

thermore, any study focused exclusively on water resources might fall short of providing a basis for coping with all of the problems that could arise if climate changes.

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## APPENDIX 5.1—WATER RESOURCE CONCERNS: REGION BY REGION AND STATE BY STATE

### New England Region

*Development of surface and groundwater is substantial here. Municipal and industrial pollution is localized. Drought is rare. The lack of redundancy of water supplies indicates vulnerability.*

Connecticut--Small reservoirs susceptible to below-average rainfall are networked with larger, robust reservoirs; point and non-point contamination; potential flooding due to convective storms in the summer, hurricanes in the fall, and snowmelt in the spring.

Maine--Abundant water resources; localized groundwater pollution due to urbanization agriculture, and industrial-municipal waste; saltwater intrusion potential in coastal areas with high groundwater withdrawals; drought rare, but characterized by low stream flows, low groundwater levels, and high forest-fire risk 20 percent of Maine's electricity is derived from hydropower flooding possible during spring snowmelt.

Massachusetts--plentiful water resources, but not well-distributed in proportion to population density (large cities in the east and reservoirs in the west); quality of certain supply lakes and reservoirs threatened by high sodium concentrations; Boston supply particularly susceptible to drought; potential widespread flooding caused by spring snowmelt with rain and tropical storms.

New Hampshire--Abundant water resources; summer stream flows and groundwater supplies rely on seasonal snowmelt tourism-recreation industry dependent on water resources; regional drought rare, but droughts do affect public water supply occasionally, possible flooding due to spring snowmelt tropical storms, ice jams, and intense thunderstorms.

Rhode Island--Generally sufficient water supply; most feasible supplies already developed and groundwater pumped at capacity, so redistribution possibly necessary to meet future water demand; coastal aquifers and reservoirs endangered by saltwater intrusion others endangered by contamination wetlands (10 to 30 percent of the State) susceptible to prolonged drought potential flooding due to convective storms, tropical storms, and snowmelt with rainfall.

Vermont--Abundant water resources of generally good quality; some localized groundwater contamination in areas of high population density, severe drought rare, but even short droughts can affect agriculture and livestock-public supply storage capacity provides 1-year buffer, flooding potential from tropical storms, intense frontal systems, or snowmelt with rainfall,

### Mid-Atlantic Region

*Water supply is becoming an issue in some metropolitan areas, saltwater intrusion is occurring along coasts, and industrial and municipal pollution is an issue.*

Delaware--Municipal and industrial usage causing increased water-supply pressure in heavily populated regions; peak usage coincides with low-flow periods, causing capacity problems; Dover relies exclusively on groundwater in a region subject to overdraft (northernmost and central Delaware); saltwater intrusion in coastal areas; toxics in the sediments, water column, and biota of Delaware estuary, but improving, regional flooding potential due to tropical storms and local flooding by convective storm.

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Maryland--Water supply well-managed for heavy reliance on surface water, drought stresses domestic supply, groundwater use on coastal plain subject to saltwater intrusion; point and non-point pollution; Hurricanes and convective storms potentially cause floods.

New Jersey--surface water in New Jersey used extensively, but supply development outpaced by demand, making drought dangerous; surface-water quality threatened by agricultural runoff and industrial-municipal discharge as well as saltwater intrusion in coastal areas; groundwater quality threatened by toxins (1,224 known or suspected hazardous waste sites in 1986); potential flooding due to frontal systems and tropical and convective storms.

New York--Demand in New York City significantly exceeds safe yield; Long Island depends solely on aquifers susceptible to saltwater intrusion and drought historic water rights create competition and restrict reallocation non-point sources of pollution threaten surface and groundwater quality in several areas; toxic plumes from inactive hazardous waste sites are mobilized by increased precipitation; sea level rise would affect the New York City and Long Island metropolitan areas and the lower Hudson River estuary (Poughkeepsie supply intake and New York City emergency pumping station); potential regional flooding from frontal systems, spring snowmelt, and tropical storms, local flooding due to convective storms.

Pennsylvania--Water supply potentially a critical problem; although supply is adequate under normal conditions, drought causes problems, especially for smaller supply systems; quality of surface and groundwater jeopardized by drainage from coal-mining areas and non-point sources in agricultural areas, all compounded by acid precipitation convective storms, tropical storms, rain on frozen ground or snow pack, and ice jams all potential instigators of flooding.

