U.S. ARMY COPRS OF ENGINEERS LOUISVILLE DISTRIST
DRAFT FINDING OF NO SIGNIFICANT IMPACT
2024 WATER CONTROL MANUAL REVISION FOR PATOKA LAKE
MIDDLE WABASH BASIN
INDIANA

The U.S. Army Corps of Engineers (USACE) Louisville District (LRL) has conducted an Environmental Assessment (EA) in accordance with the National Environmental Policy Act of 1969, as amended. The final Environmental Assessment dated [PENDING], for the Patoka Lake Water Control Manual (WCM) update addresses flood storage recovery opportunities and feasibility in the Patoka River Watershed at Patoka Lake.

The Draft EA, incorporated herein by reference, evaluated various alternatives that would provide faster flood storage recovery and reduced maximum pool levels while also not increasing flood risks within the project area. The recommended plan includes:

- The amendment of the Patoka Lake WCM to set a target of 13 feet at the Jasper, Indiana stream gage during the non-crop season.

For further information on alternative development and comparison, please refer to the Patoka Lake WCM Update Engineering Analysis.

For all alternatives, the potential effects were evaluated, as appropriate. A summary assessment of the potential effects of the recommended plan are listed in Table 1:

Table 1: Summary of Potential Effects of the Recommended Plan

	Insignificant effects	Insignificant effects as a result of mitigation	Resource unaffected by action
Aesthetics	☐	☐	☒
Air quality	☐	☐	☒
Wetlands	☐	☐	☒
Aquatic habitat	☐	☐	☒
Floodplains	☐	☐	☒
Invasive species	☐	☐	☒
Terrestrial habitat	☐	☐	☒
Threatened/endangered species/critical habitat	☐	☐	☒
Historic properties	☐	☐	☒
Hazardous, toxic & radioactive waste	☐	☐	☒
Land use	☐	☐	☒
Noise levels	☐	☐	☒
Recreation	☐	☐	☒
Socioeconomics	☐	☐	☒

Environmental justice	☐	☐	☒
Soils	☐	☐	☒
Tribal trust resources	☐	☐	☒
Water quality	☐	☐	☒
Climate	☐	☐	☒
Prime and unique farmland	☒	☐	☐
Transportation and traffic	☐	☐	☒
Health and safety	☐	☐	☒

All practicable and appropriate means to avoid or minimize adverse environmental effects were analyzed and incorporated into the recommended plan. Best management practices (BMPs) as detailed in the EA will be implemented, if appropriate, to minimize impacts.

No compensatory mitigation is required as part of the Recommended Plan.

Public review of the draft EA and Finding of No Significant Impact (FONSI) was initiated on [PENDING]. All comments submitted during the public review period will be responded to in the Final EA and FONSI, and any necessary changes will be incorporated.

Pursuant to section 7 of the Endangered Species Act of 1973, as amended, USACE determined that the Recommended Plan will have no effect on federally listed species or their designated critical habitat.

Pursuant to section 106 of the National Historic Preservation Act of 1966, as amended, USACE determined that historic properties will not be affected by the Recommended Plan. The Indiana Division of Historic Preservation and Archaeology concurred with the determination on August 24, 2023. The Nottawaseppi Huron Band of the Potawatomi (NHBP) stated the Recommended Plan would not adversely affect sites of cultural or religious interest to the NHBP on August 18, 2023. The Shawnee Tribe stated no known historic properties would be negatively impacted by the Recommended Plan on August 30, 2023.

All applicable environmental laws have been considered and coordination with appropriate agencies and officials has been completed.

Technical, environmental, and economic criteria used in the formulation of alternative plans were those specified in the Water Resources Council's 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. All applicable laws, executive orders, regulations, and local government plans were considered in evaluation of alternatives. Based on this report, the reviews by other Federal, State and local agencies, Indian tribes, input of the public, and the review by my staff, it is my determination that the Recommended Plan would not cause significant adverse effects on the quality of the human environment; therefore, preparation of an Environmental Impact Statement is not required.

Date	L. Reyn Mann Colonel, U.S. Army District Commander

DRAFT ENVIRONMENTAL ASSESSMENT

2024 WATER CONTROL MANUAL REVISION FOR PATOKA LAKE
MIDDLE WABASH BASIN
INDIANA

United States Army Corps of Engineers
Louisville District
June 2024

PAGE INTENTIONALLY LEFT BLANK

Table of Contents

1. INTRODUCTION

The Middle Patoka River Watershed (MPRW) covers 236,706 acres in Dubois, Gibson, Martin, Orange, Pike, Spencer and Warrick, counties in southwest Indiana (Figure 1). The Patoka River is a 167-mile-long tributary of the Wabash River and drains a largely rural area of forest bottomland and agricultural lands among the hills north of Evansville, Indiana. The lake lies in Crawford, Dubois, and Orange counties and the dam is located approximately 118 miles above the mouth of the Patoka River. The lake has 8,880 acres of surface water in the summer for fishing, boating, swimming, and other water-related activities. The surrounding area offers a wide variety of outdoor recreation opportunities. Patoka Lake averages 385,000 visitors annually, contributing almost $13 million to the local economy.

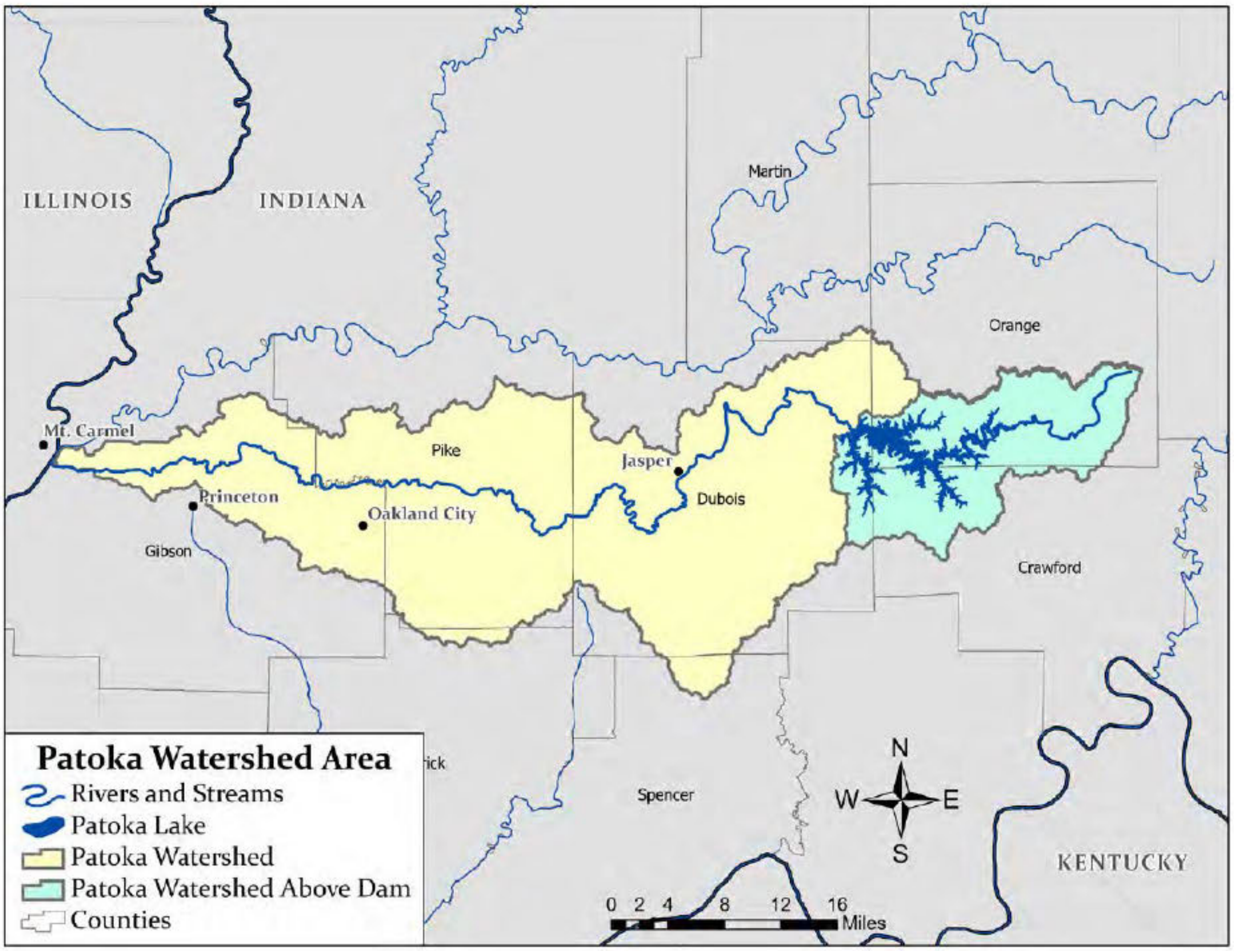


Figure 1 - Patoka River Watershed Area

In this Environmental Assessment (EA), reservoir operations refer to how USACE's Louisville District (LRL) maintains lake levels and outflows release rates, based on the current water control plan for Patoka Lake.

Flood risk management activities cannot be considered in isolation. Effective water resources management must often balance competing needs. An integrated approach to water resource planning considers flood risk management just one of many objectives needed in a watershed. Other objectives might include ecosystem restoration, recreation, water supply, hydropower, or navigation depending on the needs in the basin. A collaborative approach to water resource planning and management engages multiple, sometimes competing, stakeholders in the development of watershed management plans to fulfill these needs.

To manage and operate each water resource project, USACE district offices develop water control manuals (WCMs) to guide reservoir operations. Water resource projects include dams and their associated reservoirs across the country, for such purposes as flood control, hydropower, and water supply. Water control manuals describe the lake's dams, reservoirs, and any rivers; historic floods and storms in the project area; and data from other agencies, such as the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of the Interior's Geological Survey (USGS), that USACE uses in operating the projects. Further, WCMs describe methods for forecasting the amount of natural rainwater runoff flowing to a dam's reservoir, document policies and procedures for deciding how much water to release from the reservoirs, and generally have an associated drought contingency plan that provides guidance for district actions in response to periods of water shortages.

Information regarding hydrology, reservoir operations, and hydraulic analysis can be found in a separate report, referred to as the Engineering Analysis.

1.1 AUTHORIZATION

Patoka Lake, authorized under the Flood Control Act of 1965 (P.L. 89-298, 79 Stat. 1073, exists as a cooperative management effort between the U.S. Army Corps of Engineers (USACE) and the Indiana Department of Natural Resources (IDNR).

There are two public laws that provide USACE authority associated with conservation of fish and wildlife and conservation of endangered species which are in bullet points below.

- The Fish and Wildlife Coordination Act (FWCA), Pub. L. No. 85-624, 72 Stat. 563 (1958) (codified as amended at 16 U.S.C. § 662 (c), et seq.) authorizes the conservation of fish and wildlife as a purpose of USACE reservoirs. It provides that Federal agencies authorized to construct or operate water-control projects are authorized to modify or add to the structures and operations of such projects, and to acquire lands, in order to accommodate the means and measures for such conservation of wildlife resources as an integral part of such projects.
- The Endangered Species Act of 1973 (ESA), Pub. L. No. 93-205, 87 Stat. 884 (codified as amended at 16 U.S.C. § 1531, et seq.), with the declared policy of Congress that "Federal agencies shall cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species," provides additional authority to operate USACE projects to protect threatened or endangered fish, wildlife and plants. The Act declared it to be the policy of Congress "that all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes" of the Endangered Species Act of 1973 and that Federal agencies "cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species."

1.2 PURPOSE AND NEED STATEMENT

Patoka Lake provides flood protection to the Patoka River Valley, supplies water to the area's communities, improves low flow conditions on the Patoka River, and offers a habitat for various species of fish and wildlife.

Patoka Lake's current WCM is dated March 1986 and has not been updated in the past 4 decades. Since approximately 2006, an increasing annual rainfall trend has resulted in an increased number of events utilizing more than 50% of Patoka Lake's available flood storage capacity (9 events from 1979-2005 vs 12 events from 2006-2020), which on two occasions (2011 and 2019) resulted in uncontrolled spillway events. In 2016, 2019, and 2020, LRL requested deviations from the current WCM to target a higher stage at the gage in Jasper, Indiana to meet lake operation's needs and alleviate downstream citizens' concerns. Additionally, since 2006 there has been a nearly 20% reduction in channel capacity, likely due to sedimentation in the river channel, resulting in a reduced outflow capacity from Patoka Lake. Excess sedimentation causes channels to become unstable; flood capacity is decreased due to infilling, channel aggradation occurs (vertical raising of riverbeds), and bank erosion may increase.

The increase in frequency of high flood storage utilizations, in combination with support from downstream stakeholders (listed in Figure 2), warrants an evaluation from USACE LRL to determine what action can be taken to update the WCM to meet emerging flood risk management needs at Patoka Lake. This EA evaluates engineering modeling and uses the plan formulation process to consider several alternative changes to the water control manual and seeks to recommend the plan that maximizes the reservoir's available storge without inducing flood risk above a tolerable level.

Some of the measures considered would drain the lake more effectively to increase the flood storage capacity and reduce the likelihood of an emergency spillway event at Patoka Lake during the wettest time of the year, however measures that drain the lake more effectively could also cause downstream flooding if done too aggressively. If the water is released too aggressively the dam operation could lead to significant crop damage and adversely impact the infrastructure downstream.

This EA discusses the processes and evaluations used for USACE to recommend a change to the operating criteria for Patoka Lake. The actions needed to revise a water control plan are outlined in ER 1110-2-240.

2. NO ACTION ALTERNATIVE, CONSIDERED ALTERNATIVES, AND RECOMMENDED PLAN

A total of 12 alternatives were evaluated and compared to the current lake operations. Descriptions for individual alternatives can be found in section 2.1 below.

2.1 ALTERNATIVES DESCRIPTIONS

ALTERNATIVE 1

This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 1 instead of December 1, while keeping the target stage at the Jasper, Indiana gauge the same at 12 feet. The target date to reach winter pool will change from January 15 to December 15. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 mean sea level (msl).

ALTERNATIVE 2

This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 15 instead of December 1, while keeping the target stage at the Jasper, Indiana gauge the same at 12 feet. The target date to reach winter pool will change from January 15 to January 1. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 3 (Recommended Plan)
This alternative would involve maintaining the same guide curve for the lake and begin lowering lake levels to winter pool on December 1, but change the target stage at the Jasper Indiana gauge to 13 feet instead of 12 feet. The winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 4
This alternative would involve maintaining the same guide curve for the lake and begin lowering lake levels to winter pool on December 1, but change the target stage at the Jasper Indiana gauge to 13.5 feet instead of 12 feet. The winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 5
This alternative would involve maintaining the same guide curve for the lake and begin lowering lake levels to winter pool on December 1, but change the target stage at the Jasper Indiana gauge to 14ft instead of 12 feet. The winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 6
This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 1 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 13 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to December 15. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 7
This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 1 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 13.5 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to December 15. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 8
This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 1 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 14 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to December 15. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 9
This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 15 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 13 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to January 1. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

ALTERNATIVE 10

This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 15 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 13.5 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to January 1. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

Alternative 11

This alternative would involve changing the guide curve to begin lowering lake levels to winter pool beginning on November 15 instead of December 1, and changing the target stage at the Jasper, Indiana gauge to 14 feet instead of 12 feet. The target date to reach winter pool will change from January 15 to January 1. Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

Alternative 12

This alternative would involve changing the release schedule based on the percentage of flood storage that is utilized in Patoka Lake. At 33% utilization operations would target 13 feet at the Jasper, Indiana gauge. At 66% utilization operations would target 14 feet at the Jasper, Indiana gauge (depending on the results from operating for 14 feet during all of Non-crop season). Additionally, the winter pool elevation of Patoka Lake would remain the same at 532 msl.

2.2 ALTERNATIVE SCREENING

The 12 alternatives were screened using the Hydrologic Engineering Center Reservoir System Simulated program (HEC Res-Sim). Alternatives 1 and 2 were eliminated due to lack of impact on peak pool elevations and flood storage utilization while alternatives 4-12 were eliminated due to the increased risk of flooding low-lying roads in the Jasper area. The remaining alternative, alternative 3, was chosen as the Recommended Plan as it increased flood storage recovery without increasing flood risks to downstream Jasper, Indiana. For full results of the HEC Res-Sim and the full alternatives analysis, please refer to Attachment A, Engineering Appendix.

2.3 NO ACTION ALTERNATIVE

The No Action Alternative (NAA) would not implement revisions to the 1986 WCM. The WCM would remain the same as outlined in the 1986 version. If the Patoka Lake WCM is not updated, there would not be faster flood storage recovery during non-crop season. Therefore, if the trending increase in annual rainfall continues, the number of events utilizing more than 50% of Patoka Lake’s available flood storage would increase, which could lead to uncontrolled spillway events. There would also continue to be a reduction in channel capacity, (due to sedimentation in the river channel) resulting in a reduced outflow capacity from Patoka Lake.

2.4 RECOMMENDED PLAN

Of the 12 alternative operations that were modeled, Alternative 3 emerged as the recommended plan. Operating for a target stage of 13 feet at the Jasper gage during non-crop season with no change to the existing guide curve was chosen because it lowered peak pool elevations and flood storage utilization with minimal increase to flooding risk downstream.

The Recommended Plan involves a change to the operating criteria for Patoka Lake by increasing the non-crop season control stage from 12 feet to 13 feet at the Jasper, Indiana gage (United States Geological Survey (USGS) Gage 03375500), the project's only downstream control point. There would be no change to the crop season control stage at Jasper, which is 9 feet. Non-crop season is typically from December 1 through April 15. The winter pool elevation of Patoka Lake would remain the same at 532 feet NGVD29. This alternative represents only one operational change, which is to operate for a target stage at Jasper of 13 feet instead of 12 feet during non-crop season.

3. AFFECTED ENVIRONMENT AND IMPACTS DUE TO RECOMMENDED PLAN

The Council of Environmental Quality's (CEQ) National Environmental Policy Act (NEPA) Implementing Regulations require that an EA identify the likely environmental effects of a proposed project and that the agency determine whether those impacts may be significant. Effects (or impacts) are changes to the human environment from the Recommended Plan or alternatives that are reasonably foreseeable and include direct effects, indirect effects, and/or cumulative effects, as defined by 40 C.F.R. § 1508.1(g). Effects may include ecological, aesthetic, historic, cultural, economic, social, or health effects, and can be either beneficial or adverse.

In considering whether the effects of the Recommended Plan are significant, agencies shall analyze the potentially affected environment and degree of the effects of the action (40 C.F.R. § 1501.3(b)). In considering the potentially affected environment, agencies should consider the affected area and its resources, understanding that significance varies with the context of the Recommended Plan. Agencies should consider connected actions including actions that automatically trigger other actions, that cannot or will not proceed unless other actions are taken previously or simultaneously or are independent parts of a larger action and depend on the larger action for their justification (40 C.F.R. § 1501.9(e)). In considering the degree of the effects of the action, agencies should consider both short-term and long-term effects, both beneficial and adverse effects, effects on public health and safety, and effects that would violate laws protecting the environment. The term "degree" is not defined in the governing regulations, but generally refers to the magnitude of change that would result from the alternatives evaluated herein.

The primary change resulting from the Recommended Plan would be a greater volume of water being released into the Patoka River during the non-crop season. All potentially relevant resource areas were initially considered for analysis in this EA. Some resource topics are not discussed, or the discussion is limited in scope, due to the lack of the ability of the Recommended Plan or NAA to have an effect on the resource or because that resource is not located within the affected environment, including wild and scenic rivers, aesthetics, land use, traffic, transportation, air quality, and noise.

This section presents the adverse and beneficial environmental effects of the Recommended Plan and the NAA. The section is organized by resource topic, with the effects of alternatives discussed under each resource topic. Impacts are quantified whenever possible. Qualitative descriptions of impacts are explained by accompanying text where used.

Qualitative definitions/descriptions of impacts as used in this section of the EA include:

Degree:

- No Effect, or Negligible – a resource would not be affected, or the effects would be at or below the level of detection, and changes would not be of any measurable or perceptible consequence.
- Minor – effects on a resource would be detectable, although the effects would be localized, small, and of little consequence to the sustainability of the resource. Mitigation measures, if needed to offset adverse effects, would be simple and achievable.
- Moderate – effects on a resource would be readily detectable, localized, and measurable. Mitigation measures, if needed to offset adverse effects, would be extensive and likely achievable.
- Significant – effects on a resource would be obvious and would have substantial consequences. The resource would be severely impaired so that it is no longer functional in the project area. Mitigation measures to offset the adverse effects would be extensive, and success of the mitigation measures would not be guaranteed.

Duration:

- Short-term – temporary effects caused by the construction and/or implementation of a recommended plan.
- Long-term – caused by an alternative after construction has been completed and/or when it is in full and complete operation.

A HEC Res-Sim model comparing current dam operations with a target of 12 and 13 feet at Jasper, Indiana stream gage was created. The project area is defined as the section of Patoka River between Patoka Lake and Indiana state route 162, as well as any areas that were shown to receive more water in the USACE model due to the potential WCM change. Areas past Jasper are impacted more by uncontrolled runoff than releases from Patoka Dam and are therefore outside the scope of analysis for this EA. Any deviations from this specified project area for a specific resource will be noted in their individual sections.

Due to the nature of the Recommended Plan, the following resources were dropped from further analysis due to no potential for impacts: aesthetics, land use, traffic, transportation, air quality, and noise.

3.1 CLIMATE CHANGE CONSIDERATIONS

EXISTING CONDITION

Climate in Patoka River watershed is humid subtropical with four distinct seasons. Spring-like conditions typically begin in mid-to-late March, summer from mid-to-late-May to late September, fall in the October-November period. Seasonal extremes in both temperature and precipitation are not uncommon during early spring and late fall.

USACE performed a qualitative analysis of climate change impacts as required by Engineering and Construction Bulletin (ECB) 2018-14 “Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies”. This analysis documented qualitative impacts of climate change on hydrology within the region. Data was obtained from the MRCC (Midwestern Regional Climate Center)

Shoal Station from 1927-2021 to determine current climactic conditions. Over the 93-year period of analysis, average rainfall was 45.60 and an average daily temperature of 54.4 degrees Fahrenheit. Historical trends for the Patoka River Basin showed a long-term increase in precipitation and stream flow, and a long-term decrease in temperatures, which transitioned to a steady increase in temperatures since 1975.

The USACE climate analysis also crafted climate and hydrologic projections for the future of the project area. The climate analysis indicates conflicting projected future streamflow and precipitation within the region but does indicate strong potential for increases in future temperatures. USACE's Climate Hydrology Assessment Tool (CHAT) was used to analyze 93 combinations of global circulation models (GCM) and representative concentration pathways (RCP). Within these combinations, an increase in temperature and precipitation were identified. A statistically significant increase in river inflow was also identified in higher emissions scenarios, however, no trend was identified in lower emissions scenarios. At this time, each of the 93 scenarios included in the CHAT output are considered equally likely to occur. For the full climate report, please refer to the Engineering Analysis report.

Analysis of Green House Gas (GHG) impacts are required by USACE policy. Current levels of GHG emissions due to dam operations are unknown, however are estimated to be minimal and limited to equipment use during day-to-day work activities. Patoka Lake itself likely emits methane (CH4) due to biological activity and ebullition but may act as a carbon dioxide (Co2) sink according to an emissions study conducted on 32 reservoirs throughout the United States (Beaulieu et al. 2020).

NO ACTION ALTERNATIVE

The NAA would have no effect on climate change as no changes would occur. However, in an increased precipitation scenario, projected climate trends could exacerbate project conditions under the NAA as potential increased river flow would cause a moderate, long-term increase in risk of further deviations and uncontrolled spillway releases. GHG emissions would remain static under the NAA.

RECOMMENDED PLAN

The Recommended Plan would not result in any temporary or permanent emissions, and would therefore, not contribute to climate change. Further, in potential increased precipitation/flow scenarios, the Recommended Plan would produce a moderate long-term risk reduction of uncontrolled spillway events by recapturing flood storage more quickly. This would allow Patoka Lake operations to better regulate downstream gage height and flow during precipitation events. No changes in GHG emissions levels are anticipated due to the Recommended Plan.

3.2 INVASIVE SPECIES

EXISTING CONDITION

According to a USACE technical policy memorandum dated February 21, 2023, which updated Invasive Species guidance in regard to Section 501 of the Water Resources Development Act (WRDA), USACE is to include measures to prevent or reduce the establishment of invasive and non-native species as a component to all civil work's projects (USACE 2023b).

According to the Indiana Invasive Species Council (IISC), an invasive species is defined as, within a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic harm, environmental harm, human harm, or negative impact animal or plant health (IISC 2023). IISC released a table that outlines the exotic plant species that pose a severe threat within Indiana, which is provided in Appendix B, Environmental Documents. The proposed project area does not have a formal inventory of invasive species; therefore, their presence is not well known. However, given the heavy agricultural use and lack of natural areas along Patoka River, it can be reasonably assumed that invasive species are common.

NO ACTION ALTERNATIVE

The NAA would result in no effect to the current status of invasive species in the area. It is expected that invasive species are common and would continue to be common in the disturbed areas along the Patoka River.

RECOMMENDED PLAN

The Recommended Plan would cause portions of certain riparian areas to receive water more frequently. Historically, however, the areas flood frequently without the implementation of the recommended plan; therefore, it would be expected that there would be no effect to the status of invasive species since any potential invasive seed dispersal would remain the same.

3.3 RECREATION

EXISTING CONDITION

Patoka Lake and Patoka River are used for recreational activities such as boating, swimming, fishing, and watersports. In addition, the habitat provided by these resources provides various opportunities to view wildlife.

NO ACTION ALTERNATIVE

No changes would occur to this resource due to the NAA.

RECOMMENDED PLAN

Recreation at Patoka Lake would be unaffected by the WCM update as it mainly applies to the recovery of flood storage after rain events and the period shortly after summer pool ends since the target winter pool level of 532 feet NGVD29 would remain unchanged. Patoka River would experience marginally higher levels, which could result in a negligible positive effect on recreational boating due to easier navigation. Shoreline habitat and other wildlife viewing opportunities related to the WCM would also not be impacted.

3.4 SOILS AND GEOLOGY

EXISTING CONDITION

The project area is composed of two distinct geologic map units; Stephensport Group and Raccoon Creek Group. The Stephensport Group is composed of sandstone, micritic and skeletal limestone, and shale. The Raccoon Creek Group is composed of mostly sandstone and shale with thin layers of coal, limestone, and clay (Gray et al. 1987).

The Farmland Protection Policy Act (FPPA), 7 U.S.C. § 4201, et seq. (1981), urges federal entities to limit the conversion of prime and unique farmland to nonagricultural uses. The FPPA defines “prime farmland” as “land that has the best combination of physical and chemical characteristics for producing food, feed, fiber, forage, oilseed, and other agricultural crops with minimum inputs of fuel, fertilizer, pesticides, and labor, and without intolerable soil erosion, as determined by the Secretary.” 7 USC § 4201. The FPPA further provides that “[p]rime farmland includes land that possesses the above characteristics but is being used currently to produce livestock and timber. It does not include land already in or committed to urban development or water storage." Desktop analysis conducted via the National Resources Conservation Service's (NRCS) Web Soil Survey application indicates that multiple soil map units are classified as prime farmland within the project area (NRCS 2023). For a full soil unit map of the project area and NRCS soil descriptions, please refer to the NRCS soil report in Appendix B, Environmental Documents (NRCS 2023).

NO ACTION ALTERNATIVE

No changes to the WCM would be made, therefore, no effect to soils or geology would occur.

RECOMMENDED PLAN

The Recommended Plan would have no effect to soils or geology. While NRCS defined prime farmland soil map units do intersect areas impacted by the Recommended Plan, additional water being received during the non-crop season will not preclude agricultural use and will therefore not represent a conversion of prime farmland to nonagricultural use.

3.5 SURFACE WATERS AND OTHER AQUATIC RESOURCES

EXISTING CONDITION

The project area falls within the Patoka hydraulic unit code (HUC)8 watershed 05120209 (USGS 2023). The project area contains palustrine forested (PFO) wetland habitat, palustrine scrub-shrub (PSS) habitat, palustrine emergent (PEM) wetland habitat, agricultural ditches, and a handful of named/unnamed tributaries of the Patoka River (USFWS 2023a).

Section 303(d) of the Clean Water Act (CWA), 33 USC § 1313 (1972) requires States, Territories, and Federally Recognized Tribes to list and prioritize waters for which technology-based limits alone do not ensure attainment of water quality standards. The CWA and the United State Environmental Protection Agency (USEPA) regulations require that Total Maximum Daily Load (TMDL) be developed for all waters on the section 303(d) lists. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation or attribution of that amount to the pollutant's sources. Lists of 303(d) waters are made available to the public and submitted to the USEPA and Indiana Department of Environmental Management (IDEM) Office of Water Quality. The process of formulating TMDLs for specific pollutants is a method by which impaired water body segments are identified and restoration solutions are developed. Ultimately, the goal of TMDL process is full attainment of biological and chemical Water Quality Standards (WQS) and, subsequently, removal of water bodies from the 303(d) list (USEPA 2009).

According to the USEPA's How's my Waterway website, the Patoka Reservoir, and the Patoka River immediately downstream from Patoka dam are not impaired. Patoka River from Cuzco Road to north of Jasper is impaired for aquatic life and swimming/boating purposes due to bacteria and low oxygen levels and is on the USEPA 303(d) list. At Jasper, Patoka River is also impaired for shellfish and fish consumption and has polychlorinated biphenyls (PCB) listed as a pollutant. Davis Creek, which has a confluence with Patoka River within the project area, is not impaired (USEPA 2023a).

NO ACTION ALTERNATIVE

Since there would be no changes to the WCM, no changes to surface waters and aquatic resources would occur.

RECOMMENDED PLAN

Under the Recommended Plan, greater water release rates would occur during the non-crop season. Minimum flows would not change under the Recommended Plan; therefore, no water quality impacts or changes to 303d lists are anticipated to occur due to its implementation.

No adverse impacts to streams or wetland resources are anticipated due to implementation of the Recommended Plan.

3.6 WILDLIFE HABITATS

EXISTING CONDITION

The project area lies primarily within the Crawford Uplands Level 4 Ecoregion within the Interior Plateau Level 3 Ecoregion (USEPA 2023b). The Crawford Uplands was originally covered in forested areas. Uplands areas were dominated by species like white oak (*Quercus alba*), black oak (*Quercus velutina*), southern red oak (*Quercus falcata*), post oak (*Quercus stellata*), and pignut hickory (*Carya glabra*). Dominant mesic site species include American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), southern red oak, white ash (*Fraxinus americana*), and tulip tree (*Liriodendron tulipifera*). Riparian forested area species include American sycamore (*Platanus occidentalis*), red maple (*Acer rubrum*), river birch (*Betula nigra*), eastern hemlock (*Tsuga canadensis*), common hackberry (*Celtis occidentalis),* and sweetgum (*Liquidambar styraciflua*) (bplant 2023a). Currently, the ecoregion is a mosaic of farmland, forestland, and pastureland. Areas where farmland is being converted back to its natural state have successional habitats dominate by little bluestem (*Schizachyrium scoparium*), broomsedge bluestem (*Andropogon virginicus*), eastern redcedar (Juniperus virginiana), and sumac (*Rhus sp.*). The project area transitions to the southern Wabash Lowlands level 3 ecoregion within the Interior River Lowlands Level 4 ecoregion at its westernmost extreme (USEPA 2023b). This region primarily has been cleared for soybean, grain, livestock, and assorted vegetable production (bplant 2023b).

The habitat within the project area is primarily riparian as it is within the floodplain of Patoka River. This floodplain eventually expands into an alluvial fan closer to the Wabash River. Various wetland habitat types occur along this floodplain.

NO ACTION ALTERNATIVE.

No changes would occur to the Patoka Lake WCM; therefore, no impacts would occur to wildlife habitats.

RECOMMENDED PLAN

The Recommended Plan would result in certain riparian areas receiving water on a more frequent basis during the winter months. This would cause a negligible to minor positive impacts to wetland habitat due to more frequent flooding/ponding, which is important to wetland function. Modeling of downstream inundation showed no changes to terrestrial upland habitat; therefore, the proposed WCM update would not have the potential to impact it (USACE 2023c).

3.7 THREATENED AND ENDANGERED SPECIES

EXISTING CONDITION

The United States Fish and Wildlife Service (USFWS) Information for Planning and Consultation (IPaC) provides information on federally threatened and endangered species that have potential to occur within the project disturbance area. The IPaC report indicates that the Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), tricolored bat (*Perimyotis subflavus*), whooping crane (*Grus americana*), and monarch butterfly (*Danaus plexippus*) have ranges that intersect with the project area (USFWS 2023b). For the full USFWS IPAC report, please refer to Appendix B, Environmental Documents.

The applicable USFWS species designations are defined below (USFWS 2023b).

- Endangered
  - Any species which is in danger of extinction throughout all or a significant portion of its range. Endangered species are protected by the take prohibitions of section 9 under the ESA.
- Threatened
  - Any species which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. Threatened species are protected by the take prohibitions of section 9, consistent with any protective regulations finalized under section 4(d) of the ESA.
- Candidate
  - Any species for which the Service has sufficient information on its biological status and threats to propose it as endangered or threatened under the ESA, but for which development of a proposed listing regulation is precluded by other higher priority listing activities. Candidate species are not protected by the take prohibitions of section 9 of the ESA.
- Proposed Endangered
  - Any species the Service has determined is in danger of extinction throughout all or a significant portion of its range and the Service has proposed a draft rule to list as endangered. Proposed endangered species are not protected by the take prohibitions of section 9 of the ESA until the rule to list is finalized. Under section 7(a)(4) of the ESA, Federal agencies must confer with the Service if their action would jeopardize the continued existence of a proposed species.
- Experimental Population, Non-Essential
  - A population that has been established within its historical range under section 10(j) of the ESA to aid recovery of the species. The Service has determined a non-essential population is not necessary for the continued existence of the species. For the purposes of consultation, non-essential experimental populations are treated as threatened species on National Wildlife Refuge and National Park land (require consultation under 7(a)(2) of the ESA) and as a proposed species on private land (no section 7(a)(2) requirements, but Federal agencies must not jeopardize their existence (section 7(a)(4)))

The Indiana bat was listed by USFWS as endangered in 1967. Indiana bats hibernate during winter in caves. For hibernation, they require cool, humid caves with stable temperatures, under 50° F, but above freezing. Very few caves within the range of the species have these conditions. If bats are disturbed or cave temperatures increase during hibernation, more energy is needed, and hibernating bats may starve (USFWS 2006). In the spring, Indiana bats emerge from hibernation and migrate to summer roost sites where they usually roost under loose tree bark of dead or dying trees. During summer, males roost alone or in small groups, while females roost in larger groups of up to 100 bats or more. Indiana bats also forage in or along the edges of forested areas. Indiana bats are found over most of the eastern half of the United States. Almost half of all Indiana bats (207,000 in 2005) hibernate in caves in southern Indiana. The 2005 population estimate was about 457,000 Indiana bats, half as many as when the species was listed as endangered in 1967 (USFWS, 2006). Loss and fragmentation of forest habitat are among the major threats to Indiana bat populations. Other threats include white-nose syndrome, winter disturbance, and environmental contaminants (USFWS, 2006).

The tricolored bat was proposed as endangered on September 13th, 2022. This species occurs in caves and mines during the winter months. In its extreme southern range, species would make use of culverts, man-made structures, and trees for hibernacula. During the summer months, this species makes use of waterways, wetlands, and other riparian areas for forage and roosts in the leaf clusters or bark of trees (USFWS 2023c). The primary threats to this species are wind turbines and white nose syndrome. In addition, clearing of wooded forage habitat also has adverse impacts on this species (NatureServe 2023a).

The northern long-eared bat was listed as threatened by USFWS in 2015 and later reclassified as endangered on November 30th, 2022. The species decline has been mainly attributed to white-nose syndrome. The bats spend the winter months hibernating in caves and mines. During the summer months, the bats roost singly or in colonies underneath bark or in cavities or crevices of both snags and live trees (USFWS 2015). The primary threat to this species is white nose syndrome, which caused severe population losses in all hibernacula that were infected. Additional threats include loss of summer habitat, which includes roosting trees and other forested areas, and wind turbine strikes (USFWS 2015).

The whooping crane was listed by USFWS as endangered in 1970. The whooping crane's range within this region is designated as an experimental population that is non-essential (EXPN). This species prefers nesting in dense vegetation in shallow ponds, wet prairies, or along the margins of lakes. During migration, this species makes use of palustrine wetlands and occasionally cropland for forage (NatureServe 2023b). Primary threats to this species include accidental shooting, wind energy related bird strikes, electrocution due to power lines, disease, and development impacts at their wintering and breeding ranges. Individuals found in Ohio are primarily migrants of the eastern population migrating between Florida and Wisconsin (NatureServe 2023b).

Monarch butterflies are an iconic species with an annual, multigenerational, migratory life cycle and a cross-continental migratory range covering portions of Canada, the US and Mexico. To complete their life cycle, monarch caterpillars must feed on milkweed (Asclepias spp.) plants while adults feed on nectar from a variety of blooming plants. Threatened by habitat loss, climate change, pesticide applications, natural enemies, and other abiotic and biotic stressors, monarch butterfly populations have been in decline (USFWS 2023d). Consequently, the monarch butterfly was listed as a candidate species on December 15th, 2020. This species migrates to its breeding locations in Mexico and California starting November and lasting until early March (Monarch Joint Venture 2023). Due to this, it is unlikely that individuals would be in the project area during the timeframe the proposed WCM changes would be implemented.

NO ACTION ALTERNATIVE

No changes to the WCM would be made; therefore, no federally listed or candidate species would be impacted.

RECOMMENDED PLAN

Due to the Recommended Plan implementation, certain riparian areas would begin to see increased frequency of flooding/ponding during the non-crop season.

A karst cave density map of Indiana indicates that one zone within the project area has at least one cave entrance (Indiana Map 2023). This zone is near where Patoka River passes North Cuzco Road. The USACE HEC Res-Sim model shows minimal change in this area; therefore, impacts to this potential hibernaculum are not anticipated. Crop fields and riparian zones receiving extra water would also not impact this species. No loss of forested areas is anticipated due to the WCM change. Due to these factors, the WCM change is anticipated to have *no effect* on the tricolored bat, Indiana bat, and northern long-eared bat.

The whooping crane would occur within the project area during migration season and would make use of forage and stopover habitat. Portions of the project area receiving additional water during the non-crop season would not impact this species. No other changes are anticipated; therefore, the WCM update is expected to have *no effect* on the whooping crane.

The monarch butterfly would not be present within the project area during the months there would be increased water in low lying areas. Potential additional inundation would not damage forage habitat for the species since any new areas are already within a riparian zone. Due to this, the Recommended Plan is anticipated to have *no effect* on the monarch butterfly.

3.8 CULTURAL RESOURCES

EXISTING CONDITION

A number of steps were taken in an effort to identify cultural resources within the project area (also referred to as the Area of Potential Effects (APE)) for the proposed change to the WCM. These included a background check of the online National Register of Historic Places (NRHP) database, the USACE Geographic Information System (GIS), the Indiana State Historic Architectural and Archaeological Research Database (SHAARD) GIS database, and previous cultural resource survey reports that have occurred near the vicinity of the project area.

USACE searched the SHAARD GIS data on July 18, 2023, which identified one archaeological site intersecting the boundary of the project area, site 12Du406. This site is described as an unknown prehistoric site and is unassessed for its eligibility to the NRHP. Nine other archaeological sites are located within 100 feet of the project area but would not be affected by the proposed update to the WCM . These sites include 12Du194, 12Du283, 12Du293, 12Du386, 12Du405, 12Du407, 12Du741, 12Du754, and 12Du812. One previously recorded above ground resource, the Enlow Mill Historical Marker (037-304—2-23154), is located within 100 feet of the project area and would also not be affected by the update to the WCM. The Indiana Division of Historic Preservation and Archaeology (DHPA) informed USACE of two above ground properties and a historic district within the project area that may meet the criteria for eligibility for inclusion in the NRHP including the Hopf Farm located at 295 E. 12th Avenue (037-287-20026), the French Lick West Baden Southern Railway Historic District, including French Lick, Passenger Station (117-226-27005), Burton Tunnel (117-276-20054), seven miles of track between French Lick and Orange County Line, and an additional twenty-five miles of track into Dubois County, and the Indiana State Highway Bridge located along SR 164 (East 3rd Avenue) (164-19-03717). The background search also revealed that seven bridges were located within the project area, but have been previously demolished (HB-0435, HB-0440, HB-0441, HB-0444, HB-0445, HB-0447, and HB-0448) and would not be affected by the update to the WCM. The NRHP database does not include any property listed in the National Register within a 100-foot radius of the project area.

NO ACTION ALTERNATIVE

No changes to the WCM would be made; therefore no historic properties would be impacted.

RECOMMENDED PLAN

Based on the results of the cultural resources and historic properties background research and review of existing flood data from January 2004 through June 2023, USACE has determined that no historic properties listed in or recommended for listing in the NRHP would be affected by the Recommended Plan. USACE, in accordance with 36 CFR 800.4(d)(1), has reached a determination of no effect.

CONSULTATION AND COORDINATION

USACE consulted and coordinated the Recommended Plan under Section 106 of the National Historic Preservation Act with the Indiana Division of Historic Preservation and Archaeology (IDHPA), Nottawaseppi Huron Band of the Potawatomi (NHBP), the Shawnee Tribe of Oklahoma, the Absentee Shawnee Tribe of Oklahoma, the Eastern Shawnee Tribe of Oklahoma, Saginaw Chippewa Indian Tribe of Michigan, Delaware Nation, Delaware Tribe of Indians of Oklahoma, Miami Tribe of Oklahoma, Peoria Tribe of Oklahoma, Osage Nation, Wyandotte Nation of Oklahoma, Bad River Band of Lake Superior Chippewa, Citizen Pottawatomi Nation, Pokagon Band of Potawatomi, Forest County Potawatomi, Hannahville Indian Community, Kickapoo Tribe of Kansas, Kickapoo Tribe of Oklahoma, Kickapoo Traditional Tribe of Texas, Prairie Band of Potawatomi, Bois Forte Band of Chippewa, Grand Portage Band of Lake Superior of Chippewa, Found du lac Band of Lake Superior, Grand Traverse Band of Ottawa and Chippewa, Sokaogon Chippewa, Turtle Mountain Band of Chippewa Indians, Lac du Flambeau Band of Lake Superior Chippewa Indians, Lac Courte Oreilles Band of Lake Superior Chippewa, Leech Lake Band of Ojibwe, Mille Lacs Band of Ottawa, Ottawa Tribe of Oklahoma, Little Traverse By Band of Odawa, Red Lake Chippewa, Red Cliff Band of Lake Superior Chippewa, St. Croix Chippewa Indians of Wisconsin, Sault St Marie Tribe of Chippewa Indians, Match-E-Be-Nash-She-Wish Band of Pottawatomi Indians, Sac and Fox Tribe of the Mississippi in Iowa, Sac and Fox Nation of Missouri in Kansas and Nebraska, and Sac and Fox Nation of Oklahoma on July 27, 2023. The IDHPA responded in a letter dated August 19, 2023, that the Recommended Plan would not adversely affect significant archaeological deposits or above ground structures and that the Recommended Plan can proceed as planned. USACE received an email from the NHBP dated August 18, 2023, which stated the Recommended Plan would not adversely affect sites of cultural or religious interest to the NHBP. USACE received an email from the Shawnee Tribe dated August 30, 2023, which stated that no known historic properties would be negatively impacted by the Recommended Plan. See Appendix A for correspondence from the IDHPA, the NHBP, and the Shawnee Tribe.

3.9 HAZARDOUS AND TOXIC SUBSTANCES

EXISTING CONDITION

Pertinent databases within the USEPA and IDEM were reviewed to identify potential hazardous, toxic, and radioactive waste (HTRW) issues in and nearby the project area. Due to Patoka River running along the town of Jasper, Indiana, HTRW sites like comprehensive environmental response, compensation, and liability act (CERCLIS) sites, no further remedial action planned (NFRAP) sites, resource conservation recovery act (RCRA) sites, RCRA large quantity generators sites, RCRA small quantity generators sites, underground storage tanks (UST) sites, leaking underground storage tanks (LUST) sites, Indiana State Cleanup Program sites, Indiana Voluntary Remediation Program sites, and Brownfield sites were in proximity to the project area (USEPA 2023c-j, IDEM 2023a-f, IFA 2023, NETR 2023). However, no HTRW sites are known within the area of impact for the proposed WCM change.

NO ACTION ALTERNATIVE

In the NAA, uncontrolled spillway events would have a higher likelihood of occurring; thereby, flooding Jasper and potentially impacting known HTRW sites within the floodplain. This represents a minor to moderate adverse effect on HTRW resources.

RECOMMENDED PLAN

In the recommended plan, Patoka Lake would have lower peak pool elevations, leading to additional flood storage being available during rain events. This would produce a minor to moderate beneficial impact since the risk of uncontrolled spillway events would be lowered. Low lying areas that would receive additional water during the non-crop season do not have any HTRW resources within them, and furthermore, already receive additional water frequently without the WCM being implemented as evidenced by previous deviation requests and flood events. The recommended plan would not produce any new HTRW sites.

3.10 HEALTH AND SAFETY

EXISTING CONDITION

Since approximately 2006, an increasing annual rainfall trend has resulted in a significant increase in the number of events utilizing more than 50% of Patoka Lake's flood storage. Additionally, there has been a 20% decrease in channel capacity, likely due to sedimentation. Two uncontrolled spillway events and multiple deviations to 14 feet have occurred as well since 2006. After coordination with Jasper and other downstream stakeholders, as well as information from multiple deviation requests, it was observed that adverse flooding impacts do not occur until the Jasper gage reaches 14.5 feet (USACE 2023c). The project area lies within the floodway and Zone A special flood hazard area of Patoka River (NEPAssist 2023).

NO ACTION ALTERNATIVE.

Under the NAA, spillway events have a higher likelihood of occurring and Patoka Lake would continue to experience increased instances of 50% or more flood storage being utilized, which reduces Patoka Dam's ability to regulate downstream flow. This reduction in flood regulation capability in conjunction with the increased flood risk could have a moderate adverse long-term impact to health and safety on residents in the cities of Jasper and Dubois. The NAA would not alter the base flood elevation or introduce any obstructions to the floodplain near the cities of Jasper and Dubois, Indiana.

RECOMMENDED PLAN

The Recommended Plan would allow for Patoka Lake to recover flood storage space more quickly. Based on USACE Res-Sim modeling results, targeting 13 feet is expected to reduce peak pool elevations approximately 3 feet during the non-crop season. This change reduces the likelihood of uncontrolled events during late spring and early summer as additional storage is available for unexpected rainfall events. Further, a target of 13 feet would not increase local flood risk downstream. During flood events, releases from Patoka Dam account for only 2% of water output within the basin with uncontrolled rain runoff contributing the majority of total water output in the basin. Due to these factors, it is anticipated that the WCM change would produce a minor to moderate positive effect on safety due to quicker flood storage recovery and reduced likelihood of uncontrolled spillway events (USACE 2023c). The Recommended Plan would not alter the base flood elevation or introduce any obstructions to the floodplain near the cities of Jasper and Dubois, Indiana.

3.11 SOCIOECONOMICS AND ENVIRONMENTAL JUSTICE (EJ)

EXISTING CONDITION

The CEQ defines a minority population as an area having greater than 50% of its population made up of minority groups or having a meaningfully greater percentage of minority representation than the national average. It defines a low-income population as one identified with the annual statistical poverty thresholds from the Bureau of the Census' Current Population Reports, Series P-60 on Income and Poverty. In identifying low-income populations, agencies may consider as a community either a group of individuals living in geographic proximity to one another, or a set of individuals (such as migrant workers or Native Americans), where either type of group experiences common conditions of environmental exposure or effect (CEQ 1997). Desktop analysis conducted via the CEQ'S Climate and Environmental Justice Screening Tool (CEJST) indicates that Dubois County tracts 18037953600, 18037953500, and 18037953200 are not classified as disadvantaged and do not contain CEQ defined minority populations (CEQ 2023). The EPA's Environmental Justice Screening and Mapping Tool (EJScreen) generated a report for the project area and 0.5-mile buffer. Most EJ indicators were in line with their state and national averages; however, the area of analysis did have high readings for particulate matter, air toxics HI, traffic proximity, lead paint, proximity to RMP facility, and hazardous waste proximity. (USEPA 2023k). For the full EJScreen report, please refer to Appendix, Environmental Documents.

There are roughly 3,440 people within proximity to the project area across 1,357 households. Low-income individuals make up 30% of the project area and minority groups represent 8% of the project area. The average income is approximately $35,454 per year and approximately 59% of households are owner occupied. English is spoken in 98% of households (USEPA 2023j).

NO ACTION ALTERNATIVE

The WCM would not be changed, therefore, current conditions would continue. Patoka Dam would continue to experience more frequent uncontrolled spillway events, which would have moderate adverse impacts to downstream residents in Jasper and other downstream stakeholders. While adverse impacts would not impact disadvantaged populations any more than the general population, flooding from uncontrolled spillway events would cause economic damage to the region in the form of repairs and lost revenue.

RECOMMENDED PLAN

The WCM would be updated to change the Jasper gage target from 12 feet to 13 feet. This would allow for quicker evacuation of excess flood storage in Patoka Lake and reduce the odds of uncontrolled spillway events. The project area as a whole is not defined as economically disadvantaged by CEQ standards; however, positive effects associated with better flood control management with the change would benefit potential low-income individuals within the project area.

The change would also not further impact known EJ indicators as it would not create any new HTRW sites and does not have potential to further impact air quality within the project area.

3.12 CUMULATIVE IMPACTS

The USACE must consider the cumulative effects of the proposed project on the environmental as stipulated by NEPA. Cumulative effects are “the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions”. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR Part 1508.7).

The cumulative effects analysis is based on the potential effects of the proposed project when added to similar impacts from other projects in the region. An inherent part of the cumulative effects analysis is the uncertainty surrounding actions that have not yet been fully developed. The CEQ regulations provide for the inclusion of uncertainties in the analysis and states that “when an agency is evaluating reasonably foreseeable significant adverse effects on the human environment … and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking” (40 CFR 1502.21).

Temporal and geographical limits for this project must be established in order to frame the analysis. The temporal limits for assessment of impacts would initiate in 1970 with the passing of the NEPA and would end 50 years after the completion of the Recommended Plan. The geographical extent is broadened to consider the Patoka HUC8 watershed.

Impacts to the area that have occurred historically in this period of analysis would include the construction of Patoka Lake dam and the clearing of forested areas for agricultural uses throughout the watershed. The impoundment of Patoka River permanently altered its flow, chemistry, and temperature regimes. In addition, the mixed forested habitat that originally existed in this area was converted to agricultural uses, adversely impacting listed bat species habitat (bplant 2024a, bplant 2024b). In addition to agricultural development, urban development within cities like Jasper and Dubois, Indiana have been slowly expanding over time according to historical aerial imagery (NETR Online 2023b).

The City of Jasper has a list of project notices that represent reasonably foreseeable, future projects. Currently, the only proposed project is a courthouse square redevelopment, which is in the construction phase (City of Jasper 2023). While future developments are hard to predict due to the lack of concrete plans, it can be assumed that an increase in urban environment in Dubois and Jasper as well as increased agricultural use would occur during the 50 period of analysis.

NO ACTION ALTERNATIVE

While historical human impacts in this region have been severe, the NAA generally would not further degrade the environment as no changes would occur from existing conditions. However, there could be cumulative impacts with health and public safety related to future potential urban developments. If the NAA was implemented, uncontrolled spillway events would happen with greater frequency, increasing flood risks to downstream areas like the cities of Dubois and Jasper. Given that more urban development is anticipated within the 50-year period of analysis within this watershed, greater numbers of people and greater amounts of assets could be impacted by future flood events, resulting in a moderate adverse cumulative impact.

RECOMMENDED PLAN

While historical human impacts in this region have been severe, the Recommended Plan would not affect aesthetics, air quality, wetlands, water quality, invasive species, terrestrial habitat, federally protected species, HTRW, land use, noise levels, public infrastructure, socioeconomics, environmental justice, soils, floodplains, water quality, transportation/traffic, and health/safety; therefore, would not further contribute cumulatively to the degradation of these resources.

The Recommended Plan would cause portions of soil map units defined as prime farmland to be inundated more frequently during winter months; however, predicted impacts are expected to be negligible as no prime or unique farmland would be converted to nonagricultural use. Due to this, the Recommended plan would not contribute meaningfully to cumulative impacts to this resource when considered with other land development in the region.

Due to these factors, the Recommended Plan would not contribute significantly to cumulative impacts within the Patoka River Watershed during the period of analysis when past, present, and reasonably foreseeable future actions are considered.

4. MITIGATION OF ADVERSE EFFECTS

No mitigation is required for the implementation of the Recommended Plan.

5. PUBLIC AND STAKEHOLDER INVOLVEMENT

A kick-off public meeting was held virtually on September 21, 2021. The list of stakeholders invited to the September 2021 meeting are listed in Figure 2, with the Federal Indian Tribes list shown in Figure 3. The meeting discussed the opportunity to update the Patoka Lake WCM. USACE staff discussed existing conditions, gage data, problems, opportunities, objectives and constraints, potential alternatives, and next steps. This meeting also gave the opportunity for stakeholders to ask questions. USACE also consulted with Federal Indian Tribes listed in Figure 3 regarding the project on July 27, 2023. USACE received an email from the NHBP dated August 18, 2023, which stated the Recommended Plan would not adversely affect sites of cultural or religious interest to the NHBP. USACE received an email from the Shawnee Tribe dated August 30, 2023, which stated that no known historic properties would be negatively impacted by the Recommended Plan. See Appendix A for correspondence from the IDHPA, the NHBP, and the Shawnee Tribe.

The EA will also be released to the public on *July 1, 2024* for a 30-day review comment period.

City of Jasper
Mayor
City Attorney
City Engineer
Street Commissioner
Utility Manager
Water Manager

City of Huntingburg
Mayor

Upper Patoka River Conservancy District/Local Business and Farmers
Wabash Valley Produce
Beckman Farms
Conservation Attorney

Dubois County
County Commissioners
County Highway Superintendent
County Emergency Management Services
County Attorney

Resource Agencies
Property Manager, Natural Resource Commission
Indiana State Historic Preservation Office
Indiana Division of Historic Preservation and Archaeology

Figure 2 - List of Stakeholders

Name
Absentee Shawnee Tribe of Indians
Eastern Shawnee
Shawnee Tribe of Oklahoma
Saginaw Chippewa Indian Tribe of Michigan
Delaware Nation
Delaware Tribe of Indians Oklahoma
Miami Tribe of Oklahoma
Peoria Tribe of Oklahoma
Osage Nation
Wyandotte Nation of Oklahoma
Bad River Band of Lake Superior Chippewa
Pokagon Band of Potawatomi
Nottawaseppi Huron Band of Potawatomi
Forest County Potawatomi
Hannahville Indian Community
Kickapoo Tribe of Kansas
Kickapoo Tribe of Oklahoma
Kickapoo Traditional Tribe of Texas
Prairie Band of Potawatomi
Bois Forte Band of Chippewa
Grand Portage Band of Lake Superior of Chippewa
Fond du lac Band of Lake Superior
Grand Traverse Band of Ottawa and Chippewa
Sokaogon Chippewa
Turtle Mountain Band of Chippewa Indians
Lac du Flambeau Band of Lake Superior Chippewa Indians
Lac Courte Oreilles Band of Lake Superior Chippewa
Mille Lacs Band of Ojibwe
Little River Band of Ottawa
Ottawa Tribe of Oklahoma
Little Traverse Bay Band of Odawa
Red Lake Chippewa
Red Cliff Band of Lake Superior Chippewa
St. Croix Chippewa Indians of Wisconsin
Sault Ste Marie Tribe of Chippewa Indians
Match-E-Be-Nash-She-Wish Band of Pottawatomi Indians
Sac and Fox Nation of Missouri in Kansas and Nebraska
Sac and Fox Nation of Oklahoma

Figure 3 - List of Federal Indian Tribes

6. CONCLUSION

If the Recommended Plan is approved as a permanent change to the Patoka Lake WCM, operating the Jasper gage for a target stage of 13 feet during non-crop season would have many benefits with negligible risk. Not only does it allow recovery of flood control storage quicker during non-crop season, but it also reduces the chances of higher peak pool elevations and helps lower the pool elevation going into the wettest part of the year in the spring. Based on the Res-Sim modeling results, targeting 13 feet at Jasper during non-crop season is expected to reduce the peak pool elevations up to 3 feet, depending on the time of year high water occurs. The results showed significant benefit when high water events take place during non-crop season and the pool elevation is returned to guide curve before crop season begins. Stages at Jasper often reach up to 13 feet due to runoff from rain events, so no negative impacts to areas downstream of Patoka Lake are expected due to operating for the higher stage during non-crop season. After years of coordination, the City of Jasper and Dubois County officials have provided data confirming no impacts are observed in Jasper when a target stage of 13 feet at Jasper is achieved. This information can be found in Appendix A of the Engineering Report. Adverse impacts related to the operational change are anticipated to be negligible and limited to certain soil map units receiving additional water during the non-crop season.

7. REFERENCES

Beaulieu et al. 2020. Methane and Carbon Dioxide Emissions from Reservoris: Controls and Upscaling. Available online: Methane and Carbon Dioxide Emissions From Reservoirs: Controls and Upscaling - Beaulieu - 2020 - Journal of Geophysical Research: Biogeosciences - Wiley Online Library. Accessed May 2024.

bplant 2023a. Crawford-Mammoth Cave Uplands. Available online: https://bplant.org/region/960. Accessed July 2023.

bplant 2023b. Glaciated Wabash Lowlands. Available online: https://bplant.org/region/975. Accessed July 2023.

Council of Environmental Quality (CEQ) 1997. Environmental Justice. Guidance Under the National Environmental Policy Act. 1997. P.25-26.

City of Jasper, Indiana 2023. Project Notices. Available Online: https://www.jasperindiana.gov/department/index.php?structureid=63. Accessed July 2023.

Gray et al. 1987. Bedrock geologic map of Indiana: Department of Natural Resources, Indiana Geologic Survey, Miscellaneous Map 48, scale 1:500,000. Available online: https://www.indianamap.org/datasets/6361d48ea6474579be22ce8371f49798_47/explore?location=38.581700%2C-86.246689%2C10.10. Accessed July 2023.

Indiana Department of Environmental Management (IDEM). 2023a. State Cleanup Program. Available online: https://www.in.gov/idem/cleanups/investigation-and-cleanup-programs/state-cleanup-program/. Accessed 07 July 2023.

IDEM 2023b. Permitted, Registered, and Approved Facilities and Operations. Treatment, storage and/or Disposal Permitted Facilities. Available online: IDEM: Managing Waste: Permitted, Registered, and Approved Facilities and Operations. Accessed 07 July 2023.

IDEM 2023c. Storage Tanks. Data and Reports. Leaking Underground Storage Tanks Report. Available online: IDEM: Storage Tanks: Data and Reports (in.gov). Accessed 07 July 2023.

IDEM 2023d. Storage Tanks. Data and Reports. Underground Storage Tanks Report. Available online: IDEM: Storage Tanks: Data and Reports (in.gov). Accessed 07 July 2023.

IDEM 2023e. Institutional Controls. Intuitional Control Sites. Available online: https://www.in.gov/idem/cleanups/investigation-and-cleanup-programs/institutional-controls/. Accessed 07 July 2023.

IDEM 2023f. Voluntary Remediation Program. VRP Site List. Available online: https://www.in.gov/idem/cleanups/investigation-and-cleanup-programs/voluntary-remediation-program/. Accessed 07 July 2023.

Indiana Finance Authority (IFA) 2023. Indiana Brownfields Program. Site List. Available online: https://www.in.gov/ifa/brownfields/program-sites/. Accessed 07 July 2023.

Indiana Invasive Species Council 2023. Official IISC Invasive Plant List. Available online: https://www.entm.purdue.edu/iisc/invasiveplants.html. Accessed July 2023.

Indiana Map 2023. Karst Cave Density. Available online: https://www.indianamap.org/maps/014403db16934e03b2ed8de2eb9ba938. Accessed July 2023.

Monarch Joint Venture 2023. Migration. Available online: https://monarchjointventure.org/monarch-biology/monarch-migration. Accessed July 2023.

NatureServe 2023a. Tricolored Bat (*Perimyotis subflavus*). Available online: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.102580/Perimyotis_subflavus. Accessed July 2023.

NatureServe 2023b. Whooping Crane (*Grus americana*). Available online: https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.102973/Grus_americana. Accessed July 2023.

National Environmental Title Search (NETR) Online. 2023. Environmental Data. Available online: https://environmental.netronline.com/. Accessed 07 July 2023.

National Resources Conservation Service (NRCS) 2023. Web Soil Survey. Available online: https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. Accessed 07 July 2023.

NRCS 2024. Soil Data Access (SDA) Prime and other Important Farmlands. Available online: https://www.nrcs.usda.gov/publications/Legend%20and%20Prime%20Farmland%20-%20Query%20by%20Soil%20Survey%20Area.html. Accessed May 2024.

United States Army Corps of Engineers (USACE) 2023a. Patoka River Lake Reservoir: Qualitative Analysis of Climate Change Impacts. January 2023.

USACE 2023b. MEMORANDUM FOR COMMANDING GENERAL, U.S. ARMY CORPS OF ENGINEERS. U.S. Army Corps of Engineers Invasive Species Policy. February 21st, 2023.

USACE 2023c. Patoka Water Control Manual Update: Engineering Report. July 2023.

United States Environmental Protection Agency (USEPA) 2009. Fact Sheet: Introduction to Clean Water Act Section 303(d) Impaired Waters Lists. Available online: https://nepis.epa.gov/Exe/ZyPDF.cgi/P1008DPU.PDF?Dockey=P1008DPU.PDF

USEPA 2023a. How's My Waterway. Available at: https://mywaterway.epa.gov/community/051002020401/overview. Accessed May 2023.

USEPA 2023b. Level III and IV Ecoregions of the continental United States. Available online: https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states. Accessed July 2023.

USEPA. 2023c. Corrective Action Cleanups around the Nation. Available online: https://www.epa.gov/hwcorrectiveactioncleanups. Accessed 16 May 2023.

USEPA. 2023d. Deleted National Priorities List (NPL) Sites – by State. Available online: https://www.epa.gov/superfund/deleted-national-priorities-list-npl-sites-state. Accessed 16 May 2023.

USEPA. 2023e. Envirofacts. Available online: https://enviro.epa.gov/. Accessed 10 July 2023.

USEPA. 2023f. Institutional and Engineering Controls Data. Available online: https://rcrapublic.epa.gov/rcrainfoweb/action/modules/cor/caindex. Accessed 16 May 2023.

USEPA. 2023g. National Priorities List (NPL) Sites – by State. Available online: https://www.epa.gov/superfund/national-priorities-list-npl-sites-state. Accessed 16 May 2023.

USEPA. 2023h. Proposed National Priorities List (NPL) Sites – by State. Available online: https://www.epa.gov/superfund/proposed-national-priorities-list-npl-sites-state. Accessed 16 May 2023.

USEPA. 2023i. RCRAInfo Search. Available online: https://enviro.epa.gov/facts/rcrainfo/search.html. Accessed 16 May 2023.

USEPA. 2023j. SEMS Search. Available online: https://www.epa.gov/enviro/sems-search. Accessed 16 May 2023.

USEPA 2023k. Environmental Justice Screening and Mapping Tool (EJSCREEN). Version 2.2. Available online: https://ejscreen.epa.gov/mapper/. Accessed July 2023.

United States Fish and Wildlife Service (USFWS) 2006. Indiana bat: *Myotis sodalis*. Available at: http://www.fws.gov/sites/default/files/documents/508_Indiana%20bat%20fact%20sheet.pdf Accessed May 2023.

USFWS 2015. Northern long-eared bat: *Myotis septentrionails*. Available at: https://www.fws.gov/sites/default/files/documents/508_NLEB%20fact%20sheet.pdf. Accessed May 2023.

USFWS 2016. Endangered and Threatened Wildlife and plants; 4(d) Rule for the Northern Long-Eared Bat. Available Online: https://www.federalregister.gov/documents/2016/01/14/2016-00617/endangered-and-threatened-wildlife-and-plants-4d-rule-for-the-northern-long-eared-bat. Accessed July 2023.

USFWS 2023a. Wetlands Mapper. Available at: https://www.fws.gov/program/national-wetlands-inventory/wetlands-mapper

USFWS 2023b. Information for Planning and Consultation. Available online: https://ipac.ecosphere.fws.gov/

USFWS 2023c. Tricolored Bat. Available online: https://fws.gov/species/tricolored-bat-perimyotis-subflavus. Accessed July 2023.

USFWS 2023d. Monarch Butterfly. Available online: https://www.fws.gov/species/monarch-butterfly-danaus-plexippus. Accessed July 2023.

United States Geological Survey (USGS 2023). Locate Your Watershed. Available at: Science in Your Watershed: Locate Your Watershed By HUC - Mapping Interface (usgs.gov). Accessed July 2023.

United States Government Accountability Office. Army Corps of Engineers: Additional Steps Needed for Review and Revision of Water Control Manuals. https://www.gao.gov/products/gao-16-685

ENGINEERING ANALYSIS

2024 WATER CONTROL MANUAL REVISION FOR PATOKA LAKE
MIDDLE WABASH BASIN
INDIANA

United States Army Corps of Engineers
Louisville District
June 2024

PAGE INTENTIONALLY LEFT BLANK

Table of Contents

1. Introduction

Since approximately 2006, an increasing annual rainfall trend has resulted in a significant increase to the number of events utilizing more than 50% of Patoka's available flood storage (9 events from 1979-2005 vs 12 events from 2006-2020) including two uncontrolled spillway events (2011 and 2019). Additionally, since 2006 there has been nearly a 20% reduction in channel capacity, likely due to sedimentation in the river channel, resulting in a reduced outflow capacity from Patoka Lake. The Louisville District is recommending a change to the operating criteria for Patoka Lake by increasing the non-crop season control stage from 12 feet to 13 feet at the Jasper, Indiana gage (United States Geological Survey (USGS) Gage 03375500), the project's only downstream control point. There would be no change to the crop season control stage at Jasper, which is 9 feet. Non-crop season is typically from December 1 through April 15. This change to the non-crop season control stage would allow for faster flood control storage recovery which lowers the risk to the dam, the risk of an uncontrolled spillway event, and subsequently reduces the risk of damage to downstream agriculture and infrastructure in the City of Jasper, Indiana. See Appendix B, Res-Sim Modeling for detailed information about the analysis of changing the non-crop season control stage at the Jasper, Indiana gage and how it speeds recovery of flood control storage resulting in less flood control storage utilized during crop season.

Since 2016, downstream stakeholders including the City of Jasper and the Upper Patoka Conservancy District have consistently requested that the project target a higher non-crop season stage at the gage in Jasper, Indiana when making release decisions. Targeting a higher non-crop season stage allows evacuation of flood storage more quickly during the wettest time of the year, reducing the likelihood of an emergency spillway event in the late spring or early summer that could lead to significant crop damage and adversely impact infrastructure in the City of Jasper, Indiana. The prolonged, elevated pool levels and the concerns expressed by the downstream stakeholders led to LRL requesting deviations from the water control plan in 2016, 2019, and 2020 to make releases targeting a higher stage at the Jasper, Indiana gage.

ER 1110-2-240, Water Control Management (WCM), states that if "Significant, recurrent or prolonged deviations from operations prescribed by an approved water control plan may indicate a need for a formal change to operations prescribed by an approved water control plan." The increase in frequency of high flood storage utilizations in combination with support from downstream stakeholders warrant an evaluation to potentially change the water control plan to target a higher non-crop season stage at the Jasper, Indiana gage.

The following sections will discuss background information, a summary of the engineering analysis, alternatives considered, results of the engineering analysis, the selected alternative, and potential impacts. Additional detailed information is available in the appendices.

2. Background

The existing storage allocation of Patoka Reservoir is shown in Figure 1 below.

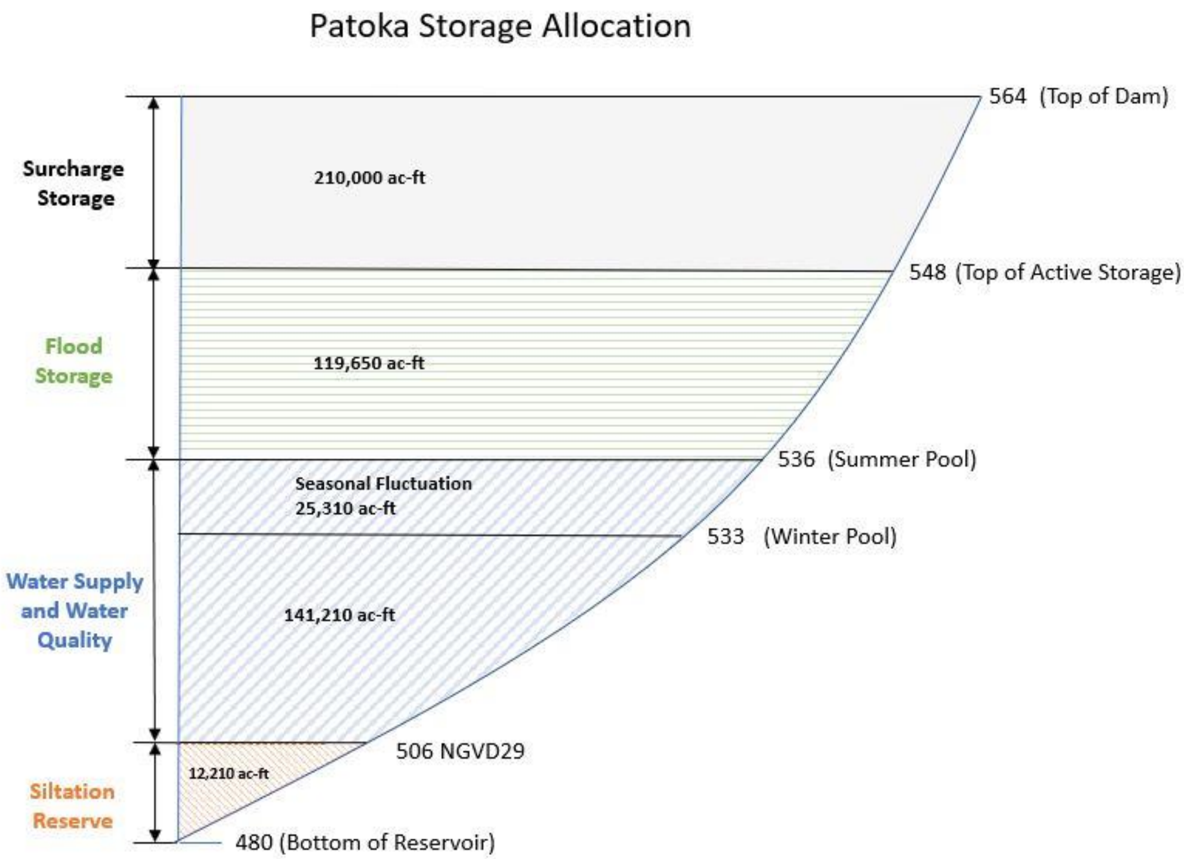


Figure 1 – Existing Storage Allocation

From the bottom of the reservoir at elevation 480 National Geodetic Vertical Datum of 1929 (NGVD29) to elevation 506, approximately 12,210 acre-feet or 1.4 inches of rainfall runoff storage is allocated for siltation/sedimentation. From elevation 506 to elevation 536, approximately 166,550 acre-feet or 18.6 inches of storage has been allocated for Water Quality and/or Water Supply. The United States Government has a water supply agreement with the state of Indiana that states the following, "the State shall have the right to utilize an undivided 77.5 percent of the aforesaid storage space for water supply purposes." With an initial pool elevation of 506, 77.5% of the storage between elevation 506 and 536 ends at an elevation of 531.6. From elevation 536 to 548, approximately 119,650 acre-feet or 13.4 inches of rainfall runoff storage has been allocated to flood risk mitigation. Finally, from elevation 548 to the top of dam at elevation 564, there is an estimated 210,000 acre-feet or 23.4 inches of surcharge rainfall runoff storage. Elevations are reported in NGVD29 in this study because that is the datum used in the current water control manual. The conversion from NGVD29 to North American Vertical Datum of 1988 (NAVD88) at Patoka Lake is -0.38386 feet.

2.1 Relevant Prior Studies and Reports

Below is a brief synopsis of key documents and projects generated by several agencies and organizations. These documents and other resources were used to inform plan development and can be found in Appendix E, Reference Documents.

- 1997: United States Army Corps of Engineers (USACE) conducted a Reservoir Reallocation Study to investigate alternative guide curves, for the operation of Patoka Lake. Several alternatives were considered and went through Plan Formulation. The Recommended Plan stated the winter pool level at Patoka Lake draw down to 531 NGVD29 in year 1997 as a trial to test the operational plan. This was approved by the USACE Great Lakes and Rivers Division (LRD).
- 2011: USACE requested a deviation to continue peak outflow following Patoka's first spillway event in 2011 until the Patoka reservoir was utilizing less than 50% flood storage. This request was made in combination with other lakes in the same situation during the 2011 flood and was approved in 2011 by LRD. A copy of the request is included in Appendix E, titled "May 2011 Pool Deviation.pdf".
- 2012: USACE requested a deviation from the current WCM to target a stage of 15 feet at the Jasper gage for the remaining part of non-crop season due to the lake utilizing 72% of its flood control storage entering the spring flood season (USACE, 2012). This was approved by LRD in 2012.
- 2016: USACE requested to increase the target stage to 13 feet at Jasper during non-crop season (December 1, 2016 – April 15, 2017), compared to the WCM procedure to target 12 feet. A memorandum dated January 27, 2017, withdrew that request. The memorandum cites that the deviation request might be reinitiated in the future after the Louisville District further investigates downstream impacts to the Patoka River system.
- 2019: USACE requested to target 14 feet at the Jasper gage due to the lake utilizing 77% of its flood control storage entering spring flood season (March through May) and was approved by LRD in 2019.
- 2020: USACE requested to target 14 feet at Jasper during the remaining part of non-crop season due to the lake utilizing 52% of its flood control storage entering spring flood season and was approved by LRD in 2020.

3. Operational History

Since impoundment, the operating criteria for Patoka Reservoir has changed several times. The following table identifies the dates and provides description of the operational changes.

Date	Operational History
1979 – September 1980	All Season target pool elevation of 536; Non-crop/crop season target on Jasper Gage of 12/7, respectively
October 1980 – May 1983	3-year trial winter pool elevation of 533, summer Pool elevation of 536; Non-crop/crop season target on Jasper Gage of 12/7, respectively
January 1984 – January 1997	Approved winter pool elevation of 533, summer pool elevation of 536; Non-crop/crop season target on Jasper Gage of 12/7, respectively

January 1997 – January 2000	Approved trial operation to target winter pool of 531/532, summer pool elevation of 536; Non-crop/crop season target on Jasper Gage of 12/9 respectively.
January 2000 - present	Approved winter pool elevation of 532; summer pool elevation of 536; Non-crop/crop season target on Jasper Gage of 12/9, respectively.
May 2011	Deviation to continue spillway event peak outflow until below 50% flood storage utilization approved
March 2012	Deviation to target 15 feet at Jasper gage for remainder of non-crop season (flood storage utilization was above 50% at the time) approved
December 2016	Deviation to target 13 feet at Jasper gage during non-crop season not approved
March 2019	Deviation to target 14 feet at Jasper gage during non-crop season approved
January 2020	Deviation to target 14 feet as Jasper gage during non-crop season approved

The current operating criteria targets a summer pool elevation of 536, a winter pool elevation of 532, and a non-crop season stage at the Jasper gage of 12 feet and a crop season stage at the Jasper gage of 9 feet. The guide curve is shown in Figure 2.

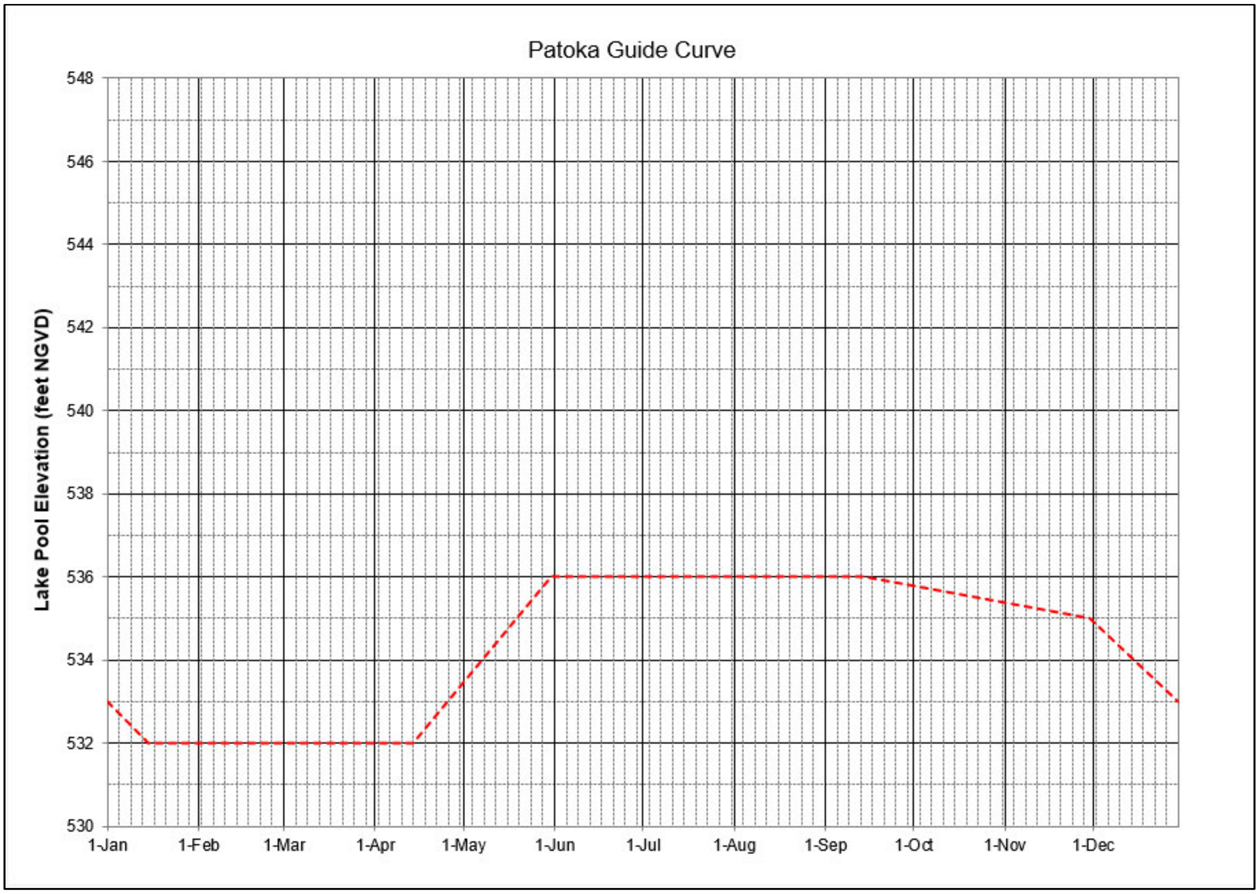


Figure 2 – Patoka Guide Curve

Jasper Stream Gage Rating Curve

The only control point used for making operational decisions at Patoka Dam is the stream gage at Jasper, Indiana (USGS Gage 03375500). Over time, the rating curve at the gage has shifted resulting in lower flows at the target stages. This has impacted the ability of Patoka Dam to evacuate flood storage at rates that were used 15+ years ago. The rating curve appears to have remained fairly stable over the past five years, but from 1997 to 2017, the rating curve shifted and resulted in a nearly 20% reduction in channel capacity at a stage of 12 feet. It is possible that changes to land use, agricultural practices or bank stability prior to 2017 may have contributed to the increased sedimentation, however that cannot be determined at this time. Dredging the Patoka River to increase channel capacity is not an option as the U.S. Army Corps of Engineers (USACE) does not have that authority. Encouraging stakeholders downstream to investigate ways to reduce sedimentation issues in the Patoka River channel might be a way to help curb future aggradation. Figure 3 illustrates the change in the rating curve over time.

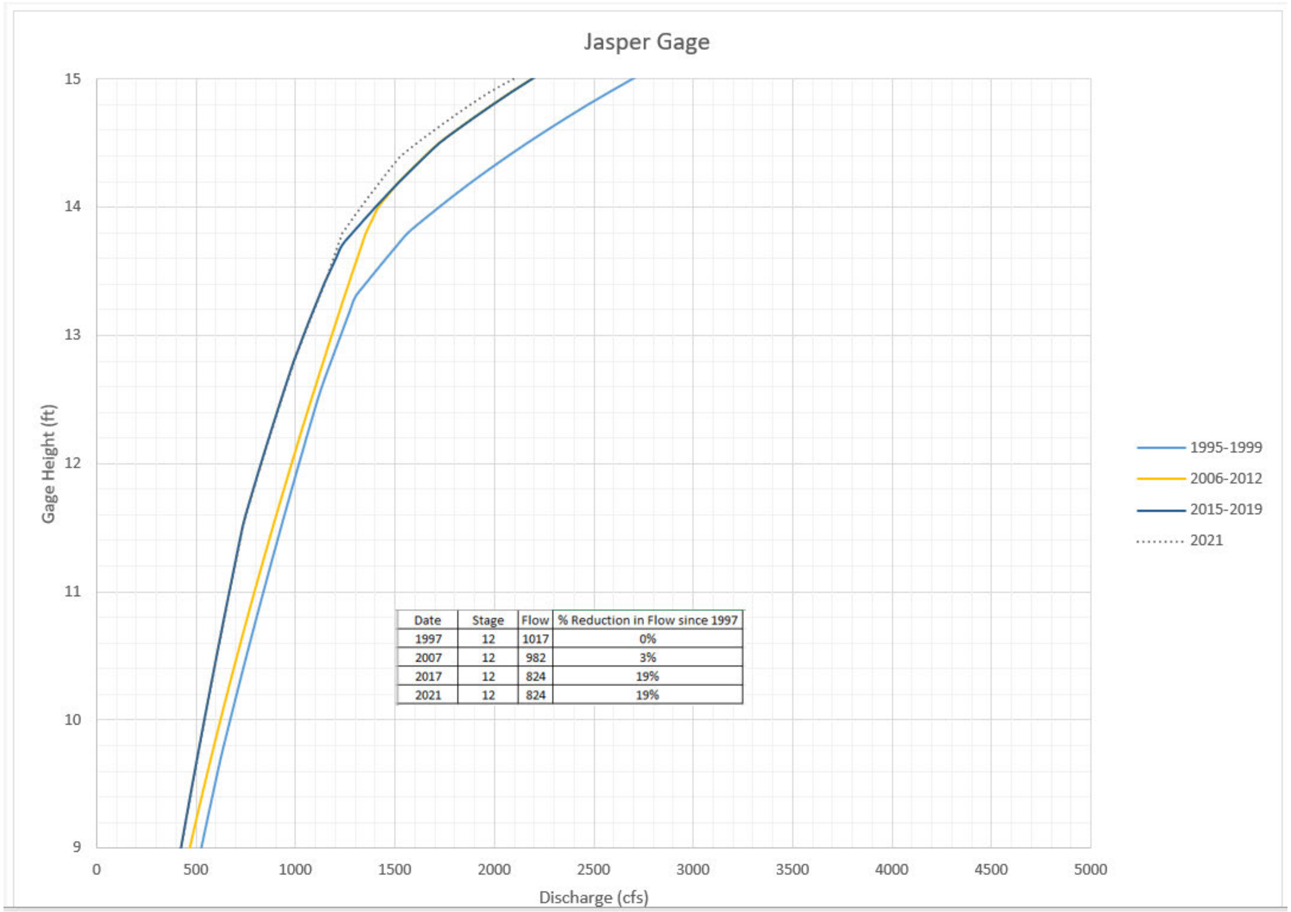


Figure 3 – Jasper Gage Rating Curve over time

This reduction in channel capacity is a significant reason why the Louisville District is recommending an increase to the non-crop season target stage, from 12-feet to 13-feet.

