ERDC Contract Report

Engineer Research and Development Center

US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

Coralville Lake, Iowa River, IA

Literature and Data Review

Chuck Theiling

September 2020

Program Title: Sustainable Rivers Program

ERDC Contract Report
August 2021

Coralville Lake, Iowa River, IA

Literature and Data Review

Chuck Theiling

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Rd
Vicksburg, MS 39180

charles.h.theiling@usace.army.mil

Final Report August 26, 2021

Prepared for U.S. Army Corps of Engineers
Rock Island District

Monitored by Environmental Laboratory
U.S. Army Engineer Research and Development Center
Vicksburg, MS 39180

Abstract

Coralville Lake, Iowa managers in the US Army Corps of Engineers Rock Island District are investigating Environmental Flows (E-Flows) opportunities for a new reservoir water regulation plan. A literature and data review of Coralville Dam operations and environmental impacts was required to assess existing conditions and need for change. Hydrologic data were summarized using E-Flows planning principles and Indicators of Hydrologic Alteration software developed by The Nature Conservancy.

The Coralville Dam created a large lake that supports environmental and recreational opportunities that are being diminished by sedimentation and nutrient enrichment. Current dam operating procedures alter hydrology by storing water which lowers flood peaks downstream and extends moderate high flows over longer durations. Average and minimum flows are higher than without the dam as floodwaters are released over longer periods.

Impacts of reduced flood peaks and sustained bankfull flow are increased stream bed and bank erosion which increases sedimentation and degrades river habitat, and reduced migratory cues and limited access to floodplain habitats for fish. Downstream geomorphic, water quality, and habitat processes and functions may also be impacted by dam operations. Resource management stakeholders were engaged to share knowledge and agency objectives prior to an April 2021 planning workshop.

Contents

Figures and Tables

Figures

Tables

Preface

This study was conducted for the Sustainable Rivers Program under Project I21-005 “Coralville Lake: Literature and Data Review” The technical monitor was C.H. Theiling.

The work was performed by the Ecological Resources Branch (EE-E) of the Ecosystem Evaluation and Engineering Division, U.S. Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Eric Britzke was Acting Chief, CEERD-EE-E; Mark Farr was Chief, CEERD-EE; and John Hickey, HEC was the Sustainable River Program manager. The Deputy Director of ERDC-EL was Dr. Mark Noel and the Director was Dr. Edmund Russo.

COL Teresa Schlosser was the Commander of ERDC, and Dr. David Pittman was the Director.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
miles (U.S. statute)	1,609.347	meters
square miles	2.589998 E+06	square meters

1 Purpose of this Hydrologic Assessment

Hydrology has been described as the “master variable” or ecological driver that establishes the physical energy shaping river and floodplain geomorphology, influencing water quality, and regulating biological cycles (Karr 1991, Poff et al. 1997). However, these complex physical and biological relationships were not appreciated during the decades following WWII through the 1970s when thousands of dams were constructed to spur economic development in the form of flood protection, hydropower, water supply, and recreation. While the complex ecological relationships of river and floodplain connections in Midwest glacial rivers were understood by the 1890s (Kofoid 1903), the social drivers for economic development and widespread lack of appreciation for the value of ecosystem goods and services (Millennium Ecosystem Assessment 2005, Postel and Carpenter 2012) outweighed environmental arguments against dams. It was not until the 1980s that the environmental movement began organizing to highlight the negative ecological consequences of large dams (International Rivers: https://www.internationalrivers.org/a-timeline-of-protecting-rivers-and-rights; McCully 2001).

> Ecosystem Goods and Services – “Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth” (Millennium Ecosystem Assessment 2005)

The Corps of Engineers began investigating the ecological impacts and opportunities of large dam re-regulation in 1999 through 2002 in partnership with The Nature Conservancy on the Green River, Kentucky (Konrad 2010). They reviewed dam operations with the intent to make modifications which would benefit freshwater mussels and native fish species in the river downstream from Corps dams. They developed a process to define environmental flow prescriptions (Richter et al 2006) which specify the characteristics of stream flow required for specific ecological outcomes

(Konrad 2010). These environmental flow prescriptions address river and floodplain flow and inundation characteristics including floods, high-flow pulses, base flows, and extreme low flows which support various ecosystem functions (see below). The Sustainable Rivers Program investigated four more river systems before 2008 and it has continued to expand since then (Figure 1). Environmental flow prescriptions have since been defined for 16 rivers and 66 federal dam sites. Sustainable River Program planning in Iowa began in 2016 at the Rock Island District, Saylorville Lake and Lake Red Rock near Des Moines, Iowa where environmental flow prescriptions were established by an interdisciplinary team making recommendations for a new reservoir regulation plan (Blann 2016, Blann 2017). The Iowa River Sustainable Rivers Program initiative shown as proposed 2020 in Figure 1 has indeed been funded and is the focus of this data and literature review which considers the environmental effects and opportunities of Coralville Dam operations.

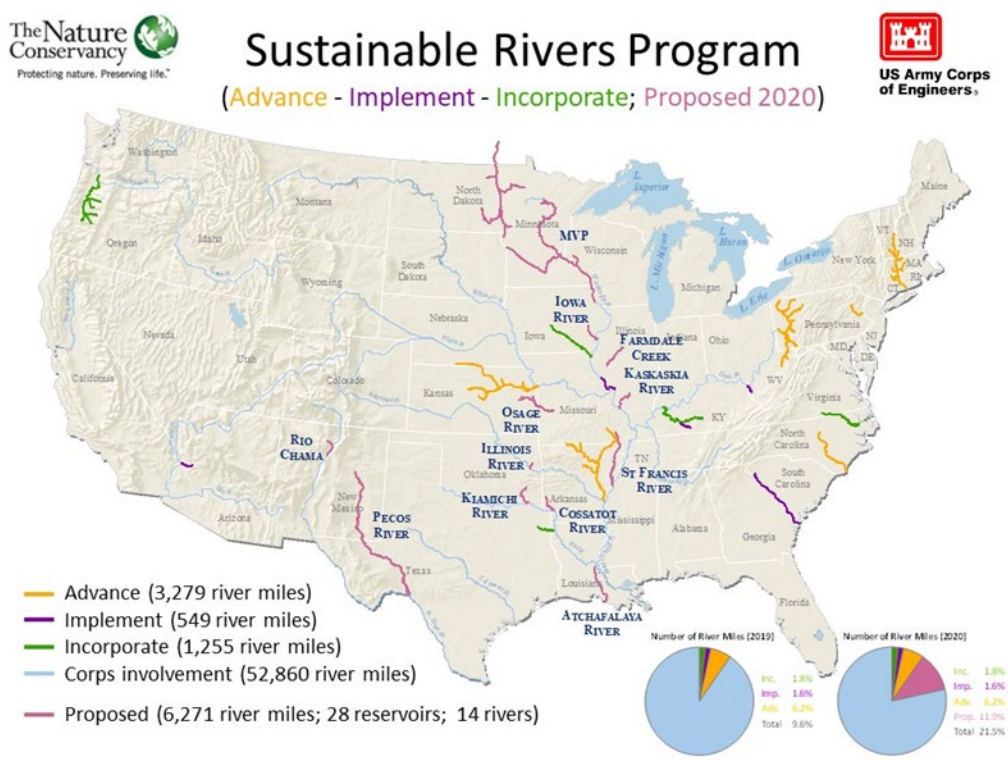


Figure 1. Sustainable River Program implementation since its inception in 1999.

1.1 What are Environmental Flows?

"Environmental flows are the quantity and timing of water flows required to maintain the components, functions, processes and resilience of aquatic ecosystems and the goods and services they provide to people." (The Nature Conservancy: https://www.conservationgateway.org/Conservation-Practices/Freshwater/EnvironmentalFlows/Concepts/Pages/environmental-flows-conce.aspx). They have been disturbed by river infrastructure like dams, levees, and navigation systems which were constructed to increase public safety and economic development. In Midwest agricultural watersheds upland drainage also caused significant alteration in runoff patterns and stream hydrology because of the conversion of natural prairie, oak savanna, and forest landscapes to agriculture which has evolved to today's ubiquitous row crop agriculture. The massive level of landscape conversion was achieved through drainage of the Prairie Pothole Region (Bishop 1981, Johnson et al. 2008, Lenhart et al. 2012) most notably, but throughout the Upper Midwest (Dahl 1990, McCorvie and Lant 1993, Rhodes et al. 2016). Ditches were dug to drain surface water and buried drainage tile were installed to increase infiltration to reduce ponding and optimize soil moisture for crop fields (McCorvie and Lant 1993, Johnson et al. 2008). Landscape conversion changed watershed drainage networks (Lenhart et al. 2012, Rhodes et al. 2016) effecting the rate and mode of runoff from snowmelt and rainfall which resulted in altered hydrology and material transport over entire watersheds (Lenhart et al. 2012).

There has been significant effort expended and policy development to conserve fish and wildlife resources through the U.S. Fish and Wildlife Service refuge system, US Environmental Protection Agency, and their state level counterparts protecting land, water, fish, and wildlife resources. Early river conservation efforts were aimed at maintaining commercial and recreational fisheries (Carlander 1954) and waterfowl populations (Rahn 1983). Single species management to optimize conditions for specific classes of wildlife on the remaining public lands was common in the past (Stalnaker and Arnette 1976; Fredrickson and Taylor 1982). A focus on stream flow requirements for fisheries resources related to hydropower and other water development projects emerged in the 1970s with the development of many different flow assessment methodologies (Tennant 1976, Orth 1987). The Instream Flow Incremental Methodology (Bovee 1982) emerged as the state of the art for many years (Orth 1987). Karr (1981) established the

Index for Biological Integrity which used fish community structure to assess stream conditions. These frameworks grew into an entire field of USEPA regulatory assessments using multi-metric habitat evaluation frameworks (Plafkin et al. 1989; Barbour et al. 1999).

Single species management and regulatory assessments provided a narrow view of ecological systems, so an emphasis on "ecosystem management" as a holistic natural resource management philosophy emerged in the 1980s (Grumbine 1984). River ecosystem management concepts in rivers were communicated as the publication of the River Continuum Concept (Vannote et al. 1980) and variations on it like the Serial Discontinuity Concept (Ward and Stanford 1983) and the Flood Pulse Concept (Junk et al. 1989).

The ecosystem approach led to the increased awareness of ecosystem "drivers" which are physical processes that regulate habitat and biological outcomes (Harwell et al. 1999). River ecologists adopted the concept and identified hydrology as a particularly strong driver of riverine and floodplain ecology which led to a series of investigations and literature reviews that coined the term and philosophy of the Natural Flow Regime (Poff et al. 1997). River scientists and managers adopted the philosophy as environmental flows management to address the complexities of river hydrology and its influence on biological outcomes (The Nature Conservancy: https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/Pages/environmental-flows.aspx; International Rivers: https://www.internationalrivers.org/environmental-flows; and IUCN: https://www.iucn.org/downloads/water_briefing_eflows.pdf).

"Unlike the natural flow regime, the environmental flow regime allows for some degree of hydrologic alteration. However, environmental flows are intended to mimic the patterns and ecological outcomes of the natural flow regime" (The Nature Conservancy: https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/Concepts/Pages/environmental-flows-conce.aspx). Natural Flow Regime assessment focuses of key aspects of hydrologic patterns including: magnitude, frequency, duration, timing and rate of change of river flows. E-flows planning considers hydrologic events as several key characteristics of river hydrology (Box 1): normal baseflow levels, drought level flows, high pulse flows, and floods. Each of these hydrologic events is a necessary component of highly connected, disturbance driven river ecosystems (Ward et al. 1999). Normal baseflow is the typical river level that supports habitat and biogeochemistry requirements of most ecological communities and species. Droughts are a disturbance that help regulate geomorphic processes and drought adapted plant species. High flows also regulate geomorphology and plant communities, as well as, maintaining connectivity and biogeochemistry. Floods provide similar functions as high flows but spread the effects over the floodplain which establishes its role as an integral component of the river-floodplain ecosystem. Flow-ecology relationships established for the Des Moines River below Lake Red Rock (Figure 2), Iowa provide examples of factors that might be important on the Iowa River.

A formal planning process for environmental flows management was developed by Postel and Richter (2003). They developed methods and tools to evaluate river conditions relative to ecological requirements and quantify the differences using a set of streamflow statistics. Understanding river conditions and the management capability of built infrastructure to support multiple objectives creates opportunities for environmental flow prescriptions, or water management strategies, to achieve greater ecosystem benefits. Environmental flows planning has been adopted worldwide, and formally within the Corps of Engineers and The Nature Conservancy as the Sustainable River Program. The objective of this review is to establish an understanding of the existing condition of Iowa River flows in relation to operation of the Coralville Dam as basis to consider future operational changes in dam operations.

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)

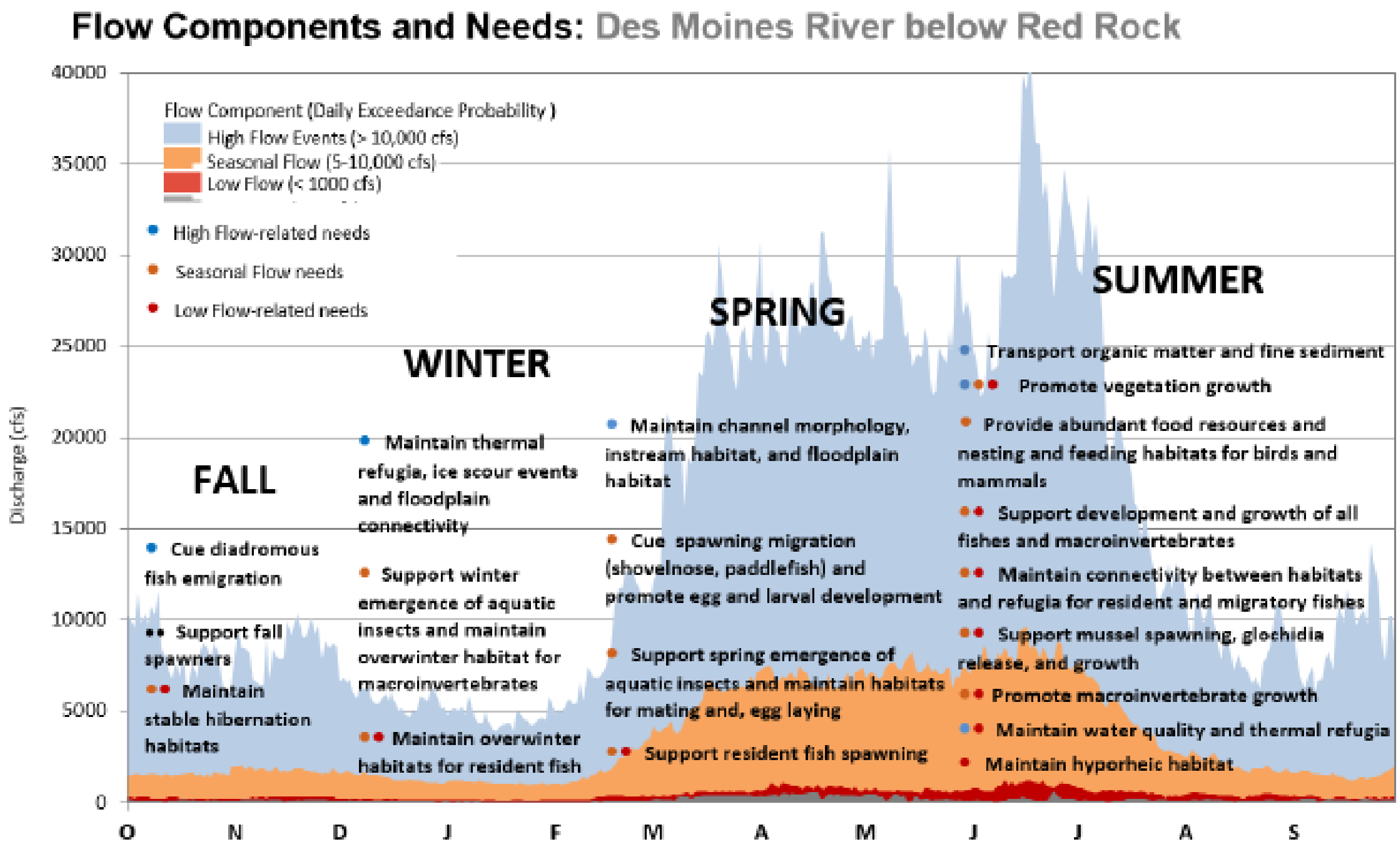


Figure 2. Flow-ecology relationships for the Des Moines River below Lake Red Rock (Source: Blann 2016).

2 Iowa River Basin Characteristics and Hydrology

2.1 Watershed Characteristics

The Iowa River flows 520 km (323 mi.) southeast across Central Iowa (Figure 3). The Cedar River is a significant subwatershed making up 20,258 km^2 (7,822 mi^2.; 5,005,861 acres) of the northern Iowa River basin. This review is for Coralville Lake which is upstream of the confluence with the Cedar River, so the focus here is on the Iowa River exclusive of the Cedar River. This subwatershed is 12,429 km^2 (4,777 mi^2.; 3,071,387 acres). The subwatershed above Coralville Lake is 8,068 km^2 (3,115 mi^2.; 1,993,600 acres) where it drains mostly cropland. Coralville Lake was completed in 1958 to provide flood control, its size ranges from 21.4 km^2 (8.5 mi^2.; 5,280 acres) at normal pool levels to 100 km^2 (38.8 mi^2.; 24,800 acres) at full flood pool. The length of the lake ranges 37 km (23 mi.) at pool stage to 67 km (41.5 mi.) at full flood pool (USACE 2001).

The land cover in the Iowa River subwatershed is predominantly in agricultural production with 73 percent in row crops and 10 percent in hay/pasture (Table 1). Forest, herbaceous (likely Conservation Reserve Program land), and woody wetlands cover only 5, 3, and 2 percent, respectively, of the subwatershed (Figure 4).

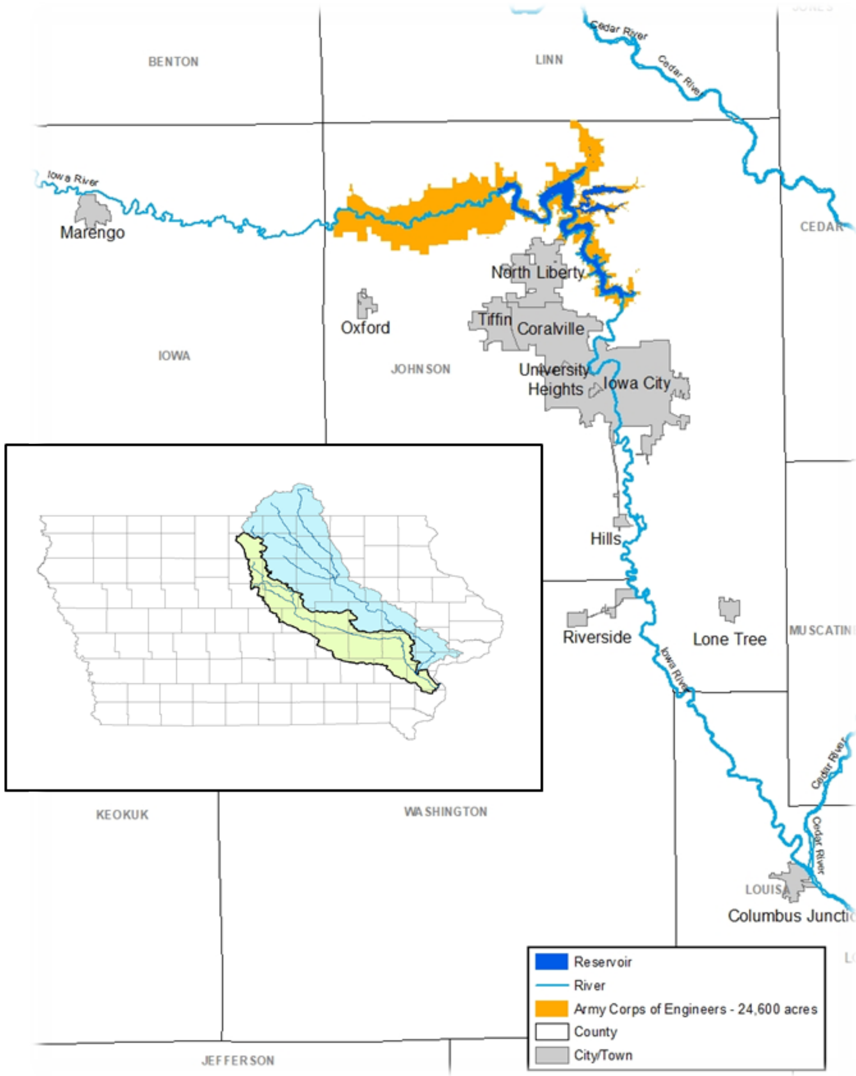


Figure 3. Iowa River near Coralville Lake and subwatershed delineation inset (Cedar River blue, Iowa River green).

