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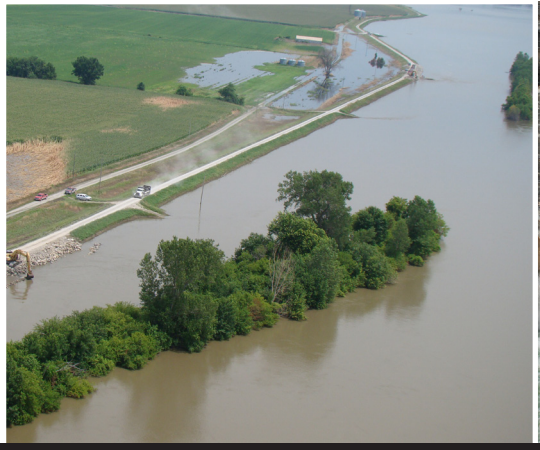
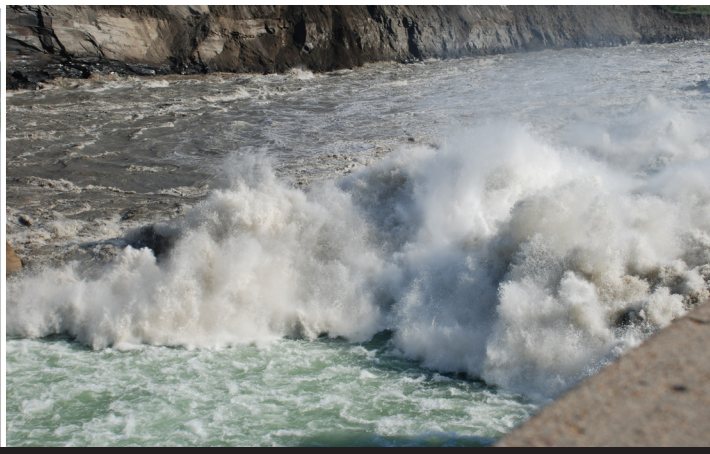


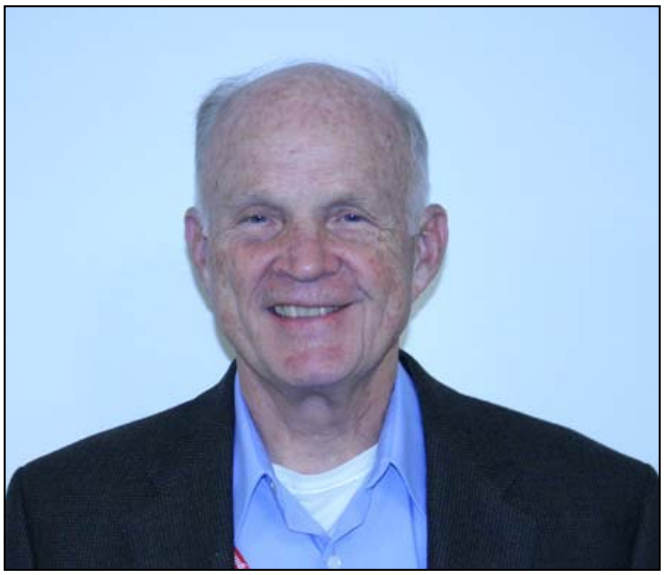


Water Management

Independent External Peer Review

PRESS KIT

Dr. Neil S. Grigg
Professor



Neil S. Grigg is a Professor at Colorado State University, where he focuses on operation and management of water resources systems for multiple purposes.

He led the Independent Water Management Technical review study for the Corps of Engineers following the Missouri River Flood of 2011.

During 30-years at Colorado State, he has also been Head of the Department of Civil Engineering and Director of the Colorado Water Resources Research Institute.

His other experience includes positions in the North Carolina State Government and University System (Assistant Secretary for Natural Resources, Director of Environmental Management, and Director of the Water Resources Research Institute) and consulting engineering.

He is a graduate of the U.S. Military Academy and received graduate degrees in civil engineering from Auburn University and Colorado State.

Neil's experience includes many assignments as a consultant or expert advisor to government study panels and he has experience in flood control issues and as an expert witness in flood court cases. He is a member and current chair of the flood advisory committee for the FEMA's HAZUS loss estimations software, a geographic information system-based software package for multi-hazards. He has written a recent book on water governance, published a total of 15 books and published numerous articles on water management. Under a Supreme Court appointment, he has served for 23 years as the River Master of the Pecos River. He is a registered professional engineer in Colorado, North Carolina, and Alabama and is a fellow of the American Academy of Water Resources Engineering.