4. Engineering Analysis Summary

In order to evaluate the impacts of this proposed change, hydrologic, reservoir, and hydraulic modeling were performed. The following section summarizes the purpose and intent of the data used and the modeling that was completed.

a. Data Sources:

After evaluating accumulated rainfall from 1983 through 2020, it was decided the most representative period of record to analyze was water years 2006-2020 due to the increase in average annual rainfall and project data was compiled for this time frame. Data sources included the USGS and internal USACE records. Model simulations used an hourly time step. Figure 4 illustrates the operational history of the project and the trends in the period of record rainfall.

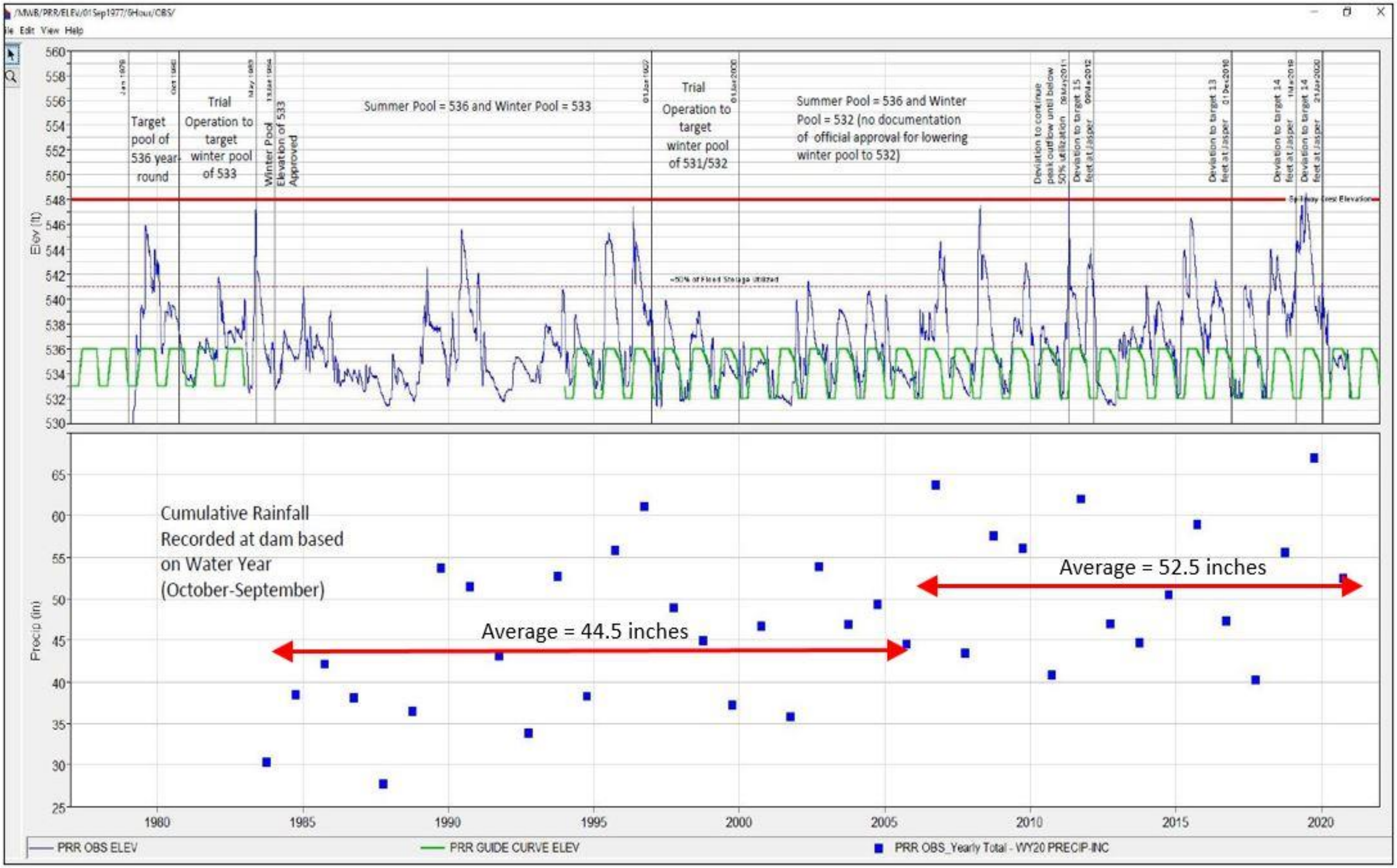


Figure 4 – Operational History of Patoka Lake and Historical Rainfall Trends

The flow data sources used in the modeling effort included the following:

- Jasper Total Flow- Observed Stages converted to flow using the 2019 rating curve
- Jasper Local Flow-routed (Muskingum-Cunge) observed Patoka outflows subtracted from Jasper Total Flow
- Winslow Total Flow- Observed flow obtained from the USGS website
- Winslow Local Flow-routed (Muskingum-Cunge) observed Patoka outflows subtracted from Winslow Total Flow
- Princeton Total Flow- Observed flow obtained from the USGS website
- Princeton Local Flow-routed (Muskingum-Cunge) observed Patoka outflows subtracted from Princeton Total Flow
- Patoka Inflow-Observed Patoka Inflow (calculated from Δ Storage relationship)
- Patoka Outflow-Observed Patoka Outflow

For detailed data information see Appendix B - Detailed Res-Sim Analysis and Appendix C – RAS Modeling Appendix.

b. Hydrology: (HMS)

The Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model used in the Middle Wabash River Corps Water Management System (CWMS) model was extracted and modified to only include the Patoka River Basin. The HEC-HMS model parameters used in the Middle Wabash River Basin CWMS model allowed for the determination of local inflows in the Patoka River basin for the period from 2006-2020. Outflow from the dam was routed to the Jasper gage and that flow data set was subtracted from the observed flow at the gage. This resulted in a local flow hydrograph between the dam and the gage for simulating various operational alternatives using Hydrologic Engineering Center-Reservoir System Simulation (HEC-Res-Sim). This same process was followed to determine local inflow between the Jasper and Winslow gages, and between the Winslow and Princeton gages to support the hydraulic modeling evaluation. Figure 5 shows the Middle Wabash River Basin CWMS model and Figure 6 shows the Patoka River Basin HEC-HMS model.

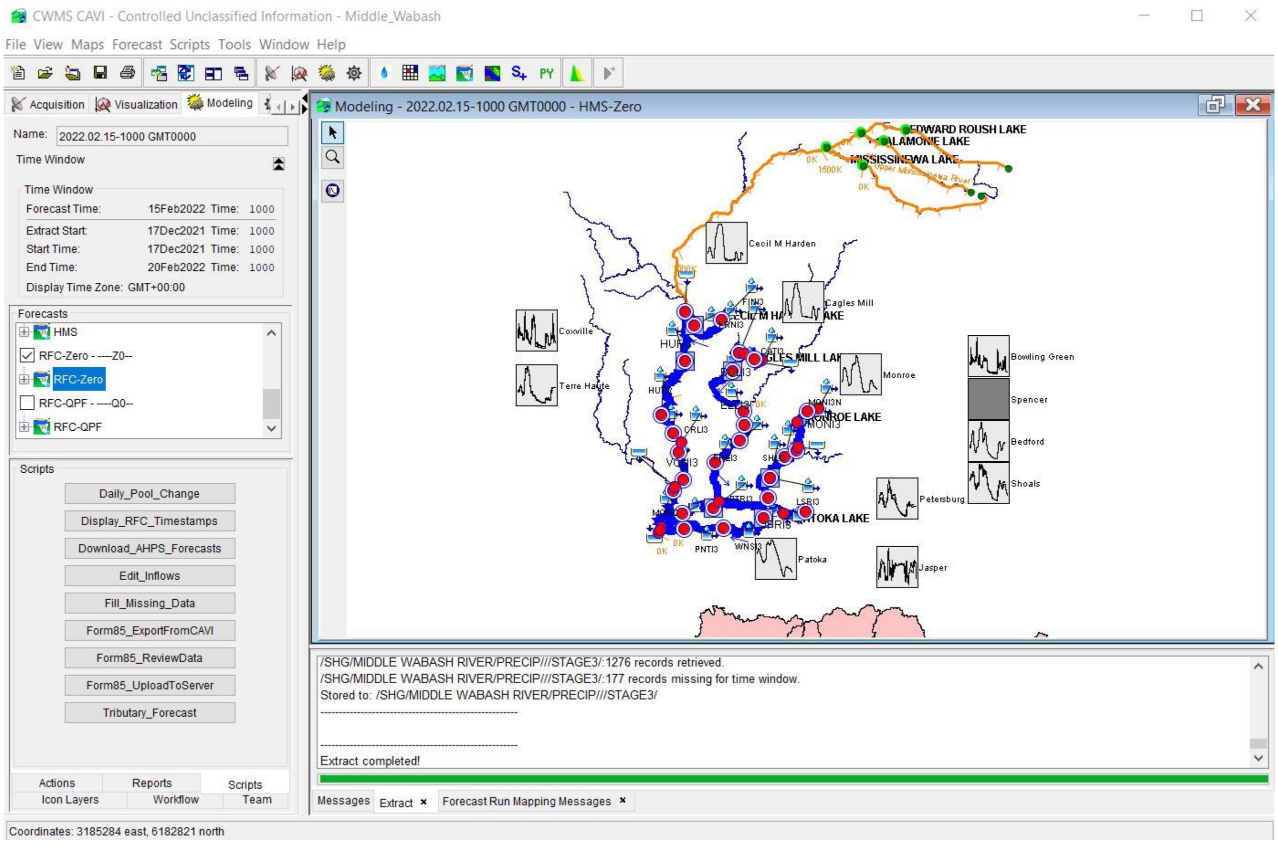


Figure 5 - Middle Wabash CWMS model

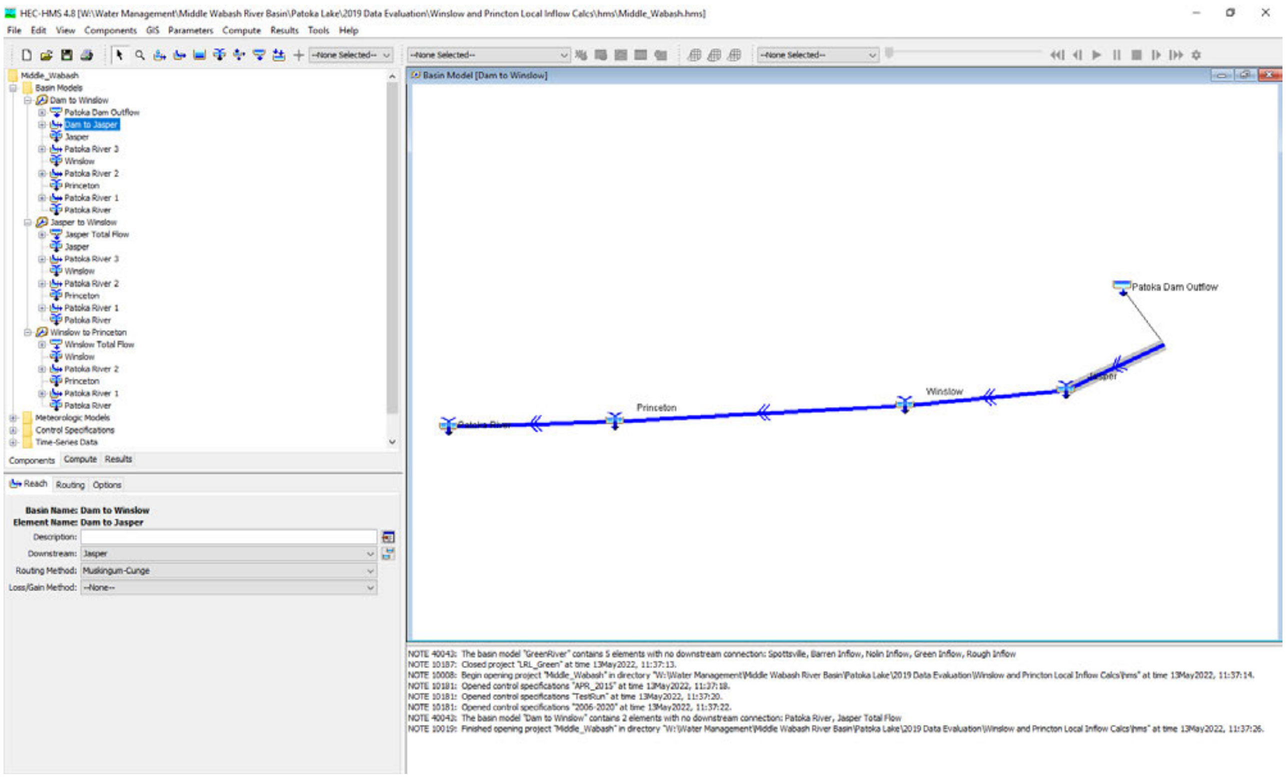


Figure 6 – Patoka River Basin HEC-HMS model

c. Reservoir Operations: (reference Res-Sim Modeling Appendix B for more detailed information)

In order to determine the effect on storage utilization relationships resulting from a change in the downstream control for the Patoka Reservoir project, a series of reservoir routing simulations were performed. This modeling effort was performed with HEC Res-Sim using a modified version of the HEC-CWMS model of the Middle Wabash River Basin.

From the Middle Wabash River CWMS model, a separate HEC Res-Sim model was created for the Patoka River Basin. The Patoka basin's modeling information was taken out of the larger Middle Wabash River Basin's CWMS model including all reservoir logic rules, storage-elevation curves, downstream control points, etc. This allowed for rapid model creation with a focus on the individual reservoir system while maintaining consistency with the overall Middle Wabash River Basin model. See Appendix B, Res-Sim Modeling for detailed information about how the Patoka Res-Sim model was calibrated. Simulations were performed to examine the effects on storage utilization using a combination of different drawdown dates and increases in the downstream control stage at the Jasper, Indiana gage.

For the Patoka Reservoir model, every effort was made to maintain consistency with the authorized Water Control Manual. Reservoir release rules were based on the actual schedule of releases, accounting for all constraints such as downstream control points, minimum or maximum releases, etc. Figure 7 shows the Patoka River Basin HEC Res-Sim model.

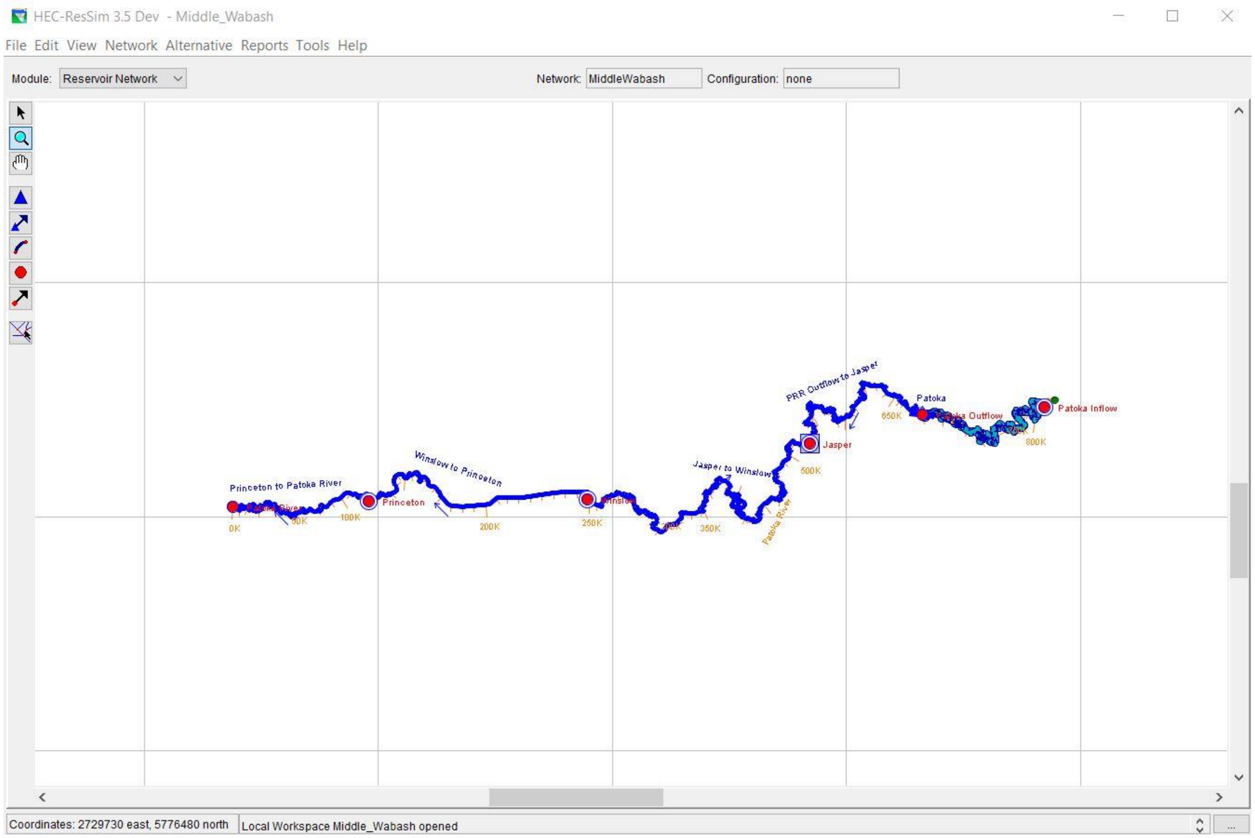


Figure 7 - Patoka River Basin Res-Sim Model

The Patoka River Basin Res-Sim model contrasted the difference in flood storage utilization resulting from the current operating criteria with 12 alternatives that included different combinations of proposed operations. These included changes to the initiation date of the fall drawdown and/or increasing the downstream control stage at Jasper, Indiana, during non-crop season from water year 2006-2020. All other modeling parameters and inputs were kept consistent.

d. Hydraulic Analysis: reference HEC-RAS Modeling Appendix C for more detailed information

To evaluate and illustrate the potential impacts of higher releases from Patoka Dam, a Hydrologic Engineering Center-River Analysis System (HEC-RAS) model was developed. The base hydraulic model was extracted from the Middle Wabash River CWMS model and several geometry refinements were incorporated. This included bathymetry developed from surveyed channel data at approximately 1-mile intervals, utilization of detailed model geometry developed by the United States Geological Survey around the city of Jasper, the addition of 2-dimentional grids representing overbank geometry at numerous locations, as well as some other refinements. The model was calibrated and used to develop inundation mapping for various operational scenarios. Figure 8 illustrates the HEC-RAS model geometry. A detailed explanation of the HEC-RAS modeling efforts is included in Appendix C.

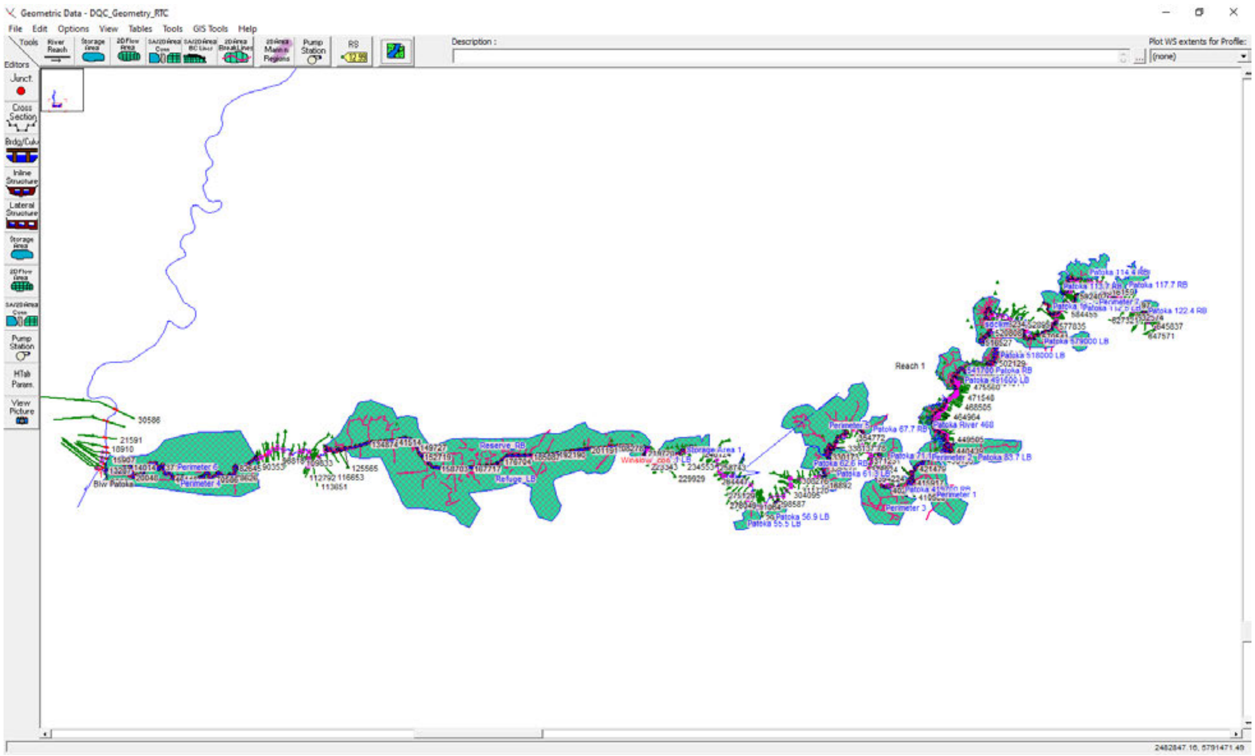


Figure 8 - Patoka River Basin HEC-RAS Model

5. Alternatives Evaluated

A total of 12 alternatives were evaluated to assess the impacts on flood storage utilization and to the Patoka River downstream of the dam. The evaluated alternatives are as follows:

1. Change guide curve to start lowering to winter pool on Nov 1 instead of Dec 1, keep Jasper the same. Winter pool target date would change from Jan 15 to Dec 15. Winter pool of 532.
2. Change guide curve to start lowering to winter pool on Nov 15 instead of Dec 1, keep Jasper the same. Winter pool target date would change from Jan 15 to Jan 1. Winter pool of 532.
3. Do not change guide curve but operate Jasper for 13 feet instead of 12 feet. Winter pool of 532.
4. Do not change guide curve but operate Jasper for 13.5 feet instead of 12 feet. Winter pool of 532.
5. Do not change guide curve but operate Jasper for 14 feet instead of 12 feet. Winter pool of 532.
6. Change guide curve to start lowering to winter pool on Nov 1 instead of Dec 1 AND operate Jasper for 13 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Dec 15. Winter pool of 532.
7. Change guide curve to start lowering to winter pool on Nov 1 instead of Dec 1 AND operate Jasper for 13.5 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Dec 15. Winter pool of 532.
8. Change guide curve to start lowering to winter pool on Nov 1 instead of Dec 1 AND operate Jasper for 14 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Dec 15. Winter pool of 532.

9. Change guide curve to start lowering to winter pool on Nov 15 instead of Dec 1 AND operate Jasper to 13 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Jan 1. Winter pool of 532.
10. Change guide curve to start lowering to winter pool on Nov 15 instead of Dec 1 AND operate Jasper to 13.5 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Jan 1. Winter pool of 532.
11. Change guide curve to start lowering to winter pool on Nov 15 instead of Dec 1 AND operate Jasper to 14 feet instead of 12 feet. Winter pool target date would change from Jan 15 to Jan 1. Winter pool of 532.
12. Change release schedule based on percentage utilized…at 33% operate Jasper for 13 feet and at 66% operate Jasper for 14 feet. Winter pool of 532.

The “baseline” is Current5, which represents Current Operations (Ops).

6. Results Summary

All 12 alternatives were evaluated and compared to the Current Operations. The Res-Sim Modeling Appendix B includes more detailed information and plots of the results.

Alternatives 1 and 2: Begin Lowering to Winter Pool Earlier than Current Operations

Two alternatives were considered that change the start date of lowering the lake elevation to winter pool. They include Alt 1 - start date down to winter pool on Nov 1 and Alt 2 - start date down to winter pool on Nov 15. Both Alt 1 and Alt 2 were eliminated because there was zero to less than a 0.06-foot decrease in peak pool elevations, as compared to each other. There was zero to less than a 0.1-foot decrease in peak pool elevations when these 2 alternatives were compared to “current” operations. See Figure 9 through Figure 12 for a few different flood event plots (Alt 1-green line, Alt 2-red line, and Current Ops-yellow line).

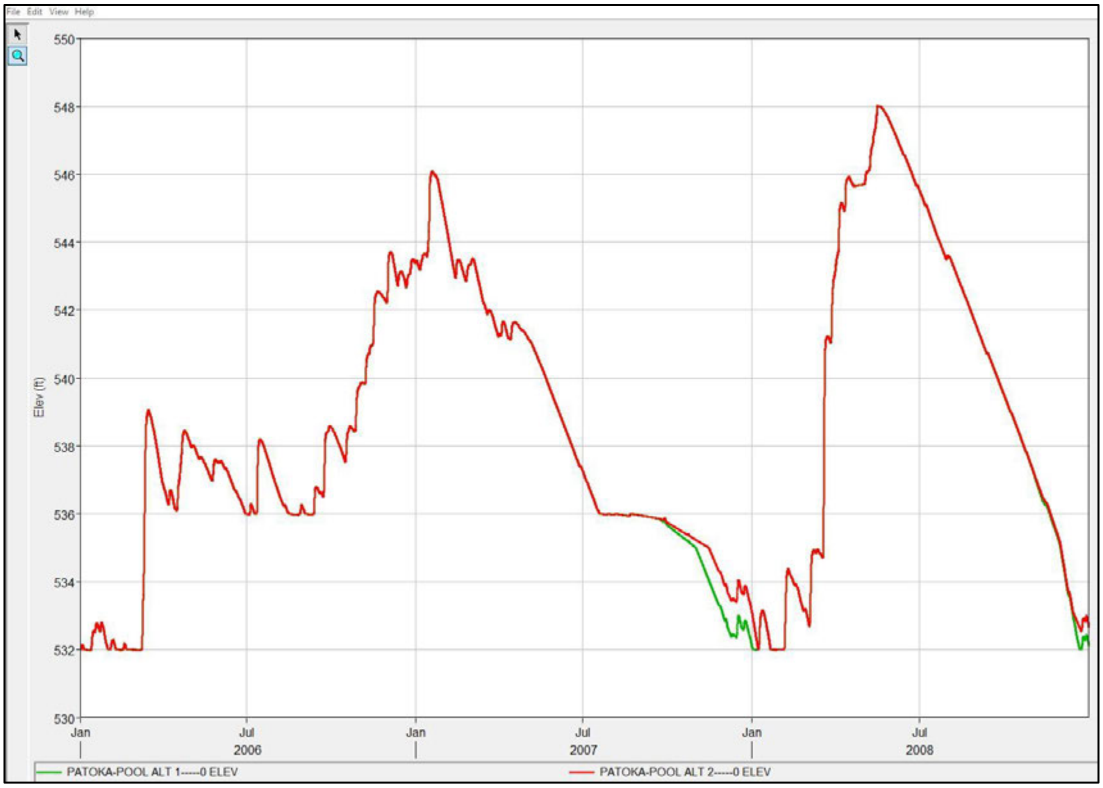


Figure 9: Patoka Pool Elevation Plots Alt 1 and Alt 2

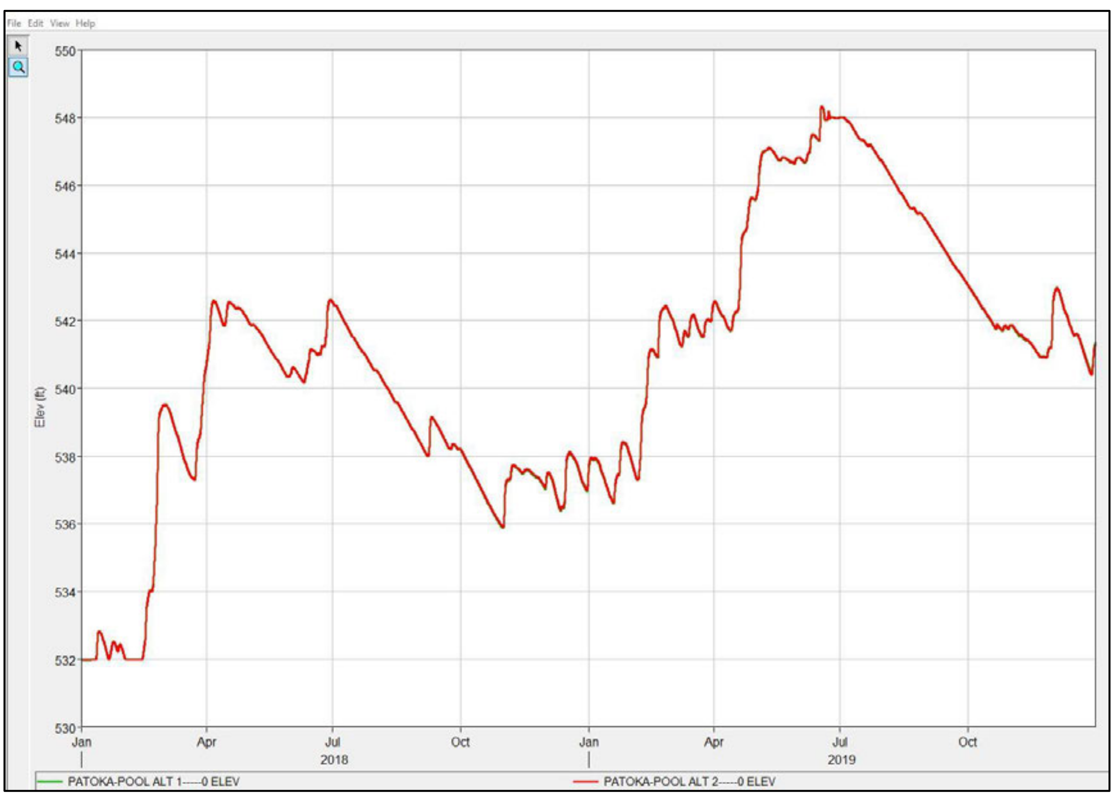


Figure 10: Patoka Pool Elevation Plots Alt 1 and Alt 2

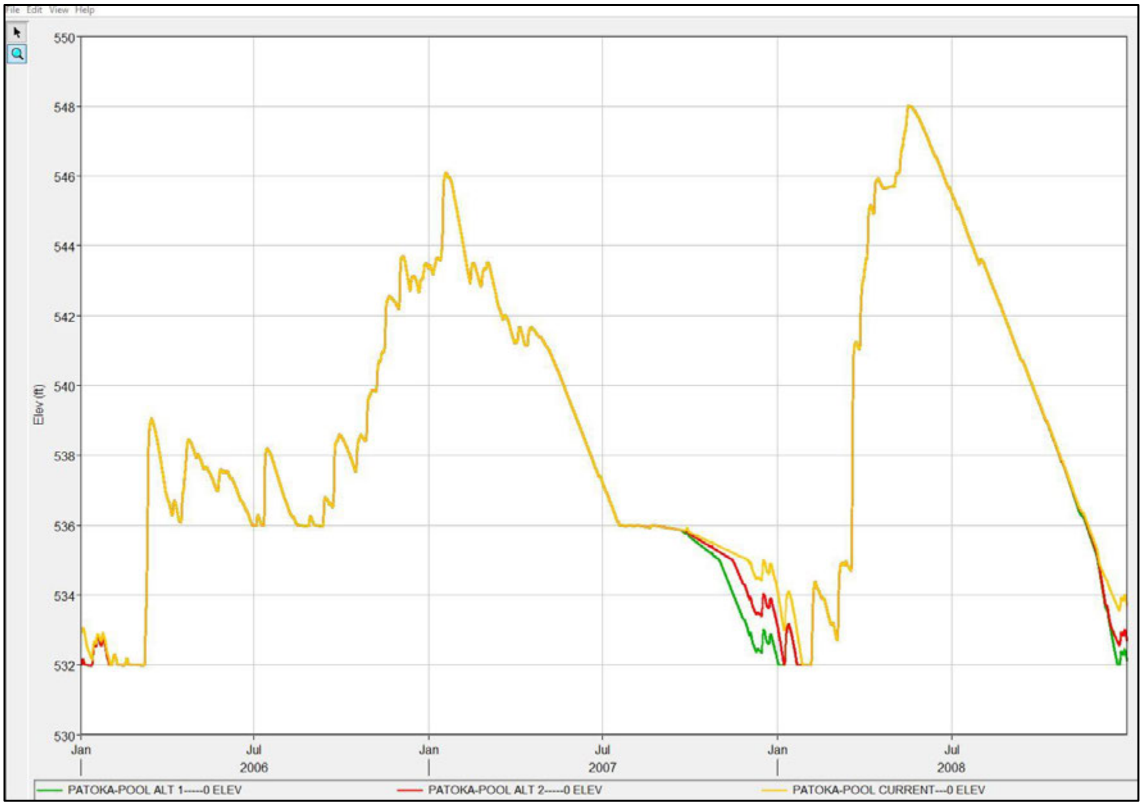


Figure 11: Patoka Pool Elevation Plots Alt 1 and Alt 2 versus Current Operation

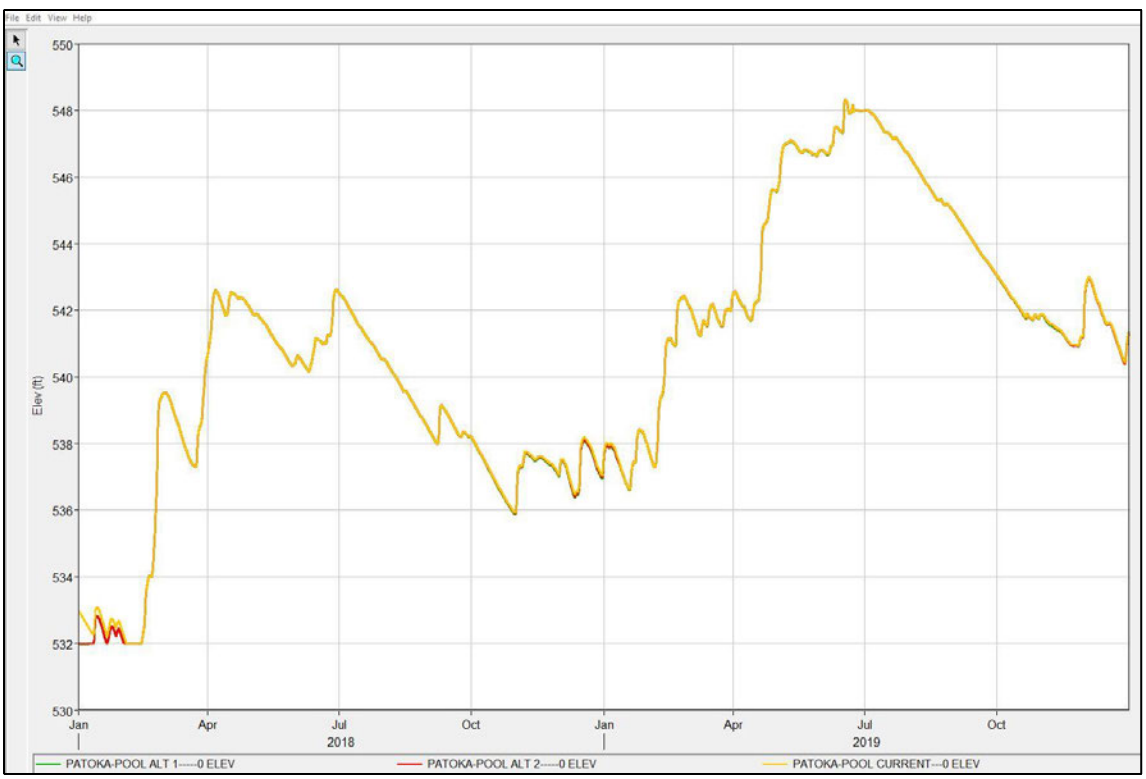


Figure 12: Patoka Pool Elevation Plots Alt 1 and Alt 2 versus Current Operation

Alternatives 3, 6, and 9: Jasper Operated for 13 Feet

Three alternatives were compared for operating Jasper for 13 feet. They include Alt 3 - no change to the guide curve, Alt 6 - start down to winter pool on Nov 1, and Alt 9 - start down to winter pool on Nov 15. For most peak pools that occur during the spring or summer there was no increase in flood storage capacity by changing the start and end dates of the winter drawdown. For some events that occur during the winter drawdown period the peak pool elevations were reduced by less than 0.5 feet and that reduction carried through into the next year. Alt 6 and Alt 9 were eliminated because there was zero to less than a 0.5-foot difference in peak pool elevations between the 3 scenarios, resulting in little to no increase in flood storage capacity. See Figure 13 and Figure 14 for previously presented flood events analyzed for these alternatives (Alt 3-green line, Alt 6-red line, and Alt 9-yellow line).

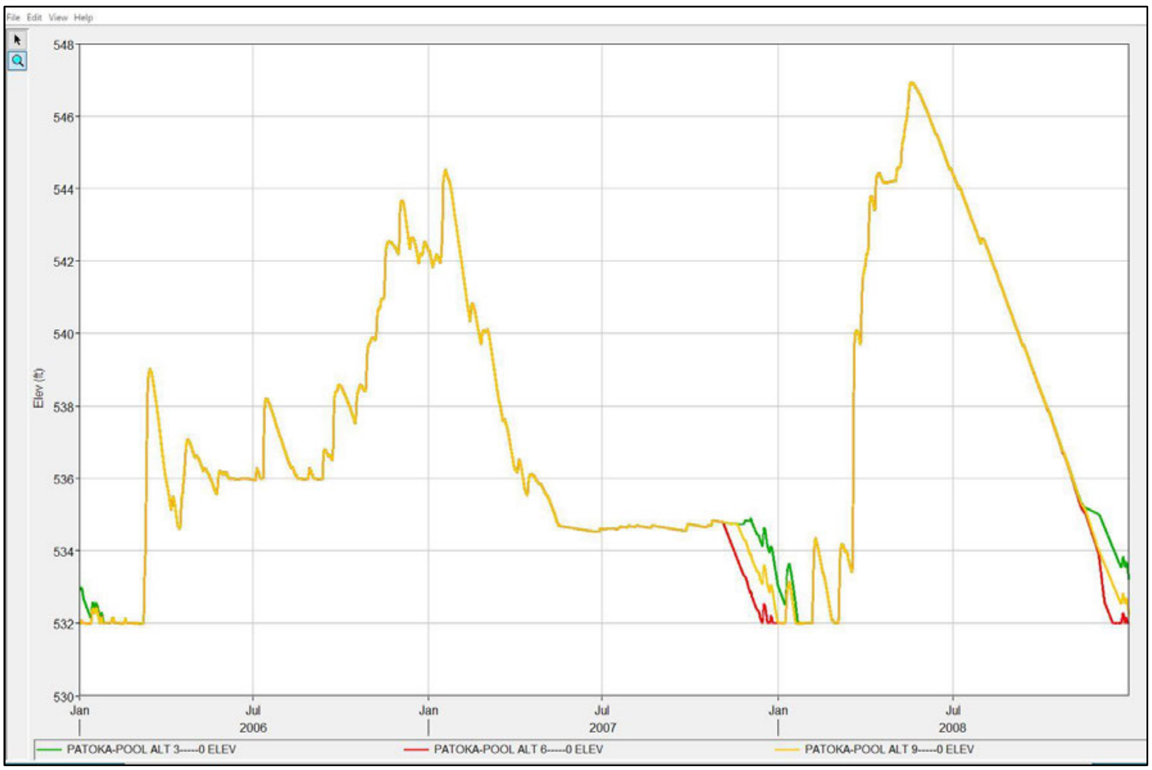


Figure 13: Patoka Pool Elevation Plots Alt 3, Alt 6, and Alt 9

Figure 14: Patoka Pool Elevation Plots Alt 3, Alt 6, and Alt 9

Alternatives 4, 7, and 10: Jasper Operated for 13.5 Feet

Three alternatives were compared for operating Jasper for 13.5 feet. They include Alt 4 - no change to the guide curve, Alt 7 - start down to winter pool on Nov 1, and Alt 10 - start down to winter pool on Nov 15. There was zero to less than a 0.05-foot decrease in peak pool elevations by changing the start and end date of the drawdown to winter pool. Alt 7 and Alt 10 were eliminated because there was negligible difference in peak pool elevations between the 3 scenarios, resulting in little to no increase in flood storage capacity. See Figure 15 and Figure 16 for previously presented flood events analyzed for these alternatives (Alt 4-green line, Alt 7-red line, and Alt 10-yellow line).

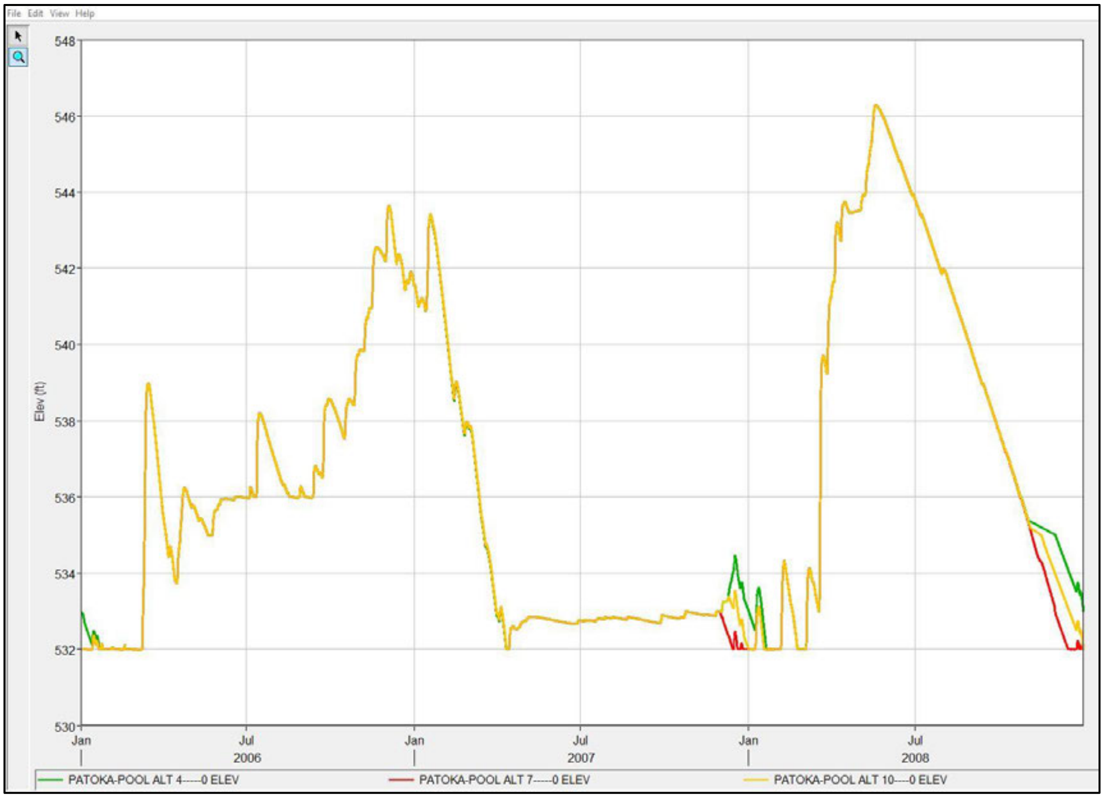


Figure 15: Patoka Pool Elevation Plots Alt 4, Alt 7, and Alt 10

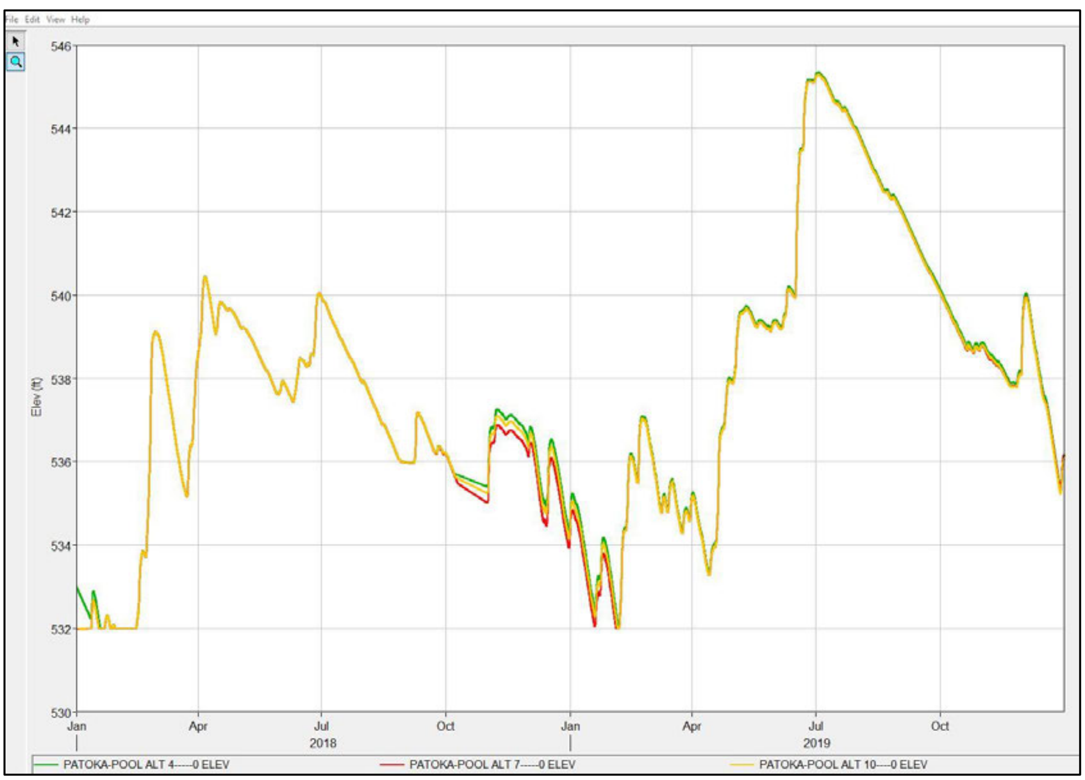


Figure 16: Patoka Pool Elevation Plots Alt 4, Alt 7, and Alt 10

Alternatives 5, 8, and 11: Jasper Operated for 14 Feet

Three alternatives were compared for operating Jasper for 14 feet. They include Alt 5 - no change to the guide curve, Alt 8 - start down to winter pool on Nov 1, and Alt 11 - start down to winter pool on Nov 15. There was zero to less than a 0.05-foot decrease in peak pool elevations by changing the start and end date of the drawdown to winter pool. Alt 8 and Alt 11 were eliminated because there was negligible difference in peak pool elevations between the 3 scenarios, resulting in little to no increase in flood storage capacity. See Figure 17 and Figure 18 for previously presented flood events analyzed for these alternatives (Alt 5-green line, Alt 8-red line, and Alt 11-yellow line).

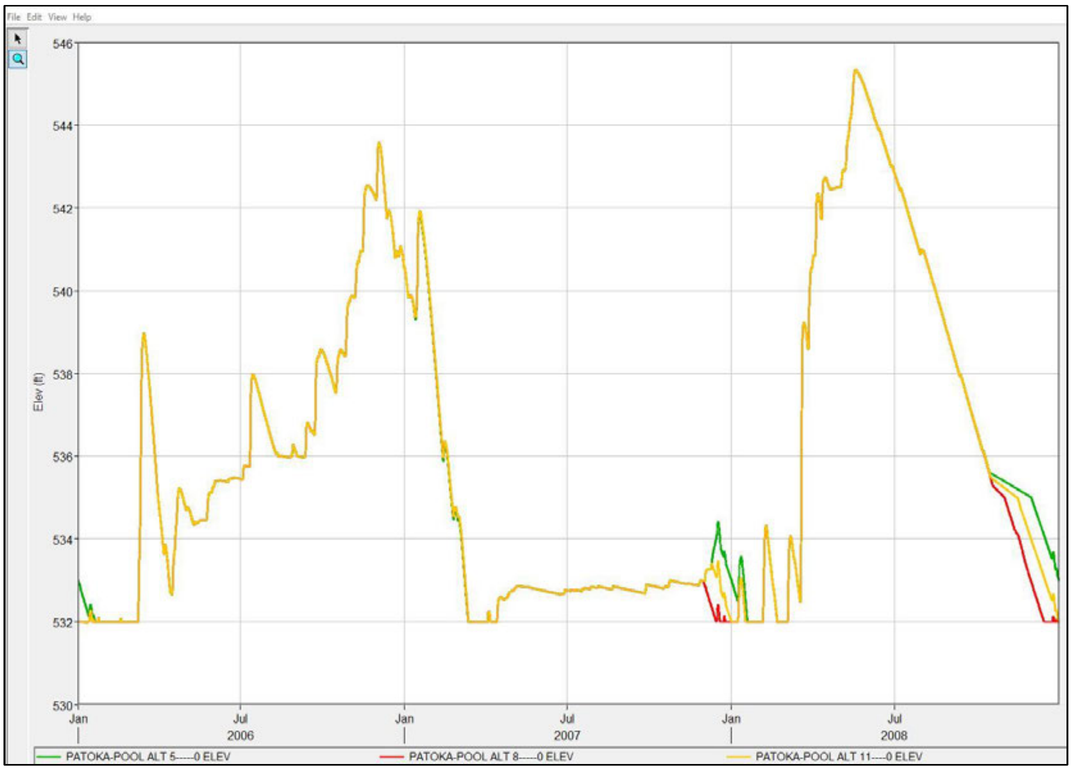


Figure 17: Patoka Pool Elevation Plots Alt 5, Alt 8, and Alt 11

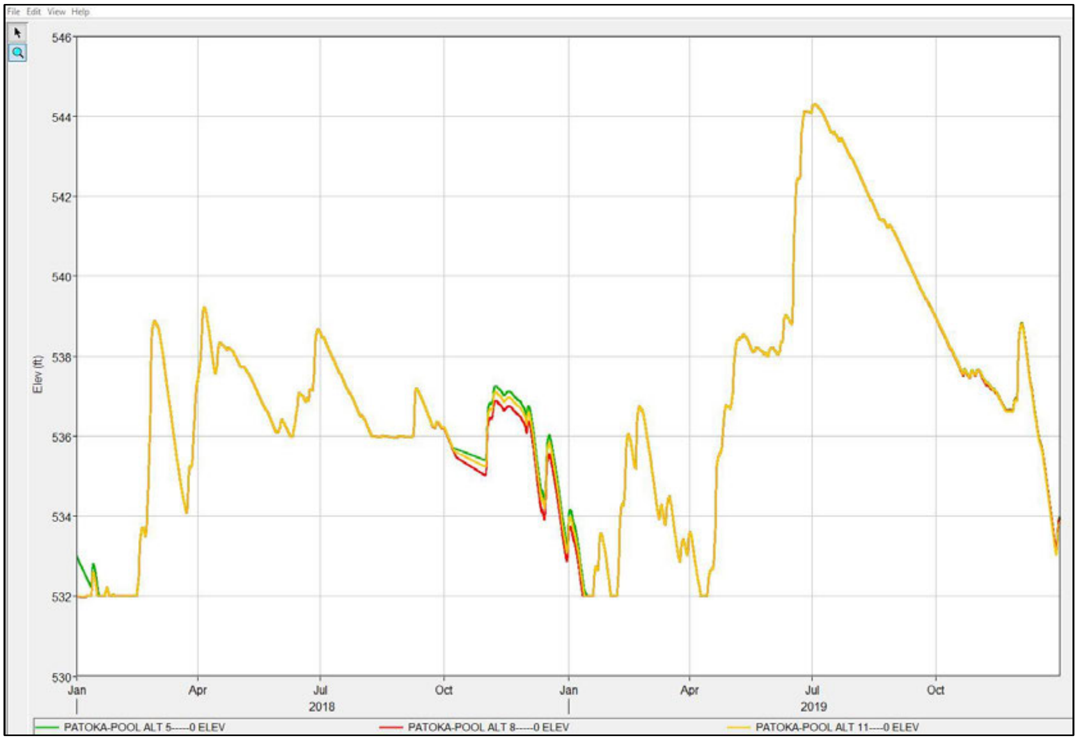


Figure 18: Patoka Pool Elevation Plots Alt 5, Alt 8, and Alt 11

Potential Impacts with Alternatives 4, 5, and 12:

Four alternatives were considered that had no change to the guide curve. They include Alt 3 – operate Jasper for 13 feet, Alt 4 – operate Jasper for 13.5 feet, Alt 5 – operate Jasper for 14 feet and Alt 12 – operate Jasper for 13 feet when above 33% utilized or 14 feet when above 66% utilized. Despite the overall peak pool elevations being lowered slightly, Alt 4, Alt 5, and Alt 12 were eliminated. Under the current operating criteria and when hypothetically targeting a stage of 13 feet, the travel time of releases from Patoka Lake Dam to the Jasper gage is approximately 24 hours. When targeting 13.5 feet and 14 feet at Jasper, additional low-lying areas are inundated, causing the river to take longer than normal to respond to increases or decreases in outflow. This results in operational decisions being made two or more days prior to expected rainfall. Targeting a stage at Jasper higher than 13 feet provides less freeboard for unexpected or higher than forecasted rainfall events that occur in the Patoka River Basin.

A sample of events were chosen to look closer at potential impacts of operating Jasper for a target stage of 13 feet versus 14 feet. See Figure 19 below describing the observed rainfall reported at Patoka Lake Dam, the resulting rate of rise, the observed crest at Jasper, the potential crest if had the project been operating Jasper for a target stage of 13 feet, and the associated increase in peak at Jasper. For a few select events, the potential crest had the project been operating Jasper for a target stage of 14 feet instead of the current 12 feet would have resulted in a peak at Jasper above the 14.5 feet threshold at which flooding starts in the City of Jasper. See Figure 19 below.

Events at Jasper, IN

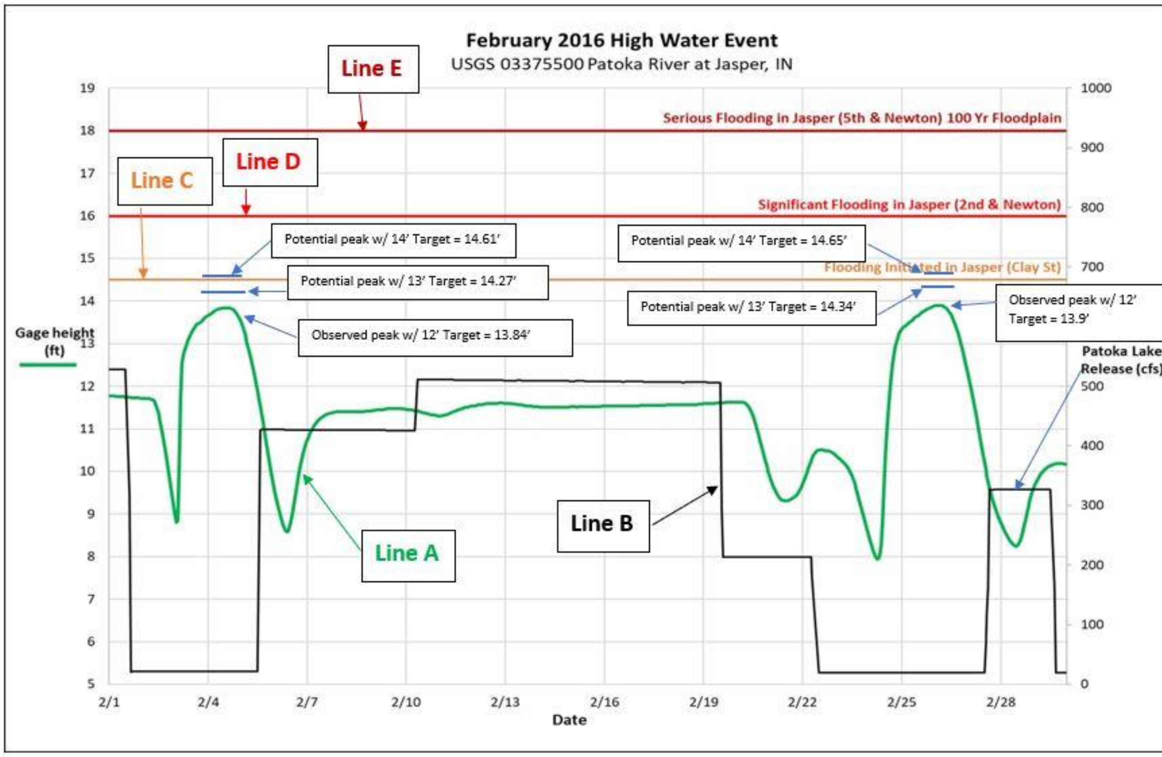
Date	Rain at Patoka Lake Dam	Resulting Rate of Rise	Observed Peak at Jasper (feet)	Potential Peak at Jasper w/ 13' Target (feet)	Potential Peak Increase 12' to 13' Target (feet)	Potential Peak at Jasper w/ 14' Target (feet)	Potential Peak Increase 12' to 14' Target (feet)
Jan-08	1.94" in 24 hrs	3.7' in 6 hrs	14.96	15.1	0.14		
Mar-08	4.6" in 24 hrs	6' in 18 hrs	17.8	17.83	0.03		
Feb-10	0.1" in 24 hrs	0.7' in 7 hrs	13.2	13.85	0.65		
Dec-13	1.57" in 24 hrs	5.8' in 10 hrs	16.0	16.07	0.07		
1-Feb-16	1.44" in 24 hrs	3.8' in 4 hrs	13.84	14.27	0.47	14.61	0.77
26-Feb-16	1.28" in 48 hrs	5.3' in 16 hrs	13.9	14.34	0.44	14.65	0.75
Mar-16	1.71" in 48 hrs	5' in 20 hrs	14.0	14.32	0.32	14.62	0.58
Apr-16	1.31" in 48 hrs	3' in 7 hrs	13.92	14.29	0.37	14.62	0.7
Feb-19	2.19 in 48 hrs	3' in 6 hrs	14.35	14.56	0.21		
May-19	3.11" in 48 hrs	0.7' in 8 hrs	14.8*				
Mar-20	0.68" in 24 hrs	0.4' in 4 hrs	14.3*				

* Deviation to target 14' at Jasper in place

Figure 19: Potential Impacts of Alternatives at Jasper

The events above highlighted in yellow (Figure 19) illustrate how significant observed rises in a short period of time can be problematic if targeting a stage of 14 feet at Jasper, especially when unexpected or higher than forecasted rainfall occurs at or below Patoka Lake Dam. See the plots below (Figure 20 through Figure 22) for more detailed information for these four events.

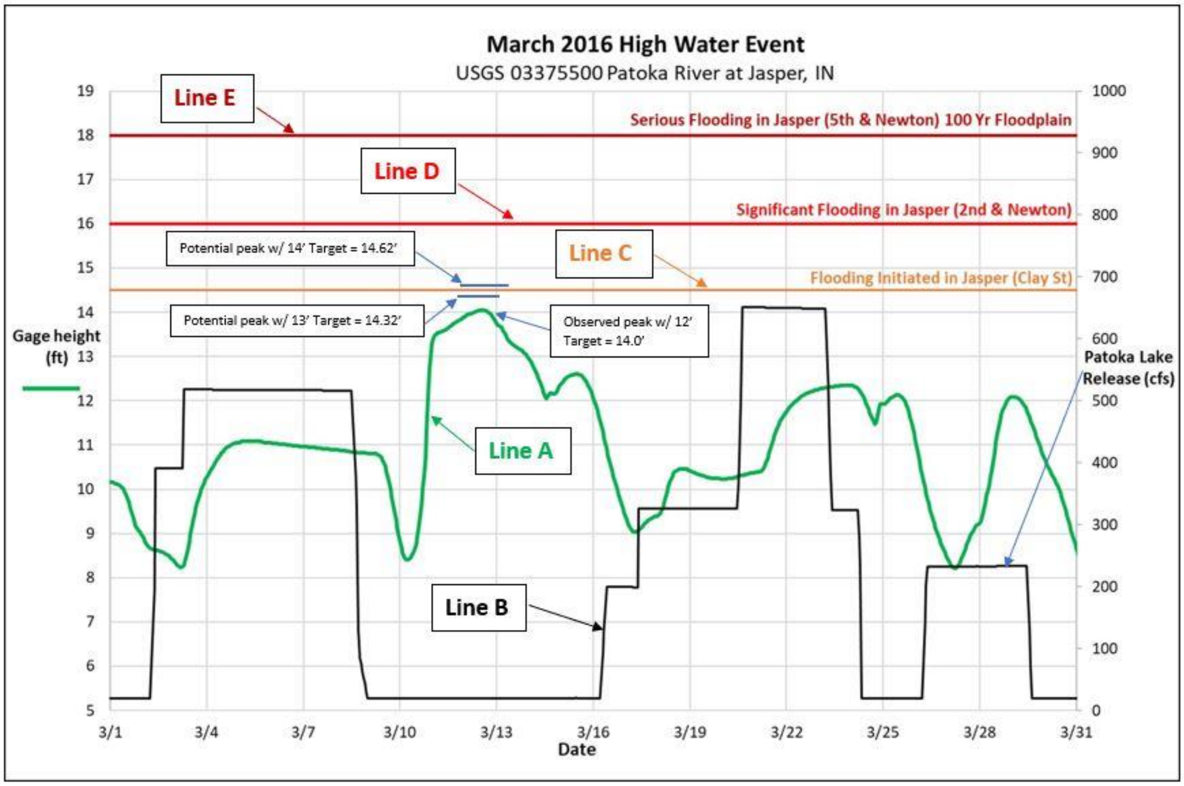
These events in February 2016 illustrate the potential for crests higher than expected at the Jasper gage if the starting stage before the event is 1 or 2 feet higher by operating for a target stage at Jasper of 13 or 14 feet, respectively (Figure 20). Lines C, D, and E reflect the point at which flooding begins in the City of Jasper, as provided by the City of Jasper and Dubois County officials. See Appendix A-Impact Summary for detailed impacts at various stages.



Rainfall at Patoka Lake Dam: 1.44' fell 2/2-2/3…0.27" fell 2/20-2/21, 1.01" fell 2/23-2/24 and 0.27" fell 2/24-2/25

Line A (green)	Observed Jasper gage height in feet
Line B (black)	Outflow from Patoka Lake in cfs
Line C (orange)	Stage at which flooding begins in the City of Jasper, at Clay Street (14.5 feet)
Line D (red)	Stage at which significant flooding begins in the City of Jasper, at 2nd and Newton Streets (16 feet)
Line E (dark red)	Stage at which serious flooding begins in the City of Jasper, at 5th and Newton Streets (18 feet)

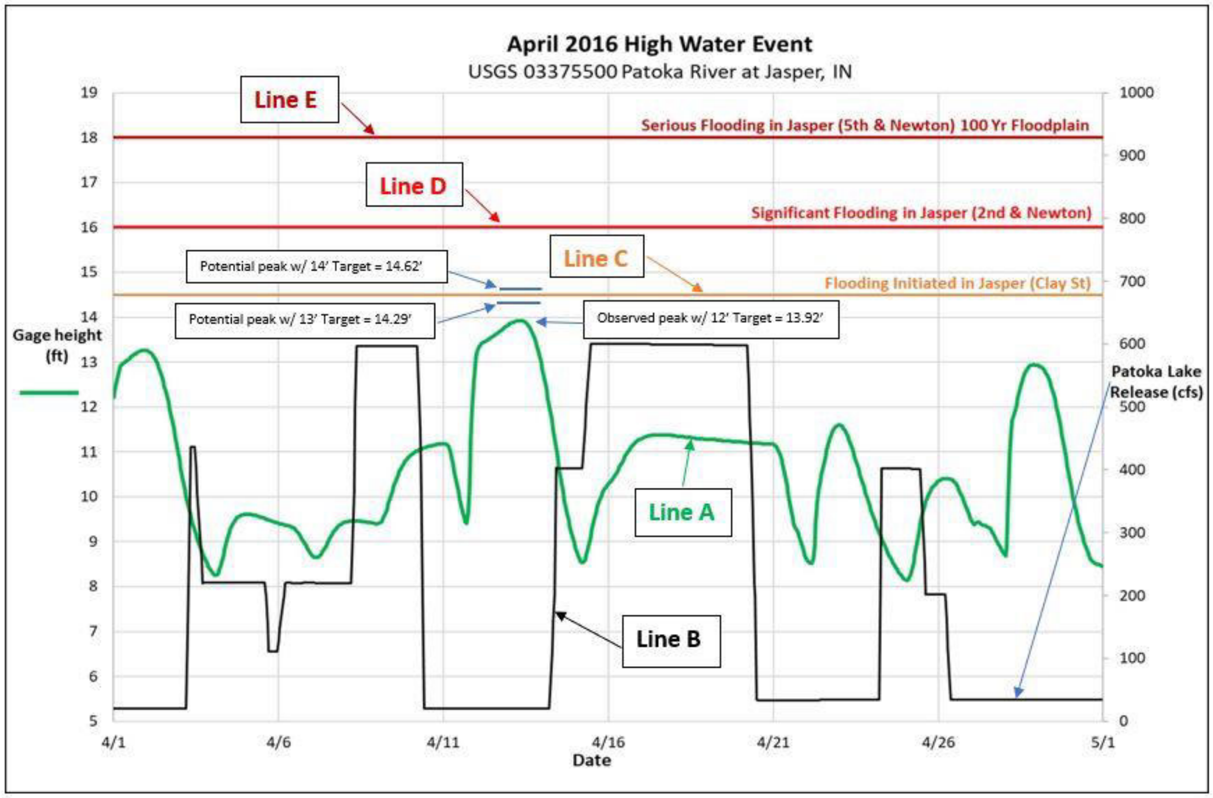
Figure 20: Plots of Potential Impacts for the February 2016 Events



Rainfall at Patoka Lake Dam: 0.88" fell 3/9-3/10 and 0.83" fell 3/10-3/11

Line A (green)	Observed Jasper gage height in feet
Line B (black)	Outflow from Patoka Lake in cfs
Line C (orange)	Stage at which flooding begins in the City of Jasper, at Clay Street (14.5 feet)
Line D (red)	Stage at which significant flooding begins in the City of Jasper, at 2nd and Newton Streets (16 feet)
Line E (dark red)	Stage at which serious flooding begins in the City of Jasper, at 5th and Newton Streets (18 feet)

Figure 21: Plots of Potential Impacts for the March 2016 Event



Rainfall at Patoka Lake Dam: 0.36" fell 4/10-4/11 and 0.95" fell 4/11-4/12

Line A (green)	Observed Jasper gage height in feet
Line B (black)	Outflow from Patoka Lake in cfs
Line C (orange)	Stage at which flooding begins in the City of Jasper, at Clay Street (14.5 feet)
Line D (red)	Stage at which significant flooding begins in the City of Jasper, at 2nd and Newton Streets (16 feet)
Line E (dark red)	Stage at which serious flooding begins in the City of Jasper, at 5th and Newton Streets (18 feet)

Figure 22: Plots of Potential Impacts for the April 2016 Event

Actual Operation Under an Approved Deviation

Two additional events that illustrate the difficulty in operating Jasper for a target stage of 14 feet are May 2019 and March 2020, when deviations were in place to target 14 feet at Jasper until growing season began. During the May 2019 event, outflow was decreased on May 1, 2019, due to forecasted rainfall. The initial 1.19 inches of rainfall caused Jasper to rise 0.7 feet in 8 hours, pushing Jasper above 14 feet. Outflow was reduced to minimum release on May 3, 2019, after 1.92 inches of additional rainfall fell, however Jasper continued to rise, cresting at 14.8 feet. In March 2020, outflow was increased from Patoka Lake on March 26, 2020, but due to the longer travel time and 0.68 inches of rainfall/resulting rise on March 29, 2020, Jasper did not crest until March 31, 2020, at a stage 0.3 feet above the temporary target stage of 14 feet. These two events demonstrate how unexpected rainfall combined with longer-than-normal travel time at higher outflows can impact the timing and peak stage at Jasper.

Summary of Results

In general, by targeting a stage of 14 feet at Jasper, an increase of approximately 0.5-0.8 feet would be expected to the peak stages at the Jasper gage. In addition, there is increased risk of areas being impacted between the dam and Jasper, as well as further downstream (ex. Patoka River Wildlife Refuge below Winslow, IN). The above examples show actual Patoka Lake outflows, rainfall, and the resulting impacts from local runoff (which often cause Jasper to go above 14 feet) while making conservative lake operations targeting 12 feet at Jasper.

7. Selected Alternative

Of the 12 alternative operations that were modeled, one emerged as the preferred option. Alternative 3, operating for a target stage of 13 feet at the Jasper gage during non-crop season with no change to the existing guide curve, was selected because it lowered peak pool elevations and flood storage utilization with a tolerable increase to flooding risk downstream. Detailed calibration and model results for Alternative 3 versus current operations are shown in the Res-Sim Modeling Appendix B.

If needed, temporary deviations can be considered in the future on a case-by-case basis, depending on the conditions.

8. Impacts Due to Selected Alternative

A summary of potential impacts associated with increasing the non-crop target stage from 12 feet to 13 feet at Jasper are listed in the following section. Appendix A includes additional impact details.

8.1 Impacts to Authorized Purposes

Impacts to Authorized Purposes of raising the target stage from 12 feet to 13 feet (Positive impact is noted as (+), negative impact is noted as (-), neutral impact noted as N/A):

Authorized Purpose	Maintain existing non-crop target stage at Jasper of 12-feet		Increase non-crop target stage at Jasper to 13-feet.	
Flood Control	Expected flood storage utilizations would remain the same.	-	Res-Sim modeling indicates that non-crop peak pool elevations could be decreased from 0.1 to approximately 3 feet. The faster increase in flood storage recovery has a cumulative effect over time, resulting in antecedent elevations closer to the guide curve. As such, there is also some decrease to peak pool elevations during crop season. Peak pool elevations of the two uncontrolled spillway events would have been lowered by 0.4 feet.	+
Water Quality	Water Quality is expected to remain the same.	N/A	Faster flood storage recovery would allow the project to be better	+

			positioned to affect downstream temperatures during the early part of the spring (last portion of non-crop season). By releasing larger volumes of water to return to guide curve quicker, low-flow bypasses can be utilized sooner with some measure of temperature selectivity.	
Recreation	Recreational facilities designed to optimally function at summer pool would continue to experience the same duration of high water after flood events	-	With faster flood storage recovery, recreational facilities designed to optimally function at summer pool elevation would experience an increase in the percent of time the pool elevation is at that level	+
Water Supply	Water supply is expected to remain the same	N/A	No positive or negative impacts expected to Water Supply	N/A

8.2 Impacts to Project Risk

In preparation for the 2022 Periodic Assessment a pool-elevation frequency curve was developed using observed data from 1974 to 2022, as well as additional data from other floods to extend the historical curve. To understand how the proposed operation change may impact the pool-elevation frequency curve, new curves were developed exclusively using the 2006-2020 simulated data from Res-SIM. This allows for a consistent comparison between the pool-elevation annual exceedance probability with and without the proposed change to the Jasper operating criteria, as shown in Figure 9. If data were available to re-simulate the entire period of record, as was performed for the Periodic Assessment, it is expected the reduction in probability of reaching spillway crest would be approximately the same. The proposed alternative, operating Jasper for 13 feet during non-crop season, reduces the annual exceedance probability (AEP) of reaching spillway crest from 1/5 AEP to 1/9 AEP (Figure 23) and would therefore slightly lower the risk for potential failure modes initiating with reservoir levels near spillway crest.

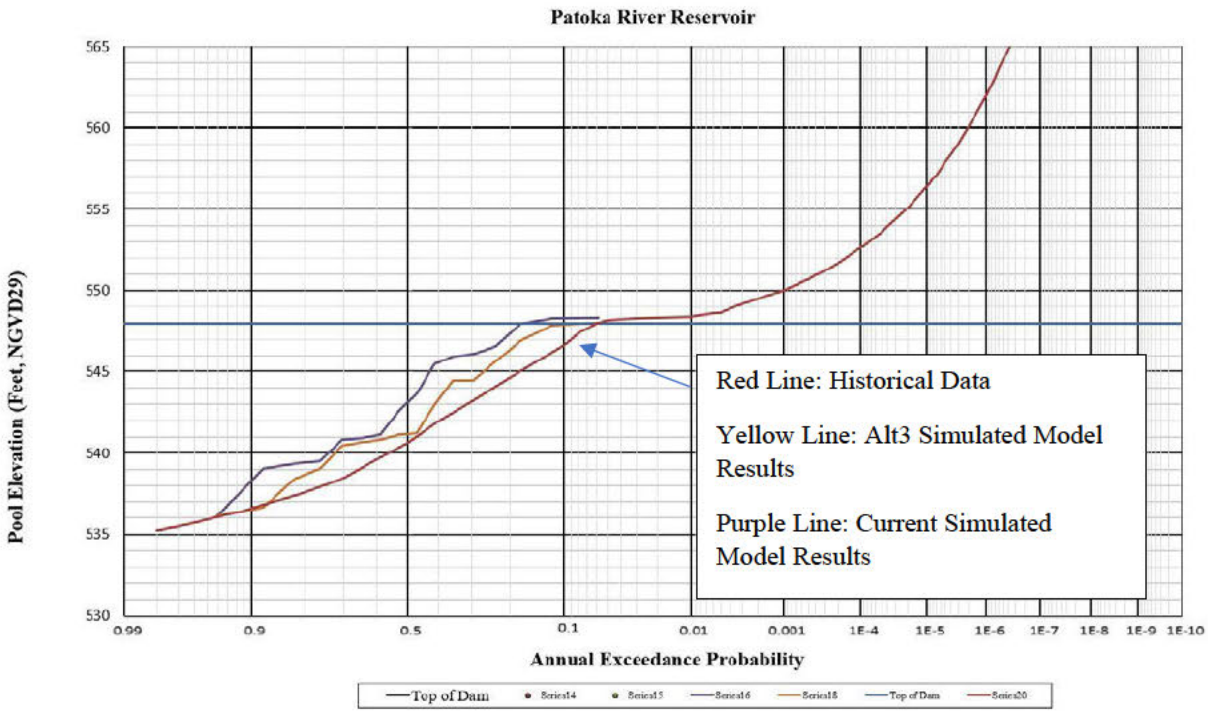


Figure 23 – Pool Elevation Annual Exceedance Probability Curve

In addition to the shift of the pool elevation frequency curve, the impacts to identified risk-driving failure modes were qualitatively evaluated. Based on the Semi-Quantitative Risk Assessment for Patoka Dam, dated January 2015, the risk driving failure modes for Patoka Dam are internal erosion of the dike embankment into the Glen Dean Limestone in the valley center downstream of the cutoff trench, internal erosion along the conduit, overwash erosion of the dam or dike embankment, internal erosion along the Glen Dean/Concrete bulkhead at the left dam abutment, internal erosion in to the Glen Dean Limestone foundation in the right dike abutment, and internal erosion into the Glen Dean limestone foundation in the left dam abutment. This operational change would reduce the duration required for the Patoka Lake pool to return to the guide curve, effectively reducing the probability of any of these failure modes initiating and progressing to failure and the associated downstream consequences.

8.3 Downstream Impacts

Since approximately 2016, numerous discussions regarding impacts at various river levels have occurred with downstream stakeholders. These discussions have indicated that during non-crop season, farm fields are not significantly impacted at most stages, and impacts in and around the City of Jasper generally do not occur until river levels reach a stage of about 14.5 feet on the gage. This has been confirmed as deviation requests in 2019 and 2020 were coordinated with downstream stakeholders and resulted in a temporary target stage of 14 feet at Jasper. Additionally, due to the amount of uncontrolled runoff between the dam and the Jasper gage, river levels reach or exceed a stage of 13 feet regularly because of the uncontrolled runoff. During these periods, releases from the dam are generally on the order of 20-50 cfs, or less than about 2% of the flow at the gage. Appendix A illustrates high water events from 2008 up through 2019 by comparing the dam release and the observed stage at the Jasper gage. This

Appendix also includes field observations during two events in May 2019, as well as correspondence with downstream stakeholders regarding the impacts during various flood events.

8.4 Climate Change Considerations

The climate change analysis for Patoka Reservoir, included as Appendix D of this report, indicates increasing trends in historically observed precipitation near the reservoir site. These observed increases in precipitation have resulted in statistically significant increasing trends identified in monthly-average inflow volume into the reservoir. Future projections of climate change seem to indicate the observed increases in precipitation are likely to continue into the future, although projections of streamflow are more variable and depend on future greenhouse gas emission scenarios. There is also high confidence that temperatures in the project area are likely to increase in the future.

These increasing trends in observed and projected rainfall have the potential to increase the frequency of reservoir loading in the future. For example, spillway events may occur more frequently in the future compared with their historic occurrence. Additional details regarding potential impacts and analysis of climate change are included in Appendix D of this report.

9. Conclusion

If approved as a permanent change to the Patoka Water Control Manual, operating Jasper for a target stage of 13 feet during non-crop season would have many benefits with very little risk. Not only does it allow recovery of flood control storage quicker during non-crop season; it also reduces the chances of higher peak pool elevations and helps lower the pool elevation going into the wettest part of the year in the Spring. Based on the Res-Sim modeling results, targeting 13 feet at Jasper during non-crop season is expected to reduce the peak pool elevations up to 3 feet, depending on the time of year high water occurs. The results showed significant benefit when high water events take place during non-crop season and the pool elevation is returned to guide curve before crop season begins. Stages up to 13 feet at Jasper are experienced often due to local runoff from rain events so no negative impacts are expected downstream of Patoka Lake due to operating Jasper for 13 feet during non-crop season. After years of coordination, Jasper and Dubois County officials have provided data confirming that no impacts are observed in Jasper when a target stage of 13 feet at Jasper is achieved.

