IMPLICATIONS OF MINIMUM SUMMER WATER RELEASES FROM GAVINS POINT FOR POWER PLANTS

FAPRI-UMC Report #11-04
September 23, 2004

Prepared by the Food and Agricultural Policy Research Institute

101 Park DeVille Drive, Suite E
Columbia, MO 65201
573-882-3576
www.fapri.missouri.edu

FAPRI
At the University of Missouri
Food and Agricultural
Policy Research Institute

College of
Agriculture
Food and
Natural
Resources

blank page

IMPLICATIONS OF MINIMUM SUMMER WATER RELEASES FROM GAVINS POINT FOR POWER PLANTS

By John R. Kruse, Abner Womack, and Seth Meyer
FAPRI – University of Missouri-Columbia

The purpose of this study is to evaluate the potential impacts on power plants of minimum water releases from Gavins Point to the Missouri River as presented in the U.S. Army Corp of Engineers' (Corps) Master Manual (Corps 2004). The Corps regulates the flow of the Missouri River to support navigation and control flooding by controlling water releases from Gavins Point, the lowest of the six reservoirs. The system is designed to support navigation by increasing water releases during the summer when tributary inflows below Gavins point seasonally decline. However, there must be sufficient water in the upper six reservoirs to support increased summer flows. Under the Master Manual (U.S. Army Corp of Engineers) , the minimum level of water-in-storage in these upper reservoirs as of March 15 each year is required to be 31 million acre feet. Under Senate bill S.2804 (appropriations for the Department of Interior), the minimum water-in-storage would be increased to 40 million acre feet. The Corp reports that as of the end of August 2004 water storage in the upper reservoirs was 36.6 million acre feet. If Senate bill S.2804 is enacted, the implication is minimum water releases from Gavins Point in 2005.

Under the Master Manual, the schedule of minimum water releases from Gavins Point follows the following guidelines:

December – February	12,000 cfs
March – April	9,000 cfs

May – August	18,000 cfs
September – November	9,000 cfs

This study considers the impact of these minimum flows over the June through September period, when the thermal regulations may be most binding to the power plants. Low fall and winter flows could also have significant impacts on power generation, but those impacts are not included in this paper.

Fifteen of the eighteen coal and nuclear plants below Gavins Point that use the Missouri River for cooling water are evaluated in this study. The three other power plants, operated by Mid American Energy, declined to participate in the study and are not included in the estimated impacts. The fifteen plants studied are operated by eight power companies who have reviewed the results of this analysis and found the individual plant results to be representative, possibly conservative, of the expected impacts for their power company. Any errors in the individual plant analysis or aggregation of the plant results are the responsibility of FAPRI.

Power Plants on the River

The 18 power plants on the Missouri River have a total summer generation capacity of 11,253.8 megawatts and represent about 25 percent of the total power generation capacity in Missouri, Kansas, Nebraska, and Iowa (Kruse and Womack 2004). As base load units, these plants typically produce about 36 percent of the summer power because they are the most inexpensive plants to operate.

Sources of Power Plant Impacts

Over the summer months, power plants are primarily impacted by river flow rate and water temperature. It is important to note that power plants are not uniformly affected by flow rate and water temperature. Lower flow rates will reduce the amount of water available for compliance with thermal effluent limitations and will generally result in higher ambient river temperatures. Extreme low flows may also result in water accessibility problems for individual power plants. Water access problems occur when a plant cannot pump sufficient quantities of water to support full operation. Water access problems may force a plant to reduce load or completely shut down.

Each plant has a water intake positioned to withdraw water from the river. These water intakes are usually very large, fixed structures. As the flow rate falls, the water intake may not be able to pull enough water into the power plant to maintain cooling, causing the plant to de-rate from its summer capacity rating. The affected power plant has a limited ability to compensate for intake problems since the pump suction elevation is fixed within the intake structure. Through the use of auxiliary pumps and other operations, low flows lasting only a few days can sometimes be compensated for, but usually not without damage to pumps and/or other equipment. Not all power plants on the Missouri River are affected by water intake problems.

