Identifying Environmental Flow Requirements for the Des Moines River:
Background Literature Review and Summary

January 2017

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Contents

Acknowledgments

This project was made possible with funding from the Iowa Chapter of The Nature Conservancy, in part through funding from the Anne Ray Charitable Trust, Meredith Corporation Foundation, and the Principal Financial Group Foundation, Inc. Kristen Blann, Freshwater ecologist with The Nature Conservancy in MN, ND, and SD, prepared the bulk of the report. Dave DeGeus, The Nature Conservancy, and Hugh Howe, U.S. Army Corps of Engineers, Red Rock District, initiated the project as well as provided essential input, guidance, and feedback throughout this initial phase (literature review and summary). Multiple staff at the U.S. Army Corps of Engineers, Rock Island, Illinois, have also contributed time, expertise, information and resources. Stakeholders and partners listed in the Workshop Report also provided the input, expertise and hypotheses on current and historical conditions as well as issues and needs. We are grateful to everyone who has participated for their interest and contribution to improving the health of the Des Moines River. The U.S. Army Corps of Engineers has supported the goals of the Sustainable Rivers Partnership through general appropriations and the Institute for Water Resources, Hydrologic Engineering Center.

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Executive Summary

Figure 1. Map By Kmusser, based on USGS data, https://commons.wikimedia.org/w/index.php?curid=3213668

Following a series of floods on the Des Moines River, Congress authorized construction of two major flood control dams and reservoirs on the Des Moines River at Red Rock (finished in 1969) and Saylorville Lake (placed in operation in 1977). Although the primary purpose of both reservoirs was initially flood risk management, both projects are designed and operated to provide other benefits including recreational opportunities, water supply, fish and wildlife habitat, etc.

As in many other large river systems, construction and operation of both dams resulted in potentially significant implications for fish and wildlife habitat, water quality, and other natural resources. Operation of the dams results in alterations to the flow regimes of the river and its tributaries, specifically reduced peak flows, lower spring flows, increased summer flows and substantially modified/reduced floodplain inundation. At the same time, the natural flow regime of the river has been significantly altered by upstream land use and drainage modifications as well as significant climate change trends over the past 100 years that have resulted in increased annual and seasonal flows. These changes have impacted resident and migratory fish and mussels, in addition to wildlife that depends on aquatic, riparian and floodplain habitat.

The Des Moines River Sustainable Rivers project is designed to identify environmental flow requirements for the Des Moines River, and develop hypotheses for alternative flow releases from the U.S. Army Corps of Engineer dams that might establish more natural flow regimes and/or enhance multiple benefits within the project area (Figure 2). The goal of the project is to explore whether it is possible to modify Corps of Engineers' dam operations by managing for a more "naturalized" flow regime that would benefit fish and wildlife populations, ecosystem function, river and floodplain habitat, and water quality. Restoring at least some aspects of the natural flow regime would be expected to benefit numerous species, including several ancient river fishes, such as paddlefish, shovelnose and lake sturgeon, as well as floodplain plant communities and terrestrial wildlife. The Des Moines SRP flow restoration project may also be linked to a larger Des Moines River watershed project. The project involves development of a literature review and initial hypothesized recommendations for environmental flow adjustments. The project will also identify whether proposed modifications are within current guidelines allowed by the Corps' water regulation manual, or might require adjustments to the operations regulations in the course of updates to the water regulation manuals scheduled over the next several years.

The Nature Conservancy (the Conservancy) in Iowa, in collaboration with the U.S. Army Corps of Engineers and other partners and subject area experts, is leading the project using a process for identifying and refining environmental flow objectives that has been developed and tested by the Conservancy and the Army Corps of Engineers at a number of sites across the United States, including the Green River in Kentucky, the Savannah River in Georgia and the Bill Williams River in Arizona. The process utilizes a series of steps to define environmental flow requirements, implement changes in operation of dams to meet those flow objectives, monitor and model the effects of those changes on both the river ecosystem and the operation of the dams, and refine over time.

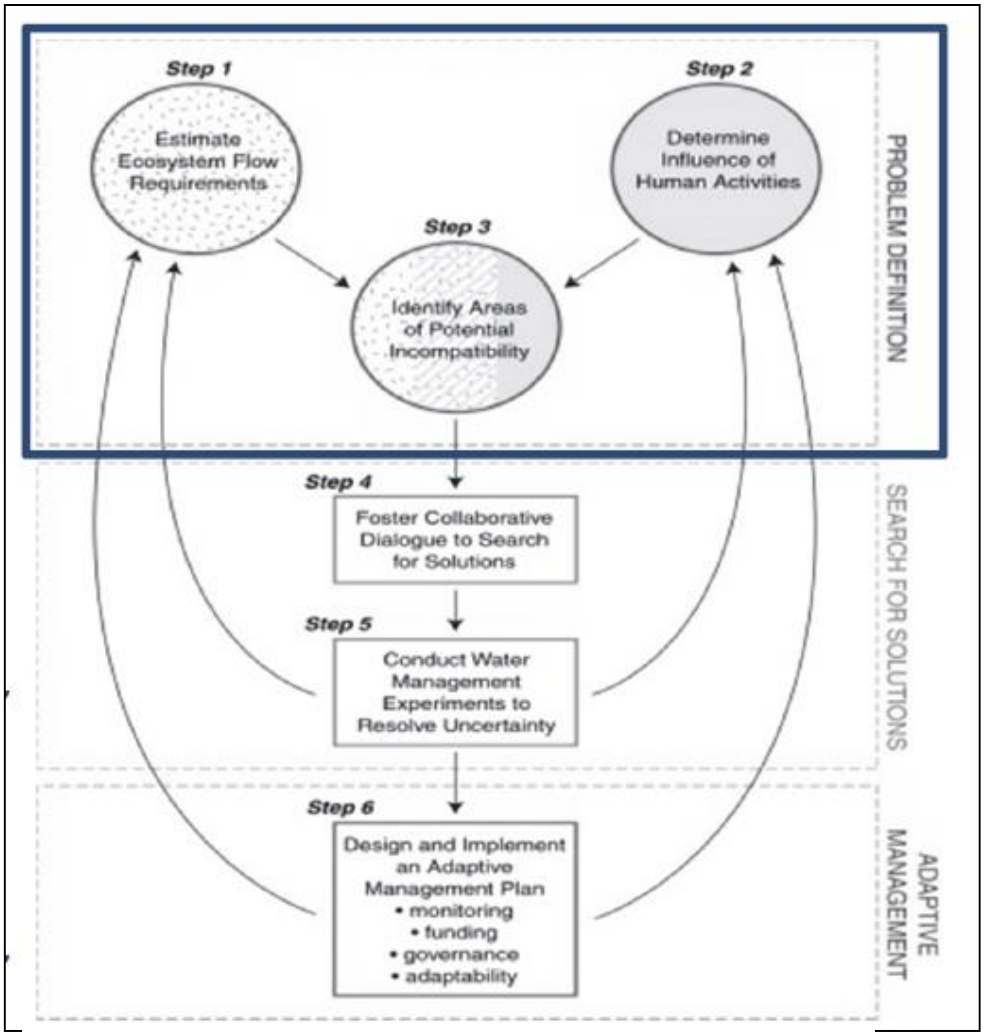

Figure 2. Ecologically Sustainable Water Management framework. This project focuses on the "Problem Definition" phase (box).

The project involves development of a literature review and initial hypothesized recommendations for environmental flow adjustments, including whether proposed modifications are within current guidelines allowed by the Corp's water regulation manual, or might require adjustments to the operations regulations in the course of updates to the water regulation manuals the Corps' is scheduled to explore over the next 2-5 years. Ultimately, the goal is to identify and integrate understanding of flow needs into real-time decisions about how and when water is released from the reservoirs to achieve more natural flow regimes, and to adjust operations as needed in response to monitoring and modeled responses.

The first phase of the Des Moines River SRP involved identifying issues of concern expressed by stakeholders and experts; as well as conducting a literature review/summary report identifying key aspects of flow regimes that are important in sustaining the ecological health of the river-floodplain systems on the Des Moines River. The stakeholder workshops and interviews led to identifying 8 key issues of concern. The literature review focused on compiling existing data and literature on the flow requirements of native species and communities and the natural flow regimes of the river system. The report also addressed the 8 issues identified by stakeholders listed below.

This literature review and summary was designed to support development of flow hypotheses and recommendations for an October 2016 workshop involving expert stakeholders. The review proposed initial hypotheses regarding environmental flow components; summarized natural and current range of variation in low flow, high flow and flood pulses, duration and frequency of each, and the rate of change from one condition to another. The report also explored the potential for modified flow regimes to produce benefits related to the 8 stakeholder issues, and possible flow alternatives to be explored in the e-flow workshop.

Summary of Literature Review and Preliminary Flow Hypotheses

The natural flow regime provides a range of specific parameters (timing and magnitude of high and low flows pulses and floods, duration of high and low flow pulses, rate of rise and fall) that can be used to design managed flow regimes designed to mimic natural flows (Richter et al., 1996, 1997; The Nature Conservancy, 2005). A key concept in riverine ecology is that to maintain the ecological integrity of floodplain ecosystems, connectivity to the mainstem river environment is critical—to the point that this idea is considered an overarching theme in river restoration water management (Sparks, 1995). The central concept in the River Pulse Floodplain model and similar models (Junk et al. 1989) is that flow events that connect floodplain and mainstem systems on regular (usually annual) intervals promotes connectivity between the floodplain and river, thus increasing the exchange of nutrients, sediments, lateral connectivity and fish between the two systems that directly affects community composition. When connectivity between these systems is lost, changes in floodplain depth, surface area and shape have been found to lead to additional alterations to a suite of abiotic and biotic characteristics that directly and indirectly affected fish communities. Direct effects included loss of habitat via increased sedimentation that results in unsuitable spawning habitat for many fish species and loss of woody structure that provides attachment sites for many macroinvertebrate species. As floodplain systems become more isolated, they often become shallower, leading to increased temperatures and susceptibility to hypoxic conditions during warm weather conditions, thus allowing for the dominance of species with higher tolerances for poor water quality.

In the Des Moines River Basin, native fish and aquatic communities and species historically depended on a mosaic of riverine habitats and fluvial processes to complete their life cycles. To define the flows needed to support this complex ecosystem, we organized species into groups that share a sensitivity to one or more aspects of the flow regime. Biological and ecological traits are commonly used to describe groups of species with similar life histories, physiological and morphological requirements and adaptations, thereby providing a mechanistic link to understanding or predicting responses to varying hydrologic conditions (Poff et al. 2006, Merritt et al. 2010, Mims and Olden 2012; Parks 2013). Quantitative and qualitative information about how species respond in other river systems can help set expectations about the potential mechanisms and taxa response of species with similar functional traits. Below, we further elaborate on the link between flow-dependent taxa and physical and chemical processes within the basin. For each taxa group, we summarize flow needs and key hydro-ecological relationships identified through literature review (Tables 2-3). For species within each group, we attempt to synthesize known information on critical life history stages and timing for species within each group, as well as to associate groups with habitat types. By overlaying key life history requirements for each group on representative hydrographs for each habitat type, we highlight relationships between species groups and seasonal and interannual streamflow patterns (Figure 3).

Table 2.

Group	Life history
Aquatic-lotic species *Smooth softshell, spiny softshell turtles, map turtles, mudpuppy (lungless salamanders)*	• some depend on specific hydraulic conditions, depth, velocity, width • use specialized stream- dependent feeding habits • sensitive to changes in water quality • require aquatic connectivity
Semi- aquatic lotic species *wood turtle, northern water snake, northern leopard frog*	• rely on flowing waters within the active channel for one or more life stages, typically hibernation • depend on access to and quality of floodplain and riparian habitats for migration, feeding, and reproduction
Riparian and floodplain- terrestrial and vernal habitat species *bog turtle, northern cricket frog, blue spotted salamander*	• mating, egg and larval development may occur in vernal pools within the floodplain or in intermittent streambeds • terrestrial connectivity within riparian and floodplain habitats

Table 3.

Group	Description	Examples
Large river species (wide ranging)	• occur in tributaries and large rivers • spring spawners with migration typically cued by temperature and rising water levels • require connectivity to floodplain and backwater habitats as well as to upstream tributaries • long- lived, large- bodied, pelagic feeders requiring maintenance of deep, open waters	Shovelnose Sturgeon Paddlefish Longnose Gar Skipjack Herring Channel Catfish Flathead Catfish
Migratory residents	• spring spawners requiring connectivity between tributary and small river habitats during spawning migrations • medium body size requiring moderately deep habitats esp. during overwinter period	Lamprey, Sauger, Walleye, American Eel
Backwater dependent/ specialist species	• Species that utilize or depend upon backwater habitats preferentially for at least part of their life cycle	Golden Shiner, Longnose Gar, Tadpole Madtom, Brook Silverside, Red Shiner, Mississippi Silvery Minnow, Blackchin and Blacknose Shiner, Weed Shiner and Topeka Shiner
Fluvial specialists	• Almost always found only in lotic systems, i.e. streams and rivers; described as needing flowing water habitats throughout their life cycle	Black Redhorse, Blacknose Dace, Longnose Dace, Common Shiner, Hornyhead Chub, Northern Hogsucker, most Darters
Fluvial dependent	• Found in a variety of habitats but require access or use of stream habitats or flowing waters at some point in their life cycle, such as for tributary spawning. May have significant lake or reservoir populations that use tributary streams for some life requirement	White Sucker, Golden and Shorthead Redhorse, Paddlefish, Mud Darter, Tadpole Madtom, Topeka Shiner

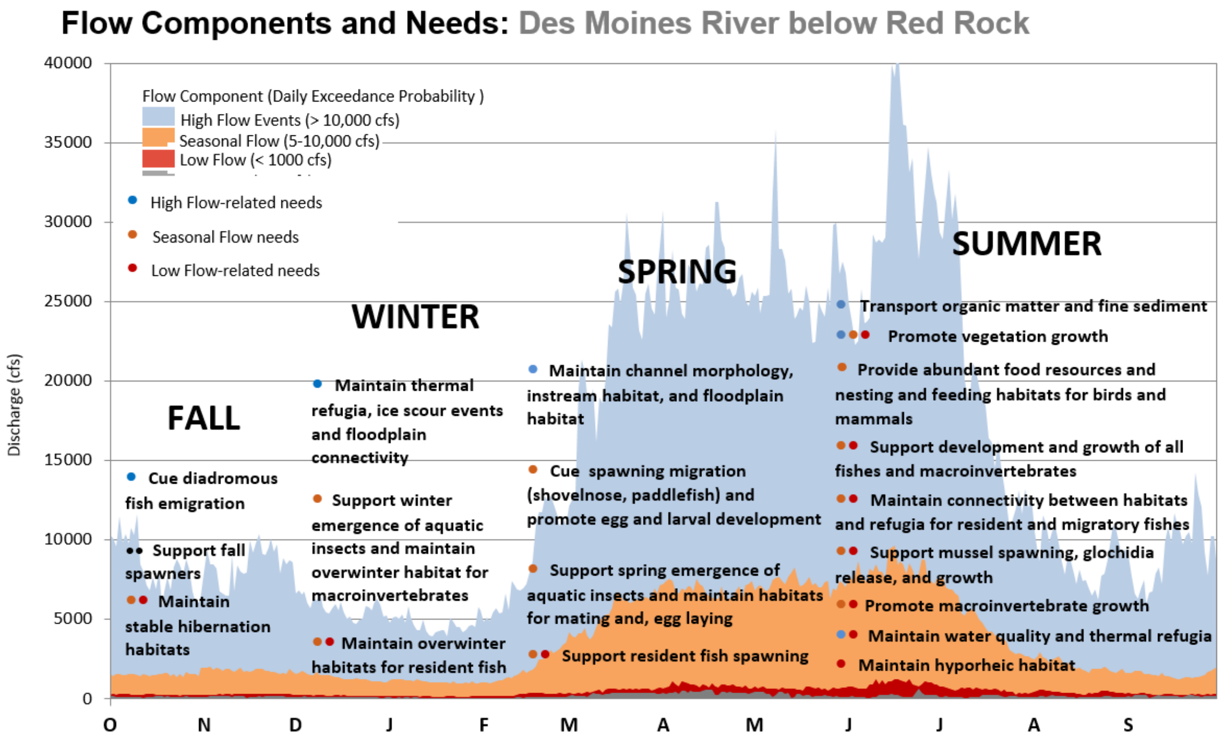

Figure 3. Preliminary hypotheses of flow components and needs for the Des Moines River downstream of Red Rock Dam.

Overall, the most dramatic changes to hydrology in the Des Moines River Basin have occurred due to the extensive conversion of tallgrass prairie to annual row crops, shallow-rooted pasture/lawn grasses, impervious surface and other non-native land cover; combined with extensive drainage modifications and significantly increased rainfall in the 2nd half of the 20th century. All of these changes have dramatically altered the magnitude, timing, and frequency of a range of environmental flow components. Understanding the impacts of the USACE flood control projects at Saylorville and Red Rock therefore requires teasing out changes due to the dams versus these larger scale changes in basin hydrology. Although the historical flow record is extensive, many changes to the Iowa landscape were already significant by the time gages were installed in 1918. We assume that complete restoration of presettlement natural hydrology is at this point not feasible, and that the goals of this project are to understand ecological flow needs and move towards restoring natural hydrology within the constraints of the modern context. The literature review, comparing daily flow statistics for the 10th percentile, median, and 90th percentile flows, showed significant differences in the frequency distributions of daily and seasonal flows (TNC 2016).

Table 4. Preliminary flow hypotheses for environmental flow needs by reach.

Saylorville & upstream	Saylorville to Red Rock	Below Red Rock
Explore whether pool elevations can better mimic natural seasonal inflows to improve fish, herp, & bird habitat	Coordinate Saylorville releases with recreational use, boating & fishing initiatives in DMMA	Bolster low flow releases during heat waves to moderate instream temperatures and reduce downstream fish and mussel mortality
Explore implications of manipulating reservoir time for denitrification	Explore implications of manipulating reservoir time for denitrification	More gradual rise and fall rates; reduce rapid fall storage drawdown and winter releases
Implications of sedimentation for waterfowl/shorebird habitat	Explore whether pool elevations can better mimic natural seasonal inflows to improve fish, herp, & bird habitat	Short-term low flow releases to benefit downstream recreation (as long as rise rate is not too rapid)
	Implications of excess sedimentation for habitat	Restore more natural seasonal pattern of low flows (higher & more variable)
		Explore costs & benefits of restoring natural flood frequency & duration for floodplain inundation / channel maintenance / off-channel habitat

Background and Introduction

The Des Moines River is the largest river flowing across the state of Iowa, approximately 525 miles (845 km) long from its headwaters in southern Minnesota. to its confluence with the Mississippi River in southeast Iowa near Keokuk. The river drains an area of 14,802 sq mi (38,337 km^2) (12,884 square miles in Iowa, nearly one-quarter of the state) and has an average discharge at the mouth of 8,678 cu ft/s (246 m^3/s) (USGS). Saylorville Dam has a drainage area of 5,823 square miles. Large tributaries above the dam include the East Fork of the Des Moines River (1,315 square miles), the Boone River (906 square miles), and Lizard Creek (437 square miles). Lake Red Rock has a drainage area of 12,323 square miles. The major tributaries above the dam include the Raccoon River (3,441 square miles), North River (590 square miles), Middle River (558 square miles), South River (590 square miles), and Whitebreast Creek (430 square miles). Land use is predominantly agricultural, consisting of 78.5 percent row crops of corn and soybeans, 14.3 percent grass, 2.7 percent forest, 2.5 percent urban and 1.9 percent water and wetlands.

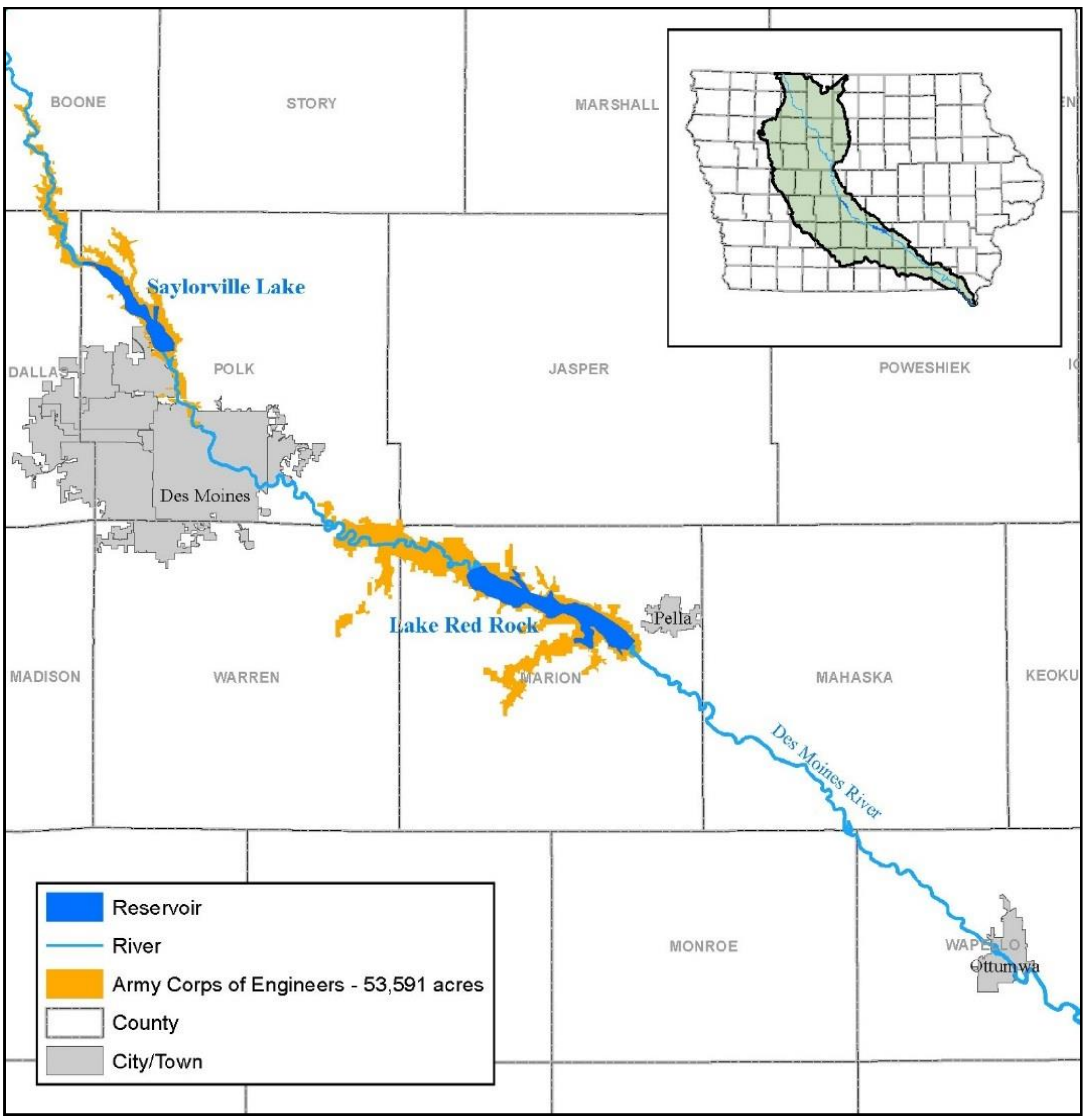

Figure 4. Project geographic scope

Goals and Objectives

1) Compile existing data and literature on the flow requirements of native species and communities and the natural flow regimes of the river system, as well as the 8 stakeholder issues listed below.
2) Identify key environmental flow components and summarize natural and current range of variation in low flow, high flow and flood pulses, duration and frequency of each, and the rate of change from one condition to another.
3) Develop flow hypotheses about the potential for modified flow regimes to produce benefits to fish and wildlife and other ecosystem services while minimizing conflict with existing authorized purposes.

This literature review and report is designed to identify key aspects of flow regimes that are important in sustaining the ecological health of the river-floodplain systems on the Des Moines River, as the basis for exploring possible improved future flow alternatives. Ultimately, the goal is to identify and integrate understanding of flow needs into real-time decisions about how and when water is released from the reservoirs to achieve more natural flow regimes, and to adjust operations as needed in response to monitoring and modeled responses.

<u>Issues to Be Explored:</u>

How have dam operations changed river hydrology and morphology?

- Hydrogeomorphic processes – including channel formation, sediment dynamics and gravel movement.
- Current and pre-dam channel morphology in the Des Moines River from the upper limits of Saylorville to the Mississippi River.
- Key indicator species – including a range of species with different life histories, with flow requirements identified for specific life-history stages.
- Floodplain processes and functions – including functions such as vegetation establishment, seed dispersal, riparian community structure and function, seasonal access for fish, habitat for species such as amphibians and birds, etc.
- Water quality – including temperature, DO and nutrients.
- Implications for population dynamics of non-native species and their interactions with native species and communities.

Summarize environmental flow components including: a) Low flows (seasonal, annual and extreme low flows; b) High flow pulses (up to bank full discharge); c) Small Floods (overbank flows, approximately 2- to 10-year return period); d) Large Floods (floodplain maintenance flows, > approximately 10-year return period). (See Box 1 for examples of ecological functions performed by specific environmental flow components.)

What opportunities exist in the Des Moines River to develop structure or off-channel habitat for aquatic and bird life (e.g. reconnection of old ox-bows)? When considering birds, herps, mussels and fish species of greatest conservation need, are there flow management strategies that would benefit all?
How do instream withdrawals and water use impact river levels? How has usage changed since the dams were initially put in service?

The Red Rock Dam and reservoir currently has a conservation pool to maintain no less than 300 cubic feet per second (cfs) outflows during dry periods. The Saylorville Dam and reservoir currently has a conservation pool to maintain no less than 200 cfs outflows during dry periods. How do these minimum flows relate to natural low flows, and what are the implications for aquatic life?

The ultimate goal for the project is to develop an integrated summary report of information available to identify flow hypotheses and inform ecological flow recommendations, and to explore alternative flow regimes that might provide additional ecosystem service benefits. The final draft of this summary report will include: (a) key findings about linkage between specific environmental flow components, geomorphic processes and biotic responses and ecological processes (b) conceptual ecological models illustrating connection between natural hydrographs and life cycles of representative species and/or ecological processes and functions (c) suggest possible flow alterations for testing (See Table 1 previous page).

Box 1. Ecological Functions Performed by Different River Flow Levels

Normal baseflow levels:
• Provide adequate habitat space for aquatic organisms
• Maintain suitable water temperatures, dissolved oxygen, and water chemistry
• Maintain water table levels in floodplain, soil moisture for plants
• Provide drinking water for terrestrial animals
• Keep fish and amphibian eggs suspended
• Enable fish to move to feeding and spawning areas
• Support hyporheic organisms (living in saturated sediments)
Drought level low flows:
• Enable recruitment of certain floodplain plants
• Purge invasive, introduced species from aquatic and riparian communities
• Concentrate prey into limited areas to benefit predators
High pulse flows
• Shape physical character of river channel including pools, riffles
• Determine size of stream bed substrates (sand, gravel, cobble)
• Prevent riparian vegetation from encroaching into channel
• Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants
• Aerate eggs in spawning gravels, prevents siltation
• Maintain suitable salinity conditions in estuaries
Floods
• Provide migration and spawning cues for fish
• Trigger new phase in life cycle (e.g., insects)
• Enable fish to spawn on floodplain, provide nursery area for juvenile fish
• Provide new feeding opportunities for fish, waterfowl
• Recharge floodplain water table
• Maintain diversity in floodplain forest types through prolonged inundation (i.e., different plant species have different tolerances)
• Control distribution and abundance of plants on floodplain
• Deposit nutrients on floodplain
• Maintain balance of species in aquatic and riparian communities
• Create sites for recruitment of colonizing plants
• Shape physical habitats of floodplain
• Deposit gravel and cobbles in spawning areas
• Flush organic materials (food) and woody debris (habitat structures) into channel
• Purge invasive, introduced species from aquatic and riparian communities
• Disburse seeds and fruits of riparian plants
• Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)
• Provide plant seedlings with prolonged access to soil moisture

(from Richter et al., 2006)

Basin Characteristics and Water Management

Basin climate and physiography

The headwaters of the Des Moines are in the Des Moines lobe, an area of rolling prairie, lakes and wetlands often referred to as the "prairie pothole landscape" that extends north and west into Minnesota, the Dakotas and Canadas. In Iowa, the Des Moines lobe represents the southern extent of the most recent Wisconsin glaciation (12,000 years b.p.). Owing to the deep, rich prairie soils, this area has become one of the most intensively row-cropped regions of Iowa. The Des Moines River and its tributaries flow across Iowa glaciated plains into the unglaciated hills near the capital city of Des Moines, in the center of the state; then through the central and eastern portions of the Southern Iowa Drift Plain. The river joins the Mississippi River in southeast Iowa near Keokuk, forming the Mississippi alluvial plain.

Climate is humid continental, with generally hot summers, cold winters, and wet springs. Temperatures vary widely during the year, ranging from average July highs of 86 °F and January lows of ~10 °F, with an annual average temperature of ~49°F (9°C). Rainfall averages 33 inches per year, increasing from northwest to southeast, and snowfall totals generally average 30 inches.

History

> *"The Des Moines River and its Tributaries afford fine lands, well diversified with wood and prairie…some fifty miles above the "Upper Forks." There is much that is inviting in the general character of the country bordering on the Des Moines; level meadows, rolling woodlands, and deep forests present themselves by turns. The soil is usually rich and productive; and when there are no natural springs, there is no difficulty in obtaining water, by digging, at almost any point in the highland-prairies."*
>
> - Lt. Albert Lea (1835)

Prior to European settlement, the Des Moines River region was occupied by many different Native American groups. One of the earliest French maps (1703) depicting the Des Moines refers to it as *"R. des Otentas,"* which translates to "River of the Otoe"; the Otoe Tribe lived in the interior of Iowa in the 18th century (Wikipedia 2016). The Dakota Indians, who lived near its headwaters in present-day Minnesota, referred to it as "*Inyan Shasha*". At the mouth of the river, the town of Keosauqua derives its name from the term given to the river the Meskwaki and Sauk people: "*Ke-o-shaw-qua*", (Hermit's River). Another Siouan name was "*Eah-sha-wa-pa-ta,*" or "Red Stone" river, possibly referring the bluffs at Red Rock or the reddish Sioux Quartzite bedrock near its headwaters (Wikipedia 2016).

During the mid-19th century, as the largest of Iowa's interior rivers, the Des Moines River served as the main hub for commercial transportation by water in Iowa. From the 1860s on, river traffic was replaced by the railroads.

Hydrology

Figure 5. Flood of Des Moines, 1851 (Wikipedia)

As do most rivers, the Des Moines River has a history of seasonal flooding as well as periods of drought. Major floods occurred in 1851, 1893, 1903, 1944, 1947, and 1948. Some of the worst flooding occurred prior to modern recordkeeping. In 1851, a year which still holds the record for annual rainfall in Iowa (74.5 in, or 191.5 cm), major flooding occurred May to June in the Des Moines River Basin. The winter of 1850-1851 had already been wet, such that the town of Fort Des Moines was "a muddy mess, and the ground completely saturated prior to the Spring rains. After strong rains in May, "…the Des Moines and Raccoon rivers rose to an unprecedented height, inundating the entire country east of the Des Moines river. Crops were utterly destroyed, houses and fences swept away."[1] Basinwide, the floods of 1903 and 1947 were the most damaging since the 1851 event, though newspaper accounts suggest that other significant floods occurred between 1851 and 1902, almost always between April and July (USACE 2005).

Beginning in the late 19th century, massive attempts were made to contain river flooding throughout the U.S. with dams, levees, diversions, and reservoirs. Following a series of floods on the Des Moines River as well as the larger Mississippi River system, Congress authorized construction of the Red Rock[2] and Saylorville flood control dams and reservoirs on the Des Moines River between 1938 and 1955. In the wake of their construction and operation, the Corps estimates that the Saylorville and Red Rock dams have prevented hundreds of millions of dollars in flood damages. However, major floods continue to occur. In the recent period of record, major floods occurred in 1993, 2008, and 2010. During the Great Flood of 1993 which affected much of the upper Mississippi River system, much of the city of Des Moines and nearby communities had to be evacuated. Polk County (within which the city of Des Moines is located) suffered more than $152M in flood damages, and water service was interrupted for more than a week, impacting most businesses and industries in the city (USACE 2005). Although flooding on the Des Moines in 2008 was not as severe as flooding on the Iowa and Cedar Rivers, which caused billions of dollars of damage to towns, cities, and properties along those rivers, voluntary evacuation orders were issued for much of downtown Des Moines and other areas bordering the Des Moines River.

Droughts. Some degree of drought has also occurred periodically in the Des Moines River Basin, about 30% of the time, with severe drought occurring about 10% of the time. Noteworthy drought occurred in 1976-1977, when the gage station at S.E. 6th Street recorded a record low flow of 26 cfs (USGS Water Year report 2008).

Based on a hydrologic classification of streams and rivers of the conterminous U.S. developed by Poff (1996), the Des Moines River basin like most streams in Iowa is dominated by "Perennial- runoff" and "Perennial-flashy" stream types (Figure below.) As later modified by McManamay et al. (2014), regional flow characteristics also include "Late timing of runoff" and unpredictable intermittent tributaries.

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[1] Mills and Company 1866 *Des Moines City Directory and Business Guide for the Year 1866-7*. Mills and Company, Des Moines Iowa. Microfilm, State Historical Society Library, Iowa City; cited in Wikipedia contributors, "Flood of 1851," *Wikipedia, The Free Encyclopedia*,https://en.wikipedia.org/w/index.php?title=Flood_of_1851&oldid=727389797 (accessed June 28, 2016).

[2] Red Rock was authorized in Flood Control Act of 1938 and 1944

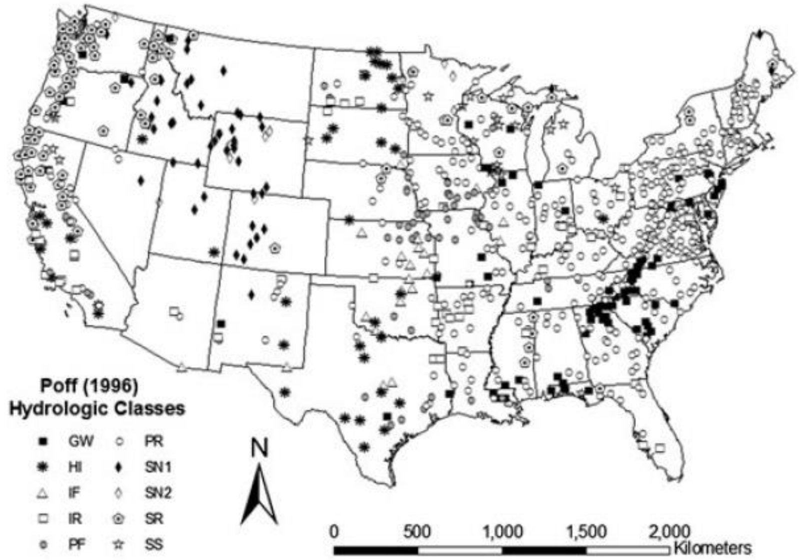

Figure 1. US hydrologic classification of 806 stream gauges into ten classes taken from Poff (1996). GW = groundwater, HI = harsh intermittent, IF = intermittent flashy, IR = intermittent runoff, PF = perennial flashy, PR = perennial runoff, SN1 = snowmelt 1, SN2 = snowmelt 2, SR = snow and rain, SS = super-stable.

Figure 6. Reprinted from Figure 1, McManamay et al. (2014).

USGS Annual Water Data reports mean flows for the Des Moines River range from 3729 cfs (1978-2008) at Saylorville gage to 8624 cfs (1970-2008) at Keosauqua, which equates to about 8.35-8.9 inches of mean annual runoff (~25% of Des Moines' 36" annual precipitation).

Water Resource Management in the Project Area

Dams and reservoirs

Red Rock, located downstream of Des Moines, was the first major dam on the Des Moines River, with construction completed by the USACE in 1969. Upstream of Des Moines, Saylorville is a 26,000 acre multipurpose USACE project completed in 1977. Both projects were originally authorized for flood control (now referred to as flood risk management, FRM) and for low-flow augmentation, and were later authorized for additional purposes of providing recreation, fish and wildlife management and water supply storage. At the "normal" pool level of 742' NGVD, Lake Red Rock is 15,250 acres and stores 189,000 acre-feet of water for a distance of 18 miles upstream from the dam. At the flood control pool level of 780', the lake has 64,480 surface acres and stores 1.4 million acre-feet of water for 33.5 miles upstream. The dam project consists of a control structure with 14 hydraulically operated sluice gates which operate when outflows are less than 38,000 cfs. During "Large Flood Magnitude" operations, water is released through the spillways (upper) Tainter gates, designed to pass excessive inflows and protect the dam. In total the Lake Red Rock project encompasses ~53,000 acres of land and water, which includes 23,054 acres managed by Iowa Department of Natural Resources (DNR) and 1,788 acres managed by Marion County Conservation Board. These lands are managed under a lease agreement from the Corps to facilitate stewardship and expand outdoor recreation opportunities.

Saylorville Lake's pool is maintained at an elevation of 836' throughout the year, with the exception of a fall pool raise that varies from 836' to 840' (Both Saylorville and Red Rock now also allow for a fall pool raise (discussed later), that allows for some flexibility, but otherwise the conservation pools are designed to be maintained at a steady state.) At 836', Saylorville Lake has 5,520 surface acres and stores 73,600 acre-feet of water for a distance of 24 miles upstream from the dam. The conservation pool occupies approximately 11.5 % of Saylorville's total storage capacity, leaving 88.5% strictly for flood storage capacity. Since the initial Regulation Plan went into effect, major revisions to the Regulations Manual have happened 3 times (1983, 1999, and 2001). Changes have allowed the Corps to increase the maximum release to 16,000 cfs during the growing season, as long as Lake Red Rock was below elevation 758'. Drought operation is also part of the water regulation plan. The Corps' maintains the conservation pool at 836' as "a balance that tries to maximize all of the reservoir benefits and authorized purposes", an elevation that is designed to account for snowmelt runoff, predicted and actual rainfall, and to allow for an additional 54' of water of storage on top of that if needed to minimize downstream flooding, as well as to minimize bank erosion which contributes to sedimentation on the lake.

