The 1988 Drought, Barges, and Diversion

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Abstract

The drought of 1988 rated as one of the nation's worst in the past 100 years, resulting in a myriad of impacts and responses. A notable, largely unexpected impact involved stoppages of barge traffic on the lower Mississippi River during June and July, a result of shallow areas produced by record low flows and shoaling. The barge industry hauls 45% of all bulk commodities (grains, coal, petroleum) shipped in the central United States. The low flows were a result of the unusually large areal extent of drought conditions across most of the Mississippi Basin, which comprises 40% of the continental United States. Most 1987 months had been relatively warm and dry, minimizing moisture in the soils and shallow ground water. Then deficient snowmelt (due to low winter snowfalls) and record low spring 1988 precipitation combined to produce the record low flows along much of the Mississippi River.

Most responses to the drought came in a crisis mode and included concentrated dredging to open channels, government enforced reductions in barge loads and in numbers of barges per tow, tripled barge shipping rates, and shifts in transportation modes. The barge industry suffered a 20% income loss. The total losses to the barge industry coupled with higher costs for shipping were $1 billion. The Illinois Central Railroad, which parallels the major blocked waterways, used a climate prediction to anticipate the low flows 3 months in advance. They leased additional cars to help handle the increased shipments transferred from barges and made a sizable profit. A response proposed by Illinois and shippers—a temporary increase in the water diverted from Lake Michigan to raise the levels on the lower Mississippi River—was met with strong objections by other lake states and Canada. The federal government declined the proposal, but the sizable controversy it engendered reflects the growing sensitivity to water resources issues in the Great Lakes Basin and is also illustrative of problems to be expected from a drier future climate (as hypothesized by certain global climate models as a result of ever-increasing trace gases in the atmosphere). This case study illustrates the value of using seasonal climate predictions of limited skill, and the need for better near real-time climatic data, including information about physical impacts of current climatic conditions.

1. Introduction

The drought of 1988 was ubiquitous, directly affecting large parts of the nation. Its severity created many major problems and produced diverse responses. United States and Canadian citizens once again became acutely aware of how sensitive the environment and socio-economic systems are to weather abberations. Major impacts occurred to all sectors, including agriculture, water resources, transportation, tourism, and the environment. Local, state, and federal governments responded in many ways.

One of the more interesting impacts related to the halted midsummer barge movement caused by low flows on the major rivers (Mississippi, Ohio, and Missouri) that drain most of the central United States. National attention to this event was enhanced by a controversial proposed response—the added diversion of waters from Lake Michigan into the Illinois and Mississippi rivers to increase their levels.

Together these events provide valuable lessons for the scientific community and policy makers. They illustrate interesting uses (and nonuse) of weather and climate information, the economic value of long-range climate predictions, and needs for faster and well-interpreted climate information for decision making in the public and private sectors (Changnon et al. 1988). The unexpected impacts and ensuing controversy are also examples of problems that a drier future climate could produce in the humid eastern United States, particularly if the hypothesized CO_2-induced greenhouse effects are realized (Koellner 1988). The rapid response of the U.S. Army Corps of Engineers (COE) after the river blockages occurred and the ensuing shifts to alternative means of transportation reveal the resilience of the total existing support systems and the value of having redundancy in the shipment of critical goods sensitive to weather.

This paper describes how the 1988 drought created the highly unusual late spring low streamflows, identifies the types of problems that ensued, the various types of responses employed and proposed, and the major winners and losers. Implications for future research, policy development, and drought planning are identified.

2. Background

Barge movements were restricted by low streamflows in portions of the lower Ohio and Mississippi rivers in channels south of the lock and dam systems on each river, essentially south of Cairo, Illinois (figure 3). This series of locks and dams controls the movement of water, helps prevent flooding, and sustains flows for waterborne transportation, power generation, irrigation, and urban water supplies. South of these controlled flow systems, river levels became minimal by late May 1988, and the slow water movement led to increased sediment deposits. Both rivers developed shallow areas where barges and tows be-

TABLE 1. Classification of average temperature and precipitation conditions prevailing in three regions during 1987–1988.

		Missouri Basin		Upper Mississippi and Ohio basins		Tennessee and Lower Mississippi basins	
1987		Temp[1]	Precip[2]	Temp	Precip	Temp	Precip
Jan		A	B	A	B	N	B
Feb		A	N	A	B	A	N
Mar		A	A	A	B	A	B
Apr		A	B	A	B	N	B
May		A	N	A	B	A	B
Jun		A	B	A	B	A	N
Jul		A	N	A	N	N	N
Aug		B	A	N	A	A	B
Sep		N	B	N	B	N	B
Oct		B	B	B	B	B	B
Nov		A	B	A	A	A	N
Dec		A	A	A	A	A	A
	SUMS	A = 9	3	9	3	7	1
		N = 1	3	2	1	4	4
		B = 2	6	1	8	1	7
1988							
Jan		N	A	N	N	B	B
Feb		N	B	B	B	N	B
Mar		A	B	A	B	N	B
Apr		A	B	N	B	N	B
May		A	B	A	B	N	B
Jun		A	B	A	B	N	N
Jul		A	B	A	B	N	N
Aug		A	B	A	N	A	B
	SUMS	A = 6	1	5	0	1	0
		N = 2	0	2	2	6	1
		B = 0	7	1	6	1	7

[1]A = >2°F above normal; B = >2°F below normal; N = ±2°F of normal.
[2]A = >125% of normal; B = <75% of normal; N = ±25% of normal.

came stuck. The river depth during parts of June and July was too slight to permit the movement of loaded barges and their tows. Barge traffic was stopped at several locales over a 4-week period, with traffic reduced throughout the summer. This loss of barge transport led to the movement of the major commodities hauled on barges (grains, petroleum, chemicals, and coal) by railroads and often to ships operating from Great Lakes ports instead of New Orleans. The significance of the impact is further revealed in the statement "The Mississippi River navigation system is entirely dependent on its abilities to transport commodities efficiently" (Koellner 1988). This efficiency was greatly reduced in midsummer 1988.

The barge and tow business in the United States is sizable. More than 300 tow and barge companies operate on the Ohio, Mississippi, and Illinois river systems, and many river ports serve the barges. The annual revenue of the barge industry is approximately $1 billion (*News-Gazette* 1 August 1988). The barge industry carries 60% of the grain exported from the United States, 40% of all petroleum transported within the United States, and 20% of all the coal shipments in the United States (American Waterways Operators 1988). Barge shipments typically represent 45% of all the Midwestern grain crop (*Chicago Sun Times* 24 July 1988). Thus, the industry is one of the nation's major means for hauling bulk commodities, and as such is a key United States transportation industry.

