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Northwestern Division

Technical Analysis of Missouri River Mainstem Flood Control Storage

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BG John R. McMahon
Commander and Division Engineer

Brigadier General John R. McMahon assumed command of the Northwestern Division, U.S. Army Corps of Engineers, on November 20, 2009.

In this position, he oversees an annual program of more than $3.7 billion in civil works, environmental restoration, and military construction in more than a dozen states, primarily within the Columbia and Missouri river basins. BG McMahon directs Corps of Engineers' efforts with those of other federal, state and local agencies, the Army and Air Force, the Administration and the Congress to ensure that the Corps delivers superior performance for the Nation.

As Division Commander, he is responsible for providing guidance and direction to five operating district commands located in Portland, OR, Seattle and Walla Walla, WA, Kansas City, MO, and Omaha, NE, with a combined professional workforce of nearly 5,000 DA civilians. Key missions include support to military installations and civilian communities throughout the region, managing the nation's water resources infrastructure for economic growth and environmental sustainability, and strengthening national security.

Prior to this assignment, BG McMahon served as Director of Engineering, U.S. Forces-Afghanistan, Jan - Oct 2009. Earlier assignments include: Division Commander, U.S. Army Engineer Division, South Pacific, San Francisco, CA, Aug 2006 - Jan 2009; Chief of Staff at Corps Headquarters in Washington D.C., Jul 2004 - Jul 2006; and Commander and District Engineer, Japan Engineer District, Camp Zama, Japan, Jul 2001 - Jun 2004.

His numerous stateside and overseas assignments also include serving as Chief of the U.S. European Command Customer Operations Division, and Plans Officer, U.S. Pacific Command, National Imagery and Mapping Agency, 1998-2001; Commander, 70th Combat Engineer Battalion, Ft. Riley, KS, 1995-1997; and Professor of Military Science, Rose-Hulman Institute of Technology, Terre Haute, IN, 1993-1995. From 1990-1993, he served consecutively as the Director of Engineering and Housing for the Aschaffenburg Military Community; Brigade Engineer, 3rd US Infantry Division (3ID), Kuwaiti Theater of Operations; Assistant Division Engineer for 3ID in Wuerzburg; and Battalion Executive Officer, 10th Combat Engineer Battalion, in Schweinfurt, Germany.

BG McMahon was commissioned through the Reserve Officers Training Corps (ROTC) Program at Syracuse University where he earned a Bachelor of Science degree in Biomedical Engineering in 1977. He subsequently earned master's degrees in Applied Mathematics at the Naval Postgraduate School, Monterey, CA, and in National Resource Strategy from the National Defense University.

His military education includes the Engineer Officer Basic and Advanced Courses, the Mapping, Charting & Geodesy Officer Course, the Command and General Staff College, and the Industrial College of the Armed Forces. He is a registered Professional Engineer in the Commonwealth of Virginia.

BG McMahon's awards include the Defense Superior Service Medal (1 Oak Leaf Cluster), the Legion of Merit (2 Oak Leaf Clusters), Bronze Star Medal, the Meritorious Service Medal (3 Oak Leaf Clusters) and the Army Commendation Medal, among others.

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Jody Farhat

Chief, Water Management Division

Jody Farhat has served as the Chief of the Missouri River Basin Water Management office since May 2009. Her office, which is part of the Corps of Engineers' Northwestern Division, is located in Omaha, Nebraska. She and her staff regulate the six Corps' dams on the main stem of the Missouri River to serve the Congressionally authorized project purposes. Jody has spent the past 22 years of her career working in all aspects of Missouri River Water Management. Prior to coming to the Northwestern Division, she worked in the Hydrologic Engineering Branch of the Corps' Omaha District.

Jody is native of Iowa, and has a bachelor's degree in Civil Engineering from the University of Iowa. She is a Registered Professional Engineer in the State of Nebraska.

Post 2011 Flood Event
Analysis of Missouri River
Mainstem Flood Control Storage

Executive Summary

This analysis was initiated as a result of the record 2011 flood event in the Missouri River Basin. The primary purpose was to examine how additional flood control storage may improve flood risk reduction in the future. The analysis also provides a limited investigation at the impacts of providing additional flood control storage on several Congressionally authorized project purposes.

This analysis showed that providing additional flood control storage in the Missouri River Mainstem Reservoir System (System) would enhance flood risk reduction in a repeat of the 2011 flood event. However, due to the tremendous volume of water that must be moved though the System, record releases would be required regardless of the amount of flood control storage provided. If flood control storage were increased by approximately 30 percent, peak release could potentially be reduced from 160,000 cubic feet per second (cfs) to 100,000 cfs. These lower releases would reduce flood risk below the reservoirs, but would not have prevented widespread damages.