Land Cover class	Percent of Subwatershed
Barren Land	0%
Cultivated Crops	73%
Deciduous Forest	4%
Developed, High Intensity	0%
Developed, Low Intensity	2%
Developed, Medium Intensity	1%
Developed, Open Space	3%
Emergent Herbaceuous Wetlands	1%
Evergreen Forest	0%
Hay/Pasture	10%
Herbaceuous	3%
Mixed Forest	1%
Open Water	1%
Shrub/Scrub	0%
Woody Wetlands	2%

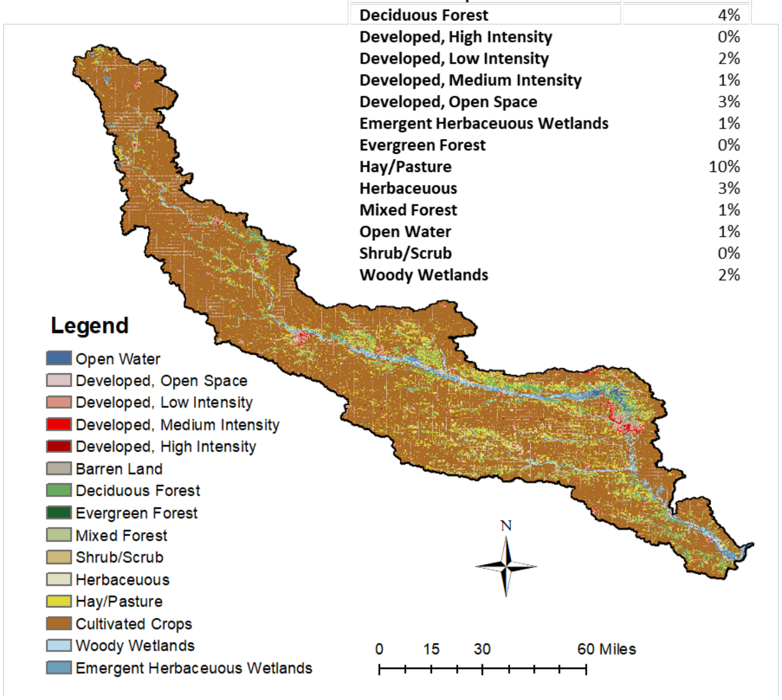


Figure 4. Iowa River land cover (Source: 2016 National Land Cover Database).

2.2 Geology and Soils

Iowa is a glacial region with diverse landscape characteristics as a result. Glaciers advanced and retreated many times over 2 million years until about 14,000 – 12,000 years ago with the end of the Wisconsin Age glacial advance (Prior 1991; https://www.iihr.uiowa.edu/igs/landscape-features-of-iowa/?doing_wp_cron=1592236127.8692739009857177734375). Glaciers shaped the landscape as they transported massive amounts of soil and rock which was left in place as mixed glacial till hundreds of feet deep in some places. Glacial meltwaters transported and sorted sediment which formed many interesting landscape features, like kames, eskers, and moraines, as water flowed into, under, and along the edge of the retreating ice sheets.

The prominent glacial landforms in the Iowa River watershed are the Des Moines Lobe in the upper part of the watershed and the Southern Iowa Drift Plain in the lower two-thirds (Figure 5). There is a small region of the Iowan Surface and Iowa-Cedar Lowland below the confluence with the

Cedar River downstream to the Mississippi River Alluvial Plain. The Des Moines Lobe is the most recent glaciation which created the “Prairie Pothole” region extending north through Minnesota, the Dakotas, and Canada. Glaciers left small lakes, prairie potholes and other depressions (Prior 1991) that held water and created lakes, ponds, and numerous permanent and seasonal wetlands in a prairie environment. The young, flat landscape was poorly drained (Prior 1991) and held water seasonally in potholes as water seeped slowly through deep prairie soils and glacial till with poorly defined surface drainages (LaBaugh et al. 2018; Hayashi et al. 2016). The Southern Iowa Drift Plain is a much older landscape, last glaciated hundreds of thousands of years ago (Prior 1991). Erosion and weathering has obliterated the glacial features leaving only thick deposits of glacial till as evidence of the distant past. The branching stream networks carved down through the glacial plains and into older landform surfaces to create the “deeply creased” landscapes familiar to most of southern Iowa. The Iowa-Cedar Lowland is one of three large alluvial sediment regions in Iowa which were created over hundreds of thousands of years as rivers transported, sorted, and deposited sediment during glacial retreat and seasonal flooding over thousands of years (Prior 1991). Through the Holocene epoch and continuing to the present period, stream networks experienced periods of entrenchment, erosion and net transport, and aggradation and soil formation as they formed into well connected drainage systems that erode and transport sediment and materials through watersheds (Bettis and Mandel 2002).

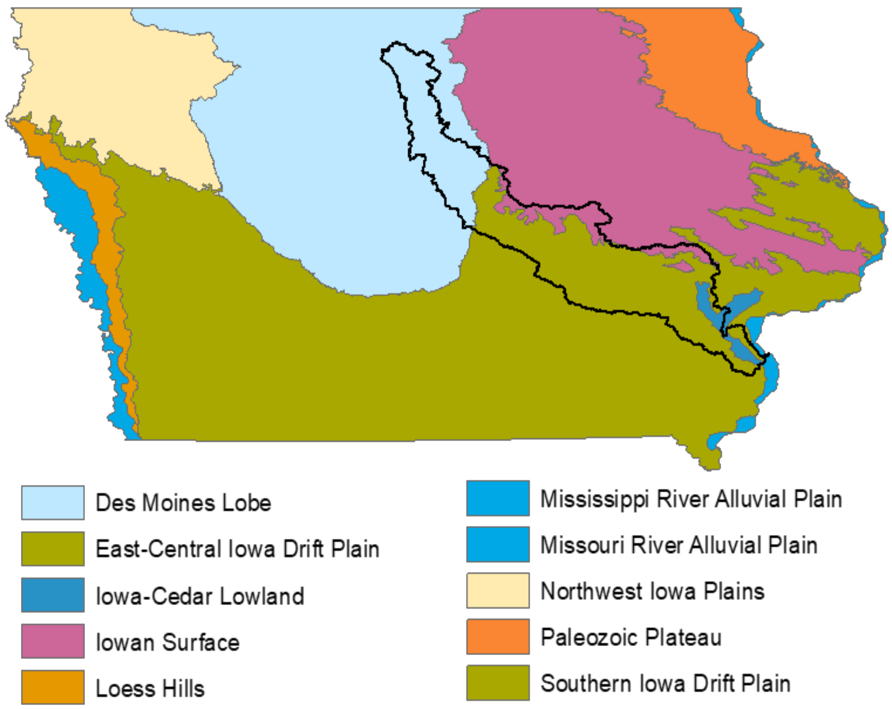


Figure 5. Iowa Landform Regions (Prior 1991; Source: Iowa Geological Survey).

As glaciers retreated and the Holocene climate stabilized the landscape transitioned through tundra, boreal forest, and finally prairie over the course of the ensuing 8,000 years (Bettis and Mandel 2002). The prairie landscape formed in response to dry westerly air for 6 – 9 months in normal years and 9 – 12 months in drought years (Ruhe 1974). The prairies were a subclimax community maintained by climate, fire, and successional advantage of prairie communities to limit germination of trees and other competitors (Transeau 1935). The rich prairie humus formed dark organic soils common throughout Iowa. The Iowa River Basin is mostly loamy Wisconsin glacial till in the upper watershed and loess through the lower two-thirds of the basin (Figure 6). Smith, Allaway, And Riecken (1950) describe the Tama soil series found in central and eastern Iowa as the "ideal" prairie soil and provided a lengthy description.

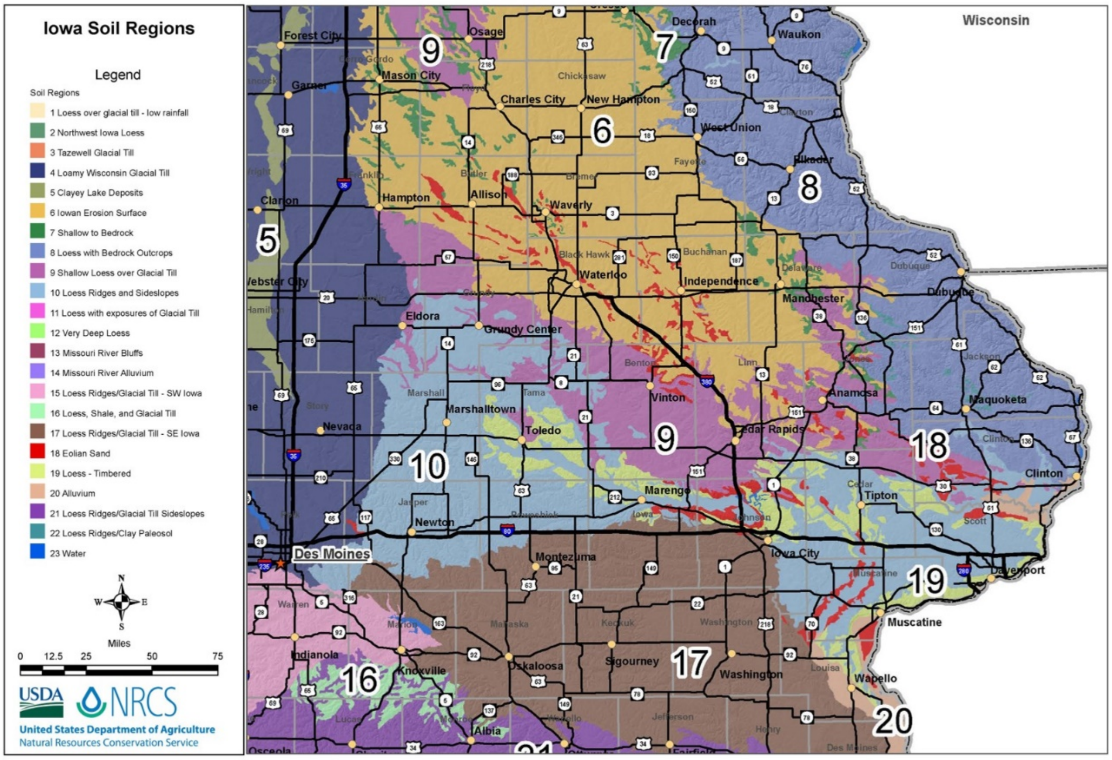


Figure 6. Iowa soil regions mapped by US Department of Agriculture, Natural Resources Conservation Service.

2.3 Climate and Hydrology

Iowa has a humid continental climate with seasonal extremes. The average temperature is around 10 °C (50 °F) with trends indicating change toward slightly warmer winters, spring is warmer, and summer and autumn temperatures are steady (Hillaker, 2014). Annual precipitation is 81 cm (32 inches), annual evaporation is 61 cm (24 inches), and annual runoff is 20 cm (8 inches) (Hillaker, 2014), average snowfall in Iowa City, Iowa is 66 cm (26 inches) falling from December to March (U.S. Climate data; https://www.usclimatedata.com/climate/iowa-city/iowa/united-states/usia0414). The likelihood of severe weather is high during the summer months. Iowa precipitation and runoff have been steady in winter, increasing during spring and summer, and steady in the autumn (Hillaker, 2014). The eastern side of the Iowa River basin receives more rain than the west.

The timing of Iowa River flow is seasonal with flow increasing with snowmelt in March and precipitation maintaining high flows from April through June. Discharge typically drops to summer low flows followed by a “fall bump” with a slight increase in flows in October-November that coincide with waterfowl migrations (Figure 7; Eash et al. 2015). Incidentally, the fall pool raise at Coralville Lake and other Rock Island District reservoirs mimics the fall bump for waterfowl management. Examining two time periods, Eash et al (2015) identify higher discharge in the recent (1984-2013) period compared to the long term (1957-2013) average daily discharge which is consistent with precipitation trends (Figure 7).

Flow magnitude increases downstream as tributaries add their contributions to Iowa River flows. The large difference in discharge above and below the Cedar River confluence is illustrated by the average annual discharge at Marengo, Iowa above Coralville Lake and at Wapello, Iowa which is the gage closest to the confluence with the Mississippi River (Figure 7). The average discharge is approximately four time higher at the downstream gage.

Average annual hydrology helps identify patterns while long term discharge records help understand the magnitude and duration of flow events. Daily discharge for the duration of gage records at upstream, Coralville Dam, and downstream locations (Figure 8; plotted on a log scale) illustrate the long-term flow variability. The long-term pattern of flow timing is similar among the gage sites, but the magnitude differs. Discharge at Marengo often exceeds the discharge at Coralville because of the flow attenuation capabilities of the flood control project. Flood mitigation is apparent in most years because discharge at Marengo frequently exceeds 10,000 cubic feet per second (cfs), but rarely exceeds 10,000 cfs at the dam outflow. Flood mitigation was not possible when the project design standards were exceeded during 2008 historic floods when discharge upstream of the lake was nearly 51,000 cfs in June and was still over 39,000 cfs at the dam outflow. Other large floods were controlled; during May/June 2013 discharge was 37,100 cfs upstream and only 18,400 cfs downstream of Coralville Lake and July 2014 flood attenuation was apparent with discharge of 26,800 cfs upstream and only 18,250 downstream. Discharge at Wapello, Iowa is largely unaffected by Coralville Dam operation because of the overwhelming influence of the Cedar River downstream from the confluence.

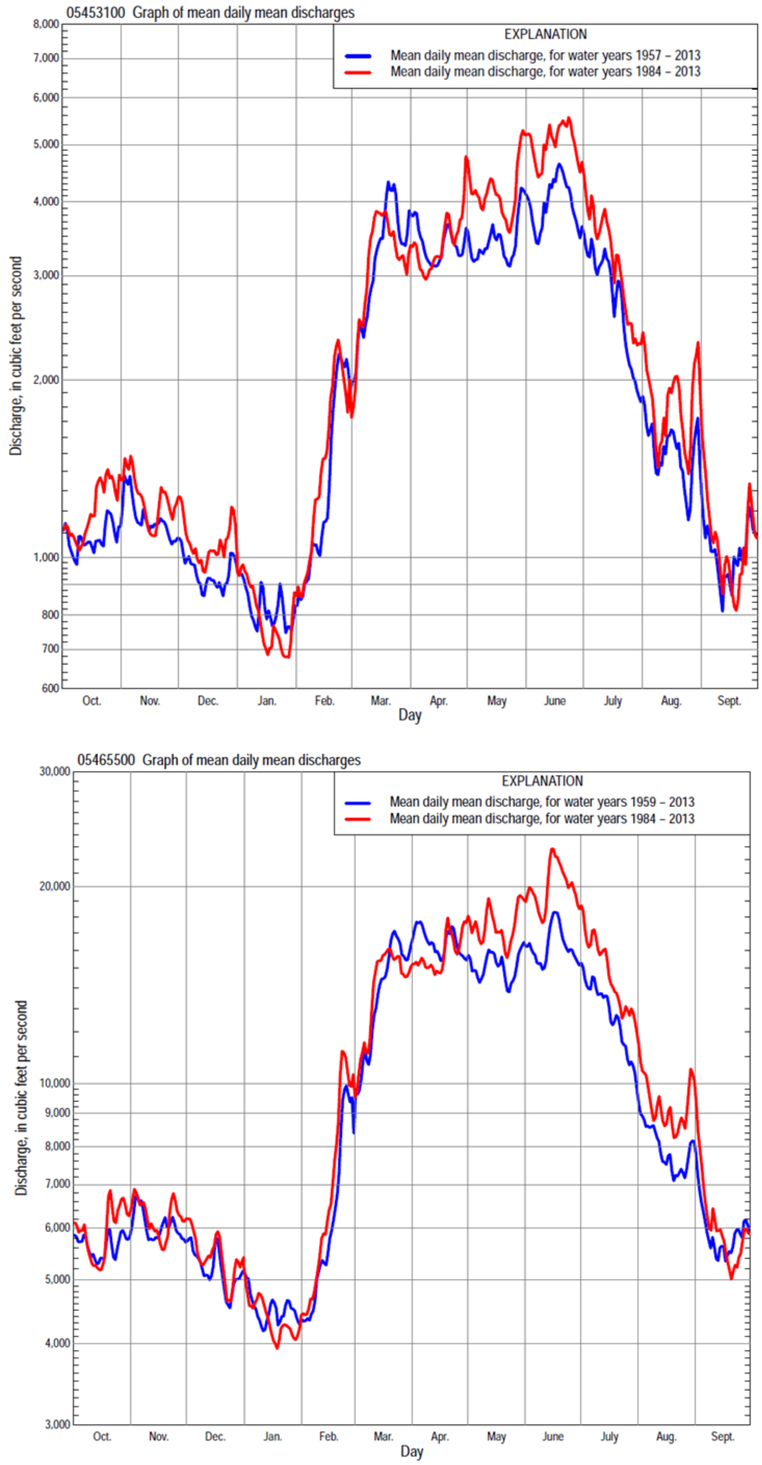


Figure 7. The annual hydrologic pattern in the watershed above Coralville Lake at Marengo (top) and below Coralville Lake and the Cedar River at Wapello, IA (bottom) is similar, but flow magnitude is much greater downstream (note: logarithmic scale and wider range of flows).

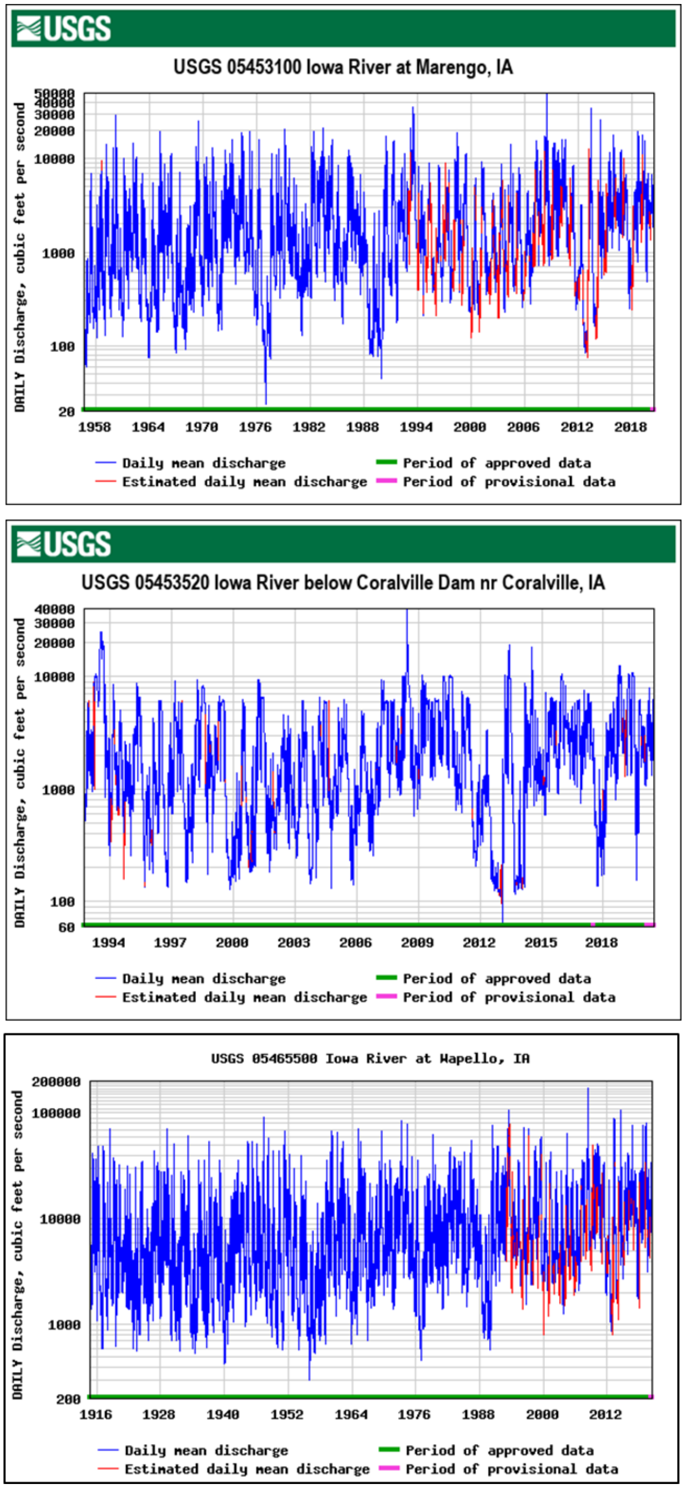


Figure 8. Daily discharge (cfs) for the period of record at gages upstream of Coralville Lake (Marengo, Iowa), below the Coralville Dam (Coralville, Iowa), and downstream of the Cedar River confluence (Wapello, Iowa) (Note: logarithmic scale, wider range of flows, and different periods of record for each gage).

The gage record at Wapello is the only one on the Iowa River that shows an increasing trend of discharge (Figure 9) seen throughout the Midwest U.S. (Changnon 1983, Knox 1993, Zhang and Schilling 2006).