3. Antecedent climate and streamflow conditions

Climate and streamflow conditions in 1987 were examined to discern their role in the resulting low flows of 1988. Prevailing monthly temperature and precipitation conditions for 1987 in three regions, the Missouri Basin (MB), the Upper Mississippi–Ohio Basin (UMOB), and the Tennessee–Lower Mississippi Basin (TLMB), are shown in table 1. The 1987 sums reveal the preponderance of warm and dry conditions in all three basins with few months rated as relatively cool

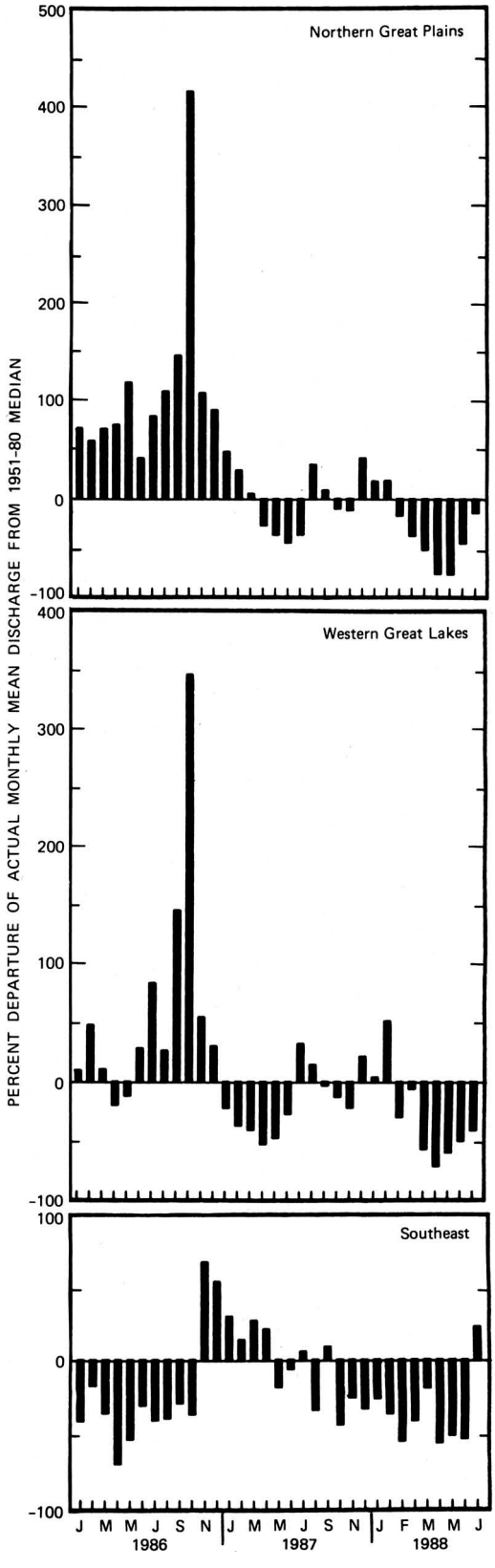

FIG. 1. Area-mean streamflow in three major regions comprising most of the Mississippi River Basin, expressed as a percent of the 1951–80 median.

and wet.

The warm and dry conditions during most of 1987 led to reduced streamflows in the three major areas that comprise most of the Upper Mississippi, Ohio, and Missouri basins. The average monthly flows of all gaged streams in the northern High Plains (North Dakota, South Dakota, Minnesota, Iowa, and Nebraska), the western Great Lakes (Illinois, Wisconsin, Indiana, Ohio, and Michigan), and the Southeast (Kentucky, Tennessee, West Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi) appear in figure 1 expressed as percentage departures from the median discharge for 1951–80. These areas closely approximate those assessed in table 1. The departures of flows in the northern High Plains (figure 1a) and western Great Lakes (figure 1b) were both consistently well above median levels during 1986, but flows in both areas fell below median levels during the spring and summer of 1987. Heavy rains in August (table 1) restored flows to near median levels. The above-average precipitation in November and December 1987 produced, with normal lags, slightly above-median flows in both areas in December 1987–February 1988. The average flow in the southeast area (figure 1c) illustrates the effects of severe drought conditions during 1985–86 (Bergman et al. 1986) causing the prolonged low flows in 1986. After above-average precipitation in late 1986, dry conditions returned in 1987 (table 1) leading to below-median flows (25–50% of median) by mid 1987.

Thus, all these areas of the Mississippi Basin were experiencing low flows during most of 1987. The consistently warm and dry conditions from January to June 1987 in the Midwest led to a closure (to barges) along the Mississippi River for 10 days in July 1987 when once in 10-yr low flows occurred (Koellner 1988).

4. Principal factors causing the low flows in 1988

The low-flow problems that developed during 1988 in the Mississippi, Missouri, and Ohio river systems, which collectively drain 40% of the United States, were largely produced by two conditions in early 1988. Although heavy snowmelt in the Upper Mississippi and Ohio rivers brings occasional spring floods, and snowmelt is normally a key input to the spring river flows, this was not to be the case in the spring of 1988. Unfortunately, heavy snowfalls after 1 January 1988 were infrequent. The 1988 snowfall in the states in the Upper Mississippi drainage area ranged from 57% (Illinois) to 89% (Minnesota) of their long-term averages, and the basin-wide value

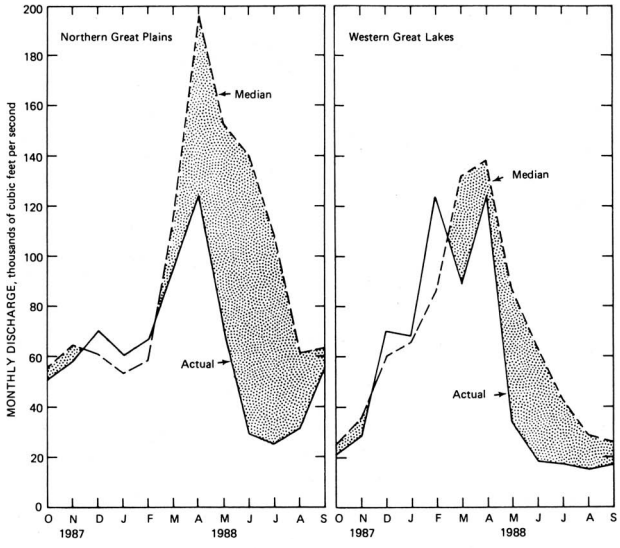

FIG. 2. Monthly mean streamflows for October 1987–September 1988 and median flows (1951–80 base period) for two major regions.

was only 70% of the average spring snowmelt. The highest monthly median streamflows in the central United States occur in February, March, April, and May (figure 2) when snowmelt occurs plus the year's heaviest monthly average precipitation. However, as shown in figure 2, river levels in the western Great Lakes began falling in March when levels are normally rising rapidly. This was a key indicator of problems to come.