Virginia--Considered to be a water-rich state; still, some community-supply systems face insufficient capacity (especially along the southeastern coast); saltwater intrusion potential in coastal areas; localized pollution of surface and groundwater, possible flooding caused by tropical and convective storms.

### South Atlantic Region

*Here, the use of available water resources is increasing, and municipal and industrial development causes shortages in some cities.*

Alabama--Abundant water resources and some highly industrialized areas risk shortages during drought if development continues; localized groundwater contamination due to mine-tailing leaching, saltwater intrusion, and waste sites; potential flooding due to tropical storms or hurricanes and frontal systems.

Florida--State's water resources are a source of competition between municipal, industrial environmental and recreational uses; population pressure in some areas; coastal aquifers **subject to saltwater intrusion, so sea** level rise would reduce safe yield; need for increased storage capacity western and southwestern Florida particularly vulnerable to drought sensitive ecosystems and brackish water subject to flooding; Everglades National Park is entirely below the 8.5-foot (2.5-meter)<sup>1</sup> contour, 34 percent below 1-foot contour majority of population lives on coastlines, very low elevation so sea level rise could be devastating, frequent flooding usually along the coast due to hurricane and tropical-storm surges; most thunderstorms per year in the Nation

Georgia--Surface water extensively used in the northern parts of the state and groundwater in the south; high-growth areas with increasing municipal, industrial environmental, and downstream requirements susceptible to drought; saltwater encroachment on coastal aquifers (would be exacerbated by sea level rise); competition for water stored in major reservoirs groundwater overdraft in southwestern corner due to agriculture; potential flooding due to frontal systems, convective storms, tropical storms and hurricanes.

North Carolina--Abundant water resources some areas approaching limits of available supply; localized pollution by toxins, nutrients, and sediments; flooding and coastal erosion potential, saltwater intrusion from sea level rise, drought impacts agricultural and domestic use, exacerbates increasing competition for water regional flooding potential associated with tropical storms and hurricanes.

South Carolina--Plentiful water resources; need management and coordination of surface and groundwater resources; quality generally good, some nutrient, dissolved oxygen, saltwater intrusion and suspended solids problems locally, development pressure on wetlands; potential flooding caused by hurricanes, tropical storms, and thunderstorms.

### Lower Mississippi Basin

*Water supplies here for medium- to small-sized communities are vulnerable to drought, and industrial pollution and salinity present problems.*

Arkansas--Abundant water resources dissolved solids sediment and saltwater intrusion in the southeast corner restrict use in some areas; **groundwater overdraft in some areas; agriculture susceptible to drought**; possible flooding from tropical and convective storms.

Louisiana--Water resources for municipal and industrial supply, agriculture, navigation, environmental uses, and recreation; due to reliance on rain and shallow water tables, even short droughts greatly affect agriculture; coastal erosion, loss of marshes, and subsidence claim large amounts of state land annually, more than half of the state is a floodplain so hurricanes and tropical storms, convective storms, or upstream events can endanger large parts of State.

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<sup>1</sup>To convert feet to meters, multiply by 0.305.

Mississippi-Abundant water resources; agricultural base of the State economy (and catfish farming) creates large drought **risk** (1988 drought was devastating); saltwater intrusion of aquifers; desire to tap into Tennessee and Tombigbee Rivers for more supply; potential flooding due to frontal systems in the winter and hurricanes and tropical storms in the summer.

### Ohio River Basin

*Municipal water supplies for median and small-sized communities and Ohio River flows are vulnerable to drought here.*

Indiana--Abundant water resources; self-supplied industry is the major user; quality problems downstream from municipal and industrial discharge points; low flows of drought hamper navigation on Ohio River possible flooding from frontal systems, convective storms, and rain with snowmelt.

Kentucky--Abundant water resources during most of the year, seasonal and areal variation; competition between municipal water supply and irrigated agriculture during low flows; coal mining oil and gas operations, agriculture and domestic waste discharge adversely affect water quality; agricultural loss and forest-fire danger during drought; possible flooding from frontal systems and convective storms.

Ohio-Ample surface-water supplies; municipal supply for medium-sized communities fragile during drought agricultural runoff, sedimentation, mining, and hazardous-waste-disposal sites create quality problems; instream flows for navigation are an important consideration during drought despite public works, floods from frontal systems and convective storms affect the State every year.