Patoka Water Control Manual Update

Engineering Report

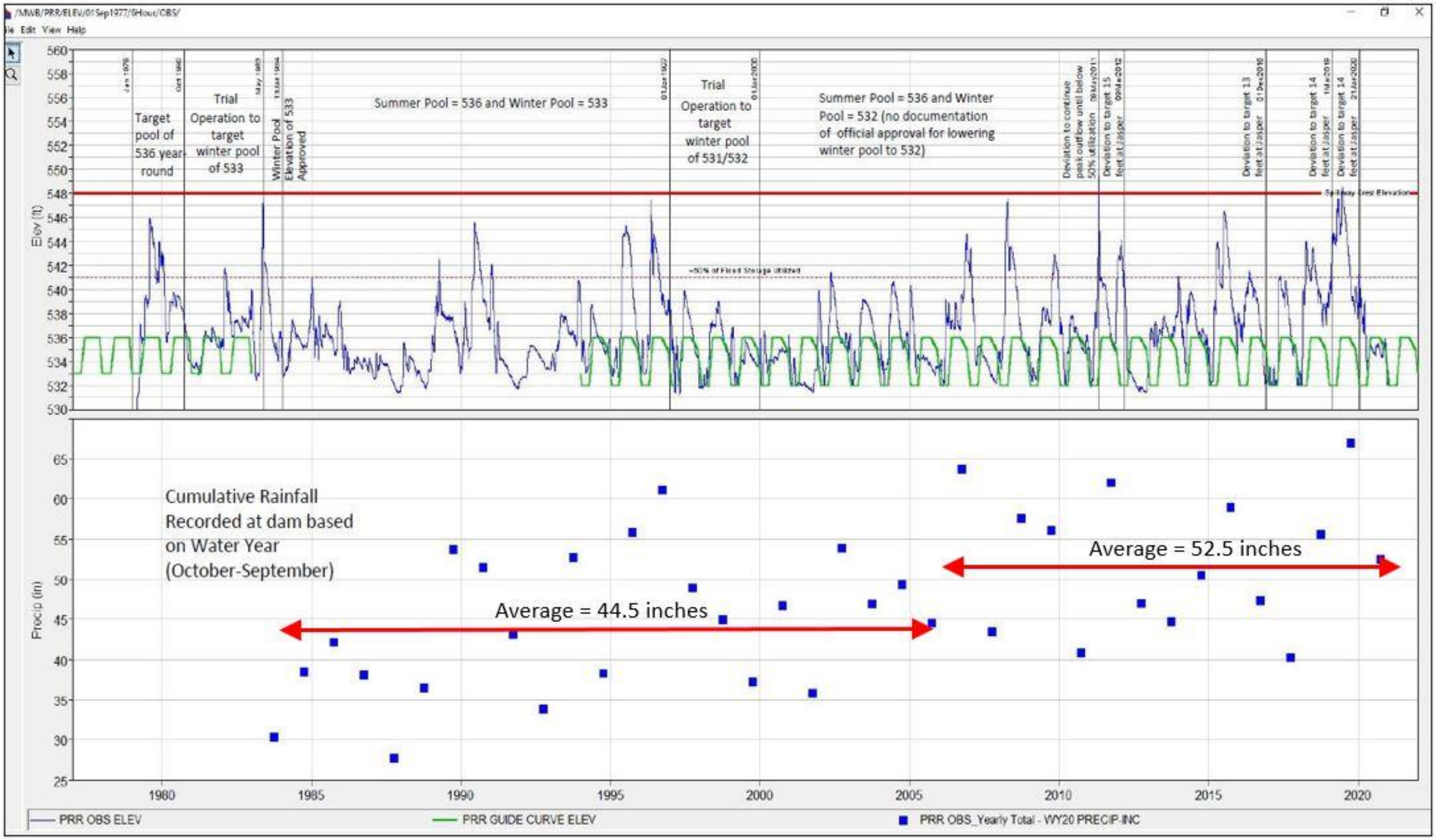
Appendix A – Impact Summary

June 2024

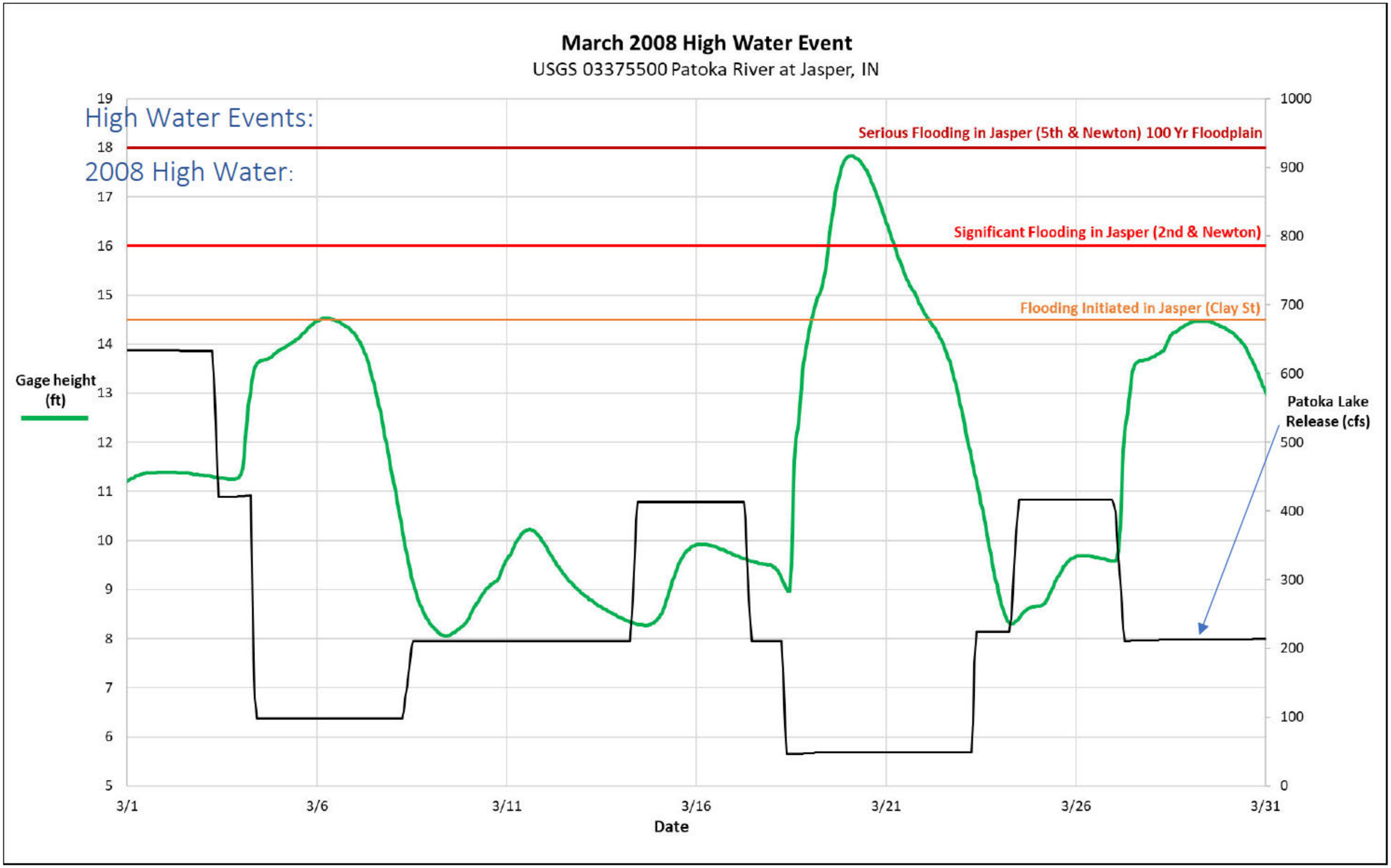
Appendix A summarizes data collected/observed downstream of Patoka Lake during high water events. Data was collected from Corps personnel, City of Jasper Street Department and Dubois County officials. A chart summarizing past deviations, historical rainfall, and pool elevations is included. Plots of observed river levels that are cross-referenced with Patoka Lake outflows for significant floods in the City of Jasper are shown. Also included are photos taken at downstream locations on the Patoka River on two different days to provide visual evaluation of impacts. Comparison of previous ratings for the Patoka River at Jasper illustrate how much storage capacity has been lost in the channel over the years, as well as comparisons for the Patoka River at Princeton and Winslow. Appendix A concludes with supporting email correspondence and additional observations provided by the City of Jasper and Dubois County officials, as well as Fish and Wildlife Service Patoka Wildlife Refuge Manager.

In summary, based on the frequency at which Jasper exceeds 13 feet due to rainfall runoff, the photo evidence and email exchanges with the City of Jasper and Dubois County officials indicate no significant impacts to operating Jasper for a target stage of 13 feet during non-crop season.

Patoka Pool Elevations, Observed Rainfall and Historical Deviations:

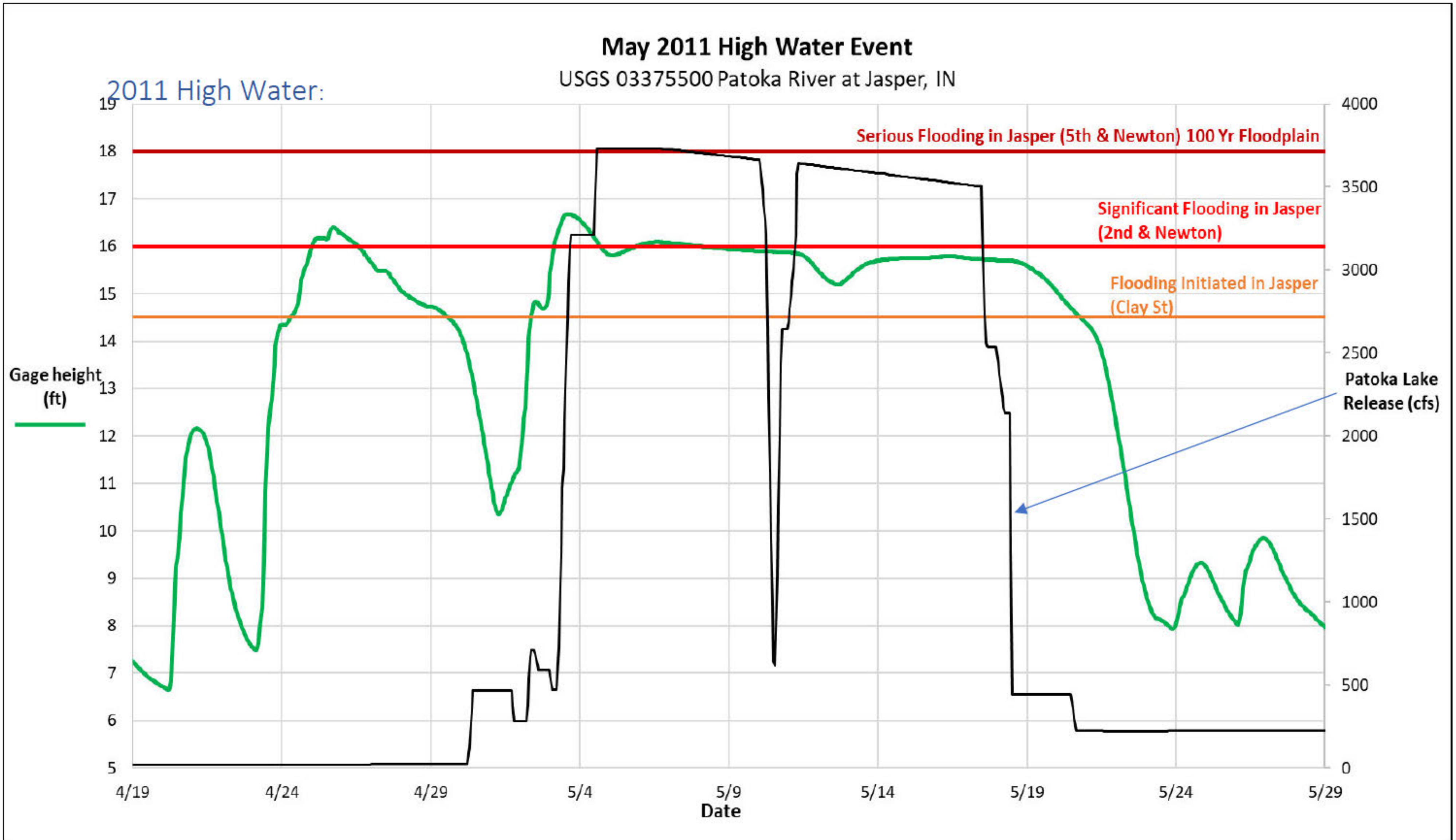


Below are a series of plots illustrating a variety of high water events at Jasper. The plots include the Jasper gage height, releases from Patoka Lake, and how they compare to levels identified by the City of Jasper that cause flooding issues, as well as specific impacts to particular roads.



SUMMARY: Heavy Rain on third day followed by high water/flooding that subsided over a few days.
Serious flooding 3/19 and 3/20 with peak water at 4th St. and Main. Receding flood 3/21 with river back in banks by 3/22.

2011 High Water:

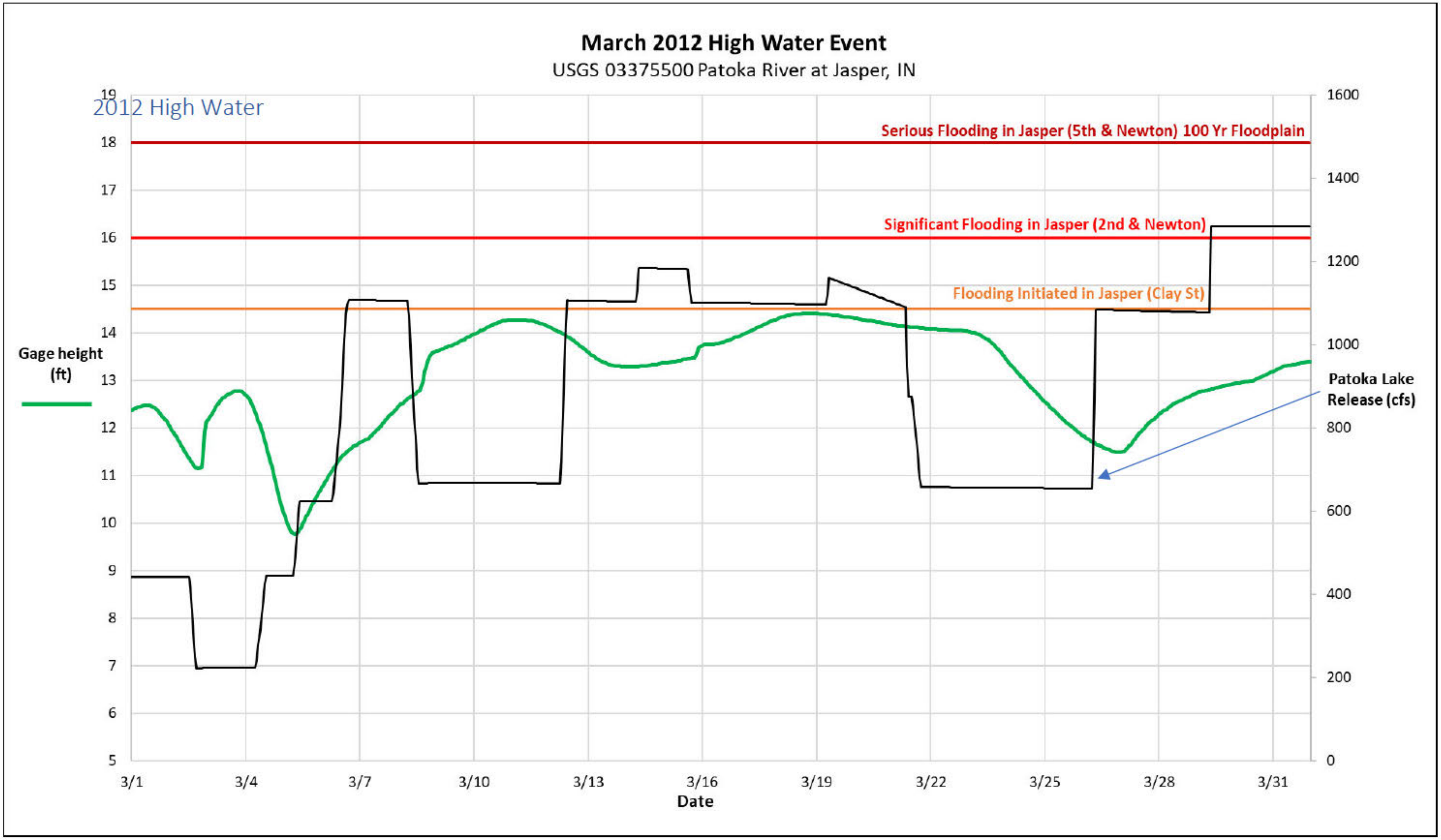


SUMMARY: 2 rounds of rain with the first being heavy rain over multiple days with a few days of light rain followed by 2 days of heavy rain with a drawn-out recovery.

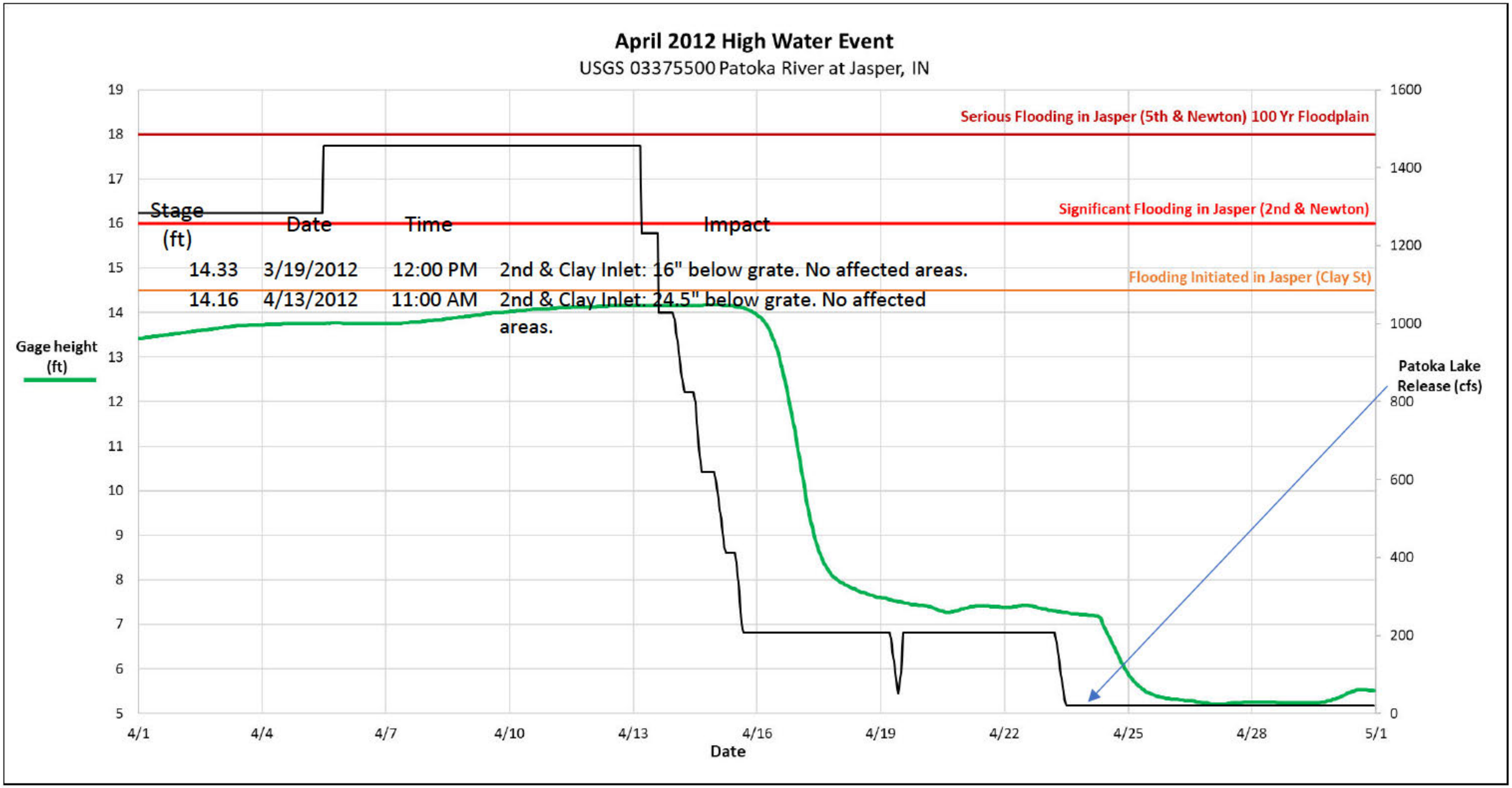
List of roads closed due to flooding on April 25, 2011:

- W 2nd Street between 231 and Main St
- S Clay Street between Wernsing Rd and 3rd St
- E 4th Street between Mill St and 3rd St
- S Main Street between Main St and S Newton St
- S Newton Street between 3rd St and Brucke Strasse
- Cathy Lane between Kellerville Rd and 25th St

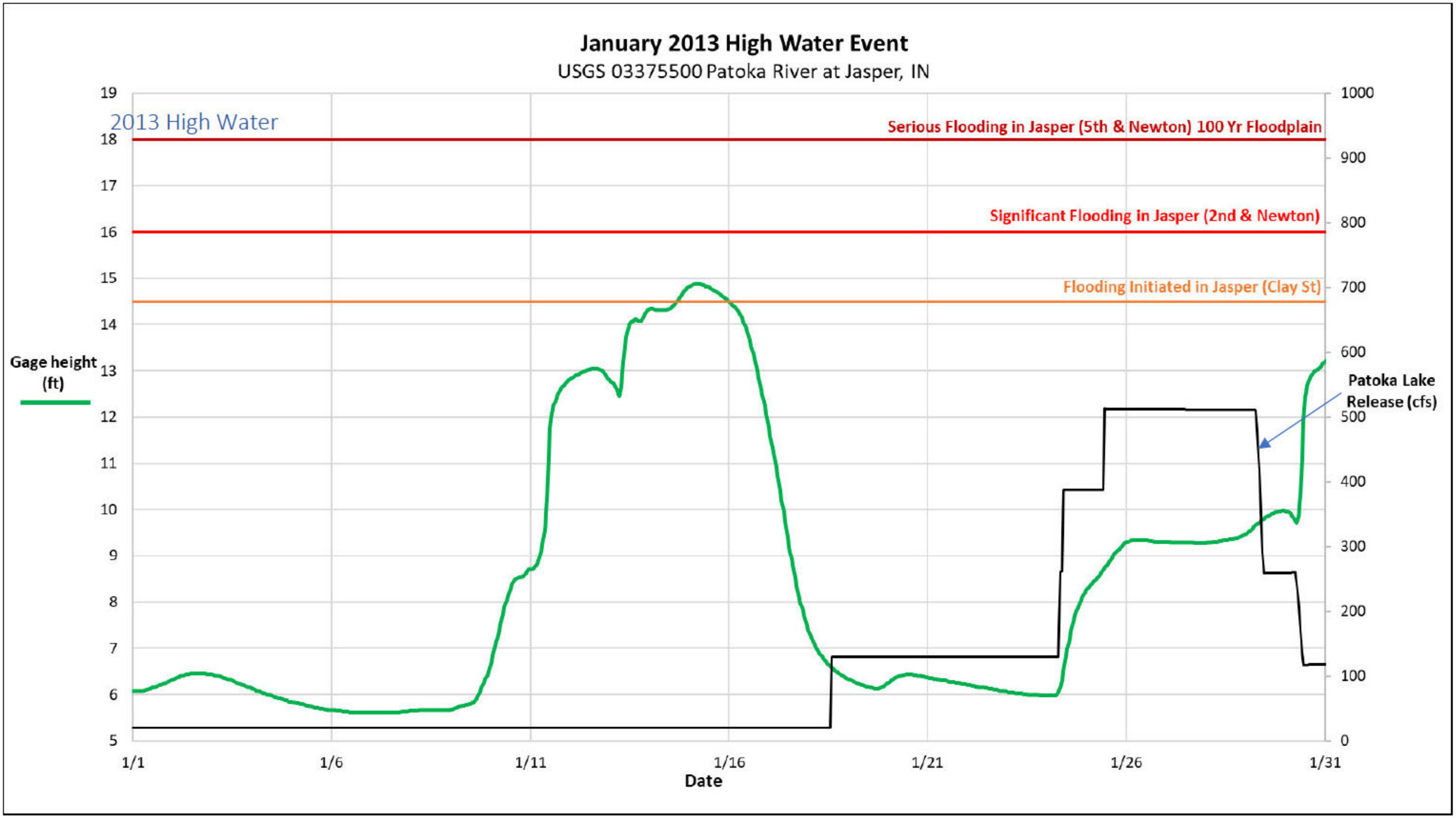
~Jasper City Streets.pdf from [Non-DoD Source] FW: Patoka Lake Spillway Event.msg



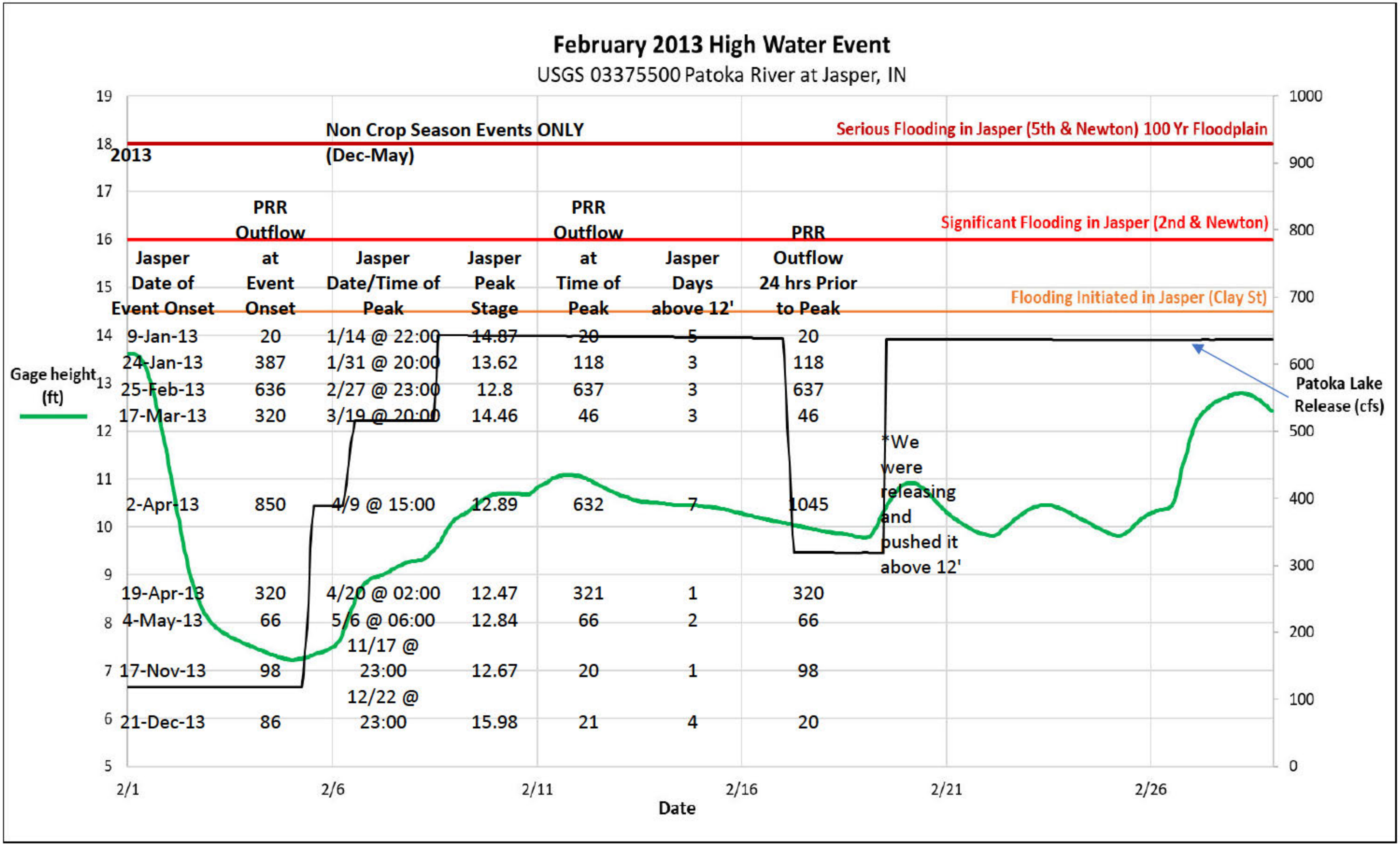
SUMMARY: Rain events – 1 inch on 3/2, 0.4 inches on 3/4 , minimal rain on 3/7, 1 inch on 3/8, minimal on 3/11, 0.1 inches on 3/14, 0.9 inches on 3/15, minimal on 3/17, 0.1 inches on 3/22, 0.5 inches on 3/23, minimal on 3/28, and 0.2 inches on 3/30.



SUMMARY: 5 minor rain events. 0.3 inches on 4/4, minimum rain on 4/13, 0.15 inches on both 4/14 and 4/15, 0.15 inches on 4/20, minimal rain on 4/24 and 4/25, 0.5 inches on 4/28, minimal rain on 4/29, 0.7 inches on 4/30.

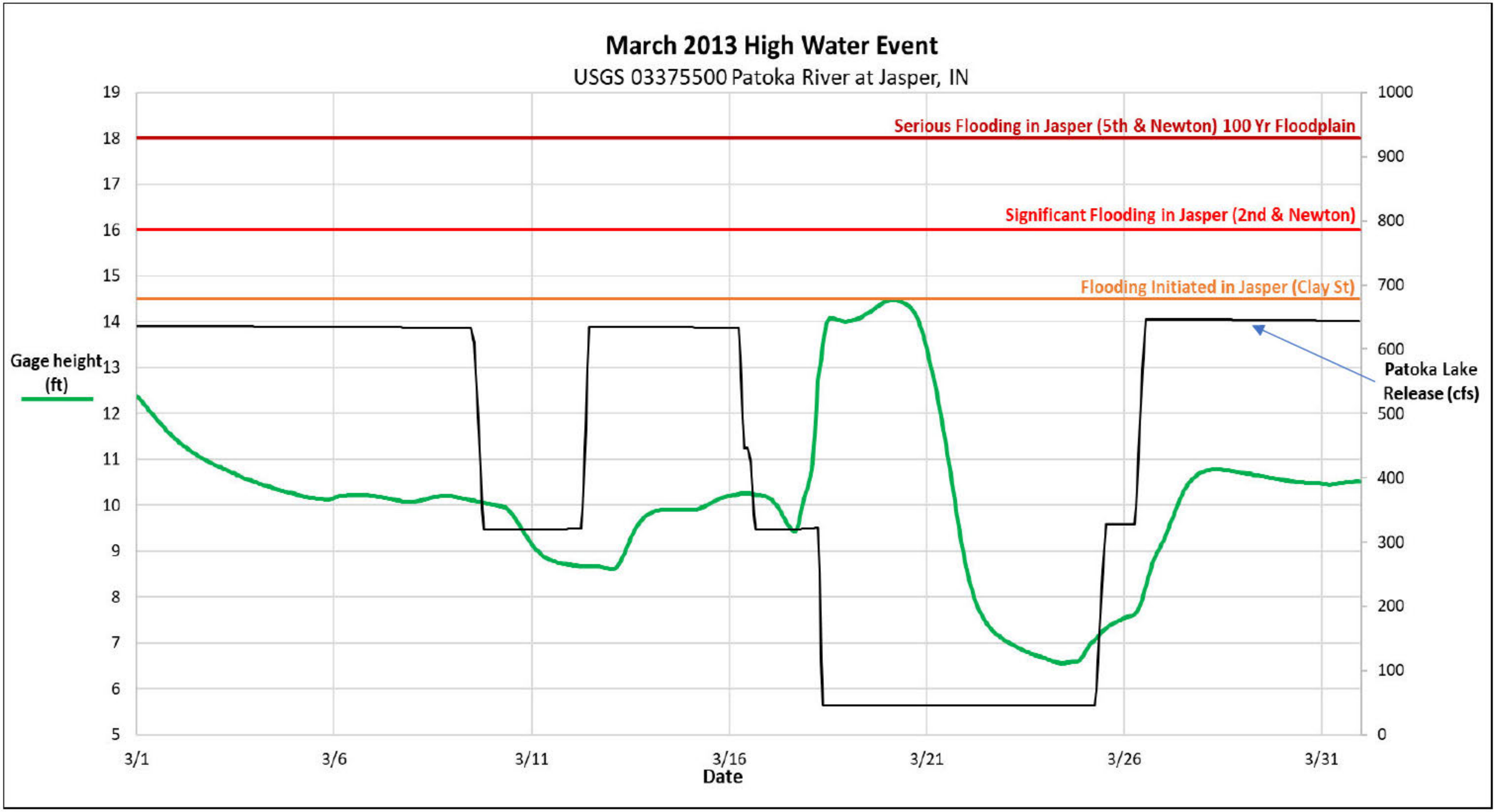


SUMMARY: multiple rain events. 0.1 inches on 12/31 with minimal rain on 1/1, minimal rain on 1/8 and 1/9, 1.2 inches on 1/10, 1.7 inches on 1/12, 1 inch on 1/13, 1.3 inches on 1/29, and 0.1 inches on 1/30.

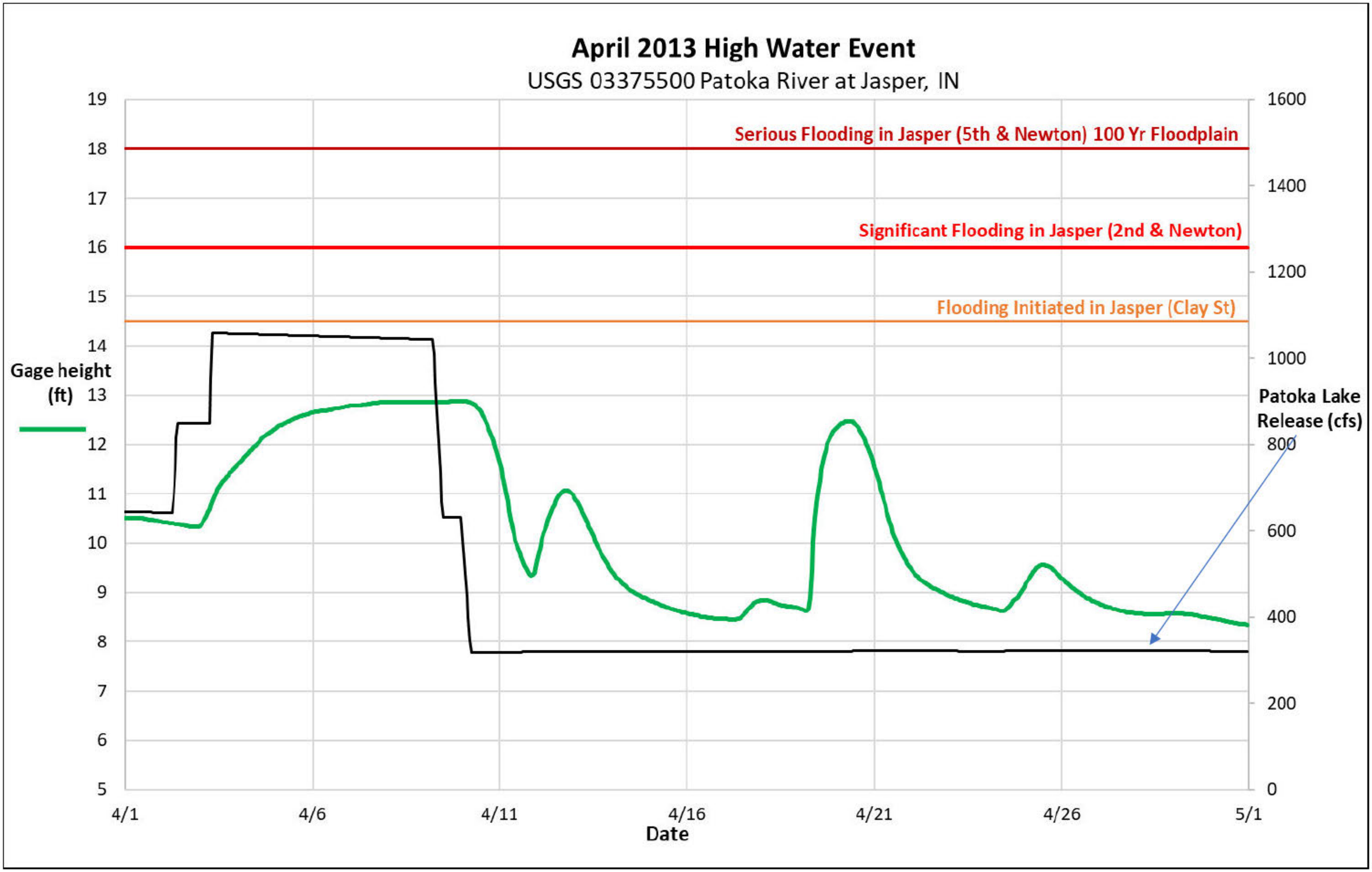


Jasper Date of Event Onset	PRR Outflow at Event Onset	Jasper Date/Time of Peak	Jasper Peak Stage	PRR Outflow at Time of Peak	Jasper Days above 12'	PRR Outflow 24 hrs Prior to Peak
9-Jan-13	20	1/14 @ 22:00	14.87	20	5	20
24-Jan-13	387	1/31 @ 20:00	13.62	118	3	118
25-Feb-13	636	2/27 @ 23:00	12.8	637	3	637
17-Mar-13	320	3/19 @ 20:00	14.46	46	3	46
2-Apr-13	850	4/9 @ 15:00	12.89	632	7	1045
19-Apr-13	320	4/20 @ 02:00	12.47	321	1	320
4-May-13	66	5/6 @ 06:00	12.84	66	2	66
17-Nov-13	98	11/17 @ 23:00	12.67	20	1	98
21-Dec-13	86	12/22 @ 23:00	15.98	21	4	20

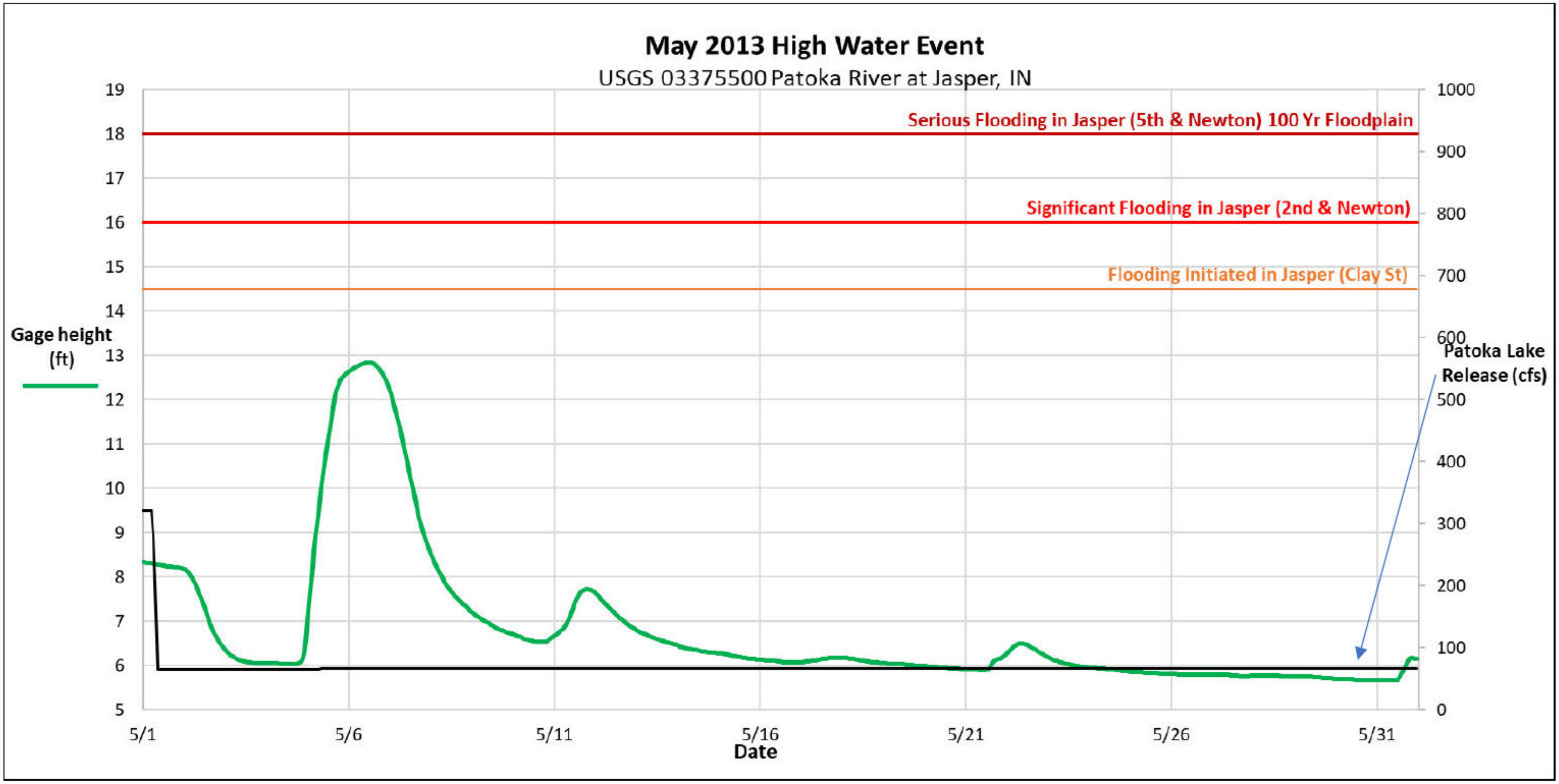
SUMMARY: Many rain events. Minimal rain on 2/1 and 2/3, 0.1 inches on 2/4, 0.45 inches on 2/7, minimal rain on 2/9, 0.25 inches on 2/10, 0.1 inches on 2/13, 0.35 inches on 2/18, 0.4 inches on 2/21, 0.3 inches on 2/25, 0.55 inches on 2/26, 0.1 inches on 2/27, minimal rain on 2/28.



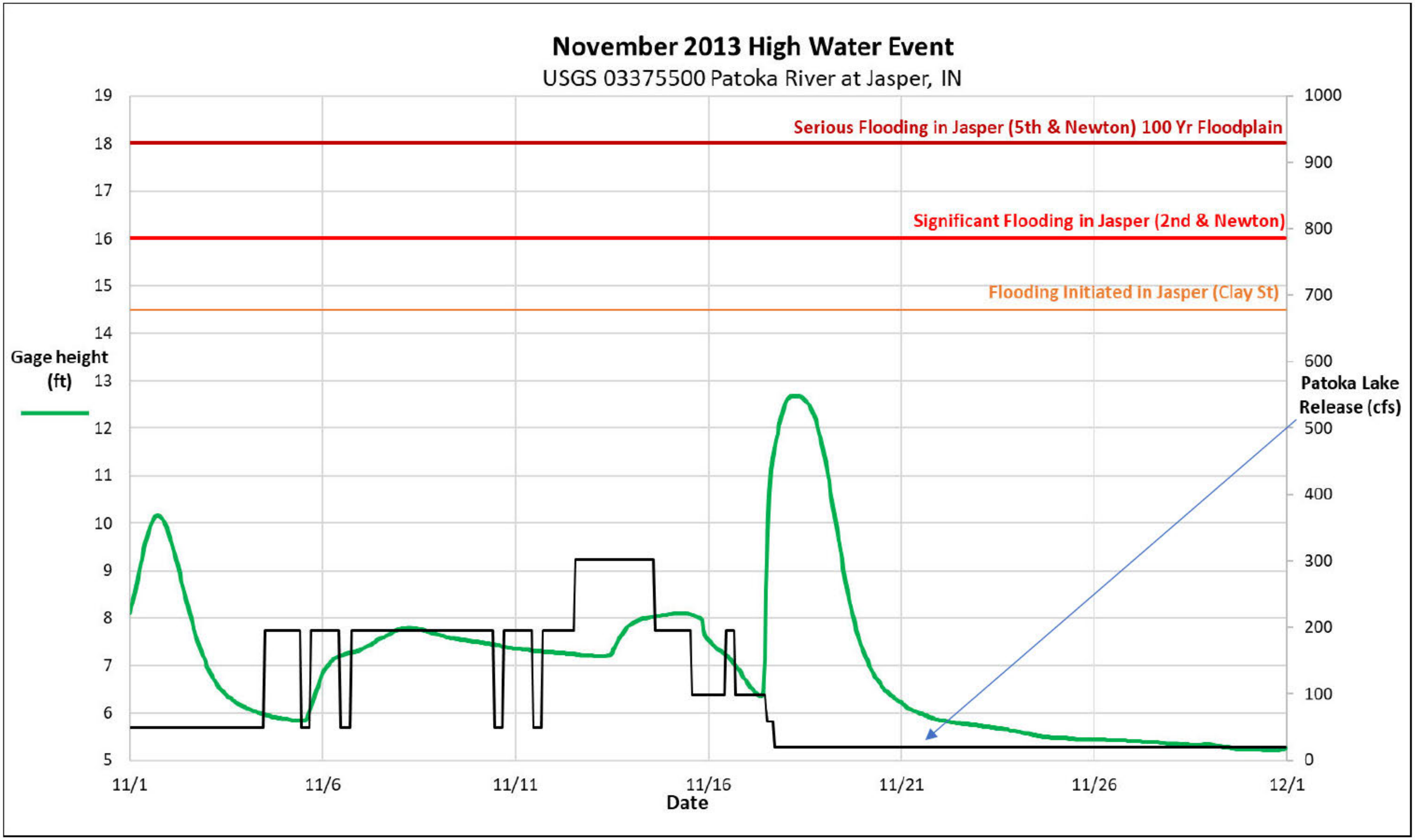
SUMMARY: Multiple rain events. Minimal rain on 3/2 and 3/4, 0.4 inches on 3/5, 0.3 inches on 3/6, 0.1 inches on 3/10 and 3/12, minimal rain on 3/14, 0.4 inches on 0.4, 2.0 inches on 3/17, 0.1 inches on 3/18, 0.2 inches on 3/23, 0.3 inches on 3/24, minimal on 3/25, 0.15 inches on 3/30, and minimal rain on 3/31.



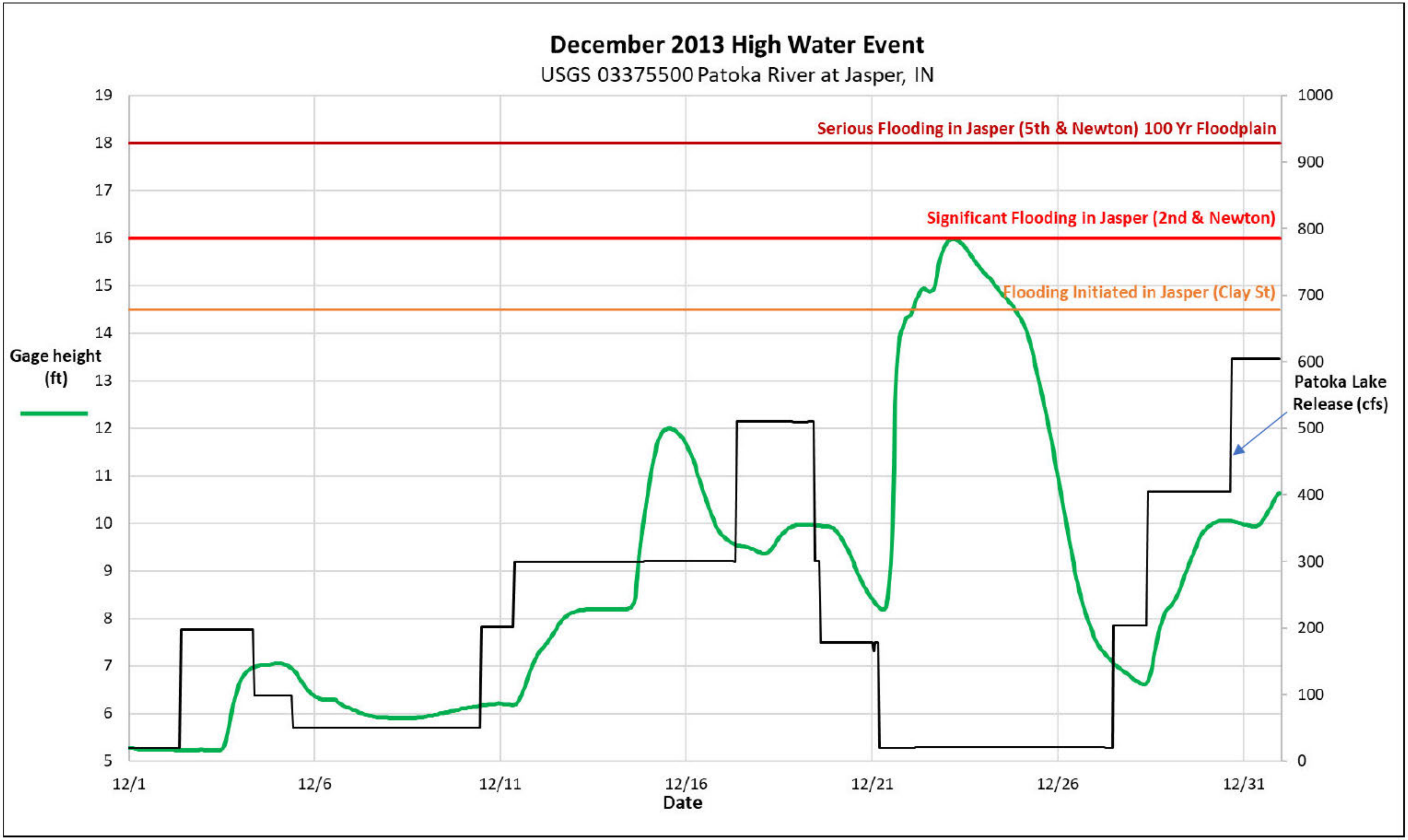
SUMMARY: Multiple rain events. 0.6 inches on 4/10, 0.7 inches on 4/11, 0.1 inches on 4/16, 0.25 inches on 4/17, 1.1 inches on 4/18, minimal rain on 4/19, 0.2 inches on 4/23, 0.5 inches on 4/24, 0.1 inches on 4/27, 0.15 inches on 4/28, and minimal rain on 4/30.



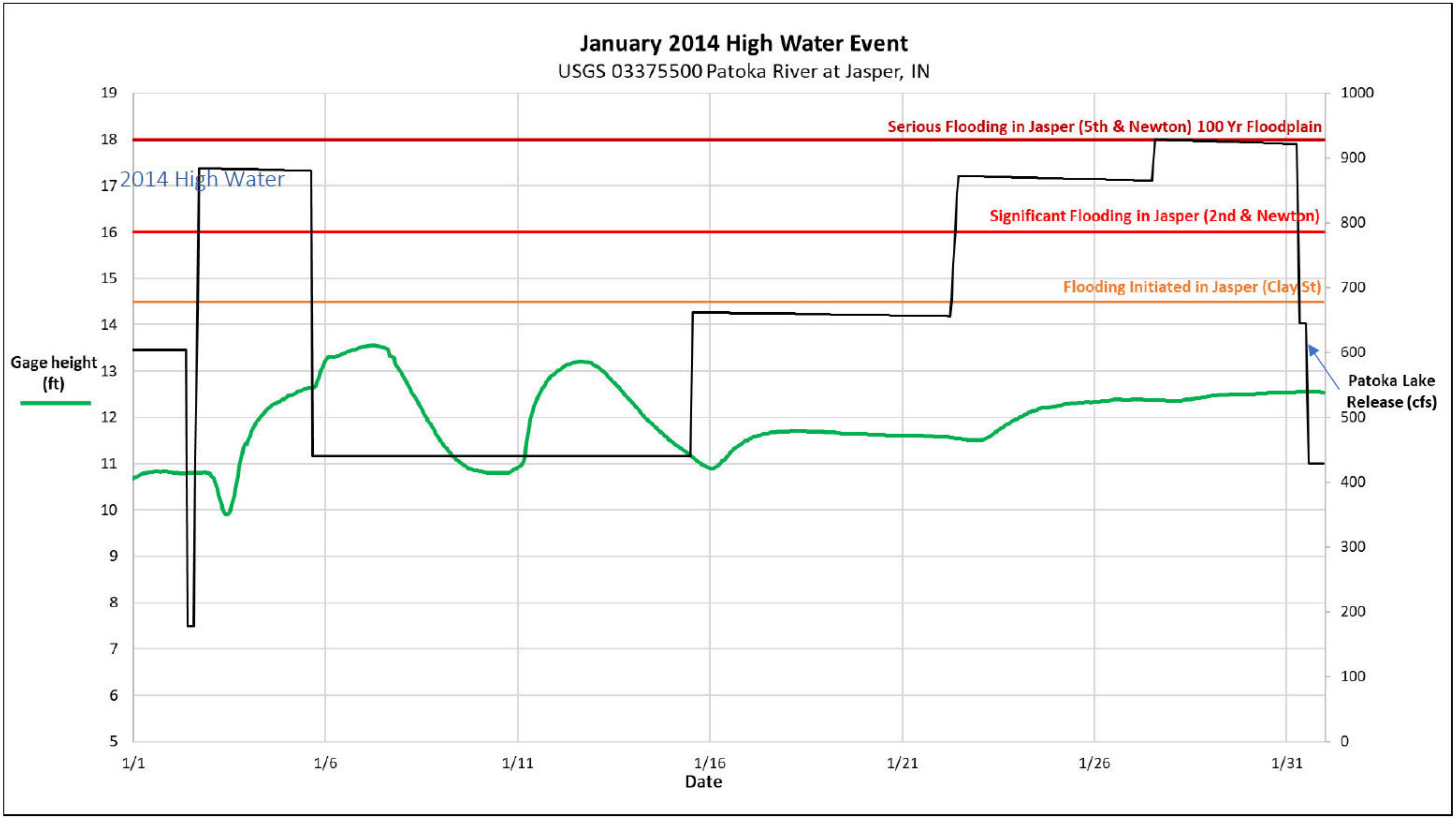
SUMMARY: Multiple rain events. 0.1 inches on 5/1, 1.5 inches on 5/4, 0.4 inches on 5/5, minimal rain on 5/6, 0.1 inches on 5/9, 0.65 inches on 5/10, 0.4 inches on 5/16, minimal rain on 5/17, 5/18, and 5/20, 0.45 inches on 5/21, minimal rain on 5/22 and 5/23, 0.2 inches on 5/27, and 0.7 inches on 5/31.



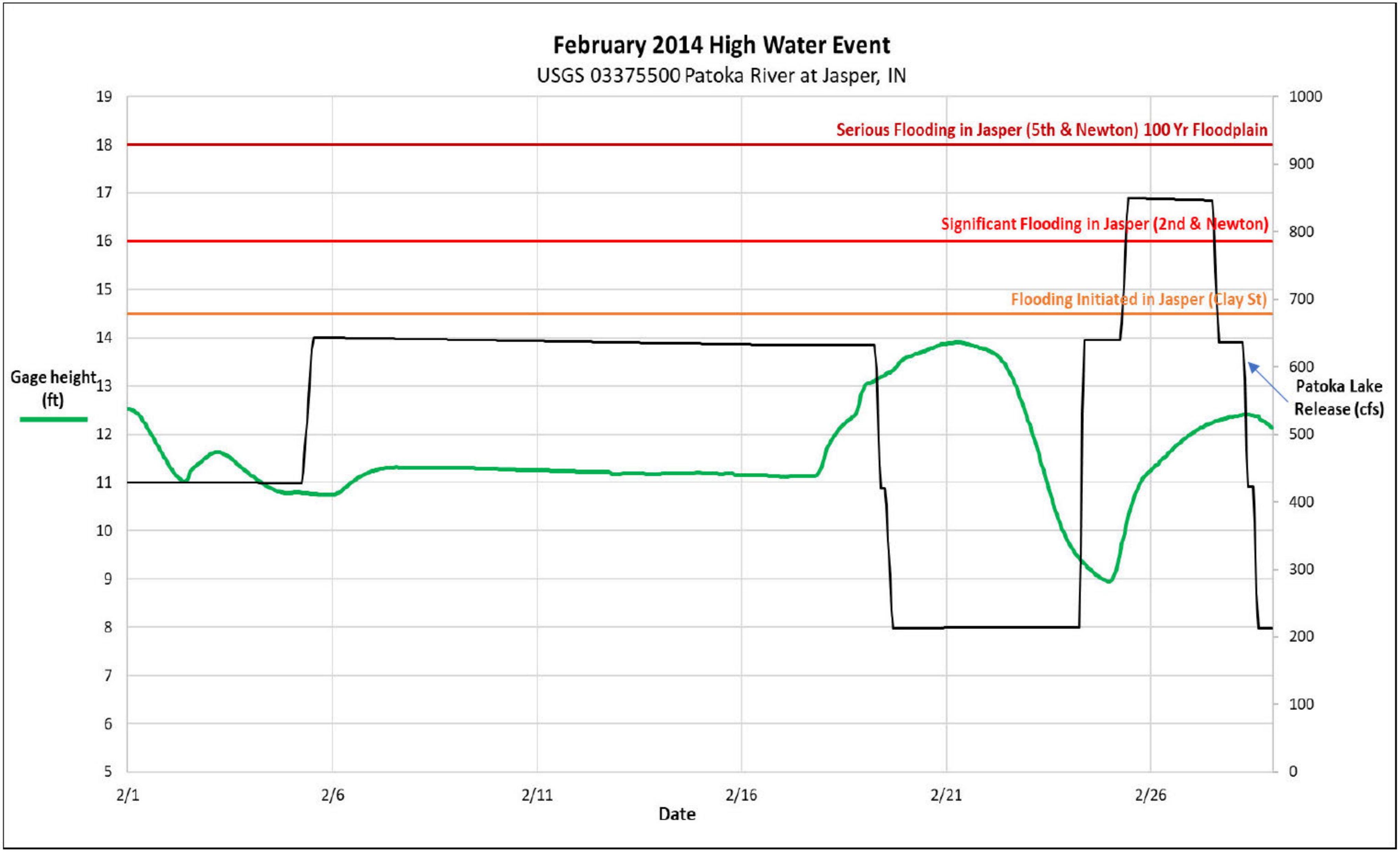
SUMMARY: 0.9 inches on 10/31, minimal rain 11/4, 0.6 inches on 11/6, 0.1 inches on 11/11, 1.7 inches on 11/16, 0.5 inches on 11/17, 0.1 inches on 11/21, minimal rain on 11/22, 11/25, and 11/26.



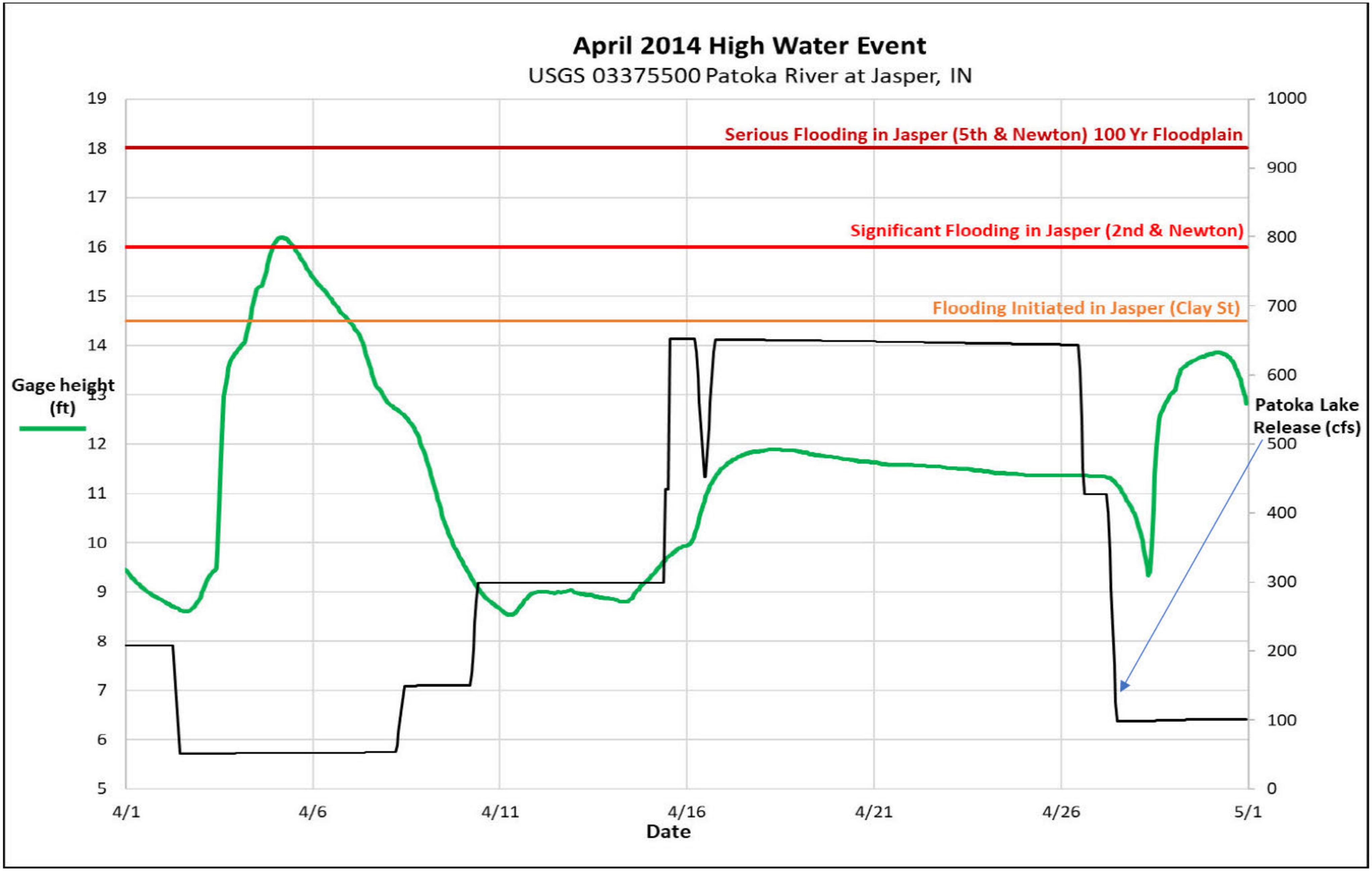
SUMMARY: 0.1 inches on 12/4, 0.5 inches on 12/5, 0.85 inches on 12/6, 0.1 inches on 12/9, 0.1 inches on 12/13, minimal rain on 12/14, 0.2 inches on 12/20, 1.6 inches on 12/21, 0.1 inches on 12/22, 0.25 inches on 12/28, 0.1 inches on 12/31.



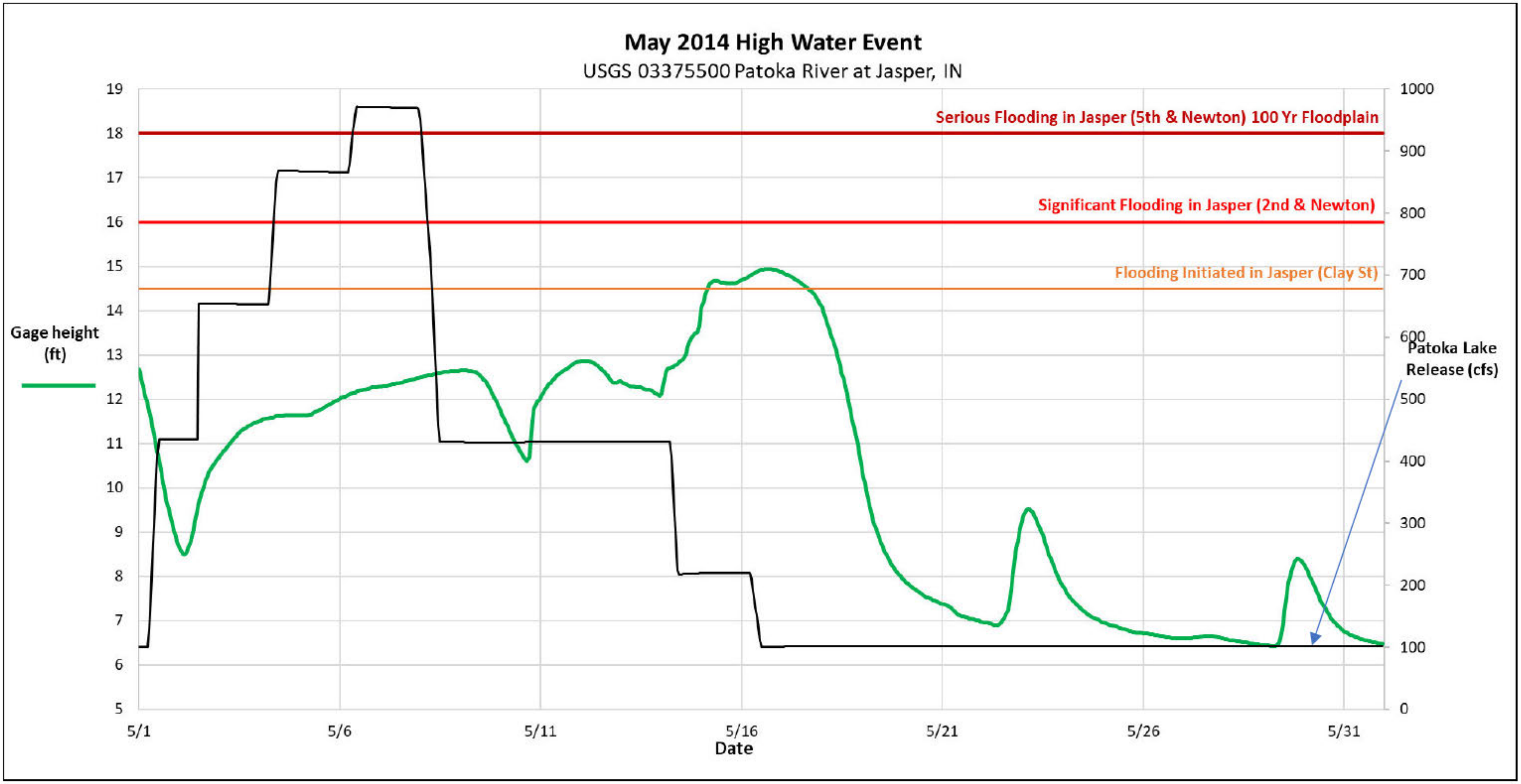
SUMMARY: 0.15 inches on 1/1, minimal rain on 1/2, 0.35 inches on 1/5, minimal rain on 1/9, 1/10, 1/13, 1/14, 1/16, 1/17, 1/18, 1/20, 1/22, 1/24, and 1/31.



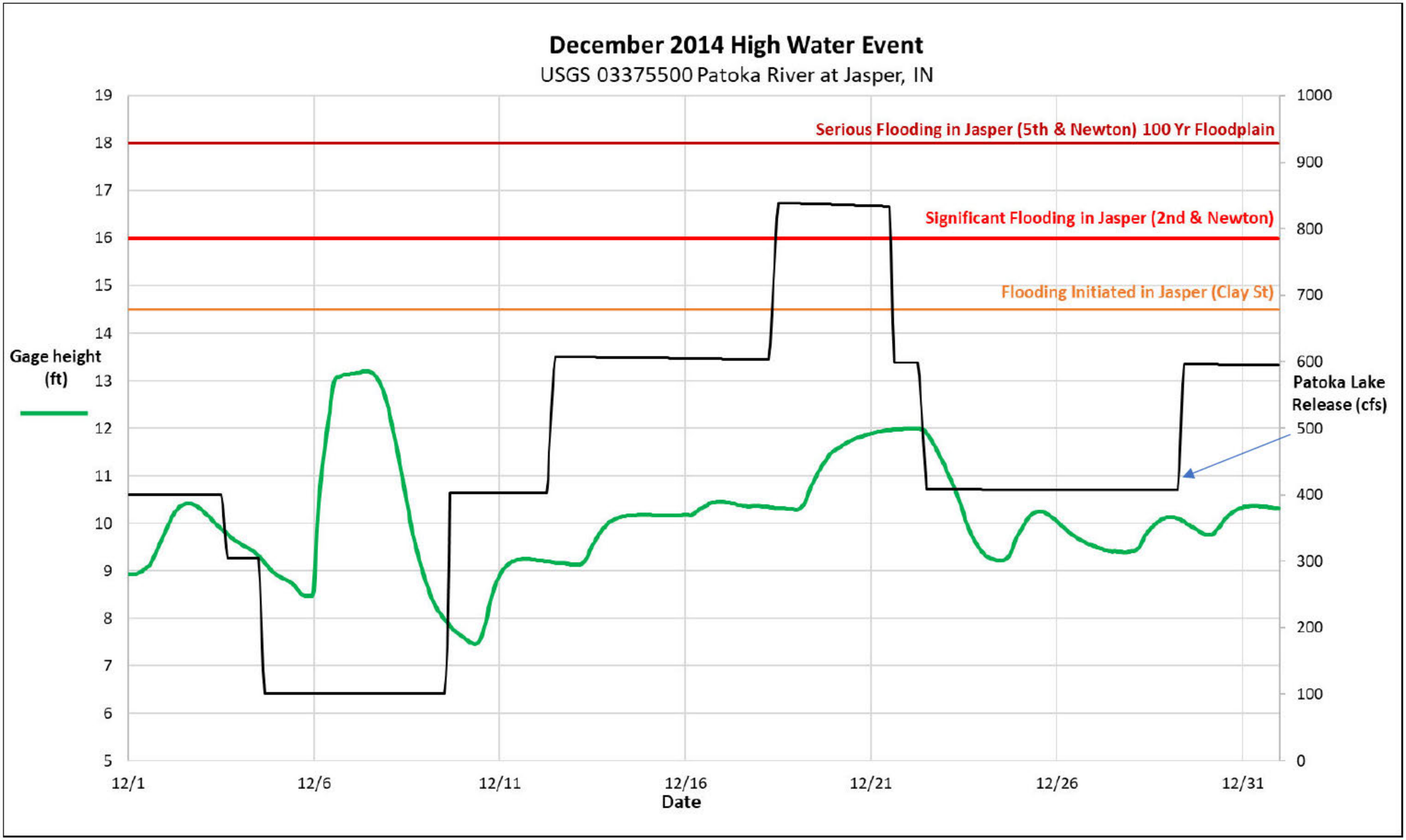
SUMMARY: 0.45 inches on 2/41, 0.9 inches on 2/4, minimal rain on 2/14 and 2/15, 0.65 inches on 2/17, minimal rain on 2/19, 0.45 inches on 2/20



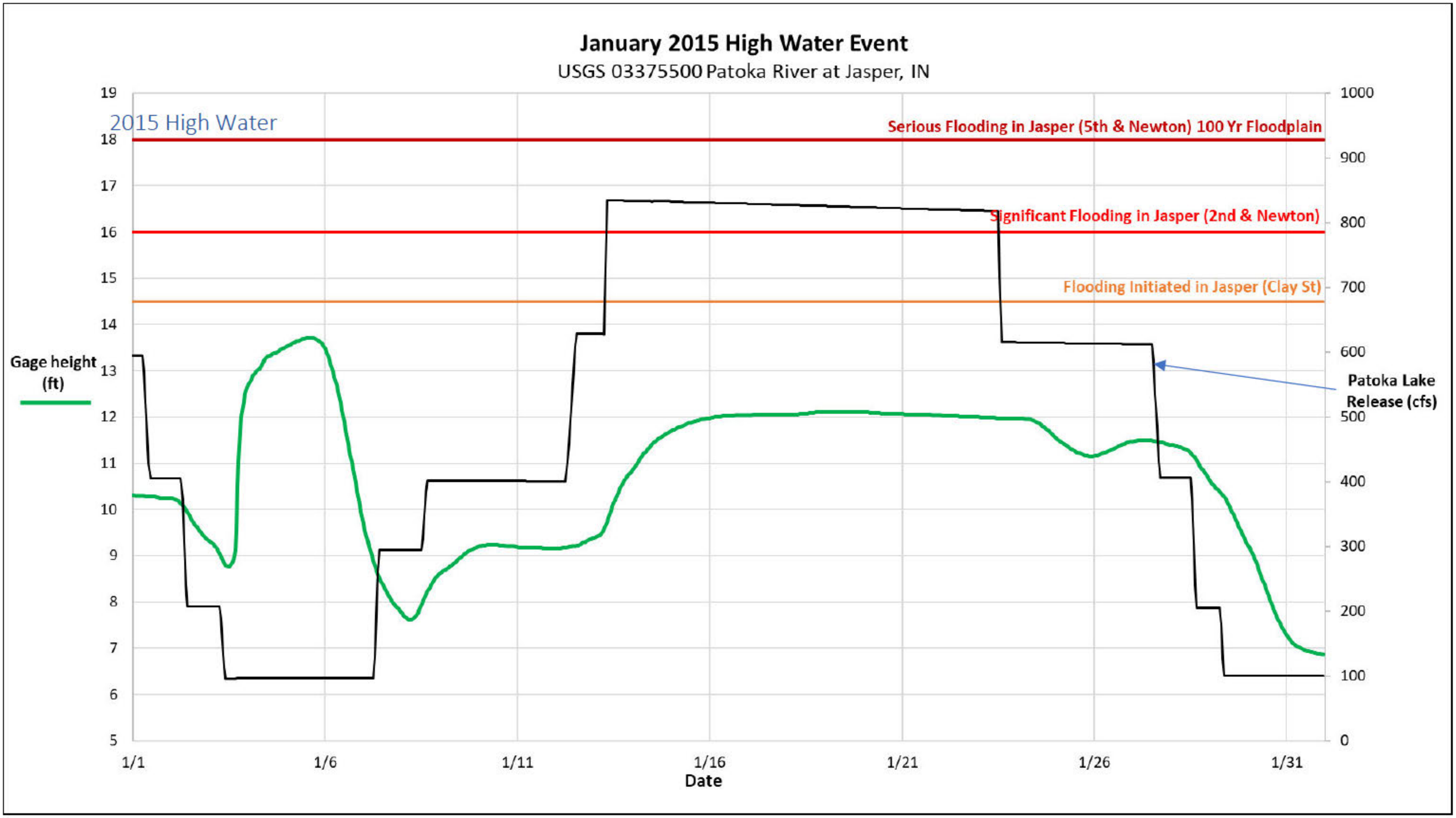
SUMMARY: Rain event 4/2 – 4/5; 1.3 inches on 4/2, 2.25 inches on 4/3, minor rain both 4/4 and 4/5. Flooding began 4/5: 4th St between McCrillus and Anderson, 2nd and Clay St, and 3rd and Newton all flooded. Flooding dissipated by 4/7.



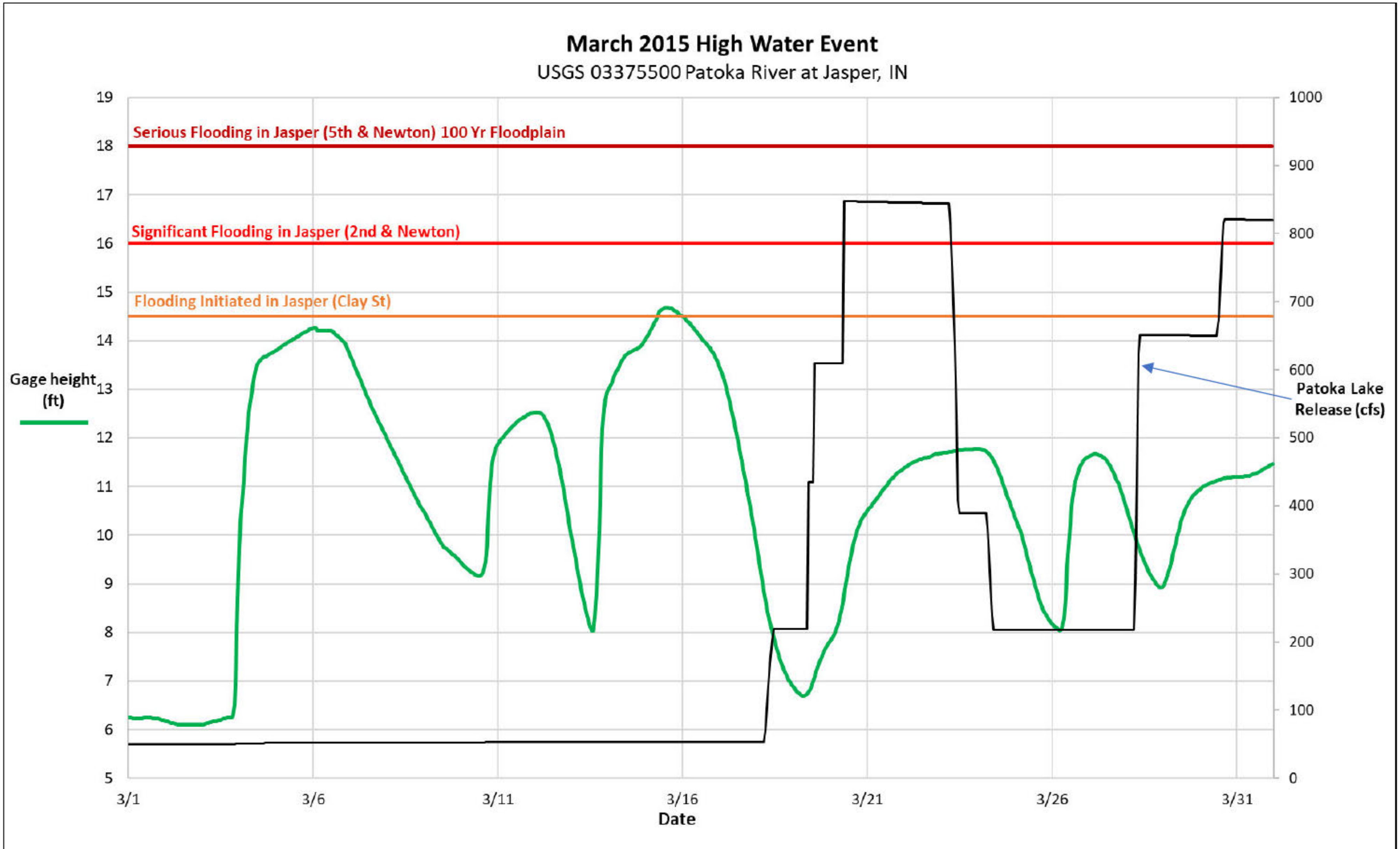
SUMMARY: 0.15 inches on 5/9, 2.25 inches on 5/10, 0.25 inches on 5/11, 0.45 inches on 5/12, 1.1 inches on 5/13, 1.55 inches on 5/14, 0.1 inches on 5/15, minimal rain on 5/16, 1.15 on 5/21, minimal rain on 5/26 and 5/27, 0.5 inches on 5/28, and 0.25 inches on 5/30.



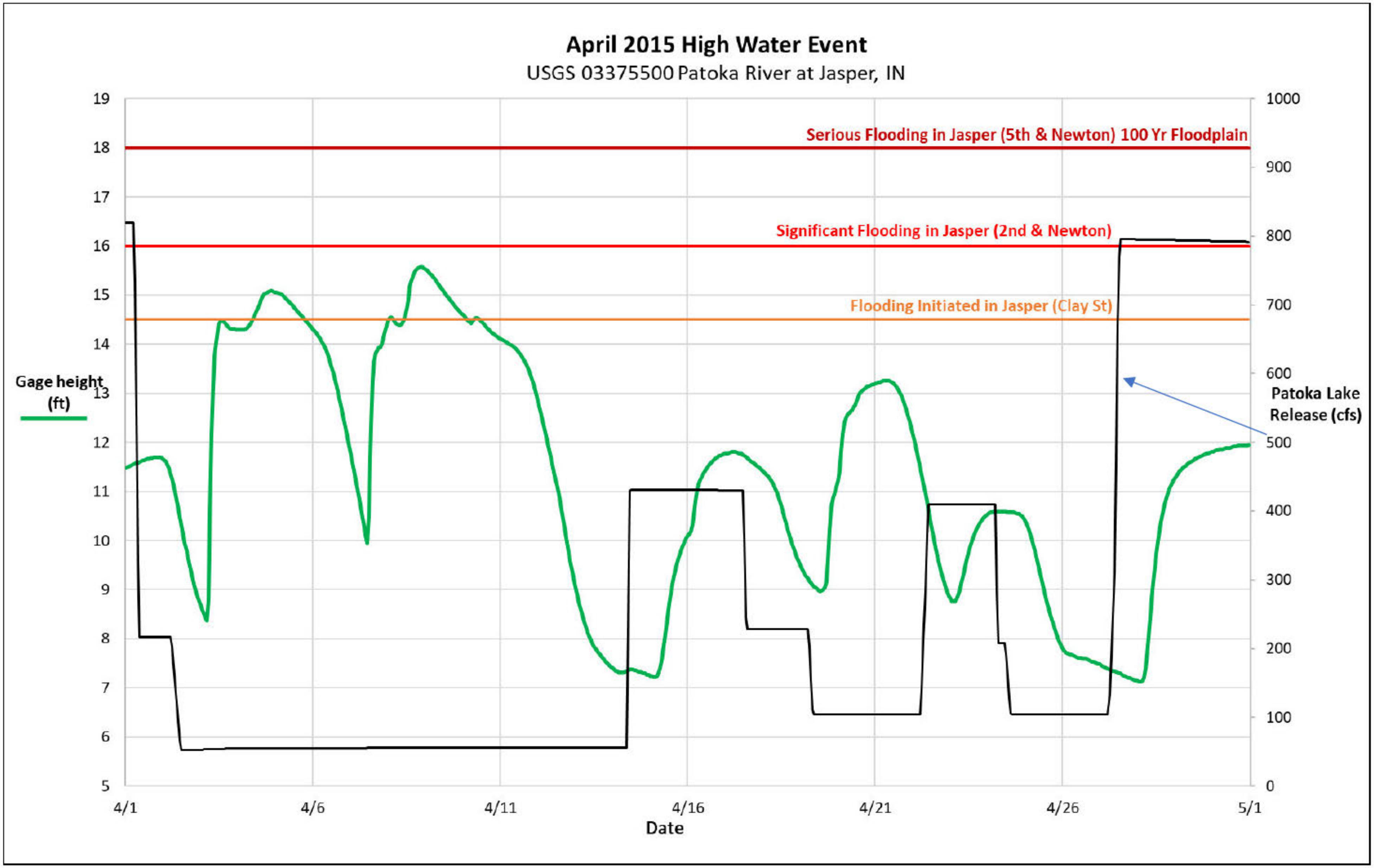
SUMMARY: 0.4 inches on 11/30, 0.3 inches on 12/1, minimal rain on 12/2 and 12/4, 1.2 inches on 12/5, minimal rain on 12/8, 12/9, and 12/14, 0.1 inches on 12/15, minimal rain on 12/16, 1.5 inches on 12/22, 0.3 inches on 12/23, 0.25 inches on 12/24, minimal rain on 12/26, 0.25 inches on 12/27.



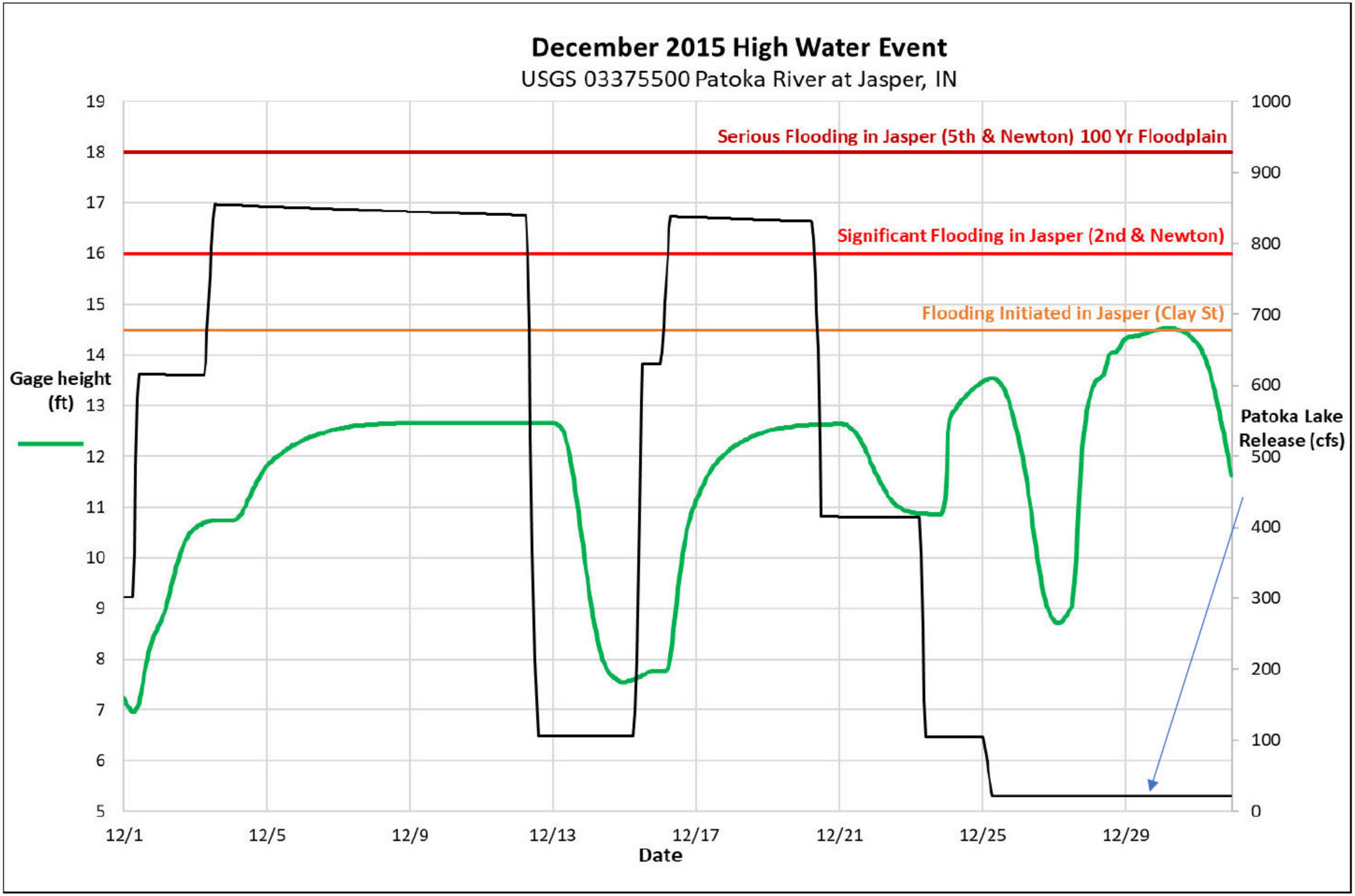
SUMMARY: 0.1 inches on 1/1, 0.6 inches on 1/2, 1.5 inches on 1/3, minimal rain on 1/4 and 1/6, 0.35 inches on 1/11, 0.1 inches on 1/12, 0.25 inches on 1/17, 0.55 inches on 1/25, minimal rain on 1/26 and 1/28.