William E. Lawrence
Hydrologist in Charge
Arkansas Red River Forecast Center, National Weather Service
Tulsa OK

William E Lawrence is the Hydrologist in Charge at the Arkansas-Red Basin River Forecast Center in Tulsa, Oklahoma. He has 20 plus years of experience in the field.

A 1986 graduate of the Rutgers University, Lawrence holds a bachelor of science degree in Atmospheric Sciences. Shortly after graduation, he joined the National Weather Service in Little Rock, Ark. as a Meteorologist Intern.

In 1989, Lawrence transferred to the Mid Atlantic River Forecast Center (MARFC) in Harrisburg, Pa., where he worked as a hydrologist for a few years before taking a position as one of the nation's first hydrometerologists at the ABRFC in 1991.

Lawrence has played an active role in a several professional hydro-meteorological teams throughout his career, including short-term hydrologic ensemble forecasting, verification of hydrologic forecasts, quantitative precipitation forecasting and hourly Web page development and enhancement.

In 2008, he transitioned into a position as the first Service Coordination Hydrologist (SCH) at the ABRFC, a position that entailed outreach and regular coordination with other government, state and local agencies. Finally in March 2011, Lawrence was selected as the Hydrologist in Charge at the ABRFC. His 25 years of expertise in meteorology and hydrology have exposed him to numerous diverse experiences in the field of water management and expanded his expertise in the field of River Forecasting.

Cara McCarthy
Senior Forecast Hydrologist

Cara McCarthy recently joined the Natural Resources Conservation Service as a senior forecast hydrologist for the National Water and Climate Center in Portland, Oregon.

Cara previously worked for the Bonneville Power Administration (BPA) generating daily and long-term streamflow forecasts for points within the Columbia River Basin that were used in determining hydropower and fish operations, system reliability, and power marketing. In addition, she was project manager of the development of a large streamflow dataset used extensively by BPA and other Pacific Northwest entities.

Prior to working for BPA, she was a senior hydrologist for the Colorado Basin River Forecast Center in Salt Lake City, Utah. She was the team lead for the Lake Powell forecast group and produced volume and peak flow forecasts that directly benefited, among others, the Bureau of Reclamation, Denver Water, and water districts in managing water supply on the Colorado River.

Cara also was a research hydrologist for the National Weather Service in Silver Spring, Maryland, focusing on technical and field support of the Ensemble Streamflow Prediction (ESP) model, part of National Weather Service River Forecast System.

She holds a B.S. in Geology from the College of William and Mary, in Virginia, and a M.S. in Hydrology from the University of Arizona, Tucson. Her thesis work focused on water rights and the reallocation of water uses.

Darwin Ockerman
Hydrologist

Darwin Ockerman began his U.S. Geological Survey career in 1991 in South Florida, working with emerging technology involving instrumentation and techniques related to measurement of streamflow. Darwin has conducted numerous watershed modeling studies to simulate streamflow, sediment transport, groundwater recharge, and effects of dams and reservoirs. He has also managed a variety of water-quality studies, ranging from urbanizing watersheds on the Edwards aquifer recharge zone to agricultural watersheds in the Texas Coastal Bend area.

Darwin grew up in South Florida and received his Bachelor of Science degree in electrical engineering from University of Florida and his Master of Science degree in environmental engineering from Florida International University.

For most of his 20 years with the USGS Darwin has served as a project hydrologist and section chief in the Florida and Texas USGS Water Science centers. He is now a staff hydrologist for the USGS Office of Surface Water, in Reston Virginia.

Missouri River System Operation 2011
Post Flood Review – Charter

PURPOSE: This independent review is intended to assess USACE operation of the six Missouri River mainstem reservoirs (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, Gavins Point), and any appropriately related dams and reservoirs, prior, during and after the 2011 sequence of flooding, for the purpose of gaining lessons learned and recommendations to improve future operations.

PANEL: The review panel is composed of non-USACE independent experts in hydrology and/or dam and reservoir system operations and regulation. USACE staff will provide all available data, records and other information that the panel deems relevant to its review, but will not serve directly on the panel. The panel may choose to select a Chairman and assign duties and responsibilities among its members as it deems appropriate.

Review Panel Members

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SCOPE: The panel is charged to review, analyze, and assess any and all information it determines necessary and that is relevant to pre-flood, flood, and post-flood operations in order to reach findings regarding the planning and execution of reservoir operations as they may have affected, or been affected by hydrologic conditions, operational constraints, and other conditions in the Missouri River basin. Relevant information such as the Annual Operating Plan, hydrologic forecasts and forecast methods, real time chronology and decisions, coordination and communication with other reservoir owners/operators and agencies shall be considered. The panel shall review the Missouri River Master Manual to determine the consistency of the AOP and the actual operations. In its review, the panel shall consider consistency of the operations

with system authorized purposes from a technical, but not legal perspective. The panel is encouraged to reach out to external agencies and entities for information and input.

