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Framing Water Policy in a Carbon Affected and Carbon Constrained Environment

Robert H. Abrams

Noah D. Hall

ROBERT H. ABRAMS & NOAH D. HALL*

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ABSTRACT

Climate change driven by greenhouse gas emissions is substantially altering water availability while increasing water demand. Shifts in domestic energy policy and production, while needed to confront the challenge of climate change, may further stress the nation's water resources. These changes and new demands will be most severe in regions that are already experiencing water stresses and conflicts. This article examines the extent of the changes in water supply and demand by assessing how water conflicts will be addressed in the four overarching water use categories: water for population security, water for ecological security, water for energy security, and water for food security. The analysis suggests that water governance institutions and policies need to be retooled to better accommodate the necessary reallocation of water that will serve the nation's water security needs.

INTRODUCTION

This article addresses the potentially immense stress recently thrust upon the nation's water resources by massive changes affecting water supply and demand. The climate, driven by emissions of carbon and other greenhouse gases (GHG), is changing in ways that substantially alter water availability in the United States. At the same time, fundamental changes in the domestic energy sector, aimed at reducing GHG emissions and increasing energy independence, will restructure water demand in relation to fuels and electric generation. The upheaval in the energy sector comes at the same time other vital water demands for population security, ecological security, and food security are also escalating. This article is meant to be informative more than prescriptive, offering broad approximations of what the changed water supply and demand patterns will look like in the next few decades. The article also examines

* Robert Haskell Abrams is a Professor of Law at Florida A & M University, College of Law. Noah D. Hall is an Associate Professor of Law at Wayne State University Law School. The authors are grateful for the assistance of Anjali Patel (J.D., University of Michigan Law School), Wesley Lamey (J.D., Wayne State University Law School), and Joseph Dillon (J.D. candidate at Florida A & M University, College of Law) for their excellent research and technical assistance.

several foreseeable water use conflicts and how they are likely to be resolved under the influence of economics, politics, and legal doctrines.

What this article does not do is prescribe a laundry list of specific policies or actions to be taken, nor does it offer certain or specific predictions. Projections made now about the impacts of climate change begin against a backdrop of uncertainty about specific localized impacts and the likely pace at which alternative energy and transportation technologies will develop.

Governance structures are also uncertain. The sovereign interests of the states, the programmatic interests of federal agencies, and the economic interests of water using entities and individuals ensure that even finding a forum for broad-scale policymaking will be difficult. Nevertheless, one set of conclusions will describe what parts the national government, the state governments, and regional institutions will play in making decisions and creating solutions to the nation's water use problems.

This uncertainty and complexity does not, however, justify policy and scholarly inaction. Failing to undertake a water policy inquiry in the face of a carbon affected and carbon constrained future is not a viable option. To refuse to envision that future is risking being unprepared for when today suddenly becomes tomorrow and water demands greatly outstrip reliable supplies. Failing to grasp the key relationships in advance risks intolerable social and economic dislocations that are traceable to the misuse of water resources.

A few things are clear at the outset. Since the path to a coherent water policy response is a long one, and the means of implementing it longer still, starting sooner is good, and planning for extra time in which to achieve the result is better. As noted above, embarking on the path to a coordinated state-federal water policy is immediately necessary. For now, water conservation, vigorously sought and obtained, can ease the supply-demand imbalance, thereby offering additional time to fashion appropriate long-term policy. Conservation is not extensively discussed in this article because it is such an obvious first option in virtually every sector of water use. Conservation cannot forestall all short-term conflicts, but it can sufficiently reduce their number and severity, which allows for each conflict to simultaneously be a case study of policymaking processes and results. Longtime observers of the field have a sense that the improving response of contemporary water law to many other allocation problems, such as tribal reserved rights and interstate water disputes,[1] is an accretive result of lessons learned by trial and error as past cases demanding resolution have come and gone.

Having established issue awareness as the primary goal of this article, what follows is a high-level description of foreseeable changes in domestic American water supply and demand, linked to a discussion of the policy implications of the changing supply and demand functions. The water supply side is "carbon affected." Regional climate change associated with global warming is altering the timing of flows, the intensity of both precipitation and drought events, and the amount of water available.

The changes on the water demand side are more complicated, however. Anticipating changes in water demand laps over into making predictions about water use, water allocation, and water law. As has always been the case historically, water law evolves instrumentally in ways that support a society's most pressing needs.[2] The periods of greatest change in water law tend to be the ones where serious and protracted shortage or unsatisfied demand is felt in one or more key economic sectors. At such times, even without adopting a hierarchy of uses, water law evolves to reallocate the available water to ensure sufficient supply for the most important uses. For the purposes of this article, the four water uses that are canvassed and have the potential to affect changes in water law and allocation are water for: (1) population security, (2) environmental security, (3) energy security, and (4) food security. These water uses are discussed in order of their hierarchy for water supply needs. While energy security is not at the top of the hierarchy of uses, it is the most significant water use by volume and is at the center of the climate change challenge, and thus will be the principle focus of this article.

Water for population security includes, of course, enough water for drinking and basic household needs. Providing that water for con-

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1. It is tempting to object that the Apalachacola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) disputes undermine the assertion in the text, but by western water dispute standards these cases are still young, and, more tellingly, the participants are inexperienced. *See, e.g.*, Robert Haskell Abrams, *Settlement of the ACF Controversy: Sisyphus at the Dawn of the 21st Century*, 31 HAMLINE L. REV. 679 (2008). These cases are discussed *infra*, at Part III.A. Contrast with the ACF and the ACT the stability of the Delaware River Basin Compact and Susquahenna River Basin Compact in the East, and recent progress on the Colorado and Columbia in the West, and the claim of the text rings true.

2. *See, e.g.*, Morton J. Horwitz, *The Transformation in the Concept of Property in American Law: 1780–1860*, 40 U. CHI. L. REV. 248 (1973); Robert H. Abrams, *Charting the Course of Riparianism: An Instrumentalist Theory of Change*, 35 WAYNE L. REV. 1381 (1989). *But cf.*, KARL WITTFOGEL, ORIENTAL DESPOTISM: A COMPARATIVE STUDY OF TOTAL POWER 15–18 (1957) (water supply necessity having a determinative role on social organization).

centrated populations is of particular concern.[3] The concept as used here is broader and extends beyond mere domestic water use to a category more or less congruent with municipal and industrial (M & I) water use—that is, water that supports concentrated populations and their means of earning a livelihood.[4] Population growth increases total water demand, and the vast majority of contemporary rapid population growth in the United States is in areas that are already decidedly water stressed.

Water for ecological or environmental security is a category created as an acknowledgment of the fact that ecosystems cannot be sustained without water. Whether the measure is the canary in a coalmine approach of listing species under the Endangered Species Act, or prescribed minimum levels and flows, or a benefit-cost analysis that considers ecosystem services,[5] ecosystem collapse brought on by overuse of water resources is no longer an acceptable outcome. Whether as a matter of stewardship or self-interested harvesting of the myriad water and non-water benefits that will otherwise be lost, water for the environment is as necessary as water for people. Water for ecosystem security is, almost by definition, only a problem when water has become so scarce that further drafts on the water source threaten to harm the underlying resource complex. This form of water security also has a push-pull relationship with population. Particularly in the contemporary era, the quality of the natural environment is one of the attractions that excite regional growth and, with that growth comes an increase in water demand for population security.[6]

Water for energy security is a somewhat novel blending of two concepts. The first thread addresses the familiar concern of reducing energy dependence on unstable foreign sources. This is a century-old concern[7] that has recently been exacerbated by rapidly growing oil demand in China and India. The increased demand-side pressure caused world oil prices to skyrocket in 2008, slowing the American economy. Without

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3. Water for dispersed populations is of equal importance, but it is seldom problematic. Most locales, even most arid ones, have sufficient water resources to support small numbers of people at low densities.

4. The part that is less congruent with most current examples of M & I use is a requirement of stringent conservation, particularly in regard to limits on landscape irrigation.

5. *See, e.g.*, J.B. Ruhl & James Salzman, *The Law and Policy Beginnings of Ecosystem Services*, 22 J. LAND USE & ENVTL. L. 157 (2007).

6. There are exceptions, such as the in-migration into the Las Vegas, Nevada, area. But widespread regional growth of the West is spurred by the desire of new residents, increasingly joined by existing residents, to protect and preserve the ecological foundation and environmental quality of the region.

7. *See infra* note 133 and accompanying text (discussing issues created by U.S. foreign energy dependence).

considering the geopolitical insecurity of many oil sources, the impact of high prices is in itself a justification to pursue the goal of reduced oil dependence.

The second thread of water for energy security highlights the often-overlooked water demand associated with energy production. Linking those threads is the vast trans in domestic energy production facilities needed to sustain long-term economic growth. Here, the security concept begins by taking account of the national imperative to reduce dependence on costly and dwindling oil reserves from unstable sources. To achieve energy independence, the United States must offset its foreign oil consumption with energy generated from other fuels. The thread continues by looking at the water footprint of the domestically available alternatives. Energy generation requires massive amounts of water, and under the current energy security climate, the total amount of water consumed through energy production is increasing rapidly.

The "carbon constraint" is a crucial element that increases water demand in three distinct ways: (1) water for "clean" fuel production, (2) cooling water for energy generation that allows the substitution of "cleaner" fuels for "dirtier" carbon fuels, and (3) water for carbon emissions reduction. Carbon emissions from energy generation (both stationary and mobile sources) are at the heart of global warming, and eliminating a large proportion of the world's high carbon-emission fuel sources is a global imperative. Biofuels produced from irrigated corn or sugar crops—and ethanol in particular—are an obvious example of the energy-water link. Cultivating corn requires irrigation, which increases regional water demand. Transforming corn into fuel is also water intensive. Generating energy from the new fuel, if it takes the form of electricity, requires water for cooling the power plant. In this and other examples, increased water use is one of the key components of increased domestic energy production and generation.

Water for food security is a category that includes the water needed to raise enough food for domestic consumption in the United States and, increasingly, for economic and humanitarian export. The problem in this category is that current American food production is water intensive. The largest and most productive farms and ranches are disproportionately located in arid and semi-arid areas that are likely to become even more arid with climate change. In the Ogallala Aquifer region, a combination of decreased precipitation and more intense rainfall has reduced the already slow rate of recharge. In the Colorado River Basin and California's Central Valley, reduced winter snowpack and increased summer evaporation due to higher temperatures will undercut already short water supplies that are increasingly being sought to sustain population and ecological security. If additional water cannot be found, the lost food and fiber production in those regions will either disappear altogether, or migrate to areas with a more abundant water supply.

The remainder of this article will delve into selected aspects of the water future of the United States. The overall goal is to sketch broad outlines of water supply and demand changes, focusing on those that hold the potential to create substantial conflict over water use. Assessing the potential for conflict requires some degree of localization. Large-volume water availability and use are significantly place related. Cheaply and easily transporting large quantities of water is achievable only by force of gravity, and usually only within their basins of origin.

Part I of this article explores the supply side of the U.S. water future as it relates to climate change. The severity and types of expected impacts are not uniform across the United States. In areas where water supplies diminish as a result of climate change, current water use conflicts will be intensified and new ones may emerge. Water management challenges are also predicted for areas that have ample precipitation due to the intensification of extreme weather events.

Part II is an examination of historic patterns of water use and how future demand can be predicted from past use. Recent water use data, broken down by sector and location, provides a series of time sequence measures that can be seen as the intersection of the curves for water supply and water demand in each region and use sector. Across a 50-year time horizon, several discernible trends can help predict future demand, although not necessarily demand that will be satisfied. Water use conflict indicates that regional demand already exceeds supply. Conversely, absence of conflict indicates that the current use figures reliably reflect current demand and that water supply has not been a substantial limiting factor. Looking to the future, Part II then extrapolates water use trends as a baseline measure of demand. This effort helps to identify which current conflicts will continue and intensify. In regions where there has been little past conflict, but in which water use is trending upward, the possibility of conflict is heightened.

Parts III and IV are attempts to address water use sectors that need water security. The security concept emphasizes the importance of the uses. The four areas, as previously noted, are water for population security, ecological security, energy security, and food security. Despite the grave importance of all four types of security, there is an inevitable hierarchy among them when water is scarce.

Part III is an examination of the most indispensable hierarchal elements, water for people and the environment. It is also an attempt to explain the priority of these uses, the quantities of water involved, and situations that will present conflicts between these two preeminent uses.

Part IV is a treatment of the two mammoths of water use, energy and agriculture. These sectors account for the vast majority of the nation's water withdrawals and consumption.[8] The water consumption rate in the energy sector is an especially critical variable because these already enormous withdrawals are increasing at an alarming rate. Thus, even a small change in consumption rates would make a large difference in the remaining water available for other uses. The bulk of Part IV addresses water for energy security by trying to project the quantities of additional water that will be needed and the locations where the water will be used. The energy sector will experience massive changes in its structure due to the immense pressure to reduce dependence on imported fuels and to produce energy while still reducing GHG emissions.

Part IV ends with a brief look at water for food security. The examination is premised on the belief that the competition over water between energy security and food security ordinarily will be won by energy security for two related reasons. First, lost food production can be more easily averted or replaced. Increased irrigation efficiency reduces the water needs of agriculture while maintaining production levels. Where increased efficiency is too expensive, or water must move to serve a higher security demand, replacement of food production, and hence the maintenance of food security, will be achieved by relocation of the agricultural production to regions where water is more plentiful.

The conclusion of the article sorts out the implications of the analysis. Predicted events are ranked in terms of their likelihood and potential for significance. In a similar fashion, the conclusion suggests what parts of the water supply and demand picture require proactive responses and what parts can be left for gradual adjustment by existing water governance structures.

I. FORETELLING WATER SUPPLY IN THE UNITED STATES IN A CARBON ALTERED CLIMATE

Giving a meaningful account of domestic U.S. water supply is a complicated undertaking. Historically, however, there is an ample body

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8. Water withdrawn is the total amount of water taken from the natural source. Of this total, water consumed is the portion of the withdrawal lost or otherwise not returned to the natural source due to evaporation, incorporation into products, or other processes. Consumptive use can be far less than the total withdrawal. Estimated consumptive-use rates vary by water use sector. One study from the Great Lakes region shows that consumptive-use rates range from 1 to 2 percent for many power plants, to 10 to 15 percent for public water supplies, to 70 to 90 percent for agricultural irrigation. *See* GREAT LAKES COMM'N, TOWARD A WATER RESOURCES MANAGEMENT DECISION SUPPORT SYSTEM FOR THE GREAT LAKES—ST. LAWRENCE RIVER BASIN 60 (2003), *available at* http://www.glc.org/wateruse/wrmdss/finalreport.html (last visited July 21, 2010).

of data from which to calculate accurate average annual streamflow and surface water measures for all regions of the nation. Similarly, the science of hydrogeology has advanced enough that the contours of most important aquifers, the amount of recharge they receive, and their productive capacity can be measured. Together these two sources of water set the physical upper bound of possible domestic water supply in the United States.[9] As a practical and legal matter, the physical water supply available for human initiated uses is determined after sufficient surface water is left in place for fundamentally important *in situ* uses. Groundwater supplies are similarly limited because some are too expensive to be worth producing or are reserved for future use.

Vagaries of climate and topography skew the natural distribution of water across a nation as vast as the United States, giving water supply a very distinct localization effect. Generally, water is relatively scarce in the Southwest and Mountain West and relatively plentiful from the Mississippi Valley eastward. Correspondingly, the broad regional water supply profiles vary considerably. At a more detailed level, each region has a natural distribution of supply due to water's physical characteristics—it is a heavy, hard to confine liquid that under the ever-present force of gravity travels freely downhill if it is allowed to do so, following the evolved natural channels that the water itself has cut over geologic time. Some alterations of the natural patterns of supply are possible—the most common of which are time-shifting storage projects and a number of interbasin transfers to meet critical demands. While water is not invariably a purely local resource, new water supply projects come with a tremendous economic and ecological price tag.[10]

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9. Additional freshwater can be produced by techniques such as desalination of seawater. This is technologically feasible, but the cost of producing that water is sufficiently high that only municipal supply and a small number of industrial uses can bear the cost. The cost is largely a function of the energy required for desalination. Desalination requires 2,500 to 15,000 kilowatt hours to produce an acre-foot of water. SUSAN E. PANTELL ET AL., CAL. COASTAL COMM'N, SEAWATER DESALINATION IN CALIFORNIA Ch. 1 (1993). The city of Santa Barbara's desalination plant is relatively energy efficient, and still its energy requirement of 50 million kilowatt hours 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.* A more recent proposal from San Clemente, California, known as the Dana Point Ocean Desalination Project, is expected to produce freshwater at a cost of $1,287 per acre-foot. *See* Norb Garrett, *A Desalination Plant for San Clemente?*, SAN CLEMENTE TIMES, Apr. 23, 2008, *available at* http://www.sanclementetimes.com/view/full_story/6696518/article-A-Desalination-Plant-for-San-Clemente-? (last visited July 21, 2010).

10. California has reached a bipartisan deal to spend almost $10 billion on new water storage and conveyance projects (the deal also includes some good water conservation and ecosystem restoration initiatives). *See* Press Release, State of California, Office of the Governor, *available at* http://gov.ca.gov/press-release/10148/ (last visited July 21, 2010).

For both ground and surface water, the extent of the predictably available water supply is a matter for scientific assessment. A sustainable water supply requires renewable sources such as surface flows, groundwater recharge, and, occasionally, reliable imports. In some regions these renewable sources are meaningfully supplemented by drafts on nonrenewable supplies that almost always take the form of anciently stored groundwater that is not being recharged. A good example of the latter type of resource is most of the groundwater drawn each year from the Ogallala Aquifer. Whatever portion of the groundwater withdrawn that is recharged by percolation is part of the renewable supply, but most drafts on that aquifer are of water that will not be replaced because of the very small rate of recharge.[11]

The above description of U.S. water supply can be fairly summarized as, "it is what it is and it is where it is." What might be added is a common sense adjustment for patterns of natural variations in rainfall and temperature that have been gleaned from past observation. Thus, the amount and location of local water supplies are subject to a predictable range of fluctuation. The layman's sense of what might be called "water supply positivism" has a parallel scientific conceptualization that is called "stationarity," or

> [s]ystems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year-periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under stationarity, pdf estimation errors are acknowledged, but have been assumed to be reducible by additional observations, more efficient estimators, or regional or paleohydrologic data.[12]

Anthropogenic climate change (climate change caused by human activities such as pollution) has undercut the reliability of the stationarity

11. V.L. McGuire, U.S. Geological Survey (USGS), Water Level Changes in the High Plains Aquifer, Predevelopment to 2005 and 2003 to 2005 Scientific Investigations Report 2006-5324 7 (2007), *available at* http://pubs.usgs.gov/sir/2006/5324/pdf/SIR20065324.pdf.

12. P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 Sci. 574, 574 (2008), *available at* http://www.gfdl.noaa.gov/reference/bibliography/2008/pcm0801.pdf.

assumption. That is the conclusion of leading scientists,[13] and is already evidenced by observed changes in means and extremes of precipitation, evaporation, and rates of discharge of rivers.[14] The changes being observed in recent years are beyond what can be explained using the stationarity hypothesis, but are consistent with the observed results and updated predictions of improved climate change models.[15] In layman's terms, what stationarity-based models cannot explain, climate change models do explain. Moreover, the changes that those improved climate models predict for water availability in the United States are momentous because the impacts exacerbate, rather than relieve, existing regional shortages and flooding events.[16]

Climate change models predict that most dry, water-stressed regions will become drier. Looking at two of the most stressed regions, the Lower Colorado River Basin and Central and Southern California, higher ambient temperatures decrease water availability in a variety of ways, the most critical of which is decrease in snowpack that provides a major component of streamflow. To begin with, higher temperatures increase evaporation rates at all times of the year. Thus, having more winter precipitation fall as rain rather than as snow will increase immediate evaporation losses.[17] A second effect of reduced snow and snowpack is a loss of the amount of land covered by snow, which in turn reduces the snow's reflection, a characteristic that tends to retard evaporation loss by lowering surface temperatures. More vitally, snowpack functions as a reservoir by time-shifting the availability of the water from the winter months when the snowpack is deposited to the growing season when the water is in highest demand.