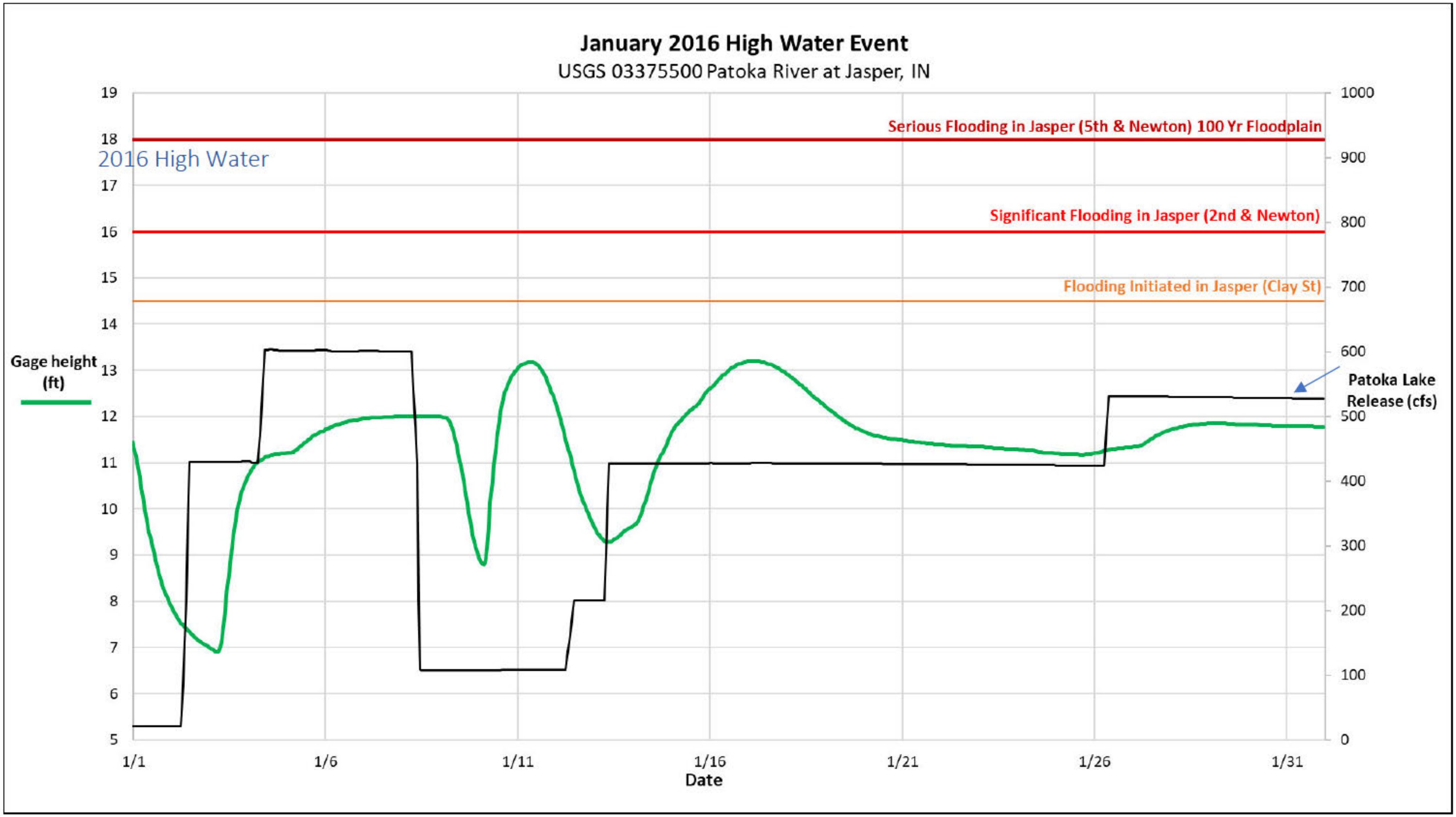
SUMMARY: Minimal rain on 3/1, 1.5 inches on 3/3, 0.25 inches on 3/4, minimal rain on 3/9, 0.75 inches on 3/10, minimal rain on 3/12, 2.3 inches on 3/13, 0.1 inches on 3/14, 0.25 inches on 3/19, 0.3 inches on 3/24, 0.55 inches on 3/25, 0.1 inches on 3/26, 0.1 inches on 1/29.



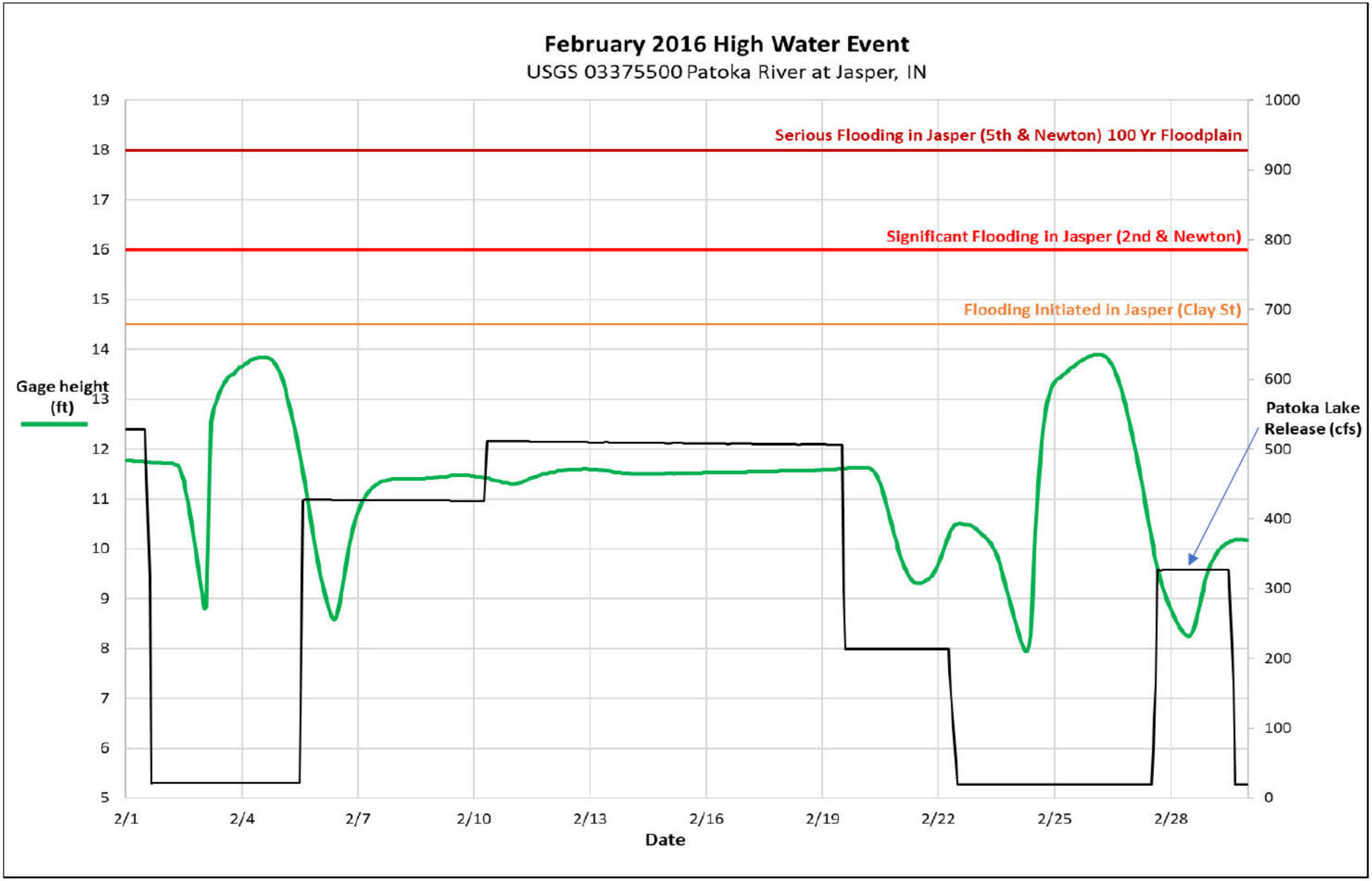
SUMMARY: Multi-day rain event. 2.5 inches on 4/2, 0.67 inches on 4/3, minor amount of rain on 4/6, 3 inches on 4/7, and 0.5 inches on 4/9. Clay St flooded from 4/4 through 4/6. Intersection at 2nd and Clay St flooded on 4/9 and 4/10.



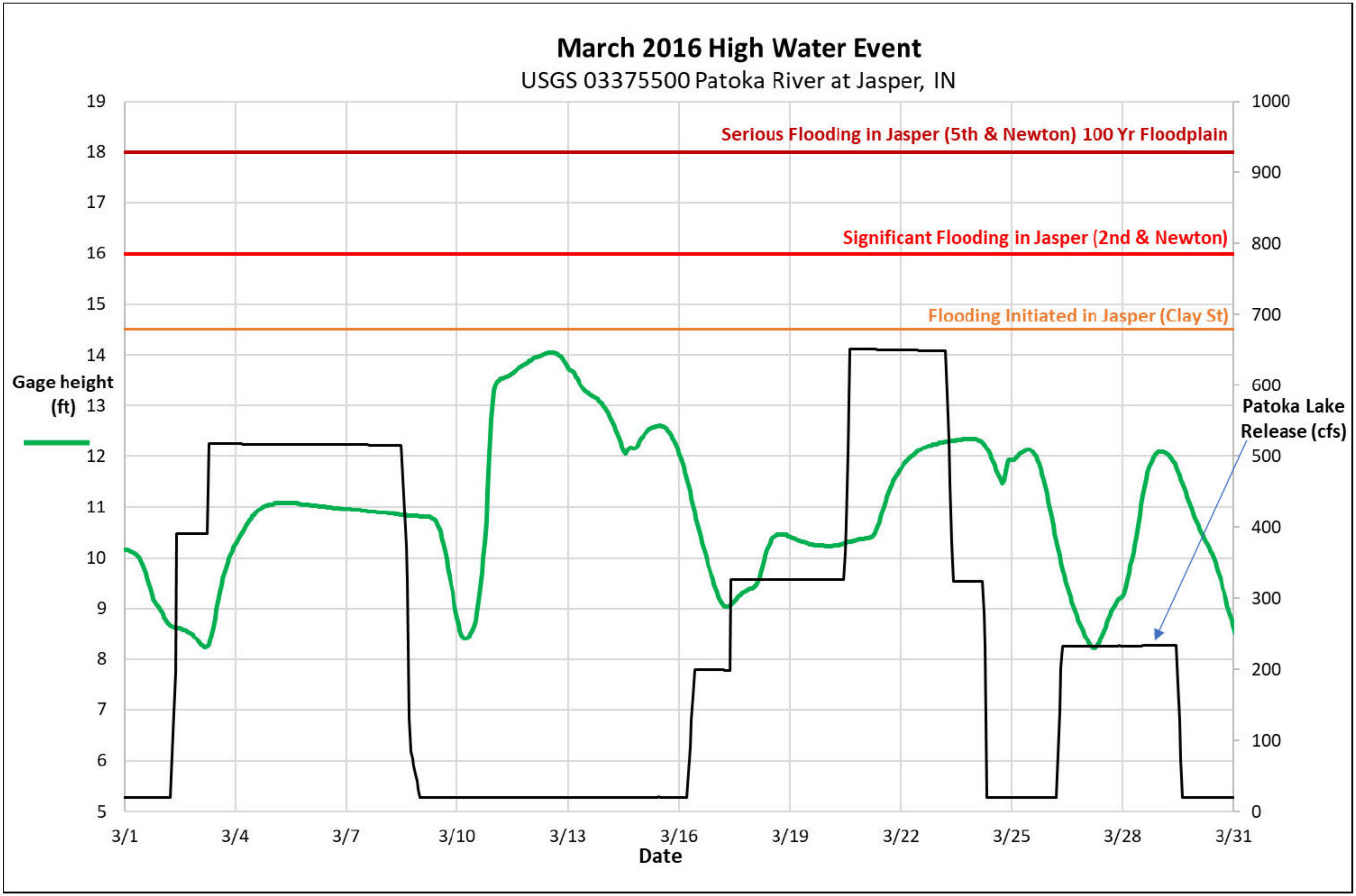
SUMMARY: Multi-day rain event. 0.3 inches on 12/26, 1.9 inches on 12/27, and 0.6 inches on 12/28. Resulted in no flooded roads and the water level observed below the grate at the 2nd and Clay St Inlet.



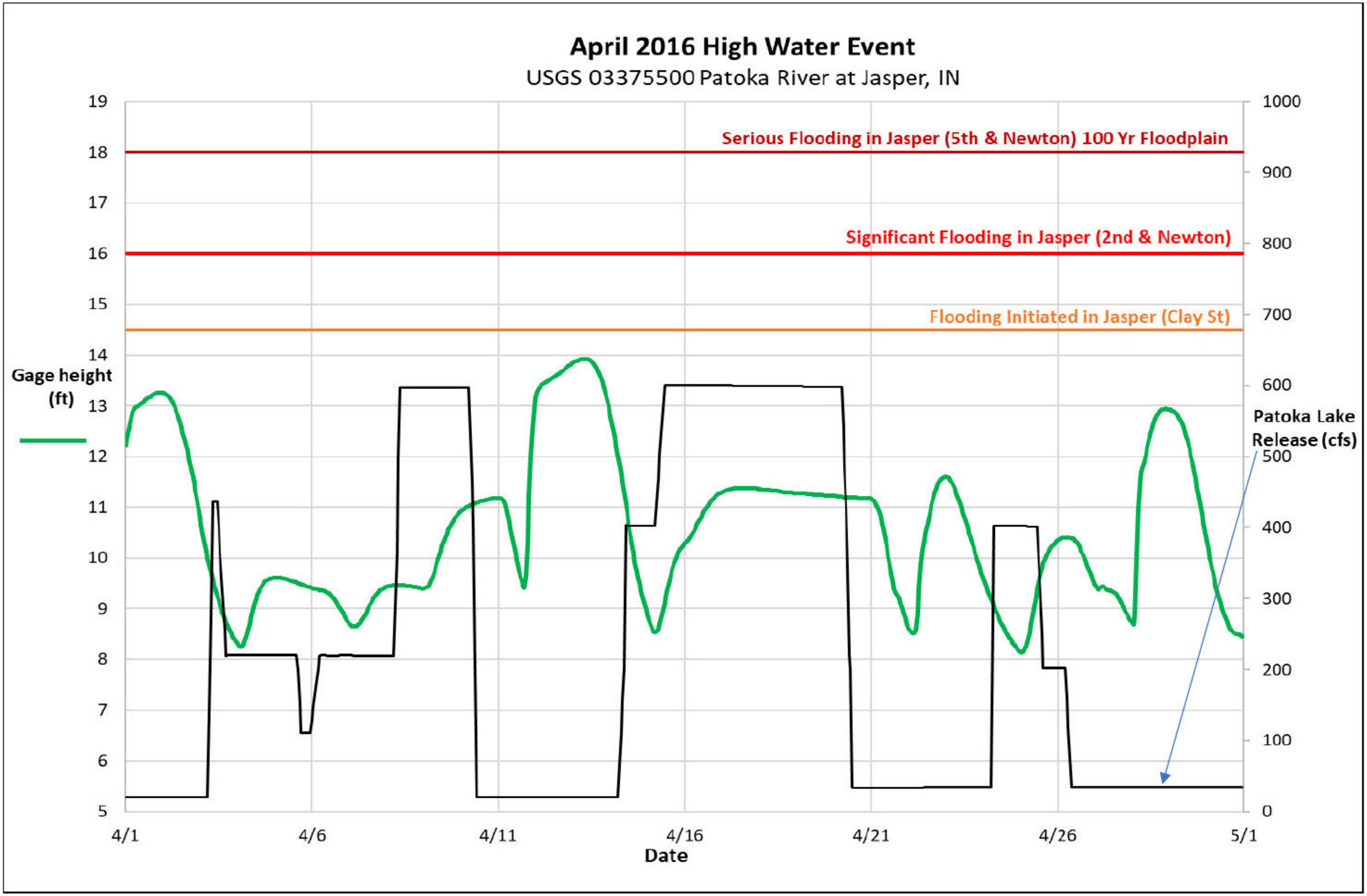
SUMMARY: minimal rain on 1/7, 1.1 inches on 1/9, 0.1 inches on 1/10, minimal rain on 1/12, 0.3 inches on 1/15, minimal rain on 1/21 and 1/22.



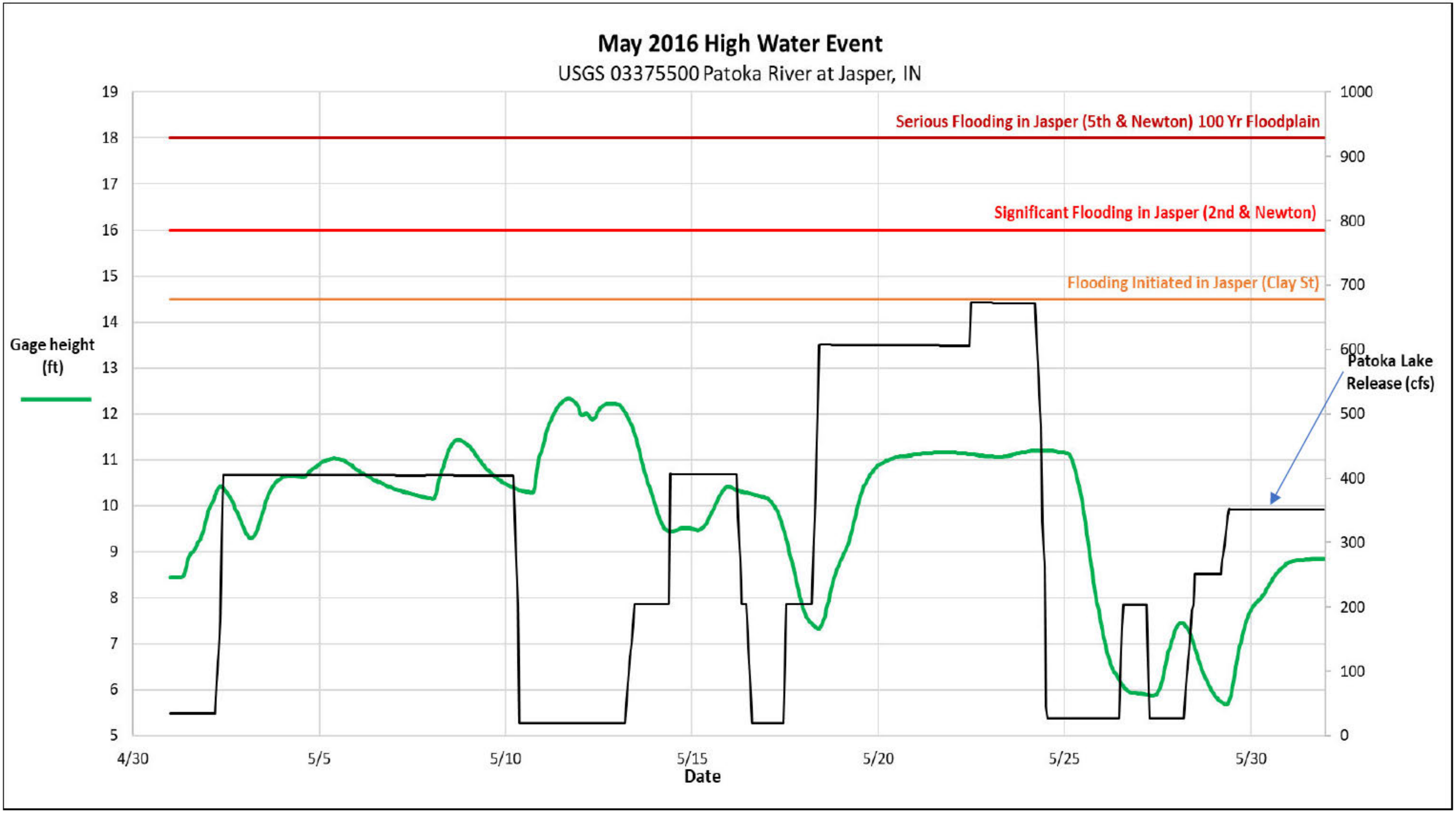
SUMMARY: 1.5 inches of rain on 2/2. Flooding observed 2/10 on low volume roads. Assumed a result from Patoka tributary flooding/runoff.



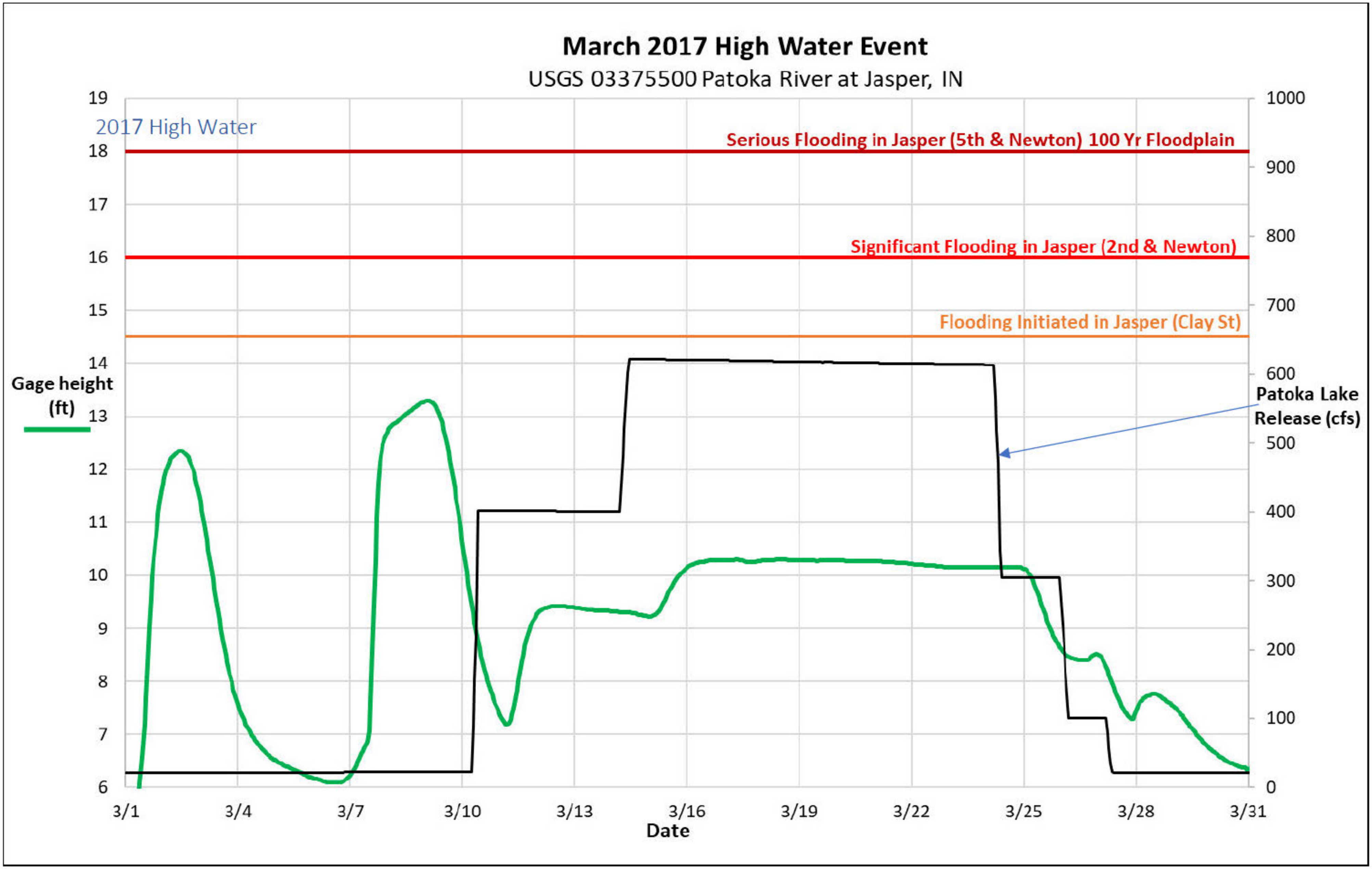
SUMMARY: Multi-day rain event. 0.9 inches on 3/9 and 3/10, 0.25 inches on 3/12 with minimal rain on 3/13.



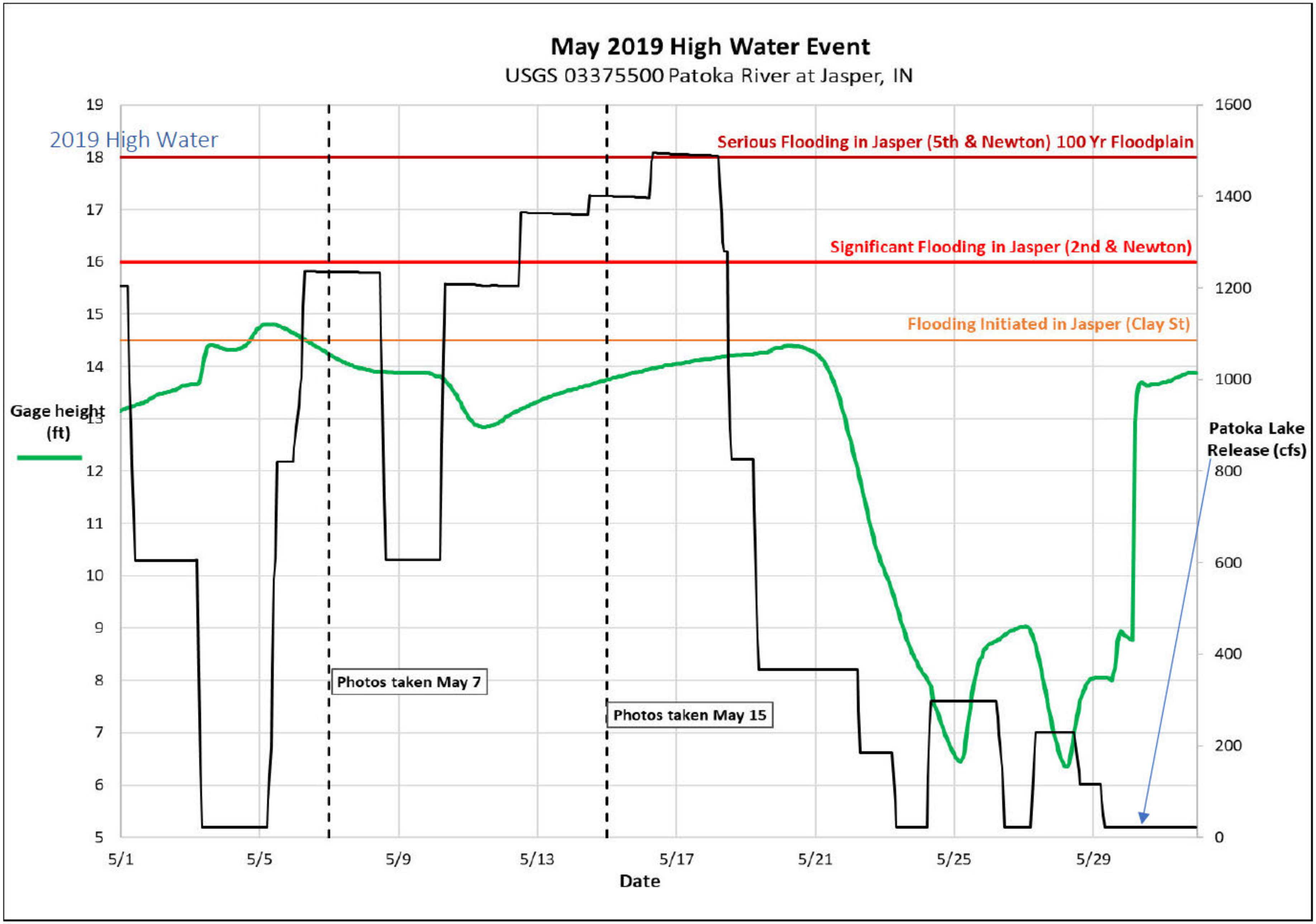
SUMMARY: 0.3 inches on 4/6, 0.1 inches on 4/8, 0.35 inches on 4/10, 0.9 inches on 4/11, 0.1 inches on 4/20, 1.0 inches on 4/21, 0.1 inches on 4/22, 0.55 inches on 4/26, 0.65 inches on 4/27, 0.8 inches on 4/30.



SUMMARY 0.15 inches on 5/1, 0.35 inches on 5/4, 0.55 inches on 5/7, minimal rain on 5/8 and 5/9, 0.85 inches on 5/10, 0.55 inches on 5/11, minimal rain on 5/12 and 5/13, 0.15 inches on 5/16, 0.35 inches on 5/17, 0.2 inches on 5/20, 0.1 inches on 5/21, minimal rain on 5/22, 0.2 inches on 5/26.



SUMMARY: 2 rain events. 0.8 inches on 2/28, 0.3 inches on 3/1, minimal rain on 3/5, 0.75 inches on 3/6, and 0.5 inches on 3/7. Expected county roads flooded. Delayed this year. Normally occurs in January.



SUMMARY: Multiple rain events. 1.2 inches on 5/1, 2 inches on 5/2, minimal rain on 5/3, 0.6 inches on 5/4, 0.25 inches on 5/9 and 5/11, 1.25 inches on 5/19. Many flooded roads in the county throughout date range. Minor flooding in Jasper 5/5 and 5/6.

A deviation was approved starting in March 2019 to target 14 feet at Jasper to evacuate additional flood control storage before planting season began on May 19, 2019. Between May 1-5, 2019, a total of 3.77 inches of rain fell at Patoka Dam, releases were reduced during this period. Once the river stage at Jasper started falling, releases were increased up to 1236 cfs by May 7, 2019, resulting in a stage at Jasper just under 14 feet. Between May 10-13, 2019, a total of 0.62 inches of rain fell at Patoka Dam. On May 15, 2019, Patoka was releasing 1400 cfs and the stage at Jasper was about 13.9 feet. The following photos were taken May 7 and May 15 by Corps employees along the Patoka River in the Jasper area, including locations upstream and downstream. These photos illustrate the impact of local runoff from the rain event May 1-5 with more areas inundated versus when the Jasper stage is close to 14 feet solely due to releases from Patoka Dam.

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

Photos Taken May 7

Photos Taken May 15

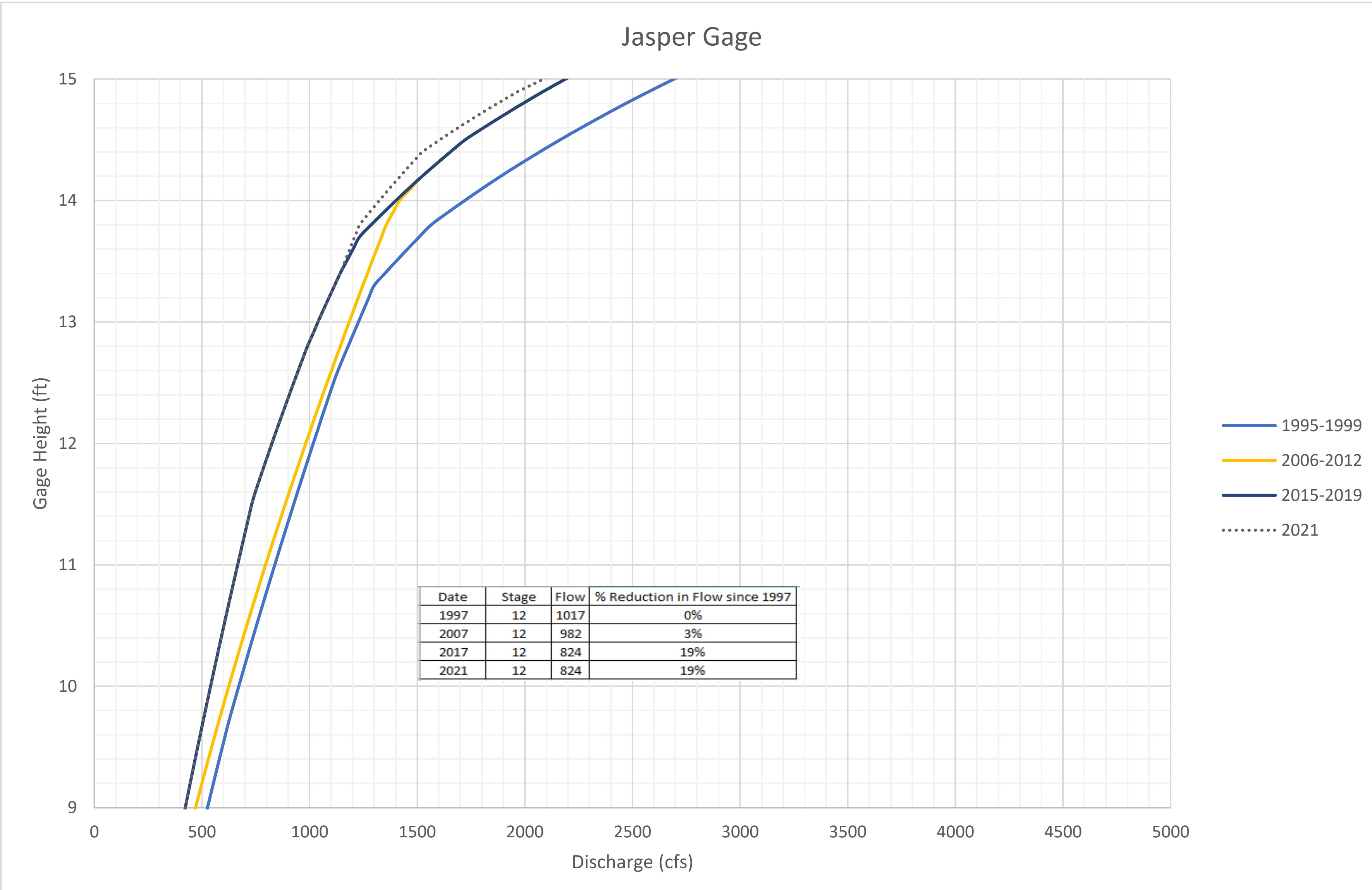
Photos Taken May 7

Photos Taken May 15

The following rating curve comparisons illustrate the amount of storage that has been lost in the channel of the Patoka River due to sedimentation, especially in the range most often observed. The Jasper gage at a stage of 12 feet has lost almost 20% of channel storage since 1997. Whereas Princeton and Winslow have been much more stable, particularly on the lower half of the curve.

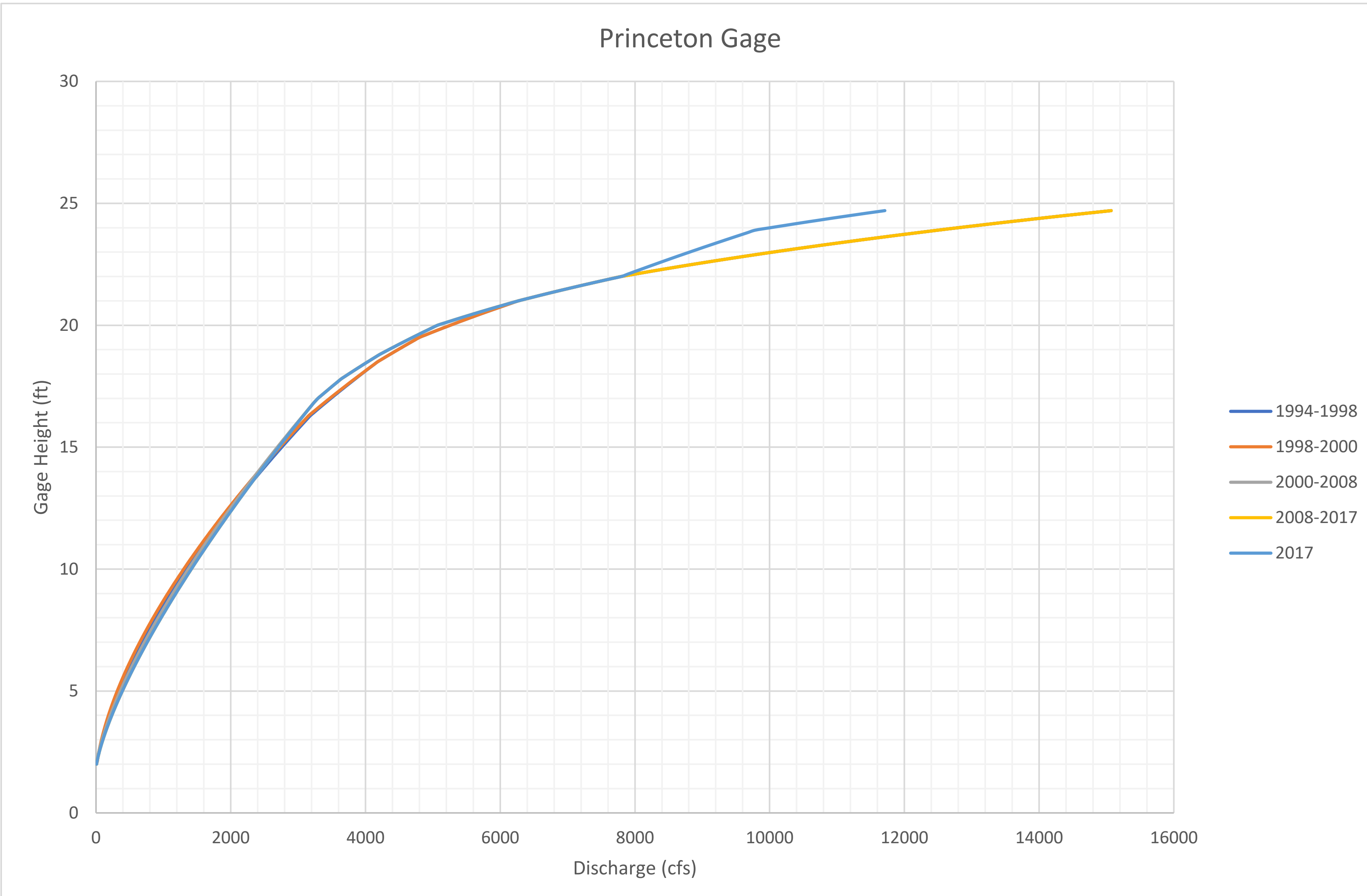
Rating Curves

Jasper Gage

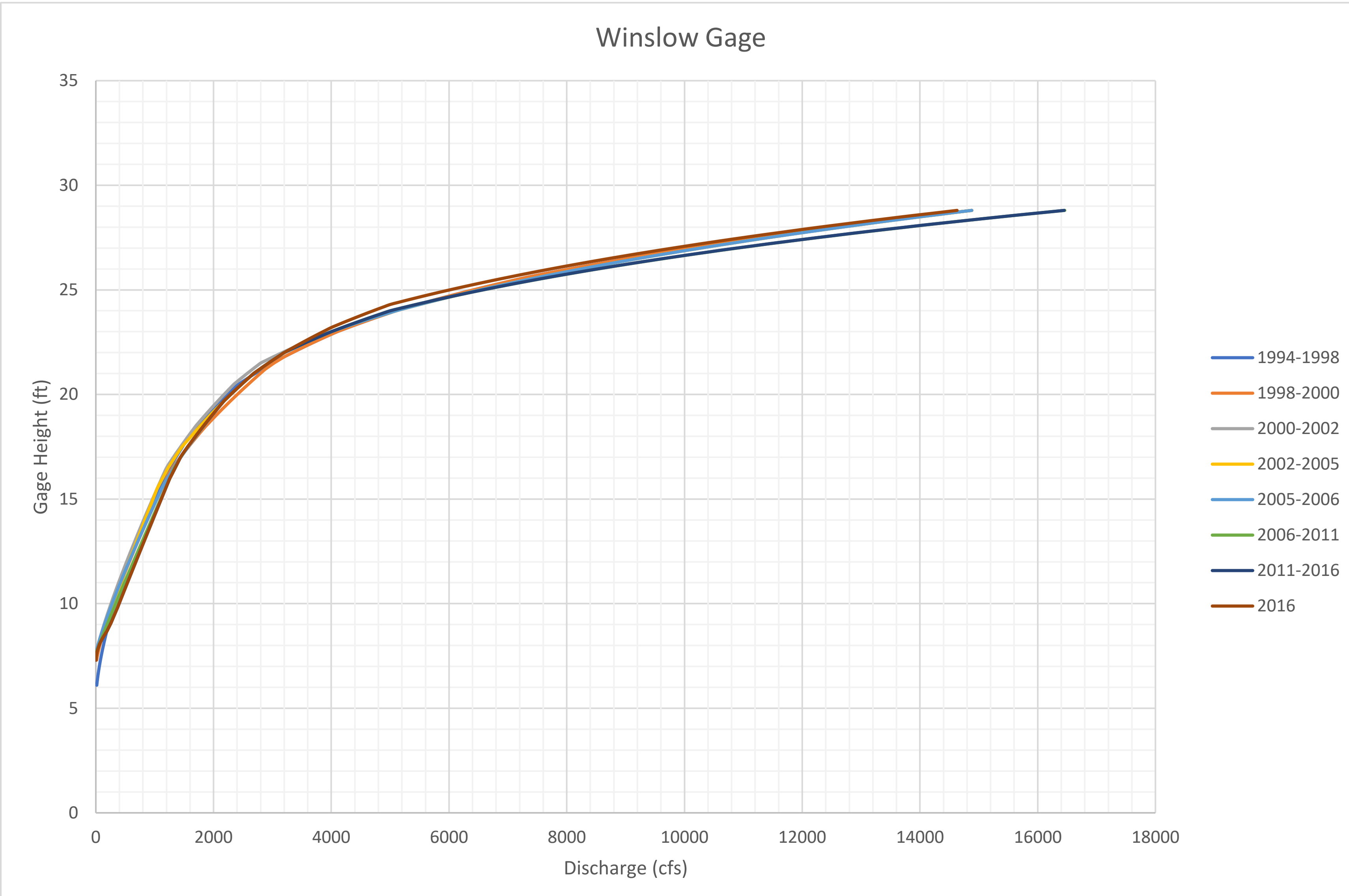


Date	Stage	Flow	% Reduction in Flow since 1997
1997	12	1017	0%
2007	12	982	3%
2017	12	824	19%
2021	12	824	19%

Princeton Gage



Winslow Gage



Below is a collection of emails, mostly from City of Jasper and Dubois County officials. Most of the information is related to historic river levels in the Jasper area and the corresponding street closures/impacts, if any. There are also photos with descriptions of impacts from the Fish & Wildlife Service, Patoka River Wildlife Refuge Manager. In summary, the City of Jasper and areas of Dubois County don't start seeing road impacts until the gage at Jasper goes above 14.5 feet, with the exception of local heavy rainfall events that can lead to some minor road closures unrelated to releases from Patoka Lake.

From: [redacted]

To: [redacted]

Cc: [redacted]

Subject: [Non-DoD Source] FW: Patoka Lake Spillway Event **Date:** Tuesday, June 18, 2019 11:36:29 AM **Attachments:** JASPER CITY STREETS.pdf

RESERVOIR INFORMATION.pdf

Importance: High

Please see attached data based on past events. Thanks,

[redacted]

-----Original Message-----
From: [redacted] Sent: Tuesday, June 18, 2019 11:25 AM
To: [redacted] Subject: FW: Patoka Lake Spillway Event
Importance: High Hello tammy:

In anticipation of future Patoka Reservoir/local flood events, the attached, detailed documentation was created based on the event of April 20, 2011.

Thanks, [redacted]

-----Original Message-----
From: [redacted] Sent: Tuesday, June 18, 2019 11:12 AM
To: [redacted] Subject: FW: Patoka Lake Spillway Event Importance: High

[redacted], Director
[redacted]

-----Original Message-----

From: [redacted] J CIV USARMY CELRL (USA) [redacted] Sent: Tuesday, June 18, 2019 10:56 AM
To: [redacted]
Cc: [redacted] A CIV USARMY CELRL (USA) [redacted]; [redacted] M CIV USARMY CELRL (US) [redacted]; [redacted] CIV USARMY CELRL (USA) [redacted]; [redacted] CIV USARMY CELRL (USA)
[redacted] Subject: Patoka Lake Spillway Event Importance: High

[redacted],

Could you send everyone attached on the email from your best knowledge or surveying, what happens if Patoka River at Jasper gauge reaches 16', 17', 18', 19'.

Also, What flood proofing measures have been taken since 2011 and what if any flood proofing you have done for this event?

We are not saying that we are anticipating record levels at this time but just trying to get a better feel for those levels.

[redacted]

[redacted]
[redacted]

DUBOIS COUNTY EMERGENCY MANAGEMENT AGENCY

PATOKA RESERVOIR

&

RIVER INFORMATION

Updated 3/7/12

PATOKA RESERVOIR & RIVER STATISTICS

|------------------------ Reservoir Specifications -------------------------- |

Winter Pool	Summer Pool	Spillway Crest	Top Dam	Record Date	Record Elevation
532.0	536.0	*548.0	566	3-May-2011	549.66

* Water actually flows through spillway at 548.5 feet. When elevation exceeds 549.5 feet an emergency drawdown may be initiated.

* Jasper river gauge not to exceed 9' after April 15 (normal limit is 12')

|--------------- Reservoir Outflow Time to Jasper ---------------------- |

18 Hours	Time to Jasper gauge three miles upstream
22 Hours	Time to Jasper

|-------------- *Reservoir Drawdown Estimated Rates ---------------------|

Outflow	Time	Reduction	Rate
1200 CFS	90.0 Hours	12.00 Inches	0.011 feet per hour
3700 CFS	37.5 Hours	12.00 Inches	0.027 feet per hour

* Assuming negligible inflow

|--------- *Patoka River @ Jasper Gauge Elevation Impact-----------|

Elevation	CFS	Impact
14.50	1400	River overflows banks / starts flooding Clay street
15.00	2200	River over Clay street / approaching 2'nd Street
16.00	3400	River @ 2'nd & Newton
17.00	5200	River between 3'rd & 4'th & Newton
18.00	7600	River @ 5'th & Newton (*459 foot elevation / 100 year flood plain)*
19.00	10,900	460 foot elevation (*Jasper Street Dept. loses access)*

|--------- *Reservoir Storage Capability (Near Flood Pool) ---------- |

One inch of rain causes approximately 0.825 foot rise in reservoir elevation

Updated 3/7/12

PATOKA RESERVOIR & RIVER FLOOD DATA

|---------------- Historical Information from 2008 Event --------------- |

Date	Lake Elevation	Outflow CFS	Rain	*Gauge 3 Miles North of Jasper	Jasper Status
	------------------(1200 HRS)---------------------				
03/16/08	537.97	244	0.00	9.81	
03/17/08	538.33	60	0.60	9.53	
03/18/08	542.61	48	4.60	12.53	
03/19/08	543.78	49	0.58	17.83 (8PM)	Serious Flooding By Evening. Peak
03/20/08	543.93	49	0.00	17.13	With Water at 4/th St. & Main
03/21/08	543.99	49	0.00	15.10	Flood Receding
03/22/08	544.04	207	0.03	13.55	River back in banks
03/23/08	544.05	376	0.15	9.92	
03/24/08	544.01	415	0.00	8.59	

|-------------- Historical Information from 2011 Event ----------------- |

Date	Lake Elevation	Outflow CFS (Gate)	Rain	*Gauge 3 Miles North of Jasper	Jasper Status
	---------------(6:00 AM)---------------				
04/19/11	539.52	20	0.07	6.96	
04/20/11	539.89	20	1.12	9.26	
04/21/11	540.13	20	0.02	11.91	
04/22/11	540.18	20	0	8.37	
04/23/11	540.5	20	1.36	10.84	
04/24/11	542.9 (+2.82)	20	2.57	14.63	River at Clay Street
04/25/11	544.2 (+1.3)	21	1.61	16.16	River @ 2'nd & Newton
04/25/11	544.3 (1 PM)	21	NA	16.33 (1 PM)	River @ 3'nd & Newton
04/26/11	545.0 (+1.2)	21	1.12	16.06 (down 0.27)	River @ 2'nd & Newton
04/27/11	545.7 (+0.7)	21	1.05	15.40 (down 1.02)	River below 2'nd Street
04/28/11	546.4 (+0.7)	21	0.56	14.95 (down 0.45)	River over Clay Street
04/29/11 (Barely)	546.6 (+0.2)	21	0.22	14.57 (down 0.29)	River over Clay Street
04/30/11	546.8 (+0.2)	22	0.04	13.04 (down 1.53)	River back in banks
05/01/11	546.7 (+0.1)	465	0.18	10.61 (down 2.43)	
05/02/11	548.1 (+0.4)	600	3.19	14.77 (up 4.16)	**Reservoir Exceeds Flood Pool**
05/03/11	549.4 (+1.3)	1800	1.58	16.61 (up 1.84)	River @ 3'nd & Newton
05/04/11	549.47 (+0.07)	3213	0.00	16.20 (down 0.41)	River @ 3'nd & Newton
05/05/11	549.00 (-0.47)	3213	0.00	15.88 (down 0.32)	River below 2'nd & Newton
05/06/11	548.40 (-0.60)	3730	0.00	16.08 (up 0.20)	River below 2'nd & Newton
05/07/11	547.80 (-0.60)	3723	0.00	16.04 (up 0.20)	River below 2'nd & Newton
05/08/11	547.20 (-0.60)	3702	0.05	15.98 (up 0.20)	River below 2'nd & Newton
05/09/11	546.60 (-0.60)	3681	0.00	15.92 (up 0.20)	River below 2'nd & Newton

(discontinuing daily update - river stabilized at Jasper – USACE maintaining 3700 CFS through May 10)

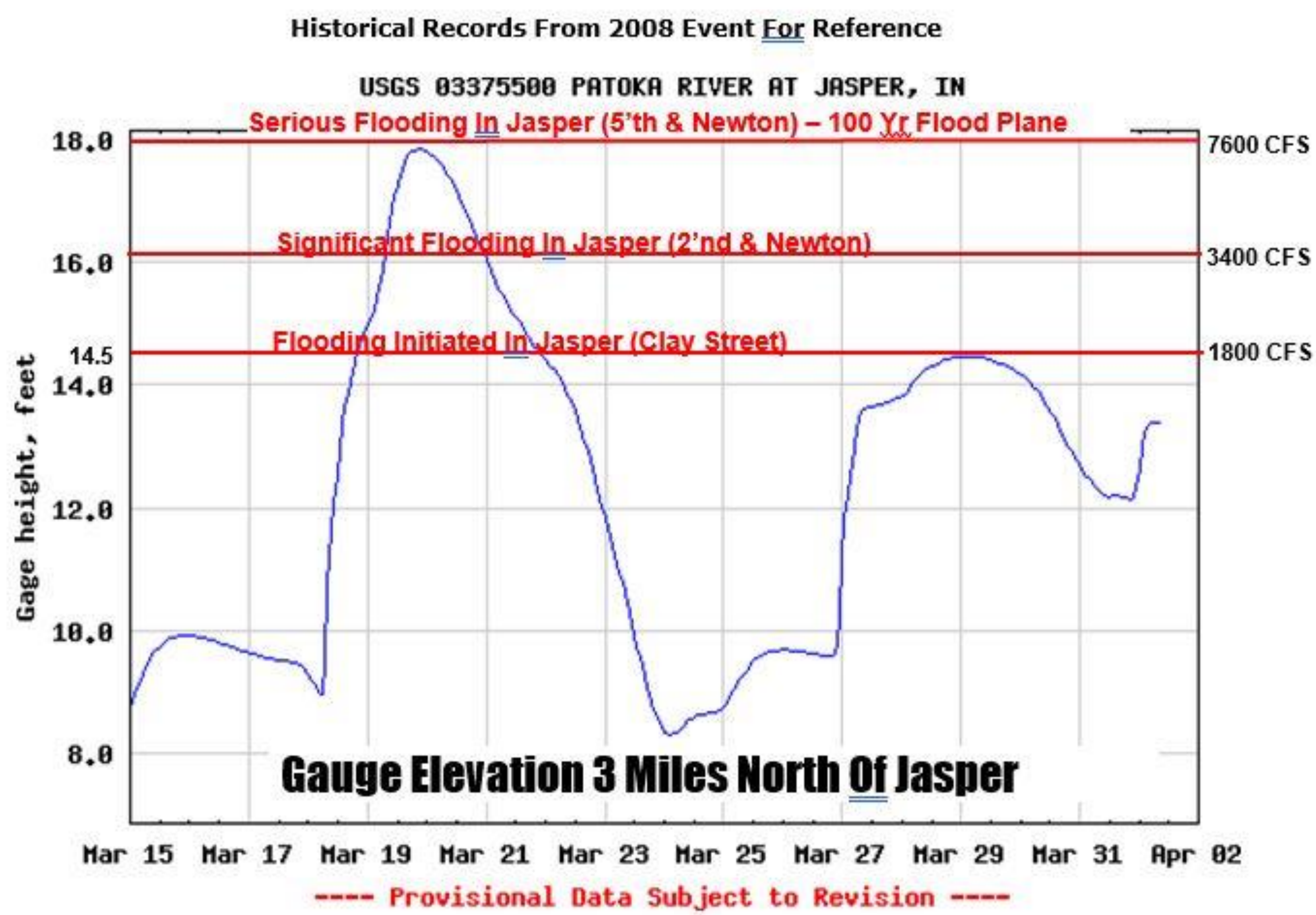
Updated 3/7/12

HISTORIC RESERVOIR/JASPER FLOOD RECORDS

(1964 to Present)

	Year	Date	Gauge 3 Miles North of Jasper --Flow (CFS)--	--Height--	Reservoir Elevation	Reservoir Outflow
	1964	March 11	14,100	**21.20'**	NA	NA - Pre-Reservoir
#1	2008	March 19	7,130	**17.83'**	543'	Maintained 49 CFS for several days (Mar 19-22) to mitigate impact on Jasper. After crest outflow increased to **appx 2000 CFS** and maintained for 20 days **until 542' elev achieved**.
		Reservoir crest at 547.47' on April 12, 2008				
#2	1996	April 30	6,370	**17.21'**	543'	Maintained 49 CFS for several days (Apr 30 – May 8). After crest outflow increased to **appx 2250 CFS** & maintained 20 days until 541' achieved.
		Reservoir crest at 547.43' on May 12, 1996				
#3	2011	May 3	4,430	**16.61'**	549'	Maintained 22 CFS for several days leading to spillway event on May 3. Combined emergency drawdown targeted **6000 CFS** / reached 548' May 7 & maintained **appx 3500 CFS** for 15 days until 541 achieved'. During this time level at river gauge at Jasper stayed at appx 16' with very limited flooding (river below 2'nd and newton)
		Reservoir crest at 549.47' on May 4, 2011 (Spillway Event)				

Updated 3/7/12



Updated 3/7/12

JASPER CITY STREETS CLOSED DUE TO FLOODING (April 25, 2011)

W 2’nd Street between 231 and Main St.

S. Clay Street between Wernsing Rd and 3’rd St.

E. 4th St. between Mill St. and Anderson St.

S. Main St. between Main St and S. Newton St.

S. Newton St. between 3rd St. and Brucke Strasse

JASPER CITY STREETS CLOSED DUE TO FLOODING (April 25, 2011)

Cathy Lane between Kellerville R. and 25th St.

2011 Spillway Event, Observed Impacts near Jasper:

From: Steve L. Berg <slberg@duboiscountyin.org>

Sent: Wednesday, June 19, 2019 9:54 AM
To: [redacted] USARMY CELRL (US)
Cc: [redacted]
Subject: [Non-DoD Source] Flooding information 2011
Attachments: doc06480320190619093637.pdf

Good morning [redacted],

I attached information and notes from the 2011 spillway event that you asked for during yesterday's conference call. If you have any questions on anything, I would be more than happy to explain the information. I felt at the time during that event, much of the information could be useful in the future. There are a lot of numbers to sift thru but there was a "method to the madness".

Thanks,

[redacted]

ROAD FLOODING vs RIVER /LAKE LEVELS

EVENT DATE APRIL 21, 2011 and MAY 2, 2011.

* information collected from the Louisville District Daily Lake Report on May 27th, 2011.

*** RECORD LAKE ELEVATION

Week of 4/22/11 - 4/27/11	4/22/2011	4/23/2011	4/24/2011	4/25/2011	4/26/2011	4/27/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV.	N/A	540.52	542.9	544.2	545.0	545.7
RAINFALL THIS 24 HOUR PERIOD	0"	1.36"	2.57"	1.61"	1.12"	1.05"
DISCHARGE - CUBIC FEET / SECOND	21 CFS	21 CFS	21 CFS	21 CFS	21 CFS	22 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	7.75	12.47	14.8	16.16	16.08	15.48
FLOW - 1000 CUBIC FT / SECOND	KCFS	KCFS	2.01 KCFS	3.67 KCFS	3.55 KCFS	2.73 KCFS
ROADS FLOODED AS REPORTED @ 8:00am.	23	42	39	46	37	36

Week of 4/28/11 - 5/3/11	4/28/2011	4/29/2011	4/30/2011	5/1/2011	5/2/2011	5/3/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV. 548.00"	546.4	546.63	546.8	546.8	***548.6'	***549.46'
RAINFALL THIS 24 HOUR PERIOD	0.56"	0.22"	0.04"	0.19"	3.19"	1.58"
DISCHARGE - CUBIC FEET / SECOND	22 CFS	22 CFS	22 CFS	466 CFS	284 CFS	1800 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	14.88	14.57	12.3	10.84	14.77	14.77
FLOW - 1000 CUBIC FT / SECOND	2.08 KCFS	1.81 KCFS	0.97 KCFS	0.72 KCFS	KCFS	KCFS
ROADS FLOODED AS REPORTED @ 8:00am.	32	25	20	14	46	46

Week of 5/4/11 - 5/9/11	5/4/2011	5/5/2011	5/6/2011	5/7/2011	5/8/2011	5/9/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV. 548.00"	***549.5'	548.97'	548.39'	547.74'	547.21'	546.6'
RAINFALL THIS 24 HOUR PERIOD	1.58"	0.00"	0.00"	0.00"	0.05"	0.00"
DISCHARGE - CUBIC FEET / SECOND	3213 CFS	4520 CFS	3730 CFS	3723 CFS	3702 CFS	3700 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	16.2"	15.87'	16.08	16.04'	15.98'	15.93'
FLOW - 1000 CUBIC FT / SECOND	3.73 KCFS	3.24 KCFS	3.55 KCFS	3.49 KCFS	3.40 KCFS	3.33 KCFS
ROADS FLOODED AS REPORTED @ 8:00am.	43	38	34	34	34	25

Week of 5/10/11 - 5/15/11	5/10/2011	5/11/2011	5/12/2011	5/13/2011	5/14/2011	5/15/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV. 548.00"	545.97'	545.3'	544.9'	544.27'	543.6'	542.9'
RAINFALL THIS 24 HOUR PERIOD	0.0	0.00"	0.00"	0.00"	0.02"	0.98"
DISCHARGE - CUBIC FEET / SECOND	3658 CFS	3125 CFS	3623 CFS	3723 CFS	3577 CFS	3553 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	15.89'	15.83'	15.25'	15.56'	15.73'	15.76'
FLOW - 1000 CUBIC FT / SECOND	3.27 KCFS	3.18 KCFS	2.46 KCFS	2.83 KCFS	3.05' KCFS	3.09 KCFS
ROADS FLOODED AS REPORTED @ 8:00am.	25	25	25	21	21	21

Week of 5/16/11 - 5/21/11	5/16/2011	5/17/2011	5/18/2011	5/19/2011	5/20/2011	5/21/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV. 548.00"	542.31'	541.69'	541.1'	540.95'	540.8'	540.8'
RAINFALL THIS 24 HOUR PERIOD	0.27"	0.00"	0.00"	0.00"	0.02"	0.00"
DISCHARGE - CUBIC FEET / SECOND	3531 CFS	3550 CFS	2139 CFS	443 CFS	442 CFS	222 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	15.78'	15.73'	15.69'	15.41'	14.74'	11.95'
FLOW - 1000 CUBIC FT / SECOND	3.11KCFS	3.05 KCFS	2.99KCFS	2.64KCFS	1.96 KCFS	
ROADS FLOODED AS REPORTED @ 8:00am.	21	19	15	12	11	7

Week of 5/22/11 - 5/27/11	5/22/2011	5/23/2011	5/24/2011	5/25/2011	5/26/2011	5/27/2011
PATOKA LAKE EMERGENCY FLOOD STAGE ELEV. 548.00"	540.7'	540.7'	540.9'	540.94'	541.0'	541.06'
RAINFALL THIS 24 HOUR PERIOD	0.00"	1.17"	0.00"	0.00"	0.68"	0.05"
DISCHARGE - CUBIC FEET / SECOND	222 CFS	222 CFS	223 CFS	223 CFS	223 CFS	223 CFS
COON SEITZ BRIDGE ELEV - 3 MILES NORTH JASPER	10.49'	8.7'	8.9'	8.7'	9.26'	9.38'
FLOW - 1000 CUBIC FT / SECOND				0.41 KCFS	0.49 KCFS	0.50 KCFS
ROADS FLOODED AS REPORTED @ 8:00am.	7	5	3	3	1	1

CHRONOLOGICAL EVENTS PRIOR TO AND THROUGHOUT THE HISTORIC PATOKA LAKE EMERGENCY OVERFLOW ON MAY 3, 2011.

NOTES: 3:00pm ON SUNDAY MAY 1st, 2011. WITH THE CURRENT DRYING CONDITIONS PRIOR TO THE DRIZZLE RAINFALL SEEN DURING SUNDAY, THE RIVER ELEVATION 3 MILES EAST OF JASPER HAS DROPPED FROM IT'S PREVIOUS HIGH RECORDED ON 4/25/11 AT 16.16 TO 10.36'. FLOODED ROAD LEVELS ALSO DECREASED FROM 52 TO 14 BY SUNDAY NIGHT.

NOTES: MIDNIGHT ON 5/2/2011 RIVER ELEVATION INCREASED 2.23 FEET IN THE LAST NINE HOURS. RIVER ELEVATION READING @ 6:00am WAS 14.69' SHOWING AN ADDITIONAL INCREASE OF 2.1 FEET IN THE LAST 6 HOURS. THIS WAS A RESULT OF THE 3 1/2" RAIN WE GOT IN THE PAST 12 HOUR PERIOD.

NOTES: AT 7:15am ON 5/2/2011 STAN ACKIN FROM THE ARMY CORP REPORTED THAT THE CURRENT LAKE ELEVATION STOOD @ 548.43'. HE STATED THAT EVEN THOUGH THE ELEVATION IS OVER THE 548.0' CURTAIN WALL, THE GRASS WAY HAS A 6" RISE BEFORE IT FALLS OFF AS A DISCHARGE.

S/W TIME: 0:00Hrs

NOTES: AT 5:25pm ON 5/2/2011 STAN ACKIN FROM THE ARMY CORP REPORTED THAT WATER WAS NOW BEGINNING TO RUN OVER THE TOP OF THE EMERGENCY SPILLWAY. WE BOTH DECIDED THAT CUZCO ROAD SOUTH SHOULD BE CLOSED OFF FOR PUBLIC SAFETY TO KEEP TRAFFIC OUT OF RUNNING WATER BEGINNING TO BE NOTICED HERE. I PICKED UP BARRICADES FROM THE CITY OF HUNTINGBURG, PICKED UP LARRY VOLLMER WHO HELPED ME PUT THEM IN PLACE. WATER FLOW OVER THE SPILLWAY IS EXPECTED TO INCREASE THROUGH OUT THE NEXT 24 HOURS. LAKE ELEVATION RECORDED AT 8:00pm TONIGHT IS AT 548.96'.

S/W TIME: 15:13 Hrs
TOWER CLK TIME: 0:00 Hrs

NOTES: AT 8:38am ON 5/3/2011 STAN ACKIN FROM THE ARMY CORP REPORTED THE LAKE ELEVATION ROSE TO 549.47'. THE LOUISVILLE OFFICE HAS STATED THAT AT LAKE ELEVATION 549.5', THEY ARE REQUIRED TO RELEASE WATER. THEY PLAN TO RELEASE THRU THE CONTROL TOWER A FLOW OF 3600CFS AT 8:45am. THIS WILL BE AN ESTIMATED RELEASE OF NEARLY 5000 CFS AS AN ESTIMATED 2000 CFS IN NOW FLOWING OVER THE SPILLWAY. OPERATION WILL BE TO OPEN THE TOWER 200 CFS EACH HOUR UNTIL THEY REACH THEIR TARGET. IT IS ESTIMATED THAT THEY WILL REACH THIS TARGET IN 18 HOURS OR BY 2:45am ON 5/4/2011. HE ALSO MENTIONED THAT THE RIVER ELEVATION WILL EXCEED 17.00'.

S/W TIME: 16:05 Hrs
TOWER CLK TIME: 0:52 Hrs

NOTES: AT 9:30am ON 5/3/2011 LARRY VOLLMER, RANDY FLECK STOPPED BY THE GARAGE. THE THREE OF US OBSERVED THE FLOW OF WATER OVER THE TOP OF THE SPILLWAY. THE CULVERT UNDER CUZCO RD SOUTH WAS STILL HOLDING ON AS THE FLOW OF WATER COMING DOWN THE PAVED DITCH WAS MUCH GREATER THAN THE CULVERT COULD HANDLE. ALL EXCESS WATER WAS BEING EVENLY DISBURSED OVER THE GRASS BANK. NO EROSION HAS BEEN VISIBLE.

CHRONOLOGICAL EVENTS PRIOR TO AND THROUGHOUT THE HISTORIC PATOKA LAKE EMERGENCY OVERFLOW ON MAY 3, 2011.

S/W TIME:	23:00 Hrs
TOWER CLK TIME:	7:47 Hrs

NOTES: 4:25pm ON 5/3/2011 STAN ACKIN ADVISED THAT DUBOIS CUZCO ROAD WILL BECOME FLOODED DUE TO THE DISCHARGE. PLANS WERE BEING MADE THRU THE E.M.A. OFFICE AND SHERRIF'S DEPARTMENT TO ADVISE RESIDENTS OF THE HIGH WATER SOON TO COME. LARRY BETZ, BRAD MC CAIN AND MYSELF PICKED UP ADDITIONAL SIGNS AND BARRICADES FROM INDOT, JASPER, AND FERDINAND. ORDERED CLOSURES WERE PLACED AT SR 545 AND AT THE CAFÉ' IN CUZCO FOR CUZCO RD SOUTH. BARRACADES WERE PLACED ON CR 330 NORTH AT 760 EAST AND AT DUBOIS ROAD NE ON DUBOIS CUZCO ROAD.

S/W TIME:	41:05 Hrs
TOWER CLK TIME:	25:52 Hrs

NOTES: 10:30am ON 5/4/2011 STAN ACKIN ADVISED THAT LAKE ELEVATION PEAKED AT 549.66'. HE ESTIMATED THE PEAK DISHARGE WHICH WOULD INCLUDE EMERGENCY DISCHARGE WOULD BE JUST OVER 5000 CFS @ 6:00pm ON MAY 3rd 2011. SURPRISINGLY THE RIVER ELEVATION AT 10:00am WAS FALLING EVEN WITH THE ADDITIONAL DISCHARGE. ELEVATION AT THIS TIME IS 16.09'. AT THIS TIME, CUZCO ROAD SOUTH AND DUBOIS CUZCO ROAD REMAIN CLOSED TO TRAFFIC.

RIVER ELEVATION OBSERVATION: RIVER ELEVATION AT TIME OF THE NOTICE OF SPILLWAY DISCHARGE WAS @ 14.75'. NOW 41 THE RIVER ELEVATION IS AT 16.09', AND FALLING. WE SAW A PEAK OF 16.86'@ 10:00am ON MAY 3rd. FROM THE PEAK THAT WAS NOTICED AT 10:00am ON MAY 3rd, A SLOW DROP HAS BEEN SEEN. IT APPEARS THAT THIS PEAK WAS CAUSED BY THE UNCONTROLLED RUN OFF OVER THE SPILLWAY.

S/W TIME:	44:35 Hrs
TOWER CLK TIME:	29:22 Hrs

NOTES: 2:00pm ON MAY 4, 2011 I SURVEYED WATER LEVELS AT VARIOUS BRIDGE ELEVATIONS NEAR THE RIVER FROM CUZCO DOWN TO JASPER TO GET A BETTER IDEA OF THE RIVER FLOW. WITH THE RIVER GUAGE READING AT 15.95', BRIDGE # 40 ON DUBOIS CUZCO ROAD HAD A WATER LEVEL 39" LOWER THAN THE DECK ON THE NORTHWEST CORNER. CRYSTAL STATION BRIDGE # 46 HAD A WATER ELEVATION 89" BELOW THE NORTHEAST CORNER. CULVERT NUMBER CO1N5162-2.356 HAD AN ELEVATION OF 34" BELOW THE NORTHWEST CORNER, JOHN SEITZ BRIDGE ON CR 175 EAST SOUTH OF 325 EAST HAD AN ELEVATION OF 63" AT THE NORTHWEST CORNER, AND RUXER BRIDGE # 250 HAD AN ELEVATION OF 83" FROM THE BASELINE. SOUTHWEST CORNER. IT IS HOPEFUL THAT THESE ELEVATIONS MAY BE USEFUL AS A 15.95'

S/W TIME:	62:35 Hrs
TOWER CLK TIME:	47:22 Hrs

NOTES: 8:00am ON MAY 5, 2011 LARRY VOLLMER CALLED AND SAID HE GOT A CALL FROM JFS IN DUBOIS SAYING THE WATER LEVELS WERE RISING. WE MADE A CHECK AT THE BRIDGE # 40 CHECK POINT AND DID SEE A 6" RISE IN ELEVATION. RIVER LEVELS AT THE TIME OF THE CALL WERE AT 15.90'. THE TIME OF THE BRIDGE # 40 CHECK WAS 9:00am AND THE RIVER LEVEL WAS 15.91. EIGHTEEN HOURS HAVE PASSED SINCE THE BRIDGE #40 SURVEY WITH A SIX INCH RISE. THE 18 HOUR CHANGE AT THE RIVER GUAGE SHOWED A 0.05' DROP. IT WOULD BE EVIDENT A RISE IN THE RIVER IN COMING.

CHRONOLOGICAL EVENTS PRIOR TO AND THROUGHOUT THE HISTORIC PATOKA LAKE EMERGENCY OVERFLOW ON MAY 3, 2011.

S/W TIME: 82:35 Hrs	TOWER CLK TIME: 67:22 Hrs

NOTES: 4:00am ON MAY 6, BASED ON THE RATE OF FALL ON THE LAKE ELEVATION, IT COULD BE ASSUMED THAT THE LAKE LEVEL FELL BELOW THE OVERFLOW ELEVATION. ALL DISCHARGE IS NOW FLOWING THROUGH THE TOWER. ACCORDING TO THE NOTES I WAS ABLE TO COLLECT, WATER FLOWED OVER THE EMERGENCY SPILLWAY FOR A PERIOD OF APPROXIMATELY 82 HOURS AND 35 MINUTES.

S/W TIME: 82:35 Hrs	TOWER CLK TIME: 71:22 Hrs

NOTES: 8:00am ON MAY 6, 2011 I CHECKED THE WATER ELEVATION AT THE BRIDGE #40 CHECKPOINT AND MEASURED 36" WHICH IS A 3" DROP IN WATER ELEVATION IN A 23 HOUR PERIOD. I SENT A CLEANUP CREW TO THE AFFECTED AREA ON CUZCO ROAD SOUTH TO CLEAN UP DEBRIS FROM THE FLOW AND PATCH A SMALL AREA OF ROAD. SOME DAMAGE IS VISIBLE HERE NOW THAT THE WATER IS GONE. THE DISCHARGE OF THE APRON IS DESTROYED AND SOME SETTLING OCCURRED AROUND THE DISCHARGE END OF THE CULVERT. AT THE INLET END, MUCH CONCRETE DEBRIS WAS LODGED IN FRONT OF THE INTAKE. SOME SWIRLING HAPPENED CAUSING SOME EROSION AT THE APRON. WE WILL REPAIR FOR NOW BUT WILL LOOK INTO REPLACEMENT OF THIS STRUCTURE. THE PRE-EXISTING CONDITION OF IT HAD SOME RUST AT THE BOTTOM OF THE CULVERT. IT APPEARS TO HAVE HELD UP, BUT WITH THE PRESSURES IT WENT THROUGH, IT WOULD BE WISE TO PLAN REPLACEMENT LATER THIS FALL.

S/W TIME: 82:35 Hrs	TOWER CLK TIME: 77:22 Hrs

NOTES: 2:00pm ON MAY 6, 2011 CLEANUP IS FINISHED HERE ON CUZCO ROAD SOUTH. WE HAVE NOW REOPENED THIS ROAD.

S/W TIME: 82:35 Hrs	TOWER CLK TIME: 335:22 Hrs

NOTES: 8:00am ON MAY 17, WE GOT WORD FROM PATOKA LAKE THAT THEY HAVE BEGUN A SLOW DECREASE IN WATER DISCHARGE. THEY PLAN TO REDUSE IT TO 225 CFS WITHIN THE NEXT 24 HOURS. LAKE ELEVATION AT THIS TIME CURRENTLY STANDS AT 541.69 FEET.

NOTES: 8:00am ON MAY 23, THE RIVER LEVEL HAS FINALLY GONE UNDER THE 10.00' RANGE AT COON SEITZ BRIDGE. THIS SIX DAY PERIOD HAS SEEN A SURPRISINGLY SLOW PERIOD OF DECLINE. WHAT MAKES SENSE IF THERE WAS LIKELY SO MUCH WATER IN LOW LYING AREAS THAT DRAINED BACK INTO THE RIVER, IT JUST TOOK THIS LONG TO GET AWAY. AT THIS TIME THE RIVER LEVEL SITS AT 8.7' AND STILL 5 ROADS REMAIN FLOODED. THESE INCLUDE: THE OLD HUNTINGBURG ROAD, 400 SOUTH WEST OF ELL CREEK RD, ELL CREEK ROAD, CR 150 SOUTH WEST OF OLD HUNTINGBURG ROAD, AND CR 800 WEST NORTH OF 300 SOUTH.

NOTES: 2:00pm ON MAY 27, THIS IS MY FINAL DAY OF REPORTING THIS EVENT. REPORTED RAINFALL AT PATOKA LAKE WAS 1.9" IN THE LAST FOUR DAYS. CR 800 WEST REMAINS THE ONLY FLOODED ROAD. LAKE ELEVATION STANDS @ 541.0'. RIVER ELEVATION IS 9.26'.

BRIDGE BENCHMARKS RELATIVE TO THE RIVER GUAGE 3 MILES EAST OF JASPER AT COON SEITZ BRIDGE   RIVER ELEVATION READING HERE @15.95'

* THESE SELECTIONS WERE USED TO PREDICT A POSSIBLE SURGE OF HEAD WATER COMING DOWN STREAM FROM THE DAM. ASSUMING A READING OF 33" @ BENCHMARK #1, WE COULD PREPARE FOR A 6" RISE OF WATER IN JASPER. A BENCHMARK #1 READING OF 27" MAY MEAN A 12" RISE IN JASPER.

THESE READINGS WERE TAKEN ON 5/4/2011 @ 2:00pm

BENCHMARK #	STRUCTURE	ROAD LOCATION	LOCATION OF MEASURE	WATER FROM TOP OF DECK
#1	PATOKA RIVER BRIDGE # 40	DUBOIS - CUZCO RD	NW CORNER @ WALL	39" @ 15.95'
#2	CRYSTAL STATION BRIDGE # 46	DUBOIS ROAD N E	NE CORNER @ WALL	89" @ 15.95'
#3	CULVERT BEAM # CO1N5162-2.356	DUBOIS ROAD N E	NW CORNER @ WALL	34" @ 15.95'
#4	JOHN SEITZ BRIDGE # 28	CR 175 EAST	NW CORNER @ WALL	63" @ 15.95'
#5	RUXER BRIDGE # 250	15th STREET - JASPER	SW CORNER @ WALL	83" @ 15.95'

MAY 5, 2011 - 9:00am READING @ BM # 1 WAS 33" INDICATING THAT WATER ROSE 6" IN THE 19 HOUR PERIOD FROM BENCHMARK ESTABLISHMENT. OUR FORECAST TO JASPER WAS TO ANTICIPATE A 6" RISE FROM THEIR CURRENT ELEVATION.

MAY 6, 2011 - 7:45am READING @ BM # 1 WAS 36" INDICATING THAT WATER DROPPED 3" IN THE 23 HOUR PERIOD FROM THE LAST READING. OUR FORECAST TO JASPER WAS TO ANTICIPATE A 3" DROP FROM THEIR CURRENT ELEVATION.

Correspondence:

2016:

From: [redacted]

To: [redacted]

Subject: FW: increasing to 13 feet at Jasper

Date: Wednesday, February 10, 2016 3:33:33 PM

FYI"

[redacted]) chimed in and it sounds like he had no noticeable road impoundment issues during the rain event.

[redacted]

-----Original Message-----
From: [redacted] [redacted]Sent: Wednesday, February 10, 2016 11:17 AM
To: [redacted] LRL [redacted] Cc: [redacted] [redacted]
[redacted] Subject: [EXTERNAL] RE: increasing to 13 feet at Jasper

Thanks Tom. During the last event, we saw 6 low volume roads that experienced some flooding. Most of them were likely due to runoff in the Hundley/Brunner Creek areas. The Old Huntingburg Road was flooded for a few days as were a few roads near the Ell Creek area. Division Road waters were 3 to 4 feet before it got to the road. CR 800 West had very minor flooding in the farm bottoms but did not cover the road. Looked like it could have held a few feet more before it got to the road. I'll keep in touch, thanks for the update.

Thanks,

[redacted]

-----Original Message-----
From: [redacted] E LRL [redacted] Sent: Wednesday, February 10, 2016 10:30 AM
To: [redacted]
Subject: FW: increasing to 13 feet at Jasper

FYI:

[redacted],
Wanted to keep you in the loop. [redacted]

-----Original Message-----
From: [redacted]
Sent: Wednesday, February 10, 2016 10:19 AM
To: [redacted] LRL [redacted]
Cc: [redacted] [redacted]; [redacted] LRL [redacted]; [redacted] LRL [redacted]
Subject: RE: increasing to 13 feet at Jasper

Thanks for the info [redacted]. I will talk to [redacted] when she return next week to see if we want to try to get a temporary deviation request approved this year. I suspect by the time it were to be approved, we will probably already be in crop season....maybe we can get it in place next year. Stay warm and have a good day!

[redacted]

-----Original Message-----
From: [redacted]
Sent: Wednesday, February 10, 2016 10:16 AM
To: [redacted] M LRL [redacted] Cc:
[redacted]
Subject: increasing to 13 feet at Jasper

[redacted]
I received a phone call (this morning) from Jeff Theising (Jasper Street Dept. Supervisor):
Mr. Theising studied the last rain event (3/4 Feb 2016, river elevation reached 13.84 feet) and Mr. Theising did not see any flooding issues associated with that elevation. Mr. Theising stated that he supports raising the Jasper gauge trigger to 13.00 feet.
Jeff's phone number is 812-482-1130 , his email address is jtheising@jasperindiana.gov

I opened up to 511 cfs this morning (0830/as requested) , my calculations for the river gauge is a crest of 11.82 at Jasper . Stream info this morning is at 354 cfs and our 511 cfs contribution should put is close to 854 cfs in the channel.

Thank you, if you need anything just yell.

[redacted]

From: [redacted]

To:

Cc:

Subject: [EXTERNAL] RE: Coordination / set suspense"s for letter for deviation to 13 feet.

Date: Wednesday, June 08, 2016 12:25:38 PM

Attachments: High Report.xlsx

The attached is a summary of information gathered by Raymie or me. I listed only the events in which the levels got close to causing a problem. You will see that if the Jasper Gauge got above 13.90 feet and the markings on the 3rd Avenue (SR164, see attached picture) bridge showed at or above 454.0 feet we have flooding on Jasper Streets. If only one of these goes above and the other does not flooding gets close but does not cause problems on City streets. A gauge near the Dubois-Pike County line would aid in determining if free board downstream is available. I hope this helps!

[redacted]

-----Original Message-----
From: [redacted] LRL [redacted]
Sent: Thursday, June 02, 2016 1:28 PM
To: [redacted]
Cc: [redacted]
Subject: FW: Coordination / set suspense's for letter for deviation to 13 feet.

[redacted]
Please refer to email from Jamie asking about submission of impact lists from you. They were to be attached to the request for deviation as supporting documentation, and they may have been but we only have the signed requests, no supporting documentation from you guys. Can you please forward your impact lists and I'll forward to Jamie. If we need to talk please call.
Thank you,
[redacted]

-----Original Message-----
From: [redacted] LRL
Sent: Thursday, June 02, 2016 12:14 PM
To: [redacted] LRL [redacted]
Subject: FW: Coordination / set suspense's for letter for deviation to 13 feet.

[redacted]
I went back to previous emails because I couldn't remember but it looks like Jasper and Dubois Co Street/Hwy were going to submit their list of impacts w/ this request letter as supporting documentation. Has that come in and I missed it?