Current operational regulations are designed in part to respond to climate forecasts. Partly in response to the 1993 flooding, Georgakakos and Yao (1998) conducted a modeling study to evaluate the sensitivity of flow forecasts to climate variability. Results suggested that current reservoir management practices cannot accommodate historical climate variability, and that substantial resilience to climate variability could be gained by operating the reservoirs based on a control scheme that takes into account both forecasts and their uncertainty. A review of the operating procedures for the floods of 1993 also indicated that damage could not have been significantly reduced unless inflows were accurately predicted 2-3 months in advance. Needham et al. (1999) found that optimal results for most floods was obtained by operating each reservoir independently.

In addition to Saylorville and Red Rock, there are numerous smaller dams located along the river, discussed in Hoogeveen (2010). A hydroelectric facility at Ottumwa, below Red Rock ("Market Street Dam"), was most recently relicensed under FERC following an Environmental Assessment in 2007. The project reservoir has a surface area of 500 acres and a storage capacity of 5,000 acre-feet. As required by the current license, the project currently operates in run-of-river mode, maintaining a reservoir elevation of 638.5 ±0.5 foot msl, and maintains a minimum downstream flow of 300 cfs, based on a required minimum flow release of 300 cfs from the upstream Red Rock dam. Operational changes were committed to during the relicensing period based on Iowa DNR concerns, designed primarily to decrease river level fluctuations downstream of the project during low-flow periods (FERC 2007.) Ottumwa also proposed to use stoplogs to isolate the Tainter gates during annual maintenance, to preclude the need for these reservoir drawdowns. Other dams on the system include Center Street Dam in downtown Des Moines near the confluence of the Raccoon with the Des Moines, as well as Scott Street and Fleur Drive Dam; three in Boone County upstream of Saylorville (Fraser Dam and Boone Waterworks); five in Webster county on the mainstem and tributaries (Little Dam, Ft. Dodge Hydro Dam, Trestle Weir, Clare Gaging Dam, and Lizard Creek Mill Dam); three in Humboldt county--two on the West Fork (Reasoner and Rutland Dam) and one at the confluence of the East and West Forks (Corn Belt Power Dam). There are also numerous dams on tributaries including the Boone River, Middle Raccoon, South Raccoon, and Middle River. All of these dams serve to impair fish passage to some degree.

Water Supply and Use. The Corps has provided water supply storage space in its multi-purpose reservoirs for many years, generally managed through its Water Supply program. A water-supply contract with the State of Iowa, in place at Saylorville Lake since 1982, allows the State of Iowa to utilize 18.86 percent of the usable storage space (estimated to be 11,940 acre feet) in the lake between elevations 812. National Geodetic Vertical Datum (NGVD) and 836. NGVD. Iowa has sub-allocated that water to the Des Moines Water Works and Iowa Southern Utilities (Alliant Energy). There are no direct water intake structures in Saylorville Lake, but water is withdrawn from releases made through the Saylorville Dam (Saylorville Master Plan). Changes made in 1983 to the Regulation Plan-- when the water supply contract with the state was initiated --increased the conservation pool from 833’ to 836’ to increase the reliability of water supply.

Physical Processes and Conditions

Floodplain and channel maintenance: Geomorphology

As a river which gets its start draining the relatively young glacial landscape of the prairie pothole region, the Des Moines River can be thought of as relatively young in geological terms. As noted in the Annals of Iowa in 1957,

> “It is hard to think of the Des Moines River, with its wooded banks and clear waters, as having ever been a small edition of the muddy Missouri; but that is what it was many years ago—at least not many years ago as geological time is measured. Not only was it muddy and dirty and ugly to the sight, but its channel was as shifty as that of the "Big Muddy." The mound- builder who went to bed at night on the bank of the Des Moines didn't have the least assurance that the river would be anywhere in the neighborhood, when he woke up in the morning. The fact is that the river wandered around over pretty much the whole surface of Polk county, at one time or another in the last 8,000 years; and the geological evidences are that the channel now occupied is almost entirely different from the original one that was formed when the glacier melted. In Polk county there are many miles of old river bed, and it is believed, although the geological evidences have not been so carefully examined in other counties, that the same is true in the counties to the north and south.
>
> …
>
> There probably was no such stream till after the big Wisconsin glacier melted, and the river formed along the southeastern line of the great sheet of ice, to carry off the waters. At first it was an ill-defined series of ponds and rivulets, but in time it developed into a distinct stream.
> Its main channel, however, changed at frequent intervals; old courses were deserted in a day, when the water was high, and new ones were cut by the rushing torrents.”

Lt. Albert Lea (1835) described the reaches of the river below the Raccoon as “from 80 to 100 yards in width, shallow, crooked, and filled with rocks, sand bars, and snags, and is impetuous in current at high water; yet it is certain that keel-boats may navigate this portion of the river, being 96 miles, during a great part of the spring and fall; and it is not impossible that even steam-boats may run there.”[3] He described the lowest reaches of the river as highly navigable, 150-250 yards wide, “except a few miles above the mouth, where it is only from 80 to 100 yards wide; its bed is perfectly smooth and flat; and the bottom is generally a thin coating of sand and gravel over a blue limestone rock, until you descend within the influence of the backwater from the Mississippi, where there is much alluvial deposit with many snags. By the removal of a part of these snags and a few loose rocks above, everything will be done for the navigation that can be done without augmenting the supply of water.” Prior to Pool 19 lock and dam construction, the Des Moines Rapids (a series of rapids on the Mississippi River above the confluence with the Des Moines) did present some obstacles to navigation (Griffith, 1870).

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[3] From Notes on the Wisconsin Territory, by Lt. Albert Lea, 1839. (Dragoon Expedition of 1835)

Streambank Erosion and Sedimentation

In the time since European settlement, Midwestern river morphology has been substantially modified by a combination of land conversion, agricultural drainage, channelization, levees, dams, and river flow modifications. Accelerated streambank erosion is a major resource management concern in the Des Moines River Basin, as in much of Iowa, due to the erodibility of the bank soils (Odgaard 1987). In recent decades, an increasing proportion of instream sediment and phosphorus load has been attributed to bank erosion and other results of hydrologic modification, specifically increased water yield (Zaimes et al. 2006; Belmont et al. 2011). Bressan et al (2014) note that intensive agriculture in the Des Moines River, coupled with extreme rainfall events, has induced accelerated bank fluvial erosion, resulting in significant mass failures, which are manifested with the slumping and sliding of large soil blocks (up to 10m) into the channel in certain locations.

The water regime in the Midwest has changed dramatically over the last 70-100 years, with increases in seasonal and annual water yields of >50% in Midwestern rivers since 1940, and channel widening of 10–40% (Schottler et al. 2014). Land use change, increase in the use of drainage, and climate change all have changed the timing and amount of water moving through the system. Increases in row crops and decreases in small grains, perennial crops, and hay rotations over the same period have shifted evapotranspiration rates and seasonal water use (Hatfield et al. 2009). This problem is exacerbated because in the Mississippi River basin and throughout the agricultural areas of the Midwest, the climate has changed dramatically over the past 50 years and is predicted to continue to change (Jha et al 2004). Total rainfall has increased annually but more importantly the rainfall is occurring in dramatically larger events delivering between 4-12 inches of rainfall in a single event (Jha et al. 2004, Soil and Water Conservation 2006, Tomer and Schilling 2009, Gullickson 2014). Land use induced changes in ET likely influenced stream flows from the 1940-1970s, but climate change took over as a driver in the 1970s until present day (Tomer and Schilling 2009). As a result, average annual stream flow on most Midwestern and eastern streams has increased by 40-100% (Tomer and Schilling 2009, Villarini and Strong, 2014, Jha et al. 2004).

Increased rainfall intensity also impacts P delivery to streams because most P is attached to soil particles and water is the primary driver of soil erosion from fields and stream banks. In many agricultural areas up to 80% of the soil lost from a watershed is lost from stream banks that also store lots of P deposited after generations of farming (Wilson, et al. 2008). Furthermore, significant proportions of the annual soil and nutrient losses can occur in just a few major events (Soil and Water Conservation Society 2006, Helmers et al, 2012). For instance, in the Maumee River Basin in the Great Lakes Basin between 1976 and 1995 just 23 storms with flows of 40,000 cfs or more accounted for 32% of the total phosphorus load (Soil and Water Conservation Society 2006). In general, most currently promoted agricultural best management practices do not effectively address these sources of sediment and phosphorus delivery to surface waters.

Operation of the dams at Saylorville and Red Rock means that a significant proportion of sediment upstream of the dams ultimately ends up being trapped in the reservoir. The rate of sedimentation within the reservoir is influenced by regional and site specific conditions, including annual and seasonal precipitation patterns and associated storm water runoff, as well as river bank erosion and agricultural runoff. Sedimentation is unavoidable for reservoirs such as Saylorville and Red Rock due to steep banks, frequent high water events, and wind and wave action. Accounting for sedimentation was included in the design and management of the reservoir; however, sedimentation rates have been higher than anticipated (Saylorville Master Plan). For example, periodic sedimentation surveys of Saylorville Lake conducted to analyze water storage capacity for the water supply contract with the State of Iowa estimate the volume of storage capacity set aside for water supply that has been lost due to reservoir sedimentation. In 1982, it was projected that 14,900 acre feet or ~19 % of the storage between elevations 812 and 836 would be available for water supply at the end of 25 years. The actual available storage in 2007 in that elevation range was just 12,300 acre-feet. The 2014 resurvey indicates there is currently 11,940 ac-ft of usable storage available for water supply (USACE 2014).

The impact of suspended solids is of even greater concern at Red Rock Reservoir than at Saylorville Reservoir, and several increases in the conservation pool have been necessary to offset storage losses resulting from excess sedimentation, most of which comes from upstream. The conservation pool has risen a total of 17 feet since 1968 (Lutz 2013). Originally designed and built for a 100-year lifespan, the Corps estimates the normal lake pool has lost 44 percent of its conservation pool capacity to silt since 1969 (Grimes 2011). The Middle and South Rivers and Whitebreast Creek (which enters Red Rock Reservoir from the southwest through Whitebreast Bay) are estimated to account for 55% of the sediment delivered to Red Rock Reservoir, despite the fact that they account for only 24% of the area (Grimes 2011). The average rate of soil erosion on steeper cropland in the area is about three times the average rate for cropland in Iowa (U.S. Department of Agriculture 2000). The majority of this sediment comes from channel erosion and stems in part from the difference in soil erodibility and topography between ecoregional land types (i.e. Des Moines Lobe vs. Southern Iowa Drift Plains).

Anecdotally the channel in the reach between Red Rock and Ottumwa has become wide and shallow, a phenomenon commonly observed in rivers that have lost access to their floodplains downstream of dams. Downstream of the Red Rock dam, the Des Moines River may even be sediment-hungry, both in response to settling of sediment in the reservoir as well as in response to overall increased duration and magnitude of flows. Bressan and colleagues (2014) documented channel changes in response to changes in flow, both historically and in response to recent trends. Trend analysis using the time series of the daily mean flows (MF) revealed that daily mean flows on the lower Des Moines River in Van Buren County have been increasing, especially in recent years, with a 10% increase observed just since 2006. As noted elsewhere in this report, the overall increase in flows and annual water yields experienced in the Des Moines River over the last 50 years means that high flows continue to periodically exceed flood storage capacity of the reservoirs, resulting in the river accessing a substantial floodplain area outside its banks in spite of the dams and levees.

<u>Loss of floodplain habitat.</u> In general, one of the major impacts of dams on large river systems is to reduce the extent of and/or access to floodplain habitat by fish, waterfowl, and other biota. For example, the completion or “closure” of Lock and Dam 19 at Keokuk, Iowa represented one of the first major alterations on the upper Mississippi River (Scarpino 1985, Grubaugh and Anderson 1988). Early studies describe immediate impacts on fish and wildlife, e.g impacts on fish passage, fish and mussel populations (Coker 1914; Coker 1930), deflection of fish upstream the Des Moines River (Coker 1914), impacts to the mussel fishery due to sedimentation, and the beginning of shifts in planktonic community towards lentic environment. Grubaugh and Anderson (1988) describe in detail how the creation of Pool 19 resulted in loss of floodplain areas by permanent inundation, and how this coupled with shortening of the spring rise in the hydrograph reduced floodplain habitat available to the fishery. They observed that a third of the 66 known species spawn in or have larvae that use shallow backwater areas of floodplains. Shortening of the spring rise can negatively impact spawning and recruitment success by constraining the period of time these species can spend accessing cover and food resources within the floodplain. Fisheries data do appear to indicate that many backwater, fluvial specialist, and intolerant fish species have experienced declines on the Des Moines River (Parks 2013; Parks et al. 2014); however, it is unclear how much of those declines may be ascribed to Saylorville and Red Rock projects versus other changes in the Basin. However, similar changes in the hydrograph can be expected to have occurred, based on the Corps operational preference for maintaining constant pool elevations at Red Rock and Saylorville.

The loss of the autumn pool rise on the Mississippi River negatively affected migratory birds of the UMR (Grubaugh and Anderson 1988). Dams and subsequent levees have drastically reduced floodplain habitat available to the biota of the UMR, and extensive areas have been lost to permanent inundation and/or conversion to agriculture. Remaining wetland habitat was often available to fish and wildlife for a shorter period of time because of the shortened spring rise and elimination of the autumn rise in the general hydrograph (Figures 7-8). In part based on the need for this type of habitat, provisions have been made with Iowa DNR to raise the fall pool elevation at Saylorville and Red Rock. During the fall rise, elevated water levels flood areas of moist-soil vegetation, making seed crops readily accessible and providing a valuable food source to dabbling duck populations (Bellrose et al. 1979). Inputs of organic matter are highest during autumn senescence of floodplain vegetation which coincides with biomass increases of filter feeding benthos (Anderson and Day 1986). In the reservoirs, siltation and sedimentation can actually compensate for some of the habitat loss by raising bottom elevation in areas inundated by dam closure. This has certainly occurred above both Red Rock and Saylorville, where mudflats support extensive floodplain and emergent vegetation. Below Red Rock, reduction of levee and drainage districts could also help to reclaim floodplain habitat.

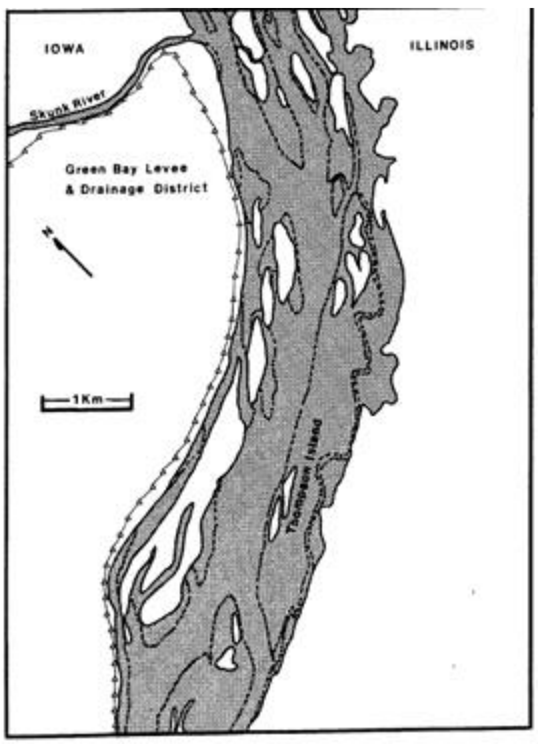

Figure 7. Diagram of Mississippi river width at Thompson Island, 13.0 km downstream from Burlington, Iowa, before and after construction of Lock and Dam 19. Shaded area is postdam river area, dotted lines predam floodplain habitat permanently inundated by closure of the dam. Note area behind levee (triangles) that became permanently separated from the river. [reprinted from Grubaugh and Anderson 1988]

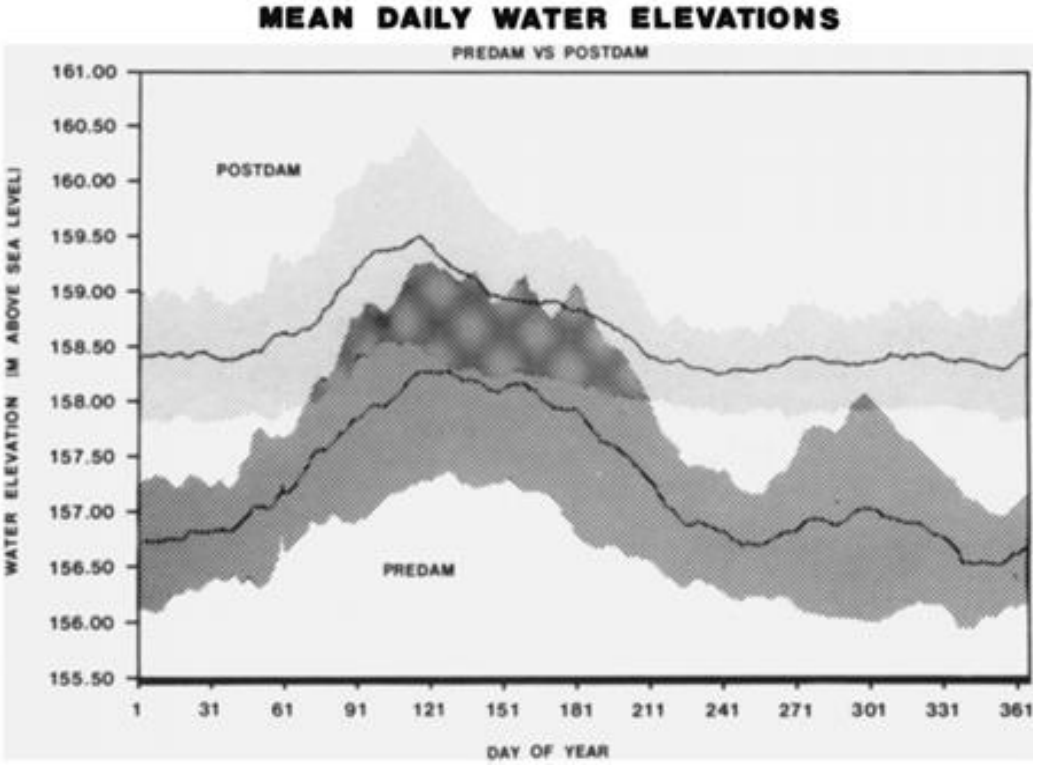

Figure 8. Generalized Mississippi River annual hydrograph elevations for the period prior to Lock and Dam 19 construction (dark shading, n=34 years) and postdam (light shading, n=74 years) periods. Shaded areas indicate +/- 1 s.d from the mean. Reprinted Figure 5 from Grubaugh and Anderson 1988.

The combination of channel armoring, land use change, floodplain disconnection, and flow changes has resulted over time in the loss or simplification of much high quality floodplain habitat. Figures D-1 through D-3 (Appendix D) show a series of three views of the channel below Red Rock dam comparing 1930s to 2009 aerial photos. The side-by-side comparisons do suggest evidence of channel widening, though it is unclear if the photos were taken at the same flow level. They also show obvious simplification of the channel and floodplain form and habitat, including loss of oxbows, loss of sandbar/point bars and bends, and straightening of the channel in that reach. It might be valuable to develop 2-D hydraulic models comparing 1930s habitat to 2009. This would allow a comparison of the areal extent and availability of different depth and velocity habitats across a range of flows. Overall, the comparison suggests that in addition to flow restoration, active channel and floodplain restoration may be needed to accelerate ecological recovery.

Water quality

The Des Moines River Basin is located in the heart of the Midwestern corn belt, a region responsible for some of the highest nitrogen loading to the Mississippi River, a major contributor to Gulf of Mexico hypoxia. Within the Des Moines River watershed, areas such as the Raccoon River Basin have some of the highest estimated nitrogen loading rates within the Upper Mississippi River Basin. Nitrate concentrations in the Raccoon and Des Moines Rivers, the two main water sources for Des Moines drinking water, have steadily increased over the past 25 years. The city of Des Moines water utility has for many years struggled with high levels of nitrate in source water that increasingly exceed the EPA drinking water standard of 10 mg/L, and therefore cost the city in terms of required investments in water treatment technology and other solutions. In 1989 and 1990, DMWW exceeded the Environmental Protection Agency's (EPA) maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) for nitrate in drinking water for the first time.

A nitrate removal facility was designed in 1989 and built during the winter of 1990-1991 at a cost of $4.1 million. Costs to Des Moines of treating N during times when they are in violation of the MCL of 10 mg/L exceed $1.5 million annually and are increasing. For example, in 2015, Des Moines Water Works operated its nitrate removal facility for a record 177 days, surpassing the previous record of 106 days set in 1999. 2015 also marked the first time the utility has needed to run its costly nitrate-removal facility during the winter. Continued increasing trends in recent years have caused the utility to begin planning for $80-100 million in new capital investment over the next six years, including expansion and renovation of the current nitrate removal facility and a proposed 80-acre constructed wetland. Ongoing water quality problems have also prompted the city to pursue an unprecedented lawsuit against the upstream counties (Boards of Supervisors of Buena Vista County, Calhoun County, and Sac County) charging that, as trustees of 10 drainage districts, they bear some fiscal and legal responsibility for the discharge of nitrate pollutants into the Raccoon River, and for failing to ensure that water leaving the districts meets federal water quality standards. The lawsuit is currently moving through the legal system.

Water quality in the reservoirs:
Saylorville Reservoir. In general, water quality in Saylorville Reservoir meets state and federal water quality standards for designated uses of primary contact recreation and fish consumption. Results of bacteria monitoring at the ISU/ACOE long-term station on the main reservoir near the dam suggest the recreational use assessment designation is "fully supporting." However, from time to time the reservoir violates state water quality standards for indicator bacteria, sometimes triggering beach closures or warnings. Significant increased development and agricultural intensification adjacent to and within the immediate watershed of the reservoir is contributing to increased sedimentation, nutrient loading, and stormwater-related concerns. These environmental impacts have the potential to impair Saylorville Lake water quality for water related recreation. Blue green algal blooms and elevated levels of E. coli are common water quality issues that hinder recreational use of the lake. The Corps views the need to improve infrastructure while maintaining water quality to meet recreational demand as an ongoing and increasingly difficult challenge.

Red Rock. The Class A1 (primary contact recreation) uses of the Red Rock Reservoir are assessed (monitored) as "partially supported" due to levels of turbidity that create "aesthetically objectionable conditions" (Lutz 2013). The Class B(WW-1) (aquatic life) uses are assessed as "fully supported" although sediment loading and a large population of common carp are a concern. Fish consumption uses were assessed as "fully supported" based on ACOE-sponsored annual fish contaminant monitoring from 2008-10 (Lutz 2013).

Data from the 2006-2010 ISU and UHL surveys suggest a moderately large population of cyanobacteria exists at Red Rock Reservoir, which does not suggest impairment generally; median cyanobacteria wet mass (19.5 mg/L) was the 65th lowest of the 134 lakes sampled. Results of ISU/ACOE monitoring suggest that blooms of cyanobacteria do occasionally occur at Red Rock Lake. According to the ISU/ACOE annual monitoring reports (e.g., Lutz 2004, Lutz et al. 2010, Lutz 2013), blooms of cyanobacteria typically occur during July and August, especially under elevated pool conditions. These reports contain a summary of when these blooms have occurred at Red Rock Lake since 1990.

Potential for dam operations to enhance denitrification

Denitrification is an important process in saturated and aquatic sediments, wherever there is sufficient residence time, including riparian areas, wetlands, and floodplains, as well as lakes and reservoirs. Globally, floodplain nitrogen processing is greatly influenced by the pervasive anthropogenic flood-control measures that currently exist on most major river floodplains. The cumulative N processed by frequent smaller floods is likely large relative to that processed by larger, less frequent floods (Gergel et al. (2005). Denitrification is likely to be impacted by future changes in flood probabilities that will likely occur as a result of climate shifts. Denitrification can be enhanced through restoring connectivity of the river to the floodplain.

Denitrification in floodplain sediments plays an important role in reducing nitrate concentrations in groundwater. Agricultural drainage and land use changes to regional stream hydrology and geomorphology are contributing to increased nitrate loads, both through increased loading as well as altered geomorphology and hydrology that impacts nutrient cycling and can reduce denitrification potential of riparian zones. Where channels have become incised, riparian zones can function as a potential source of nitrate to streams during spring recharge periods when the near-stream riparian zone is largely unvegetated. Schilling and colleagues (2006) evaluated surface and groundwater interaction in the riparian zone at Walnut Creek (Neal Smith NWR), an incised stream in the Des Moines River project area, during a spring high flow period. Using detailed stream stage and hydraulic head data from six wells, they found that bank storage of stream water from Walnut Creek during a large storm water runoff event was limited to a narrow 1.6 m zone immediately adjacent to the channel. Nitrate concentrations in riparian groundwater were highest near the incised stream where the unsaturated zone was thickest. Nitrate and dissolved oxygen concentrations and nitrate-chloride ratios increased during a spring recharge period, then decreased in the latter portion of the study. The study underscored the role of channel incision and altered hydrology in driving long-term legacy effects on nutrient and sediment cycling.

Water level management practices in reservoirs can significantly impact nutrient cycling and processing. When it comes to denitrification, the Saylorville and Red Rock reservoirs have the potential to generate substantial downstream water quality benefits, benefits that could potentially be enhanced intentionally through active manipulation of reservoir pool elevations and residence times. David and colleagues demonstrated how reservoir-based denitrification can substantially reduce nitrate loading to streams and rivers for Lake Shelbyville reservoir in central Illinois, a large (4400 ha) upper-Midwestern (USA) reservoir that receives large agricultural riverine N inputs. From 1981 to 2003 the average NO_3-N inlet flux was 8900 Mg N/yr. About 58% of the total NO_3-N input was removed, and annual NO_3-N removed as a percentage of inputs was significantly related to reservoir retention time (average = 0.36 yr for the 23 years, range = 0.21–0.84 yr). Rates were highest during spring and early summer of 2002, when maximum NO_3-N concentrations were measured (10–14 mg NO_3-N/L). Total denitrification was estimated at between 2580 and 5150 Mg N for 2002. Areal rates of sediment denitrification in the reservoir ranged from 62 to 225 g $N \cdot m^{-2} \cdot yr^{-1}$, with rates a function of both denitrification intensity (µg $N \cdot g$ dry $mass \cdot h^{-1}$) and the overall mass of sediment present.

Bierl (1982) documented how completion of the Saylorville Dam resulted in alterations to the monthly flow regime, thereby altering the monthly transport and concentration percentages of most water quality parameters. Shortly after reservoir completion, Bierl (1982) found that the reservoir trapped 90% of suspended sediment and 56% of total phosphate, but only 10% of total N (26% of organic N, 8% of nitrate+nitrite). Ammonia N actually inccreased in the outflow, due to hypolimnetic release. For most parameters, construction of the Saylorville Reservoir essentially had an evening-out effect: peak transport percentages during high-flow months were reduced, whereas minimum transport percentages during low-flow months were raised. The most noticeable effect of the reservoir on flow was a reduction in flow percentage during the months of March and August. Increases in flow percentage during low-flow months were not as obvious.

Averages of water year loadings to Saylorville from 1974-2012 range from 17,000-53,000 Mg NO_2+NO_3 per year (Lutz 2013). Schoch et al. (2009) showed that Saylorville Reservoir may be reducing nitrate concentrations more significantly than earlier estimates (22±6% reduction in monthly average nitrate concentration) based on a dynamic regression model that described nitrate concentrations as a function of the concentrations entering the reservoir. Even more recently, Ng and colleagues (2009) conducted modeling that suggested that by implementing a simple control scheme involving manipulation of residence time in Saylorville reservoir, nitrate concentrations during vulnerable periods could be reduced by 1.23 mg/l and drinking water violations could be reduced by nearly 26%. When the residence time is long (> 26 days), more nitrogen nitrate is removed by the reservoir (16.7%) than when the residence time is short (< 26 days; 8.5%). These removal rates equate to anywhere from 150-8700 Mg N/year.

Lutz (2013) reported that the time of travel for water from the headwaters of the Des Moines River to Saylorville Dam is about nine days, from Saylorville Dam to Red Rock Dam is about two days, and from Red Rock Dam to the Mississippi River about three days (see March 1994 annual report). The time of travel is important when evaluating pollutant loading and stream hydrographs and when predicting river flows and subsequent flooding, as well as when understanding residence time in the reservoirs. The critical time for increasing residence time would be April-June, when concentrations in the river near the drinking water intake are most likely to exceed the 10 mg/L standard. Given operating parameters, it is unclear whether residence time could be substantially manipulated without conflicting with authorized purposes and/or natural hydrograph and habitat restoration goals.

Water temperature. Temperature is one of the most important components of aquatic habitat in freshwater systems. Many species of aquatic organisms are adapted to specific thermal regimes and critical aspects of biology, physiology, and life history are strongly tied to seasonal and annual variation in water temperature. Temperature is strongly influenced by flow regime, and human modifications of rivers through dams and reservoirs can significantly alter thermal regimes both in-reservoir and in remaining lotic stretches of the river. Saylorville typically discharges from surface waters at the top of the reservoir, and can therefore significantly alter downstream river temperatures. Red Rock draws water from the bottom of the lake during sluice gate operations, and operation of Tainter gates during large magnitude flooding operations is drawing water well below the surface of the flood pool. Lutz (2013) reported maximum differences in water temperature above and below Saylorville in 2012 of as much as 4.3°C (7.7°F), and 4.5°C (8.1°F) above and below Red Rock. Maximum differences in upstream downstream temperatures occurred in October. However, thermal stratification differences within the reservoirs (i.e., surface to bottom) was greatest in July for Saylorville (5.4°C / 9.7°F)) and September for Red Rock (6.5°C / 11.7°F).

Biological and Ecological conditions

Major habitat types

The Des Moines River Basin covers two ecoregions, crossing from the Northern Tallgrass Prairie upstream of Saylorville into the Central Tallgrass Prairie in the Des Moines area. Based on the original public land surveys of Iowa conducted ~1832 to 1859 by the General Land Office (GLO), although the landscape at the time of European settlement was dominated by prairie in the uplands, ravines and tributary streams were often partially wooded with grass understory and many scattered openings. Moving downstream along the tributary corridors and main river valleys, riparian areas were increasingly dominated by extensive floodplain forest and "timber"—most likely savanna woodlands. Dense timber was likely only found on steep north facing slopes where fires carried less frequently. Floodplains in Iowa were also prairie dominated with trees occupying thin gallery forests along the river edge. The width was often widest on the south side of rivers because this was the downwind side and fires were less intense or missed the downward edge of the river. Since settlement, a significant proportion of floodplain and adjacent forests as well as prairie uplands have been almost completely replaced by agriculture and other modern land uses, accompanied by extensive surface and subsurface drainage systems. Upstream of Des Moines, the dominant use is row crop agriculture. South of the Des Moines River from Des Moines to the Mississippi River agricultural land uses outside the immediate river corridor include significant pasture and woodland and a lower proportion of cropland. Urban and suburban land uses dominate the Des Moines metropolitan area between Saylorville and Red Rock, and in a few smaller municipalities located along the river, including Ottumwa and Keosauqua.

The vast majority of the watershed is privately owned, with the exception of USACE lands surrounding Saylorville and Red Rock, the nearly 14 square mile Neal Smith National Wildlife Refuge, and a number of smaller state and county lands (parks, natural areas, wildlife areas, state forests, etc) located on or within a few miles of the river. Due to intensive agriculture conversion and lack of public lands, large projects like Saylorville Lake (26,000 acres) and Red Rock (15,000 acres of water + 35,000 acres of land) today play an important role in maintaining fish and wildlife resources in Iowa. These public areas represent the majority of remnant natural communities in the Tallgrass Prairie Biome in central Iowa, and play a significant role at the state level as a prominent wildlife migratory corridor. Fish and wildlife resources are diverse across the broad spectrum of habitats found on USACE lands (See Saylorville Master Plan Appendix G.8, Multiple Species Inventory and Monitoring Report.) Statewide species richness data provided by Iowa Gap Analysis shows relatively high biodiversity on these lands for nearly all groups, including birds, mammals, amphibians, reptiles and aquatic species. However, in the absence of fire, many grassland habitats are slowly being lost as areas succeed to trees and shrubs, many of which are non-native.

An additional major publicly owned conservation land in the project area is the **Neal Smith NWR** , established in 1990 as Walnut Creek NWR. Still one of the largest prairie restoration efforts in the U.S., the Refuge is ultimately authorized to acquire up to 11,875 acres of land to reconstruct a piece of the tallgrass prairie and savanna ecosystem. More than 5,000 acres have been acquired so far. Bison and elk have been reintroduced to the Refuge to demonstrate the natural role of large herbivores in the tallgrass ecosystem, and visitors can drive through the 700-acre bison enclosure. Landscape-scale conservation goals articulated in the Neal Smith Comprehensive Conservation Plan (CCP) include authorization to expand the Refuge boundary to the east and west to include all tributaries of Walnut Creek that flow through the Refuge, as well as working with partners to further reduce erosion and improve water quality throughout the watershed, and to establish wildlife habitat corridors between the Refuge, Lake Red Rock, and Chichaqua Bottoms Greenbelt.

The value of this constellation of green spaces and natural areas is recognized by biodiversity oriented conservation groups such as The Nature Conservancy, Iowa Audubon, American Bird Conservancy (Red Rock was also deemed a Globally Important Bird Area by the ABC in 1998), and the Iowa Natural Heritage Foundation. The Iowa Wildlife Action Plan also recognizes the value of these existing large habitat complexes [Figure 9 below, from Appendix 19 IWAP].

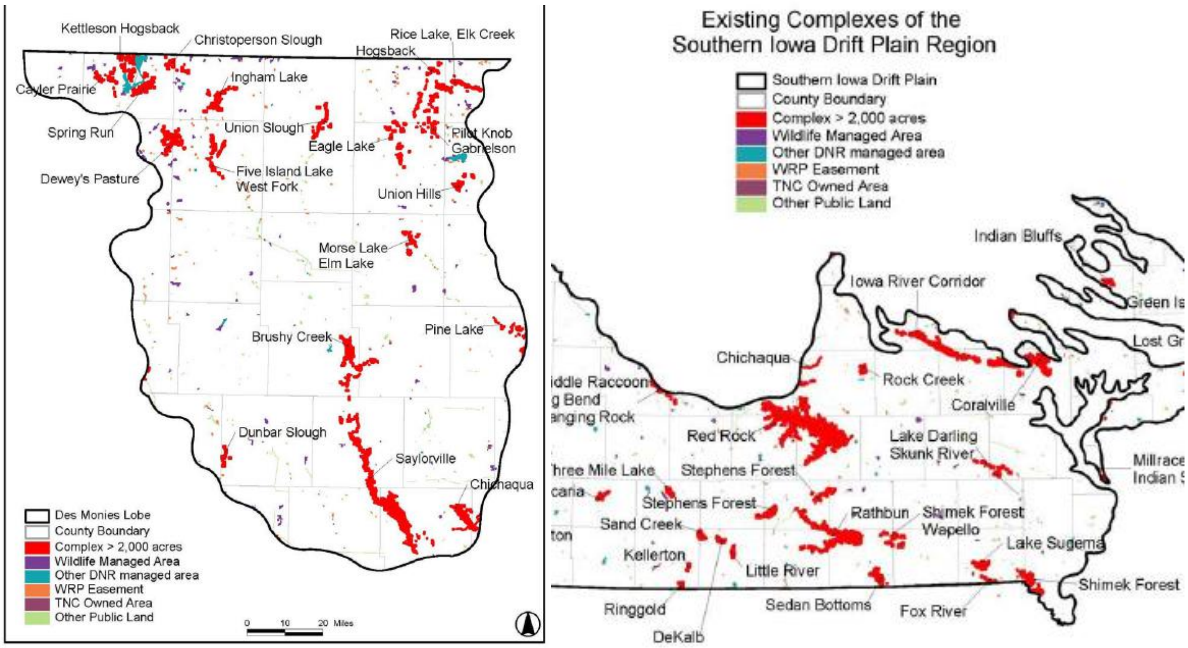

Figure 9. Existing large habitat complexes of the Des Moines Lobe and Southern Iowa Drift Plain.

Terrestrial and Riparian Communities and Habitat Types

Terrestrial natural communities of the Des Moines River Basin that are the primary focus of conservation, management, and restoration include northern and central tallgrass prairie, as well as oak savanna--all among the rarest of North America’s original ecosystem types.

Tallgrass prairie. Tallgrass Prairie once covered over 80 percent of Iowa’s landscape; today, less than 0.1 percent of that original prairie remains. Small tracts of remnant prairie are located on government lands and are being actively managed through prescribed fires. Species of interest protected by Central Iowa prairie remnants include regal fritillary butterflies and eastern gamma grass, the ancestor of the corn plant. At Saylorville, Red Feather Prairie is Iowa’s second-largest restored prairie at over 170 acres As the original borrow site for Saylorville Dam, poor soil conditions made reforestation of the area infeasible. Restored prairies are often less diverse than remnant prairies. Nevertheless, given the few remaining untilled prairies remaining, restored prairies are an important part of the prairie conservation landscape. Today Red Feather contains 10 species of grasses and 40 species of forbs, and is one of Saylorville’s richest birding areas with approximately 142 species recorded, including Henslows’ sparrows, bluebirds and bobolinks.

Prairie communities range from upland or dry prairie types, found on better drained sites and soil types, to wet prairies, or sedge meadows, which occur in low-lying areas, on prairie soils with high water holding capacity. Plant communities consist of a wide diversity of sedges, wildflowers, and other non-woody plants. In the Des Moines River Basin, conditions supporting wet prairies can be found along streams such as Walnut Creek and smaller drainages, as well as on hillsides where seeps emerge. Historically, frequent fire functioned to prevent shrub or tree encroachment, and most prairie species are fire-adapted or fire-dependent.

The Nature Conservancy owns and manages only a handful of lands in the Des Moines River project area. Medora Prairie is a tallgrass prairie remnant located in the gently rolling hills of the Southern Iowa Drift Plains. The rolling landscapes of this preserve feature approximately 60 acres of native tallgrass prairie dissected by wooded ravines. Medora supports a diverse array of plants and rare prairie butterflies, dominated by big bluestem and Indian grass. Rolling Thunder Prairie State Preserve, a 123-acre tallgrass prairie preserve owned and managed by the Warren County Conservation Board, is within 1½ miles of Medora Prairie. These two preserves make a significant contribution to the conservation of tallgrass prairie in southern Iowa.

