, most precipitation during winter months in western North American mountains such as the Rockies and the Sierra Nevadas has fallen as snow. Snow accumulates until spring and early summer, when warming temperatures melt the snowpack, releasing water as runoff. In most river basins of the West, snow is the largest source of water storage (even greater than man-made reservoirs). As a result, snowpack has been the primary source of water for arid western states during the spring and summer, when their water needs are greatest.

Climate change will continue to cause increasing snowpack losses each year. Under warmer climate conditions such as those expected during the next century, precipitation will be more likely to fall as rain than snow, especially in autumn and spring at the beginning and end of the snow season. This trend is already observable, as the volume of snowpack has been dropping over much of the American West since 1925, and especially since 1950. A study of western snowpack measurements from 1945 to 1955 until the 1990s found that snowpack volume has fallen 15.8 percent in the Rockies, 21.6 percent in the Interior West, and 29.2 percent in the Cascades. *Id.* at 44. Similarly, a review of the scientific literature by the Pacific Institute noted that during the twentieth century, April through July runoff in California's Sacramento River decreased on average by 10 percent, while snowmelt runoff in general came earlier in the year. MICHAEL KIPARSKY & PETER H. GLEICK, CLIMATE CHANGE AND CALIFORNIA WATER RESOURCES: A SURVEY AND SUMMARY OF THE LITERATURE 25 (2003). [hereinafter CALIFORNIA WATER RESOURCES].

Reductions in snowpack volume will accelerate during the twenty-first century. Stream inflows to reservoirs will decline significantly because of diminished snowpack, reduced soil moisture, and increased evaporation before midcentury. By the 2020s, 41 percent of the water supply to Southern California is expected to be in jeopardy due to the effects of reduced snowpack. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: CLIMATE CHANGE IMPACTS, ADAPTATION, AND VULNERABILITY, CONTRIBUTION OF WORKING GROUP II TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 633 (2007) [hereinafter IPCC WORKING GROUP II). In California, inflows to the entire state could be reduced by as much as 27 percent by 2050. JOSUE MEDELLIN, ET AL., CLIMATE WARMING AND WATER SUPPLY MANAGEMENT IN CALIFORNIA: A REPORT FROM THE CALIFORNIA CLIMATE CHANGE CENTER 9 (2006). By 2069, snow cover in California may be almost completely depleted by the end of winter. CALIFORNIA WATER RESOURCES, *supra*, at 10. By the end of the twenty-first century, snowpack volume is expected to decrease by as much as 89 percent for the Sierra-Nevada region draining into the Sacramento-San Joaquin river system. Katharine Hayhoe, et al., *Emissions Pathways, Climate Change and Impacts on California*, 101:34 PROC. NAT. ACAD. SCI., Vol. 101, No. 34, 12422, 12425 (2004).

The situation is similar throughout most of the western United States. The Colorado River is the only significant water source for much of the Southwest. While important to Southern California, it also supplies water to Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. As a result of reduced snowpack, streamflow in the Colorado River is expected to decrease significantly in the twenty-first century, with predicted reductions of as much as 45 percent by 2050. Brad Udall, *Recent Research on the Effects of Climate Change on the Colorado River*, INTERMOUNTAIN WEST CLIMATE SUMMARY 2, 6 (May 2007). In addition to the obvious resulting water shortages, the expected loss of snowpack may also lead to increased river salinity, which impacts compliance with the 1944 Colorado River Treaty. *See* PETER H. GLEICK, ET AL., WATER: THE POTENTIAL CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE, REPORT OF THE NATIONAL WATER ASSESSMENT GROUP FOR THE U.S. GLOBAL CHANGE RESEARCH PROGRAM 55–57 (2000) [hereinafter NATIONAL WATER ASSESSMENT GROUP REPORT].

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Relatively humid coastal areas will face their own challenges. Increasing salinity in freshwater supplies will become a bigger concern in coastal areas as the sea level rises due to thermal expansion (expansion of water as it warms) of the oceans, increased melting of glaciers, and melting of the Greenland and Antarctic ice caps. The oceans are warming from absorbing more than 80 percent of the heat that is added to the climate system; increases in ocean temperature are observable down to depths of almost 10,000 feet (ft) (3000 meters (m)). INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, SUMMARY FOR POLICYMAKERS 5 (2007).