Tennessee--Generally considered a water-rich State, but limitations visible during drought; smaller supply systems of eastern Tennessee susceptible to drought non-point-source pollution and toxic-waste sites affect quality of surface waters; low dissolved-oxygen concentrations in reservoir releases; localized groundwater contamination some localized **overdraft** during drought; hydroelectric-power generation at 24 dams susceptible to drought thermal-power generation suffers from increased surface water temperatures during low flows; lack of irrigation infrastructure stresses agriculture during drought; flooding potential due to frontal systems and thunderstorms greatly mitigated by flood-control works.

**West Virginia--Abundant water resources; some localized water-quality** problems due to non-point sources such as manufacturing, municipal waste, coal mines, and farms; drought not a major concern, but potential flooding of flat and narrow valley floors due to frontal systems and cyclonic and convective storms is a major problem.

### Upper Great Lakes-Upper Mississippi Basin Region

*Management of the Mississippi and Missouri River systems is difficult during drought. Additional problems arise as a result of fluctuating Great Lakes levels and of impacts on water quality. The heavy chemical and biological loading of the upper Mississippi due to industrial, municipal, and agricultural pollution is a problem.*

Illinois-Abundant water resources; self-supplied industry is major user; small community water supplies susceptible to drought; point-source pollution prevention improving, non-point sources such as agriculture harmful; drought impacts navigation on the Mississippi; potential flooding due to rainfall with snowmelt or stalled frontal systems.

Iowa--Municipal water supply generally sufficient even under drought conditions; agricultural and livestock production would suffer significant losses in any drought; water-quality problems caused by agrochemicals leached into ground and surface water; many naturally tainted aquifers; potential flooding due to rapid spring snowmelt or convective storms.

Michigan-Abundance of water resources; industry is major user; competition between upstream and downstream users; potential drought impacts on water level in Great Lakes and diversion practices; control of toxics in surface and groundwater and Great Lakes water quality has become priority, flooding infrequent, but usually due to rainfall during snowmelt.

Minnesota-Abundant water resources; drought affects Mississippi River management for water supply and navigation; Minneapolis-St. Paul needs alternative veto Mississippi for water supply; rural withdrawals depend on groundwater; potential flooding due to convective storms and snowmelt with rain in the spring.

Missouri-Abundant water resources; northwestern water supplies subject to drought stress; increased groundwater withdrawals and impact on water-based recreation during drought saltwater intrusion into aquifers; Occasional flooding due to Thunderstorms and stalled frontal systems.

**Wisconsin--Water-rich** state; industry is largest user; agriculture and tourism affected by drought 5 percent of State energy from hydropower, increasing competition for use; potential flooding caused by frontal systems, snowmelt, and convective storms.

### Plains States Region

*Drought is a frequent problem in this region. Competing uses of Missouri reservoirs--agricultural, tribal, recreational, and downstream--have led to management stresses. Small-community water supplies are vulnerable, water tables are low due to intense agricultural and urban consumption and groundwater depletion. Agricultural runoff has caused pollution, and the salinity of surface water is high.*

**Kansas--Water** resources distributed unevenly, surface water in the east and groundwater in the west; most diversions are for irrigation; groundwater overdraft (e.g., the Ogallala Aquifer) is occurring, and many areas are closed to further appropriation; adverse water-quality

**impacts** due to irrigation, petroleum production, agrochemicals, waste sites; agricultural droughts fairly routine; potential flooding due to stalled frontal systems, intense convective and tropical storms.

Nebraska--Abundant water supply although quantity varies annually, seasonally, and annually; irrigation is major user, localized groundwater overdraft; salinity problems in the South Platte River and canal systems originating in Colorado; interstate legal compacts and decrees on North and South Platte, Republican, and Blue Rivers; reservoir releases necessary to navigation on the Missouri; significant drought impact on agriculture, small community supplies, older well systems, and fish and wildlife; potential flooding due to thunderstorms, ice jams, and snowmelt in the Rocky Mountains.

North Dakota--Water is an important but scarce resource; reservoir system is critical due to seasonality of flows; limited water-distribution systems from reservoirs; agriculture, tourism, and recreation affected by drought high salinity of surface water agricultural drainage of wetlands; potential flooding due to spring snowmelt with rainfall.

South Dakota--Missouri River is the only reliable stream flow because of seasonal variability; demands on reservoir system from recreation, downstream navigation, agriculture, and future users--strong desire to stabilize agricultural production with reservoir system; drought disastrous for agriculture industry; eastern half of State vulnerable to groundwater overdraft interstate water resource conflicts on the Missouri; potential flooding due to snowmelt with rainfall, frontal systems.