Low river flows also affect the efficiency with which plants operate. The first efficiency loss is associated with the physical movement of the water from the river to the plant. When the river flow is low it takes more energy to pump the water into the power plant. Low river flows result in increased accumulation of debris around the screens protecting the intake area, which also reduces efficiency.

River water temperature can impact power plants significantly due to the thermal regulations. Each plant has a different set of regulations depending on its state and the specific profile of the Missouri River at its location. Under the Clean Water Act, thermal regulations were initially tied to the temperature of the water released into a mixing zone of the river. Occasionally, states established more rigorous regulations by shrinking the mixing zone area, which effectively reduced permitted thermal releases. Power plants can apply for a "variance" from the thermal regulation if they can show that the river ecosystem is not affected by exceeding their thermal regulations. Some of the power plants are now operating with a variance from their original regulations. Under alternative water control plans that include lower summer river flows, it would be more difficult for the power plants to show that the river ecosystem is unaffected and the power plants may be unable to obtain a variance in the future under a low flow water control plan.

Simulation of Missouri River Flows

In order to accommodate analysis of alternative water control plans, FAPRI developed a flow model for the Missouri River which simulates downstream flows at specific locations based on releases from the Gavins Point Dam using actual historical data on flows at specific locations and tributary inflows. The model was matched against simulation results for alternative water control plans from the Corps and replicated their model's results within one to two percent. The flow model was used to derive the Corps simulated inflows under the GP2021 and PA scenarios (Kruse and Womack 2004). This was necessary in order to use the same assumption the Corps made about inflows adjusted for the 1987 level of depletions under the GP2021 and PA scenarios. The resulting implied inflows were virtually identical for the GP2021 and PA scenarios, further validating the FAPRI model's consistency with the Corps' flow model.

The minimum releases from Gavins Point were then simulated using the FAPRI flow model and the derived inflows from the GP2021 and PA scenarios. This was done to insure a consistent assumption regarding the level of water depletions along the river back through time. For example, in 1987 water depletions for irrigation and municipal water facilities are considerably higher than they were in 1898. In order to accurately simulate the variance in inflows, one must take the actual inflows adjusted for current levels of depletion.

In order to generate a distribution of flows, the minimum releases from Gavins Point were simulated for the 1898 to 1997 period over the months of June through September. Water releases from Gavins Point were simulated at 18,000 cfs for the June – August period, and 9,000 cfs for September. This produced daily flows at Sioux City, IA; Omaha, NE; Nebraska City, NE; Rulo, NE; St. Joseph, MO; Kansas City, MO; Waverly, MO; Boonville, MO; Hermann, MO; and St. Louis, MO for 1898 to 1997. These flow levels were then combined with daily air temperature data and tributary inflow data to estimate average river water temperature. Many of the river water temperature equations that were estimated using data from the 1990s that exhibited maximum river temperatures in the high 80s or low 90s in degrees Fahrenheit. Combinations of low flows and high air temperature generated simulated river temperatures above these levels in a few cases. However, these high river water temperatures had no impact on the analysis as the affected power plants were fully de-rated before these extreme temperatures were generated.

Tables 1 through 5 present the probability distributions of the flows at five primary locations along the Missouri River.

Table 1. Percentage of Missouri River flows at Omaha, NE by flow rate under simulation of minimum releases from Gavins Point, 1898 to 1997*

Flow Rate, cfs	Jun	July	Aug	Sept
< 15000	0.3%	0.5%	0.0%	77.7%
15000 to 16000	1.0%	2.3%	0.6%	3.9%
16000 to 17000	2.4%	7.7%	3.6%	2.5%
17000 to 18000	6.6%	8.2%	10.9%	3.1%
18000 to 19000	8.3%	10.1%	13.1%	2.7%
19000 to 20000	8.0%	8.7%	15.5%	1.8%
20000 to 21000	7.8%	9.5%	16.5%	1.8%
21000 to 22000	6.7%	8.4%	10.6%	1.3%
22000 to 23000	5.6%	5.5%	7.9%	1.3%
23000 to 24000	4.6%	5.3%	5.1%	0.9%
24000 to 25000	5.1%	5.9%	3.5%	0.7%
25000 to 26000	6.0%	4.5%	2.6%	0.4%
26000 to 27000	5.0%	3.6%	1.6%	0.3%
27000 to 28000	4.3%	2.7%	1.7%	0.4%
28000 to 29000	2.9%	2.2%	2.1%	0.2%
> 30000	25.4%	14.9%	4.6%	1.0%

* Releases from Gavins Point simulated as 18,000 cfs June - August and, 9,000 cfs in September.