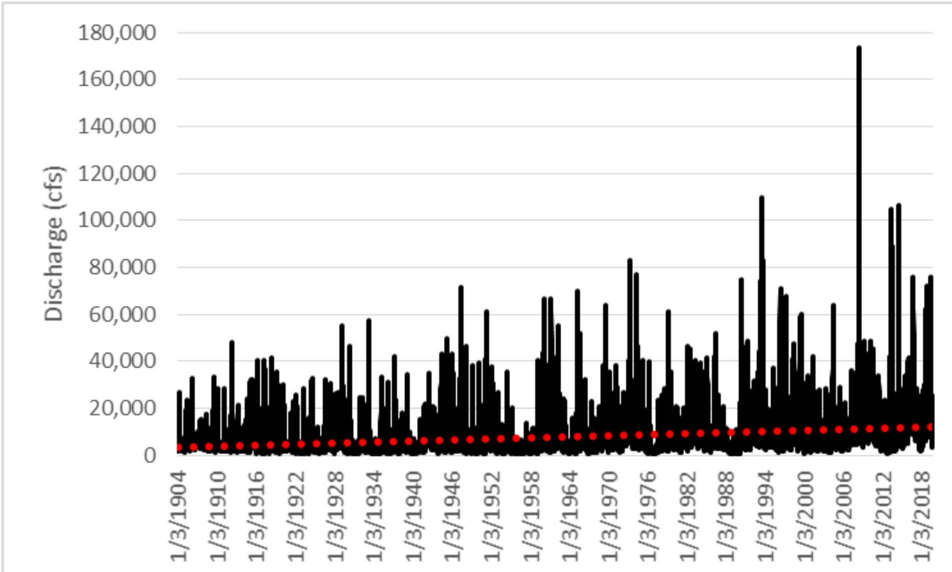


Figure 9. Long term discharge (cfs) at Wapello, Iowa shows an increasing trend over the period of record (see red dash trend line).

The Coralville Dam has varying degrees of influence on Iowa River hydrology downstream of the project (Table 1). The dam manages 100 percent of the discharge within design capacity at the Coralville tailwater. The level of influence on downstream hydrology declines in Iowa City below Clear Creek (95%), at Lone Tree below the English River (73%), and it declines to only 25% below the Cedar River at Columbus Junction.

Table 1. Percent of drainage area at each gage influenced by the Coralville Dam and reservoir (Source: Rock Island District, Hydrology and Hydraulics Branch).

GAGE	Percent of Drainage Area
Coralville Tailwater	100 %
Iowa River at Iowa City	95 %
Iowa River at Lone Tree (Tri-County Bridge)	73 %
Iowa River at Columbus Junction	25 %
Iowa River at Wapello	25 %
Iowa River at Oakville	25 %
Mississippi River at Burlington	2.7 %

Another way to examine the influence of dams on hydrology is to simulate river flow without the dam in place. USACE Rock Island District developed regulated and unregulated flow scenarios to support such an analysis. The post-dam period of record compared to the unregulated simulation at the Coralville Dam tailwater clearly shows how the dam can attenuate flows downstream (Figure 10) The influence of the dam on the Iowa River downstream from Coralville Dam to the Mississippi River is plotted in Figure 11 which illustrates the differences between the high, average, and low flow unregulated and regulated hydrology. Unregulated flow has higher peaks and shorter duration floods compared to regulated flows with lower discharge extending for longer periods. Differences between average and low flows are not significant. Figures 12 and 13 plot the prior 10 years of record to help visualize potential differences between unregulated and regulated conditions. Unregulated flows would exceed 20,000 cfs at Coralville several times, but regulated flows rarely exceed 10,000 cfs. Large floods in 2013 and 2014 are attenuated slightly at Wapello because of Coralville Dam operations.

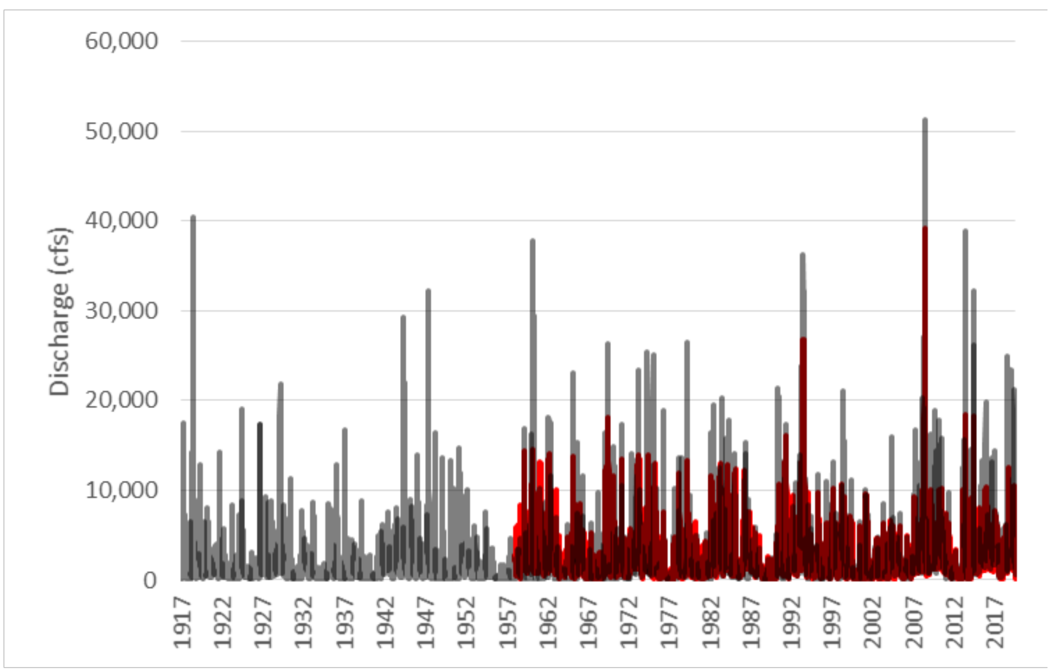


Figure 10. Coralville Dam discharge volume (cfs) under regulated (red; 1958-2019) and simulated unregulated (grey; 1917-2019) conditions. Brighter red bars are dates when unregulated discharge would be lower than sustained flood storage release from the dam.

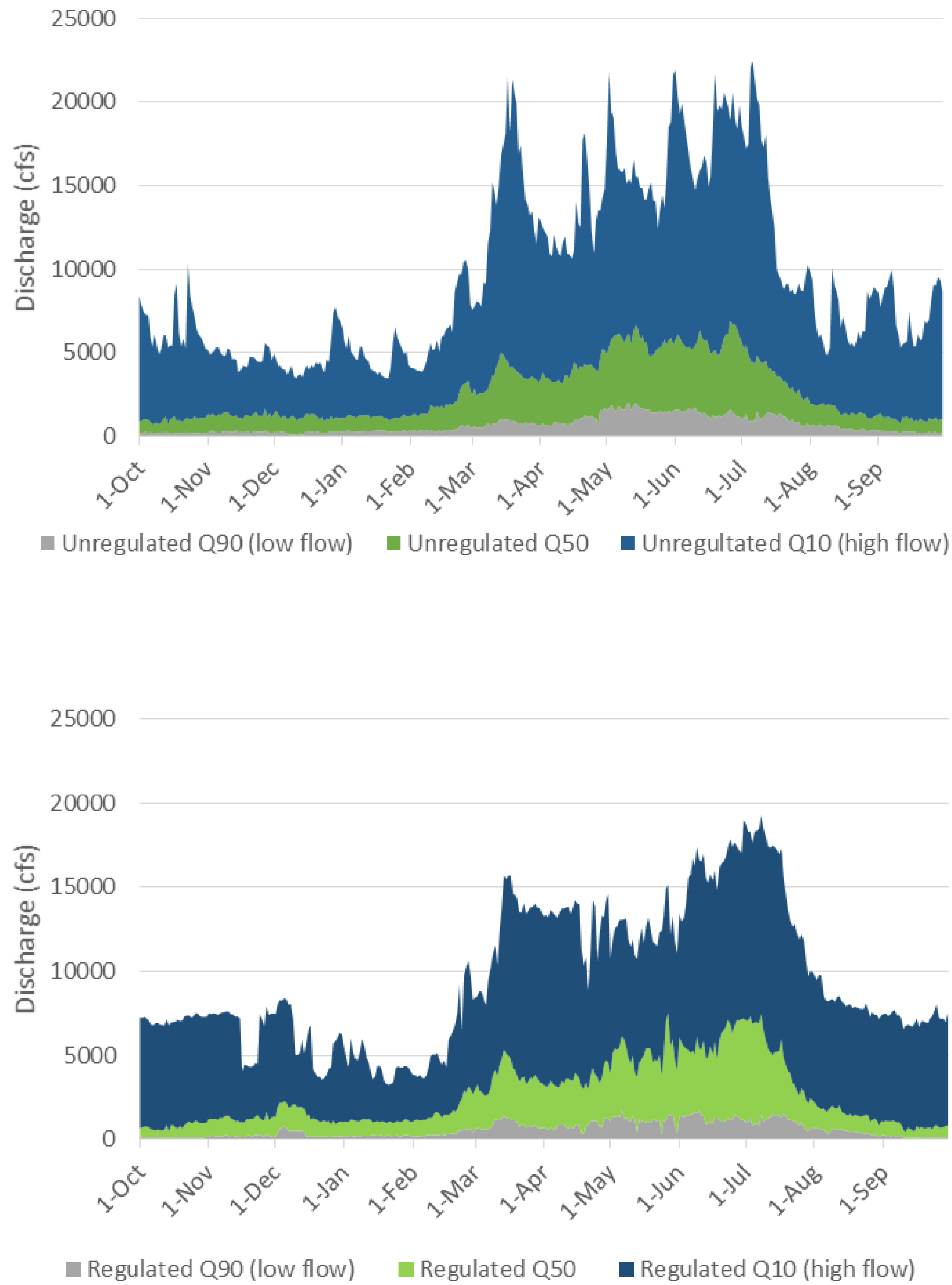


Figure 11. Comparison of simulated daily average unregulated (top) and regulated (gage data) hydrology (bottom) downstream from Coralville Dam.

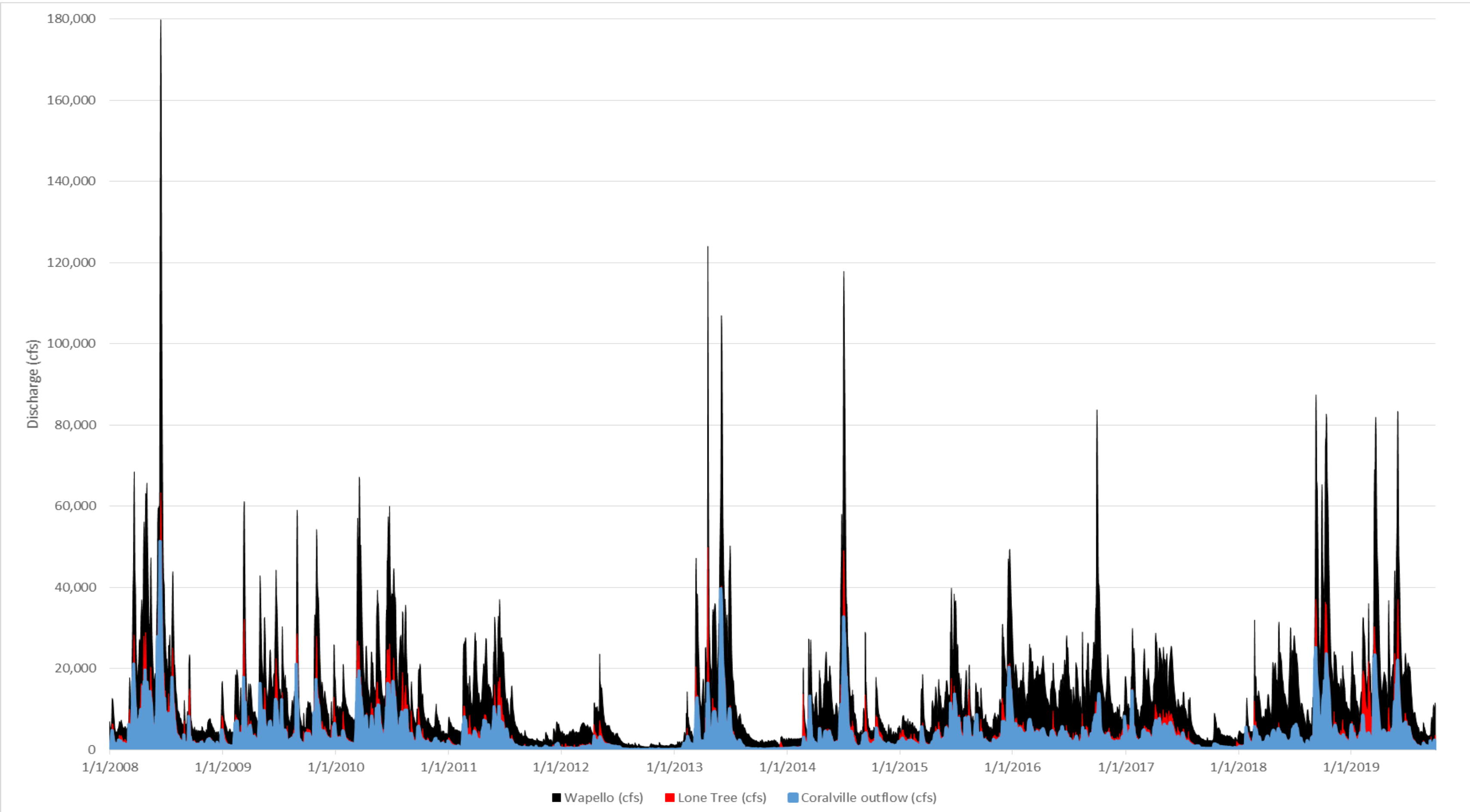


Figure 12. Prior decade of simulated unregulated hydrology downstream from Coralville Dam.

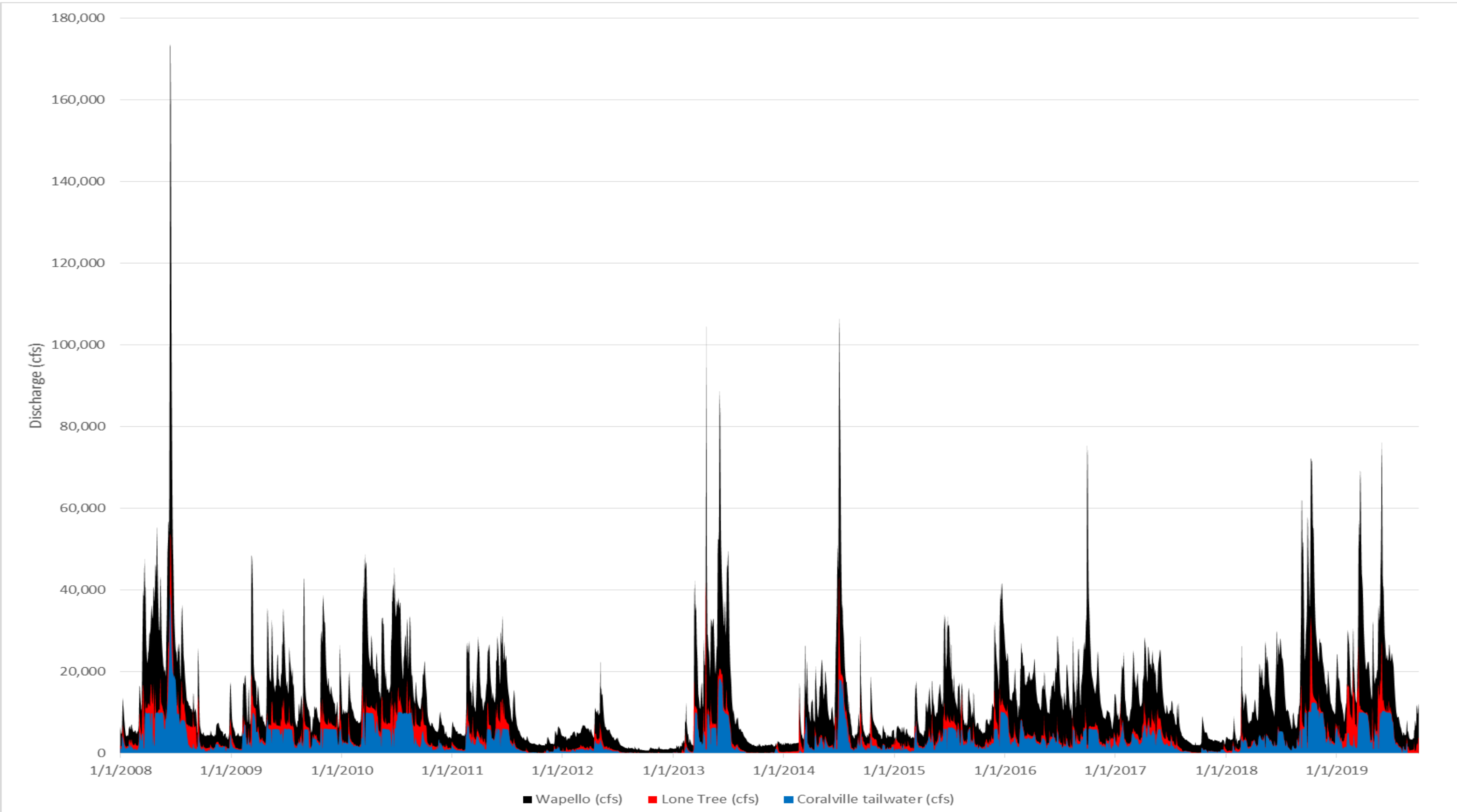


Figure 13. Prior decade regulated (gage data) hydrology downstream from Coralville Dam.

2.4 Environmental Flow Alterations

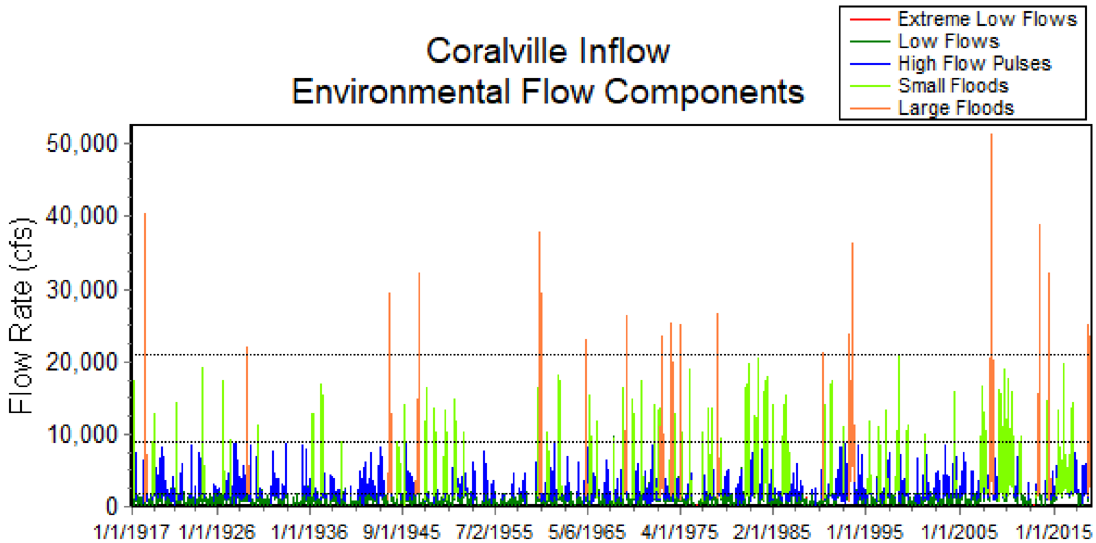
Hydrologic variability is responsible for the dynamic equilibrium that promotes high biodiversity in stream ecosystems. Environmental flows analysis considers the role that typical, normal flows and extreme, unusual flow events have on shaping biological communities and ecosystem function (Junk et al. 1989; Poff et al. 1997). Species are adapted to the regional norms, but their year-class strength or abundance may fluctuate in response to annual hydrology. The dominance of one guild may shift during extreme events, such as when vegetation encroaches on the channel during low flow cycles or may be flooded out during high flow cycles (Bendix and Hupp 2000). Extreme, large floods can reshape channel and floodplain geomorphology while vegetation encroachment during low flows can stabilize floodplain landforms. Climate change and infrastructure like dams and levees can drive long term and widespread shifts in biotic communities, stream channel dimensions, and access to the floodplain (Shafroth et al. 2002). The environmental flow response to the flood control infrastructure above and below the Coralville dam is considered here. Identifying opportunities to naturalize hydrology downstream from the dam are important objectives, but even the highly altered pool environment can be managed for greater ecosystem goods and service benefits.

Matthews and Richter (2007) recommend that high flows and floods, seasonal flows, and low flows need to be considered in an environmental flows assessment. The ecological functions of these flow events are listed in Box 1 but bear repeating. Seasonal flows provide the “normal” conditions that sustain ecological communities in a typical year. Spring, summer, fall, and winter each have their expected range of variation which can be assessed with environmental flows statistical analysis using routinely collected river hydrology data and the Indicators of Hydrologic Alteration (IHA) software (The Nature Conservancy: https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/IHA-Software-Download.aspx). Seasonal flows maintain channel geomorphology, physical habitat, and water quality, and can cue biological activity like spawning or seasonal migrations. High flows that occur on a 2 – 5 year cycle in the Midwest expand aquatic habitat into floodplain areas where geomorphic conditioning and chemical transformations maintain sediment, nutrient, and plant community balance that support biota during aquatic and terrestrial phases (Junk et al. 1989, Sparks et al. 1998). Extreme high flows, like a “100-year flood”, can create great disturbance that completely transforms some areas while causing little change in others which maintains the dynamic equilibrium. Low flows may challenge aquatic species whose habitat area shrinks and may experience poor water quality from low dissolved oxygen, high temperatures, and nutrient enrichment leading to algal blooms. Floodplains, conversely, may flourish if there is adequate soil moisture to maintain plant communities, many of which are adapted to exploit groundwater. Wetland processes during the dry phase are important to condition soils and nutrient status through complex biochemical functions of ephemeral wetlands.