The other major factor was a relatively warm (high maximum temperatures) and very dry spring in 1988. As shown in table 1, precipitation was below normal in all the major basins in February 1988, and amounts were 25–75% below average over 90% of the Northern Great Plains, Midwest, and Southeast. March continued the dry tendency (with above normal temperatures) with below normal precipitation over 68% of the total basin. Higher-than-average temperatures in the Upper Mississippi and Missouri basins after February increased evapotranspiration above normal levels. Thus, at the beginning of April 1988, the Palmer drought severity index (PDSI), which represents the long-term soil water balance, showed either moderate or severe drought conditions existed in (1) Montana, the Dakotas, and Minnesota (i.e., the upper portions of the Mississippi and Missouri rivers); (2) in Kentucky, West Virginia, and Tennessee (portions of the Ohio and Tennessee rivers); and (3) in Arkansas (portions of the lower Mississippi and Arkansas rivers). By mid-May, these areas of very severe drought had expanded to include Iowa, Illinois, Indiana, and Ohio. Precipitation was much below normal (<50%) in April and May and dryness extended across all regions comprising the Mississippi Basin (table 1).

Figure 3 presents the pattern of the PDSI in mid-June 1988, showing the great extent of extreme dryness across most of the major river basins (Ohio, Missouri, and Mississippi). Eighty-three percent of the Mississippi Basin (40% of the United States) experienced severe to extreme drought, and 17% of the basin experienced extreme drought. Severe drought seldom exists in the Midwest during spring and, of greater importance, less seldom does its areal extent cover most of the total basin of the Mississippi (Karl 1988). Intensification of widespread droughts during spring is extremely unusual in the Midwest; only 3% of all 3-month droughts in Illinois since 1905 occurred during March–May (Huff and Changnon 1963).

Figure 4 presents the ranking of April–June 1988 rainfall values for the Midwestern states where the drought attained its greatest severity (Kunkel 1988). The ranks of 1 indicate where this 3-month total ranked as worst in the twentieth century, revealing that most states experienced the lowest April–June amount ever recorded. Thus, these very deficient spring rains (coupled with above-normal temperatures) and the less-than-normal snowmelt were the two main factors causing the record low late-spring and summer streamflows.

The reactions of the Mississippi River to the extreme weather abberations are revealed by the daily streamflow values for October 1987–September 1988 as measured at two locations. Flows at Keokuk, Iowa (in the middle of the Upper Mississippi River Basin, figure 3), and at Vicksburg, Mississippi (part of the middle of the Lower Mississippi River Basin), are depicted in figure 5 along with their record extreme monthly average discharges. The lack of snowmelt in February–March left flows near average with declines beginning in late March. Heavy early April rains on the Illinois and Wabash River basins—major tributaries to the Ohio and Mississippi—caused them to briefly reach flood stage, and these rains are reflected in the abrupt flow increases on the Mississippi during the first half of April (figure 5). Very deficient rainfall in the last 3 weeks of April and throughout May brought rapid declines in flow. Normally this is the time increasing flows reach normal annual peaks in April–May. Thus, the rapid decline in April was a strong indication there would be very low flows in coming months. Before the end of May the flows at both locales had reached record low levels which continued throughout the summer.

Another factor involved in the very low flows of the lower few miles of the Ohio and the Lower Mississippi rivers relates to a lack of river control there; the depth problems all occurred where there is no lock and dam system. Most of the Ohio and the Upper Mississippi rivers (and their main tributaries) have

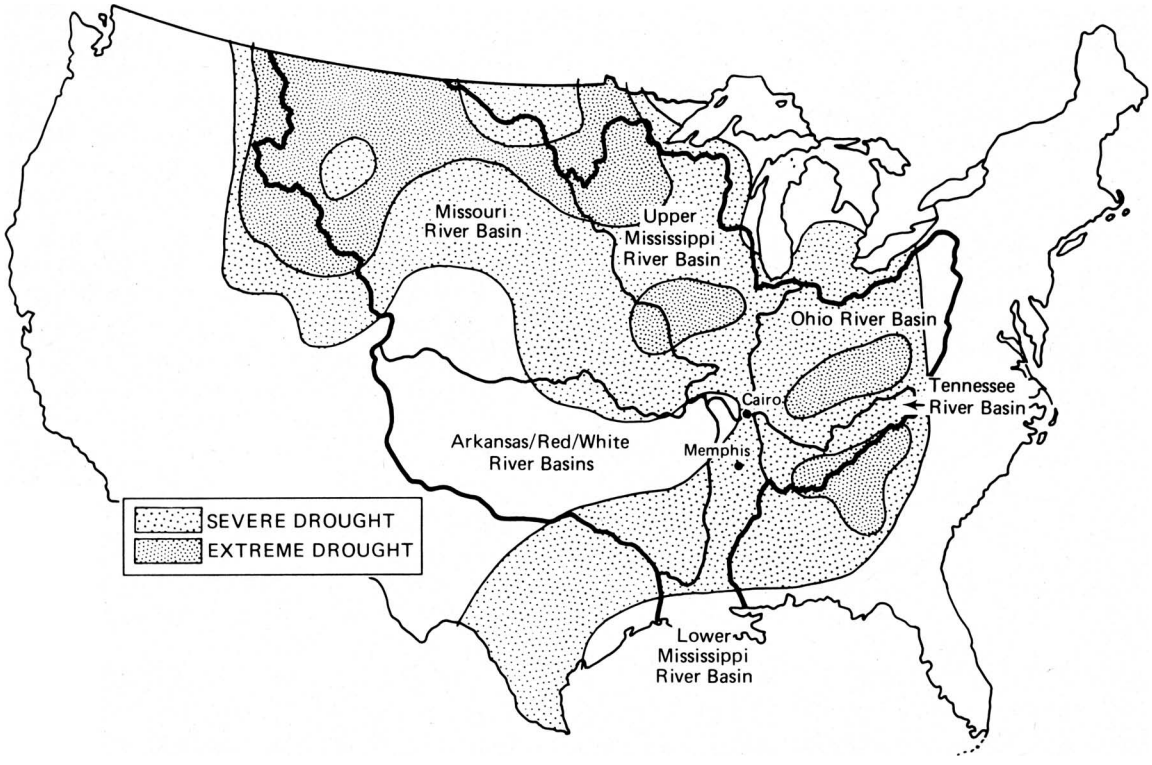

FIG. 3. The areas of severe and extreme drought in the Mississippi River Basin on 15 June 1988 (based on Palmer drought severity index).