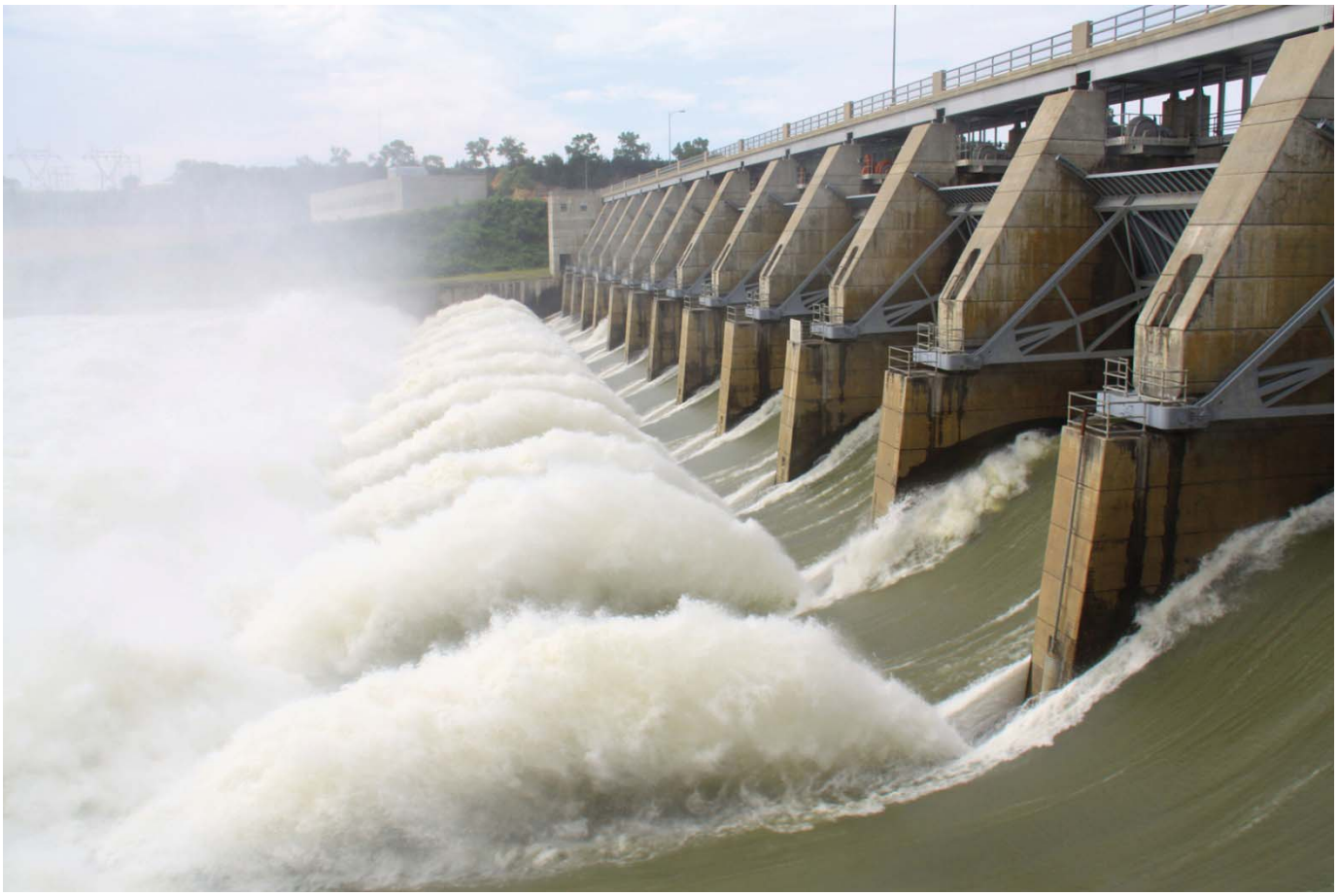
The panel shall address, but is not limited to, the following questions:

1. According to the Missouri River Master Manual and other pertinent documents, how should the mainstem reservoir system and the Corps and U.S. Bureau of Reclamation (USBR) tributary reservoirs within the system have been operated, how were they actually operated, and what were the reasons for any differences in the operation?
2. Were the Water Management decisions made during the Flood of 2011 appropriate and in line with the approved water control manual?
3. Could the Corps have prevented or reduced the impact of the flood by taking other management actions leading up to the flood?
4. Did operations for environmental or other purposes influence flood risk management operations, and if so how did they influence the operations?
5. Were accurate and timely hydrologic and weather forecasts and other pertinent data available? What data improvements (plains and mountain snowpack information, river gages, and observed weather data) are warranted in light of this flood event to properly manage the system?
6. Did the Corps properly assess basin conditions and properly forecast runoff from plains snowpack, mountain snowpack, and precipitation? If not, what additional information and/or tools are needed to better forecast runoff?
7. Did the Corps' long-term regulation forecasts properly account for the runoff?
8. Did the Corps' regulation of the mainstem system during the Mississippi River flood contribute to flooding on the Missouri River, and did it have a discernable impact on the Mississippi River flooding?
9. How should the Flood of 2011 be characterized in terms of frequency or recurrence interval?
10. Does the Master Manual adequately address reservoir operations during extreme flood events? Does Plate VI-1 adequately address the hydrologic conditions like those experienced this year? Do the downstream flood control constraints adequately balance flood risk in the upper and lower basins?
11. Did climate change play a role in this year's record runoff? Should future regulation of the reservoir system be adjusted to account for climate change? And if so, what types of additional studies would be required to integrate climate change?
12. What role did flood plain development play in the operation of the reservoir system prior to and during the event?

REPORT, FINDINGS AND RECOMMENDATIONS: The panel shall prepare a report that presents the scope of its investigation, methods used, data and information cited, contacts and other sources of information, and its assessment including any findings and recommendations for USACE to consider.

SCHEDULE: The panel shall initially convene in person no later than the week of 26 September 2011 and complete it work with its report no later than 2 December. Meetings and means of coordination and communication subsequent to the initial meeting is at the panel's discretion.

Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011



Review Panel Members

Neil Grigg, PhD, Professor, Colorado State University, Fort Collins, Colorado

Cara McCarthy, Senior Forecast Hydrologist, Natural Resources Conservation Service, National Water and Climate Center, Portland, Oregon

Bill Lawrence, Hydrologist In Charge, Arkansas Red Basin River Forecast Center (ABRFC), National Weather Service, Tulsa, Oklahoma

Darwin Ockerman, Hydrologist, U.S. Geological Survey, Office of Surface Water, Reston, Virginia

Cover: Photograph of spillway release of 140,000 cubic feet per second at Gavins Point Dam, near Yankton, South Dakota, June 24, 2011 (U.S. Army Corps of Engineers).

Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011

Executive Summary

In 2011 the mainstem Missouri River Reservoir System experienced the largest volume of flood waters since the initiation of record-keeping in the nineteenth century. The high levels of runoff from both snowpack and rainfall stressed the System's capacity to control flood waters and caused massive damage and disruption along the river. As a result of its experiences during the flood, the U.S. Army Corps of Engineers (Corps) appointed a panel to conduct an independent technical review of its operations of the reservoir system during the flood event. The panel was appointed in September of 2011 and held its first meeting in early October in Omaha, Nebraska. Members of the panel represent Federal agencies with missions in water data and studies and Colorado State University. The panel's work was conducted independently from the Corps and is similar to a technical performance audit. The panel charter and members' appointment letters are included in the Appendix of the final report.

During October and November the panel reviewed documents and studies, interviewed staff of the Corps and other agencies and offices as well as members of the public, visited reservoir sites, and attended public meetings. The expertise of each member of the panel was applied to the assessment of elements of Corps' operations, and the panel members considered the full report as a group. In addition to this cross-evaluation of the panel's work, the report was subjected to independent technical peer review arranged by the U.S. Geological Survey. The Corps also was asked to respond to the draft report of the panel by checking for factual errors, breadth of coverage, and whether the report responds fully to the charter presented given to the panel. The panel considered these responses in preparing the final report.

In conducting the review of the Missouri River mainstem reservoir system during the 2011 flood, the review panel divided its findings into two areas:

- Conclusions regarding regulation of the reservoir system by the Corps during 2011 for the authorized purpose of flood control. The conclusions are summarized as answers to a set of questions that served as the starting point of the review process. The original questions posed by the Corps were supplemented by additional questions that arose during the panel investigation.
- Recommendations for actions to prevent or reduce damages from similar, or larger floods in the future.

Conclusions Regarding the 2011 Regulation of the Missouri River Mainstem Reservoir System

Question 1. According to the Missouri River Master Manual and other pertinent documents, how should the mainstem reservoir system (System) and the Corps and U.S. Bureau of Reclamation (USBR) tributary reservoirs within the system have been operated, how were they actually operated, and what were the reasons for any differences in the operation?

See answer to Question 2.

Question 2. Were the water-management decisions made during the flood of 2011 appropriate and in line with the approved water control manuals?