Thanks,
[redacted]

PATOKA RIVER GAUGE READING AND AFFECTED AREAS IN JASPER

Date	Time	Jasper Gauge	3rd Ave Bridge	2nd & Clay Inlet	JayKem Inlet (271 Clay St.)	Notes of affected area:
3/19/2012	12:00pm	14.33'	453.0'	16" below grate		No affected areas
4/13/2012	11:00am	14.16'	452.5'	24.5" below grate		No affected areas
4/3/2014	4:00pm	13.67'		24" below grate		
4/4/2014	6:00am	14.67'		level with grate		
4/5/2014	7:00am	16.03'	456.50'			4th St. b/t McCrillus & Andersond 3-5" deep
"						2nd & Clay flooded to Jasper Group S. entrance
"						3rd & Newton (SR164) flooded
"						Cathy Lane near Kellerville Rd. passable
4/7/2014	6:15am	13.80'	454.50'	Below grate		
4/8/2014	6:00am	12.60'	453.25'			
4/3/2015	5:00am	12.92'	453.5'			
4/4/2015	5:30am	13.95'	454.0'			Water over Clay St. near Jasper Salvage
4/5/2015			454.50'			Water over Clay St. at JayKem
4/6/2015	5:30am	13.30'	454.50'			
"	11:30am	12.62'				Water off Clay St at both locations
4/7/2015	11:00am	12.85'	453.0'			
4/8/2015	5:00am	13.96'	454.0'			
"	2:30pm		454.5'	2" over grate		
"	4:00pm	15.00'	455.0'			
4/9/2015	6:00am	14.57'	455.50'	Intersection flooded		
4/10/2015	6:00am	13.93'	455.25'	"		
4/11/2015	6:00am	13.29'	454.0'	Below grate		2nd & Clay Sts. Clear
12/29/2015	5:15am	14.39'	453.25'			
3/8/2016	6:00am	10.85'				
3/10/2016	9:00pm	13.49'				
3/11/2016	5:00am	13.61'	452.17'		10" below grate	
	3:00pm	13.82'	452.17'		10" below grate	
3/12/2016	9:00am	14.04'	452'		12.5" below grate	
3/13/2016	9:00am	13.24'			13" below grate	
3/14/2016	6:00am	12.17'			25" below grate	
	This event resulted in no water on Jasper City streets.					

2017:

From: [redacted]

To: [redacted]

Subject: FW: [EXTERNAL] Re: Jasper at 13"

Date: Wednesday, March 8, 2017 10:52:14 AM

See [redacted] response below...

-----Original Message-----
From: [redacted]
Sent: Wednesday, March 08, 2017 10:45 AM
To: [redacted] CIV USARMY CELRL (US) [redacted]
Subject: [EXTERNAL] Re: Jasper at 13'

Hi [redacted]

When Winslow water gauge hits 15.5, we figure Oatsville Road 850 on the Pike- Gibson County line is starting to flood. At 18.7, we call that full flood at Oatsville Road 850.

Oatsville Bottoms on CR 850 on the Pike -Gibson County line flooded last Thursday, 3/02/17 for the first time this winter. The road was impassable but that's normal this time of year usually earlier in January. The gauge at Winslow read 16.22 at 12:30 EST.

This morning 3/08/17, the water gauge at Winslow read 18.60 but it was no longer rising. My guess is if the lake is increasing the outflow, we'll see the river rise at Winslow for the next couple of days. With more rain forecast and an increase of water release from the lake, we expect an extended period of road inundation especially with the Wabash River rising.

Flooding at this time of year in the Oatsville Bottoms is expected and the north-south roads are always impassable.

Let me know if this is what you are looking for in the way of correlation.

[redacted]

On Wed, Mar 8, 2017 at 8:21 AM, [redacted] CIV USARMY CELRL (US)
[redacted] > wrote:

Good morning,
Jasper is currently at 13.08' and still slowly rising. I don't expect it to get too much higher before cresting. If you might have time today to take a look at impacts to problem areas we would really appreciate it. I know this is last minute and you may be too busy but figured it wouldn't hurt to ask. Thanks!!

Sincerely,
[redacted]

[redacted]

--

[redacted]

From: [redacted]

To: [redacted]

Cc: [redacted]

Subject: [EXTERNAL] Flooding from Patoka River on Two County Roads in Patoka River NWR

Date: Thursday, March 9, 2017 6:07:57 PM

Hi,

Sorry this is late. The river was still rising when these photos were taken. Will send several sets of photos.
1st Set:
1419- Oatsville Road Pike County 700W - north of river looking south with tree line on river. 1422- closer view.
1423- farm field to east of CR700W. 1424- farm field to west of CR 700W.

[redacted]

--

[redacted]

1419 - Oatsville Road Pike County 700W-north of river looking south with tree line on river

1422 – closer view

1423 – farm field to east of CR700W

1424 – farm field west of CR 700W

2019:

From: [redacted]
Sent: Thursday, May 9, 2019 10:54 AM
To: [redacted]
Cc: [redacted]ry
[redacted]
Subject: RE: Flooded roads
[redacted],
Thank U, your input is always appreciated. I will pass this along to our folks so they are in the loop.
Tom
-----Original Message-----
From: [redacted]
Sent: Thursday, May 9, 2019 10:14 AM
To: [redacted]
Cc: [redacted]; [redacted]; [redacted]; [redacted]; [redacted]; [redacted]
Subject: [Non-DoD Source] Flooded roads
Hi [redacted],
As of now with the river gauge settling in to just under 14’ for the last day and a half, I wanted to report that we are currently at 8 flooded roads. There is a good possibility that without additional rain today the Old Huntingburg Road gates will reopen. Since our meeting on May 1st where a more aggressive discharge has taken place mixed in with the rain event during the past weekend, it appeared that the high water mark on the Jasper gauge reached around a 14.80’ elevation reading. With that in mind, we peaked at 25 flooded roads and no visible impacts to report by the County at this time. In my opinion, what we have seen with the discharge and steadier river levels since our May 1st meeting, is what many of us expected to see when the original deviation request for a 14’ elevation was requested several months ago. We would like to meet later this summer and have a discussion and toss about ideas for future concerns. Many of us would look forward to that. Just wanted to say, Great job. We will keep you posted on the progress.
Thanks!
[redacted]
2
[redacted]

Patoka Water Control Manual Update

Engineering Report

Appendix B-Detailed Res-Sim Analysis:

Data Sources and Quality Control:

DSS paths used in Final_Patoka_Data.DSS for the Res-Sim model runs……..

//JASPER/FLOW//1HOUR/JASPER LOCAL INFLOWS/

These local inflows were developed by the following method:

a. The most complete record available at the Jasper gage is stage. Since the rating curve has shifted over time, the current (2019) rating curve was applied to the stages to develop total flows from 2005-2018. That way the analysis compares consistent data throughout the period of record. See 4.a. for description of total flows added from 2019-2020.

b. Patoka outflows were taken out of the CWMS database and corrected where necessary. The outflows were routed from the dam to the Jasper gage using the routing methodology in the CWMS model (Muskingum-Cunge). The computed travel times for the routing seemed fairly consistent with what is typically observed.

c. The routed Patoka Dam Outflows were subtracted from the computed total inflows to develop a local inflow hydrograph between the dam and the Jasper gage. Then any negative flows were changed to zeros.

//JASPER/FLOW//1HOUR/JASPER TOTAL INFLOWS/

These total inflows were developed by the following method:

a. The most complete record available at the Jasper gage is stage. Since the rating curve has shifted over time, the current (2019) rating curve was applied to the stages to develop total flows from 1/1/2005-12/31/2018. That way the analysis compares consistent data throughout the period of record. Data from 10/1/2018-12/31/2020 was added using 15 min USGS-REV flow directly from the CWMS database (which was then converted to 1 Hour) because the Jasper rating did not change significantly from 2019 to 2020.

//JASPER/STAGE//1HOUR/LRGS-REV_UPDATED/

LRGS stages were used with any missing data filled in with USGS stages.

//PATOKA/FLOW-OUTFLOW/1HOUR/PATOKA DAM OUTFLOW/

These are computed hourly outflows from the CWMS database. These were compared against the Daily Lake Bulletins through 2006 through 2018 and corrected where necessary. Data was later updated through 12/31/2020.

/MWB/PRR/ELEV//6HOUR/OBS/

Observed 6-hr elevations from the mastdb.dss. It is not expected that simulated pool elevations using the computed uncontrolled Jasper flows are going to match observed elevations very well because 1. the rating curve has changed over time, and 2. we generally operate a little more conservatively than the model will (i.e. generally close down in advance of incoming rainfall.) We will likely need to use the simulated pool elevations using the computed Jasper inflows when comparing the various alternatives.

/MWB/PRR/FLOW//1HOUR/OBS_2005-2019_1HR/

These inflows were developed by taking the computed 6-hr average inflow in the mastdb.dss and changing the time step to 1-hr. It was felt this was the best representation of hourly inflow volume (as compared to the computed 1-hr inflows). Data was later updated through 12/31/2020 but did not change the F part of the path name.

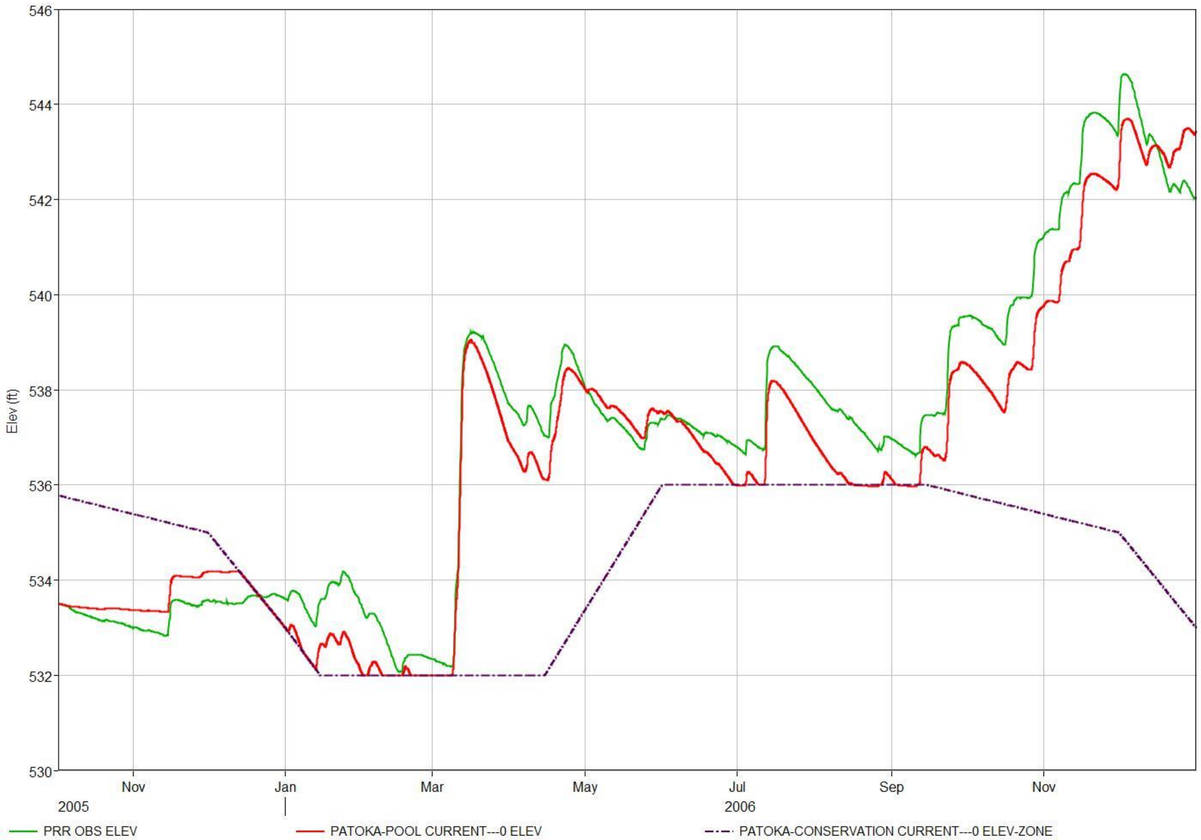
/PATOKA/JASPER/ELEV-FLOW//JUN2019/JUNE 2019 RATING CURVE/

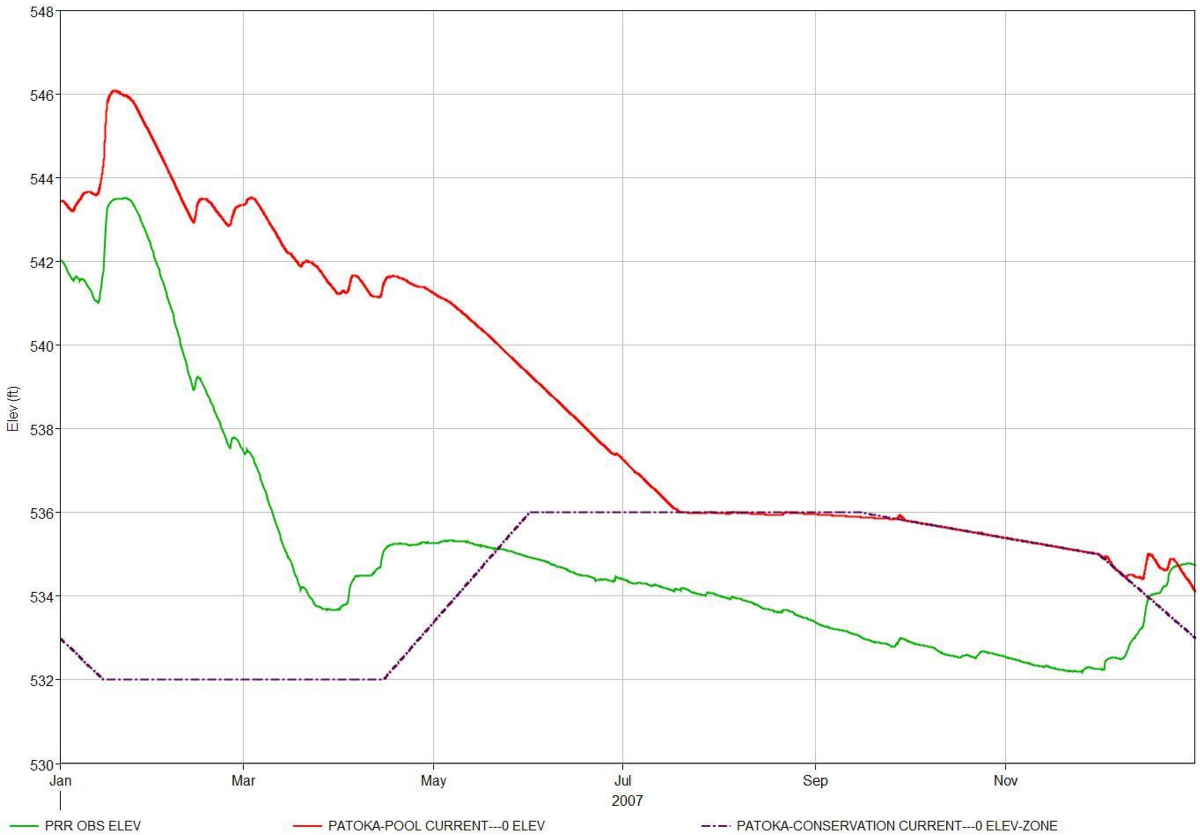
Latest Rating Curve at Jasper (as of Feb 2019)

Calibration

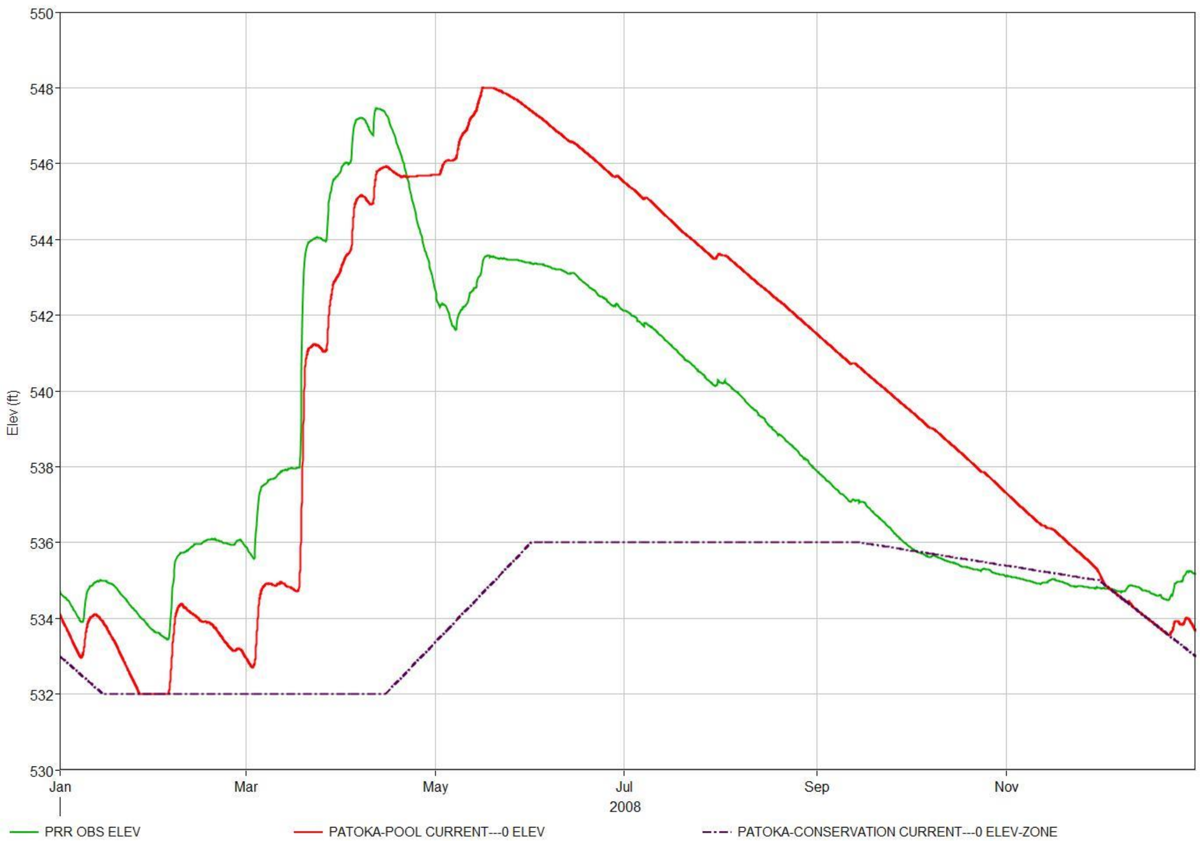
The Patoka Res-Sim model was derived from the calibrated Middle Wabash River CWMS model. An independent in-house calibration effort was undertaken for this study. Modeled pool elevation results for the “Current” simulation operations were compared to observed pool elevations and these results underwent two internal reviews by two other members of the LRL water management team. In the reservoir model all major differences in modeled vs. observed pool elevations were attributable to operational deviations. Examination of local USACE records show that the reasons for the discrepancies in all cases were the result of changes to normal operations due to deviations, maintenance, drought contingencies or flood operations. For the years where there were no deviations or major discrepancies between modeled and observed pool elevations, no notes are provided following the graphs. See yearly plots below.

Broken Purple Line: Guide Curve
Green Line: Observed Pool Elevations
Red Line: Current Simulated Operations, Winter Pool=532 and Jasper=13' (Alternative 3)

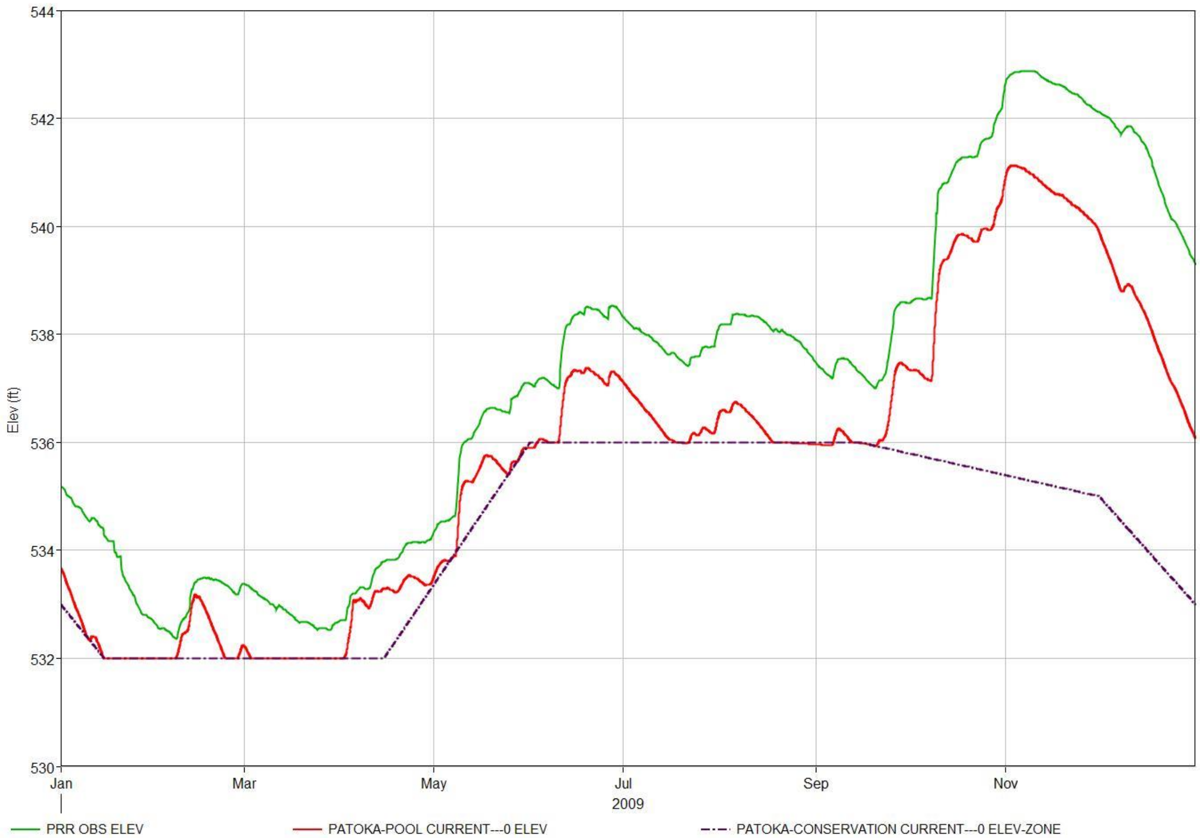




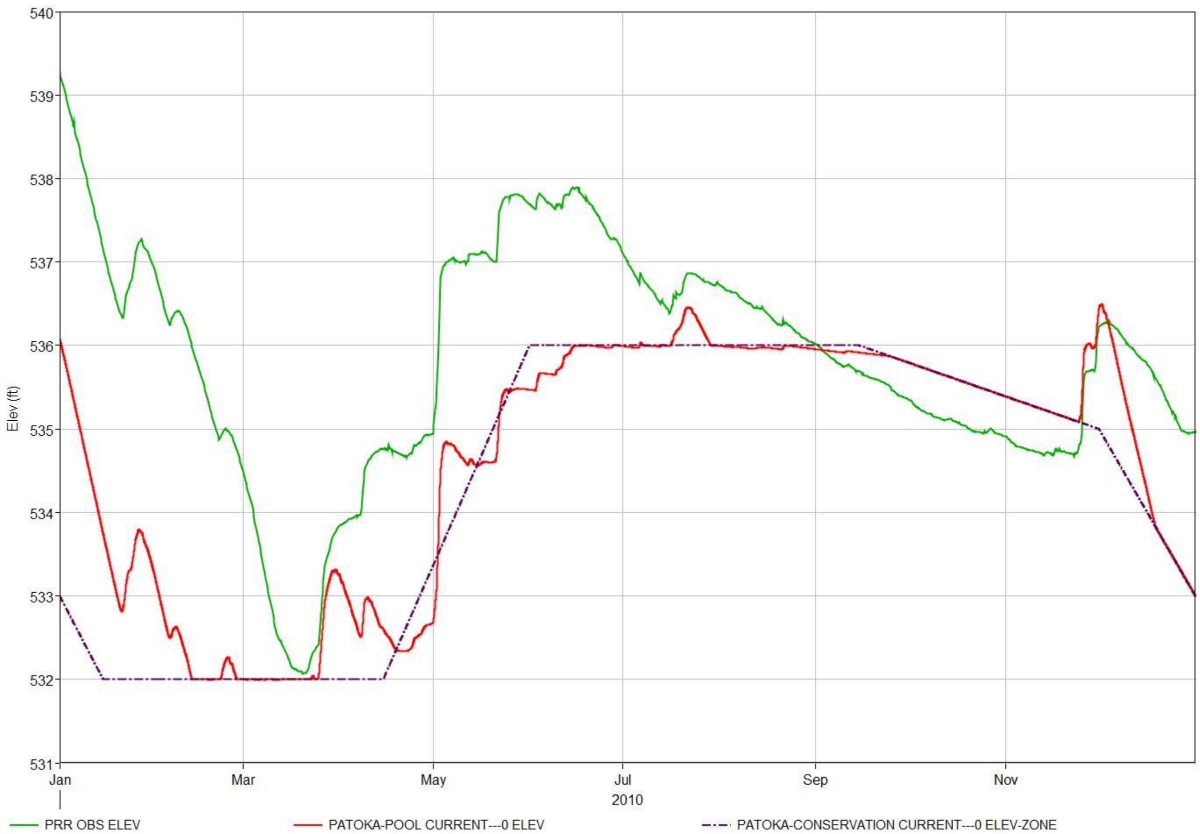
2007: We pushed Jasper to 14' where the model kept it at 12' Dec 2006-Mar 2007, which is why the simulated elevations are higher than observed and that is carried forward until the model catches up near the end of 2007. In earlier years there were no known impacts up to 14' and we unofficially pushed Jasper above 12'. The summer of 2007 was exceptionally dry and because we were able to draw the pool down faster than simulated, we ended up falling below the guide curve and stayed below until mid-Dec.



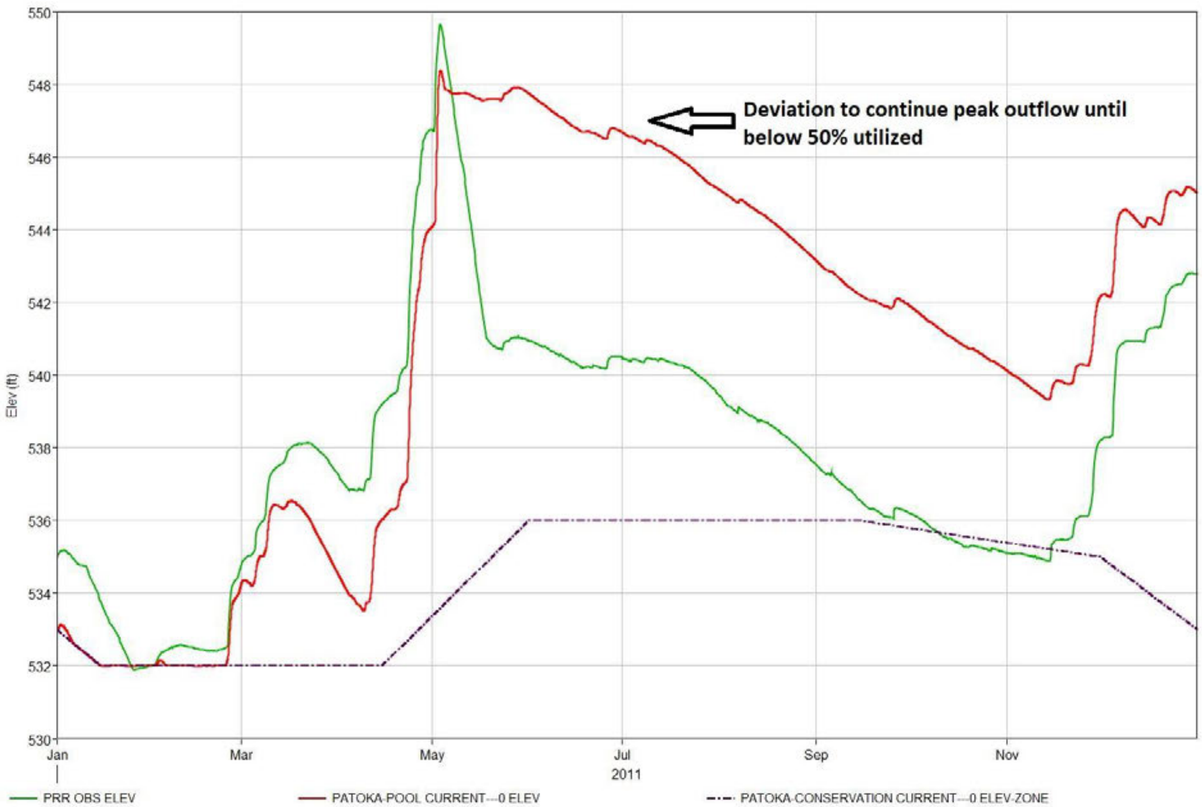
2008: In April we again pushed Jasper to 14’ until mid-May, due to the high pool and a delay in crops being planted due to wet Spring, the simulated does not reflect this change in operation.



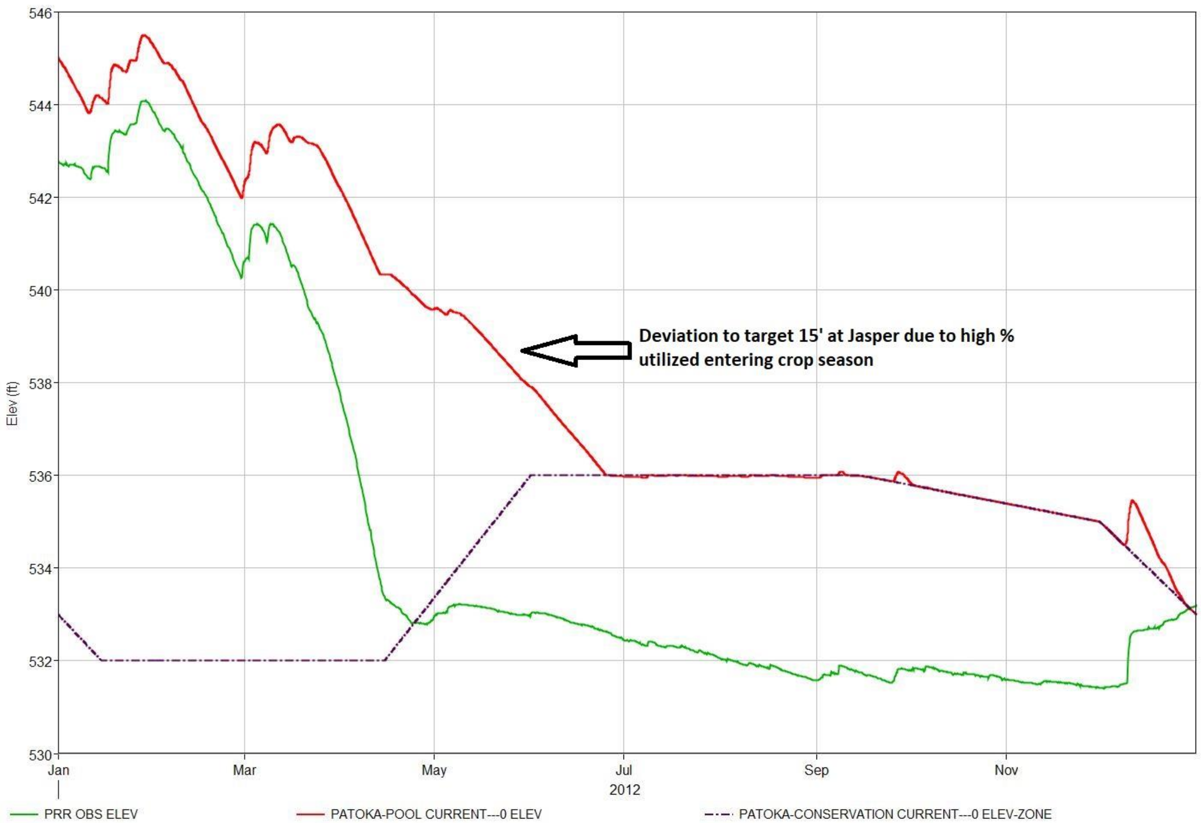
2009: We kept releases much lower than the model late Sep-early Nov, we assume based on forecast rainfall because it looks like Jasper went above 9’ a few times.



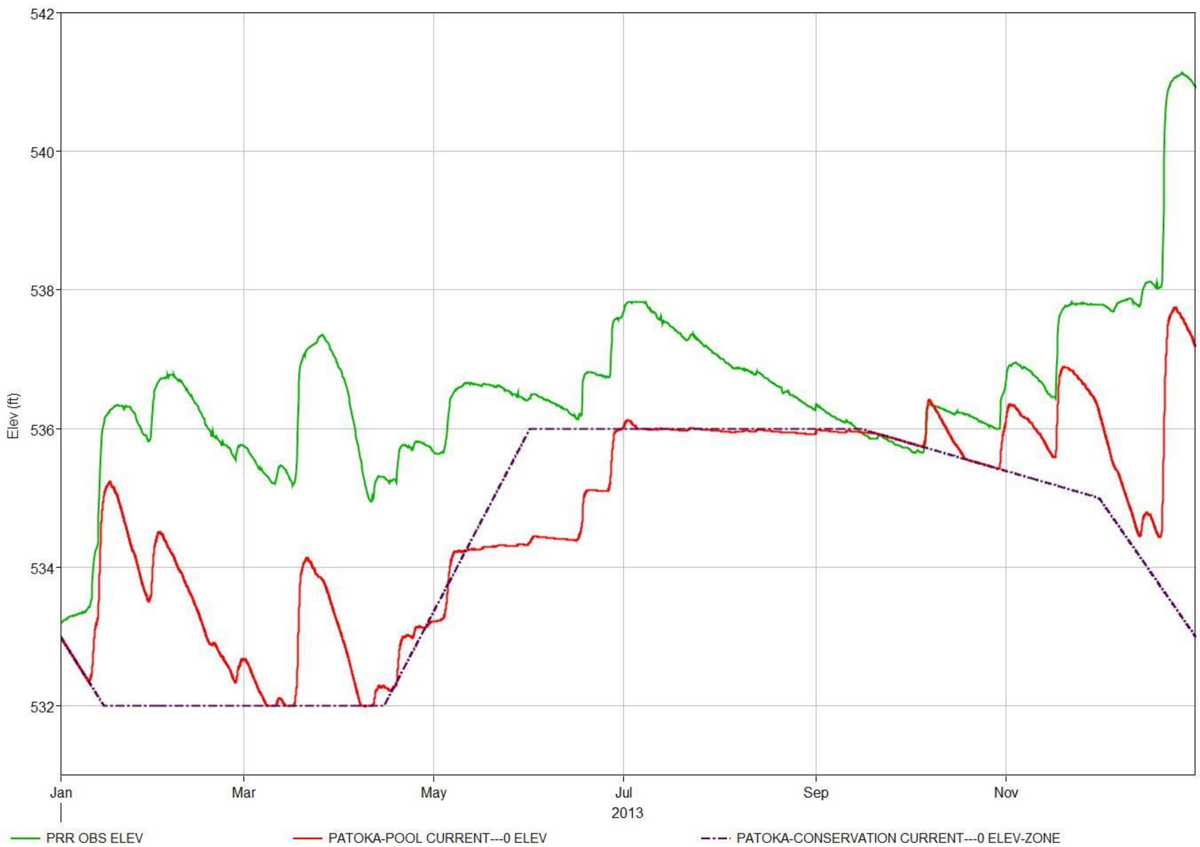
2010: We assume our observed elevations are higher in the spring because of a combination of forecasted rainfall and possibly starting crop season early. It looks like we may have started filling to summer pool a little early and/or the farmers wanted to start planting earlier than normal.



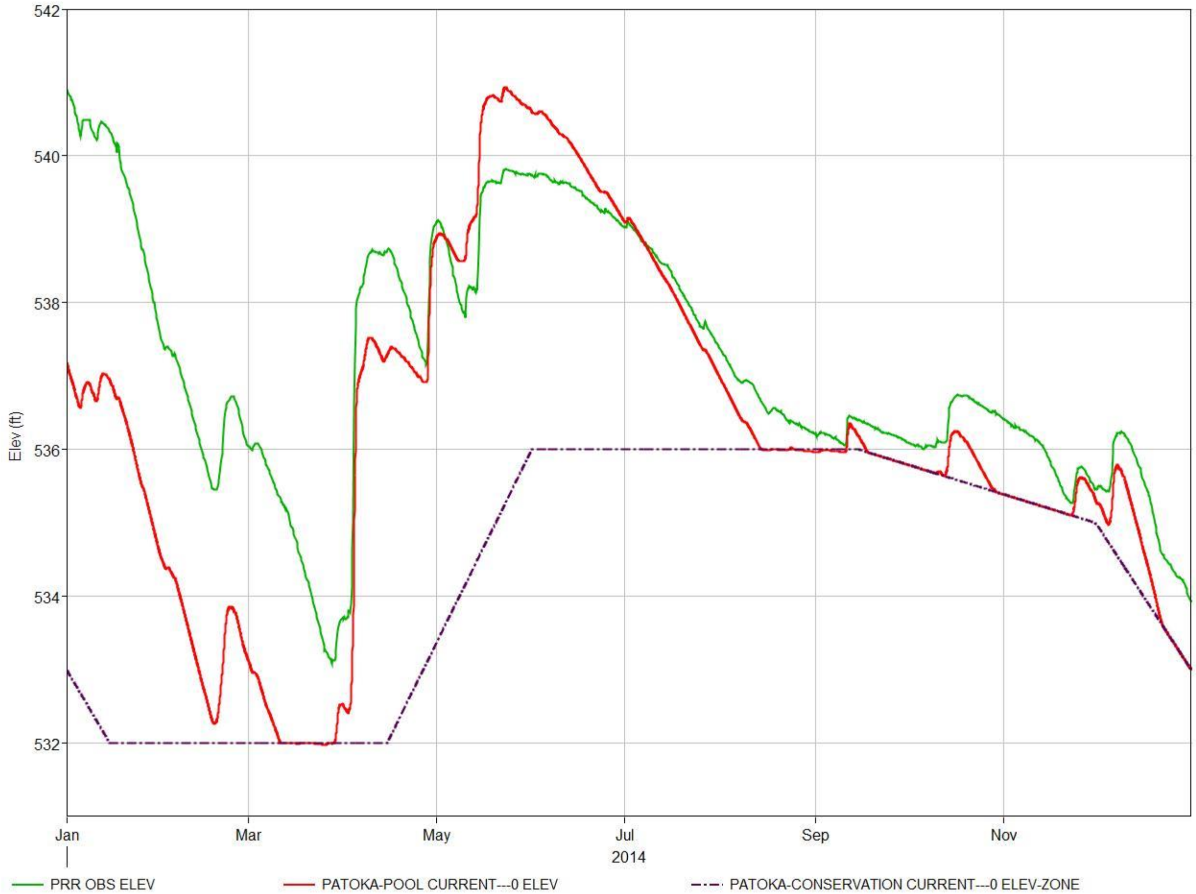
2011: It looks like crop season lasted until late Dec 2010 instead of Dec 1, which is what is in the model, and that resulted in higher observed elevations until late Jan. Rain events started coming back-to-back in late Feb. We were most likely not releasing when the model was releasing due to forecasted rainfall. During the spillway event in early May, the model released over 1,000 cfs more than we did. After the pool fell below the spillway, we had a deviation to release at the rate obtained during the spillway event (through the conduit) until the pool fell below 50% utilized. We also had to reduce outflow once during that time frame to allow a turkey producer to feed his animals (his access road was cut off due to our high releases).

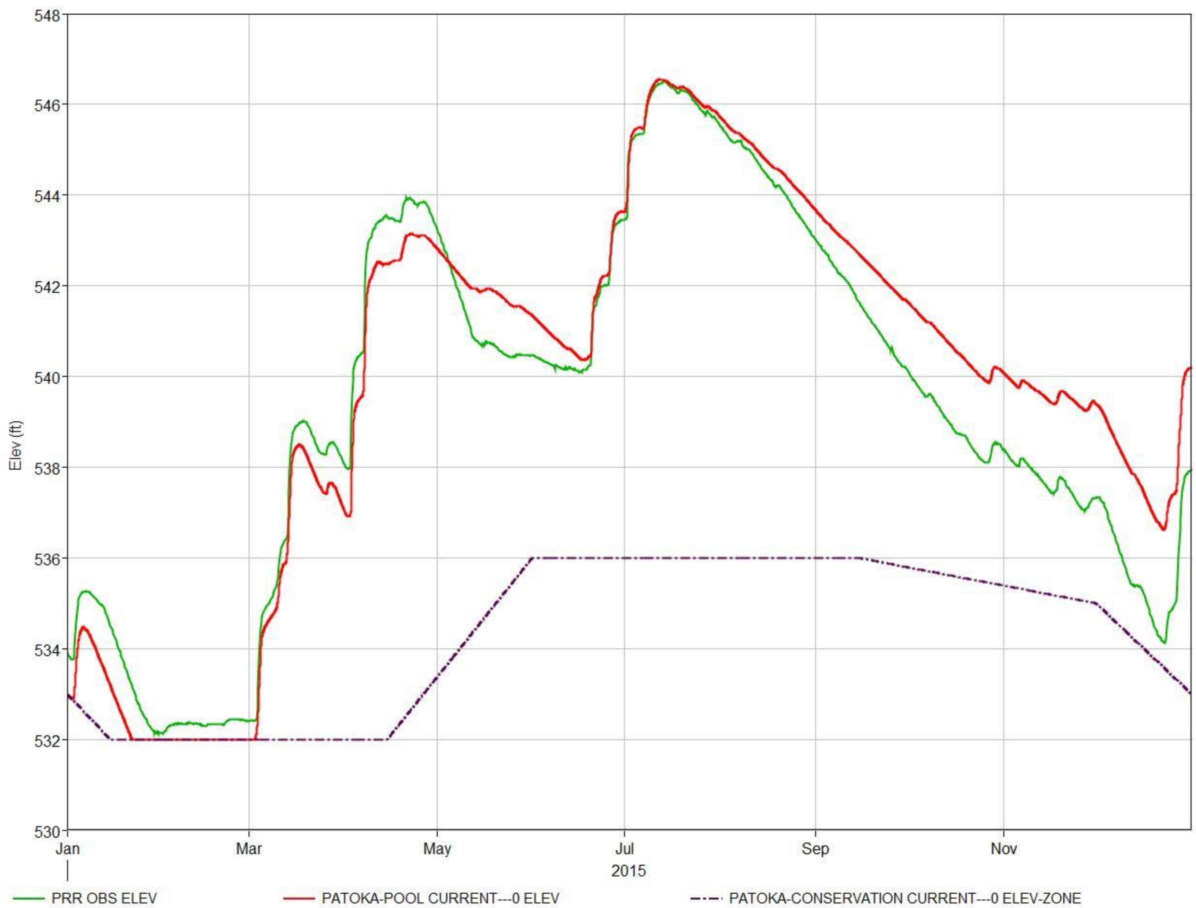


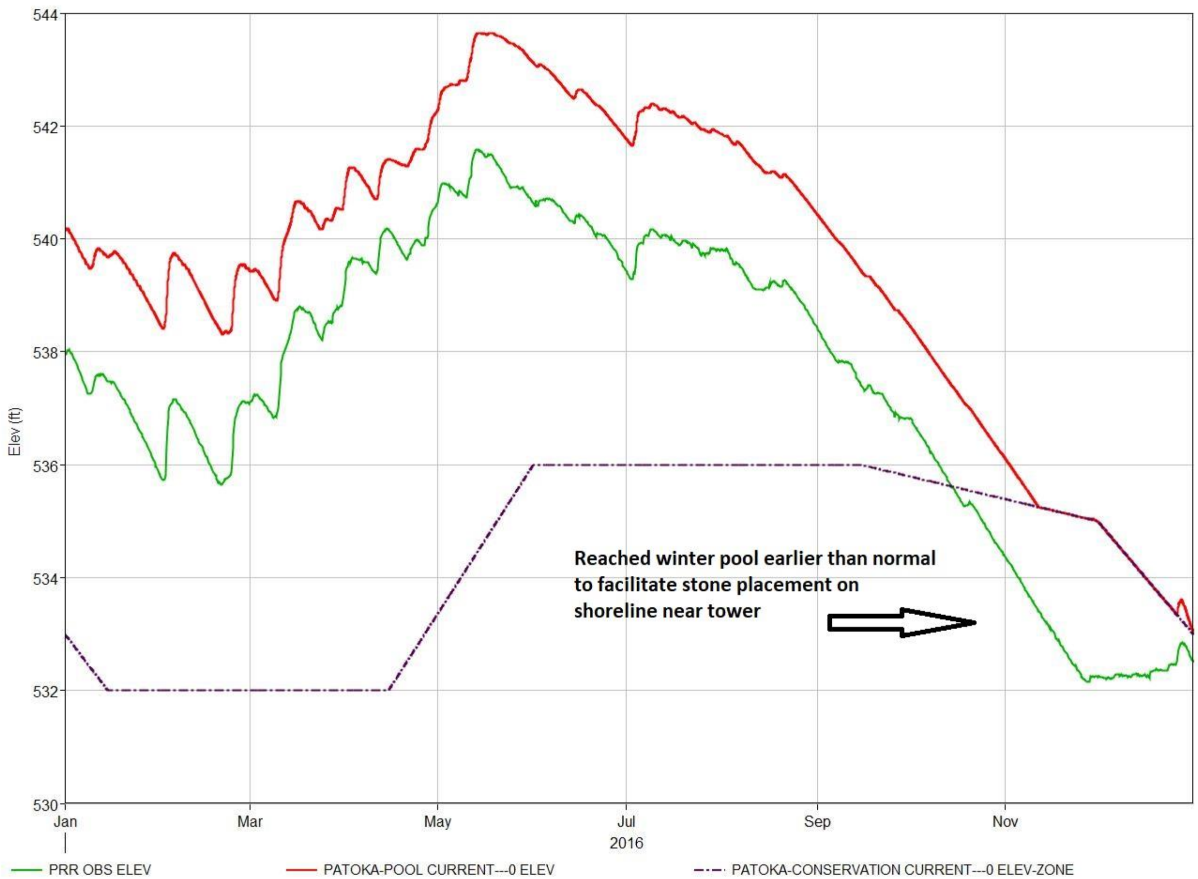
2012: We had a deviation in the spring of 2012 to operate Jasper for 15' (though we didn't quite push it that high) to bring the pool down to guide curve faster before crop season started (fear of another spillway event). Then a drought hit that area and we didn't make it to summer pool.



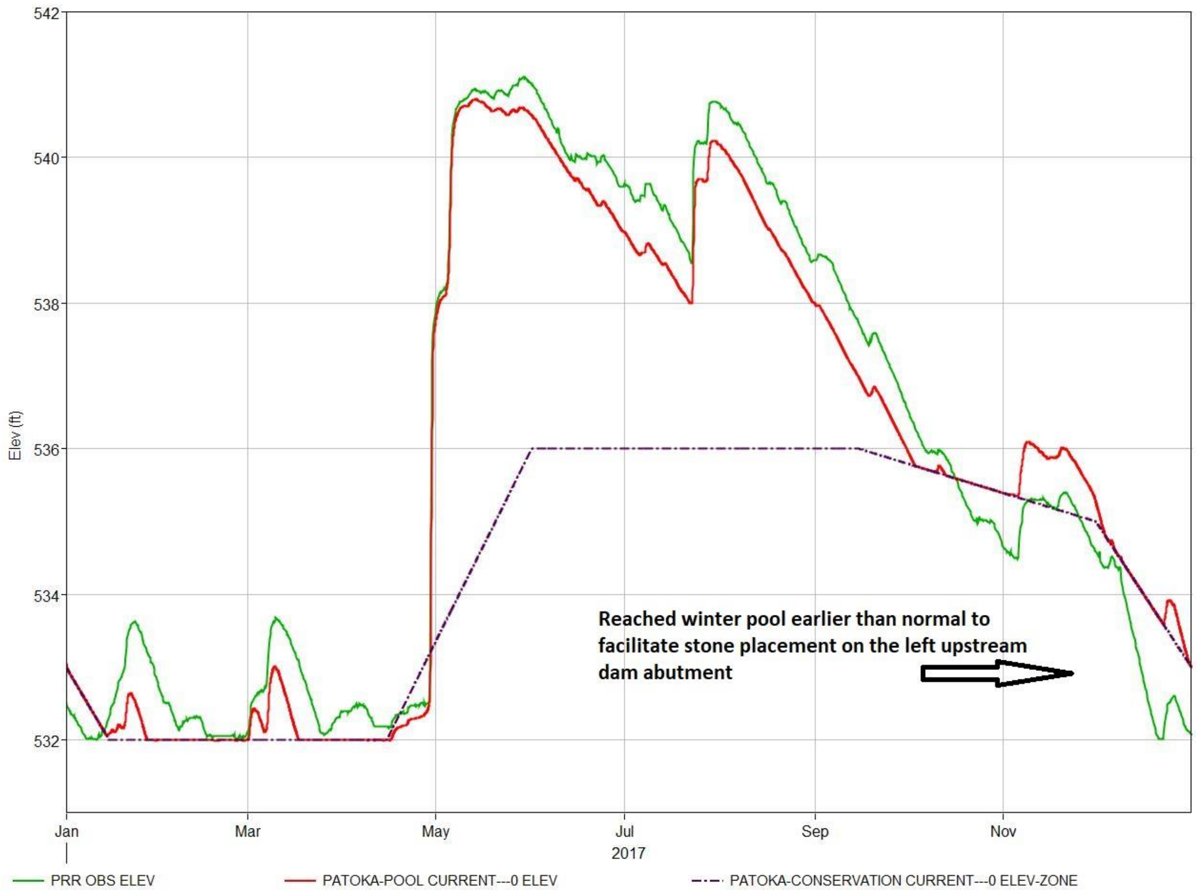
2013: It looks like crop season lasted well into Dec and we didn't start non crop releases until mid-Dec.


542
540
538
536
534
532
Elev (ft)
Jan
Mar
May
Jul
Sep
Nov
2014
PRR OBS ELEV
PATOKA-POOL CURRENT---0 ELEV
PATOKA-CONSERVATION CURRENT---0 ELEV-ZONE

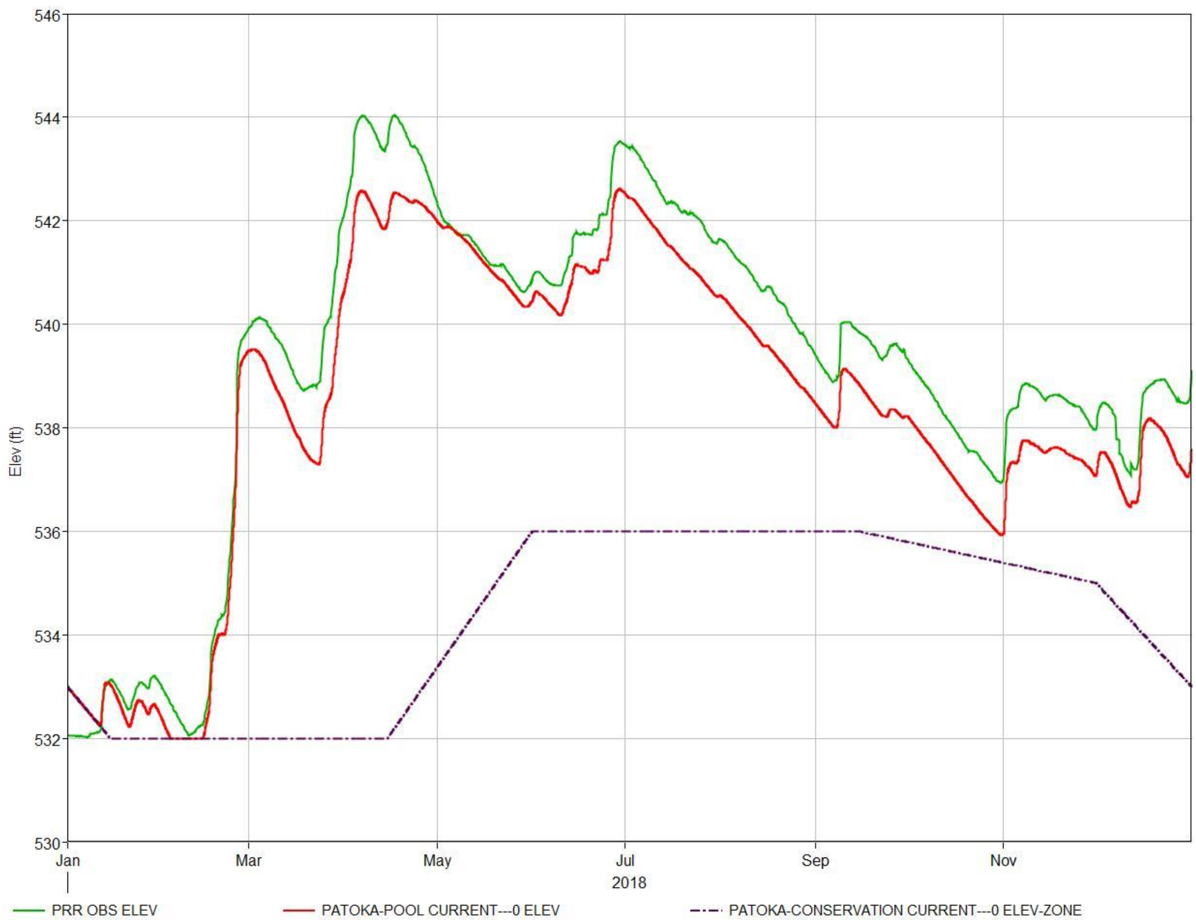

548
546
544
542
540
538
536
534
532
530
Elev (ft)
Jan
Mar
May
Jul
Sep
Nov
2015
PRR OBS ELEV
PATOKA-POOL CURRENT---0 ELEV
PATOKA-CONSERVATION CURRENT---0 ELEV-ZONE

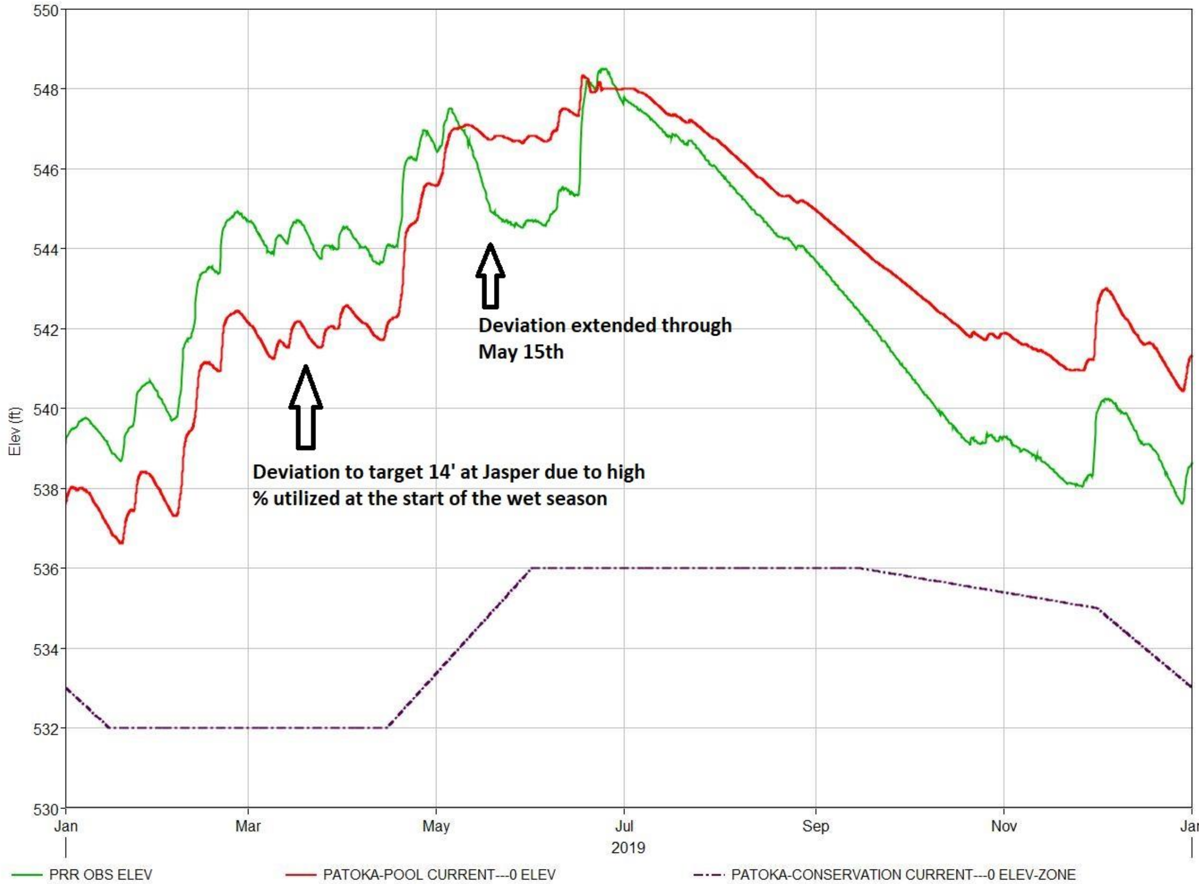


2016: We lowered the lake down to winter pool early (late Nov) that year so that stone could be placed on the shoreline near the tower due to erosion.

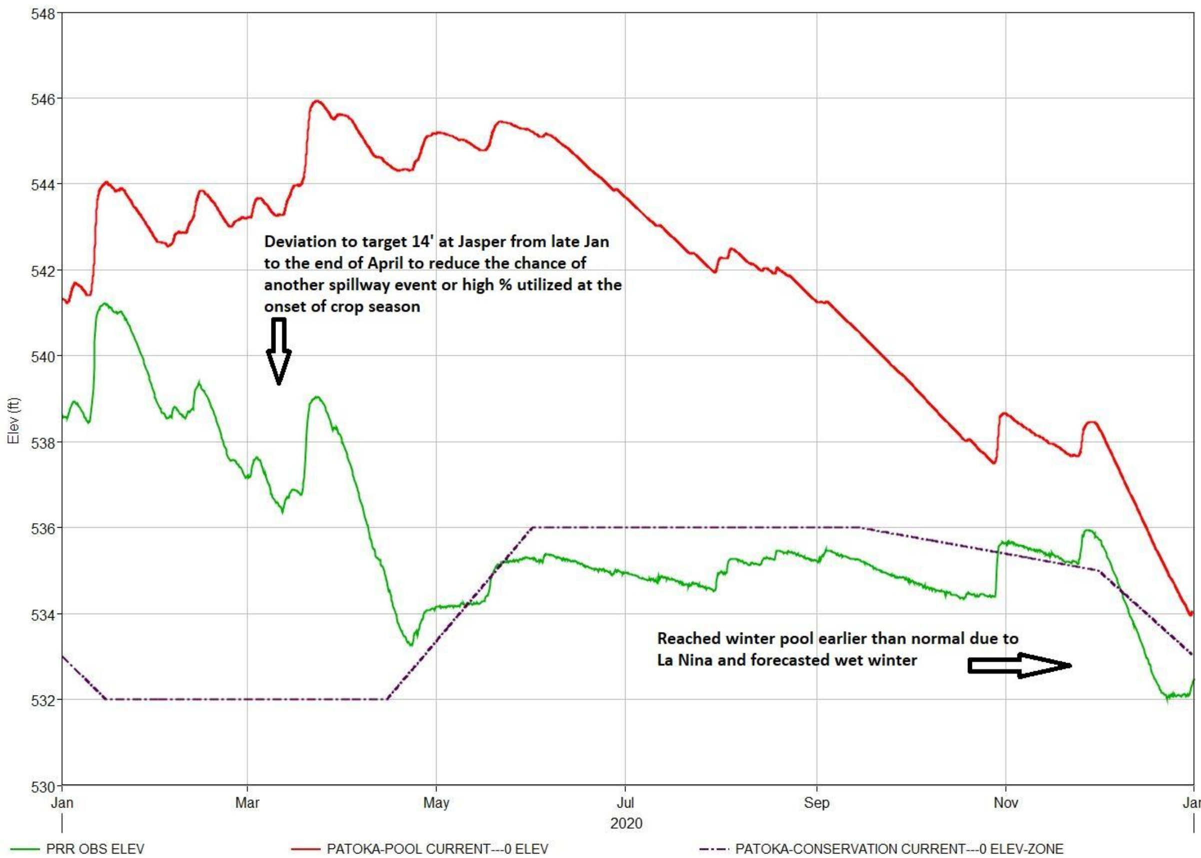


2017: We lowered the lake down to winter pool early that year so that rip rap could be placed on left upstream dam abutment.


546
544
542
540
538
536
534
532
530
Elev (ft)
Jan
Mar
May
Jul
Sep
Nov
2018
PRR OBS ELEV
PATOKA-POOL CURRENT---0 ELEV
PATOKA-CONSERVATION CURRENT---0 ELEV-ZONE



2019: Deviation to operate Jasper for 14' from mid-March to mid-May before crops were planted, which was later than usual due to the wet spring. Spillway event in late June (the model released way more than we did during the spillway event).

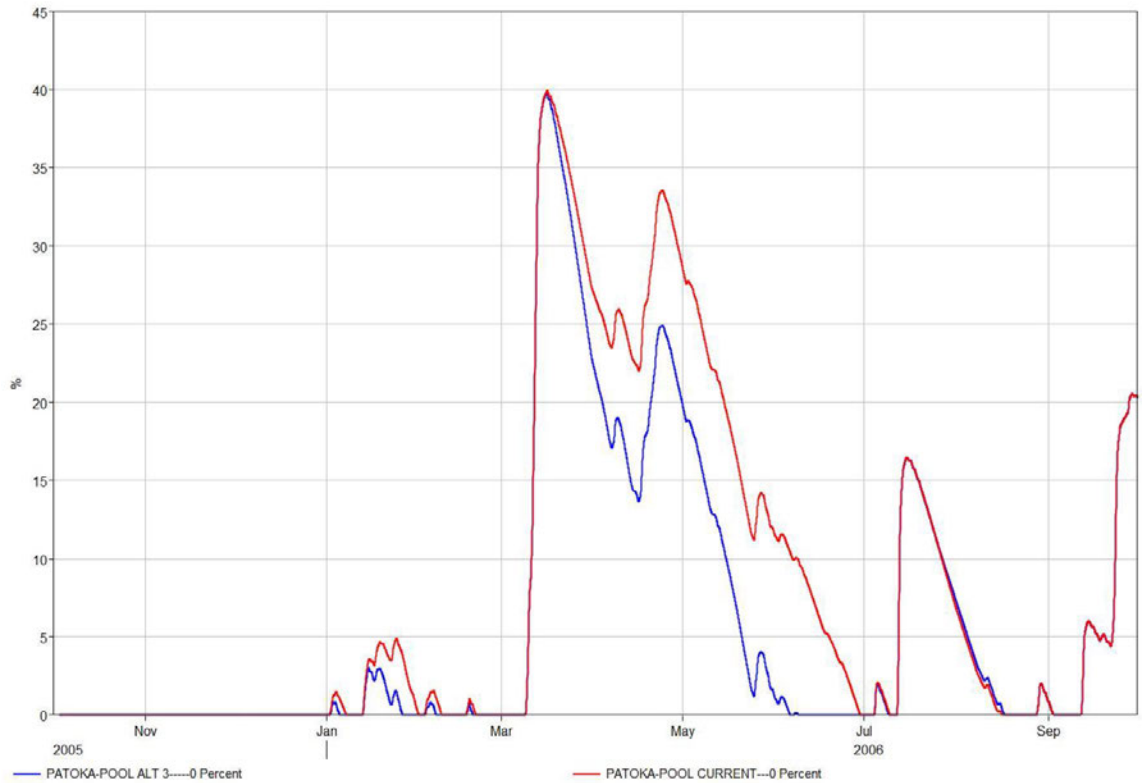


2020: Deviation to operate Jasper for 14' Jan-May. Lowered to winter pool early due to La Nina/wet winter forecast.

Modeling simulations for Patoka's Current Operations as well as 12 alternatives (see section "Alternatives Evaluated" in the Patoka Engineering Report) were performed from WY 2006 through 2020, resulting in storage utilization relationships. Though a total of 12 alternative operations were modeled, only one emerged as a realistic option. Alternative 3, combining the Current winter pool of 532 feet with operating Jasper for 13' during non-crop season, proved to lower peak pool elevations and storage utilization while resulting in minimal risk downstream. The other 11 alternatives were ruled out due to the lack of impact on peak pool elevations and/or storage utilization or the fact that the operational changes increased the risk of flooding downstream, outweighing any benefit.

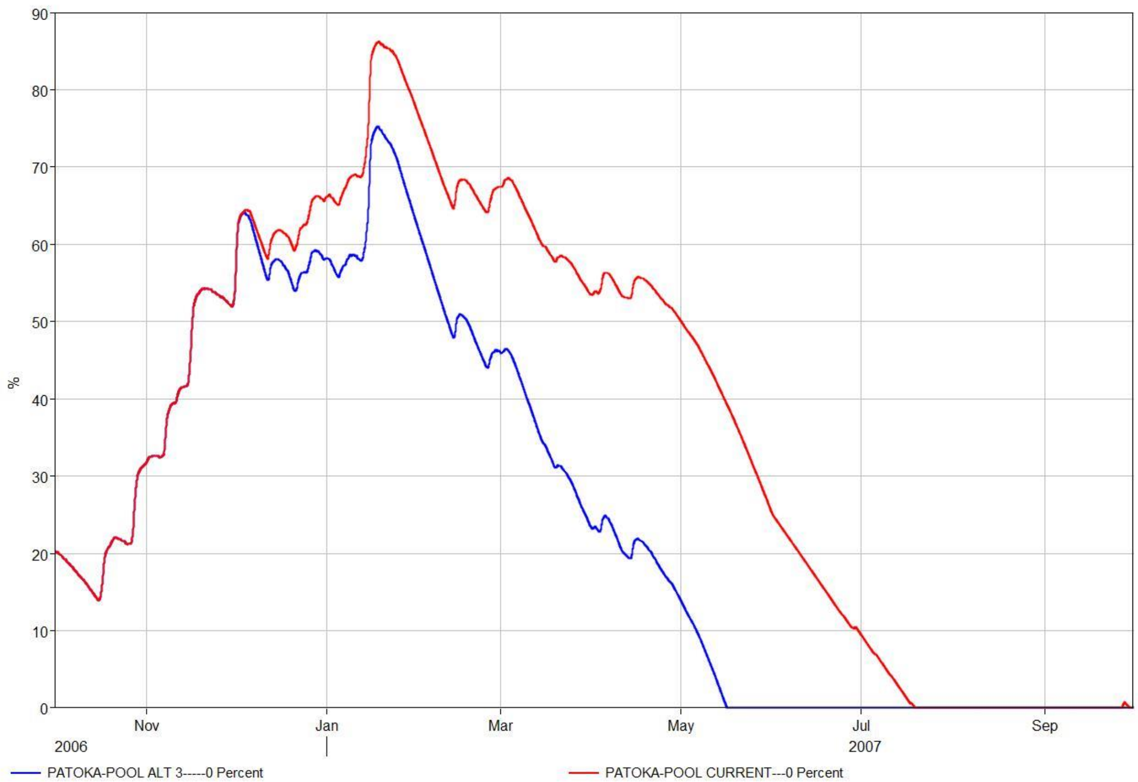
Storage Utilization Comparison:

Below are year by year plots of storage utilization to show the impacts between the Current Simulated Operations and Alternative 3, operating Jasper for 13' during non-crop season.



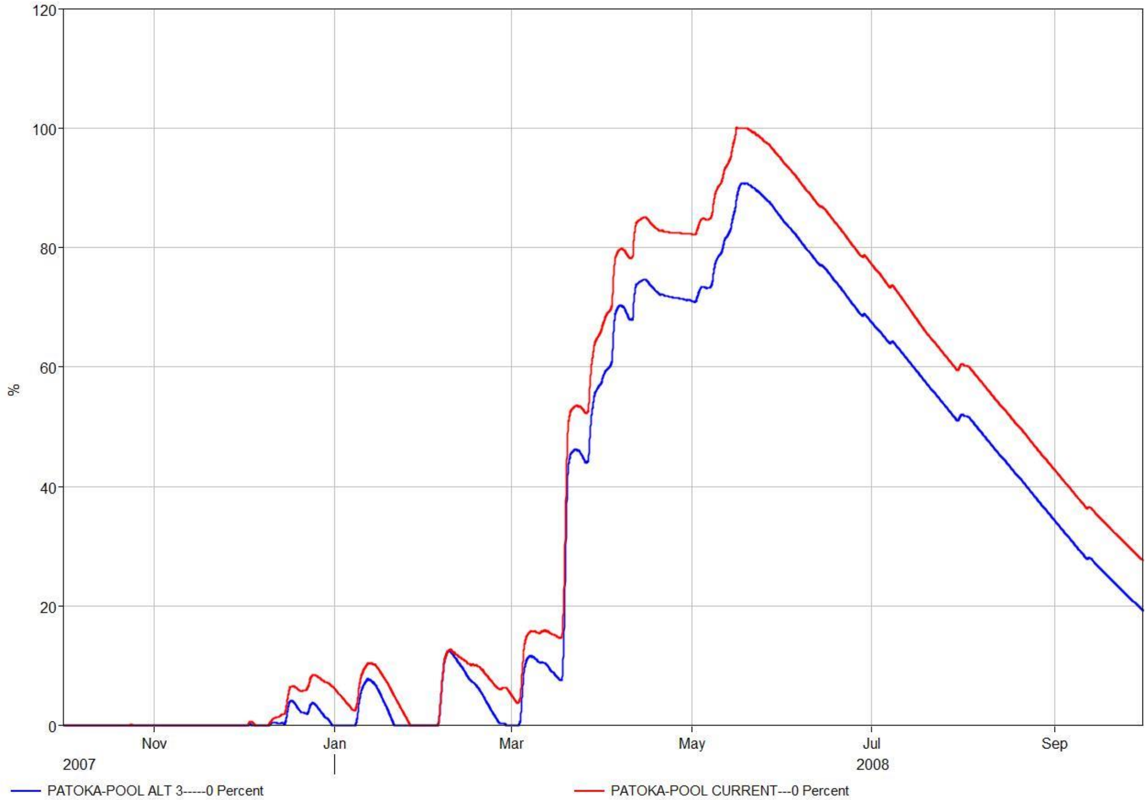
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

Operating Jasper for 13’ has a big impact, drawing the pool down faster after a rain event before crop season starts.



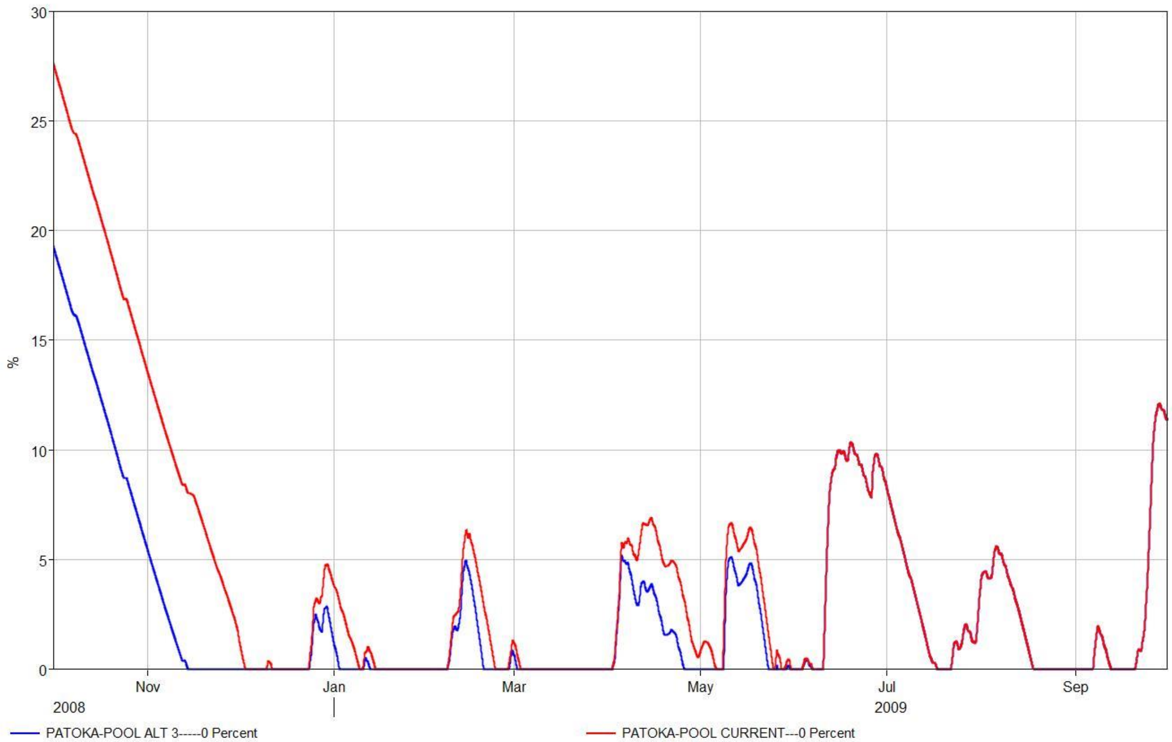
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Operating Jasper for 13’ during non-crop season allowed the pool to be drawn down faster, resulting in significantly less percent utilized when entering crop season.



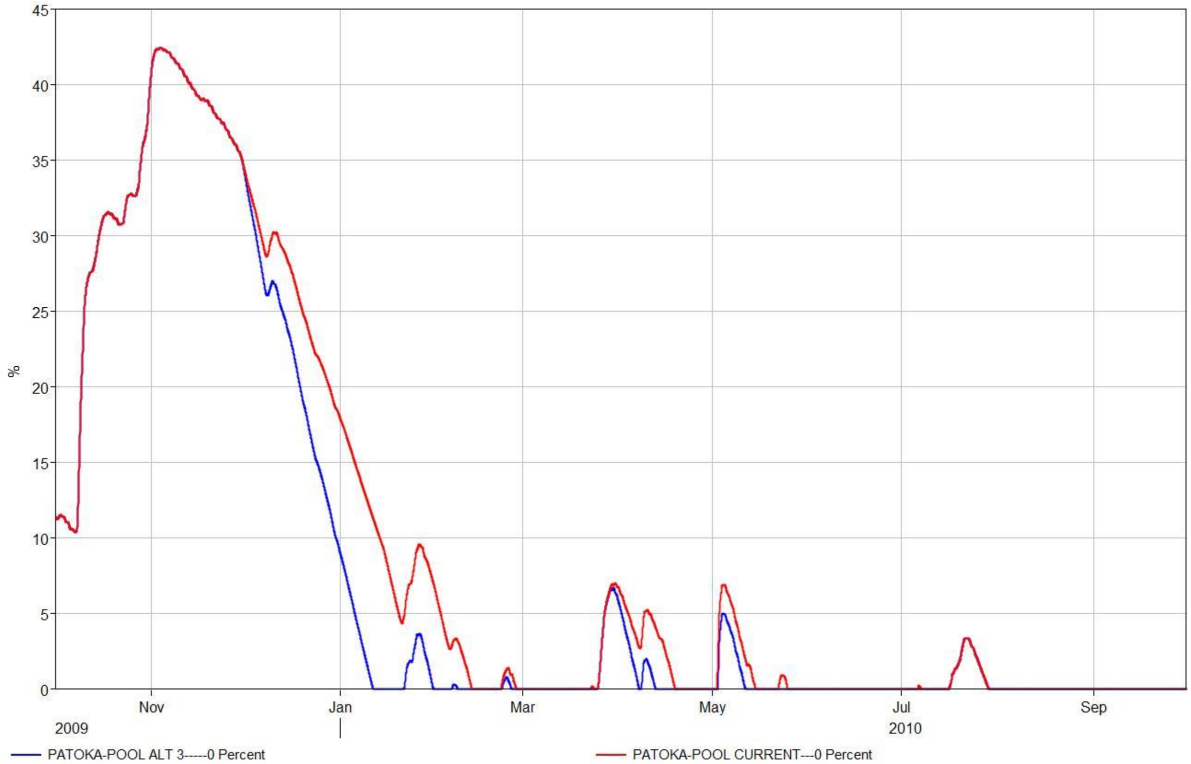
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- Operating Jasper for 13' during non-crop season resulted in less of an improvement this year because the rain events occurred into crop season when Jasper is operated for 9'.



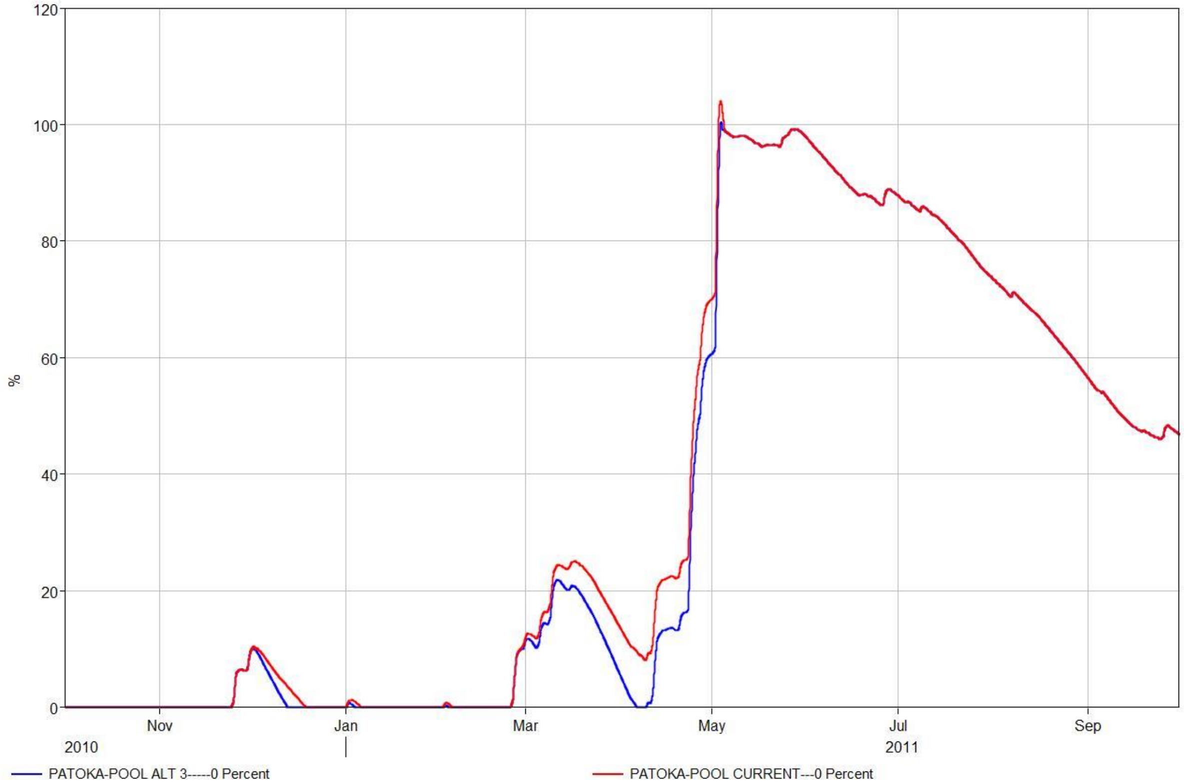
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- No significant events.



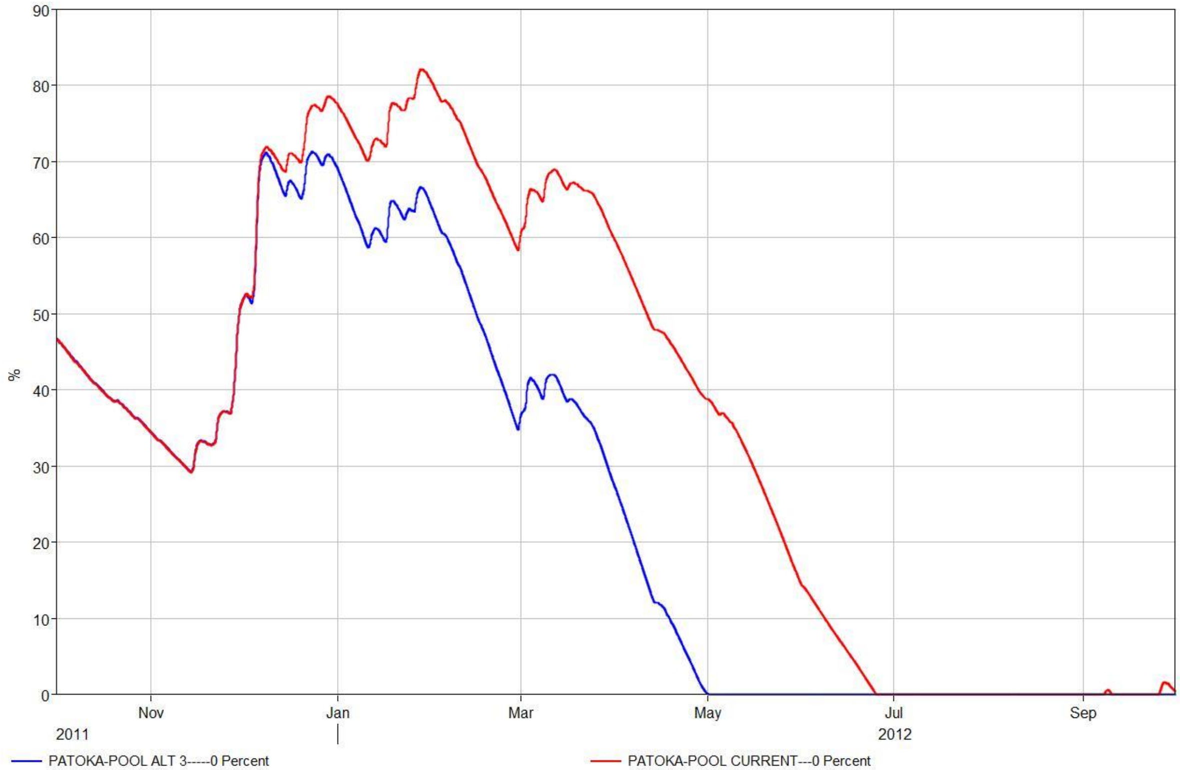
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Operating Jasper for 13’ during non-crop season resulted in quicker drawdown and less percent utilized for the remainder of non-crop season.