Oak savanna and oak woodlands. Oak Savanna represents the transition between areas of forest and prairie and is comprised of large open-grown oak trees with a variety of shade tolerant grasses and forbs making up the ground cover. Most savannas are either overgrown due to lack of fire and grazing, which changes the forest composition and species, or have been converted to agriculture. Remnant Oak Savanna is found across Corps' lands, but is slowly converting to closed canopy forests in the absence of fire. Although high quality examples are rare, these may contain a mix of mature white oak, red oak, basswood and shagbark hickory woodland, as well as many rare wildflowers and fungi. On Corps and other lands, primarily publicly owned, land managers are working closely with federal, state, county, and private entities such as the Conservancy to coordinate efforts to restore Oak Savanna to the Iowa landscape through combinations of mechanical thinning and prescribed fire.

Floodplain and riparian forest. Both today and at the time of settlement, the majority of forested lands in Iowa were located in bottomlands and riparian corridors, transitioning into woodland and savanna on the edges into upland prairie, all interspersed by a mosaic of wetland sizes and types. GLO maps suggest the extent of riparian forest has also declined significantly since the 19th century. Floodplain natural communities in Iowa, as elsewhere, vary based on natural hydrology, ranging from silver maple and cottonwood dependent on and tolerant of frequent floodplain inundation, to swamp white oak and bur oak. Once extremely common throughout the Midwest, these floodplain oak savannas and woodlands are both extremely rare and extremely biodiverse. Most of this loss has occurred along the larger rivers, for example in the lower reaches of the Des Moines. The lowest reaches of the Des Moines near Keokuk are extensively leveed, especially on the Missouri side. The floodplain in this reach is dominated by agriculture.

The Conservancy's 2003 Upper Mississippi River Basin ecoregional assessment identified the following specific communities as terrestrial conservation targets within the lower Des Moines River basin: white oak-hickory forest, white oak central glaciated woodland, and central bur oak openings. Additional communities identified as conservation targets in the lower Des Moines included dry and wet caves, limestone glades (characterized by little bluestem *Schizachyrium scoparium,* sideoats grama *Bouteloua curtipendula*, Missouri coneflower *Rudbeckia missouriensis - Mentzelia oligosperma),* sinkhole pond marsh (Longhair sedge *Carex comosa* -cypressknee sedge *Carex decomposita*, threeway sedge *Dulichium arundinaceum,* and stalked water horehound *Lycopus rubellus*).

In the lower Des Moines, Shimek State Park is another significant area of public land, at 9,148 acres (37 km^2). The Park contains one of the largest remaining contiguous forests in Iowa, with large stands of mixed oak-hickory forest, along with about 1,000 acres (4 km^2) of planted pine. In nearby Lacey Keosauqua state park, upland forest types include mature eastern dry-mesic forest, with white oak (*Quercus alba*), red oak (*Q. borealis*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*) dominant. Large-diameter oaks typically form a tall canopy in these woods. Along the bluffs of the Des Moines River in the northwest part of the park, the mature forest community includes individual white oak trees that are 200-300 years old. Ironwood (*Ostrya virginiana*) and buckeye (*Aesculus glabra*) are the common understory trees in the woody vegetation layer between the forest canopy and the forest floor. Shrubs are generally sparse, but include species such as fragrant sumac (*Rhus aromatica*) and gooseberry (*Ribes missouriense*). Pennsylvania sedge (*Carex pennsylvanica*), bottlebrush grass (*Hystrix patula*), slender wildrye (*Elymus villosus*), shining bedstraw (*Galium concinnum*), pointed-leaf tick-trefoil (*Desmodium glutinosum*), woodland phlox (*Phlox divaricata*), and wild ginger (*Asarum canadense*) are common herbaceous plants of the forest floor. Documented state threatened or special concern plants include false hellebore (*Veratrum woodii*, threatened), pagoda plant (*Blephilia ciliata*, threatened), and prairie-tea (*Croton monanthogynus*, special concern). Slender ladies'-tresses orchid (*Spiranthes lacera*, threatened) is often included in environmental assessments as a state-listed species of concern, but it may not have ever been confirmed.

Invasive species pose a significant threat to remnant natural communities in the Des Moines, especially in frequently disturbed riparian areas and cropland field edges. Vegetative threats include reed canary grass (*Phalaris arundinacea*), Chinese bush clover (*Sericea lespedeza)*, emerald crown vetch (*Coronilla varia)*, garlic mustard (*Alliaria petiolata*), and Japanese honeysuckle (*Lonicera japonica*). All of these species have the ability to significantly alter native ecosystems. Invasive pests also threaten Iowa's trees. Emerald ash borer (EAB) is a major concern to foresters, and is expected by many forest experts to completely eliminate all species of ash from the landscape over the next few decades. Other forest pests of great concern include gypsy moth (oak) and thousand cankers disease (walnut). All told, more than 50 invasive species have been identified on USACE lands as posing an immediate or near-term threat to a range of different plant communities. Once established, invasive species such as reed canary grass, *Phragmites*, etc. can be extremely resistant to control. Eradication is rarely attainable, but control can be effective although expensive. Restoration of natural floodplain hydrology has been suggested as one of the most cost effective ways to restore native floodplain vegetation and reduce the impact of non-native invasives (Predick and Turner 2008, Seavy et al. 2009; Poff and Zimmerman 2010); however, in practice, restoration of disturbance regimes alone has not always been sufficient to reestablish native vegetation communities (Richardson *et al*. 2007; Zedler 2009.)

Aquatic and Wetland Communities

Freshwater Mussels

The Des Moines River was historically inhabited by more than 36 species of mussels (Dodd and Flammang 2005). Historical accounts suggest that many species of mussels were highly abundant in dense populations at the time of European settlement and initial agricultural conversion in the 19th century. Mussel populations and diversity declined precipitously in response to exploitation for the pearl button industry beginning in the late 1800s, and have continued to decline steadily throughout the past 150 years in response to water quality and habitat degradation associated with river modifications, agricultural runoff, hydrologic alteration and drainage. Even within the past 50 years, however, the more tolerant species have shown significant declines in density and abundance. Scott Gritters describes mussel beds in the Red Rock reach as vastly reduced from 35 years ago "when we used to pick them up like rocks below the dollar bridge. I think these were just giant floaters and heelsplitters, but I challenge anyone to find even significant numbers of them now!"

Recently published peer-reviewed literature on the Des Moines River contains only qualitative references to contemporary status of mussels, and no records of rare or listed species in the state natural heritage database in the project study reach (i.e. Saylorville to Ottumwa). Mussel experts consulted for this project were not surprised by this lack of literature, as most listed species have been eliminated along with many non-listed species such as ebonyshell (*Fusconaia ebena)* and spike (*Elliptio dilatatus*). Several recent statewide surveys have been conducted by state agencies in Iowa (Terrance Frest in 1986-1987, Kelly Arbuckle (now Kelly Poole) in 2000, and most recently Jen Kurth 2011-2016.) The latter survey has many sites on the Des Moines within the project area, and should soon provide up to date and comprehensive information regarding which species are currently present. The most comprehensive recent information available comes from Gritters' 2003 survey and compilation of other surveys, which documented 26 species (12 if only live individuals counted; see Table 5.)

On the whole, there is still much that is unknown when it comes to understanding status and ecology of mussel communities. Different species of mussels each have different habitat preferences, as do their fish hosts. There are extensive gaps in our understanding of life cycle and reproductive needs of individual mussel species and our ability to assess impacts related to habitat variables and stressors such as water flow, water depth, temperature, oxygen, host species, stability of substrate, nutrients, and sediment. Generally speaking, due to their limited mobility, mussels prefer firmer and/or more stable habitats, i.e. reaches that are not highly geomorphically active or subject to excessive erosion or deposition. In the upper Mississippi River system, the USGS and others have done studies on the relationship of mussels to sediment stability and velocity sheer stress on beds and these are good predictors. Accounting for all variables is tough, for instance if the fish host is not present due to dams or population declines.

Mussels are also highly sensitive barometers to a host of water quality parameters. Although there is much unknown, researchers have found mussels sensitive to emerging contaminants such as those often detected in wastewater, such as low levels of pharmaceuticals, antibacterial soaps, etc. Recent research suggests many species and life stages are vulnerable to a host of nutrient and chemical contaminants at levels that may be much lower than those previously thought protective of fish and other aquatic organisms. For example, juvenile mussels have been shown to be vulnerable to nitrate and ammonia at much lower concentrations than those that are protective of adults, at concentrations well under the 3 mg/L EPA aquatic life standard for nitrate (Newton et al. 2003).

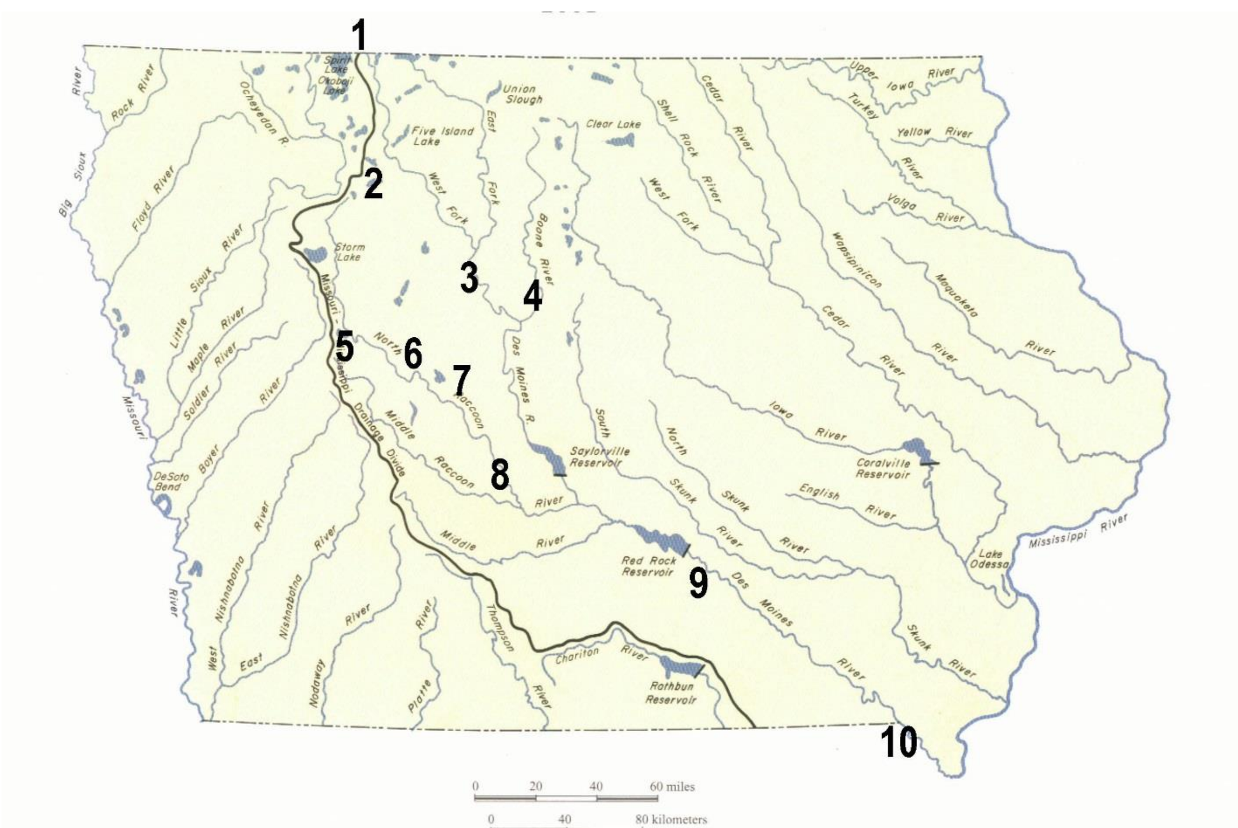

Figure 10. Map of mussel study locations summarized in Table 5 [From Gritters 2003]

Table 5. [Reprinted Table 1 from Gritters 2003] Known mussel studies completed on the Des Moines River System. T=state threatened species, E=endangered species, *=winged mapleleaf identified by Mueller 1993, as historically present. Federally endangered.

Species	Common name	1. Minnesota	2. Lizard Creek 2000	3. Des Moines R. 1987	3. Des Moines R. 2000	4. Boone River 1987	4. Boone River 2000	5. Elk Run 2000	6. Hardin Cr. Green Co. 2000	7. E & W Buttrick Cr. 2000	8. North Racoon River 2000	9. Gritters-2003	10. IA survey Kurth 2016	Any Living since 1987?	number site w/ living clams
Actinonaias ligamentina	mucket	D		D	X	D	D	D	X	X	D	D		yes	3
Alasmidonta marginata	elktoe			D	X									yes	1
Amblema plicata	three-ridge	X		D		X	X	D	X	X	D	D		yes	5
Anodonta grandis	giant floater	X		X	D		D	D	X	D		X		yes	4
Anodontoides ferussacianus^{T}	cylinder	X					D		D	X				yes	2
Cyclonaias tuberculata^{T}	purple wartyback											D		no	0
Elliptio dilatata	spike	D		D	X	D						D		yes	1
Fusconaia ebena	ebony shell											D		no	0
Fusconaia flava	wabash pigtoe	D		D		D	X		X	X		D		yes	3
Lampsilis cardium	plain pocketbook	D	X	X	X	X	X	X	X	X	X	X		yes	10
Lampsilis siliquoidea	fat mucket	X	D	X	X	X	D			X				yes	5
Lampsilis teres^{E}	yellow sandshell			D								D		no	0
Lasmigona complanata	white heelsplitter	X	D	X	D	X	X	X	X		D	X		yes	6
Lasmigona costata	fluted-shell			D		D					D			no	0
Leptodea fragilis	fragil papershell			X	X		X	X	X	X	X	X		yes	8
Ligumia recta	black sandshell	D		X	X	D	X					D		yes	3
Ligumia subrostrata	pondmussel								D					no	0
Megalonaias nervosa	washboard											D		no	0
Obliquaria reflexa	three-horn													no	0
Obovaria olivaria	hickorynut											X		yes	1
Plethobasus cyphyus^{E}	sheepnose			D								D		no	0
Pleurobema sintoxia^{E}	round pigtoe	D		D		D						D		no	0
Potamilus alatus	pink heelsplitter			D						X		X		yes	2
Potamilus ohiensis	pink papershell				X		X				D	X		yes	3
*Quadrula frugosa**	winged mapleleaf													no	0
Quadrula metanevra	monkeyface	D		D					X			D		yes	1
Quadrula nodulata	wartyback								X	X				yes	1
Quadrula pustulosa	pimpleback			D	D	D		X	X	X	D	X		yes	4
Quadrula quadrula	mapleleaf			D					X	X	D	X		yes	3
Simpsonaias ambigua	salamander mussel			D										no	0
Strophitus undulatus^{T}	creeper	D	D	D	X	X		D	X	X		D		yes	4
Toxolasma parvus	lilliput	X												yes	1
Tritogonia verrucosa^{E}	buckhorn			D								D		no	0
Truncilla donaciformis	fawnsfoot											X		yes	1
Truncilla truncata	deertoe											X		yes	1
Utterbackia imbecillis	paper pondshell						X		X	X	D	X		yes	4
No. live species		6	1	6	9	5	8	4	13	13	2	12		24	
Total species		14	4	22	12	12	12	8	15	14	10	26		36	
% Living Species		0.43	0.25	0.27	0.75	0.42	0.67	0.50	0.87	0.93	0.20	0.46		0.67	

Status of mussels in Red Rock and above.

The status of mussel populations in the Des Moines River and tributary watersheds upstream of Red Rock is variable. Above the reservoirs there are locations and tributaries with decent mussel populations, such as the Boone River, a Conservancy freshwater priority watershed identified as a conservation priority in part based on its historic importance to mussels. However, as with most mussel populations throughout eastern Iowa, even these populations are "healthy" only in small pockets. There are many miles of reach almost devoid of mussels, with only small pockets of incredible diversity. These are increasingly difficult to find and requires significant effort, in sharp contrast to the historical period when mussels were noticeably abundant throughout central Iowa.

The MSIM involved surveys for freshwater mussels at one site on the Saylorville Project (Polk City Refuge), but no mussels were detected. In 2010, when Red Rock reservoir was sampled prior to and during a maintenance drawdown, it actually had more mussels in it than surveyors expected, with five relatively common species. However, mussel mortality was significant during the actual 2010 drawdown, which occurred over the winter.

Both Red Rock Dam[4] and Saylorville Dams serve as essentially impassable barriers to upstream fish migration. Because these dams represent barriers to the fish that serve as obligate hosts for some mussel species and mussels are dependent on fish hosts for upstream migration, stocking represents the only way to recover many historically present species above the dams. A large mussel and host restoration effort would need to be implemented above Red Rock (and Saylorville) to overcome the obstacle of the large dams and stand a chance at restoration. Although it has been discussed, up to this point, IDNR has lacked funding and staff capacity to pursue implementation of this type of mussel recovery project (Dodd, pers comm).

Status of mussels below Red Rock.

The Nature Conservancy's 2003 Upper Mississippi River ecoregional assessment identified Ebonyshell, Black Sandshell, Wartyback, and Pondhorn Mussels as aquatic conservation targets in the lower Des Moines. The majority of mussel species in the Des Moines River, particularly in the dam affected reaches, are struggling to maintain their populations (Gritters 2003). It has been suggested that there may be pockets of higher density and diversity below the Ottumwa reach. In 2005, Dodd and Flammang conducted a survey of mussels at Ottumwa and found 11 species, including the nonnative Asian clam (Table 6). Additional inventories of stranded mussels were conducted in conjunction with the 2010 drawdown at Red Rock and the 2014 drawdown at Ottumwa (see next section.) The Iowa natural heritage database and county records suggest the presence of two listed species in the lower reaches (Sheepnose, Spectaclecase, both of which were recently added to the federal Endangered Species List), but no live individuals have been recovered in recent surveys. Missouri DOC surveyed close to the Mississippi River confluence many years ago but did not find any live mussels. Table 3 lists mussel species that have been noted found in recent surveys the Des Moines River system, along with information about where they are found if known.

[4] Red Rock dam represents a barrier to fish migration—essentially impassable in most if not all years-- and is even being thought of in recent years as a useful barrier to upstream migration of major nuisance invasive species such as Asian Carp (Hoogeveen 2010). Saylorville also represents an impassable barrier for any fish that are upstream of Red Rock.

Table 6. Species list of freshwater mussels noted in recent surveys from the Des Moines River project area.

Species		2005 Ottumwa survey	Red Rock 2010	2014 Ottumwa mortality event	2016 statewide mussel survey
Plain pocketbook	*Lampsilis cardium*				L
White heelsplitter	*Lasmigona complanata*	D	D	D	L
Fragile papershell	*Leptodea fragilis*	L	D	D	L
Pink papershell	*Potamilus ohiensis*	D		D	L
Pimpleback	*Quadrula pustulosa*	D		D	L
Mapleleaf	*Quadrula quadrula*		D	D	L
Lilliput	*Toxolasma parvus*	D			L
Threeridge	*Amblema plicata*				D
Black sandshell	*Ligumia recta*				D
Giant floater	*Pyganodon grandis*	D	D	D	D
Paper pondshell	*Utterbackia imbecilis*	D		D	D
Mucket	*Actinonaias ligamentina*				
Asian clam	*Corbicula fluminea*	D			
Spike	*Elliptio dilatata*				
Fatmucket	*Lampsilis siliquoidea*				
Pink heelsplitter	*Potamilus alatus*	D			
Creeper	*Strophitus undulatus*				
Fawnsfoot	*Truncilla donaciformis*	D		D	
Deertoe	*Truncilla truncata*	R			

L=live; D=fresh dead; R=relic only

Mussel Mortality

Dam operations and maintenance on the Des Moines River contribute to periodic episodes of significant mussel mortality. Although mussels are capable of some movement both laterally and vertically, most species have very limited ability to migrate in response to rapid changes in water levels and are therefore highly vulnerable to rapid or major drawdown events (Newton et al 2)011. For example, the Ottumwa impoundment is drawn down periodically (usually annually) for inspection of the hydropower dam. In September 2005, unseasonal high temperatures that occurred at the time of the drawdown contributed to significant mortality. In an attempt to reduce the likelihood of a repeat mortality event, Iowa DNR requested subsequent drawdowns be conducted later in the year. Unfortunately, in 2014, the drawdown was delayed by high flows well into November, when an early cold snap also resulted in excessively high mussel mortality. Mussel movements of up to 10 to 15 feet were observed, but the majority of mussels perished. Likewise, in 2010, when Red Rock Lake was drawn down 10 feet below the conservation pool for maintenance on the Tainter gates, mussels experienced significant mortality. Some mussels were able to migrate down to inundated areas, but water levels remained low through the spring, and freezing temperatures contributed to additional mortality. At that time, at least four species of mussels (mapleleaf, white heelsplitter, giant floater and fragile papershell) were found in the reservoir basin. Mortality events of this magnitude are likely to have significant population level effects due to the complex life cycle and demonstrated limited abilities to recolonize and recruit juveniles – i.e., only when conditions are favorable, long-time to mature. In general, mussels are more tolerant of dewatering during seasons when temperatures are moderate, but cannot long survive freezing temperatures (pers comm.).

Fish

As Iowa's largest river and a direct tributary to the Mississippi River, the Des Moines River represents a significant fishery resource, with fish communities ranging from small headwater stream fishes of the upper tributaries to significant large river species including Paddlefish (*Polyodon spathula*), Shovelnose Sturgeon (*Scaphirhynchus platorhyncus*), and even occasional Lake Sturgeon (*Acipenser fulvescens*). However, of all

Iowa's interior rivers, the Des Moines River has been subjected to the largest increase in water storage capacity in impoundments since the 1950s (Falcone et al. 2010, Parks 2013). Impoundments alter riverine environments by affecting local hydrology through changes in stream flow upstream and downstream of dams (Dynesius and Nilsson, 1994; Poff et al., 1997), and by transforming a lotic (flowing water) system into an artificial lentic (=lake-like) environment which leads to shifts in biological assemblages from lotic- to lentic-adapted fish and other aquatic species. Water level fluctuations are known to strongly influence the reproduction of fishes that spawn in near-shore areas (Sammons and Bettoli, 2000), with fluctuating water surface elevations during spawning leading to potential disruption of spawning, egg desiccation, or an increased susceptibility to predation of young (Poff and Zimmerman 2010).

Exploring historical changes in fish assemblage structure in Iowa's larger interior rivers (Des Moines, Maquoketa, Iowa, Cedar and Wapsipinicon), Parks and colleagues (2014) found that declines of specialist fishes (e.g. backwater specialists, fluvial and fluvial dependent species) were most evident in the Des Moines River, with 63% of species showing declines. Species richness declined from 80 species from the historic period (1884-1969) to 74 in the recent period (1990-2011), with many changes and substitutions (Table 7). Declines and extirpations of fluvial specialists (*e.g.,* Common Shiner *Luxilus cornutus* and Black Redhorse *Moxostoma duquesni*) described the primary shift in fish assemblage structure. More than 60% of fish species classified by the state as "species of greatest conservation need (SGCN)" had experienced declines in the Des Moines (18% increased, 20% no change or unknown). Table 7 lists Des Moines River species as reported by Parks (2013), with state SGCN as well as Conservancy UMRB fish conservation targets (Weitzell et al. 2003) identified. Note that many of the species identified as SGCN are absent from the fish community in recent surveys, especially those that were rare to begin with (<5% of samples). SGCN species that have more or less been extirpated include Black Redhorse, Blacknose Dace, Blackside Darter, Gravel Chub, Tadpole Madtom, Topeka Shiner, and Western Sand Darter (refer to Table 7 for scientific names). Some species have increased. Notable species showing greater abundance in the recent record include the federally-listed Paddlefish, as well as state SGCN Longnose Gar and Blue Sucker.

Floodplain habitats in braided and meandering rivers often contain a variety of microhabitats, creating important temperature refugia, and are therefore able to support a high diversity of fishes. Highly specialized fishes in floodplain and off-channel habitats are often phytophilic species (e.g., Bowfin, Blacknose Shiner, and Banded Killifish) that pursue floodplain habitats with high water clarity and abundant aquatic macrophyte substrates for spawning. Parks et al. (2013) attributed local extirpations of 13 backwater species (e.g., Blacknose Shiner and Black Bullhead) and 8 fluvial specialists (e.g., Hornyhead Chub and Blackside Darter) in downstream river sections to potential reductions in availability of thermal microhabitats. Other factors contributing to declines of historically occurring backwater specialist fishes (additional examples: Golden Shiner, Tadpole Madtom, and Brook Silverside) across rivers include channelization, destruction of riparian and floodplain habitat, and other effects of altered flow regimes (Menzel, 1981; Sparks, 1995; Armitage and Rank, 2009), such as increased sedimentation that accelerates disconnecting or filling off-channel habitats (Sparks, 1995; Bunn and Arthington 2002). Distribution and abundance of aquatic macrophytes can be reduced directly due to changes in the flow regime or result from increased turbidity in the water column (Rogers and Theiling, 1999; Bunn and Arthington, 2002).

Shovelnose sturgeon (*Scaphirhynchus platorynchus)*, is a large river species identified by the Conservancy as a priority UMRB conservation target in the lower Des Moines River, along with Paddlefish. No other UMRB fish species targets (Pugnose Shiner, Gilt Darter, Western Sand Darter, Gravel Chub, or Topeka Shiner) were recorded in the recent survey record from the Des Moines SRP project reach. Anecdotally, it is believed likely that both Shovelnose Sturgeon and Lake Sturgeon—another Conservancy and UMR fish species of conservation concern--are spawning and rearing successfully in the Des Moines River to some extent, as suitable substrate for spawning is available (Hansen, personal communication). Microchemistry studies show that immigration of sturgeon from the Upper Mississippi River is common and that sturgeon in the lower Des Moines also spend considerable time in the Mississippi River (Hupfeld et al. 2014). As has been observed on the Cedar River, it is likely that a majority of sturgeon return to the Mississippi River shortly after spawning, with a much smaller percentage remaining in the Des Moines year round as a resident population (Hansen, pers communication).

In the Des Moines River, Hupfeld et al (2012) attributed a spate of recent mortality events for Shovelnose Sturgeon to thermal stress, and suggested that a combination of river modifications and climate change are exacerbating the problem for sturgeon and other thermally sensitive species across their U.S. range. Multiple fish kills occurred on the lower Des Moines River during the summer of 2012, at a time when water temperatures were exceedingly high (29–35°C), while dissolved oxygen levels varied between 4 and 10 mg/L. Population simulation modelling suggested that only ~14% mortality would need to occur to reduce the reproductive potential below sustainable levels, and this was almost certainly exceeded (Hupfeld et al. 2012). Because future climate projections indicate that increases in temperature on the Des Moines River are likely, the population may be at significant risk.

The relative importance of Des Moines River sturgeon as a source or sink for the overall shovelnose sturgeon population in the Mississippi River below Keokuk is unknown. The influence that major mortality events on the Des Moines River has on the Upper Mississippi River population is unknown but could certainly be significant at a population scale. To avoid creating a situation where the Des Moines serves as a “sink” for Shovelnose Sturgeon and other Upper Mississippi River threatened and sensitive fish populations, proactive measures are needed to reduce the frequency and severity of these types of mortality events. One proposal involves bolstering low flows during periods of extreme heat to buffer water temperatures against excessive heat gain, given that all else being equal, water temperatures tend to warm relatively more rapidly in response to air temperatures during periods of low flow. In some cases, cool and coldwater fisheries can be enhanced in the tailrace waters of dams. It is perhaps worth exploring whether manipulating the depth from which water is discharged from the reservoir is a feasible way to moderate downstream temperatures when downstream river temperatures near critical thresholds for sturgeon in the Des Moines.

Many declines in backwater, fluvial, or other habitat specialists in large rivers were already well underway by the time Red Rock and Saylorville Dams were constructed. Modification of river channels in the late 1800s contributed to rapid loss of habitat heterogeneity and connectivity to off-channel habitats around the turn of the 20th century. Additional loss of floodplain habitat occurred due to agricultural drainage and channelization, levee construction, sedimentation, and decline of aquatic macrophytes (Menzel, 1981, 1983). Historically, records suggest that much of the 500-year floodplain and beyond in the lower half of the Des Moines River would have been dominated by floodplain forest, along with savanna and wet prairie. Today much of the area in the Des Moines River from Saylorville to Red Rock is in urban and suburban development; while the floodplain from Red Rock to the confluence with the Mississippi River contains significant row crop agriculture. In the short term, this presents a constraint on the opportunity to restore floodplain connections downstream of Red Rock.

Table 7. Fish species surveyed in the Des Moines River in historic (**1884-1969**) and recent (**1990-2011**) period of record (From Parks 2013).

Common name	***Scientific name***	**H**	**R**	**Trophic**	**Reproductive (-phil)**	**Habitat**	
Skipjack Herring	*Alosa chrysochloris*	0	4	carn	phytolitho-	FD	
Northern Rock Bass	*Ambloplites rupestris*	18	4	carn	poly-	MG	
Black Bullhead	*Ameiurus melas*	32	11	omni	speleo-	MG	X
Yellow Bullhead	*Ameiurus natalis*	3	11	omni	speleo-	MG	X
Brown Bullhead*	*Ameiurus nebulosus*	3	0	ben inv	speleo-	MG	X
Western Sand Darter*	*Ammocrypta clara*	21	0	ben inv	psammo-	FS	
American Eel	*Anguilla rostrata*	21	4	carn		FD	
Freshwater Drum	*Aplotinodus grunniens*	27	64	ben inv	pelago-	MG	
Central Stoneroller	*Campostoma anomalum*	23	4	herb-det	litho-	FS	
River Carpsucker	*Carpiodes carpio*	18	72	omni	lithopelago-	MG	
Quillback Carpsucker	*Carpiodes cyprinus*	41	53	omni	lithopelago-	MG	
Highfin Carpsucker	*Carpiodes velifer*	12	14	omni	lithopelago-	FS	
White Sucker	*Catostomus commersoni*	71	14	omni	lithopelago-	FD	
White Amur	*Ctenopharyngodon idella*	0	11	herb-det	pelago-	FD	
Brook Stickleback	*Culaeus inconstans*	3	0	invert	ariadno-	MG	X
Blue Sucker*	***Cycleptus elongatus***	0	11	ben inv	lithopelago-	FS	
Red Shiner	*Cyprinella lutrensis*	21	18	omni	speleo	MG	X
Spotfin Shiner	*Cyprinella spiloptera*	33	54	invert	speleo	FS	
Common Carp	*Cyprinus carpio*	76	82	omni	phytolitho-	MG	
Gizzard Shad	*Dorosoma cepedianum*	15	47	planktivore	lithopelago-	MG	
Gravel Chub*	*Erimystax x-punctatus*	18	0	herb-det	litho-	FS	
Northern Pike	*Esox lucius*	29	14	carn	phyto	MG	X
Mud Darter	*Etheostoma asprigene*	0	4	ben inv	phyto	FD	X
Iowa Darter	*Etheostoma exile*	9	4	ben inv	phytolitho-	FD	X
Fantail Darter	*Etheostoma flabellare*	15	14	ben inv	speleo-	FS	
Johnny Darter	*Etheostoma nigrum*	26	11	ben inv	speleo-	MG	
Orangethroat Darter	*Etheostoma spectabile*	0	4	ben inv	litho-	FS	
Banded Darter	*Etheostoma zonale*	21	11	ben inv	phyto-	FS	
Banded Killifish	*Fundulus diaphanus*	3	0	invert	phyto-	MG	X
Goldeye	*Hiodon alosoides*	27	14	invert	lithopelago-	FD	
Mooneye	*Hiodon tergisus*	0	22	invert	lithopelago-	FD	
Western Silvery Minnow	*Hybognathus argyritis*	0	4	herb-det	lithopelago-	FS	
Brassy Minnow	*Hybognathus hankinsoni*	18	7	herb-det	phyto-	MG	

Common name	*Scientific name*	H	R	Trophic	Reproductive (-phil)	Habitat	
Mississippi Silvery Minnow	*Hybognathus nuchalis*	6	4	herb-det	lithopelago-	FD	X
Pallid Shiner*	*Hybopsis amnis*	3	0	invert		FS	
Northern Hog Sucker	*Hypentelium nigricans*	23	25	ben inv	litho-	FS	
Bighead Carp	*Hypophthalmichthys nobilis*	0	4	planktivore	pelago-	FD	
Channel Catfish	*Ictalurus punctatus*	91	64	carn	speleo-	MG	
Silver Lamprey	*Icthyomyzon unicuspis*	3	0	carn	litho-	FD	
Smallmouth Buffalo	*Ictiobus bubalus*	0	57	omni	lithopelago-	MG	
Black Buffalo*	*Ictiobus niger*	6	4	invert	lithopelago-	MG	
Brook Silverside	*Labidesthes sicculus*	3	0	invert	phytolitho-	MG	X
Spotted Gar	*Lepisosteus oculatus*	0	7	carn	phyto	FD	
Longnose Gar*	***Lepisosteus osseus***	**12**	**14**	**carn**	**phytolitho-**	**FD**	**X**
Shortnose Gar	*Lepisosteus platostomus*	3	21	carn	phyto-	MG	X
Green Sunfish	*Lepomis cyanellus*	68	39	carn	poly-	MG	
Orangespotted Sunfish	*Lepomis humilis*	39	14	invert	litho-	MG	X
Bluegill	*Lepomis macrochiris*	44	61	invert	poly-	MG	X
Longear Sunfish*	*Lepomis megalotis*	3	0	invert	poly-	MG	X
Redear Sunfish	*Lepomis microlophus*	0	4	ben inv	poly-	MG	X
Common Shiner	*Luxilis cornutus*	27	4	invert	litho-	FS	
Redfin Shiner*	*Lythrurus umbratilis*	3	0	invert	litho	FS	
Shoal Chub	*Macrhybopsis hyostoma*	21	22	ben inv	lithopelago-	FS	
Smallmouth Bass	*Micropterus dolomieu*	50	39	carn	poly-	MG	
Largemouth Bass	*Micropterus salmoides*	35	39	carn	poly-	MG	
White Bass	*Morone chrysops*	3	50	carn	phytolitho-	FD	
Yellow Bass	*Morone mississippiensis*	6	0	carn	phytolitho-	FD	x
Silver Redhorse	*Moxostoma anisurum*	27	18	ben inv	litho	FD	
Black Redhorse*	*Moxostoma duquesnei*	*9*	0	ben inv	litho-	FS	
Golden Redhorse	*Moxostoma erythrurum*	27	47	ben inv	litho-	FD	
Shorthead Redhorse	*Moxostoma macrolepidotum*	41	46	ben inv	litho-	FD	
Hornyhead Chub	*Nocomis biguttatus*	21	11	invert	litho-	FS	
Golden Shiner	*Notemigonus crysoleucas*	15	4	omni	phyto-	MG	
Pugnose Shiner*	***Notropis anogenus***	3	0	herb-det	phyto	MG	X
Emerald Shiner	*Notropis atherinoides*	24	43	planktivore	pelago-	MG	
River Shiner	*Notropis blennius*	26	7	invert	litho-	FS	

Common Name	***Scientific name***	**H**	**R**	**Trophic**	**Reproductive (-phil)**	**Habitat**	
Bigmouth Shiner	*Notropis dorsalis*	32	36	ben inv	FS		
Blackchin Shiner*	*Notropis heterodon*	3	0	invert	phyto	MG	X
Blacknose Shiner*	*Notropis heterolepis*	3	0	invert	phyto	MG	
Rosyface Shiner	*Notropis rubellus*	21	4	ben inv	litho-	FS	
Sand Shiner	*Notropis stramineus*	41	50	invert	psammo-	FS	
Topeka Shiner*	*Notropis topeka*	12	0	invert		FD	X
Mimic Shiner	*Notropis volucellus*	0	7	invert	phyto		
Channel Shiner	*Notropis wickliffi*	0	7	carn		FS	
Stonecat	*Noturus flavus*	47	18	ben inv	speleo	FS	
Tadpole Madtom*	*Noturus gyrinus*	18	0	ben inv	speleo-	FD	X
Yellow Perch	*Perca flavescens*	18	7	carn	phytolitho-	MG	X
Northern Logperch	*Percina caprodes*	12	0	ben inv	litho-	MG	
Gilt Darter*	***Percina evides***	3	0	ben inv	litho-	FS	
Blackside Darter*	*Percina maculata*	30	0	ben inv	litho-	FS	
Slenderhead Darter*	*Percina phoxocephala*	18	14	ben inv	litho-	FS	
Suckermouth Minnow	*Phenacobius mirabilis*	32	11	ben inv	litho	FS	
Bluntnose Minnow	*Pimephales notatus*	38	50	herb-det	speleo	MG	
Fathead Minnow	*Pimephales promelas*	35	25	omni	speleo	MG	
Bullhead Minnow	*Pimephales vigilax*	32	32	omni	speleo-	MG	
Paddlefish*	***Polyodon spathula***	3	4	planktivore	lithopelago-	FD	
White Crappie	*Pomoxis annularis*	41	18	carn	phyto-	MG	X
Black Crappie	*Pomoxis nigromaculatus*	30	32	carn	phyto	MG	X
Flathead Catfish	*Pylodictis olivaris*	35	57	carn	speleo	FD	
Blacknose Dace*	*Rhinichthys atratulus*	12	0	invert	lithopelago-	FS	
Longnose Dace	*Rhinichthys cataractae*	0	7	ben inv	lithopelago-	FS	
Shovelnose Sturgeon*	***Scaphirhyncus platorynchus***	0	7	ben inv	lithopelago-	FS	
Creek Chub	*Semotilus atromaculatus*	47	7	carn	litho	MG	
Sauger	*Stizostedion canadense*	3	7	carn	lithopelago-	MG	
Walleye	*Stizostedion vitreum*	59	50	carn	lithopelago-	MG	
		80	74				

* = SGCN
X = Backwater specialist

***Other sources of mortality*.** Dissolved gas supersaturation is a condition that results from both natural (e.g. waterfalls) and human-caused (e.g. dam spillways) processes (Weitkamp 2008). Supersaturation can result in gas bubble disease which has been described in a wide variety of fishes and invertebrates. The presence of elevated total dissolved gas (TDG) downstream of a spillway may result in an increased incidence of gas bubble disease in fish, and can result in significant fish kills. Symptoms of gas bubble trauma include emphysema (gas blisters) and exophthalmia (popeye, i.e. fish with bulging eyes.)