The second part of the analysis examined the impact of additional flood control storage on five authorized purposes. Flood control is the only one of these authorized purposes that requires empty space in the reservoirs. This analysis indicates that the other four analyzed purposes, which all require water-in-storage to maximize benefits, would experience negative impacts with additional flood control storage.

<u>Background</u>

Record runoff occurred in the Missouri River basin during 2011 as a result of historic rainfall over portions of the upper basin coupled with heavy plains and mountain snowpack. Runoff in the Missouri River basin above Sioux City, Iowa during the 5-month period of March through July totaled 48.4 million acre-feet (MAF). This runoff volume was more than 20 percent greater than the design storm for the System, which was based on the 1881 March-July runoff of 40.0 MAF, coupled with releases of 100,000 cfs from Fort Randall, during the same 5-month period.

Flood control regulation of the System is centered on the concept of capturing water in the reservoirs during periods of high runoff, typically in the spring and early summer, and evacuating it later in the year at the lowest rate possible over a long period of time to reduce flood damages in the downstream reach. A key objective in this operation is to evacuate all of the flood water stored in the six reservoirs prior to the start of the following runoff season. Flood water is not carried over from year to year because doing so would limit the ability of the System to reduce flood risk in subsequent years. This means that all of the runoff that occurs in the basin in any given year must be released from the reservoirs and must pass through the downstream river reach prior to the start of the next runoff season. Simply put: “what comes in, must go out." Alternatives that would examine multi-year flood control regulation were beyond the scope of this analysis.

Without the opportunity to carry flood water over from one year to the next, the options available to manage tremendous runoff volumes like that experienced in 2011 are limited. The annual runoff volume for 2011 totaled 61.0 MAF. The sheer magnitude of this volume is difficult to visualize. If the 61 MAF of runoff were spread equally across all 365 days in a year, it would equate to 83,500 cfs of water flowing past Sioux City every minute of every day. Prior to 2011, the record release from Gavins Point, which is located 79 miles upstream of Sioux City, was 70,000 cfs, and typical tributary flows in the reach between Gavins Point and Sioux City would add 3,000 to 5,000 cfs during non-flood periods.

During the winter months, ice restricts channel capacity, making releases of that magnitude infeasible. Therefore, if flows past Sioux City were restricted to 30,000 cfs during the 90 days of winter, the remaining 275 days would require flows past Sioux City of approximately 101,000 cfs to evacuate all of the flood water. This assumes perfect foresight of the flood event and would preclude the lower releases during the fall to inspect and repair any damages associated with the event, as was done in 2011.

Methodology

As a result of this record runoff event, this technical analysis was initiated to determine how additional flood control storage in the System may reduce flood risk for storms greater than the current design storm, including runoff volumes equal to and greater than the 2011 event. This analysis also included a limited investigation of the potential impacts on other authorized purposes if flood control storage was increased.

For this analysis, a two-step process was followed. The first step was to determine the potential effect of additional flood control storage on the 2011 flood releases. The second step evaluated potential economic impacts of alternative flood control scenarios.

Under the first step, a range of scenarios was developed to determine the volume of additional flood control storage necessary to limit Gavins Point peak releases. For the 2011 flood volume, limiting peak releases to 140,000 cfs, 120,000 cfs and 100,000 cfs required 0.9 MAF, 2.6 MAF and 4.6 MAF of additional flood control storage, respectively.

Under the second step, these three flood control storage scenarios were modeled to determine the impact of this additional storage on reservoir levels and releases over the period of record. The Daily Routing Model, which was used in this analysis, simulates the regulation of the System using historic inflows from 1930 through 2011. Since flood control is the only authorized purpose that requires empty space in the reservoirs, increasing the volume of flood control storage impacts the other purposes. The degree of impact varies depending on how the alternative is implemented, and in particular, whether or not the navigation and winter release rule curves are adjusted. Therefore, each storage scenario was modeled twice – the first time with the existing navigation and winter release rule curves, and the second time with rule curves lowered an amount equivalent to the additional flood control volume. For comparison purposes, the “No Action” alternative that has the existing flood control volume of 16.3 MAF was also modeled. Output of this modeling includes reservoir levels and releases and flows at key gaging stations for the 80+ year period of record.

Output from the Daily Routing Model was then used as input to several key economic impact models. These models were used to determine the potential economic effects of changes in the regulation of the reservoir system to authorized purposes. These purposes include flood control, navigation, water supply, hydropower, and recreation.

Limitations of the Current Analysis

This report is not intended to be a complete analysis of impacts and is not intended to be a decision document. It includes a limited investigation of the potential impacts on other authorized purposes for flood risk reduction alternatives. Given the complexity of the System, further studies of economic, environmental, and cultural resource impacts would be required if alternatives to the design regulation are pursued. Additional modeling may also be required to properly assess the coincident flood risk in the lower basin.

This analysis utilizes a portion of the historic hydrologic period-of-record. The analysis does not incorporate future climate change scenarios that might alter the frequency and magnitude of high and low runoff events represented in the historic record. The analysis did not include alternatives that incorporate multi-year flood control regulation or new storage projects.