## Southwest Region

*The agricultural economy here is vulnerable to drought.*

Oklahoma--substantial water resources, unevenly distributed; groundwater in the west, surface water and reservoir storage in the east drought detrimental to agriculture, industrial-municipal water supply, tourism and recreation, instream flows, and hydropower, salinity problems in the Arkansas and Red Rivers; water-rights-allocation controversy; potential flooding due to convective and tropical storms.

New Mexico--Water scarce in generally arid state; surface water is completely appropriated and any supply reduction brings shortages; agriculture vulnerable to drought extensive storage capacity on perennial streams; groundwater overdraft in aquifers not associated with streams; irrigation is the largest user of water, quality **degraded** by municipal-industrial discharge into Rio Grande, saline and contaminated agricultural runoff, urban contamination of some groundwater, most water use governed by interstate compacts, Supreme Court decrees, international treaty; intrastate conflict over instream-offstream uses; potential flooding due to local thunderstorms, melting snowpack with rainfall frontal systems from Pacific.

Texas--A semiarid to arid state; only eastern third of State has sufficient water on dependable basis; Houston, Corpus Christi, Dallas, and Fort Worth dependent on surface reservoirs of limited capacity Ogallala Aquifer of High Plains very slow recharge, substantial overdraft, Seymour Aquifer contaminated by oil-drilling activities; saltwater intrusion possible in coastal aquifers, salinity problems in Ogallala Aquifer and Rio Grande; low and hypersaline flows into coastal estuaries and wetlands threaten species; agriculture and livestock losses due to drought; increasing competition between irrigation, urban uses, recreation, wildlife, tourism, and saltwater-intrusion correction; potential flash floods due to convective storms and **regional flooding** due to tropical storms and hurricanes; potential conflict with Mexico over allocation of groundwater.

## Rocky Mountain Region

*In this region, competition between instream and offstream users is growing, and water rights are controversial--American Indians vs. States vs. Federal Government. The salinity of surface and groundwater is high, agriculture in the region is vulnerable to drought, and there are shortages in municipal water supplies during low flow.*

Colorado--Rapidly approaching maximum utilization of water resources; increasing conflicts among urban, agricultural, recreational and environmental uses of water, especially during drought; downstream States claim rights to water originating in Colorado; groundwater overdraft problems in arid eastern Colorado; contamination of ground and surface water near toxic-waste sites; salinity problems in lower Arkansas River and in the San Luis and Grand Valleys; potential flooding due to thunderstorms, snowmelt, rain on saturated ground.

Montana--Abundant water in major rivers; seasonal flow in smaller eastern rivers, so supply can be a problem; persistent water shortage in some areas; competition between irrigators and instream users (especially trout fishers); competition with downstream states; dependence on surface water makes agriculture more vulnerable; potential quality degradation due to mining, agriculture, forest practices; potential flooding due to snowmelt with rainfall, spring runoff.

Utah--Relatively scarce water resources; supply sources near population centers exhausted; variability of supplies (6 years of drought preceded by 4 wettest years on record); water-quality problems with seasonal low flows; localized drought at least once a year affects small communities, agriculture (especially grazing), instream flow for fish and wildlife; salinity high in lower reaches of streams; potential flooding due to rapid snowmelt with rainfall, intense thunderstorms, and lake rise.

Wyoming--Water resources dispersed unevenly, perennial streams in the west and ephemeral streams in the east; extended drought well-known affects agriculture and forest-fire hazard; most surface water committed under interstate compacts and court decrees; competition for surface waters between agriculture, municipalities, and industry; thunderstorms, snowmelt with rainfall, and stalled frontal systems can cause flooding.

## Lower Colorado River Basin South Pacific Coast Region

*The competition between municipal supply and irrigation in this region is increasing, as are conflicts between instream and offstream uses and over Indian, State, and Federal water rights. Salinity problems occur with surface and groundwater.*

Arizona-Water a limited resource; shortages on Colorado River system (water apportioned to Arizona by the Colorado River Compact); groundwater overdraft due to both agricultural and population growth; industrial wastes, agrochemicals, salinity, and mining contamination of groundwater, 30 Superfund sites; Colorado River desalinization at national border, drought impact on rangeland, agriculture, recreational use of reservoirs; potential flooding due to snowmelt with rainfall, thunderstorms.