series of locks and dams operated by COE to control flooding and to sustain sufficient water in the pools to maintain adequate [>9 feet (2.7 m)] river levels for barge transportation and to control flows for transportation, water supplies, hydroelectric power generation, and other uses (Koellner 1988). Managed releases by COE of the water in these systems helped keep river levels in the lower reaches of both rivers (from just north of Cairo southwards, see figure 3) from falling lower than they did. In these uncontrolled areas of the Lower Mississippi and Ohio, dredging is used routinely to maintain channels for navigation.

5. Problems

The drought conditions led to rapidly decreasing flows in the lower portions of the Ohio River and the lower half of the Mississippi River by the end of May. In several channels near and south of Cairo, Illinois (figure 3) the depth of the rivers fell to less than 8 ft (2.4 m) by early June. Barges became stuck. The rivers were moving slowly, leading to shoaling (the deposition of sediment) in some channels, which helped to make the rivers more shallow.

The first grounding occurred on 8 June 1988 on the Mississippi River south of St. Louis. A dredge was sent by COE to dredge the area, and the Coast Guard established restrictions in the area limiting it to vessels drafting no more than 6 ft (1.8 m) (COE 1988). By 15 June 1988, the level of the river passing Memphis was the lowest since records began in 1872. A 10-mile (16-km) stretch of the Ohio River from Cairo to Mound City, Illinois (just north of the confluence with the Mississippi), was also subject to shoaling and had river levels of less than 8 ft (2.4 m) by 14 June (*News-Gazette* 20 June 1988).

Fully loaded barges must have 9 ft (2.7 m) of water for movement. Thus, by mid June large numbers of tows and barges were halted in the Mound City area of the Ohio River, and near Greenville (Mississippi) and Memphis, both along the Lower Mississippi River (figure 3).

On 14 June 1988, the U.S. Coast Guard closed the stretch of the Ohio River north of Cairo (*News-Gazette* 17 June 1988). More than 700 barges were backed up at nearby Mound City, and intensive dredging began on 14 June. The river was reopened by 17 June 1988. The daily cost for a tow with 20 barges ranges from $5000 to $10,000 (Interagency Drought Policy Committee 15 July 1988). Mound City is a river port where three firms load midwestern grain on barges. The inability to maintain barge movements and hence to have empty barges available led to the storage of 200 000 bushels of grain on city streets. By 27 June 1988, there was more than $1 million worth of grain in open storage on city

streets because elevators were unable to store the regional influx of grain that could not be moved by barges (*News-Gazette* 27 June 1988)[1]. This situation confirmed Koellner's (1988) earlier prediction that low Mississippi system water levels could cause many tows and barges to be stranded near areas used for fleeting and loading, and that port storage systems would accordingly be inadequate to handle incoming shipments.

By 17 June 1988, 700 barges were backed up at Greenville, Mississippi, and dredging had begun there to clear a 2000-ft (600 m) channel. By 19 June 1988 130 tows and 3900 barges were backed up in the Mississippi River at Memphis, but dredging temporarily opened the blockage on 20 June. The barge traffic was again halted in the Cairo area of the Ohio River on 27 June 1988, and 2000 barges were halted by low flows for several days in early July at Memphis (*Farm Week* 4 July 1988). Other blockages occurred along the Lower Mississippi at seven locales south of Cairo (Helpa 1988).

The blockages in the Ohio and Mississippi rivers greatly reduced the movement of bulk commodities down them. By early July, river traffic was down by 20%, and the summer loss of loads shipped represented 30 million tons (27.3 million metric tons) (Helpa 1988). Shippers, as well as barge and tow owners, experienced these problems and the resulting economic losses. Most river ports along the central and upper river system were experiencing reduced shipments and commodity backups such as those at Mound City.

As the difficulties of moving loads became widely known in mid-June, movement of many commodities was shifted to railroads and north to Great Lakes ports, bringing a loss of business to most river ports. By late July the river flows had increased sufficiently (figure 5) due to heavy July rainfalls in the eastern Corn Belt, to avert further major blockages. However, the flow of the Mississippi at Vicksburg (figure 5) on 11 August 1988, was only 80 000 cfs (3,920 m^3 sec^{-2}), as compared to a normal of 320 000 cfs (8960 m^3 sec^{-1}), and barge loads remained less than average (*Chicago Tribune* 2 August 1988). Only one analysis of the potential problems of low flows on these rivers due to the drought could be located; a COE staff member, asked in 1987 to consider possible problems related to a climate change leading to drier conditions in the Midwest, had estimated the problems that would occur in 1988 (Koellner 1988). No drought contingency plans for the Lower Mississippi River existed in COE.

[1] One barge hauls the equivalent of the load of 15 railroad cars or 60 semi trailer trucks (American Waterways Operators 1988).

FIG. 4. The ranks of the April–June 1988 precipitation values in each midwestern state, with rank 1 indicating the lowest in the 1900–88 period.

The low flows produced other notable impacts. Included was a decrease of 25% in hydropower generation, a decrease of recreational uses of rivers and lakes by 15%, and salt water intrusion 105 miles (168 km) up the Mississippi River and extending past New Orleans (Helpa 1988). However, these impacts are beyond the scope of this study.

6. Responses

As might be expected from the severity of the problems to the barge industry, several major responses quickly developed. One important act was the formation in June of the River Industry Executive Task Force, composed of relevant federal government agencies (COE and U.S. Coast Guard) and leaders of private companies (shippers, tow owners, and port managers). The American Waterways Operators convened the task force in Washington, D.C., in late June and acted in concert to identify the best responses (American Waterways Operators 28 October 1988). However, it was a crisis mode of response, not one based on a strategic plan coupled with early awareness of the impending low flows evident by the rapidly falling levels in April (figures 2 and 5).