Economic models that were part of the Missouri River Master Water Control Manual Review and Update Study (Master Manual Study) were used for this report. These models were not updated to 2011 economic conditions for this analysis, however, relative differences between alternatives can still be examined and remain a valid representation of the impacts of changing the regulation of the System utilizing the best available information. The report does not present updated stage/damage relationships at key downstream locations.

Summary of Economic Impacts

The analysis shows that when compared to the No Action alternative, the average annual benefits of the System decrease as the amount of additional flood control storage increases. The reduction in average annual benefits is, for the most part, due to negative impacts to the authorized purposes including navigation, hydropower, water supply and recreation. This loss of economic benefits to other purposes is not offset by an increase in flood control benefits on an average annual basis. The addition of flood control storage has little impact on flood control benefits on an average annual basis, although it can provide significant benefits in a single high runoff year like 2011.

For the period of 1930-2010, there was essentially no change in flood control benefits under all the alternatives modeled. This is because additional flood control storage does not change the volume of runoff that must be passed through the System annually; it simply changes the magnitude and timing of releases. In some cases, the shift in timing of flood evacuation releases can exacerbate flooding and result in an overall reduction in flood benefits. The report contains additional information regarding the 2011 analysis. When 2011 is considered alone, flood control benefits show a 1.5 to 3 percent increase as flood storage increases. With the inclusion of 2011, average annual flood benefits (1930-2011) increase. The percentage change from the No Action alternative, though higher, remains less than one percent.

Navigation benefits diminish as additional flood control storage is added when there is no change to the current navigation rule curves. Lowering the rule curves an amount corresponding to the flood storage change results in the general retention of the navigation benefits. Reductions in navigation benefits range from less than one percent when the rule curves are lowered in the 2.6 and 4.6 MAF scenarios, to more than 22 percent with 4.6 MAF of additional storage without modified rule curves.

In the case of water supply, there is a direct relationship between the flood control storage and the water supply benefits in the reservoirs. Reservoir benefits drop as flood storage increases. Impacts to water supply in the river reaches are not as well defined. Overall benefits are not changed significantly for water supply with the addition of flood control storage.

Overall hydropower benefits generally drop as flood control storage is added. Reductions range from less than one percent for the 0.9 MAF alternative with existing rule curves, to 2.4 percent with the 4.6 MAF alternative with modified rule curves. Modifying the rule curves accentuates the drop in each scenario. In addition, hydropower revenues decline as flood control storage space increases. Capacity at risk and energy-at-risk were also analyzed and showed increased losses as the flood storage increases.

Average annual recreation benefits generally decline as flood storage increases. In general, increasing the amount of flood control storage reduces the recreation benefits for the upper three reservoirs, but has little impact on the lower three reservoirs or the river reaches. The lowering of the rule curves has a varying impact on recreation benefits in the reservoirs and river reaches.

Many of the impacts noted above are a result of a general lowering of the upper three reservoirs, particularly during periods of extended drought. Results of the period-of-record simulation shows that minimum reservoir levels during the most recent drought, which extended from 2000 through 2008, would have been 5.3 to 6.0 feet lower with the alternative with 4.6 MAF of additional flood control storage and modified rule curves.

