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Article

INTERSTATE WATER COMPACTS AND CLIMATE CHANGE ADAPTATION

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ABSTRACT

Over 95% of the available surface freshwater resources in the United States are interstate in nature and governed by interstate water compacts. These interstate compacts vary tremendously in how they allocate and manage interstate waters. Until recently, the water resources governed by interstate compacts have been relatively stable and unaffected by drastic changes in long-term weather patterns. However, within the next few decades North America is expected to experience increased regional variability in precipitation and susceptibility to drought. This article first looks at these expected changes on a macro and regional level to evaluate the increased stress on water resources that is expected to arise in some watershed. Interstate compacts may be the most important legal consideration in assessing water supply risks from climate change, and this article provides a critical evaluation of every interstate water compact: how it works, the resources it governs, and the rights and responsibilities it assigns to the party states. The article then assesses the relative risk and legal uncertainty resulting from climate change for interstate water resources subject to interstate compacts. The article concludes with a comparative assessment of the watersheds most at risk from climate change and the interstate compacts most able to adapt to climate change.

INTRODUCTION

Over 95% of the available freshwater resources in the United States are interstate in nature and governed by interstate water compacts. Interstate compacts are essentially contracts between states, subject to federal approval. There are twenty-seven interstate compacts for managing and allocating water resources in the United States, and they vary tremendously in how they allocate and manage interstate waters.

Until recently, the water resources governed by interstate compacts have been relatively stable and unaffected by drastic changes in long-term weather patterns. However, the Earth's climate is now warming, and within the next few decades North America is expected to experience increased regional variability in precipitation and susceptibility to drought. Part I of this article focuses on these changes on a macro level and on the increased demand for water resources that is expected to arise in certain sectors of the country.

Climate change will force water managers to address new problems, including enormous changes in supply and demand. But while many water users and managers are focused on state water law, interstate compacts may be the most important legal consideration in assessing water supply risks from climate change. Part II of this article provides a background on interstate water compacts: how they work, the resources they affect, and the rights and responsibilities they assign to the parties they govern.

The primary purpose of this article is to assess the relative risk and legal uncertainty resulting from climate change for interstate water resources subject to interstate compacts. Part III describes the methodology for assessing this risk. First, every interstate watershed governed by a compact is analyzed for climate change vulnerability based on the following factors:

- *Total water supply relative to water demand.* This factor is based actual historical water usage and supply. Watersheds with historically low supply/demand ratios will probably have more difficulty coping during future shortages.
- *Natural variability.* This factor indicates how likely streamflow within a watershed may deviate from its average. Watersheds with high variability are more difficult to manage and thus are more susceptible to severe impacts from climate change.
- *Groundwater depletion.* This factor measures the current level of groundwater depletion within the watershed. When available, groundwater can be used to soften the impacts of droughts. Conversely, groundwater overdraft areas indicate regions of potential unsustainability.
- *Dryness ratio.* This factor measures the proportion of annual precipitation in the watershed that is lost through evapotranspiration. Dry watersheds are at greater risk in a warming climate.

- *Expected impact on water supplies from climate change.* This factor looks at expected changes in streamflow, temperature, evapotranspiration rates, and precipitation within the watershed over the next fifty years to assess the expected impact on water supplies.
- *Infrastructure for storing and delivering water supplies.* This factor is based on the reliability of current water delivery infrastructure. Watersheds with older and less reliable infrastructure will require more investment to cope with climate change.
- *Water use flexibility.* This factor is based on a measurement of industrial water consumption relative to withdrawals, and indicates a watershed's potential ability to make low-cost efficiency improvements. Watersheds that can make low-cost efficiency improvements easily will be less vulnerable to future water shortages.
- *Instream use factors.* This factor evaluates current instream uses, including navigation, recreation, and threatened aquatic ecosystems. The intensity of instream uses could make adjusting to climate changes more difficult.

Next, every interstate water compact is evaluated for adaptability to climate change impacts based on the following factors:

- *Data collection and reporting.* This factor evaluates the quality and types of data collected under the compact, including whether water use registration and reporting is required, and whether groundwater resources are monitored.
- *Geographic and hydrologic scope.* This factor evaluates the degree to which the scope of the compact matches the hydrologic realities of the watershed. Important considerations include whether the whole watershed, tributary waters, and groundwater are covered by the compact.
- *Flexibility and adjustability of allocation.* This factor evaluates how well the compact can adapt to changed climate conditions. A more flexible allocation system will adjust better to climate change and provide more legal certainty and economic security as conditions evolve.
- *Water conservation.* This factor evaluates the compact's water conservation strategies, if any. Strategies might include prohibiting unreasonable use, requiring efficient use, or requiring water conservation in general.
- *Ecosystem protection.* This factor evaluates the extent to which the compact encourages or requires proactive

ecosystem management. Proactive ecosystem management can help watersheds to avoid federal restrictions on water use intended to protect endangered species under the Endangered Species Act ("ESA"). In some interstate water basins, enforcement of the ESA has drastically reduced the supply of water available for consumptive uses.

- *Restrictions on transbasin diversions.* This factor evaluates the extent to which the compact restricts transbasin diversions, if at all. Transbasin water diversions can undermine sustainable and adaptive water management efforts by opening the door to demands from other watersheds.
- *Watershed governance institutions.* Most compacts create some sort of watershed governance institution. This factor evaluates the quality of the governance institution, including whether the institution is empowered to promulgate and enforce rules to adapt to climate change, and whether the institution has the authority to plan, conduct research, prepare reports on water use, and forecast water levels.
- *Duration, revision, and rescission.* This factor gauges the permanence of the compact.

Part IV then applies the risk assessment methodology to each of the twenty-seven compacts. In the conclusion for each compact, each watershed receives an overall climate change risk score of **modest**, **substantial**, or **severe** based on the eight watershed vulnerability factors. Then, considering the overall watershed risk as well as the eight compact vulnerability factors, each compact is judged to be **adequate**, **somewhat adequate**, or **inadequate** to address the climate risks now beginning to emerge. The overall watershed risk and the compact effectiveness are presented in the conclusion at the end of each watershed and compact analysis.

The article concludes with a comparative assessment of the watersheds most at risk from climate change and the interstate compacts most able to adapt to climate change. In general, western watersheds are at the most risk, and unfortunately western compacts are far less adaptive than the more modern eastern water compacts. As policy-makers and state leaders struggle with water management and climate change, some compacts may need to be amended and revised to provide adequate tools to adapt to the challenge of climate change.

I. OVERVIEW: HOW CLIMATE CHANGE WILL AFFECT REGIONAL WATER SUPPLIES IN THE UNITED STATES

A brief review of how climate change will affect regional water supplies demonstrates the pressures and challenges the United States will face. Climate change is expected to lead to reductions in water supply in most regions in the United States. Scientists predict significant loss of snowpack in the western mountains, a critically important source of natural water storage for California and other western states. As sea levels rise, salt water will intrude on surface freshwater supplies and aquifers on the Pacific, Atlantic, and Gulf coasts. Even the Great Lakes region, which has over 90% of the available surface freshwater in the United States, will experience water supply impacts from climate change. Groundwater supplies are also vulnerable to climate change, as evapotranspiration losses (the loss of water to the air through evaporation and plant transpiration) will drastically reduce aquifer recharge and storage. Expected increases in water demand due to higher temperatures will compound the loss of water supplies, unless new conservation and allocation policies are widely applied. As if those predictions were not dire enough, they take no account of the additional water demand in the energy sector that will accompany vigorous efforts to reduce carbon emissions, unless such energy demands are displaced through efficiency measures and are met with solar and other non-hydro renewable resources.

A. The Changing Climate

The warming of the Earth is evident in average global air and ocean temperatures. Polar snow and ice are melting, and the average sea level around the globe is rising. Not only is the Earth becoming warmer, but it is warming faster than at any time during the 20th century. Global mean surface temperatures rose 1.33° F (0.74° C) over the period between 1906 and 2005. But during the past fifty years, the rate of global warming has nearly doubled. Eleven of the last twelve years rank among the twelve warmest years on record since 1850.[1]

It is very likely that the increase in global average temperatures since the mid-20th century was due to

1. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 237 (2007) [hereinafter IPCC PHYSICAL SCIENCE BASIS].

anthropogenic releases of greenhouse gases. Thus, it is quite probable that the changes to the global climate system during the 21st century will be larger than those observed during the 20th century. Over the next two decades, global warming is forecast to be about 0.4° F (0.2° C) per decade. During the 21st century, the best estimates are that average global temperatures will increase 3.2° to 7.2° F (1.8° to 4.0° C), with more intense warming in most of North America. Some regions, such as the southwestern United States, will see greater temperature increases than the North American average.[2]

Similarly, climatologists anticipate temporal and regional variability in precipitation. The incidence of both floods and droughts will increase. One effect of the rising temperatures expected over the next century is that the atmosphere's capacity to hold moisture will go up. For every 1.8° F (1° C) increase in temperature, the water-holding capacity of the atmosphere rises 7%.[3] Increased moisture in the atmosphere will lead to more intense precipitation events – even when the annual total amount of precipitation is slightly reduced. In a phrase, when it rains it will pour, but when it doesn't, you might be looking at a drought.

B. The West and Southwest

The southwestern United States will become even more arid during the 21st century as the subtropical dry zone expands poleward. Over the next century, temperatures in the American West are expected to rise 3.6° to 9° F (2° to 5° C).[4] The added heat from global warming can increase temperature and increase the water holding capacity of the atmosphere, since warmer air has higher saturation humidity than cooler air. In very wet areas (like over oceans) where there is adequate moisture, added heat is used up primarily by evaporation, so it moistens the air instead of warming it. But in already-dry areas like the western and southwestern U.S., there is little moisture to soften the impact of added heat. As a result, in these areas the added heat from global warming will go primarily to increasing temperature. Relative humidity will decrease and, with the increased saturation humidity, result in even less precipitation.

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2. *Id.* at 850, 889.
3. *Id.* at 13.
4. Philip W. Mote, et al., *Declining Mountain Snowpack in Western North America,* 86 BULL. AM. METEOR. SOC. 39, 48 (2005).

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

Climate change will continue to cause increasing snowpack losses each year. Under warmer climate conditions such as those expected during the next century, precipitation will be more likely to fall as rain than snow, especially in autumn and spring at the beginning and end of the snow season. This trend is already observable, as the volume of snowpack has been dropping over much of the American West since 1925, and especially since 1950. A recent study on the declining mountain snowpack in western North America showed that between the periods from 1945-1955 until the 1990's, snowpack volume measured on April 1 has fallen 15.8% in the Rockies, 21.6% in the Interior West, and 29.2% in the Cascades.[5] Similarly, a review of the scientific literature by the Pacific Institute noted that during the 20th century, annual April through July runoff in California's Sacramento River decreased on average by 10%, while snowmelt runoff in general came earlier in the year.[6]

Reductions in snowpack volume will accelerate during the 21st century. Stream inflows to reservoirs will decline significantly because of diminished snowpack, reduced soil moisture, and increased evaporation before mid-century. By the 2020's, 41% of the water supply to Southern California is expected to be in jeopardy due to the effects of reduced snowpack.[7] In California, inflows to the entire state could be

5. *Id.* at 44.

6. Michael Kiparsky & Peter H. Gleick, Climate Change and California Water Resources: A Survey and Summary of the Literature 25 (2003).

7. Intergovernmental Panel on Climate Change, Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change 633 (2007) [hereinafter IPCC Climate Change Impacts].

reduced by as much as 27% by 2050.[8] By 2069 snow cover in California may be almost completely depleted by the end of winter.[9] By the end of the 21st century, snowpack volume is expected to decrease by as much as 89% for the Sierra-Nevada region draining into the Sacramento-San Joaquin river system.[10]

The situation is similar throughout most of the western United States. The Colorado River is the most significant water source for much of the southwest region. While important to southern California, the Colorado River also supplies water to Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming. As a result of reduced snowpack, streamflow in the Colorado River is expected to decrease significantly in the 21st century, with predicted reductions of as much as 45% by 2050.[11] In addition to the obvious resulting water shortages, the expected loss of snowpack may also lead to increased river salinity which could impede compliance with the 1944 Colorado River Treaty.[12]

C. The East and Southeast

The eastern and southeastern United States will become warmer and more humid over the next century. Depending on location within the region, temperatures are expected to rise anywhere from 2.0° to 5.6° F (1.1° to 3.1° C) by mid-century.[13] Precipitation is also expected to increase (between 5% and 8%), but at the same time, rising evapotranspiration will pull much of the new moisture into the air.[14] In addition, the southeastern United States will experience a greater clustering of storms over the next century.[15]

As a result of the rise in precipitation, runoff will probably increase during the next century, but just slightly (perhaps

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8. Josue Medellin, et al., Climate Warming and Water Supply Management in California: A Report From the California Climate Change Center 9 (2006).

9. Kiparsky & Gleick, supra note 6, at 10.

10. Katharine Hayhoe et al., Emissions Pathways, Climate Change and Impacts on California, 101 Proc. Nat. Acad. Sci. 12422, 12425 (2004).

11. Brad Udall, Recent Research on the Effects of Climate Change on the Colorado River, Intermountain West Climate Summary 2, 6 (May 2007).

12. See Peter H. Gleick et al., Water: The Potential Consequences of Climate Variability and Change, Report of the National Water Assessment Group for the U.S. Global Change Research Program 55-57 (2000).

13. PETER BACKLUND ET AL., U.S. CLIMATE CHANGE SCIENCE PROGRAM AND THE SUBCOMMITTEE ON GLOBAL CHANGE RESEARCH, U.S. DEP'T OF AGRIC., SYNTHESIS AND ASSESSMENT PRODUCT 4.3 (SAP 4.3): THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURE, LAND RESOURCES, WATER RESOURCES, AND BIODIVERSITY IN THE UNITED STATES 141 (Margaret Walsh ed., 2008) [hereinafter DEP'T OF AGRIC. ASSESSMENT PRODUCT].

14. *Id.*

15. National Assessment Synthesis Team, *Climate Change Impacts on the United States*, U.S. GLOBAL CHANGE RESEARCH PROGRAM 424 (2001).

between 2% and 5%).[16] The increased runoff may simply be the result of more intense precipitation events. This was the case over the last half of the 20th century in the east and south, when streamflow rose due to increasing trends in heavy precipitation events.[17] Streamflow in the eastern United States has increased 25% in the last sixty years.[18]

Over the same time period, however, groundwater has become depleted in many parts of the southeast.[19] In the likely event that this trend continues, shrinking groundwater supplies will make it more difficult for the region to adapt to the water demands of a warming environment. Although total agricultural water use in the United States has been declining since 1980, it has been increasing in the southeast where there was a 39% jump in irrigated acreage of row crops between 1970 and 1990.[20] However, increased irrigation over the next century would be unsustainable on any kind of widespread basis. Groundwater tables are already low in many regions of the southeast. Coastal Florida and southwestern Georgia, for example, are currently plagued by groundwater overdrafts.[21] Increased irrigation could lead to salt water intrusion in coastal regions, creating salt residues on irrigated crops and soils.[22]

The future changes in temperature and precipitation portend several issues related to agriculture. Soils will become drier if the higher temperature projections are correct. Evapotranspiration would then increase, creating demand for more extensive crop irrigation and further aggravating water shortages already affecting the southeast.[23] These and other changes in climate conditions will require increased use of fertilizers and pesticides which would further contaminate runoff.[24]

The precise impact from climate change on agricultural yields is unclear. The wetter of the two principal climate circulation models projects increases of 10% to 20% in the yields of non-irrigated crops in the southeast (except in the Gulf Coast area) through the 2030's and the 2090's.[25] Under a somewhat

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16. DEP'T OF AGRIC. ASSESSMENT PRODUCT, *supra* note 13, at 138.
17. National Assessment Synthesis Team, *supra* note 15, at 413.
18. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.
19. National Assessment Synthesis Team, *supra* note 15, at 421.
20. *Id.* at 419.
21. U.S. GLOBAL CHANGE RESEARCH PROGRAM, REGIONAL PAPER: THE SOUTHEAST (2003) [hereinafter GLOBAL CHANGE: SOUTHEAST].
22. *Id.*
23. *Id.*
24. *Id.*
25. US GLOBAL CHANGE RESEARCH PROGRAM, CLIMATE CHANGE IMPACTS ON THE UNITED STATES (2001) [hereinafter CLIMATE CHANGE: UNITED STATES].

warmer (and therefore drier) scenario, however, some crop yields decrease from 10% to 30% by 2030 and decrease by 80% by 2090.[26] In general, agriculture in the lower Mississippi Valley and the Gulf Coast regions is more likely to be negatively affected by climate change, and the northern Atlantic Coastal Plain is more likely to be positively affected.[27]

Many activities and climate trends will affect water quality. Urban development, coastal processes, and mining activities will lead to increased contamination. Higher temperatures will result in reduced dissolved oxygen levels in water. Flooding will likely become more frequent, bringing waters contaminated by sewage, rotting carcasses, fuel, and chemicals.[28] In addition, population is expected to increase significantly in the southeast over the next century, exacerbating stresses on water resources.

The southeast is particularly vulnerable to climate change in its coastal regions. Rising sea levels and more intense storms pose significant threats to the heavily populated coasts.[29] Barrier islands and wetlands may disappear, accelerating harms.[30]

Cumulatively, all of these trends suggest that the east and southeast will require a flexible water management system in the future. Agricultural changes are certain, but predicting the direction of the changes is difficult. Rising sea levels are a certainty, and rising populations on the coasts will create new demands for water resources. Unfortunately, even now the east is hampered by aging infrastructure and inadequate storage capacity.[31]

D. The Great Lakes and Midwest

The Great Lakes, the largest freshwater resource in North America will also be impacted by climate change. Historically, while lake levels in the Great Lakes have fluctuated, the changes in levels have not been radical.[32] This has been beneficial to the region, since in the Great Lakes, both high and low water levels

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26. *Id.*
27. *Id.*
28. *Id.*
29. GLOBAL CHANGE: SOUTHEAST, *supra* note 21.
30. *Id.*
31. NATIONAL ASSESSMENT SYNTHESIS TEAM, *supra* note 15, at 409.
32. GREAT LAKES REGIONAL ASSESSMENT GROUP, PREPARING FOR A CHANGING CLIMATE (2000) [hereinafter GREAT LAKES ASSESSMENT]. There is only a 6.5 foot (2.0 meters) difference from the recorded monthly maximum lake level to the recorded monthly minimum. *Id.*

can be extremely disruptive.[33] Most climate models predict that Great Lakes water levels will drop during the next century below historic lows. Lake levels in Lake Michigan and Lake Huron may drop by as much as 4.5 feet (1.38 meters) due to changing precipitation and increased air temperature/evapotranspiration.

Temperature is expected to rise significantly within the Great Lakes region—anywhere from 3.6°F (2°C) to 7.2°F (4°C) by the end of the century—with more warming in the western part of the region than in the eastern part.[34] Precipitation may increase in the Midwest, though there will be considerable variation across the region. The northwest may be somewhat drier, but some models predict precipitation increases in the rest of the region.

Drastic reductions in ice cover may also result from air and lake temperature increases – by 2090 most of Lake Erie is projected to be ice-free over the winter 96% of the time.[35] The loss of ice cover will lead to increased evaporation losses for the Great Lakes. In addition, winters with less ice result in more coastal erosion and property damage.[36]

Lower lake levels and rising temperatures (both in the air and water) will significantly impact fisheries, wildlife, wetlands, shoreline habitat, and water quality in the Great Lakes region. The impacts are not only an environmental concern, but also have a huge economic cost. Tourism and shipping are critically important to the region, and both industries are extremely vulnerable to climate change impacts on water resources.

Aquatic life will be impacted by changes to the lakes' chemistry. The Great Lakes are a dynamic system and depend on periodic mixing of their waters to transport nutrients where they are needed. The warm lakes predicted by climate models, however, would be less dynamic than the Great Lakes have historically been. As a result, less oxygen would mix down from the surface of the lakes to deep waters, effectively reducing biomass productivity by around 20%.[37]

In addition, the increased variability in timing, intensity, and duration of precipitation under global warming conditions is expected to increase the frequency of droughts and floods in the Great Lakes region and upper Midwest. Overall, stream runoff is expected to decrease, and baseflow—the contribution of

33. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.

34. GREAT LAKES ASSESSMENT, *supra* note 32.

35. Brent Lofgren, et al., *Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two GCMs*, 28 J. OF GREAT LAKES RESEARCH 537, 546, 550-51 (2002).

36. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.

37. GREAT LAKES ASSESSMENT, *supra* note 32.

groundwater to streamflow—could drop by nearly 20% by 2030.[38] Also, inland rivers in the region that are primarily snowmelt driven with peak flows in early spring may have earlier peaks as a result of less snow and more rain.[39]

These changes will lead to significant impacts to agriculture and livestock. Even where precipitation increases, any gains could be wiped out by greater evaporation, leading to drier soils.[40] Nonetheless, some crop yields could increase through the first half of the century, but then may decrease as rising temperatures dry up the increased precipitation, especially in the southern and western parts of the Midwest.[41] Further, the suitability of crops to their traditional regions may shift. Invasive species may out-compete native plants, and southern plains states could lose crops to the north.[42]

E. Coastal Regions

Coastal areas throughout the country will face additional challenges. Rising sea levels are caused by thermal expansion of the oceans and increased melting of glaciers and the Greenland and Antarctic ice sheets. Water expands as it warms, and the oceans are getting warmer. The oceans are absorbing more than 80% of the heat that is added to the climate system. Increases in ocean temperature are observable down to depths of almost 10,000 feet (3,000 meters).[43] Further, rising air temperatures will cause glaciers and icecaps to melt faster.