2.4.1 Coralville Dam

The prior section examined the role of the Coralville Dam in the context of Iowa River hydrology and established that the influence is greatest in the pool upstream through the Hawkeye Wildlife Management Area about ½ mile downstream from the Hwy 220, 220th Trail bridge (USACE 2001) between West Amana and South Amana. The downstream influence is greatest above the Cedar River confluence because of the higher discharge of the Cedar River and backwater effects from the Mississippi River. This section examines the environmental flows into and out of the lake where the flood control objectives are apparent (Figure 14; Appendix).

The Coralville Lake flood control project has been effective at reducing small floods and most of the large floods (Figure 14, Figure 15). Dam operations limited small floods from almost 14,000 cfs to about 11,000 cfs (Figure 14, Figure 15). Large floods that exceeded the project design criteria in 1993 and 2008 could not be constrained as effectively (Figure 15), but flows were less than they would have been in an unregulated condition.



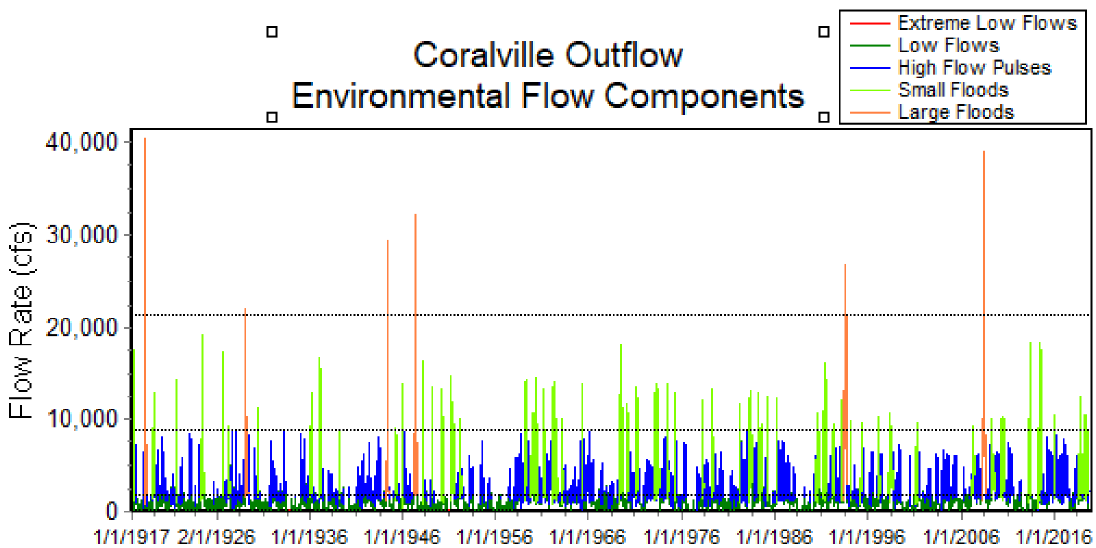


Figure 14. Indicators of Hydrologic Alteration environmental flow components summary for the Coralville Lake inflow and outflow gages.

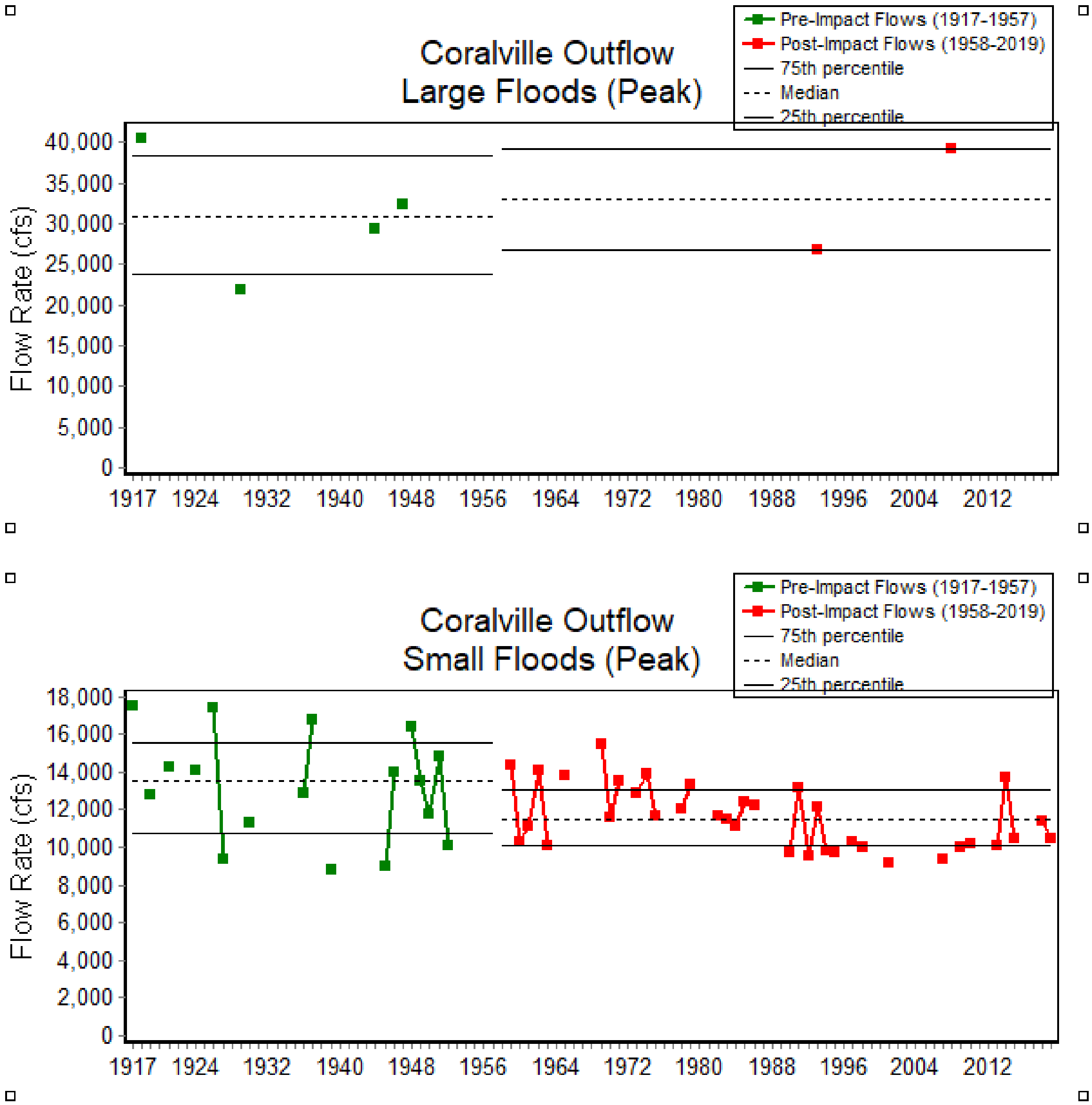
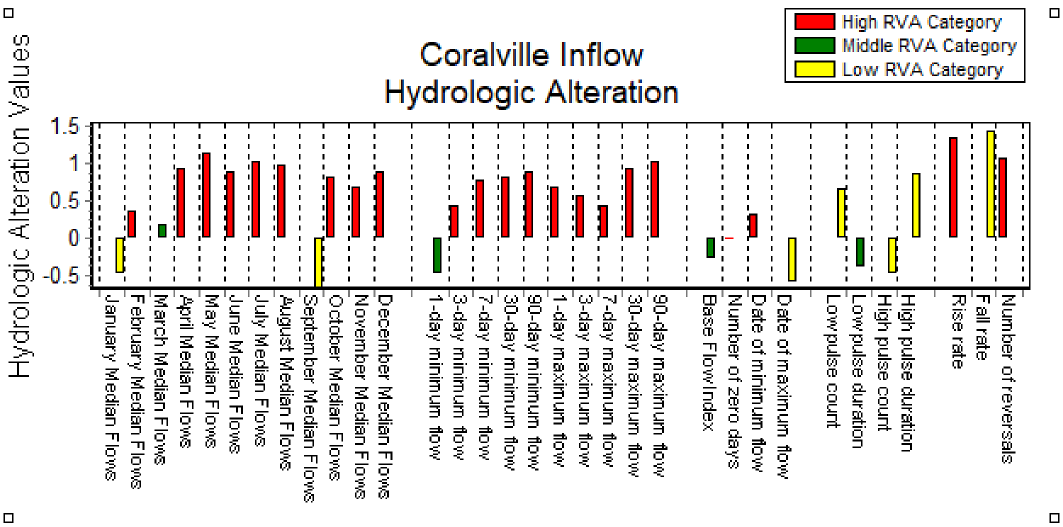


Figure 15. The effect of Coralville Dam operations regulation of large and small flood peaks.

The IHA summary graphs plot the degree of hydrologic alteration for high, medium, and low standard of deviation (33 percent) percentiles for each of the 33 standard parameters (Figure 16). The summary for Coralville Lake inflow and outflow helps identify the biggest changes over pre-dam and post dam periods, and the comparison helps identify changes because of dam operation. The difference between 1, 3, and 7-day maximum flows is the largest among IHA parameters (Figure 16). The 1-day maximum inflow, for example, increased while the Coralville Dam regulated releases to counteract the increased runoff from the watershed (Figure 17). The 1-day minimum outflows increased after Coralville Dam implementation while there was little change in the inflow (Figure 18). The frequency of low pulses is also diminished, with significantly fewer post dam low pulse counts (Figure 19). Flow variability, measured as reversals (Figure 20), has been reduced by dam operations, and an increase in upstream variability is masked by dam operations.



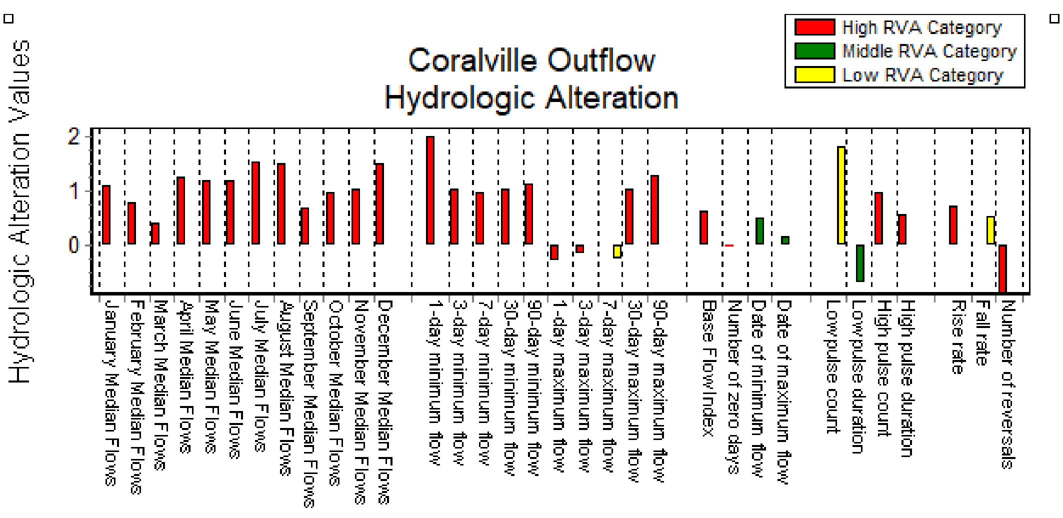
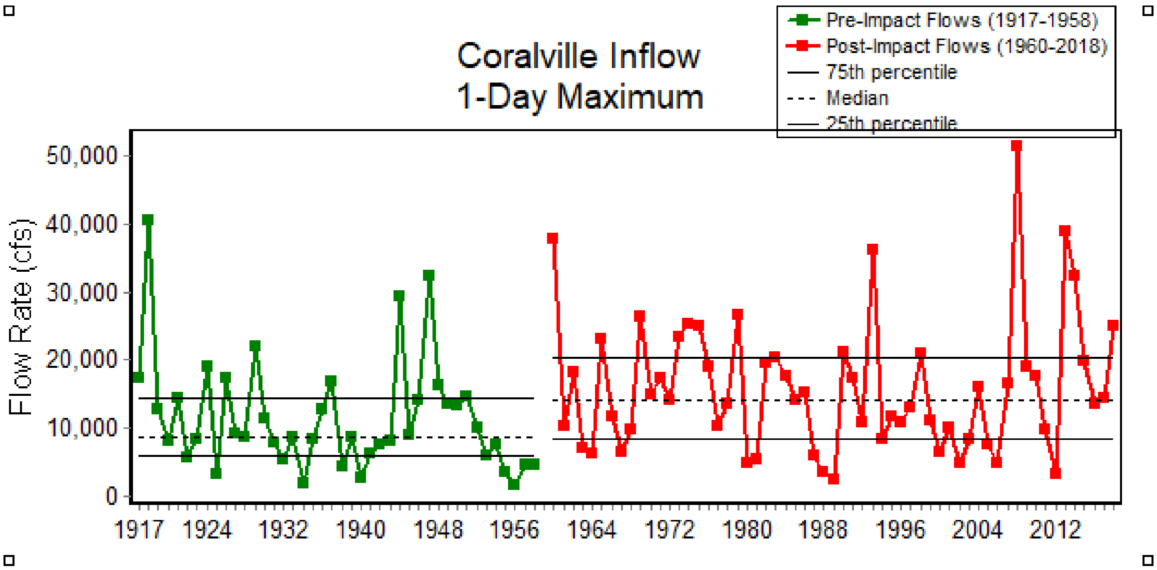


Figure 16. Indicators of Hydrologic Alteration summary for the largest changes at Coralville Lake inflow and outflow. (RVA = Range of Variation)



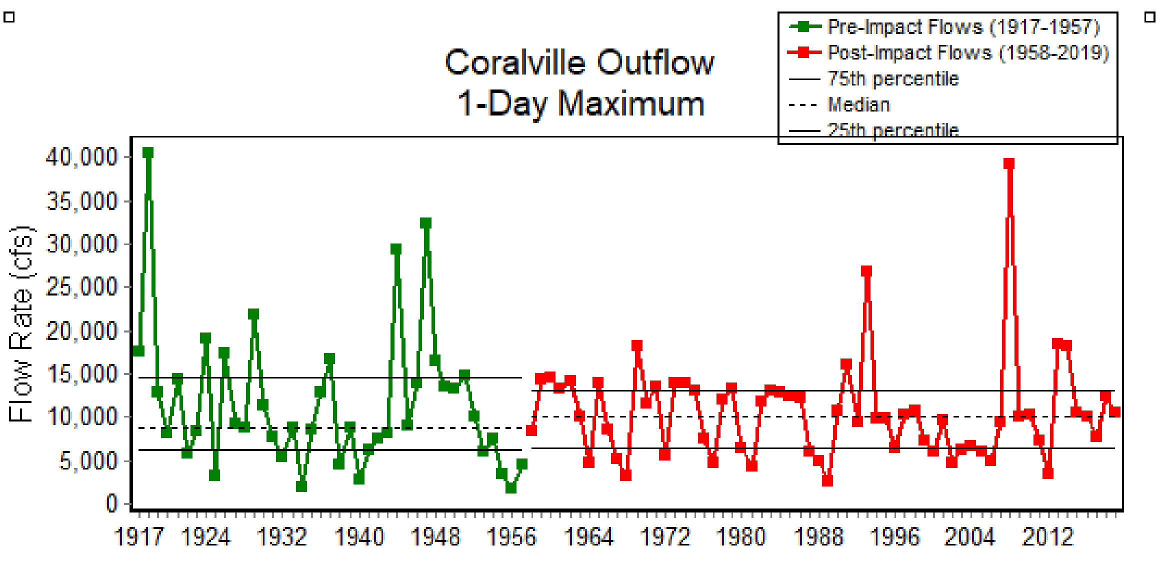
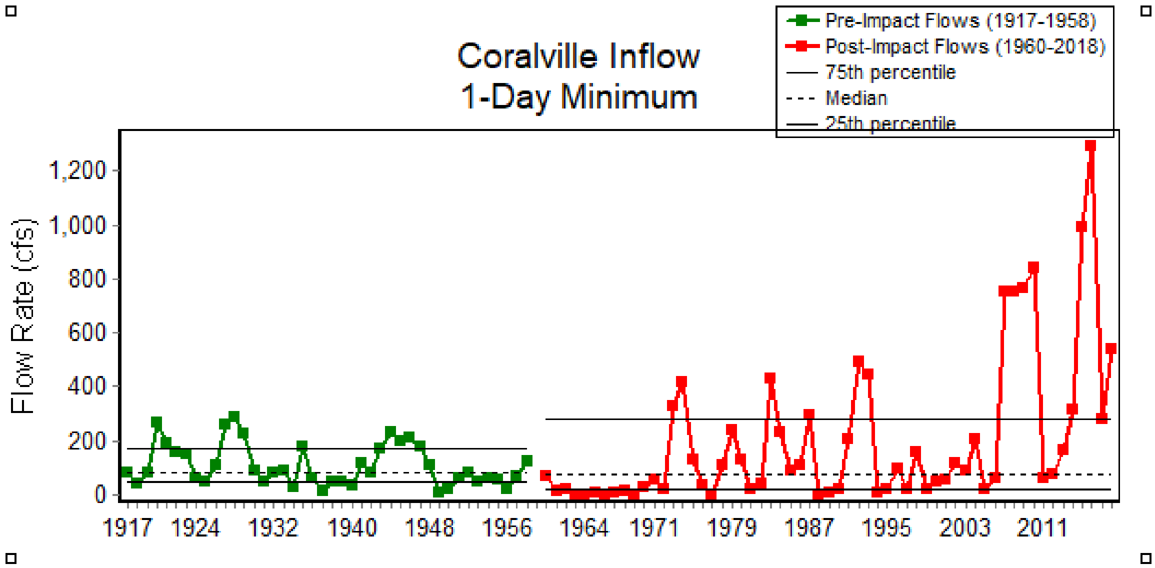


Figure 17. Indicators of Hydrologic Alteration comparison of changes in 1-day maximum inflow and outflow from Coralville Lake.



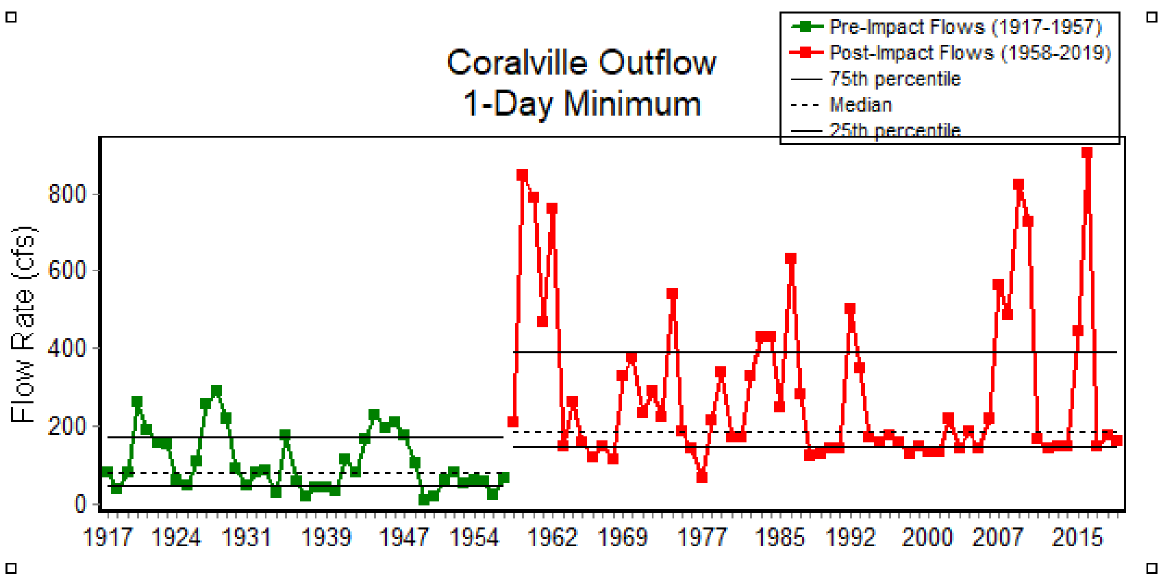
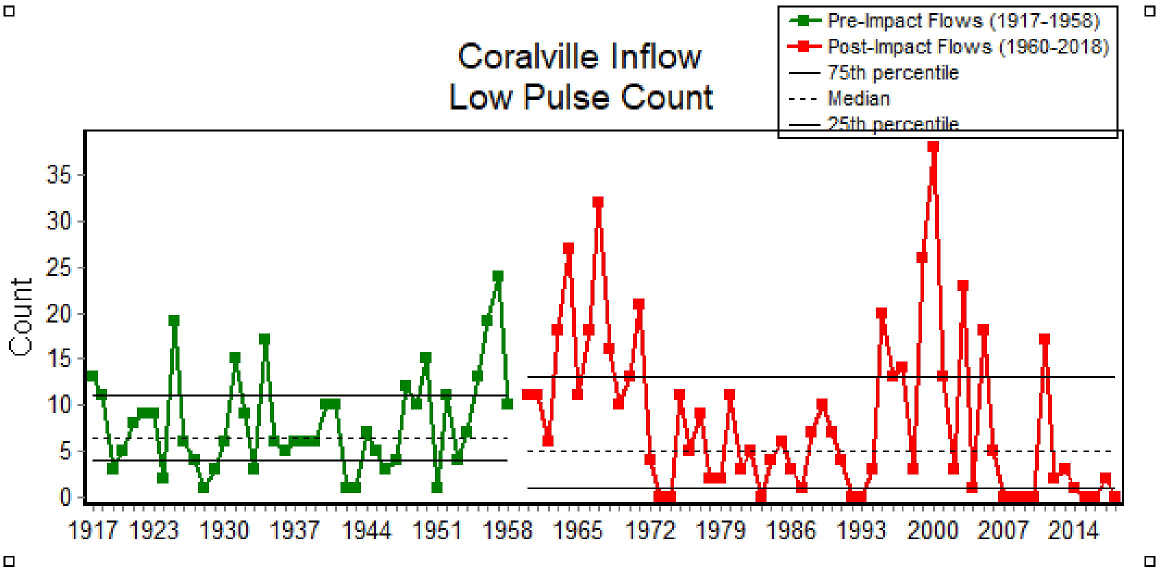


Figure 18. Indicators of Hydrologic Alteration comparison of changes in 1-day minimum inflow and outflow from Coralville Lake.