Conclusions

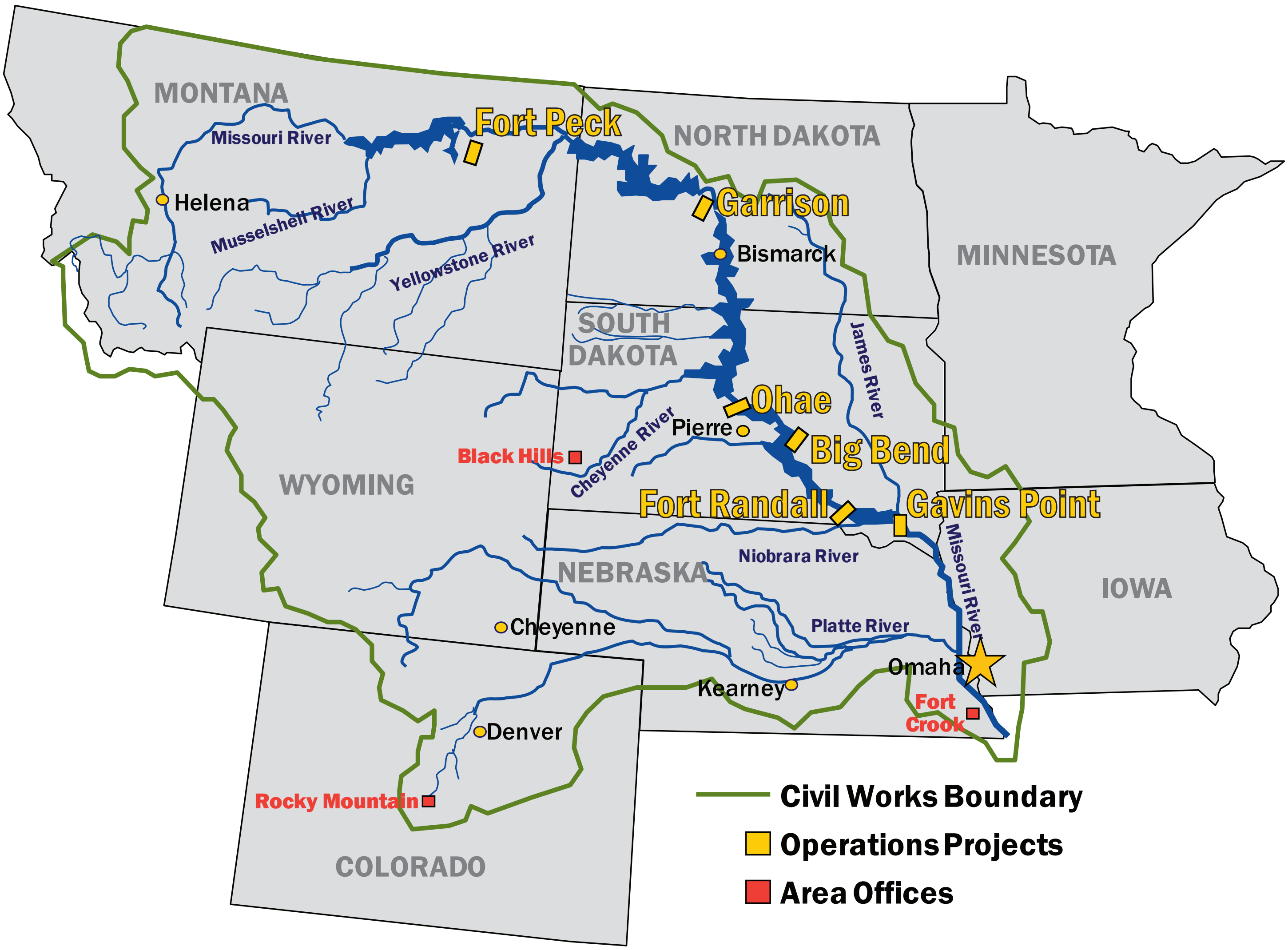
This analysis showed that increasing the volume of flood control storage in the System would enhance flood risk reduction in a repeat of the 2011 flood event, but would not have prevented record releases from the reservoirs or widespread damages. When analyzed over the 82-year period (1930-2011), despite additional flood control storage, there was no significant increase in average annual flood benefits for any of the alternatives when compared to the No Action alternative. The largest increase in annual flood benefits was less than one percent. When 2011 is considered alone, flood control benefits show a 1.5 to 3 percent increase as flood storage increases. Utilizing the additional flood control storage to reduce flows for long periods in the spring may reduce peak stages during that part of the year, but floods that occur at other times may be aggravated by the higher releases made to evacuate the water stored during that extended low release period.

The lower basin has experienced several years, 2010 being the most recent, when downstream flooding has occurred primarily due to runoff from downstream rainfall events, rather than System releases. Additional flood control storage may reduce flood risks on the lower river during certain runoff events; however, peak downstream flows and maximum stages cannot be reduced in all events. This is due to the difficulty in predicting flood-producing rainfall below the System, including during the late summer and fall evacuation period. The ability to reduce downstream stages depends on the timing of the peak flows and the distance from the control point. Therefore, flood control storage in the System is just a piece of the solution; increasing channel capacity and reducing encroachment in the flood plain are two of many additional methods to effectively reduce flood risk.