The declines in snowpack already observed and predicted by the climate models are harrowing. The volume of snowpack has been dropping throughout the American West since 1950. From 1945–55 until the 1990s, snowpack volume measured on April 1 has fallen 15.8 percent in the Rockies, 21.6 percent in the interior West, and 29.2 percent in the

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13. *Id.*

14. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE IPCC (AR4) 1–18 (2007); IPCC, CLIMATE CHANGE 2007: CLIMATE CHANGE IMPACTS, ADAPTATION AND VULNERABILITY, CONTRIBUTION OF WG II TO AR4 1–16 (2007).

15. *See, e.g.*, P.C.D. Milly, K.A. Dunne, & A.V. Vecchia, *Global Pattern of Trends in Streamflow and Water Availability in a Changing Climate*, 438 NATURE 347 (2005).

16. *See generally* Noah D. Hall, Bret B. Stuntz & Robert H. Abrams, *Climate Change and Freshwater Resources*, 22 NAT. RESOURCES & ENV'T (Winter 2008).

17. Much precipitation evaporates shortly after falling because the moisture that is subject to evaporation covers a far greater area immediately after hitting the surface, before it has infiltrated into the ground or traveled into confined surface channels.

Cascades.[18] Similarly, 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.[19]

Reductions in snowpack volume are expected to accelerate during the twenty-first century. Diminished snowpack, reduced soil moisture, and increased evaporation will cause stream inflows to reservoirs to decline significantly before mid-century. Intergovernmental Panel on Climate Change (IPCC) climate models for as early as the 2020s indicate that loss of snowpack will jeopardize over 40 percent of southern California's water supply.[20] In the Colorado River Basin, the predictions of reduced snowpack are similarly dire, with an expected loss of 45 percent of streamflow by 2050.[21] These are currently the two most water stressed regions of the United States, so substantial reductions of supply are certain to threaten water security and generate conflicts.

Even areas projected to receive additional precipitation may not find it beneficial. The increased precipitation often will come in the form of more intense rain events mixed with greater periods of intermittent drought.[22] The "feast or famine" pattern of precipitation events will challenge water managers' ability to adapt existing infrastructure to more extreme water availability scenarios. The flooding experienced in the nation's midsection in both 2007 and 2008 seems to be a harbinger of this new climate pattern in which the severity of the flooding exceeds levels consistent with stationarity. Droughts in humid regions are also intensifying, again pressing the limits of what stationarity would predict. Conditions of lowered supply and increased intensity are expected under the climate change models. Thus, even before water demand is taken into account, changes in water supply are making plain the need to prepare

18. Philip W. Mote et al., *Declining Mountain Snowpack in Western North America*, 86 BULL. AMER. METEOR. SOC. 39, 44 (2005).

19. MICHAEL KIPARSKY & PETER H. GLEICK, CLIMATE CHANGE AND CALIFORNIA WATER RESOURCES: A SURVEY AND SUMMARY OF THE LITERATURE 25 (2003).

20. 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). Projections reaching further out in time are even more dire. *See* Hall, *supra* note 16, at 31. By 2069, snow cover in California may be almost completely depleted by the end of winter. *See* KIPARSKY & GLEICK, *supra* note 19, at 11. By the end of the 21st 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 Proc. Nat. Acad. Sci. 12422, 12425 (2004).

21. BRAD UDALL, RECENT RESEARCH ON THE EFFECTS OF CLIMATE CHANGE ON THE COLORADO RIVER, INTERMOUNTAIN WEST CLIMATE SUMMARY 2, 6 (2007).

22. *See* Hall, *supra* note 16, at 30.

for a new future unanticipated by existing water management regimes—physical, institutional, or legal.

II. PAST PATTERNS OF U.S. WATER USE AS PROLOGUE TO THE FUTURE

Similar to water supply, water demand is largely place specific because the activities demanding the water take place in fixed locations. Some activities, such as light manufacturing or general office and administrative uses, may be capable of easy relocation, were water availability an issue, but those are generally small water uses and water is not a factor in their choice of location.[23] Most large water users are in their particular locale for a discernible reason. Long-distance water transport involves great expense and difficulty.[24] Cities, farms, mines, most heavy manufacturing, and, of course, the ecosystem of each watershed, create water demand in a specific locale. This may be for reasons relating to historic human migration patterns, advantageous soil and climate combinations, proximity to key raw materials, transportation opportunities (including waterways), or evolutionary adaptation to an area's riparian environments. Consequently, it is important to consider water demand on a regional basis.

Somewhat similar to the stationarity assumption about water availability, most assessments of future water use and water demand patterns in the United States begin with collected water use data. From the data, planners make adjustments to account for identifiable anticipated changes, the most obvious of which are growth of population and the growth in economic activity.[25] This process will be termed "growth adjusted extrapolation."[26]

23. T. ALLISON & F.J. CALZONETTI, U.S. DEP'T OF ENERGY, THE ROLE OF AMENITIES AND OTHER FACTORS IN INFLUENCING THE LOCATION OF NONMANUFACTURING INDUSTRY IN THE UNITED STATES 10–11, 13 (1992), *available at* http://www.osti.gov/bridge/servlets/purl/138371-iasyuh/138371.pdf (giving examples of factors affecting the location of nonmanufacturing industry, such as, population density, transportation costs and access to labor markets).

24. PETER ANNIN, THE GREAT LAKES WATER WARS 68–69 (2006) (discussing the cost of transporting water from the Great Lakes to the Ogallala aquifer).

25. Economic growth may be either associated with growth in population (services, infrastructure, etc.) or it may be independent (new technologies, newly discovered resources, etc.).

26. This term is not a term of art, it is meant to be purely descriptive of a methodology that seeks to predict a future level of water use/demand by extrapolation from past trends in a type of water use/demand, making adjustments for foreseeable influences on water use in that sector.

The classic example of this process is the projection of municipal water demand, a form of water demand that in the modern era is strongly correlated with population and, therefore, is used as the principal determinant in planning for future municipal supply needs.[27] A closer examination of the U.S. Geological Survey (USGS) water use data for the second half of the twentieth century in the United States shows a somewhat different picture that fits the general trend, but also requires adjustment for a change in lifestyle brought on by new domestic technology; in-home dishwashers and washing machines. While in the first half of the twentieth century, per capita water use was relatively steady,[28] water use increased markedly in the 30-year period after the Second World War, mostly due to increased use of water intensive household appliances. During that 30-year period, per capita water use in the United States increased more than 50 percent.[29] The rate of increase in municipal water use was nearly double the rate of population growth, but both before and after that period, municipal water use rose in near lockstep with population increases. Since 1980, the per capita water use figure for the combination of municipal use and domestic rural use in the United States has remained remarkably static, varying by less than two percent over a 20-year period. Thus, absent an impending significant lifestyle change, municipal demand for water for population security will likely be driven by changes in the population.[30]

Unfortunately, no other categories of water use are as simple to predict using a single variable. Across sectors, water use generally grows in rough proportion to population, gross domestic product (GDP), and other similarly large-scale variables that measure the nation's overall trends.[31] In the relevant periods of observation for which data is available, the trends of both the U.S. population and the U.S. GDP have been upward and, up until 1980, when water use leveled out for the next 20

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27. WATER DEMAND FORECASTING 73–76 (1990).

28. *Id*.

29. The per capita use figures used here are derived from the USGS data by taking the total of municipal supply water plus the total rural domestic use water and dividing by the total population. *See* HUTSON ET AL., USGS, ESTIMATED USE OF WATER IN THE UNITED STATES, 2000 U.S. GEOLOGICAL SURVEY CIRCULAR 1268, 40 (2004) [hereinafter 2000 USGS Report], *available at* http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf.

30. Such a change is possible with stringent conservation, especially conservation measures that reduce the amount of municipal supply used on landscape irrigation. As noted below, such change is likely only possible in regions where there is a marked water shortage.

31. PETER H. GLEICK ET AL., THE WORLD'S WATER 2008–2009: THE BIENNIAL REPORT ON FRESHWATER RESOURCES 6 (2009).

years, water use in the various sectors followed on roughly the same economic trajectory.[32]

Without meaning to denigrate the qualitative importance of the quantitatively lesser water use sectors, in thinking about macro trends, only four sectors really count: municipal supply, agriculture, thermoelectric power generation, and industrial (other than thermoelectric). In 2000, these four sectors accounted for 98 percent of the withdrawals. [33] In 1995, using slightly different categorizations, those sectors evidenced the same degree of domination of withdrawals, and accounted for virtually all water consumption.[34]

As with municipal supply, the other major areas of water demand have also seen anomalous increases or decreases that are attributable to discernible changes in the water use environment. Two sector-specific factors are of particular note. In the agricultural sector, the advent and widespread use of centripetal pumps supported massive increases in groundwater irrigation. The advent of this technology brought large volumes of low cost water to farms in semi-arid regions of the nation that were previously unable to access surface water for irrigation. In the industrial sector, the change was in the other direction, where a regulatory event, the implementation of the Clean Water Act (CWA),[35] reduced water use. In that instance, the vast decline in industrial use was triggered by treatment requirements for discharged water that made it economically preferable to discharge less water.[36] In order to discharge less water and avoid the additional treatment costs associated with treating larger volumes of water, many firms moved to recirculation technologies or made process changes that reduced water use, thereby reducing the amount of intake water, which resulted in decreases in water demand. This impact was first observed in 1980 and continues to the present time, where industrial water use (excluding power generation) continues to decline slightly despite the opening of many new water-using facilities and the substantial and continuous growth of industrial productivity.[37]

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32. HUTSON ET AL., *supra* note 29.

33. *See id.* at 5.

34. WAYNE B. SOLLEY ET AL., USGS, ESTIMATED USE OF WATER IN THE UNITED STATES, 1995 U.S. GEOLOGICAL SURVEY CIRCULAR 1200, 19 (1998) [hereinafter 1995 USGS Report], *available at* http://water.usgs.gov/watuse/pdf1995/html (last visited July 21, 2010).

35. Clean Water Act, 33 U.S.C. §§ 1251–1387 (2000).

36. *See* Deborah S. Lumina et al., *Summary of Water Use in the United States, 2000*, U.S. GEOLOGICAL SURVEY FACT SHEET 2005-3051, http://ga.water.usgs.gov/edu/wateruse2000.html (last visited July 21, 2010) ("[s]elf-supplied industrial is the only category to decline consistently during the past two decades"). *See also* HUTSON ET AL., *supra* note 29, at 29.

37. *See* HUTSON ET AL., *supra* note 29, at 42.

With these examples of past demand forecasting as a template, it is possible to construct a generalized methodology for predicting future U.S. regional water demand. Forecasters can begin by looking at and extrapolating from the levels of past water use in each sector by assessing trends and factoring in correlated variables such as population growth. They may then adjust those predictions by factoring in important matters that affect the scope of use likely to be made. The adjustments under study are primarily those linked to the carbon effect on supply and the carbon constraint on emissions. Also of importance is the broader concern for ensuring water for security for the United States in four crucial areas—population, ecology, energy, and food. In the energy security field, in addition to carbon-linked pressures, one must also consider the policy imperative to reduce dependence on foreign supplies. Subsequent sections of this article will attempt to make those predictions in relation to water for population, ecology, energy, and agriculture. The remainder of this section will attempt to identify some salient "truths" and baselines for future projections of water demand that can be derived from a review of U.S. water use during the second half of the twentieth century.

A clear picture of America's principal surface water systems emerges from the USGS data compiled since 1950 together with other data that the USGS maintains. One may also observe how much water was used in each of several water use sectors from both surface water sources and groundwater sources, by noting the amount of water withdrawn and, up through 1995, the amount of water used consumptively. The water use data in particular is disaggregated along a number of lines, the first of which is a basin-by-basin breakdown into the major drainages.

Although there are some variations over time in the usage categories, and what each category includes, the key categories are public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power. The 2000 USGS Report is the most current, and Table 1 (below) is a reproduction of the broadest summary of the longitudinal data arranged by category of use in that report.[38] The 2000 Report does not include water consumption data, which was discontinued because inadequate data prevented reliable computation.[39] Since uncon-

38. *See* HUTSON ET AL., *supra* note 29.

39. The 1995 USGS Report was the last to compile consumptive-use figures. *See* HUTSON ET AL., *supra* note 29, at 50. The USGS explanation of the change was lack of reliable data, since the data upon which the reports were based were, in many regards, generated by state and local entities. *See* e-mail from Carole Marlow, Hydrologic Info. Assistant, USGS to Robert Haskell Abrams, Professor of Law, Fla. A & M Univ., College of Law (July 3, 2008) (on file with author). The percentage relationship of the amount withdrawn and the amount consumed is vitally important to a clear understanding of water use patterns

sumed water returns to the water supply as surface water runoff or recoverable groundwater,[40] that returned water often is available to satisfy additional demands. Because consumptive percentages of the differing uses vary so greatly and because some of the uses tend to dominate the overall water use calculus, it is important to maintain the distinction between consumed and unconsumed water. Using the 1995 USGS Report as the basis, it is possible to calculate the approximate consumptive percentage of each of the eight use categories as follows:[41]

TABLE 1: WATER WITHDRAWAL AND CONSUMPTIVE USE BY USAGE CATEGORIES[42]

Usage Categories	1995 Withdrawals (mgd)*	1995 Consumptive Use (mgd)	1995 Consumptive Use Percentage	2000 Withdrawals (mgd)	2000 Estimated Consumptive Use (mgd)	2005 Withdrawals (mgd)	2005 Estimated Consumptive Use (mgd)
Public Supply	40,200	7,718	19.2%	43,300	8,314	44,200	8,486
Domestic	3,390	Not reported	Not reported	3,590	Not available	3,830	Not available
Irrigation	134,000	80,520	61%	137,000	83,570	128,000	78,080
Livestock	5,490	3,200	58%	1,760	1021	2,140	1,241
Mining	3,770	1,020	27%	3,500	945		
Thermoelectric Power	190,000	3,800	2%	195,500	3,910	201,100	4,022
Aquaculture	Not reported	Not reported	Not reported	3,700	Not available	8,780	Not available
Industrial	27,100	3,370	13%	19,780	2,571	18,190	2,365

* (Million gallons/day)

Taken together the USGS reports describe many key findings, but several are of great concern to the present effort at constructing a broad-brush approximation of the nation's future water demand:

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and their implications. This article will use the 1995 relationship, the most recent one available in all approximations of post-1995 consumptive use.

40. The USGS defines consumptive use as: "the part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment." This is also referred to as water consumed. HUTSON ET AL., *supra* note 29, at viii (consumptive-use estimates were included in some previous water use circulars but were omitted for 2000).

41. "2000 Estimated Consumptive Use" for each usage category is calculated by multiplying the 2000 withdrawal by the 1995 consumptive-use percent.

42. The 1995 Report of consumptive use combines public supply and domestic usages into a domestic-commercial category for which it reports the 19.2 percent consumptive-use figure. *See* 1995 USGS Report, *supra* note 34, at 19, (that report also did not report any data for aquaculture). The columns in Table 1 for "2000 Estimated Consumptive Use" and "2005 Estimated Consumptive Use" for each usage category were calculated by multiplying the 2000 and 2005 withdrawal by the 1995 consumptive-use percent. *See* JOAN F. KENNEDY ET AL., ESTIMATED USE OF WATER IN THE UNITED STATES, 2005 U.S. GEOLOGICAL SURVEY CIRCU-

- The two largest water-using sectors, by far, are thermoelectric generation (primarily water for cooling) and agriculture.
- Thermoelectric water withdrawals in 2000 were 194.5 bgd (billion gallons per day), which constituted half of all water withdrawn in the United States in 2000 (of that water, almost one-third was saline).
- Thermoelectric cooling, under the mix of methods in use in 1995, was only 3.3 percent consumptive.[43]
- Agricultural water withdrawals in 2000 were almost 140 bgd, which constituted one-third of the nation's total withdrawals and 40 percent of the nation's freshwater withdrawals.
- Agricultural use in 1995 was almost 60 percent consumptive,[44] and accounted for 85 percent of all water consumed in the United States.
- The third largest (albeit a distant third) volumetric use by withdrawals is municipal supply.

The USGS historical data that document past trends are the necessary starting point for future predictions, but only three of those four areas are addressed. Water use in those three sectors is comparatively easy to measure because the water being used is separated from the larger body of water in order for the use to be made. In contrast, quantifying the amount of water used to ensure ecological security, which is not directly represented in the USGS data, will have to be approached using different data sources.[45] The 2000 USGS Report charts the 50-year

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LAR 1344, 7 (1998). As noted in the text, *infra* at Part IV.A, the consumptive percentage for thermoelectric power has likely increased due to the increasing prevalence of closed loop cooling systems that are more highly consumptive. The usage for industrial, mining, and thermoelectric include both freshwater and saline water withdrawals; all other figures are freshwater only.

43. The consumptive percentage is a function of the type of cooling technology in use. Increasingly, plants are using technologies that withdraw less water but consume a higher percentage of that water. *See infra* Part IV.A.

44. This figure appears consistently in the USGS reports. *Compare*, *e.g.*, 1995 USGS Report, *supra* note 34, at 19, with KENNETH A. MACKICHAN, ESTIMATED USE OF WATER IN THE UNITED STATES, 1955 U.S. GEOLOGICAL SURVEY CIRCULAR 398, 12 (1957), *available at* http://pubs.er.usgs.gov/usgspubs/cir/cir398 (last visited July 21, 2010).

45. The USGS has never made much effort to quantify this data. In the first of the five-year studies it noted, "In contrast to withdrawal uses, nonwithdrawal uses do not lend themselves to evaluation in terms of the quantity of water used." KENNETH A. MACKICHAN, ESTIMATED USE OF WATER IN THE UNITED STATES, 1950 U.S. GEOLOGICAL SURVEY CIRCULAR 398, 115 (1951), *available at* http://pubs.usgs.gov/circ/1951/circ115/htdocs/text.html (last visited July 21, 2010). At that time the scope of *in situ* uses was cataloged to include "navigation, waste disposal, recreation, and conservation of wildlife," which uses were said to "have a very large economic value." *Id*. The broader concept of ecological security was not fully comprehended at that time.

progression in water use and total water withdrawals. Evident in water use and total water withdrawal patters is that they are dominated by four use categories, public supply (municipal), irrigation, thermoelectric power, and other industrial uses.[46] What is also evident is that water withdrawals grew significantly from 1950 until 1980 and have since leveled off.

By extrapolating out another 50 years from the baseline, following the recent 20-year trend of slow growth, one may predict a 10 percent to 15 percent increase across the coming half century. At that rate, the new total use level would be close to the 1980 peak of roughly 445 bgd in total withdrawals. Municipal supply would grow the most of the big three uses, thermoelectric would grow very slightly, and agricultural use might decline slightly.

The next question is whether those projected trend lines are likely to continue, or whether there are foreseeable reasons to expect variation in the water needs for population, energy, and food. Even more critical is the question of whether additional factors will increase water demand in specific locations that are already water-short in the near to mid-range future. The next two Parts of this article will canvass the four areas in varying degrees of detail, highlighting foreseeable growth of demand for each of the four types of water security. Within those discussions, a small number of regional water shortages will be discussed to exemplify water allocation challenges facing the nation.

III. U.S. WATER DEMAND FOR POPULATION SECURITY AND ECOLOGICAL SECURITY

This part of the article examines water for population and environmental security, the two demands most independent of the carbon issues driving water use. Population security and environmental security take precedence over the others. Part IV will focus on water for energy and food security and will emphasize energy independence and carbon constraints as factors that bear on "adjusted extrapolation" in projecting future water demand.

A. Water Demand for Population Security—Anticipating Growth and Shortage

Historically, people did not settle where there was no water to support them. In a modern society, however, with the technological ability to pump water from great depths, and to build dams, reservoirs, aq-

46. Industrial use is no longer computed beginning in the 2000 USGS Report. The small amount involved does not affect the resultant trends.

ueducts, pipelines, and water tunnels through mountains, and to desalinate seawater, it is possible to bring the water to the people wherever they might congregate and settle. Since people use small absolute quantities on a per capita basis, providing water for human survival is almost always affordable. This is especially true if they conserve aggressively. Lest anyone have doubts about that fact, consider the general lack of available[47] local in-basin water assets of Los Angeles, Denver, Phoenix, and Las Vegas where the cost of water has not yet been a deterrent to rapid in-migration.