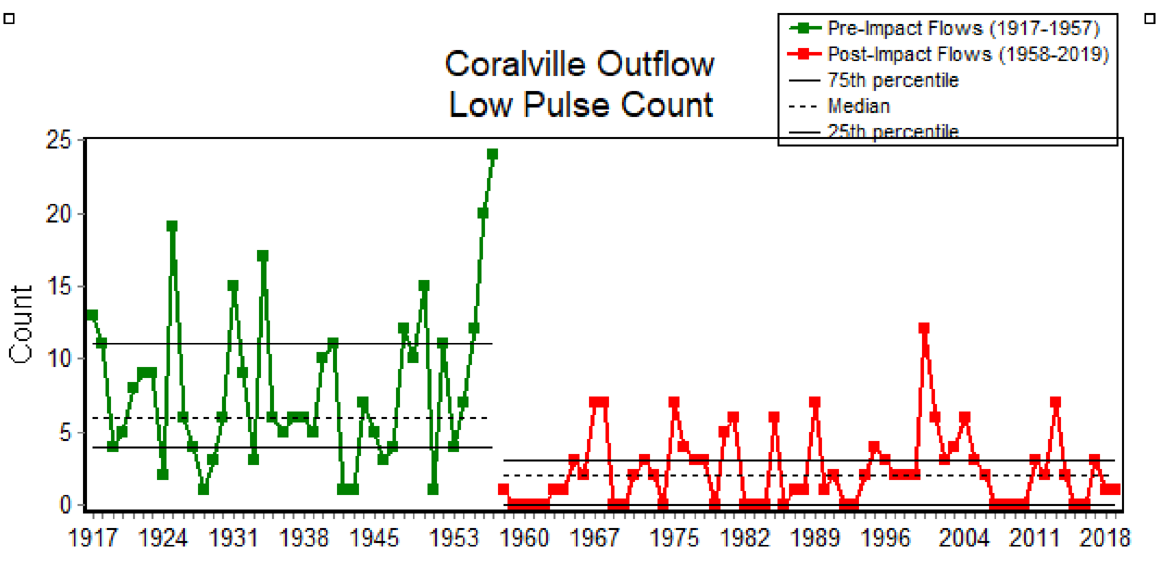
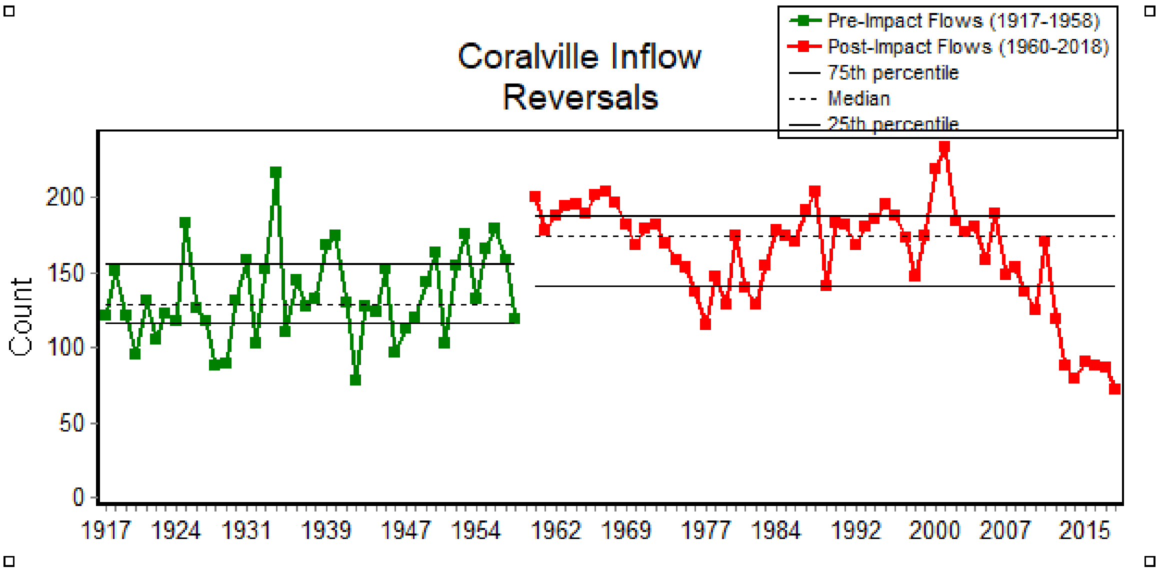


Figure 19. Indicators of Hydrologic Alteration comparison of changes in low pulse count for Coralville Lake inflow and outflow.



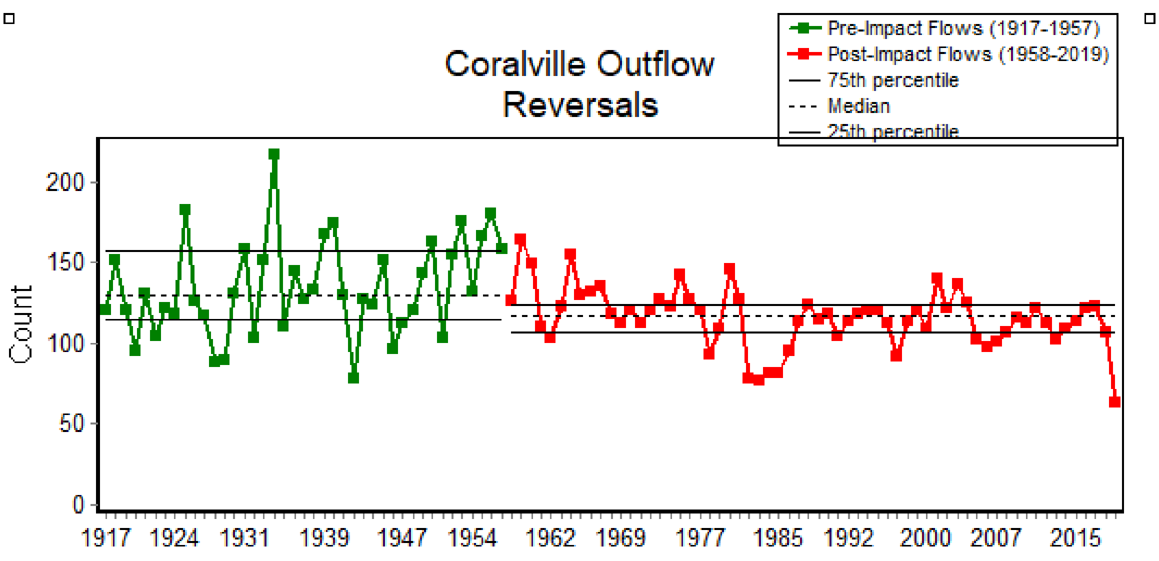


Figure 20. Indicators of Hydrologic Alteration comparison of changes in inflow and outflow variability (reversals).

2.4.2 Iowa River Downstream

Iowa River environmental flows are summarized as monthly low, median, and high flows for unregulated flow simulations of pre-dam (e.g., pre-impact) and post dam (e.g., post-impact) periods to assess hydrologic changes from watershed development and climate effects (Figure 21). The actual monthly median flow for the regulated hydrology downstream from Coralville Dam is plotted to evaluate changes due to dam operation. Low flows (Figure 21, Q90) have increased for the post impact period and the regulated flows appear very similar to what might be occurring if there was no dam. Median flow shows a similar degree of change with an increase in spring, summer, and fall flows (Figure 21, Q50). The regulated median flows are very similar to the simulated unregulated flows for the post dam period, but they are higher than the pre-dam flows because of watershed and climate effects. Post dam unregulated high flows are higher than pre-dam conditions because of changes in watershed runoff volume and the frequency of large summer storms (Figure 21, Q10). The regulated hydrology manages spring floods and extends high flow duration with managed releases.

Daily average regulated and simulated unregulated discharge for low (Q90), median (Q50), and high (Q10) flows for the prior 30 years (1989-2019) provides a clear comparison of changes imposed by the Coralville Dam (Figure 22). The largest change is reduction in average high flows to 10,000 cfs and a lengthening of moderate flows. Flood peaks and valleys are transformed to lower plateaus. The average median and low flows show similar patterns, but flows are augmented by storage released from the dam so both magnitudes of flow are higher in the regulated condition that they would be in an unregulated condition. The figure shows how high flows are reduced and low and median flows are increased.

The analysis of unregulated simulations is interesting because it provides a “what if” the dam did not exist condition that shows how regional hydrology might have changed without the dam operations, whereas the pre- and post-impact analysis compares time periods with different hydrology. While changes from pre-dam to post-dam downstream hydrology are evident, they are not as great as might be expected given changes in regional hydrology. Impacts in the pool environment and flood discharges appear to be the greatest changes imposed by the Coralville Dam.

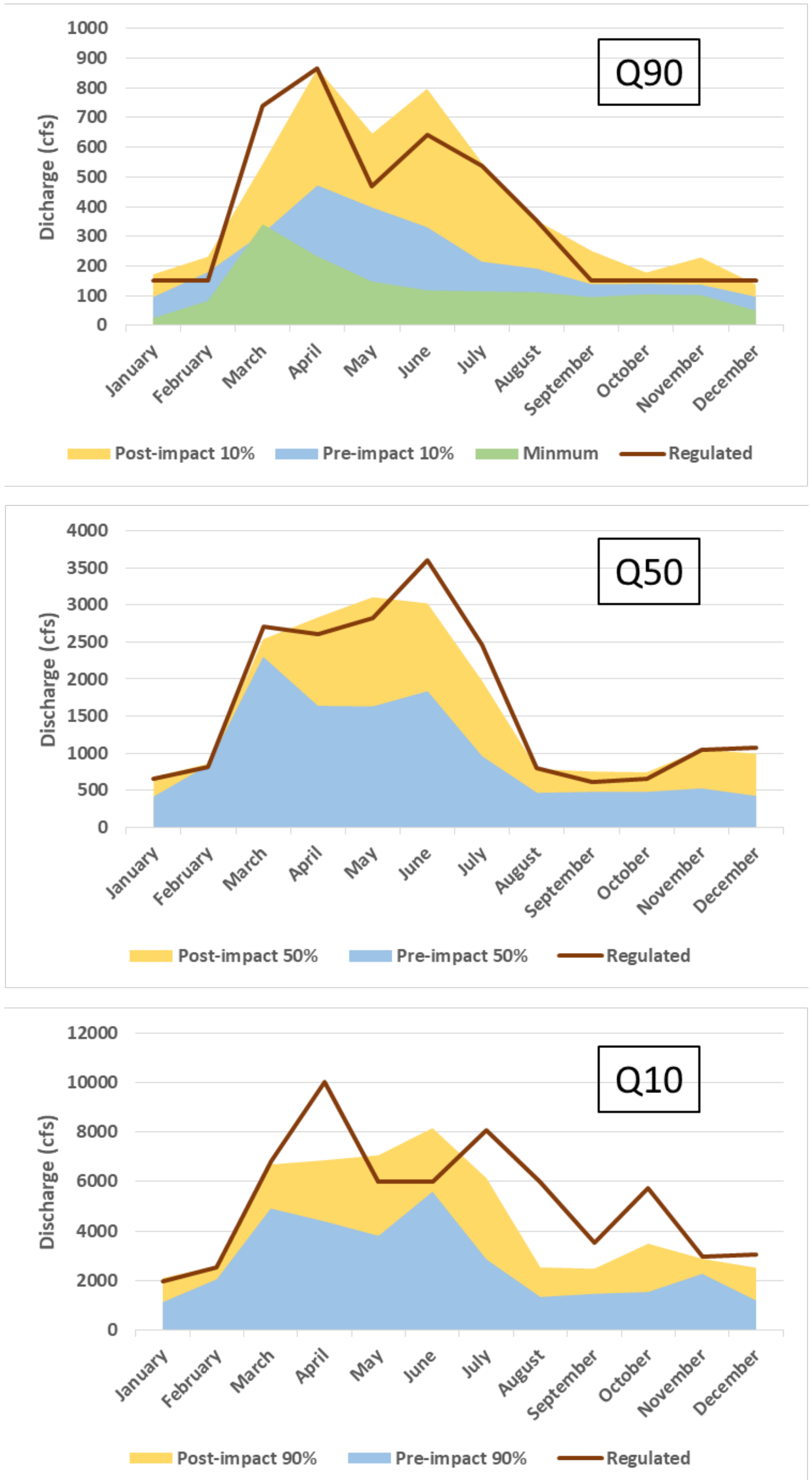


Figure 21. Summary of simulated unregulated monthly low (Q90 or flow exceeded 90% of the time), median (Q50), and high (Q10) flows for pre-dam and post dam periods and the actual regulated monthly median flows.

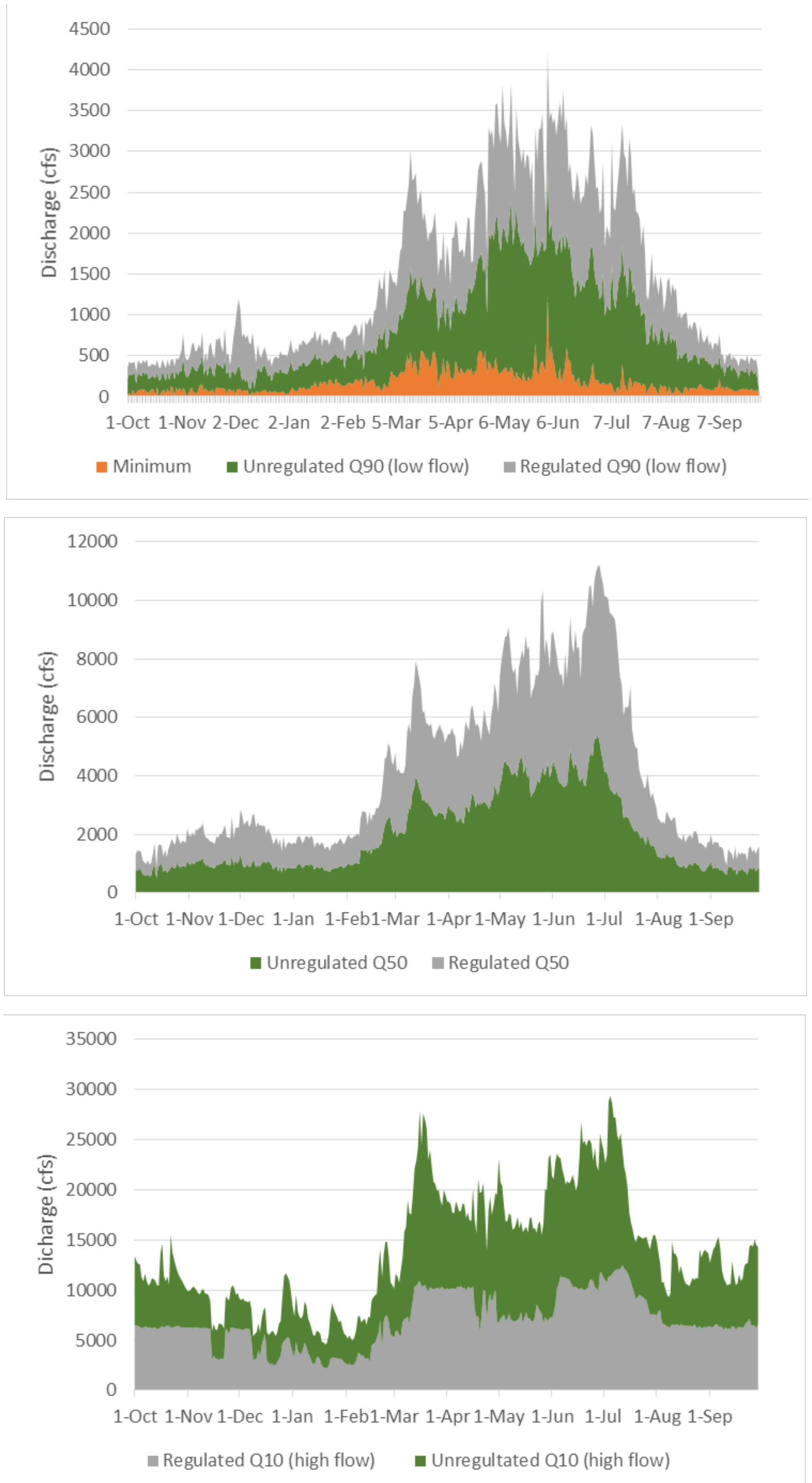


Figure 22. Average daily regulated and simulated unregulated discharge (cfs) for low (Q90), median (Q50), and high (Q10) flows.

3 Assess ecological implications of hydrologic change on native species and communities (EECs)

3.1 Connectivity/Geomorphology

The river reach containing Coralville Lake is a unique valley segment of the Iowa River down cut through glacial till and limestone ridges between resistant limestone (Leighton 1913). The reach is at the interface of the Iowan Surface and the Southern Iowa Drift Plain (see Figure 5) which are remnants of different glacial epochs. The valley is post Kansan and pre-Iowan in the vernacular of an older terminology (Leighton 1913) which means it was scoured and refilled with alluvium several times over hundreds of thousands of years. Leighton (1913) identified three sequences of down cutting which scoured glacial till and eroded through 68 ft. of limestone in some places to achieve its pre-dam valley characteristics. The reaches above the valley drained glacial drift plains which were scoured very wide and refilled with alluvium to create underfit rivers in broad floodplains with terraces representing different glacial episodes (Drury 1970). The slope of the Iowa River above Coralville Lake is greater than 4.0 percent and below the Lake it is 2.5 (Eash 2003), but the slope of the valley itself was not found. The Coralville Lake delta sediment wedge grows from upstream, thus losing depth, slope, and volume over time.

Dams can have minor to profound effects on river geomorphology and connectivity affecting the physical template for river habitats and biota in Iowa (Hoogenveen 2010). The Terrell Dam (ca. 1843 – 1905; Figure 23) was the first dam on the Iowa River built to run a successful grist mill for many years (Weber 1976; University of Iowa: https://digital.lib.uiowa.edu/islandora/object/ui%3Aictcs_236). The dam was replaced by others through time and there are currently 6 low head dams, 1 large impoundment dam, 3 rubble dams, and 3 rock dams on the Iowa River in addition to the Coralville flood control dam (https://www.iowawhitewater.org/lhd/LHDrivers.html; Iowa DNR):

- Main Street Dam, Wright Co. (Rubble Dam)
- Alden Dam, Hardin Co. (Low Head Dam),

- Iowa Falls Hydro Dam, Hardin Co. (Wastewater Plant Rock Dam),
- Eldora Dam – SE Part, Hardin Co. (Rubble Dam)
- Iowa Falls – SE side, Hardin Co. (Rubble Dam),
- Iowa Falls – SE side, Hardin Co. (Low Head Dam)
- Steamboat Rock Dam, Hardin Co. (Low Head Dam),
- Marshalltown Center Street Dam, Marshalltown, Marshall Co. (Riverview Park Rock Dam),
- Tama Hydroelectric Diversion Dam, Tama Co. (Rubble Dam),
- Amana Millrace Diversion Dam, Amana, Iowa Co. (Low Head Dam)
- Coralville Dam, Coralville, Johnson Co. (Large Impoundment Dam),
- Iowa River Power Co. Dam, Coralville, Johnson Co. (Low Head Dam),
- Burlington St Dam, Iowa City, Johnson Co. (Low Head Dam).