The operation of the reservoirs must conform to guidance in the Master Manual and project manuals, and the decisions were appropriate and in line with the appropriate manuals. The Master Manual is defined to include both the System guidance and the mainstem project manuals. The tributary reservoirs of the Corps and U.S. Bureau of Reclamation (USBR) are to be operated according to their manuals, and the operations of selected USBR tributary reservoirs are subject to controls by the Corps during flood events (see the report's section on Master Manual guidance for extreme events). While the panel found that the reservoirs were operated according to the applicable manuals, it is also important to explain that during extreme flood events such as in 2011, the Master Manual does not provide a rigid formula for operational decisions. The formula-based operational procedures in the Master Manual use the concept of service levels to apply to flood conditions up to certain magnitudes, but during extraordinary flooding such as in 2011, the Master Manual requires a great deal of experience-based judgment. Here, guidance for decision-making shifts from formulas to multiple criteria based on control of floodwaters, consideration of flood damage, and the need to operate reservoirs to protect infrastructure and public safety. The panel wants to emphasize that the operators must consider the security of the infrastructure in their decisions. The serious consequences of dam failure require the operators to take precautions such as to evacuate flood waters and increase releases as they did in 2011. The panel was able to theorize about how operations might have reduced releases and increased storage, but when it considered the large volumes of water and the information the operators had at the times they had to make decisions, the panel did not see how major reductions in releases could have been made. Therefore, rather than speculate after-the-fact about differences in the required and actual operating decisions, the panel identified ways that future flood operation might be improved through lessons learned.

Question 3. Could the Corps have prevented or reduced the impact of the flood by taking other management actions leading up to the flood?

Looking at the event in hindsight, the panel and the Corps can demonstrate how more flood storage and earlier releases could have reduced the impact of the flood. However, holding more storage available carries the risk that some authorized purposes would not be met if the flood did not materialize. The Corps showed during its public presentations how it could have reduced releases if additional flood control space had been made available earlier in the season, but such actions are not authorized specifically in the

Master Manual. Barring an approved change in the Master Manual, the panel does not see how the Corps could have left substantially more storage available leading up to the flood. The panel noted that the Corps was following its guidelines and on March 1, the total system storage still had almost all of the normal flood storage remaining. The Corps took incremental flood control actions by releasing additional water as early as late March and by April 15 they had increased the service level releases by 15,000 cubic feet per second (ft^3/s). Therefore, the Corps was responding to increasing runoff forecasts, but they could not have foreseen the need to evacuate storage faster to accommodate the heavy rain that occurred during May. In summary, the Corps could have reduced the impact of the flood with more storage and higher releases before the flood, but these actions carried risks and consequences that did not seem appropriate to the Corps at the time they were required.

Question 4. Did operations for environmental or other purposes influence flood risk management operations, and if so how did they influence the operations?

Operations for System purposes other than flood control were suspended or assigned secondary priority once significant flooding started. Therefore, during the flood the Corps did not operate for environmental or other purposes in a way to influence flood risk. Prior to the flooding, they operated according to the Master Manual, which specifies operations for all eight authorized purposes.

Question 5. Were accurate and timely hydrologic and weather forecasts and other pertinent data available? What data improvements (plains and mountain snowpack information, streamflow gaging stations, and observed weather data) are warranted in light of this flood event to properly manage the system?

See answer to Question 7.

Question 6. Did the Corps properly assess basin conditions and properly forecast runoff from the plains snowpack, mountain snowpack, and precipitation? If not, what additional information and/or tools are needed to better forecast runoff?

See answer to Question 7.

Question 7. Did the Corps' long-term regulation forecasts properly account for the 2011 runoff?

In response to questions 5–7, the Corps' long-term regulation forecasts did not accurately account for the runoff volume, however, no forecasting agency accurately predicted the volume of the extreme runoff. The Corps produced its own hydrologic forecasts, which generally reflected known meteorologic and on-the-ground hydrologic basin conditions when the forecasts were made. The exception appeared to be an accurate assessment of the amount of on-the-ground plains snow, including possible increased runoff due to the antecedent conditions. The inaccuracy of the runoff forecast as it pertained to the plains snow assessment early in the runoff season possibly prevented the Corps from increasing System releases and making additional storage available. Overall,

improvements in data availability and modeling can be made. Even with improvements, leading to better assessment of conditions and forecasts, the record precipitation that fell over much of Montana, North Dakota, and South Dakota in May and June could not have been reliably predicted with currently available forecast methods, and significant flooding still would have occurred, based upon the current guidance in the Master Manual for System flood-storage allocation.

For year-ahead planning in the Annual Operating Plan, the fact that recent decades have experienced more extreme events should be considered, rather than view the entire historical record as having equally likely chances of occurrence. For within-calendar year water supply forecasting, assessment of the plains snow requires improved data infrastructure and incorporation of scientific modeling tools for determining the amount of runoff. For short-term daily streamflow and reservoir inflow forecasts of 1 to 10 days in advance, precipitation forecasts should continue to be integrated into streamflow modeling as they were in 2011. The Corps should also consider regular coordination meetings with other water supply forecasting agencies.