Water for population security is concerned solely with concentrated populations. Dispersed populations use truly tiny amounts of water and, if they could not have gotten the needed water, those dispersed souls would not have located where they are now in the first place. If for some reason, such as climate change or exhaustion of a nonrenewable groundwater supply, the water sustaining a small number of people becomes unavailable, those few people will relocate with a negligible effect on the nation's welfare. Concentrated populations are a different matter. Hurricane Katrina, major floods, and even tornados, more than amply demonstrate the degree of economic dislocation and national tragedy that attends even partial, nonpermanent abandonment of a population center. A prolonged failure to provide water for municipal supply to a concentrated population would entail at least the same level of dislocation.

Given the absolute centrality of a secure water supply to urban populations, and the importance of cities and their people to the nation, it would be reasonable to expect water law in this country to provide special treatment granting extraordinary durability to water rights that secure urban water supplies. Oddly, in terms of basic legal doctrine, that is not the case under either riparianism or prior appropriation.

In riparian jurisdictions domestic use by a riparian proprietor is exempt from the usual reasonable use rule that requires co-riparians to share the supply.[48] That special non-sharing status does not, however, extend to municipalities in their efforts to provide water to their citizenry.[49] Municipalities, instead, can condemn the needed portion of the rights of riparians whose legal interest might otherwise be diminished by withdrawals for municipal supply.[50] In a similar fashion, the Restatement

47. This term is meant as a reminder that in Colorado, Arizona, and Nevada, water that is already appropriated by another is not "available."

48. JOSEPH L. SAX ET AL., LEGAL CONTROL OF WATER RESOURCES: CASES AND MATERIALS 32 (2006).

49. *Id*. at 80.

50. *See, e.g.*, Town of Purcellville v. Potts, 179 Va. 514, 19 S.E.2d 700 (1942).

(Second) of Torts provides that municipal use might incur liability for damages but avoid injunction in a contest with other co-riparians over a limited supply.[51] This latter imposition of liability for damages was a hallmark of nineteenth and early twentieth-century cases in which eastern and midwestern cities pumped and transported groundwater to the detriment of other users of the source water aquifer.[52]

These legal rules, together with statutory preferences in some states that place cities first,[53] have worked in the riparian jurisdictions to allow cities a way to claim whatever water they need ahead of other users. When local sources are insufficient, a number of eastern cities have become the beneficiaries of interbasin transfers. New York, Boston, and Chicago are the most prominent examples. These water supply efforts, whether from interstate or intrastate sources, have been controversial and spawned litigation.[54] Still, when all is said and done, the cities of the East eventually have emerged with secure water rights to support their population.[55]

In prior appropriation jurisdictions, cities are treated just like other users and must obtain water rights recognized in the system. Cities can and often do perfect appropriations, and their status in times of shortage is determined by their seniority in time of their water rights. In some basins, there is still unappropriated water for which cities can obtain rights.[56] Since much of the growth of western cities came well after most of the region's water was already appropriated, efforts by the cities to appropriate water would have obtained priorities too junior to be relied upon. Unlike riparian jurisdictions, water rights in prior appropriation jurisdictions are capable of quantification and transfer.[57] Transfers

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51. RESTATEMENT (SECOND) OF TORTS §§ 850A, 858 (2009); *see also* SAX ET AL., *supra* note 48, at 60.

52. *See, e.g.*, Smith v. City of Brooklyn, 160 N.Y. 357, 54 N.E. 787 (N.Y. 899).

53. *See, e.g.*, N.Y. ENV. LAW §15-0105(5), which states, "The acquisition, storage, diversion and use of water for domestic and municipal purposes shall have priority over all other purposes."

54. *See, e.g.*, Schroeder v. City of New York, 371 U.S. 208 (1962) (objecting to notice given by New York City in condemnation case); Wisconsin v. Illinois, 278 U.S. 367 (1929) (objecting to Chicago's diversion of Great Lakes water).

55. Atlanta and the ACF controversy will not be different, although Atlanta is likely to end up with superior claims on a lesser proportion of the supply than it would like to have, growth will be allowed to continue, but far greater conservation will be required. *See* Robert Haskell Abrams, *Settlement of the ACF Controversy: Sisyphus at the Dawn of the 21st Century*, 31 HAMLINE L. REV. 679 (2008).

56. *See, e.g.*, Pagosa Area Water and Sanitation Dist. v. Trout Unlimited, 170 P.3d. 307 (Colo. 2007). This case is particularly interesting because of the limits it places on cities' speculative projections of growth.

57. This difference of riparianism and prior appropriation may explain why cities in prior appropriation jurisdictions have not relied heavily on condemnation. The results are

are the principal means by which urban and suburban growth meet increasing demands.[58]

Given the disparity in the value of water in the competing uses, cities easily can afford to buy out agricultural users and pay for the structures needed to transport the water.[59] In more modern times, some cities have benefitted from decisions that allowed them to recapture treated wastewater, which gave them access to roughly 90 percent of their withdrawn water that would otherwise have discharged to downstream users.[60]

The newest water law regime, now taking root in several eastern states as water use conflicts increase, is called regulated riparianism. More than riparianism or prior appropriation, regulated riparianism recognizes municipal use as preferred in time of shortage.[61] Thus, in all regions the law has evolved means that permit cities to obtain and protect their water rights and to seek to further expand them in response to increased demand via condemnation, purchase, or regulatory allocation.[62]

Predicting just how much additional water is likely to be needed to provide continued population security is probably the best understood of all water demand functions. The calculation intuitively links increases in population to increases in water demand: The amount of water a municipality used to support historic population will continue to be used, and water demand will increase in proportion to the population. This common sense explanation of events is confirmed by extensive data of water demand and use in the municipal sector—the water demand rises in a 1:1 correlation with the growth in population.[63] Thus, as described below, some water-short areas of the country may see municipal

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the same, the city pays and gets water, but the transaction is voluntarily undertaken by the transferor of the appropriative right.

58. *See generally*, A. Dan Tarlock & Sarah B. Van de Wetering, *Growth Management and Western Water Law: From Urban Oases to Archipelagos*, 5 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 163 (1999).

59. *See, e.g.*, Lawrence J. MacDonnell & Teresa A. Rice, *Moving Agricultural Water to Cities: The Search for Smarter Approaches*, 2 HASTINGS W.- NW. J. ENVTL. L. & POL'Y 27 (1994).

60. *See, e.g.*, Arizona Public Service Co. v. Long, 773 P.2d 988 (Ariz. 1989).

61. *See, e.g.*, AMERICAN SOCIETY OF CIVIL ENGINEERS, REGULATED RIPARIAN MODEL WATER CODE 110 (2003) [hereinafter MODEL WATER CODE]. The MODEL WATER CODE places ecological water flows and levels at a similarly secure footing as domestic use. *Id.* at 8.

62. For example, in Florida, a state that would be considered a regulated riparian jurisdiction, a group of municipalities has filed a request for an allocation of surface water from the St. Johns River. *See, e.g.*, Steve Patterson, *Judge OKs Water Withdrawals from St. Johns*, THE FLORIDA TIMES-UNION, Jan. 12, 2009, *available at* http://culfwww.jacksonville.com/news/metro/2009-01-12/story/judge_oks_water_withdrawals_from_st_johns (last visited Aug. 16, 2010). *See also* N.Y. Comp. Codes R. & Regs. tit. 6, §§ 601, 602.

63. WATER DEMAND FORECASTING, *supra* note 27, at 73–76.

water demand double or triple over the next century based on projected growth in population.[64]

There is one very important caveat that must be added in discussing likely growth in urban water demand: Urban water conservation has the potential to greatly reduce urban water demand, especially when landscape irrigation practices are a major part of the conservation mix. At present, urban areas, even those in already water-short areas, are spread out over a broad continuum of conservation rigor.[65] For that reason, in some of the examples described below, much of the anticipated growth in municipal water demand could be offset by more stringent conservation.

After correlating increased municipal water demand with increased population, it is relatively easy to consult population projections, see where growth is occurring, and assess which areas are now, or are soon to be, water short. The predicted areas of fastest population growth in the early twenty-first century in the United States are situated in areas that either already face serious water shortages and long-established competition for available water, such as the Lower Colorado (especially when Southern California is included as a recipient of that water) or the Eastern Slope of the Rockies. Areas that are just now facing serious competition for water include the more humid Southeast, where Atlanta, Georgia, and Florida's major population centers have water use restrictions in place and are seeking to increase sources of water for their future needs.[66]

The western regions just mentioned are ones where climate change is likely to reduce snowpack and, with it, water availability. Population growth in those regions exacerbates a known water shortage that

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64. California's population is expected to double or triple over the next century. John Landis & Michael Reilly, How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint Through the Year 2100 (2003), http://iurd.berkeley.edu/catalog/Working_Paper_Titles/How_We_Will_Grow_Baseline_Projections_Growth_Californias_Urban (last visited July 21, 2010). Regional growth in the Portland area is expected to increase water demand by 5.7 billion gallons (20.8 million cubic meters) per year by the 2040s. *See* Intergovernmental Panel on Climate Change, Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 628 (2007).

65. Approximately 20 percent of metropolitan Atlanta's water use is outdoor and seasonal—21 percent of residential and 31 percent of nonresidential (residential is 55 percent of total water use, nonresidential is 27 percent, and unaccounted-for water use (such as leakage) is 18 percent). *See* THE PACIFIC INSTITUTE, A REVIEW OF WATER CONSERVATION PLANNING FOR THE ATLANTA, GEORGIA, REGION 12 (2006), *available at* http://www.pacinst.org/reports/atlanta/atlanta_analysis.pdf. Conservation measures could reduce outdoor water use by 24 percent to 80 percent. *Id.* at 36–37.

66. South Carolina v. North Carolina, 552 U.S. 1254 (U.S. 2008).

will become worse as the water supply decreases. In the Southeast, population growth has been seen as the change agent that is creating water shortages,[67] but climate is also a change agent. Climate models predict that regional precipitation will be about the same as in the past, but will occur as more extreme doses of heavy storms (and increased sheet runoff with decreased infiltration) along with more periods of regional drought. That dire future has already arrived in the Southeast corner of the nation, and the demise of stationarity is rearing its head on the drought front. 2007 and 2008, for example, both saw a number of new record lows in water flows and levels in the water supplies serving heavily populated areas of the Southeast such as the city of Atlanta and Central and South Florida.[68]

It is reasonable to ask whether foreknowledge of water supply shortage might be erected as a barrier to regional population growth. For example, could growth be resisted by passing laws that effectively stymie development? Most regions welcome population growth, whether as a driver of, or consequence of, economic growth.[69] Growth is such a powerful regional economic engine, that it is reasonable to believe that even cities in water-short regions will opt to continue this growth. Despite the economic benefit, a number of states and local governmental units have tried to make sure that growth is not a threat to water supply, and, conversely, that lack of water supply does not inhibit growth. In those places, what are generally termed "assured supply laws" require developers to demonstrate that the purchasers of the newly built units will have adequate water as a condition precedent to obtaining a building permit.[70] At their most felicitous, such laws channel growth to areas with available water. Those laws also may operate in tandem with state water law to create more certain opportunities for the transfer of water

67. *See* Robert Haskell Abrams, *Settlement of the ACF Controversy: Sisyphus at the Dawn of the 21st Century*, 31 HAMLINE L. REV. 679 (2008).

68. David Emory Stooksbury, *Drought Tightens Its Grip on North Georgia* (2008), http://georgiafaces.caes.uga.edu/storypage.cfm?storyid=3570 (last visited Mar. 5, 2009) ("Lake Lanier, a primary water source for metro Atlanta, is at a record low for mid-November. The previous mid-November record low was at this time last year."); South Florida Water Management District, *Lake Okeechobee Hits New Record Low of 8.88 Feet* (2007), https://my.sfwmd.gov/portal/page?_pageid=3034,19820229&_dad=portal&_schema=PORTAL (last visited Mar. 5, 2009).

69. In-migration drives economic growth, for example, in the construction and service sectors. In-migration might be spurred by job opportunities, such as a new manufacturing facility or new research center.

70. *See* Lincoln Davies, *Just a Big, 'Hot Fuss'? Assessing the Value of Connecting Suburban Sprawl, Land Use, and Water Rights Through Assured Supply Laws*, 34 ECOLOGY L.Q. 1217, 1259–60 (2007).

from other uses to support concentrated populations.[71] In other places, they simply have not worked.[72] In all events, assured supply laws seldom stop growth, although they may lead to coordination of water supply and growth.[73]

Ultimately, water for population security is not a major concern, even in areas of growing population that are located in regions of current or projected water scarcity. Cities simply do not use much water, especially when compared to agriculture. With little capital expenditure, cities can extend their existing supplies by taking more forceful action on conservation. By focusing on residential irrigation, cities can obtain large returns on their conservation efforts.[74] Cites can also afford to buy their way to water security by building water importation projects and purchasing competing water rights. They can obtain rights most easily from the low value agricultural sector, but could also purchase from the far more valuable energy sector.[75] Las Vegas, Nevada, can sustain an additional 100,000 persons with water freed up by retiring a 2000-acre farm growing alfalfa as forage for cattle.[76] Even if the price of the water was exorbitant, say $1,000 per acre-foot per year,[77] the annual per capita

71. *Id*. at 1271.

72. *Id*. at 1272–74.

73. The circumstances in which they will stop growth occur when the community enacting them is politically united in desiring to stop growth and is using assured supply as the vehicle. *See* Steve La Rue, *Babbitt Signs Historic 7-State Water Accord*, SAN DIEGO UNION-TRIB., Jan. 17, 2001, *available at* http://www.waterrights.ca.gov/IID/IIDHearingData/Local Publish/NWF_Exhibit_9.pdf.

74. The Utah Division of Water Resources reports that on average, Americans use about two-thirds of their water out doors, most of which goes on lawns. Even more disturbing, as much as one-half of this quantity is wasted through incorrect watering. Utah Division of Water Resources, Residential Lawn Watering Guide, http://www.conserve water.utah.gov/agency/materials/guide/Default.asp (last visited Feb. 10, 2009).

75. This "purchasing power" was on display in the ACF controversy in which Atlanta was able to "buy out" the hydropower interests that would have been adversely affected by the agreement that Atlanta was seeking to complete with the U.S. Army Corps of Engineers.

76. This estimate is made using the following calculation: 100 gallons per day per capita, so that results in a total of 10 million gallons per day (mgd) of water. This comes out to 11,200 acre-feet of water in a year. An alfalfa crop in that region has a water duty of at least six acre-feet per acre.

77. The value of the water to the farmer in the prior example can be measured as the profit on the alfalfa crop. For example, high yields using four cuttings per year in Colorado max out at 30 tons per acre. The price per ton in Iowa, a large alfalfa consuming state, is approximately $70 per ton. *See* Calvin Pearson, Western Colorado Alfalfa Variety Performance Test at Fruita 2007, http://www.extsoilcrop.colostate.edu/CropVar/documents/alfalfa/alfalfa_results_fruita_2007.pdf; *Pricing Forage in the Field* 2, http://www.extension.iastate.edu/AgDM/crops/pdf/a1-65.pdf. If profit is 20 percent, a high number, the farmer

water cost is only $20.[78] The cost for buying out the farmer will not be so high. The entire profit on the crops raised, if the farmer is lucky enough to have a 20 percent profit margin, is $420 per acre, or $70 per acre-foot of water. A more reasonable cost for this transfer is a fraction of the $1,000 per acre-foot amount,[79] which makes the water cost per additional person served almost negligible. After the first use of that water in Las Vegas, roughly 90 percent of that water will still be available for reuse as treated sewage effluent, which can be sold for golf course and landscape irrigation, so the purchase becomes more economically viable.[80] The more serious obstacles to transfer are attitudinal and legal, not economic. Farmers feel strongly about maintaining their way of life, and in some instances statutes block the transfer of water. Retiring farmland also causes third-party economic effects such as adverse impacts on farm workers, farm implement dealers, and the farming community tax base. While these obstacles cannot be overlooked, in the end, the cities will get the needed water for population security.

Somewhat more serious problems of providing for municipal supply, ironically, may arise in the East. There are two types of scenarios that pose difficulties. The first is cities that draw a significant portion of their water supply from coastal aquifers already threatened by saline intrusion. The threat of saline intrusion limits their growth potential, but an additional risk to their current supply arises from climate change induced sea-level rise, which may lead to saline infiltration. If their aquifers become contaminated, those cities will have no choice but to import water to supply not only future growth but also a diminishing present supply. Even if the aquifers do not become contaminated, groundwater dependent coastal cities will need to replace a portion of their current supply. With higher sea levels, groundwater pumping will have to be reduced to preserve the hydrostatic barrier that keeps seawater from infiltrating the aquifer.[81] The replacement water and water to support

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is making $420 per acre—$70 per acre-foot of water. That pricing, as noted, relies on four cuttings per year—this hypothetical has only one!

78. This figure ignores pumping, piping, or treatment costs.

79. Being more precise, the present cost of water will be the annuitized value of the value of the annual amount. Revenue bonds secured by receipts for water bills in a desert community are a safe investment, even in the current very skittish economic environment.

80. If the golf courses and landscape irrigation are not new uses, their previous water supply is now available for other uses, or, alternatively, the ability to reuse the water will reduce the amount of agricultural water that must be retired.

81. *See, e.g.*, USGS, *Groundwater depletion*, http://ga.water.usgs.gov/edu/gwdepletion.html (last visited Feb. 10, 2009).

growth will have to come from inland, over political opposition of the areas of origin.[82]

The second scenario in which climate change portends eastern states' municipal supply difficulty is, in part, typified by the Apalachicola-Chattahoochee-Flint (ACF) River basin controversy. The climate change mechanism at work in that setting is the increased intensity of storm and, particularly, drought events. Securing or increasing Atlanta's supply under drought conditions is a thorny problem due to Atlanta's location at the head of the watershed, its lack of groundwater sources, its limited storage options, and the timing of needed ecological supporting flows.[83] In the short term, most concentrated populations in the eastern United States will have a considerable margin for response to drought through conservation. For example, in response to the recent drought and water conflicts in the ACF basin, Atlanta and its northern suburbs reduced water use by 20 percent, with a total reduction of nearly 180 million gallons a day (roughly the amount that the city and northern suburbs pull out of Lake Lanier and the Chattahoochee River every day).[84]

In the East, once easy conservation solutions have been fully implemented, solving water shortage problems for cities is in some ways more difficult, because it tends to be more difficult to transfer and reallocate water than in the arid West where there is a tradition of transfers and legal experience in making them work. Nevertheless, even the most difficult eastern water for population security problems are superable due to the small absolute quantity of water that must be supplied and the plain fact that abandoning the cities is not an option. The proactive approach to protecting municipal supply through drought planning,[85] preferences,[86] and preordained emergency measures[87] is one of the principal attractions of the move to regulated riparianism that may lead to its adoption if droughts become a threat to water security for concentrated populations.

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82. The classic example of this scenario is the importation of 68 mgd of Roanoke River water (less than 1 percent of the overall flow and less than 10 percent of the low flow of record) to Virginia Beach. *See generally*, SAX ET AL., *supra* note 48, at 97–99.

83. *See, e.g.*, Robert Haskell Abrams, *Settlement of the ACF Controversy: Sisyphus at the Dawn of the 21st Century*, 31 HAMLINE L. REV. 679 (2008).

84. Stacy Shelton, *Water Use Down 20 Percent*, ATLANTA J.-CONST., Aug. 12, 2008, *available at* http://www.ajc.com/metro/content/metro/stories/2008/08/12/water_use.html (last visited July 21, 2010).

85. MODEL WATER CODE, *supra* note 61, at 54.

86. *Id*. at 110–11.

87. *Id*. at 134, 140.

A somewhat less tractable problem of urban growth is flooding and flood control. Urban growth and urban water supply both have links to flooding. Growth tends to increase flood proneness by destroying wetlands that absorb and delay water flow. Concurrently, that same growth speeds runoff at peak times by increasing the area covered by impermeable surface areas and channeling water into surface streams through collection systems.[88] Additionally, in the absence of rigid and well-enforced planning, considerable growth has occurred in flood plains.

Climate change models have predicted rainfall events of increased intensity throughout the continental United States.[89] Recent flood events, including floods in both 2007 and 2008 in the Missouri and Mississippi basins have been, in some places, 100-year or even 500-year events. If these floods are evidence that the demise of stationarity is a reality, flooding will become an even larger concern. Existing flood control defenses, including storage facilities that also provide water supply, are designed with capacities and operational plans that rely on the stationarity assumption.