At this point, the impacts and responses need to be put into a historical context. Equally low flows in the lower half of the Mississippi River had occurred in the 1930s and mid 1950s, but the tow and barge

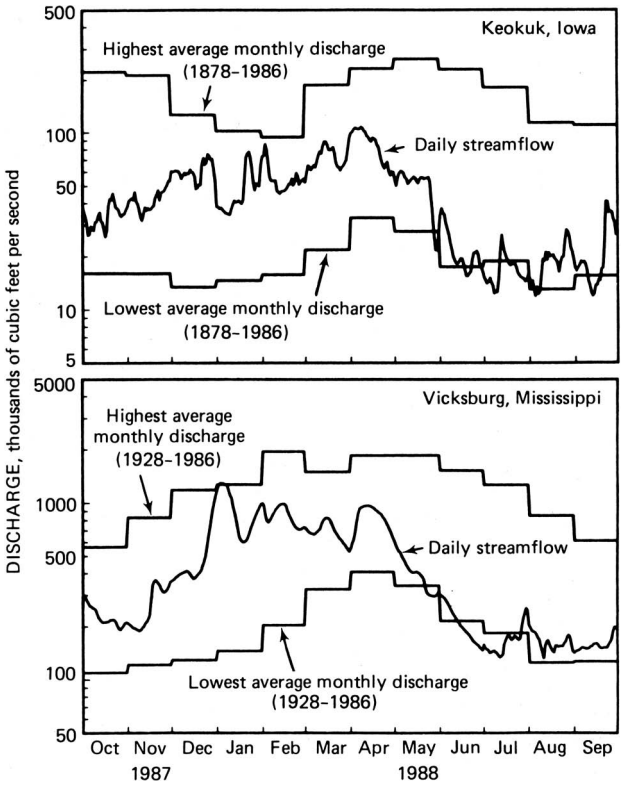

FIG. 5. Daily streamflows on the Upper (Keokuk) and Lower (Vicksburg) Mississippi River during October 1987–September 1988 (1988 Water Year).

industry was an infant in the 1930s and just beginning to develop in the 1950s (Koellner 1988). For example, the 9-ft (2.7 m) navigation channelization of the Mississippi River (south of Minneapolis) was not completed until 1939. By 1950 the Mississippi system carried 8 million tons (7.2 metric tons) of commodities; but in 1980 this had increased to 100 million tons (90.9 metric tons). Hence, the 1988 low flows were the first this now major industry had encountered since becoming a significant part of the bulk commodity transportation network of the central United States. This first-time experience also faced COE, at least in terms of its magnitude of severity.

The first response was *dredging* of blocked river reaches. COE did the dredging in 11 blocked areas, but the three primary trouble areas were near Cairo on the Ohio River and along the Mississippi River (one site near Memphis and one near Greenville, Mississippi). Dredging activities at any one blockage typically involved several days of constant activity by several dredges. For example, a 2100-ft channel (630 m), 300 ft wide (90 m), and 11 ft (3.3 m) deep was dredged near Cairo between 14 and 17 June. Thirteen dredges were operating around the clock during the last 2 weeks of June and throughout July to maintain navigable channels along the Mississippi (Helpa 1988). COE was responsible for this response. Seven dredges were still in use in late October as river flows continued to be well below average.

The second area of response related to *reduced tows and barge loads*. On 23 June 1988, the U.S. Coast Guard issued an order to reduce the number of barges per tow on the Mississippi and Ohio rivers. Thirty to 40 barges per tow are a typical load for a tow south of Cairo, but the order set the maximum number at 20 per tow. Subsequently, the Coast Guard issued tonnage restrictions for barges (*News-Gazette* 9 July 1988). The result of these actions from late June through August was fewer barge movements with lesser loads, and greatly reduced shipping of bulk commodities up and down the Mississippi and Ohio rivers. This had very adverse economic effects on barge and tow companies, river ports, shippers, and producers. The Coast Guard lifted its tow size restrictions in September, but issued advisories recommending that tow sizes and loads continue to be reduced during the fall of 1988.

A third response was the *careful management of the water releases* from the lock and dam systems along the Missouri, upper Mississippi, and Ohio rivers. The COE balanced the water releases from each river to try to release as much water as possible to the lower reaches, but they also had to meet the water requirements in the controlled reaches of the rivers.

A fourth response was *increased use of the Tennessee-Tombigbee Waterway*, a system built and operated by COE. It parallels the Mississippi from Cairo to New Orleans. It is not as favored as the Mississippi because the speed and direction of the river currents do not aid southward movement of loaded barges as much as the flow of the Mississippi does; hence, it is more costly for barge movement. Traffic began to be diverted to this waterway in June, and the cargoes on barges on the waterway increased to 2.1 million tons (1.82 million metric tons) in July 1988, compared with 300 000 tons (272 000 metric tons) in July 1987 (Helpa 1988).

Another response to the negative effects on the barge and tow companies was an *increase in barge shipping rates*. During 9–16 June 1988, barge shipping rates were raised from $5 a ton (909 kg) for bulk commodities to $14 or $15 per ton (909 kg), due to reduced tonnage on barges and the longer travel times on the rivers (*Farm Week*, 20 June 1988). This increase made shipping by other means (Great Lakes ships and railroads) more competitive with barges, which is unusual. It is notable that the towing and barge industry chose not to seek financial aid or relief from the federal government (*News-Gazette* 1 August 1988).

Another major area of response was use of *alternative means of transportation*. The most immediate

of the two sources of alternative transportation were railroads that served the same commodity source areas and connected local producers to the ports along the major rivers. The ports and shipping industry operating on the Great Lakes became an alternative means of moving exportable commodities such as grain out of the Midwest. The railroads moved the grain to the ports of the Great Lakes instead of to New Orleans.

The Illinois Central Railroad, which is a north-south system connecting the Great Lakes at Chicago with New Orleans (and thus is parallel to the heavily used Illinois River–Mississippi River barge system and its major ports), became a major factor in the response to the barge problems. The Illinois Central Railroad (ICRR) and the tow-barge industry are major competitors. The railroad continually monitors barge rates as well as present and future river conditions. In March 1988, a COE spokesman reported that river levels could drop to a crisis level if spring precipitation did not dramatically increase (G. F. Mohan, senior vice president, ICRR, letter to the author, 7 November 1988). This led ICRR to seek predictions of future rainfall. In April they employed a firm to provide them with an outlook for spring precipitation (*Chicago Sun Times* 24 July 1988). In April, these analysts predicted the forthcoming spring drought, and the railroad's management team concluded that there would be very low river flows with severe impacts on barge shipment (G. F. Mohan, senior vice president, ICRR, letter to the author, 7 November 1988).

