Norway and Oakdale Dams
Modified Flood Operation Study

The Norway and Oakdale dams are operated in a run-of-river mode, meaning that whatever flow comes into the lakes is released from the lakes as it comes in. This keeps the lakes at a constant level (plus or minus 3 inches of the normal lake level) and keeps the flows in the lakes and river the same as the natural flow: that is, flows in the Tippecanoe River are not changed as a result of the dams being there.

A study has been conducted to see if changes in the way the dams operate could reduce the amount of downstream flooding from natural river flows.[1] The study was conducted to see what is theoretically possible assuming perfect forecasting information and operation.[2] The study, its assumptions, and its results are described in the following paragraphs.

The changes in operation included in the study involve lowering both lakes below the normal lake level in advance of a storm, assuming advance notice is available. The speed with which the lakes can be lowered cannot exceed 13,000 cfs maximum discharge because anything faster would cause flooding downstream, according to the White and Carroll County Emergency Management Agencies. Also, lowering the lakes at a rate faster than one foot per eight hours would risk failure of slopes, seawalls, and other structures around the lakes. These considerations, along with how much advance notice is available, represent practical constraints on how far the lakes can be lowered in advance of a storm. For purposes of this study, these constraints on lowering the lake levels are ignored in order to explore a wide range of theoretical operating conditions.

The study assumes that after the lakes are lowered to the target level, the discharges from the dams would match river flow until river flow causes the lakes to start rising. As river flow increases above 13,000 cfs and the lakes start rising, the discharge from the dams is held at 13,000 cfs until lake levels get back to the normal levels. At this point, the lakes are allowed to rise up to the maximum level for abnormal conditions as defined in NIPSCO's FERC license, which is normal level plus nine inches (El. 647.4 ft +0.75 ft at Norway Dam and El. 612.6 ft +0.75 ft at Oakdale). When each lake rises to this maximum abnormal operating level, discharges are increased (using flood gates, overflow spillways, siphons, and powerhouses) to match river flow to keep the lakes at this upper level as long as possible. If the storm's river flow increases to something

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[1] The study was conducted by MWH Americas, Inc. ("MWH"). MWH is a leading engineering firm in the area of hydroelectric dam design, operations and construction.

[2] There is no one source of data that a dam operator can rely on to forecast the location and likelihood of flooding. For example, the National Weather Service's 36-hour Flood Watch typically covers a fairly large area, but in the experience of NIPSCO's dam operator, for rain to significantly impact flooding along the Tippecanoe River in White and Carroll Counties it must fall within an approximate 30-mile radius of the Project. Additionally, as with Tornado Watches and other severe weather alerts issued by the National Weather Service, often the flood event does not occur and rarely does it happen in every part of the area covered by the Watch.

greater than the ability of the dams to discharge water, then the lake levels will continue to rise, and there is nothing that can be done to hold or lower the lake levels. If lake levels rise above the maximum abnormal level, then the river flow could spill over the top of the dams and possibly cause the dams to fail.

Four different scenarios were studied based on lowering the lake levels by 1 foot, 3 feet, 6 feet and 15 feet at the dams. The average depth of Lake Shafer is 10 feet (the deepest part of the lake is 30 feet at the dam) and the average depth of Lake Freeman is 16 feet (the deepest part of the lake is 45 feet at the dam). So for the 15-foot drawdown, almost all of both lakes would be empty, except for right in front of the dams. Eight different flood events were studied, ranging from the 10-year recurrence interval flood (10-yr flood) up to the 500-year flood, plus the January 2008 flood.

The rate of river flow over time and the maximum river flow for the floods used in the study (i.e. the flood inflow hydrographs) were obtained from two sources. For the January 2008 flood, the flow data that was used was recorded at the USGS gauge near Delphi, Indiana. This flood was apportioned between each dam using data actually recorded at the dams. For the other flood cases, the input data for the study was based on the flood inflow hydrograph that was developed as part of the FERC licensing process for Norway and Oakdale dams.