As early as 1976, the Master Plan for Red Rock recognized the potential problem of gas bubble disease below Red Rock, and identified a goal of improving water quality below the spillway. Since 1983, there have been 51 fish kills documented at the Station 9 location below Red Rock (ranging from minor to major severity and affecting many different species), 33 of which were attributed to acute gas bubble trauma (Lutz 2013). The majority occurred when total gas saturation was 120% or greater (corresponding to the EPA standard) and river depth was shallow. Eight of the other episodes occurred when the river flow had either been drastically reduced over a short period of time or significantly reduced for dam maintenance work. One fish kill occurred as the $N_2:O_2$ ratio increased to the maximum. Another fish kill was prompted by extreme flows and high total gas pressure. Historically, fish kills from gas bubble trauma did not have a sudden onset and many different species and sizes of fish were affected. Gas bubbles present in tissues of dead fish or in fish removed from supersaturated conditions do disappear over time, so visual indications may not remain present in dead fish discovered after the kill.

According to a review by Weitkamp (2008), TDG supersaturation results in little or no gas bubble disease (GBD) at levels up to 120% of saturation when compensating depths (2 m or more) are available. Fish have the capacity to rapidly recover from GBD when they reach compensating depths or TDG supersaturation is decreased. However, symptoms may be observable and mortality may be significant even when there is not a noticeable or documented fish kill.

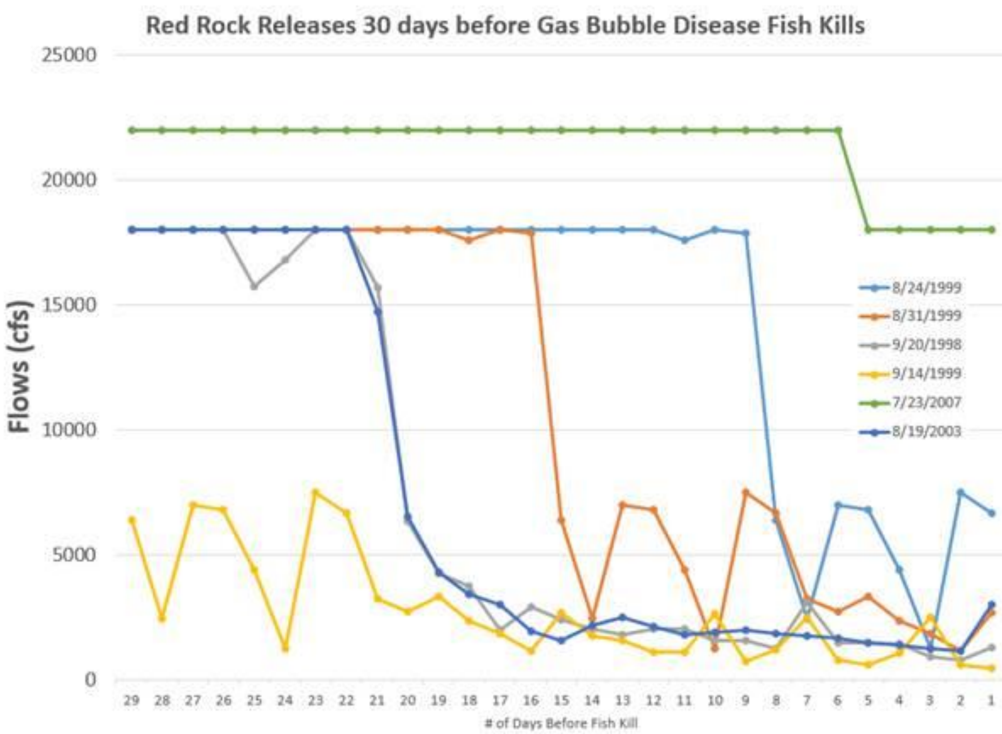

Figure 11. (For readability, the graph leaves out the high flow fish kill occurrence from 6/23/2008).

Mitigation efforts can be made to reduce the incidence of supersaturation, using both technology or operational changes. Most of the mitigation efforts have been in the Northwest, specifically on the Columbia and Snake Rivers. Technologies such as flow deflectors or flip gates are being used in those cases, but these would unlikely provide cost-effective benefits at Red Rock, as the Tainter Gates are rarely in use (Lutz, 2011 email exchange with Ben Dodd)). Feng et al (2014) recommended adoption of an interval-discharge pattern instead of a continuous-discharge pattern to minimize the negative effect caused by supersaturated TDG at an upstream power station, and adoption of a surface tunnel rather than a bottom tunnel as a release structure for a downstream power station, for an African reservoir. Politano (2012) modeled operational strategies for minimizing gas supersaturation downstream of a dam in ___, and suggested that in order to obtain the lowest TDG concentration, it is best to concentrate most of the flow in a central spillway bay.

The Corps has taken operational steps to reduce gas supersaturation below the dams via selection of the sluice gates under normal operations and limited use of the Tainter gates except during high flows. However, one of the most effective operational mitigations is to limit the fall rate, i.e. not to reduce flows too quickly. Swift reduction in river depth under high supersaturation is hypothesized to be the primary trigger for historically observed fish kills. Although the currently downloadable Iowa Fish Kills database only contains records for 7 fish kills ascribed to gas bubble disease, we examined 30 day flows preceding the date of each of those 7 fish kills and found evidence supporting the hypothesis that rapid step down in flows is a potential cause or contributor.

Fish kills do seem to have become less common in recent years, which Lutz (2013) attributes primarily to higher flows rather than to operational changes. Higher flows do increase gas pressure, but they also increase river depth, and therefore, hydrostatic pressure. The hydrostatic pressure compensates gas supersaturation, keeping gases in solution and not forming bubbles. However, there was one fish kill below Red Rock Dam attributed to gas bubble disease on August 8, 2013, when the river flow had decreased while the gas pressure was high. In 2013, total gas pressure at Stations 5 and 9 exceeded the 110% EPA criterion in 3 of 19 readings (16%) and 16 of 19 readings (84%), respectively.

With the construction of the new hydropower facility at Red Rock, it is expected that the problem of supersaturation may even be slightly reduced, due to run-of-the-river operations and the assumption that no changes to flows are expected based on the placement and operation of the turbines (FERC 1987). However, this assumption should be monitored.

Migrating Waterfowl and Shorebirds

Currently, Lake Red Rock and Saylorville Lake both provide some of the most important habitat for songbirds, migrating waterfowl and shorebirds in the state of Iowa. Saylorville Lake is deemed Globally Important Bird Area by the American Bird Conservancy, while the Iowa Audubon Society has designated Lake Red Rock an Important Bird Area. Waterfowl management has become a priority at Saylorville Lake. Every year 50-70,000 migrating waterfowl use the lake along with large proportions of the nation’s water birds such as gulls, terns, and pelicans. Open water in the tail waters of the dam also attracts dozens of Bald Eagles each winter.

Saylorville Lake and Lake Red Rock Regulation Manuals currently allow the Iowa Department of Natural Resources to request an annual fall lake raise (hydrometeorologically permitting) for the purpose of aiding waterfowl. The pool raise is from 836 feet up to 840 feet at Saylorville and from 742 feet up to 744 feet at Red Rock. Some of this habitat is jeopardized by sedimentation affecting the extent of shallow water habitat available as well as the hydroperiod dynamics of existing shallow water and mudflat habitats.

The fall pool raise is designed to accommodate migrating bird species, but the lake level is dropped to the authorized conservation pool level before entering the winter period. At Lake Red Rock, levels can be raised from September to December 15th of each year. Saylorville Lake can hold the fall lake raise through March 1st of the following year. IDNR Wildlife Bureau managers do not believe the allowable raise is adequate due to accumulated sediment and impact on hunting access via water.

In the very shallow upper reaches of the reservoir, a shallow water island complex locally identified as the “mud flats” identified in the most recent plan as a sensitive area because it is the largest contributor to Saylorville

Lake's globally significant designation as a bird conservation area by the American Bird Conservancy. The area is highly visited by birders and is a primary stop on the Makoke Bird Trail. Under the Master Plan it is designated as a "No Motorized Vessel" area from 1 April through 31 August. Motorized vessels are highly disruptive to thousands of birds that forage and rest in this shallow water environment. However, after 1 September, the motor restriction is lifted to allow waterfowlers' access to these mudflats for the waterfowl hunting seasons. The lake may be raised up to four feet in the fall per the current water regulation manual. During periods of flood storage of 840' NGVD elevation and rising, this motorized vessel restriction may be lifted until the lake returns to conservation pool. (See USACE 2015c, Saylorville Master Plan, Appendix H.25, Saylorville Lake Water Zoning Map.)

Sedimentation and erosion problems are associated with frequent flooding events and runoff from adjacent farm land. However, increased sedimentation has also created mud flats above the Mile Long Bridge. This large complex of mudflats provides excellent wildlife habitat for migrating waterfowl. (See Saylorville Master Plan, Appendix H.3, Saylorville Lake Mudflats Map, and Appendices H.34 and H.35, 2014 Report of Sedimentation Resurvey Maps.)

Although the fall pool raise is certainly beneficial to migrating waterfowl and shorebirds, the general practice of keeping the pool elevation constant throughout the year may not be sufficient to optimize regeneration of shoreland and mudflat habitat. Furthermore, it would appear that under current operations, the practice of restoring the lower pool for the purposes of flood storage results in large unseasonal changes to flows over the winter months.

Reptiles and amphibians

The Des Moines River Basin as a whole provides habitat for a large number of Iowa's known herpetofauna (46 species of reptiles and 22 species of amphibians). Herpetofauna play an important role as insect and rodent predators and as valuable prey for various birds, mammals, fish and insects. Nearly 1/5th of Iowa's amphibians and 1/3 of Iowa's reptiles (33%) are listed as either threatened or endangered species. The leading causes for herpetofaunal decline in Iowa, as globally, are habitat destruction, degradation, and fragmentation.
Saylorville. Multiple Species Inventory and Monitoring (MSIM) conducted on 18 different habitat types identified throughout the Saylorville project supports the assumption that Saylorville is an important conservation area for Iowa's herps. Mont Woods had the most amphibian and reptile species found with 14. SGCN reptile and amphibians were found on the Saylorville Project including Northern Cricket Frog (*Acris crepitans*), and Smooth Earth Snake (*Virginia valeriae*), as well as Prairie Ringneck Snake (*Disdophis punctatus arnyi*), and Bullsnake (*Pituophis melanoleucus*). MSIM also identified 3 species of crayfish including Devil Crayfish (*Cambarus diogenes*), Papershell Crayfish (*Orconectes immunis*), and Prairie Crayfish (*Procambarus gracilis*). Appendix G-3 of the Saylorville Master Plan lists the reptile and amphibian species found at Saylorville, by site.

Red Rock. Iowa DNR frog and toad call surveys indicate that there are nine species of frogs and toads present on the Red Rock Project area. However, no significant surveys have been conducted there for nongame mammal or reptile taxa. Species inventories collected at Saylorville Lake through the MSIM as well as for the CCP at Neal Smith may present similar species, especially common species, as the habitat types at Saylorville and Neal Smith are similar to Red Rock and both in relatively close proximity. Therefore, we include these species in development of flow recommendations by groups of taxa with similar flow requirements.

- See Appendix G-3 of the Saylorville Master Plan for reptile and amphibian species found at each site/habitat type in Saylorville.
- Appendix J of the Neal Smith CCP lists birds, amphibians, and reptiles likely to occur in the area.

Below Red Rock. Because of the connection to the Mississippi River, the lower Des Moines River and its remnant floodplain areas are likely significant for many large river threatened and endangered species, of both state and federal significance. Although the lower Des Moines is outside the project area, it is impacted by Red Rock operations all the way to the confluence with the Mississippi River, as well as by management of the Lock and Dam system on the mainstem Mississippi River. Protection and restoration of floodplain and adjacent upland habitat in the entire reach could be expected to significantly improve habitat for herpetofauna.

River Recreation

Most water-related recreation on the Des Moines River is based around the two Corps reservoirs at Saylorville and Red Rock. Saylorville Lake is one of the most popular recreation spots in Iowa, primarily due to its location in the Des Moines metro area, with an average of 1.4 million visits per year, primarily April through September. The majority of visitors come from within a 50-mile radius of Des Moines. The Corps has identified significant needs for upgraded facilities to accommodate additional water related recreation activities, including new and non-traditional recreation opportunities. New types of recreation are creating demand for more "upscale" facilities than those typically found in Corps-operated parks. Sedimentation continues to be an area of concern for recreation on Saylorville Lake. While sedimentation helps to mitigate for lost floodplain habitat by creating mudflats, this impacts the amount of surface acres available for recreation boating.

Demand is increasing for river-based recreational opportunities and services such as tubing, kayaking and canoeing. Data from the 2013 Statewide Comprehensive Outdoor Recreation Plan (SCORP) supports the growing popularity of kayaking in central Iowa, ranging from interest in adventure/whitewater kayaking to wildlife viewing and leisure paddling. Kayaks and canoes can easily operate in shallow water conditions, and allow for some spatial segregation of designated recreational uses to help minimize conflict with both motorized uses and wildlife needs (in the reservoirs, non-motorized vessels are allowed to boat within "no-wake" zones designated for wildlife management and safety).

The Des Moines Recreational River and Greenbelt (Greenbelt) extends over 410,000 acres from Fort Dodge and Webster City in the north to downstream of Red Rock Dam. Authorized by Congress in 1985, the Greenbelt is designed to provide central Iowa with recreation facilities and opportunities, as well as streambank stabilization and environmental enhancement along the Des Moines, Boone, and Raccoon Rivers. The Des Moines River Water Trail is a National Recreation Trail that extends through four counties in Iowa and including Saylorville Lake. The DMRWT encompasses designated water trails at both Saylorville and Red Rock, discussed in both the Saylorville and Red Rock Master Plans.[5] These trails are designed to connect rural and urban trail users, provide access to recreation areas and campgrounds, as well as provide bird and wildlife viewing opportunities for boaters and paddlers.

Saylorville to Red Rock

As early as 1975, the Saylorville Corridor Master Plan recognized the potential value to visitors to enjoy a significant wild tract of land embedded in the metropolitan complex. In recent years, the Iowa Department of Natural Resources partnered with the Des Moines Area Metropolitan Planning Organization (MPO) to create a master plan for improving the water trails and nearby greenways in the Greater Des Moines region. The master plan is intended to provide a long-range regional vision for how local governments, businesses and other organizations can collaborate to improve the region's waterways for better recreation, enhanced conservation and improved economic vitality.

The Greenbelt most recently focused on four projects: the Fort Dodge Riverfront, the Des Moines Riverwalk, the Marion County Cordova Center on the Rock, and the Red Rock Volksweg Trail Segment 4B (designed to connect the North Overlook campground and the City of Pella with the Cordova area)[6]. Further progress on completion of the Greenbelt plan (USACE 1987) is dependent on continued authorization of federal and non-federal cost share funding.

Today much of the area is accessible through trail systems for biking, hiking, canoeing, and kayaking. The original master plan identified sites for additional small parks and athletic fields to be constructed by the managing agencies, some of which were never constructed. However, recreation areas and trail areas which

[5] http://www.mvr.usace.army.mil/Portals/48/docs/Recreation/ODS/Master%20Plan/Draft%20Master%20Plan/Posters/DMRiverWaterTrail_Improve_sign.pdf

[6] http://www.mvr.usace.army.mil/About/Offices/Programs-and-Project-Management/Greenbelt-Program/

traverse the west side of the river represent a large riparian zone, covering several thousand acres of fee title and flowage easements. These areas include extensive wetland oxbows and forested wetlands and have the potential to support a diversity of wildlife. Outflows from the dam keep water open throughout the winter season and the area has become an important wintering bald eagle area. Eagles are regularly seen along the river in the very urban environment of downtown Des Moines, as well as large numbers of wintering waterfowl. Both ducks and geese are annually surveyed during midwinter national survey dates and individual counts are commonly over 10,000 birds. This area was also identified as being sensitive for bird species with conservation concern. Results from breeding bird studies along with recommendations from the Iowa Ornithologist Union, and Iowa Audubon verify sensitive area classification. The Multi-Species Inventory and Monitoring (MSIM) Report also identified this zone as being under the highest threat from identified human related stressors.

Subsequent plans have recognized the value of having publicly owned lands in the river corridor extending into the heart of Des Moines to benefit all project purposes. Acquisition of an additional 2,085 acres in fee title lands along with 315 acres of flowage easement allowed the Corps to alter the water regulation manual to accommodate an increase in the design flood flow, from 8000 up to 12,000-16,000 cubic feet per second. The Saylorville Corridor Master Plan Supplement recognized the ecological value of a significant greenway running deep into the city of Des Moines. Environmentally significant tracts and sensitive areas were identified to be avoided for high density recreation development and preservation. Much of this newly expanded corridor, including areas formerly slated for development as recreational areas, has been set aside or redesignated as wildlife refuge or forest preserve. The Neal Smith Trail on the east side of the river was designed to be a link between Des Moines residents and Saylorville Lake.

The urbanized reach below Saylorville has significant restoration potential. Because of their location in the heart of the metro area, portions of the landscape that are currently in agriculture may actually have higher economic value as open space and natural green infrastructure. These areas can be reforested, planted to wet prairies or restored as wetlands. The most recent Master Plan outlines the intent to designate and manage as wildlife refuge all Corps-owned lands from the Saylorville Dam south to the 6th Avenue Bridge, in partnership with the U.S. Fish and Wildlife Service (USFWS) under a program titled Urban Wildlife Refuge Initiative (See USACE 2015c, Appendix G.4.) The goals under this program attempt to protect valuable wildlife landscapes within urban areas, while assuring public access to the resource. All agencies involved in the management of Corps lands within this corridor will continue to manage the resource with the assistance of USFWS. The Urban Wildlife Refuge Initiative program attempts to connect urban populations with nature through natural settings. Proximity of this greenbelt to many City of Des Moines residents as well as many elementary schools, makes the Saylorville Corridor an ideal resource. The corridor provides urban residents access to trails as well as sport hunting opportunities. The most recent Master Plan also identifies and recommends expansion of the Saylorville Corridor from south of 6th Avenue to the Lake Red Rock boundary. (See Appendix H.1, Saylorville Lake Project Area Map.)

The advantages of having contiguous corridors are well documented. However, challenges in maintaining this corridor are significant. Stressors to the resource are mostly urban in nature. Pollution, fragmentation pressures associated with population growth and development, and invasive species all play a role in threatening the resource. The proposal to become an urban wildlife refuge will take significant amount of time and agency coordination. Four agencies are involved: the Corps, Iowa DNR, Polk County Conservation Board and Des Moines Parks and Recreation. Significant coordination with these agencies and other interest groups will be required.

The Des Moines River Water Trail, a 20-mile National Recreation Trail that runs through the heart of Saylorville Lake and features several accesses to recreation areas, campgrounds, and towns and cities, is a major part of that focus. Beginning in 1999-2001, 17 county conservation boards (including Hamilton County and Kossuth County) endorsed the water trail. The Des Moines River Water Trail has gained support as a vehicle for promoting healthy communities and economies along the river. Efforts are ongoing, since only Van Buren, Polk, Webster, Marion and Boone counties have officially developed designated water trails in their sections of the river.[7]

The Iowa DNR also completed a Dam plan in 2010 that sets statewide priorities for removing or upgrading hazardous aging dams as well as for improving fish passage (see Figure 12; Hoogeveen 2010). As part of that, there is growing support for eliminating 177 aging and largely useless low-head dams, driven at first by safety concerns among a growing number of river recreationalists. Dam removals in other parts of Iowa have resulted in significant improvements in fish communities. Modification of low-head dams by creating free passage of fish with a rock arch dam, can lead to increase in desirable fish species such as smallmouth bass as well as SGCN such as black redhorse. The water parks created after the dams' removal, including whitewater rafting areas, have also proven to be beneficial in terms of local economic and recreational development (Hoogeveen 2010).

As part of the regional water trails plan, the two riverfront dams in downtown Des Moines (that combined have had the highest number of deaths in the state) are a key part of the discussion. The dams currently inhibit boating and easy river access downtown, and their management also creates concerns. Iowa River Revival, a river advocacy organization, is advocating for removal of the dams as part of a significant but “vital” investment in downtown and the riverfront.

[7] http://www.iowadnr.gov/Things-to-Do/Canoeing-Kayaking/Water-Trails

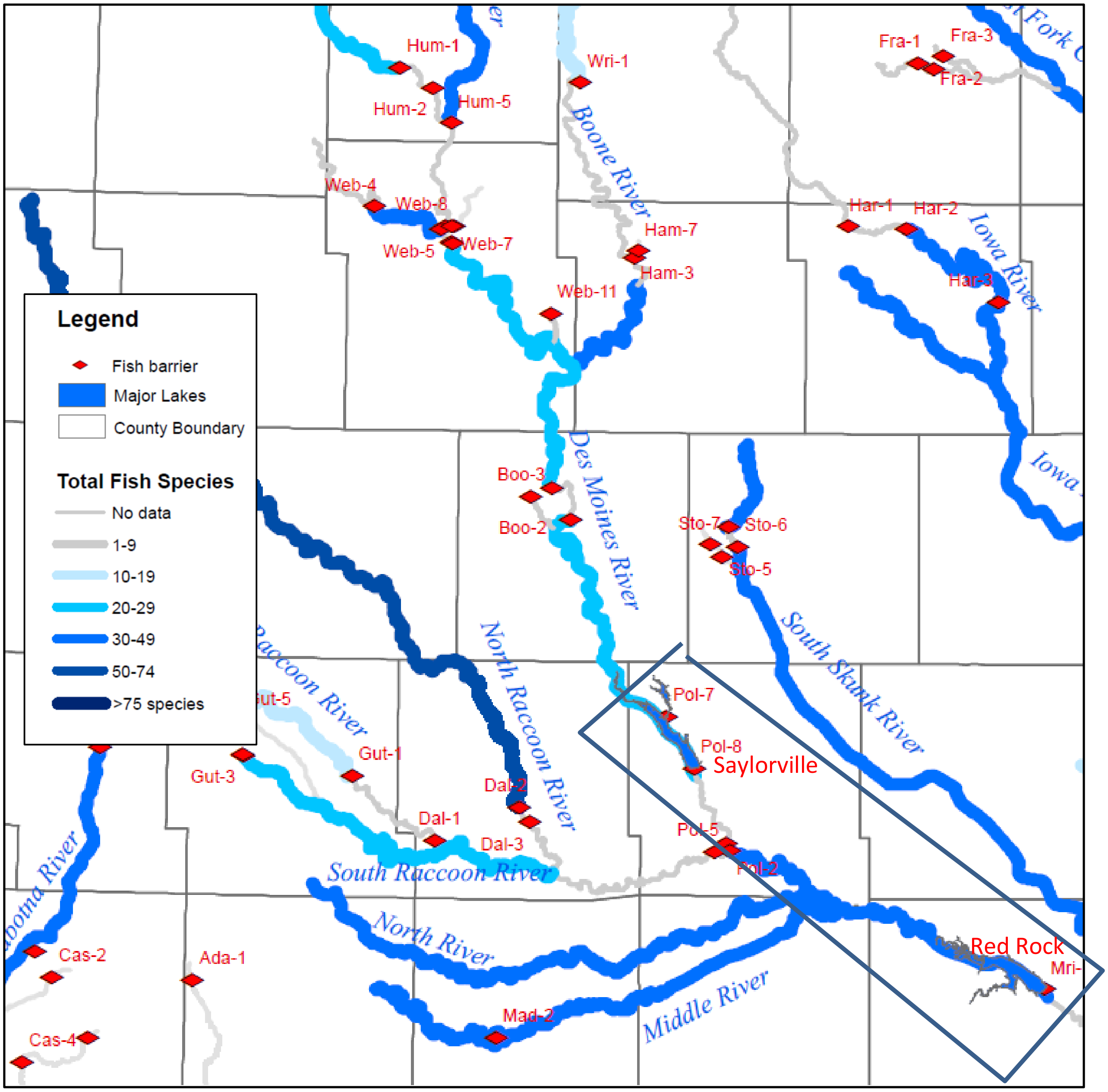

Figure 12. Map of dams that serve as barriers to fish passage on the Des Moines and surrounding rivers, with the project area outlined in black (Ottumwa hydro not shown; Reprinted map excerpt from Figure 3-b. Presence and absence of fish species analysis from combined datasets, Hoogeveen 2010). Appendix B and C of the dam report rank dams by priority in terms of reducing safety hazards and risks as well as restoring biological fish passage.

Below Red Rock

Below Red Rock, the Van Buren County Water Trail links into the 400-mile long Des Moines River Water Trail that runs from Estherville to the Mississippi River[8].

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[8] Maps and access points are shown at www.desmoinesriver.org.

Water levels on the lower river can vary dramatically throughout the year, and depend on discharge rates from Red Rock Dam. Spring and early summer water levels can sometimes be at flood level or higher. During these periods the river carries dangerous amounts of driftwood and debris. Large snags imbedded in the stream bed can create hazards to boaters of all types. During these periods of flooding even highly experienced boaters should stay off the river. During the late summer and fall season the water levels can be extremely low.

Since 2002, Project AWARE has conducted annual river cleanups in Iowa. In July 2016, the 14^{th} annual cleanup removed 40 tons of trash from the lower Des Moines River. Coordination on river levels between Corps and cleanup organizers. Below Red Rock, organizers of a summer kayak festival have also requested that during periods of unusually low flow that would interfere with the festival, the Corps could make provisions to enhance flows, hydrometeorologically permitting, as long as it was consistent with meeting authorized project purposes and did not lead to overly rapid rise or fall rate.

Defining Ecosystem Flow alterations and restoration needs

Flow-ecology hypotheses are designed to describe how specific taxa and ecological processes are expected to respond to changes to the flow regime. Related hypotheses can be aggregated based on similar timing, flow-sensitive life stages and ecosystem function into a set of related flow needs that combine one or more responses of a group of taxa expected to respond similarly to a change in flow conditions.

High flows and floods. In Midwestern rivers, high flow events and floods provide cues for fish migration, maintain channel and floodplain habitats, inundate submerged and floodplain vegetation, transport organic matter and fine sediment, and help maintain temperature and dissolved oxygen (DO) concentrations. These events range from relatively small, flushing pulses of water (e.g., after a summer rain) to extremely large events that reshape floodplains but historically have occurred infrequently (e.g., large snowmelt or rain-on-snow events, major regional spring and summer storm events such as 2008). For the purposes of defining environmental flow components as per Mathews and Richter (2007), we distinguish between high flow pulses, small floods, and large floods. High flow pulses refer to flow rises above seasonal flows that remain within the channel. "Small floods" are those that typically exceed bankfull flow, when flood waters allow fish and other organisms access to floodplains or flooded wetlands, secondary channels, backwaters, sloughs, and other off-channel habitats. In the Midwest, these typically occur on a 2-5 year recurrence interval. "Large" or "extreme" floods will often re-shape the physical structure of the channel and floodplain, scouring some areas and depositing sediment in others to form new channels, point bars, and off-channel habitats. We represent these floods as those with a 5% probability or lower (20 year recurrence interval or more).

Increased magnitude and/or frequency of any of these types of events can lead to channel instability, floodplain and riparian disturbance, and/or prolonged floodplain inundation. Reduced frequency of these events typically leads to channel aggradation, loss of floodplain inundation, and altered vegetation communities. Although the bankfull and overbank events that provide channel and floodplain maintenance commonly occur in May-July in the Des Moines River system, these events can occur in any season.

Seasonal flows. Seasonal flows provide habitat for spring, summer, and fall spawning fishes and mussels; ensure that eggs in nests, redds, and various substrates are wetted; provide overwinter habitat and prevent formation of anchor ice; maintain bank habitat for nesting and hibernating mammals/herpetofauna; and maintain a range of persistent habitat types. Naturally-occurring variability within seasons helps maintain a variety of habitats and provides conditions suitable for multiple species and life stages.

Seasonal flows – often represented by median daily and monthly flows – are correlated with area and persistence of critical fish habitat, juvenile abundance and year-class strength, juvenile and adult growth, and overwinter survival. In summer, fall, and winter, studies in other rivers have shown that decreases in median monthly flow correspond to reduced macroinvertebrate density and richness, reduction of sensitive taxa, increase in tolerant taxa, and decrease in mussel density. Many studies cited tie ecological response to change in median monthly flows in a specific month or throughout a season. These flows represent a "typical" range of flows in each month and are useful for describing variation between seasons (e.g., summer and fall). Most of the time – in all but the wettest and driest portions of the flow record – flows are within this range.

Low flows. Low flows provide habitat for aquatic organisms during dry periods, maintain floodplain soil moisture and connection to the hyporheic zone, and maintain water temperature and DO. Although low flow events naturally occur, decreases in flow magnitude and increases in frequency or duration of low flow events affect species abundance and diversity, habitat persistence and connectivity, water quality, increase competition for refugia and food resources, and decrease individual species' fitness. When they do occur, extreme low flows enable recruitment of certain aquatic and floodplain plants; these periodic disturbances help maintain populations of a variety of species adapted to different conditions. Decreases in low flow magnitude have been correlated with changes to abundance and diversity of aquatic insects, mussels, and fish. Low flows also influence habitat persistence and connectivity, including riffle, pool, backwater and hyporheic habitats critical for fish, aquatic insect, crayfish, mussel, and reptile reproduction and juvenile and adult growth. Water quality, specifically DO concentrations, is directly correlated to low flow magnitudes.

Hydrologic Characteristics of Major Project Reaches

We used flow data from the regulated and unregulated flows for 3 reaches within the Des Moines River basin to characterize the range of long-term monthly exceedance values within each reach: (1) below Red Rock (2) between Saylorville and Red Rock, including Red Rock reservoir, and (3) above Saylorville (including the reservoir). Unregulated flows are calculated by the Corps to represent flow without the projects, based on inflows from the Basin. Water years 1918-2015 were used to define interannual variability of these statistics. This period is the maximum available period of record covering long-term variability within the basin and includes major droughts and floods.

Flow Statistics

We adopted flow statistics based on the key environmental flow components discussed in the Indicators of Hydrologic Alteration guidance (Matthews and Richter 2007). We used the Indicators of Hydrologic Alteration to calculate the monthly median flow (Q50) and two monthly low flow statistics (Q75 and Q90) for each location below the reservoirs. The IHA provides these values for each month in each year of the period of record. Then, it calculates the median of the monthly values over the period of record (i.e., median Q50, median Q75, and median Q90 based on two period analysis of years of record). For the pre-project record, we used the USACE-provided time series of simulated flows for the “unregulated’ (i.e., without the projects) scenario. For the post project time series (1969 for Red Rock, 1977 for Saylorville), we used the simulated “regulated” flow time series values. Within the high flow component, we include high flow pulses (below bankfull), bankfull events, and flood events with 5-year (small) and 20-year (large) flood recurrence intervals. Therefore we are effectively representing all of the components defined by Mathews and Richter (2007).

Impacts of Saylorville and Red Rock Projects on River Habitat and Hydrology

As noted earlier, the most dramatic changes to hydrology in the Des Moines River Basin have occurred due to the extensive conversion of tallgrass prairie to annual row crops, shallow-rooted pasture/lawn grasses, impervious surface and other non-native land cover; combined with extensive drainage modifications and significantly increased rainfall in the 2nd half of the 20th century. All of these changes have dramatically altered the magnitude, timing, and frequency of a range of environmental flow components. Understanding the impacts of the USACE flood control projects at Saylorville and Red Rock therefore requires teasing out changes due to the dams versus these larger scale changes in basin hydrology. Although the historical flow record is extensive, many changes to the Iowa landscape were already significant by the time gages were installed in 1918. We assume that complete restoration of presettlement natural hydrology is at this point not feasible, and that the goals of this project are to understand ecological flow needs and move towards restoring natural hydrology within the constraints of the modern context.

Analyses of hydrologic changes below are based on comparing historical flow time series (1918-2015) for the regulated versus unregulated (simulated flows without either of the projects) generated by the U.S. Army Corps of Engineers (Landwehr, pers. communication). Daily flow statistics were summarized for regulated and unregulated flows over the entire period of record at each location provided (i.e., below Saylorville and below Red Rock). For the two-period comparison using the Indicators of Hydrologic Alteration software (TNC, 2007), flow time series were analyzed as follows: for the flow releases below Red Rock, using the pre-dam unregulated flow series prior to 1969, and the regulated flow series data for water year 1969 and after and (b) for flow releases below Saylorville, using the pre-dam unregulated flow series prior to 1977, and the regulated flow series data for water year 1977 and after.

Hydrograph changes below Red Rock dam

Low flows. Dam operations have had relatively minor impacts on low flows. Extreme low flows have been completely eliminated by the 300 cfs minimum flow requirement. In general, low flows are more consistent across years than prior to the project. The magnitude of the 7-day and 30-day minimum flows have all increased. The 10th percentile (90 percent exceedance) monthly flows are almost all significantly greater post-1969, both regulated and unregulated flows, likely reflecting the overall increase in basin yield.

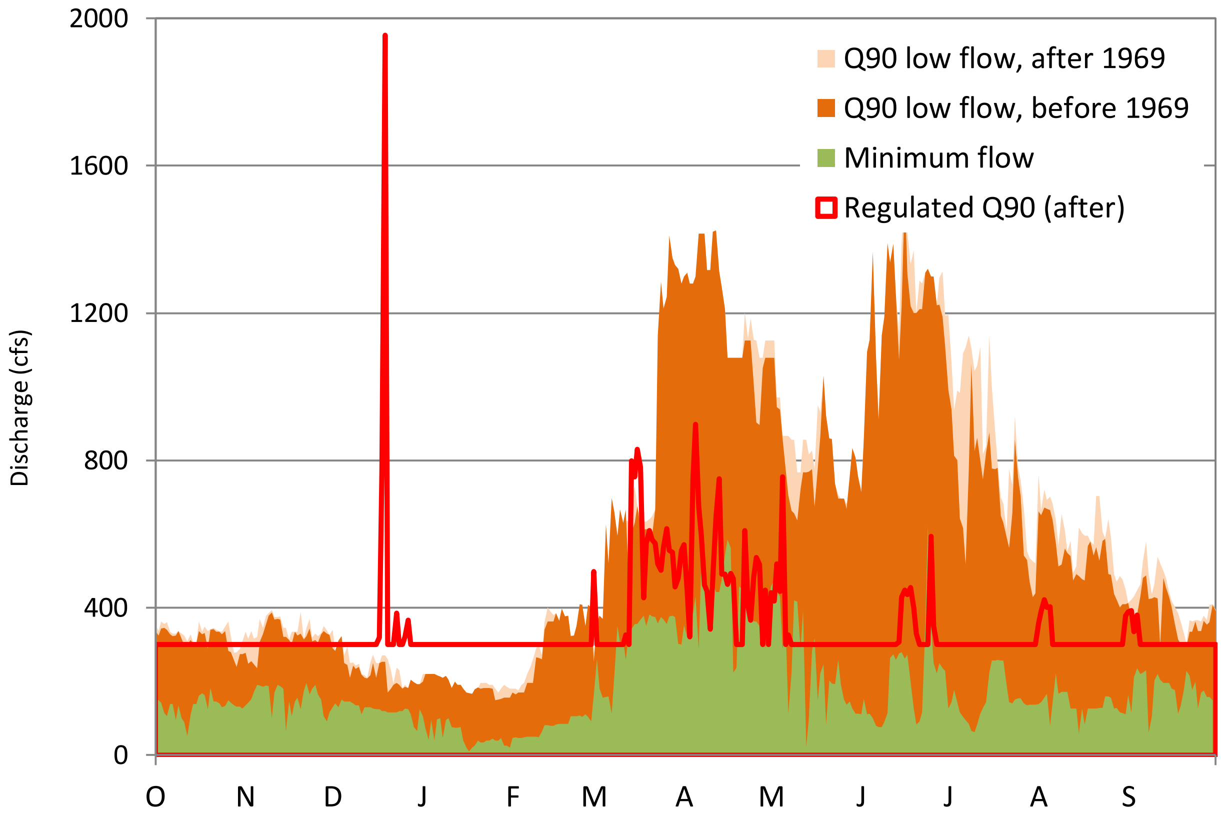

Figure 13. Low Flow data for Des Moines River, unregulated vs regulated below Red Rock

Seasonal flows. Since 1969, analysis of the flow time series indicates significant increases in seasonal flow magnitudes (median daily, monthly, and annual flows). Some monthly median flows have as much as doubled. Both the regulated flows and estimated flows without the project (unregulated flows) show this increase, therefore a good portion of the increase can be attributed to basinwide changes in land use, drainage, climate, and/or all of the above, rather than alterations due to the dam. However, relative to the "unregulated" flows, reservoir operations have increased seasonal (median) daily flows significantly in December, when the conservation pool is being restored to the lower level after the fall pool raise. Median flows are especially elevated relative to the unregulated flow regime from May through September. Only October flows are lower under the regulated scenario; however, all other median flows post-1969 are significantly elevated over the pre-1969 flow regime.

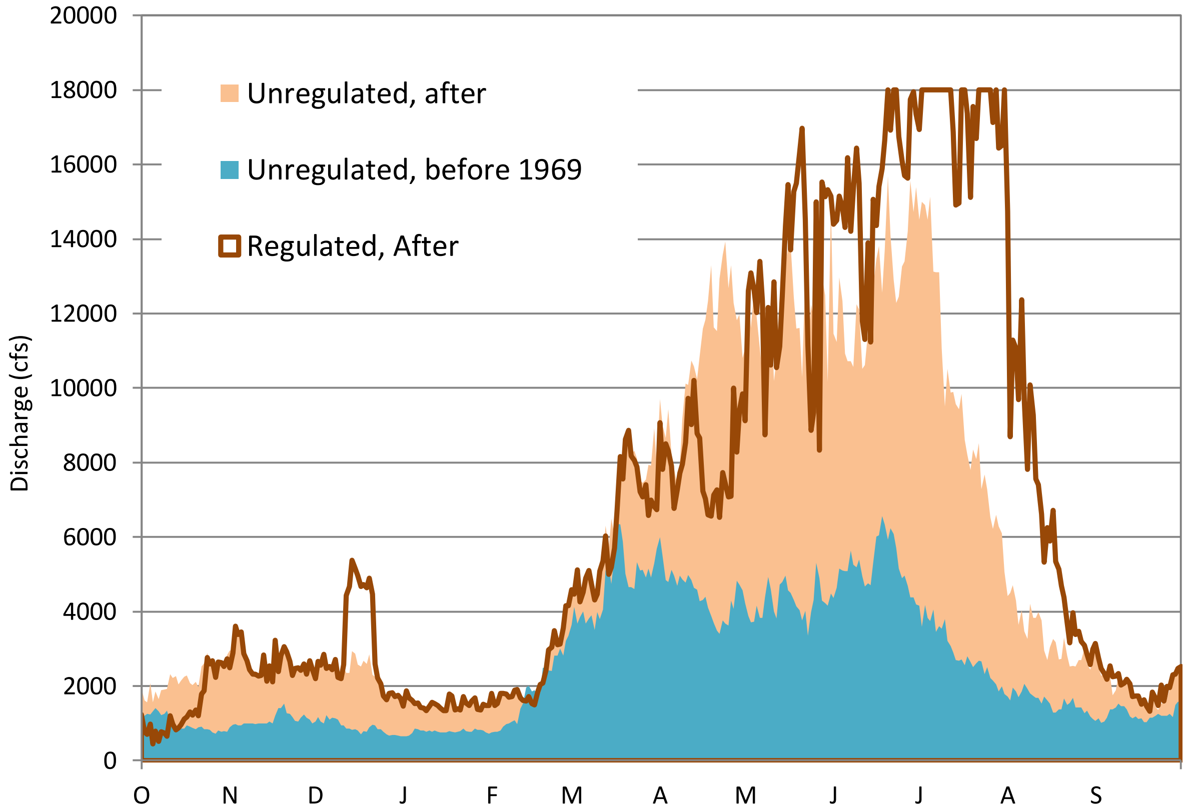

Figure 14. Example: Median Flow data for Des Moines River, regulated vs unregulated below Red Rock

Mean monthly flows are higher for every month of the year in the post-project era, and in many cases the post-project means are outside the Range of Natural Variation (RVA) boundaries for the pre-project period as calculated in the IHA (see Appendix B).