The railroad decided to stockpile large (100-ton, or 90.9 metric tons) hopper cars which could be used to haul extra coal and/or grain. Their belief in the predicted problem led to a decision in early May 1988 to lease hopper cars from other railroads, and by 1 June more than 521 hopper cars had been leased to supplement their fleet of 4000. The leasing cost was $700,000 (*Chicago Tribune* 2 August 1988).

The railroads charged $8–12 per ton (909 kg) to carry grain in 1988, and gained a competitive advantage over the barges when they increased prices to $14–15 per ton. The ICRR normally loses money during low summer traffic in coal and grains; however, the great increase in railroad shipping during the summer of 1988 led the railroad to its first profit for July since 1851. In July 1988 ICRR hauled 9201 grain cars to New Orleans, 4801 more than in July 1987; they carried 12 972 cars of coal in July 1988, which was 4361 more than 1987 (*News-Gazette* 3 August 1988). The beneficial experience was sufficient to cause the railroad to reassess its competitive stature with barges and to look to future challenges to the barge industry. ICRR's advisors issued long-range outlooks for continued dry conditions in 1989, with low flows occuring during the winter of 1988–89 with the potential for more easily frozen shallow rivers and reduced barge traffic (Peterson 1988). This led the railroad to retain the leased hopper cars through the spring of 1989 (*News-Gazette* 3 August 1988).

Great Lakes shippers and midwestern ports also responded to the barge problems. They too became economically competitive due to the uncertainty over barges, the higher barge prices, and the more expensive shipping costs related to moving grain to New Orleans. A spokesman for the Illinois International Port at Chicago on 11 July 1988, stated, "The drought is a windfall" (*Chicago Sun Times* 24 July 1988). By 24 July 1988, that port had loaded three ships with grain that would have normally gone down the Mississippi River to New Orleans, and these three ships carried $1.87 million in cargo. The income to the port was $0.5 million for these three ships. By mid-August, the shipping on the St. Lawrence Seaway had increase 7% above average due to diverted river traffic shipments.

7. Increased water diversion: A potential response

A response that had technical feasibility but a high potential for policy problems was proposed by Illinois, a major grain-producing state. The plan originated in early June 1988 as the low flows and the subsequent barge problems became severe. According to newspaper accounts, the Metropolitan Sanitary District of Greater Chicago (MSDGC) suggested the concept of an increased water diversion from Lake Michigan at Chicago with the increased flow moving down the Illinois River to enter the Mississippi near St. Louis (*Windsor Star* 19 July 1988). The plan was to increase the diversion, which is limited by U.S. Supreme Court decree from 3200 cfs (89.6 m^3 sec^{-1}) to 10 000 cfs (280 m^3 sec^{-1}) for a 100-day period based on an emergency declaration by President Reagan or the court; this is required since the diversion level is set by federal mandates (Kudrna et al. 1980).

This proposal was not without precedent; an earlier one added diversion to increase Mississippi River flows occurred during the severe 1953–56 drought. Then, the MSDGC first allowed an increased diversion (up to the limit of the U.S. Supreme Court's annual limit) for 10 days in October 1956. The Supreme Court approved in December 1956 a request from Illinois for an emergency increase in the diversion (Illinois sought 10 000 cfs for 100 days, the same as in 1988) but modified it to 8500 cfs (238 m^3 sec^{-1}) for 76 days.

At a meeting of state officials on 22 June 1988, the Illinois director of agriculture reportedly proposed

that COE be directed to channel additional water through the Illinois River to the Mississippi to aid in the barge handling (*News-Gazette* 23 June 1988). On 23 June 1988, Governor James Thompson of Illinois proposed the plan to triple the diversion during the National Governor's Association Drought Conference in Chicago (*Chicago Tribune* 24 June 1988). The plan asked COE to increase the diversion to 10 000 cfs (280 m^3 sec^{-1}). This proposed diversion was predicted to raise the Mississippi River level at St. Louis by 1 ft (30 cm) and that at Memphis by 6 in. (15 cm), and, in turn, to lower Lake Michigan by about 1 in. (2.5 cm). The plan was technically feasible; why not proceed?

The negative aspects of the proposed plan rested on the long history of conflicts between Illinois and the other lake states (and Canada indirectly) over the amount of diversion at Chicago (Kudrna et al. 1980). The current allowable diversion level (3200 cfs, or 89.6 m^3 sec^{-1}) is fixed by U.S. Supreme Court decisions. Hence, it would be extremely difficult to get the court to change the diversion amount. Illinois proponents of the plan apparently hoped than an increase could be approved as an emergency measure. When proposed at the 23 June 1988 National Governor's Conference, the governor of North Dakota indicated the plan was inappropriate to raise at the conference (*Chicago Tribune* 24 June 1988). Most other lake state governors objected strenuously. Operators of major ports around Lake Michigan were incensed by the proposal (*News-Gazette* 9 July 1988). *Farm Week* (18 July 1988) called the plan a "political hot potato." The director of the Seaway Port Authority in Duluth (which ships wheat from the Great Plains) was one of many who spoke strongly against the plan. He was quoted as saying, "Every inch of water in the Great Lakes is essential to navigation and reacting to the proposal favorably would create a litigation nightmare" (*News-Gazette* 9 July 1988).

Lake interests were aware and concerned over a critical condition that the Illinois proposal appeared to ignore (*Chicago Sun Times* 26 July 1988). At that time, the level of Lake Superior was 8 in. (3.1 cm) below its long-term average, having fallen 1.3 ft (0.39 m) from record high levels in less than 2 yr. The other Great Lakes had also fallen precipitously from their record high levels achieved during 1985 and 1986. At the time of the diversion proposal, for example, the level of Lakes Michigan and Huron (from whence the proposed increased diversion would occur) had fallen 2.6 ft (0.78 m) from the record high levels that persisted until January 1987 (Changnon 1987), and the level was beginning in July to go below its long-term seasonal average. Hence, the Illinois proposal was also made in the face of a rapid decrease in basin water supplies. Hydrologic studies based on various historical climate scenarios indicated that it would take 4 yr or longer for the level of Lake Michigan to fall from its record heights of 1986 to average levels (Hartmann 1988), but in less than 18 months (January 1987–June 1988) the lake was already below its average level as a result of the 1987–88 drought. It would appear that hydroclimatological information about this rapid decline either was unavailable or unknown to Illinois decision makers. It also indicates the problem that water managers face in operating a large and complex watershed system that has limited flexibility.