Sea level is already rising worldwide, and the rate of sea level rise is expected to increase in the future. Mean sea levels have risen approximately five to nine inches (twelve to twenty-two centimeters) since the 1890's. Coastal regions around the U.S. are already exposed to storm-surge flooding.[44] Winter storms have been increasing in parts of the Pacific coast since 1950.[45] Some Alaskan villages will need to be relocated due to the threats presented by flooding, [46] and major hurricanes are a risk on the Gulf and Atlantic coasts every year. Increased population will only exacerbate these concerns, and coastal regions just in

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38. INTERNATIONAL JOINT COMMISSION, CLIMATE CHANGE AND WATER QUALITY IN THE GREAT LAKES REGION 45 (2003).
39. GREAT LAKES ASSESSMENT, *supra* note 32.
40. PEW CENTER ON GLOBAL CLIMATE CHANGE, SYNTHESIS REPORT (2004).
41. GREAT LAKES ASSESSMENT, *supra* note 32.
42. PEW CENTER ON GLOBAL CLIMATE CHANGE, SYNTHESIS REPORT (2004).
43. IPCC PHYSICAL SCIENCE BASIS, *supra* note 1, at 5.
44. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.
45. *Id.*
46. *Id.*

the southeast are expected to add twenty five million new residents in the next twenty-five years.[47]

The Intergovernmental Panel on Climate Change ("IPCC") has predicted that global mean sea levels are expected to go up approximately almost seven to twenty-three inches (18 to 59 centimeters) by 2100.[48] A more recent study indicates that the IPCC projections might be conservative and global sea levels could rise as much as thirty-one to seventy-nine inches (80 to 200 centimeters) by 2100.[49]

Rising sea levels, even when considered in isolation from other climate changes, present serious threats to coastal areas. For example, if predicted sea level rises are superimposed onto present-day climate and storm-surge frequency, the result is coastal erosion and flooding at levels rarely experienced today.[50] The future is likely to be even worse, as global circulation models show that the intensity of hurricanes will increase as the climate warms over the next century.[51] At the same time, many coastal areas will be sinking: regional subsidence could range from eight to forty inches (20 centimeters to 102 centimeters) during the next century, and relative sea-level rise—the combination of absolute sea-level rise and land subsidence—could range from two feet (0.6 meters) along most of the Gulf Coast to more than six feet (1.8 meters) along the Mississippi delta and coastal Louisiana.[52]

Between 1985 and 1995, southeastern states lost more than 32,000 acres (13 hectares) of coastal salt marsh due to a combination of human development activities, sea-level rise, natural subsidence, and erosion.[53] Up to 21% of the remaining coastal wetlands in the U.S. are at risk of inundation with sea water between 2000 and 2100.[54] Additional projected impacts are likely to include the loss of barrier islands and wetlands that protect coastal communities and ecosystems from storm surges, and reduced fisheries productivity as coastal marshes and submerged grass beds are displaced or eliminated.[55] Further, rising sea levels could destroy wetlands in environmentally

47. *Id.*
48. IPCC PHYSICAL SCIENCE BASIS, *supra* note 1, at 7, 13.
49. W.T. Pfeffer et al., *Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise*, 321 SCIENCE 1340, 1340 (2008).
50. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.
51. PEW CENTER ON GLOBAL CLIMATE CHANGE, COASTAL WETLANDS & GLOBAL CLIMATE CHANGE (2007).
52. *Id.*
53. U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 25.
54. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 237.
55. U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 25.

sensitive estuaries, such as the Chesapeake Bay.[56] In addition, increased flooding in low-lying coastal communities is likely to adversely impact human health; floods are the leading cause of death from natural disasters nationwide.[57]

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

F. Groundwater

Climate change will also affect groundwater resources nationwide. Groundwater contributes flow to many rivers and streams and is an important source of drinking and irrigation water. Climate change is expected to reduce aquifer recharge and water levels, especially in shallow aquifers.

In aquifers where stream-aquifer interactions dominate, aquifer levels are assumed to be directly proportional to precipitation, absent evapotranspiration.[58] But the higher temperatures and droughts expected over the next century will result in increased evapotranspiration, likely taxing aquifers even further. Aquifers will also suffer from the trend of heavier precipitation events, because more water will go to runoff before it can percolate into aquifers. Thus, even in a future where overall precipitation increases, aquifer levels may decrease, due to the increased intensity of precipitation events.

The Edwards Aquifer in Texas is expected to have lower or ceased flows from springs, reducing the supply of available water. In the Ogallala Aquifer region (which includes portions of South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas), groundwater recharge is

56. PEW CENTER ON GLOBAL CLIMATE CHANGE, SYNTHESIS REPORT (2004).
57. U.S. GLOBAL CHANGE RESEARCH PROGRAM, *supra* note 53.
58. DEP'T OF AGRIC. ASSESSMENT PRODUCT, *supra* note 13, at 144.

expected to decrease by more than 20% if temperatures increase by 4.5° F (2.5° C).[59] In the Ellensburg basin of the Columbia Plateau in Washington, aquifer recharge rates could decrease by as much as 25%.[60]

G. Water Demand

Even without the additional pressures of climate change, water resources in many regions are already stressed. In California, for example, the state's population is expected to double or triple over the next century. Regional growth in the Portland area is expected to increase water demand by 5.5 billion gallons (20.8 million cubic meters) per year by the 2040's.[61] The Colorado River Basin already has high demand relative to supply, and under predicted future growth, total system demands are expected to exceed the regional water supply.

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

The most significant water demand problems relate to irrigation. Irrigation accounts for 39% of all U.S. water withdrawals and 81% of consumptive water uses (unlike some other water withdrawals which return most of the water to the watershed, water withdrawn for irrigation is mostly consumed).[62] While it is difficult to forecast future irrigation needs, it appears that demand will increase substantially in regions where future drying is expected. Where climate becomes more variable, regions will be subject to more frequent droughts and floods. The frequency and severity of droughts is expected to increase in areas like the Southwest. Even in other areas, higher rates of evaporation will tend to offset the benefits from periods of greater precipitation, while intensifying the impacts of periods of lesser precipitation.

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59. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 629.
60. PETER H. GLEICK, ET AL., *supra* note 12, at 59.
61. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 628.
62. PETER H. GLEICK, ET AL., *supra* note 12, at 81.

Climate change is expected to directly and indirectly increase demand for agricultural irrigation. Irrigation needs will be as much as 39% higher in Nebraska and 14% higher in Kansas, assuming no change in irrigated area. Even with increased irrigation, crop yields can still be adversely affected by higher temperatures. In the corn belt of the U.S., yields of corn and soybeans from 1982 to 1998 were negatively impacted by warm temperatures, decreasing 17% for each 1.8° F (1° C) of warm temperature anomaly.[63] The reduced yields may spark efforts to increase acreage, thereby further increasing demand for water. In response to high prices from growing demand in the energy sector, farmers in other regions will begin to grow biofuels crops thereby inducing new irrigation demands in their regions. While some regions (mostly in the South) will have the water resources available, in others the added demand will be problematic. In the Great Lakes region, the growing season is expected to extend in the future, and double cropping (the planting of a second crop after the first has been harvested) could become more common, with resulting increased demand for irrigation.

II. MANAGING WATER RESOURCES WITH INTERSTATE COMPACTS

While many water users and managers are focused on state water law,[64] interstate compacts may be the most important legal consideration in assessing water supply risks from climate change. In terms of quantity, most of the available freshwater in the United States is in rivers, lakes, and aquifers that cross state boundary lines. These interstate water resources are most often managed and allocated by interstate compacts. Interstate compacts are essentially contracts between the states, subject to federal approval as provided in the U.S. Constitution. When approved by the Congress and signed by the President, interstate compacts have the full force and effect of federal law.

There are twenty-seven interstate compacts for managing and allocating water resources in force or pending approval in the United States. These compacts provide the legal framework for managing and allocating some of country's the most important freshwater resources, including the Great Lakes, the

63. IPCC CLIMATE CHANGE IMPACTS, *supra* note 7, at 624.

64. For an overview of the state-level legal and policy implications of climate change impacts of water resources see Noah D. Hall et al., *Climate Change and Freshwater Resources*, 22 NAT. RES. & ENV. 30 (2008).

Colorado River, the Rio Grande, the Arkansas River, the Susquehanna River, and the Delaware River. The compacts vary tremendously in how they allocate and manage interstate waters. Some interstate compacts, especially in the west, simply divide the waters by volume between the watershed states. Other interstate compacts, especially in the Great Lakes and east, provide for more comprehensive regulation and management of water uses. The terms, scope, and approach of interstate water compacts can significantly affect the water supply risks from climate change for potential water users.

A. The Importance of Interstate Freshwater Resources

Most major freshwater resources in the United States are shared by two or more states. For better or for worse, many rivers were used as the boundaries between neighboring states, usually giving the adjacent states shared rights to use of the water. In every part of the country, the major freshwater systems cross state lines. Eight states (Illinois, Indiana, Michigan, Minnesota, Ohio, New York, Pennsylvania, and Wisconsin, as well as the provinces of Ontario and Quebec) share jurisdiction and rights over the Great Lakes, which contain over 90% of the fresh surface water in the United States.[65] The Colorado River watershed covers seven states (California, Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming, as well as Mexico), and while it contains a relatively modest amount of water compared to the Great Lakes, it is an extremely important water supply for these western states. The largest river on the United States' east coast, the Susquehanna, is shared by New York, Pennsylvania, and Maryland. The Great Lakes, Colorado River, and Susquehanna River are all managed by interstate compacts. Other major interstate rivers subject to compacts include the Rio Grande, Arkansas River, and Delaware River.

Interstate aquifers are also an extremely important part of the U.S. water supply. Approximately 130 million people in the U.S. depend on groundwater for drinking water. Sixty-five percent of groundwater withdrawals are used for irrigation, and the amount of irrigation withdrawals in the U.S. has more than doubled since 1950.[66] Many aquifers have been depleted beyond

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65. GREAT LAKES COMMISSION, TOWARD A WATER RESOURCES MANAGEMENT DECISION SUPPORT SYSTEM FOR THE GREAT LAKES-ST. LAWRENCE RIVER BASIN 9 (2003).

66. NAT'L RES. CONSERVATION SERV., **U.S.** DEP'T **of** AGRIC., LONG RANGE PLANNING FOR DROUGHT MANAGEMENT - THE GROUNDWATER COMPONENT, http://wmc.ar.nrcs.usda.gov/technical/GW/Drought.html (last visited Nov. 12, 2010).

their safe yields, making them vulnerable to further stress from climate change.

The most significant aquifers in the United States are interstate in scope. Large, multi-state aquifers include the Ogallala, the Edwards-Trinity System, the Columbia Plateau System, and the Floridian. Although these large aquifers are crucial to the U.S. water supply, states have not yet used interstate compacts to manage them.

B. Management and Allocation of Interstate Waters in the United States

There are three ways to manage and allocate interstate waters in the United States. First, the federal government, through an act of Congress, could establish standards for the use of interstate waters or even apportion specific water resources among the states. While Congress has broad power over interstate waters, it has rarely exercised that power for managing and allocating interstate waters. Congress has taken a central role in protecting interstate water quality through the Clean Water Act,[67] but has not taken an active role in managing interstate water quantity.

Second, the Supreme Court of the United States has on several occasions reluctantly allocated interstate waters when a dispute between states has arisen. Pursuant to Article III of the United States Constitution, the United States Supreme Court has original jurisdiction over disputes between states.[68] The Court has invoked this jurisdiction several times over the past century to resolve disputes over allocation of interstate waters.[69] In these cases, the Supreme Court has not developed a uniform approach to interstate transboundary water allocation, instead resolving individual disputes with heavy reliance on the specific facts and circumstances. This approach has been termed "equitable apportionment," which only provides that no single state can command an entire interstate water to the detriment of other riparian states. The need for equity in allocating transboundary waters was best stated by Justice Holmes in the

67. Federal Water Pollution Control Act, Pub. L. No. 92-500, 86 Stat. 896 (1972) (codified at 33 U.S.C. §§ 1251–1376 (2000)).

68. *See* U.S. CONST. art. III, § 2, cl. 2 ("In all Cases affecting Ambassadors, other public Ministers and Consuls, and those in which a State shall be Party, the supreme Court shall have original Jurisdiction.").

69. *See, e.g.,* New Jersey v. New York, 283 U.S. 336 (1931); Wisconsin v. Illinois, 278 U.S. 367 (1929); Wyoming v. Colorado, 259 U.S. 419 (1922); Kansas v. Colorado, 206 U.S. 46 (1907).

Supreme Court's 1931 decision in New Jersey v. New York (1931):

A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it. New York has the physical power to cut off all the water within its jurisdiction. But clearly the exercise of such a power to the destruction of the interest of lower States could not be tolerated. And on the other hand equally little could New Jersey be permitted to require New York to give up its power altogether in order that the river might come down undiminished. Both States have real and substantial interests in the River that must be reconciled as best they may be.[70]

While the principle of equitable apportionment seems reasonable enough in theory, its application to specific disputes is frustrating and inconsistent. Managing an interstate water resource requires technical expertise, policy development, and cooperation – none of which are characteristic of litigation and judicial rulings. The Supreme Court, to its credit, has recognized that it is not well suited to managing interstate water resources. Instead, the Supreme Court has on numerous occasions recommended the third way of managing and allocating interstate waters—through an interstate compact. In suggesting the use of interstate compacts, the Supreme Court has stated that interstate water management problems are "more likely to be wisely solved by cooperative study and by conference and mutual concession on the part of representatives of the States so vitally interested in it than by proceedings in any court however constituted."[71]

C. The Interstate Compact as a Legal Authority

Interstate compacts are powerful legal tools. A compact is essentially a contract between states, subject to federal approval.[72] The compact mechanism is provided in Article I, section 10, of the U.S. Constitution, which declares that "[n]o State shall, without the Consent of Congress . . . enter into any Agreement or Compact with another State, or with a foreign Power."[73]

Many water management compacts are between only two states, though some include up to seven or eight party states, the

70. New Jersey v. New York, 283 U.S. at 342-43.
71. New York v. New Jersey, 256 U.S. 296, 313 (1921).
72. *See* Texas v. New Mexico, 482 U.S. 124, 128 (1987).
73. U.S. CONST. art. I, § 10, cl. 3.

Colorado River Compact and Great Lakes compact, respectively. Water management compacts are usually negotiated by governors and state agency officials, but can only be approved through state legislation. Just like a contract, a compact has only been agreed to when all party states, through their legislatures, approve the exact same compact terms. Because interstate compacts increase the power of the states at the expense of the federal government, they must also be approved by Congress and signed by the President to take effect.[74] Once effective, interstate compacts have the full force and supremacy of federal law.[75] This allows the terms of a compact to be enforced in federal court and prevents states from ignoring their compact duties.[76]

D. *Overview of Types of Interstate Water Compacts*

Interstate water management and allocation compacts tend to follow one of two general models – western and eastern. (There are also some interstate water compacts that confer no substantive rights and merely provide a mechanism for sharing information and conducting joint research.[77] Because these compacts do nothing to create or alter water use rights and have little effect on interstate water management, they are not considered in this article.) Interstate compacts were first used in the west in the 1920's and provide the older model. Western water compacts, such as the Colorado River Compact and the Rio Grande Compact, focus on allocating water rights to a shared river among the party states. These western compacts essentially divide the proverbial pie into agreed pieces. While western compacts restrict the total amount of water available to each individual state, the compacts usually do not provide any standards or even guidance for managing individual water withdrawals within the state's total allocation.

When eastern states began to develop interstate compacts for water management in the 1960's and 1970's, they took a very different approach. The two major eastern water compacts are the Delaware River Basin Compact and the Susquehanna River Basin Compact. These eastern water compacts create centralized interstate management authorities comprised of the party states and federal government. These authorities, termed compact commissions, have broad regulatory powers for permitting and

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74. *See* U.S. CONST. art. I, § 10, cl. 3

75. *See* Culyer v. Adams, 449 U.S. 433, 438 (1981) (stating that congressional consent "transforms an interstate compact . . . into a law of the United States").

76. *See* Texas v. New Mexico, 482 U.S. at 124, 128 (1987).

77. *See, e.g.*, Great Lakes Basin Compact, Pub. L. No. 90-419, 82 Stat. 414 (1968).

managing individual withdrawals or diversions of all waters in the respective river basins. The commissions even set regional standards for discharges of water pollution. This centralized approach has obvious benefits for uniform management of a single resource, but requires a significant loss of state autonomy.

Most recently, a new model for interstate water management compacts has been developed by the Great Lakes states. The Great Lakes-St. Lawrence River Basin Water Resources Compact 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. It also prohibits most diversions of water out of the Great Lakes basin to protect the total water supply. The Great Lakes compact creates a compact commission that evaluates very large consumptive uses and the few exceptions to the general prohibition on diversions. The compact commission also conducts research, collects data, and supports the water management work of the states.

III. ASSESSMENT METHODOLOGY: INTERSTATE WATER RESOURCE RISKS AND INTERSTATE WATER COMPACTS

The relative risk and legal uncertainty resulting from climate change for interstate water resources subject to interstate compacts is evaluated with two sets of criteria. First, the vulnerability of the interstate water resource to climate change impacts is evaluated with eight factors, including total water supply relative to water demand, the expected impact on water supplies from climate change, and infrastructure for storing and delivering water supplies within the watershed. Second, the vulnerability of the interstate water compact to climate change impacts is evaluated with another eight factors, including geographic and hydrologic scope, flexibility and adjustability of allocation, governance institutions, and the compact's terms for duration, revision, and rescission.

There are approximately fifty interstate compacts that in some way relate to interstate waters. However, many of these compacts do not allocate or manage interstate waters or substantially affect water use rights and risks. Some compacts only provide for sharing information and conducting joint research on water supplies and water use, without creating or altering water use rights. Because these compacts have little effect on interstate water management, they are not considered in this analysis. Similarly, some compacts primarily address interstate water pollution, which is now regulated pursuant to the federal Clean Water Act. Again, because these interstate water pollution compacts do not affect risk to legal water use rights from climate change, they are not included in the analysis. Finally, interstate compacts that simply enable a water supply project, such as the Animas - La Plata Project Compact, pursuant to federal law and do not otherwise manage or allocate interstate waters are not included in the analysis.

The analysis does include several compacts that have expired but are currently under continuing regional negotiations, notably the Alabama-Coosa-Tallapoosa River Basin Compact and the Apalachicola-Chattahoochee-Flint River Basin Compact, since these compacts should be considered in evaluating the relative risk of regional water supplies for water users.

The following interstate compacts relating to water management and allocation are analyzed in this article:

1. Alabama-Coosa-Tallapoosa River Basin Compact, Pub. L. No. 105-105, 111 Stat. 2233 (1997).
2. Apalachicola-Chattahoochee-Flint River Basin Compact, Pub. L. No. 105-104, 111 Stat. 2219 (1997).
3. Arkansas River Compact, Pub. L. No. 81-82, 63 Stat. 145 (1949).
4. Arkansas River Basin Compact of 1965, Pub. L. No. 89-789, 80 Stat. 1409 (1966).
5. Arkansas River Basin Compact of 1970, Pub. L. No. 93-152, 87 Stat. 569 (1973).
6. Bear River Compact, Pub. L. No. 85-348, 72 Stat. 38 (1958).
7. Belle Fourche River Compact, Pub. L. No. 78-236, 58 Stat. 94 (1944).
8. California-Nevada Interstate Compact, Nev. Rev. Stat. §538.600 (1969).
9. Canadian River Compact, Pub. L. No. 82-345, 66 Stat. 74 (1952).
10. Colorado River Compact, 70 CONG. REC. 324 (1928).
11. Costilla Creek Compact (Amended), Pub. L. No. 88-198, 77 Stat. 350 (1963).
12. Delaware River Basin Compact, Pub. L. No. 87-328, 75 Stat. 688 (1961).
13. Great Lakes-St. Lawrence River Basin Water Resources Compact, Pub. L. No. 110-342, 122 Stat. 3739 (2008).

14. Kansas-Nebraska Big Blue River Compact, Pub. L. No. 92-308, 86 Stat. 193 (1972).
15. Klamath River Basin Compact, Pub. L. No. 85-222, 71 Stat. 497 (1957).
16. La Plata River Compact, Pub. L. No. 68-346, 43 Stat. 796 (1925).
17. Pecos River Compact, Pub. L. No. 81-91, 63 Stat. 159 (1949).
18. Red River Compact, Pub. L. No. 96-564, 94 Stat. 3305 (1980).
19. Republican River Compact, Pub. L. No. 78-60, 57 Stat. 86 (1943).
20. Rio Grande Compact, Pub. L. No. 76-96, 53 Stat. 785 (1939).
21. Sabine River Compact, Pub. L. No. 83-578, 68 Stat. 690 (1954), as amended, Pub. L. No. 87-418, 76 Stat. 34 (1962).
22. Snake River Compact, Pub. L. No. 81-464, 64 Stat. 29 (1950).
23. South Platte River Compact, Pub. L. No. 69-37, 44 Stat. 195 (1926).
24. Susquehanna River Basin Compact, Pub. L. No. 91-575, 84 Stat. 1509 (1970).
25. Upper Colorado River Basin Compact, Pub. L. No. 81-37, 63 Stat. 31 (1949).
26. Upper Niobrara River Compact, Pub. L. No. 91-52, 83 Stat. 86 (1969).
27. Yellowstone River Compact, Pub. L. No. 82-231, 65 Stat. 663 (1951).