Flooding, and the increased threat of flooding, beget flood control. While wetlands restoration may be a part of the equation, it would be naïve to think that major existing encroachments of urban areas into flood plains and wetlands are going to be demolished and returned to their natural state. Rather, greater effort will go into flood control provided by storage reservoirs. How that storage is managed will impact the availability of water for population security.[90]

Operating dams for flood control can work at cross-purposes to operating them for municipal supply. Flood control demands unused storage capacity as a hedge against extreme precipitation events, while municipal supply demands water in storage as a hedge against

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88. A further problem threatening water quality relates to combined sewer overflows in storm events. If these events become more intense, the holding capacity of the urban systems will be inadequate to prevent bypass flows that include the discharge of untreated raw sewage to prevent the flooding of the treatment works, which would result in even more serious sewage discharges and the incapacitation of the plant itself for some period of time.

89. *See* University of Miami, Rosenstiel School of Marine & Atmospheric Science, *Climate Change: When It Rains It Really Pours* (Aug. 8, 2008), *available at* http://www.sciencedaily.com/releases/2008/08/080807144240.htm. *See generally*, Christine A. Klein & Sandra B. Zellmer, *Mississippi River Stories: Lessons from a Century of Unnatural Disasters*, 60 SMU L. REV. 1471 (2007).

90. Just as importantly, how reservoirs are managed has the potential to impact ecological security. *See, e.g.*, discussion of ACF reservoir and need to mimic natural hydrograph, *infra* Part III.B.

drought.[91] As an evaluative matter, with the caveat that local cases might vary, especially with somewhat smaller capacity dams, the conflict between flood control and municipal supply will more often be theoretical than real. Since cities don't really use that much water, reserving and filling some part of the storage pool for municipal supply will not significantly affect flood control efficacy. Precipitation forecasts may also allow dam operators to plan ahead and release stored municipal water early enough to move it downstream before a flood event. Such releases will not imperil storage for municipal security because they will be replaced almost immediately by the precipitation that raises the potential for flooding. What is certain is that climate change places flood risk reduction in competition with municipal water supply for reservoir storage. Sacrificing either use is perilous.

B. Water Demand for Ecological Security—Protecting Natural Systems

Water for ecological security is primarily water that remains in place in its natural system to support the natural flow regime and ensure that ecosystems continue to function. The natural flow regime uses five critical components to "regulate ecological processes in river ecosystems: the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions."[92] Water to support the natural flow regime may come from direct precipitation, surface water runoff, and hydrologically connected groundwater.[93] Ecological demand for water, whether it is derived from maintenance of riparian wetlands, fisheries and riparian habitat, sediment transport, high quality water supply, or any other as-

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91. There is a similar tension between using dams to provide water for ecological flows and using them to provide municipal supply. At least superficially, that is a major flash point in the current ACF dispute over the operation of the Corps operated Chattahoochee River dams. *See,* George W. Sherk, *The Corps' Conundrum: Reconciling Conflicting Statutory Requirements in the ACF River Basin*, Proceedings of the 2005 Georgia Water Resources Conference, at the University of Georgia, Athens, GA (Apr. 25–27, 2005), *available at* http://www.uga.edu/water/GWRC/Papers/SherkJ%20Corps%20Conundrum.pdf.

92. N. LeRoy Poff et al., *The Natural Flow Regime—A Paradigm for River Conservation and Restoration*, 47 BIOSCIENCE 769, 770 (1997), *available at* http://www.fs.fed.us/stream/Poffetal_1997.pdf.

93. *Id.* at 771. When surficial aquifers are in direct hydrologic contact with surface streams, a decline in the aquifer has the potential to drain the surface water feature. *See, e.g.*, ROBERT GLENNON, WATER FOLLIES 71–86 (2004). Less obviously, but just as importantly, aquifer discharge accounts for 40 percent of the baseflow of most streams. DAVID W. MOODY ET AL., NATIONAL WATER SUMMARY, WATER SURVEY PAPER 2325, 3 (1988). Finally, dewatering of aquifers can cause saline intrusion or movement of subsurface materials that result in sinkholes or widespread subsidence that affect secure use of the surface for human activities. SAX ET AL., *supra* note 48, at 394–95.

pect of the natural system, is of immense value. It provides a myriad of human benefits that are just beginning to be recognized under the appellation "ecosystem services."[94] The water involved in this category does not provide merely amenity value, but prevents ecological collapse.

The most devastating example of what happens when water is not provided for ecological security is the Aral Sea in Central Asia. The Aral Sea was once a thriving ecosystem that provided a foundation for an important fishing economy.[95] However, massive water diversions for agricultural irrigation beginning around 1960 steadily drained the Aral Sea of its freshwater, and it has now lost 90 percent of its volume and 75 percent of its surface area.[96] The irrigation diversions watered a booming—and temporary—cotton industry, but the system ultimately collapsed. Now the fishing industry is gone as well, with only some abandoned ships on dry lakebeds as a reminder of the past ecological and economic prosperity.[97]

Legally, water for ecological security has been treated quite differently in the major water law regimes. Riparianism in this nation has always protected reasonable water levels and flows. [98] This element has been adopted and enhanced by regulated riparianism.[99] In the West, under the prior appropriation doctrine, there is no guarantee that appropriative rights will not exhaust the stream. Even more troublesome for the protection of ecological security is that historically, water could not be appropriated to leave it in place.[100] Through legislation, the barrier in prior appropriation law against protecting *in situ* uses has diminished, but not substantially in all states.[101]

The federal Endangered Species Act (ESA)[102] indirectly supplements state protections of water for ecological security. The ESA has been used to restrict competing water uses to provide the requisite habitat conditions for endangered species.[103] Some of the West's most

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94. *See, e.g.*, J.B. RUHL ET AL., THE PRACTICE AND POLICY OF ENVIRONMENTAL LAW (2007).

95. *See* PETER ANNIN, THE GREAT LAKES WATER WARS 22–39 (2006).

96. *Id.* at 27.

97. *Id.* at 29–30.

98. *See, e.g.*, Taylor v. Tampa Coal, 46 So.2d 392, 392–394 (Fla. 1950); Glen Lake-Crystal River Watershed Riparians v. Glen Lake Ass'n, 264 Mich. App. 523, 525–43 (2005). *See generally*, SAX ET AL., *supra* note 48, at 70–79.

99. MODEL WATER CODE, *supra* note 61, at 39–42.

100. SAX ET AL., *supra* note 48, at 141–44, 454–62.

101. *See* CAL. WATER CODE § 1260 (requires party seeking to appropriate water to set forth place of diversion for water); *see also* California Trout, Inc. v. State Water Res. Control Bd., 90 Cal. App. 3d 816 (Cal. App. 1979).

102. Endangered Species Act, 16 U.S.C. §§ 1531–44 (2000).

103. *See* HOLLY DOREMUS & A. DAN TARLOCK, WATER WAR IN THE KLAMATH BASIN: MACHO LAW, COMBAT BIOLOGY, AND DIRTY POLITICS 89–100 (2008).

volatile water conflicts have arisen under the ESA, such as the closing of the headgates of the Klamath Project to protect endangered sucker and salmon species.[104] Many fish species are adapted to a river's specific natural flow regime, making them highly sensitive to flow reductions or other alterations.[105] Human interventions, particularly dam operations, can effect changes in the hydrograph that imperil the existence of threatened species.[106]

In distinct contrast to water for cities that often, in effect, buy their water security, water for environmental security is usually achieved through non-monetized regulatory actions founded on broad-based political, practical, and philosophical positions.[107] The prime example of regulatory action is the ESA, but it is joined and broadened by state minimum flow and level laws.[108] In the United States, appreciation of the value of services performed by intact ecosystems, including food and fiber production, carbon trapping, water filtration, and flood control, has increased. Policymakers are beginning to evaluate ecological services when making resource management decisions.[109]

Current scientific knowledge is sufficiently limited in that the amount of water needed to provide ecological security is not susceptible to precise measurement. Even shadow measures are hard to discern because water for ecological security is not subject to any form of commoditization as water rights,[110] and allocations of water to that use are not subject to private transfer as part of the property law regime. Indeed, water for the environment has seldom been quantified in the past. In the latter half of the twentieth century, as the concept of ecosystems gained greater prominence, the ESA forced some effort at quantification by at-

104. *See id.* at 103–11.

105. *See* Poff et al., *supra* note 92, at 775–77. This is a factor in the ACF controversy. *See, e.g.*, Robert Haskell Abrams, *Water Federalism and the Army Corps of Engineers' Role in Eastern States Water Allocation*, 31 U. ARK. LITTLE ROCK L. REV. 395 (2009).

106. *See id.*

107. The foremost of these is the political and attitudinal force of public opinion about minima of environmental quality. There are also some individual actions that find their way into the marketplace to protect ecological security, for example, conservation easements, and the dedication of water rights to instream flow.

108. *See, e.g.*, Natural Resources: Conservation, Reclamation, and Use—Minimum Flows and Levels, FLA. STAT. § 373.042 (2008).

109. *See generally*, Janet C. Neuman & Gail Achterman, *Sometimes a Great Notion: Oregon's Instream Flow Experiments*, 36 ENVTL. L. 1125, 1139 (2006).

110. Historically, a number of states following the prior appropriation doctrine forbade any setting aside of water for such uses. *See, e.g.*, COLO. CONST. art. 16, § 6 ("The right to divert the unappropriated waters . . . shall never be denied"). Over time, virtually all western prior appropriation states devised at least limited means to protect instream flows. *See*, *e.g.*, Hubbard v. State, 86 Wash.App. 119, 936 P.2d 27 (1997).

tempting to answer the question of how little water is too little for the minimal needs of particular at-risk species?[111]

There have been a number of ESA cases that feature a conflict between water for the environment and other water uses, such as water security for populations, energy, or agriculture. Perhaps the best-known recent case is the conflict between water for fishery protection and water for irrigation in Oregon's Klamath Basin.[112] Similarly, California's vast north-south water transfers that serve virtually every type of purpose have been adjusted to ensure ESA-protected ecological flows and other species protections, such as avoiding entrainment of listed fish.[113] These examples are not limited to the West, where the historic water law has encouraged off-stream beneficial use, and rewarded such use with senior property rights. In the East, the ESA is currently being asserted by the downstream states of Florida and Alabama in their litigation with Georgia over the allocation of the water in the ACF system. Florida, in particular, is using the ESA to try to obtain water it claims is necessary for endangered mussel habitat and sturgeon spawning. Georgia is resisting those claims in an effort to ensure that more water is held upstream in Atlanta's principal water-supply reservoir in drought years. Not coincidentally, the imbroglio reached epic proportions in 2007 and again in 2008,[114] both of which were extreme drought years in the Chattahoochee

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111. Many scholars have criticized the species-by-species aspect of ESA rather than a more comprehensive ecosystem protection approach. *See, e.g.*, LAURA C. HOOD, FRAYED SAFETY NETS: CONSERVATION PLANNING UNDER THE ENDANGERED SPECIES ACT 2–3 (1998); Craig W. Thomas, *Habitat Conservation Planning: Certainly Empowered, Somewhat Deliberative, Questionably Democratic*, 29 POLITICS AND SOCIETY 105, 105–30 (2001).

112. *See* Klamath Irrigation Dist. v. United States, 67 Fed. Cl. 504 (Fed.Cl. 2005). *See also* Holly D. Doremus & Dan A. Tarlock, *Fish, Farms, and the Clash of Cultures in the Klamath Basin*, 30 ECOLOGY L.Q. 279 (2003).

113. In addition to flows for spawning and fish passage, avoiding entrainment in pumps and other intakes is critical. *See*, *e.g.*, U.S. FISH AND WILDLIFE SERV., FINAL RESTORATION PLAN FOR THE ANADROMOUS FISH RESTORATION PROGRAM, *available at* http://www.delta.dfg.ca.gov/afrp/SWRCB/M.finalrestplan.pdf.

114. Georgia Governor Sonny Perdue held a prayer vigil on the state capitol grounds to pray for rain. *See* Jenny Jarvie, *Gov to God: Send Rain!—Southeast Drought Spurs an Atlanta Prayer Vigil. Critics fault Georgia's conservation efforts*, L.A. TIMES, Nov. 14, 2007, *available at* http://articles.latimes.com/2007/nov/14/nation/na-rain14 (last visited July 21, 2010). The Georgia Legislature considered seeking to revive an almost 200-year old error in surveying that resulted in establishment of its border with Tennessee being one mile farther south than had been intended. The change would have placed a part of the Tennessee River in Georgia, which then, in theory, would have allowed Georgia to transport some of its water to Atlanta. Shaila Dewan, *Georgia Claims a Sliver of the Tennessee River*, N.Y. TIMES, Feb. 22, 2008, *available at* http://www.nytimes.com/2008/02/22/us/22water.html?scp=1&sq=Georgia%20Claims%20a%20Sliver%20of%20the%20Tennessee%20River&st=cse (last visited July 21, 2010).

Basin, and both of which threatened records for low storage in the critical reservoir, Lake Lanier.

The ESA aspect of the ACF dispute, regardless of its eventual result, demonstrates that water for ecological security is a form of water demand that will compete for water with other key demands. In the ACF dispute, the apparent competition is with the highest valued of all uses, water for population security.[115] What becomes clear in breaking down some of the aspects of that particular case is that even without knowing the exact amount of water necessary for ecological security, the amount of water that must be left *in situ* to protect basic ecological functions is a comparatively large amount. Water demand for the metropolitan Atlanta region, which has a current population of 5.25 million,[116] is approximately 606 million gallons per day (mgd).[117] This computes to a per capita withdrawal of about 114.8 gallons per day. A typical city, however, returns over 90 percent of the water withdrawn, so the amount of water actually consumed by Atlanta is only about 60 mgd. In comparison, persons and groups concerned with ecological effects on the bottom reaches of the basin are attempting to ensure that a flow in excess of 4,500 cubic feet per second (cfs) be maintained at all times. That level of flow translates to about 2.9 billion gallons per day—five times the municipal withdrawal and 50 times the amount of water consumed by the metropolitan Atlanta region. While the fight is not about one day's consumption or withdrawal of water, but about holding in storage many days worth of water withdrawals as a hedge against drought, the instream need is far more voluminous.

The occurrence of the ACF case in such a water-rich region emphasizes the fact that most water demands are highly localized as to both time and place, but the common pool and flow characteristics of river systems link together demands across the length and breadth of a basin. The ACF example presents a multifaceted competition that includes water demands in all four categories of water security.[118] Most obviously,

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115. The conflict between the city of Atlanta and the environment omits the quantity of flow that the Flint River could contribute to the bottom of the basin, water which is largely consumed by Georgia farmer's unregulated irrigation. *See, e.g.*, Robert Haskell Abrams, *Settlement of the ACF Controversy: Sisyphus at the Dawn of the 21st Century*, 31 HAMLINE L. REV. 679 (2008).

116. *See* JODY W. LIPFORD, AVERTING WATER DISPUTES: A SOUTHEASTERN CASE STUDY 5 (2004) at 5, *available at* http://www.perc.org/pdf/ps30.pdf.

117. This figure is for the year 2000. *See* LIPFORD, *supra* note 116.

118. The description in the text leaves out claims for navigation and recreational use in the middle and bottom of the basin, and also omits the buyout of hydropower interests by Atlanta to remove another energy security interest from the problem. *See, e.g.*, Robert Haskell Abrams, *supra* note 115.

the linchpin for the controversy is the effort to allocate more water in upstream storage for population security in metropolitan Atlanta. Equally plain, the ESA claims and the claims of damage to the ecology of Apalachicola Bay are demands for ecological security. Alabama has lodged a claim for water for thermoelectric cooling—the Farley nuclear reactor near Dothan, Alabama, has been threatened with shutdown due to an insufficient supply of water for cooling.[119] Finally, in the low-visibility portion of the conflict, Georgia has allocated increasing amounts of Flint River water to summer irrigation use, which is water that otherwise could augment flows from the Chattahoochee into the Apalachicola[120] in the low flow periods of summer and early fall.

The most heated part of the controversy is the conflict between water for population security and water for ecological security. Atlanta's metropolitan population has swelled from 3 million in 1990 to 5.25 million,[121] and the city must supply its growing population with a source of water that is reliably secure even in drought years. Because of its particular location near the headwaters of three river basins[122] and the dearth of usable groundwater, Atlanta's water supply must come from those headwaters. Since the hydrographs of the upper reaches of the basins have long low flow periods in summer and fall, and since the area's history includes some drought years, providing a consistent year-round supply is an imperative. The metropolitan region's options are limited to impounding and storing headwaters so they will be available for municipal use in low flow or drought periods.[123]

At the other end of the basin are ecological uses that are threatened principally by low flows. Low flows eliminate endangered

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119. *See* Paul Vos Benkowski & Bonnie Urfer, *Unplanned Shutdowns Highlight Inefficiency of Nuclear Power*, NUKEWATCH QUARTERLY, Winter 2007–08 at 2, *available at* nukewatch.com/quarterly/20074winter/page2.pdf. *See also* News Release, Beth Chapman, Alabama Secretary of State, Atlanta-Based Southern Company Confirms Impact on Farley Nuclear Plant if Water Flow Reduced (Oct. 25, 2007), *available at* http://www.sos.alabama.gov/PR/PR.aspx?ID=114 (last visited Aug. 16, 2010).

120. The basin geography is fairly simple. The Chattahoochee rises not far from Atlanta and flows west to where it forms the border with Alabama. It is joined from the east by the Flint, which rose in central Georgia. Once joined the river becomes the Apalachicola, that then flows south through the Florida panhandle to the Gulf of Mexico.

121. *See* LIPFORD, *supra* note 116, at 5.

122. The second basin is the far less heralded Alabama-Coosa-Tallapoosa (ACT) with the storage facility being Lake Allatoona, a reservoir under the control of the U.S. Army Corps of Engineers. Water is drawn there and conveyed to Atlanta by a pipeline. The third basin is the Ocmulgee, which shares a divide with the Chattahoochee. The Ocmulgee flows east from Atlanta into the Atlantic Ocean, and is a small river at its Atlanta headwaters, with no significant storage sites that might be developed.

123. Conservation is also an option, but over time it seems reasonable to expect that conservation alone will not be enough to secure the population against drought.

mussel habitat by drying out many riparian areas that are usually inundated. Low flows also risk an increase in salinity of Apalachicola Bay, the saltwater estuary of the system. That change would negatively affect oyster production, a key industry in the region. The endangered sturgeon requires higher flows at certain times of the year for successful spawning and migration. Since dams control slightly more than half of the water usually available in the system, the nature of the competition is fairly plain: Atlanta's demand for water favors a maximum amount of upstream storage while the ecosystem at the bottom of the river demands some level of conformity with the natural flow regime.

The short-term resolution of the population security-ecological security conundrum took form on June 1, 2008, when the U.S. Army Corps of Engineers (Corps) issued a "Revised Interim Operating Plan" (RIOP) covering the management of water storage and releases from four Corps dams on the Chattahoochee River. As a result of the RIOP, more storage in Lake Lanier will be available to the Atlanta metro region, which can now rely on receiving a minimum, even in drought periods, of approximately 500 mgd.[124] The RIOP (supposedly) ensures a minimum flow of 4,500 cfs at the bottom of the basin.

Further, as the ACF example shows, water for ecological security demands more than just minimum flows. Some ecological demands on the natural flow regime are time-specific, such as flushing flows for spawning. Stated somewhat more abstractly, the intricate pattern of biological adaptations in all of the nation's basins relies on the natural flow regime. The natural flow regime itself is subject to variation, but typically variation within long established limits (e.g., stationarity).[125] With the settled hydrologic patterns under siege due to climate change and the stresses of increasing off-stream use, it should be no surprise that more human intervention and effort that attempts to manage and control water resources is necessary to prevent ecological collapse.

The chance of more frequent conflict between ecosystem water and other forms of water for security increases as a more robust conception of ecosystem water needs is taken into account. Improved scientific understanding of the ecological role of water flows demonstrates that ecosystems require more water. A good example of this is the recent

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124. *See generally* U.S. Army Corps of Eng'rs, Description of Proposed Action Modification to the Interim Operations Plan at Jim Woodruff Dam, http://www.sam.usace.army.mil/ACF%20Water%20Resources%20Management/ProposedActionDescription-Modification_to_IOP.pdf.