Tables 1 through 4 on the following pages summarize the results of the study for the four different levels to which the lakes were assumed to be lowered and compare the results to the existing run-of-river operation. The "Maximum Discharge - Current Operating Procedures" are the maximum discharges (releases from the dams) that would occur for the existing run-of-river operation. The "Maximum Discharge – Lowered Lake Operating Procedures " are the maximum discharges that would occur downstream if the lakes were lowered in advance of a storm and water was held back until the maximum abnormal lake level is reached, as described earlier. The "Time to Refill" is the amount of time it takes to fill the lakes from the lowered lake level to the maximum abnormal lake level after the flood inflow exceeds 13,000 cfs at the dams.[3]

[3] The Time to Refill is an estimate under perfect forecasting and operating conditions. The actual time to refill could vary significantly based on the actual severity of the event that occurs (i.e. whether the flood ends up being a 10-year, 50-year or 500-year flood). There is no way to know what the severity of the flood event will be at the outset of the event.

Table 1
Study Results - Lakes Lowered by 1 Foot

Flood Event	Norway Dam			Oakdale Dam		
	Time to Refill (hours)	Maximum Discharge (cubic feet per second)		Time to Refill (hours)	Maximum Discharge (cubic feet per second)	
		Current Operating Procedures	Lowered Lake Procedures		Current Operating Procedures	Lowered Lake Procedures
10-year	3.0	20,200	20,200	5.0	21,400	21,400
50-year	3.0	26,400	26,400	5.0	28,100	28,100
100-year	3.0	28,800	28,800	5.0	30,500	30,400
200-year	3.0	31,800	31,800	4.5	32,800	32,800
300-year	3.0	34,300	34,300	4.5	33,900	33,900
400-year	3.0	36,900	36,900	4.5	35,200	35,200
500-year	3.0	38,100	38,100	4.5	36,200	36,200
Jan '08	2.0	27,400	27,400	3.5	33,700	33,800

The results for the case where the lakes are lowered by 1 foot show no reduction in maximum discharge (river flow downstream of the dams), even for the smallest storms, though there may be some delay in when the actual downstream flooding begins.

Table 2
Study Results - Lakes Lowered by 3 Feet

Flood Event	Norway Dam			Oakdale Dam		
	Time to Refill (hours)	Maximum Discharge (cubic feet per second)		Time to Refill (hours)	Maximum Discharge (cubic feet per second)	
		Current Operating Procedures	Lowered Lake Procedures		Current Operating Procedures	Lowered Lake Procedures
10-year	6.0	20,200	20,000	11.0	21,400	19,200
50-year	4.5	26,400	26,400	7.5	28,100	28,100
100-year	4.5	28,800	28,800	7.5	30,500	30,400
200-year	4.5	31,800	31,800	8.0	32,800	32,800
300-year	5.0	34,300	34,300	8.0	33,900	33,900
400-year	5.0	36,900	36,900	7.5	35,200	35,200
500-year	5.0	38,100	38,100	7.5	36,200	36,200
Jan '08	3.5	27,400	27,400	6.0	33,700	33,700

Again, for the case where the lakes are lowered by 3 feet, there is virtually no reduction in the maximum discharge (river flow downstream of the dams) for any flood event.

Table 3
Study Results - Lakes Lowered by 6 Feet

Flood Event	Norway Dam			Oakdale Dam		
	Time to Refill (hours)	Maximum Discharge (cubic feet per second)		Time to Refill (hours)	Maximum Discharge (cubic feet per second)	
		Current Operating Procedures	Lowered Lake Procedures		Current Operating Procedures	Lowered Lake Procedures
10-year	8.5	20,200	18,600	- - -	21,400	13,700
50-year	6.5	26,400	26,300	11.5	28,100	27,600
100-year	6.0	28,800	28,600	11.0	30,500	30,500
200-year	6.0	31,800	31,600	10.5	32,800	32,700
300-year	5.5	34,300	34,100	10.5	33,900	33,700
400-year	6.0	36,900	36,800	10.5	35,200	35,000
500-year	6.0	38,100	38,000	10.0	36,200	35,900
Jan '08	5.3	27,400	27,400	9.2	33,700	33,500

For the case where the lakes are lowered by 6 feet, there is no reduction in maximum discharge (river flow downstream of the dams) except for the 10-year flood case at Oakdale. With the lowering of the lake by six feet in advance of the 10-yr flood, the storage created in Lake Freeman could allow discharges to be kept to about 13,000 cfs if the flood did not get any bigger than the 10-year flood.