High flows. Post project, 10th percent exceedance (90th percentile) flows are for the most part significantly higher than pre-project, especially March – July, due to the increased basin water yields. Without the project, spring and summer flows after 1969 (“unregulated” flows) would be even higher April-July, once again reflecting the elevated water yields associated with increased drainage density, increased tile drainage baseflow, and increased rainfall. Post project regulated 10th percentile flows from August to December are 2- 3x the magnitude of pre 1969 unregulated flows. After 1969, regulated high flows are lower and less variable than unregulated flows would be from April to July, but higher and more sustained from August through December.

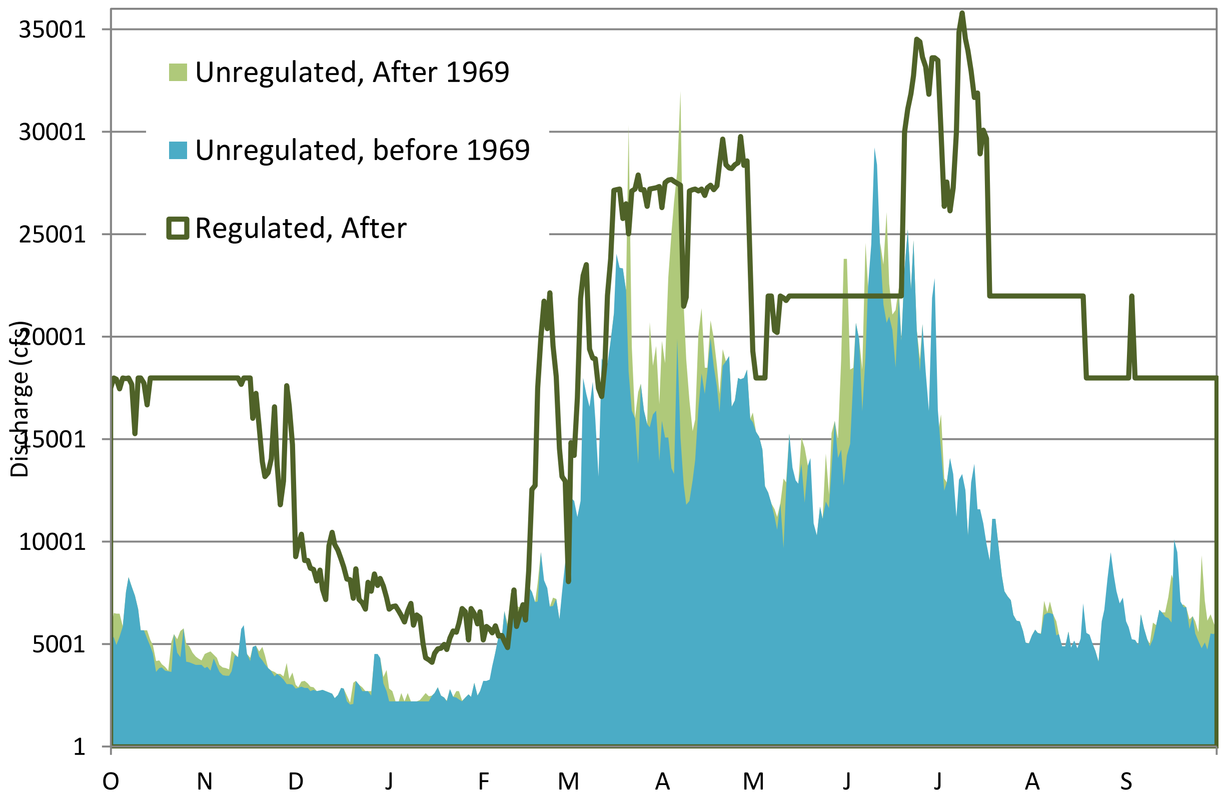

Figure 15. Example: 10th % Flow data for Des Moines River, regulated and unregulated below Red Rock

The simulated unregulated flow time series below Red Rock suggests the 20 year recurrence interval flood magnitude (“large flood”) is around 101,000 cfs. This magnitude flow only occurred once in the pre-project period, before 1969. From 1918-1969, the 20 year recurrence interval flood magnitude was around 75,000 cfs. The 2-year recurrence interval “small flood” for the entire period of record is now around 37,800 cfs, a flow which exceeds the design flood flow of 30,000 cfs. The 5-year recurrence interval flood (1 in 5 years) is around 63,000 cfs, a flow magnitude that was only exceeded five times in the pre-project period, but likely would have been exceeded 16 times since 1969 without the reservoirs.

IHA analysis comparing the pre-project period unregulated time series (1918-1969) to the post-project period regulated flows (1969-2016) generates a set of 32 indicators of hydrologic alteration, grouped into measures of magnitude, timing, frequency, and rate of change for low, seasonal, and high flow components (Richter 1997). The IHA 2 period analysis derives indicators characterizing the unregulated flow regime from the “pre-impact” period and compares them to the “post impact” (post-project). In the case of the Des Moines River, given the substantial increases in water yield that have been observed, the pre-project period is perhaps not representative of modern climate regime for the river. Regardless, IHA analysis suggests that smaller flood magnitudes (3-day and 7-day maxima) have decreased slightly, but are not substantially altered from the pre-dam period (Figures 15-16). However, small floods are much less frequent. There are many fewer flows between 25-35,000 cfs; however, the largest floods (highest flows) appear to be higher than ever, and the duration of elevated flows above the high pulse threshold (~5000 cfs) is much longer, e.g. the 90-day maximum has doubled in magnitude.

The decline in the frequency of smaller floods makes sense, given the design parameters for Red Rock Dam. Maximum design flood flows are 300,000 cfs. Flood inundation profile mapping conducted by the Corps indicates that bankfull flow below Red Rock is approximately 40,000 cfs (the "40K flood release"; see Red Rock Master Plan and Maps). Comparing unregulated flows below Red Rock before 1969 to regulated flows 1969 and after (when Red Rock Dam became fully operational), we find that flows on the Des Moines River exceeded bankfull stage a total of 18 times in the 98-year flow record. Prior to 1969, unregulated flows exceeded 40K cfs 12 out of 51 years (a little over 1 in 5), with a mean peak of 64K cfs and an average duration of 7 days. Following dam construction, bankfull flows occurred only 6 out of 47 years (1 in every 8 years); however, the average duration of flooding was almost 3 times as long at 18 days. The average peak annual flood prior to 1969 was 35,765 cfs; after 1969, it was 30,502. Therefore in general **the impact of Red Rock operations on floods has been to reduce the frequency of overbank flooding, but to increase significantly the frequency and duration of elevated flows within the channel. This could be expected to drive some of the observed habitat and channel degradation that has been observed below Red Rock.**

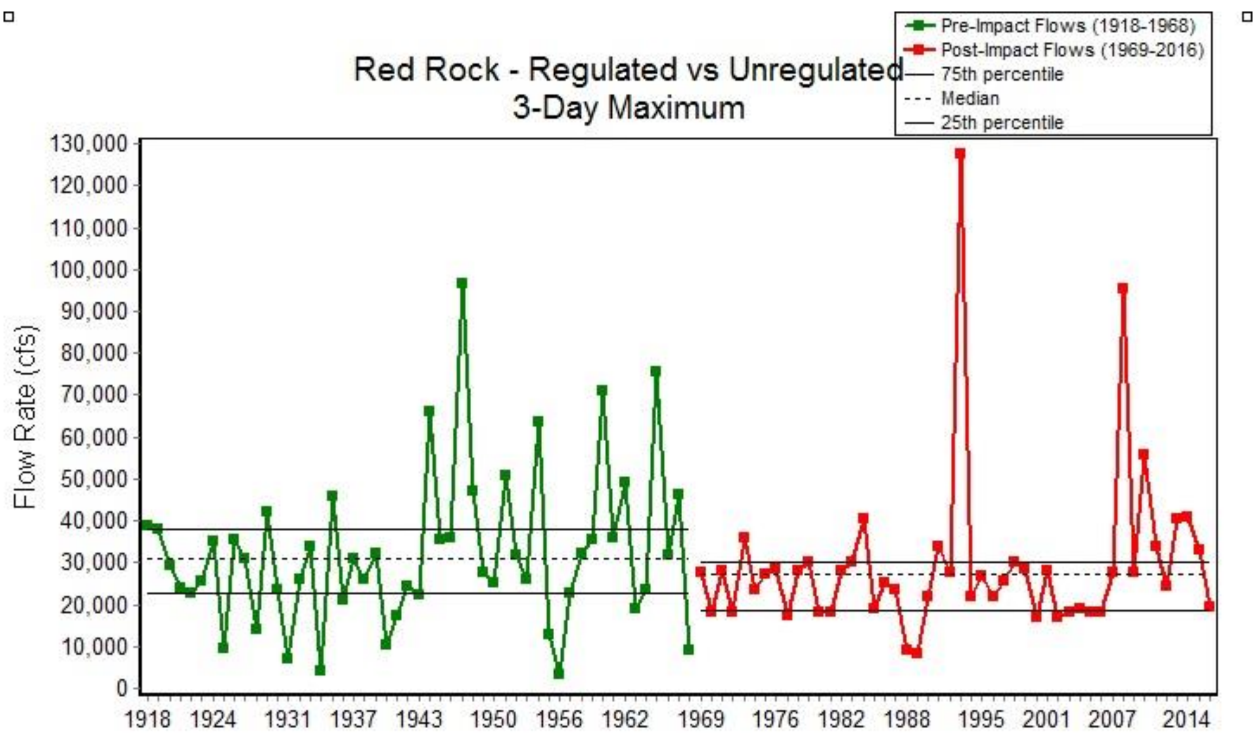

Figure 16. IHA 2 period analysis of 3-day maximum flood flows below Red Rock.

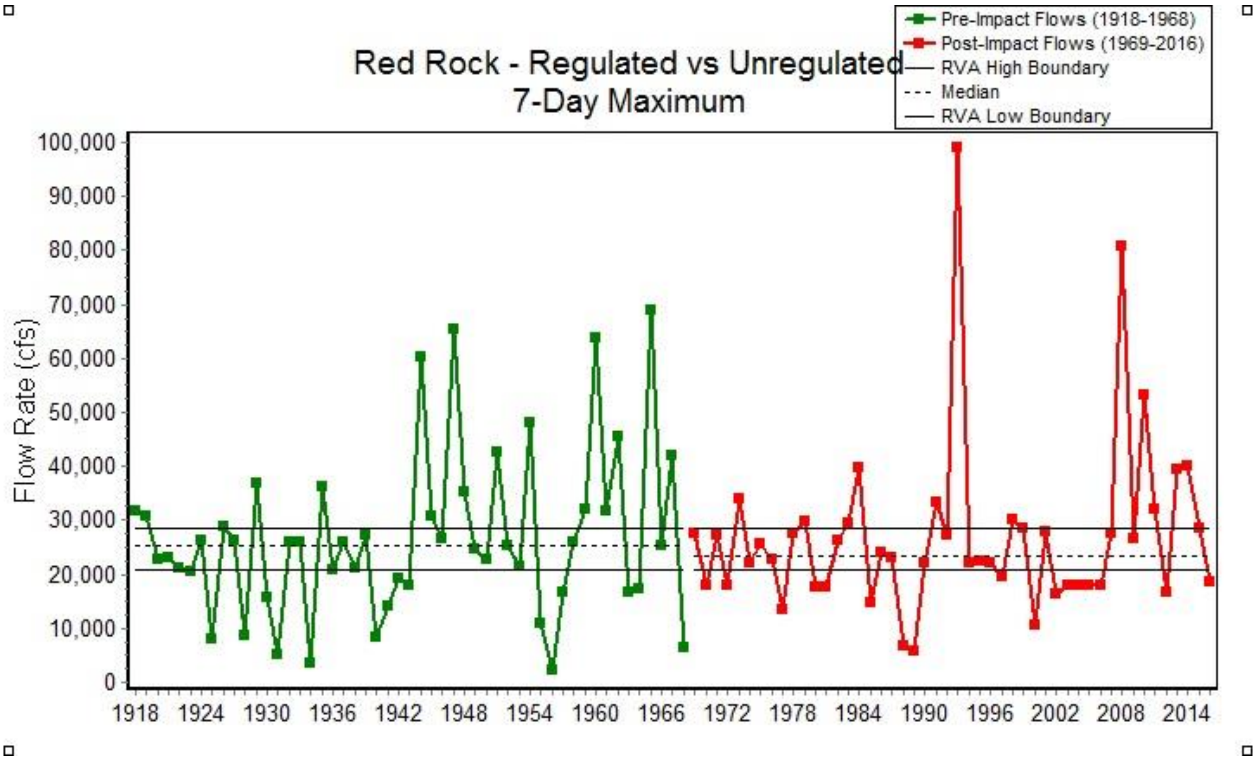

Figure 17. IHA 2 period analysis of 7-day maximum flood flows below Red Rock.

Timing, duration, and rate of change. The timing of the minimum and maximum dates has changed, with both occurring earlier in the year. The low pulse (740 cfs) count is the same, but the duration is ¼ as long. The high pulse (4990 cfs) count and duration are similar to pre-project flow regime.

The most significant impact of the project on the flow regime relative to boundaries defined by the pre-project range of natural variation based on the IHA is the rate of change. Both the rise rate and the fall rate have increased significantly, especially the fall rate (Figure 17).[9] This corresponds to observations about some of the most serious concerns about negative impacts on mussels and fish resulting from rapid changes in river flows.

[9] Rise rates: Mean or median of all positive differences between consecutive daily values; Fall rates: Mean or median of all negative differences between consecutive daily values. From IHA v7 User's Manual July 2006

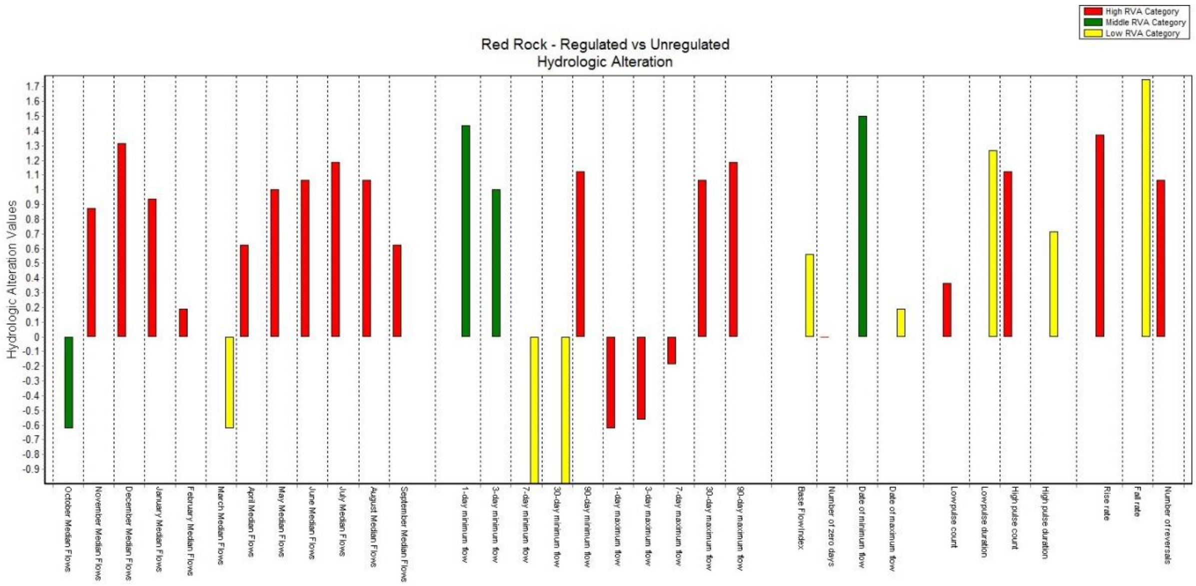

Figure 18. Hydrologic alteration factors for all 32 IHA parameters.

<u>Above Saylorville.</u> The primary impact of Saylorville reservoir construction was the inundation of the floodplain for the 24+ miles that the reservoir extends upstream of the draft. At the same time, the reservoir potentially creates new floodplain habitat along the margins of the reservoir. However, this is habitat that fluctuates according to the operational rules of the reservoir (not necessarily based on natural seasonal patterns). These impacts, in terms of acres of habitat inundated, were discussed extensively in the original Environmental Impact Statement. In the next phase of this project, analysis of Saylorville pool elevations in response to inflows and outflows will be needed to assess the implications of implementing specific changes to flow recommendations for habitat types and extend along the margins of the reservoir.

<u>Saylorville to Red Rock</u>. The primary impact of Red Rock reservoir construction was the inundation of floodplain habitat for 18-33 miles above the dam. This might have been partially mitigated by the creation of new floodplain habitat along the shoreline. However, this habitat fluctuates according to the operational rules of the reservoir (not necessarily based on natural seasonal patterns). Operation of the Saylorville reservoir also results in alteration of flows in urban Des Moines, primarily for the purposes of reducing flood damages to infrastructure in the floodplain. However, portions of this reach designated as wildlife refuge now have some potential for restoration (see the EIS).

<u>Hydrograph changes below Saylorville.</u>

As with Red Rock, total annual water yield has increased over the period of record, and is attributable to land use and climate change, not just project impacts. Below Saylorville, the post-project impact of elevated low flows from October to March is considerably more noticeable. Post project low flows are similar to pre-project flows from March through May; however, post-1977 low flows in June, July and August have increased significantly. The largest change in seasonal flows (median flows) and high flows (10^{th} percentile flows) from pre-1977 to post project is the significant increase in magnitude of both the median and 10th percentile flow magnitudes from May through September. Median flows are also significantly higher, especially during the winter pool drawdowns.

Based on median flow data below Saylorville, the only time post-project seasonal flows are similar to pre-project flows is during the October pool rise. From late October to December it appears that post-project flows are significantly higher, as the conservation pool is returned to the target pool elevation. (See Appendix A and B, flow summaries.)

Environmental Flow Requirements

Summary of hypothesized flow needs by community, taxonomic group and life history strategies

The natural flow regime provides a range of specific parameters (timing and magnitude of high and low flows pulses and floods, duration of high and low flow pulses, rate of rise and fall) that can be used to design managed flow regimes designed to mimic natural flows (Richter et al., 1996, 1997; The Nature Conservancy, 2005).

A key concept in riverine ecology is that to maintain the ecological integrity of floodplain ecosystems, connectivity to the mainstem river environment is critical—to the point that this idea is considered an overarching theme in river restoration water management (Sparks, 1995). The central concept in the River Pulse Floodplain model and similar models (Junk et al. 1989) is that flow events that connect floodplain and mainstem systems on regular (usually annual) intervals promotes connectivity between the floodplain and river, thus increasing the exchange of nutrients, sediments, lateral connectivity and fish between the two systems that directly affects community composition. When connectivity between these systems is lost, changes in floodplain depth, surface area and shape have been found to lead to additional alterations to a suite of abiotic and biotic characteristics that directly and indirectly affected fish communities (Miranda and Lucas 2004; Miranda 2005). Direct effects included loss of habitat via increased sedimentation that results in unsuitable spawning habitat for many fish species and loss of woody structure that provides attachment sites for many macroinvertebrate species. As floodplain systems become more isolated, they often become shallower, leading to increased temperatures and susceptibility to hypoxic conditions during warm weather conditions, thus allowing for the dominance of species with higher tolerances for poor water quality. Disconnected floodplain systems often also have increased turbidity that reduces the foraging ability of many visual piscivores (e.g. bass) and often favors benthic feeders (e.g. *I. punctatus*).

In the Des Moines River Basin, native fish and aquatic communities and species historically depended on a mosaic of riverine habitats and fluvial processes to complete their life cycles. To define the flows needed to support this complex ecosystem, we organized species into groups that share a sensitivity to one or more aspects of the flow regime. Biological and ecological traits are commonly used to describe groups of species with similar life histories, physiological and morphological requirements and adaptations, thereby providing a mechanistic link to understanding or predicting responses to varying hydrologic conditions (Poff et al. 2006, Merritt et al. 2010, Mims and Olden 2012; Parks 2013). Quantitative and qualitative information about how species respond in other river systems can help set expectations about the potential mechanisms and taxa response of species with similar functional traits. Below, we further elaborate on the link between flow-dependent taxa and physical and chemical processes within the basin. For each taxa group, we summarize flow needs and key hydro-ecological relationships identified through literature review. For species within each group, we attempt to synthesize known information on critical life history stages and timing for species within each group, as well as to associate groups with habitat types. By overlaying key life history requirements for each group on representative hydrographs for each habitat type, we highlight relationships between species groups and seasonal and interannual streamflow patterns (Figure 18).

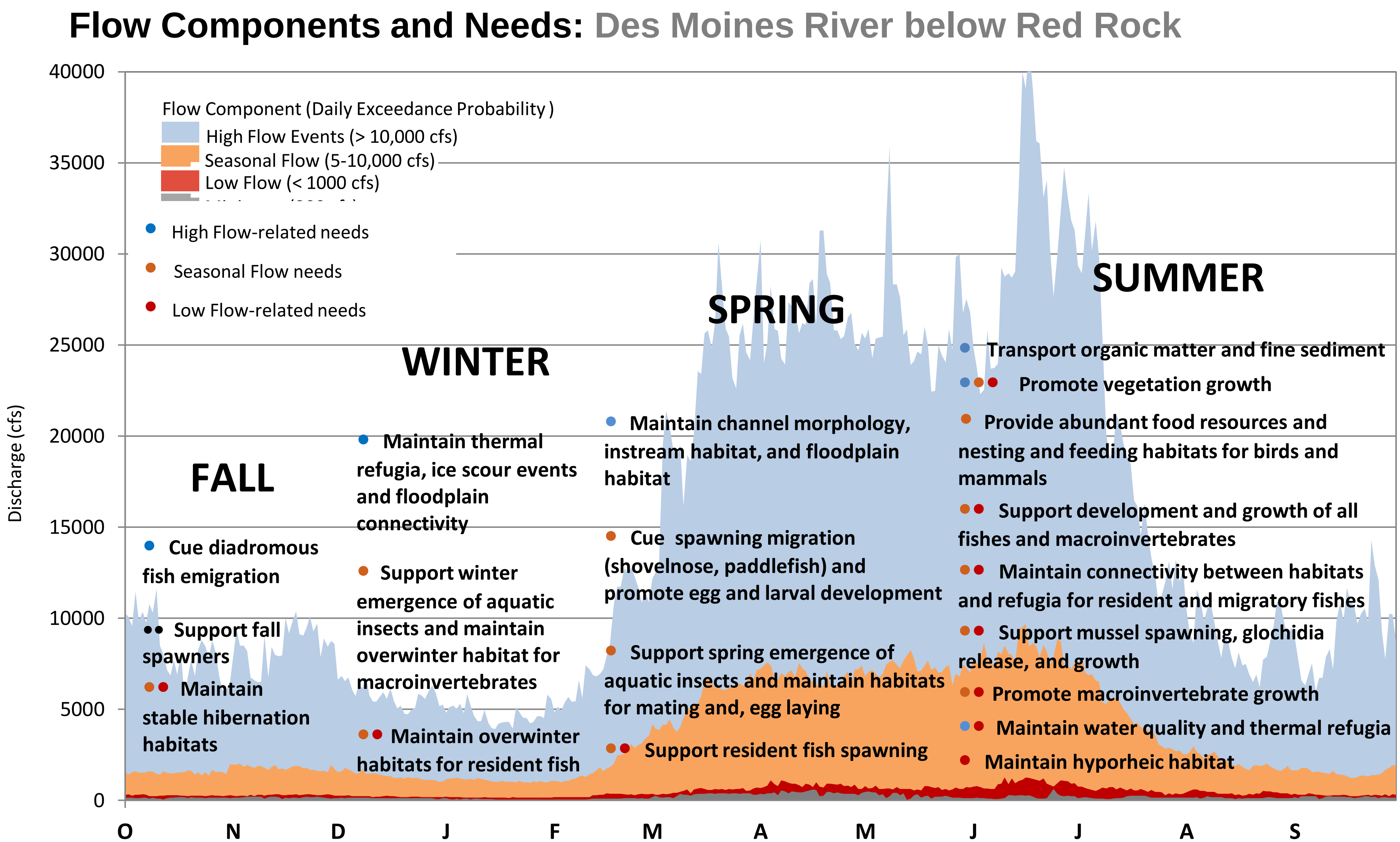

Figure 19. Summary of hypothesized ecological flow needs for fish, mussel, and other aquatic taxa in relation to low, seasonal, and high flow components for a generalized hydrograph from the Des Moines River below Red Rock.

Floodplain forest

Natural vegetation in floodplain and riparian communities of Iowa is distributed based on several interrelated factors including the frequency and duration of flooding and fire, the amount of energy received as flood (or ice) flows, the position of the site within the watershed network, physiography, substrate stability and available seed sources. Major community types can be organized into four major successional states: submerged and emergent bed, herbaceous, scrub-shrub and floodplain forest. We focused on the life history strategies of canopy dominants, recognizing that their establishment, presence and abundance is both indicative of soil moisture and substrate composition and also determines light availability for subcanopy and understory vegetation.

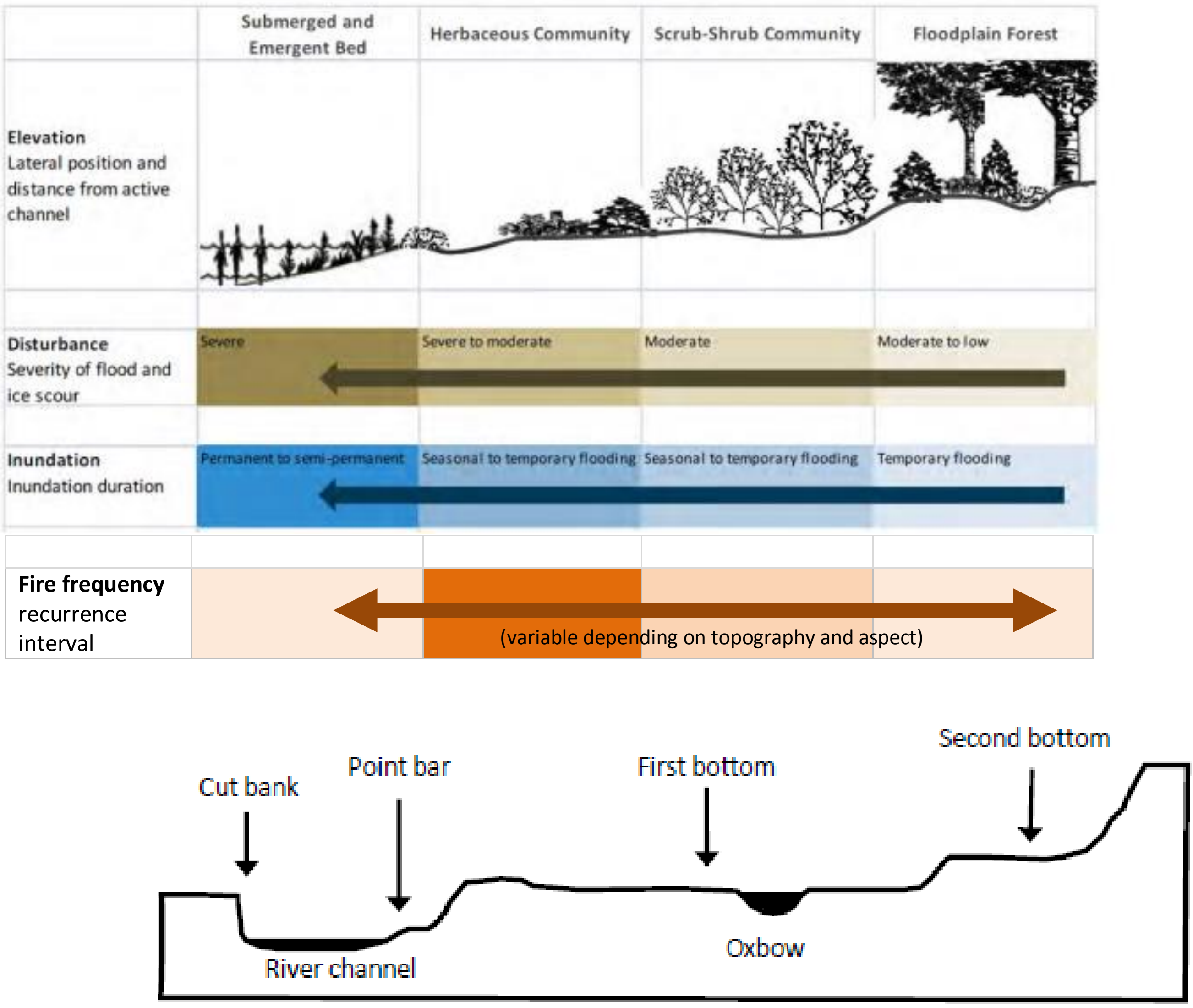

Figure 20. Cross section profile of a floodplain, characteristic vegetative communities, and major site types (from Randall and Herring 2012). Three main floodplain site types can be recognized along river sand streams: (1) point bars and oxbows; (2) first bottoms and; (3) second bottoms (terraces or benches)

Point bars and oxbows are typically inundated by water for several months at a time on an annual basis (Randall and Herring 2012). Point bars are located within the stream channel itself, created by the deposition of sand & silt as the river slows down on the inside bends of the channel and drops sediment. As the river continues to deposit material and meander in the opposite direction, they eventually build up enough elevation that they succeed to willow, silver maple, or cottonwood thickets.

Oxbows are crescent-shaped "bayous" or sloughs that were at one time part of the main river channel, but became "cut off" when the river bank eroded into a different channel. Oxbows are usually found on the "first bottom" floodplain, away from the present channel, and look like linear-shaped pools that are the same depth as the river channel. Oxbows may periodically dry out and be colonized by floodplain forest vegetation. Depending on the frequency of inundation and reconnection during large floods, they may revert to wetland, herbaceous cover or mudflats. Oxbows function across the wetland hydrology spectrum that provide critical habitat for species ranging from vernal pool wetland species, dependent on intermittent drying, to species such as the endangered Topeka shiner which tends to thrive in perennial oxbows that are periodically connected to the river at high flows (approximately every 2-5 years).

Many of these off-channel habitats have been disconnected by levees and flood control dams that reduce the frequency and extent of 2-5 year flooding. Restoration of these small, regular 2-5 year floods and restoration of oxbow connections can help enhance denitrification and nutrient uptake as well as improve fish habitat (Jones et al. 2015).

Table 8. Tree species based on tolerance of flooding/inundation (Revised from Randall and Herring 2012.)

Very tolerant	**Tolerant**	**Intermediate**	**Intolerant**
Willow, *Salix spp*	Silver maple, *Acer saccharinum*	Black walnut, *Juglans nigra*	White oak, *Quercus alba*
Black ash, *Fraxinus nigra*	Eastern cottonwood, *Populus deltoids*	Shellbark hickory, *Carya laciniosa*	Northern red oak, *Quercus rubra*
Black spruce, *Picea mariana*	Boxelder, *Acer negundo*	Northern pecan, *Carya illinoiensis*	Black oak, *Quercus velutina*
Tamarack/larch, *Larix laricina*	River birch, *Betula nigra*	Honeylocust, *Gleditsia triacanthos*	Basswood, *Tilia americana*
	Sycamore, *Plantanus occidentalis*	Eastern redcedar, *Juniperus virginiana*	Black maple, *Acer nigrum*
	Swamp white oak, *Quercus bicolor*	Hawthorn, *Crataegus* spp.	Sugar maple, *Acer saccharum*
	Bur oak, *Quercus macrocarpa*	Buckeye, *Aesculus sp*.	Shagbark hickory, *Carya ovata*
	Hackberry, *Celtis occidentalis*	Catalpa, *Catalpa specios*e	Black cherry, *prunus serotina*
	American elm, *Ulmus americana*	Norway spruce, *Picea abies*	White ash, *Fraxinus americana*
	Red maple, *Acer rubrum*	Arborvitae, *Thuja occidentalis*	Butternut, *Juglans cinerea*
		Balsam fir, *Abies balsamea*	Post oak, *Quercus stellate*
		Osage orange, *Maclura pomifera*	Bigtooth aspen, *Populus tremuloides*
		Mulberry, *Morus rubra*	Red pine, *Pinus resinosa*
		White spruce, *Picea resinosa*	Jack pine, *Pinus banksiana*
			White pine, *Pinus strobus*

"First bottoms" are essentially in direct contact with the river, and typically flood every 1-3 years under natural flow regimes. Flooding usually subsides by mid- to late-summer. Soils on first bottoms can vary dramatically in both the vertical profile and laterally across an area. Most commonly they are made up of finer silts and clay particles which drain slowly and do not hold much oxygen in the root zone.

“Second bottoms”, otherwise known as terraces or benches, are older first bottom floodplains which have become separated from the river’s floods over time as the river cuts deeper into its valley. They are located further out away from the channel, near the valley wall before it becomes steep and grades into upland terrain. Second bottoms flood infrequently, only under extreme conditions. They often contain soils that drain more quickly than the first bottom, and can grow a wider variety of species that are suited to both upland and bottomland environments. These are often some of the most productive areas for black walnut, a high value forestry species. Although flood-prone, they are also frequently modified by human land uses, from agriculture to valley roads to residential development.

Hypothesized flow-related needs for Des Moines River floodplain communities

Maintain floodplain connectivity

- High flows provide lateral connectivity to backwaters, providing inundation and soil moisture conditions that support seed dispersal and recruitment

Support establishment and recruitment of aquatic, riparian, floodplain (first bottom), terrace (second bottom) vegetative communities

- During winter and spring, seasonal and high flow events provide disturbance to sustain communities with a high scour disturbance fidelity such as silver maple floodplain forests
- High flows transport water-dispersed seeds and prepare seedbeds for propagules
- In headwater settings, groundwater elevation and overbank inundation events are critical to maintaining hydric soils and moisture regimes for mesic plants
- During the low flow season, flows must be adequate to support growth and maintain the extent of submerged aquatic vegetation
- Reduced frequency of inundation can lead to altered patterns of succession and failure of bottomland vegetative communities to establish and recruit
- Excessive high flows and prolonged inundation of floodplain and terrace areas can interfere with establishment and recruitment of native floodplain vegetation and aid the spread of invasives

Mussels

Table 9. Mussel groups of the Des Moines River and shared life history traits

Group	Life history
Moderate gradient species *elktoe, sheepnose, spectaclecase*	• occur in dynamic habitats easily scoured or dewatered by extreme events • riverine species requiring swift to moderate velocities • sensitive to changes in water quality • small-bodied host fish with small home range
Moderate to swift velocity species *mucket, round pigtoe, fluted shell, black sandshell, lilliput*	• riverine species occurring in small to large rivers • require swift to moderate velocities • most sensitive to changes in dissolved oxygen and temperature
Slow to moderate velocity, low gradient species *three-ridge, fatmucket, white heelsplitter,Wabash pigtoe, giant floater, paper pondshell, plain pocketbook*	• facultative riverine species, tolerant of deeper habitats and a range of velocities • range of host fish • somewhat tolerant of higher temperatures
Mainstem species *pimpleback, mapleleaf, pink heelsplitter, pink papershell, fawnsfoot, yellow sandshell, ebonyshell*	• facultative riverine species in moderate to slackwater velocities • generally tolerant of siltation and impoundment • ebonyshell relies on skipjack herring host

Hypothesized flow-related needs for Des Moines River mussels

Support mussel spawning, glochidia transfer and juvenile growth

- Because of their limited mobility, most mussel species are sensitive to extreme high and low flow events and rapid changes in river stage
- High or low flow events may inhibit transfer of glochidia to host fish, reducing recruitment
- Extreme low flows may expose mussels in margin habitats and increase predation or desiccation
- Extreme low flows may increase temperature, reduce dissolved oxygen and increase ammonia toxicity
- During glochidia release and excystment, high flows and associated shear forces are primary factors in determining habitat suitability for juveniles
- Growth and fitness are influenced by high and low flow conditions
- Decreased magnitude or frequency of high flows can lead to habitat degradation including embeddedness, siltation and aggrading channel morphology
- Natural flow regimes can reduce risk of establishment of non-native mussels

Maintain seasonal thermal regimes for mussels

- Seasonal flows historically support thermal regimes critical in cueing gamete development and release
- Seasonal and low flows maintain surface and hyporheic temperatures and DO conditions
- Climate change and changes in river temperature due to the reservoirs may impact the ability to mimic historical flows and thermal regimes

Support flow conditions for host fish

- The dams serve as an obstacle to restoring mussel species dependent on mainstem river fish hosts that are unable to persist above major fish passage barriers

Given limited understanding of the reproductive requirements of many individual species of mussels, both the goals and hypotheses articulated above should be viewed as provisional, to be tested through adaptive management, i.e., research and monitoring to gather evidence supporting or modifying recommendations as changes are implemented.

Fish

Table 10 lists fish taxonomic groups based on hypothesized life history flow needs**.** Species listed in bold are fish species still present in the Des Moines system, chosen as representative of life history groups for which flow hypotheses are based.