125. For a case study specific to the ACF basin, see C.A. Gibson, *Flow Regime Alterations Under Changing Climate in Two River Basins: Implications for Freshwater Ecosystems*, 21 RIVER RESEARCH AND APPLICATIONS 849 (2005), *available at* ftp://brrftp.cr.usgs.gov/pub/mows/pubs/hay_pubs/hay_pdf/gibson.pdf.

study commissioned by the World Wildlife Fund and undertaken by U.S. Forest Service personnel.[126] The four basins, the Cumberland, Tennessee, Mobile, and Alabama, are contiguous to one another and cover the heart of the Southeast, one of the most humid regions in the United States. Those particular basins were chosen because of their particularly rich ecological diversity and importance.[127] The study found that the changed climate would stress the ecological resources of the basin and that efforts are required to protect the ecological values.[128] If that sort of stress can be expected in such humid regions where past percentage water use as measured by the USGS was below 10 percent of available supplies, the same or more stress will be placed on ecological security in regions that were already subject to higher levels of water use and are similarly experiencing inroads on reliable supply.

Before moving on to consider water for energy security and water for food security, a few conclusions about water for ecological security are in order. First, ecological water use is not a luxury, it is a foundational element of regional sustainability. Water for ecological security receives legal protection in a variety of forms. The ESA is the most obvious and preemptive example of such protections. As the ACF example shows, the amount of water that is needed to sustain ecosystems is substantial and increases with improvements in scientific understanding of the water demands of such complex ecosystems. The demise of stationarity on the supply side is a special challenge, because it means more water will be needed in the times of greatest crisis to manage ecosystems for long-term sustainability. Even when the water demand of sustainable ecosystems is better understood, the precise minimum that must be provided will be debated, as a matter of science or as a matter of risk and safety policy and trade-offs for other benefits. In almost every case, whatever that minimum water requirement is, it will be allocated to ecological use because it is fundamental to social stability and values. Ecological security might take a back seat when it competes with population security.[129] While that is not a false conflict in all cases, the relatively low

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126. *See* USDA FOREST SERV., VULNERABILITY OF THE SOUTHEASTERN UNITED STATES TO CLIMATE CHANGE (2008), *available at* http://www.worldwildlife.org/who/media/press/2008/WWFBinaryitem9647.pdf.

127. *Id.* at 3.

128. *Id.* at 4–5.

129. Another reason to think the two are not entirely antagonistic uses, environmental quality is one of the factors that strongly influences current patterns of population migration and consequent growth in population driven water demand. *See, e.g.*, Larry M. Svart, *Environmental Preference Migration: A Review*, 66 GEOGRAPHICAL REV. 314, 314–30 (1976). For that reason, it is reasonable to expect that the political will to have water for both cities and the ecosystem often align. The ACF contradicts that supposition because the ecological cost

volume of population security demands will often mean that its provision will not deny needed water to ecological security if the water allocation decision is not artificially circumscribed.[130]

IV. WATER DEMAND FOR ENERGY SECURITY AND AGRICULTURAL SECURITY—TACKLING THE HIGH VOLUME WATER USES

As a prelude to making broad projections about the water demand that will attend a move toward U.S. energy security in a carbon constrained world, it is necessary to identify the suppositions regarding energy policy that undergird the discussion. Energy efficiency and conservation are the first steps in reducing the water use and carbon emission impacts of energy generation. As the president and chief executive officer of Duke Energy recently stated, "the greatest potential for reducing water and air emissions for electricity generation is through greater energy efficiency. We believe that the most environmentally responsible power plant we can build is the one that we don't build."[131]

If energy efficiency and conservation cannot adequately reduce demand, new generation of electricity in the United States will move towards technologies and fuels that result in decreased carbon dioxide emissions as a result of new regulatory and economic pressures.[132] At the same time, for economic and political reasons, the United States will make a serious, long-term effort to increase the amount of energy that is generated from domestic sources.[133] To achieve both of these goals, the

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is, in terms of geopolitical boundaries, externalized, falling two hundred miles downstream in another state.

130. Again, the ACF presents an example in two separate ways. As noted previously, Georgia has not significantly limited Flint River irrigation, which impacts Apalachicola flows. More directly, a competing dam operations plan for the Corps dams proposed by the Atlanta Regional Commission eliminated conflict between water for population security and water for ecological security across a far broader range of operating conditions, especially those at the drought end of the spectrum. *See generally* GEOR. SOIL AND WATER CONSERVATION COMM'N, FIELD MANUAL FOR EROSION AND SEDIMENT CONTROL IN GEORGIA (4th ed. 2002).

131. Statement by James E. Rogers, Chairman, President and Chief Executive Officer, Duke Energy Corporation, in WORLD ECONOMIC FORUM, THIRSTY ENERGY: WATER AND ENERGY IN THE 21ST CENTURY 1, *available at* http://www2.cera.com/docs/WEF_Fall2008_CERA.pdf.

132. *See U.S. Energy Chief Floats Carbon Tax Idea*, SYDNEY MORNING HERALD, Feb. 13, 2009, *available at* http://news.smh.com.au/breaking-news-world/us-energy-chief-floats-carbon-tax-idea-20090213-869i.html (last visited July 21, 2010).

133. Efforts of the Carter administration in this direction fizzled out when oil prices receded. *See* Jimmy Carter—National Energy Program Fact Sheet on the President's Program, *available at* http://www.presidency.ucsb.edu/ws/index.php?pid=7373 (last visited

country should first look to renewable energy sources, but may also consider increasing use of nuclear power, oil shale, coalbed methane, and biofuels. Investment in carbon dioxide sequestration technology may encourage more development of nonrenewable generation.

Changes are also expected in the transportation sector, as fuels derived from products other than traditional crude oil will become a major component of the energy budget. Gasoline refined from oil shale is already entering the market. The most immediately available new transportation energy sources include biofuels, such as corn-based ethanol. Investments are also expected to bring hydrogen fuel cells to the market, ideally with the separation of the hydrogen being powered by renewable energy sources. Further, the electricity generation and transportation sectors are beginning to intersect as vehicles utilize batteries charged by electricity from stationary power plants.

Several of the fuel-specific predictions involve very large quantitative water demands. Those technologies also pose water quality challenges in the form of pollution or heated discharge that are beyond the scope of this article.[134] The water demands of each type of source vary in terms of the amount of water, the locus of likely use, and type of impact that use will have on water quantity remaining for other users.

Mar. 1, 2009), in conjunction with, Crude Oil Prices, *available at* http://www.wtrg.com (last visited Mar. 1, 2009). Efforts in that direction called for in REPORT OF THE NAT'L ENERGY POL'Y DEV. GROUP, NATIONAL ENERGY POLICY OF MAY 2001, *available at* http://www.pppl.gov/common_pages/national_energy_policy.html (last visited July 21, 2010), have been likewise unsuccessful at reducing dependence on foreign oil, which has increased considerably from the 52 percent figure for 2000 provided in that document. *See id.* at 1–6. The most recent figures from the Department of Energy (DOE) indicate that 57 percent of oil consumed in the United States now comes from foreign sources. *See, e.g.*, U.S. ENERGY INFORMATION ADMIN., "HOW DEPENDENT ARE WE ON FOREIGN OIL?," *available at* http://tonto.eia.doe.gov/energy_in_brief/foreign_oil_dependence.cfm (last visited July 21, 2010). Despite the recent decline in world oil prices, reducing oil dependence remains a doubly good idea for the United States. Alternative fuels may have a smaller carbon footprint, and the insecurity of foreign oil sources is unchanged by the temporary decline in world demand for oil.

134. This article also makes a deliberate choice to omit hydropower generation opportunities. To be sure, some new generating dams will be built, although virtually all of the best sites were dammed long ago. The water cost of generating electricity by hydropower is due primarily to evaporation and thus varies by climate, with a national average of 4,500 gallons per megawatt hour. *See* WORLD ECONOMIC FORUM, *supra* note 131, at 21. Those evaporation losses will be larger with the advent of higher ambient temperatures. Even so, predicting where there will be enough of a change to have a significant impact on water demand is too difficult and speculative to claim as a major consideration facing future policymakers.

A. Cooling Water for Thermoelectric Energy Generation

Thermoelectric power plants use water for cooling because water can absorb 4,000 times as much heat as air for a given rise in temperature.[135] Quantitatively, the amount of water withdrawn for thermoelectric generating facilities almost staggers the imagination.[136] The USGS 2000 Report noted that of the 408 billion gallons per day of all water withdrawals in the United States, 48 percent was used for thermoelectric power generation.[137] Since groundwater supplies less than one percent of all thermoelectric withdrawals,[138] the percentage of national surface water withdrawals for thermoelectric generation is even more pronounced, just over 60 percent. Even though 30 percent of thermoelectric surface water withdrawals are saline, the freshwater surface withdrawals for thermoelectric needs still account for over half of the nation's total.[139]

The withdrawal and consumption levels of a thermoelectric plant are primarily based on the fuel source and the cooling technology employed at the plant.[140] On average, nuclear power plants, often touted for their carbon neutrality, require larger water withdrawals per unit of energy than coal or natural gas plants. Nuclear plants require an average of 830 gallons per megawatt hour (gal/mWh), while coal and natural gas plants require an average of 750 gal/mWh and 600 gal/mWh respectively.[141] These numbers are further influenced by the cooling technology, which can be divided into two categories: open loop and closed loop systems. In open loop, or once-through cooling systems (OT), water is withdrawn from a nearby source, passed through a surface condenser, and then discharged back into the original source. OT systems are characterized by high withdrawal rate and low consumption factors. Compared to OT systems, closed loop systems, either wet recirculating or air

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135. WORLD ECONOMIC FORUM, *supra* note 131, at 1.

136. Thermoelectric plants use water for cooling, handling ash, washing, wastewater treatment, and flue gas desulfurization (FGD) but generally the greatest percentage of withdrawn water is used for cooling purposes. Thomas J. Feeley III et al., *Water: A Critical Resource in the Thermoelectric Power Industry*, ENERGY 33, 3 (2008), *available at* http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/netl%20water%20estimate%20article%20Elsevier%201107.pdf.

137. HUTSON ET AL., *supra* note 29, at 5–7.

138. Only one-fifth of 1 percent of the water used in thermoelectric generation is groundwater. *Id*. at 9.

139. The remaining 30 percent of withdrawals are of saline water. *Id*.

140. Coal-fired power plants consumption levels are also dependent on which type of boiler and FGD devices are used. Feeley III et al., *supra* note 136, at 4.

141. World Business Council for Sustainable Development, *Water Woes Loom as Thirsty Generators Face Climate Change*, GREENWIRE, Oct. 4, 2007, *available at* http://www.earthportal.org/news/?p=536 (last visited July 21, 2010).

cooling, tend to make a more efficient use of cooling water and are characterized by lower withdrawal and higher consumption rates. In wet recirculating systems, cooling ponds (CP), and wet cooling towers (WCT), cooling water is brought into the plant and recycled through a cooling tower or pond so that new water is only required to replenish the amount lost through evaporation and blowdown.[142] Air cooling and indirect dry cooling systems are the most efficient as they require only negligible amounts of water, or none at all.

The actual impact of thermoelectric growth will depend in large measure on the cooling technologies employed by plants built in the future. Extrapolation based solely on current water use figures would only be accurate if future thermoelectric plants maintain the same mix and proportion of combustion technologies and cooling methods as existing plants. Currently, less than half of the nation's thermoelectric plants use OT systems,[143] but those plants account for 91 percent of the water withdrawn for thermoelectric generation; conversely, while over half of the plants use closed loop systems, these plants only account for 9 percent of the withdrawals.[144]

TABLE 2: CURRENT COOLING TECHNOLOGY BY GENERATION TYPES[145]

	Once-Through	Wet Cooling Tower	Dry	Cooling Pond
Coal	39.1%	48.0%	0.2%	12.7%
Fossil Non-Coal	59.2%	23.8%	0.0%	17.1%
Combined Cycle	8.6%	30.8%	59.0%	1.7%
Nuclear	38.1%	43.6%	0.0%	18.3%
TOTAL	42.7%	41.9%	0.9%	14.5%

As in the past, future technological choices will be heavily influenced by environmental regulations that favor the use of more efficient

142. Blowdown is the process of discharging cooling water in order to prevent the buildup of the minerals and sediments which may impair efficiency. SHUSTER ET AL., ESTIMATING FRESHWATER NEEDS TO MEET FUTURE THERMOELECTRIC GENERATION REQUIREMENTS, 2007 UPDATE 12 (2007), *available at* http://www.fypower.org/pdf/DOE_WaterNeedsAnalysis_2007.pdf.

143. *See infra* Table 2.

144. HUTSON ET AL., *supra* note 29, at 44.

145. Only 7 percent of the total combined cycle (CC) plants currently in operation are reflected in the data, the authors of the report feel that if data had been available for a larger number of CC plants, the percentage of those plants utilizing dry cooling systems would be much smaller. DEP'T OF ENERGY/NAT'L ENERGY TECH. LABORATORY, ESTIMATING

cooling systems. Prior to the 1970s, OT systems were the norm, but CWA[146] requirements concerning water temperature and quality spurred a national preference for closed loop systems in order to avoid treatment costs that tended to be proportional to the amount of water discharged.[147] This shift is reflected in the three-fold reduction in the average amount of water needed to generate a kilowatt-hour of electricity from 63 gal/kWh in 1950 to 21 gal/kWh in 2000.[148] While the exact degree to which each available technology will be employed remains up for consideration, current CWA rules[149] push for even stricter measures to protect aquatic wildlife, thus creating a presumptive preference for closed loop systems.[150]

Recently, the National Energy Technology Laboratory (NETL) released a report projecting freshwater withdrawal and consumption through the year 2030 based on five different scenarios of technological innovations and regulatory changes.[151] The report predicts that even with an increase in the absolute number of plants, withdrawal rates will experience a 0.5 to 30.5 percent decrease while consumptive rates will experience a 27.4 to 48.4 percent increase.[152] The increases in consumption under the NETL projection are substantial, but standing alone they do not majorly impact existing uses and economies. Using 2005 as the baseline, a year in which there were 149.2 billion gallons per day (bgd) in withdrawals and 6.2 bgd in consumption, one could expect 2030 with-

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FRESHWATER NEEDS TO MEET FUTURE THERMOELECTRIC GENERATION REQUIREMENTS 13 (2008 update), *available at* http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/2008_Water_Needs_Analysis-Final_10-2-2008.pdf.

146. *See* 33 U.S.C. § 1326 (1986); Clean Water Act, § 316(b); 40 C.F.R. § 401.14 (2008) requiring "[t]he location, design, construction and capacity of cooling water intake structures . . . reflect the best technology available for minimizing adverse environmental impact. . . ."

147. HUTSON ET AL., *supra* note 29, at 42.

148. *Id*.

149. CWA regulations were implemented in three phases, the first two phases are the most pertinent to thermoelectric plants. National Pollutant Discharge Elimination System: Regulations Addressing Cooling Water Intake Structures for New Facilities, 66 Fed. Reg. 65,256 (Dec. 18, 2001); National Pollutant Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities, 69 Fed. Reg. 41,576 (Jul. 9, 2004).

150. *Id*.; SHUSTER ET AL., *supra* 142, at A-3.

151. Starting in 2010, these scenarios range from keeping the status quo to only building wet recirculation plants and retrofitting 5 percent of the existing OT cooling plants every five years. Feeley III et al., *supra* note 136, at 3.

152. *Id*. at 4.

drawals to decrease by between 7.46 and 45.5 bgd, while consumption levels will rise between 1.7 bgd and 6.3 bgd.[153]

A more pressing concern for thermoelectric water demands revolves around the location of the plants and whether the water needs will place stress on local supplies. There are at least two generic settings in which location of a thermoelectric plant will create water withdrawal supply concerns of consequence. The first is in non-coastal arid regions of the country[154] where water supplies are already short and the potential for water use conflict is patent even before adding additional consumption to the system. In arid areas, the majority of plants already use closed loop systems,[155] so increases in consumption will not necessarily be offset by major decreases in withdrawals that might come about as older plants are retired, or have their cooling systems changed. Increased consumption does have the possibility of wreaking havoc for downstream users by reducing the quantity of return flow. This concern is not of a nebulous nature. In 2006, Idaho placed a two-year moratorium on the construction of new thermoelectric plants based on concerns over the environment and water availability.[156]

The second setting of concern is for plants located in humid regions that will draw their water from streams that have low flow periods (usually late summer), and limited local or upstream reservoir storage that they can reliably command. These latter plants are at risk of having to shut down for lack of cooling water under seasonal or drought-induced low flow conditions. Unreliable water supply is of particular concern in the Southeast and is one of several elements in the ACF controversy. Alabama's Farley nuclear power plant, which supplies about 20 percent of the state's electricity, is located downriver of the Lake Lanier impoundment, which is of similar importance for Georgia, and especially metropolitan Atlanta's municipal water supply. However, under the current management regime, the Lake Lanier impoundment's release schedule may not ensure adequate cooling water for the downriver nuclear plant at all times in drought years.[157] A somewhat

153. The conversion factor is 1 mgd = 1,120 acre-feet per year. *See* SAX ET AL., *supra* note 48, at 26.

154. With a few exceptions this includes everything west of the 100th meridian that starts in the Great Plains states.

155. For a state-by-state breakdown of thermoelectric withdrawals by source and cooling technology, see HUTSON ET AL., *supra* note 29, at tbl.13.

156. ID H.B. 791, 58th Leg., 2d Reg. Sess. (Idaho 2006), *available at* http://www3.state.id.us/oasis/2006/H0791.html (last visited July 21, 2010).

157. William Sweet, *Drought Forces U.S. Government to Decide Among City Residents, Nuclear Power, and River Mussels*, IEEE SPECTRUM, Nov. 19, 2007, *available at* http://spectrum.ieee.org/nov07/5727 (last visited July 21, 2010).

related problem, though more temporally distant, involves plants located in a region with a reliable flow, such as the Great Lakes, which may face inadequate cooling water supplies due to elevated water temperatures resulting from climate change effects.[158]

To what degree will new thermoelectric power plants have the freedom to choose their location to avoid potential water supply conflicts? One cost factor is the location of transmission lines. Since the current transmission grid is both outdated and unable to keep pace with the growth in energy demand and generation, construction of new thermoelectric plants may be especially constrained in areas that are already experiencing transmission bottlenecks.[159] A second cost factor for these plants is the cost of fuel transportation. Unlike nuclear fuel rods that are relatively easy to transport, coal is bulky and comparatively expensive to transport. Western coal-producing regions are all in the arid portion of the nation, as are most of the feedstocks for synfuels. A third factor involves the mandate to reduce carbon dioxide emissions. Achieving emissions reduction will require fossil fuel plants to implement mechanisms for capturing carbon. While some carbon capture techniques may be installed at the plant,[160] the proper geologic conditions for carbon sequestration, usually formerly oil- and gas-bearing formations having only saline groundwater deposits, are unevenly distributed around the nation. Many of the leading candidate storage formations are located in arid regions of the West.[161]

Imagine the decisional calculus of a firm seeking to site a thermoelectric facility on an over appropriated river in the West. To obtain water rights inexpensively, the firm would seek to purchase senior rights from highly consumptive but low value farmers so that relatively few rights have to be retired to offset the plant's entire consumptive use. If all of the additional water for NETL's thermoelectric cooling in the California and the southwestern regions were to be obtained by retiring irrigation of crops, the "cost" would be retirement of about one-quarter of a million acres from irrigated farming. The priority system will tend to provide secure rights. In the East and in the Mississippi Valley there is a sufficient supply of water to meet current and future cooling needs.

158. SMITH ET AL., POTENTIAL EFFECTS OF CLIMATE CHANGE IN THERMOELECTRIC COOLING SYSTEMS, POSTER PRESENTATION BY OAK RIDGE NATIONAL LABORATORY (2005), *available at* http://www.climatescience.gov/workshop2005/posters/P-WE1.18_Smith.B.pdf. This is especially a problem for OT plants which do not have in-house technology to cool water.

159. SPENCER ABRAHAM, U.S. DEP'T OF ENERGY, NATIONAL TRANSMISSION GRID STUDY 2–8 (May 2002), *available at* http://www.ferc.gov/industries/electric/gen-info/transmission-grid.pdf. For a map of the area with bottlenecks see Sections II and III of the study.

160. *See infra* Part IV.E for further discussion.

161. *Id*.

However, there are site-specific concerns over both the environmental footprint of a thermoelectric plant and competition with other stream uses.