California-Most water in the north, most use in the south; entire State susceptible to drought (central and southern especially), which affects every use, from irrigation to municipal-industrial supply; population pressures in south and central; drought exacerbates groundwater overdraft, increases forest-fire potential, harmful to recreation and tourism; significant hydroelectric-power generation groundwater supply pressured by toxic contamination and coastal saltwater intrusion salinity problems in parts of San Joaquin Valley due to irrigation saltwater intrusion of Sacramento@ San Joaquin Delta interstate agreements and water-law constraints; growing competition between instream and offstream uses; potential flooding due to frontal systems from Alaska meeting moist tropical air.

Nevada-A very arid state; municipal water supplies insufficient in some cities, such as Las Vegas, Reno-Sparks, Lovelock, Wendover, Dayton, and Incline Village; agricultural demand relies on surface water, so is susceptible to drought competition among urban agricultural, municipal, tribal, and environmental uses; Colorado River withdrawals governed by Colorado River Compact and Nevada has inadequate share; bi-state agreements on three western rivers; widespread groundwater overdraft due to municipal and agricultural use; localized aquifer contamination; salinity high in Virgin River; wetlands and fisheries susceptible to drought; low flows create water-quality problems; endangered fish in some Great Basin lakes; potential flooding due to snow-melt and rain, localized thunderstorms.

### Northwest and Pacific Region

*In this region, municipal supplies for smaller communities are susceptible to drought, and competition among power-generation, fish and recreation, and instream and offstream uses generally is intense. Drought has had significant impacts on forest health.*

Alaska-Water abundant overall; local supplies not sufficient for Anchorage and Juneau; sources not dependable during the winter when streams freeze or stop flowing, but drought not a major concern; suspended sediments in glacially fed rivers; ground and surface water pollution in populated areas; ice-jam floods common, intense storms and snowmelt occasionally bring floods.

Hawaii--Abundant water for size; small communities have only short-term water supply, but most droughts are short-term events; population and economic stress on island of Oahu leads to pollution; drought affects agriculture; major storms or hurricanes can bring flooding.

Idaho--Seasonality of surface water is major constraint on use, reservoirs supplement low flows; smaller communities have supply problems during drought; competition between municipal-industrial withdrawals and irrigation; drought affects agriculture, hydropower, tourism, recreation, forest-fire hazard; local pollution due to irrigation return flow, mine tailings, municipal-industrial waste; potential flooding due to snowmelt with rain, thunderstorms, ice jams.

Oregon-Abundant water in the west, limited water in the east; reservoir storage augments summer low flows, allows enormous hydroelectric production; coastal communities lack storage to deal with drought drought impacts on power production, fish, recreation agriculture, and forest-fire hazard; water-quality degradation from pasture and agricultural runoff, municipal and industrial discharge; groundwater overdraft in the east exacerbated by drought potential flooding due to snowmelt and rain in the west, convective storms in the east.

Washington--Water supply adequate, but unevenly distributed areally and seasonally; heavily populated areas of western Washington reaching limits of municipal-industrial supply; drought affects agriculture, hydropower (Washington produces 30 percent of U.S. hydroelectricity), tourism and recreation fisheries, wetlands, and navigation 60 percent of annual river flow through hydrological system is snowmelt; saltwater intrusion in San Juan and Island Counties, potential for all coastal areas; localized groundwater contamination potential flooding due to snowmelt with rain, thunderstorms in the east.

SOURCES: U.S. Geological Survey (USGS), *National Water Summary, 1985--Hydrologic Events and Surface Water Resources*, Water-Supply Paper 2300 (Washington, DC: U.S. Government Printing Office, 1986); USGS, *National Water Summary 1986-Hydrologic Events and Groundwater Quality*, Water-Supply Paper 2325 (Washington, DC: U.S. Government Printing Office, 1988); USGS, *National Water Summary 1987-Hydrologic Events and Water Supply and Use*, Water-Supply Paper 2350 (Washington, DC: U.S. Government Printing Office, 1990); USGS, *National Water Summary 1988 -89--Hydrologic Events and Floods and Droughts*, Water-Supply Paper 2375 (Washington, DC: U.S. Government Printing Office, 1991); U.S. Army Corps of Engineers, *The National Study of Water Management During Drought: Report of the First Year of Study (Fort Belvoir, VA: U.S. Army, Institute for Water Resources, 1991)*; National Regulatory Research Institute, *Compendium on Water Supply, Drought, and Conservation, NRR 89-15* (Columbus, OH: National Regulatory Research Institute, October 1989); letters from State water resource agencies.