Table 2. Percentage of Missouri River flows at Nebraska City, NE by flow rate under simulation of minimum releases from Gavins Point, 1898 to 1997*

Flow Rate, cfs	Jun	July	Aug	Sept
< 15000	1.9%	3.6%	0.7%	50.2%
15000 to 16000	1.5%	3.2%	1.6%	6.4%
16000 to 17000	2.1%	5.1%	3.5%	5.1%
17000 to 18000	2.5%	5.2%	6.9%	4.2%
18000 to 19000	2.2%	5.7%	7.5%	4.0%
19000 to 20000	2.6%	4.3%	9.9%	3.5%
20000 to 21000	3.6%	6.6%	11.9%	3.5%
21000 to 22000	5.0%	5.6%	8.8%	3.7%
22000 to 23000	4.3%	5.5%	6.7%	3.2%
23000 to 24000	3.7%	3.5%	5.2%	2.7%
24000 to 25000	3.3%	3.1%	5.1%	2.0%
25000 to 26000	3.3%	3.2%	4.2%	1.6%
26000 to 27000	3.2%	3.5%	3.5%	1.5%
27000 to 28000	3.2%	2.1%	2.8%	1.0%
28000 to 29000	3.0%	2.4%	3.2%	0.9%
> 30000	54.7%	37.3%	18.7%	6.5%

* Releases from Gavins Point simulated as 18,000 cfs June - August and, 9,000 cfs in September.

Table 3. Percentage of Missouri River flows at St. Joseph, MO by flow rate under simulation of minimum releases from Gavins Point, 1898 to 1997*

Flow Rate, cfs	Jun	July	Aug	Sept
< 15000	1.0%	1.9%	0.6%	33.4%
15000 to 16000	0.8%	2.3%	0.9%	6.1%
16000 to 17000	1.1%	3.4%	2.1%	4.5%
17000 to 18000	1.3%	3.6%	3.9%	4.1%
18000 to 19000	1.9%	3.4%	5.1%	4.5%
19000 to 20000	2.2%	3.4%	5.4%	4.2%
20000 to 21000	2.4%	4.5%	6.6%	4.0%
21000 to 22000	2.8%	3.7%	8.3%	3.8%
22000 to 23000	2.8%	3.9%	7.3%	3.7%
23000 to 24000	2.7%	3.9%	5.2%	3.5%
24000 to 25000	3.3%	4.1%	4.9%	3.3%
25000 to 26000	2.9%	3.3%	4.6%	2.7%
26000 to 27000	3.0%	3.1%	3.7%	2.4%
27000 to 28000	2.7%	2.5%	3.7%	1.8%
28000 to 29000	2.9%	2.5%	3.6%	1.9%
> 30000	66.2%	50.4%	34.2%	16.1%

* Releases from Gavins Point simulated as 18,000 cfs June - August and, 9,000 cfs in September.

Table 4. Percentage of Missouri River flows at Kansas City, MO by flow rate under simulation of minimum releases from Gavins Point, 1898 to 1997*

Flow Rate, cfs	Jun	July	Aug	Sept
< 15000	1.5%	4.4%	1.9%	21.7%
15000 to 16000	1.0%	2.4%	1.4%	4.2%
16000 to 17000	0.7%	2.3%	2.2%	3.3%
17000 to 18000	0.9%	2.0%	4.0%	3.5%
18000 to 19000	1.3%	2.6%	3.9%	3.3%
19000 to 20000	1.6%	2.6%	3.3%	2.7%
20000 to 21000	1.7%	2.5%	4.7%	3.8%
21000 to 22000	1.1%	2.4%	5.0%	3.4%
22000 to 23000	1.8%	2.3%	5.2%	3.3%
23000 to 24000	1.4%	2.0%	4.0%	2.7%
24000 to 25000	1.6%	2.9%	4.1%	3.1%
25000 to 26000	1.3%	2.5%	3.1%	2.6%
26000 to 27000	1.7%	2.4%	3.0%	2.6%
27000 to 28000	1.2%	2.0%	2.2%	2.7%
28000 to 29000	1.5%	2.3%	2.5%	3.1%
> 30000	79.7%	62.3%	49.5%	34.0%

* Releases from Gavins Point simulated as 18,000 cfs June - August and, 9,000 cfs in September.