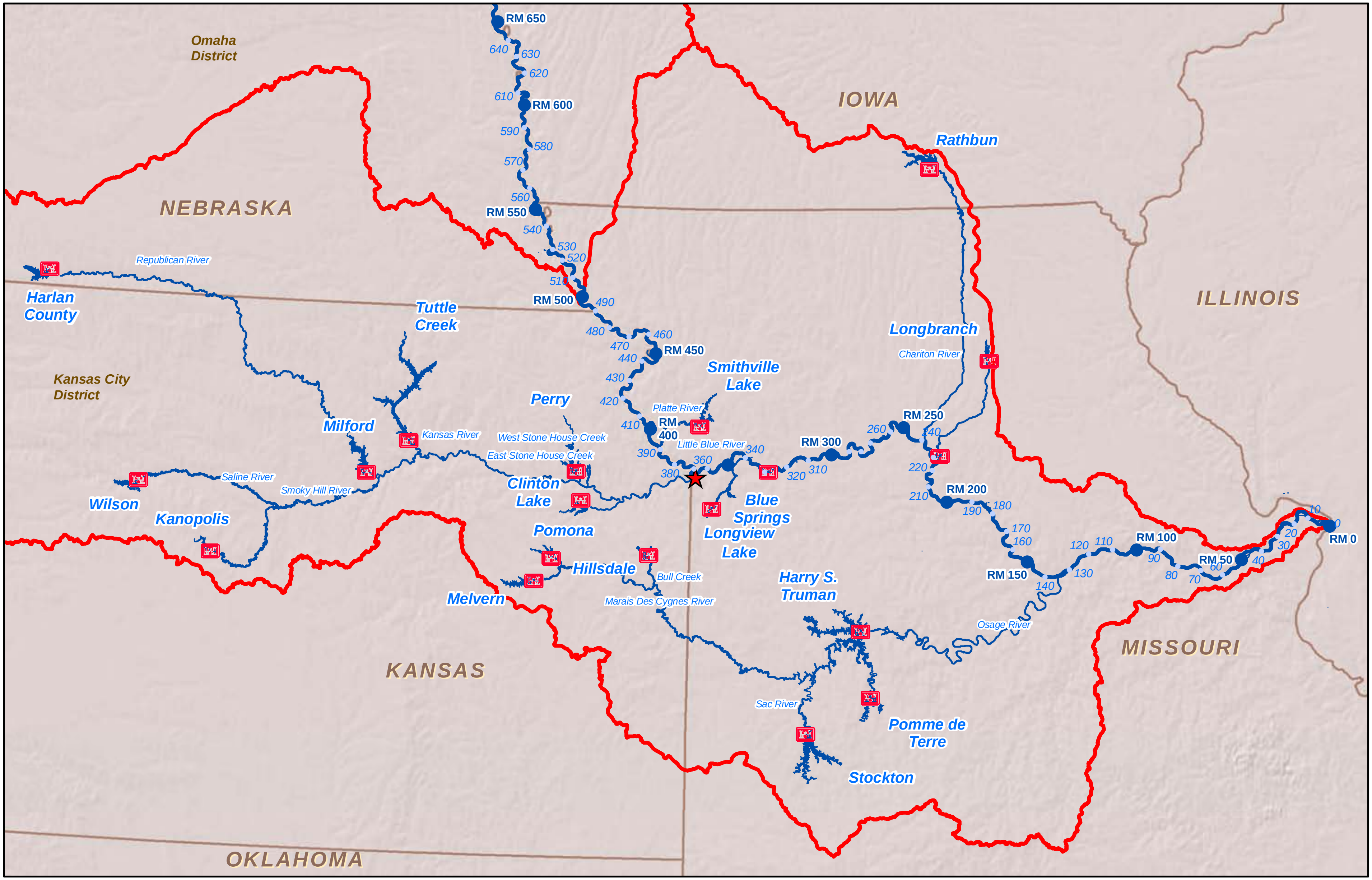
Impacts to other authorized purposes were also considered in this analysis. Flood control is the only authorized purpose that requires empty space in the reservoirs, therefore, the other authorized purposes, all of which require water-in-storage to maximum benefits, would experience negative impacts with additional flood control storage.