Increased water demand for the thermoelectric industry may be abated somewhat by potential innovations in water technology. Because potential shortage of water supply is viewed on the same level as concerns over transmission lines and fuel availability,[162] the Department of Energy (DOE) has been pushing a more comprehensive research agenda that includes consideration of water use. DOE is also attempting to spur development of advanced methods that improve the performance and lower the cost of efficient cooling technology and technologies that recover and purify water from flue gas.[163] Thus, there is potential that actual impact of water demands for the thermoelectric industry will be less significant than is currently being predicted. Regardless, thermoelectric plants are not the only sector raising water concerns for energy security.

B. Coalbed Methane

Many of the nation's electric generating facilities, especially those built between 1990 and the present, run on natural gas (i.e., methane). That gas is found in conjunction with fossil fuel deposits of both oil and coal. Domestic production of methane is decreasing and greater quantities are being imported. As a matter of energy security, developing coalbed methane (CBM), which is available in large quantities in the United States, would reduce foreign fuel dependence.

CBM has some environmental plusses and minuses. The combustion of methane gas produces carbon dioxide and water.[164] "Coalbed" methane, as the name implies, is found in coal seams, and is a particularly good source of methane because CBM is often a very pure, clean-burning form of that gas, with little sulfur or other chemicals that would become pollutants.[165] Assuming that the carbon dioxide in the waste stream can be separated and sequestered,[166] CBM would be a clean, domestically available fuel. Its production, however, has two water impacts, one a water quantity matter, and one a water quality matter.

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162. Robert Peltier, *New Coal Plant Technologies Will Demand More Water*, http://www.powermag.com/water/61.html (last visited Jan. 27, 2009).

163. Lindsay Green et al., *Finding Technological Solutions to the Energy-Water Nexus, available at* http://www.iags.org/n0829052.htm (last visited Feb. 25, 2009).

164. Elmhurst College, Virtual Chembook, http://www.elmhurst.edu/~chm/vchembook/511natgascombust.html (last visited July 21, 2010).

165. DEP'T OF ENERGY/NAT'L ENERGY TECH. LAB., COAL BED METHANE PRIMER 2 (2004), *available at* http://www.all-llc.com/page.php?92 (last visited July 21, 2010) [hereinafter CBM PRIMER].

166. *See infra* Part IV.B.

To understand these water impacts requires a rudimentary understanding of the physical characteristics of CBM in the ground.[167] One self-described "primer" on the subject begins with this description:

> Coalbed methane (CBM) is a form of natural gas that is trapped within coal seams and held in place by hydraulic pressure. The gas is adsorbed to the internal surfaces of the coal; when wells are drilled that extract the water holding the gas in place, the methane eventually flows through fractures to the well and is captured for use.[168]

Thus, the water quantity issue arises in relation to pumping the groundwater as the physical means of initiating the harvesting of the gas.[169] The water quality issue arises because the groundwater formations being pumped may be saline, or, even if they are freshwater, the groundwater may contain contaminants associated with pollutants present in conjunction with the coal seam or other parts of the formation.[170] Saline or polluted freshwater must be safely disposed.

The primary concern of this article is on the quantitative side. In that regard it is important to discern how much freshwater—water that could sustain other uses—must be pumped for commercial gas production. After that, assuming pumping occurs, it is important to calculate what other uses, if any, will be made of the now available pumped groundwater. Finally, there is something akin to an opportunity cost. Water that is pumped and not recharged could have supported alternative uses in the future had it been left in place. Those uses and their importance need to be considered.

The availability of large commercially exploitable deposits of CBM is, of course, regional, depending on the location of CBM bearing coal and groundwater in the right combination. Although there are many places in the United States where the proper mix of resources are found, the most prominent ones are in the intermountain West. Major producing regions are the San Juan Basin of Southern Colorado-Northern New Mexico, which is beginning to play out, and areas north of that in the Green River, Piceance, and Unita Basins of Colorado, Wyoming,

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167. For a succinct description of two processes by which CBM forms in conjunction with coal seams, see CBM PRIMER, *supra* note 165, at 8.

168. *See* Gary Bryner, *Coalbed Methane Development in the Intermountain West: Primer*, NAT. RESOURCES LAW CTR., UNIV. OF COLO. SCH. OF LAW 1 (2005), *available at* http://www.colorado.edu/Law/centers/nrlc/publications/ CBM_Primer.pdf. For a more technical description, *see also* CBM PRIMER, *supra* note 165, at 9–12.

169. CBM PRIMER, *supra* note 165, at 3.

170. *Id.*

Utah, and Montana.[171] All of these areas are very arid and have limited available surface water. Therefore the regional groundwater is a key part of their long-term water supply and also plays a significant role in maintaining streamflow.

Using data from the 2000–02 period, the NETL report offered a window on just how much freshwater water was being pumped and discharged in that region. Their data for the Powder River Basin, which was the only major western region producing CBM by pumping freshwater, reported that 10,358 wells were in operation, each pumping an average of 16,800 gallons per day from depths that varied from 200 to 2,500 feet below the surface, for a total of 174 mgd, which is roughly 165,000 acre-feet per year. Because of the very low barriers to entry compared to other energy sources, the Department of the Interior (DOI) in its Environmental Impact Statement (EIS) on lands leasing for Powder River CBM development projects estimated that five times as many wells will be open by 2015.[172] Using the averages just set out, that would bring water production up to around 800,000 acre-feet per year.[173] There is recharge to the aquifer, but the groundwater would be "gone" for several generations. Even the DOI's draft EIS noted that the coal aquifers would need "a hundred years or so" to recover to 95 percent of their previous levels from the peak drawdown due to CBM withdrawals.[174] Thus, improvident dewatering of the aquifer threatens to alter the regional water flow patterns and compromise other water dependent activities in the basin.[175]

Having considered CBM water availability and use concerns as a quantitative matter, and putting aside water quality and other environmental concerns,[176] there remains a more technical legal question of ob-

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171. *Id*. at 11–12.

172. U.S. DEP'T OF THE INTERIOR, BUR. OF LAND MGMT., ENVIRONMENTAL IMPACT STATEMENT AND DRAFT PLANNING AMENDMENT FOR THE POWDER RIVER BASIN OIL AND GAS PROJECT, 2–24.

173. Thomas F. Darin & Amy W. Beatie, *Debunking the Natural Gas "Clean Energy" Myth: Coalbed Methane in Wyoming's Powder River Basin*, 31 ENVTL. L. REP. 10566 (2001).

174. Bryner, *supra* note 168, at 16 (citing BUR. OF LAND MGMT, WYO. STATE OFFICE, U.S. DEP'T OF THE INTERIOR, DRAFT ENVIRONMENTAL IMPACT STATEMENT AND DRAFT PLANNING AMENDMENT FOR THE POWDER RIVER BASIN OIL AND GAS PROJECT xxiv, 4–12 (2002).

175. For example, in the Fort Union Formation where CBM production is underway, the water quality has been sufficient to serve as a municipal supply for Gillette, Wyoming. Nevertheless, its quality is not as high as all of the region's surface streams. *See* CBM PRIMER, *supra* note 165, at 20.

176. The environmental concerns are extensive:

> Coalbed methane in the hundreds of trillion cubic feet of potential reserves in the Rocky Mountains is a major, if not the biggest, threat to the region's environment and natural resources. Projections in the Wyoming Powder River Basin alone include 17,000 miles of new roads, 20,000 miles

taining rights to pump the groundwater. Several states, such as Utah[177] and Montana,[178] treat this as a question of mining law, creating a category of "byproduct water" that is somewhat distinct from their water law.[179] This is a reasonable approach when the water is saline or otherwise unusable for other beneficial purposes such as irrigation. Under those regimes, the typical regulation of that water focuses on proper disposal.[180]

When the water involved is freshwater that is available[181] to serve a wide variety of beneficial purposes or is hydrologically linked to stream flows, it would make more sense to allocate water rights to use the water for CBM production under the state's normal water law. There is relatively little firm evidence that the prior appropriation system is being used to regulate CBM water use in most western states that have major CBM operations underway.[182] Wyoming, because of its very large-scale CBM production involving a freshwater supply, is the case of greatest interest. In Wyoming, the law recognizes by-product water and treats it separately from groundwater that is subject to prior appropriation for a beneficial use. CBM water, however, is categorized as water subject to prior appropriation requiring permits from the state engineer.[183]

> of new pipelines, 5,300 miles of new overhead powerlines, and more than 200,000 acres of surface disturbance by 2017.

Thomas F. Darin, *Waste or Wasted?—Rethinking the Regulation of Coalbed Methane Byproduct Water in the Rocky Mountains: A Comparative Analysis of Approaches to Coalbed Methane Produced Water Quantity Legal Issues in Utah, New Mexico, Colorado, Montana, and Wyoming*, 17 J. ENVTL. L. & LITIG. 281, 340 (2002).

177. *See* UTAH ADMIN. CODE r.649-9-1.1 (2002).

178. *See* MONT. CODE ANN. § 82-11-111(2)(a) (2001) (first enacted in 1953) (noting that jurisdiction over regulating disposal of oil and gas byproduct water is vested with the Montana Board of Oil & Gas Conservation).

179. Bryner, *supra* note 168, at 31.

180. *See, e.g.*, Colorado Oil and Gas Conservation Commission Rule 907, *available at* http://cogcc.state.co.us (last visited July 21, 2010). *See also*, COLO. REV, STAT. § 34-60-103(4.5) ("'Exploration and Production Waste' means those wastes that are generated during the drilling of and production from oil and gas wells or during primary field operations and that are exempt from regulation as hazardous wastes under . . . the federal 'Resources Conservation and Recovery Act of 1976.'").

181. Groundwater, even if it is freshwater, may be "unavailable" if, for example, the amount involved is too deep in the ground to be economically removed for certain uses, or if the water is available in too small a sustainable amount for other beneficial uses, even those with a high ability to pay.

182. *See generally* Thomas F. Darin, *Waste or Wasted?—Rethinking the Regulation of Coalbed Methane Byproduct Water in the Rocky Mountains: A Comparative Analysis of Approaches to Coalbed Methane Produced Water Quantity Legal Issues in Utah, New Mexico, Colorado, Montana, and Wyoming*, 17 J. ENVTL. L. & LITIG. 281, 340 (2002).

183. *See* Gary Bryner, *Coalbed Methane Development in the Intermountain West: Producing Energy and Protecting Water*, 4 WYO. L. REV. 451, 550–51 (2004).

As water subject to the state's prior appropriation regime, black letter law indicates that the right to use such water should be limited to the amount beneficially used and that such use should be non-wasteful.[184] Additionally, Wyoming, like many states, has a requirement that the use be in the public interest.[185] Although there seem to be no cases on point at this time, applying that body of law to CBM water use raises three largely separable issues:

1. Is extracting groundwater water as a necessary step in the process of harvesting CBM a beneficial use of that water?

2. Assuming extracting water to produce CBM is a beneficial use, is the amount of water being extracted wasteful?

3. Is there a point at which non-wasteful beneficial uses of water to produce CBM is not in the public interest?

The resolution of the three listed issues involves increasing difficulty. The law of beneficial uses is not particularly exacting. Wyoming ranks its beneficial uses as follows: (1) drinking water for man and animals; (2) municipal purposes; (3) steam engines and cooking, laundry, and bathing; and (4) industrial purposes (including mine dewatering).[186] CBM water use, like water for energy production activities, would qualify as beneficial in the industrial category.

The waste issue is somewhat harder to resolve. Most of the examples of waste in western water law are of two types. The first category comprises outrageous ways of doing things, such as using flooding to drown gophers.[187] The second category includes using profligate amounts of water to do something that requires significant water (such as irrigation for cotton) but is of questionable wisdom in an area where water is so scarce. The water use involved in CBM, although quantitatively large, may not be wasteful. Unlike gophers that can be snared rather than drowned, CBM cannot be produced without reducing the water pressure that "holds" the gas in its adsorbed state within the coal formation. Indeed, the technical descriptions of CBM production make it appear[188] that removing the water is strictly necessary for CBM production. Thus, the amount used is not excessive in relation to the task. Taken

184. *See, e.g.*, A. DAN TARLOCK, LAW OF WATER RIGHTS AND RESOURCES § 5:66 (Westlaw current through July 2008 update).

185. *See* WYO. CONST. art. VIII, § 3, *see also* WYO. STAT. ANN. § 41-3-931.

186. WYO. STAT. ANN. § 41-3-102(b) (by application of WYO. STAT. ANN. § 41-3-906).

187. SAX ET AL., *supra* note 48, at 165–66 (citing Tulare Irrigation Dist. v. Lindsay-Strathmore Irrigation Dist., 45 P.2d 972 (Cal. 1935)).

188. Kristin Keith, Jim Bauder & John Wheaton, Frequently Asked Questions: CBM 3, *available at* http://waterquality.montana.edu/docs/methane/cbmfaq.pdf. The authors have found no material suggesting an alternative process that recovers the CBM without removing the water.

together, the inquiries into beneficiality and waste, as those terms are traditionally used in prior appropriation law, do not prohibit the creation of water rights supporting CBM extraction.

The more salient ground of objection to water extraction for CBM production is legally lodged under the public interest heading. The public interest objection may be stated in a variety of ways, but the underlying principle is this: On balance, when all of the long-term benefits and detriments are considered, extracting so much water for CBM is not a suitable use of the state's scarce freshwater resource. The energy and the economic rewards its production provide are for the good; the roads and habitat disruption, the adverse surface water quality impacts, the dewatering of aquifers,[189] the short-term surfeit of water that is not used after extraction, and the long-term reduction of future supply are negatives. Whatever one's views about the proper resolution of the debate, the public interest requirement should at least raise the visibility of the policy choice framed by the trade-offs and, through the legal system of adjudication and legislation, force a reasoned debate and decision of the matter.

CBM presently uses large and increasing amounts of groundwater that seem likely to reach one million acre-feet (maf) per year in a very arid region. In some areas, notably Wyoming's Powder River Basin, the water being pumped is freshwater.[190] In Wyoming, the amount of water involved is a significant fraction of the available supply, since it is slowly recharging groundwater that, after being pumped to permit CBM release and capture, flows off largely unused. Although this dedication of water resources to increased energy production has not yet produced a regional water shortage, it may in the future.

C. Oil Shale

The oil shale deposits in the United States most suitable for commercial exploitation are found in the Green River Formation, which is named for the modern-day Green River region of Colorado, Utah, and Wyoming.[191] For those with a long enough memory, each time needs for

189. Dewatering can cause subsidence. *See, e.g.*, SAX ET AL., *supra* note 48, at 397–407.

190. Fresh groundwater is also being pumped for CBM in the Black Warrior Formation in Alabama, but the volumes involved are not problematic.

191. *See, e.g.*, U.S. Dep't of the Interior, Western Oil Shale Potential: 800 Billion Barrels, *available at* http://www.doi.gov/archive/news/08_News_Releases/080722.html (last visited Feb. 20, 2009) [hereinafter DOI July 22 News Release]. The Green River Formation is composed of four different basins, the Green River and Washakie Basins in southwestern Wyoming, the Unita Basin in northeastern Utah, and the Piceance Creek Basin in northwestern Colorado. *See* The Oil Shale & Tar Sands Programmatic EIS Information Center,

increased domestic oil supplies seem important, discussions resume about developing this energy resource and with them concerns about the water needed. To repeat Yogi Berra's famous quip, "This is like déjà vu all over again."[192] Originally, as World War I and World War II raised concerns about secure energy sources, and following the oil shock of the early 1970s, oil shale was considered to be a domestic alternative to imports. In this last case, oil shale facilities were brought on line and, when world oil prices receded in the early 1980s, the plants were shut down because the cost of production exceeded the price brought in by the oil.

With the viability of oil shale production in this country linked to world oil prices, it is important in forecasting water demand for oil shale extraction to try to determine at what oil price the shale can be produced and refined profitably. One author with an historical approach to the subject put it at $40 per barrel (in 1989).[193] A 2005 RAND study found the price threshold is likely to be radically different depending on the type of facility.[194] For the mining and surface retorting method, RAND found oil shale is competitive at crude oil prices of $75 to $90 per barrel,[195] whereas an *in situ* retorting project of Shell Oil Company expected to operate profitably with per barrel oil prices in the mid-$20 range.[196] Either way, it seems the time for economically viable oil shale production has arrived, despite the recent dip in world oil prices.

On the political front, oil shale has found its way into the national legislative consciousness with Congress offering incentives for public lands leasing and subsidies for technology and development.[197] The amount of recoverable oil in the Green River Formation is quite large. The RAND study's midpoint estimate was 800 *billion* barrels,[198] which is somewhat more than a 100-year supply of the total domestic U.S. oil de-

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Oil Shale and Tar Sands PEIS Maps for locational and oil shale deposit maps, http://ostseis.anl.gov/guide/maps/index.cfm (last visited July 21, 2010).

192. Things People Said: Yogi Berra Quotes, http://www.rinkworks.com/said/yogiberra.shtml (last visited July 21, 2010).

193. *See generally*, ANDREW GULLIFORD, BOOMTOWN BLUES: COLORADO OIL SHALE 1885–1985 (1989).

194. These estimates include the cost of current environmental compliance but not additional costs to reduce greenhouse gas emissions. *See* JAMES BARTIS ET AL., OIL SHALE DEVELOPMENT IN THE UNITED STATES: PROSPECTS AND POLICY ISSUES x (2005) [hereinafter RAND Study Summary].

195. RAND Study Summary, *supra* note 194, at ix.

196. Research Brief, Rand Corporation, Gauging the Prospects of a U.S. Oil Shale Industry (2005), *available at* http://www.rand.org/pubs/research_briefs/RB9143/index1.html (last visited Aug. 16, 2010).

197. 42 U.S.C.A. § 15927 (West 2001).

198. RAND Study Summary, *supra* note 194, at ix.

mand. On the key issue of water use, the RAND Study Summary stated as follows:

> **Water Consumption.** About three barrels of water are needed per barrel of shale oil produced. Water availability analyses for oil shale development were conducted in the early 1980s. These analyses indicated that the earliest constraining factors would be limitations in local water supply systems, such as reservoirs, pipelines, and groundwater development. A bigger issue is the impact of a strategic-scale oil shale industry on the greater Colorado River Basin. Demands for water are expected to continue to grow for the foreseeable future, making the earlier analyses regarding oil shale development outdated.[199]

To gauge the water demand if oil shale production goes forward, there needs to be an estimate of annual production to go along with the 3:1 process water to produced oil ratio.[200] Because of the boom and bust cycle that occurred the last time production of oil shale was thought economic, but failed when world oil prices went down,[201] the RAND Study Summary postulated a more gradual ramping up of production to one million barrels a day in 20 years, and three million barrels a day in 30.[202] That computes to annual water use of approximately 47,000 acre-feet per year in 2030 and 140,000 acre-feet per year in 2040. That is a large quantity of water in relation to the available supplies of the Upper Colorado River Basin where the oil shale is located. If world oil prices return to and hold at levels in excess of $100 per barrel, it seems quite possible that the guarded estimate of gradual increases in production will be replaced by a race to the retort house, creating water demands that outpace the RAND prediction.[203]

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199. *Id*. at xiii.

200. The standard barrel of oil contains 42 gallons. Texas Oil & Gas Association, What a Barrel of Crude Oil Makes, http://www.txoga.org/articles/308/1/WHAT-A-BARREL-OF-CRUDE-OIL-MAKES (last visited Dec. 22, 2009). Shell Oil, which is proposing the *in situ* retorting method, estimates a 2:1 "wells to wheels" water:oil ratio for that method, which would take into account all water used in the oil shale field, all water used to generate electricity to heat the retort, and all water used to refine the crude into finished product. *See* JAMES R. MONTGOMERY, WATER ISSUES IN OIL SHALE DEVELOPMENT 8 (2007), (paper presented at the 4th Annual Water Law Conference, Steamboat Springs, Colo., June 22–23, 2007) (copy on file with the author) [hereinafter MONTGOMERY].

201. Donald L. Barlett & James B. Steele, *Asleep at the Switch*, TIME, Oct. 12, 2003, 2–4, *available at* http://www.time.com/time/magazine/article/0,9171,1005865-1,00.html (last visited July 21, 2010).

202. RAND Study Summary, *supra* note 194, at xi.

203. This discussion omits speculation about possible federal subsidy and economic stimulus initiatives, or the possible imposition of carbon taxes, all of which would be likely to increase the demand for clean alternative fuels.