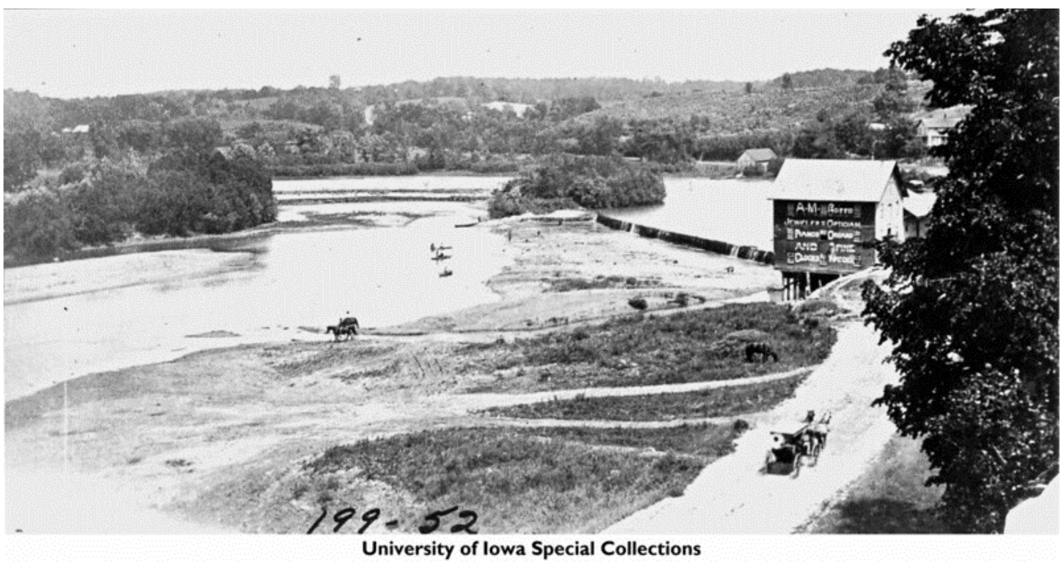
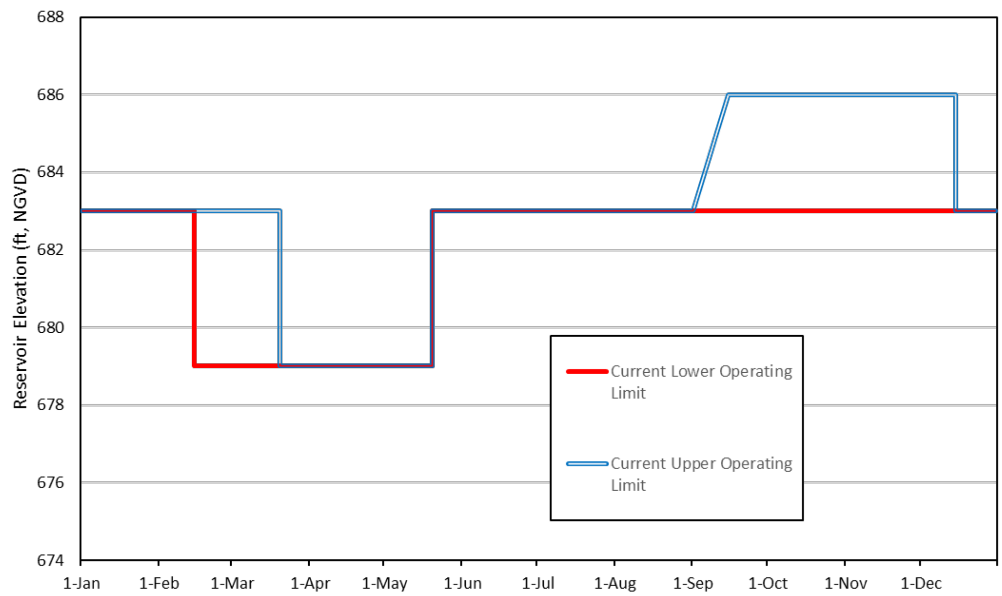


Figure 23. The Terrell Dam (ca. 1843 – 1905) was the first on the Iowa River (Source: University of Iowa Special Collections https://www.flickr.com/photos/uiowa/8039412834).

The Coralville Dam is the most prominent dam on the Iowa River. It is classified as a large impoundment dam but several of the moderate sized low head hydroelectric dams upstream impact river connectivity and hydrology also. The Iowa River is free-flowing from Iowa City over 70 miles to the Mississippi River at Wapello, Iowa. The Burlington Street and Iowa River Power Dams provide barriers to fish migration during low flow, but fish can pass during floods. The Coralville Dam 10 miles upstream is a permanent barrier to upstream fish migrations, including invasive Asian carp, and it influences seasonal flow downstream as well (see prior section). The low head dams along the river alter channel geomorphology, sedimentation, and surface water distribution at low flow, but they do not impound significant volume or acreage of water.

The Coralville Dam is located 83 miles above the mouth of the Mississippi River in Johnson County Iowa (USACE 2001). The drainage area above the dam is approximately 8,000 sq. km (3,100 sq. mi.) where 1 inch of runoff delivers 166,000 acre-feet of water to the flood control project. It is a rolled earthfill structure that is 425 m (1,400 ft.) long, 30 m (100 ft.) high with a crest elevation at National Geodetic Vertical Datum (NGVD) of 743 ft. The spillway crest is 712 ft. NGVD and the outlet works include a singular 23-ft. circular concrete conduit with three gates. Pool elevations vary with season, but are mostly held at 683 ft. NGVD according to the regulation plan (Figure 24). The major flood level is 707 ft. NGVD. Fee title land was purchased to 712 ft. NGVD and flowage easements exist up to 717 ft. which is 5 ft. higher than the spillway crest (Figure 25). Control points at Lone Tree are at 14.0 ft. (12,000 – 18,000 cfs) during the growing season and 16 ft. during the non-growing season. At Wapello the control point stages are 21 ft. and 22 ft. for growing and non-growing seasons, respectively, for flows from 40,000 – 48,000 cfs.



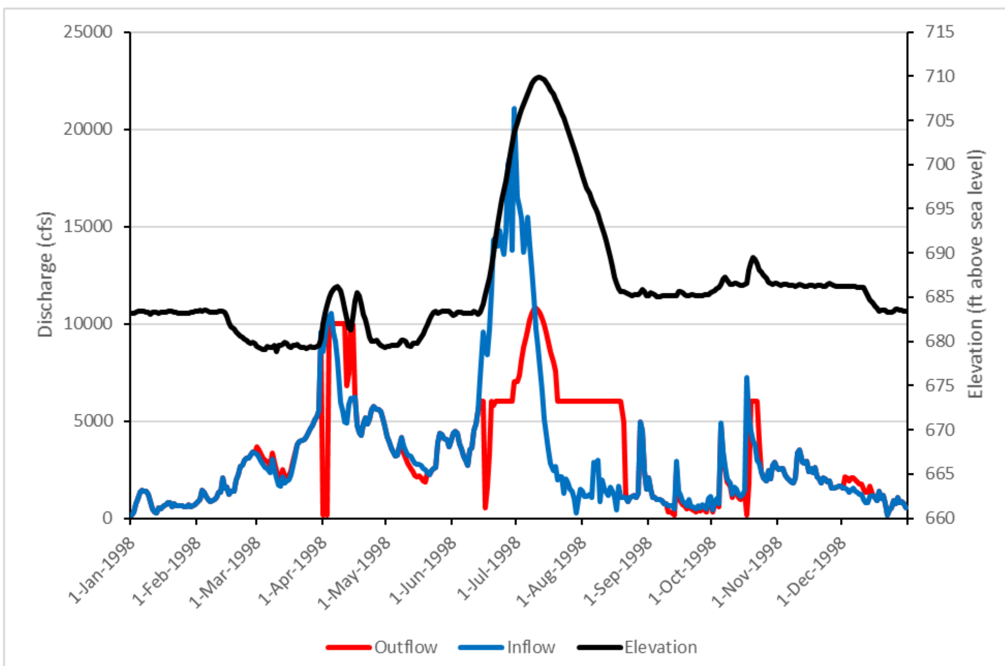


Figure 24. Coralville Lake elevation control plan (top) and Coralville Lake discharge and elevation during a single year in response to inflow illustrates water level variations in the lake.

Figure 25. Coralville Lake real estate holdings.

The downstream regulatory constraints maintain dam discharges within the Iowa River channel to minimize impacts on floodplain farming. Flood mitigation operations during high water raises pool levels and extends high discharges downstream through the summer months as floodwaters are released from the dam. High sustained river elevations during the spring can support migratory fishes, but they also lead to river bed downcutting and bank line widening which overall is creating a wide and shallow river based on comments from Iowa DNR fisheries and county conservation board staff during discussions with Iowa River stakeholders. Moderate flows may also not be large enough to cue fish movement or allow access to floodplain habitats compared to unregulated peak flows.

The river environment in the 20-mile long pool above the dam is much different than the pre-dam river which would have flowed through the valley-constrained reach. The pool size ranges from 2,380 acres at the spring pool elevation of 679 ft. NGVD to 4,050 acres at the conservation pool stage (683 ft.), 25,040 acres at the top of the flood control pool (712 ft.), and 44,000 acres at the Standard Design flood (737.9 ft.). Excessive sedimentation prevents boat/recreation access to the uppermost reaches and some coves during normal pool and spring pool conditions. Flooding and higher controlled pool operations open more areas of the lake to recreation.

3.2 Hydrology

Iowa River hydrology and the effects of the Coralville Dam were discussed extensively above, but to reiterate, the effects of Coralville Dam are not apparent above Amana, Iowa and they diminish to 25 percent of flow below the confluence with the Cedar River near Columbus Junction. Seasonal fish spawning cues of natural hydrology are impacted by a spring drawdown that limits fish spawning in the reservoir. The spring pulse is maintained downstream, but flood flow magnitude is reduced by dam mitigation which limits floodplain inundation and associated ecological benefits. The high, sustained, bank full flows from flood storage releases exacerbates streambed and bank erosion which increases sedimentation in the channel and downstream in the Mississippi River. Extreme low flows downstream of Coralville dam are augmented by minimum flow releases of 150 cfs at Iowa City unless a drought contingency plan is implemented (USAC 2001). A 3-ft. fall pool raise for migratory waterfowl habitat typically runs from September 15 to December 15. Upper pool flooding inundates wetland habitat with high waterfowl food value. The fall rise may be skipped if flooding during the growing season limits wetland development in a particular year. The Iowa River below Coralville Dam is a reach with high diversity and abundance of freshwater mussels, including threatened and endangered species. Rapid decreases in flows from the dam has stranded mussels in the past, but communication with Iowa DNR mussel experts has improved in recent years thus minimizing abrupt changes in flow and stranding.

3.3 Water quality

Coralville Dam effects on Iowa River water quality are relatively minor and somewhat positive compared to other Iowa River impairments which are mostly related to nutrient and sediment enrichment from agricultural activities. The water retention time through Coralville Lake averages 8 days which allows biogeochemical transformations to improve water quality through sedimentation and de-nitrification as seen in Saylorville Lake (Hansen et al. 2016), and phosphorus assimilation which conveys cleaner water out of Coralville Lake compared to inflows.

A long-term water quality monitoring program implemented in 1964 by the Rock Island District helps document water quality relationships in the lake. A data summary of 2010 – 2014 comparing water quality at the upstream and downstream end of the lake shows differences in the major water quality impairments: sediment, nitrogen, and phosphorus (Thomas Keller, U.S. Army Corps of Engineers, Rock Island District, Water Quality Branch, personal communication). Suspended solids decrease 177 percent (Figure 26) because of a 72 percent trap efficiency in Coralville Lake (Thomas Keller, personal communication). Turbidity, conversely, increases in the lake which may be the result of algae and bacteria growth in the slow flowing, nutrient rich environment (Figure 25). De-nitrification, algal assimilation, and settling processes are likely responsible for nitrogen reductions (Figure 26) as documented in Saylorville Lake (Hansen et al. 2016). Reductions in phosphorus concentrations (Figure 25) are likely attributable to settling and algal assimilation, but the phosphorus dynamics have not been documented in Coralville Lake. Reductions in total phosphorus are likely due to settling, while reductions in orthophosphate (PO4) is likely attributable to algal assimilation.

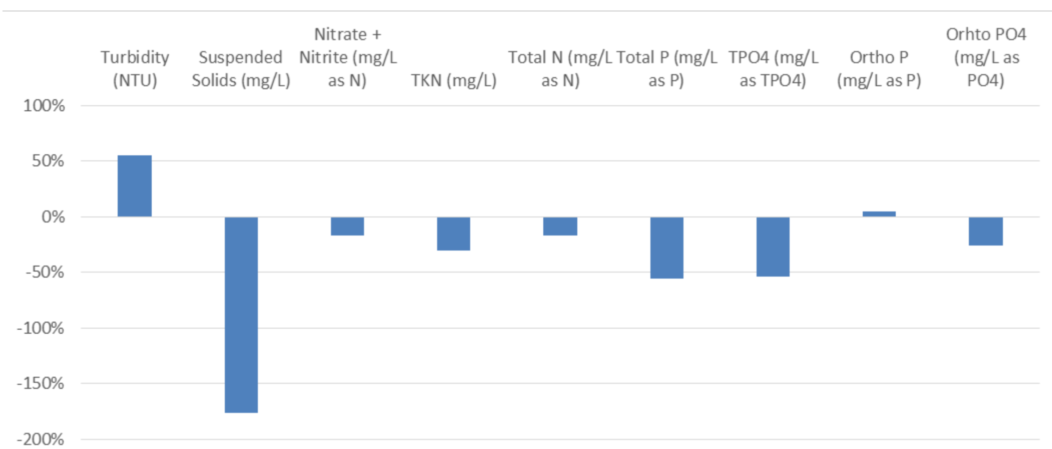


Figure 26. Differences detected between upstream and downstream sample site water quality parameters in Coralville Lake (Source: Thomas Keller, U.S. Army Corps of Engineers, Rock Island District, Water Quality Branch)

There has been accumulation of sediment and nutrients in Coralville Lake which leads to eutrophication in shallow bays and throughout the reservoir as indicated by the turbidity and bacteria impairments. Low water levels during winter and spring reduce aquatic habitat availability. Fish kills have been attributed to rainfall during winter which leads to increased oxygen demand and oxygen depletion under ice (McDonald and Schmickle 1965). During a fish kill in 2014, the Iowa DNR documented oxygen depletion as well as ammonia toxicity under ice where atmospheric oxygen was not available for mixing. Higher winter water levels and spring rises to augment fish spawning would likely reduce the potential for fish kills and increase spawning success.

The State of Iowa list of impaired waters for 2018 lists the following impairments for three reaches of the Iowa River (https://programs.iowadnr.gov/adbnet/Assessments/Summary/2018/Impaired/Map):

- Iowa River upstream of Coralville Lake: Mercury fish consumption advisory, Bacteria – E. coli, Organic enrichment – low DO, Pesticides - Dieldrin

- Coralville Lake: Turbidity, Bacteria – E. Coli, low fish and invert IBIs

- Iowa River downstream from Coralville Lake: Bacteria – E. coli, Biological – low aquatic macroinvertebrate IBI, Biological – loss of native mussel species, Pesticides - Dieldrin

3.4 Habitat

3.4.1 Coralville Lake delta wetlands

The main body of Coralville Lake is confined in a steep valley which limits its lateral expansion during floods. The delta headwaters above the Highway 965 bridge, conversely, is in a broad floodplain valley subject to extensive lateral flooding roughly indicated by the extent of fee title real estate in Figure 25. The area is managed as the Hawkeye Wildlife Management Area by the Iowa DNR. It supports significant public use including hunting, fishing, trapping, canoeing/kayaking, birdwatching, photography, hiking, and gathering. The Hawkeye Wildlife Management Area (Figure 27) is an important component of the Iowa River Corridor Bird Conservation Area (https://iowaaudubon.org/IBA/SiteDetail.aspx?l=1&siteID=307). Access to the area is limited to small boats because of excessive sedimentation leading to shallow water depths.

Habitat in the management area is shown in Table 4. Increased flood frequency is killing off bottomland forest in recent decades. Areas affected by increased flooding are converting to invasive reed canary grass (*Philaris arundinacea*) and willow (*Salix spp.*). A fall pool raise (Sept. 15 to Dec 15) to increase waterfowl migratory habitat has been in place for many decades and is included in the current water control plan (USACE 2001). A permanent pool raise would increase access and help manage invasive species.

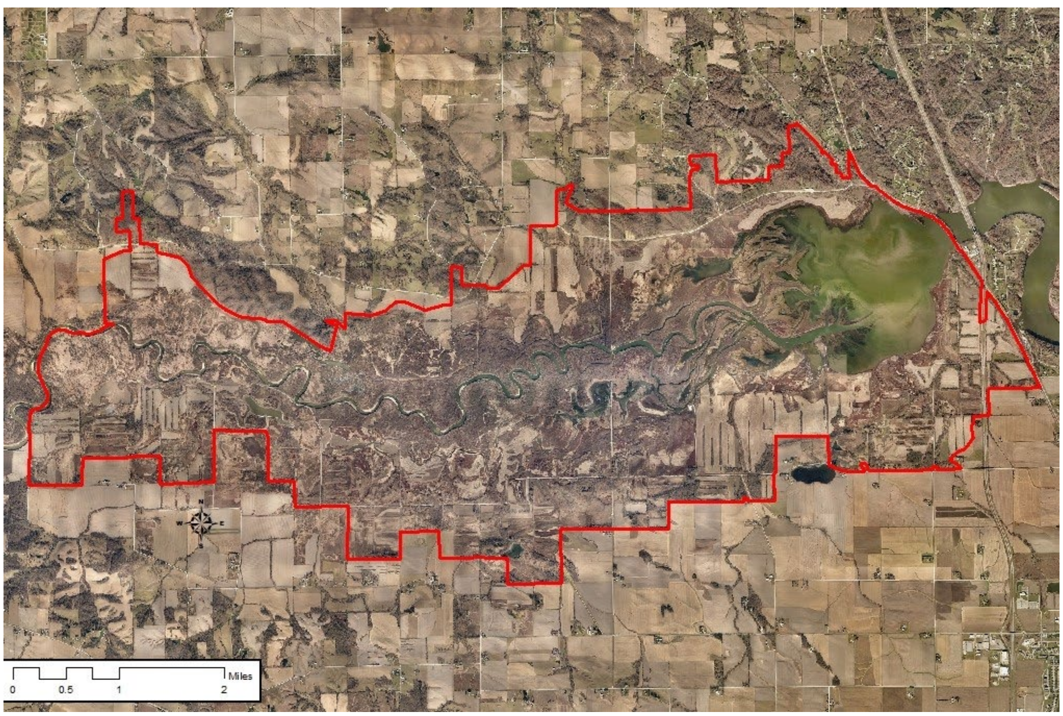


Figure 27. Iowa Department of Natural Resources Hawkeye Wildlife Management Area encompasses the Iowa River valley from the Highway 965 bridge in the east to the Amana Colonies in the west, reaching almost to the western border of Johnson County.

3.4.2 Reservoir

Coralville Lake ranges from 2,380 acres at spring draw-down levels to 4,050 acres at typical conservation pool elevation. Sedimentation in the delta is extensive and impedes access to most boating above the Highway 965 bridge. Sedimentation has also become extensive in the upper part of the main lake (downstream of the Highway 965 bridge) and is beginning to show up in the lower reaches of the lake. Boating to the Highway 965 bridge had been common in the past, but sedimentation now makes boating and recreation upstream of the bend in the lake at Scales Pointe somewhat hazardous, with water depth under 3 – 5 ft. in most places. The Friends of Coralville Lake (FoCL) group reports increased complaints about water quality, including dirty or murky waters, summer mudflats, and poor fishing. There are three marinas on Coralville Lake, one of which has been severely impacted by sedimentation.

3.4.3 Downstream

There are two distinctly different Iowa River reaches downstream from Coralville Dam: Iowa City to the Cedar River and from the Cedar River to the Mississippi River. The latter reach is mostly influenced by the Cedar River which has increased discharge and extreme floods in recent decades. Much of the floodplain in the reach has been bought-out and is now in public ownership or easement. Habitat in the reach is a diverse mix of forest, wetlands, and backwater lakes. U.S. Fish and Wildlife managers are transitioning their management from an emphasis on upland habitat, game birds, and deer to wetland communities.

The Iowa River reach below Iowa City to the English River still supports a moderate amount of agriculture in the 100-yr floodplain. Dam releases are controlled to limit the amount of flooding affecting farming in the reach (USACE 2001). Most of the non-agricultural land is classified as woody wetlands and emergent herbaceous wetlands in the National Land Cover Database. The 100-yr floodplain below the English River is almost entirely classified as wetlands.

Both reaches below Coralville Dam are popular recreation areas. Kayaking/canoeing, and fishing are popular above the Cedar River. Below the Cedar River hunting is also very popular.

Iowa DNR and county conservation staff report that bank erosion and sedimentation are serious concerns. There are many places where crop fields extend to the river where they are easily eroded. The channel is widening and becoming shallower which makes access during low water difficult. High, sustained bankfull flows from flood storage releases are the most erosive flows (Rosgen and Silvey 1996) which may be driving excessive stream bank and bed erosion.

Bottomland oak savanna habitat was identified as one rare community type that should be protected in the floodplain. High sustained flows from dam releases and extreme floods threaten tree survival. Larger, shorter duration flood flows would be more conducive to their survival.