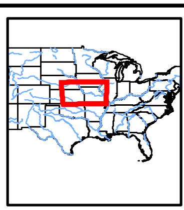
Missouri River Main Stem System

Missouri River Watershed



USACE-NWK Projects





USACE Office Locations

- ★ HQ
- Lake Office; Project Office

NWK, NWO District Boundaries

River Miles

0 5 10 20
Miles

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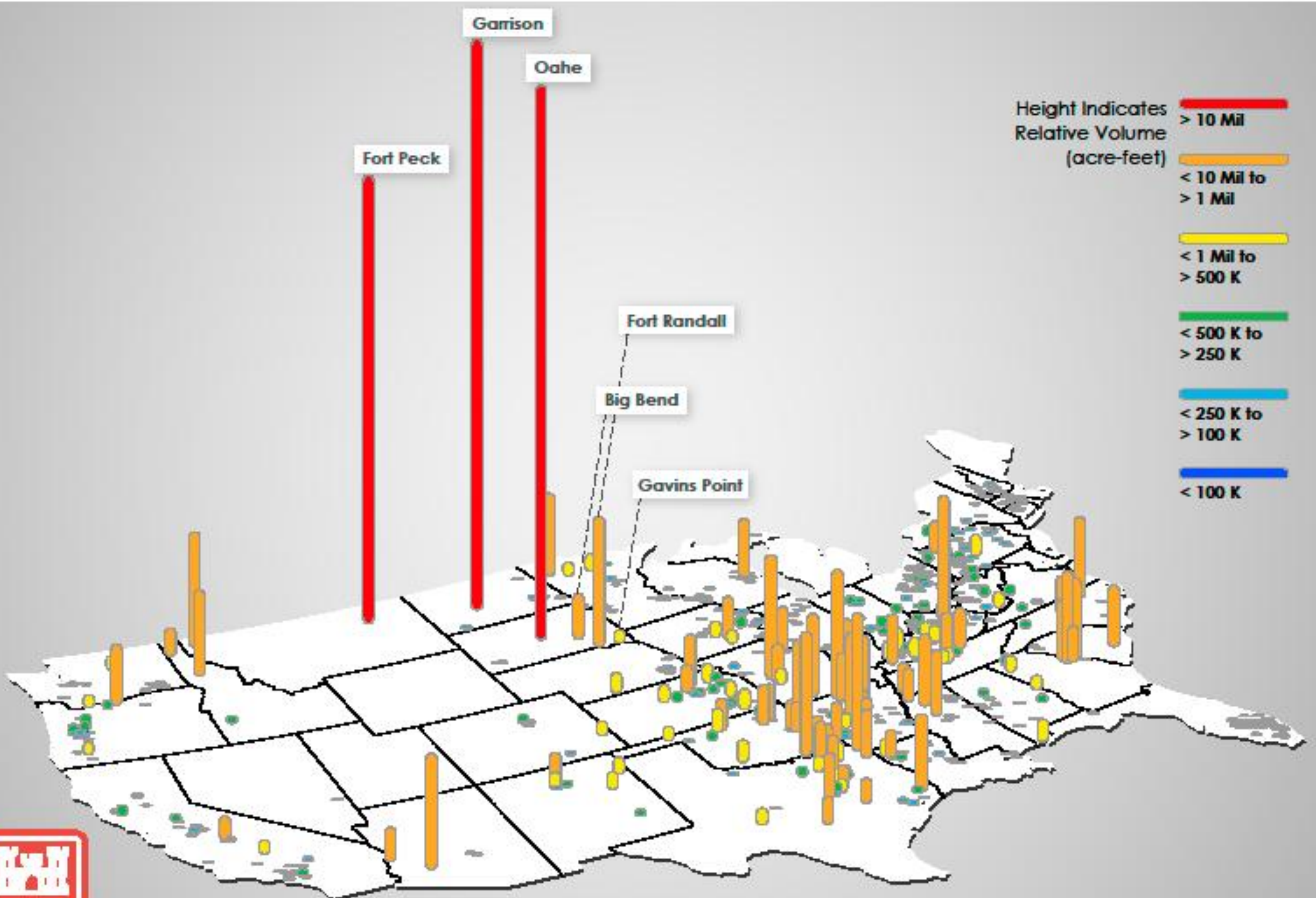
Storage Capacity of Corps Reservoirs



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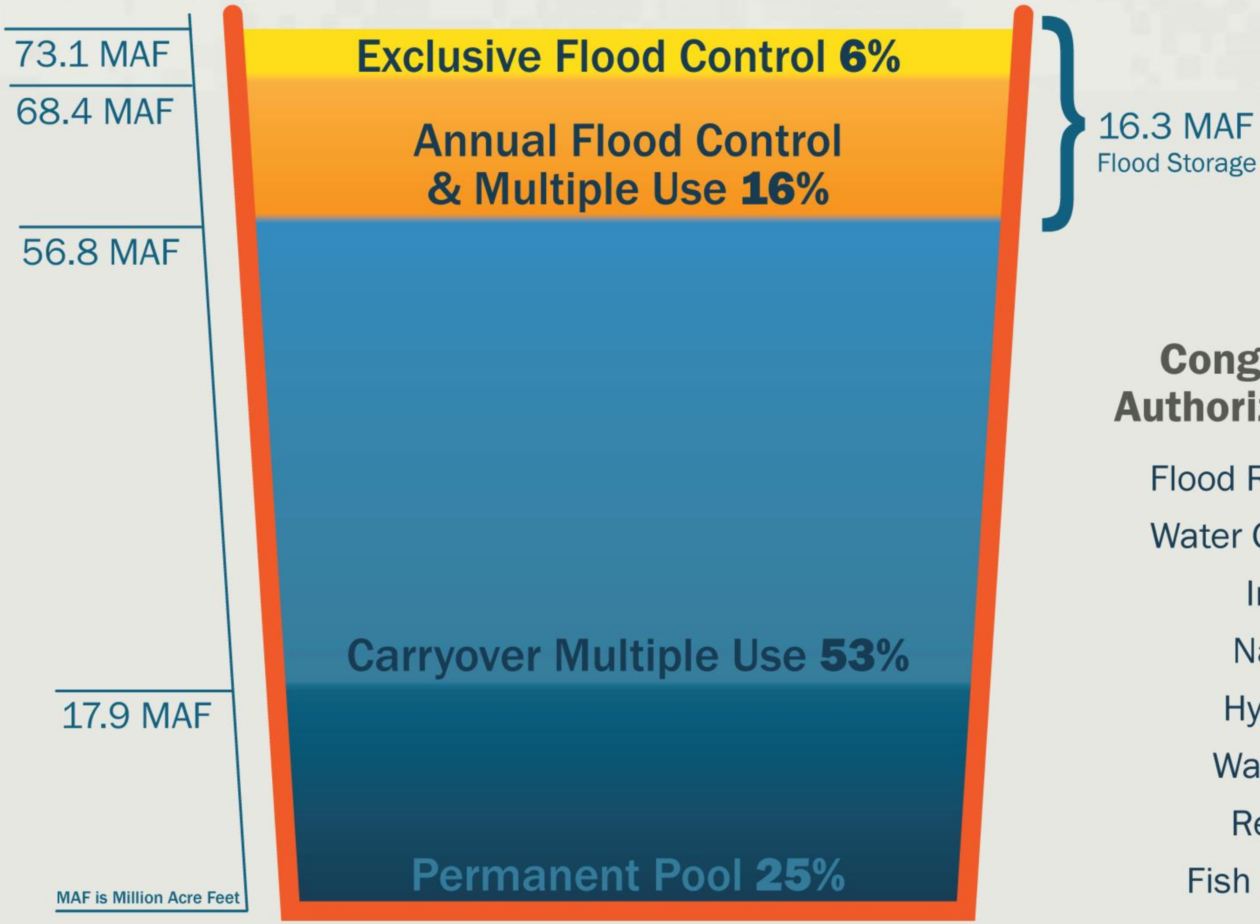
Missouri River
Main Stem Reservoir System