Sea level is already rising worldwide, and the rate of sea level rise is expected to increase in the future. Mean sea levels have risen approximately 5 to 9 inches (in) (12 to 22 centimeters (cm)) since the 1890s. *Id.* at 7. IPCC Working Group I predicts that global mean sea levels will rise about

7–23 in (18–59 cm) by 2100, assuming that melting of the Greenland and Antarctic ice sheets does not accelerate. *Id.* at 13. A more recent study indicates that the IPCC projections might be conservative and global sea levels could rise as much as 20–55 in (50–140 cm) by 2100. Stefan Rahmstorf, et al., *A Semi-Empirical Approach to Projecting Future Sea-Level Rise*, 315:5810 SCIENCE, 315, 368 (Jan. 19, 2007).

Rising sea levels push saltwater further inland in rivers, deltas, and coastal aquifers, causing saltwater intrusion on coastal freshwater supplies in many coastal states. Salinity problems in coastal areas are typically most acute during late summer and early fall. Water demand at these times is high, and additional pumping from aquifers facilitates saltwater intrusion. Releasing water from reservoirs can sometimes help keep saltwater out of aquifers (by reducing demand), but water availability to reservoirs is typically low in late summer and early fall. In addition, the earlier snowmelt expected from warming temperatures will extend the drier summer season and create more opportunity for saltwater intrusion.

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Most climate models predict that Great Lakes water levels will drop during the next century below historic lows. Lake levels in Lake Michigan and Lake Huron may drop by as much as 4.5 ft (1.38 m) due to a combination of decreased precipitation and increased air temperature/evapotranspiration. Brent Lofgren, et al., *Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two* GCMs, 28:4 J. GREAT LAKES RES., 537, 546 (2002). Drastic reductions in ice cover may also result from air and lake temperature increases. By 2090, most of Lake Erie is projected to be ice free during the winter 96 percent of the time. *Id.* at 550–51. The loss of ice cover will lead to increased evaporation losses for the Great Lakes.

Lower lake levels and rising temperatures, both in the air and water, will significantly impact fisheries, wildlife, wetlands, shoreline habitat, and water quality in the Great Lakes region. The impacts are not only an environmental concern, but also have a huge economic cost. Tourism and shipping are critically important to the region, and both industries are extremely vulnerable to climate change impacts. Further, the increased variability in timing, intensity, and duration of precipitation under global warming conditions is expected to increase the frequency of droughts and floods in the Great Lakes region. Overall, stream runoff is expected to decrease, and baseflow (the contribution of groundwater to streamflow) could drop by nearly 20 percent by 2030. INTERNATIONAL JOINT COMMISSION, CLIMATE CHANGE AND WATER QUALITY IN THE GREAT LAKES REGION 45 (2003).

Climate change will also affect groundwater resources throughout the country. Groundwater contributes flow to many rivers and streams and is an important source of drinking and irrigation water. Climate change is expected to reduce aquifer recharge and water levels, especially in shallow aquifers. Higher temperatures and droughts will result in increased evapotranspiration. Aquifers will also suffer from the trend of heavier precipitation events, because more water will go to runoff before it can percolate into aquifers. Thus, even in a future where overall precipitation increases, aquifer levels may decrease, due to the increased intensity of precipitation events.

The Edwards Aquifer in Texas is expected to have lower or ceased flows from springs, reducing the supply of available water. In the Ogallala Aquifer region, which includes portions of South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, groundwater recharge is expected to decrease by more than 20 percent if temperatures increase by 4.5°F (2.5°C). IPCC WORKING GROUP II at 629. In the Ellensburg basin of the Columbia Plateau in Washington State, aquifer recharge rates could decrease by as much as 25 percent. NATIONAL WATER ASSESSMENT GROUP REPORT, *supra* at 59.

Hotter and drier climates, loss of snowpack for water storage, rising sea levels and salt water intrusion, and declining groundwater supplies will create water shortages in many parts of the country. Some regions, such as coastal California, may be hit with all of these impacts simultaneously. Unfortunately, the loss of freshwater supplies is only part of the problem. Climate change will also increase demand for freshwater unless new conservation and water allocation policies are implemented.

Even without the additional pressures of climate change, population and economic growth are expected to put more demand on already stressed water resources in many regions. In California, for example, the state's population is expected to double or triple over the next century. Regional growth in the Portland area is expected to increase water demand by 5.5 billion gallons (20.8 million cubic meters) per year by the 2040s. IPCC WORKING GROUP II, *supra* at 628. The Colorado River Basin already has high water demand relative to supply, and under predicted future growth, total system demands are expected to exceed the regional water supply.

Climate change will only exacerbate these problems. The potential for increased demand due to higher temperatures comes from all types of water use. Domestic use, especially for outdoor purposes, such as yard and garden irrigation, is expected to rise with warming temperatures. Industrial use may increase as well. Water is used for cooling in many electrical generating systems. An increase in water temperature would decrease the cooling efficiency of the water and require more water to be used. Similarly, demand for water will increase to compensate for loss of precipitation in many areas.