Table 5. Percentage of Missouri River flows at Hermann, MO by flow rate under simulation of minimum releases from Gavins Point, 1898 to 1997*

Flow Rate, cfs	Jun	July	Aug	Sept
< 15000	0.6%	0.2%	0.0%	6.4%
15000 to 16000	0.1%	0.7%	0.5%	2.4%
16000 to 17000	0.2%	0.7%	0.4%	1.9%
17000 to 18000	0.5%	1.2%	0.9%	2.6%
18000 to 19000	0.6%	1.8%	1.6%	2.4%
19000 to 20000	0.6%	1.0%	2.1%	1.9%
20000 to 21000	0.7%	1.4%	2.0%	1.4%
21000 to 22000	0.5%	1.4%	1.9%	2.1%
22000 to 23000	0.7%	1.8%	2.3%	1.8%
23000 to 24000	0.8%	1.8%	2.8%	1.8%
24000 to 25000	0.6%	1.7%	2.8%	2.2%
25000 to 26000	0.7%	1.1%	2.4%	1.7%
26000 to 27000	0.6%	1.3%	2.7%	2.3%
27000 to 28000	0.8%	1.4%	2.3%	2.1%
28000 to 29000	0.6%	1.6%	3.0%	2.2%
> 30000	91.4%	81.0%	72.2%	64.9%

* Releases from Gavins Point simulated as 18,000 cfs June - August and, 9,000 cfs in September.

Economic Analysis

Each power company was contacted to re-verify its thermal and intake restrictions and some changes were made. Due to the sensitive nature of this information, FAPRI agreed to keep each plant's information confidential.

By using the flow and temperature requirements provided by each plant, the number of affected days and average de-rating for each month during the summer was calculated. Based on the capacity of the power plant and the average de-rating, the number of megawatt hours of reduced power production was calculated for each month. Each non-holiday weekday was assumed to have 16 hours of peak power demand and 8 hours of off-peak power demand, with different replacement power prices for peak and off-peak hours. Holidays and weekends were also assumed to have 16 hours of peak power demand and 8 hours of off-peak demand with different power prices from the grid for each period. For each month the number of hours of weekday on peak, holiday and weekend on peak, and off peak hours was calculated. The total number of megawatt hours lost to de-ratings was then distributed to each of the three categories based on the share per month. The number of megawatt hours of de-rating in each category was then multiplied by the purchase price of power from the grid to calculate a gross economic damage. Since the power plant is not consuming fuel during the de-rate period, the fuel cost savings are then subtracted from the gross economic damage to determine a net economic damage.

The economic impacts in this study have been generalized to reflect consistent assumptions regarding the cost of replacement energy across all plants. Based on the power plant surveys and discussions with power industry experts, replacement energy prices on the grid were assumed to increase when power demand from all river power plants increases simultaneously. Table 6 presents the grid prices used in this study.

Table 6. Average power prices

	June	July	August	September
Megawatts Demanded	*Dollars Per Megawatt*			
Weekday On-Peak				
0 - 500 Megawatts	42	49	49	39
500 - 1000 Megawatts	45	52	52	42
1000 - 2000 Megawatts	54	62	62	50
2000 - 3000 Megawatts	65	74	74	60
3000 - 4000 Megawatts	78	89	89	72
4000 - 5000 Megawatts	94	107	107	86
5000 - 12,000 Megawatts	105	120	120	96
Weekend and Holiday On-Peak				
0 - 500 Megawatts	32	37	37	29
500 - 1000 Megawatts	34	39	39	32
1000 - 2000 Megawatts	41	47	47	38
2000 - 3000 Megawatts	49	56	56	45
3000 - 4000 Megawatts	59	67	67	54
4000 - 5000 Megawatts	71	80	80	65
5000 - 12,000 Megawatts	79	90	90	72
Off-Peak				
0 - 500 Megawatts	21	25	25	20
500 - 1000 Megawatts	23	26	26	21
1000 - 2000 Megawatts	27	31	31	25
2000 - 3000 Megawatts	33	37	37	30
3000 - 4000 Megawatts	39	45	45	36
4000 - 5000 Megawatts	47	54	54	43
5000 - 12,000 Megawatts	53	60	60	48

Source: Industry estimates.