Zones & Allocations of the Total Storage Capacity



Congressionally Authorized Purposes

Flood Risk Reduction
Water Quality Control
Irrigation
Navigation
Hydropower
Water Supply
Recreation
Fish and Wildlife

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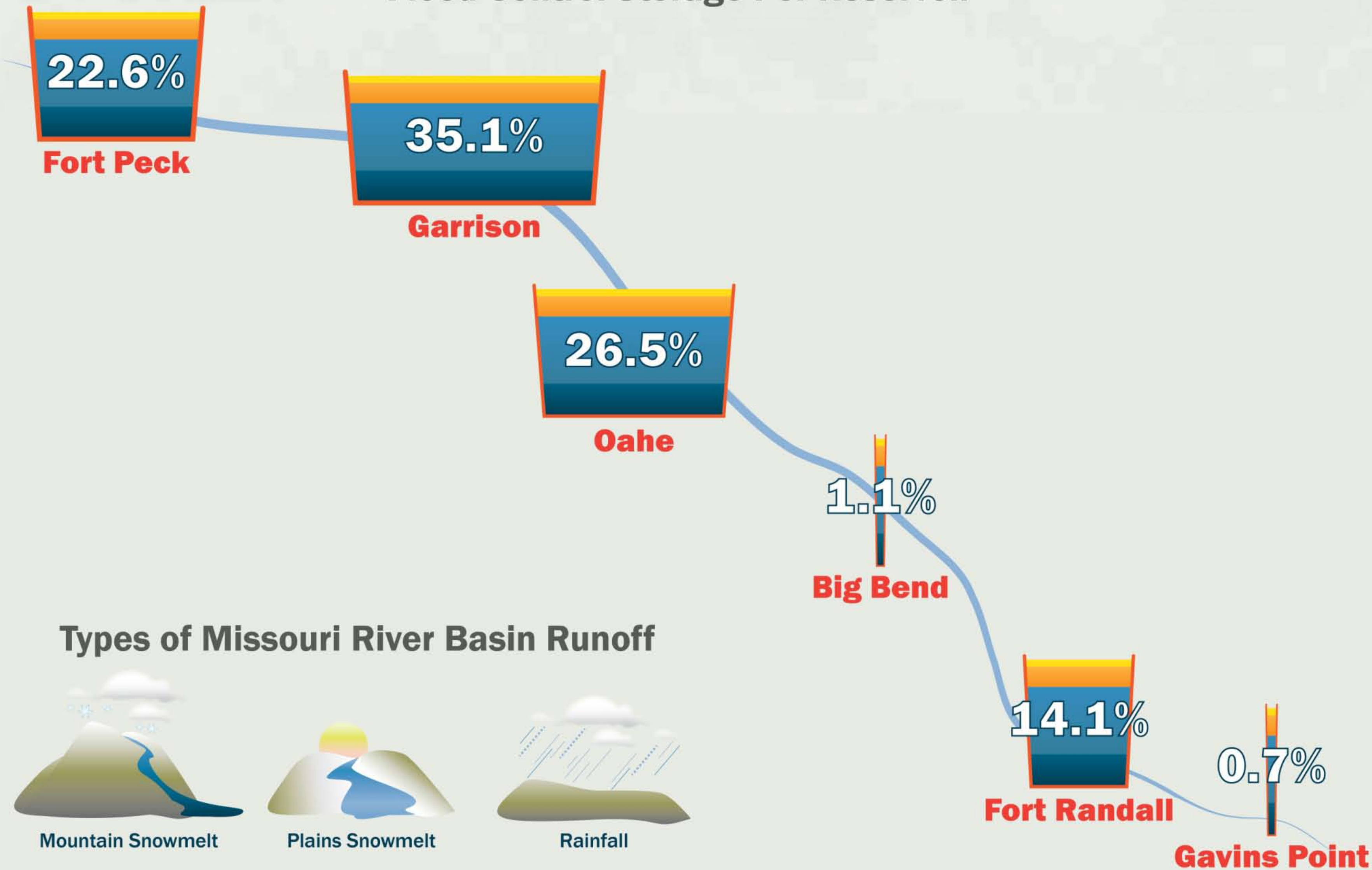