Obtaining rights for that much water, particularly in the Colorado system in which engineering standards and quantification are so exacting, is potentially very challenging.[204] Quite importantly, however, conditional rights to a significant quantity of water for oil shale development are already extant. In part because Colorado has such a highly articulated and carefully administered water rights system, it has long been possible to obtain a decreed conditional water right; that is, a water right awarded a priority date when issued, but as to which there is a lag in the time between the award of the right, the completion of the project, and the application of the water to a beneficial use.

In Colorado, conditional water rights must be diligently pursued to completion[205] and are subject to forfeiture in the absence of such diligence.[206] Several conditional water rights from the Colorado River mainstem for oil shale development were adjudicated during two of the previous eras in which oil shale development seemed promising and have priority dates that cluster in the 1950s and around 1980.[207] Due diligence showings must be made on a hexennial basis, but there is no limit to the length of time a conditional right can remain conditional, as long as adequate proof of diligence is made every six years.[208] The factors considered in assessing whether due diligence has been shown include economic feasibility, pursuit of needed permits, expenditures to develop the appropriation, ongoing engineering and environmental study, design and construction efforts, and landholdings and contracts that demonstrate intent and ability to use the water once the right is perfected.[209]

Maintaining conditional water rights for oil shale under those standards became problematic after the oil price decline of the early 1980s made proceeding uneconomic because the remaining cost of production would exceed the revenue received from selling the oil. Potential producers could continue planning, studying, and arranging for eventual operations, but they could not afford to put the water to use. The industry turned to the state legislature, which in 1990 enacted a provision that continuation of a conditional right could not be denied solely on the ground that economic conditions beyond the applicant's control,

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204. Another concern that is not addressed in this article is whether water used for oil shale production might interfere with interstate compact obligations. *See* MONTGOMERY, *supra* note 200, at 17.

205. *See* COLO. REV. STAT. § 37-92-103(6).

206. *See, e.g.*, Mooney v. Kuiper, 573 P.2d 538 (Colo. 1978).

207. *See* MONTGOMERY, *supra* note 200, at 13–14 (describing five decreed conditional rights and their terms).

208. Municipal Subdist., N. Colo. Water Conservancy Dist. v. Getty Oil Exploration Co., 997 P.2d 557, 560–61 (Colo. 2000).

209. *See* Dallas Creek Water Co. v. Huey, 933 P.2d 27, 36 (Colo. 1997).

"adversely affect the feasibility of perfecting a conditional water right or the proposed use of water from a conditional water right."[210] The effect of that provision was litigated in regard to oil shale conditional water rights, and the Colorado Supreme Court ruled in favor of the oil shale firms. Thus, even minimal efforts during the diligence period were sufficient to sustain the conditional right because of the economic conditions facing the oil shale industry.[211]

As a legal matter, it is fair to conclude that the existing conditional rights of the oil shale companies will remain intact until it becomes commercially viable to proceed. Some oil shale firms, including OXY, which won the leading case preserving conditional rights when oil prices rendered oil shale production uneconomic, let their rights expire. They based that decision on their assessment of the politics of world oil prices. They had observed the near billion-dollar loss that Exxon suffered[212] when the Organization of the Petroleum Exporting Countries (OPEC), in their estimation, deliberately lowered world oil prices to force the closure of the oil shale plants as a means of eliminating that source of long-term competition.[213] Under the circumstances, they believed that the same price manipulation would be used against them in the future.

A number of firms have retained their conditional oil shale rights, which preserve the holder's seniority as of the date the conditional right was first granted in accordance with the doctrine of first in time, first in right. In theory, those rights could be put to use and thereby perfected now that world oil prices appear likely to stabilize at a level that makes oil shale production economically viable.[214] These rights, especially those with 1950s priorities, are senior enough on the Colorado River mainstem to pose a threat to important junior uses. Those junior uses include interbasin transfers to the East Slope in support of urban populations, both on the East Slope via interbasin transfer, and on the West Slope in the

210. COLO. REV. STAT. § 37-92-301(4)(c).

211. *See* Municipal Subdist., N. Colo. Water Conservancy Dist. v. Chevron Shale Oil Co., 986 P.2d 918, 924 (Colo. 1999); *see also* Municipal Subdist., N. Colo. Water Conservancy Dist. v. OXY USA, Inc., 990 P.2d 701, 705–08 (Colo. 1999) (discussing the application of the "can and will" requirement for due diligence findings imposed by COLO. REV. STAT. § 37-92-305(9)(b)).

212. *See* MONTGOMERY, *supra* note 200, at 4.

213. Author Abrams conversation on July 28, 2008, with William Paddock, the attorney who represented OXY in the 1980 litigation of its conditional rights.

214. The collapse in oil prices in late 2008 was triggered by the global economic recession, a phenomenon that is temporary. The factors that triggered the price rise, the economic emergence of China and India and other nations, and the increased demand for oil that triggered, will reemerge.

Colorado mainstem basin itself.[215] A less critical impact on other water uses arises once the oil shale plants begin using the water. At that point their plans for augmentation will lead to the retirement of a number of senior agricultural uses in order to protect users downstream whose rights would be adversely affected by the oil shale depletions.

Colorado, anticipating the threat the oil shale water rights pose to junior water rights that provide water for population security and other established uses, commissioned a study of the water-energy nexus.[216] The first phase of the study found that the completion and utilization of the conditional water rights is potentially hugely disruptive.[217] In five selected administrative water districts located in Water Divisions Five and Six, the study found conditional oil shale water rights totaling 607,486 acre-feet of storage rights and 4,332 cfs of direct flow rights.[218] If brought on line, such vast amounts of water with relatively early priority dates will likely trigger ferocious legal battles in the region.

Although the oil shale conditional rights have withstood past attacks based on due diligence, other avenues of attack are likely to be tried. Despite the federal government's support for ramping up oil shale production,[219] its federal lands leasing plan,[220] and subsidies, a great deal of opposition will be raised using federal laws as a fulcrum. If federal leased lands are involved,[221] the whole gamut of challenges to the administrative rules and other federal actions will be raised under the National Environmental Policy Act[222] in efforts to delay or derail projects. There are four listed endangered fish in the Upper Colorado River covered by a U.S. Fish and Wildlife Service Species Recovery Plan. This too will offer many opportunities to challenge the oil shale water use.

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215. The priorities held by later developing East Slope towns, such as Aurora, and some of the transfers to Colorado Springs, are junior to the as yet unexercised 1950s oil shale rights. The West Slope has many towns and developments that grew up far later, in the most recent 30 years, a period in which that region's population grew from about 250,000 to one million. The priorities supporting their uses are junior to almost all of the oil shale conditional rights.

216. *See* H.B. 05-1177, 65th Gen. Assem., Reg. Sess. (Colo. 2005). The overall inquiry is referred to as the Statewide Water Supply Initiative.

217. *See* URS Corp., Energy Development Water Needs Assessment (Phase I Report) Section 7, Sept. 2008, *available at* http://www.crwcd.org/media/uploads/20080925_Energy_Needs_Report.pdf.

218. *Id.* at 6–7.

219. *See, e.g.*, DOI July 22 News Release, *supra* note 191.

220. The Final Oil Shale Regulations were issued November 18, 2008. 43 C.F.R. §§ 3900, 3910, 3920, 3930 (2008).

221. Seventy-two percent of the Green River Formation oil shale underlies federal lands. *See* DOI July 22 News Release, *supra* note 191.

222. 42 U.S.C. §§ 4321–4347 (2000).

A second way in which water for oil shale production could destabilize water rights is the possibility that the Naval Oil Shale Reserves, set aside by executive order in 1916 and 1924, have reserved rights with a priority date as of the date on which the lands were withdrawn from the public domain and set aside for that purpose.[223] The U.S. Supreme Court has stated: "The Department of the Navy administers certain naval petroleum and oil shale reserves which, if ever developed, would require water to accomplish the federal purpose for which the reservations were made."[224] Even in the face of that statement, some commentators argue that the amount of water reserved would not include production, but only water for "purposes of investigation, examination and classification" of the reserves.[225] Much of the disruptive potential of these possible federal claims was diminished by a ruling of the Colorado Supreme Court that had the effect of defeating the early priority date of those claims.[226] What is fairly certain, however, is that should the oil shale beneath the federal reserved oil shale lands be developed, they will be entitled to appropriate water, with a priority as of the date on which they are properly claimed in a Colorado proceeding.

There are state law issues that may become important relating to how allocations of water are to be adjusted in seeking to comply with Colorado's interstate compact obligations under the Colorado River Compact of 1922[227] and the Upper Colorado River Basin Compact of 1948.[228] Under those Compacts, Colorado has firm water delivery obligations that may be difficult to meet because both Compacts were fashioned with reference to an annual virgin flow of the Colorado River of 17.5 million acre-feet, a figure that significantly exceeds Colorado's twentieth-century average flows and seems even less likely to be met

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223. 10 U.S.C. § 7420 (2000).

224. United States v. District Court In and For Water Dist. No. 5, 401 U.S. 527, 529 (1971).

225. Michael Blumm, *Unconventional Waters: The Quiet Revolution in Federal and Tribal Minimum Stream Flows*, 19 ECOLOGY L.Q. 445, 459 (1992).

226. *See* United States v. Bell, 724 P.2d 631 (Colo.1986). The Colorado Supreme Court held that the federal government was disallowed from amending its claim for reserved rights for Naval Oil Shale Reserves in the relevant water districts and having the amendment relate back to the date of the reservation. More specifically, the original filing of the claim was too indefinite to put potential objectors on notice. The amendment allowed the claim to be recognized, but the failure to raise the claim timely had two separate effects on the priority date. First, the failure to claim vitiated the reservation date as date of priority and, second, the non-relation back meant the claim dated from the date of the amendment, which was nearly a decade later than it would otherwise have been.

227. See 43 U.S.C.A. § 617l (1928) for the text and its dates of enactment and signing. See COLO. REV. STAT. § 37-61-101 (Lexis 2008) for its current place in Colorado law.

228. 63 STAT. 31 (1949); COLO. REV. STAT. § 37-62-101 (Lexis 2008).

under the changed climate conditions in the region. There is a degree of uncertainty at this time about how Colorado would curtail appropriations if it found itself at risk of an under-delivery situation.[229]

Fitting water for oil shale into the larger picture of water demand for energy security at this point in time is fraught with uncertainty. The principal uncertainty is whether oil shale will be tapped on a large scale and, if so, how soon. The current volatility of world oil prices makes oil shale developed using above-ground retorting methods an economically risky substitute for imported crude oil. The past oil shale industry experience that saw hundreds of millions of dollars invested wiped out by declining world oil prices has bred caution into the decisional process. Even if world prices rebound, which seems inevitable, there is a considerable lead-time to large-scale production. However, once oil shale becomes a proven and economically successful substitute for imported crude oil, the reserves are so vast and world oil demand is growing so significantly, the RAND Study's three million barrel per day estimate of eventual production levels and its associated water demand seem low. From a demand assessment standpoint, oil shale is not an immediate concern. In the longer term, the limited and possibly shrinking water availability in the Upper Colorado region and the relative seniority of the conditional oil shale water rights foretell a serious problem that has the potential to place oil shale water rights ahead of some of the region's intermountain diversions and also ahead of most West Slope municipal supply water rights.

D. The Special Case of Biofuels

Biofuels have a unique place in the projections of future water for security because they simultaneously create a new demand for water and, by displacing present agricultural food security production, cause the very likely relocation of food production to other regions.[230] Somewhat simplistically, assume that the pre-biofuels mix of crops being grown in their current locations was a sensible pattern in relation to overall food demand, taking into account values of crops, growing seasons, water availability, soil types, etc. Add to that a new and significant demand for growing biofuels crops. For ethanol these crops include corn, sorghum, cane sugar, and perhaps cellulose sources; for biodiesel these

229. States are required to curtail in-state uses to meet compact obligations. *See, e.g.*, Hinderlider v. La Plata River & Cherry Creek Ditch Co., 304 U.S. 92 (1938). *See also* Texas v. New Mexico, 462 U.S. 554 (1983).

230. See *infra* note 247 for a brief consideration of the impact of biofuels production on world food process.

crops include soybeans, vegetables, and again, the possibility of cellulose.[231]

As a simple supply and demand function, any added demand for biofuels crops will induce additional production of those crops. The change will be even more immediate and dramatic because the crop value of those commodities in energy production is higher than it is in food production. The impact will take three forms. The simplest is that current production will continue, but will be used to serve the energy sector rather than the food sector. Second, some lands that are presently in use for other food crops will be switched to biofuels crops. Finally, some new lands will be pressed into service because their cultivation will become profitable. Continuing the chain of events, dedication of output and additional lands to biofuels crops will shorten food supply, which will increase food prices, which has the potential to bring new lands under cultivation. Since the United States has a sufficient land base available to support additional cultivation, the overall result of an increase in biofuel crop demand will be an increase in the amount of land used for crops. Predicting where additional lands will be added to growing biofuel or food crops is difficult because of the many variables.[232]

The broad shape of the changes will be very strongly influenced by federal policy. It is already apparent in the United States that the federal program promoting corn-to-ethanol has had an upward impact on corn production, a trend that will continue. In 2007, the National Corn Growers Association reported that 2.3 billion bushels of corn were used in the production of 6.5 billion gallons of renewable fuel.[233] This represents a tripling since 2000 and quintupling since 1990.[234] In December of 2007, Congress mandated a renewable fuels standard, which requires 36 billion gallons of renewable fuel to be blended into the nation's fuel supply by 2022, with an allowance for 15 billion gallons of corn-based ethanol by 2015.[235]

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231. *See* NAT'L RES. COUNCIL OF THE NAT'L ACAD. OF SCI., WATER IMPLICATIONS OF BIOFUELS PRODUCTION IN THE UNITED STATES 10 (2008) [hereinafter WATER IMPLICATIONS].

232. Climate, water availability, and soil type, among others, are all factors that influence the suitability of land as a situs for growing any particular crop.

233. *See* National Corn Growers Ass'n, Ethanol & Coproducts, http://www.ncga.com/ethanol-coproducts (last visited July 21, 2010).

234. *See* LINWOOD HOFFMAN ET AL., U.S. DEP'T OF AGRIC., FEED GRAINS BACKGROUNDER 6 (2007), *available at* http://www.ers.usda.gov/Publications/FDS/2007/03Mar/FDS07C01/fds07C01.pdf. There is every reason to believe that ethanol production will continue to rise. For the first time ever, in 2007, the price of ethanol fell to a point equal to or below that of unleaded gasoline. *See* Nebraska Energy Office, Ethanol and Unleaded Gasoline Average Rack Prices, http://www.neo.ne.gov/statshtml/66.html (last visited July 21, 2010).

235. Energy Independence and Security Act of 2007, Pub. L. No. 110-140, 121 Stat. 1492 (2007).

These levels of corn-based ethanol production have two distinct water impacts. First, water is consumed in the refining process at the rate of approximately four gallons of water per one gallon of ethanol produced.[236] If production reaches 36 billion gallons by 2022, in that year the processing water will be 144 billion gallons, or 440,000 acre-feet of water. The second "water cost" of corn-based ethanol is the water used in growing the corn crop.[237] This is much harder to estimate because conditions affecting the amount of irrigation that will maximize corn yields vary with climate and soil type. The National Corn Growers Association offers a capsule summary of water used in corn production when it states, "nearly 600,000 gallons per acre for each growing season, or 4,000 gallons per bushel of harvested corn. This amounts to between 20 and 25 inches of water."[238] Using U.S. Department of Agriculture data that puts the number of acres in corn in the year 2004 at approximately 81 million, the water demand, including precipitation, is about 150 maf. A considerable majority of that water came from precipitation and soil moisture, not irrigation water, because most corn is grown without irrigation,[239] but the portion of that crop being irrigated was almost certainly irrigated precisely because of arid local conditions at key points in the growing cycle of the corn.

If most of the growth in corn production for ethanol is met by adding lands to production in the corn belt that runs from western Ohio out to eastern South Dakota and Kansas, the added water demand is problematic. The 440,000 acre-feet of process water that will be consumed at the production facilities will likely be groundwater. Particularly in the western portions of that region, groundwater sources are already overtaxed, resulting in serious declines in the water table.[240] The crop demands, likewise, are falling on a region that experiences irrigation-induced groundwater disputes,[241] a sign of generally tight supply and demand conditions or localized well interference issues.

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236. *See, e.g.*, WATER IMPLICATIONS, *supra* note 231, at 46.

237. An acre of corn transpires between 3,000 and 4,000 gallons of water per day over the growing season. WATER IMPLICATIONS, *supra* note 231, at 12.

238. NAT'L CORN GROWERS ASS'N, TRUTHS ABOUT WATER USE, CORN AND ETHANOL, http://www.ncga.com/files/GetTheFactsOnWaterUse.pdf [hereinafter CORN TRUTHS]. This figure is not compatible with another figure provided on the same page, whichlists corn's annual evapotranspiration at between 1.0 and 1.5 million gallons per year for each acre. However, the figure in the text is generally consistent with the water use suggested by WATER IMPLICATIONS, *supra* note 231, at 12.

239. CORN TRUTHS, *supra* note 238 (eighty-seven percent of corn in the United States is grown without irrigation).

240. USGS, *supra* note 81.

241. *See, e.g.*, Prather v. Eisenmann, 261 N.W.2d. 766 (Neb. 1978); Prohosky v. Prudential Ins. Co., 584 F.Supp. 1337 (N.D. Ind. 1984).

The biofuels boom opens another possibility that is less prone to creating water shortages—the movement of crop production to the most humid areas of the United States. For example, one recent study showed that Alabama farmers could very successfully grow corn for ethanol production.[242] Using a well-timed application of very small amounts of irrigation water if needed during key times in the corn cycle, that region could compete with the Midwest in corn production despite soils that hold less moisture. The study finds that six to nine inches of irrigation water per acre would maximize crop yields in Alabama so that they could reach a level equal to normal levels in the corn belt, where two or three times as much irrigation would be needed from groundwater sources that are already in decline. The capital cost and energy cost of irrigating would be low because of the ease of creating on-farm ponds as a source of the irrigation water, and the relatively small amounts needed would reduce the variable cost of applying the water to the crops.

As a matter of water resources, the increasing use of biofuels will have the obvious impact of increasing water demand for irrigation. That increase will be uneven across the nation, but it seems unlikely to trigger severe water shortages. In water-short areas, it seems more likely that the water for increased biofuels production will be taken from water that was already in use growing crops for food. The change will tend to be substitutionary, leading to little or no increase in water demand and use. As the displaced food production spreads to new areas, the low value of water in food production will tend to drive that production toward well-watered regions of the country, again posing few regionally significant water supply difficulties.

E. Carbon Sequestration

Efforts to arrest the release of greenhouse gases into the atmosphere include technologies that would capture carbon dioxide from the energy generation waste stream and sequester that material underground. These processes are commonly referred to as either geologic sequestration (GS) or carbon capture and storage (CCS). Physically, the carbon dioxide:

> is captured from flue gas produced by fossil-fueled power plants or industrial facilities, typically compressed to convert

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242. Richard McNider, John Christy, Dennis Bragg, James Hairston, & Donn Rodekohr, *Hydrological and Hydro-illogical Cycles: Managing Short Term Droughts in the Southeast*, Jan. 31, 2007 (presentation given to U.S.D.A. Conference in Savannah, GA), *available at* http://www.usawaterquality.org/conferences/2007/PPTs&Posters/Meetings/Water_Quantity/McNider.pdf.

> it from a gaseous state to a supercritical fluid, and transported to the sequestration site, usually by pipeline. The CO_2 is then injected into deep subsurface rock formations through one or more wells, using technologies that have been developed and refined over the past several decades. To store the CO_2 as a supercritical fluid, it would likely be injected at depths greater than approximately 800 meters (2,625 feet), where the pressure and temperature below the earth's surface are sufficient to keep the CO_2 in a supercritical state.[243]

The U.S. Environmental Protection Agency has noted that appropriate GS sites are widely available throughout the United States, with a site within 50 miles of all existing and proposed power plant locations.[244] Other studies have highlighted Texas, Indiana, Florida, Ohio, Pennsylvania, Illinois, New York, Kentucky, California, and West Virginia as the leading locations for GS.[245]

The water usage in the CCS process might be described as indirect—no water is used as a chemical agent or medium of transportation. CCS requires water because of the additional energy that must be generated and used to accomplish the discrete steps of (1) capture and compression, (2) pipeline transport, and (3) deep well injection. The DOE has modeled the amount of water needed to provide the additional energy for CSS for pulverized coal plants (PC)—the most common current technology, and integrated gas combined cycle plants (IGCC)—one of the cleaner advanced technologies for coal plants. Traditional plants will require between 20 percent and 33 percent more water if carbon sequestration is added, and even the newer IGCC technology will require almost 10 percent more water per unit of energy produced.[246] Recalling the amount of water needed for thermoelectric generation, the water cost of going "carbon clean" is another major factor adding to water demand.