Results

Table 7. Probability of summer economic damages to power plants by damage level*

100%	$0 or >
50%	>$52,186,097
25%	>$158,639,668
20%	>$196,551,468
10%	>$364,344,980
5%	>$527,514,312
2%	>$613,674,412
1%	$708,632,265
Expected Value	$128,655,205

* Based on Gavins Point releases of 18,000 cfs for June through August and 9,000 cfs for September.

Simulation of the minimum flows from Gavins Point over the 1898 to 1997 summer period produced the aggregate results presented in Table 7. From Table 7, one can see that the expected impact on power plants from minimum flows is 128.7 million dollars. Economic damages exceeding 196.6 million dollars occur with a 20 percent chance and damages exceeding 527.5 million dollars occur with a 10 percent chance. Further details are available from the cumulative distribution presented in Figure 1.

Precisely predicting a blackout or rolling blackout is very difficult. In reviewing simulations of power plant de-ratings from the reliability regions, power transmission rather than power generation capacity may be the most limiting constraint. The Southwest Power Pool (SPP) ran three alternative scenarios of capacity de-ratings in the Kansas City area (SPP 2004). The scenarios included three alternative capacity de-ratings of 629, 1076, and 2406 megawatts. Under these scenarios, SPP was able to find the replacement power, but power transmission problems increased with additional de-ratings. However, under these levels, SPP concluded that they expected no major regional problems.

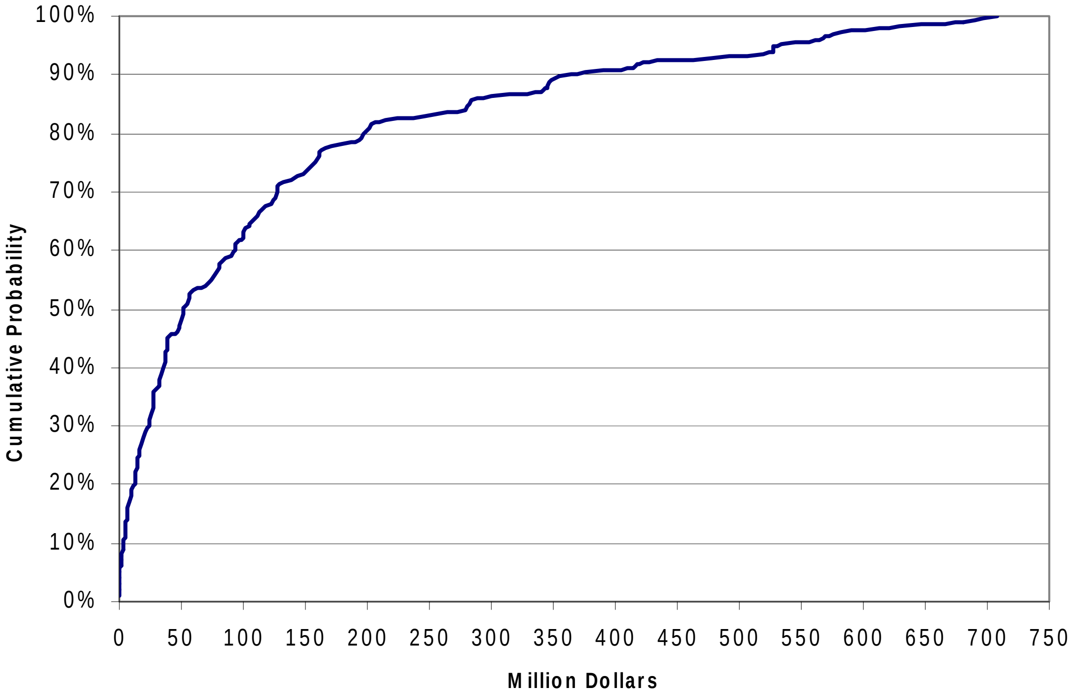

Figure 1. Cumulative distribution of power plant damages under minimum releases from Gavins Point