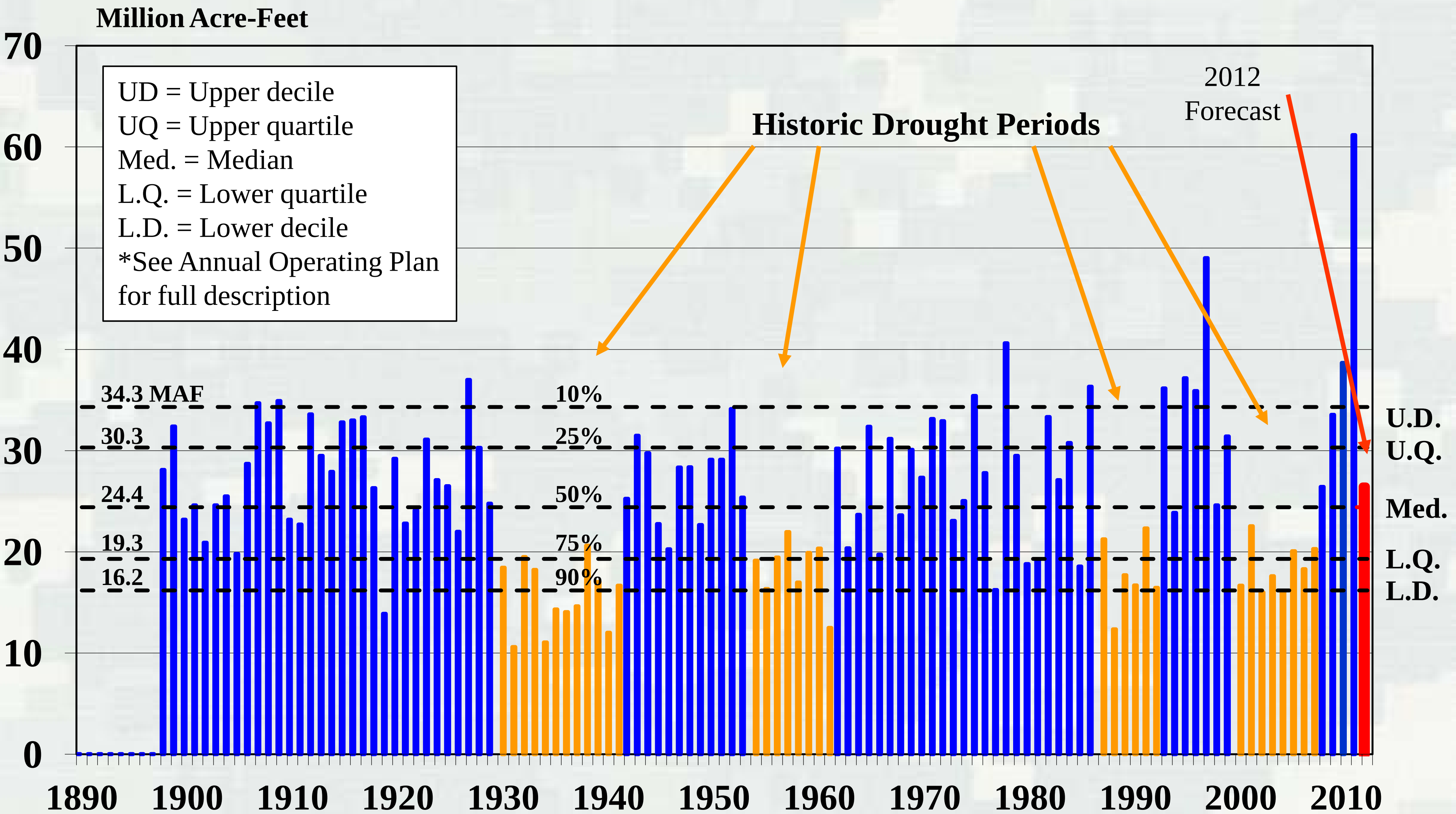
Missouri River Mainstem Reservoir System

Total Percent of System Flood Control Storage Per Reservoir



Missouri River Mainstem System
Annual Runoff above Sioux City, IA



*January 1 Forecast