The most significant water demand problems relate to irrigation. Irrigation accounts for 39 percent of all U.S. water withdrawals and 81 percent of consumptive water uses. Unlike some other water withdrawals that return most of the water to the watershed, water withdrawn for irrigation is mostly consumed. NATIONAL WATER ASSESSMENT GROUP REPORT, *supra* at 81. Although it is difficult to forecast future irrigation needs, it appears that demand will increase substantially in regions where future drying is expected, such as the Great Lakes region and the Southwest.

Climate change is expected to directly and indirectly increase demand for agricultural irrigation. Irrigation needs will be as much as 39 percent higher in Nebraska and 14 percent higher in Kansas, assuming there are no changes in the irrigated area. Even with increased irrigation, crop yields can still be adversely affected by higher temperatures. In the corn belt of the United States, yields of corn and soybeans from 1982 to 1998 were negatively impacted by warm temperatures, decreasing 17 percent for each 1.8°F (1°C) of warm temperature anomaly. IPCC WORKING GROUP II, *supra* at 624. The reduced yields may spark efforts to increase planted acreage, thereby further increasing demand for water. In response to high prices from growing demand in the energy sector, farmers in other regions will begin to grow biofuel crops, thereby inducing new irrigation demands in their regions. Some regions, mostly in the South, will probably have the necessary water resources, but other regions will experience problems due to the added demand. In the Great Lakes region, the growing season is expected to extend in the future, and double cropping (the planting of a second crop after the first has been harvested) could become more common, with resulting increased demand for irrigation.

The predictions for increased water demand present a major challenge but also an opportunity. Water conservation policies and laws will slow these trends and in certain places will have the potential to reverse them. Just as mitigating climate change requires a national effort to invest in energy conservation and efficiency, adapting to climate change will require every sector of the economy to invest in water conservation. Similarly, all levels of government will need to reexamine policies that often produce inefficient water allocation outcomes. By adopting new laws and policies that adapt to increasing water scarcity with an emphasis on water conservation and more efficient allocation of water at the local, regional, and national scales, the United States can prepare for the new challenges of climate change.

## *Reforming Water Law and Policy to Adapt to the Challenges of Climate Change*

Meeting the challenge of climate change requires both policies to mitigate the greenhouse gas emissions that cause climate change and policies to adapt to the unavoidable climate change impacts on water resources. To avoid the worst impacts of global warming, many experts warn that the United States must reduce its greenhouse gas emissions by 80 percent by 2050, or about 2 percent per year, which is the goal of bills currently pending in Congress. This is an attainable goal, and many of the technologies and tools needed to accomplish it are already available. *See* TACKLING CLIMATE CHANGE IN THE U.S.: POTENTIAL CARBON EMISSIONS REDUCTIONS FROM ENERGY EFFICIENCY AND RENEWABLE ENERGY BY 2030 (Charles F. Kutscher, ed., American Solar Energy Society 2007), *available at* www.ases.org.

The general notion that there is always more water available from another source may be history as climate change stresses almost every source of freshwater.

At the same time, it is imperative to reform water resource laws and policies to adapt to a changing climate. In the past, when water supplies have been stressed or demand has exceeded supply in a given location, the general approach has been to find more water from another source. Surface water users start pumping groundwater, water sources from increasing distances are utilized, and communities look to divert water from other basins or regions. These approaches, however, may no longer be viable in a future of climate change for at least three reasons.

First, the general notion that there is always more water available from another source may be history as climate change stresses almost every source of freshwater. As river flows decrease due to loss of snowpack, freshwater aquifers will suffer from salt water intrusion in coastal areas due to sea level rise. Similarly, the same climate conditions that may cause Great Lakes levels to drop will also reduce aquifer recharge due to higher evapotranspiration rates. Nearly every part of the country will feel the water stress of climate change, so attempts to divert water from neighboring or distant basins and regions may not be viable and would certainly be strongly opposed.

Second, simply taking more water from the natural system has biological, ethical, and increasingly legal limitations. In recent decades, we as a society have become increasingly protective of all of our natural water systems. Our scientific understanding of the ecological needs of freshwater systems has improved dramatically. People value rivers not just as a source of water for irrigation or cooling a power plant, but also for fishing, recreation, aesthetics, and deeper ethical purposes. This increased knowledge and awareness of broader values for freshwater has reformed water resource law and policy. The public trust doctrine, in-stream flow protections, the Endangered Species Act, and environmental review laws at the federal and state level have increased protections for natural water systems. As a result, simply diverting more water from a river or pumping more water from a lake is no longer as legally easy as it used to be, nor should it be. Further, adapting to climate change will require increased protections for natural systems to withstand new stresses and for preservation of wildlife, fisheries, and ecosystem services.