Backwater specialists still present in the system include longnose and shortnose gar, golden shiner, yellow bullhead, mud darter, and redear sunfish. Shortnose gar and yellow bullhead are both backwater species but are also classified as tolerant. Eggs deposited on stones, shallow water, rocky shelves, vegetation or smallmouth nests. Young gar stay in vegetation for the first summer. Golden shiners prefer quiet waters, weedy areas, tolerant of turbidity, low DO, and high temperatures. Both longnose gar and golden shiners spawn in late spring (April to early July) when temperatures are around 20 C.

Fluvial specialists still present include shovelnose sturgeon, longnose dace, central stoneroller, hornyhead chub, northern hogsuckers, blue suckers. Male and female sturgeon typically spawn every 2 and 3 years, respectively (Tripp et al. 2009). Peak numbers of shovelnose with mature gametes are typically observed during rising river stages and high flows (Jacobson and Galat 2010). Some evidence suggests shovelnose sturgeon may be capable of spawning during fall as well as spring under the right conditions. Spawning is believed to occur over hard substrates (i.e. rock, rubble, or gravel) in primary tributary streams or along borders of main river channels (Keenlyne, 1997). Although actual spawning has not been observed, captures of fish in spawning condition indicates that shovelnose sturgeon spawn from 14.4 to 24 °C (Keenlyne, 1997.) The hypothesis that spring-pulse flows would operate to clean off spawning substrate is based on similar processes that have been documented with other sturgeon species, notably the Kootenai white sturgeon (Jacobson and Galat 2010). Many of these species spawn from March – June. Blue suckers, which spawn March-June at ~53 °F (12 °C), have increased in the Des Moines since the historic period. They are classified as intolerant to pollution.

Fluvial dependents. Representative examples include Skipjack Herring, Paddlefish, Golden and Shorthead Redhorse, Goldeye. Paddlefish reach sexual maturity fairly late (7-10 years). As with sturgeon, an increase in water flow appears to be the trigger to stimulate spawning. Upstream spawning migrations are triggered in late spring provided the proper combination of events occur, including water flow (small floods), temperature (50-61 F) photoperiod, and availability of gravel substrates suitable for spawning. They are mass spawners (broadcast spawners) over bare rocks or gravel. Hatching occurs after 7 days. Young are swept downstream after hatching and grow to adulthood in deeper freshwater pools. They also require floods for nursery and feeding areas. Goldeye and Skipjack Herring, a schooling fish, are both important as forage fish for other species. Golden Eedhorse, like other redhorse, typically spawn in spring once water temperatures reach a certain temperature. Spawning most often occurs in a runs or riffles within the main stream, but some individuals may move into smaller, more well protected tributaries

Macrohabitat generalist species of interest include smallmouth bass, which typically move up larger streams to spawn in Iowa during the early part of May as water temperatures reach 60' F. Another macrohabitat generalist native to the Mississippi River that is listed as a state SGCN is Black Buffalo, *Ictiobus niger*. Though more abundant in river habitats, buffalo also occur in impoundments and reservoirs. Whether in large rivers, shallow riffles or impoundments, they prefer strong current.

Historically a small component of the fish community, the following species of greatest conservation need were not found at all in the recent records (Parks 2013): banded Killifish, Blacknose Shiner, Northern Logperch, Brown Bullhead, Gilt Darter, Longear Sunfish, Pallid Shiner, Pugnose Shiner, Redfin Shiner, and Silver lamprey. Many of these species are either intolerant of declining water quality; phytophils requiring vegetation for spawning, or backwater or fluvial specialists dependent on habitat types that have been negatively impacted by hydrologic changes in the river system.

Reservoir species include many popular game fish: crappie, bluegill, green sunfish, largemouth bass, smallmouth bass, northern pike, hybrid striped bass (stocked); channel and flathead catfish, white and yellow bass, carp and walleye.

Table 10. Fish taxonomic groups based on life history flow needs. Species listed in bold are fish species still present in the Des Moines system, chosen as representative of life history groups for which flow hypotheses are based.

Group	Description	Examples
Large river species (wide ranging)	• occur in tributaries and large rivers • spring spawners with migration typically cued by temperature and rising water levels • require connectivity to floodplain and backwater habitats as well as to upstream tributaries • long-lived, large-bodied, pelagic feeders requiring maintenance of deep, open waters	Channel Catfish Flathead Catfish **Shovelnose Sturgeon** **Paddlefish** **Longnose Gar** **Skipjack Herring**
Migratory residents	• spring spawners requiring connectivity between tributary and small river habitats during spawning migrations • medium body size requiring moderately deep habitats esp. during overwinter period	Lamprey, Sauger, Walleye, American Eel
Backwater species	• Species that utilize or depend upon backwater habitats preferentially for at least part of their life cycle	Golden Shiner, Tadpole Madtom, Brook Silverside, **Longnose and Shortnose Gar**, Red Shiner, Mississippi Silvery Minnow, Blackchin and Blacknose Shiner, Weed Shiner and Topeka Shiner
Fluvial specialists	• Almost always found only in lotic systems, i.e. streams and rivers; described as needing flowing water habitats throughout their life cycle	Black Redhorse, Blacknose Dace, **Longnose Dace**, **Common Shiner, Hornyhead Chub, Northern Hogsucker**, Most Darters
Fluvial dependent	• Found in a variety of habitats but require access or use of stream habitats or flowing waters at some point in their life cycle, such as for tributary spawning. May have significant lake or reservoir populations that use tributary streams for some life requirement	White Sucker, **Golden And Shorthead Redhorse, Paddlefish**, Mud Darter, Tadpole Madtom, Topeka Shiner
Riffle obligates	• occur in all river types • require moderate to fast velocity habitats with coarse substrates • small home-range makes them sensitive to localized extreme conditions	**Longnose Dace**, Madtoms, Darters
Riffle associates	• occur in all river types • require connectivity during spring to between overwinter habitats and upstream spawning riffles • upstream migration cued by temperature and rising water levels • most prefer clear water streams	White Sucker, **Northern Hogsucker, Redhorses**
Nest builders	sensitive to flow conditions during spring and summer nest building • most require maintenance coarse substrate for nest building	**Hornyhead Chub, Smallmouth Bass**, Stonerollers

Lithophilic spawners	Sensitive to the accumulation of fine sediments, particularly as driven by impoundments	**Redhorses, Northern Hogsucker**, Redfin Shiner, Lamprey, Stonerollers
Pelagophilic	Spawn with numerous buoyant eggs, none or poorly-developed embryonic respiratory organs, little pigment and no photophobia,	Carp, Freshwater Drum, Emerald Shiner, American Eel
Lithopelagophilic	Rock and gravel spawners with pelagic larvae, some eggs soon buoyant. After hatching free embryos are pelagic by buoyancy or active movement.	Walleye, **Shovelnose Sturgeon, Paddlefish**.
Invertivores	Specialized feeding almost exclusively on aquatic invertebrates	**Goldeye, Black Buffalo**, **Hornyhead Chub**, many species of shiners

Hypothesized flow-related needs for Des Moines River basin fish

Maintain heterogeneity of and connectivity between habitats for resident and migratory fishes

- Extreme low flows reduce availability of persistent, high velocity habitats and may decrease access to and abundance of food; species with small home ranges would be particularly sensitive
- Prolonged low flows may reduce habitat heterogeneity and increase sedimentation

Maintain fall and spring spawning habitat and promote egg, larval and juvenile development

- Seasonal flows maintain sediment distribution for nest construction and maintenance

Maintain overwinter habitats for resident fish

- Winter baseflows are needed to provide persistent habitats and thermal refuges
- Excessively high winter flows may scour nests and disrupt refugia for small bodied fishes

Support resident fish spawning; Cue spawning migration and maintain access to upstream spawning habitat

- High flows in spring cue spawning migration and maintain connectivity to upstream and floodplain spawning habitats
- High seasonal flows are needed to maintain spawning habitat and keep nests sediment-free, but flows cannot be so high that they scour and flush eggs

Maintain access to and quality of shallow-slow margin and backwater spawning and nursery habitats

- A decrease in summer and early fall flows or reduced frequency of overbank flood magnitudes may reduce access to shallow, slow velocity nursery habitats in margins and backwaters

Herpetofauna

To be successful, restoration and management of wildlife areas for herpetofauna must take all stages of their life history into account, including access to food, shelter and migration corridors as well as hibernation, aestivation, breeding, and nesting sites. Other than highly aquatic turtles and the Mudpuppy, riverine herpetofauna spend the majority of their time along stream shores, shallows, and adjacent floodplains. Recognizing that herpetofauna require a connected mosaic of diverse habitat types to complete their life cycles, NRCS advocates restoring wetlands in a mosaic pattern, and managing stream banks to support a multitude of habitats including sand and gravel bars. Diverse, ecologically based water regimes should be recognized. However, given the extent of wetland loss, NRCS suggested a minimum hydroperiod for wetlands of 2.5 months and shallow ephemeral pools no further than 300 meters from a permanent water source to provide water during drought periods. Artificial water level manipulations during the breeding or hibernation seasons can result in excess desiccation and death of hibernating herpetofauna or amphibian eggs and larvae. Fishless wetlands are often important because fish can be superefficient predators on amphibian eggs.

In general, amphibians are very dependent on the water and are an important part of the aquatic ecosystem. They are not especially dependent on flow, but can be affected negatively by artificially rapid changes in water levels in reservoirs or rapid increase in dam discharges. Frogs such as Northern Cricket Frog (*A. crepitans*) are important as an indicator of wetland health and general environmental quality in the areas they inhabit.

Several documents provide recommendations for restoring and managing prairies, woodlands, streams, rivers, and wetlands for Iowa herpetofauna, including avoiding direct mortality due to management practices such as fire, mowing or herbicide application. (see NRCS Helping People Help the Land). Most best management practices (BMPs) are focused on maintaining migratory connectivity between habitat areas to allow herpetofauna to successfully traverse from aquatic riparian and floodplain habitats to upland areas, by removing barriers and reducing direct causes of mortality. In general, upland areas should be protected within a minimum 300-meter radius from the edge of a wetland or stream; an area termed "core habitat". The establishment of core habitat is essential to the survival of riparian herpetofauna that require upland habitat for foraging, nesting, aestivation, and hibernation. In important high quality habitat areas especially, an additional 50-meter buffer zone adjacent to core habitat and/or land use zones restricting activities such as hiking, birding, etc. may provide critical additional protection.

Table 11. Reptile and amphibian groups and shared life history traits

Group	Life history
Aquatic-lotic species *Smooth Softshell, Spiny Softshell Turtles, Map Turtles, Mudpuppy (lungless salamanders)*	• some depend on specific hydraulic conditions, depth, velocity, width • use specialized stream-dependent feeding habits • sensitive to changes in water quality • require aquatic connectivity
Semi-aquatic lotic species *Wood Turtle, Northern Water Snake, Northern Leopard frog*	• rely on flowing waters within the active channel for one or more life stages, typically hibernation • depend on access to and quality of floodplain and riparian habitats for migration, feeding, and reproduction
Riparian and floodplain-terrestrial and vernal habitat species *bog Turtle, Northern Cricket Frog, Blue Spotted Salamander*	• mating, egg and larval development may occur in vernal pools within the floodplain or in intermittent streambeds • terrestrial connectivity within riparian and floodplain habitats

Key flow-related needs for Des Moines River reptiles and amphibians

Promote/support the development and growth of reptiles and amphibians

- A decrease in seasonal flows may reduce availability of stable, cool, highly oxygenated habitats
- Low flows facilitate access to benthic invertebrates, especially crayfish, which are eaten by specialist feeders, including water snakes, river otters, and carnivorous fish. However, prolonged or extreme low flows may also increase predation mortality for mussels.
- Maintain stable hibernation habitat for reptiles and amphibians
- A decrease in flows may decrease water temperatures or dewater hibernation habitats resulting in stress or mortality during hibernation Maintain streamside and vernal egg-laying and larval development habitat for reptiles and amphibians
- High flows of sufficient magnitude and duration are needed to inundate vernal pools in the floodplain that support amphibian egg-laying and larval development; however, prolonged inundation interferes with drying out of pools and introduces fish predators
- An increase in high flows may scour larvae that develop in stream margins
- Seasonal flows keep eggs and larvae of streamside salamanders wetted during the incubation period

Summary of Flow Restoration Hypotheses and/or Recommendations by Reach:

Saylorville reservoir and above

We recommend that the USACE conduct the following analyses:

- Map of changes in floodplain habitat caused by the reservoir (floodplain habitat inundated by as well as that created by the reservoir)
- Mapping extent of mudflat habitat that has been created/lost by recent sedimentation (with reference to shorebirds and migratory waterfowl)
- Revised mapping of use areas and zone classifications should be conducted, based on already observed changes driven by reservoir sedimentation
- Mapping extent of habitat at various depths that would be created by each additional foot of pool elevation rise, as well as implications for flood storage and a frequency analysis based on the recent historical data of how often storage capacity would be exceeded
- Exploring the implications of managing pool elevations to match natural seasonal patterns in inflows to enhance denitrification and vegetation, control invasives, etc
- Explore feasibility of increasing residence time in reservoir during high nitrate loading periods (i.e. March - June) and implications for other authorized purposes: water supply, flood risk, conservation pool, fish and wildlife and recreation

Below Saylorville (between Red Rock and Des Moines)

- Coordinate Saylorville releases with recreational restoration initiatives in urban Des Moines
- Enhance ecosystem services and natural habitat in the Des Moines Metro Area Greenbelt for recreation and habitat, biodiversity by mimicking natural pattern of flows, allowing for much longer step up and step-down periods

Below Red Rock

- Bolster low flow releases during heat waves to moderate instream temperatures and reduce downstream fish and mussel mortality risk
- Consider how to manipulate releases to moderate downstream temperatures during periods of low flow that occur during heat waves
- Consider how to reduce the impact of fall storage drawdown and sudden winter releases
- Authorize short-term low flow releases to benefit downstream recreation as long as it doesn't result in excessively rapid rise rate
- Avoid massive drawdown or maintenance and construction; mitigate for mussel exposure if summer or winter maintenance drawdowns absolutely economically necessary (relocate and captive propagation and reintroduction)
- Develop prescriptions to limit the rise and fall rates and make more gradual adjustments to flows below Red Rock to avoid TDG supersaturation
- Consider allowing higher flood releases occasionally, and maintaining outflows closer to inflows to mimic frequency of small high flow pulses.
- Explore the cost/benefit of what would be required to increase maximum operating (floodplain inundation maintenance floods) for Red Rock over the long run (floodplain buy-outs?)

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Appendix

Appendix A. Flow analyses and Inundation maps

Appendix B. Comparison of Pre- and Post-project Flow Time Series using the Indicators of Hydrologic Alteration (IHA)

Appendix C. Stakeholder Issues

Appendix D. Observations of channel change below Red Rock Dam

Appendix

Appendix A. Flow frequency and inundation profile analysis

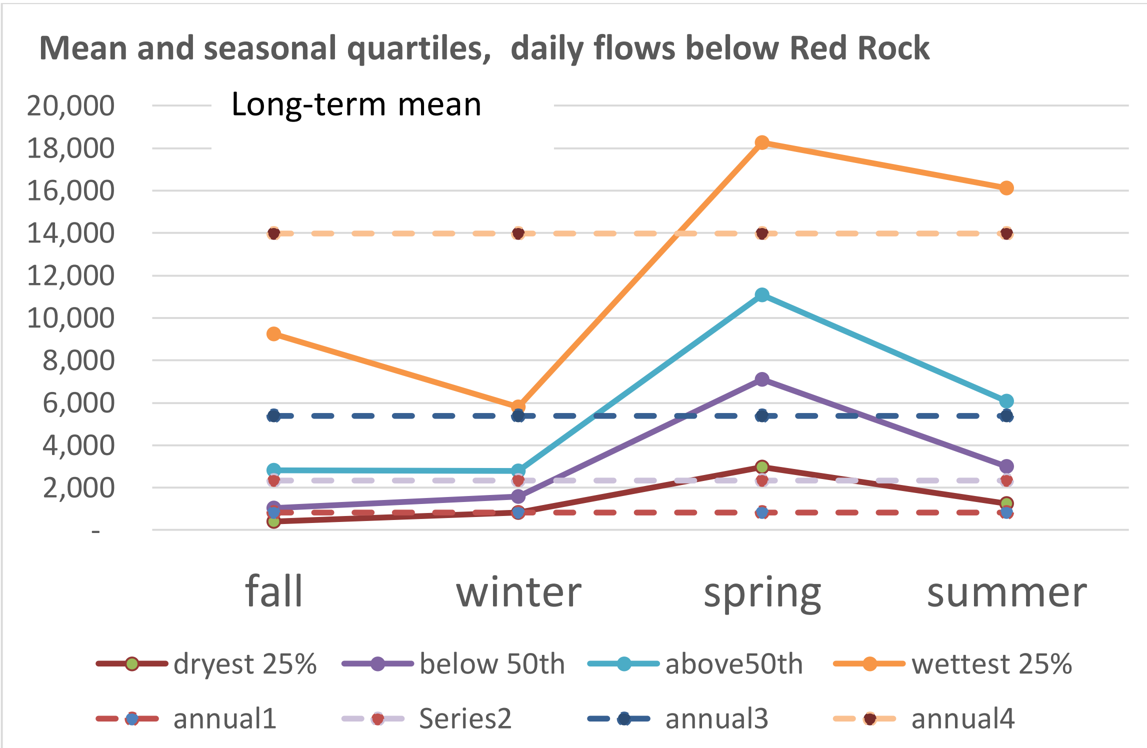


Figure A-1. Long-term mean and seasonal flow statistics for the Des Moines River below Red Rock, by 25th percentile flows (cfs).

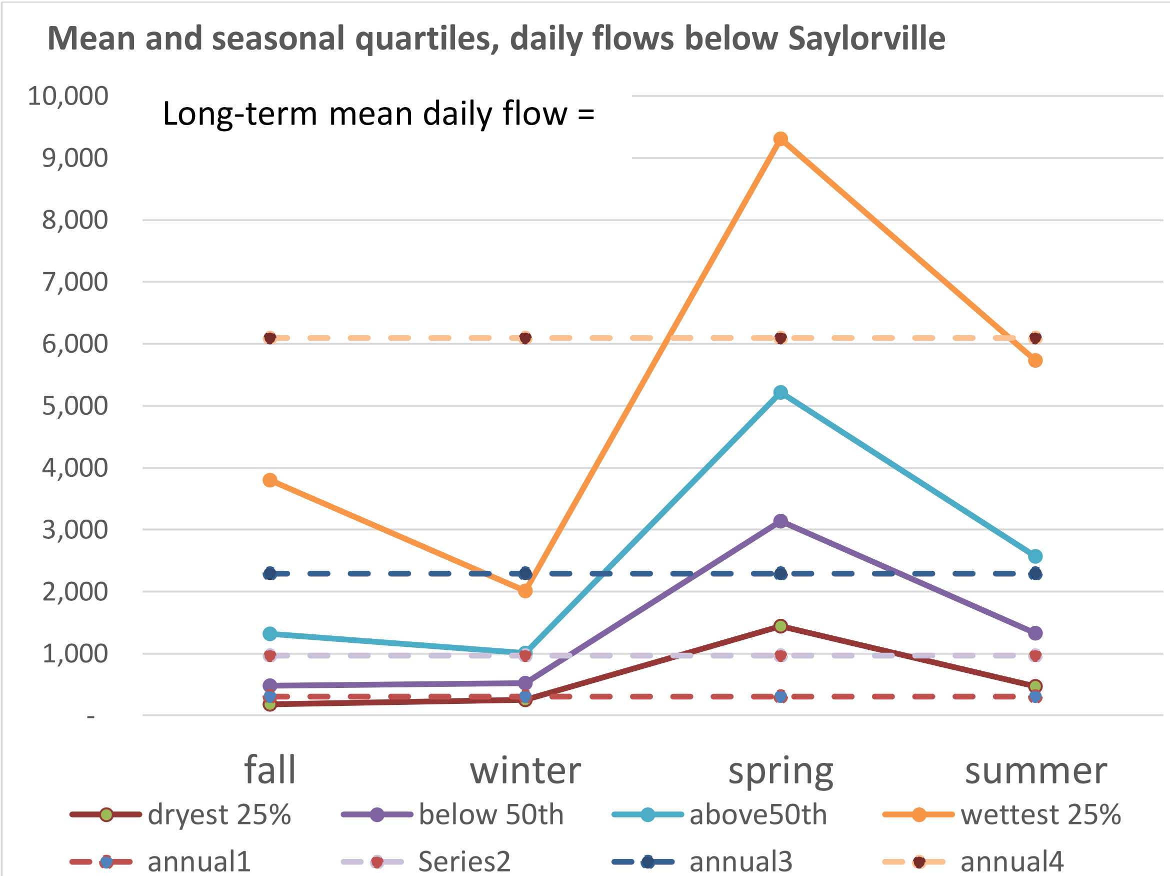


Figure A-2. Long-term mean and seasonal flow statistics for the Des Moines River below Saylorville Dam, by 25th percentile flows (cfs).

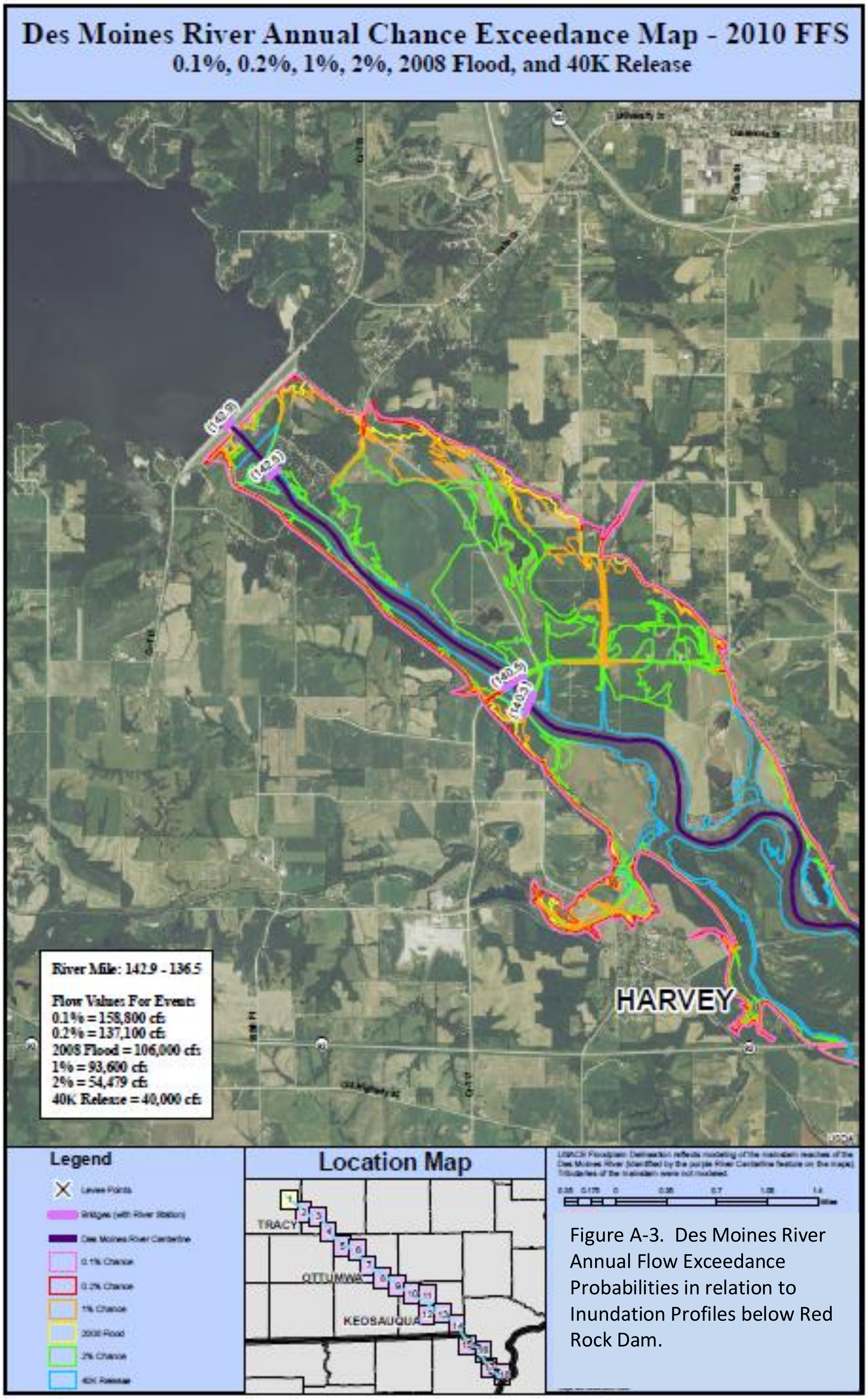


Figure A-3. Des Moines River Annual Flow Exceedance Probabilities in relation to Inundation Profiles below Red Rock Dam.

Figure A-3. Des Moines River Annual Flow Exceedance Probabilities in relation to Inundation Profiles below Red Rock Dam. Example: Reprint of Plate 1 from USACE Des Moines River Map Book (2010). Flood inundation profile mapping conducted by the USACE suggests that bankfull flow below Red Rock is approximately 40,000 cfs (i.e., the 40K flood release).

We evaluated frequency and duration of flows exceeding three magnitudes corresponding to exceedance probabilities mapped in relation to the inundation profiles depicted in Figure A-3. Comparing unregulated flows below Red Rock before 1969 to regulated flows 1969 and after (when Red Rock Dam became fully operational), we find that flows on the Des Moines River exceeded bankfull stage a total of 18 times in the 98-year flow record. Prior to 1969, unregulated flows exceeded 40K cfs 12 out of 51 years (a little over 1 in 5), with a mean peak of 64K cfs and an average duration of 7 days. Following dam construction, bankfull flows occurred only 6 out of 47 years (1 in every 8 years); however, the average duration of flooding was 18 days. The average peak annual flood prior to 1969 was 35,765; after 1969, it was 30,502. Before dam completion, flows exceeded 30K 27 times out 51 (nearly every other year, for an average of 9 days). After dam completion, flows exceeded 30K only 10 out of 47 years (~1 out of 5), but lasted 3 times as long (30 days).

Table B-1. Frequency and duration of flows exceeding three magnitude thresholds near- and above bankfull.

		> 30,000 cfs		*> 40,000 cfs*		*>54,000 cfs*	
period	**Mean annual flood peak**	**freq**	**duration**	**freq**	**duration**	**Freq**	**duration**
All years	33,000	37	15	18	11	9	9
Before 1969	36,000	27	9	12	7.3	6	6
After 1969	31,000	10	30	6	18	3	15

They estimated the channel-forming discharge (i.e., flow level that occurs every 1.5 years), was estimated to be 881 cm (~31,100 cfs), consistent with previous studies in the Des Moines River (Odgaard 1987). Historical analysis of aerial photos for the reach showed that OB flow occurred when the discharge exceeded a value of 1832 cm (~65,000 cfs) and their flood frequency analysis indicated that such an event has a return period of about 6.5 years. However, given increases in discharge in recent years, they suggested that this magnitude of overbank flow probably occurs even more frequently than every 6.5 years. Bressan and colleagues also estimated the 100-year flood on the lower Des Moines River at 125,000 cfs, and the 500-year flood at 165,000 cfs.

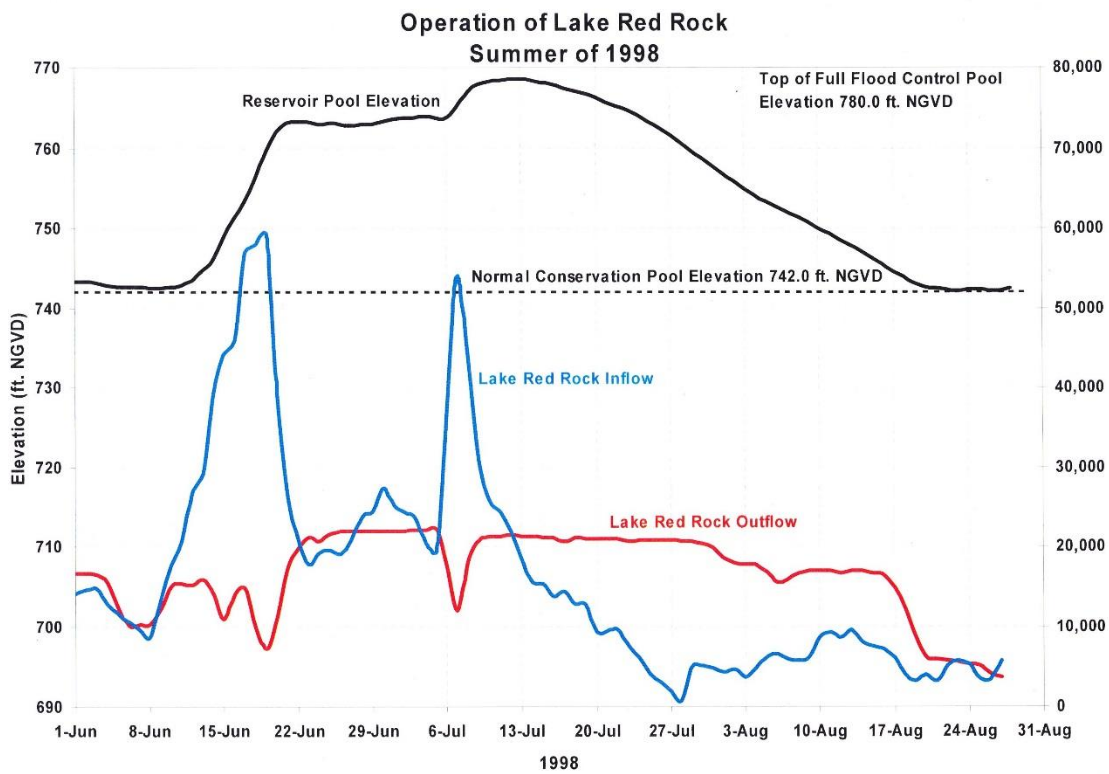


Figure A-4. Example comparison of Red Rock Reservoir inflows versus outflows (summer 1998), as well as how dam operations and inflows affected conservation pool elevations.

Appendix B. Summary of Indicators of Hydrologic Alteration (IHA) Two-Period Analysis

Red Rock

- Pre-impact flow series: unregulated flow times series for Water Years 1919-1968.
- Post-project flows: regulated flow time series 10/1/1968 – 9/30/2015.

Summary: Overall consistent increases in magnitude of all environmental flow components (low flows, monthly and seasonal flows, small floods, and high flows) are primarily attributable to basinwide changes in yield related to basin land use, management, and climate change. The main impacts attributable to the project/dam operations are a reduction in the magnitude and frequency of small floods; reduced frequency and duration above bankfull flow magnitudes; increased duration (prolonged high flows) in years of large floods that exceed design flood magnitudes; and significantly increased mean and median rise and fall rates.

Low flows:

- Extreme low flows (< 300 cfs) eliminated.
- Low flows remain evenly at a lower level and are less variable than before the project (e.g. 1d, 3d), but the medians are still within the RVA boundaries
- The 7-day and 30-day minima have increased

Seasonal flows

- Mean and median monthly flows have nearly all increased significantly, some as much as double.

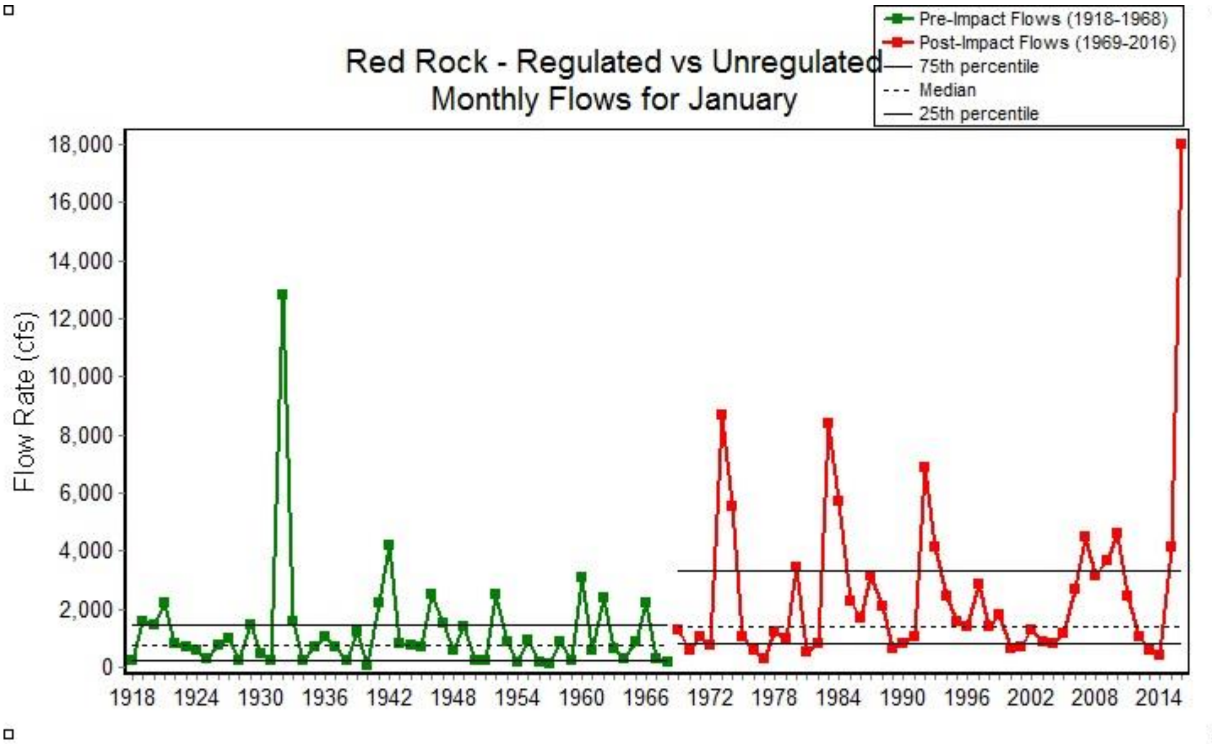
High flows

- 3 and 7-day maxima have decreased, but otherwise not substantially altered
- “Small floods” are smaller and much less frequent (3-day maximum)
- 7-day max – there are many fewer flows between 35,000-70,000 cfs; however, there are a few flows higher than ever
- The 90-day max has doubled in magnitude.