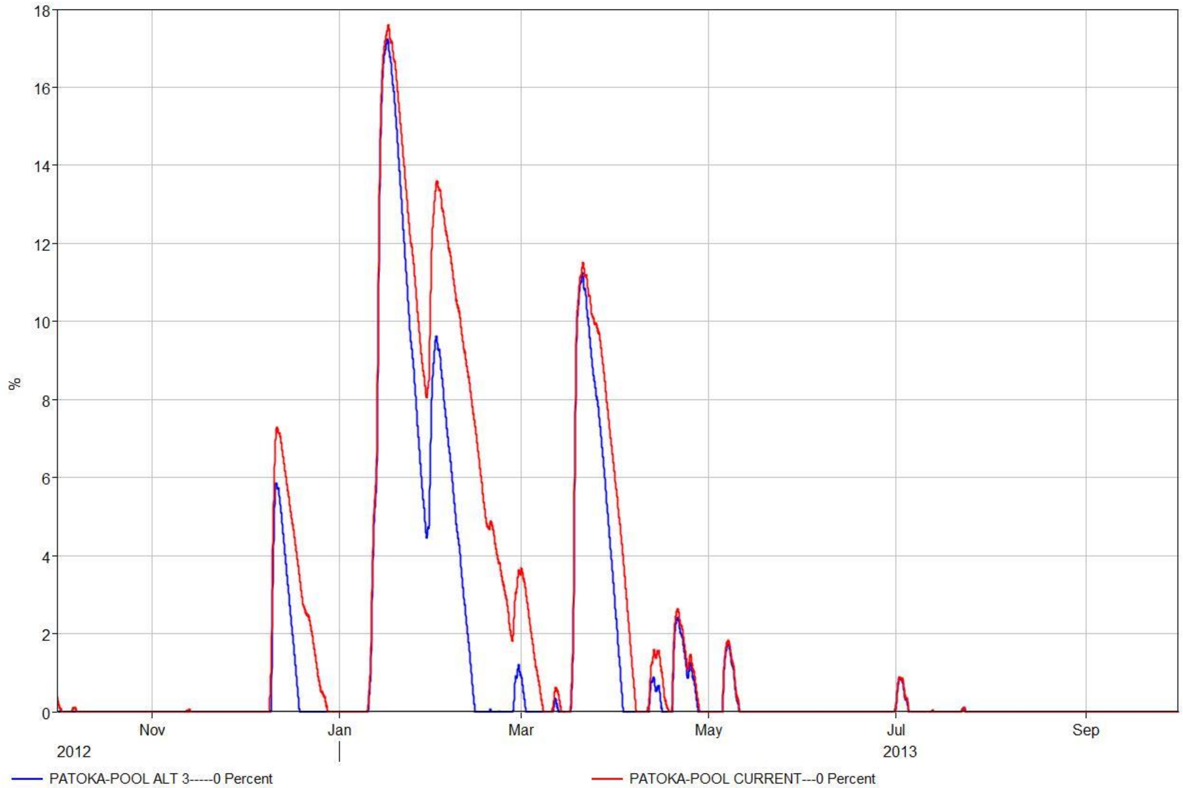
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Due to the heavy rain occurring early in crop season, there is no difference because Jasper is operated for 9’.



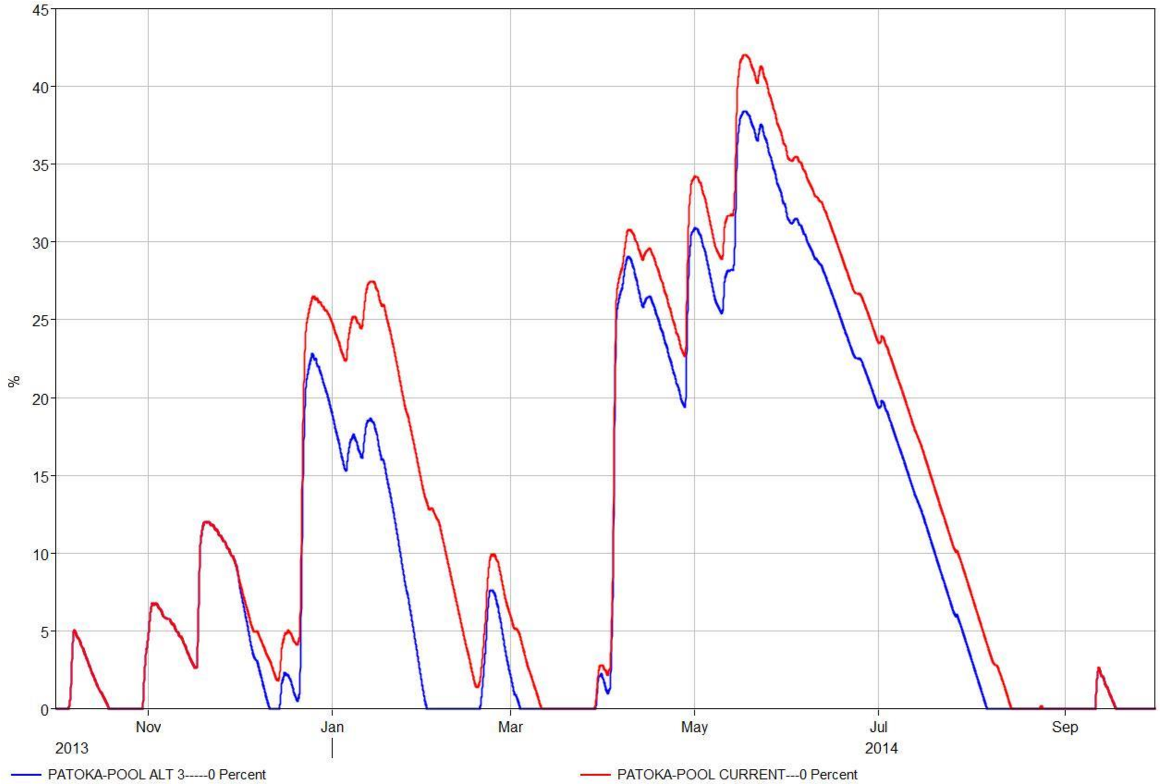
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- There is a cumulative effect by operating Jasper for 13' during the non-crop season months, lowering the percent utilization going into crop season.



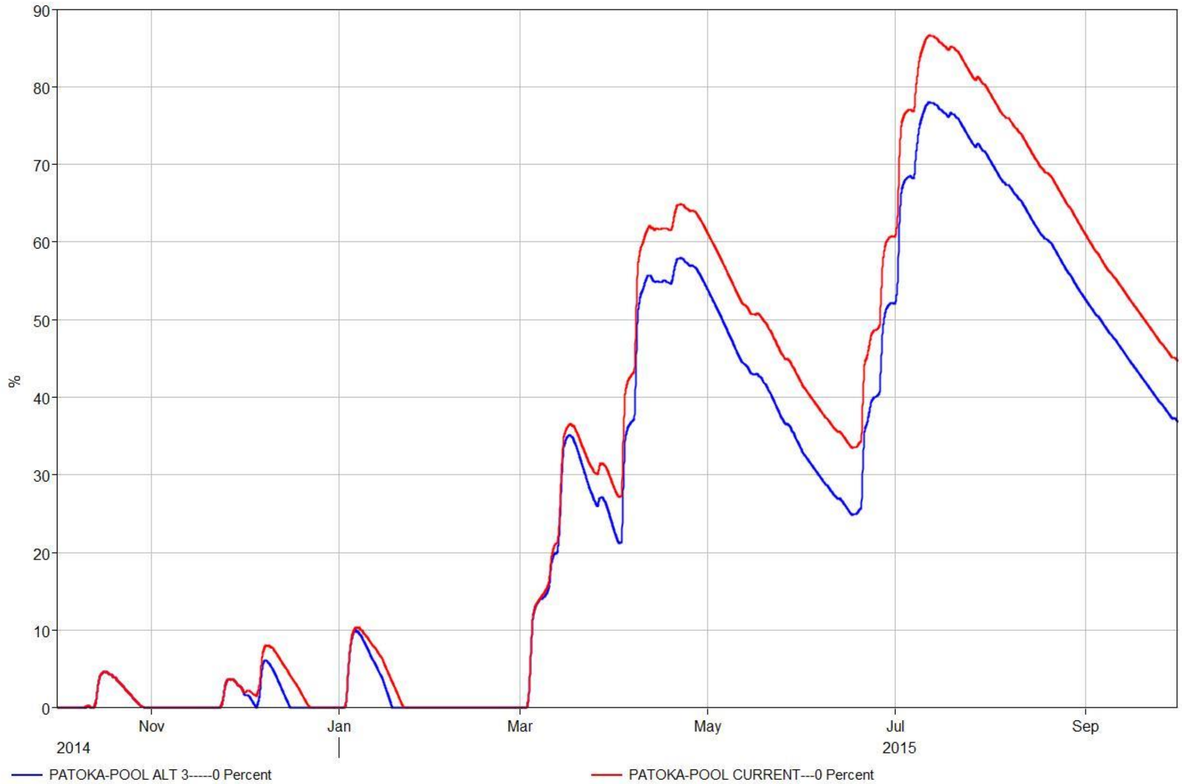
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- No significant events.



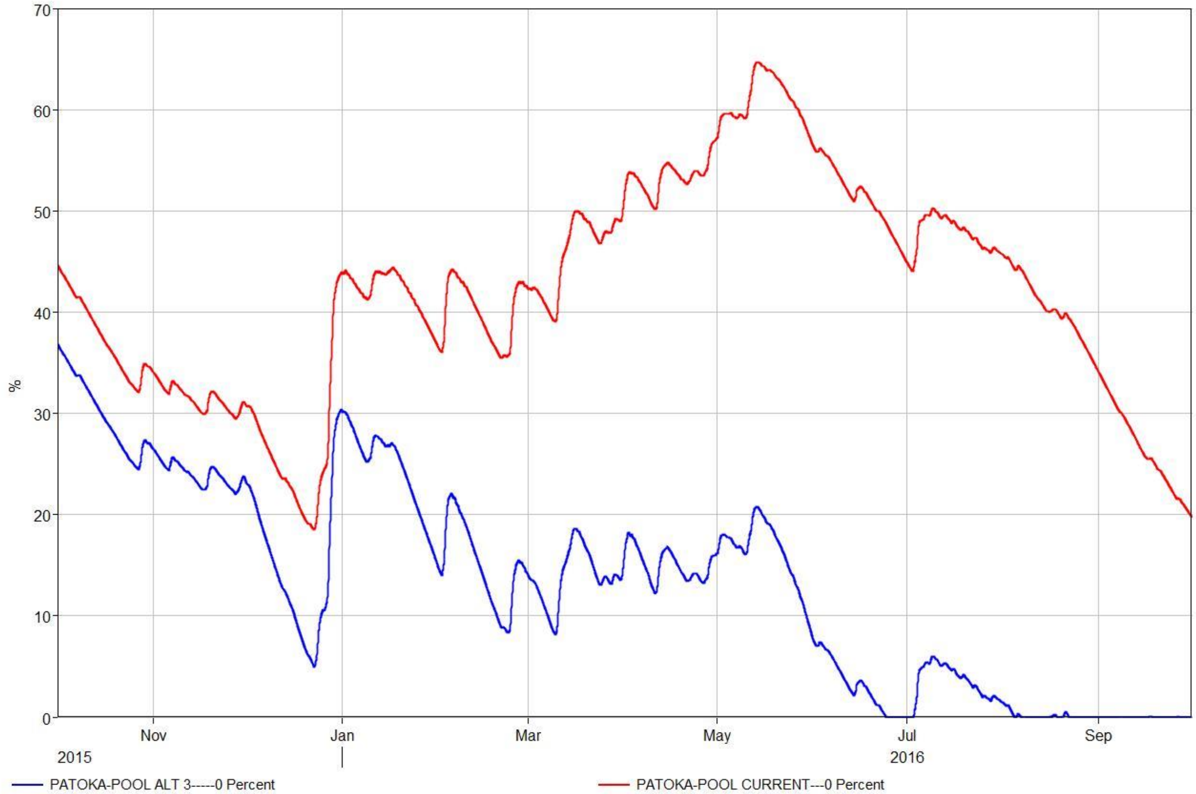
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Operating Jasper for 13’ during non-crop season lowers the percent utilization by the start of crop season.



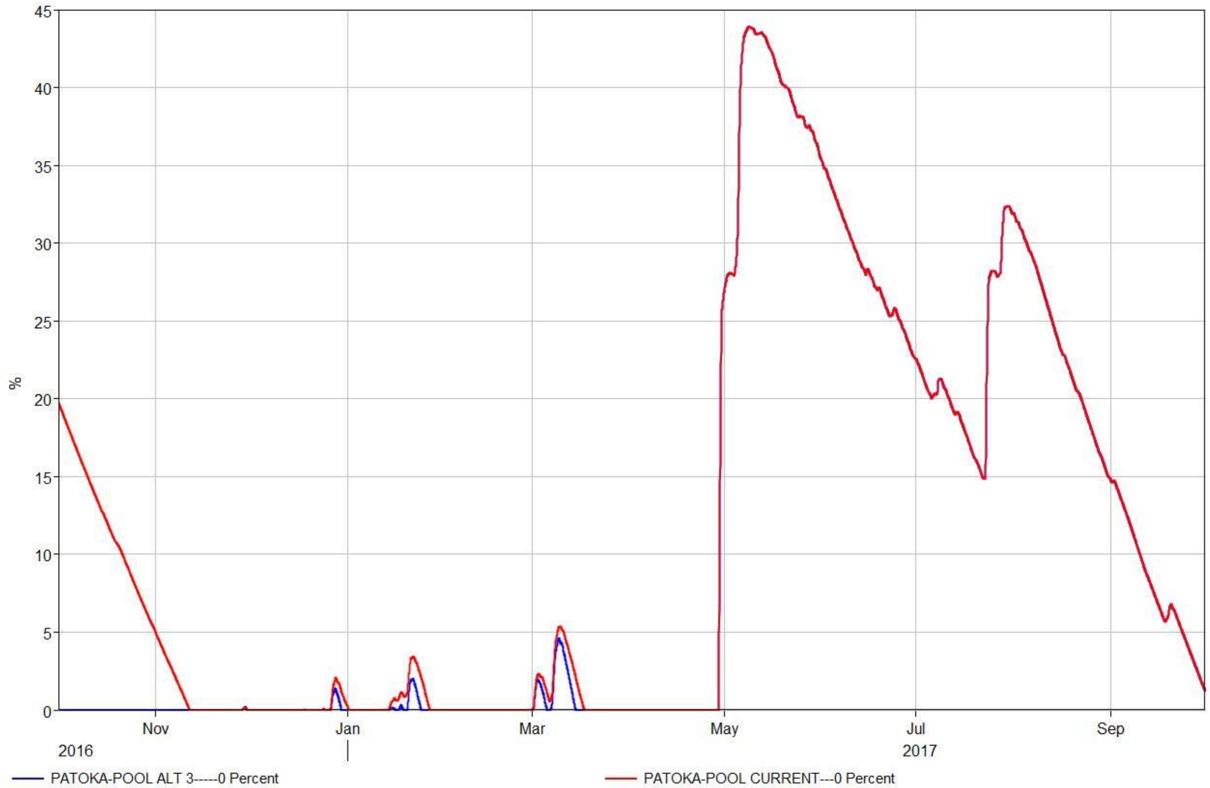
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Operating Jasper for 13’ during non-crop season resulted in less of an improvement this year because the rain events occurred into crop season when Jasper is operated for 9’.



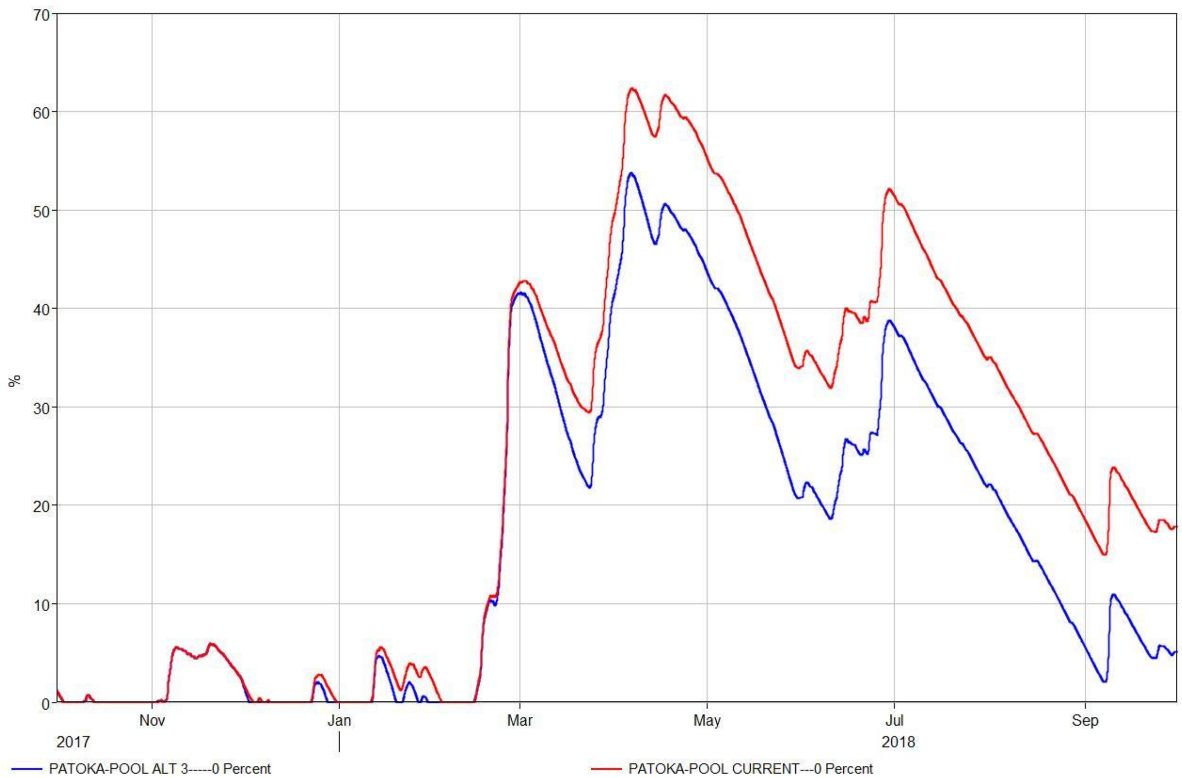
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- Operating Jasper for 13' during non-crop season reduced percent utilization significantly in December, allowing much less flood control storage to be utilized the rest of the year.



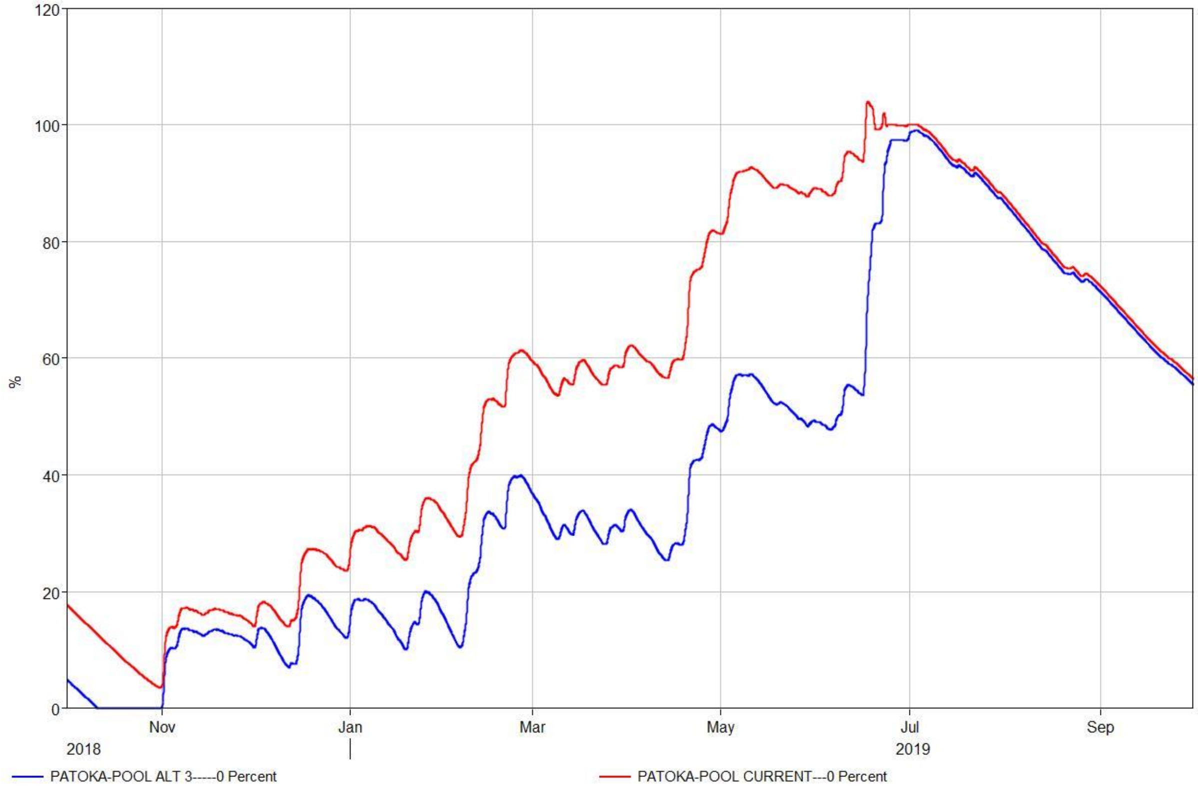
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- Operating Jasper for 13' during non-crop season resulted in no improvement this year because the heavy rain events occurred during crop season when Jasper is operated for 9'.



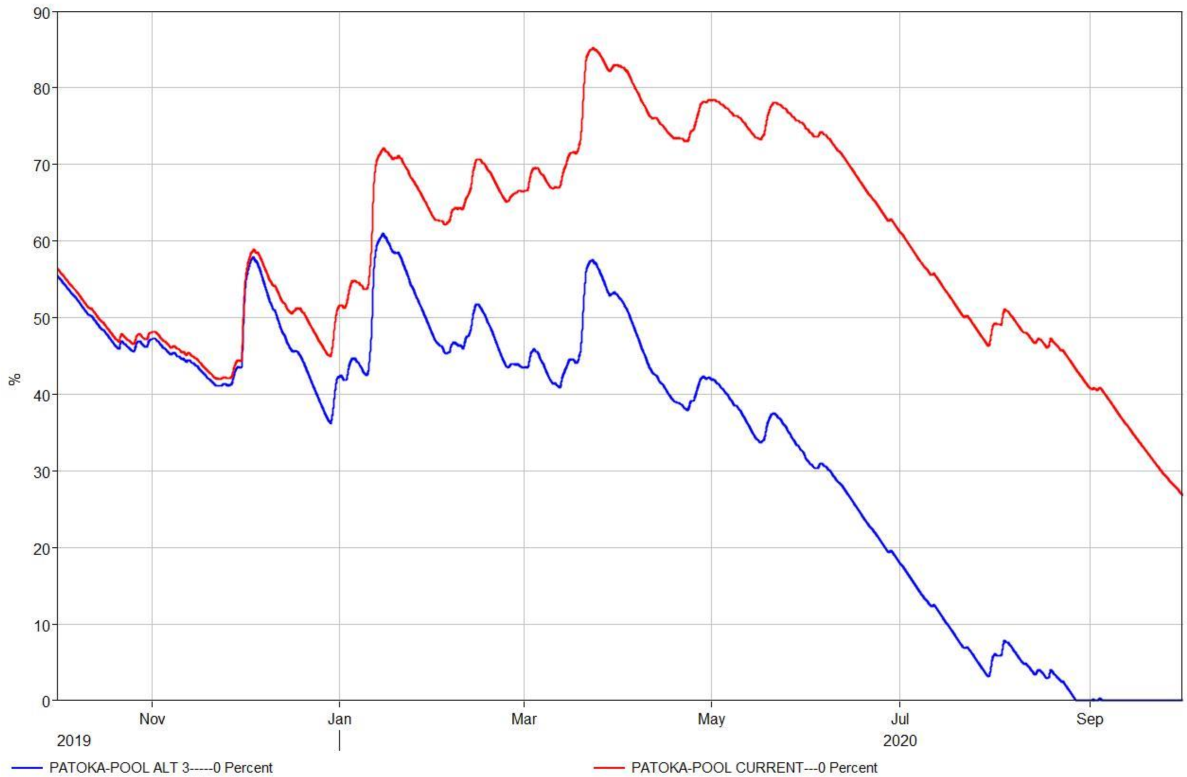
Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- Operating Jasper for 13' during non-crop season resulted in less of an improvement this year because the rain events occurred right before and during crop season.



Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13’ (Alternative 3)

- Operating Jasper for 13’ during non-crop season allowed for lower percent utilization in the spring, keeping the pool below spillway crest in late June. There is no difference in operation after the crest because it occurred during crop season.



Red Line: Current Simulated Operations with Winter Pool=532
Blue Line: Winter Pool=532 and Jasper=13' (Alternative 3)

- There is a cumulative effect of operating Jasper for 13' during non-crop season, lowering the percent utilization going into crop season.

Peak Pool Elevations:

Water Year	WP=532 ("Current Simulated Operations")			WP=532 and Jasper at 13' ("Alternative 3")		
	Date	Peak Elev	Crop or Non-Crop Season	Date	Peak Elev	Crop or Non-Crop Season
2006	3/16/2006	539.1	Non-Crop	3/16/2006	539.0	Non-Crop
2007	1/18/2007	546.1	Non-Crop	1/18/2007	544.5	Non-Crop
2008	5/16/2008	548.0	Crop	5/18/2008	546.9	Crop
2009	10/1/2008	539.5	Crop	10/1/2008	538.4	Crop
2010	11/4/2009	541.1	Crop	11/4/2009	541.1	Crop
2011	5/3/2011	548.4	Crop	5/3/2011	548.0	Crop
2012	1/28/2012	545.5	Non-Crop	12/8/2011	544.5	Non-Crop[1]
2013	7/2/2013	536.1	Crop	7/2/2013	536.1	Crop
2014	5/23/2014	540.9	Crop	5/23/2014	540.5	Crop
2015	7/12/2015	546.6	Crop	7/12/2015	545.6	Crop
2016	5/14/2016	543.7	Crop	10/1/2015	540.7	Crop[2]
2017	5/14/2017	540.8	Crop	5/14/2017	540.8	Crop
2018	6/29/2018	542.6	Crop	4/6/2018	541.3	Non-Crop[3]
2019	6/17/2019	548.3	Crop	7/3/2019	547.9	Crop[4]
2020	3/23/2020	545.9	Non-Crop	10/1/2019	542.9	Crop[5]

[1] In WY2012, the peak elevation for Alternative 3 occurred at an earlier date because the pool was drawn down faster by operating Jasper for 13' during non-crop season.

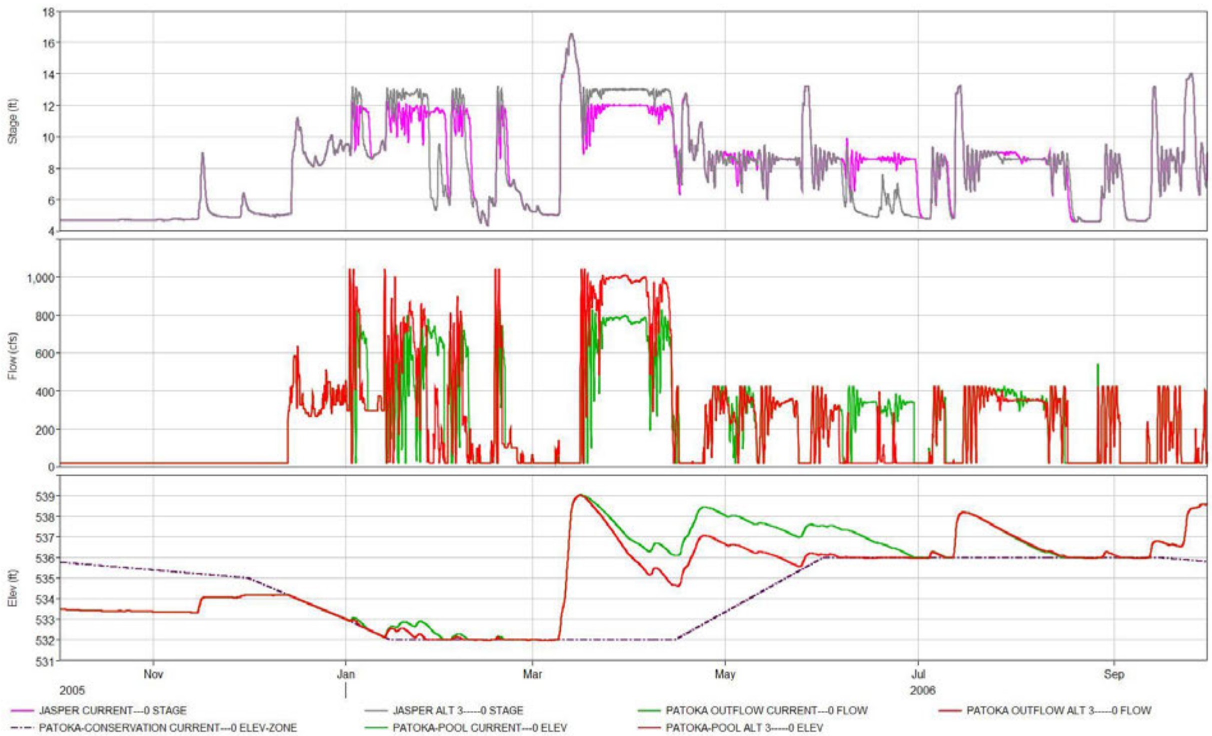
[2] In WY2016, during non-crop season of 2015/2016 with the Alternative 3 operations the pool was drawn down significantly more than the Current Simulated Operations, therefore the peak from the spring rain events resulted in a much lower peak at a different time of year.

[3] In WY2018, the April 2018 event and the late June 2018 events were very close to the same elevation for Current Simulated Operations and Alternative 3. It just happens that the peak for Current Simulated Operations occurred in June, where the peak for Alternative 3 occurred in April.

[4] In WY2019, due to operating Jasper for 13' during the non-crop season of 2018/2019, the pool was drawn down quicker over the winter which allowed the pool to be lower when the spring and summer rain events occurred. This operation kept the pool from reaching spillway crest, where the Current Simulated Operations reached spillway and produced a peak elevation that occurred slightly earlier than the Alternative 3 operation.

[5] In WY2020, during non-crop season of 2019/2020 with the Alternative 3 operation the pool was drawn down significantly more than the Current Simulated Operations, therefore the peak from the spring rain events resulted in a much lower peak at a different time of year.

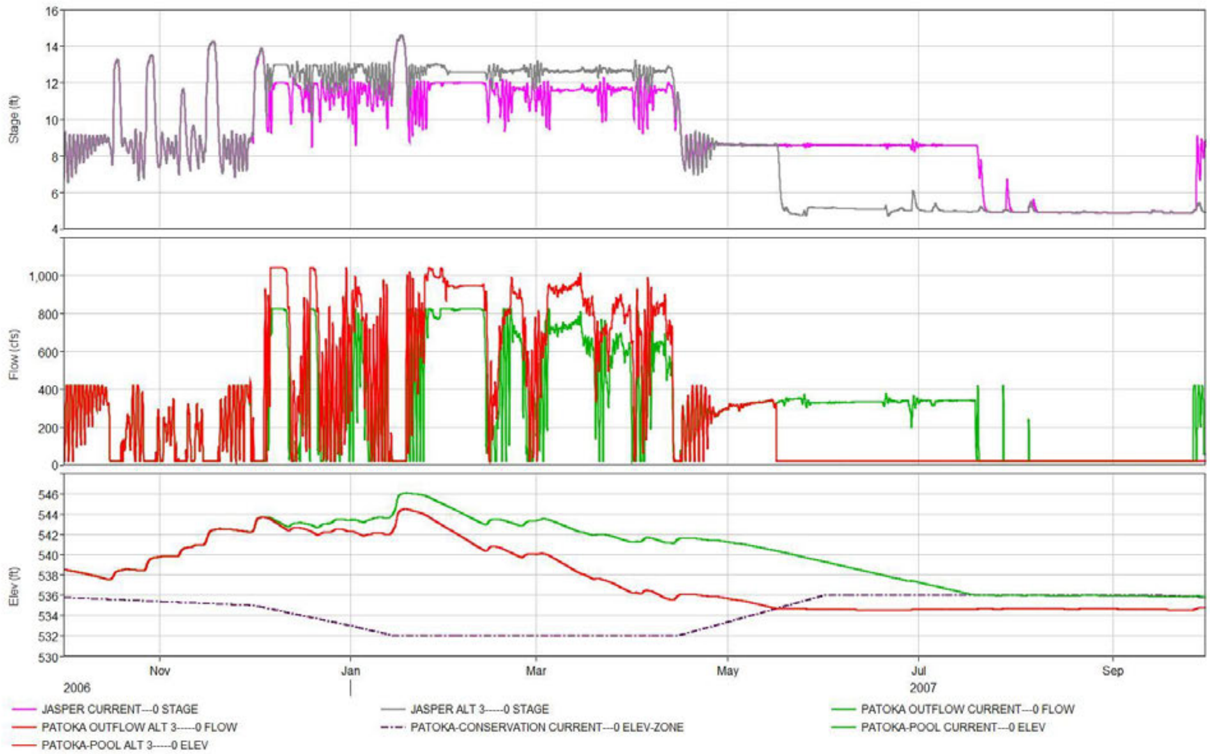
Below are year by year plots showing elevations and outflows, as well as resulting stages at Jasper for Current Simulated Operation and Alternative 3, operating Jasper for 13’ during non-crop season.



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

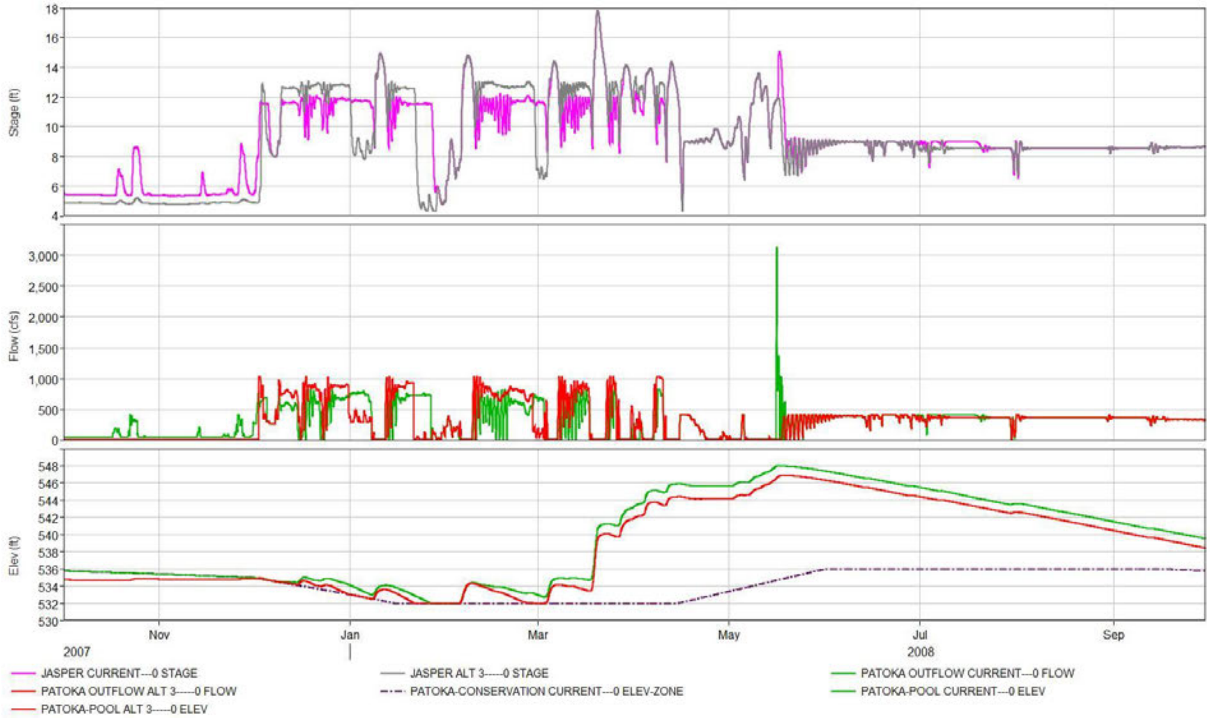
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

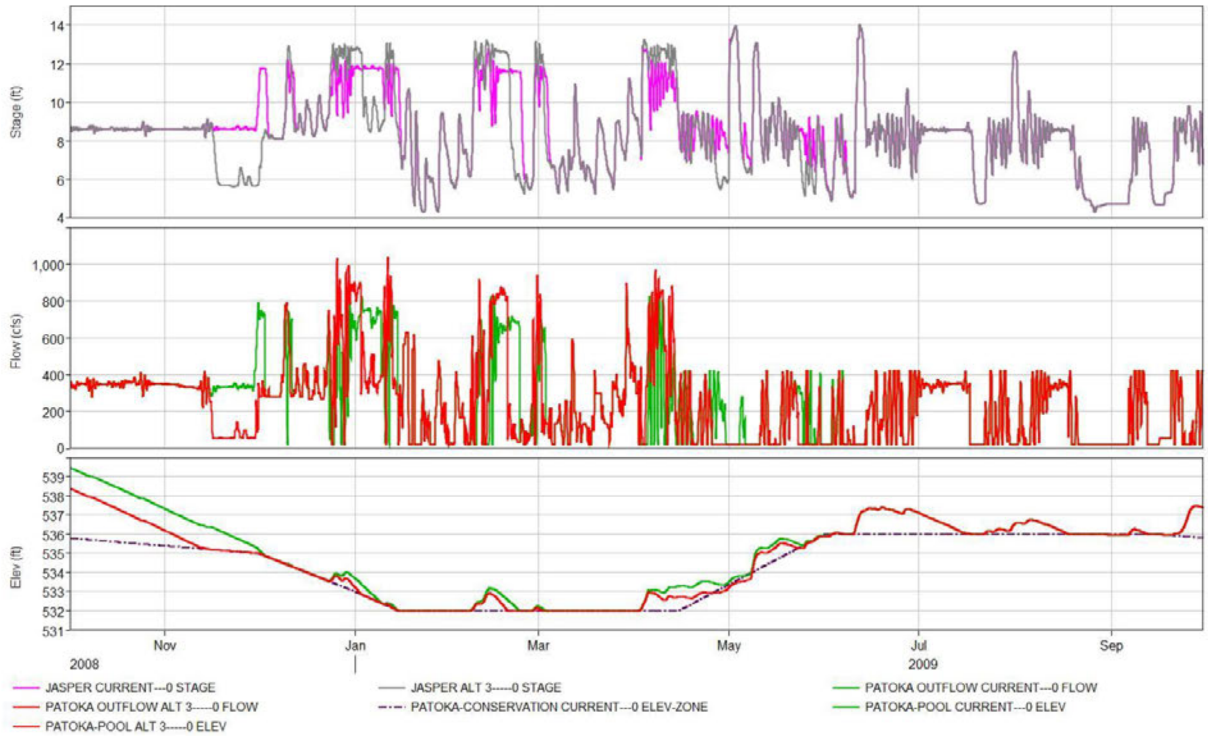
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

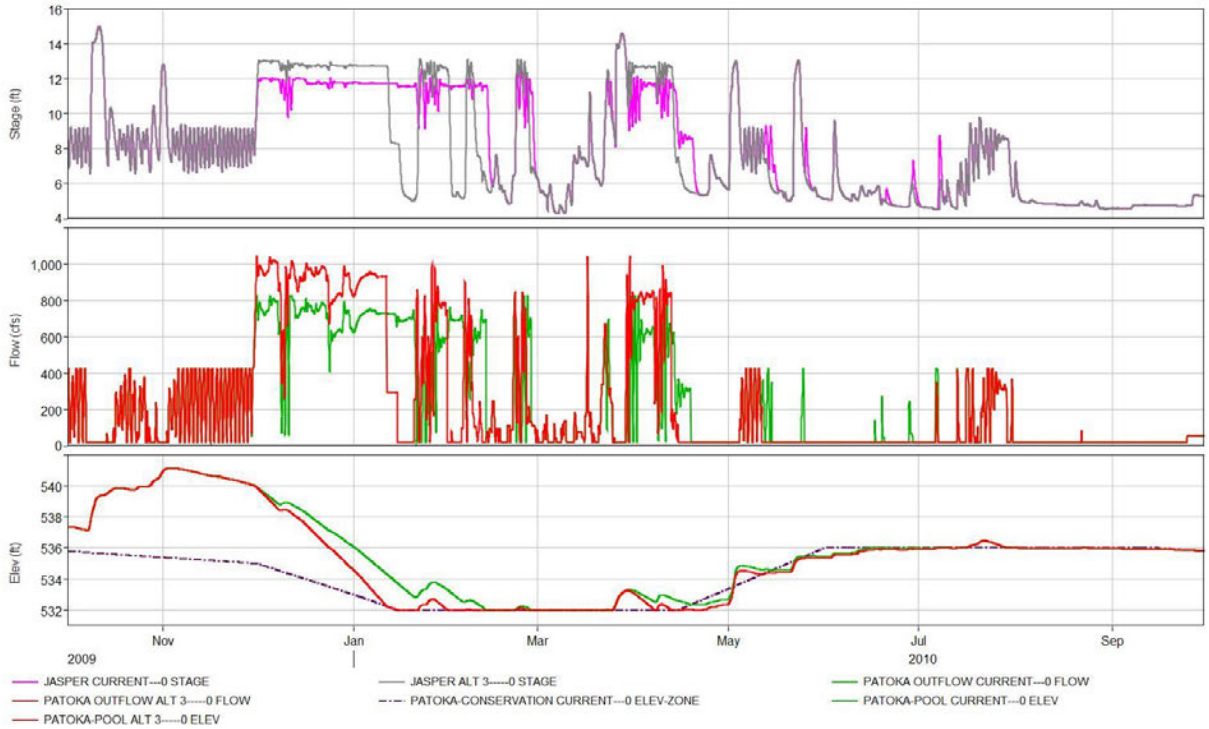
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

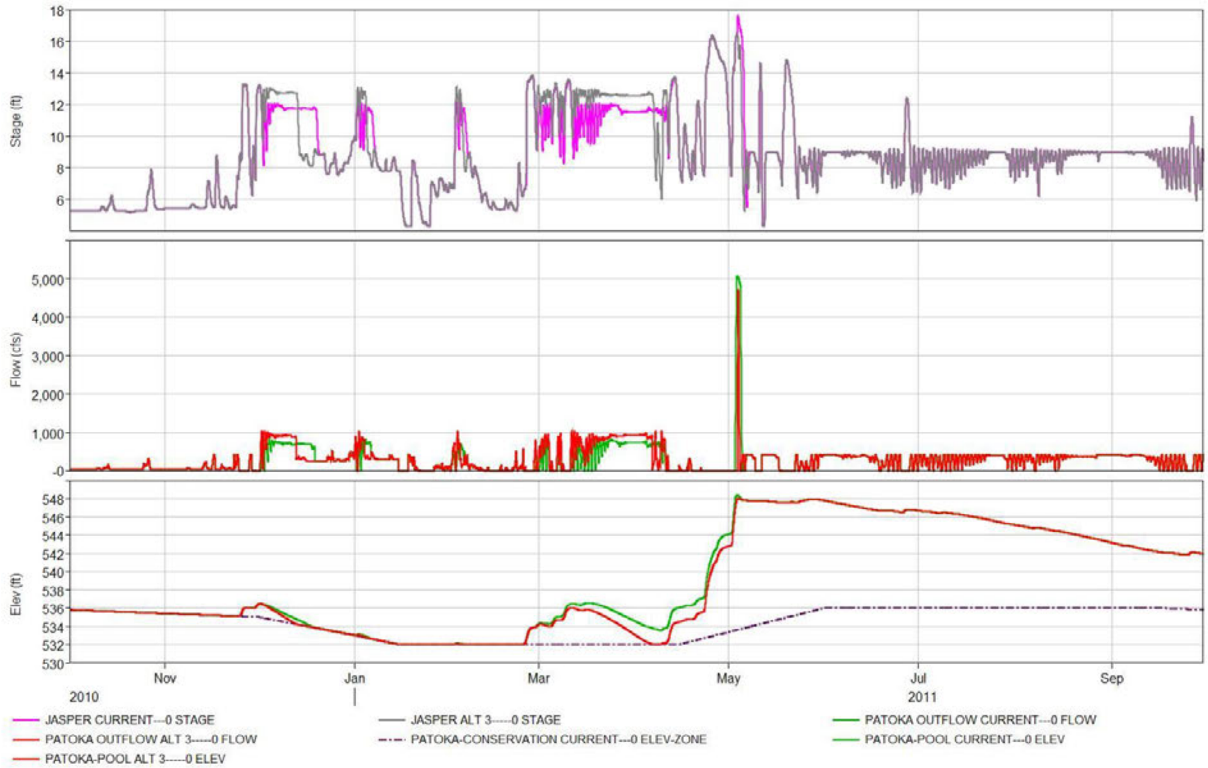
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

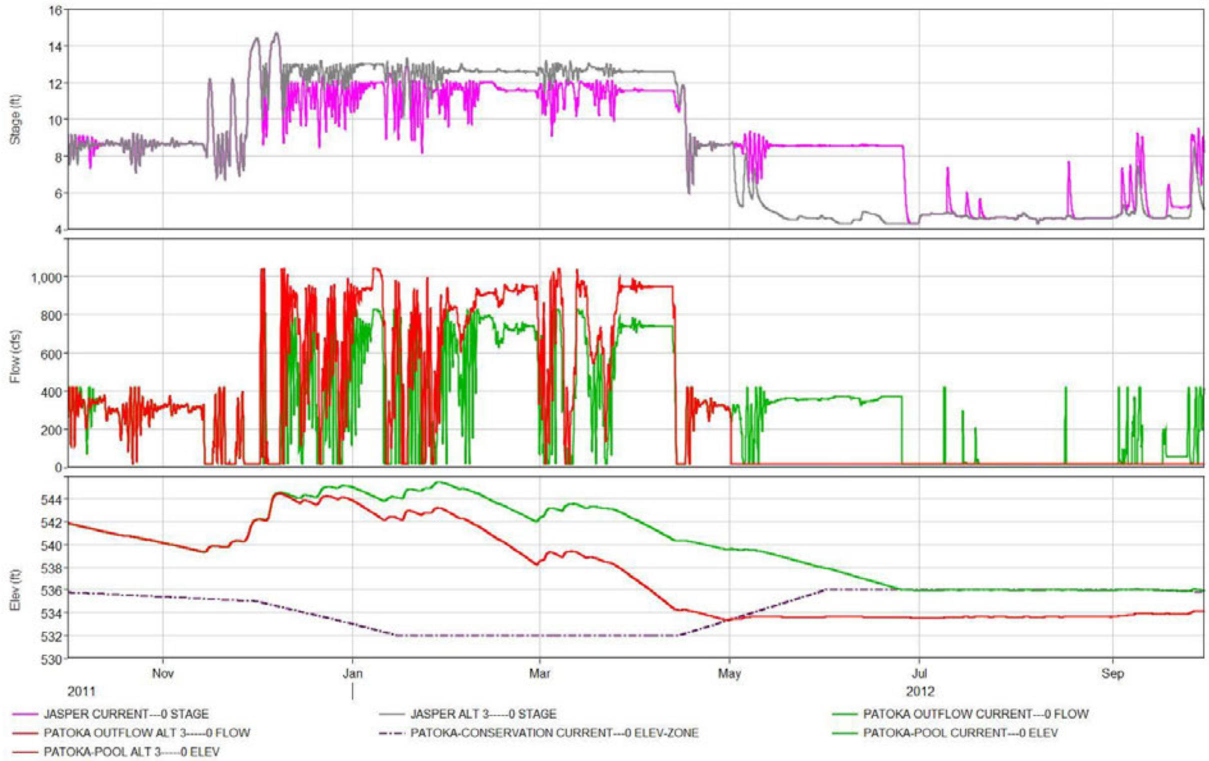
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

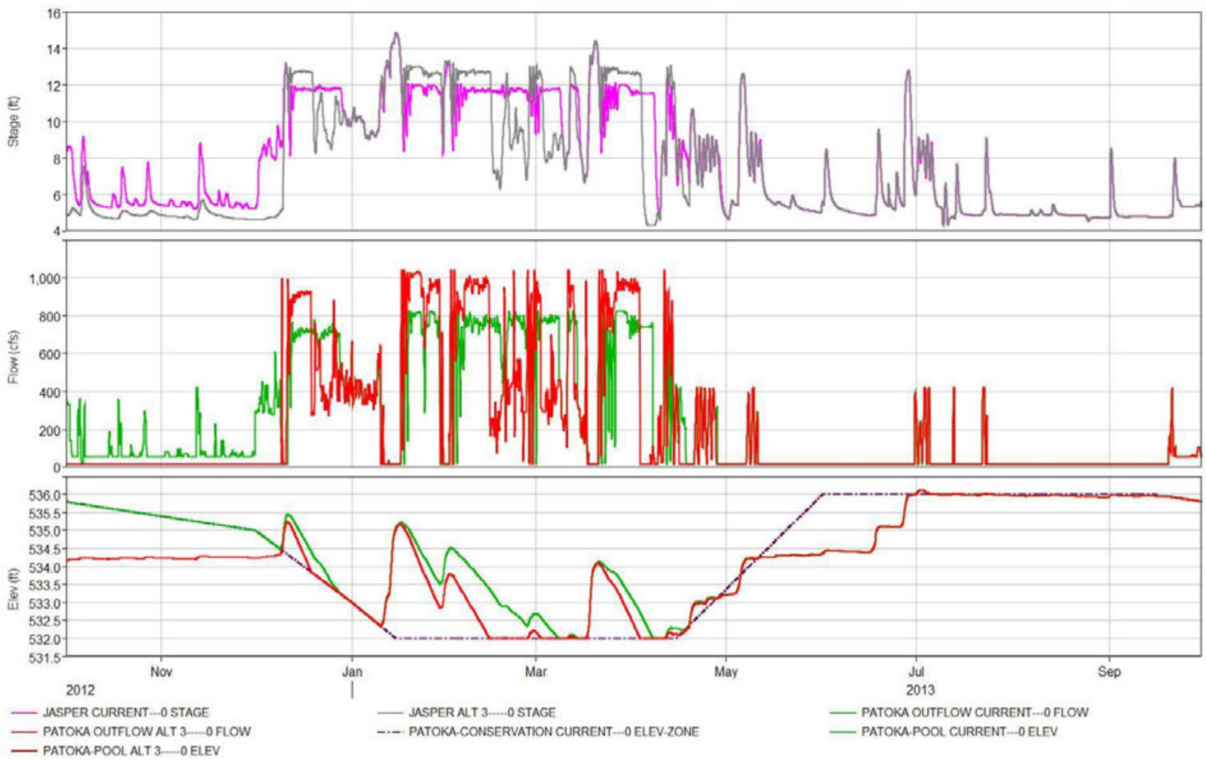
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

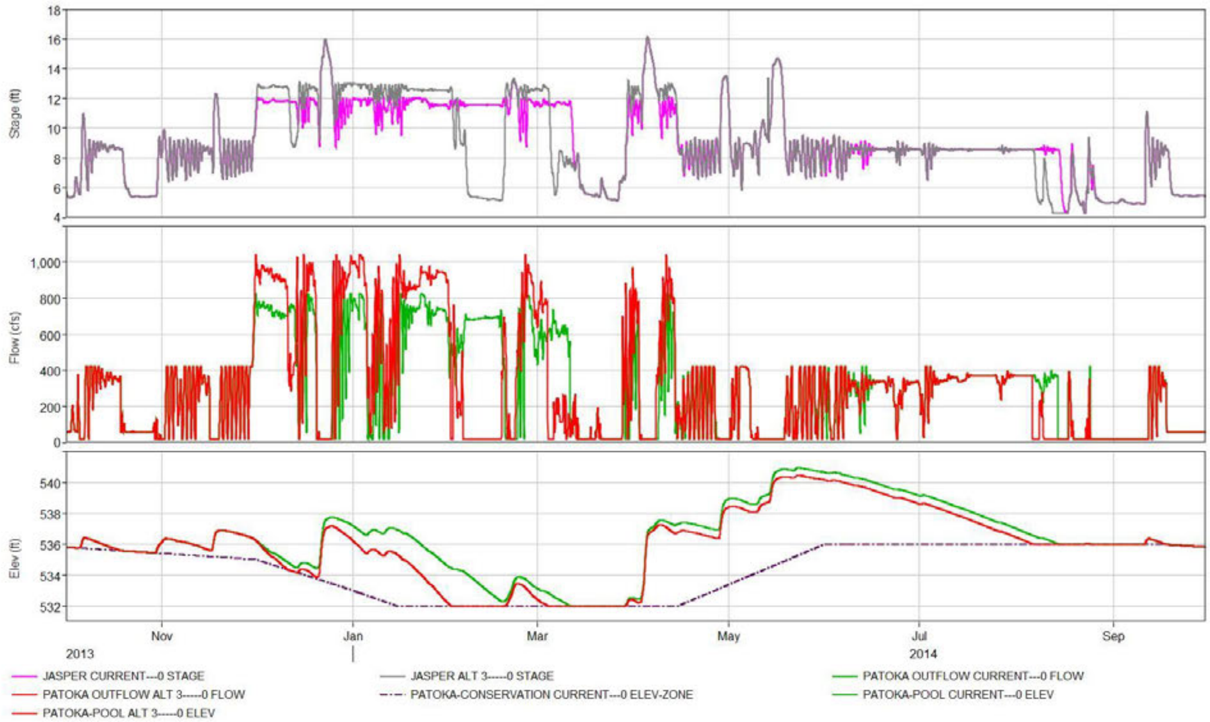
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

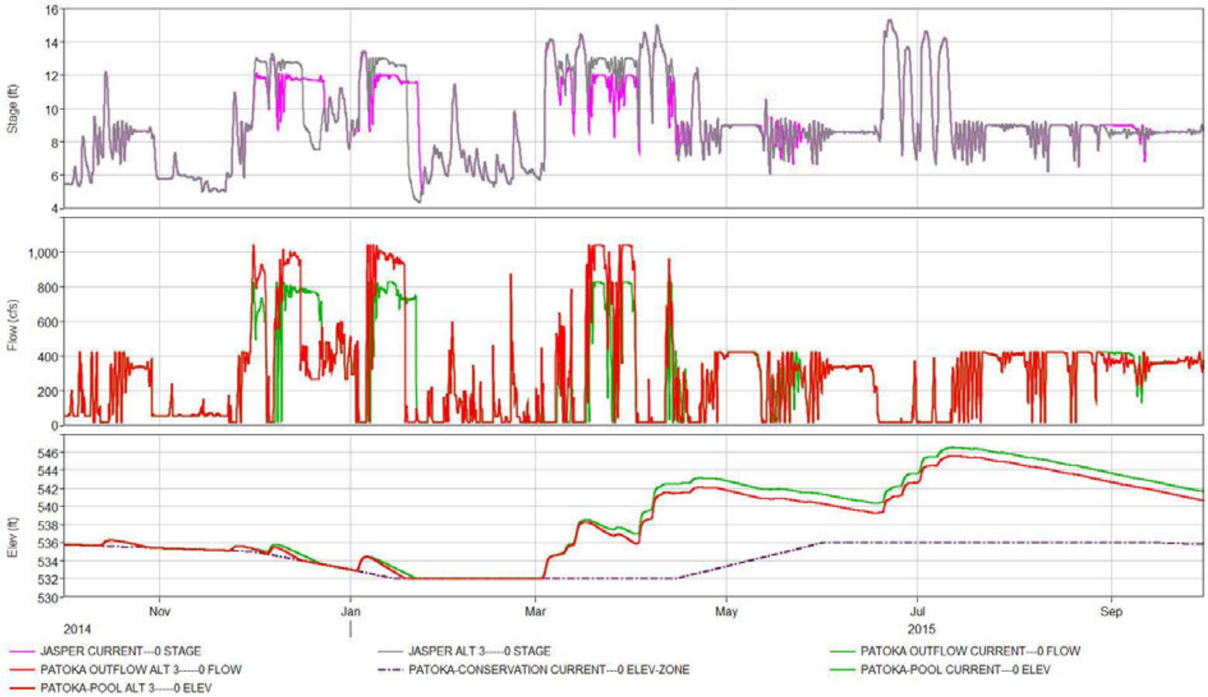
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

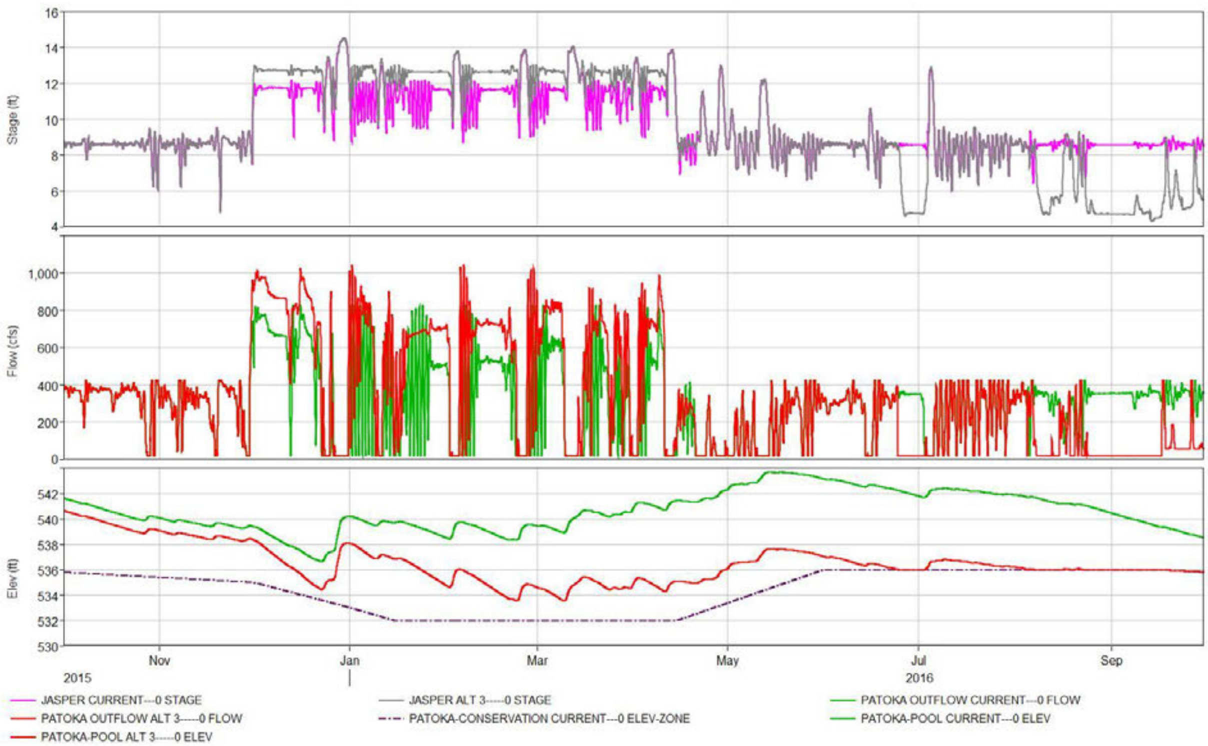
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

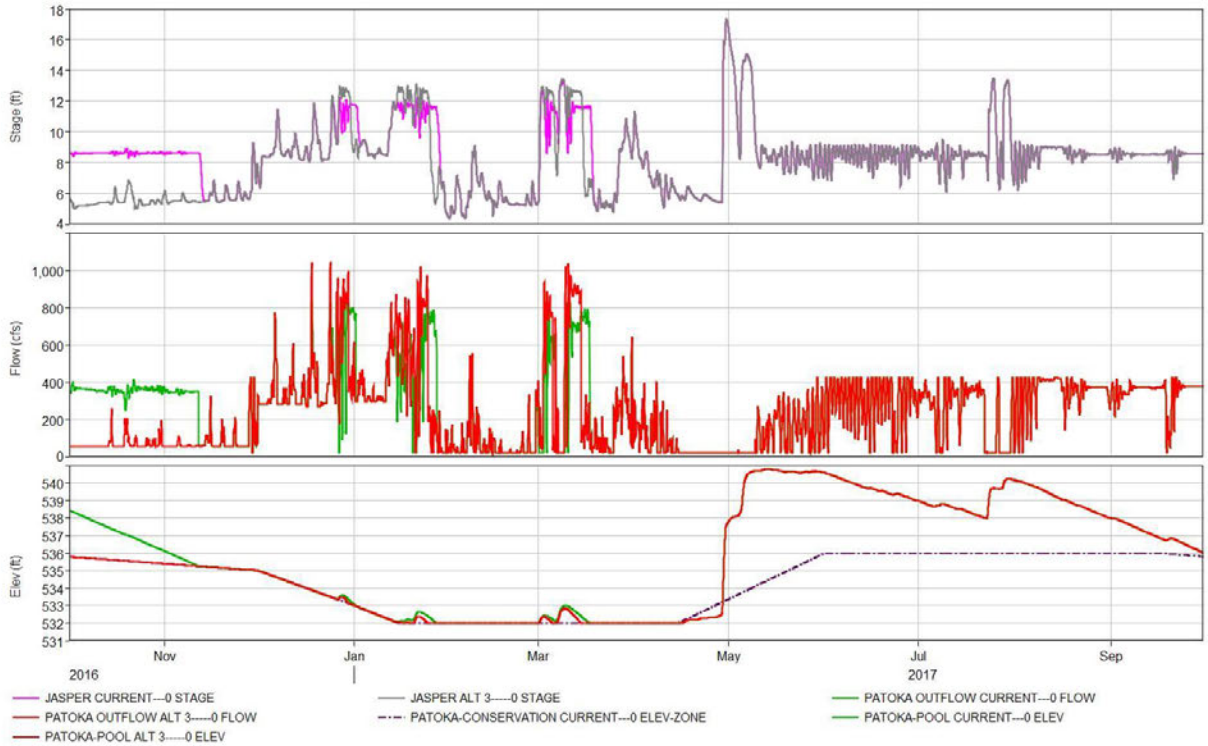
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

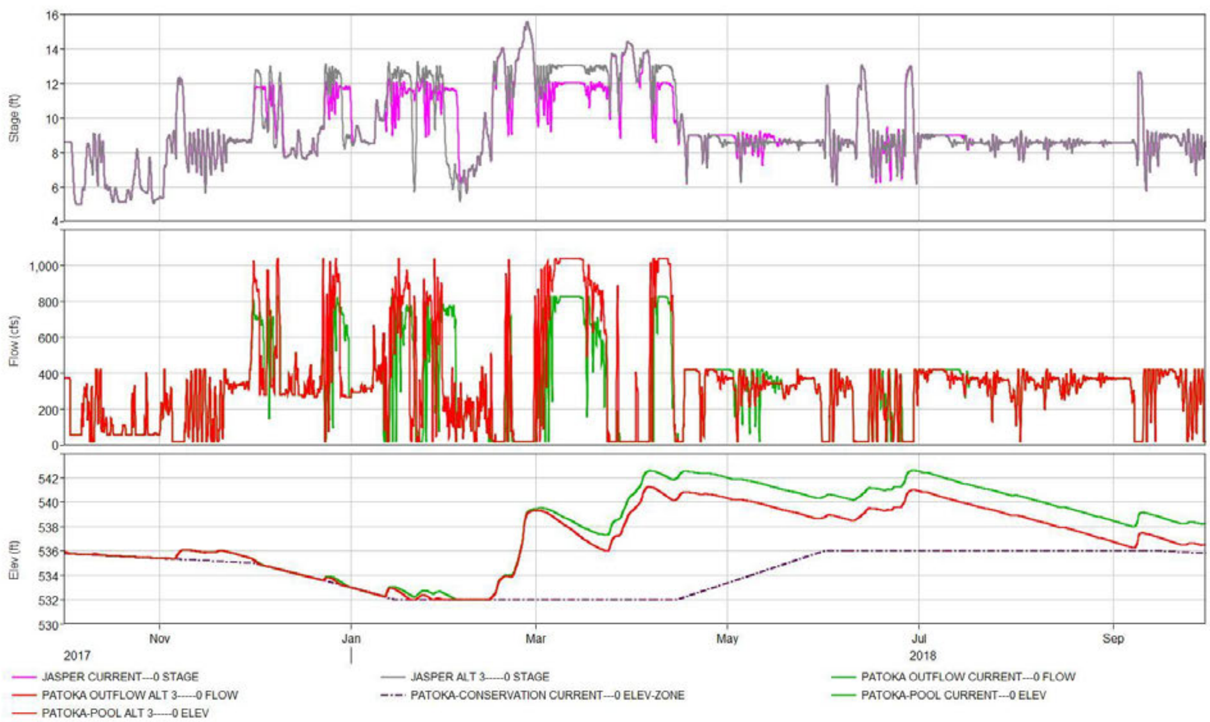
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

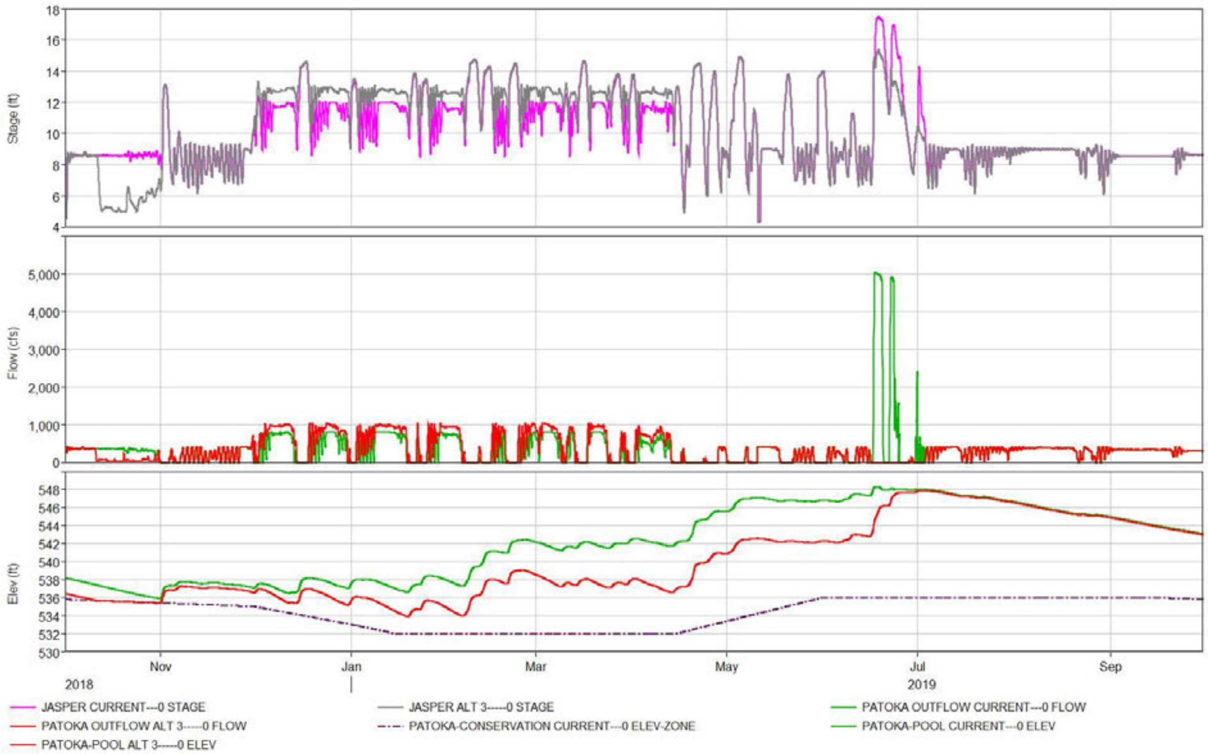
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

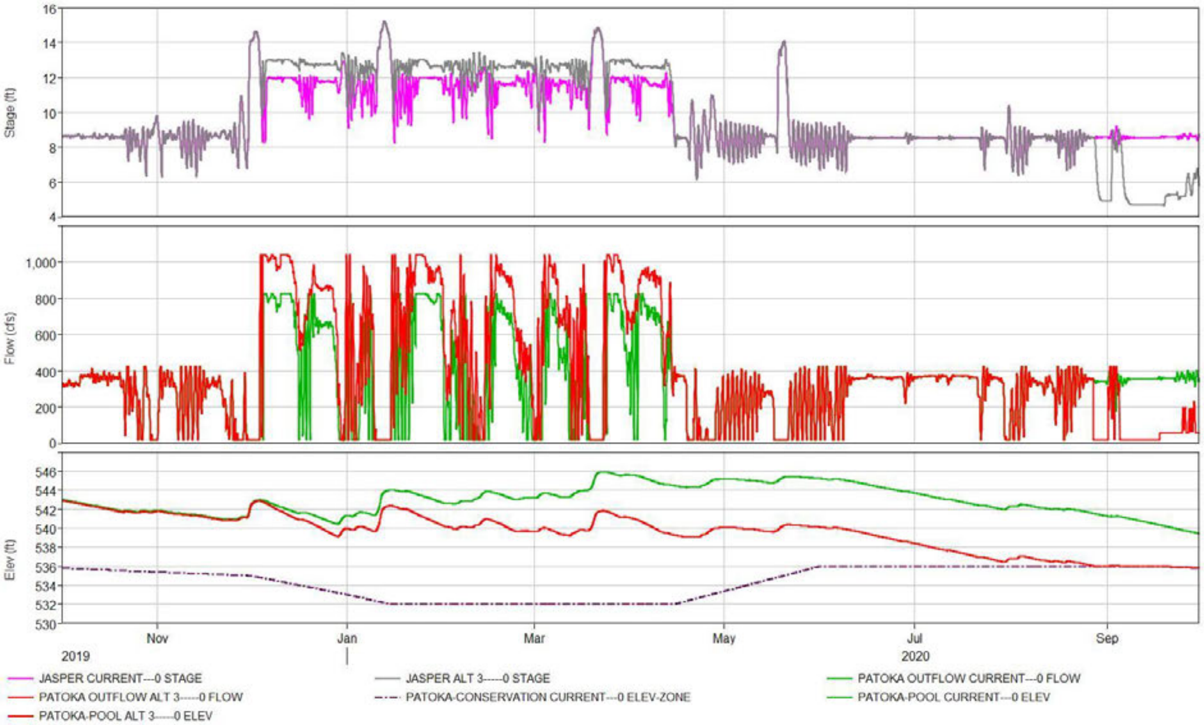
Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3



Jasper Stage:
Pink Line: Current Simulated Operations
Grey Line: Alternative 3

Patoka Dam Ouflow:
Green Line: Current Simulated Operations
Red Line: Alternative 3

Patoka Lake Pool Elevation:
Broken Purple Line: Guide Curve
Green Line: Current Simulated Operations
Red Line: Alternative 3

Prepared by/for:

Lakes and Rivers Division

Louisville District

Patoka Lake Dam Appendix C

NID: IN03018

Hydraulic Modeling Summary

Patoka River
(Dubois County, IN)

U.S. Army Corps of Engineers

June 2024

Controlled by: USACE LRL

[redacted]

CONTENTS

LIST OF TABLES

LIST OF FIGURES

THIS PAGE IS INTENTIONALLY BLANK.

Introduction

The purpose of this Hydraulic Model and report is to determine the increase in Water Surface Elevation (WSE) associated with increase in releases from Patoka Lake Dam for a given range of elevations. Flow and stage data is analyzed at the location of USGS 03375500, Patoka River at Jasper, IN.

The RAS model uses previous RAS models developed for CWMS, as well as a model developed by the USGS for the study area. Additionally, surveyed cross sections are utilized for channel development.

The model is developed in the North American Vertical Datum of 1988 (NAVD 88) and Albers Equal-Area horizontal map projection. Vertical datum may be shifted from a different datum (e.g., National Geodetic Vertical Datum of 1929 [NGVD 29] to NAVD 88), and the datum shift (in feet and decimal feet) will be recorded within this document. All elevations within this document are in NAVD 88.

SECTION 1
Project Description

1.1 GENERAL PROJECT INFORMATION

Patoka Lake Dam is located on the Patoka River at approximately 118 miles upstream from its confluence with the Wabash River at Mt. Carmel, Ill. The dam is in Dubois County, Indiana about 50 miles west of Louisville, Kentucky. The drainage area of the Patoka River Basin is approximately 862 square miles, about 170 square miles or about 19.5 percent of the basin is impounded by Patoka Lake Dam.

1.2 PERTINENT DATA

Table 1-1 lists pertinent project data for Patoka Lake Dam.

Table 1-1. Patoka Lake Dam Pertinent Project Data

Physical Data	
Dam Type	Rolled Earthfill
Dam Length (feet)	1,550
Top of Dam Elevation (feet)	563.62
Spillway Crest Elevation (feet)	547.62
Spillway Type	Uncontrolled
Spillway Width (feet)	370
Number of Spillway Gates (dimensions (feet))	N/A
Outlet Structure Description	Bypass system and 8'H x 12'V oblong conduit. 2 service – 1 emergency.
Hydrology	
Drainage Area, square miles (square miles)	170
Maximum Pool Elevation (feet)	563.62
Maximum Historic Release (cubic feet per second [cfs])	3,730 (5-6 May 2011)
Maximum Historic Pool Elevation (feet)	548.12 (25 June 2019)
Patoka River Channel Capacity (cfs)	710 cfs
Datum adjustment from NGVD 29 TO NAVD 88 (feet)	-0.38

Note: All elevations in this report are expressed in NAVD 88. Elevations in this table are rounded to two decimal places. All subsequent elevations in this report will be rounded to one decimal place.

1.3 GEOGRAPHIC INFORMATION SYSTEM TERRAIN DATA AND LAYERS

Several types of terrain data and data layers were used to perform the hydrologic and hydraulic analysis of the study area. The data, source, and description are summarized in Table 1-2. Base geometry data was obtained from a previous CWMS model for Patoka Lake Dam, as well as a USGS HEC-RAS study. The 3.5-foot Digital Elevation Model (DEM) obtained from the district was used for this modeling effort.

Surveyed cross sections were provided by the LRL survey team at approximately one-mile increments for a total of 56 cross sections. Survey was not taken around the city of Jasper since the USGS had already developed cross sections for this area. Cross sections were cut from LRL surveyed cross sections and the USGS model cross section and incorporated into the terrain as bathymetry. Mapping products were developed with a combined DEM with a grid resolution of 10-feet.

Table 1-2. Summary of Geospatial Data

Data	Description	Source
Digital Elevation Model	3.5-foot DEM data were used for the hydraulic analysis in this study. A 10-foot DEM is laid underneath the 3.5-foot DEM.	LRL
Surveyed Cross-Section Data	Survey was performed by district survey team and incorporated into the terrain as a burned channel.	LRL
Imagery	Environmental Systems Research Institute, Inc. (ESRI) Aerial Imagery (2019)	ESRI web services

Figure 1-1. System Map

SECTION 2
Hydraulic Model Development

2.1 HYDRAULIC MODEL FLOW SCENARIOS

The purpose of this study is to evaluate the impacts of potential dam release increases for Patoka Lake Dam. The Hydrologic Engineering Center-River Analysis System (HEC-RAS) was used to route hydrographs to simulate Patoka Lake Dam operational scenarios and to route the resulting hydrographs down the Patoka River.

2.2 HYDRAULIC MODEL DEVELOPMENT

The HEC-RAS model includes component geometry, cross sections, and storage areas capable of conducting one-dimensional (1D) and two-dimensional (2D) computations. The combined use of 1D and 2D components is determined with the intent to most appropriately model the reach to determine the impact to the floodplain.

The model consists of both the Wabash River and the Patoka River. The Patoka River portion of the model runs from the outflow of the Patoka Lake Dam to the Patoka River's confluence with the Wabash River at Mt. Carmel, Ill. The Wabash River portion of the model runs from USGS 03340500 WABASH RIVER AT MONTEZUMA, IND. to USGS 03377500 WABASH RIVER AT MT. CARMEL, ILL.

The Wabash River reach was included solely for the boundary conditions and was not developed beyond that utility.

2.2.1 Cross-Section Elevation Data

The cross-sections cut from the DEM data did not contain information below the water surface. This affects both the river channel geometry and the computation of the water surface profiles. As described in Section 1.3, surveyed cross sections and USGS study cross sections were used to develop the channel profile, from which channel cross sections were cut. Overbanks were cut from the 3.5-foot DEM.

Bank stations noted by the survey team were utilized as bank stations in the model where applicable. Bank stations, levees points, and ineffective flow areas were incorporated on a cross section-by-cross section basis.

2.2.2 Manning's "n" Values

Manning's "n" values were taken from CWMS model and the USGS model directly and assessed to be reasonable. Through three calibration events, Manning's "n" values were adjusted accordingly, and validated with two additional events. For 2D areas, the 2016 NLCD values were incorporated.

2.2.3 Bridges and Culverts

Bridges that existed in the CWMS model within the study area were maintained, and their channel adjusted in accordance with new data. Attempts were made to acquire data for other bridges along the Patoka River via county agencies were not fruitful. However, based on low chord elevations from FEMA FIA studies, these bridges were assessed to have low chords that would not be reached by the water surface profile, and therefore not significant for this modeling effort.

2.2.4 Storage Areas

Storage areas were used to model the available storage in smaller tributaries that would incur backwater from the Patoka River. When storage areas are used, the lateral structure feature in HEC-RAS is used to connect the main channel to a storage area. Lateral structure weir coefficients are used to model these backwater areas and a uniform value of 0.25 was used. Simulated water surface elevations in storage areas result in a horizontal water surface. The location and station elevation data of the top of the lateral structures is extracted from the DEM data. Additional information required by these structures is then entered into the HEC-RAS model.

2.2.5 Tributaries

Tributaries that experience more than ten miles of backwater flooding or a lateral transfer of flow during the flood wave were modeled as separate reaches. These were not required in this study.

2.2.6 Levees

There are no NLD levees in Dubois County. Small levees and lateral barriers to flow were modeled using Lateral Structures or 2D Breaklines at the modeler's discretion.

2.2.7 Model Calibration and Downstream Boundary Condition

Three events were chosen for calibration, and one additional event was chosen for validation. Events were chosen based on the stage at stream gage USGS 03375500 PATOKA RIVER AT JASPER, IN. Stages and flows were calibrated at the same location. Calibration and Validation events are summarized in Table 4-1 and presented in Figures 4-1 through 4-5. The downstream boundary condition is more than 100 miles away from Patoka Lake Dam. The downstream boundary condition was set to stage hydrograph, referencing the stage at stream gage USGS 03377500 WABASH RIVER AT MT. CARMEL, ILL.

SECTION 3

MODELING ASSUMPTIONS

3.3 MODELING CHALLENGES/ASSUMPTIONS

The purpose of this effort is to create a model that can be used to obtain a reasonable estimate of consequences associated with increased dam releases over a range of releases from Patoka Lake Dam. In some cases, modeling challenges led to simplified approximation of model geometry and/or dam operation. Following is a discussion of model features that have been simplified (or excluded), modeling assumptions and known or expected modeling inaccuracies. These items may well be addressed in future, more detailed modeling efforts.

- Local flow to Jasper, Winslow, and Princeton calculated by routing releases from Patoka Lake Dam down to the appropriate stream gage using HEC-HMS, then subtracting these routed values from known flow values from the USGS.
- Aforementioned local flows are input into the system directly above the stream gage of interest in order to prevent HEC-RAS routing flows after HEC-HMS has already routed them.
- The Wabash reach is modeled, but no significant effort went into refining this reach. Two large 2D flow areas were incorporated to catch backwater effects from the Wabash River.
- Normal 2D flow equations are used on some lateral structures due to their submerged nature. If head differential is significant or issues with stability arose, weir equation was used instead.
- A seasonal average (taken February through May) of 300 cfs was used for the local inflow above Jasper for all steady state runs.

SECTION 4

Model Summary and Results

4.1 MODEL SUMMARY AND RESULTS

Three events during the flood season were chosen for calibration based on the frequency with which the gage height was in the 12 to 14-foot range of interest. Two validation events were chosen based on the same criteria. Calibration and validation events are summarized in Table 4-1. Calibration results are visualized in Figure 4-1 through Figure 4-5.

Following calibration of the RAS model, an average seasonal (February through May) local inflow of 300 cfs was assumed based on period of record data at stream gage USGS 03375500 PATOKA RIVER AT JASPER, IN. Five dam outflow scenarios were considered and run through the Patoka River reach along with the local flow from the watershed.

These scenarios released flow to target 12, 13, and 14 feet at stream gage USGS 03375500 PATOKA RIVER AT JASPER, IN. Once these targets were achieved, incremental releases, as well as releases that surpassed the 14-foot targeting release, were chosen to observe the change in stage between release scenarios. Note that in each of these scenarios, the steady 300 cfs is assumed to be the local flow at the stream gage. For USGS gages USGS 03376300 PATOKA RIVER AT WINSLOW, IN and USGS 03376500 PATOKA RIVER NEAR PRINCETON, IN, high local flow values of 3,000 cfs and 1,500 cfs, respectively, as well as low local flow values of 800 cfs and 600 cfs, respectively, were chosen based on historical releases from Patoka Lake Dam, which were subtracted from the total flow. Whether high or low local flows were modeled at these locations did not have an appreciable impact on results at USGS 03375500 PATOKA RIVER AT JASPER, IN. Results are summarized in Table 4-2.

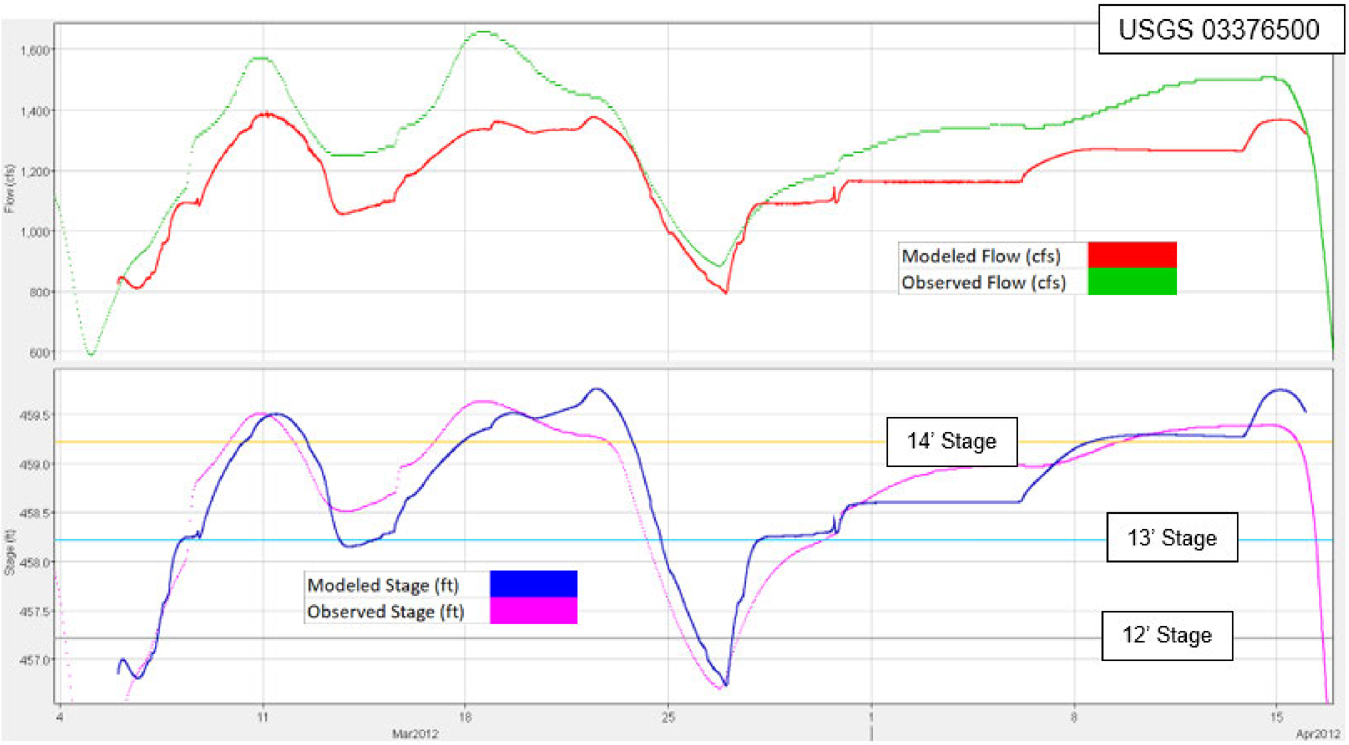
Additionally, the rating curve from the modeling effort at USGS 03375500 was compared to the existing USGS rating curve. This result is presented in figure 4-6.