The answer is both simple in its logic and tremendously radical in its policy implications—we need to use less water to meet our needs.

Third, and most significant, all of the traditional methods of getting more water require energy. Pumping groundwater from deeper levels requires more electricity, so as aquifer levels drop, electricity demands and costs increase. The land and ecosystem costs of adding reservoirs are high, and their presence, though helpful, adds new evaporative losses that increase as a function of temperature. Similarly, just moving water over long distances and over elevation changes requires huge amounts of energy, not to mention the energy embedded in the massive infrastructure. Yet energy use because of carbon emissions has been the root cause of climate change. Mitigating this problem will require large reductions in the use of fossil fuels, which are the major energy source in the United States. At a minimum, it is a good bet that energy will become more expensive as the externalities of carbon emissions are reduced through new laws and policies. So using more energy to get more freshwater will be robbing Peter to pay Paul in the era of climate change.

The tradeoff between energy usage and freshwater supply is not just limited to the pumping and transportation of water. Desalination, the technological oasis in the desert for freshwater supply, is tremendously energy intensive. Estimates for energy consumption range from 2,500 to 15,000 kilowatt hours (kWh) per acre-foot of water. SUSAN E. PANTELL, ET AL., SEAWATER DESALINATION IN CALIFORNIA, CHAPTER 1 (1993). The city of Santa Barbara's desalination plant operates toward the lower end of this range, and its energy requirement of 50 million kWh per year to produce 7,500 acre-feet of water is two to three times as much as that required to pump the same amount of water from the Colorado River Aqueduct or the State Water Project to the Metropolitan Water District of Southern California. *Id.*

Further, the largest carbon-neutral source of electricity in the United States presently is hydropower. Hydropower accounts for approximately 7 percent of the electricity consumed in the United States. *See U.S. Energy Information Administration*, www.eia.doe.gov/. Certain regions are particularly hydropower dependent. Washington State leads the pack with about 71 percent of its electricity coming from hydropower, while New York comes in at 18 percent. *Id.* Hydropower is highly sensitive to reductions in flow, and the same climate change impacts that will reduce water supplies will also diminish the output of hydropower plants. For example, the complicated management system on the Columbia River has been developed over more than sixty years and seeks to balance the Columbia's historical seasonal flows with flood control and power demands in the Pacific Northwest. But by 2095, climate models suggest that the Columbia River Basin will no longer be dominated by snowmelt dynamics, and the infrastructure that took so long to develop may need to be replaced or updated to respond to new conditions.

So if we cannot simply find new sources of water, take more water from the natural systems, or trade energy for water to meet the challenge of climate change, what is the solution? The answer is both simple in its logic and tremendously radical in its policy implications—we need to use less water to meet our needs. To meet this challenge, we must reform water law and policy to emphasize conservation and efficient, environmentally sound allocation at the individual/local, regional, and national scales.

At the local/individual level, water law has historically paid only lip service to water conservation. Eastern riparian water law only allows use of water that is "reasonable," *see, e.g., State v. Zawistowski*, 290 N.W.2d 303, 309 (Wis. 1980), yet this has rarely been interpreted to require conservation technologies and even more rarely used to question the fundamental appropriateness of certain water uses in the context of total water supplies. Under the stress of climate change, courts may be urged to put teeth into reasonable use determinations and recognize that uses that may have been historically reasonable when freshwater was relatively abundant may no longer be acceptable. Similarly, western prior appropriation law prohibits "waste" of water, yet again courts (and more commonly now state water agencies charged with managing appropriative rights) have been reluctant to scrutinize the wisdom of any given water use or overall water use allocations in light of environmental conditions. *See* Steven J. Shupe, *Waste in Western Water Law: A Blueprint for Change*, 61 OR. L. REV. 483 (1982).

The enormity of the task and its implications for interests vested in the status quo of water use may explain courts' reluctance to use existing water law doctrines to adapt to climate change stress. Perhaps courts, faced with competing demands for a limited water supply, will require improved water conservation measures by all parties in an attempt to make most people happy. But managing water by adjudicating disputes between competing users is not adequate to meet the challenges of climate change. Litigation over water rights is incredibly time consuming, and rulings may soon be mooted by changed conditions. Further, courts are not the best forum to address the fundamentally inefficient system of water use and allocation in the United States that needs to be reformed.