The Iowa River below Coralville Lake supports important fish, freshwater mussel, and turtle habitat (discussed below). Migratory fish including sturgeon, paddlefish, and large catfish are known to use the Iowa River. Freshwater mussels occur in small numbers throughout the lower Iowa River, but they are abundant is areas with gravel and cobble substrate which also provide fish spawning habitat. The Coralville Dam tailwater reach supports a large and diverse mussel population. The Horseshoe Bend area and lower Iowa River reach support important reptile and amphibian habitat. Turtle nesting is common on the natural levees in the reaches below Coralville Dam.

3.5 Biota

3.5.1 Freshwater Mussels

Freshwater mussels are among the most endangered fauna in North America with over 70 percent of species considered endangered, threatened, or of special concern in 1993 (Williams et al. 1993). The primary reasons for their decline are common in Iowa: siltation, pollution, dams, and overharvest (Heidebrink 2002). Siltation is a significant factor in the Iowa River where >80 percent of the watershed is in agricultural land use. Altered hydrology and dam releases below Coralville Lake are also increasing bank full stream flow which exacerbates bed and bank erosion.

About 55 species of freshwater mussels were found in Iowa waters at the time of European settlement. Today, only about half of those species are regularly found (Heidebrink 2002). The Iowa Wildlife Action Plan documents 54 native mussel species with 3 extirpated and 53 percent of species being species of greatest conservation need (Iowa DNR 2015). Recent surveys in the Iowa River above and below Coralville Lake document 32 species on the entire Iowa River (Table 2, Scott Gritters and Jennifer Kurth, Iowa Department of Natural Resources, personal communication).

The Iowa River reach below Coralville Dam has exceptionally high mussel diversity and abundance as represented in Table 2. The lower Iowa River also supports good mussel populations because the reach is unimpounded to the Mississippi River and fish can migrate to disperse larval mussels. The reach was selected for Higgin's eye pearly mussel recovery efforts because of the presence of its host, skipjack herring fish, which migrates upstream from the Mississippi River. The upper Iowa River supports fewer species than the lower Iowa River. The Iowa River Corridor has been targeted for species recovery in the Iowa Wildlife Action Plan because it currently supports only 2 silt-tolerant mussel species (Jennifer Kurth, Iowa DNR personal communication).

The Coralville Dam influence on freshwater mussels is significant in that the tailwaters support one of the richest populations in the State of Iowa. The site includes both Higgin's eye pearlymussel and yellow/slough sandshell which are endangered species in Iowa. Dam operations can be detrimental to freshwater mussels if flow reductions are made rapidly and mussels may be stranded if they don't have time to react to changing conditions. Recognition of the impacts has led to closer coordination on operational changes so flow reductions are more gradual and allow time for mussels to relocate to deeper water.

Table 2. Iowa River Freshwater mussel species (Source: Scott Gritters and Jennifer Kurth, Iowa Department of Natural Resources; SGCN = Species of Greatest Conservation Needs)

Common name	Scientific name	Iowa Conservation status	Upper Iowa	Lower Iowa
Mucket	Actinonaias ligamentina	SGCN	X	X
Elktoe	Alasmidonta marginata	SGCN	X	
Threeridge	Amblema plicata	SGCN	X	X
Cylindrical papershell	Anodontoides ferussacianus (South Fork Iowa River only)	Threatened	X	X
Asian clam	Corbicula fluminea			X
Butterfly	Ellipsaria lineolata	Threatened		X
Wabash pigtoe	Fusconaia flava	SGCN	X	X
Plain pocketbook	Lampsilis cardium		X	X
Higgins eye	Lampsilis higginsii	Endangered		X
Fatmucket	Lampsilis siliquoidea	SGCN	X	X
Slough sandshell	Lampsilis teres anodontoides	Endangered		X
White heelsplitter	Lasmigona complanata	SGCN	X	X
Creek heelsplitter	Lasmigona compressa	Threatened	X	
Flutedshell	Lasmigona costata	SGCN	X	
Fragile papershell	Leptodea fragilis			X
Black sandshell	Ligumia recta			X
Threehorn wartyback	Obliquaria reflexa	SGCN		X
Hickorynut	Obovaria olivaria	SGCN		X
Round pigtoe	Pleurobema sintoxia	Endangered		X
Pink heelsplitter	Potamilus ohiensis	SGCN	X	X
Pink papershell	Potamilus ohiensis	SGCN		X
Giant floater	Pyganodon grandis		X	X
Monkeyface	Quadrula metanevra	SGCN	X	X
Pimpleback	Quadrula pustulosa	SGCN	X	X
Mapleleaf	Quadrula quadrula	SGCN	X	X
Squawfoot (strange floater)	Strophitus undulatus	SGCN	X	
Lilliput	Toxolasma parvus		X	X
Pistolgrip (buckhorn)	Tritogonia verrucosa	SGCN		X
Fawnsfoot	Truncilla donaciformis	SGCN		X
deertoe	Truncilla truncata	SGCN		X
Pond papershell	Utterbackia imbecillis	SGCN		X
Ellipse	Venustaconcha ellipsiformis (South Fork Iowa River only)	Threatened	X	

3.5.2 Fish

Fish are recreationally important species in Iowa, and they are a focus of significant management concern. Iowa DNR Fisheries and Wildlife staff participating in Iowa River stakeholder outreach meetings all reported the importance of recreational fishing. The Hawkeye Management Area is used extensively for fishing and kayaking/canoeing in the shallow marsh habitat. Sedimentation has been impacting the quality of fish habitat in the upstream reaches and coves of Coralville Lake. Fish kills have been attributed to loss of oxygen and ammonia toxicity under ice when winter storms deliver nutrients and organic matter from fertilizer and manure to shallow parts of Coralville Lake. Loss of depth from sedimentation is increasing eutrophication and creating algae blooms through the summer and fall. Boat traffic in shallow areas is increasing sediment resuspension, which reduces water clarity and creates poor water quality. Spawning is negatively impacted by spring reservoir drawdowns, which were designed to increase storage for snowmelt and spring rain events. Higher water levels in Coralville Lake are desirable to increase overwintering habitat and spring spawning. Boaters would prefer higher water levels to increase access to upper reaches of Coralville Lake.

Fishing below Coralville Dam is seasonal, with walleye and crappie being sought during spring spawning. Channel and flathead catfish fishing is popular during summer months. Large flathead catfish are sought because they are abundant in this reach and can exceed 50 pounds. Despite the large individuals, the flathead population between Coralville and Hills, Iowa appears stunted overall due to overpopulation compared to reaches downstream. Fishing in the reach below Iowa City focuses on river species, like catfish and walleye. The Horseshoe Bend and Wapello areas are popular for fishers at the lower end of the Iowa River.

The Coralville Dam splits the Iowa River into upper and lower reaches, and the Cedar River adds significant discharge that divides the lower reach into two ecologically distinct reaches. That creates 4 ecological reaches including Coralville Lake. The upper Iowa River reach includes the headwater streams and mainstem Iowa River through the Iowa River Corridor to the Hawkeye Wildlife Management Area. Fisheries managers reported there is an active fishery and significant kayaking/canoeing but did not identify unique characteristics or problems in the reach.

Lower Iowa River fisheries managers focused on the importance of fluvial dependent species that migrate from the Mississippi River including: flathead catfish, skipjack herring, and shovelnose sturgeon. Greg Gelwicks, Iowa DNR interior streams fisheries biologist, reported on a flathead catfish telemetry study in the lower Iowa River. Fish move freely through the reach and concentrate in deepwater overwintering areas. Flatheads are more abundant in the reach below the Coralville Dam to Hills, Iowa where the fish appear to be smaller and stunted, unlike other Iowa River reaches and in rivers with no control structures.

Shovelnose sturgeon were another fluvial species of concern. Sturgeon migrate from the Mississippi River to unidentified spawning sites on the Iowa River and tributaries. There have been recent fish kills consisting of shovelnose sturgeon on the Des Moines and other rivers, some attributed to hot water during low flow conditions. There have been commercial fishing restrictions imposed on interior rivers, but the recreational fishery is popular on Iowa's large rivers and sturgeon are commercially harvested on Iowa's border rivers.

During stakeholder meetings, all of the fisheries biologists who participated thought restoring flows to approximate a more natural hydrograph will be important. Seasonal flooding during the spring is an important biological cue to initiate spawning migrations upstream and onto floodplain habitats. Water regulation below the dam has reduced the magnitude of seasonal flooding and extended the duration of bank full flows which fisheries managers identified as stressors on the fishery. In addition to loss of seasonal spawning cues, sustained bankfull flows increase bed and bank erosion which is widening the riverbed and making it shallower with excessive sedimentation. Agricultural encroachment, farming to the bank, was also a driver for excessive erosion and sedimentation in the lower Iowa River. Another hydrologic alteration from dam operation can be rapid drops in flow which can strand fish and mussels, and force young-of-year fish out of rearing habitat.

Fish are useful ecological indicators of stream quality where the Index of biotic integrity is a standard method for stream assessments (Karr 1981, Plafkin et al. 1989, Barbour 1999). Iowa DNR Fisheries sampling was documented for 3 Iowa River sites in the BioNet database (Table 3; Iowa DNR https://programs.iowadnr.gov/bionet/). Eldora, Iowa represents the upper Iowa River; Iowa City, Iowa represents the reach directly below the

Coralville dam; and Wapello represents a far downstream reach near the confluence with the Mississippi River. Differences in abundance of species in Iowa City samples is markedly lower with only 19 species compared to 39 and 36 in the upper and lower reaches, respectively. The difference in species composition between upper and lower reaches documents the flow relationships identified by Parks et al. (2016). Iowa City had no intolerant species compared to the upper reach which supports several intolerant species and the lower reach which had large river oriented intolerant species. The historic survey of Cleary (1953) had more intolerant species than current sampling. Parks et. al. (2016) and Cleary (1953) documented most species present with some occurring only in recent sampling and some only in historic sampling, although some name changes may also be reflected in differences.

Research on the Iowa and Cedar Rivers indicates that mean annual discharge and dams are the most important features structuring fish communities (Parks et al. 2016). Land cover in the region is very homogeneous agriculture so it was difficult to identify fish community associations with land cover. The strongest associations of fish community structure were flow magnitude and connectivity with downstream reaches supporting "large river" species. Intolerant fish species were associated with distance to upstream dams, woody cover, and coarse substrates, while tolerant species were associated with percentage of agriculture and fine substrates. Habitat guild associations showed that macrohabitat generalists were associated with rip rap and discharge, while fluvial dependents were associated with percentage of canopy cover, and fluvial specialists were associated with distance to downstream dams. The role of dams in structuring fish communities is accentuated by the lack of migratory species upstream of the Burlington Street Dam where many had previously been documented, including: shovelnose sturgeon, longnose gar, shortnose gar, bowfin, mooneye, shoal chub, emerald shiner, river shiner, mimic shiner, channel shiner, blue sucker, western sand darter, and sauger. Parks et al. (2016) provided the most comprehensive assessment of Iowa River fishes, documenting structural (dams), geographic (reaches differences), and reach-scale environmental drivers affecting fish assemblages.

Table 3. Fish species found in the Iowa River as documented in Iowa BioNet and 2 comprehensive surveys. Tolerance ratings follow USEPA rapid bioassessment protocol terminology.

Common Name	Eldora, IA 2005 IBI 63/71 MBI 68/71	Iowa City, IA 2005 IBI 6/10 MBI 20/37	Wapello, IA 2019 IBI 43 2002 IBI 40 2019 MBI 22 2008 MBI 45 2002 MBI 38	Parks 2016	Cleary 1953	Tolerance (Barbour 1999)
Banded Darter	X			X		I
Bigmouth Buffalo	X	X	X	X	X	M
Bigmouth Shiner	X			X	X	M
Black Buffalo			X	X	X	M
Black Bullhead	X			X	X	M
Black Crappie	X	X		X	X	M
Black redhorse				X	X	I
Blackchin shiner					X	I
Blacknose dace				X	X	T
Blackside Darter	X			X	X	M
Blackstipe topminnow				X	X	M
Blue Sucker			X	X	X	I
Bluegill	X	X	X	X	X	M
Bluntnose Minnow	X		X	X	X	T
Bowfin				X	X	M
Brassy Minnow			X	X	X	M
Brook Silversides			X	X	X	M
Brook stickleback				X	X	M
Bullhead Minnow			X	X	X	M
Carmine Shiner			X		X	N/A
Carpiodes spp.			X	X	X	N/A
Central mudminnow					X	T
Central Stoneroller	X			X	X	M
Channel Catfish	X	X	X	X	X	M
Channel Shiner			X	X	X	M
Common Carp	X	X	X	X	X	T
Common shiner					X	M
Creek chub				X	X	T
Emerald Shiner			X	X	X	M
Fantail Darter	X			X	X	M
Fathead Minnow	X			X	X	T
Flathead Catfish		X	X	X	X	M

Freckled madtom				X	X	M
Freshwater Drum			X	X	X	M
Gizzard Shad	X	X	X	X	X	M
Golden Redhorse	X			X	X	M
golden shiner				X	X	T
Goldfish				X	X	T
Grass Carp	X	X	X	X	X	M
Green Sunfish	X	X	X	X	X	T
Highfin Carpsucker	X			X	X	I
Hornyhead Chub	X			X	X	I
Iowa darter				X	X	M
Johnny Darter	X			X	X	M
Largemouth Bass	X	X		X	X	M
Logperch				X		M
Longnose Gar			X	X	X	M
Mimic shiner				X		I
Mississippi Silvery Minnow			X	X		M
Mooneye				X		I
Mud darter				X		M
Northern Hog Sucker	X			X	X	I
Northern Pike	X			X	X	M
Orangespotted Sunfish	X		X	X	X	M
Paddlefish					X	I
Quillback Carpsucker	X	X	X	X	X	M
Red Shiner		X		X	X	T
River Carpsucker	X	X	X	X	X	M
River redhorse				X	X	I
River Shiner			X	X		M
Rock bass				X	X	M
Rosyface shiner				X	X	I
Sand Shiner	X		X	X	X	M
Sauger			X	X	X	M
Shoal Chub			X	X	X	N/A
Shorthead Redhorse	X	X	X	X	X	M
Shortnose Gar			X	X	X	M
Shovelnose Sturgeon			X	X		M
Silver chub					X	M
Silver Redhorse	X			X	X	M
Slenderhead Darter	X		X	X		I
Smallmouth Bass	X		X	X	X	M
Smallmouth Buffalo	X	X	X	X	X	M
Spotfin Shiner	X	X	X	X	X	M

Spotted sucker					X	M
Stonecat	X			X	X	I
Suckermouth Minnow	X		X	X	X	M
Topeka shiner					X	N/A
Walleye	X			X	X	M
Warmouth					X	M
Western sand darter					X	I
Western silvery minnow					X	N/A
White Bass		X	X	X	X	M
White Crappie	X	X		X	X	M
White Sucker	X			X	X	T
Yellow bass					X	M
Yellow Bullhead	X			X	X	T
Yellow perch					X	M

3.5.3 Amphibian and Reptiles

The lower Iowa River is an area with exceptionally high amphibian and reptile diversity due to the abundance of river and wetland habitat in the Iowa-Cedar Lowland and Mississippi Alluvial Plain ecoregions. The Iowa GAP Analysis provides a geographical approach for assessing the abundance and distribution of amphibians (Figure 28) and reptiles (Figure 29) in the region (Kane et al. 2003). In an effort to preserve the high biodiversity in the area the Iowa Department of Natural Resources and several partners created the 470,000- acre Southeast Iowa Amphibian and Reptile Conservation Area in the Mississippi River floodplain in southeastern Iowa (http://www.iowadnr.gov/portals/idnr/uploads/Wildlife%20Stewardship/2007_success.pdf). It was the first Partners in Amphibian and Reptile Conservation site established to increase public awareness following the model of other conservation initiatives (Southerland and deMaynadier 2012). Criteria for establishing sites include:

- Capable of supporting viable amphibian and reptile populations
- Occupied by rare, imperiled, or at-risk species, and
- Rich in species diversity or endemism.

Iowa DNR Fisheries staff are actively monitoring and managing turtle populations in the area which supports an active commercial turtle harvest with vocal constituents upset by recent harvest restrictions (Chad Dolan, Iowa Department of Natural Resources, Washington, Iowa, personal communication). Turtles are harvested for Chinese markets where they are shipped live. Softshell and common snapping turtles are particularly vulnerable to harvest. Management efforts focus on evaluating the effects of harvest regulations on turtle populations. Monitoring, which includes capture and tagging, is conducted to evaluate the age and mortality rate of turtle populations. Natural and constructed levees, which provide higher elevation habitat in the lower Iowa River, support some of the most important turtle nesting habitat in the reach. Maintaining higher reservoir stages through the winter would benefit overwintering opportunities for reptiles and amphibians in Coralville Lake.

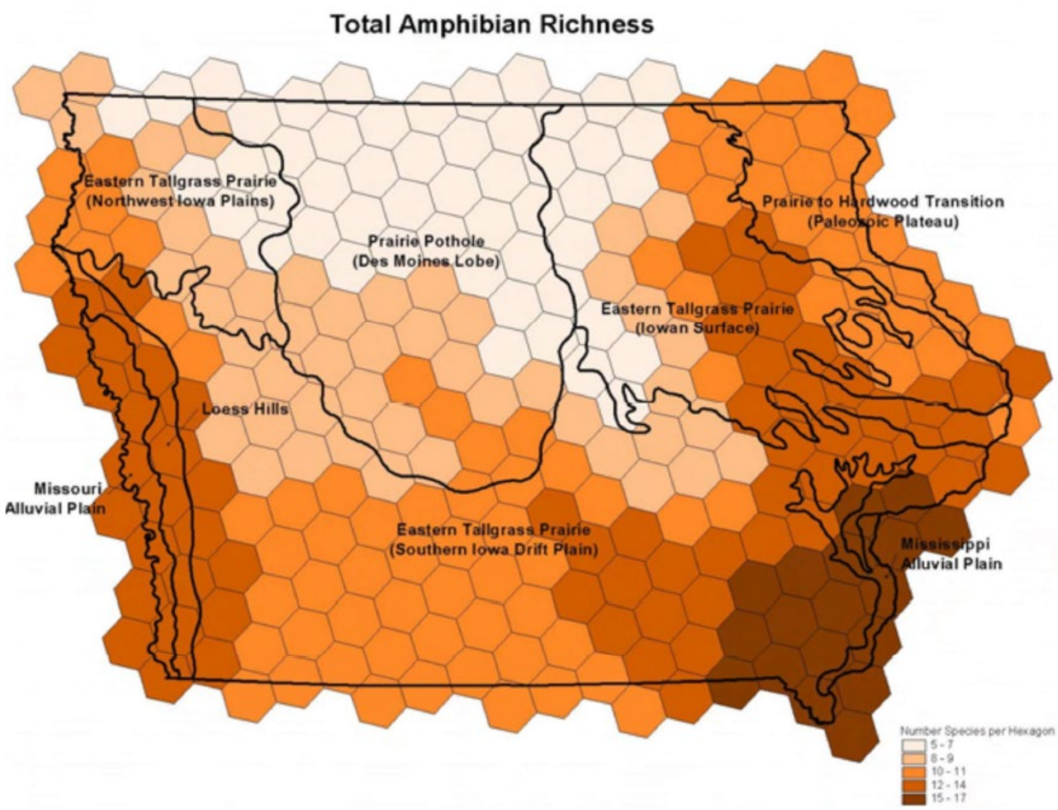


Figure 28. Iowa GAP Analysis of amphibian species richness distribution (source: Iowa Wildlife Action Plan https://www.iowadnr.gov/portals/idnr/uploads/Wildlife%20Stewardship/iwap_chap8.pdf).