The ensuing political controversy included the fact that governors of four states (Wisconsin, Michigan, Indiana, and Ohio) threatened court action. Illinois citizens living along the Illinois River objected, fearing that the tripled diversion would lead to flooding of valuable lowlands (*News-Gazette* 9 July 1988).

On 8 July 1988, 13 senators (from Illinois and several southern states) asked President Reagan to authorize the emergency diversion request (*News-Gazette* 9 July 1988). Other senators (Ohio, New York) strongly opposed this, and President Reagan did not respond. COE studied the Illinois plan from June 24 to mid-July, trying to decide whether to begin the complex process of seeking permission for the diversion from the Supreme Court.

During this deliberation, the Canadian government also reacted. Environment Minister McMillan was quoted as saying on 7 July 1988 the Illinois plan was an "insane idea" (*News-Gazette* 9 July 1988). Canadian newspapers carried articles of outrage. The Canadian ambassador to the United States delivered a formal note to the U.S. State Department on 9 July 1988 stating "Canada was unalterably opposed to the diversion" (*News-Gazette* 9 July 1988). The diversion plan and its opposition had thus become an international controversy, as well as a state and national controversy. Illinois officials admitted in early July that the strong opposition hurt their chances of winning approval of their request (*News-Gazette* 9 July 1988). The assistant secretary of the Army for Civil Works on 14 July 1988 declined the Illinois request indicating "there was no reason now or in the foreseeable future to increase the amount of water diverted out of Lake Michigan to enhance navigation on the Mississippi River" (Interagency Drought Policy Committee 1988). The COE analysis concluded there would be little improvement in channel conditions with a diversion of 10 000 cfs. The news media reported that the decision was based on an engineering analysis showing the added water was not needed and that the decision was not politically motivated (*Farm Week* 18 July 1988).

8. Winners and losers

The drought and low flows leading to the loss of barge shipping produced a series of losers. Identifiable in the list of losers are producers such as the farmers, petroleum companies, manufacturers of agricultural chemicals, and coal companies who found it more costly to ship their products. Eventually the cost of shipping the bulk commodities either doubled or tripled, depending on how and where shipments were made. The effect was doubly damaging to midwestern farmers who were already experiencing a severe drought with consequent crop yield reductions of 50% to 70% of expectations. This followed several years of low crop prices caused by weather-induced high yields and production abundance coupled with a weak export demand.

Obviously, the shippers and the barge and tow industry were severely impacted economically. They raised shipping rates and the total amount of shipping decreased about 20%. A study indicated that the losses to the barge and tow industry from 15 June to 30 September 1988 would amount to $200 million (*Chicago Tribune* 2 August 1988) or 20% of their net annual income. The cost of the additional dredging done by COE has not been estimated because it is seen as a part of their operational capability requiring no added staff or facilities.

Other losers were the consumers of the commodities shipped. Utilities, the main users of the coal shipped on barges, were paying higher prices for their coal, whether it came by barges or railroads. There was speculation that these additional costs might be passed on to the consumer as requests for higher rates in 1989 (*Chicago Tribune* 2 August 1988). Time will tell. Most ports along the major rivers, including the Mississippi, Illinois, and Ohio rivers, suffered losses, having shipments diverted to railroads, and to the Great Lakes ports. The President's Interagency Drought Policy Committee (1988) concluded that the "economic costs due to less efficient barge transportation may reach $1 billion." Another area of loss, although not studied, was the environment. The low flows caused fish kills, damage to wetlands along the rivers, and the salt intrusion up the lower Mississippi River past New Orleans (Helpa 1988).

The major winners economically were the alternative shippers. As noted, the railroads collocated along the river systems were major beneficiaries. The ICRR doubled its average hauling of grains and had a 35% increase in the hauling of coal, thus making profits in the summer well in excess of that of any past year. Great Lakes shipping companies and ports were also winners from the changed patterns of transportation of exportable bulk commodities.

9. Significance and implications for the future

This unique set of drought impacts and responses, including the equally interesting proposed diversion response, offers several lessons about droughts and their management.

First, and from a climatological standpoint, ICRR's use of a climate prediction in a major economic decision (with a very positive outcome) favorably impressed management, but ICRR leaders recognize that they took a risk. Their decision to retain the lease of the hopper cars through the 1988/89 winter based on other climate trend outlooks may not prove as valuable. Changnon and Vonnahme (1986) earlier showed how climate predictions could be used effectively to hedge in a water management decision during drought. Conversely, without the use of climate predictions, neither the COE officials nor barge companies anticipated the intensification of the drought and the concomitant river flow problems. Earlier anticipation in the April–May period could have led to different tactics to react earlier (i.e., added dredging) and in more cost-effective ways, such as an earlier diversion of traffic onto the Tennessee-Tombigbee Waterway.

Second, it appears that near real-time hydroclimatic information about the severity of the drought and, in particular, the serious decreases of the Great Lakes water supplies and levels, was not involved in the decisions to propose an increased diversion. Thus, too few understood soon enough that the 1988 drought was developing and would be an extremely severe event.

The controversy over the increased diversion provides lessons for the future. The proposal was feasible hydrologically and technically, but politically flawed. The diversion amount had been contested for 60 yr (Kudrna et al. 1980). The opposition to the added diversion saw the granting of a changed diversion as a precedent-setting event, more than a problem resulting from a loss of water. Interestingly, the proposal came only 3 yr after all the governors of the lake states had agreed in the Great Lakes Charter (1985) to protect the Great Lakes water supplies. Of further interest is the fact that Illinois did not propose to increase the diversion during the record-high lake levels of 1985–86 to help relieve the shoreline damages (Changnon 1987).