To evaluate interstate watersheds' vulnerability to climate change impacts, watersheds are assessed by looking at the following factors:

1. *Total water supply relative to water demand* – Water demand already exceeds water supply in some regions. Even without climate change impacts, some regions and watersheds are severely stressed in meeting current demand. Climate change will increase water demand in many ways, including irrigation to compensate for less predictable precipitation, increased domestic and industrial water use as temperatures rise, and new water demands created by climate change mitigation policies (such as ethanol plants).

2. *Natural variability* – Some watersheds have a higher degree of interannual streamflow variability than others. The

natural variability factor indicates the tendency of streamflow within a watershed to deviate from the norm. Those areas that have historically high streamflow variability are at greater risk to more frequent and more severe effects from the variability of climate change.

3. *Groundwater depletion* – Many regions are heavily dependent on groundwater for their water supplies. Areas where average groundwater withdrawals exceed long-run average recharge rates are particularly vulnerable to climate changes that reduce runoff and aquifer recharge. These groundwater overdraft areas can be unsustainable and create situations where increased groundwater use may not be a viable adaptation in the future.

4. *Dryness ratio* – Dry watersheds are extremely vulnerable to climate change. Small changes in precipitation in dry watersheds stress biological systems significantly more than the same changes in more humid areas. The effects of drying due to climate change will be felt in agricultural and domestic uses. This factor evaluates the dryness of watersheds by measuring the portion of total annual precipitation in the watershed that is lost through evapotranspiration.

5. *Expected impact on water supplies (including timing) from climate change* – Climate change will not produce a uniform warming or change in precipitation. Rather, anticipated temperature and precipitation (amount and timing) changes vary tremendously by region. Evapotranspiration rates will also vary regionally. As a result, some regions will experience more severe changes in water supply than others.

6. *Infrastructure for storing and delivering water supplies* – Water management and supply infrastructure (dams, reservoirs, and pipelines) is designed based on historic precipitation and flow patterns which will not continue with climate change. New infrastructure is expensive and politically difficult to build. Cost allocation issues and environmental protection laws can delay or prevent new projects from being built. Systems that rely heavily on infrastructure to store and deliver water supplies are at increased risk from climate change impacts.

7. *Water use flexibility* – Future climate conditions are expected to result in greater variability in water supply than has historically been the case. Regions that have the flexibility to make relatively low cost improvements in water use efficiency will be better situated to contend with future variability in supply. A region's flexibility is suggested by its rate of industrial water consumption relative to withdrawals. Where the ratio is low (low consumption despite high withdrawals), there is a

greater potential for extensive and low cost improvements in water use efficiency. Where the ratio is high, further increases in water efficiency may come only at an increased cost, and the watershed will be more vulnerable to climate change.

8. *Instream use factors* – Intensive instream uses place additional pressures on maintaining existing streamflow levels and can make water diversions more expensive or difficult. Navigation depends on the amount and timing of streamflows and on the volume of sediment deposited into shipping channels and harbors. Aquatic ecosystems, which generate considerable economic value from tourism, recreational use, and property values, are sensitive to changes in temperature, dissolved oxygen content in the water, and streamflow level. In addition, watersheds that contain threatened and endangered species are particularly vulnerable to climate changes. Endangered species laws may restrict the amount of water that can be used for other purposes and limit water management options.

To evaluate interstate water management compacts' adaptability to climate change impacts, compacts are assessed by looking at the following factors:

1. *Data collection and reporting* – It is critical to have accurate and up-to-date water supply and use data for adaptively managing water resources. The quality of data regarding water supply varies considerably. In general, there is less information regarding groundwater supplies than surface water supplies. Similarly, the quality of data regarding water use varies by state, watershed, and sector. In some circumstances, water use can only be estimated with limited accuracy, especially for agricultural uses. The most effective way to ensure quality data for demand management is to require water use registration and reporting.

2. *Geographic and hydrologic scope* – To most effectively manage an interstate water system under stress from climate change, management and allocation must be comprehensive in geographic and hydrologic scope. Some compacts only cover portions of a river basin, while other compacts fail to include tributary waters and groundwater. Many river systems rely heavily on groundwater inputs to maintain baseflow and water quality. Not including groundwater creates a hydrological loophole around surface water use regulations. When the compact's scope does not match the hydrologic realities of a watershed, it puts regulated water uses and investments at risk from unmanaged withdrawals.

3. *Flexibility and adjustability of allocation* – Some interstate water compacts create rights to a fixed quantity of water, while others provide more flexible allocation systems. Fixed allocations may seem to offer water users more certainty, but the allocations are based on past conditions which will not necessarily continue with climate change. A more flexible allocation system can better adapt to climate change and thus provide more certainty and reduced transaction and legal costs as conditions change. When an interstate water compact does use fixed and quantified allocation rights, those rights should be subject to adjustments that are based on changed conditions.

4. *Water conservation* – Water conservation is the single most important "no regrets" strategy for reducing risk from climate change impacts on water resources. In theory, both eastern riparian law and western prior appropriation law require water conservation, by prohibiting unreasonable water use and water waste, respectively. However, in practice both legal systems do little to encourage water conservation, and in some ways affirmatively discourage efforts to reduce water use. To fill this void, some interstate water compacts require water conservation and efficient water use, reducing total demand and freeing up saved water for other consumptive and/or environmental uses. Efficient water use also saves energy and water treatment costs, creating additional economic and environmental benefits.

5. *Ecosystem protection* – Proactive management to protect and restore aquatic habitat for fisheries and wildlife not only leads to a healthier ecosystem, it also prevents species from becoming endangered. This avoids the risk of resulting federal restrictions on water use to protect endangered species under the Endangered Species Act. In some interstate water basins, enforcement of the Endangered Species Act has drastically reduced the supply of water available for consumptive uses. The Endangered Species Act is an unforgiving statute, and has been called the "pit bull" of environmental law for its impact on water rights. The best way to avoid Endangered Species Act conflicts and resulting water use restrictions is to proactively incorporate protection of aquatic habitat into water management.

6. *Restrictions on transbasin diversions* – Climate change will increase the pressure to find new water supplies through transbasin diversions. Transbasin water diversions can undermine sustainable and adaptive water management efforts by opening the door to demands from other watersheds. The best water management efforts would not be rewarded with reduced risk for water users if transbasin water diversions are allowed. In

addition, the total demand relative to supply increases when water demands from other basins are included.

7. *Watershed governance institutions* – The stress and uncertainty of climate change requires regional governance institutions to adaptively manage water resources as conditions change and new information becomes available. Ideally, an interstate water management compact creates a governance institution empowered to promulgate and enforce rules to adapt to climate change. A governance institution should also have the authority to plan, conduct research, prepare reports on water use, and forecast water levels to ensure the best science is used in managing water resources.

8. *Duration, revision, and rescission* – The permanence of compacts has been questioned in recent years, in part because of the changed conditions resulting from climate change. Some compacts are indefinite in term, while others have a specific duration. Similarly, compacts vary in their provisions for revision and/or rescission due to changed circumstances. (Note: this element is not scored; instead the compact's duration and ease of revision/rescission will be noted in the analysis.)

IV. INDIVIDUAL INTERSTATE WATER RESOURCE RISK ASSESSMENTS

1. Alabama-Coosa-Tallapoosa River Basin Compact (Alabama and Georgia)

The Coosa and the Tallapoosa rivers arise near the Georgia-Alabama border and flow southwestward across Alabama, merging with the Alabama River just north of Montgomery. The Alabama River then joins the Mobile River, which empties into the Gulf of Mexico. Major cities in the watershed include Rome, Georgia and Montgomery, Alabama. The river system is navigable and important for commerce. Water is also used for farming, particularly around the Alabama River, which passes through rich agricultural land. Dams in the system provide hydroelectric power to Alabama citizens. Recently, Georgia has considered using the Tallapoosa to provide water for rapidly growing Atlanta, spurring concerns in Alabama that the resulting decline in water levels would damage river ecosystems and affect Alabama's power-generation capabilities.[78]

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78. AMERICAN RIVERS, AMERICA'S MOST ENDANGERED RIVERS OF 2003 30-31 (2003), http://www.americanrivers.org/site/DocServer/mertallapoosa.pdf?docID=686.

Meanwhile, Alabama is growing at a rate faster than the national average.[79] Urban centers will grow as Alabama moves away from agriculture toward a service-oriented economy, with projected declines in farming, fishing and forestry occupations.[80]

The average temperature in the Alabama-Coosa-Tallapoosa basin in Alabama and Georgia is expected to rise as much as 3°F during the next century. Annual precipitation is expected to increase modestly (less than 5%) throughout the year. Stream runoff is also expected to increase modestly (perhaps 2% to 5%) by mid-century.

Alabama, Georgia, and the Federal government entered into the Alabama-Coosa-Tallapoosa River Basin Compact[81] to equitably apportion the waters of the Alabama-Coosa-Tallapoosa River Basin, engage in collaborative water planning, and develop and share common databases related to the Basin's management.[82] Specifically, the Compact calls for the creation an allocation formula that will equitably apportion the waters of the Alabama-Coosa-Tallapoosa River Basin among the states and protect the Alabama-Coosa-Tallapoosa River Basin's water quality and biodiversity pursuant to the Clean Water Act, the National Environmental Policy Act, the Endangered Species Act, and the Rivers and Harbors Act of 1899.

The Compact created the Alabama-Coosa-Tallapoosa River Basin Commission to establish the allocation formula (with the consent of the federal government) and administer the Compact.[83] Once adopted, the allocation formula may only be revised upon the unanimous consent of the Commission, and the Commission may bring a legal action against any person to enforce the Compact's provisions. Importantly, until an allocation formula is established, water users in either state are permitted to withdraw, divert or consume water pursuant to the laws of the respective states.

The Compact also vests the Commission with the authority to monitor and coordinate the Basin's water resources and to conduct studies and share the studies' results with the public. Moreover, through the Compact, the States agree to

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79. Center for Business and Economic Research, University of Alabama, *Alabama Population Trends,* 76 ALA. BUS. 10-11 (2007), http://cber.cba.ua.edu/rbriefs/ab2007q2_poptrends.pdf.

80. LABOR MKT. INFO. DIV., ALA. DEP'T OF INDUS. RELATIONS, ALABAMA OCCUPATIONAL PROJECTIONS 2006-2016 (2008), http://www2.dir.state.al.us/projections/Occupational/Proj2016/Statewide/alabama%2006_16.pdf.

81. Alabama-Coosa-Tallapoosa River Basin Compact, Pub. L. No. 105-105, 111 Stat. 2233 (1997).

82. Alabama-Coosa-Tallapoosa River Basin Compact, art. I.

83. Alabama-Coosa-Tallapoosa River Basin Compact, art. VII.

cooperate in the investigation, abatement, and control of sources of interstate pollution and to maintain the quality of the Basin's waters.[84] At the same time, apart from pegging the allocation formula's validity to compliance with federal environmental and natural resources management acts, the Compact does not contain any specific provisions related to ecosystem protection, water conservation, or limitations or prohibitions on transbasin or interbasin diversions.

The Compact expired on July 31, 2004 and the States failed to agree on an equitable apportionment formula. While there was considerable progress on a permanent management system, the agreement was contingent on Georgia reaching an agreement with Florida regarding the Apalachicola-Chattahoochee-Flint system, which did not occur.

Overall, the Alabama-Coosa-Tallapoosa watershed faces **modest** climate change risks. However, it lacks an appropriate framework to address climate change risks since the Alabama-Coosa-Tallapoosa River Basin Compact has expired (and is thus **inadequate**). Negotiations to develop a new compact have been combined to some extent with the negotiations over the contentious Apalachicola-Chattahoochee-Flint River Basin system. While many of the issues under negotiation regarding the Alabama-Coosa-Tallapoosa River Basin can be resolved by the parties, the Apalachicola-Chattahoochee-Flint River Basin dispute threatens to undermine cooperation on the Alabama-Coosa-Tallapoosa River Basin. Still, at least compared to the neighboring Apalachicola-Chattahoochee-Flint River Basin, the Alabama-Coosa-Tallapoosa River Basin has ample water to meet immediate and expected future needs if a new cooperative agreement can be reached.

2. *Apalachicola-Chattahoochee-Flint River Basin Compact (Alabama, Florida, and Georgia)*

The Chattahoochee and Flint Rivers flow southward across Georgia and converge at the Georgia-Florida border to form the Apalachicola River, which continues southward and empties into the Gulf of Mexico. Together, the 107 miles of the three rivers drain an area of almost 20,000 square miles, including ecologically sensitive wetland and swampland areas. Atlanta is within this watershed, and the necessity of water for municipal and domestic use creates a stress on the river system.

The waters of the upper Apalachicola-Chattahoochee-Flint basin supply drinking water, wastewater assimilation,

84. Alabama-Coosa-Tallapoosa River Basin Compact, art. XVII.

hydropower, agricultural irrigation, and navigation to the region.[85] To preserve navigation on the southern Chattahoochee and on the Apalachicola, water must be released periodically from dams, which impacts the state of Georgia's access to drinking water in times of drought. There have been numerous legal disputes regarding the apportionment of the water for this reason. These problems will likely continue, as Georgia's population growth is one of the most rapid in the nation.[86] The population in the metropolitan area around Atlanta expanded by 97% in the period between 1970 and 1995, and is expected to continue growing.[87] Also, pollution from non-point and municipal point sources is problematic in the watershed.

The average temperature in the Apalachicola-Chattahoochee-Flint basin in Alabama, Georgia, and Florida is expected to rise as much as 3°F during the next century. Annual precipitation is expected to increase modestly (less than 5%) throughout the century. Stream runoff is also expected to increase modestly (perhaps 2% to 5%) by mid-century.

Through the Apalachicola-Chattahoochee-Flint River Basin Compact,[88] Alabama, Florida, and Georgia agreed to equitably apportion the surface waters of the Apalachicola-Chattahoochee-Flint River Basin, engage in water planning, and develop and share common databases related to the management of the Basin.[89] Specifically, the Compact calls for the creation an allocation formula that will equitably apportion the surface waters of the Basin among the party states and protect the Basin's water quality and biodiversity pursuant to the Clean Water Act, the National Environmental Policy Act, the Endangered Species Act, and the Rivers and Harbors Act of 1899.

The Compact created the Apalachicola-Chattahoochee-Flint River Basin Commission to determine the allocation formula. Once adopted, the allocation formula may only be revised upon the unanimous consent of the Commission, and the Commission may bring a legal action against any person to enforce the Compact's provisions. Importantly, until an allocation

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85. The Nature Conservancy, Apalachicola River, Florida, http://www.nature.org/initiatives/freshwater/work/apalachicola.html (last visited Nov. 12, 2010).

86. Leon Bouvier & Sharon McCloe Stein, Negative Population Growth, Georgia's Dilemma: The Unintended Consequences of Population Growth (2001), http://www.npg.org/ga_poll/georgia.html (last visited Nov. 12, 2010).

87. River Basin Center, University of Georgia, Chattahoochee-Flint River Basin, http://www.rivercenter.uga.edu/education/k12resources/basinsofga2.htm (last visited Nov. 12, 2010).

88. Apalachicola-Chattahoochee-Flint River Basin Compact, Pub. L. No. 105-104, 111 Stat. 2219 (1997).

89. Apalachicola-Chattahoochee-Flint River Basin Compact, art. I.

formula is established, water users in either state are permitted to withdraw, divert or consume surface water pursuant to the laws of the respective states.

The Compact also vests the Commission with the authority to monitor and coordinate the Basin's water resources and to conduct studies and share the studies' results with the public. Moreover, through the Compact, the States agree to cooperate in the investigation, abatement, and control of sources of interstate pollution and to maintain the quality of the Basin's waters.[90] At the same time, apart from pegging the allocation formula's validity to compliance with federal environmental and natural resources management acts, the Compact does not contain any specific provisions related to ecosystem protection, water conservation, or limitations or prohibitions on transbasin or interbasin diversions.

The Apalachicola-Chattahoochee-Flint River Basin Compact expired on August 31, 2003. Negotiations and litigation are ongoing, and the controversy and lawsuits create significant risk for water users.

Overall, the Apalachicola-Chattahoochee-Flint watershed faces **modest** climate change risks. However, it lacks an appropriate framework to address climate change risks since the Apalachicola-Chattahoochee-Flint River Basin Compact expired on August 31, 2003 (and is thus **inadequate**). There are numerous lawsuits pending over management and allocation of the Apalachicola-Chattahoochee-Flint River Basin, creating terrible uncertainty for water users. At this time, with severe droughts and water shortages in the region and political positioning by the respective states, a new cooperative agreement is not immediately likely. The Apalachicola-Chattahoochee-Flint River Basin is in the middle of one of the most contentious interstate water disputes in the country, and there is little reason to believe that the parties will soon put aside their differences and develop a suitable interstate water management agreement. Even if a new interstate agreement for the Apalachicola-Chattahoochee-Flint River Basin can be reached, the population growth in the basin and relative scarcity of water supplies for the Atlanta metropolitan region create significant risk and uncertainty for water users.

3. Arkansas River Compact (Colorado and Kansas)

The Upper Arkansas River runs through Colorado and Kansas, draining 3,950 square miles. The watershed is home to

90. Apalachicola-Chattahoochee-Flint River Basin Compact, art. XVII.

20% of the residents of Colorado, including the cities of Colorado Springs, Pueblo, and Lamar.

The Arkansas River is heavily used for recreational, industrial, and domestic purposes. Although it is a popular site for trout fishing, threats to water quality and water levels have been introduced into the river by agriculture and oil and natural gas production, the dominant economies in the upper reaches of the basin. While most of the irrigation systems use groundwater from the Ogallala-High Plains Aquifer, there is also an extensive network of ditches to divert surface water from the Arkansas River.[91] Of these surface water diversions, 55% go to agricultural irrigation, and the rest go to industrial, municipal, and domestic uses.[92] Kansas has objected to the quantity of water that Colorado uses, as these diversions are decreasing the quantity of water available to Kansas and increasing the salinity of groundwater aquifers in Kansas. In addition, Colorado has many mines which release acids and chemicals into river water.

The Arkansas River basin in Colorado and Kansas is expected to become warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Precipitation may increase modestly during the winter, but it should drop off significantly during the summer. Decreased precipitation will be exacerbated by increased evapotranspiration, creating a significantly drier environment. Stream runoff is expected to fall between 5% and 10% by mid-century.

Colorado and Kansas developed the Arkansas River Compact[93] after a protracted dispute over their relative rights "in and to the use of the waters of the Arkansas River."[94] Congress ratified the Arkansas River Compact on May 31, 1949. Through the Compact, Colorado and Kansas hoped to "equitably divide and apportion" water from the Arkansas River, the benefits that flowed from the water, and the utility derived "from the construction, operation and maintenance" of the John Martin Reservoir.[95]

Specifically, the Compact uses the John Martin Reservoir's conservation pool as a monitoring device to ensure that water from the Arkansas River Basin is not depleted and that both states can access the Arkansas River's water up to a

91. Kan. Dep't of Argic., Upper Arkansas River Subbasin, http://www.ksda.gov/subbasin/content/200 (last visited Nov. 12, 2010).

92. http://kmgh.envirocast.net/index.php?pagename=ow_watershed_arkansas.

93. Arkansas River Compact, Pub. L. No. 81-82, 63 Stat. 145 (1949).

94. Arkansas River Compact, art. I.

95. Arkansas River Compact, art. I.

predefined point. The Compact safeguards the water in the John Martin Reservoir by prescribing strict "release" limits during summer and winter storage seasons.[96] These limits are administered and monitored by the Arkansas River Compact Administration, which can authorize releases greater than the prescribed limits in order "to meet extraordinary conditions" and proscribe all water release demands if the John Martin Reservoir's conservation pool "will be or is liable to be exhausted" within fourteen days. In the latter scenario, the Administration can also oblige Colorado, the upstream state, to restrict water diversions until a sufficient level of water in the conservation pool is again achieved.[97]

The efficacy of this water management regime depends on accurate measurements of flows into and out of the John Martin Reservoir and across state lines. The Compact encourages the Administration to cooperate with state and federal agencies in collecting and publishing data, such as the flow rate of the Arkansas River as it crosses state lines.[98] In addition, the Compact assigns the U.S. Geological Survey and the U.S. Army Corps of Engineers collaborative roles in analyzing the implications that data collected from the gauging stations have on the Compact's management.

The Administration has some important management powers. It can order state officials to compile and share water diversion data and require water users in each state to install, at their own cost, water meters to measure individual diversions from the Arkansas River. In one important area, however, such authority is explicitly circumscribed: although the Administration can investigate Compact violations, enforcement of the Compact is ultimately left to State agencies and the officials "charged with the administration of water rights" in each state.[99] The Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the upper Arkansas River watershed faces **severe** climate change risks. The area is relatively dry, water resources are scarce relative to demand, and groundwater resources are already depleted. The Arkansas River Compact between Colorado and Kansas is **inadequate** to address many of

96. Arkansas River Compact, art. V.

97. Arkansas River Compact, art. V.

98. The Compact defines this measurement as the "Stateline flow." Arkansas River Compact, art. III.

99. Arkansas River Compact, art. VII.

these risks. Its limited hydrologic scope prevents comprehensive watershed management and there are no provisions for water conservation or ecosystem protection. The Arkansas River Compact does provide some governance capabilities and provisions for adjusting allocation, but overall it is not adequate to address the climate change and water supply risks in the watershed.