At the regional scale, two models of interstate water management dominate. In the West, management of shared freshwater resources such as the Colorado River and the Rio Grande typically focus on allocating defined water rights among the party states. An interstate compact is used to divide the proverbial pie into agreed pieces. However, not only do these compacts fail to require water conservation, but the assumed quantities on which the allocations are made may be less in a future of climate change. The Colorado River Basin states are beginning to grapple with this problem, and while some progress has been made, they are far from a lasting solution. In addition, there are many unresolved issues regarding the existence and measurement of the federally reserved water rights of Indian tribes. *See* Robert T. Anderson, *Moving Beyond the Current Paradigm: Redefining the Federal-Tribal Trust Relationship for this Century*, 46 NAT. RES. J. 399, 414 (2006).

In the East, management of shared river systems has been more comprehensive and regulatory. For example, the Delaware River Basin Compact, 75 Stat. 688 (1961), creates a centralized interstate management authority with broad regulatory powers for permitting and managing individual withdrawals or diversions of all waters in the river basin. *See* Joseph W. Dellapenna, *Interstate Struggles Over Rivers: The Southeastern States and the Struggle Over the "Hooch,"* 12 N.Y.U. ENVTL. L. J. 828 (2005). This approach provides a far better foundation for both requiring water conservation of individual users and proactively planning for changes in water supply that necessitate new allocations. The proposed Great Lakes-St. Lawrence River Basin Water Resources Compact, currently under consideration by the Great Lakes states, requires individual state programs to regulate water uses with conservation and environmental protection standards. *See* Noah D. Hall, *Toward A New Horizontal Federalism: Interstate Water Management in the Great Lakes Region*, 77 COL. L. REV. 405 (2006). It also creates a regional body to plan, conduct research, prepare reports on water use, and forecast water levels—all critically important elements of adapting to climate change.

Thus, while some reform is needed at the individual/local and regional scales, many of the building blocks are in place, and progress is being made. The most fundamental and difficult reforms will be needed at the national scale. The changed water supply picture associated with climate change portends economic relocations and dislocations. For example, in the Colorado River Basin, it is hard to imagine that any agricultural use of the shrinking water supply will be able to withstand the political and economic pressure to give up the water to support growth and development in the region's fast-growing population centers in Southern California, Central Arizona, Las Vegas, and on the Front Range. Indian water rights must also be considered in any settlements. *See generally* FELIX COHEN, HANDBOOK OF FEDERAL INDIAN LAW 366–382 (United States Government Printing Office 1945) (2005).

The change in the cost and availability of water will eventually recalibrate the competitive agricultural balance. Under conditions of increased temperature and even less favorable timing of water flows, continued reliance on irrigated agriculture for low-value forage crops and associated ranching in the most arid regions will cease and move to areas where either water or dry-land forage is more plentiful. Similarly, the energy cost of pumping groundwater from greater depths in the Ogallala Aquifer will increase the cost of corn production there. Eventually, even with corn prices likely to be buoyed by the growth of the biofuels industry, that same corn will be more competitively produced in water-rich regions, such as Alabama. Despite poorer soils, Alabama currently receives over 50 in of rain per year and may see an increase with climate change. If Alabama corn farms irrigated about 4 to 8 in per growing season from easily dug on-farm ponds, its corn yields could be competitive with average yields from the current corn belt. Richard McNider, et al., *Hydrological and Hydro-illogical Cycles: Managing Short-Term Droughts in the Southeast*, *available at* www.usawaterquality.org/conferences/2007/PPTs&Posters/Meetings/Water_Quantity/McNider.pdf.

Using water markets to more efficiently allocate water resources has some promise, but there are also severe hurdles to overcome. Water use is heavily subsidized, and rights in water are less certain than in many other forms of property, making a true market difficult to achieve. In the West, water subsidies for irrigation alone amounted to $4.4 billion per year, according to a 1997 study. David Pimentel, et al., *Water Resources: Agriculture, the Environment, and Society*, 47 BIOSCIENCE 97, 102 (1997). In the East, the system of riparian rights gives water users a limited right to use a certain location's water if it is not easily transferred to other uses and locations. Further, water in its natural state is a public good, especially in navigable waterbodies, limiting the ability to privatize and market the resource.

There is no single silver bullet for adapting to the stress that climate change will put on water resources. Water will become more scarce and valuable, and many of the historic responses to water shortages will not work in a future of climate change. The legal system provides some tools for adaptation, but only if water conservation is taken seriously. Even with conservation and adaptive management at the local and regional scales, water resource management will require federal attention. Agricultural production will need to move to areas better able to sustain the associated water demand, water use subsidies will become even harder to justify, and a culture of water conservation will need to be promoted in all sectors. The days of taking freshwater for granted will be over, and a new water ethic will be needed.