Refer to the section, 'Assessment of Forecasting Operations and Accuracy' and 'Effects of Climate Change on 2011 flooding' for more information.

Question 8. Did the Corps' regulation of the Missouri River mainstem system during the Mississippi River flood contribute to flooding on the Missouri River, and did it have a discernable impact on the Mississippi River flooding?

This question stems from a concern that flooding on the lower Missouri River, and flooding on the Mississippi River were factors in the Corps' decision to delay releases from the reservoirs. There was evidence of substantive communication and coordination among the Corps' water management offices in the Missouri River basin (Northwestern Division), Mississippi River basin (Mississippi Valley Division), and the Ohio River basin (Lakes and Rivers Division) during the respective floods, but actions taken did not significantly contribute to lack of available flood storage and subsequent flooding on the Missouri River. Nor did the Missouri River operations have a discernible impact on the Mississippi River flood.

Question 9. How should the flood of 2011 be characterized in terms of frequency or recurrence interval?

The range of possible interpretations of the 2011 event makes it impossible to characterize its likelihood on an exact basis, but it was clearly an extreme event with the largest volume of annual runoff on record and it was substantially larger (by greater than 20 percent) than the next largest runoff year in 114 years of record. A review by the U.S. Geological Survey (USGS) that considered an 80-percent confidence level described the recurrence interval as within a range of 50–1,070 years. Statistical analysis by the Corps characterized the annual runoff as approximately a 500-year event (annual 0.2 percent probability), which is in the middle of this range. Therefore, the recurrence interval is not

known exactly, but the 500-year designation might be a reasonable approximation of the extreme nature of the flooding.

Question 10. Does the Master Manual adequately address reservoir operations during extreme flood events? Does Plate VI-I of the Master Manual adequately address the hydrologic conditions like those experienced during 2011? Do the downstream flood control constraints adequately balance flood risk in the upper and lower basins?

The Manual addresses reservoir operations during extreme events, but its procedures can be improved. The unprecedented size of the 2011 runoff event mandates a re-evaluation of the Manual's guidance about how to handle such extreme events. The Manual is based on statistical analyses of hydrologic events, but behavior of the system is difficult to analyze or predict statistically during such large-scale flood events. More definite and specific procedures to respond to emergency scenarios can be included in the Manual, which currently leaves a large degree of discretion to the Corps' Missouri River Basin Water Management (MRBWM) and the Division and District Commanders during flood events. While this discretion is appropriate and needed, the possible consequences of an event such as in 2011 or larger are of such magnitude that a fresh 360-degree look at all aspects of the emergency might lead to additional procedures and technical resources to improve preparedness and reduce consequences of future events.

Plate VI-1 is effective during lower-magnitude flood events, but it does not apply directly during periods of extraordinary flooding such as in 2011. In particular, it does not apply well when both storage and runoff are high, which was the case in 2011. Plate VI-1 did not address how to manage the system once the extreme flooding began in 2011. The combination of mainstem and tributary storage and forecasted inflow was unprecedented and gave no guidance for "service level" or "target flows." Also, Plate VI-1 does not address the schedule for drawdown, especially for an extreme event such as the 2011 flood.

Question 11. Did climate change play a role in the record runoff during 2011? Should future regulation of the reservoir system be adjusted to account for climate change? If so, what types of additional studies would be required to integrate climate change planning into the system regulation?

Although climate change is not fully understood and how it might have affected the flooding is beyond the scope of this report, given that more extreme runoff events have occurred in recent decades compared to the data on record, the panel recommends re-examining the Missouri River System planning that is based on the entire historical record dating back to 1898. In addition, the panel recommends studying the incorporation of greater flexibility in operating the System to adapt to varying climatic extremes.

Question 12. What role did floodplain development play in the operation of the reservoir system prior to and during the event?

During the 2011 event, the Corps considered floodplain development but was unable to protect all properties and facilities due to the extreme volume of runoff to be passed through the System. The Master Manual identifies vulnerable areas where floodplain development has occurred, and the panel perceived that many floodplain residents thought that the dams provided more protection than they did. Prior to the event the System operators were following the Manual, which provides for downstream protection. During the period when the flood levels were increasing rapidly, there were episodes where the Corps took certain actions to protect downstream entities, such as in the March 15–28 period when Garrison releases were reduced from 26,000 ft^3/s to 15,000 ft^3/s to provide downstream channel capacity for inflows from plains snowmelt. When peak inflows were experienced and releases had to be increased, the System operators made some short-term decisions to delay the increase in releases so as to enable levee construction to be completed. The MRBWM received news from multiple sources and was aware of many local needs, but in many cases the travel time of flood waters and the inflows below the System prevented the Corps from controlling flooding in the vulnerable areas. Ultimately, when inflows became so large due to the combination of snowmelt and record rainfall, the priority shifted to emergency releases for dam safety and to maintain some storage capacity for the eventuality that much larger inflows would be experienced. In this emergency situation, the Corps was considering floodplain developments but was focusing on emergency actions to respond to the greatest risks.