4. *Arkansas River Basin Compact of 1965 (Kansas and Oklahoma)*

After originating in central Colorado, the Arkansas River flows eastward through Kansas and then southward into Oklahoma, draining most of northern and central Oklahoma with a drainage area of nearly 47,000 square miles.[100] Major cities in this subbasin include Wichita and Tulsa. In Kansas and part of Oklahoma, the river floods seasonally, due in part to its wide shallow banks. After passing through Tulsa, a series of dams and reservoirs make the river navigable by large craft, thus making it important for commerce.

Agriculture and livestock production are major parts of the Kansas economy. The eastern part of the state, which relies mainly on surface water, has a high concentration of major urban areas as well as livestock farms.[101] Aircraft manufacturing is particularly important in the Wichita region. Most Kansas counties have some oil and gas extraction facilities. Population projections for the state of Kansas are high in the Arkansas River basin area, with a 20% to 49% increase in population is expected over the next twenty years.[102] Like Kansas, agriculture has been historically important to the economy of Oklahoma, but today manufacturing and oil and gas production are growing industries.[103] Pumping of groundwater in Colorado and eastern Kansas has significantly affected the amount of water available to western Kansas and Oklahoma.

100. Okla. Historical Soc'y, Encyclopedia of Okla. History and Culture, http://digital.library.okstate.edu/encyclopedia/entries/A/AR010.html (last visited Nov. 12, 2010).

101. CENTER FOR INTEGRATIVE ENVIRONMENTAL RESEARCH, UNIVERSITY OF MARYLAND, ECONOMIC IMPACTS OF CLIMATE CHANGE ON KANSAS (2008), http://www.cier.umd.edu/climateadaptation/Kansas%20Economic%20Impacts%20of%20Climate%20Change.pdf.

102. KANSAS WATER OFFICE, POPULATION ESTIMATES AND PROJECTIONS STATE OF KANSAS 1990 – 2040 (1999), http://www.kwo.org/reports%20&%20publications/Population_assessment_statewide.pdf.

103. City-Data.com, Oklahoma – Economy, http://www.city-data.com/states/Oklahoma-Economy.html (last visited Nov. 12, 2010).

The Arkansas River basin in Kansas and Oklahoma is expected to become warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Precipitation may increase modestly during the winter, but it should drop off significantly during the summer. Decreased precipitation will be exacerbated by increased evapotranspiration, creating a significantly drier environment. Stream runoff is expected to fall between 5% and 10% by mid-century.

The Arkansas River Basin Compact of 1965[104] apportions the waters of the Arkansas River Basin lying within Kansas and Oklahoma between the two states. This apportionment is measured through baseline storage allocations afforded to the states within five major sub-basins. These allocations are preliminary and can be increased upon approval from the Kansas-Arkansas River Commission (described below). As a result, until such approval is obtained, Kansas' ability to divert and store water from the five sub-basins is limited to specific storage allotments within each sub-basin, while Oklahoma's free and unrestricted use of waters within the basin is circumscribed by a storage capacity limitation placed on one of the sub-basins.

The Compact does not prohibit interbasin diversions, nor does it reward them. If a state diverts water from one of the sub-basins, such diverted water counts toward the state's total allotted storage capacity within that sub-basin. If a state imports water from outside of the basin, the imported water does not count toward that state's storage capacity in a particular sub-basin, and the importing state has "exclusive use of such imported waters."[105] Under the Compact, the states agree to investigate and control sources of natural and manmade pollution within the Arkansas River Basin that affects public health and/or threatens the beneficial use of the water.[106] However, the Compact does not contain any provisions related to water conservation or ecosystem protection.

The Kansas-Arkansas River Commission is responsible for administering the Compact. The Commission must "collect, analyze and report on data" about water quality, stream flows, and conservation storage, either on its own or by contracting state or federal agencies.[107] As previously mentioned, the Commission uses this data to approve or deny state proposals to

104. Arkansas River Basin Compact of 1965, Pub. L. No. 89-789, 80 Stat. 1409 (1966).
105. Arkansas River Basin Compact of 1965, art.VIII.
106. Arkansas River Basin Compact of 1965, art. IX.
107. Arkansas River Basin Compact of 1965, art. XI.

construct new conservation storage capacity within a particular sub-basin.

Overall, the middle Arkansas River watershed faces **severe** climate change risks. Like the upper Arkansas River, the area is relatively dry, water resources are scarce relative to demand, and groundwater resources are already depleted. And like the Arkansas River Compact between Colorado and Kansas, the Arkansas River Compact between Kansas and Oklahoma is **inadequate** to address many of these risks. Its limited hydrologic scope prevents comprehensive watershed management and there are no provisions for water conservation or ecosystem protection. The Arkansas River Compact does provide some governance capabilities and provisions for adjusting allocation, but overall it is not adequate to address the climate change and water supply risks in the watershed.

5. Arkansas River Basin Compact of 1970 (Oklahoma and Arkansas)

The Oklahoma-Arkansas portion of the Arkansas River basin is the river's last leg before emptying into the Mississippi River in southeastern Arkansas. In this portion of the river, dams deepen and widen the channel to make it commercially navigable and thus vital for commerce. It is also a popular spot for fishing and whitewater rafting.[108] It includes the cities of Little Rock, Arkansas and Tulsa, Oklahoma. Population projections for the region predict that it will grow at a rate slightly slower than that of the nation as a whole.[109]

The Arkansas River basin in Arkansas and Oklahoma (excluding a portion of the Canadian River) is expected to become warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps more than 3°F. Winter precipitation may not change much, but summer precipitation will likely decrease. Evapotranspiration should rise, amplifying the impact of the diminished precipitation. Stream runoff in portions of the basin is expected to fall between 5% and 10% by mid-century.

Oklahoma and Arkansas entered into the Arkansas River Basin Compact of 1970[110] to work toward five broad goals: (1) to

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108. Arkansas.com, Arkansas River (Olka. To Little Rock), http://www.arkansas.com/lakes-rivers/river/id/1 (last visited Nov. 12, 2010).

109. INSTITUTE FOR ECONOMIC ADVANCEMENT, UNIVERSITY OF ARKANSAS AT LITTLE ROCK, U.S. CENSUS BUREAU INTERIM STATE POPULATION PROJECTION 2005-2030, http://www.iea.ualr.edu/research/demographic/population/interim.pdf (last visted Nov. 12, 2010).

110. Arkansas River Compact of 1970, Pub. L. No. 93-152, 87 Stat. 569 (1973).

promote interstate comity between the two states; (2) to equitably apportion the waters of the Arkansas River and promote the development of such waters; (3) to create an agency to administer the water apportionment arrangement; (4) to maintain an "active pollution abatement program" and to reduce pollution in the Arkansas river basin; and (5) to "facilitate the cooperation of the water administration agencies" of the two states "in the total development and management of the water resources of the Arkansas river basin."[111]

In furtherance of the goal of equitable apportionment, the Compact allocates water development and use rights between Arkansas and Oklahoma within specific sub-basins. The Compact affords one state exclusive and unlimited rights to develop, use, and store all water originating within some sub-basins; but for most sub-basins, the Compact limits a state's development, use, and storage by mandating that a sub-basin's annual yield cannot be depleted beyond a specific annual percentage.[112] Because much of the apportionment is yield-based, the Compact created the Arkansas-Oklahoma River Compact Commission and charged it with measuring the Arkansas River Basin's annual state line yield. The Commission is also responsible for collecting, analyzing, and reporting on "data as to stream flows, water quality, annual yields and such other information as is necessary for the proper administration" of the Compact.[113]

Although Arkansas and Oklahoma agree to work together and individually to reduce pollution in the Arkansas River Basin, the Compact does not bind the states to any other form of ecosystem protection. And the Compact neither encourages nor prohibits transbasin or interbasin diversions.

Overall, the lower Arkansas River watershed faces **substantial** climate change risks. The area is not as dry as the upper and middle Arkansas River regions, and water resources are not as scarce relative to demand as in the upper and middle regions. Groundwater resources are already stressed but not severely depleted. The Arkansas River Compact between Oklahoma and Arkansas is **somewhat adequate** to address these risks. As with the other Arkansas River Compacts, its limited hydrologic scope prevents comprehensive watershed management and there are no provisions for water conservation or ecosystem protection. However, the Arkansas River Compact between Oklahoma and Arkansas does provide some governance capabilities and provisions for adjusting allocation, and given the

111. Arkansas River Basin Compact of 1970, art. I.
112. Arkansas River Basin Compact of 1970, art. IV.
113. Arkansas River Basin Compact of 1970, art. IX.

less severe water problems expected in the lower Arkansas River Basin relative to the upper and middle basin, it is somewhat adequate to address the climate change and water supply risks in the watershed.

6. Bear River Compact (Idaho, Utah, and Wyoming)

The Bear River makes the shape of an inverted letter "u," ending just ninety miles from its source after flowing for over 350 miles. It flows northward through southwestern Wyoming, then turns westward in southeastern Idaho. From there it flows southward through northern Utah before emptying into the Great Salt Lake. It is the largest tributary of the Great Salt Lake and is the largest river in the Western Hemisphere that does not empty into an ocean. The watershed encompasses 7,500 square miles.

The Bear River is used extensively for agricultural irrigation, particularly in Idaho and northern Utah. Many of the streams and lakes in the basin are classified as impaired water bodies because of pollution from animal feeding operations, grazing, agriculture, wastewater, mining, logging, and oil and gas exploration.[114] The portion of the river near its delta on the Great Salt Lake is protected as part of a bird refuge.

The area in Idaho, Utah, and Wyoming that includes the Bear River and its tributaries is expected to become warmer and much drier during the next century. The average annual temperature is predicted to increase, perhaps more than 3°F. Precipitation may increase modestly during the winter, but it is expected to drop significantly during the summer. Decreased precipitation will be exacerbated by markedly higher evapotranspiration, creating a significantly drier environment. Stream runoff could fall between 10% and 25% by mid-century.

Idaho, Utah, and Wyoming developed the Bear River Compact[115] to resolve existing and future disputes over the use and distribution of the waters of the Bear River. The states also hoped to encourage efficient and varied water use along the river, promote additional development of the river's water resources, and advance interstate comity.

The Compact created the Bear River Commission and charged it with enforcing the Compact and its provisions "by suit or other appropriate action."[116] The Compact also vests the

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114. Bear River Commission, Nomination of the Tri-state Bear River Basin for the U.S. EPA Water Initiative Program (2004), *available at* http://www.epa.gov/twg/2004/2004proposals/04bearriver.pdf.

115. Bear River Compact, Pub. L. No. 85-348, 72 Stat. 38 (1958).

116. Bear River Compact, art. III, cl. D(1).

Commission with authority to declare "water emergencies" and establishes guidelines for identifying and declaring such emergencies within three different divisions of the Bear River. Under such an emergency, the Compact specifies the percentage of remaining divertible flow that must be allocated and how it must be allocated. The allocation schedule is unique in each division. For example, in the Lower Division, water is distributed during water emergencies according to delivery schedules based on the priority of rights of individual water users regardless of the state in which they reside. When a water emergency exists in the Upper Division, on the other hand, water is allocated between state- and division-specific sections according to a fixed percentage.[117]

Importantly, the Commission also has the authority to: (1) declare a water emergency when diversions are being made in the Lower Division that violate the Compact and "encroach upon water rights in a lower State"; (2) issue orders aimed at preventing such encroachments; and (3) enforce such orders by administrative actions or court proceedings.[118] The Compact also allows individual water users in downstream states to file a petition with the Commission if diversions in upstream States render the instream flow in the lower state insufficient to satisfy the user's legally established water allotment. In response, the Commission can declare a water emergency and administer water delivery schedules based on the priority of rights.[119]

The Commission is also responsible for developing the interstate water delivery schedules based on several factors, including the priority and extent of water rights and the class of crops grown in a particular division.[120] Because the water delivery schedules could potentially hinder economically and socially important activities in an upper state, states that have diverted more than their allotment can transfer water from outside of the basin into the Bear River watershed for downstream use, as long the introduced water is not "inferior in quality for the purposes used or diminished in quantity."[121] The Compact does not place any other limitations on interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Bear River watershed faces **severe** climate change risks. The area is very dry and water resources are

117. Bear River Compact, art. IV, cl. A(1)(A).
118. Bear River Compact, art. IV, cl. A(3)(B).
119. Bear River Compact, art. IV, cl. A(3)(C).
120. Bear River Compact, art. IV, cl. A(3)(D).
121. Bear River Compact, art. IX.

already scarce relative to demand. Loss of snowpack will have a dramatic effect on surface water supplies, and groundwater resources are already stressed. The Bear River Compact is **somewhat adequate** to address these risks. While it lacks any viable provisions for water conservation or ecosystem protection, it does provide some data collection and governance capabilities. Most importantly, the Bear River Commission has the ability to adjust allocations and establish new water delivery schedules. Given the severe water problems expected in Bear River Basin, the Bear River Compact is somewhat adequate to address the climate change and water supply risks in the watershed.

7. Belle Fourche River Compact (South Dakota and Wyoming)

A tributary of the Cheyenne River, the Belle Fourche is approximately 290 miles long and flows through Wyoming and South Dakota. Cities and towns in the watershed are small. The Belle Fourche provides flood control, recreation, and agricultural irrigation for western South Dakota. The principal land use in the area is pastureland, followed by woodland and cropland. Declines in population and economic activity are projected for the coming years.[122]

The Belle Fourche River basin in South Dakota and Wyoming is expected to warm significantly during the next century, perhaps as much as 4°F. Precipitation is expected to decrease slightly during the summers, though winter precipitation will rise more substantially. Evapotranspiration may increase modestly, but stream runoff is not expected to change significantly by mid-century.

South Dakota and Wyoming developed the Belle Fourche River Compact[123] to (1) ensure that the waters of the Belle Fourche River Basin were utilized efficiently to encourage development, (2) divide the waters equitably between the two states, and (3) promote "joint action by the States and the United States in the efficient use of water and the control of floods."[124] Under the Compact, each state appoints an official to administer the Compact and to collect and analyze data necessary to the Compact's execution.[125] The officials are required to collaborate with the United States Geological Survey in their administration and data collection efforts.

122. http://www.usd.edu/sdsdc/PDFs/stateppsample.pdf
123. Belle Fourche River Compact, Pub. L. No. 78-236, 58 Stat. 94 (1944).
124. Belle Fourche River Compact, art. I.
125. Belle Fourche River Compact, art. III.

The Compact allocates 90% of the Belle Fourche River to South Dakota, and the remaining 10% to Wyoming.[126] The States are responsible for monitoring this allocation through the creation, maintenance, and operation of water gauging stations.[127] Either state can divert or store any unused part of the other state's allocation, but such diversions or storage do not vest a new water right in the diverting or storing state.[128] The Compact does not prohibit or limit transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Belle Fourche River watershed faces **substantial** climate change risks. While the area is very dry, water resources are sufficient relative to demand. Climate change will not have as dramatic an effect on surface water supplies as in more snowpack-dependent watersheds. The Bear River Compact is **somewhat adequate** to address these moderate risks. While it lacks any viable provisions for water conservation, ecosystem protection, or restricting transbasin diversions, it does provide good data collection and governance capabilities. Most importantly, it allocates water based on percentage of flow rather than actual quantity, so as conditions change water rights remain predictable.

8. California-Nevada Interstate Compact (California and Nevada)

The California-Nevada Interstate Compact applies to Lake Tahoe and the Truckee, Carson, and Walker rivers, located high in the Sierra Nevada Mountains on and around the California-Nevada border.[129] Lake Tahoe covers an area of 191 square miles and at 1,645 feet is the second deepest lake in the United States. The Truckee River is approximately 140 miles long. It flows out of the northwest corner of Lake Tahoe, past Reno, Nevada, and empties into Pyramid Lake. Much shorter is the Walker River, which arises southeast of Lake Tahoe and flows fifty miles, largely eastward, into Walker Lake. Meanwhile, the 150-mile long Carson River, whose headwaters are located between Lake Tahoe and the Walker River, flows northeasterly through Carson City, Nevada and terminates in the Carson Sink.

The waters of all three rivers have been heavily appropriated. Water is used for irrigation throughout the watershed. The Truckee-Carson Irrigation District was formed in

126. Belle Fourche River Compact, art. V.
127. Belle Fourche River Compact, art. IV.
128. Belle Fourche River Compact, art. V.
129. California-Nevada Interstate Compact, Nev. Rev. Stat. §538.600 (1969).

1918 to support agricultural use in the watershed. The District operates dams on Lake Tahoe and the Truckee River. Lake Tahoe is used for water storage, controlling outflow with a dam at the mouth of the Truckee River. A hydroelectric dam is located on the Carson River. In addition, the several Lake Tahoe communities and Reno, Sparks, and Carson City, Nevada, all depend on the watershed for residential and industrial water supplies. The waters in the area are also used extensively for recreational purposes, such as rafting, kayaking, and fishing.

Lake Tahoe is a tourist mecca and is intensively used for recreational purposes. In recent years, the environmental impacts from population growth and a changing climate have become acute. The lake is warming, and its famously clear waters are at risk of becoming cloudier.[130] Warming temperatures could have the effect of reducing or even eliminating the periodic mixing of lake waters. This mixing is essential for the oxygenated conditions that are critical to maintaining clear water and Lake Tahoe's grandeur.

The area covered by the California-Nevada Interstate Compact is expected to warm significantly during the next century, perhaps more than 3°F. Precipitation is expected to increase slightly during the winter, but warming winter temperatures will lead to a reduction in snowpack. Summer precipitation will decrease more significantly, and evapotranspiration will rise. Stream runoff is expected to plummet by 10% to 25% by mid-century.

The California-Nevada Interstate Compact[131] apportions the waters of Lake Tahoe, the Truckee River, the Carson River, and the Walker River basins between California and Nevada. The aim of such apportionment is to protect and improve the States' economies, forestall existing and present disputes, and promote orderly and comprehensive development, use, and conservation of the water within the four basins. Congress has not approved the Compact, but both States have ratified it and are abiding by it. Further, the Fallon Paiute Shoshone Indian Tribes Water Rights Settlement Act of 1990 addresses some of the issues covered by the compact.[132]

The Compact assigns California and Nevada the right to divert annually for use within the Lake Tahoe Basin no more

130. *Global Warming Could Radically Change Lake Tahoe in Ten Years*, SCIENCEDAILY.COM, Mar. 28, 2009, http://www.sciencedaily.com/releases/2008/03/080325141202.htm.

131. California-Nevada Interstate Compact, Nev. Rev. Stat. §538.600 (1969).

132. Fallon Paiute Shoshone Indian Tribes Water Rights Settlement Act of 1990, P.L. 101-618, 104 Stat. 3289 (1990).

than 23,000 and 11,000 acre feet of basin water, respectively. The Compact allows the States to reuse and export the diverted water, and to continue transbasin diversions from the Lake Tahoe Basin as long as such diversions involve water that was part of a recognized vested legal right as of December 31, 1959. The Compact also limits the pumping of water from the Lake Tahoe Basin for the benefit of downstream users to instances when the Commission declares drought emergencies because basic water needs cannot be met.[133]

The Compact also allocates diversion and storage rights to the waters of the Truckee River, Carson River, and Walker River basins based on past decrees and a complicated balancing of storage capacities, flow rates, conservation yields, and return flows. A number of these diversion and storage rights are contingent upon the existence of specified water quantities and flow rates, and can be stayed or modified under specified conditions. Interbasin transfers are allowed under the Compact, and the Compact encourages the States to import water into the four basins.

Under the Compact, both States have the right to develop and use groundwater within their respective boundaries provided that such development and use does not reduce the amount of water that the other State would receive under the allocation absent ground water development. The Compact also recognizes the merit and indispensability of the use of waters for ecosystem preservation, but it does not mandate such a use. The Compact allows States to use water for nonconsumptive uses, such as preservation and recreation, insofar as these uses do not infringe on the other State's water allocation.

The Compact is administered by the California-Nevada Commission which has the authority to install and maintain measuring devices – and to require water users in the two states to do the same at their own expense – in any pertinent water body to ensure that the Compact is administered properly.[134] The Commission also has the power to enforce Compact provisions through legal means. And the Compact affords citizens a private right of action to compel Compact compliance, as long as the citizens first submit the matter to the Commission.

Overall, the Lake Tahoe, Truckee River, Carson River, and Walker River Watersheds face **severe** climate change risks. The area is very dry and precipitation is highly variable. Water resources are already insufficient to meet demand, and

133. California-Nevada Interstate Compact, art. V, cl. F.
134. California-Nevada Interstate Compact, art. IV.

groundwater is severely overused. Climate change will significantly impact surface water supplies as snowpack decreases and stream runoff is expected to fall by 10% to 20% by mid-century. The California-Nevada Interstate Compact is **inadequate** to address these severe risks. While it has some provisions for ecosystem protection, restricting transbasin diversions, and data collection, its allocation mechanism is not adequate for the severe changes expected in surface water supplies. As a result, water users will face significant risk and uncertainty as snowpack and streamflow decrease from climate change.

9. Canadian River Compact (New Mexico, Oklahoma, and Texas)

The Canadian River flows about 760 miles from Colorado eastward across New Mexico, the Texas panhandle, and Oklahoma before joining the Arkansas River. In total, the river drains about 47,700 square miles of the three states. With sufficient rain, it can carry large amounts of water, but it is more typically a low-volume, slow-flowing river. Forest, shrubland, and grassland make up about 97% of the land cover, while agriculture makes up 2% and small urban centers and communities less than 1%.[135] Land uses include ranching, farming, recreation, and municipal activities.