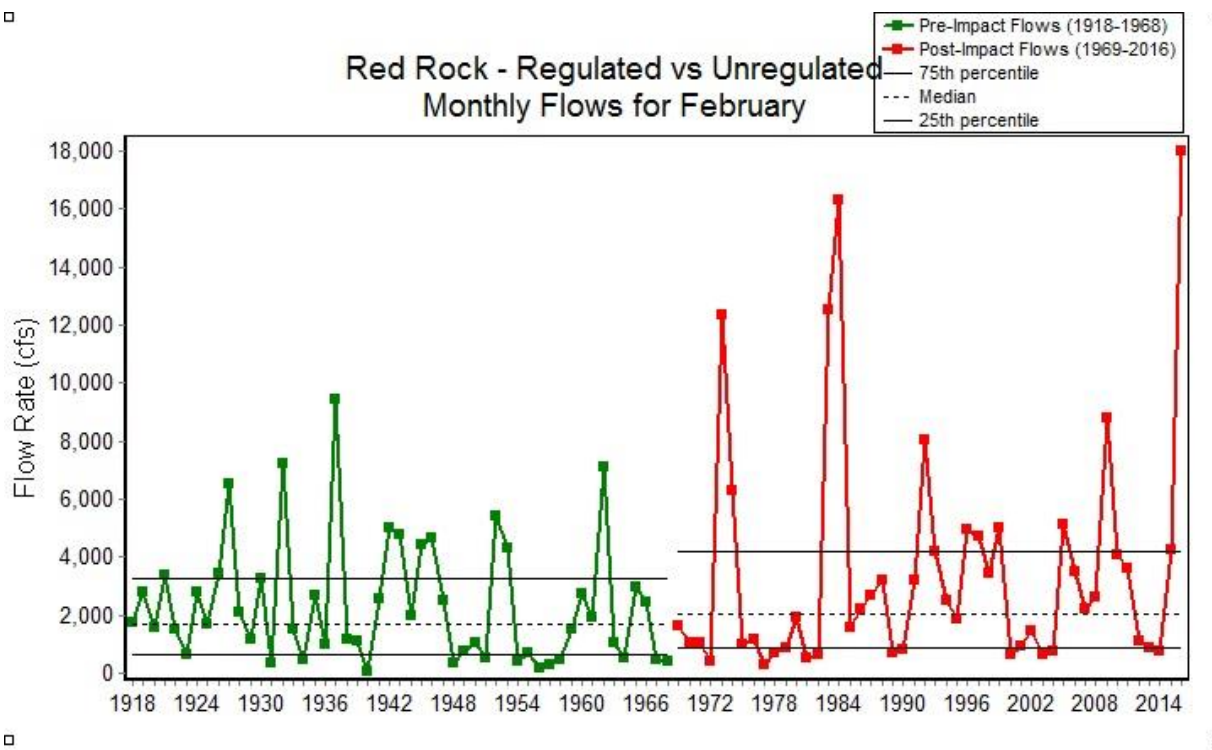
Timing, duration, and Rate of change

- The timing of the minimum and maximum dates has changed, occurring earlier in the year in both cases
- The low pulse (740 cfs) count is the same but the duration is ¼ as long
- High pulse (4990 cfs) count and duration are similar
- Both the rise rate and the fall rate have increased significantly, especially the fall rate[1]

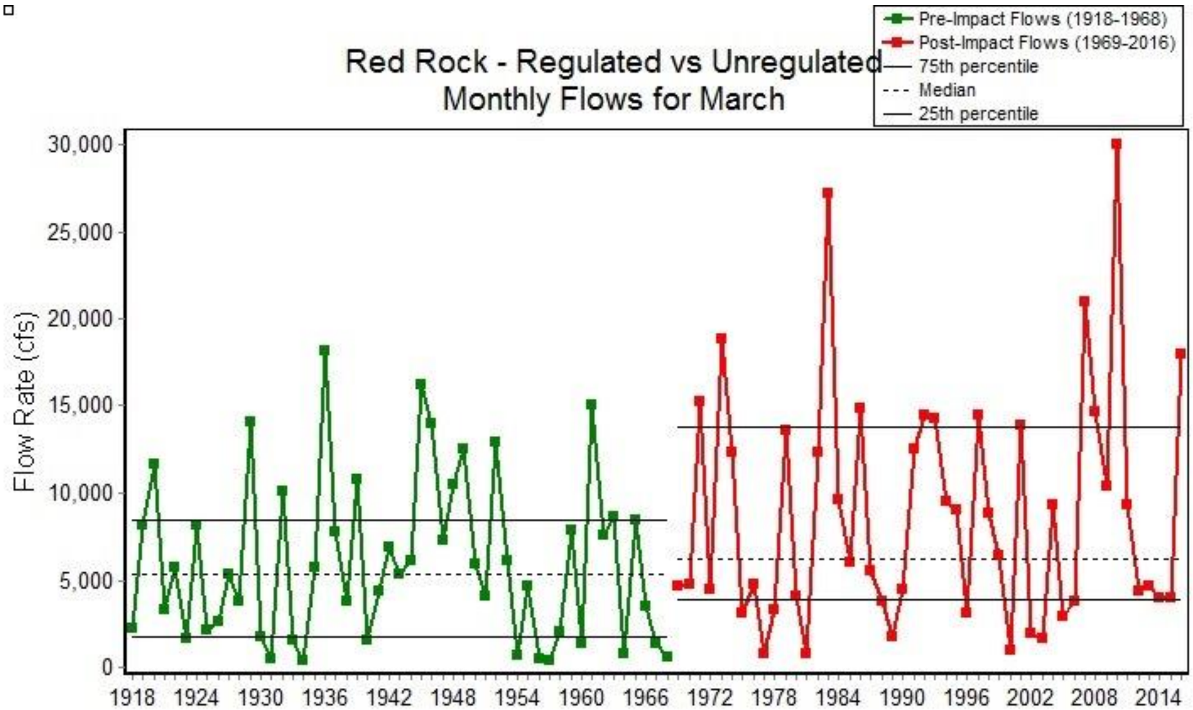
[1] Rise rates: Mean or median of all positive differences between consecutive daily values
Fall rates: Mean or median of all negative differences between consecutive daily values
-from IHA v7 User’s Manual July 2006

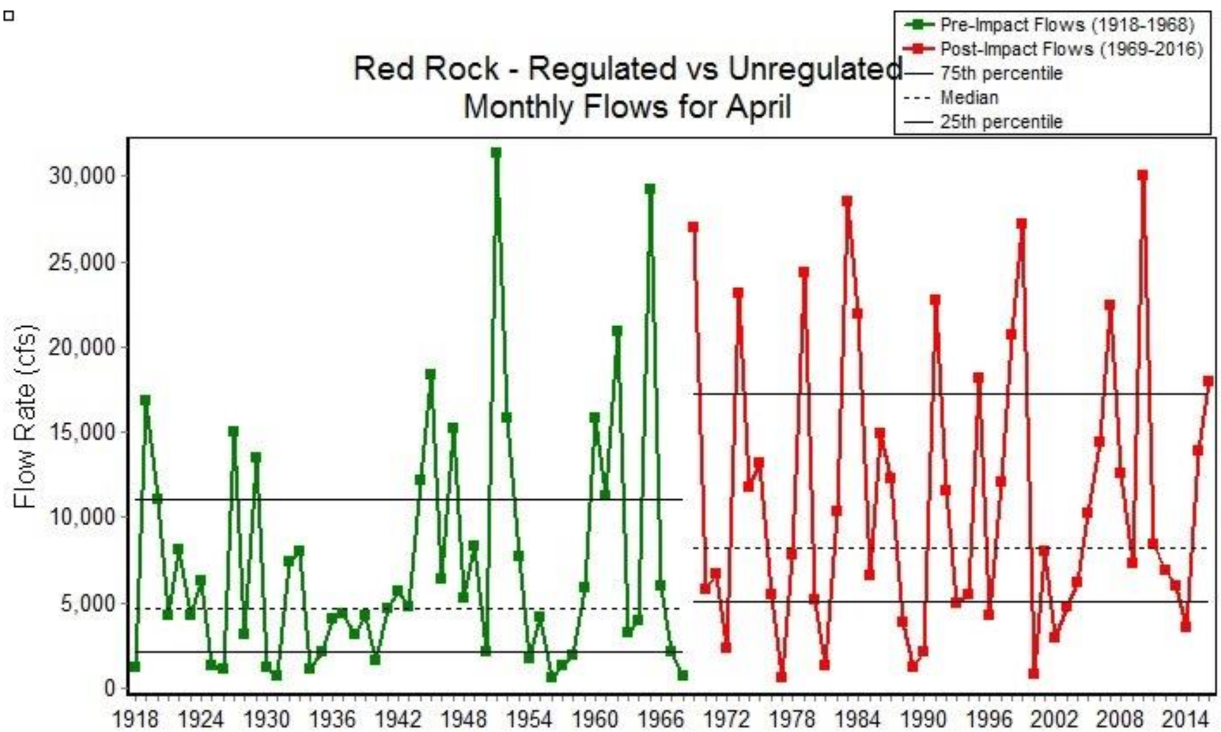


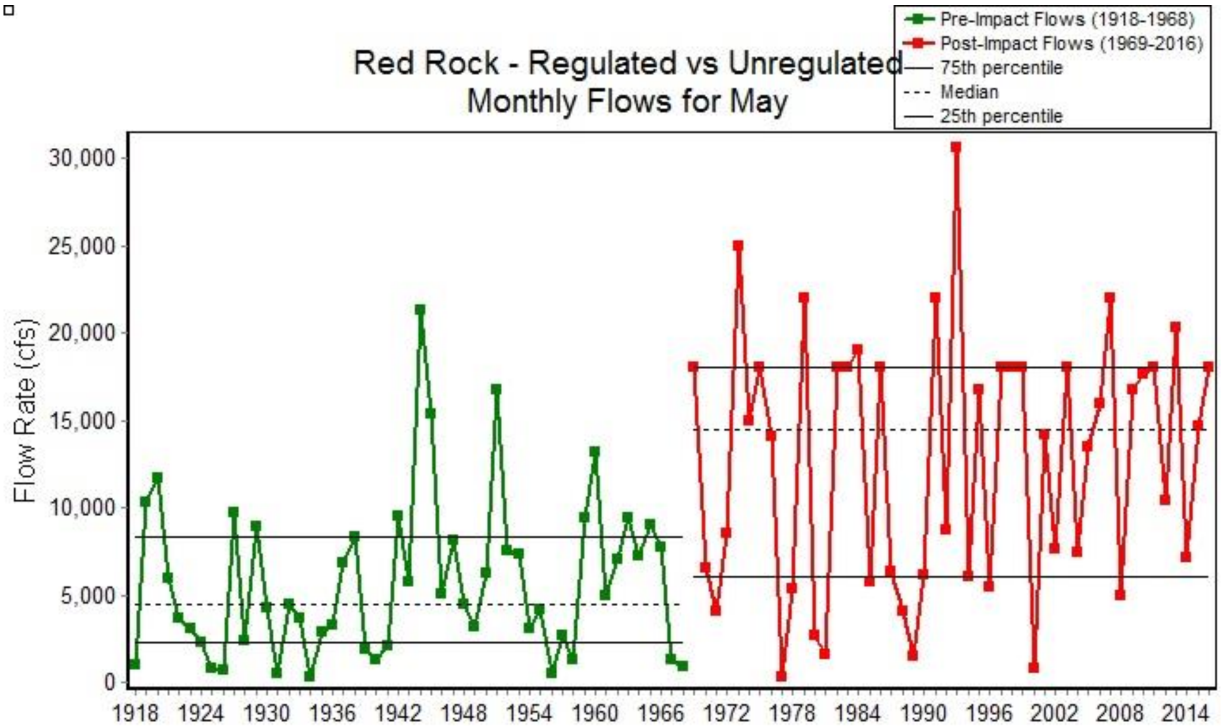
Red Rock - Regulated vs Unregulated
Monthly Flows for January
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

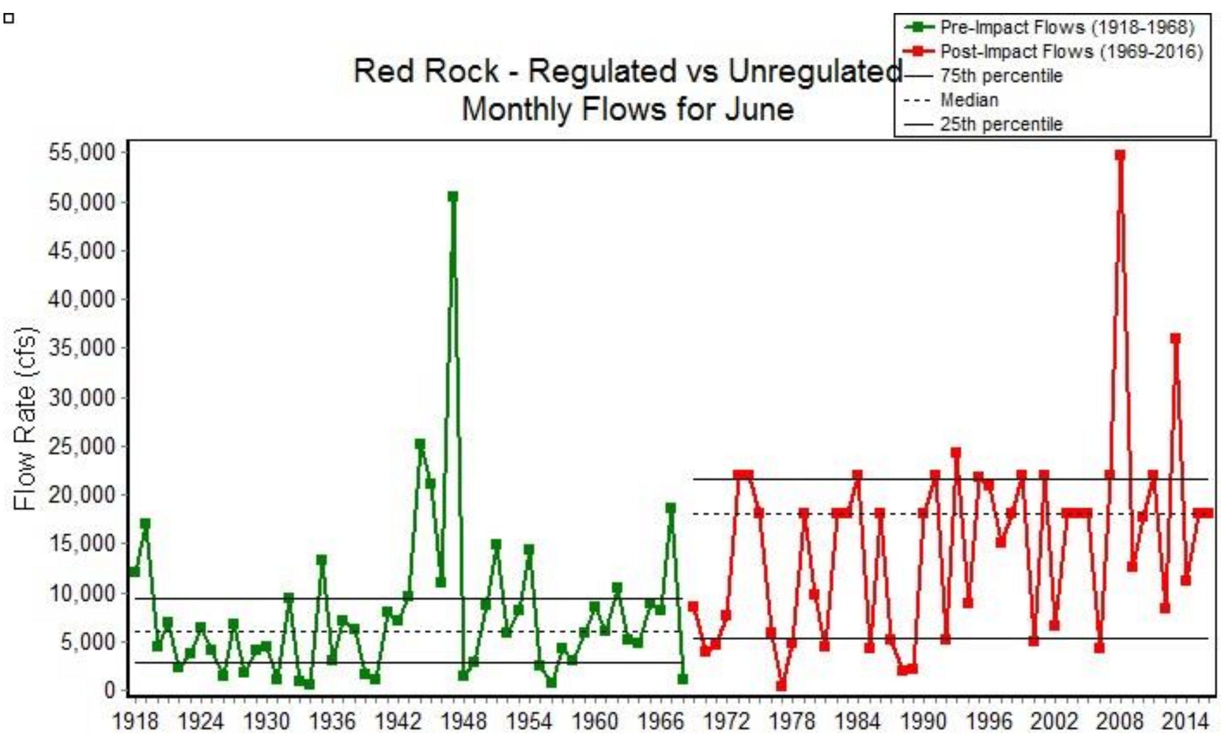


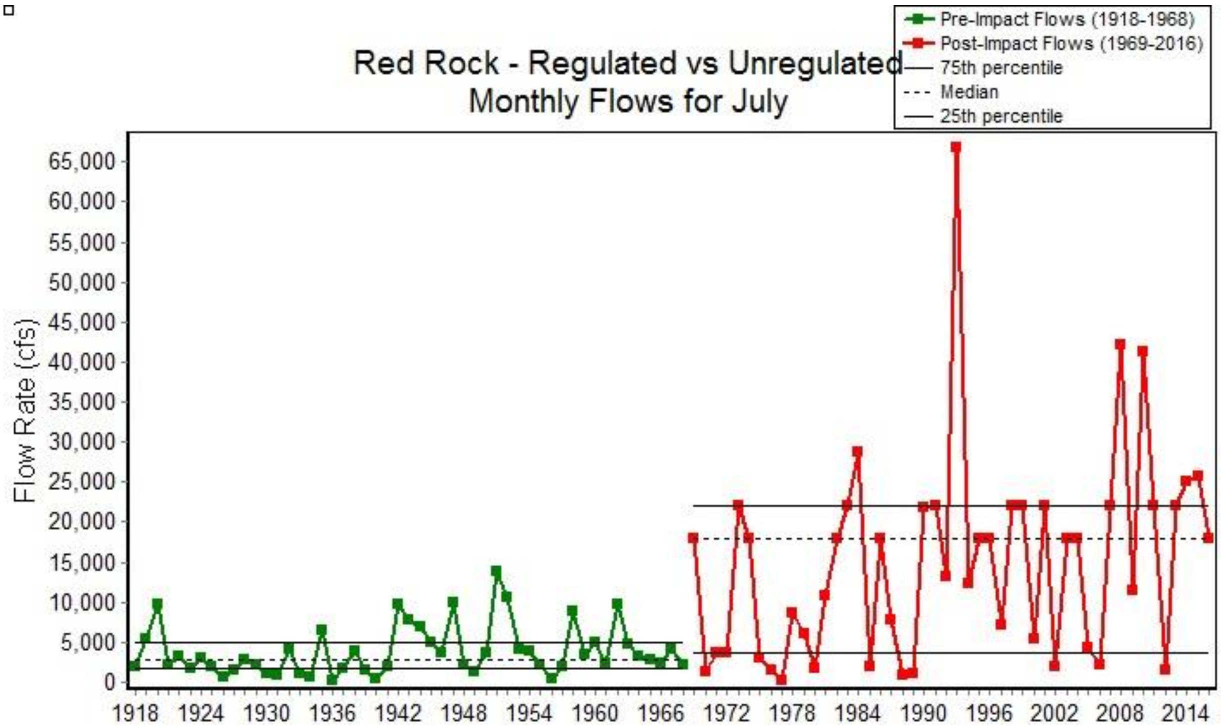
Red Rock - Regulated vs Unregulated
Monthly Flows for February
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

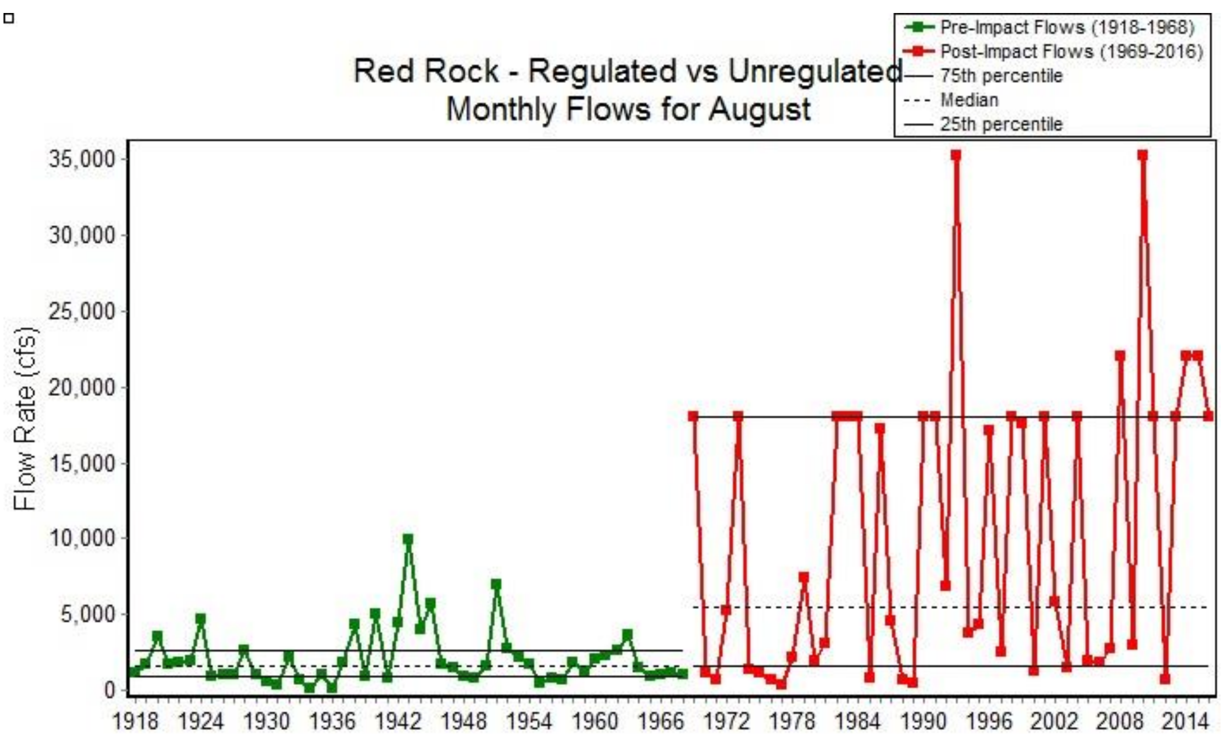

Red Rock - Regulated vs Unregulated
Monthly Flows for March
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

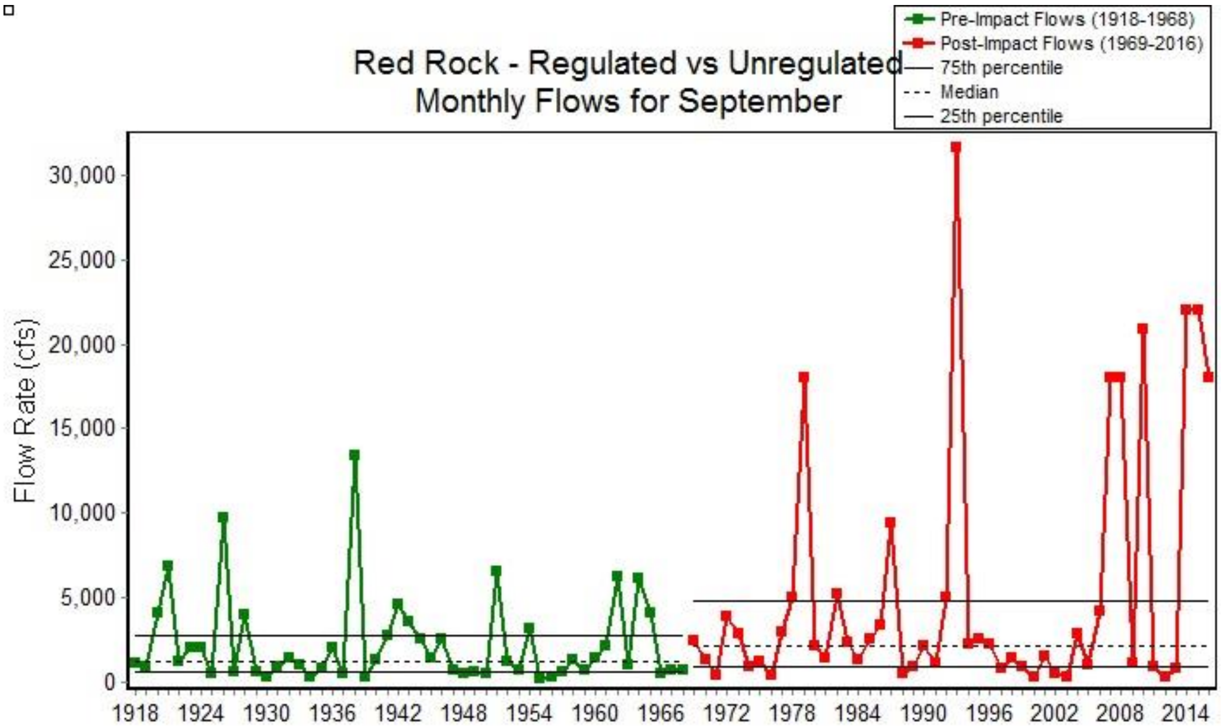

Red Rock - Regulated vs Unregulated
Monthly Flows for April
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

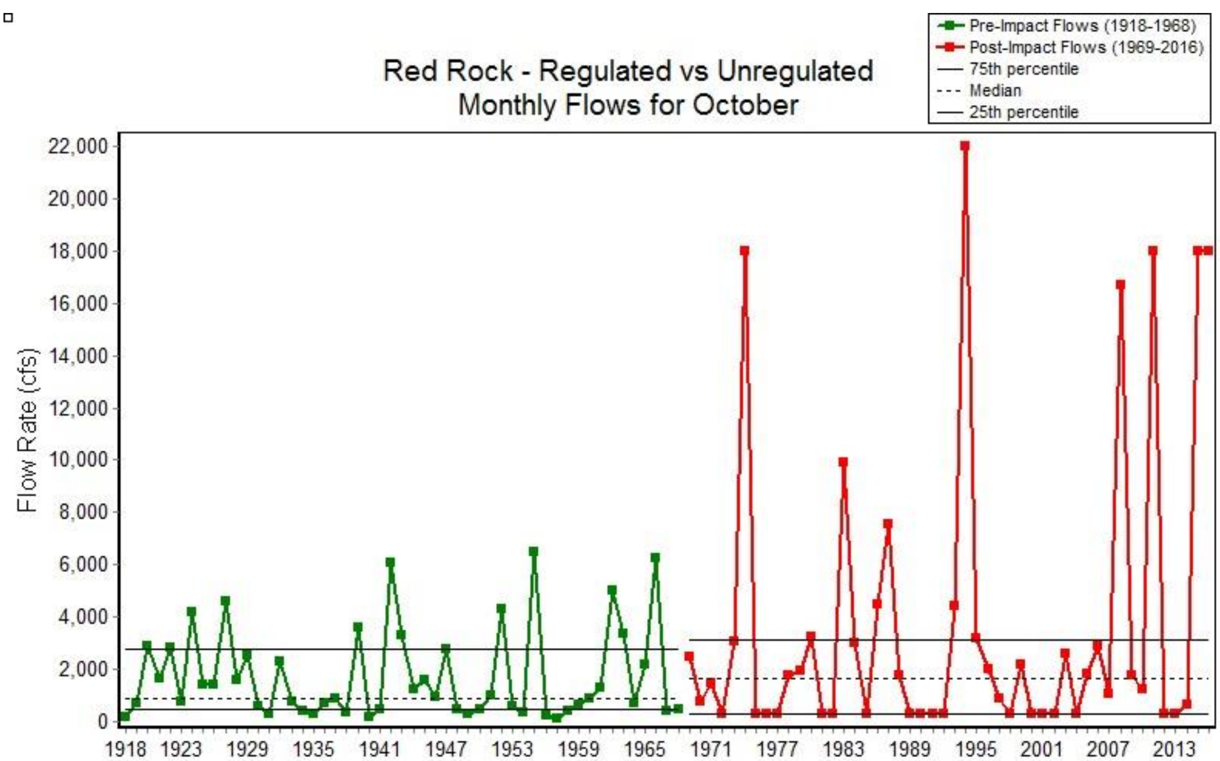

Red Rock - Regulated vs Unregulated
Monthly Flows for May
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

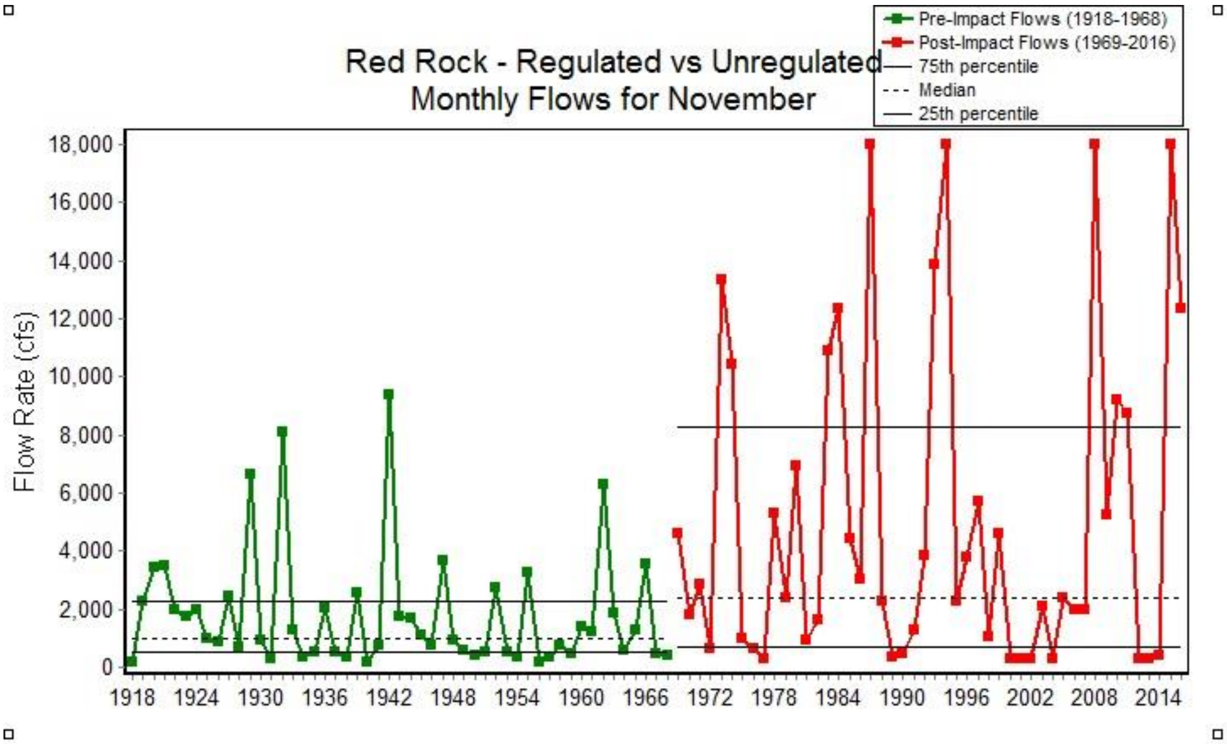

Red Rock - Regulated vs Unregulated
Monthly Flows for June
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

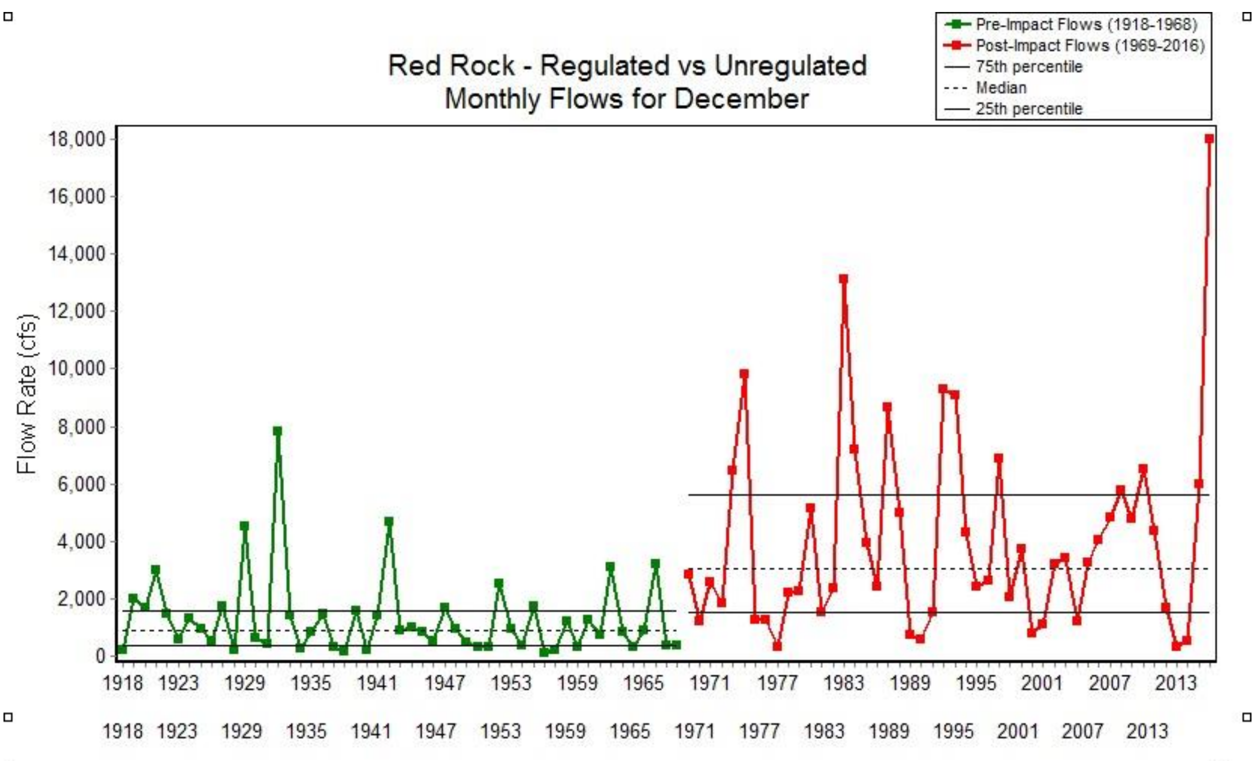

Red Rock - Regulated vs Unregulated
Monthly Flows for July
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

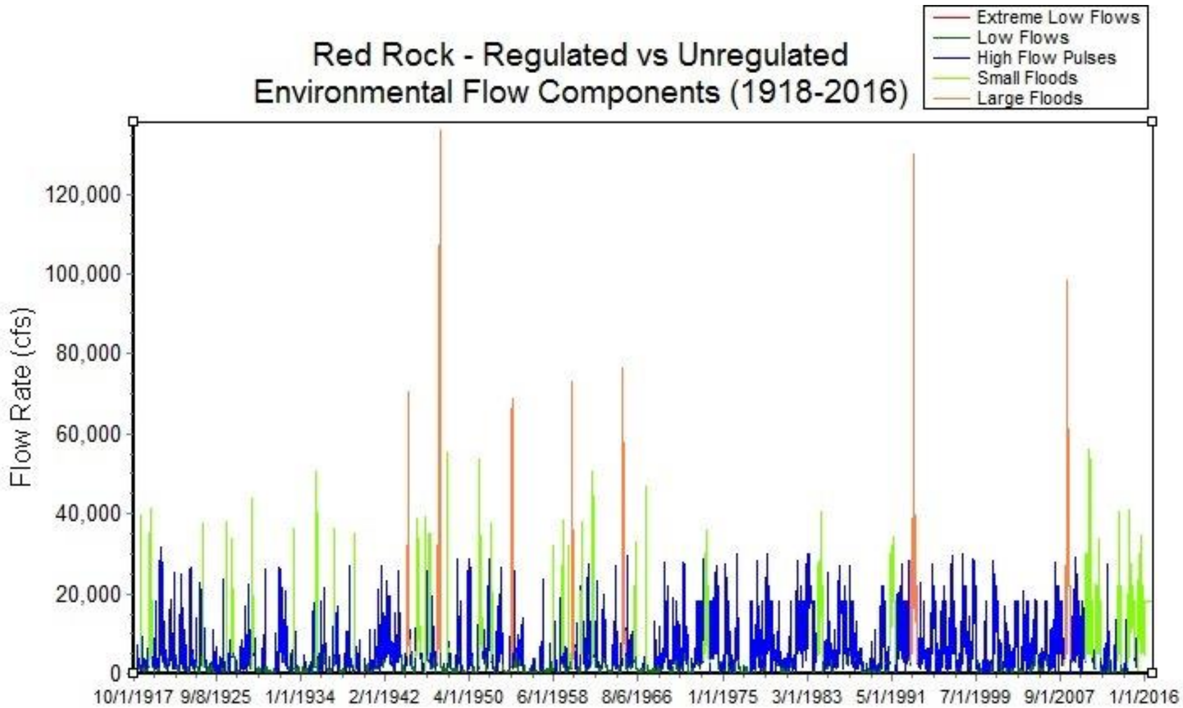

Red Rock - Regulated vs Unregulated
Monthly Flows for August
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

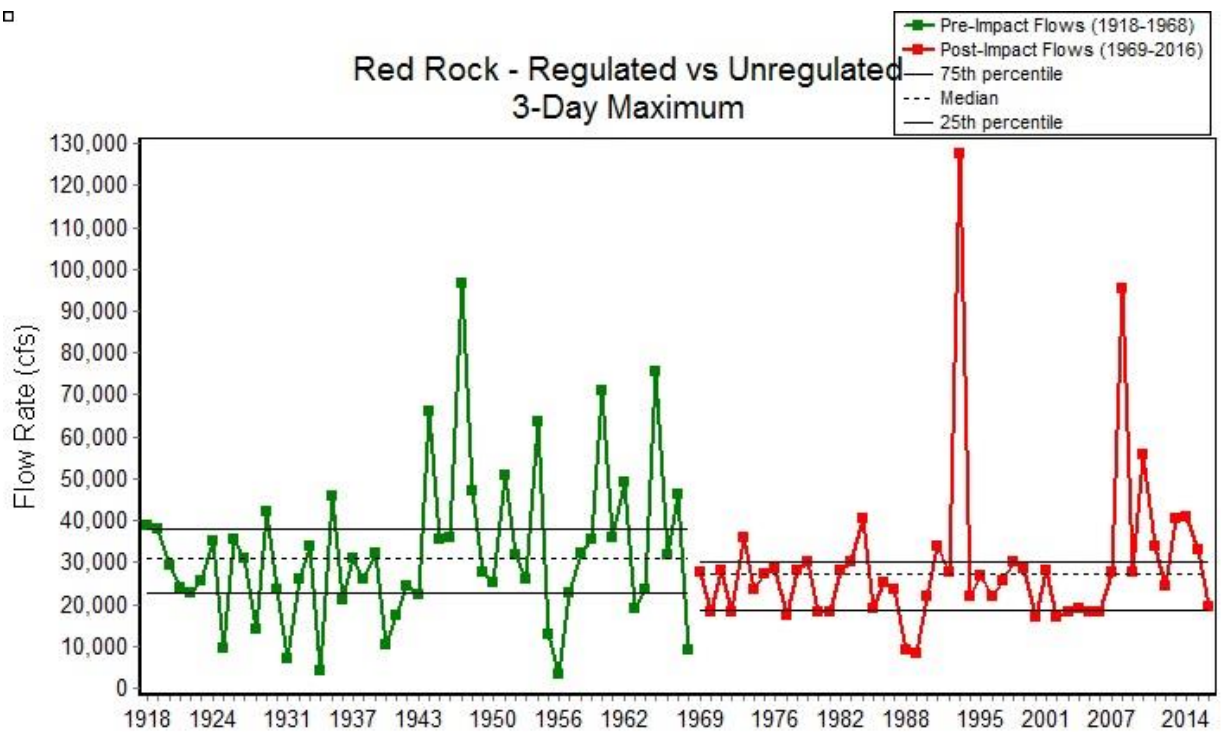

Red Rock - Regulated vs Unregulated
Monthly Flows for September
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

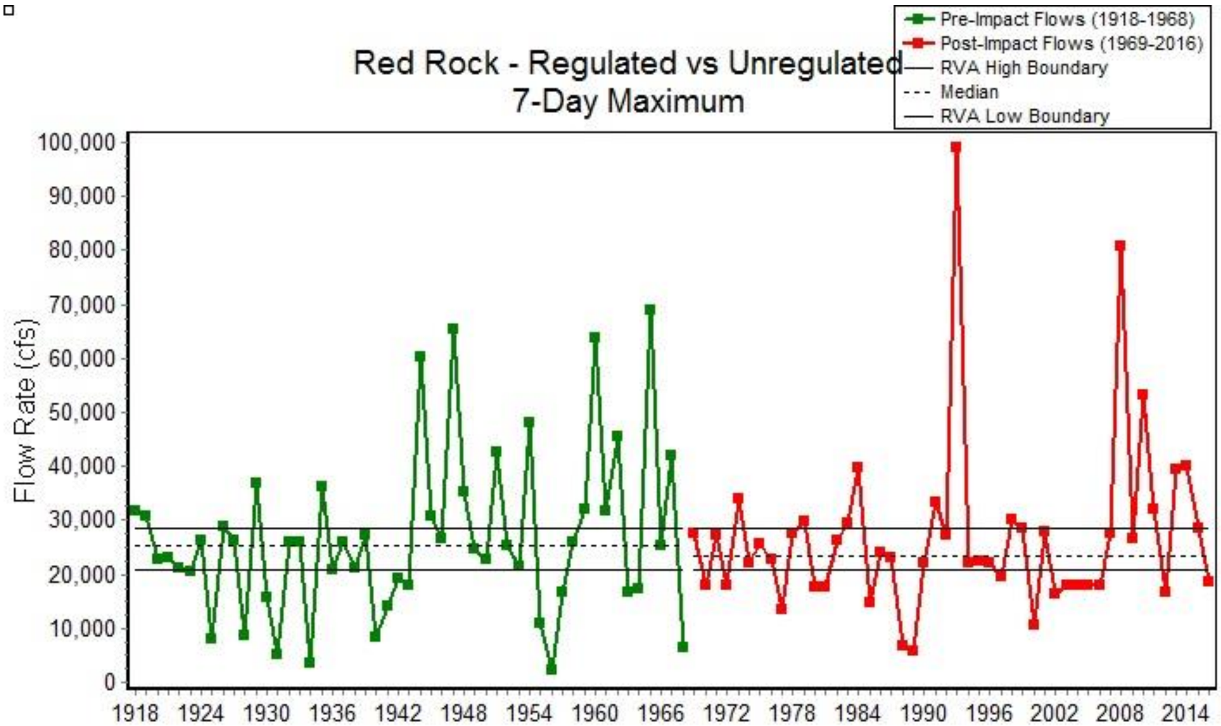

Red Rock - Regulated vs Unregulated
Monthly Flows for October
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1918 1923 1929 1935 1941 1947 1953 1959 1965 1971 1977 1983 1989 1995 2001 2007 2013


Red Rock - Regulated vs Unregulated
Monthly Flows for November
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