Question 13. How much flood-control storage was needed on March 1 (or earlier) to control the flood? Or, what releases should have commenced on March 1 (or earlier) to control or reduce damages caused by the flood?

The panel noted that different combinations of storage and releases could be shown to reduce damages from the flood (see answer to Question 2 above). While it did not conduct exhaustive studies to determine the combinations of storage and/or releases that would have reduced the damages, the panel agrees with the general conclusions of the Corps staff that additional storage of 4.6 million acre-feet (MAF) could have limited the releases at Gavins Point to 100,000 ft^3/s. However, it is important to also note the necessity that the release rate of 100,000 ft^3/s would have to have been maintained into November.

Question 14. Were there System infrastructure-related factors that contributed to poor flood response?

After studying the system infrastructure and visiting sections of it, the panel judged that infrastructure condition did not materially affect the Corps' capability to manage the flood. However, there were situations where concern about infrastructure restricted the Corps' options, such as concern about the spillway and use of surcharge storage at Oahe Dam. In answering this question, the panel was acutely aware of the unprecedented magnitude of the flood volume and the large-scale nature and difficulty of maintaining the infrastructure in perfect condition. Therefore, the answer to the question "Was the condition of the project infrastructure a factor in operation of the system reservoirs?" is: "Yes, infrastructure condition was a factor in operation of the reservoirs, and with such

massive and high-risk structures it will always be a factor in such extreme events." It is imperative that the facilities be maintained at high levels of readiness and monitored and protected during the heat of operation while extreme events are in progress. The panel believes that the Corps did an impressive job of using the infrastructure and that the absence of major, or even catastrophic failures is evidence of performance that should be acknowledged and appreciated. The other lesson is that adequate funding and guidance for future maintenance of the infrastructure are required and all concerned should guard against complacency about the need for strategic investment to maintain a high level of System readiness.

Question 15. Were peak releases managed effectively? Could maximum releases have been reduced in order to lessen downstream flood damages?

Given the System storage conditions and rate of runoff into the System during peak inflow conditions in early June, the panel concluded that the System reservoir capacity was utilized almost to capacity. Downstream releases were minimized while still accomplishing necessary flood-water evacuation from the reservoirs to manage the safety of the system. Given the rapid increase in release rates, there could have been improvements in communication to all emergency managers about the MRBWM's awareness of conditions and plans for high releases from the reservoirs.

Question 16. Is a multi-year operation plan, taking into consideration climate cycles, worth considering?

The panel believes that recognition of climate cycles might enable the Corps to sustain the management of the eight congressionally mandated purposes while focusing more on flood control during wet cycles. It is clear that the basin experiences varying periods of dry and wet weather. While there is no guarantee that these will continue in the future, recognition of them might provide the Corps with opportunities to increase regulatory flexibility of the System. During dry periods the Corps could try to maximize storage in the System while reducing storage during a wet period. The panel realizes the difficulty of predicting the runoff for the following year and deciding which path to follow. Such actions might be taken only after well-defined periods of dryness or wetness are evident. For example, 2011 was the fourth year in a row of above average runoff after 7 years of drought. Had different patterns of regulation of the System started after the second year of above normal runoff, additional storage may have lessened, but not necessarily prevented the 2011 flooding . In sum, the Corps needs to be given the flexibility to manage to changing, wetter conditions but also needs to be removed from reproach, if, after successive wet years, the following year turns out dry.

Question 17. Was reservoir (mainstem and tributary) storage utilized effectively? Did storage capacity go unused? What changes are needed to better utilize storage for future flooding?

The System reservoir storage for flood control comprises the annual flood control and multiple use zone, the exclusive flood control zone, and possibly some of the surcharge storage zone. Also, some of the tributary reservoirs have enough flood control storage to affect overall System releases. The answers to the questions are "yes, the storage was utilized effectively," and also "some storage did go unused." It would not be prudent to use 100 percent of all storage because there would be no remaining capacity for the contingency of additional runoff and it would not be prudent to use 100 percent of surcharge storage because that action might increase risk to infrastructure to an unacceptable level.