The water from the river is used for agricultural, domestic, and municipal purposes, along with the underlying Ogallala Aquifer. The river supplies water for many small communities in addition to larger ones such as Oklahoma City (over one million residents) and Amarillo, Texas (about 200,000 residents). Parts of the watershed have been identified as prime sites for new wind-power plants because of the region's strong winds. However, growth in the region varies. The population growth of Oklahoma is expected to be slower than the national average,[136] while the panhandle region of Texas is expected to grow more quickly (though this growth is not expected to significantly alter water use).[137]

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135. SURFACE WATER QUALITY BUREAU, NEW MEXICO ENV'T DEP'T, USEPA-APPROVED TOTAL MAXIMUM DAILY LOAD (TMDL) FOR THE CANADIAN RIVER WATERSHED – PART 1 (2007), http://www.nmenv.state.nm.us/SWQB/Canadian/CanadianTMDL-Pt1.pdf.

136. Okla. Dep't of Commerce, Census Highlights 2006, http://staging.okcommerce.gov/test1/dmdocuments/Census_Highlights_2006_0202072099.pdf.

137. Panhandle Water Planning Group, 2011 Executive Summary (2011), http://www.panhandlewater.org/2011_draft_plan/Main_Report/Executive%20Summary.pdf.

The Canadian River basin in New Mexico, Oklahoma, and Texas is expected to become warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Precipitation is expected to decrease during both winter and summer months. Decreased precipitation will be exacerbated by increased evapotranspiration in parts of the basin, creating a significantly drier environment. Stream runoff is expected to fall between 5% and 10% by mid-century.

New Mexico, Texas, and Oklahoma created the Canadian River Compact[138] to protect existing developments along the Canadian River and to authorize the construction of "additional works for the conservation of the waters of the Canadian River."[139] The Compact divides diversion and storage rights to the waters of the Canadian River among the three states. Under the Compact, Oklahoma (the most downstream state) is afforded free and unrestricted use of all of the waters of the Canadian River in Oklahoma.[140] Similarly, New Mexico has unrestricted use of the river's waters within its borders that are above the Conchas Dam. For waters below the Conchas Dam, New Mexico's right is more qualified. Texas' ability to use and store the waters of the Canadian River is limited by a priority use schedule and the availability of water supply in Oklahoma.

The Canadian River Commission administers the Compact. The Commission is authorized to contract with federal agencies to collect and present data relevant to the Compact. The Commission is also required to operate gauging and evaporation stations to monitor compliance with the Compact's provisions. The states must provide the Commission with "accurate records of the quantities of water stored in reservoirs pertinent to the administration of [the] Compact."[141] Importantly, using this data, the Commission can increase Texas' and New Mexico's water impoundment quotas, as long as the increase does not deprive another state of water needed for beneficial use. The Compact does not place any limitations on interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Canadian River watershed faces **severe** climate change risks. The area is very dry and groundwater is rapidly being depleted. However, because population growth is not significant, water resources have been sufficient relative to

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138. Canadian River Compact, Pub. L. No. 82-345, 66 Stat. 74 (1952).
139. Canadian River Compact, art. I.
140. Canadian River Compact, art. VI.
141. Canadian River Compact, art. VIII.

demand. Climate change is expected to make the region warmer and drier, further stressing water resources. The Canadian River Compact is **inadequate** to address these risks. It lacks any viable provisions for water conservation or ecosystem protection. Most importantly, the Canadian River Compact does not provide for any adaptive management or allocation, which combined with the expected impacts of climate change in the region, creates considerable risk for water users.

10. Colorado River Compact (Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming)

The Colorado River Basin encompasses 242,900 square miles. The river arises in Rocky Mountain National Park in Colorado and flows through Utah, Arizona, Nevada, and California southward toward Mexico (Wyoming and New Mexico also contain portions of the river's watershed). At one time, the river emptied into the Gulf of California in Mexico. However, massive diversions have dried out the lower portions of the river, and it no longer reaches the ocean on a consistent basis. In addition, rising global temperatures are decreasing the volume of water in the basin. The years 2000 to 2004 were the only five consecutive years in recorded history with water flow below average, and main reservoirs are shrinking in size.[142]

Millions of people depend on the Colorado River for domestic, irrigation, and industrial uses. Major cities such as Los Angeles, Las Vegas, San Diego, Phoenix, and Tucson get some of their water from the Colorado. Major dams have been built over the years to facilitate municipal and agricultural use, including the Glen Canyon, Hoover, Parker, Davis, and Imperial dams. Almost 90% of water diverted from the river is used for irrigation. The Southwest is currently one of the fastest growing regions in the country.[143] If current demographic trends continue, the economy and population of the region will continue to expand, placing increased burdens on the Colorado River.

The Colorado River basin in is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Precipitation may increase slightly in the northern portion of the basin, but it will decrease more markedly in the south. Increased

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142. ROCKY MOUNTAIN CLIMATE ORG. & NAT. RES. DEF. COUNCIL, HOTTER AND DRIER: THE WEST'S CHANGING CLIMATE (2008), http://www.nrdc.org/globalwarming/west/west.pdf.

143. Press Release, U.S. Census Bureau, Florida, California, and Texas to Dominate Future Population Growth, Census Bureau Reports (Apr. 21, 2005), http://www.census.gov/newsroom/releases/archives/population/cb05-52.html.

precipitation in the north will likely be offset by increased evapotranspiration. Evapotranspiration may decrease in the southern portion of the basin due to the reduced precipitation. As a result of reduced snowpack, streamflow in the Colorado River is expected to decrease significantly in the 21st century, with predicted reductions of as much as 45% by 2050.

Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming developed the Colorado River Compact[144] after the U.S. Supreme Court's decision in Wyoming v. Colorado.[145] After the ruling, the slower developing states became worried that water users in faster growing states like California would quickly divert (and thus gain rights to) the undeveloped basin water.

The Compact divides the Colorado River Basin into an upper and lower basin at Lee's Ferry, a point on the Colorado River in Arizona just south of the Utah border. Under the Compact, Colorado, New Mexico, Utah and Wyoming are "Upper Division" states, while Arizona, California, and Nevada belong to the "Lower Division."[146] The goal of the Compact was to ensure the equitable division and apportionment of the waters of the Colorado River among the party states, apportioning each basin 7,500,000 acre-feet of water per year. However, the Compact's effective apportionment has proven problematic. For example, under the Compact the Upper Division states agreed not to "cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years." [147] Because the original apportionment was based on water flow measurements taken during an unusually rainy season, the Compact effectively guaranteed that the Lower Division states would enjoy greater apportionment rights in dry years than the Upper Division states. Further, although the Compact ended the prior appropriation system between the two basins, such a system remained in effect between the states within each respective basin. Consequently, the states in each basin were left to determine how to divide the established allocation within their basin.

The Compact accords the chief official of each party state, along with the Director of the U.S. Reclamation Service and the Director of the U.S. Geological Survey, the task of administering water rights. Concomitant with this responsibility, these administrators are in charge of collecting, analyzing, and publishing data related to flow, appropriation, consumption and

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144. Colorado River Compact, 70 CONG. REC. 324 (1928).
145. Wyoming v. Colorado, 259 U.S. 419 (1922).
146. Colorado River Compact, art. II.
147. Colorado River Compact, art. III, cl. d.

use of the waters of the Colorado River.[148] The Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

The Colorado River Compact is just one component of the complex law of the Colorado River, and there are ongoing efforts to adapt management of the river to changing climate conditions. For additional resources on the Colorado River and Colorado River Compact, see the University of Colorado and the National Oceanic and Atmospheric Administration's Western Water Assessment.[149]

Overall, the Colorado River watershed faces **severe** climate change risks. The area is very dry, groundwater has been depleted, and agriculture and population growth have driven water demand to exceed the limited supply. Climate change is expected to further stress and destabilize water resources. As a result of reduced snowpack, streamflow in the Colorado River is expected to decrease significantly in the 21st century, with predicted reductions of as much as 45% by 2050. The Colorado River Compact is **inadequate** to address these risks. It lacks any provisions for water conservation, ecosystem protection, restricting transbasin diversions, or otherwise managing water demand. Most problematic, the Colorado River Compact allocates quantities of water which simply will not exist in the future with climate change. The watersheds' reservoirs are already depleted and the ability of the United States to meet its delivery obligations to Mexico is in jeopardy. The Colorado River Basin is in many ways the poster child for regional uncertainty and risk for water users from climate change.

11. Costilla Creek Compact (Colorado and New Mexico)

Costilla Creek is a small river which arises thirty-five miles north-northeast of Taos, New Mexico, and crisscrosses the New Mexico-Colorado border before merging with the Rio Grande in southern Colorado. The watershed is approximately 230 square miles and contains no major cities.[150] Water flows only occasionally into the Rio Grande from Costilla Creek, since diversions and high evaporative losses usually exhaust the flow before the river's end. The river is short—only fifty miles long—

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148. Colorado River Compact, art. V.

149. Western Water Assessment, Colorado River Resources, http://wwa.colorado.edu/colorado_river/ (last visited Nov. 12, 2010).

150. SURFACE WATER QUALITY BUREAU, NEW MEXICO ENV'T DEP'T, TOTAL MAXIMUM DAILY LOAD FOR THE UPPER RIO GRANDE BASIN WATERSHED ch. 3 (2004), http://www.nmenv.state.nm.us/swqb/projects/RioGrande/Upper/TMDL/03.pdf.

but it is intensively used for irrigation and recreation. The Costilla Creek irrigation system removes water from the creek by way of a system of ditches and transports water to the high desert plains of Colorado and New Mexico. The river is popular with anglers.

The Costilla Creek basin in Colorado and New Mexico is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Annual precipitation will likely decrease more than 5%. Decreased precipitation will be exacerbated by increased evapotranspiration. Stream runoff is expected to fall by more than 10% by mid-century.

The Costilla Creek Compact[151] equitably divides and apportions the waters of Costilla Creek between Colorado and New Mexico. Specifically, the Compact aims to facilitate the most efficient use of Costilla Creek's waters by promoting the integration of existing and prospective irrigation facilities on the waterway in the two States.[152]

The Compact apportions the natural flow of Costilla Creek and allocates water from the Costilla and Eastdale Reservoirs. Such apportionment is based on specific flow rate allotments, percentage threshold entitlements to water stored in the Costilla and Eastdale Reservoirs, allowances necessary to afford certain areas "sufficient water for beneficial use on meadow and pasture lands,"[153] and set flow rates for specified quantities of irrigatable land. The Compact also apportions water to Colorado during irrigation season according to a direct flow delivery schedule, and it creates a safe yield schedule that can be used to determine the equitable division of water between the states when the usable capacity of the Costilla Reservoir changes.

The Compact established the Costilla Creek Compact Commission. The Commission is charged with the creation and maintenance of stream-gauging stations at specified points along Costilla Creek. With the collaboration of the U.S. Geological Survey, the Commission collects and publishes the data collected from these stations, specifically analyzing the impacts such data have on the administration of the Compact. The Compact does not place any limitations on interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Costilla Creek watershed faces **severe** climate change risks. As is typical for the region, the watershed

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151. Costilla Creek Compact (Amended), Pub. L. No. 88-198, 77 Stat. 350 (1963).
152. Costilla Creek Compact, art. I.
153. Costilla Creek Compact, art. IV.

is very dry, groundwater has been depleted, and agricultural water demand has exceeded the limited supply. Often the Costilla Creek does not even reach its natural outlet in the Rio Grande. Climate change is expected to further stress and destabilize water resources. The Costilla Creek Compact is **inadequate** to address these risks. It lacks any provisions for water conservation, ecosystem protection, restricting transbasin diversions, or otherwise managing water demand. Most importantly, it is totally inadequate for adaptively managing or allocating water rights under the expected stress from climate change.

12. Delaware River Basin Compact (Delaware, New Jersey, New York, and Pennsylvania)

The Delaware River headwaters are located in upstate New York, and the river empties into the Delaware Bay. In between, it drains 13,539 square miles of land, including parts of Pennsylvania, New Jersey, New York, and Delaware. Approximately 5% of the United States' population (almost fifteen million people) relies on the river for domestic and industrial use. This figure includes about seven million people who live in New York City and its suburbs, since although it is outside the basin, the city gets half its water from the river.[154]

Other major cities in the watershed include Philadelphia, Allentown, and Reading, Pennsylvania, as well as Salem, Trenton, and Camden, New Jersey. Future population growth is expected to be slow in Pennsylvania[155] and New Jersey.[156] The watershed is particularly important for commerce (Delaware contains the largest freshwater port in the world), and for heavy industry. However, the economic outlook in the region is mixed: growth is expected in the service industry, and losses are expected in the manufacturing industry.

The Delaware River basin in Delaware, New Jersey, New York, and Pennsylvania is expected to become warmer and more humid during the next century. The average annual temperature is predicted to increase approximately 3°F. Annual precipitation may increase between 5% and 10%, with most of the increase

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154. Delaware River Basin Commission, The Delaware River Basin, http://www.state.nj.us/drbc/thedrb.htm (last visited Nov. 12, 2010).

155. PA. ST. DATA CTR., PA. ST. HARRISBURG, CENSUS BUREAU RELEASES STATE POPULATION GROWTH PROJECTIONS: PENNSYLVANIA TO CONTINUE SLOW GROWTH (2005), http://pasdc.hbg.psu.edu/pasdc/data_and_information/briefs/RB042105_jenn1.pdf (last visited Nov. 12, 2010).

156. Workforce New Jersey Public Information Network, Projections 2014, http://www.wnjpin.net/OneStopCareerCenter/LaborMarketInformation/lmi03/Projection%202014%20WEB.pdf.

coming during winter months. Increased evapotranspiration will lead to higher humidity. Stream runoff is expected to increase modestly, perhaps between 2% and 5%.

The Delaware River Basin Compact[157] is an agreement between Delaware, Pennsylvania, New Jersey, New York, and the federal government to create a regional agency, the Delaware River Basin Commission, to manage the water resources of the Delaware River Basin. Each party appoints a representative to the Commission, and the Commission is authorized to act only upon the unanimous consent of the five representatives.

The Compact affords the Commission exclusive administrative authority over the Delaware River Basin. Specifically, the Commission is responsible for formulating a comprehensive water management plan for the basin and a water resources program which tracks the quantity and quality of water resources needs in the basin.[158] The Commission also has limited authority to allocate the waters of the basin among the signatory States and to impose conditions and obligations on the use of such waters. Along with its water management authority, the Commission may conduct and sponsor research on water resources and management, as well as collect, analyze, and report on data related to water use, quality, and protection within the basin.[159] The Compact also vests the Commission with the power to develop and administer water plans and projects within the basin.

The Compact creates a rigorous water conservation and ecosystem protection regime. For example, the Compact prohibits water development projects that substantially affect the water resources in the basin unless the Commission finds that a proposed project would "not substantially impair or conflict with the comprehensive plan."[160] Moreover, the Compact allows the Commission to develop water projects to protect "public health, stream quality control, economic development, improvement of fisheries, recreation, dilution and abatement of pollution, [and] the prevention of undue salinity."[161] The Commission can also sponsor any soil conservation, forestry, or fish and wildlife project that is related to the water resources of the basin.[162] Indeed, through the Compact, each of the signatory States agrees to enact legislation necessary to protect the utility and quality of

157. Delaware River Basin Compact, Pub. L. No. 87-328, 75 Stat. 688 (1961).
158. Delaware River Basin Compact, art. III.
159. Delaware River Basin Compact, art. III, cl. 3.6.
160. Delaware River Basin Compact, art. III, cl. 3.8.
161. Delaware River Basin Compact, art. IV, cl. 4.2(a).
162. Delaware River Basin Compact, art. VII.

the Basin's water and ecosystem. And the Compact vests the Commission with the authority initiate legal action against any entity in violation of the Compact's provisions.[163]

The Commission can also control and regulate withdrawals and diversions from the basin's surface and ground waters.[164] Specifically, the Commission can issue withdrawal permits to prescribe the amount of water that can be withdrawn in the basin's protected areas. Interbasin diversions are allowed when authorized by the Commission.

Overall, the Delaware River Basin faces only **modest** climate change risks. While fifteen million people (including the urban populations of New York and Philadelphia) rely on the river for domestic and industrial water use, climate change is not expected to decrease water supplies. Rather, precipitation may actually increase, with resulting increases in runoff and streamflow. While this may raise water quality and flooding concerns, lack of water supply is not expected to be a significant problem. The Delaware River Basin Compact is **adequate**, and in many ways a model compact for adapting to the risks and uncertainties of climate change. It provides comprehensive planning and enforcement, rigorous water conservation, and an ecosystem protection regime. Most importantly, the Delaware River Basin Commission has the legal authority and resources to address new circumstances and stresses without severely disrupting water uses and rights. The combination of relative water abundance and adaptive interstate water management make the Delaware River Basin well suited for the future.

13. Great Lakes-St. Lawrence River Basin Water Resources Compact (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin)

The Great Lakes are the largest surface freshwater system on the Earth. They contain almost 90% of North America's surface fresh water and over 20% of the world's supply. Their watershed drains almost 200,000 square miles. The United States' portion of the Great Lakes shoreline is over 4,500 miles long, longer than the United States' East and Gulf coasts combined. The total Great Lakes shoreline is over 10,000 miles long, including 35,000 islands. The Great Lakes-St. Lawrence watershed contains the cities of Chicago, Detroit, Milwaukee, Toronto, Buffalo, and Cleveland.

163. Delaware River Basin Compact, art. V, cl. 5.4.
164. Delaware River Basin Compact, art. X

Nearly 25% of Canadian agricultural production and 7% of American farm production are located in the basin. More than thirty million people live in the Great Lakes basin - roughly 10% of the U.S. population and more than 20% of the Canadian population. Over twenty-five million people in the U.S. rely on the Lakes for their drinking water. The watershed contains 20% of all U.S. timberland and 20% of all U.S. manufacturing (58% of cars made in the U.S. and Canada are made in the basin). The Lakes support a one billion-plus dollar recreational fishing industry.

The Great Lakes-St. Lawrence basin in is expected to become warmer and more humid during the next century. The average annual temperature is predicted to increase more than 3°F. Annual precipitation may increase between 5% and 10%, with most of the increase coming during winter months. Increased evapotranspiration will lead to higher humidity. Stream runoff is not expected to change significantly in the basin by mid-century.[165]

The Great Lakes-St. Lawrence River Basin Water Resources Compact[166] provides a comprehensive water management regime for the eight Great Lakes states: Illinois, Indiana, Michigan, Minnesota, Ohio, New York, Pennsylvania, and Wisconsin. The provinces of Ontario and Quebec are parties to a companion non-binding agreement.

Under the Compact, withdrawals of Great Lakes water are managed pursuant to a "decision making standard"[167] administered primarily under the authority of individual states. The decision making standard requires water conservation, return flow within the watershed, prevention of significant environmental impacts, and compliance with riparian reasonable use principles.[168] While the decision making standard only applies to new or increased water withdrawals, its hydrologic scope is broad. The Great Lakes Compact specifically defines the waters of the Great Lakes to include all tributary surface and ground waters.[169] Further, the Compact makes clear that the decision making standard is only a minimum standard, and states may impose more restrictive standards for water

165. For a more thorough discussion of climate change impacts on Great Lakes water resources, *see* Noah D. Hall and Bret B. Stuntz, *Climate Change and Great Lakes Waters Resources: Avoiding Future Conflicts with Conservation*, 31 HAMLINE L. REV. 641 (2008).
166. Great Lakes-St. Lawrence River Basin Water Resources Compact, Pub. L. No. 110-342, 122 Stat. 3739 (2008).
167. Great Lakes Compact § 4.11.
168. Great Lakes Compact § 4.11.
169. Great Lakes Compact § 1.2 (defining "Waters of the Basin" or "Basin Water").

withdrawals under their authority,[170] an approach term "cooperative horizontal federalism."[171]

The Compact creates two separate approaches to managing new or increased water withdrawals in the Great Lakes basin. The differentiation is based almost entirely on whether the water is used inside or outside of the Great Lakes basin surface watershed boundary. Water use inside of the Great Lakes basin is managed solely by the individual states, with limited advisory input from other states for very large consumptive uses.[172] Water withdrawals diverted and used outside of the basin are subject to a spectrum of collective rules and approval processes, including a general prohibition on most interbasin diversions.[173]

The Compact establishes a Council comprised of the governors of each party state (or their designated alternates). One of the most significant functions of the Council is its sole authority to approve the limited exceptions to the general prohibition on interbasin diversions.[174] The Council can also promulgate and enforce rules to implement its duties under the Great Lakes Compact.[175] Further, the Council has broad authority to plan, conduct research, prepare reports on water use, conduct special investigations, and forecast water levels.[176]

Overall, the Great Lakes-St. Lawrence River Basin faces only **modest** climate change risks. With almost 90% of North America's surface fresh water, the Great Lakes watershed is by far the largest source of freshwater in the country. While climate change will negatively impact the Great Lakes (harming water quality, habitat, shorelines, and fisheries) and lower lake levels, the total available water supply will not be drastically reduced. The region's population and water usage are not increasingly significantly (in some locations and sectors they are actually decreasing), and freshwater is relatively abundant. The recently enacted Great Lakes-St. Lawrence River Basin Water Resources Compact is **adequate** – it is the most modern interstate water compact and was developed with a recognition of the risks of climate change. It does not allocate water quantity; instead it ensures sustainable water use by requiring states to comprehensively regulate water use to meet water conservation,

170. Great Lakes Compact § 4.12(1).
171. *See generally* Noah D. Hall, *Toward a New Horizontal Federalism: Interstate Water Management in the Great Lakes Region*, 77 U. COLO. L. REV. 405 (2006).
172. Great Lakes Compact § 4.3 and § 4.6.
173. Great Lakes Compact § 4.8 and § 4.9.
174. Great Lakes Compact § 4.7 and § 4.9.
175. Great Lakes Compact §§ 2.1–2.3, 3.3(1).
176. Great Lakes Compact § 3.2.

ecosystem protection, and other standards. It prohibits most transbasin diversions and establishes a regional governance council with adaptive management capabilities. The relative abundance of freshwater in the Great Lakes region combined with the legal certainty of the new Great Lakes-St. Lawrence River Basin Water Resources Compact make it the least risky region for water users in the country.