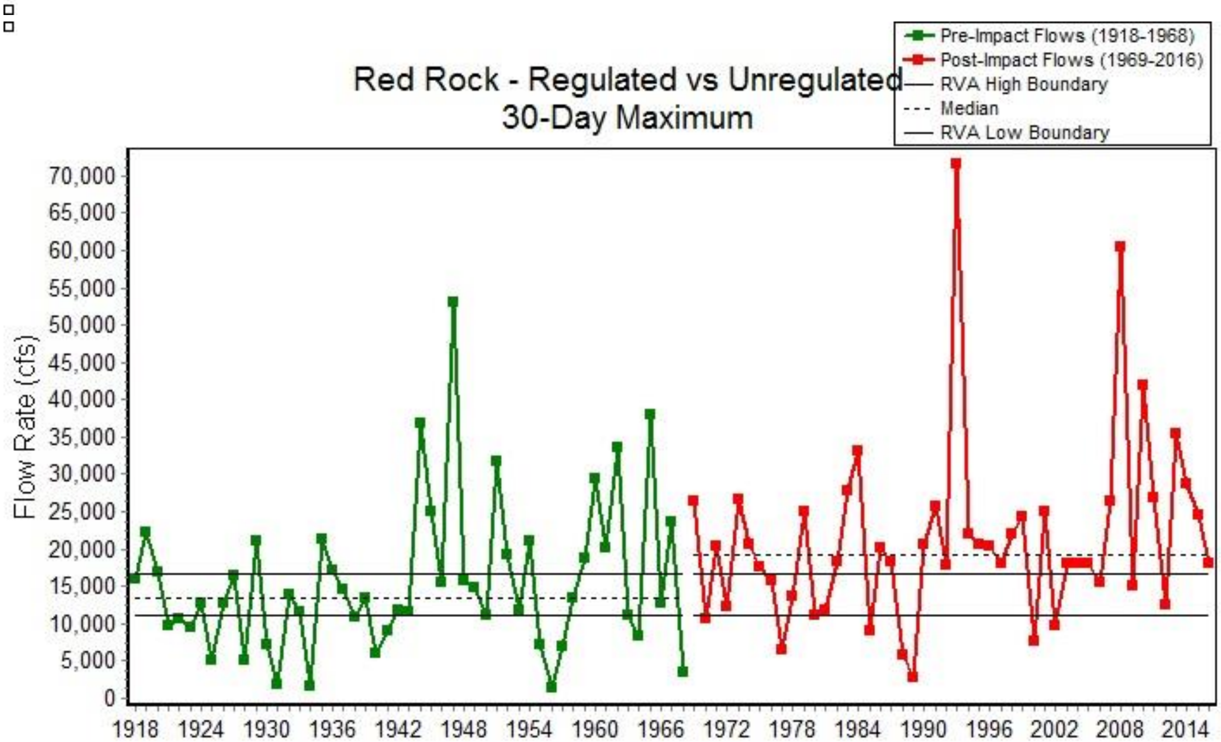

Red Rock - Regulated vs Unregulated
Monthly Flows for December
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1918 1923 1929 1935 1941 1947 1953 1959 1965 1971 1977 1983 1989 1995 2001 2007 2013
1918 1923 1929 1935 1941 1947 1953 1959 1965 1971 1977 1983 1989 1995 2001 2007 2013


Red Rock - Regulated vs Unregulated
Environmental Flow Components (1918-2016)
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods
Flow Rate (cfs)
120,000
100,000
80,000
60,000
40,000
20,000
0
10/1/1917
9/8/1925
1/1/1934
2/1/1942
4/1/1950
6/1/1958
8/6/1966
1/1/1975
3/1/1983
5/1/1991
7/1/1999
9/1/2007
1/1/2016

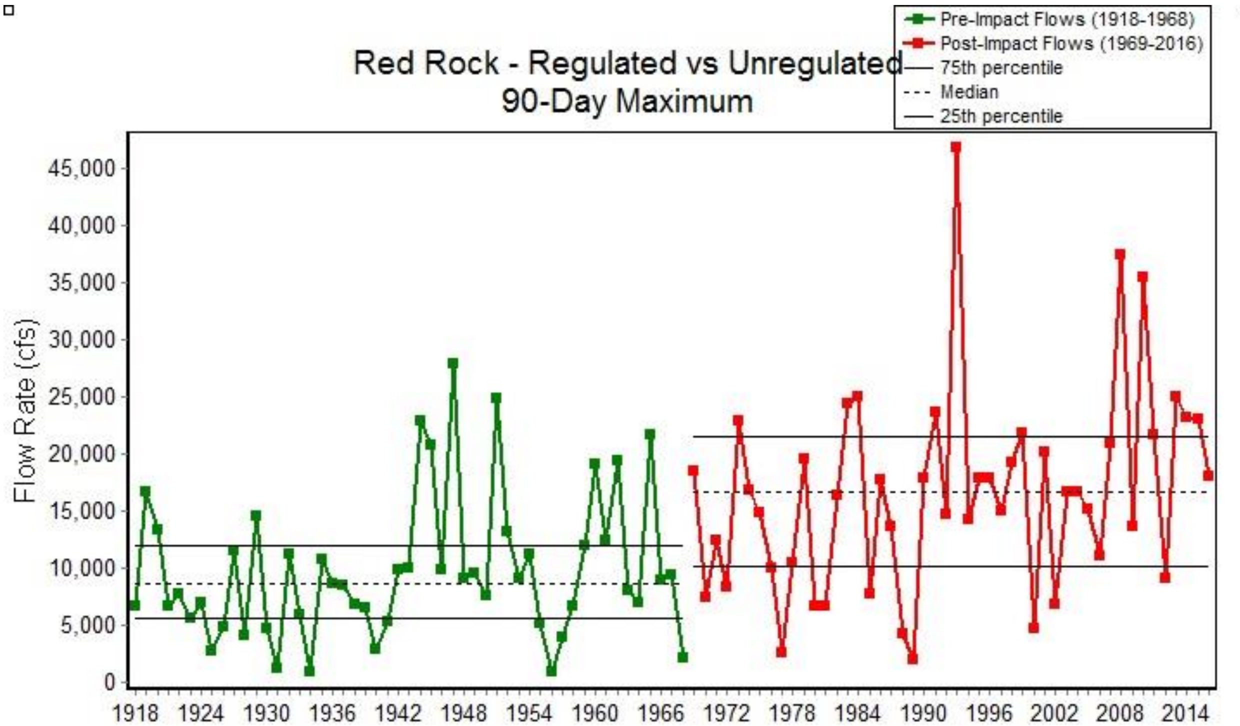

Red Rock - Regulated vs Unregulated
3-Day Maximum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1918
1924
1931
1937
1943
1950
1956
1962
1969
1976
1982
1988
1995
2001
2007
2014

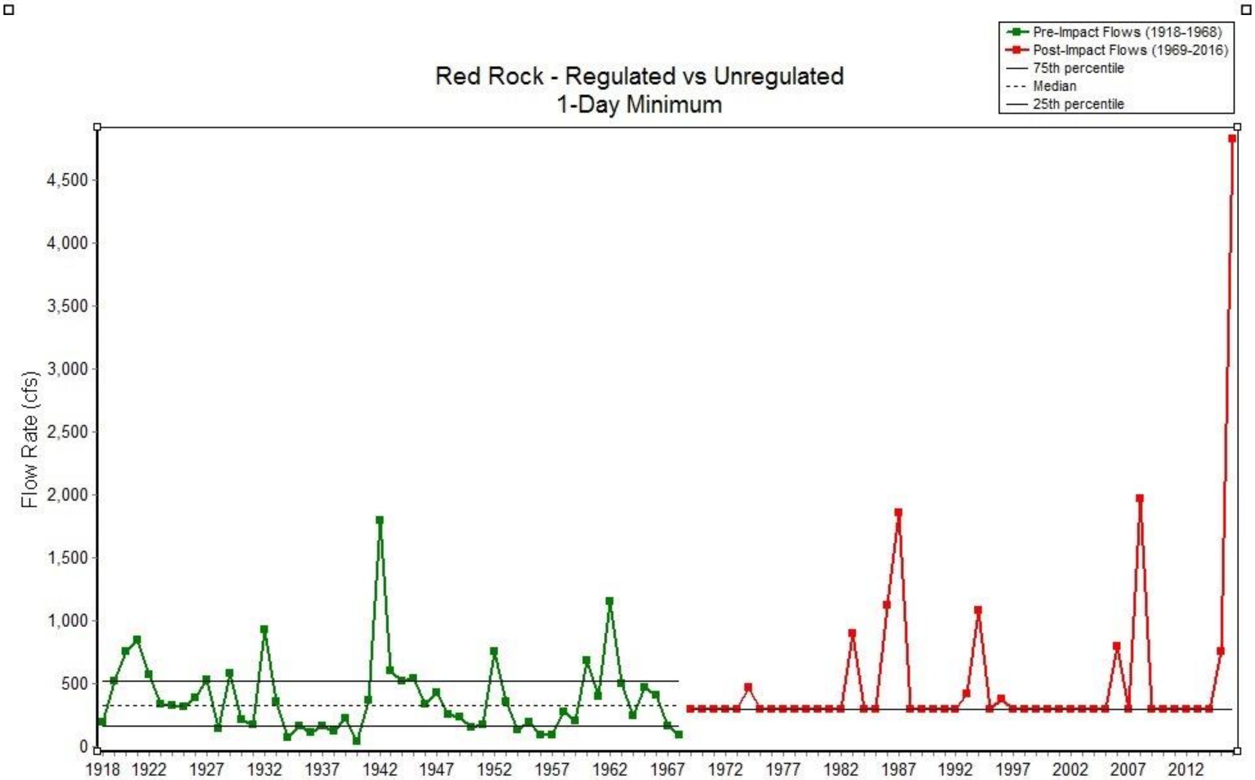


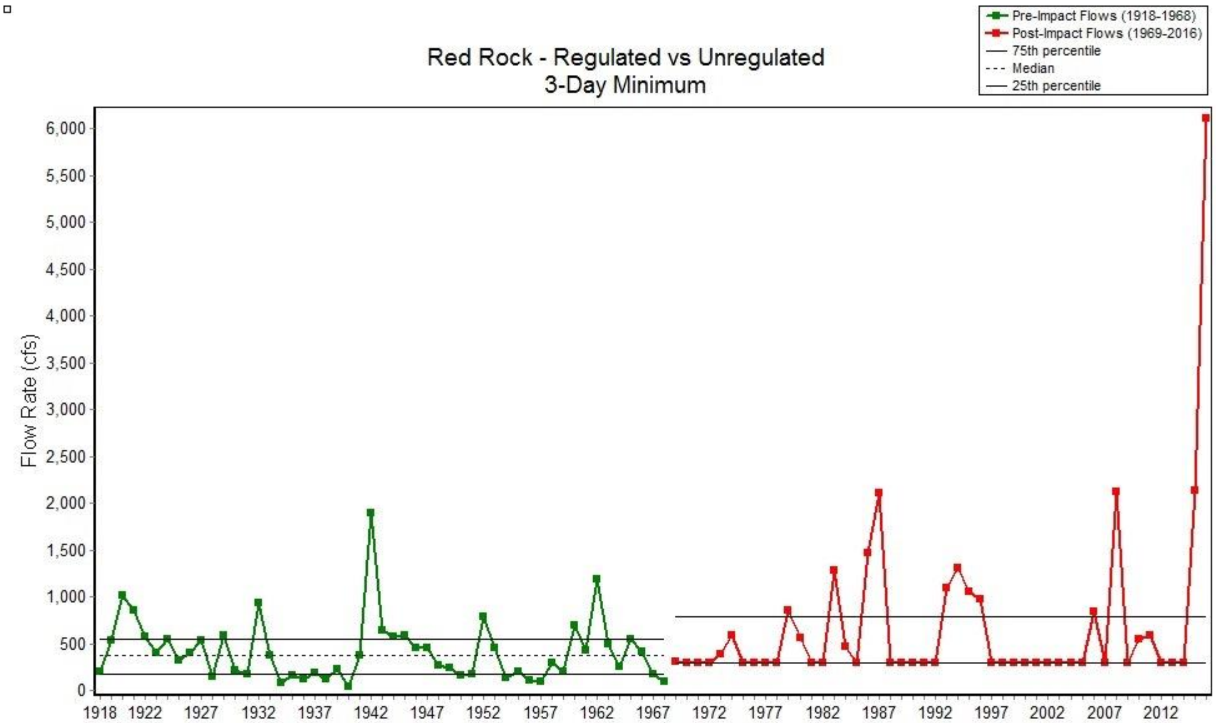
Red Rock - Regulated vs Unregulated
7-Day Maximum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
RVA High Boundary
Median
RVA Low Boundary
Flow Rate (cfs)
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

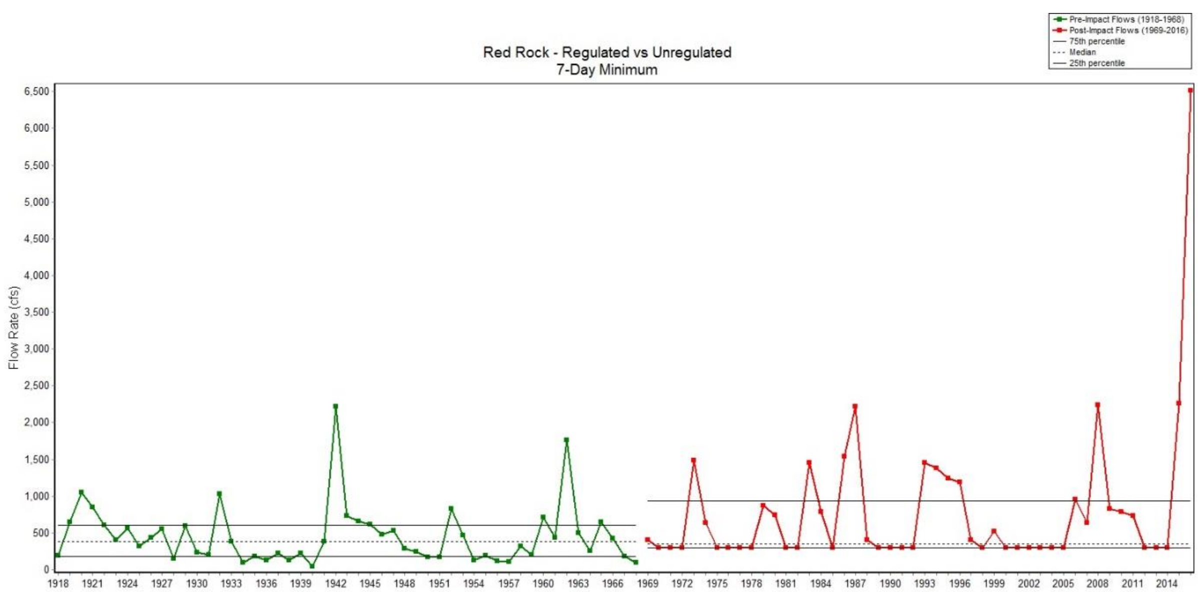


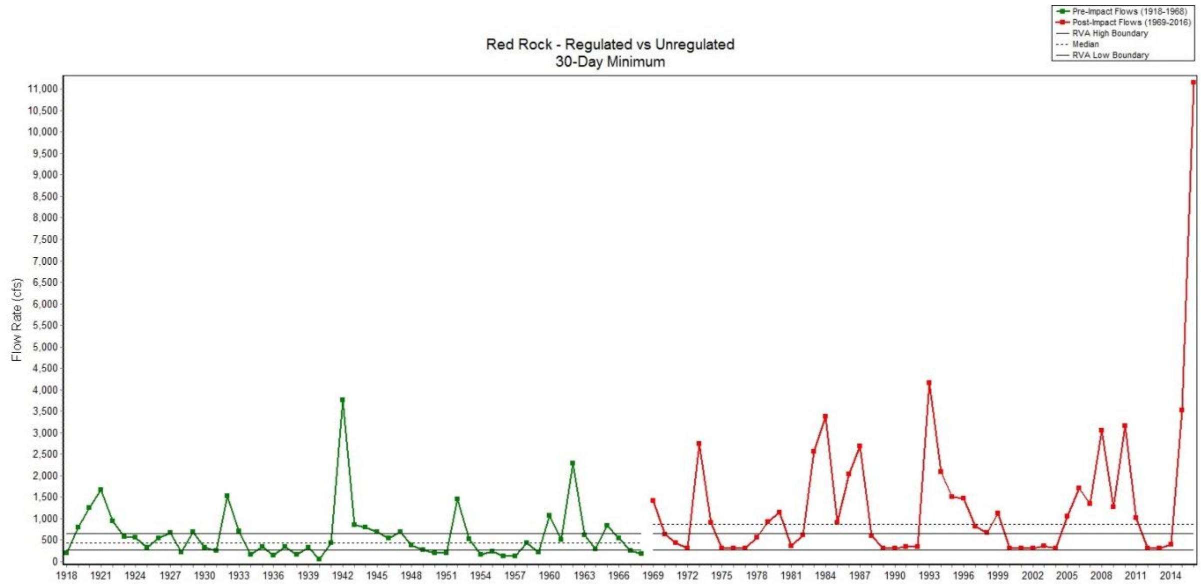
Red Rock - Regulated vs Unregulated
30-Day Maximum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
RVA High Boundary
Median
RVA Low Boundary
Flow Rate (cfs)
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

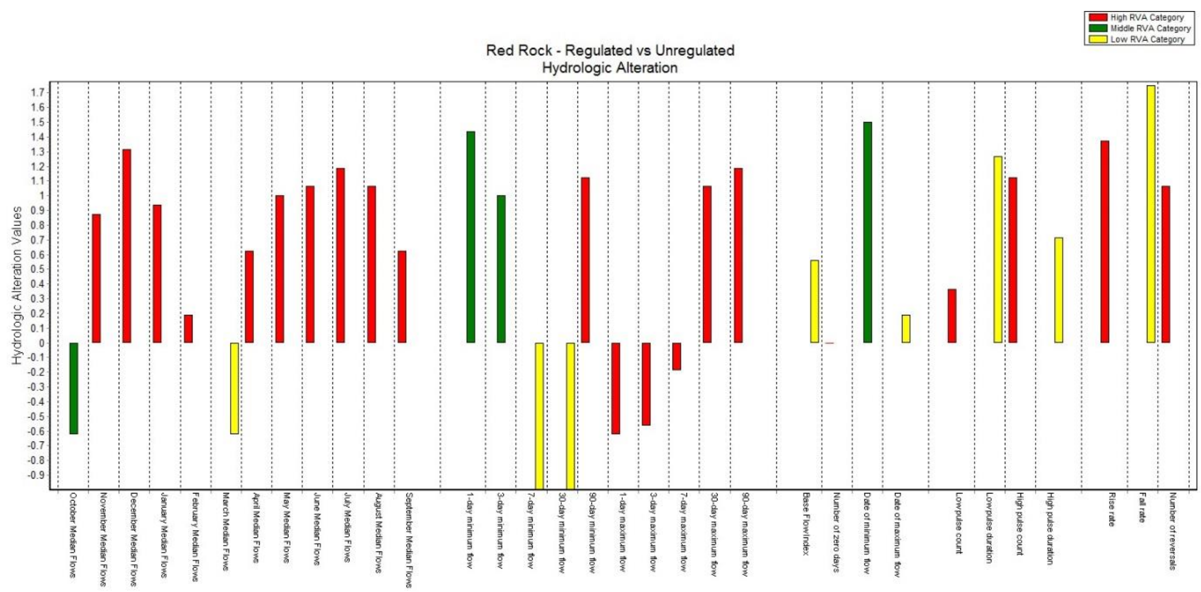

Red Rock - Regulated vs Unregulated
90-Day Maximum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1918 1924 1930 1936 1942 1948 1954 1960 1966 1972 1978 1984 1990 1996 2002 2008 2014

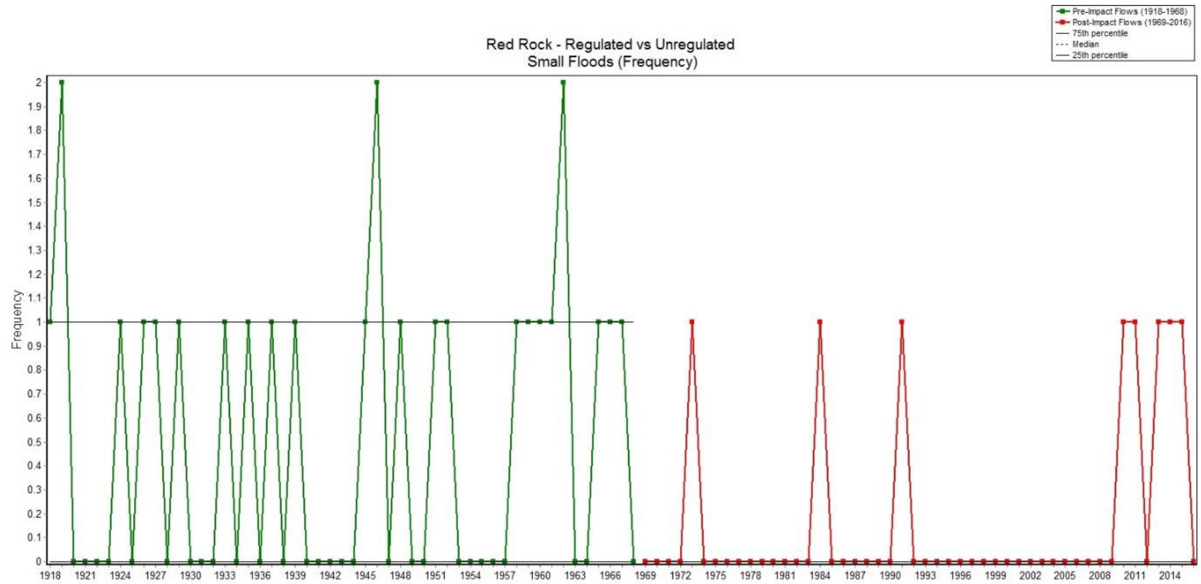

Red Rock - Regulated vs Unregulated
1-Day Minimum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1918 1922 1927 1932 1937 1942 1947 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 2002 2007 2012

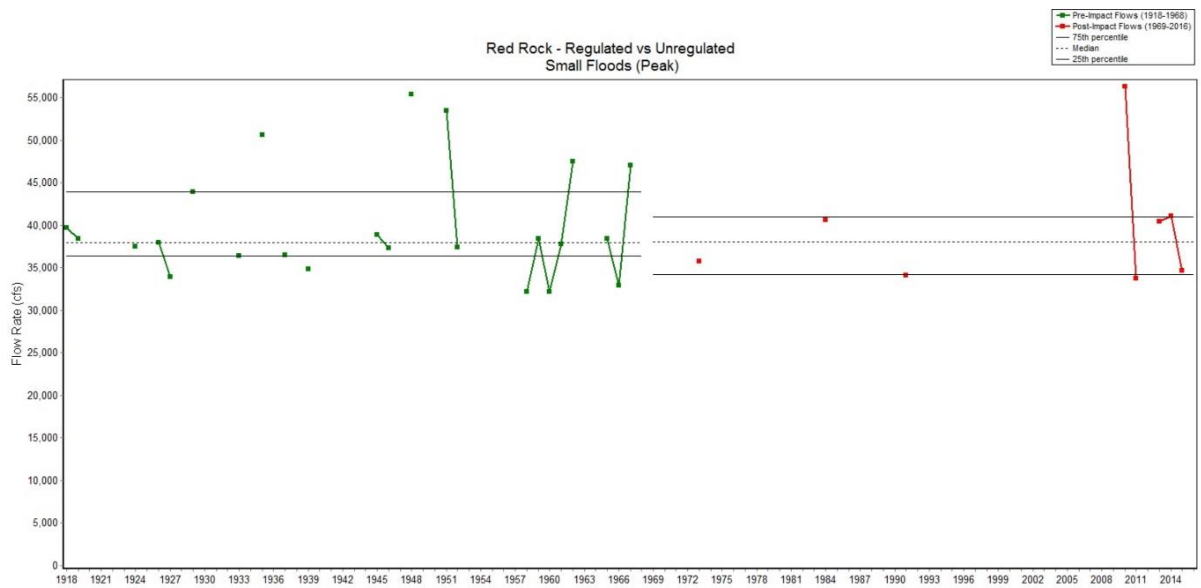

Red Rock - Regulated vs Unregulated
3-Day Minimum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1918 1922 1927 1932 1937 1942 1947 1952 1957 1962 1967 1972 1977 1982 1987 1992 1997 2002 2007 2012


Red Rock - Regulated vs Unregulated
7-Day Minimum
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1918 1921 1924 1927 1930 1933 1936 1939 1942 1945 1948 1951 1954 1957 1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014


Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
RVA High Boundary
Median
RVA Low Boundary
Red Rock - Regulated vs Unregulated
30-Day Minimum
Flow Rate (cfs)


High RVA Category
Middle RVA Category
Low RVA Category
Red Rock - Regulated vs Unregulated
Hydrologic Alteration
Hydrologic Alteration Values
October Median Flows
November Median Flows
December Median Flows
January Median Flows
February Median Flows
March Median Flows
April Median Flows
May Median Flows
June Median Flows
July Median Flows
August Median Flows
September Median Flows
1-day minimum flow
3-day minimum flow
7-day minimum flow
30-day minimum flow
90-day minimum flow
1-day maximum flow
3-day maximum flow
7-day maximum flow
30-day maximum flow
90-day maximum flow
Base Flow Index
Number of zero days
Date of minimum flow
Date of maximum flow
Low pulse count
Low pulse duration
High pulse count
High pulse duration
Rise rate
Fall rate
Number of reversals


Red Rock - Regulated vs Unregulated
Small Floods (Frequency)
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Frequency


Red Rock - Regulated vs Unregulated
Small Floods (Peak)
Pre-Impact Flows (1918-1968)
Post-Impact Flows (1969-2016)
75th percentile
Median
25th percentile
Flow Rate (cfs)

Saylorville

- Pre-impact flow series: unregulated flow times series for Water Years 1919-1976.
- Post-project flows: regulated flow time series 10/1/1977 – 9/30/2015.

Summary: Impacts of the dam on downstream flows pre- versus post-project are similar to those observed below Red Rock. Overall consistent increases in magnitude of all environmental flow components (low flows, monthly and seasonal flows, small floods, and high flows) are primarily attributable to basinwide changes in yield related to basin land use, management, and increased precipitation associated with climate change. Impacts of the project have been to reduce the frequency and duration of flow magnitudes exceeding bankfull, as well as significantly increased mean and median rise and fall rates.

Appendix C. Stakeholder Issues

The following is a synthesis of issues to be explored in the literature review, identified by stakeholders in a series of meetings and workshops led by Hugh Howe and Dave DeGeus 2015-2016.

<u>Stakeholders have identified 8 issues as primary issues of concern for flow regime management</u>

1. Nitrate levels
2. Mussel Mortality
3. Sturgeon Mortality
4. Gas Bubble Trauma
5. Migrating Waterfowl and Shorebirds
6. Herptiles
7. Streambank Erosion and Sedimentation
8. River Recreation

What are the opportunities for flow management with respect to these 8 issues? How have dam operations changed river hydrology and morphology? How does current and pre-dam channel morphology in the Des Moines River from the upper limits of Saylorville to the Mississippi River. How do current flows and changes in flow affect channel habitat? What opportunities exist in the Des Moines River to develop structure or off-channel habitat for aquatic and bird life (e.g. reconnection of old ox-bows)? When considering birds, herps, mussels and fish species of greatest conservation need, are there flow management strategies that would benefit all? How do instream withdrawals and water use impact river levels? How has usage changed since the dams were initially put in service? The Red Rock Dam and reservoir currently has a conservation pool to maintain no less than 300 cubic feet per second (CFS) outflows during dry periods. The Saylorville Dam and reservoir currently has a conservation pool to maintain no less than 200 CFS outflows during dry periods. How do these minimum flows relate to natural low flows, and what are the implications for aquatic life? For all of the above, recommend metric(s) to gauge results and most efficient method to monitor.

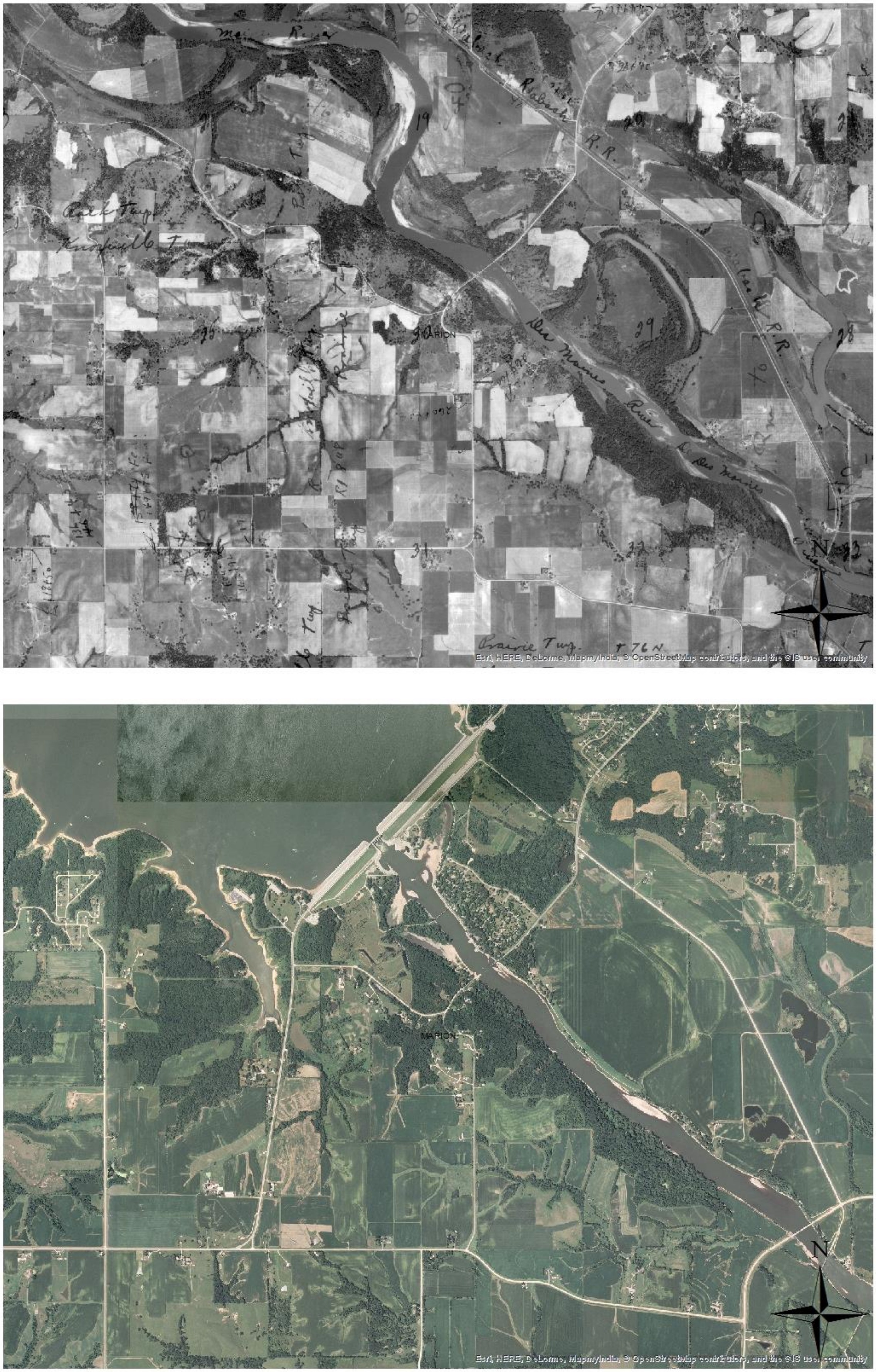
1. **Reduce Nitrate Levels**
    a. What water level management practices can maximize nitrate reductions within Saylorville and Red Rock reservoirs?
    b. What flow management practices at Saylorville and Red Rock can maximize nitrate reductions for downstream customers and aquatic life? Quantify benefits on a graduated scale.
    c. Correlate nitrate reduction to economic benefit in water treatment for users on the Des Moines River.
2. **Reduce Mussel Mortality**
    a. In general, identify presence and status of mussel species from upper limits of Saylorville to the Mississippi. What are the seasonal habitat preferences of mussels and what is their ability to move with changing flows and water levels? What are the lifecycle and reproductive needs of mussels and or impacts related to water flow, water depth, temperature, oxygen, host species, stability of substrate, nutrients, and sediment? Which mussels are reproducing fast enough in the lower Des Moines to sustain healthy populations? Which mussels are in decline or not longer present?

   b. Are mussel host species able to pass upstream of the Ottumwa hydroelectric plant? During what flows and/or gate settings? Are there flow management strategies that could benefit mussels relative to current operations?
3. **Reduce Sturgeon Mortality**
   a. How do sturgeon populations below the Red Rock Dam respond to temperature stimuli and low flows during hot periods and what measures (in-stream and riparian structural or flow management) can be utilized to help mitigate those adverse periods? How can flows be altered to reduce temperature induced mortality?
   b. What are the reproductive requirements and habits of sturgeon and how important is the lower Des Moines River to the overall population of sturgeon in the Mississippi River for spawning?
   c. Identify time of the year sturgeon are in the Lower Des Moines River and identify geographically their major areas of use.
   d. Identify flow management strategies that would potentially benefit sturgeon.
4. **Reduce Gas Bubble Trauma**
   a. What flow conditions from both Saylorville and Red Rock dams cause gas bubble trauma and what specific measures can be taken to reduce or eliminate these effects?
5. **Improve Conditions for Migrating Waterfowl and Shorebirds**
   a. Lake Red Rock and Saylorville Lake is deemed a Globally Important Bird Area by the American Bird Conservancy. The Iowa Audubon Society has designated Lake Red Rock an Important Bird Area, citing its values of rare or unique habitats, and significant species concentrations. What are the specific needs and optimal reservoir conditions for migrating birds at Saylorville Lake and Lake Red Rock?
   b. What reservoir water management practices would encourage germination of wild plants for waterfowl to benefit migrating birds?
   c. Saylorville Lake and Lake Red Rock Regulation Manuals currently allow the Iowa Department of Natural Resources to request a fall lake raise for the purpose of aiding waterfowl. Lake Red Rock can raise the lake from September to December 15th of each year and Saylorville Lake can hold the fall lake raise through March 1st of the following year. IDNR Wildlife Bureau managers do not believe the allowable raise is adequate due to accumulated sediment and impact on hunting access via water. What are the ideal fall lake raise parameters for waterfowl hunting at Saylorville Lake and Lake Red Rock?
   d. Recommend flow management strategies that are most beneficial to migrating waterfowl and shorebirds.
6. **Improve Conditions for Herps**
   a. What are the seasonal habitat preferences of herps and what is their ability to move with changing flows and water levels in the Des Moines River from the upper limits of Saylorville to the Mississippi? Are there riparian or riverine habitat restorations that could benefit reptiles and amphibians when subjected to changing flow regimes?
   b. Which herps are reproducing fast enough in the Des Moines River to sustain healthy populations? Which herps are in decline or not longer present? In general, geographically identify presence of herps species from upper limits of Saylorville to the Mississippi.
   c. What flow management practices at Saylorville and Red Rock Dam could aid herp life cycles?
7. **Reduce Stream Bank Erosion**
   a. Are there opportunities to reduce stream bank erosion with specific flow regime practices at Saylorville and Red Rock Dams?
   b. Identify geographically the areas of most active bank erosion along the Des Moines River from upper limits of Saylorville to the Mississippi.
8. **Improve Conditions for River Recreation**

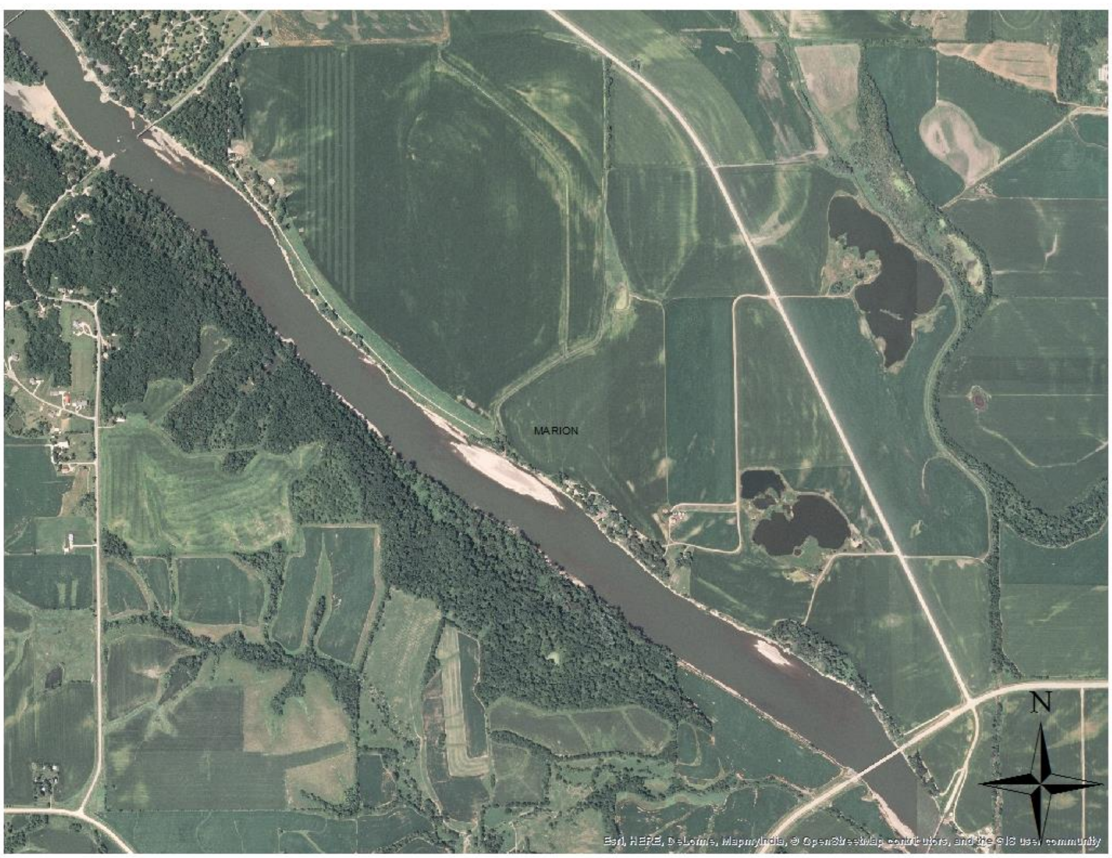
a. Identify events in the past five years (canoe/kayak/triathlon) that have been affected by stream flows in the Des Moines River and determine what, if any, could have been improved with short term flow deviations from Saylorville and Red Rock Dams.
b. What are the ideal flows for specific stretches of the Des Moines River for canoe/ kayak/boating?
c. Recommend flow management strategies that would be most beneficial to Des Moines River non-motorized boating.

Appendix D. Observations of channel change below Red Rock Dam: comparison of aerial photos 1930s versus 2009

Figures D-1 through D-3. Side-by-side comparisons of aerial photos from 1930 (top photo) versus 2009 (bottom photo). In Figures D-1, and D-2 the dam site is located at the upper left corner of the photo. In each case, the view extent is the same for the top and bottom photo.



Figures D-2. Side-by-side comparisons of aerial photos from 1930 (top photo) versus 2009 (bottom photo). This series shows the lower portion of Lake Red Rock in the upper left and the reach extending from the dam to , a zoomed-in view relative to Figure D-1.



Figures D-3. Side-by-side comparisons of aerial photos from 1930 (top photo) versus 2009 (bottom photo). This photo shows a closeup of the abandoned oxbow visible in the 1930s and labelled “29” (top photo). In the 1930s, the oxbow area had significant perennial vegetation and may still experienced connectivity with the river at high flows. In the 2009 photo, the trees have been removed and the area appears to be in crop rotation.