Table 4
Study Results - Lakes Lowered by 15 Feet

Flood Event	Norway Dam			Oakdale Dam		
	Time to Refill (hours)	Maximum Discharge (cubic feet per second)		Time to Refill (hours)	Maximum Discharge (cubic feet per second)	
		Current Operating Procedures	Lowered Lake Procedures		Current Operating Procedures	Lowered Lake Procedures
10-year	---	20,200	13,900	---	21,400	13,700
50-year	7.5	26,400	25,900	---	28,100	13,900
100-year	7.0	28,800	28,000	18.5	30,500	21,800
200-year	7.0	31,800	30,900	15.0	32,800	31,100
300-year	7.0	34,300	32,900	14.0	33,900	32,500
400-year	7.0	36,900	34,900	14.0	35,200	33,400
500-year	7.0	38,100	36,200	14.0	36,200	34,000
Jan '08	6.5	27,400	26,700	14.0	33,700	32,600

Table 4 summarizes the case where the lakes are lowered by 15 feet, regardless of whether or not it would be realistic to do so. For purposes of this study, it is assumed that it is both possible and acceptable to lower the lakes this far. For this case there is some reduction in maximum discharge (river flow downstream of the dams) for events up to about a 100-year flood. Thereafter there is virtually no reduction. Even with the reduction for the 100-year flood, however, flooding would not be eliminated, only reduced somewhat.

Further evaluation was done comparing the timing and magnitude of discharges under the current operating procedures and the assumed lowered lake operating procedures. Figure 1 on the following page shows the discharges at Norway and Oakdale dams plotted against time for the 6-foot drawdown case during the January 2008 flood under both current and the assumed lowered lake operating procedures. Because the flood flow is very large compared to the size of lakes, whatever storage volume created by lowering the lakes is fully used up before the worst of the flood arrives at the dams. This is depicted in the graph by the solid and dashed lines basically coming together again before the maximum flood flow is reached. By the time the maximum river flow gets to the dams, the lakes have already refilled to the normal level plus more. At this point, the river flows must be discharged as they come in or the integrity of the dams could be at risk. Because the available storage volume created by lowering the lakes is used up very early in the flood, there is no storage capacity available later. That is why there is no reduction in the maximum discharge (river flow downstream of the dams), as the lakes simply are not large enough to make a difference. Even if the lakes were just about fully drained (lowered 15 feet) before the January 2008 flood, the available storage would have been used up early in the flood, and there would have been virtually no reduction in the maximum discharge (river flow downstream of the dams).