14. Kansas-Nebraska Big Blue River Compact (Kansas and Nebraska)

The Big Blue River flows for 250 miles from central Nebraska into Kansas, and it is the largest tributary of the Kansas River. Its watershed includes approximately 9,960 square miles of land, most of which is used for agriculture.[177] A lake on the Big Blue supplies water for Topeka, Lawrence, and Kansas City, Kansas.

Land use in the Nebraska portion of the watershed is approximately 77% agricultural, nearly half of which consists of irrigated crops to which herbicides are applied. Cropland is the dominant land use downstream in Kansas, but only 3% of the agricultural land in that area is irrigated. The flow of chemicals downstream from Nebraska into Kansas has caused controversy between the states and continues to fuel concerns about the safety of the water used for domestic and municipal purposes in Kansas.[178] Slow but steady economic and population growth is expected in the region.

The Big Blue River basin in Kansas and Nebraska is expected to warm significantly during the next century, perhaps more than 3°F. Precipitation is expected to decrease slightly—between 5% and 10%—during the summers, and winter precipitation will rise by about the same amount. Evapotranspiration may increase modestly. Stream runoff not expected to change significantly by mid-century.

Kansas and Nebraska developed the Big Blue River Compact[179] to equitably apportion the waters of the Big Blue River Basin, promote the development of these waters, and continue programs in both States aimed at reducing man-made

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177. Unversity of Nebraska Lincoln, Conservation Buffers: Big Blue River Basin, http://web.archive.org/web/20080501160228/http://conservationbuffers.unl.edu/blueriverbackground.htm (last visited Nov. 12, 2010).

178. T.G. Franti et al., *Improving Water Quality in the Big Blue River Basin, Nebraska and Kansas: An Extension and Case Research Study*, http://agecon.okstate.edu/isct/labranza/franti/sinaloa.doc (last visited Nov. 12, 2010).

179. Kansas-Nebraska Big Blue River Compact, Pub. L. No. 92-308, 86 Stat. 193 (1972).

and natural pollution of the basin's waters.[180] The Compact establishes the Kansas-Nebraska Big Blue River Compact Administration to administer the Compact.[181]

Specifically, the Compact vests the Administration with the authority to compel compliance with the Compact through legal action.[182] Moreover, the Administration is responsible for the development of any data collection facilities necessary for the administration of the Compact. State agencies are also required, upon the Administration's request, to assist in data collection. In addition, "any local, public, or private agency collecting water data or planning, designing, constructing, operating, or maintaining any water project or facility in the Big Blue River Basin shall keep the Administration advised of its investigations."[183]

Under the Compact, water from the Big Blue River Basin is apportioned differently in each state. In Nebraska, the government must cancel any apportions of record that were inactive on November 1, 1968.[184] Nebraska must also regulate diversions within the state between May 1 and September 30 of each year so that minimum daily flows at state-line gauging stations are maintained.[185] Kansas, on the other hand, has free and unrestricted use of the waters of the Big Blue River Basin that flow into the state from Nebraska.[186] Importantly, the Compact encourages both states to divert water into the Big Blue River Basin by affording the importing state the exclusive right to use the imported water.[187] Conversely, diversions out of the basin (or interbasin diversions) are prohibited without the consent of the Administration.

Through the Compact, agencies of both states cooperate to investigate, abate, and control sources of alleged interstate pollution within the Big Blue River Basin.[188] The states also agree to collaborate to ensure that the basin's water satisfies appropriate water quality standards. However, the Compact does not promote water conservation as end in itself, nor does the Compact endorse measures aimed at ecosystem protection.

Overall, the Kansas-Nebraska Big Blue River watershed faces **substantial** climate change risks. The area is very dry and

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180. Kansas-Nebraska Big Blue River Compact, Art. I.
181. Kansas-Nebraska Big Blue River Compact, Art. III.
182. Kansas-Nebraska Big Blue River Compact, Art. III, cl. 3.4.
183. Kansas-Nebraska Big Blue River Compact, Art. III, cl. 3.4.
184. Kansas-Nebraska Big Blue River Compact, Art. V, cl. 5.2(a).
185. Kansas-Nebraska Big Blue River Compact, Art. V, cl. 5.2(b).
186. Kansas-Nebraska Big Blue River Compact, Art. V, cl. 5.3.
187. Kansas-Nebraska Big Blue River Compact, Art. V, cl. 5.4.
188. Kansas-Nebraska Big Blue River Compact, Art. VI, cl. 6.2.

groundwater is rapidly being depleted. However, because population growth is not significant, water resources have been sufficient relative to demand. Climate change is expected to make the region warmer and drier, putting new stress on water resources. The Kansas-Nebraska Big Blue River Compact is **inadequate** to address these new climate change risks. It lacks any viable provisions for water conservation or ecosystem protection. Most importantly, the Kansas-Nebraska Big Blue River Compact does not provide for any adaptive management or allocation, which combined with the expected impacts of climate change in the region, creates considerable risk for water users.

15. Klamath River Basin Compact (California and Oregon)

The Klamath River is 250 miles long and flows through southern Oregon and northern California before emptying into the Pacific Ocean. It drains an area of 15,751 square miles, almost 1,000 of which are used for agriculture. The rest of the land is comprised of forests, and rangeland, with a small portion being devoted to urban, commercial, or residential sites. Long term population projections for this region predict a slow but steady expansion, with growth rates exceeding the national average. The driving forces of the economy in the coming years will largely depend on decisions regarding water use, as the region has struggled to maintain its agricultural activities in the face of droughts.

Agricultural activities comprise most of the water demand in the basin. Several hydroelectric power plants provide electricity to nearby communities. In addition, the river is used for whitewater rafting and kayaking, and is prime habitat for salmon and trout. The region has continued to face challenges in watershed management since 2001, when application of the Endangered Species Act prevented irrigation water from reaching 1,300 farms during a drought.

The Klamath River basin in is expected to become somewhat warmer and drier during the next century. The average annual temperature will increase less than most of the continental U.S., probably less than 3°F. Annual precipitation may increase slightly (less than 5%), but summer precipitation will decrease markedly. Increased evapotranspiration will lead to higher drier weather. Stream runoff is expected to fall approximately 5% by mid-century.

California and Oregon developed the Klamath River Basin Compact[189] to "facilitate and promote the orderly, integrated, and

189. Klamath River Basin Compact, Pub. L. No. 85-222, 71 Stat. 497 (1957).

comprehensive development, use, conservation, and control" of the waters of the Klamath River Basin.[190] According to the Compact, the waters of the Basin should be used for domestic needs, irrigation, ecosystem protection, recreation, industry, hydroelectric power production, navigation, and flood prevention.

To meet these ends, the Compact aims to equitably distribute the Basin's water among California, Oregon, and the federal government. Although any water originating in the Upper Klamath River Basin that was unappropriated when the Compact took effect could be acquired through appropriation by any individual residing in the two states, the Compact mandates that, in the case of conflicting appropriation applications, preference should be given to those applications that involve preferred water uses. The Compact delineates and codifies these preferences in a hierarchy of uses, and accords domestic use the highest priority. Irrigation is the next preferred use, and recreation takes precedence over industrial use and hydroelectric power generation.[191] In the case of appropriation applications for identical uses, the Compact grants preference to the party that acquired the vested water right earliest.

Importantly, the Compact proscribes all diversions of waters from the Upper Klamath River Basin in Oregon, except for out-of-basin diversions of waters that originate within the drainage area of Fourmile Lake. Furthermore, any unused water originally diverted from the Upper Basin for use in Oregon should be returned to the Klamath River or its tributaries. Similarly, the Compact prohibits transbasin diversions of water taken from the Upper Klamath River Basin for use in California, and California must not prevent return flows and waste water from these diversions from flowing back into the Klamath River. Ultimately, the Compact grants superiority to those water rights acquired after the effective date of the Compact that use such waters within the Upper Klamath River Basin, as long as this use does not exceed the amount of water necessary to irrigate 100,000 and 200,000 acres of land in California and Oregon respectively.

The Compact assigns administrative duties to the Klamath River Compact Commission. The Commission can direct each State to establish gauging stations at relevant points along streams, reservoirs, or conveyance facilities to determine, record, and publish the volume of diversions at particular points in the Basin.[192] The Commission is also charged with safeguarding the

190. Klamath River Basin Compact, art. I.
191. Klamath River Basin Compact, art. III.
192. Klamath River Basin Compact, art. V.

water quality of the Basin. Despite the Compact, there have been significant water disputes in the Klamath basin for over a decade, with continuing litigation and uncertainty for all affected interests.

Overall, the Klamath River Basin faces **substantial** climate change risks. However, conflicts over water use, especially in the upper basin, create significant risk for water users. There are numerous lawsuits and contentious disputes between upstream agricultural water users and the downstream fishing industry. The Klamath River Basin will be further stressed by climate change in the future, especially through loss of snowpack. The Klamath River Basin Compact is **inadequate** to address the current disputes and future stresses of climate change. While the Klamath River Basin Compact has some provisions for governance, data collection, and restricting transbasin diversions, its failure to provide proactive ecosystem protection has led to litigation and resulting water restrictions under the federal Endangered Species Act. Overall, there is currently considerable uncertainty for water users in the basin, and this will continue with climate change in the future.

16. La Plata River Basin Compact (Colorado and New Mexico)

The La Plata River is an upper branch of the Colorado River. It arises in Colorado and flows into New Mexico. Water supplies in the region are being stressed by changing demographics and climate. In southwestern Colorado, the population is expected to grow by 90% by 2035. Municipal water demand is expected to grow almost 70% by 2030. The region will need new water projects to serve agricultural and ranching needs if it hopes to avoid future shortages, but such projects may not be feasible. In addition, there is a growing recreational economy in southwest Colorado. The city of Durango recently applied for the region's first recreational water right.[193]

The La Plata River basin in Colorado and New Mexico is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Annual precipitation will likely decrease more than 5%, with losses coming during both the winter and summer. The decreased precipitation in an already dry environment will lead to somewhat decreased

193. Joe Hanel, *Southwest Colorado wrestles with New Mexico over water issues*, DURANGO HERALD, Jan. 2, 2008, http://archive.durangoherald.com/asp-bin/printable_article_generation.asp?article_path=/news/news080102_2.htm.

evapotranspiration. Stream runoff is expected to fall by more than 10% by mid-century.

The La Plata River Compact[194] apportions the river between Colorado and New Mexico. Between December 1 and February 15, each state has unrestricted use of water within its boundaries. The rest of the year, each state has unrestricted use of the water within its boundaries, provided that mean daily flow at the state line gauging station is 100 cubic feet per second or more. If not, Colorado must deliver to New Mexico one half of the preceding day's mean flow, not to exceed 100 cubic feet per second. During times of extremely low flow, the states may agree to use water during alternating periods.

Under the Compact, Colorado is responsible for collecting the stream flow data necessary for the Compact's administration. As such, Colorado is required to establish and maintain two stream-gauging stations on the La Plata River.[195] State engineers from both states are required to cooperate to exchange, record, and publish data collected at the two stations. Importantly, these engineers are authorized to respond appropriately to the data by formulating rules and regulations necessary to carry out the provisions of the Compact.[196]

The Compact ensures that the water allocation between the States is flexible enough to respond to fluctuating water flows: regardless of the La Plata's flow, there is a mechanism to allocate the water. Indeed, allocation can be adjusted on a daily basis, and the Compact itself can be modified by mutual consent of the signatory states. At the same time, this codified flexibility is restrained in practice by the Compact's vague data collection provisions. The Compact does not place any limitations on interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the La Plata River watershed faces **severe** climate change risks. The area is very dry and precipitation is highly variable. Climate change is expected to make the region warmer and drier, and reduced snowpack will further stress water resources. The La Plata River Compact is **inadequate** to address these risks. It lacks any viable provisions for water conservation, ecosystem protection, or restricting transbasin water diversions. The La Plata River Compact does ensure that the water allocation between the party states is flexible enough to respond to fluctuating water flows with a mechanism to reallocate available water. Still, given the severe climate change

194. La Plata River Compact, Pub. L. No. 68-346, 43 Stat. 796 (1925).
195. La Plata River Compact, art. I.
196. La Plata River Compact, art. III.

risks facing the La Plata River watershed, the La Plata River Compact is not adequate.

17. Pecos River Compact (New Mexico and Texas)

The Pecos River arises near Santa Fe, New Mexico, and flows through Texas, emptying into the Rio Grande. It drains about 38,300 square miles of land, and dams on the river irrigate about 25,000 acres. Due to the large size of the Pecos basin, water use in the basin has a significant impact on water availability in the Rio Grande basin.[197]

The principal cities in the watershed are Las Vegas, Santa Rosa, Fort Sumner, Roswell, Artesia, and Carlsbad. The river is crucial to these and other communities for domestic use, irrigation, recreation, and wildlife habitat, and to recharge underlying aquifers. Major land uses are rangeland, pastureland, and irrigated crops. In the lower river valley, oil and gas development is present. The counties in the watershed have experienced positive population growth, with only one county showing a decline from 1990 to 2000.[198] The New Mexico's economy is expected to grow in the coming years, with many new jobs in the oil and gas development sector as well as in healthcare, mining, and– in contrast to much of the United States – manufacturing.[199]

The Pecos River basin in Colorado and Texas is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase more than 3°F. Annual precipitation will likely decrease between 5% and 10%, with the heaviest losses coming during winter. The decreased precipitation in an already dry environment will lead to somewhat decreased evapotranspiration. Stream runoff is expected to fall between 5% and 10% by mid-century.

The Pecos River Compact[200] created the Pecos River Commission to administer provisions for the storage, equitable division, and use of the Pecos River and its tributaries in New Mexico and Texas.[201] Pursuant to the Compact, New Mexico may

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197. Texas Water Resources Institute, Pecos River WPP Implementation Plan, http://pecosbasin.tamu.edu/ (last visited Nov. 12, 2010).

198. N.M. DEP'T OF GAME AND FISH, COMPREHENSIVE WILDLIFE CONSERVATION PLAN FOR NEW MEXICO ch. 5 (2006), http://www.wildlife.state.nm.us/conservation/comp_wildlife_cons_strategy/documents/ch5_pecos.pdf.

199. Kathleen Young, *Economics on the stormfront – New Mexico Economic Forecast*, 15 N.M. BUS. J. 66 (1991), *available at* http://findarticles.com/p/articles/mi_m5092/is_n1_v15/ai_9867213/.

200. Pecos River Compact, Pub. L. No. 81-91, 63 Stat. 159 (1949).

201. Pecos River Compact, art. I.

not deplete the flow of the Pecos River at the New Mexico-Texas line below a specified amount. Moreover, the Compact affords Texas exclusive rights to the beneficial use of water from the river. The Compact assigns each state either the exclusive right or a predefined allotment to the beneficial consumptive use of water salvaged through federal- and state-initiated water projects depending on where the projects are administered.[202]

The Compact vests the Commission with significant administrative authority. The Commission, consisting of one member from each state and one (non-voting) member appointed by the President of the United States, has the power to adopt rules and regulations, collect water data related to water flow, use, storage, diversions, and salvage, engage in water supply studies, make findings on water usage and the impacts human activity has on the river, and issue reports.[203]

Importantly, the Compact requires the states to cooperate to reduce salinity in the river and to support legislation that authorizes projects to eliminate non-beneficial consumption of water. The Compact also encourages the states to import water from outside of the basin by granting the importing state exclusive use of imported water. At the same time, the Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Pecos River watershed faces **severe** climate change risks. The area is very dry and precipitation is highly variable. Climate change is expected to make the region warmer and drier, and reduced snowpack will further stress water resources. Groundwater is already severely depleted and total water demand exceeds supply in some areas. The Pecos River Compact is **inadequate** to address these challenges. It lacks any viable provisions for water conservation, ecosystem protection, or restricting transbasin water diversions. Most importantly, the assignment of water rights is inflexible and not suited to potentially changing conditions. Water users in the Pecos River Basin will face considerable risk and uncertainty in the future.

18. Red River Compact (Arkansas, Louisiana, Oklahoma, and Texas)

The Red River Basin covers about 94,599 square miles and spans several southern states. The river flows for 1,360 miles from eastern New Mexico, across the Texas Panhandle, down the

202. Pecos River Compact, art. III.
203. Pecos River Compact, art. VI.

Texas-Oklahoma border, through southwestern Arkansas, and into Louisiana, where it joins the Atchafalaya River. About half of the basin area is in the state of Texas. Amarillo and Wichita Falls are both within the basin. The watershed includes farmland, prairies, rolling plains, wooded areas, and rugged canyons. The major industries are oil and gas production, agriculture, ranching, manufacturing, and tourism. Four reservoirs provide water for farms, oil and gas drilling facilities, and municipal and domestic use.

The greatest limitation to water use in the basin is salinity, as the upper part of the basin contains naturally occurring salt springs, and salt concentrations in parts of the river can sometimes exceed that of ocean water.[204] Parts of the watershed have been identified as prime sites for new wind-power plants because of the region's strong winds. However, growth in the region varies; the population of Oklahoma is expected to be slower than the national average,[205] while the panhandle region of Texas is expected to grow (though growth is not expected to significantly alter water use).[206]

The Red River has a large basin, and the effects on physical conditions as a result of climate change will vary regionally. Overall, temperatures are expected to increase between 3°F and 4°F, with the warmest temperatures being felt in the western portion of the basin. Precipitation will also increase throughout the basin, with smaller percentage gains in the already wet southeast (0% to 5%) than in the western portion of the basin (5% to 10%). However, increased evapotranspiration in the southeastern region is expected to reduce the impact of precipitation increases, and stream runoff is not expected to change significantly. In the western portion of the basin, however, stream runoff is expected to decrease between 5% and 10% by mid-century.

The Red River Compact[207] apportions the waters of the Red River and its tributaries among Arkansas, Louisiana, Oklahoma, and Texas. The Compact apportions the water by dividing the Red River into five "reaches." Each reach is further

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204. STANLEY BALDYS & D. GRANT PHILLIPS, U.S. GEOLOGICAL SURVEY, STREAM MONITORING AND EDUCATIONAL PROGRAM IN THE RED RIVER BASIN, TEXAS, 1996-1997 (1997), http://pubs.usgs.gov/fs/fs-170-97/pdf/FS-170-97.pdf.

205. Okla. Dep't of Commerce, Census Highlights 2006, http://staging.okcommerce.gov/test1/dmdocuments/Census_Highlights_2006_0202072099.pdf.

206. Panhandle Water Planning Group, 2011 Executive Summary (2011), http://Pwww.panhandlewater.org/2011_draft_plan/Main_Report/Executive%20Summary.pdf.

207. Red River Compact, Pub. L. No. 96-564, 94 Stat. 3305 (1980).

divided into its component streams, and each subdivision is allocated water by percentage or specific amount. The Compact creates the Red River Compact Commission to administer the Compact.[208] The Commission is charged with adopting rules and regulations necessary to carry out the Compact's provisions, establishing and operating gauging stations, and collecting and analyzing data from these stations related to stream flows, water quality, and water storage on the Red River. The Commission is also responsible for reporting such data to the governors of the signatory states and the federal government.

The Compact aims to promote an active program of pollution abatement and to establish a water management program aimed at mitigating floods, improving water quality, and developing navigation on the river.[209] The Compact also encourages the states to import water from outside of the basin by granting the importing state exclusive use of imported water. Aside from these protections, the Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Red River watershed faces **substantial** climate change risks. The area is very dry and precipitation is highly variable. Climate change is expected to warm the region, with resulting increased evapotranspiration rates. Groundwater is already stressed, although future population growth is not a major concern. The Red River Compact is **somewhat adequate** to address these challenges. The Red River Compact Commission has some adaptive management resources, especially in the areas of data collection and protecting water quality. The Red River Compact allows for an active water management program aimed at mitigating floods, improving water quality, and developing navigation on the river. Water users in the Red River Basin will face modest risk in the future.

19. Republican River Compact (Colorado, Kansas, and Nebraska)

The Republican River originates in eastern Colorado and flows eastward along the southern border of Nebraska and into Kansas, where it merges with the Smoky Hill River to form the Kansas River. The watershed encompasses 24,000 square miles, and the apportionment of water between the three states has been hotly contested. Though even the bigger cities in the region tend to have fewer than 10,000 inhabitants, population

208. Red River Compact, art. X.
209. Red River Compact, art. I.

projections forecast growth in the region, with a loss in rural areas and increased density in urban centers.[210]

Agriculture is a significant driver in this region, with large percentages of land devoted to crops, livestock and dairy production, and there have been conflicts regarding water pumping and agricultural irrigation.[211] Nebraska in particular has a growing population and has exceeded its allotment of river water in recent years, sparking discontent from the downstream state of Kansas.[212] Other water uses include domestic (most of which comes from groundwater), and industries such as oil, natural gas, coal, and building stone. Water-based recreation is also important to the economy in the basin.