The 1988 controversy also reflects the great societal sensitivity to the water resources of the Great Lakes and elsewhere throughout the humid eastern United States (Changnon 1987). It illustrates the high likelihood for future controversies if the climate shifts to the more arid regime suggested by some CO_2 scen-

arios. The policy makers and scientists concerned about the greenhouse effect and a potential future climate change that entails a drier climate for the Midwest and the Great Lakes Basin, were impressed by the controversy as an indication of the future problems an altered climate may bring (*Chicago Tribune*, 24 June 1988). The severe drought and the impacts to the barge industry, plus the Great Lakes diversion controversy, helped bring the issue to the forefront of public consciousness (*Time* 4 July 1988). Prolonged drier conditions resulting from a changed climate and the inherent lower river flows in the central United States would have disastrous effects on the barge industry (Koellner 1988). New transportation patterns would evolve, and favor railroads.

The timing of the controversial diversion proposal raises questions of who was for it and why? Those for it apparently included MSDGC, the governor of Illinois, certain members of congress, barge firms, certain grain and coal shippers, and the American Waterways Operators (*News-Gazette* 9 July 1988). However, the American Waterways Operators shifted to an antidiversion position in late July 1988 (*News-Gazette*, 1 August 1988), stating that July conditions were not serious enough to warrant diversion.

Recognition that the proposal would certainly engender great opposition from the Canadians, other lake states, and many Illinois citizens, raises the question, Why did Illinois offer this plan in the face of such likely and strong opposition, and in a situation where the proposal's acceptance appeared unlikely? Certain speculations can be offered. One possibility is the lack of knowledge about the perceived seriousness of the water supply problem in the Great Lakes and the rapid rate of decline in lake levels related to the drought. This situation helped produce the negative attitudes of the other lake states and Canada.

A second possibility was that the plan was politically expedient. One view is that it was offered as a response to wealthy Illinois interests in the barging and agricultural products areas. One newspaper report (*News-Gazette* 9 July 1988) indicated that a major contributor to the Illinois Governor's campaign fund, the chief executive officer of Arthur Daniel Midlands (ADM), had urged this increased diversion (ADM owns one of the larger barge fleets and was experiencing losses). ADM subsequently purchased 14% of the ICRR stock in January 1989, as a move to hedge against future problems.

Another possibility, based on an engineering standpoint and a historical perspective, was that the plan seemed feasible and would have had only a slight effect on the net basin supply and the level of Lake Michigan; this reasoning could lead to a belief there would be only minor objections. Furthermore, the granting of permission to a similar Illinois proposal in 1956 to enhance the diversion for 76 days may have been a factor in deciding to propose a similar diversion in 1988. However, since 1956, there were important events that greatly affected the 1988 decision. Controversies between Illinois and other lake states over the Illinois diversion led to two U.S. Supreme Court decisions, one issued in 1966 that set the diversion at 3200 cfs (89.6 m^3 sec^{-1}) by 1967. The second one in 1979 redefined the diversion accounting processes, and allowed for a 20% increase in diversion in any 2-yr period of severely low precipitation (Changnon 1981). These circumstances could have suggested acceptance for the proposal, but the rapidly declining lake levels in June 1988, coupled with the new water protectionist theme set by the Great Lakes Charter (1985), and the 1967 and 1979 controversies that went to the U.S. Supreme Court, argued against its approval.

Regardless of the reasons, the plan was rejected by COE. The proposal and its controversy have implications for regional attitudes toward the water resources of the Great Lakes Basin. It may serve as a harbinger of the type of political controversies that will result from any type of proposed diversion increase for any location in the basin, particularly given the existence of drier climate scenarios of the central United States (Koellner 1988).

The impacts of and responses to the drought also reveal a lack of planning by industry and the relevant public sector entities. Crisis management, rather than strategic planning, was widespread. Drought contingency planning by COE in the past had been on a project-by-project basis, done for each lock and dam. When the 1988 drought developed, COE was developing a regional drought plan for the southeast United States. There was no basin scale-plan for the Mississippi River Basin. Helpa (1988) reported that in the fall of 1988 COE was anticipating future low flows (and related added dredging) during the winter of 1988/89. COE is also now asking Congress for funding to conduct drought-related planning studies. COE is also now developing drought contingency plans for all areas under their management or control. While these are encouraging developments, many losses could have been averted in this situation had contingency plans existed along with better hydrometeorological monitoring and predictions.

Another area of adjustment concerns possible shifts in shipping patterns and costs. ICRR reacted to the enhanced 1988 shipping and their resulting economic advantages, and reportedly began planning for permanent future changes in shipping (*News-Gazette* 3 August 1988). Advisors to ICRR offered long-range predictions of continuing drought (and low river flows) persisting for another 5–10 yr based on

the outlooks of two private forecasters, the climate outlooks of scientists at Iowa State University and the National Center for Atmospheric Research (NCAR), and the widely circulated 1988 statements by the National Aeronautics and Space Administration (NASA) and NCAR scientists about how the greenhouse effect will soon lead to warmer and drier conditions. They also used such outlooks to conclude that low flows would occur during the winter of 1988/89 with resulting greater ice coverage and ice jams, and reduced barge traffic (Peterson 1988).

The outlook for drier conditions, including possible future changes due to the greenhouse effect, has caused regional railroads and Great Lakes shippers to reassess their rates for bulk commodities with efforts to seek a greater competitive advantage (*News-Gazette* 3 August 1988). This could lead to adjustments by the shippers of grain, coal, and other bulk commodities. However, barge leaders saw no permanent loss of business from the 1988 drought, despite the fact that even in October 1988 barge rates were still 8–10% higher than in 1987 (President's Interagency Drought Policy Committee 1988). A campaign to compete more widely for bulk commodity shipments in the Midwest is occurring as a result of the 1988 drought.

The implications of this event for climatologists include recognition of the value of rapid integration of weather information, near real-time interpretation of the significance of its impacts on the physical environment, and the continuing issuance of drought status reports. The ICRR case on one hand also illustrates the value that can be derived by the use of probabilistic-based seasonal predictions. On the other hand, it also illustrates how various sources of information about future climates can be combined to derive a singular long-term outlook that would be considered highly questionable by most of the scientific community. Regardless, the great difference in the reactions to the waterways problems (massive dredging after blockages developed in June) and the planned responses of ICRR (the decision to lease hopper cars based on April predictions) underscores the value of long-range climate predictions and the wisdom in how to use them, as previously demonstrated (Changnon and Hsu 1985).

Acknowledgments. This research has been conducted as part of the applied studies program of the Midwestern Climate Center, supported by National Oceanic and Atmospheric Administration/NCPO funds (Grant COMM NA8711-D-CP119) and State of Illinois funds. The assistance of Michael Helpa of COE was helpful. The review and useful comments of Peter J. Lamb are deeply appreciated.

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