Study Results - Discharge Through Dams During January 2008 Flood

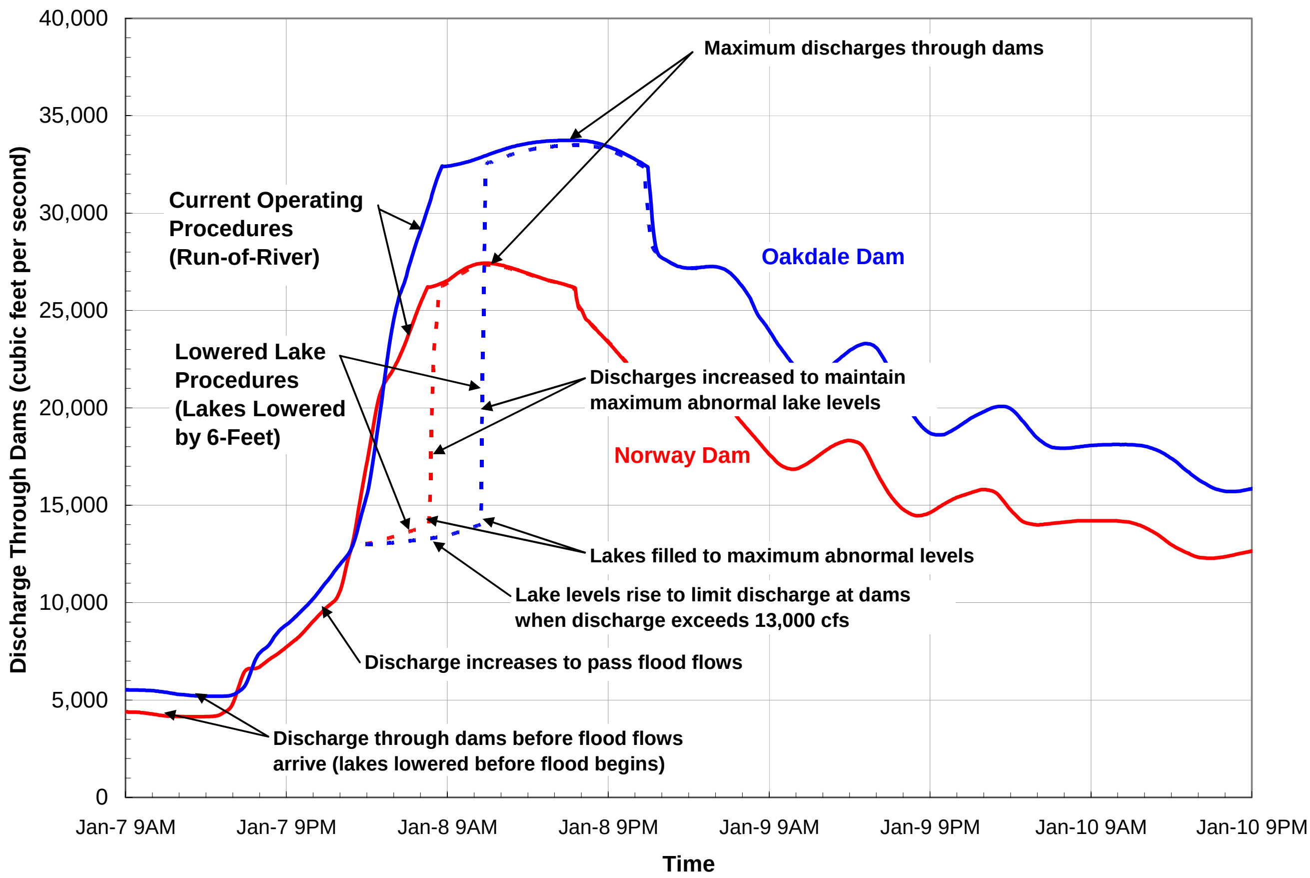

Figure 1

Even though the maximum discharge (river flow downstream of the dams) is not affected by lowering the lakes, Figure 1 does indicate that there could be a delay when the discharges first start to go above 13,000 cfs. For Norway, there could be a 5-hour delay and for Oakdale a 9-hour delay.

Figure 2 on the following page shows a plot of the water levels just downstream of Oakdale for both the current operating procedures (solid line) and the assumed lowered lake operating procedures (dashed line) for the case where the lakes are lowered by 6 feet during the January 2008 flood event.

Study Results - Water Levels Immediately Below Oakdale Dam During January 2008 Flood