The Republican River basin in Colorado, Kansas, and Nebraska is expected to become warmer and drier during the next century. The average annual temperature is predicted to increase more than 3°F. Annual precipitation may increase a little (between 0% and 5%), but modest winter gains are expected to be offset by sharper summer losses. Substantially increased evapotranspiration may also offset any precipitation increases. Stream runoff is expected to fall between 5% and 10% by mid-century.

The Republican River Compact[213] apportions the waters of the Republican River and its tributaries between Colorado, Kansas, and Nebraska.[214] The Compact computes the average virgin water supply in the tributaries and main stream of the Republican River and allocates the River's waters among the States according to this average. If the future computed virgin flow varies more than 10% from the average, allocations will be adjusted relative to the proportion that the new annual virgin flow diverges from the computed average. Of the calculated average flow, Colorado receives 54,100 acre-feet, Kansas receives 190,300 acre-feet, and Nebraska receives 234,500 acre-feet per year.

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210. KANSAS WATER OFFICE, KANSAS-LOWER REPUBLICAN BASIN (2007), http://www.kwo.org/KWA/Mailing_Materials/JAN_2008/rpt_KLR_BasinDescription_publisher_12_20_07_mb.pdf.

211. COLO. DIV. OF WATER RES., REPUBLICAN RIVER COMPACT ADMINISTRATION GROUND WATER MODEL (2003), http://web.archive.org/web/20070710040212/http://www.water.state.co.us/wateradmin/republicanriver/rrca_model.pdf.

212. Nate Jenkins, *Lawmakers back water money, but dispute with Kansas not resolved*, LINCOLN J. STAR, Mar. 12, 2008, *available at* http://journalstar.com/news/local/govt-and-politics/article_d486bbd1-71aa-5898-a8da-1f74d3d320f8.html.

213. Republican River Compact, Pub. L. No. 78-60, 57 Stat. 86 (1943).

214. Republican River Compact, art. I.

The Compact assigns administrative and data collection responsibilities to the officials in each state charged with administering the public water supply.[215] These officials may, through unanimous vote, adopt rules and regulations to carry out the Compact's provisions. Pursuant to a 2003 settlement, the states adopted a groundwater model that will be used to quantify groundwater consumptive use by each state as part of the Compact's accounting procedures. While the Compact does not include any explicit water conservation or ecosystem measures, after the 2003 settlement the states and federal government developed a plan for a five-year study of conservation practices on the basin's water supply. At the same time, the Compact does not place any limitations on interbasin diversions.

Overall, the Republican River watershed faces **substantial** climate change risks. The area is very dry and precipitation is highly variable. Groundwater is already stressed, and growth in population and agricultural irrigation have already severely stressed water resource supplies relative to the growing demand. The Republican River Compact, while strong in several ways, is only **somewhat adequate** to address these current and future water supply challenges in the watershed. The Republican River Compact has been strengthened with improved groundwater management and has provisions for revising allocations if flows change significantly. However, with the current disputes and demand already exceeding supply in some areas, the compact does not offer enough proactive management to avoid future conflicts and uncertainties.

20. Rio Grande Compact (Colorado, New Mexico, and Texas)

The Rio Grande flows across New Mexico after originating in the mountains of southern Colorado. Its watershed encompasses a vast array of climates, from tundra to desert. The river continues through Texas and forms the border between the United States and Mexico. It drains 182,200 square miles of land[216] and includes major urban centers such as Albuquerque, Santa Fe, and El Paso. There are some ten million people living in the watershed, with seven million in New Mexico alone.

Water flow is affected by snowmelt and summer rains, but irrigation diversions and agricultural reservoirs have altered flow patterns in recent years. There is an extensive system of

215. Republican River Compact, art. IX.

216. U.S. GEOLOGICAL SURVEY, FACT SHEET: MONITORING THE WATER QUALITY OF THE NATION'S LARGE RIVERS, RIO GRANDE NASQAN PROGRAM (1998), *available at* http://web.archive.org/web/20080514110144/http://water.usgs.gov/nasqan/progdocs/factsheets/riogfact/engl.html.

reservoirs which control flow for agricultural, domestic, and industrial purposes. Much of the land within the watershed is under federal ownership and is used for livestock grazing, irrigation, and conservation. Agriculture, including cropland and orchards, is dense in several valleys.

The Rio Grande watershed is home to 63% of the population in New Mexico, and that population is rapidly expanding. The population increased by 19% within the watershed between 1990 and 2000.[217] The New Mexico economy is expected to grow in the coming years, with many new jobs in the oil and gas development sector as well as in healthcare, mining, and even – in contrast to much of the country – manufacturing.[218]

The Rio Grande basin in Colorado, New Mexico, and Texas is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Annual precipitation will likely decrease between 5% and 10%, with the sharpest declines coming during winter. Evapotranspiration may decrease due to reduced precipitation, except in the northern tip of the basin. Stream runoff is expected to fall between 5% and 10% by mid-century.

The Rio Grande Compact[219] apportions the waters of the Rio Grande River Basin between Colorado, New Mexico, and Texas. Under the compact, Colorado agrees to deliver a specified amount of water to the Colorado-New Mexico state line. The amount is calculated annually, starting at 10,000 acre-feet and modified based on water runoff measured at four stations in the Rio Grande headwaters. Similarly, New Mexico is required to deliver a certain amount of water in the Rio Grande at San Marcial. Under certain circumstances, a system of debits and credits permits water storage in two reservoirs.[220]

The Compact creates a Commission to administer the Compact. In keeping with this responsibility, the Commission must develop and operate gauging stations at various points along the river to record the flow of the river and its

217. N.M. DEP'T OF GAME AND FISH, COMPREHENSIVE WILDLIFE CONSERVATION PLAN FOR NEW MEXICO ch. 5 (2006), http://www.wildlife.state.nm.us/conservation/comp_wildlife_cons_strategy/documents/ch5_pecos.pdf.

218. Kathleen Young, *Economics on the stormfront – New Mexico Economic Forecast*, 15 N.M. BUS. J. 66 (1991), *available at* http://findarticles.com/p/articles/mi_m5092/is_n1_v15/ai_9867213/.

219. Rio Grande Compact, Pub. L. No. 76-96, 53 Stat. 785 (1939).

220. Rio Grande Compact, art. VI.

tributaries.[221] The Commission is also authorized to prepare and maintain a comprehensive plan for the river, monitor land use activities affecting water quality, engage in water banking, and rulemaking. The Commission may also, by unanimous action, authorize the release from storage of any amount of water by reason of accrued debts of Colorado or New Mexico.

While the Compact requires the states to monitor the river's salinity level, the Compact does not contain any provisions related to ecosystem protection or water conservation. The Compact allows transbasin diversions, and it encourages interbasin diversions into the Rio Grande River by awarding importing states credit for the imported water.[222]

Overall, the Rio Grande watershed faces **severe** climate change risks. The area is very dry, groundwater has been severely depleted, and agriculture and population growth have driven water demand to exceed the limited supply. The region's population, especially in New Mexico, is predicted to continue rapidly growing, despite the lack of available water supplies. Climate change is expected to further stress and destabilize water resources as increased temperatures and reduced snowpack lead to decreased and disrupted flows. The Rio Grande Compact is **inadequate** to address these risks. It lacks any provisions for water conservation, ecosystem protection, restricting transbasin diversions, or otherwise managing water demand. Unlike the Colorado River Compact, it does provide for adjusted allocations based on actual flow levels. But overall, the Rio Grande Compact does not do enough to manage the severe climate change risks expected in the watershed.

21. Sabine River Compact (Louisiana and Texas)

The Sabine River Basin covers a large portion of east Texas, and has a population of approximately 650,000. The basin drains 9,756 square miles.[223] The Sabine River flows through prairies and pine forests and continues through the wetlands and bayous of Louisiana. The largest city on the river, Longview, Texas, has a population of about 76,000. Unlike most rivers in Texas, the river lies in an area where rainfall is abundant, and it discharges the largest amount of water of any river in the state. Flooding is frequent, with major events occurring every five years.

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221. Rio Grande Compact, art. II.
222. Rio Grande Compact, art. X.
223. Sabine River Auth. of Tex., Economic Deveopment, http://www.sratx.org/services/ecodev/default.asp (last visited Nov. 12, 2010).

Much of the basin is rural in nature, but the watershed has a diversified economy based on mineral production, agriculture, manufacturing, recreation, and tourism. It also has a distribution and shipping center to direct the many products produced in the basin to their final destinations.

Pollution is a particular problem in the region.[224] Runoff from fertilizers and pesticides, discharges from oil refineries, salt water backup due to deepened canals, and treated wastewater effluent all contribute to the polluted state of the Sabine. Population in the area is projected to gravitate toward urban centers in the future.[225]

The average temperature in the Sabine River basin is expected to rise more than 3°F during the next century. Annual precipitation is expected to decrease modestly (less than 5%), with most of the reduction coming during summer months. Stream runoff is expected to decrease somewhat, perhaps 5%, by mid-century.

The Sabine River Compact[226] establishes the Sabine River Compact Commission to apportion the waters of the Sabine River and to manage and conserve the water resources of the Sabine River Basin in Louisiana and Texas.[227] The Compact affords Texas free and unrestricted use of all waters of the Sabine River and its tributaries above the state line between Louisiana and Texas, provided it ensures thirty-six cubic feet per second minimum flow at the state line.[228] The Compact also governs the construction and operation of reservoirs with the Basin.

The Compact creates the Sabine River Compact Administration to administer the Compact.[229] The Administration is charged with: monitoring compliance with the allocation formula; collecting, analyzing, and compiling data related to water supply, stream flows, storage, diversions, salvage, and use of the Sabine River's waters and tributaries; preparing and maintaining a comprehensive river plan for interrelated activities; undertaking project construction and financing; approving interstate and interbasin transfers;

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224. TEX. COMM'N ON ENVTL. QUALITY, SABINE RIVER NARRATIVE SUMMARY, http://www.tceq.state.tx.us/assets/public/compliance/monops/water/02twqmar/basin5.pdf.

225. TEX. STATE DATA CTR., POPULATION PROJECTIONS (2006), *available at* http://web.archive.org/web/20080618190602/http://txsdc.utsa.edu/tpepp/2006projections/summary/.

226. Sabine River Compact, Pub. L. No. 83-578, 68 Stat. 690 (1954), as amended, Pub. L. No. 87-418, 76 Stat. 34 (1962).

227. Sabine River Compact, preamble.

228. Sabine River Compact, art. IV, V.

229. Sabine River Compact, art. VII.

engaging in rulemaking; and mediating disputes under the Compact.

The Compact does not contain any provisions relating to transbasin diversions or ecosystem protection. Nor does the Compact encourage water conservation, except insofar as Texas must maintain the minimum flow at the state line.

Overall, the Sabine River watershed faces **substantial** climate change risks. The area is relatively humid, and water resources are sufficient relative to demand. While water quality and pollution are major concerns, the total water supply is not stressed. The Sabine River Compact is **somewhat adequate** to address future climate change risks. The Sabine River Compact Administration has some authority and resources for water planning, data collection, and other adaptive management tools. While the Sabine River Compact lacks any provisions for water conservation, ecosystem protection, or restricting transbasin diversions, it does offer enough governance resources to minimize some of the climate change risks expected in the watershed.

22. Snake River Compact (Idaho and Wyoming)

The Snake River arises in Yellowstone National Park and flows through mountain ranges, canyons, and plains in Wyoming, Idaho, Oregon, and Washington before joining the Columbia River. The underlying Snake River Aquifer is particularly productive. The watershed drains 108,000 square miles, including the cities of Idaho Falls, Twin Falls, and Lewiston, Idaho, Jackson Hole and Jackson, Wyoming, and Kenniwick, Richland, and Pasco, Washington.

The waterway is heavily used for commerce, as a portion of the river is navigable by seagoing vessels. Tourism is also important to the region, and the portion of the river designated as a National Wild and Scenic River designation is a popular destination for whitewater rafting. There are around twenty dams on the river, providing hydroelectric power, navigational capabilities, and irrigation. Agriculture and ranching remain steady forces in the area, and both rely heavily on water resources.

The Snake River basin in Idaho and Wyoming is expected to become much warmer during the next century, perhaps as much as 4°F. Although annual precipitation is predicted to change only modestly (perhaps a 5% increase), seasonal swings may be more erratic. Winter precipitation is expected to increase 10% to 15%, and summer precipitation is expected to decrease about the same amount. Increased evapotranspiration will result in higher humidity. Stream runoff is expected to fall by 2% to 5% by mid-century.

The Snake River Compact[230] apportions the waters of the Snake River between Idaho and Wyoming. The Compact aims to provide for the most efficient use and equitable division of the River.[231] According to the compact, Idaho is entitled to divert 96% of the Snake River's waters for direct use or storage, while Wyoming is allotted the remaining 4% as long as it provides a specific amount of water storage space to Idaho water users. The specific amount of water that is subject to this allocation schedule is determined on an annual basis by measuring the quantity of water in the Snake River that passed the Wyoming state line in the preceding year, the change in such flow from the previous year, the quantity of water stored during the previous year in Wyoming, and the amount of water each state diverted from the River in the previous year.[232]

Along with promulgating guidelines for the equitable apportionment of the waters of the Snake River, the Compact prohibits each state from transferring water from the Snake River Basin outside of the Basin, unless the other state agrees to such a diversion.[233] However, the Compact does not does contain any provisions related to water conservation or ecosystem protection.

The Compact assigns administrative duties to the official in each state who is charged with the administration of public water supplies.[234] In keeping with this responsibility, these officials are responsible for the management of public water supplies, the collection, correlation, and publication of data necessary for the Compact's administration, and the establishment of any water gauging stations needed to obtain these data.

Overall, the Snake River watershed faces **severe** climate change risks. Portions of the watershed are very dry and water resources are already scarce relative to demand. Loss of snowpack will have an effect on surface water supplies, and groundwater resources are already stressed. The Snake River Compact is **somewhat adequate** to address these risks. While it lacks any viable provisions for water conservation or ecosystem protection, it does limit transbasin diversions and provides some data collection and governance capabilities. Most importantly,

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230. Snake River Compact, Pub. L. No. 81-464, 64 Stat. 29 (1950).
231. Snake River Compact, art. I.
232. Snake River Compact, art. III.
233. Snake River Compact, art. IV.
234. Snake River Compact, art. VI.

the Snake River Compact allocates water as percentage of flow rather than guaranteeing one party state a specific quantity of water at the expense of another party state.

23. South Platte River Compact (Colorado and Nebraska)

The South Platte River is a tributary of the Platte, draining much of the Colorado Rockies before flowing into Nebraska. Its basin drains part of southern Wyoming, including Cheyenne. It also encompasses much of Colorado, including Boulder and Denver. Amongst the three states, the basin is home to about 2.8 million people, over 95% of whom live in Colorado. Outside the dense concentrations in the cities, populations tend to be clustered in small towns on the principal streams of the system.

According to the USGS, the principal economy in the mountainous headwaters is based on tourism and recreation; the economy in the urbanized south-central region mostly is related to manufacturing, service and trade industries, and government services; and the economy of the basin downstream from Denver is based on agriculture and livestock production.[235] Much of the basin – about 40% – is devoted to rangeland, and about 37% of the land is in agricultural production. Employment opportunities in recreation and tourism continue to climb.

Water withdrawals for agricultural and urban uses in recent years have resulted in a reduced capacity to dilute contaminants. Meanwhile, the region is growing quickly, and population increases are putting greater demands on water resources. For the decade from 1990 to 2000, for example, the population of the state of Colorado grew by 30.6%, making it one of the fastest growing states in America.[236]

The South Platte River basin in Colorado and Nebraska is expected to become much warmer during the next century, perhaps as much as 4°F. Although annual precipitation is predicted to change only modestly (perhaps a 5% increase), seasonal precipitation will become more irregular. Large winter gains are expected to offset summer losses. Increased evapotranspiration will result in higher humidity. Stream runoff is not expected to change significantly by mid-century.

The South Platte River Compact[237] apportions the waters of the South Platte River between Colorado and Nebraska.

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235. U.S. Geological Survey, National Water-Quality Assessment Program, South Platte River Basin, http://co.water.usgs.gov/nawqa/splt/html/spbasininfops.html.

236. CENTER OF THE AMERICAN W., PEOPLE IN THE WEST, COLORADO POPULATION TRENDS (2001), http://www.centerwest.org/futures/archive/people/population_co.html.

237. South Platte River, Pub. L. No. 69-37, 44 Stat. 195 (1926).

Between October 15 and April 1 of each year, Colorado has full use of the water of the South Platte River, except what is necessary to supply valid appropriations from the Perkins County Canal. During the remainder of the year, if the mean South Platte flow at an official gauging station is less than 120 cubic feet per second, Colorado cannot permit diversions from the lower section of the River to users that acquired appropriation priority dates subsequent to June 14, 1897.

Under the Compact, Colorado and Nebraska agree to jointly maintain a stream-gauging station on the South Platte River to measure and record the amount of water flowing in the River from Colorado into Nebraska.[238] Colorado's state engineer and Nebraska's secretary of public works are responsible for coordinating data exchange and publication. The Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the South Platte River watershed faces **severe** climate change risks. The area is very dry and water resources are already scarce relative to demand. Loss of snowpack will have a dramatic effect on surface water supplies, and groundwater resources are already stressed. Significant population growth is expected and will further stress water supplies. The South Platte River Compact is **inadequate** to address these risks. It lacks any viable provisions for water conservation or ecosystem protection, although it does provide some data collection and governance capabilities. However, the allocations are fixed and do not allow for any significant adaptive management for changed conditions. Given the severe water problems and population growth expected in the South Platte Basin, water users will face significant risks and uncertainty in the future.

24. Susquehanna River Basin Compact (Maryland, New York, Pennsylvania)

The Susquehanna River Basin drains 27,510 square miles of Chesapeake Bay's drainage area, covering half the land area of Pennsylvania and portions of New York and Maryland. It has a population of four million people, and includes 49,000 miles of

238. South Platte River Compact, art. II.

waterways. This basin is prone to floods, experiencing a major flood every fourteen years.[239]

Though the region is made up of 69% forest lands, a substantial number of businesses draw on the basin's water resources. Water-dependent industries in the area include plants that manufacture textiles, paper products, wood products, chemicals, plastics, nonmetallic mineral products, metals, machinery, and transportation equipment. There are 132 electrical generation and distribution facilities in the watershed. [240] Agriculture also plays an important role, with over 4,000 square miles devoted to farmland in Pennsylvania alone.[241] There has been recent interest in capturing natural gas, a process which necessitates breaking up rock formations by injecting large amounts of water into the ground.

Pennsylvania is one of the slowest growing states in America, but some recent growth has occurred around major metropolises within the Susquehanna watershed.[242] Pennsylvania towns in the Susquehanna watershed include Towanda, Scranton, Wilkes-Barre, Williamsport, Renovo, Clearfield, Altoona, Lewistown, Harrisburg, Lancaster, and York.

New York is also a slow-growing state. In general, there has been a decrease in manufacturing jobs and an increase in service jobs.[243] The Susquehanna watershed includes the towns of Cortland, Norwich, Oneonta, Corning, Elmira, Cooperstown and Binghamton.

The Susquehanna River basin is expected to become warmer and more humid during the next century. With an average temperature increase of 2.5°F to 3°F, the area is predicted to warm slightly less than most of North America. Precipitation is expected to rise between 5% and 10% on average, with more of the increased precipitation coming during winter months. Humidity will rise due to significantly increased

239. **Error! Bookmark not defined.** SUSQUEHANNA RIVER BASIN COMM'N, INFORMATION SHEET: SUSQUEHANNA RIVER BASIN (2006), *available at* http://www.srbc.net/pubinfo/docs/Susq%20River%20Basin%20General%20(11_06).PDF.

240. SUSQUEHANNA RIVER BASIN COMM'N, INFORMATION SHEET: ECONOMIC VALUE OF WATER RESOURCES (2006), *available at* http://www.srbc.net/pubinfo/docs/FactSheetEconValue1106.pdf.

241. JEFF ZIMMERMAN, JR., SUSQUEHANNA RIVER BASIN COMM'N, AGRICULTURE RELATED LAND USE (2005), *available at* http://www.srbc.net/atlas/downloads/BasinwideProjects/AgCU/1182_AgPaLU.pdf.

242. *Pennsylvian's Future Demographics: Warning Signs for Policymakers*, ISSUESPA, Aug. 1, 2005, http://issuespa.org/content/pennsylvania%E2%80%99s-future-demographics-warning-signs-policymakers (last visited Nov. 12, 2010).

243. PAUL WING, PUBLIC POL. INST., NEW YORKERS AT THE MILLENIUM (2003), *available at* http://www.ppinys.org/reports/2003/censusbook.pdf (last visited Nov. 12, 2010).

evapotranspiration. Stream runoff in the basin is expected to increase slightly, between 2% and 5%.