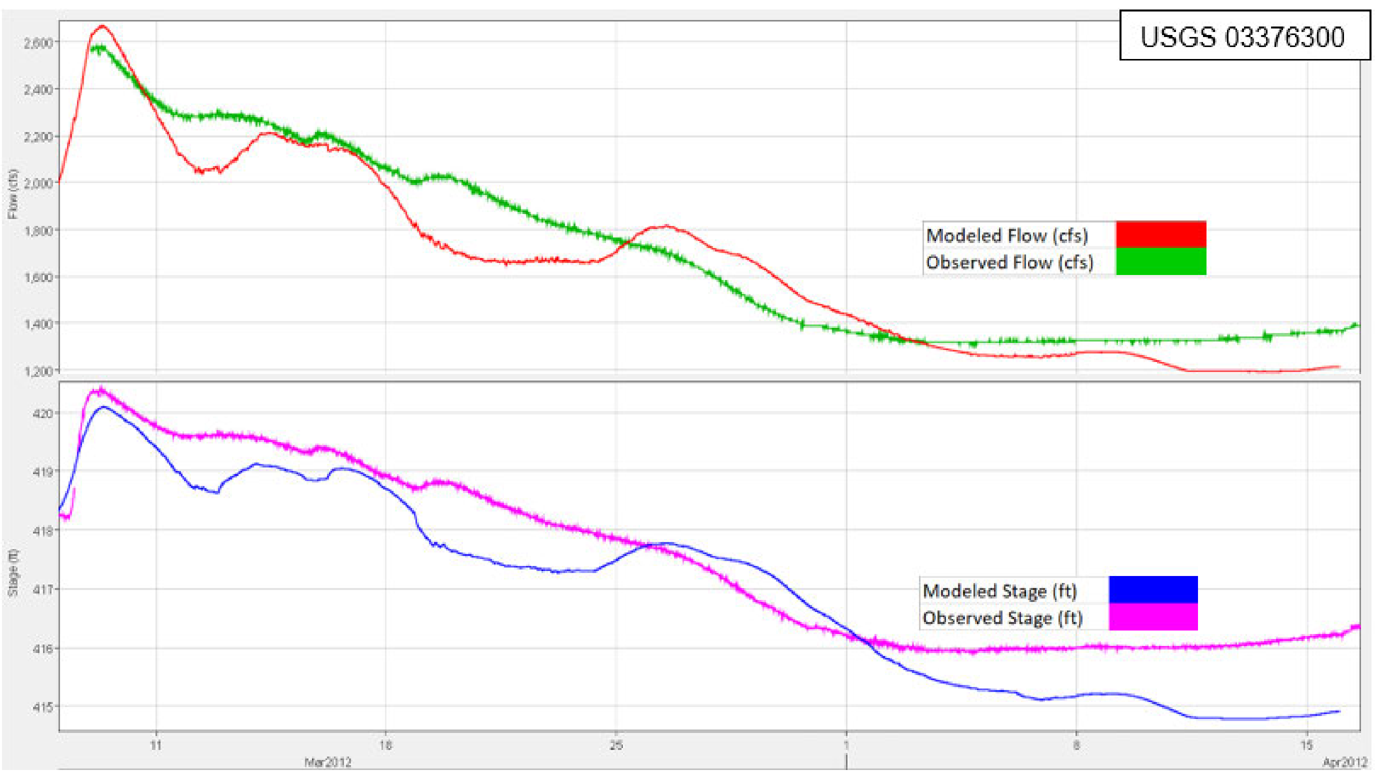
Table 4-1. Summary of Calibration and Validation Events

06 March 2012 – 16 April 2012	15 March 2015 – 15 May 2015	01 February 2016 – 01 May 2016	19 March 2019 – 22 May 2019	22 January 2020 – 22 April 2020
Calibration	Validation	Validation	Calibration	Calibration

Table 4-2. Summary of Steady Flow Results at USGS 03375500

Patoka Lake Dam Release (cfs)	Local Flow	Flow at Gage	WSE NAVD88	Gage Height
525	300	893.69	457.26	12.04
775	300	1,079.92	458.17	12.95
1,000	300	1,267.07	459.05	13.83
1,100	300	1,298.46	459.17	13.95
1,300	300	1,344.89	459.71	14.49
1,450	300	1,344.02	459.88	14.66


USGS 03376500
Flow (cfs)
1,600
1,400
1,200
1,000
800
600
Modeled Flow (cfs)
Observed Flow (cfs)
Stage (ft)
459.5
459.0
458.5
458.0
457.5
457.0
14' Stage
13' Stage
12' Stage
Modeled Stage (ft)
Observed Stage (ft)
4
11
18
25
1
8
15
Mar2012
Apr2012


USGS 03376300
Flow (cfs)
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
Modeled Flow (cfs)
Observed Flow (cfs)
Stage (ft)
420
419
418
417
416
415
Modeled Stage (ft)
Observed Stage (ft)
11
18
25
1
8
15
Mar2012
Apr2012

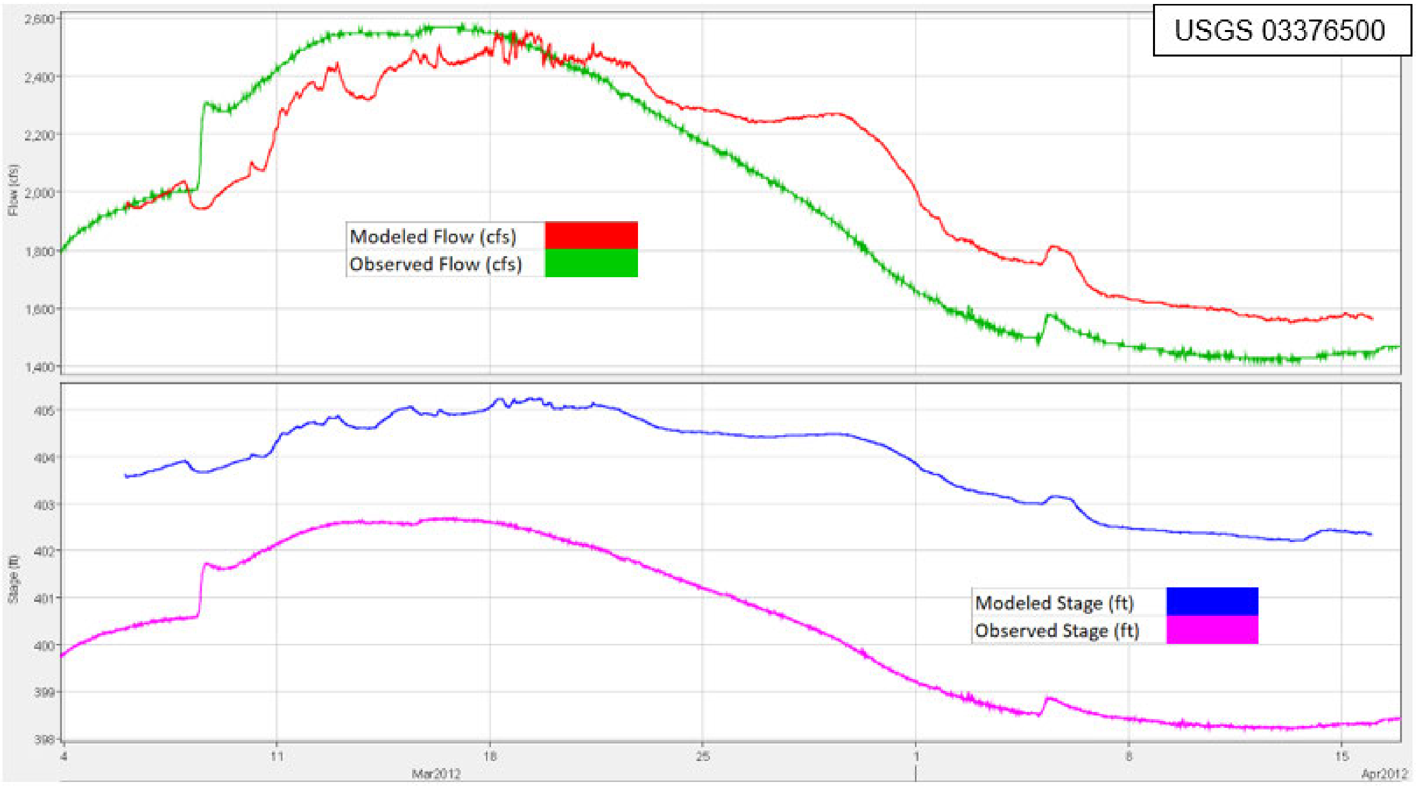
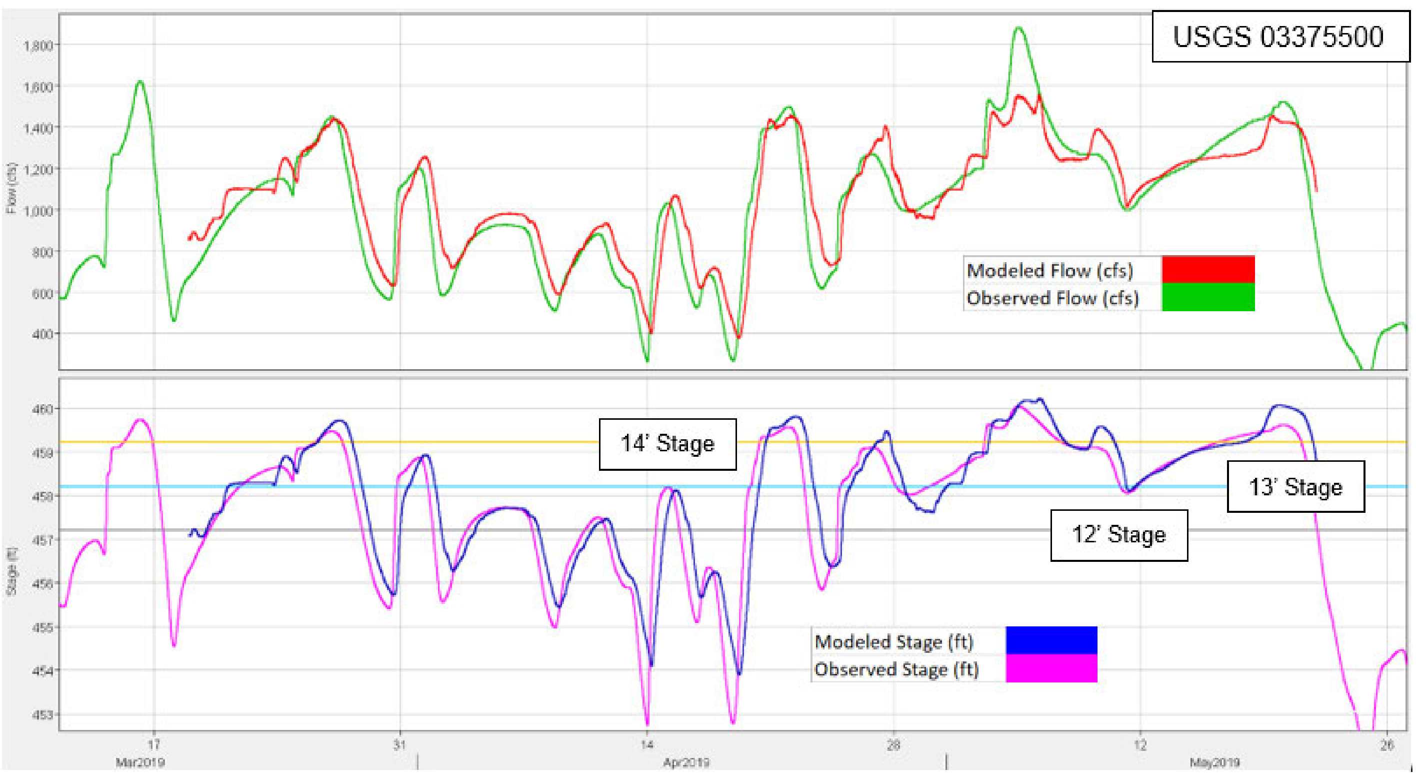


Figure 4-1. 2012 Calibration Event for USGS 03375500, USGS 03376300, and USGS 03376500.



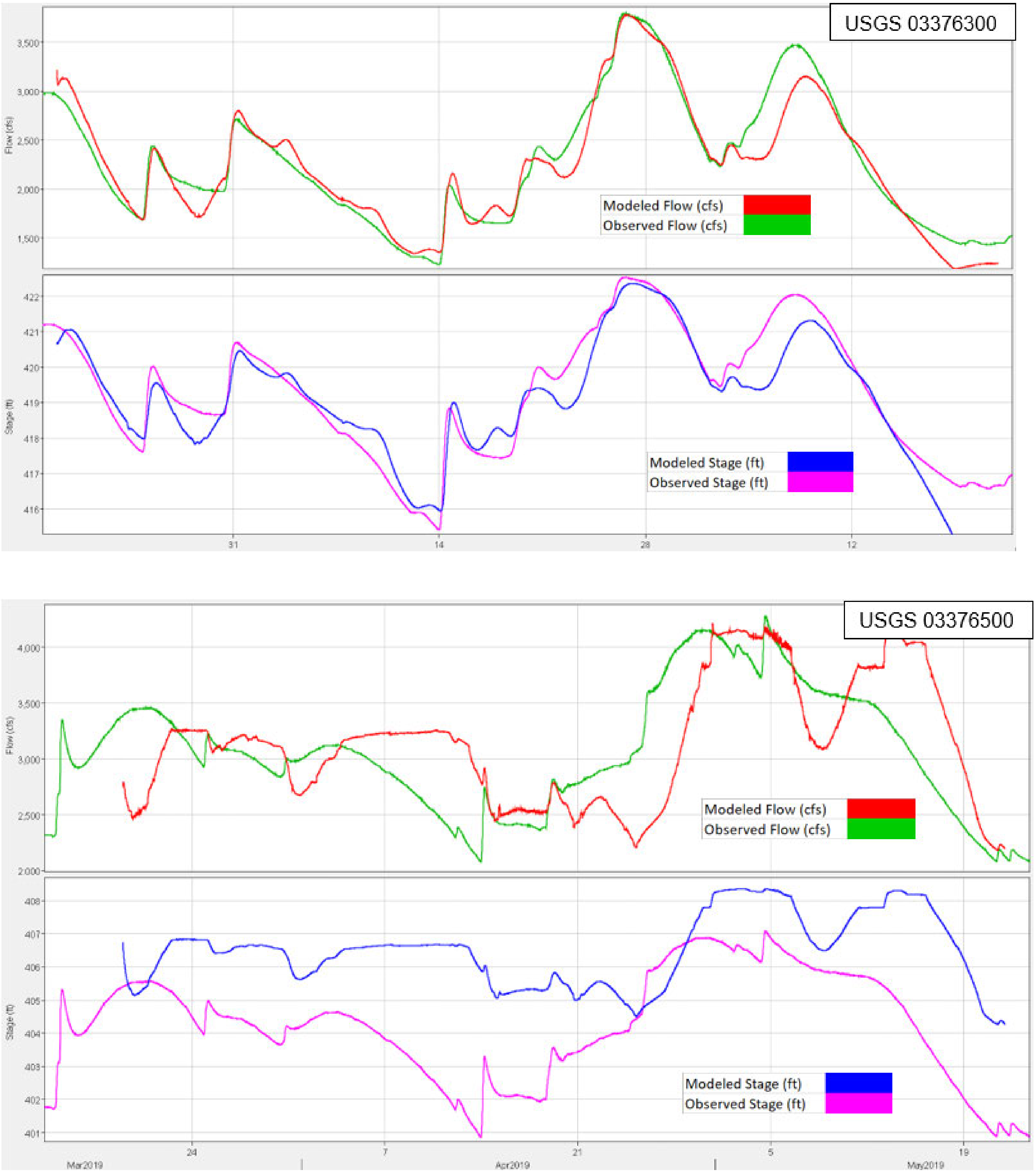
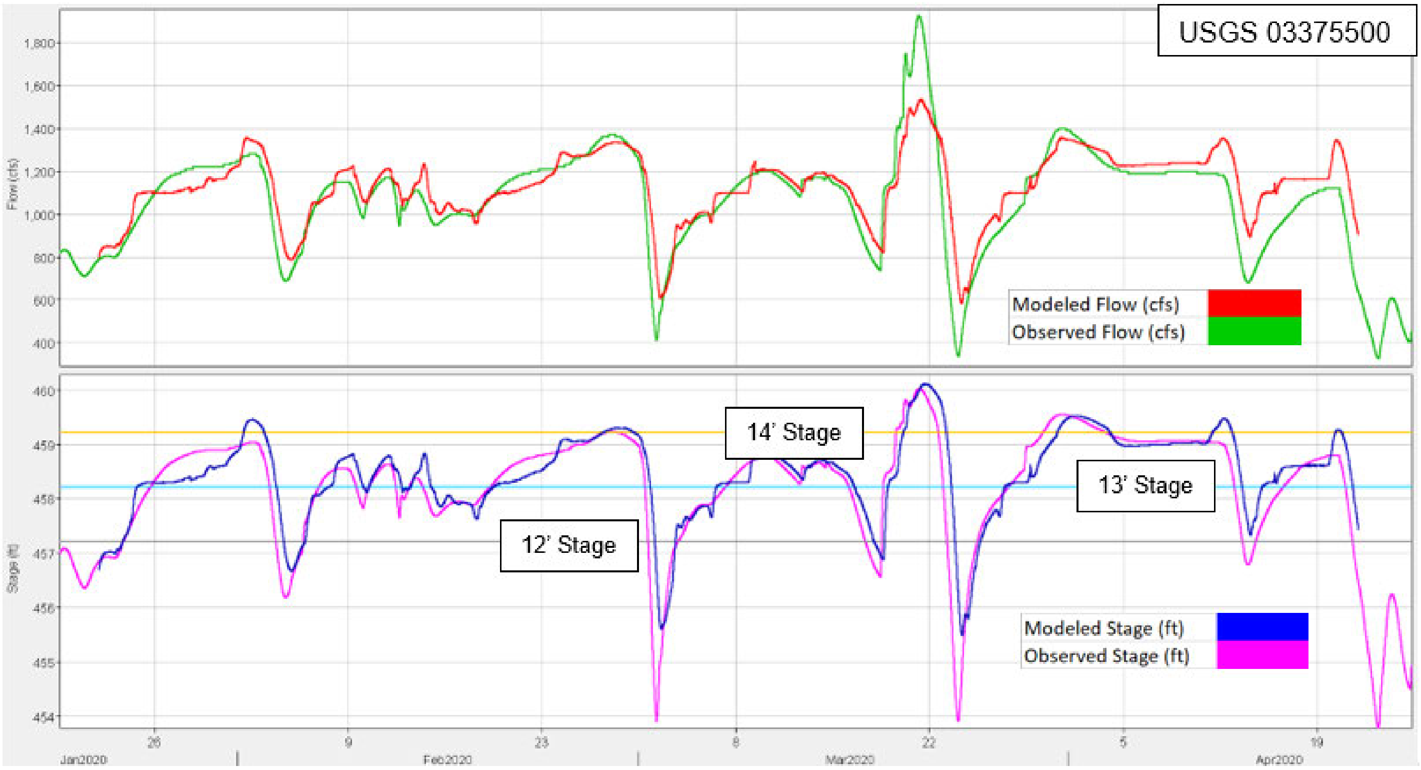
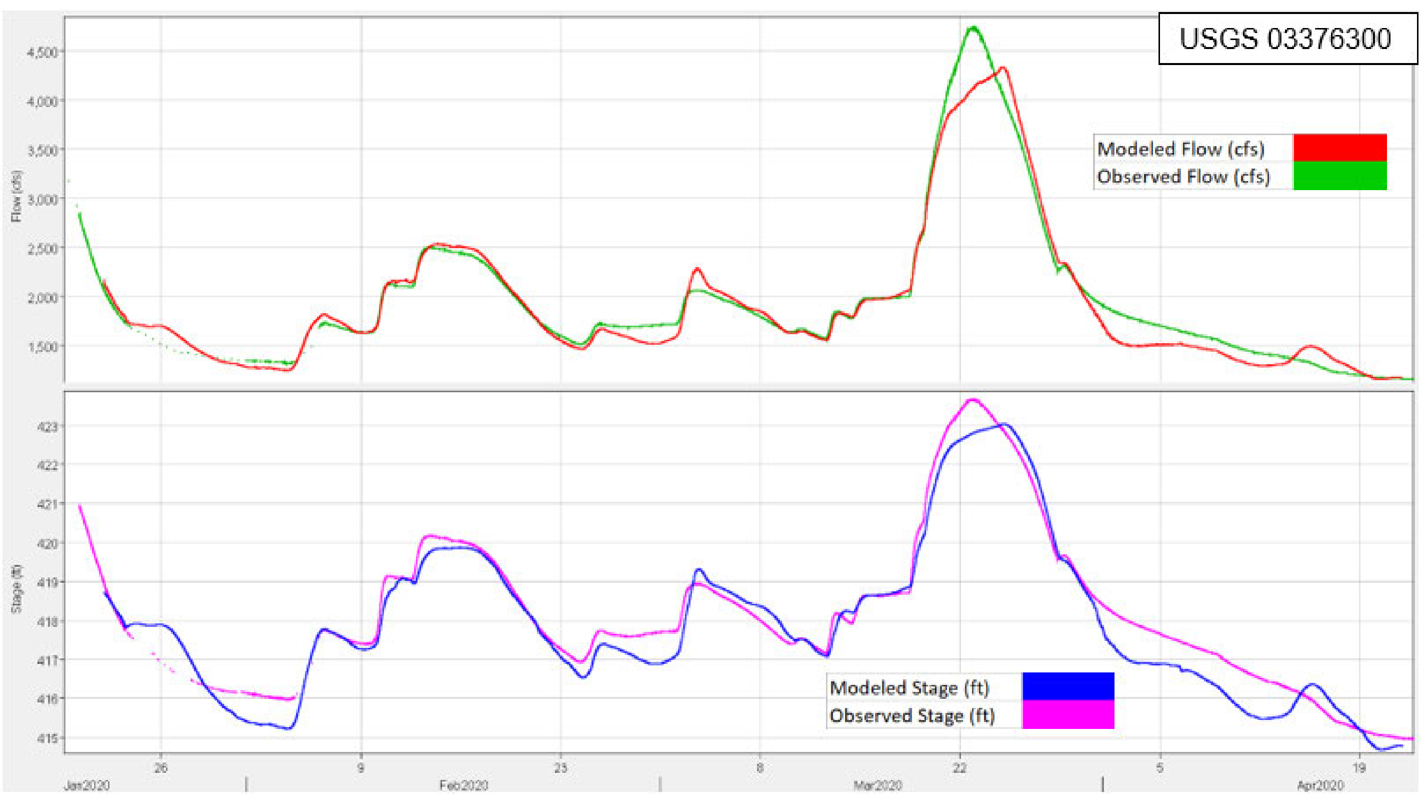


Figure 4-2. 2019 Calibration Event for USGS 03375500, USGS 03376300, and USGS 03376500.


USGS 03375500
Flow (cfs)
1,800
1,600
1,400
1,200
1,000
800
600
400
Modeled Flow (cfs)
Observed Flow (cfs)
Stage (ft)
460
459
458
457
456
455
454
14' Stage
13' Stage
12' Stage
Modeled Stage (ft)
Observed Stage (ft)
26
9
23
8
22
5
19
Jan2020
Feb2020
Mar2020
Apr2020


USGS 03376300
Flow (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
Modeled Flow (cfs)
Observed Flow (cfs)
Stage (ft)
423
422
421
420
419
418
417
416
415
Modeled Stage (ft)
Observed Stage (ft)
26
9
23
8
22
5
19
Jan2020
Feb2020
Mar2020
Apr2020

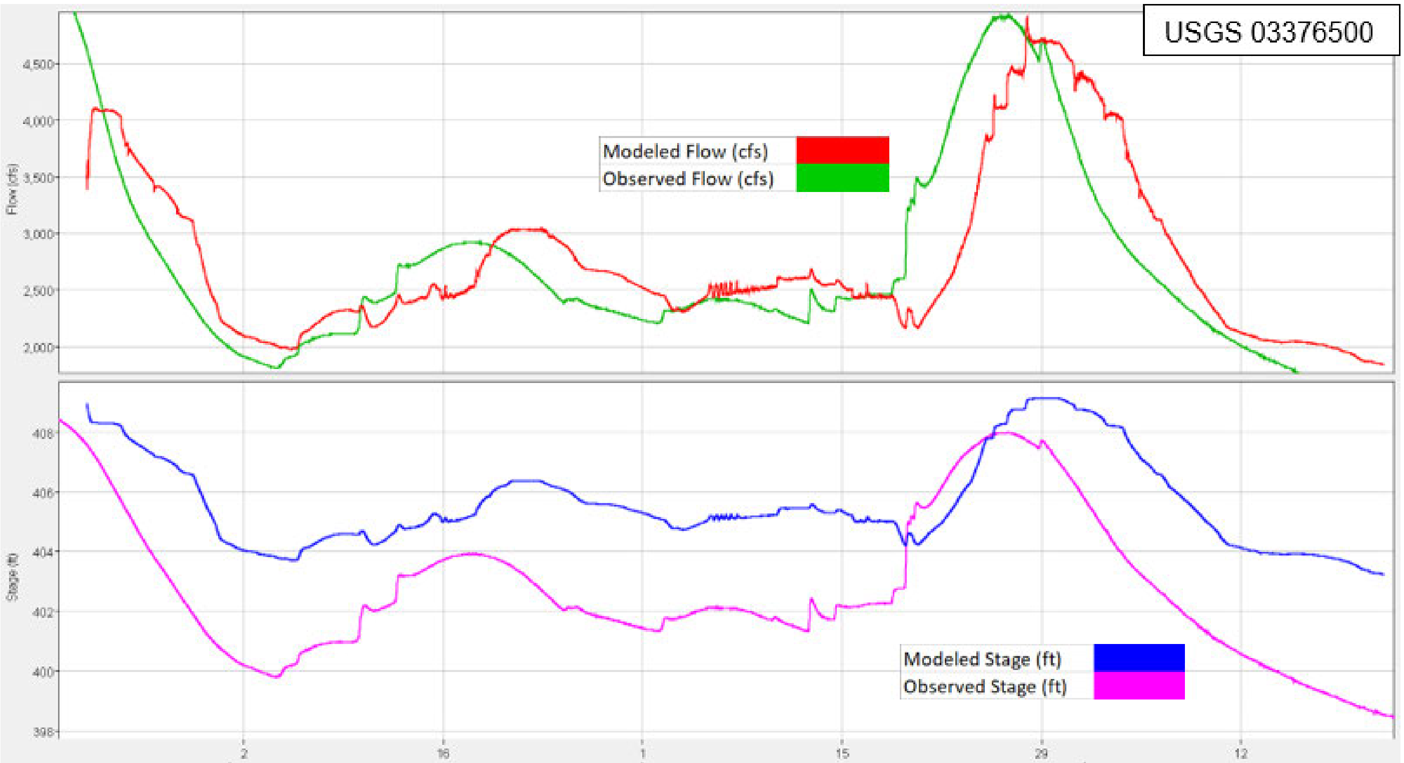
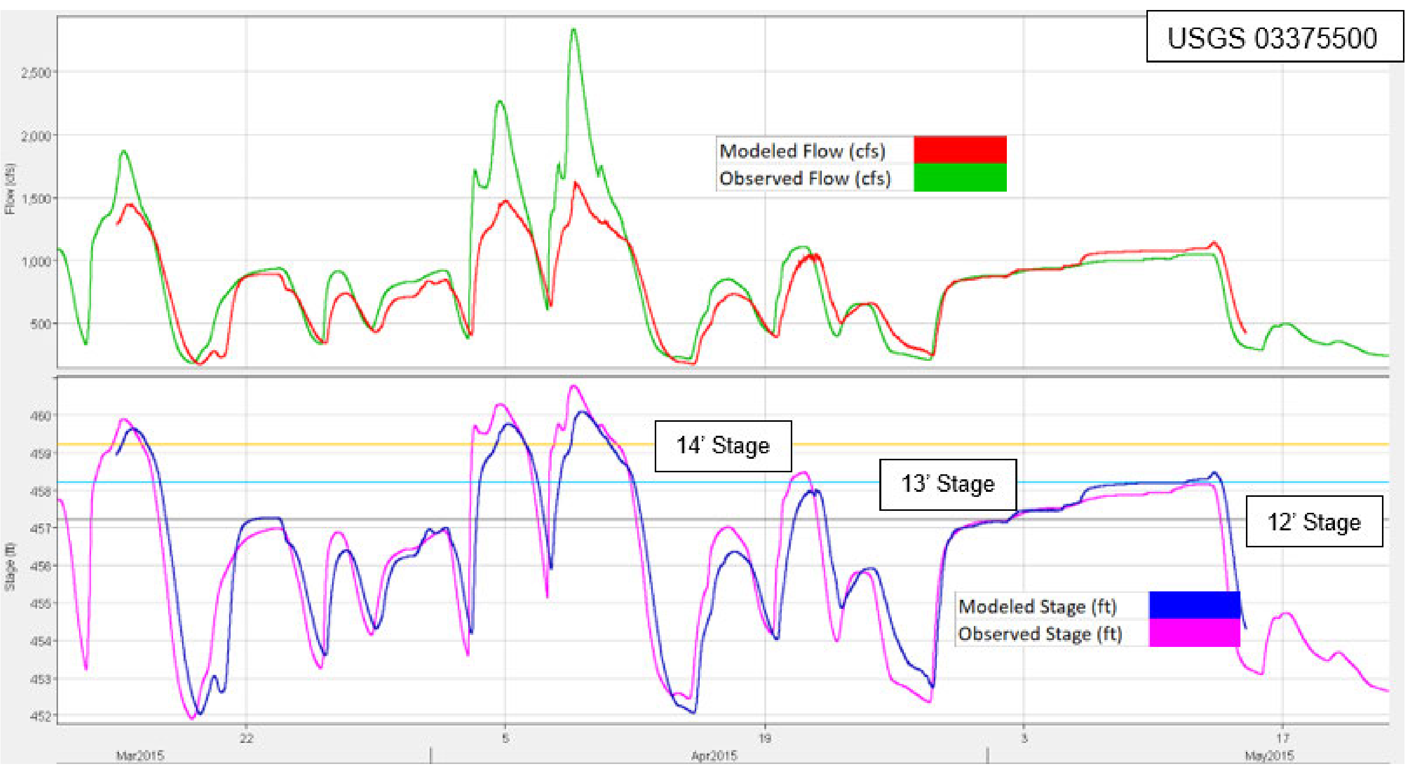
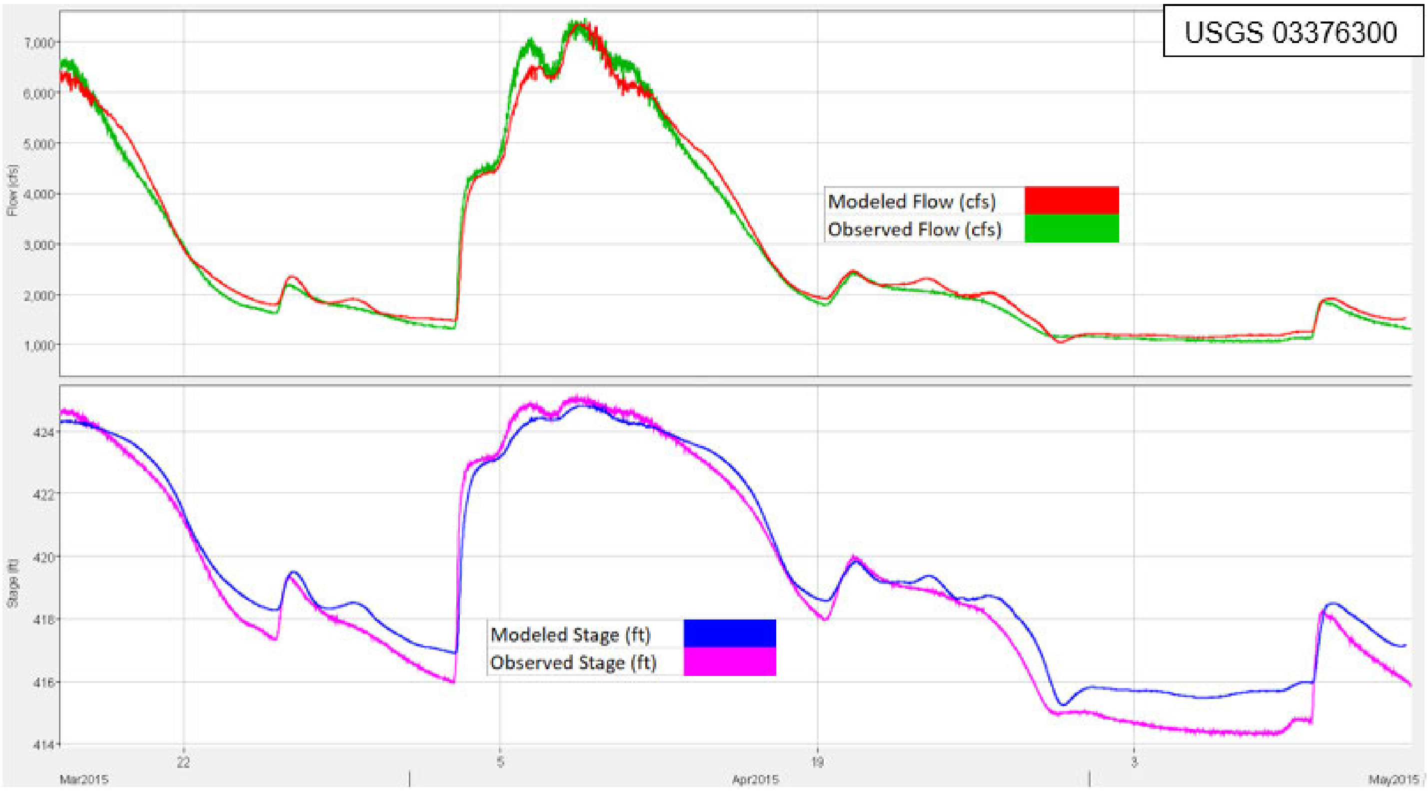


Figure 4-3. 2020 Calibration Event for USGS 03375500, USGS 03376300, and USGS 03376500.





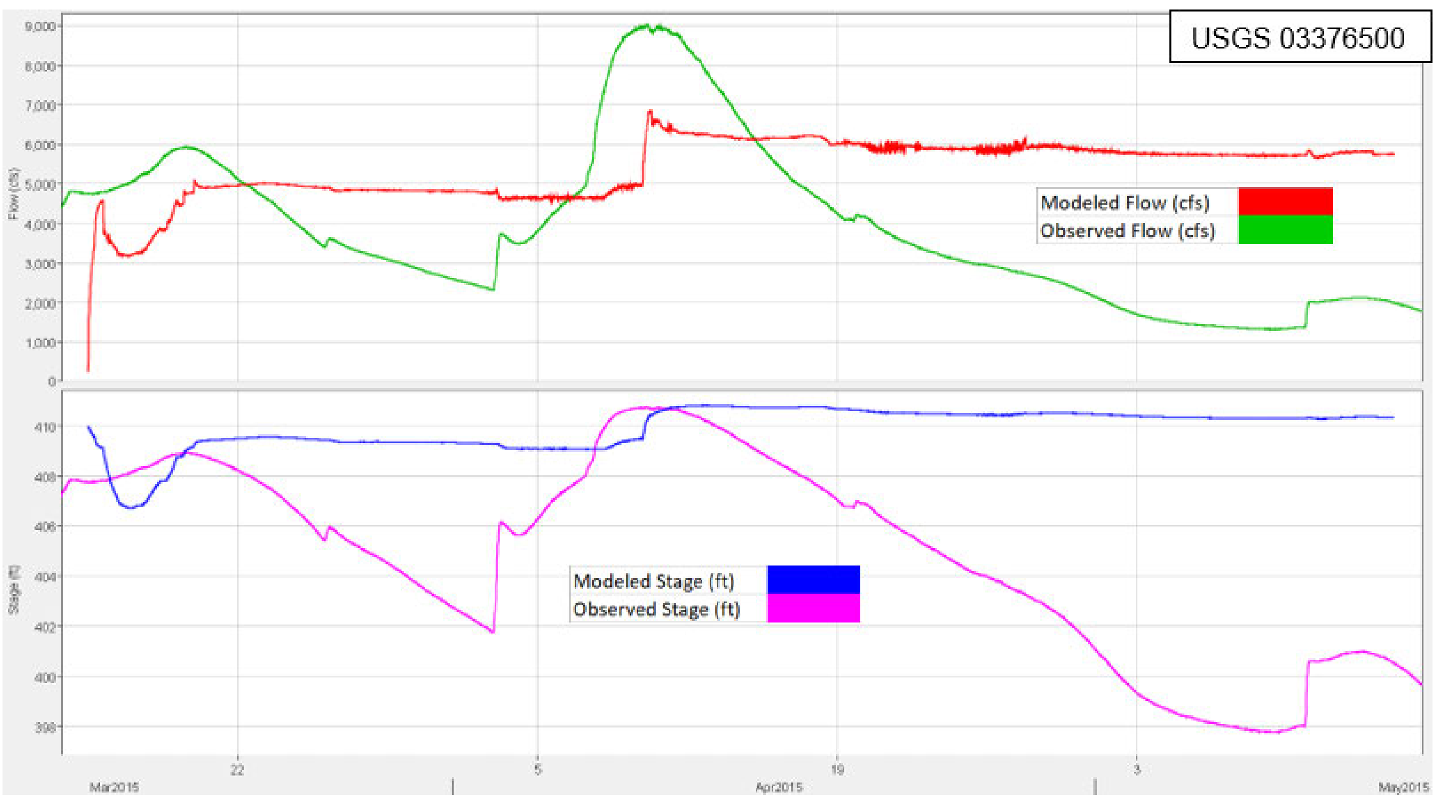
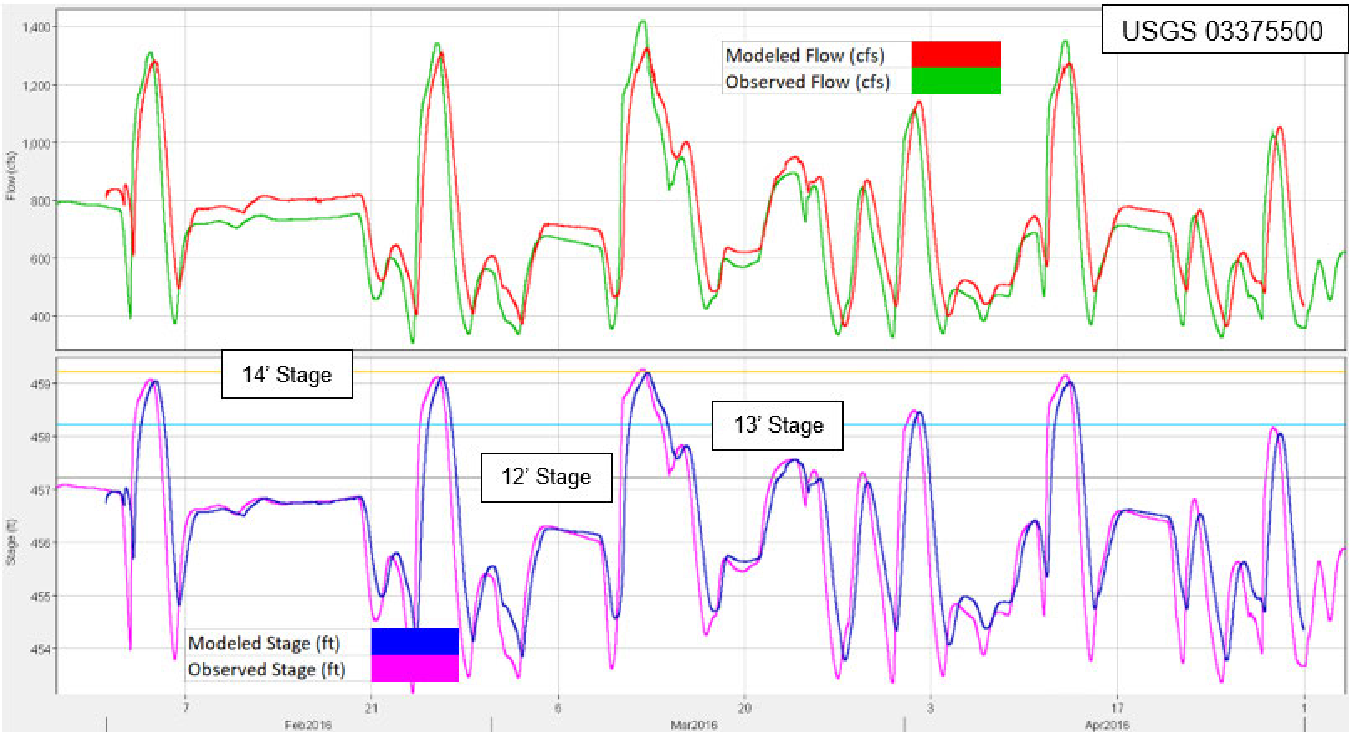
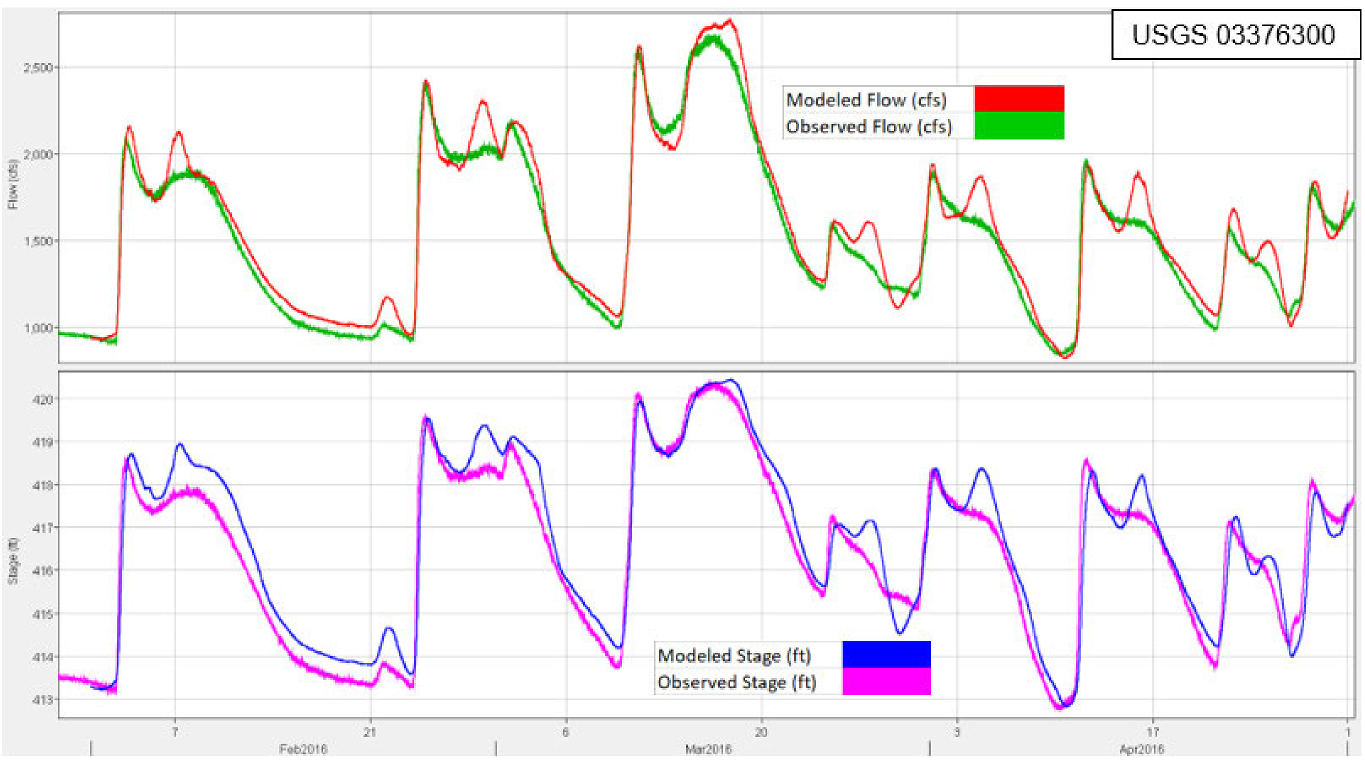


Figure 4-4. 2015 Validation Event for USGS 03375500, USGS 03376300, and USGS 03376500.


USGS 03375500
Modeled Flow (cfs)
Observed Flow (cfs)
14' Stage
13' Stage
12' Stage
Modeled Stage (ft)
Observed Stage (ft)
Feb2016
Mar2016
Apr2016


USGS 03376300
Modeled Flow (cfs)
Observed Flow (cfs)
Modeled Stage (ft)
Observed Stage (ft)
Feb2016
Mar2016
Apr2016

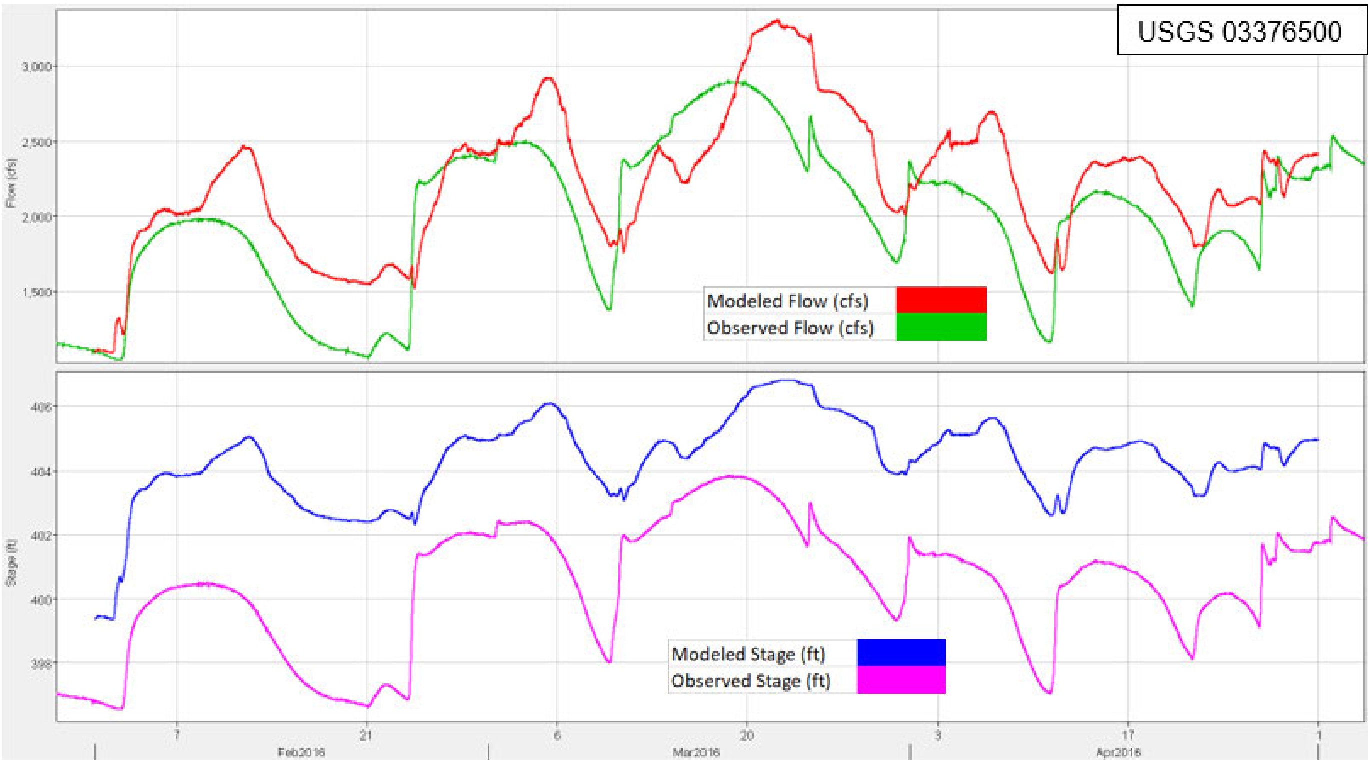


Figure 4-5. 2016 Validation Event for USGS 03375500, USGS 03376300, and USGS 03376500.

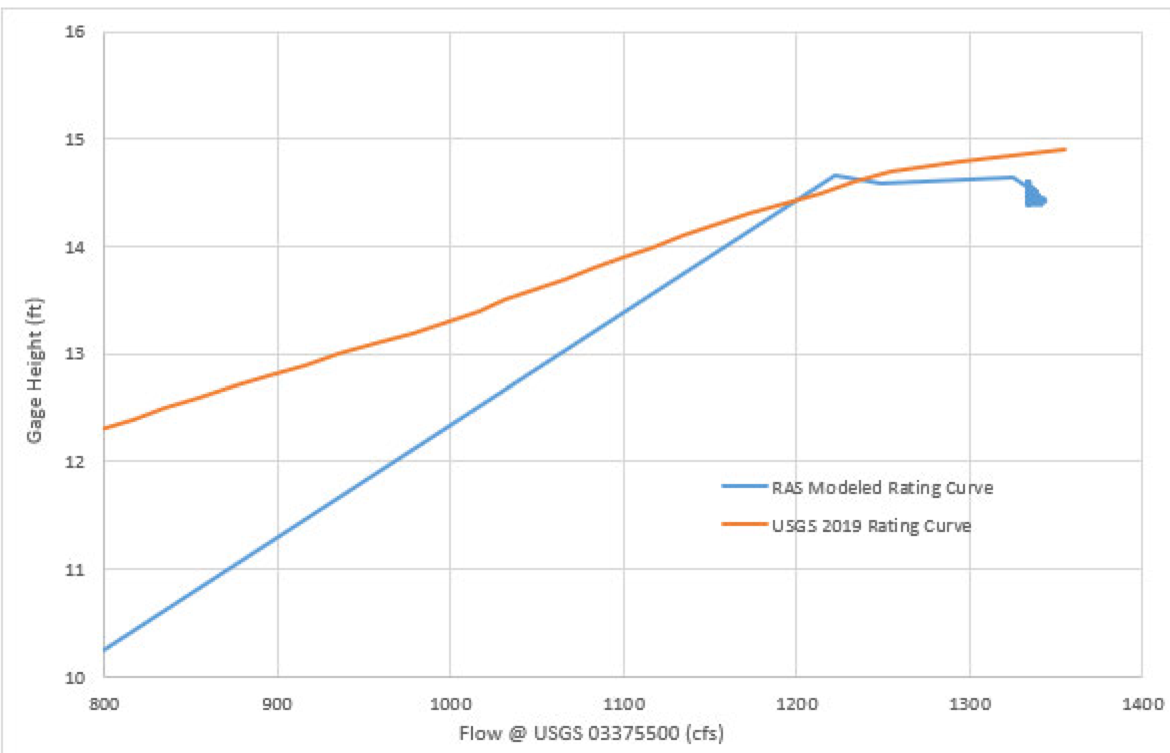


Figure 4-6. Rating Curve Comparison

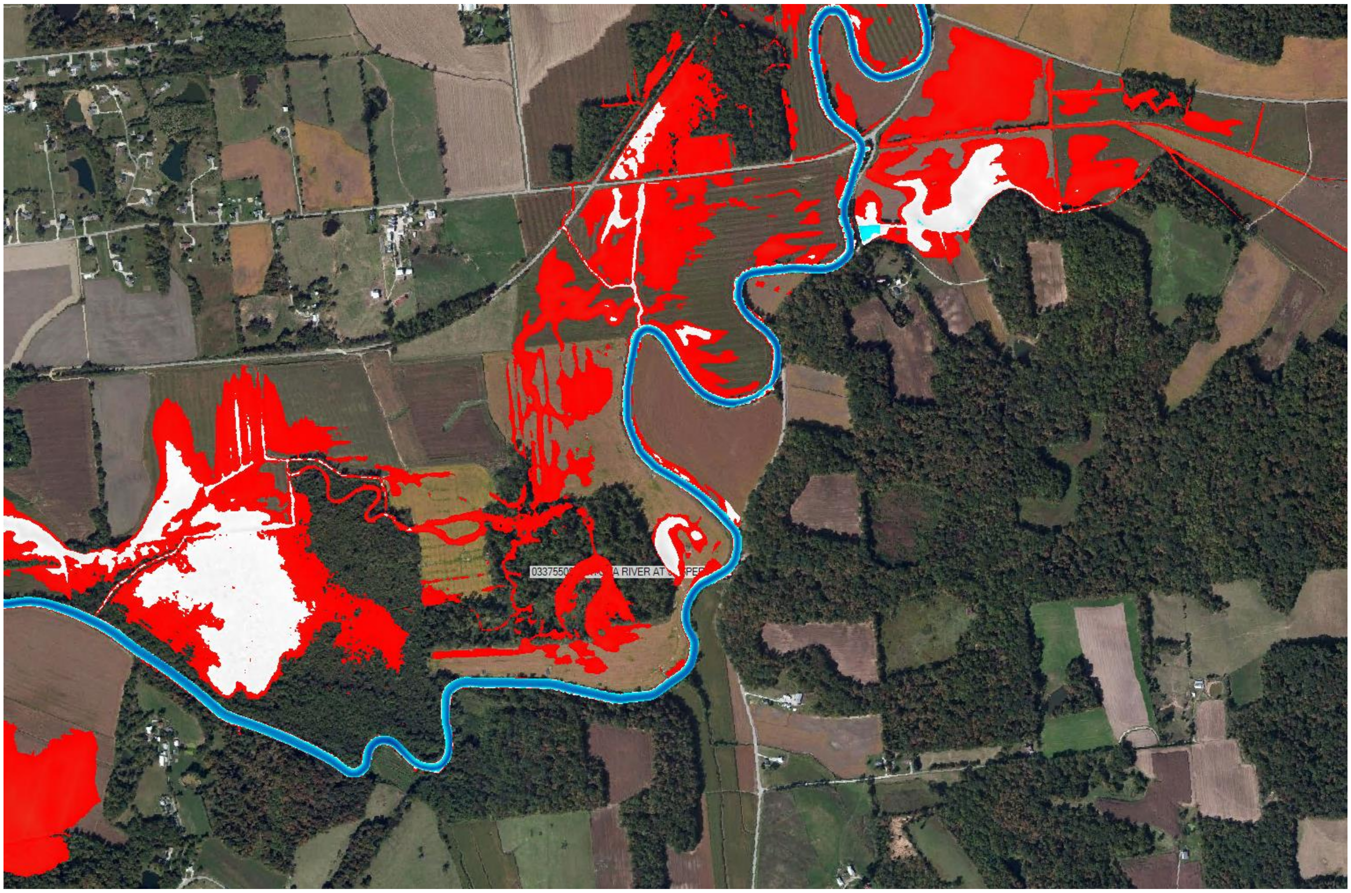


Figure 4-7. 12', 13', and 14' (blue, white, and red) inundation at Stream Gage USGS 03375500

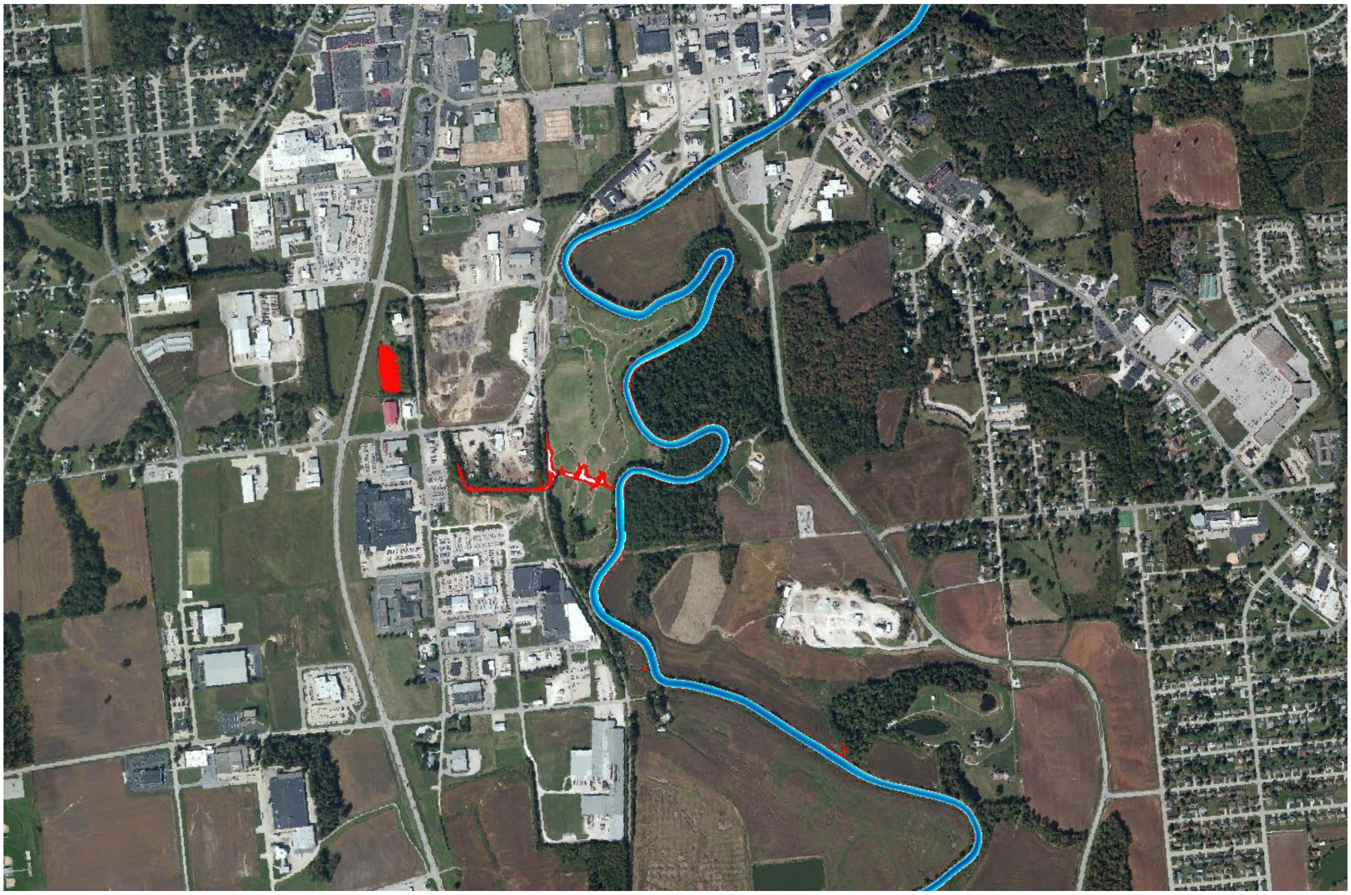


Figure 4-8. 12', 13', and 14' (blue, white, and red) inundation at downtown Jasper

Figure 4-9. 13' inundation vs. photos.

References and Resources

USACE Staff

Engineer:

[redacted]

Model Technical Reviewer:

[redacted]

Hydraulic Model Quality Check:

[redacted]

Report Writer:

[redacted]

Report Quality Reviewer:

[redacted]
Louisville District (CELRL)
[redacted]

List of Acronyms and Abbreviations

1D	one-dimensional
2D	two-dimensional
cfs	cubic feet per second
CRM-D	common risk for dams
DEM	digital elevation model
ESRI	Environmental Systems Research Institute, Inc.
FEMA	Federal Emergency Management Agency
FIS	flood insurance studies
FOUO	For Official Use Only
GIS	Geographic Information Systems
HAZUS-MH	Hazards U.S., Multi-Hazard analysis system
HEC-DSS	Data Storage System
HEC-GeoRAS	Geographic RAS
HEC-LifeSim	Life Loss Estimation
HEC-RAS	River Analysis System
IDF	inflow design flood
IH	intermediate high
LOB	left overbank
LL	life loss
MH	maximum high
MMC	Modeling, Mapping and Consequences
NAVD 88	North American Vertical Datum of 1988
NGVD 29	North Geodetic Vertical Datum of 1929
NLCD	National Land Classification Dataset
NLD	National Levee Database
NH	normal high
PAR	population at risk
PMF	probable maximum flood
RM	river mile
ROB	right overbank
SDF	spillway design flood
SS	security scenario
TAS	top of active storage
U.S.	United States
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
WCM	water control manual

Patoka River Lake Reservoir

Qualitative Analysis of Climate Change Impacts

June 2024

Table of Contents

List of Figures

List of Tables

1. Qualitative Assessment of Climate Change Impacts

1.1. Introduction and Background

This assessment of climate change impacts is required by U.S. Army Corps of Engineers (USACE, "the Corps") Engineering and Construction Bulletin (ECB) 2018-14, "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects." This assessment documents the qualitative effects of climate change on the hydrology in the region. The ECB 2018-14 analysis is targeted at identifying potential impacts and risks to the Patoka River Lake Reservoir Flood Risk Management Study from climate change.

USACE projects, programs, missions, and operations have generally proven to be robust enough to accommodate the range of natural climate variability over their operating life spans. However, recent scientific evidence shows that in some places and for some impacts relevant to USACE operations, climate change is shifting the baseline about which that natural climate variability occurs and may be changing the range of that variability as well. This is relevant to USACE because the assumptions of stationary climate conditions and a fixed range of natural variability, as captured in the historic hydrologic record may no longer apply. Consequently, historic hydrologic records may no longer be appropriately applied to carry out hydrologic assessments for flood risk management in watersheds such as the Wabash River Basin of which Patoka River Reservoir is a part.

1.1.1. Watershed Description

Patoka River Reservoir is located on Patoka River, a tributary of Wabash River, in the southern portion of Indiana about 50 miles west of Louisville, Kentucky. The location of the reservoir is shown in Figure 1.1 and Figure 1.2. The dam site is about 118 miles upstream from the confluence of Patoka River with the Wabash River. The reservoir's drainage area is approximately 168 square miles and located in Orange, Dubois, and Crawford Counties. The pool extends about 25 miles upstream from the dam when at all-season level.

Patoka River Reservoir serves as a unit of the comprehensive plan for the Ohio River Basin to effect reduction in flood stages downstream from the dam. The lake provides water supply storage and operates to augment natural low-flow condition downstream of the dam in the interest of water quality control. In addition, the lake provides general and fish and wildlife recreation. The watershed is depicted in Figure 1.1 below.

A large proportion of the reservoir's drainage area lies within Hoosier National Forest. As a result, the Patoka River watershed upstream of the dam has not experienced significant urbanization and still largely remains forested. Table 1.1 displays upstream watershed land coverage and usage from the 2016 National Land Coverage Database (NLCD, 2016).

Table 1.1. Patoka River Lake Upstream Land Usage

2016 National Land Cover Dataset Type	Area, sq. mi.	Percent of Total Area
Deciduous Forest	105.26	62.82%
Mixed Forest	11.92	7.11%
Evergreen Forest	0.98	0.58%
Hay/Pasture	18.96	11.31%
Cultivated Crops	6.73	4.02%
Developed, Open Space	6.44	3.85%
Developed, Low Intensity	0.63	0.37%
Developed, Medium Intensity	0.13	0.08%
Developed, High Intensity	0.03	0.02%
Open Water	14.48	8.64%
Herbaceous	1.33	0.79%
Barren Land	0.37	0.22%
Shrub/Scrub	0.22	0.13%
Emergent Herbaceous Wetlands	0.06	0.04%
Woody Wetlands	0.04	0.02%

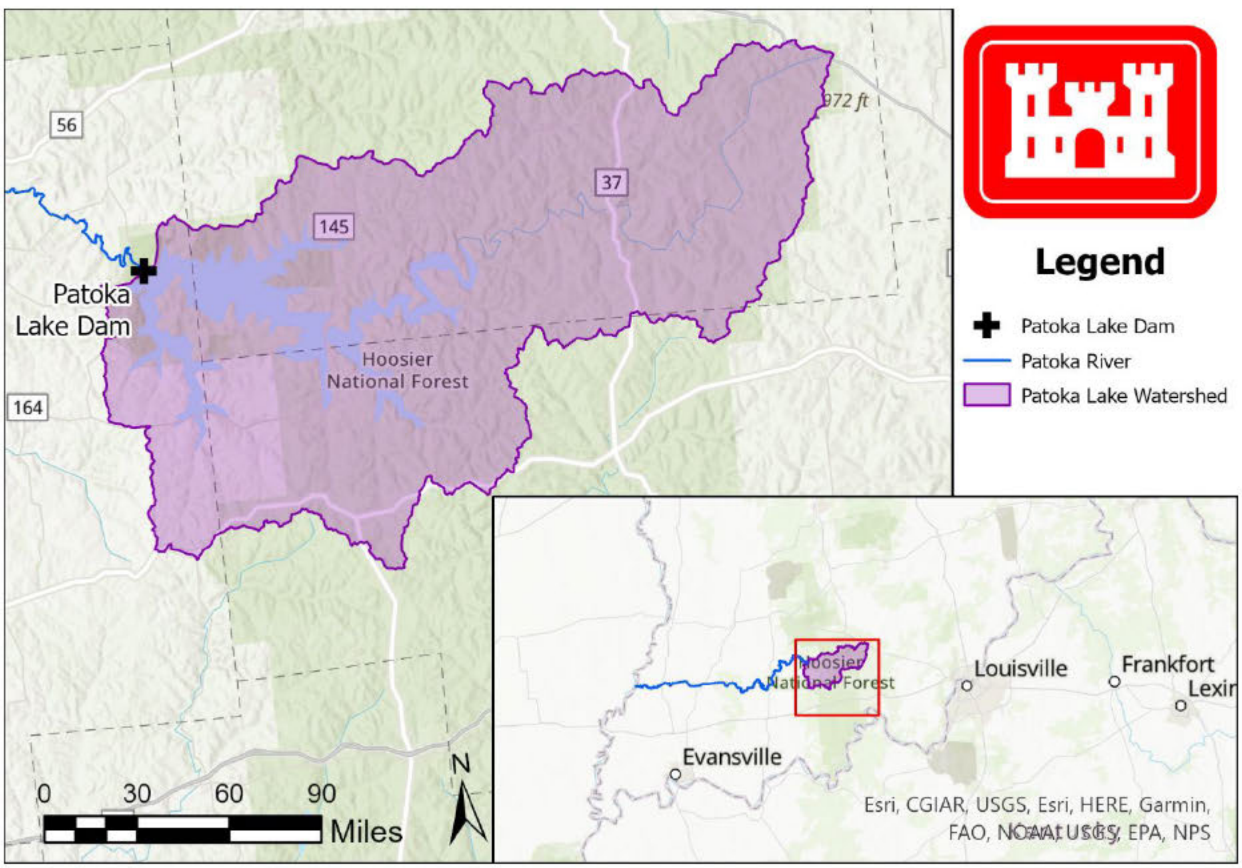


Figure 1.1: Patoka River Watershed

Figure 1.2. Ohio River Watershed including USACE Districts and Political Boundaries (project area circled in red)

1.1.2. Regulation in the Study Area

The only flood risk management reservoir within the study area is Patoka Lake Dam and Reservoir. No additional impoundment or regulation exists upstream of the lake.

1.1.3. Discharge and Precipitation Gages in the Study Area

There are no USGS streamflow gages within the watershed upstream of Patoka Lake Dam. Reservoir inflow and volume data was provided by Louisville District (LRL) Water Management (WM). Reservoir inflow was computed at 6-hour increments based upon observed reservoir elevation and recorded reservoir outflow for a period of 1983 through 2021. Additional datasets were generated for this climate analysis from the 6-hour reservoir inflow record, these include: annual peak inflow, annual average inflow, and total annual inflow volume. Additionally, total annual precipitation for the same period of record (POR) was provided by Louisville District Water Management and included in this climate analysis.

In addition to the Water Management inflow and precipitation data for Patoka Lake Dam, daily temperature and precipitation timeseries were gathered from a nearby weather station at Shoals, Indiana. This location (38.5528°, -86.7944°) is approximately 17 miles northwest of Patoka Lake Dam and was provided by the Midwestern Regional Climate Center (MRCC) in cooperation with the National Weather Service. This temperature and precipitation dataset has a longer period of record, although with some periods of intermittent and missing data, with observations extending back to 1908.

The MRCC daily records were processed to obtain annual-total precipitation, monthly-average precipitation, annual-average temperature, and monthly-average temperature datasets. These datasets and associated periods of record are shown in Table 1.2.

Table 1.2. Relevant Stream and Rain Gages used in Qualitative Analysis

Site Name *(Data Source)*	Data Type (units)	Data Period of Record	Years of Record
Patoka Lake Dam *(WM)*	Annual-Peak Inflows (cfs)	1983-2021	39
Patoka Lake Dam *(WM)*	Annual-Average Inflow (cfs)	1983-2021	39
Patoka Lake Dam *(WM)*	Annual-Total Volume (ac-ft)	1983-2021	39
Patoka Lake Dam *(WM)*	Annual-Total Precip. (in)	1983-2021	39
Shoals, IN *(MRCC)*	Annual-Total Precip. (in)	1927-2020	94
Shoals, IN *(MRCC)*	Monthly-Average Precip. (in)	1908-2021	114
Shoals, IN *(MRCC)*	Annual-Average Temp. (°f)	1913-2020	108
Shoals, IN *(MRCC)*	Monthly-Average Temp. (°f)	1908-2021	114

1.1.4. Overall Climate within the Patoka River Reservoir Watershed Area

Climate in Patoka River watershed is humid subtropical with four distinct seasons. Spring-like conditions typically begin in mid-to-late March, summer from mid-to-late-May to late September, fall in the October-November period. Seasonal extremes in both temperature and precipitation are not uncommon during early spring and late fall.

Records from the MRCC at Shoal Station have an average annual rainfall of 45.60 inches and an average daily temperature of 54.4°F. These average values are based on a 93-year period from 1927-2021. Extremes from the entire period of record include a maximum observed temperature of 114°F in 1936 and a minimum observed temperature of -23°F in 1963 and 1994. Of the top ten wettest days in Patoka River watershed, one occurred in March, one in May, two in June, one in July, one in August, two in September, one in October, and one in November. The greatest daily precipitation amount occurred on 24 March 2013, with 6.66 inches. Figure 1.3 displays historic average monthly temperature and precipitation for the Patoka River watershed according to the MRCC for a period of record of 1908-2021.

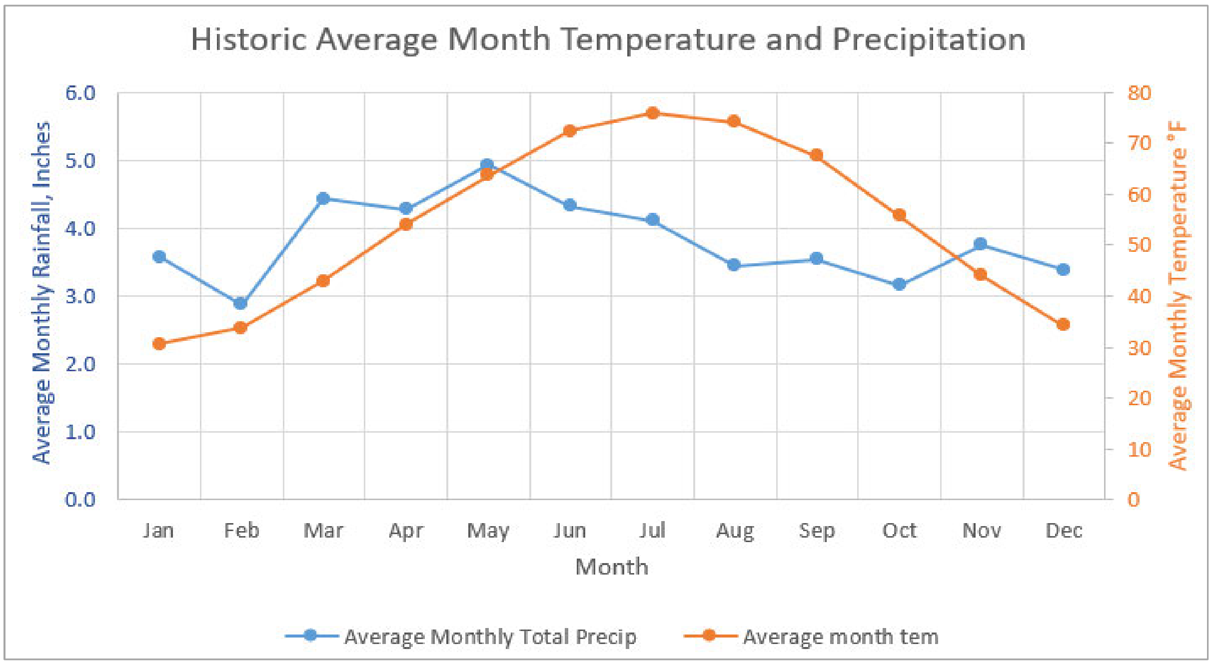


Figure 1.3. Historic Average Monthly Temperature and Precipitation

1.2. Observed Trends in Current Climate and Climate Change

1.2.1. Observed Trends in Historic Temperature, Precipitation, and Inflow Volume

An assessment of observed trends in historic temperature and precipitation was conducted using local climate data available from both the MRCC at Shoals IN and Louisville District Water Management. Temperature and precipitation datasets analyzed include the average annual temperature and total annual precipitation. These data, associated trends, and statistical significance values are displayed in Figure 1.4 through Figure 1.6.

A statistically significant decreasing trend was identified in the annual average temperature dataset, Figure 1.4, and shows a linear regression slope of -0.022°F per year (p-value < 0.0001). However, if a subset of the timeseries from 1975 – 2020 is analyzed, a statistically significant increasing trend is identified with a positive slope of 0.056 and a p-value of 0.0016. The temperature dataset exhibits significant nonstationarity as well, which likely helps to explain the differing trend directions.

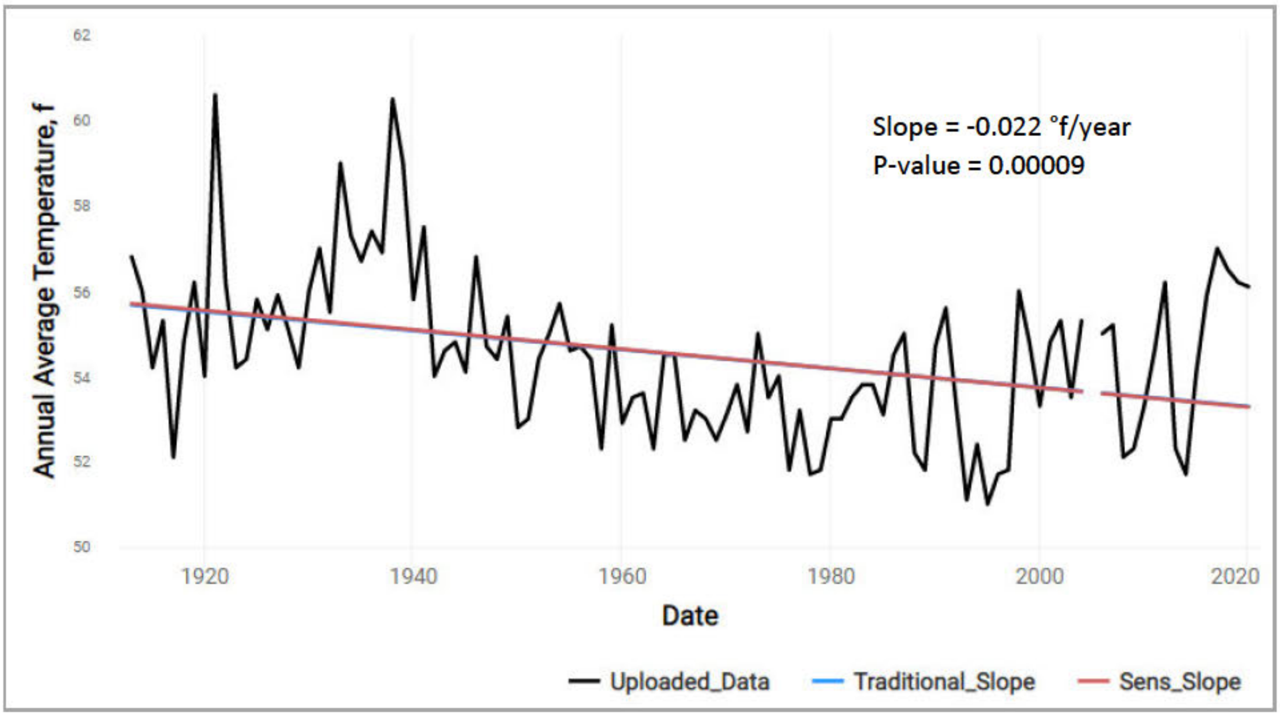


Figure 1.4. Trends in Observed in Annual Average Temperature (Shoals, IN)

Trends in total annual precipitation were analyzed for both the MRCC (POR = 1927 – 2020) and Water Management datasets (POR 1983 – 2020), these are displayed in Figure 1.5 and Figure 1.6. Both datasets exhibited statistically significant increasing trends (i.e. p-value < 0.05) in total annual precipitation over their periods of record. Data, trend slope, and p-values are shown in the respective figures.

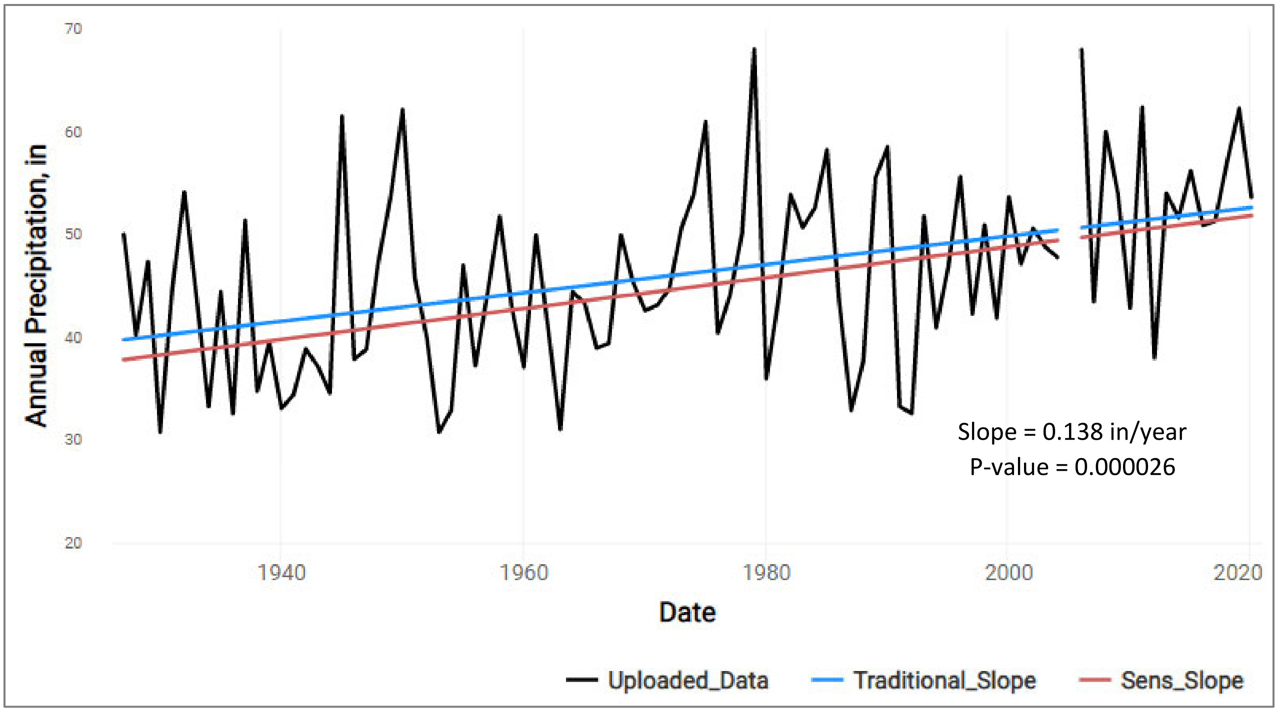


Figure 1.5. Trends in Observed Annual Precipitation (MRCC @ Shoals, IN)

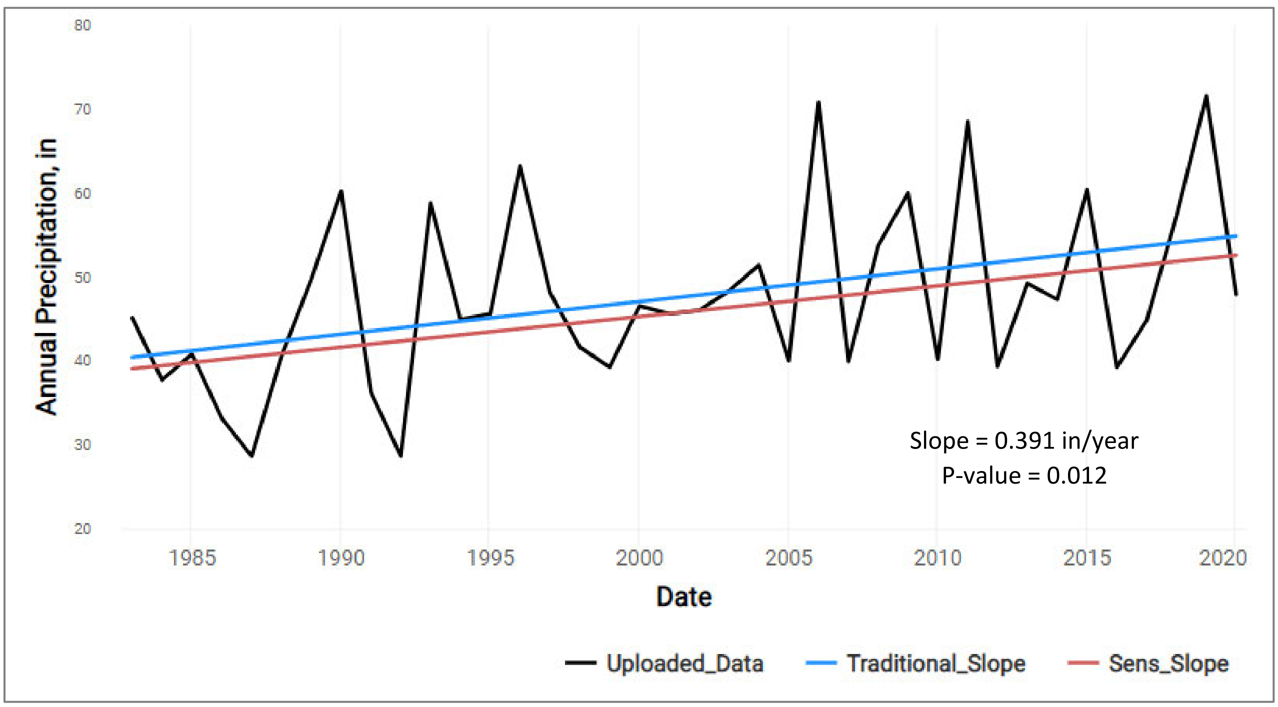


Figure 1.6. Trends in Observed Annual Precipitation (LRL WM)

To further evaluate the increasing trends identified in the observed precipitation record, trend analysis of reservoir inflow volume was also analyzed. Inflow volume was analyzed by aggregating inflow data in three ways: monthly-average inflow volume, annual-average inflow volume, and annual-max of monthly-average inflow volume. Louisville District Water Management 6-hour records were used as a base data source for this analysis. Trends associated with monthly-average inflow volume are shown in Figure 1.7, annual-average inflow volume in Figure 1.8, and annual-max of monthly-average inflow volume in Figure 1.9. Statistical properties including slope and p-value are included in these figures.