Further discussion by FAPRI with the power plants suggested that significant transmission problems would likely occur when power transfers must replace 3000 megawatts or more of generation capacity, or, given Table 6, approximately 100 million dollars in damages. As the power plants consulted in this study point out, it is the power generation capacity that must be replaced that determines the potential for a blackout, not the dollar level of damage. This distinction is important because the power companies will always try to supply power to their customers even at very high power prices (exceeding the levels in Table 6) if the grid will allow the power to be transferred. Since the power prices above 3000 megawatts presented in this study are considered conservative by some power industry analysts, in the actual event, economic damages to power plants could be higher than 100 million dollars before a blackout occurred.

Conclusions

- Simulation of the minimum flows from Gavins point over the 1898 to 1997 summer period produced expected economic damages to power plants of 128.7 million dollars.

- Summer economic damages to power plants exceeding 196.6 million dollars occur with a 20 percent chance and damages exceeding 527.5 million dollars occur with a 10 percent chance.

- While blackouts or rolling blackouts are difficult to precisely predict, the stress on the power transmission system is significant when annual summer economic damages exceed 100 million dollars. Simulated minimal summer releases from Gavins Point indicated economic damages exceeding 100 million dollars would occur 37 percent of the time.

- Economic impacts on power plants of minimal summer flows are considered only for the June through September period. Power plants may experience negative impacts, particularly in the late fall period, that are not quantified in this study.

- This study considers the economic impact of replacement power costs only. In the event of a blackout or rolling blackout, the economic damages to business are expected to be considerably higher than the impact to power companies alone.

- The power plants commented that the replacement energy prices used in this study were very conservative, especially when de-ratings totaling 3 gigawatts or more occurred.

REFERENCES

Kruse, John R. and Abner Womack. April 2004. "Implications of Alternative Missouri River Flows for Power Plants." FAPRI Staff Report #04-04. Food and Agricultural Policy Research Institute, University of Missouri – Columbia.

Southwest Power Pool. March 12, 2004. "Impacts of Possible Changes in Missouri River Flows on SPP Electric Utilities." SPP Engineering and Planning. Little Rock, AR. http://www.spp.org/Publications/Missouri_River_Flows_on_SPP.pdf

US Army Corps of Engineers. March 2004. "Missouri River Mainstream System Master Water Control Manual." Final Draft, Northwestern Division, Missouri River Basin, Water Management Division.

DATA SOURCES

The following sources were not directly referenced in the text but were used as data sources for the analysis:

Energy Information Administration. http://www.eia.doe.gov, 2004.

National Weather Service. http://nws.noaa.gov, 2004.

Nebraska Power Association Joint Planning Subcommittee. December 2003. "Impacts of Possible Changes in Missouri River Flows on Nebraska's Electric Energy Industry."

US Army Corps of Engineers. July 1994. "Economic Studies Water Supply Economics" Volumne 6B: Missouri River Master Water Control Manual, Review and Update Study, Missouri River Division.

US Army Corps of Engineers. July 1994. "Low Flow Studies, Gavins Point Dam to St. Louis, Missouri" Volumne 3A: Missouri River Master Water Control Manual, Review and Update Study, Missouri River Division.

US Army Corps of Engineers. August 2001. "Revised Draft Environmental Impact Statement" Volumne 1: Main Report, Missouri River Master Water Control Manual, Review and Update, Northwestern Division, Missouri River Basin, Water Management Division.

US Army Corps of Engineers. November 2003. “Final Biological Assessment On The Operation of the Missouri River Mainstem Reservoir System, The Operation and Maintenance of the Bank Stabilization and Navigation Project, and the Operation of Kansas River Reservoir System.” Northwestern Division, Missouri River Basin, Water Management Division.

US Army Corps of Engineers. September 7, 2004. “Water Management Monthly News Release” Northwestern Division, Public Affairs Office.

US Geological Survey. http://www.usgs.gov, 2004.