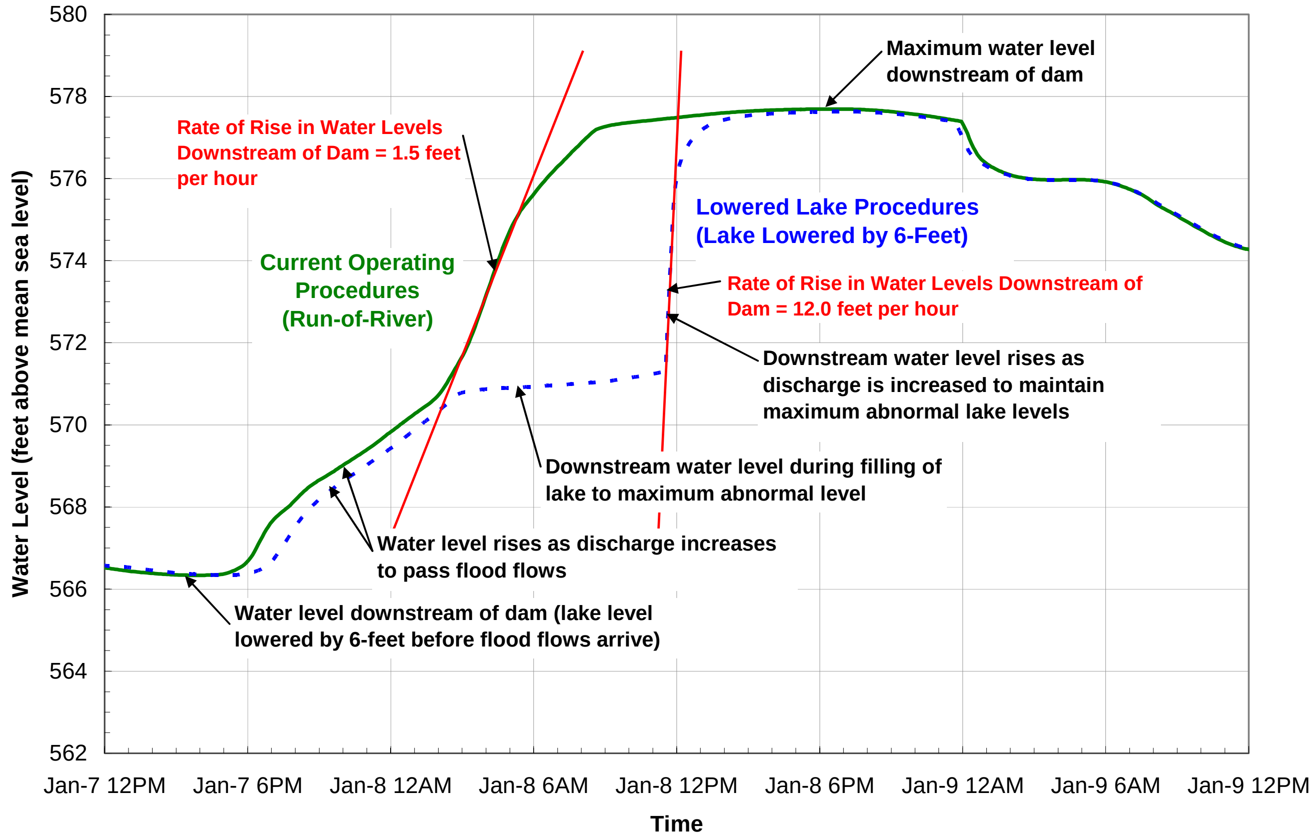

Figure 2

Figure 2 shows that lowering the lake in advance of the January 2008 flood and holding the maximum discharge to 13,000 cfs as long as possible could have delayed the onset of downstream flooding by about 9 hours, but would not have reduced the total amount of flooding in the end. However, holding back the water early in the flood means that the water has to be released more quickly later in the flood in order for the lakes not to go above safe levels. By comparison, the fastest the water would rise under the current operating procedures is 1.5 feet per hour versus a rise of 12 feet per hour if the lakes were lowered in advance of the flood and maximum discharge held at 13,000 cfs as long as possible. As shown in Figure 2, the water level downstream of Oakdale Dam would rise approximately 6 feet within half an hour under the lowered lake operating conditions.

Figure 3 on the following page shows a plot of the water levels 9 miles downstream of Oakdale versus time for both the current operating procedures (solid line) and the assumed lowered lake operating procedures (dashed line) for the case where the lakes are lowered by 6 feet during the January 2008 flood event. As shown in the figure, the fastest the water would rise under the current operating procedures is 1.3 feet per hour, versus a rise of 3.7 feet per hour if the lakes were lowered in advance of the flood and maximum discharge held at 13,000 cfs as long as possible. Thus, as shown in Figure 3, the water level 9 miles downstream of Oakdale Dam would rise approximately 4 feet within approximately one hour under the lowered lake operating conditions.