Recommendations for Future Management of the Missouri River Mainstem Reservoir System

The panel makes the following recommendations:

1. **Support for a program of infrastructure enhancement to ensure all flood release spillways and tunnels are ready for service and that all levees are in good condition. One of the main functions of the Corps is to maintain the water-resources infrastructure that was constructed in the past. The panel would like to emphasize the importance of adequate funding and direction for a program of infrastructure repair and rehabilitation to ensure that all flood-release spillways and tunnels are ready for service as soon as possible.**

2. **Hydrologic studies to update the design flood with new probabilities. The panel recommends re-examining the Missouri River System planning that is based on the entire historical record and adjusting to the recent decades of varying climatic extremes. In addition, the Corps should be given the flexibility to manage the System storage depending on anticipated dry and wet cycles. This modification to the Master Manual procedures might be controversial and require collaborative development with state and Federal agencies.**

3. **A review of the System storage allocations, based upon the 2011 flood event. The unprecedented inflow volume tested the reservoir system more than ever before. The panel recommends a review of the System storage allocations, to include the flood-control storage needed for floods like 2011 or larger. The panel noted that the Corps is already considering a storage allocation study such as this.**

4. **The panel recommends improved future cooperation and collaboration with the National Weather Service (NWS), and its already-established forecast systems as well as with USGS,**

possibly through the Integrated Water Resources Science and Services (IWRSS) initiative. Coordination meetings should be held with the other agencies that produce water supply forecasts, specifically the NWS and the Natural Resources Conservation Service (NRCS), to help alert the Corps to potential trouble spots. State, local, city officials, and other emergency managers, such as Federal Emergency Management Agency (FEMA) and Sheriff's departments, should be included in these meetings during periods of heightened flood risk. Communication systems for awareness of other agency forecasts and distribution of current conditions, forecasts, and planned releases for the System to all local officials and emergency managers.

5. **Studies to enhance data collection, forecasting, and resulting runoff from plains snow. Suggested activities include establishment of additional permanent plains snow measurement stations (using already established snow measurement standards), focused on the development of improved historical record at permanent stations; and research on the effects of prairie soils, geomorphology, and hydrology on snowmelt runoff. Also, the Corps should work to improve collaboration with other groups that collect and analyze snow data, for example, the Community Collaborative Rain, Hail, and Snow (CoCoRaHS) network.**

6. **A decision support system to include real-time status information on tributary reservoirs and inflows and linked to a modern interactive graphic forecast system. In noting the complexity of the communication systems required to manage the mainstem reservoirs, while considering the status of weather, downstream flooding, inflows, and storage in tributary reservoirs, the panel observed that a program of modernization is needed to create an effective decision support system linked to a modern interactive graphic forecast system.**

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Independent external review findings to be released

Omaha, Neb. – Following more than two months of analysis, interviews and research, the Missouri River Independent Expert Review Panel released its findings today.

As part of post-flood assessment efforts, the U.S. Army Corps of Engineers, Northwestern Division, enlisted the assistance of experts in meteorology, hydrology, streamflow forecasting and reservoir system operations to review, analyze and assess the Corps' operation of the six mainstem dams along the Missouri River leading up to, and during, the Flood of 2011.

The review panel members are:

- Bill Lawrence, Meteorologist/Hydrologist in charge for the Arkansas-Red Basin River Forecast Center, National Weather Service
- Darwin Ockerman, Hydrologist, U.S. Geological Survey
- Cara McCarthy, Senior Forecast Hydrologist, Natural Resources Conservation Service National Water and Climate Center
- Neil Grigg, PhD, Professor of Civil Engineering, Colorado State University

The panel reviewed and assessed a number of questions, including whether water management decisions made during the Flood of 2011 were appropriate and aligned with the Missouri River Master Manual, the water control plan that guides the operation of the Missouri River. The team also looked at whether the Corps could have prevented or reduced the impact of flooding by taking other management actions prior to the flood. Factors reviewed included 1) if long-term regulation forecasts properly accounted for the runoff into the main stem system, 2) the effects, if any, that climate change might have played in this year's record runoff, and 3) the role that floodplain development played in reservoir system operations before and during the 2011 flood event.

"We appreciate the work the panel has done to help us improve our management of the Missouri River main stem reservoir system," said Brig. Gen. John R. McMahon, Northwestern Division Commander, "and we look forward to reviewing its recommendations in detail for areas of improvement."

Corps officials will review the report to determine what elements of the panel's recommendations can be incorporated into to the 2012 Annual Operating Plan scheduled for public release in early January.

"Some of the recommendations may take time to implement, but we are paying close attention to the 2012 water situation as it develops and the status of levee and other infrastructure repairs along the Missouri River," McMahon said.

The panel began its independent review on Oct. 4, 2011.