The impact of CCS water demand will vary depending on location. CCS will congregate around existing carbon producing power plants and the new ones slated to come on line, many of which are going

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243. U.S. Envtl. Prot. Agency, *EPA Proposes New Requirements for Geologic Sequestration of Carbon Dioxide*, July 24, 2008, at 1, EPA-816-F-08-832, *available at* http://www.epa.gov/safewater/uic/pdfs/fs_uic_co2_proposedrule.pdf.

244. *Id.* at 2.

245. U.S. Dep't of Energy, Carbon Sequestration Atlas II of the United States and Canada 134–39 (2008), *available at* http://www.netl.doe.gov/technologies/carbon_seq/refshelf/atlasII (last visited July 21, 2010).

246. *See* Barbara Bennett, Massood Ramezan & Sean Plasynski, U.S. Dep't of Energy Nat'l Energy Technology Laboratory, *Impact of Carbon Capture and Sequestration on Water Demand for Existing and Future Power Plants*, *available at* http://www.netl.doe.gov/publications/proceedings/07/carbon-seq/data/papers/wed_006.pdf.

to be in the arid west where the "new" fuel resources are located. Adding carbon sequestration water and energy demands to the underlying water and energy demand that is driving the process will exacerbate the already anticipated water conflict. However, to the extent new generation and CCS siting is more widespread, much of the water demand will be in regions that have ample supply, and the remainder will cause local concern, but of lesser severity since the aggregate increase in regional demand, as a proportion of available supply, will not be as large.

F. Water Demand for Food Security—Adapting Production to Water Availability

Even if water scarcity becomes a factor in choices about how much, how, or whether to irrigate in some regions of the country,[247] and even if some crops can no longer compete for water in their present locales, there are abundant opportunities for changes in farming style and crop relocation that virtually ensure U.S. food security can be easily sustained.[248] It is likely that the United States will remain a food exporter.

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247. This article makes no attempt to discuss the potential water savings that can be provided by improved irrigation methods. Improved methods can reduce demand, especially demand for withdrawals of water. To a far lesser degree, highly controlled application and timing can even reduce the amount of water the plant transpires while still providing a full yield. The cost of implementing those systems will, in some cases be affordable, but for the purposes of this article, the operating assumption is that production will relocate away from shortage.

248. While it is beyond the scope of this article, two recent reports have raised alarming possibilities that will flow from the water supply impacts of global warming as they relate to the world food supply and the present and future impact on that supply of biofuels production, which diverts crops and land from food production. *See Hearing Before the House Permanent Select Committee on Intelligene House Select Committee on Energy Independence and Global Warming*, 110th Cong. 14 (2008) (statement of Thomas Fingar, Deputy Dir. of Nat'l Intelligence, Nat'l Intelligence Council), *available at* http://www.dni.gov/testimonies/20080625_testimony.pdf (reduced production of cereal crops in poorest nations); Aditya Chakrabortty, *Secret Report: Biofuel Caused Food Crisis*, THE GUARDIAN, July 3, 2008, *available at* http://www.guardian.co.uk/environment/2008/jul/03/biofuels.renewableenergy (last visited July 21, 2010) (confidential World Bank report states that biofuels forced global food prices up 75 percent); ROBERT BAILEY, OXFAM INT'L, ANOTHER INCONVENIENT TRUTH (2008), *available at* http://www.oxfam.org.uk/resources/policy/climate_change/downloads/bp114_inconvenient_truth.pdf; *The Cost of Food: Facts and Figures*, BBC NEWS, Oct. 16, 2008, *available at* http://news.bbc.co.uk/2/hi/7284196.stm (last visited July 21, 2010) (highlights the dramatic price increase in cereals, such as wheat, soya, rice, and corn). Taken together, these reports point out the momentous implications of agricultural changes in the United States and, therefore, sound a cautionary note about what policy options will be pursued in the longer term.

Decreased water use may not even harm the total quantity and diversity of crops produced.[249]

The foregoing optimistic assessment of overall food security is not intended to mask potential water shortages that will affect food production in many of the nation's most agriculturally productive regions. To the contrary, looking at California and the Colorado River Basin, for example, the cumulative picture is fairly plain, and agricultural water use will inevitably decline. There was little, if any, surplus water in the system by the end of the twentieth century, climate change impacts have been reducing reliable supply, water used in the other three areas of water security water is more valuable than it is in agriculture (and demand is going up in all of those areas), and, as always, food production remains the 800-pound gorilla when it comes to freshwater consumption.[250] The conclusion is that there will be much more conflict over the available water, and agriculture will, eventually, reduce the share of water it uses.

In the short term, particularly in the West, there will be a different story because agriculture will "win" many of the initial legal battles. In that region, agricultural and livestock interests control large allocations pursuant to senior appropriative water rights that have the ability to continue to control the water. Those rights, however, will be under economic and political pressure to sell out or reduce their water use. The reality in the West is that farmers pay a fraction of what municipal users and industries pay for water. In California, for example, in 2002, taxpayers provided a supply of water worth up to $416 million to farmers in the Central Valley while charging less than 6 percent of the price paid by Los Angeles residents.[251]

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249. *See* HEATHER COOLEY, JULIET CHRISTIAN-SMITH & PETER H. GLEICK, PACIFIC INSTITUTE, MORE WITH LESS: AGRICULTURAL WATER CONSERVATION AND EFFICIENCY IN CALIFORNIA 5 (2008), *available at* http://www.pacinst.org/reports/more_with_less_delta/more_with_less.pdf ("Reducing water use can also create a more resilient agricultural sector by increasing the quantity of water in storage, reducing the risk of drought, and improving the reliability of the available water. In addition, certain water conservation and efficiency improvements actually increase farm productivity and profitability, further bolstering the agricultural sector.").

250. The 85 percent figure (freshwater used by irrigated agriculture) will eventually decline as thermoelectric cooling using closed loop systems vastly increases water consumption in that sector. HUTSON ET AL, *supra* note 29. Agriculture will remain an immense, highly consumptive water use, but it will not be able to compete successfully with water needed for population, ecology, or energy security.

251. RENEE SHARP & BILL WALKER, ENVTL. WORKING GROUP, BIG AG'S $100 MILLION ENERGY SUBSIDY (2007), *available at* http://www.ewg.org/reports/powersubsidies (last visited July 21, 2010).

Agricultural water users will also face increasing legal pressure to make more efficient use of the water. Claims of waste may spur water transfers[252] or result in administrative and/or judicial reduction of water rights.[253] Either way, the amount of water devoted to food production in areas of water scarcity will decrease as that water moves to the service of population, ecology, or energy. That production and the use of other water will migrate to areas of the nation, most likely in the South and Mid-Atlantic regions, where water will still be relatively abundant.

Alternatively, western agriculture may be able to adapt to less available water through water conservation. A recent study by the Pacific Institute looked at four scenarios for improving water use efficiency in the agricultural sector in California's Sacramento-San Joaquin Delta region:

- Modest Crop Shifting—shifting a small percentage of lower-value, water-intensive crops to higher-value, water-efficient crops
- Smart Irrigation Scheduling—using irrigation scheduling information that helps farmers more precisely irrigate to meet crop water needs and boost production
- Advanced Irrigation Management—applying advanced management methods that save water, such as regulated deficit irrigation
- Efficient Irrigation Technology—shifting a fraction of the crops irrigated using flood irrigation to sprinkler and drip systems.[254]

The study concluded that each of these scenarios would result in water savings from 0.6 to 3.4 million acre-feet in the Sacramento-San Joaquin Delta, with no or little effect on the region's agricultural productivity.[255]

V. CONCLUSION

The goal of this article was to look ahead 20 to 50 years at the water landscape of the United States and anticipate macro changes in water supply and demand. As little as 20 years ago, and certainly 50 years ago, in every region of the nation the polestar of that effort would

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252. *See* CAL. ENVTL PROT. AGENCY, DIV. OF WATER RIGHTS, IMPERIAL IRRIGATION DISTRICT LONG TERM TRANSFER (2005), *available at* http://www.swrcb.ca.gov/waterrights/water_issues/programs/hearings/iid_sdcwa (last visited July 21, 2010); OR. REV. STAT. § 537.455 (2003).

253. *See* State Dep't of Ecology v. Grimes, 852 P.2d 1044 (Wash. 1993).

254. *See* COOLEY, CHRISTIAN-SMITH & GLEICK, *supra* note 249, at 6.

255. *Id.*

have been growth-adjusted extrapolations of past water use patterns. More people and their associated economic activity meant just that much more of the same mix of uses of water. The few exceptions to that pattern would have been found on the East Slope of the Rockies in Colorado, in the desert Southwest, and in southern California, where population growth was high, and available water was already fully utilized. In those regions there was a sort of zero sum game: More water for the growing population centers meant a little less water for agriculture. And so, for example, Arizona cities bought "water farms" to get at that groundwater.[256] California developed the California Water Project that brought water southward from the more humid, less developed regions of the north. Growing Denver had already found additional unused West Slope water that gravity would bring to it, generating power as it came. Those challenges and solutions all seem so simple now.

The modern craft of water projection in the United States is more complex, and it is neither purely art nor purely science. Climate change effects have already upset the historical water supply patterns in complex and non-linear ways. Water demand is no longer a simple function of population and economic growth. Revamped world energy policies and politics are changing the domestic energy industry, an immense water user. Many parts of the nation that had become accustomed to water abundance are beginning to see growth in demand finally reach the limits of available supply, creating contentious water allocation choices. This article anticipates the changed conditions and describes a multitude of new and emerging water competitions, some more certain to arise than others, but still worth considering.

Taking the broad view, climate change and energy policy are the catalysts that will force adaptation upon U.S. water management institutions. The national importance and breadth of those issues make them ideal candidates for federal policymaking. Due to the decentralized nature of water management described in the introduction, the policies are going to be framed by groups whose main focus is not water.[257] There will not be a "water czar" sitting at the table—there may not even be a "table" at which to sit. Indeed water management in this country is so decentralized that it is hard to imagine that water managers are going to have any leadership role in framing climate or energy policy, or that the

256. Bonnie G. Colby, Dana R. Smith & Katherine Pittenger, *Water Transactions: Enhancing Supply Reliability During Drought*, *in* ARIZONA WATER POLICY: MANAGEMENT INNOVATIONS IN AN URBANIZING, ARID REGION (2007).

257. The George W. Bush administration attempted to lead in the energy field, but stubbornly resisted framing a strong national program to address climate change. The Obama administration has announced that it intends to take a different course, but the details are still few, and congressional support may vary from those plans.

kinds of water use conflicts predicted by this article will be considered a significant concern in framing national climate change and energy policy. Water managers will be left largely in a reactive role.

In preparing to react, from a water management perspective, there is little difference between climate change initiatives and energy initiatives, whether adopted in furtherance of climate change goals or the separate problem of energy independence. Past emissions have already placed in motion the conditions that will generate the new patterns of supply. As to that part of the equation, water managers have no choice but to react. In relation to future water supply in the United States, new policies aimed at reducing future climate change impacts will be directed at GHG emissions, which translates into the energy sector changes described in Part IV of this article. The laws and regulations for these energy and climate change policies are going to address such topics as fuel sources for vehicles, vehicle fuel efficiency standards, vehicle fleet fuel type composition, leasing of federal lands and subsidies for specific forms of energy development, limitations on GHG emissions, and perhaps carbon taxes— not water supply.

Some federal environmental laws will factor into water management more directly. The ESA has already controversially ensured water for ecological security in the settings where it applies. Under predictions of greater water scarcity in the West, and more intense drought in other regions, the ESA will more frequently affect water use. In the context of western scarcity, the ESA may limit appropriations that de-water riparian habitats.[258] Quite often, as demonstrated by the ACF controversy, the ESA will constrain not only federal irrigation deliveries, but also dam and reservoir operations that become more critical with the demise of stationarity, and with it, the assumptions on which the dams were originally built and managed. If the ACF has taught observers anything, water users should be proactive in this arena. Devising consensus dam and reservoir management regimes takes a long time. Water managers must collect data, build accurate models, vet concerns, and build political consensus around ultimate priorities. Both the U.S. Army Corps of Engineers and the Bureau of Reclamation, as the operators of most of the nation's large reservoirs, will be deeply involved in this process. In neither case, however, do their existing legal mandates include the authority to address directly, much less solve, difficult questions of water allocation. As suggested by the ACF controversy, each of the competing

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258. *See, e.g.*, SAN JUAN RIVER BASIN: RECOVERY IMPLEMENTATION PROGRAM, SAN JUAN-CHAMA PROJECT WATER SUPPLY (2007), *available at* http://www.fws.gov/southwest/sjrip/pdf/DOC_San_Juan_Chama_Project_Water_Supply_Report.pdf.

water-using factions will wage a legal and political battle to force the water to be managed according to its interest.

The second federal law having a direct impact on water management is the Clean Water Act (CWA). The treatment standards for point source dischargers changed industrial and municipal water use levels dramatically and, seemingly, permanently. Those provisions, or similar ones, have influenced and will likely continue to influence the cooling system choices of new thermoelectric power generation units, as discussed in Part IV.A. If more attention is given to heat as a pollutant in CWA administration, the impact of that law on water use will be profound.[259] In this setting, the water use-affecting response to the federal law will come primarily from water users and will probably not require a specific coping strategy on the part of water managers.

The remainder of the federal influence on water use will be of two types, programmatic energy and clean fuels initiatives that spur water demand and regulatory laws that permit challenges to proposed water-using actions. The events unfold, almost like a play's script. Congress enacts legislation to pursue one or another energy initiative, a federal agency begins the steps toward implementation. These events probably include promulgation of administrative rules and the preparation of environmental impact statements.[260] Constituencies who feel they will be adversely affected should the program go forward, use federal administrative law, such as the National Environmental Policy Act and any other legal small-handle they can get to delay, block, or alter the project. Delay increases cost and may discourage private firms from entering the field, or the objections may win substantive changes in how the program is pursued, or even in rare cases, may galvanize sufficient popular support to defeat or derail the program in Congress. In this drama, the water users are sometimes protagonists, other times mere extras. Water managers are part of the audience, who, at most, are likely to offer comments in various stages of the regulatory scenes.

The next level below the national level in water policy and management is the multistate regional level, which is the most appropriate level for interstate water basin management. It is difficult to overstate the magnitude and importance of interstate water basins, which contain al-

259. The CWA presents some less-broadly applicable controls on water use, such as the creative use of Section 401 by the State of Washington to further ecological use of water. *See* PUD No. 1 of Jefferson County v. Washington Dep't of Ecology, 511 U.S. 700 (1994).

260. A farsighted variation on this pattern would be for Congress to require energy planning at the state level, and include water availability and water use impacts as mandatory considerations in the state plans. This would focus all of the states on the implications of the energy-water nexus in a fashion similar to that already underway in Colorado and a few other states.

most all of the nation's available fresh surface water.[261] This article has done no more than note examples of current or potential water conflicts with interstate dimensions, such as the competing demands in the ACF basin and the Colorado River Compact implications of oil shale development. If the hydrologic dimensions of a water problem cross state lines, a managerial solution must also cross state lines. To develop the needed problem-solving consensus requires an institutional framework capable of operating across state lines. That is a subject for another day. In this context, the prescriptive advice is that states should look to examples in which interstate water problems have been successfully addressed.

The hallmarks of what will be successful in the post-stationarity era will be interstate institutions that have the ongoing managerial capacity to address dynamically a range of possible water supply and demand futures that cannot be completely foreseen at the time the agreement is put in place. The leading example at present is the Delaware River Basin Compact[262] and its Commission, which in comparison to almost all other interstate compact commissions, has extraordinary ongoing water management authority.[263] A path-breaking approach has been adopted by the Great Lakes states; the Great Lakes-St. Lawrence River Basin Water Resources Compact,[264] which does not allocate specific quantities of water, nor does it give its compact commission allocation powers. Instead, it requires the party states to manage their water withdrawals with common minimum standards for water conservation and sustainable use.[265] What must be kept in view, however, is the need to achieve broad consensus about what is truly important in times of shortage, and then to design a management strategy that operates on that basis.

Finally, there is state water law and policy, the most direct form of water allocation and management in the complex system of water gov-

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261. The Great Lakes Basin alone, shared by eight states (Illinois, Indiana, Michigan, Minnesota, Ohio, New York, Pennsylvania, and Wisconsin), as well as the provinces of Ontario and Quebec, contains 90 percent of the available fresh surface water in the United States. *See* GREAT LAKES COMM'N, TOWARD A WATER RESOURCES MANAGEMENT DECISION SUPPORT SYSTEM FOR THE GREAT LAKES-ST. LAWRENCE RIVER BASIN (2003), *available at* http://glc.org/wateruse/wrmdss/finalreport.html (last visited July 21, 2010).

262. Delaware River Basin Compact, Pub. L. No. 87-328, 75 Stat. 688 (1961).

263. For a detailed discussion of the Delaware River Basin Compact, 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, 837–50 (2005).

264. Great Lakes-St. Lawrence River Basin Compact, Pub. L.No. 110-342 (2008).

265. *Id.*; *see also* Noah D. Hall, *Toward a New Horizontal Federalism: Interstate Water Management in the Great Lakes Region*, 77 U. COLO. L. REV. 405 (2006).

ernance. With a very few exceptions not relevant here,[266] water users have no ability to take water other than in accordance with state law. These laws, as noted in Part III.A, vary between the East's riparianism and regulated riparianism, and the West's prior appropriation. While each of those systems of water law has a unique manner for addressing water conflicts, each has shown a marked tendency to ensure that the most important needs get water at the expense of less important needs. Even prior appropriation, where the most senior right-holders get the water in time of shortage, has adapted that rigidity by devising transfers and plans for augmentation that allow those senior rights to change from support of old, outmoded or less valuable uses, to support security for concentrated populations and more valuable industrial and commercial uses. The West also experimented successfully with water banking that facilitates short-term transfers in dry years. Obtaining appropriately located water rights to support population, and ecological energy security, will occasionally take time, but eventually those uses will be served, and the food security component, important but less valuable, will be protected by either improvements in efficiency or the relocation of lost production to other areas where rainfall or available water can sustain it.

When all the water availability and water demand predictions and all the managerial admonitions are lumped together, there are reasons for both confidence and worry. At the largest of macro-levels, the United States has enough flexibility in how and where it provides water for food security that the more place-limited foreseeable needs of water for population security, ecological security, and energy security all can be met simultaneously and without risk to the food supply. Adjusting water use to reach that result will, in many cases, be a cause for worry because the transition will involve conflict for many, dissatisfaction for some, and far-reaching non-water costs related to dislocation of existing water users, disruption of the environment, and higher costs for water in every sector.

At the water management level, the greatest challenge will be to create durable institutional arrangements capable of allocating water in a future where supply, demand, flooding, and drought become unpredictable due to deviations from historical patterns. At present, there are almost no examples of management that begins from a broad-based

266. Federal reserved water rights arise independent of state law and, under the sway of the U.S. Constitution's Article VI Supremacy clause, will defeat conflicting state law water rights. *See*, *e.g.*, Winters v. United States, 207 U.S. 564 (1908). Few of the water use conflicts foreseen in this article, however, involve federal reserved water rights. The federal government could authorize condemnation of state law water rights, but large-scale use of that power in contravention of the states' traditional hegemony over the field seems unlikely.

agreement about policies and priorities that is capable of then translating into a dynamic response to conditions in the watershed.[267] There will be enough conflicts in the coming years to gain substantial experience in consensus building and, thereafter, making it operational. By looking in those directions from the outset, the carbon affected and carbon constrained water future in the United States will be less traumatic.

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267. Dr. Daniel P. Sheer, founder of Hydrologics, has created a software system, OASIS, that enables parties to "simulate the routing of water through a water resource system. This creates an opportunity for parties with diverse and often conflicting goals—such as cities, power facilities, environmentalists, and agriculturalists—to work together to develop operating policies and solutions that mutually satisfy their diverse objectives. *See* OASIS Software, http://www.hydrologics.net/pdf/oasis.pdf.