The Susquehanna River Basin Compact[244] coordinates the use of river water resources in New York, Pennsylvania, and Maryland. The Compact created the Susquehanna River Basin Commission and charged it with enhancing public welfare through comprehensive planning, water supply allocation, and management of the water resources of the Susquehanna River Basin.[245]

In order to achieve these goals, the Commission is vested with extremely wide-reaching powers. For example, the Commission can establish standards and conduct research. It has a duty to administer, manage, and control water resources in all matters determined by the Commission to be interstate in nature or to have a major effect on the water resources and water resources management. The Commission also regulates flood plain management, water supply, water quality, watershed protection, recreation, fish and wildlife issues, and cultural and aesthetic concerns. The Compact also vests the Commission with the authority to collect, compile, coordinate, interpret, and publish data on water resources and use in the Basin. And the Commission may initiate legal action against any entity that is violating the Compact's provisions.

The Compact has broad geographic and hydrologic scopes. Indeed, the Compact governs all of the water resources of the Basin, including groundwater. Proposed withdrawals are evaluated on several criteria, including the reasonableness of the need, potential environmental impact, and potential adverse impact on other users. The Commission may also temporarily assign certain areas "protected" status, and proscribe diversions from these areas without a Commission-issued permit.[246] In addition, water rights can be modified subject during periods of low river flow.

Importantly, the Compact mandates policies for water resources conservation. Commission approval of project plans is generally contingent upon a project sponsor's agreement to maintain certain minimum conservation standards. Moreover, through the Compact, the signatory states agree to uphold specific water quality requirements.[247] The Compact also encourages the states to promote ecosystem protection within the Basin.

244. Susquehanna River Basin Compact, Pub. L. No. 91-575, 84 Stat. 1509 (1970).
245. Susquehanna River Basin Compact, art. III.
246. Susquehanna River Basin Compact, art. XI.
247. Susquehanna River Basin Compact, art. V.

Overall, the Susquehanna River Basin faces only **modest** climate change risks. Population growth is not significant overall in the basin, and while the river is used extensively for thermoelectric power plants, climate change is not expected to significantly stress water supplies. As with the Delaware River Basin, precipitation may actually increase, with resulting increases in runoff and streamflow. While this may raise water quality and flooding concerns, lack of water supply is not expected to be a significant problem. The Susquehanna River Basin Compact is **adequate** to address future climate change risks. Like the Delaware River Basin Compact, it is in many ways a model compact for adapting to the risks and uncertainties of climate change. It provides comprehensive planning and enforcement, rigorous water conservation, and an ecosystem protection regime. Most importantly, the Susquehanna River Basin Commission has the legal authority and resources to address new circumstances and stresses without severely disrupting water uses and rights. The combination of relative water abundance and adaptive interstate water management make the Susquehanna River Basin as well suited for the future as the Delaware River Basin.

25. Upper Colorado River Basin Compact (Arizona, Colorado, New Mexico, Utah, and Wyoming)

The Upper Colorado River Basin encompasses 110,000 square miles. The river originates in the Rocky Mountains of Colorado and flows through Colorado, Utah, and Arizona before heading further south. The upper Colorado watershed includes portions of Colorado, New Mexico, Utah, and Wyoming.[248]

Major land uses in the basin are mining, agriculture and livestock production, and urban development. Irrigation accounts for 97% of the water use in the basin.[249] Water is also used for municipal and industrial purposes, electric power generation, livestock, fish and wildlife, and recreation. Much of the water is exported to adjoining areas, including California and Las Vegas.[250] Economic and population growth are expected in the

248. U.S. DEP'T OF INTERIOR, UPPER COLORADO RIVER BASIN CONSUMPTIVE USES AND LOSSES REPORT (2007), *available at* http://www.usbr.gov/uc/library/envdocs/reports/crs/pdfs/cul2001-05.pdf.

249. U.S. GEOLOGICAL SURVEY, WATER QUALITY IN THE UPPER COLORADO RIVER BASIN (2000), *available at* http://pubs.usgs.gov/circ/circ1214/pdf/circ1214.pdf.

250. Wyo. Water Dev. Office, Wyoming State Water Plan, Green River and Little Snake River Basins, http://waterplan.state.wy.us/basins/green/issues.html (last visited Nov. 12, 2010).

headwater areas.[251] This growth is projected to increase water demand by 700,000 acre-feet per year by 2020 and by 1.5 million acre-feet per year by 2050.[252]

The Colorado River basin in Arizona, Colorado, New Mexico, Utah, and Wyoming is expected to become much warmer and drier during the next century. The average annual temperature is predicted to increase, perhaps as much as 4°F. Precipitation may increase slightly in the northern portion of the basin, but it will decrease more markedly in the south. Increased precipitation in the north will likely be offset by increased evapotranspiration. Evapotranspiration may decrease in the southern portion of the basin due to the reduced precipitation. Stream runoff in the basin may fall by as much as 25%.

The Upper Colorado River Compact[253] governs the division of the water allotted to the Upper Colorado River states (Wyoming, New Mexico, Utah, and Colorado) and Arizona by the Colorado River Compact. The Colorado River Compact requires the Upper Basin states to deliver 7.5 million acre-feet per year to the Lower Basin states. At the time the Colorado River Compact was signed, it was believed that this would leave another 7.5 million acre-feet for the Upper Basin States, after 1.5 million acre-feet was reserved for Mexico in accordance with an international treaty. The Upper Colorado River Compact divides waters annually as follows: Arizona receives 50,000 acre feet, and of the remainder, Colorado receives 51.75%, New Mexico receives 11.25%, Utah receives 23%, and Wyoming receives 14%.[254] The Compact also provides guidelines for managing the waters of the La Plata, Little Snake, and Yampa rivers, insofar as they affect the Upper Colorado Basin States.

The Compact creates the Upper Colorado River Commission to administer the Compact. The Commission promulgates rules and regulations, operates gauging stations along the Colorado River, collects, analyzes, and reports on data from these gauging stations, and forecasts future conditions in the Upper Bain.[255] The Compact encourages the states to import water from outside of the Basin, although it does not contain any provision related to any other form of transbasin or interbasin diversion, water conservation, or ecosystem protection.

251. INTERBASIN COMPACT COMM., MAJOR ISSUES IN THE COLORADO RIVER BASIN, http://web.archive.org/web/20080110223912/http://ibcc.state.co.us/Basins/Colorado/Major WaterIssues/ (last visited Nov. 12, 2010).

252. Wyo. Water Dev. Office, *supra* note 252.

253. Upper Colorado River Basin Compact, Pub. L. No. 81-37, 63 Stat. 31 (1949).

254. Upper Colorado River Basin Compact, art. III.

255. Upper Colorado River Basin Compact, art. VIII.

Overall, the Upper Colorado River Basin faces **severe** climate change risks. The area is very dry, groundwater in many areas is stressed, and agricultural irrigation and population are expected to continue growing. Climate change is expected to further stress and destabilize water resources. As a result of reduced snowpack, streamflow in the Colorado River is expected to decrease significantly. The Upper Colorado River Basin Compact is **inadequate** to address these risks. It lacks any provisions for water conservation, ecosystem protection, restricting transbasin diversions, or otherwise managing water demand. While it does allocate percentages of flow (with the exception of Arizona's relatively small allocation), it does so within the framework of the Colorado River Compact's erroneous assumptions of total flows, leaving significant risk and uncertainty for the region's water users.

26. Upper Niobrara River Compact (Nebraska and Wyoming)

The Niobrara is Nebraska's longest river. It flows east out of Wyoming and through northern Nebraska before joining the Missouri River. The basin covers 15,195 square miles. Streams in the basin are ephemeral, dependent upon mountain runoff, summer thunderstorms, or groundwater, with peak flows in March and June. High plains Ogallala aquifers lie underneath the Niobrara River Basin in Wyoming, supplying good quality water, but aquifer levels have been declining.[256] Valentine, Nebraska is the largest city in the watershed, with a population of around 2,800. Most of the counties in the river basin enjoy low unemployment rates, ranging from 0% to 2.9%. Slow but steady growth is expected for the region's economy.[257]

A seventy-six-mile stretch of the Niobrara in Nebraska is designated as a National Wild and Scenic River. This portion of the river basin attracts over 65,000 recreational users per year and is home to several endangered species. Over 600,000 square miles of the land are irrigated, and agricultural uses have been increasing with the growing demand for corn-based ethanol. In the first six months of 2007, irrigators applied more than five times the amount of water than had been applied in the decade between 1980 and 1990. New and projected corn ethanol plants will increase ethanol production capacity by 900%.

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256. Wy. State Water Plan, Niobrara River Basin Overview, http://waterplan.state.wy.us/sdi/NI/NI-over.html (last visited Nov. 12, 2010).

257. Neb. Dep't of Econ. Dev., Recent Trends in Selected Nebraska Economic Numbers (2010), available at http://www.neded.org/files/research/trends/trends.pdf.

Because of the ecological threats posed by increased irrigation, the Washington-based nonprofit American Rivers placed the Niobrara on a list of the ten most endangered rivers of 2008.[258] The Nebraska Game and Parks Commission is looking into securing instream flow rights to protect the basin. The Upper Niobrara White Natural Resources District oversees the basin, and has instated a Ground Water Management Plan[259] that goes into effect when water levels decline.

The Niobrara River basin in Nebraska and Wyoming is expected to become 3°F to 4°F warmer during the next century. On average, precipitation is expected to increase slightly (not more than 5% per year). However, water users in the basin will need to adapt to significantly higher winter precipitation (plus 5% to 15%) and significantly drier summers (as much as 10% less precipitation). On average, annual stream runoff is not expected to change significantly by mid-century.

The Upper Niobrara River Compact[260] provides for the equitable division of available surface water in the Upper Niobrara Basin between Wyoming and Nebraska.[261] Under the Compact, Wyoming has no restrictions on the use of the River's surface waters provided that the state complies with various restrictions that the Compact places on reservoir use and capacity. The Compact also proscribes groundwater appropriation within the Basin until adequate data on groundwater within the Basin exists. As such, the Compact provides guidelines for groundwater investigations within the Basin, and calls for cooperation between the States and the U.S. Geological Survey.[262]

The Compact primarily restricts the size of reservoirs that may be constructed and reaffirms the prior apportionment law of the River. The Upper Niobrara River Compact contains no provisions that directly encourage water conservation or efficient water use. The Compact does not place any limitations on interbasin diversions, nor does it contain any provisions related to ecosystem protection.

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258. American Rivers, America's Most Endangered Rivers, Niobrara River (2008), *available at* http://www.nxtbook.com/nxtbooks/americanrivers/endangeredrivers/index.php?startid=38

259. Upper Niobrara White Natural Res. Dist., Reflections, Spring 2008 Static Water Levels Measured (2008), *available at* http://www.unwnrd.org/downloads/spring2008.pdf.

260. Upper Niobrara River Compact, Pub. L. No. 91-52, 83 Stat. 86 (1969).

261. Upper Niobrara River Compact, art. I.

262. Upper Niobrara River Compact, art. VI.

The Compact assigns administrative duties to the official in each state in charge of administering public water supplies.[263] Under the Compact, these officials are responsible for collecting, correlating, and publishing any data necessary for the proper administration of the Compact. In order to assist the officials in their data collection responsibilities, each State is required to establish and operate any water gauging stations along the Niobrara River that are necessary to obtain such data. The Compact is not particularly flexible, as amendments must be approved by both states and the U.S. Congress. There are no provisions in the Compact to provide a mechanism for allocation adjustments.

Overall, the Upper Niobrara River watershed faces **substantial** climate change risks. The area is very dry and groundwater resources are already severely depleted. While significant population growth is not expected, the area will see increased pressure from agricultural irrigation. The Upper Niobrara River Compact is **inadequate** to address these risks. It lacks any viable provisions for water conservation, ecosystem protection, or restricting transbasin diversions. While it does provide some data collection and governance capabilities, it does not allow for any significant adaptive management for changed conditions. Given the stress expected in the Upper Niobrara River Basin from agricultural irrigation, water users will face significant risks and uncertainty in the future.

27. Yellowstone River Compact (Montana, North Dakota, and Wyoming)

The longest undammed river in the lower 48 states, the Yellowstone River flows northward through central and northern Wyoming, southeastern Montana, and a small portion of North Dakota. There are many coal mines and oil and gas production facilities in the region. Over half the land in the basin is used for agriculture, grassland, and grazing. Agriculture uses far more water than any other use (6,900 million gallons per day of surface water and 93 gallons per day of ground water compared to the second-biggest use, thermoelectric power, which uses 33 million gallons per day of surface water and no groundwater).[264]

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263. Upper Niobrara River Compact, art. III.

264. DAVID A. PETERSON & STEPHEN D. PORTER, U.S. GEOLOGICAL SURVEY, BIOLOGICAL AND CHEMICAL INDICATORS OF EUTROPHICATION IN THE YELLOWSTONE RIVER AND MAJOR TRIBUTARIES DURING AUGUST 2000 (2002), *available at* http://web.archive.org/web/20080415230346/http://wy.water.usgs.gov/YELL/nwqmc/index.htm; U.S. GEOLOGICAL SURVEY, NATIONAL WATER QUALITY ASSESSMENT PROGRAM,

Major cities in the basin include Riverton, Wyoming, Livingston, Billings, and Miles City, Montana, and Williston, North Dakota. Population predictions for the region vary by state, with Montana expecting losses[265] while Wyoming anticipates growth.[266] Across the river basin, recent population and economic growth has been spurred by the development of energy and mineral resources, including uranium mines, surface coal mines, and coal-fired electric generating facilities. More recently, interest in coal bed methane ("CBM") production has spurred increased economic activity.

The Yellowstone River basin is expected to become 3.5°F to 4°F warmer during the next century. On average, precipitation is expected to increase slightly (not more than 5% per year). However, water users in the basin will need to adapt to significantly higher winter precipitation (plus 10% to 15%) and significantly drier summers (as much as 10% less precipitation). On average, annual stream runoff is not expected to change significantly by mid-century.

Montana, North Dakota, and Wyoming created the Yellowstone River Compact[267] to equitably divide, apportion, and encourage the beneficial development of all of the waters of the Yellowstone River and its tributaries, except for the portion of the River that flows through Yellowstone National Park. Specifically, the Compact allocates any water of the Yellowstone River's interstate tributaries that is unused and unappropriated as of January 1, 1950 among the States according to proportional allotments of the unappropriated and unused water.[268]

The Compact also creates a Yellowstone River Compact Commission to administer the Compact between Wyoming and Montana. According to the Compact, no such Commission is necessary to administer the Compact between Montana and North Dakota. In keeping with its administrative duties, the Commission is responsible for collecting, correlating, and presenting factual data related to the Compact's administration. Relevant federal agencies must cooperate with the Commission

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YELLOWSTONE RIVER BASIN (1997), *available at* http://pubs.usgs.gov/fs/FS-149-97/fs-149-97.pdf.

265. Population information in part from SUSAN OCKERT, DEP'T OF CORRECTIONS ADVISORY COUNCIL, MONTANA POPULATION AND LABOR FORCE TRENDS (2008), *available at* http://www.cor.mt.gov/content/Resources/CorAdvCouncil/Archive/February2008/LaborForce.pdf.

266. WY. STATE WATER PLAN, NORTHEAST WYOMING RIVER BASINS PLAN, POPULATION PROJECTIONS (2002), http://waterplan.state.wy.us/plan/newy/techmemos/popproj.pdf.

267. Yellowstone River Compact, Pub. L. No. 82-231, 65 Stat. 663 (1951).

268. Yellowstone River Compact, art. V.

in its data collection duties, and provide, correlate, and publish any data that the Commission deems pertinent to the Compact. Moreover, the Commission is responsible for (with the assistance of the appropriate federal agencies) the creation and operation of any gauging and evaporation stations within the Yellowstone River Basin that are necessary to properly administer the Compact.[269]

The Compact does not place any limitations or prohibitions on transbasin or interbasin diversions, nor does it contain any provisions related to water conservation or ecosystem protection.

Overall, the Yellowstone River watershed faces **substantial** climate change risks. Portions of the watershed are very dry and water resources are already scarce relative to demand. Loss of snowpack will have an effect on surface water flows, especially timing. The Yellowstone River Compact is **somewhat adequate** to address these risks. While it lacks any viable provisions for water conservation or ecosystem protection, it does provide some data collection and governance capabilities. Most importantly, the Yellowstone River Compact allocates water as percentage of flow rather than guaranteeing one party state a specific quantity of water at the expense of another party state.

V. CONCLUSION

As the analysis in Part IV makes clear, almost every major western interstate watershed faces substantial to severe stress on water resources from climate change. Further, western interstate water compact are at best somewhat adequate, and generally inadequate, to adapt to these stresses. This is in stark contrast to the east, where most interstate watersheds face only modest to substantial stress and the interstate compacts are generally adequate to somewhat adequate. This is not surprising, given that the west is generally more water stressed than the east, and climate change impacts (most notably loss of snowpack) will be more severe in the west than the east.

Putting aside macro issues of mitigating climate change and reforming western water law (two very contentious environmental policy issues beyond the scope of this article), what can state policy makers do to prepare for stress on

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269. Yellowstone River Compact, art. IV.

interstate water resources in the west? Quite simply, look to the east for modern models of interstate water compacts that include adaptive tools. The Delaware River Basin Compact, Susquehanna River Basin Compact, and Great Lakes-St. Lawrence River Basin Water Resources Compact all provide numerous tools and a governance structure that will help the states and water users adapt to climate change impacts.

As a basic starting point, good data is critical for adaptively managing water resources. Historic, current, and predictive data on both water supply and water demand is necessary. As precipitation patterns begin to vary from historic norms, relying on historic data will become increasingly problematic. Water managers and users should have current real-time data, and the benefit of predicted future conditions, when making regulatory and use decisions. Further, as groundwater supplies become more stressed, far more information on aquifer levels, groundwater flows, and recharge rates is desperately needed. Water use data must also be improved, as many states rely on estimates and models rather than actual monitored use. The single most effective way to ensure quality data for demand management is to require water use registration and reporting. States can do this without altering or amending compact terms, and should generally apply registration and reporting requirements to all water users regardless of watershed.

Ideally, interstate water compacts would be comprehensive in geographic and hydrologic scope, covering not only the entire surface water system (including tributaries), but also connected groundwater. Admittedly, such a change would face significant political opposition, subjecting far more water users to the interstate governance regime. However, not including groundwater creates a hydrological loophole around surface water use regulations. Water managers and conservationists may find political allies in the regulated surface water users, whose use and investments are at risk from unmanaged groundwater withdrawals.

The key feature of many western water compacts – a set allocation of water for each party state – is also one of the most problematic obstacles to adaptive management. The appeal of fixed allocations is obvious, giving water users legal certainty to help guide investments and infrastructure decisions. When water supply patterns were fairly static, the system worked well enough. However, fixing legal water allocations when supply trends are changing beyond historic observations puts water users on a collision course with reality. Water users must give up some fixed certainty to avoid drastic results. Simple prorated reductions in allocation to match current and expected water supply is a good first step, but as the complexities of changing water supply become more apparent, more flexible allocations will be necessary.

Water conservation is the single most important "no regrets" strategy for reducing risk from climate change impacts on water resources. The legal tools for water conservation exist in both eastern riparian law and western prior appropriation law. For example, riparian water law prohibits unreasonable water use, while the appropriation doctrine prohibits water waste. However, in practice both legal systems do little to encourage water conservation, and some legal rules affirmatively discourage efforts to reduce water use. While water law reforms to encourage conservation can be made at the interstate compact level, it may be easier politically to make the reforms at the state level, regardless of watershed. Water conservation is critical for adapting to climate change and would complement efforts to mitigate greenhouse gas emissions that cause climate change due to the tremendous energy use of water treatment and supply.

Management of water resources is not simply an issue of allocation among competing water users, but also of balancing environmental and human needs. In many watersheds, environmental health is completely ignored in water management or given a back seat to water users. This inevitably leads to ecosystem degradation and puts aquatic species at risk. The buck stops when the health of an endangered species is put at risk, triggering the federal Endangered Species Act, which can be a hammer to restrict water use. Proactive management to protect and restore aquatic habitat for fisheries and wildlife would result in a healthier environment and diminished risk of triggering the Endangered Species Act.

Just as climate change will put more pressure on water to be taken from in-stream environmental uses, it will also increase the pressure to find new water supplies through transbasin diversions. Transbasin water diversions are a notoriously contentious issue, as communities feel threatened by 'outsiders taking their water.' Transbasin diversions are also inefficient and expensive compared to demand management and water conservation. The dollars and energy required to move water may not be available as states struggle to adapt to climate change and mitigate climate change pollution. Transbasin diversions should be an option of last resort.

Most fundamentally, the stress and uncertainty of climate change requires interstate governance institutions to adaptively manage water resources as supply and demand conditions change. The eastern compacts that create interstate commissions with broad regulatory powers over water use in the watershed are the ideal, at least in terms of adaptation. Obviously this model requires states to relinquish some level of sovereignty and control, which can be a significant political obstacle. More modestly, governance institutions can be created and empowered to plan, conduct research, prepare reports on water use, and forecast water levels to ensure the best science is used in managing water resources.

While some of these reforms can happen at the state level or through operational changes in compact administration, more fundamental changes will require revision of existing compacts. Compacts are notoriously difficult to enact, and many of the political obstacles apply to revision. While scientific information, policy recommendations, and consensus building can help overcome these obstacles, what is really needed is leadership and political will. A crisis can often spur political leaders to action. For better or worse, many interstate water systems will soon be facing crises, and the best hope is for political leaders to use these crises as an opportunity to make fundamental changes in interstate water management to adapt to the challenge of climate change.