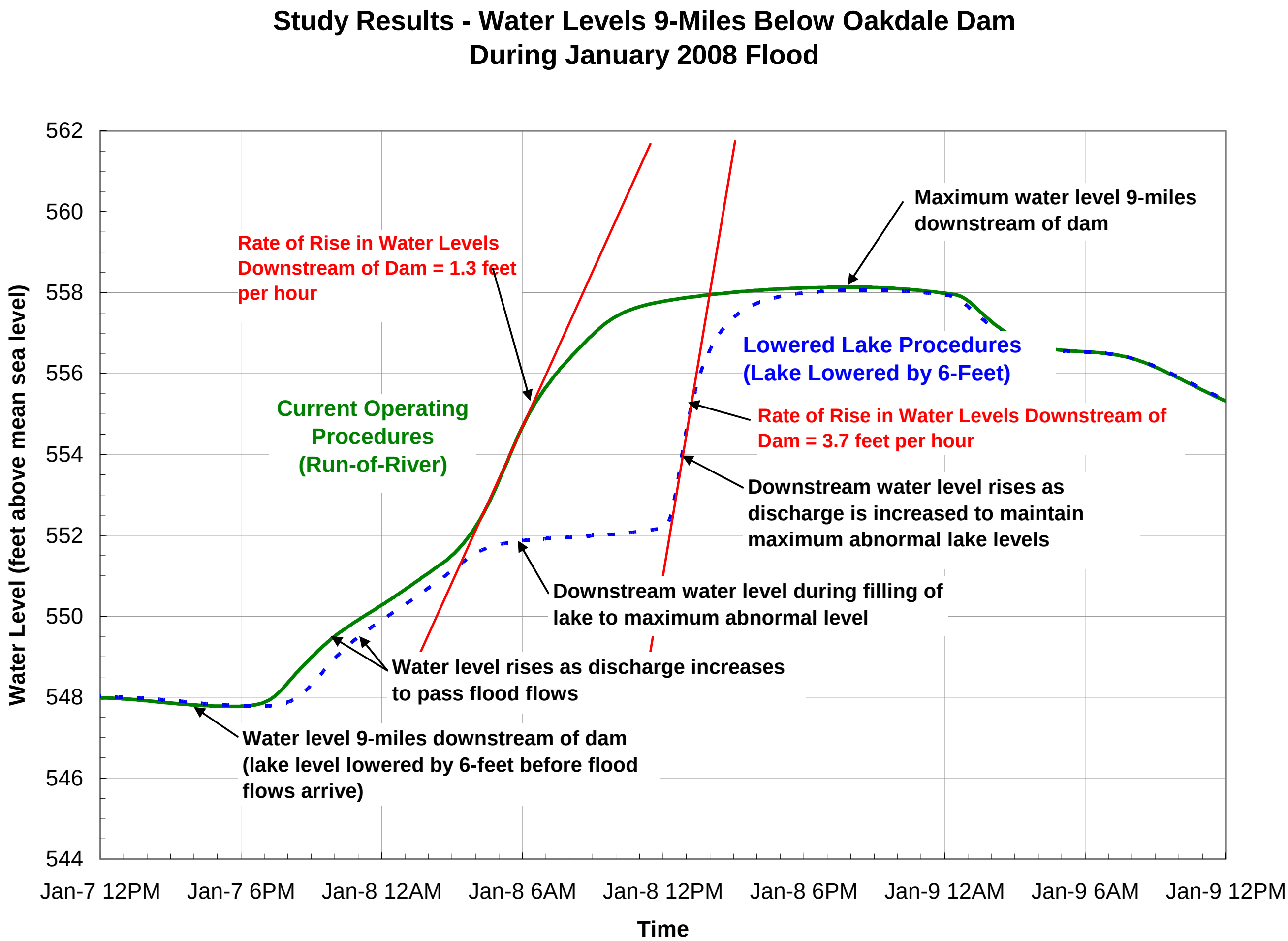

Figure 3

Results and Conclusions

This study evaluated possible changes in the way the dams operate in order to eliminate or reduce downstream flooding that occurs under the current run-of-river operating procedure for floods ranging from a 10-year flood to a 500-year flood.

The study looked at the impact on downstream flooding from lowering both lakes below the normal lake level in advance of a storm by 1 foot, 3 feet, 6 feet and 15 feet, assuming advance notice is available to do so. The focus of the study was on downstream flood impacts: the study did not evaluate impacts on structures around the lakes, on the lake shorelines, on aquatic life or habitat, on recreation, regulatory issues or jurisdictional agency concerns, or other factors that may need to be considered if a decision is made to implement operational changes. For purposes of this study, known constraints on lowering the lake levels in advance of a flood, such as available advance notice, were ignored in order to explore a wide range of possible operating conditions.

The results of these studies show that lowering the lakes by as much as 6 feet does not reduce the maximum discharge or reduce the ultimate amount of downstream flooding for any flood from the 10-year flood to the 500-year flood, with one exception. The only case where any significant reduction was found was for a 10-year flood event with Lake Freeman lowered by 6 feet.

The studies also show that lowering the lake levels in advance of a flood could delay the onset of downstream flooding by up to 10 hours or so under some circumstances, even if the maximum discharge and total amount of flooding would not be reduced. In those cases where the onset of flooding could be delayed, the rate at which the downstream water levels rise would increase as much as 8 times, from about 1.5 feet per hour under the current operating procedures, to a rise of 12 feet per hour if the lakes were lowered in advance of the flood and maximum discharge held at 13,000 cfs as long as possible. The increased rate of rise in water levels downstream compounds the potential for loss of life.

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