Of the three inflow volume datasets analyzed, monthly-average inflow volume showed a statistically significant increasing trend with a p-value of 0.048. The magnitude of this trend is 147 acre-ft/year, or roughly a 42% increase since the beginning of the period in 1983. Both other inflow volume datasets analyzed also showed increasing trends, but not at a statistically significant levels (assuming a significance threshold of p = 0.05). Annual-maximum inflow was also analyzed for trends, but did not exhibit any statistically significant trends.

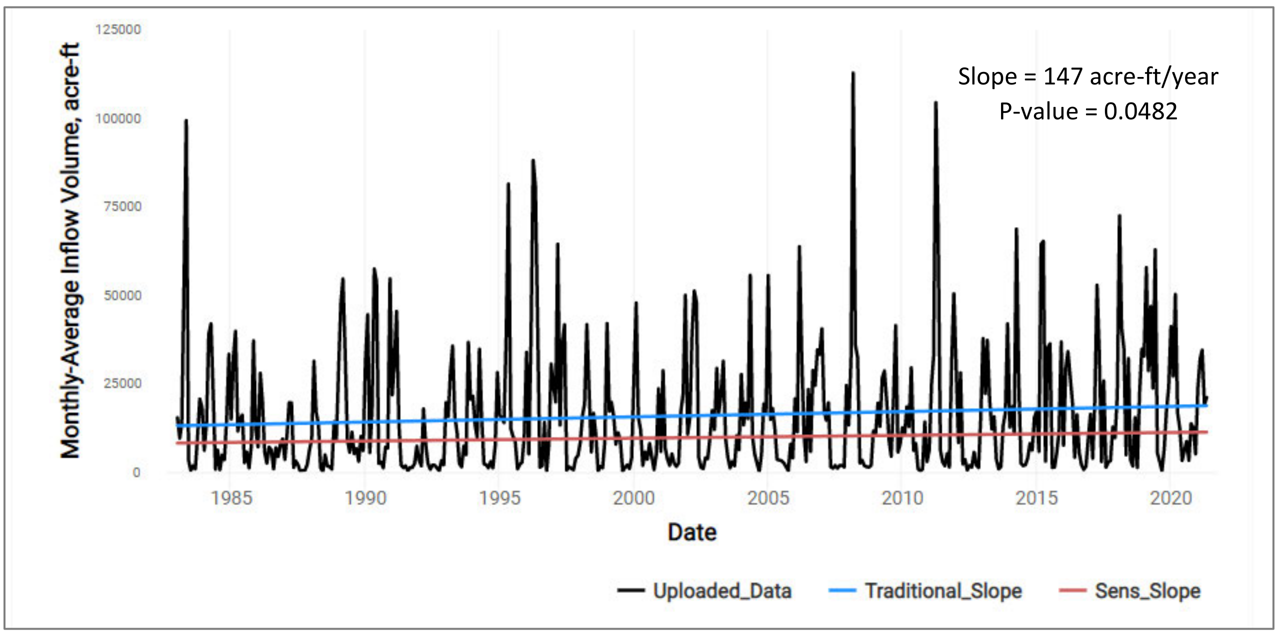


Figure 1.7. Trends in Monthly-Average Inflow Volume

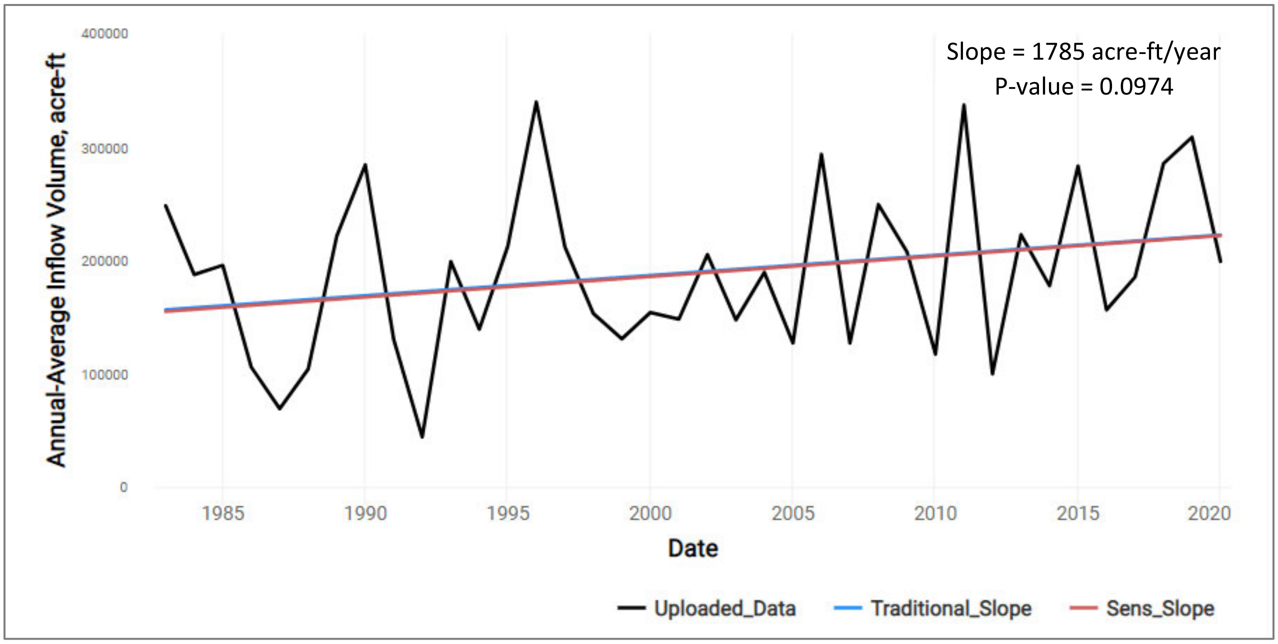


Figure 1.8. Trends in Annual-Average Inflow Volume

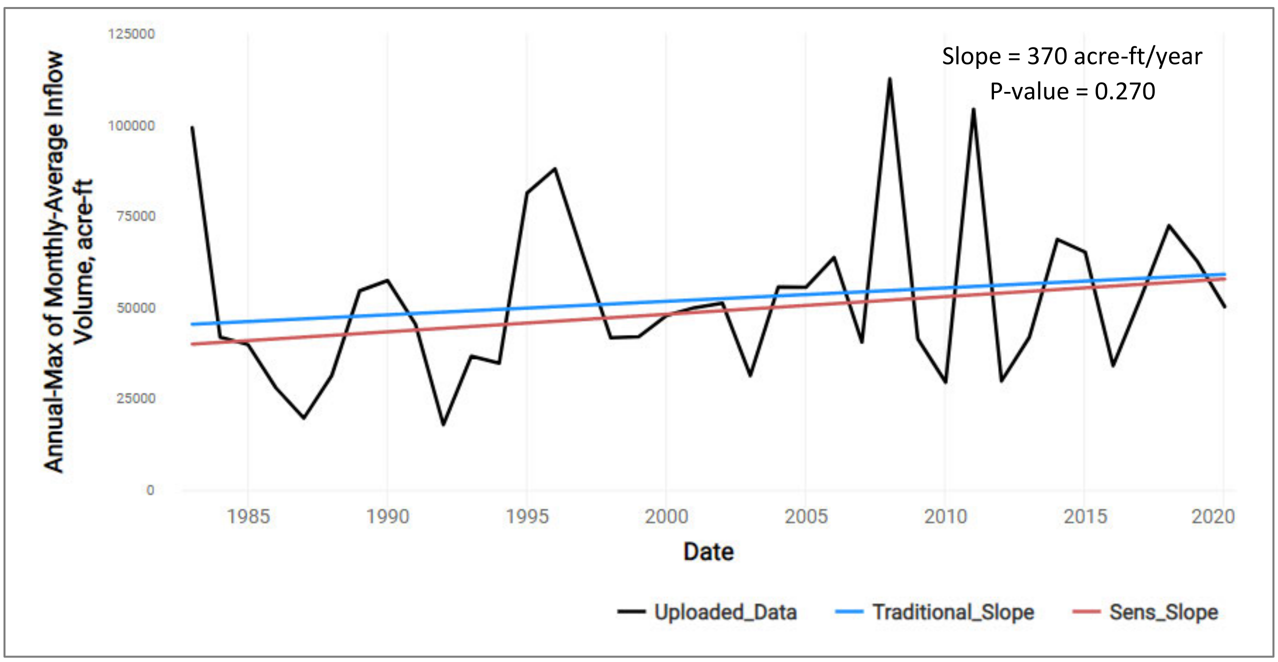


Figure 1.9. Trends in Annual-Max of Monthly-Average Inflow Volume

1.2.2. Literature Review

1.2.2.1. Recent US Climate Change and Hydrology Literature Syntheses

A September 2015 report conducted by the USACE Institute of Water Resources summarizes the available peer reviewed literature related to trends in both observed and projected hydrometeorological variables for the Ohio Region (HUC 05), which includes the Wabash River Basin and Patoka River watershed. Figure 1.10 below summarizes the findings from the literature synthesis and results are discussed in additional detail in the following paragraphs. It should be noted that this figure was produced in 2015 and substantial research has occurred since its publication. Were this figure to be updated, the number of relevant literature studies reviewed (n) would likely increase for all hydrologic variables.

Temperature. The 2015 USACE Literature Synthesis found that a majority of reports supported increasing trends in observed temperature for the Ohio Region. However, there is a general consensus that the Ohio Region spans a transition zone between a century-long warming trend of the north and a cooling trend of the south. There have been inconsistent findings about the geographic extent and seasonality of the warming and cooling zones.

Precipitation. According to the USACE Literature Synthesis: “A mild increasing trend in precipitation in the study region, in terms of both annual totals and occurrence of storm events, has been identified by multiple authors but a clear consensus is lacking. Results show increases in precipitation in some portions of the Ohio Region and show decreases in other portions. Recent reports indicate that rainfall may be concentrated more in larger events now than in the past.”

Hydrology / Streamflow. The 2015 USACE Literature Synthesis found the studies reviewed were split on conclusions about streamflow trends in the Ohio Region for the past 60 years. However, more authors indicated an upward trend in streamflow for the region than did not.

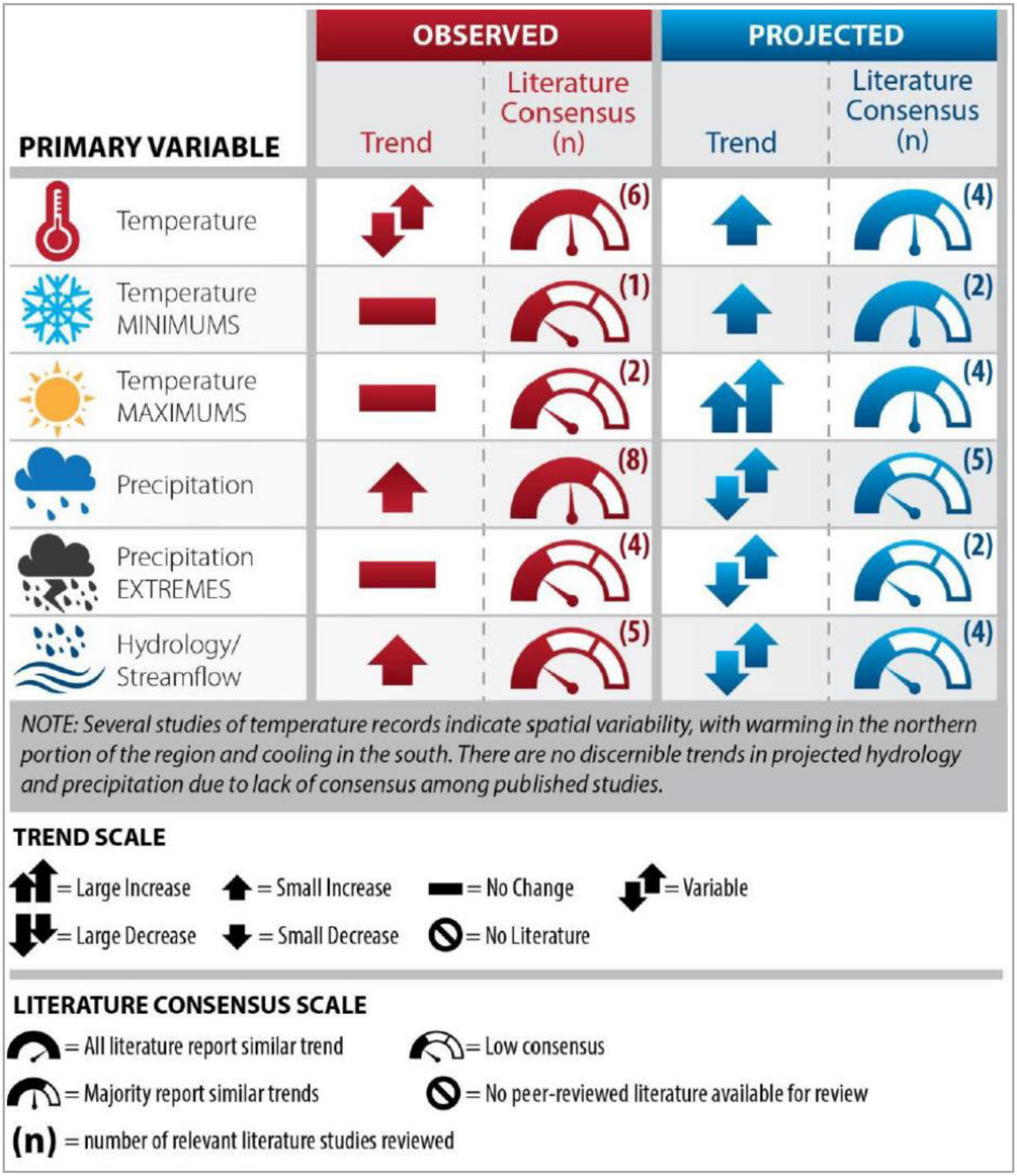


Figure 1.10. Summary of Findings from 2015 USACE Literature Synthesis, Ohio Region 05

1.2.2.2. Fourth National Climate Assessment

The Fourth National Climate Assessment (NCA4) Volume II, released in 2018, draws on science described in NCA4 Volume I and focuses on human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics. Particular attention is paid to observed and projected risks, impacts, consideration of risk reduction, and implications under different mitigation pathways. Of interest to this qualitative analysis are the chapters regarding changing climate, and water.

Temperature. Nationally, annual average temperatures have increased over the continental U.S. by 1.2°F from 1986-2015 and 1.8°F relative to the beginning of the last century Figure 1.11, adapted from NCA4, displays observed changes in temperature for the period from 1986 – 2016, as compared with the historic average from the period of 1901 – 1960 (for the continental U.S.). Note that the vicinity of the project area has experienced warming of 0 to 1-degree Fahrenheit. The approximate study area is circled in red in the following figures.

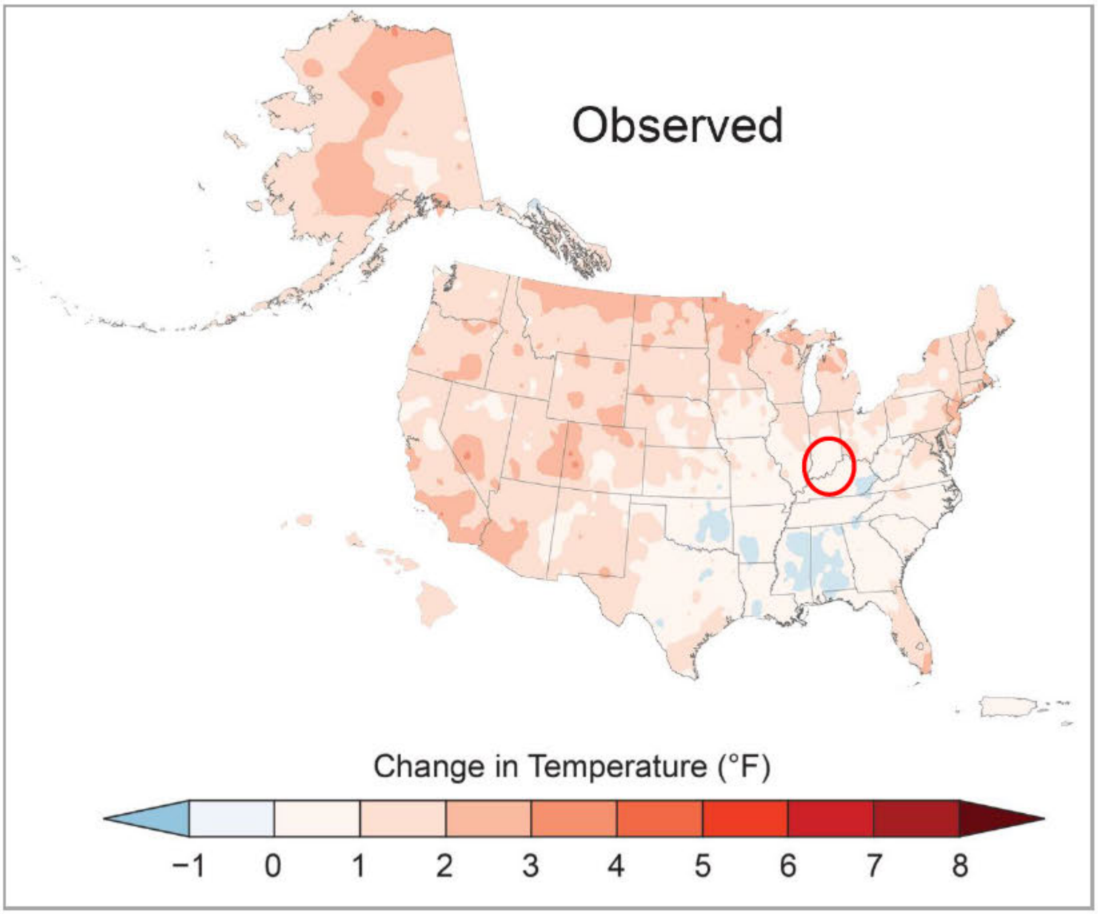


Figure 1.11. Observed changes in Temperature

Precipitation. Annual Precipitation since the beginning of the last century has increased across most of the northern and eastern U.S, whereas decreases have been observed across much of the southern and western U.S. There is much more regional variation in observed precipitation change as compared with observed temperature change, as the influence of temperature on precipitation varies greatly based upon terrain, elevation, and proximity to moisture sources.

Figure 1.12 displays the percent change in annual precipitation for the period of 1986 – 2015, as compared with the historic baseline of 1901 – 1960. Looking more closely at the East-Central U.S., the Patoka River watershed has observed an increase in annual precipitation between 5% and 20%. The magnitude of trends previously discussed and shown in Figure 1.5 (~15% increase over the same period of time) closely matches the figure from the NCA4.

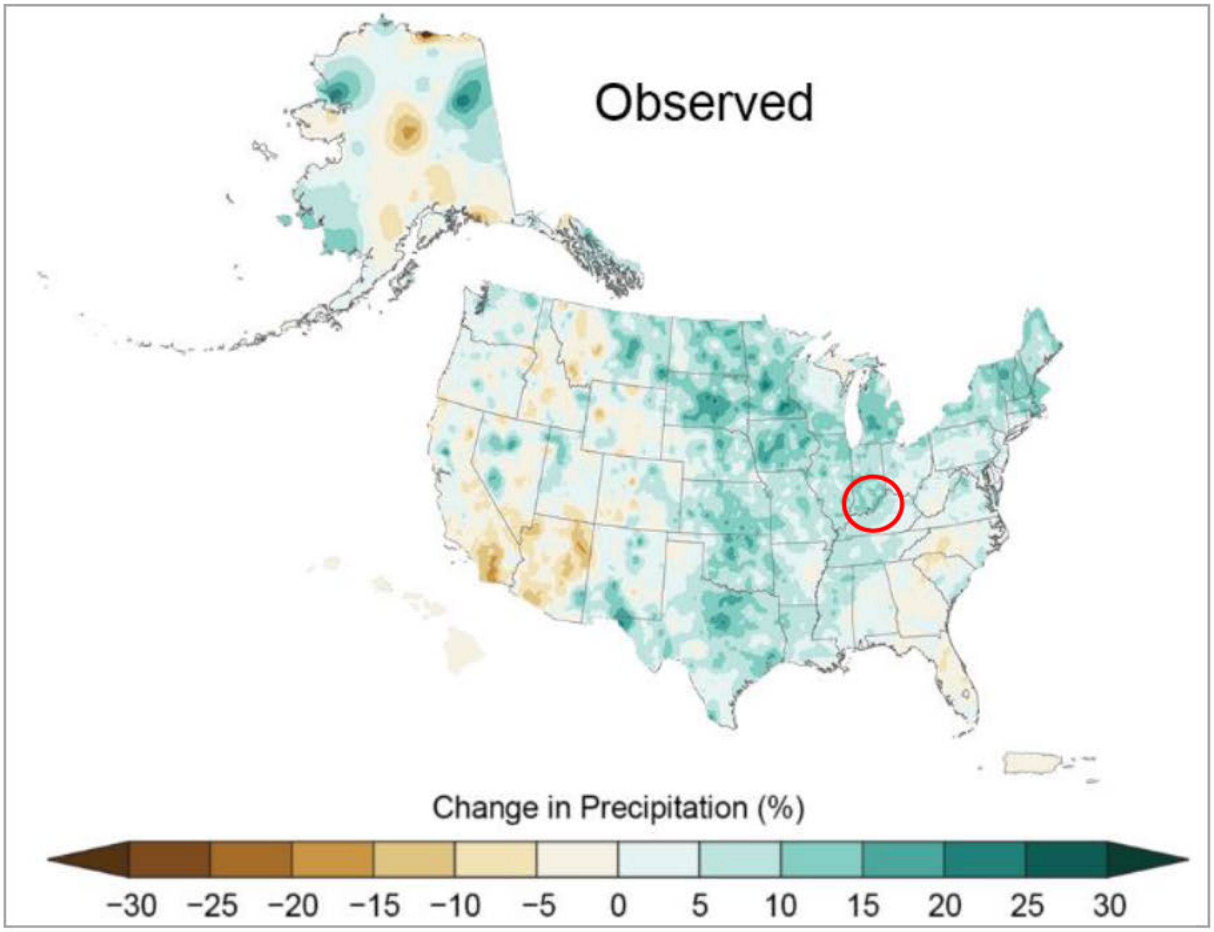


Figure 1.12. Observed changes in Precipitation

Additionally, there have been observed increases in the frequency and intensity of heavy precipitation events throughout much of the U.S. Figure 1.13 displays the percent increase in the amount of precipitation falling during the heaviest 1% of events (99th percentile of the distribution). The left map within Figure 1.13 displays the percent difference between the 1901-1960 historic baseline versus the 1986-2016 period, whereas the right map displays linear trend changes over the period between 1958 and 2016. Note that in both the left and the right side of the figure, the project area has experienced an increase in the precipitation falling during extreme events. This indicates that extreme events have been becoming increasingly intense over the past decades. The observed trends in heavy precipitation are supported by well-established physical relationships between temperature and humidity.

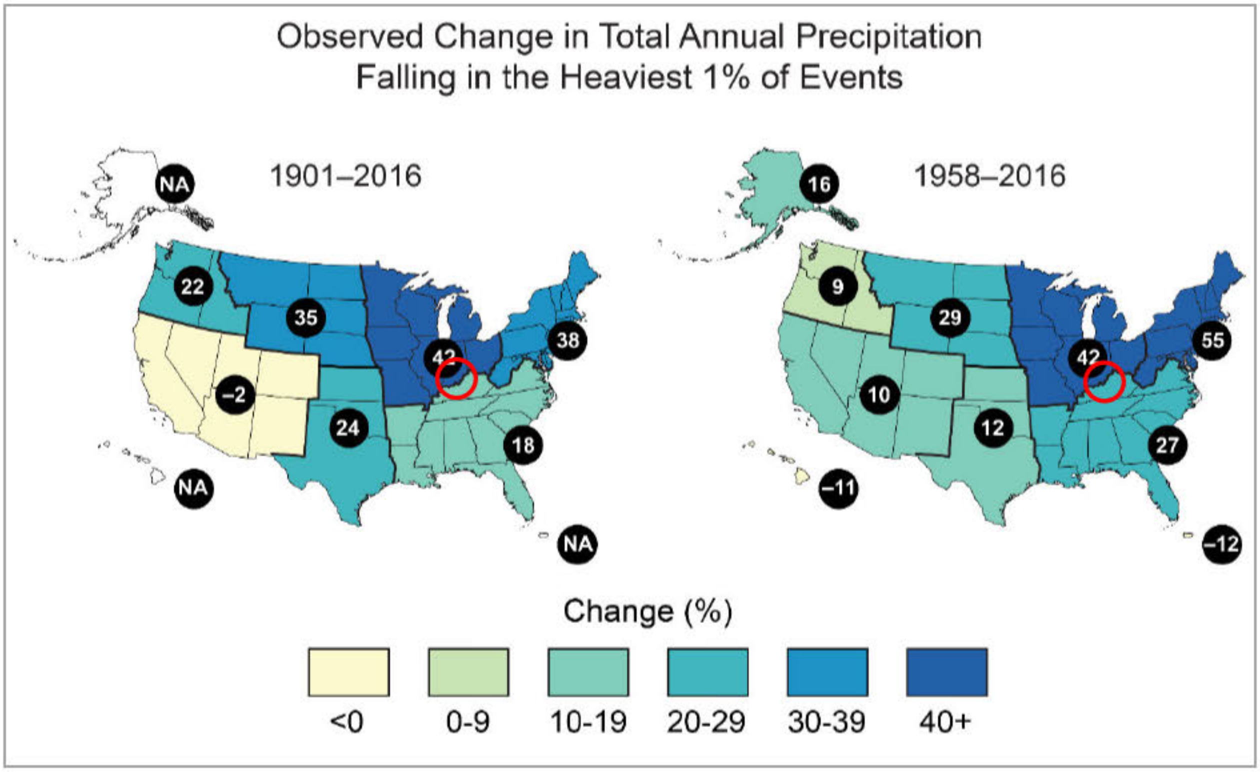


Figure 1.13. Observed percent change in the amount of precipitation falling during the heaviest 1% of events

1.2.3. Nonstationarity Detection

The Time Series Toolbox (TST) Nonstationarity Detection was used to assess whether the assumption of stationarity, which is the assumption that the statistical characteristics of a time-series dataset are constant over the period of record, is valid for a given hydrologic time-series dataset. Nonstationarities are detected using 12 different statistical tests which examine how the statistical characteristics of the dataset change with time (Engineering Technical Letter (ETL) 1100-2-3, *Guidance for Detection of Nonstationarities in Annual Maximum Discharges*; *Nonstationarity Detection Tool User Manual*, version 1.2). Abbreviations of the 12 statistical tests are shown in the table below this section.

The analysis was applied to the following datasets: annual peak inflow, annual-average inflow volume, and annual-max of monthly-average inflow volume. No nonstationarities were detected in these datasets and they can therefore be considered stationarity and appropriate for trend analysis.

1.3. Projected Trends in Future Climate and Climate Change

1.3.1. Literature Review

1.3.1.1. Recent US Climate Change and Hydrology Literature Syntheses

In addition to the observed trends discussed previously, the 2015 USACE Literature Synthesis for the Ohio Region 05 also summarizes available literature for projected future trends in various hydrometeorological variables. These variables are projected using a variety of statistical methods in conjunction with global circulation models (GCMs). Figure 1.10 above summarizes the findings of the literature synthesis regarding projected climatic trends. Additional discussion is provided in the following paragraphs.

Temperature. The 2015 USACE Literature Synthesis found strong consensus in the literature that temperatures will increase in the study area over the next century. "The projected increase in mean annual air temperature ranges from 0 to 8°C (0 to 14.4°F) by the latter half of the 21st century. The largest increases are generally projected for the summer months. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long-term future compared to the recent past."

Precipitation. "Projections of precipitation in the study region are less certain than those associated with air temperature. Most studies project increases, but some predictions are for decreases, or for increases in some portions of the region and decreases in others. Similarly, while the projections trend toward more intense and frequent storm events than the recent past, some show a reduction in parts of the Ohio Region."

Hydrology / Streamflow. Low consensus exists amongst the literature with regards to projected changes in hydrology for the region. Large variability in the projected hydrologic parameters (e.g. runoff, streamflow, SWE) exist across the literature and varied with location, hydrologic modeling approach, GCM used, and adopted emission scenario.

1.3.1.2. Fourth National Climate Assessment

In addition to the observed trends discussed previously, the NCA4 offers climatic projections, as well as the implications of these projections on risk, infrastructure, engineering, and human health.

Temperature. Increases in temperature of about 2.5°F are expected over the next few decades regardless of future greenhouse gas emissions. Temperature increases ranging from 3° to 8°F are expected by the end of the century, depending on whether the world follows a higher or lower future emission scenario. Extreme temperatures are expected to increase proportionally to the average temperature increases. Figure 1.14 displays future projected, annual, average temperatures for two future time periods, the mid-21st century and late 21st century. These are compared with the historic baseline period of 1986-2015. Additionally, projections are shown for two emission scenarios, or representative concentration pathways (RCPs) of greenhouse gases. RCP8.5 is a higher emission scenario and RCP4.5 is a moderate emission scenario.

Note that in general, increases in projected temperature are greater in higher latitudes and lessen farther south in the country. The project area tends to span a north-south transitional area of warming. Regardless of spatial variation, temperature increases are projected for the entire country under all emission scenarios.

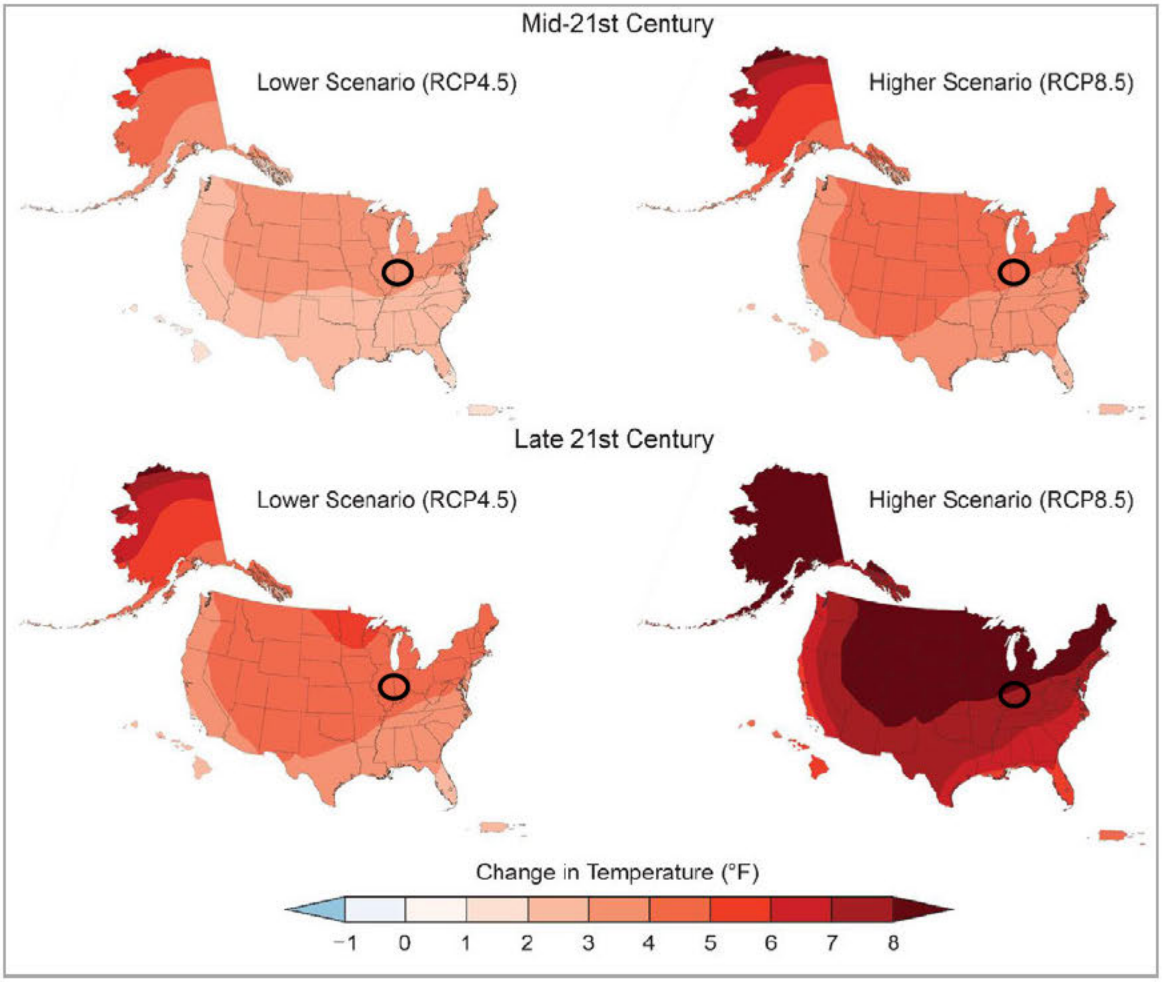


Figure 1.14. Future projections of temperature for various time frames and emission scenarios

Precipitation. Both increase and decreases in average annual precipitation are expected over the coming decades depending on location, season, and various other factors. Figure 1.15 displays the seasonal variation in annual precipitation in the later part of the century as compared with the historic period of 1986-2015. Note that there is significant variation in projections depending on location and season. Also note that red dots indicate that the projected trends due to climate change are considered to be large as compared with natural variations in climate, whereas the hatched areas show areas where the projected trends due to greenhouse gas emissions are considered to be relatively insignificant when compared to natural climate variability. Looking more closely at the Patoka Reservoir watershed area, most of the trends in precipitation during the summer and fall months can be considered relatively insignificant. However, winter and spring precipitation both show projected increases in annual rainfall of approximately 10% - 20%. Surface soil moisture is expected to decrease across most of the U.S. and will be accompanied by large declines in snowpack in the western U.S. as winter precipitation shifts from falling as snow to falling as rain. This hydrologic shift may cause changes in the behavior of the Patoka River Reservoir inflows and other systems influenced by snow melt.

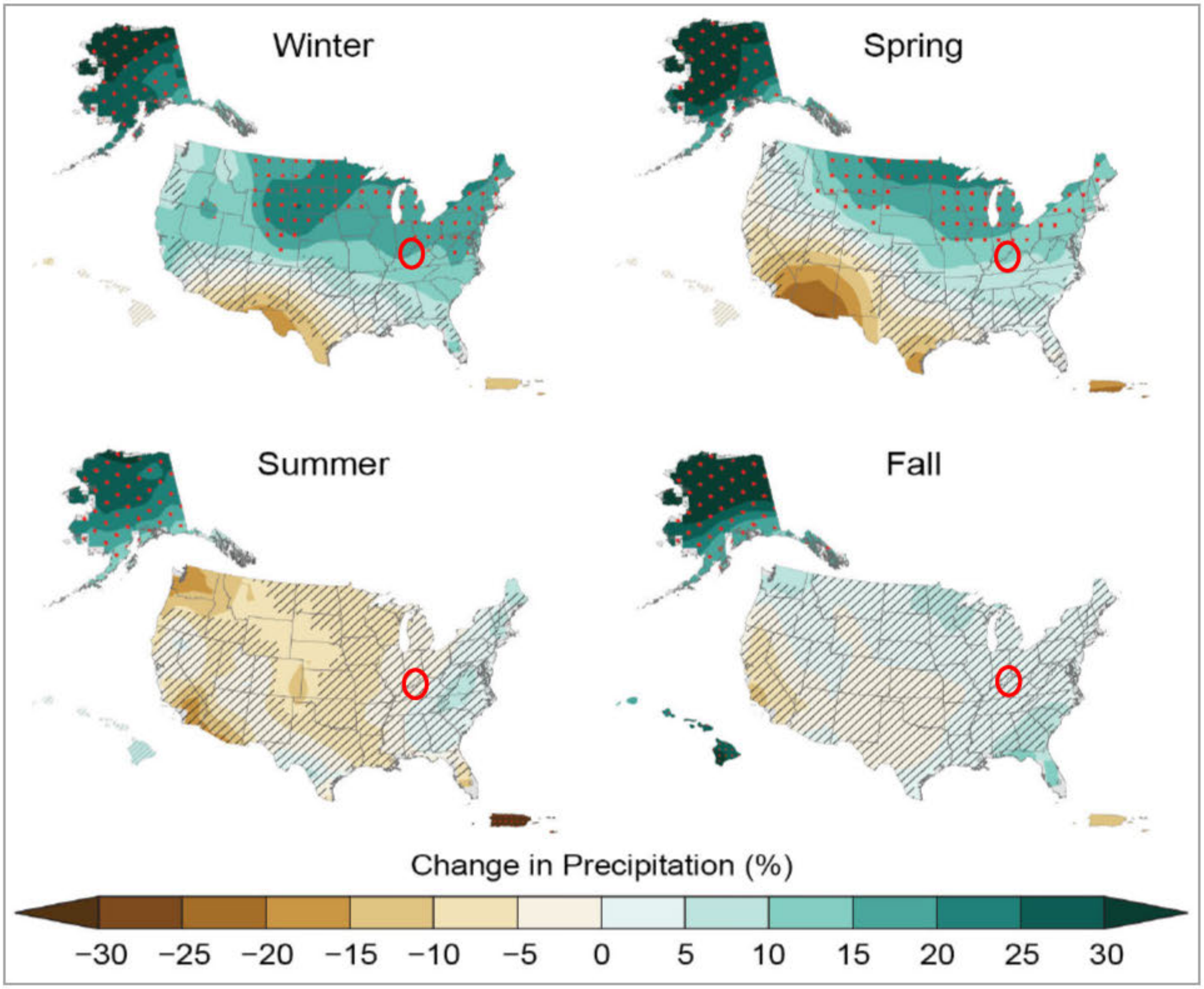


Figure 1.15. Projected percent change in future precipitation for different seasons under a high emission scenario (RCP8.5)

The observed increases in frequency and intensity of heavy precipitation discussed earlier are projected to continue, with higher emission scenarios producing stronger increasing trends. Figure 1.16 displays the projected change in total annual precipitation falling during the heaviest 1% of storms for a time period between 2070 and 2099. Note in the vicinity of the Patoka Reservoir watershed area, under a moderate emission scenario (RCP4.5), the annual precipitation falling during the heaviest 1% of events is expected to increase by approximately 20% to 29%. Under a higher emission scenario (RCP8.5), the basin is expected to experience extreme event precipitation increases in excess of 40%. These trends are consistent with what would be expected with warmer temperatures, as increased evaporation rates lead to higher levels of water vapor in the atmosphere which in turn leads to more frequent and intense precipitation events.

The NCA4 qualitatively discusses some of the risks associated with projected climate conditions. The NCA4 report emphasizes that the likelihood of hydrometeorological phenomena like droughts, extreme storms and flood events may be misrepresented when defined using historic records that are limited in length (approximately 10-100 years). Selected points from the discussion relevant to this project are below.

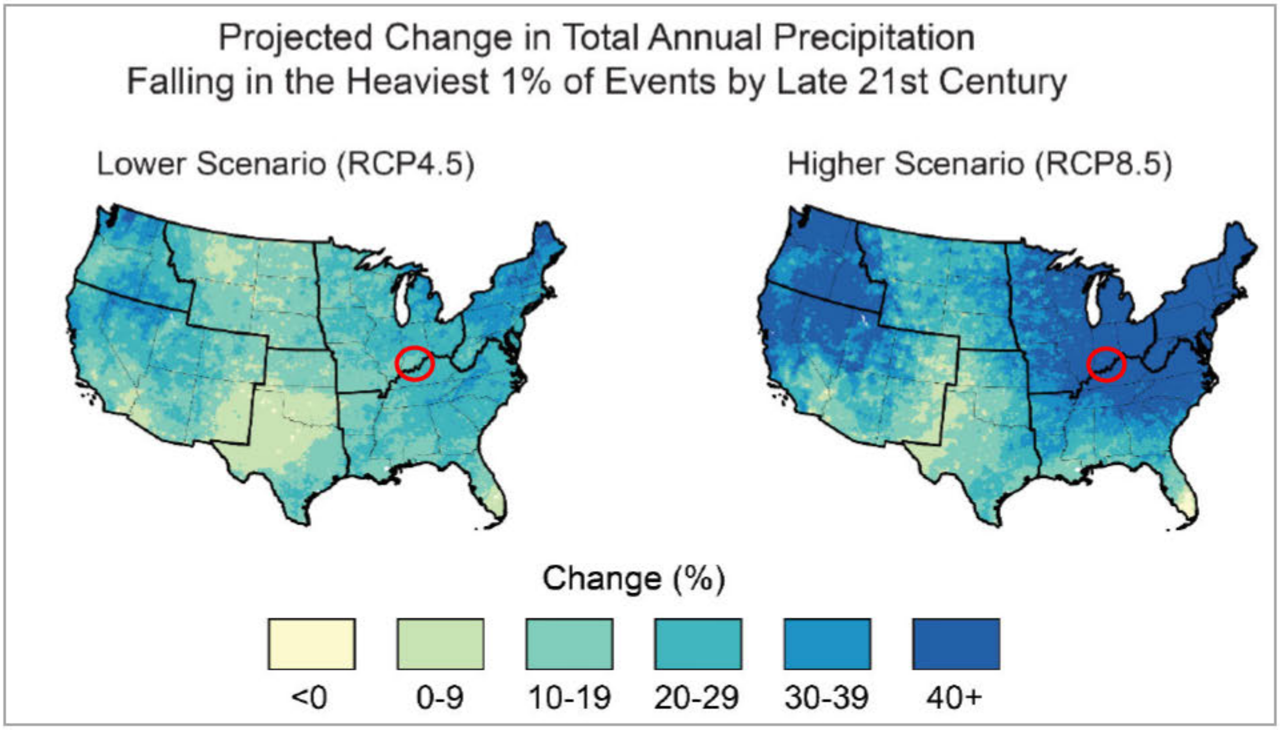


Figure 1.16. Projected percent change in the amount of precipitation falling during the heaviest 1% of events under various emission scenarios

Flood Risk Reduction. There is also potential for climate change driven changes to hydrologic conditions to increase stress on infrastructure within the Patoka River Reservoir watershed. As higher temperatures increase the proportion of cold season precipitation falling as rain rather than snow, higher inflow is projected to occur in many basins, raising flood risks. The more extreme drought and heavy rainfall events can compromise the reliability of flood risk management. The growing number of extreme rainfall events is stressing the deteriorating infrastructure in the Southeast and Mid-Western United States. Many transportation and storm water systems have not been designed to withstand these events which poses a greater risk of failure. Statistical methods have been developed for defining climate risk and frequency analysis that incorporate observed and/or projected changes in extremes. However, these methods have not yet been widely incorporated into infrastructure design codes, risk assessments, or operational guidelines.

The procedures used to design water resources infrastructure, estimations of probability of failure, and risk assessments for infrastructure typically rely on 10-100 years of observed data to define flood and rainfall intensity, frequency, and duration. This approach assumes that frequency and severity of extremes do not change significantly with time. However, numerous studies suggest that the severity and frequency of climatic extremes, such as precipitation and heat waves, have in fact been changing due to human-driven climate change. These changes represent a regionally variable risk of increased frequency and severity of floods and drought. Additionally, tree ring-based reconstructions of climate over the past 500 years for the U.S. illustrate a much wider range of climate variability than does the instrumental record (beginning around 1900). This historic variability includes wet and dry periods with statistics very different from those of the 20th century. Infrastructure design that uses recent historic data may underrepresent the risk seen from the paleo record, even without considering future climate change.

1.3.1.3. Patoka River Reservoir Basin – Formulating Climate Change Mitigation/Adaptation Strategies – Climate Change Pilot Study Report (Drum et. al., 2017)

In 2017 the USACE Institute for Water Resources (IWR) in coordination with Huntington District, Lakes and Rivers Division (LRD), Ohio River Basin Alliance, and various other agencies, published a multidisciplinary report providing downscaled climate modeling information for the entire Ohio River Basin, which included Patoka River Reservoir watershed, with forecasted precipitation and temperature data, along with streamflow at various gaging points throughout the basin. The projections are presented at the HUC-4 subbasin level through three 30-year time periods between 2011 and 2099.

In general, the modeling results indicate a gradual increase in annual mean temperatures from 2011 to 2040 of an approximate magnitude of one-half degree per decade. From 2041 to 2099, the rate of warming increases to one-full degree per decade. Changes in streamflow show much more variability than temperature across the Ohio River Basin which included Patoka River Reservoir basin. HUC-4 watersheds in the northeast, east, and south of the Ohio River are expected to see increases in precipitation and streamflow of up to 50%. Conversely, HUC-4 watersheds located to the north and west of the Ohio River are expected to experience decreasing precipitation, particularly in the fall-season, resulting in decreasing streamflows – up to 50% reductions – during the coming decades.

1.3.1.4. Analysis of Projected Changes in Precipitation IDF Values Based on Climate Change Projections

This analysis performed by CH2M Hill of projected changes in precipitation IDF values based on climate change projection was done for Louisville, Kentucky, in 2015. Louisville is 50 miles southeast of Patoka River Reservoir and is thought to be similar enough in landscape and climate to the Patoka Project location to inform this literature analysis.

CH2M Hill performed an analysis projecting precipitation values into the future and developing precipitation frequency estimates, comparable with Atlas 14, from these projected values. The future climate projections were accomplished using a circulation model known as SimCLIM, which utilizes 22 daily general circulation models and two emission scenarios at two different future time periods, 2035 and 2065. Selected emission scenarios include Representative Concentration Pathway (RCP) 8.5, which represents a “high” growth scenario for greenhouse gasses, and RCP 6.0 representing a “moderate” growth scenario.

When CH2M Hill’s projected future frequency estimates are compared with their estimates based on the observed precipitation record, the estimates increase from 10% to 16% by the year 2065. For example, for the 100-yr 24-hr storm, the precipitation depth is projected to increase from 7.81 inches to between 8.56 and 9.05 inches. Figure 1.17 displays a comparison between the precipitation projections and the “historical” baseline for a range of return periods. Note that the “historical” baseline is referring to a 2015 study where CH2M Hill updated Atlas 14 estimates with new data and stations through 2014. All projections were done using a 3-station average of the previously analyzed gages.

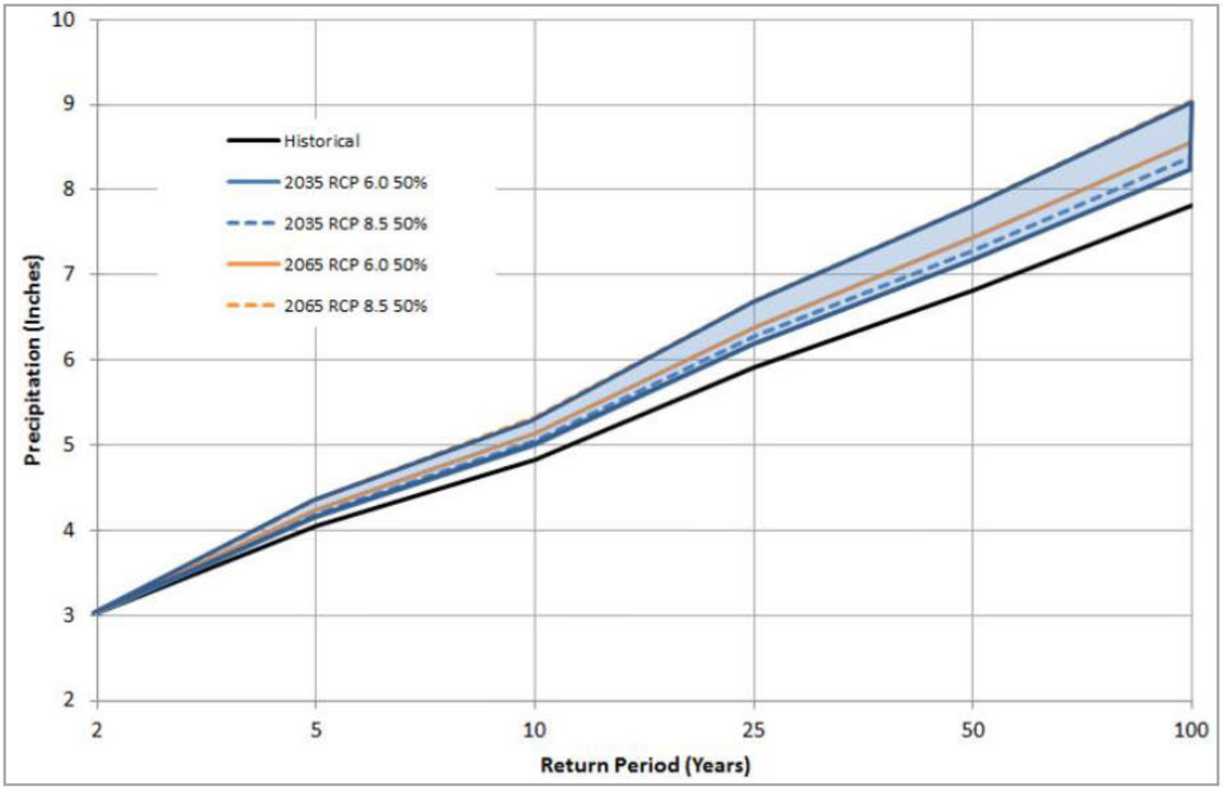


Figure 1.17. Comparison between Historical (2015 CH2M Hill Study) and Projected 24-hr Precipitation Frequency Estimate Climate Hydrology Assessment

1.3.2. Climate Hydrology Assessment

The USACE Climate Hydrology Assessment Tool (CHAT) can be used to assess projected future changes to streamflow in the watershed. Projections are at the spatial scale of a HUC-4 watershed, with flows generated using a Variable Infiltration Capacity (VIC) model from temperature and precipitation data statistically downscaled from GCMs using the Bias Corrected, Spatially Disaggregated (BCSD) method. The VIC model is set up to simulate unregulated basin conditions. The Patoka Lake Reservoir is in HUC 05120209 (Patoka River) and a stream segment near Patoka Lake Dam (segment 05002986) was selected for analysis. Figure 1.18 displays the range of output presented in the CHAT using 93 combinations of GCMs and representative concentration pathways (RCPs) of greenhouse gas emissions applied to generate climate-changed hydrology using the VIC model. The range of data is indicative of the uncertainty associated with projected climate-changed hydrology.

Upon examination of the range of model results for streamflow and precipitation, there is a clear increasing trend in the higher projections, whereas the lower projections appear to be relatively stable and unchanging through time. The spread of the model results also increases with time, which is to be expected as uncertainty in future projection increases as time moves away from the model initiation point. Sources of variation and the significant uncertainty associated with these models include the boundary conditions applied to the GCMs, as well as variation between GCMs and selection of RCPs applied. Each GCM and RCP independently incorporate significant assumptions regarding future conditions, thus introducing more uncertainty into the climate changed projected hydrology. Climate model downscaling and a limited temporal resolution further contribute to the uncertainty associated with CHAT results. There is also uncertainty associated with the hydrologic models.

Figure 1.19, Figure 1.20, and Figure 1.21 display trends associated with projected future streamflow, precipitation, and temperature. Table 1.3 displays the trend magnitude (regression slope) and statistical significance (p-value) for each of the parameters. Specifically, the datasets analyzed are: Annual-Maximum of Mean-Monthly Streamflow, Projected Annual-Maximum 1-day Precipitation, and Projected Annual-Mean Temperature. For each parameter trendlines are generated for both the RCP 4.5 and RCP 8.5 future greenhouse gas emission scenarios. Except for the RCP 4.5 streamflow parameter which does not exhibit significant trends, all other trends analyzed are considered statistically significant at a 0.05 p-value threshold. The magnitude of the streamflow projection under an RCP 8.5 future scenario is approximately 1 cfs/year, or roughly a 6.5% increase in annual-maximum of mean-monthly streamflow over a 50-yr timeframe.

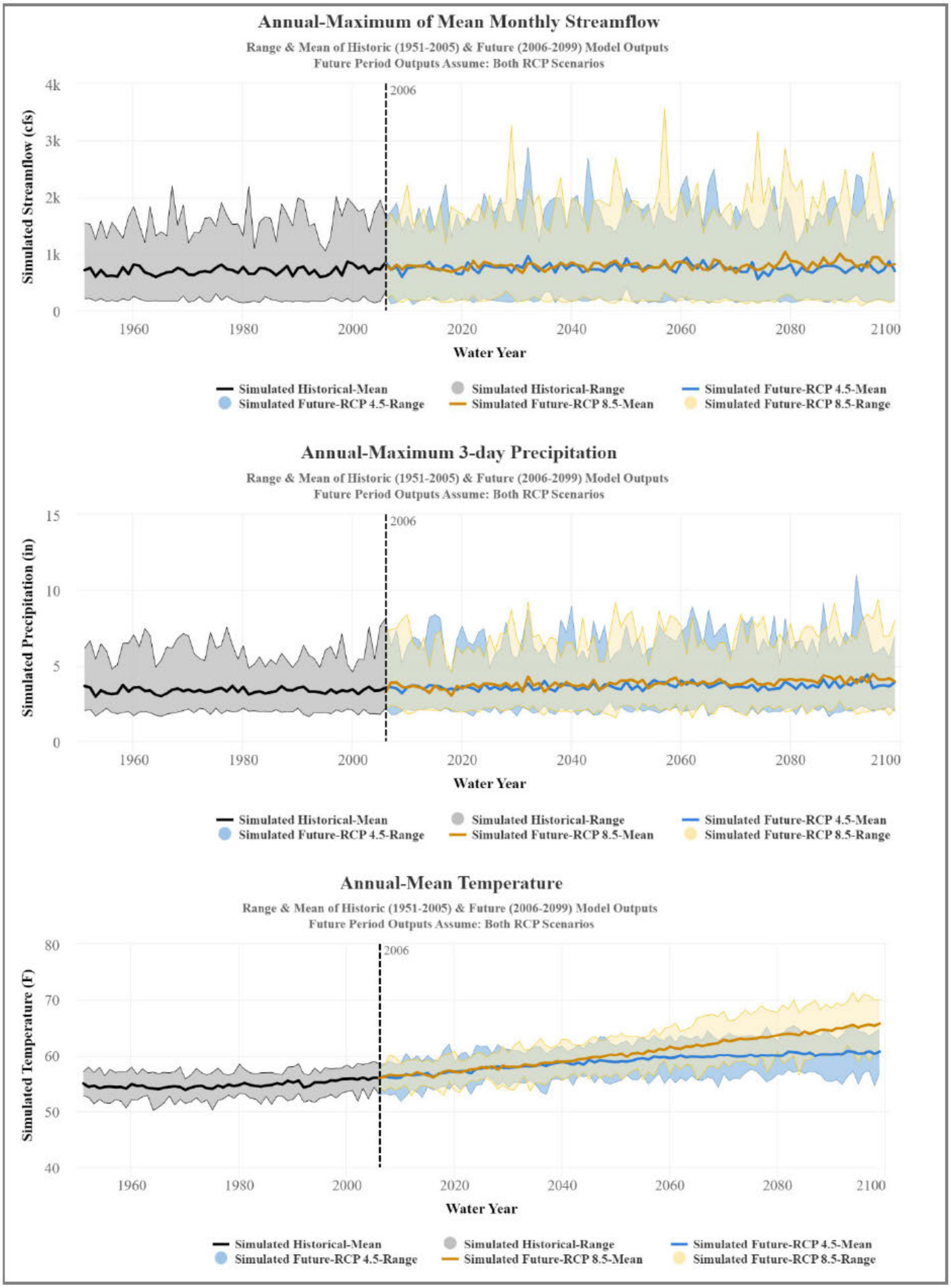


Figure 1.18. Range of 93 Climate-Changed Hydrology Model Output for Patoka River. Mean monthly streamflow, annual-maximum 3-day precipitation, and annual-mean temperature.

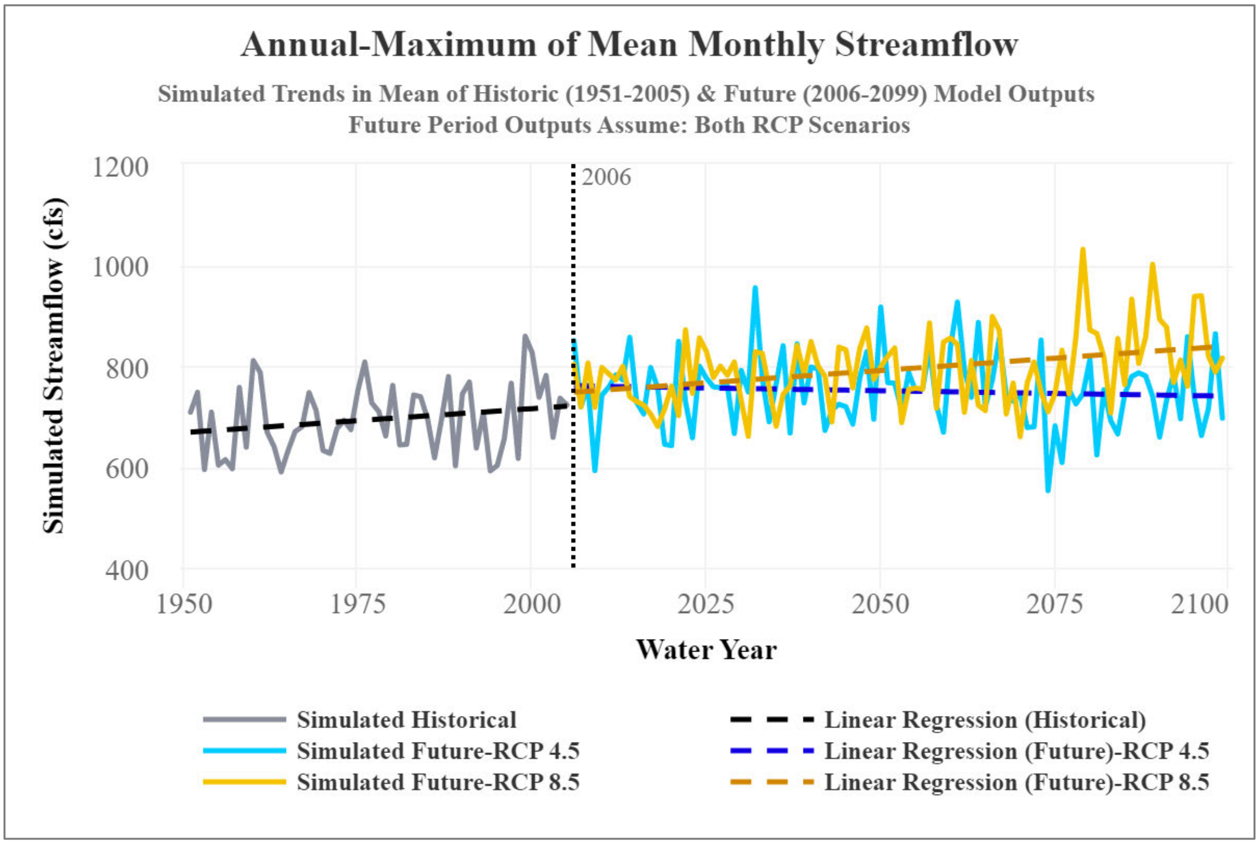


Figure 1.19. Projected Annual-Maximum of Mean-Monthly Streamflow

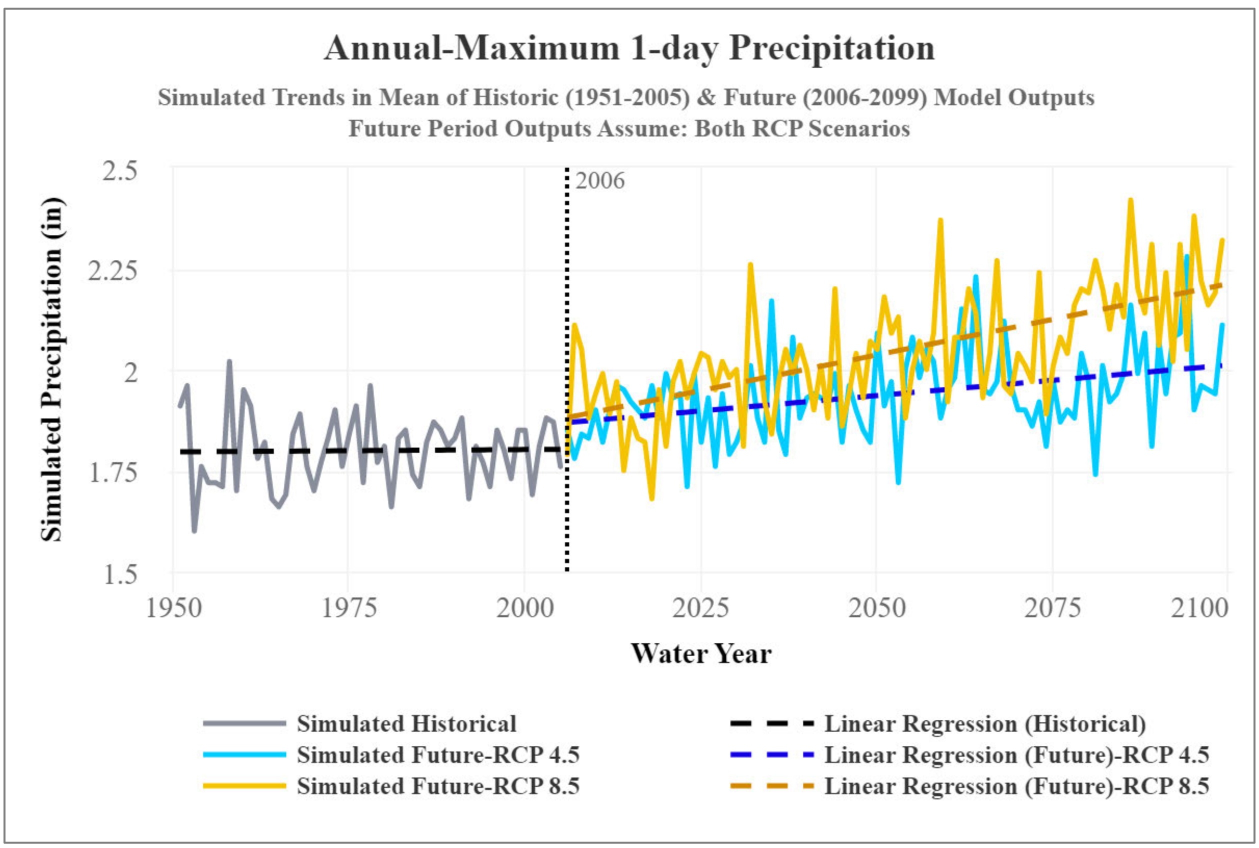


Figure 1.20. Projected Annual-Maximum 1-day Precipitation

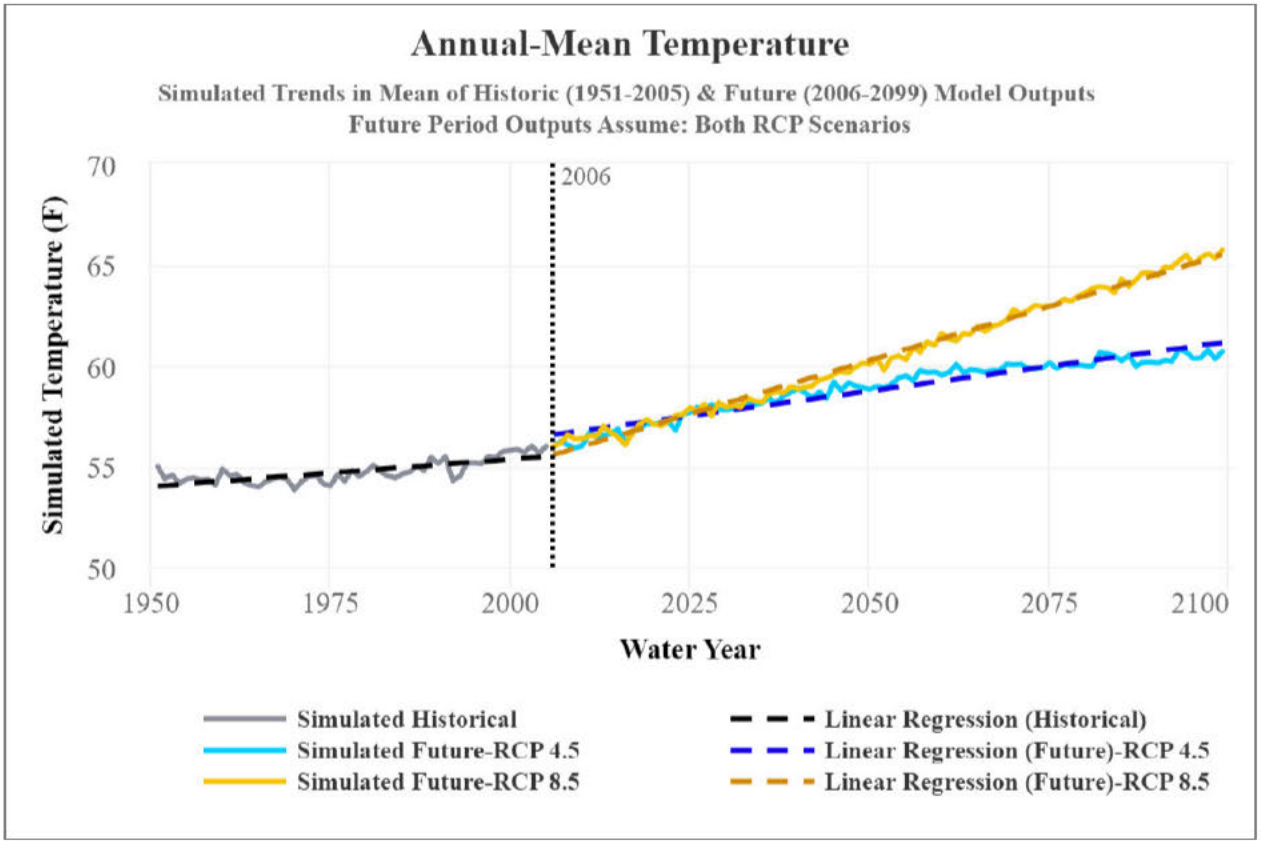


Figure 1.21. Projected Annual-Mean Temperature

Table 1.3. Summary of Projection Trends

Projected Hydrology Parameter	Regression Slope		p-value	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Annual-Maximum of Mean-Monthly **Streamflow** *(cfs / year)*	-0.22	1.0	0.43	0.00023
Projected Annual-Maximum 1-day **Precipitation** *(inches / year)*	0.0015	0.0035	0.00013	<0.00001
Projected Annual-Mean **Temperature** *(°F / year)*	0.049	0.11	<0.00001	<0.00001

1.3.3. Vulnerability Assessment

The USACE Watershed Climate Vulnerability Assessment Tool (VA Tool) facilitates a screening level, comparative assessment of how vulnerable a given HUC-4 watershed is to the impacts of climate change relative to the other 202 HUC-4 watersheds within the continental United States (CONUS). The tool can be used to assess the vulnerability of a specific USACE business line such as "Flood Risk Reduction" or "Navigation" to projected climate change impacts. Assessments using this tool help to identify and characterize specific climate threats and particular sensitivities or vulnerabilities, at least in a relative sense, across regions and business lines. The tool uses the Weighted Ordered Weighted Average (WOWA) method to represent a composite index of how vulnerable a given HUC-4 watershed (Vulnerability Score) is to climate change specific to a given business line. The HUC-4 watersheds with the top 20% of WOWA scores are flagged as being relatively vulnerable.

Flood Risk Reduction (Management) is the most relevant business line to Patoka River Reservoir and was the primary business lines analyzed with the USACE Climate Vulnerability Assessment Tool. Business lines included in the VA tool include ecosystem restoration, emergency management, flood risk reduction, hydropower, navigation, recreation, regulatory, and water supply. While only the flood risk reduction business line is discussed in detail, the water supply and recreation business lines were also assessed as they are pertinent to the authorized purposes of Patoka Lake. These two business lines did not exhibit outstanding vulnerability.

When assessing future risk projected by climate change, the USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs of analysis centered at 2050 and 2085. These two periods were selected to be consistent with many of the other national and international analyses. The Vulnerability Assessment tool assesses how vulnerable a given HUC-4 watershed is to the impacts of climate change for a given business line using climate hydrology based on a combination of projected climate outputs from the general circulation models (GCMs) and representative concentration pathway (RCPs) resulting in 100 traces per watershed per time period. The top 50% of the traces is called “wet” and the bottom 50% of the traces is called “dry.” Meteorological data projected by the GCMs is translated into runoff using the Variable Infiltration Capacity (VIC) macro-scale hydrologic model. For this assessment, the default National Standards Settings are used to carry out the vulnerability assessment.

For the Flood Risk Management business lines, the Wabash River Basin (HUC 0512) is not within the top 20% of vulnerable watersheds within the CONUS for any of the four scenarios, which is not to say that vulnerability to future climate change does not exist within the basin. The indicators driving the residual vulnerability for the flood risk management is shown in Figure 1.22. Table 1.4 displays the indicators contributing to vulnerability within the Wabash River Basin for the flood risk reduction business lines; the tables are generally sorted from largest to smallest average indicator contribution to vulnerability. Additionally, the tables display the indicator code, name, and a brief description of the indicator’s meaning.

For the Flood Risk Reduction business line, the primary indicators driving vulnerability within the watershed are the flood magnification factor (indicators 568C and 568L) and the large elasticity between rainfall and runoff (indicator 277). The flood magnification factor represents how the monthly flow exceeded 10% of the time is predicted to change in the future; a value greater than 1 indicates flood flow is predicted to increase, which is true for the Wabash River Basin. The rainfall/runoff elasticity (indicator 277) measures the tendency for small changes in precipitation to result in large changes in runoff. These three factors contribute to approximately 80% of the vulnerability for this business line.

Note that some of the indicators contain a suffix of “L” (local) or “C” (cumulative). Indicators with an “L” suffix reflect flow generated within only one HUC-4 watershed, whereas indicators with a “C” suffix reflect flow generated within a HUC-4 watershed and any upstream watersheds.

It is important to note the variability displayed in the VA tool’s results highlights some of the uncertainty associated with the projected climate change data used as an input to the VA tool. Because the wet and dry scenarios each represent an average of 50% of the GCM outputs, the variability between the wet and dry scenarios underestimates the larger variability between all the underlying projected climate changed hydrology estimates. This variability can also be seen between the 2050 and 2085 epochs, as well as various other analysis within this report, such as output from the CHAT.

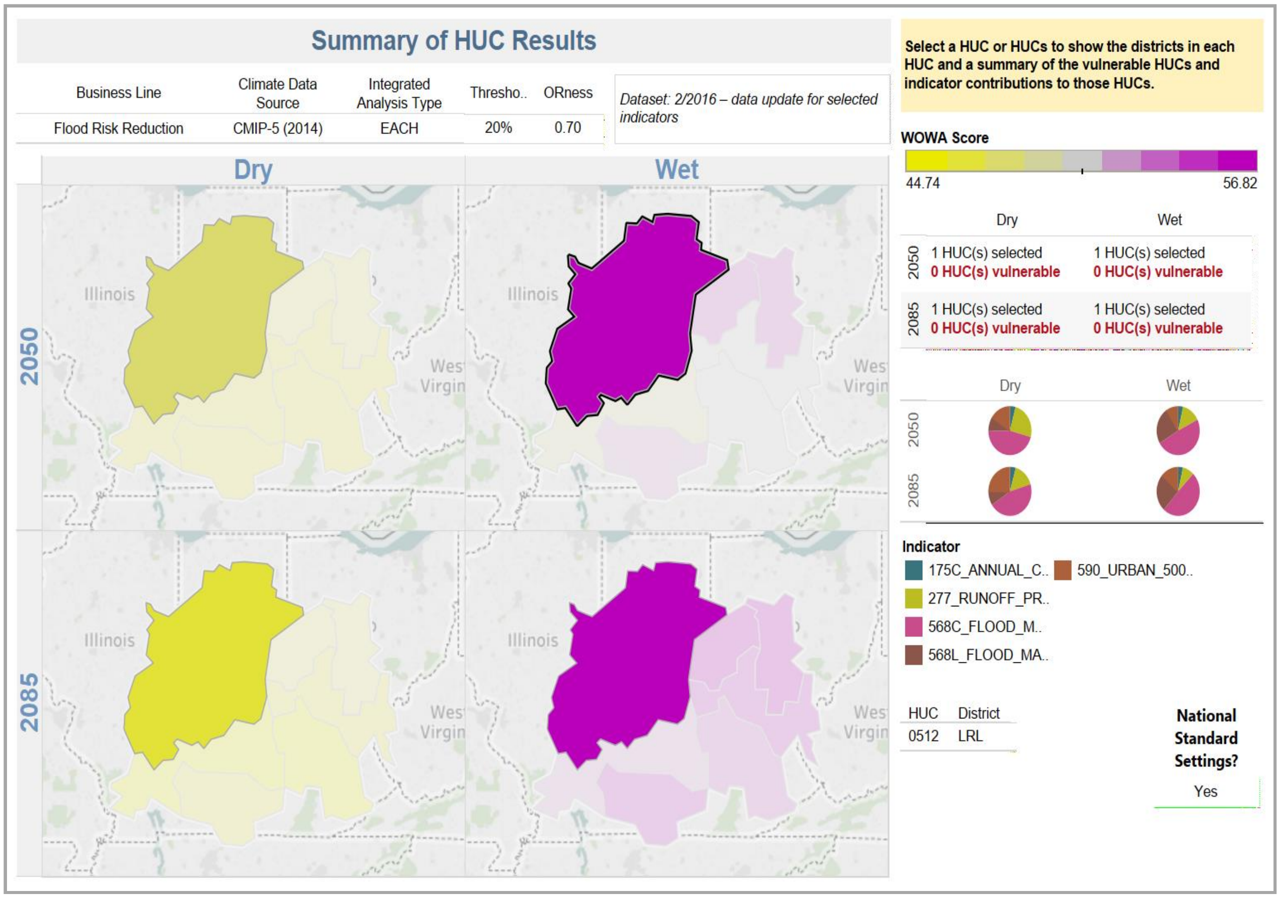


Figure 1.22. VA Tool Summary of HUC Results for Flood Risk Reduction Business Line

Table 1.4. Vulnerability Indicators for Flood Risk Reduction Business Line. Sorted by highest to lowest indicator contribution to vulnerability.

Flood Risk Reduction Business Line			2050	2050	2085	2085
Indicator Code	**Indicator Name**	**Description**	**Dry**	**Wet**	**Dry**	**Wet**
568C	Cumulative Flood Magnification Factor	Change in flood runoff: ratio of indicator 571C (monthly runoff exceeded 10% of the time, including upstream freshwater inputs) to 571C in base period.	45.50%	48.92%	45.40%	49.35%
277	Percent Change in Runoff Divided by the Percent Change in Precipitation	Median of: deviation of runoff from monthly mean times average monthly runoff divided by deviation of precipitation from monthly mean times average monthly precipitation.	25.02%	13.94%	15.88%	8.74%
568L	Local Food Magnification Factor	Change in flood runoff: Ratio of indicator 571L (monthly runoff exceeded 10% of the time, excluding upstream freshwater inputs) to 571L in base period.	9.70%	24.72%	9.68%	24.93%
590	Acres of Urban Area Within 500-Year Floodplain	Acres of urban area within the 500-year floodplain.	15.58%	8.76%	24.67%	13.45%
175C	Cumulative Annual Covariance of Unregulated Runoff	Long-term variability in hydrology: ratio of the standard deviation of annual runoff to the annual runoff mean. Includes upstream freshwater inputs (cumulative).	4.21%	8.76%	4.37%	3.53%

1.4. Summary and Conclusions

Summary of Historic Trends in Hydrometeorology.

Based on the literature review, there is consistent consensus among the available sources supporting trends of increasing precipitation and streamflow in the observed record within the region. These literature review findings are further strengthened by trend analysis of locally observed hydrology datasets which show increasing trends in precipitation and reservoir inflow volume. Trend analysis of locally observed temperature data shows a long-term decreasing trend, with a more recent increasing trend since around 1975.

Summary of Projected Trends in Hydrometeorology.

The literature review indicates conflicting trends in projected future streamflow and precipitation within the region, but does indicate strong potential for increases in future temperature. Results from the CHAT tool using future projections of climate-changed hydrology are less conflicted and indicate increases in precipitation and temperature for both future emission scenarios analyzed. Future projections of streamflow show statistically significant increasing trends under the higher emission scenario (RCP 8.5), but no trend was identified under the lower emission scenario (RCP 4.5). It should be noted that substantial uncertainty exists within future climate projections, this uncertainty is effectively illustrated by the range of GCM projections shown in Figure 1.18. At this time, each of the 93 climate projections included in this figure's range can be considered equally likely to occur.

Results from the USACE Vulnerability Assessment tool were analyzed for the project area and found no outstanding vulnerabilities compared with other HUCs across the continental United States. While the project area is not within the top 20% of vulnerable HUCs nationally, that does not imply that vulnerability to climate change does not exist. The VA tool indicates the flood magnification factor and rainfall/runoff elasticity factor are driving vulnerability within the Wabash River watershed. These two factors highlight the potential for increased runoff and streamflow in the future.

Table 1.5 displays some potential residual risks to the project due to climate change. This table lists potential climatic triggers, hazards, harms, and approximate qualitative likelihood of occurrence. The right-most column of the table indicates the qualitative likelihood that an event will occur, these are based largely upon the findings within the literature review and various climate assessment tool outputs.

Table 1.5. Residual Risk Table for the Patoka River Lake Reservoir Water Control Manual Update

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Flood Risk Reduction	Increased and increased-extreme Precipitation	Increased inflow volume	Increased storage utilization Increased frequency of spillway flows Increased loading of dam embankment and likelihood of dam overtopping	Likely Likely Possible
Water Supply	Drought Increased temperature	Intermittently decreased inflow volume Increased evaporation	Decreased volumes allocated for water supplies	Possible
Water Recreation	Drought/decreased precipitation	Difficulty in maintaining water level in the recreation pool	Reduced access to the recreation features	Possible
Water Quality	Increased temperature	Reduced water quality	Reduced dissolved oxygen in the water and higher downstream water temperatures	Likely

1.5. References

Drum, R. G., J. Noel, J. Kovatch, L. Yeghiazarian, H. Stone, J. Stark, P. Kirshen, E. Best, E. Emery, J. Trimboli, J. Arnold, and D. Raff (2017), Ohio River Basin–Formulating Climate Change Mitigation/Adaptation Strategies Through Regional Collaboration with the ORB Alliance, Civil Works Technical Report, CWTS 2017-01, U.S. Army Corps of Engineers, Institute for Water Resources. May 2017.

Fourth National Climate Assessment, Volume II, Chapter 2, National Topics: Our Changing Climate, 2018.

Fourth National Climate Assessment, Volume II, Chapter 3, National Topics: Water, 2018.

Fourth National Climate Assessment, Volume II, Chapter 24, Southeast Region, 2018.

Laughlin S, Loechle J, Buckler J. CH2M Hill. (2015) Analysis of Historical Precipitation Intensity-Duration Frequency for Jefferson County, Kentucky.

Laughlin S, Loechle J, Buckler J. CH2M Hill. (2015) Analysis of Projected Changes in Precipitation IDF Values Based on Climate Change Projections.

National Weather Service (NWS) Cooperative Observer Program (US-COOP), accessed through the Midwestern Regional Climate Center (MRCC), Purdue University. https://mrcc.purdue.edu/

U.S. Army Corps of Engineers, Climate Hydrology Assessment Tool (CHAT). Issued 2016.

U.S. Army Corps of Engineers, Climate Preparedness and Resilience (CPR) Community of Practice (CoP) Applications Portal. https://maps.crrel.usace.army.mil/projects/rcc/portal.html

U.S. Army Corps of Engineers, Engineering and Construction Bulletin 2016-25 (Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects). Issued 16 September 2016.

U.S. Army Corps of Engineers, Engineering and Construction Bulletin 2018-14 (Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects). Issued 10 September 2018.

U.S. Army Corps of Engineers, Engineering Technical Letter (ETL) 1100-2-3. (Guidance for Detection of Nonstationarities in Annual Maximum Discharges.) Issued 28 April 2017.

U.S. Army Corps of Engineers, Nonstationarity Detection (NSD) Tool and User Guide. Version 1.2. Issued May 2016, updated September 2018.

U.S. Army Corps of Engineers, Semi-Quantitative Risk Assessment (SQRA) of Louisville Flood Protection System. November 2019.

U.S. Army Corps of Engineers, Vulnerability Assessment (VA) Tool and User Guide. Version 1.1. Issued November 2016.

U.S. Army Corps of Engineers, Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions, Ohio Region 05. January 2015.

U.S. Army Corps of Engineers, Time Series Toolbox, Trend Analysis and Nonstationarity Detection. 2018.

U.S. Army Corps of Engineers website with climate impact analysis tools: https://maps.crrel.usace.army.mil/projects/rcc/portal.html

U.S. Army Corps of Engineers Louisville District, Qualitative Assessment of Climate Change Impacts on the Willamette River Basin, Oregon. 2019.

U.S. Census Bureau, Decennial Census, Population for Louisville Kentucky. 2019.

White K, Arnold J, CDM Smith (2015) Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions – Ohio Region 05.