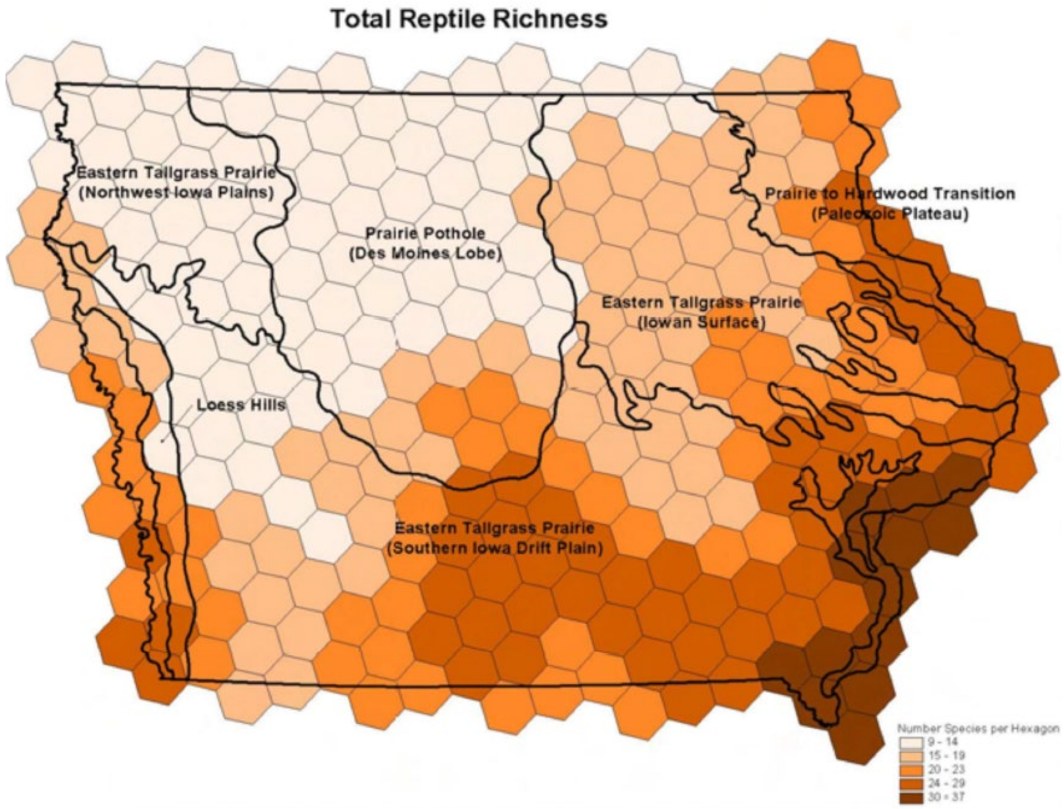


Figure 29. Iowa GAP Analysis of reptile species richness distribution (source: Iowa Wildlife Action Plan https://www.iowadnr.gov/portals/idnr/uploads/Wildlife%20Stewardship/iwap_chap8.pdf).

3.5.4 Birds

Birds are a large, complex community of migratory and resident species that use Iowa River resources in many ways. The Iowa Wildlife Action Plan documents 201 species of breeding birds and 204 species of non-breeding birds that migrate through the State (Iowa DNR 2015). The dominance of a homogeneous agricultural landscape in the region makes habitat diversity along river corridors important refuge, feeding, and breeding areas. A thorough review of bird species is beyond the scope of this report, so stakeholder meetings were the mechanism to learn which issues were important to Iowa wildlife managers and conservation groups.

Discussion of birds in the Iowa River Corridor focused on bird habitat management objectives which fell into three significant regions: the Iowa River Corridor, the Hawkeye Wildlife Management Area, and the lower Iowa and Cedar Rivers management areas which includes refuges at Horseshoe Bend, Lake Odessa, and the Swamp White Oak Preserve.

The Iowa River Corridor (Figure 30) is the reach farthest upstream to be emphasized at stakeholder meetings. The management area was created following the "Great Flood of 1993" which caused substantial damage to farms and the levees that had experienced repeated damage in prior floods. The Emergency Wetland Program provided floodplain landowners a permanent solution by granting easements to restore their land to original wetland conditions (USFWS 2013). The river reach, which is upstream of the Coralville Dam influence, is in USFWS, NRCS, and DNR management (Figure 30). The Iowa River Corridor is also an agency and NGO partnership designated Bird Conservation Area (Figure 31) and was the first in the nation BCA centered on a river corridor (Iowa DNR: https://www.iowadnr.gov/Portals/idnr/uploads/wildlife/bca/Iowa%20River%20Corridor.pdf). The area extends along 45 miles of river floodplain habitat in Tama, Benton, Poweshiek, and Iowa Counties.

The Iowa River Corridor provides habitat for 80% of Iowa's 85 Bird Species of Greatest Conservation Need. Bald eagle, least bittern, grasshopper sparrow, cerulean warbler, black-crowned and yellow-crowned night-herons, bobolink, loggerhead shrike, and red-headed woodpecker are examples of species that rely on this area for nesting or migration (Iowa DNR, USFWS 2013). An Iowa City Bird Club representative reported that all species of resident and migratory birds may use the site. Waterbirds and floodplain dependent species are common in the river wetlands. Iowa DNR wildlife biologists report that the Corridor is popular with hunters and birdwatchers. Invasive reed canary grass and willow encroachment are management concerns that are exacerbated by frequent flooding. There are considerable wetland restoration opportunities in floodplain oxbow habitats.

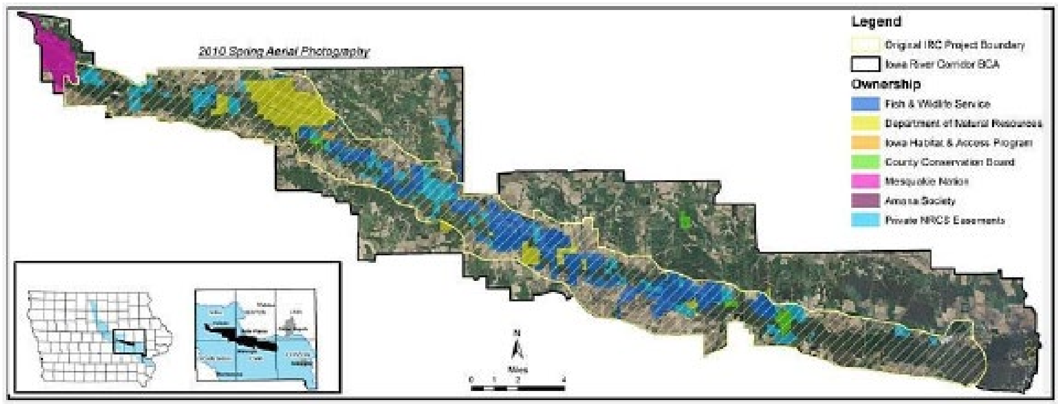


Figure 30. Iowa River Corridor Project showing Bird Conservation Area. USFWS acquisition, and land ownership (source: USFWS 2013).

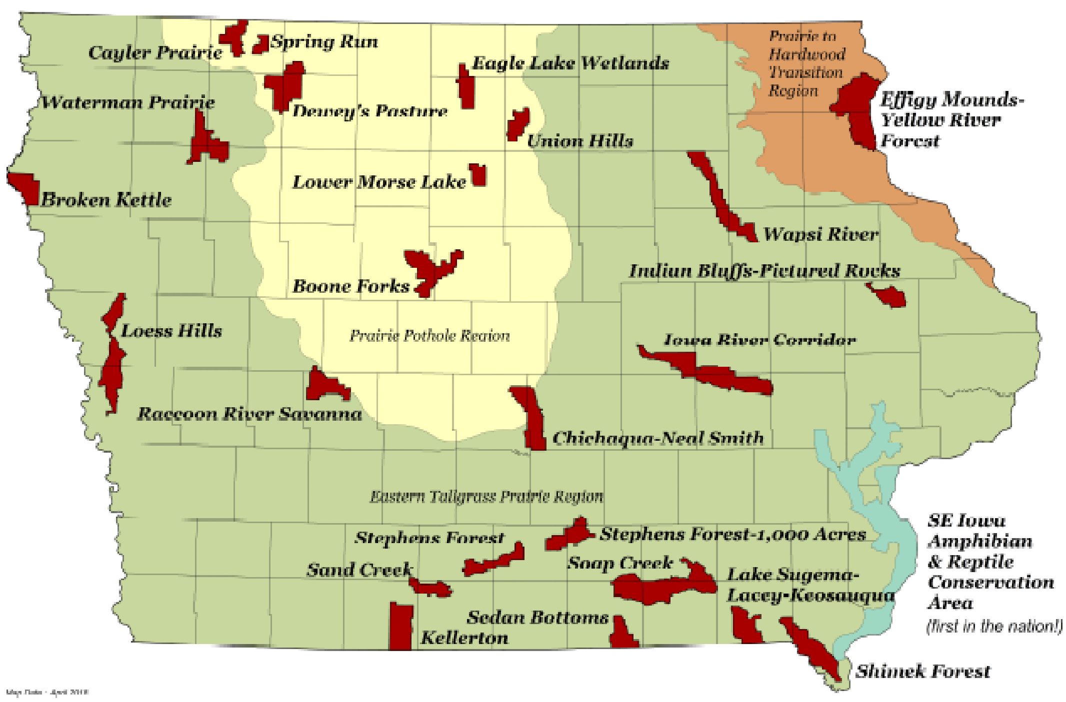


Figure 31. Iowa Bird Conservation Areas overlaid on broad ecoregions.

The Hawkeye Wildlife Management Area is in the upstream delta of Coralville Lake (Figure 32). The area covers nearly 14,000 acres of mostly forest and wetland habitat (Table 4). The area is a popular recreation area that supports hunting, bird watching, and other activities. The Iowa DNR wildlife biologists report that spring drawdowns in Coralville Lake are good for shorebirds. Fall pool raises requested several decades ago by DNR biologists benefit migratory waterfowl. Increased flooding over the last decade is killing floodplain forest and encouraging invasive reed canary grass encroachment which leads to large areas of homogeneous habitat. Water management objectives include lower water levels through the growing season and higher water levels in the fall. Increasing pool stages can help with invasive species management and other habitat objectives.

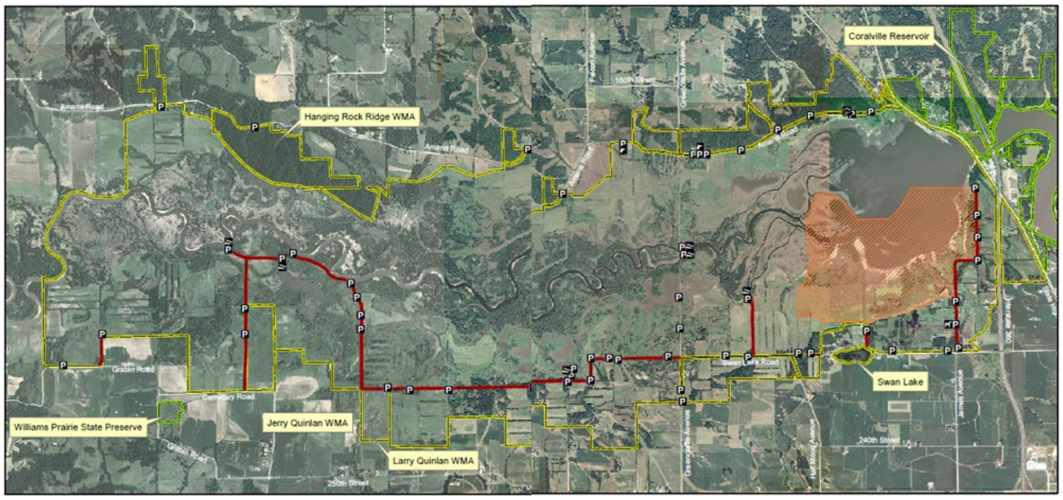


Figure 32. Iowa DNR Hawkeye Management Area (source: Iowa DNR)

.

Table 4. Hawkeye Wildlife Management Area land cover.

Habitat class	Acres	Percent of area
Forest	3,737	28%
Prairie	378	3%
Wetland	2,836	21%
Deep Water (Lake)	1,911	14%
Scrub/shrub	987	8%
Developed	3,487	26%
TOTAL	13,336	100%

Wildlife conservation areas, refuges, and wetland conservation easements on private land are abundant in the bottomlands at the confluence of the

Iowa and Mississippi Rivers (Figure 33). Much of the land was purchased by the Corps of Engineers for the Upper Mississippi River Navigation System who granted land management to the USFWS Louisa Division refuge (2,300 acres) and the Iowa DNR Odessa Wildlife Management Area (4,100 acres). The management areas are contiguous and are influenced by interior water management and effects of Mississippi and Iowa River flooding. The areas are managed by lowering water levels during the growing season to encourage wetland plant production and flooded in the fall to support waterfowl migrations. They provide outstanding habitat for many species, unless river flooding impacts management objectives.

The Horseshoe Bend Division refuge and Wapello Bottoms Wildlife Management Area are located on the Iowa River upstream from its confluence with the Mississippi River. The 2,606 acre Horseshoe Bend Division was purchased by the USFWS following the Flood of 1993. It was one of the first "non-structural" flood response measures, which means the land was purchased from farmers for conservation, rather than repairing the levees which had previously been damaged and repaired an average of every 4 years (USFWS 2004). The Wapello Bottoms Wildlife Management Area covers over 2,600 acres in several different management units. The Iowa River sites are open to the river and don't have water regulating capability. Low levees remain, but they were never repaired and are overtopped frequently. DNR lands are open to hunting while USFWS lands are managed as waterfowl refuges during the fall migrations.

Wildlife managers identified Iowa River flooding as their primary management concern. Water levels are staying high through the growing season and causing a shift in management objectives. Areas that were previously managed for pheasants, deer, and turkey are now becoming wetlands with different management objectives. Wildlife managers expressed concern that increased flood flows from Coralville Lake might overtop levees and impact management objectives. While releases from Coralville Dam are typically only 25% of the flow in the lower Iowa River, implementation of larger releases during early spring months may support management objectives.

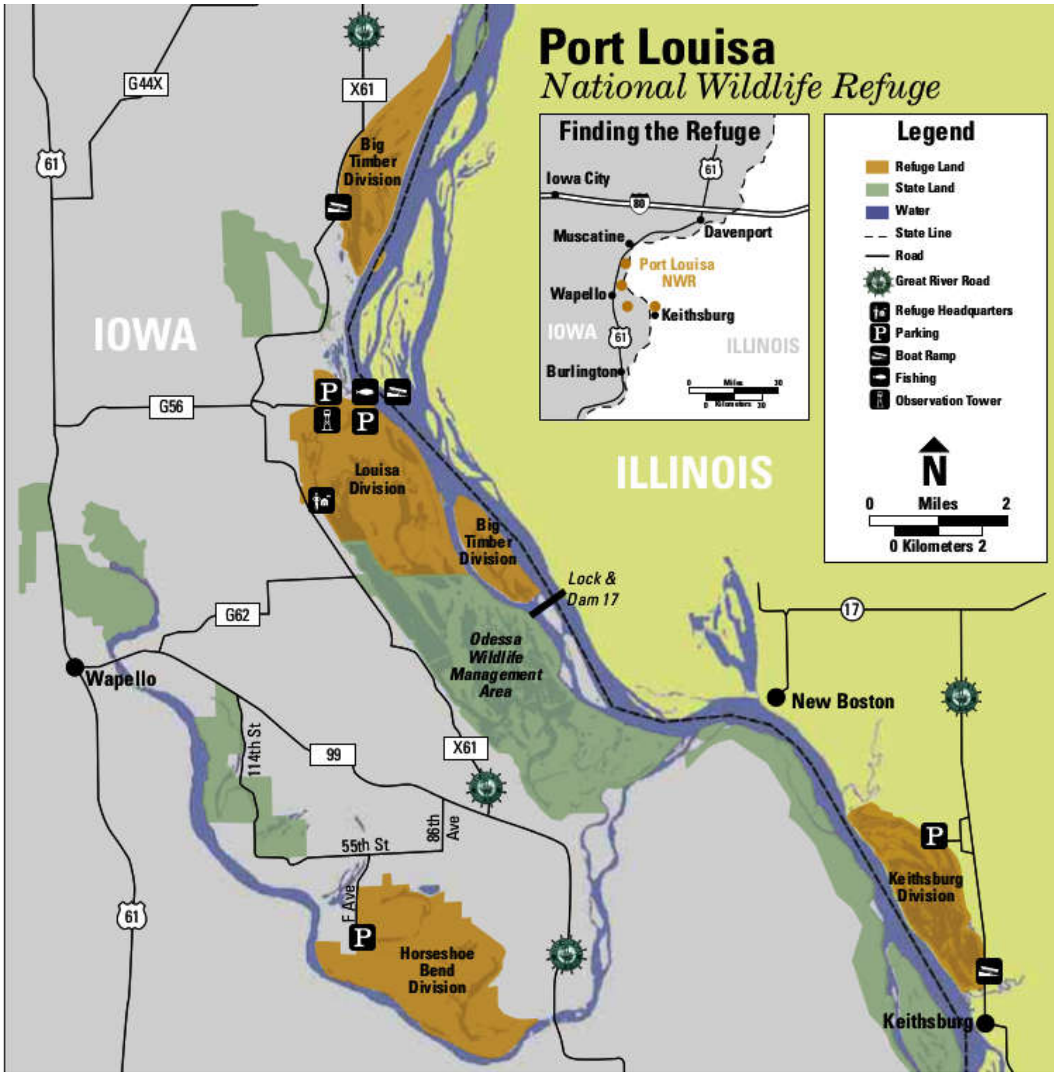


Figure 33. Lower Iowa River wildlife management areas (source: USFWS).

3.5.5 Habitat Management

As illustrated clearly by wildlife and fisheries managers, habitat considerations are the most important factors driving biological outcomes. The Iowa Wildlife Action Plan has been referenced many times because it provides the most comprehensive analysis of fish and wildlife management objectives. The plan focuses on the species of greatest conservation need and their habitats. An ecoregion approach is used to identify the drivers and biological potential for each region. Major habitats and impacts from development are considered. The scale of impacts from agriculture, municipal, and urban development are very significant with only 0.2 percent of prairies, 5 percent of wetlands, and 37 percent of forests (mostly on steep slopes) remaining. Flowing waters and wetlands support the greatest number of species of greatest conservation need even though they cover only 1 percent of Iowa. Rare and sensitive communities were also considered, and floodplain prairie potholes, sand prairies, fens, and oak savannas all occur in the Iowa River watershed. During stakeholder meetings, high river flows in the reach downstream from Coralville Lake were highlighted for their impact on rare habitats. The map of high opportunity areas for conservation (Figure 34) illustrates the importance of the Iowa River corridor for supporting fish and wildlife management objectives.

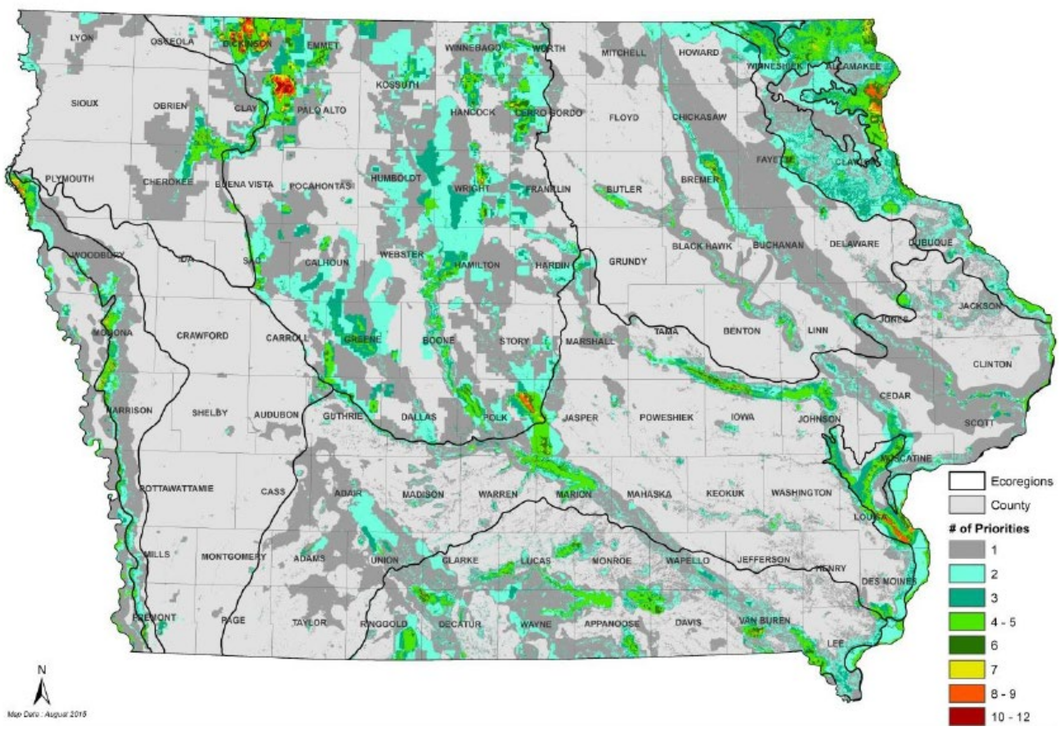


Figure 34. Iowa Wildlife Action Plan high opportunity areas for cooperative conservation actions.

4 Stakeholder Concerns

Stakeholders organized by area of expertise or management concerns were convened in a series of conference calls to get responses to a standard set of questions guiding discussions:

- What is your job/connection to the Iowa River?
- Why is the Iowa River important to you or your constituents?
- What are your concerns regarding or relating to the Iowa River?
- Are they directly related to Iowa River water management?
- Do you feel it is possible to alleviate your concerns?
- Do you have suggestions or ideas you would like considered for Iowa River water management related to your concerns?

Their responses were recorded in meeting minutes and then itemized and tabulated to gauge their relative importance. Their responses covered 8 major concerns and a miscellaneous category that was identified by only one or two stakeholder groups. The participants and other experts will be convened in an environmental flows planning workshop planned for 2021.

- **Flooding, E-flows, Water Management, Natural Hydrology**

  Flooding was the most prominent concern among stakeholders. They related a desire to return to a historic reference hydrology or natural hydrology that fell under the category of environmental flows. The impact of Coralville Dam operations was considered.

- **Nutrient Reduction, Water Quality, Public Health**

  Nutrient reduction objectives were common among stakeholders. Their concerns focused mostly on water quality impacts affecting aquatic habitat and public health as a water supply.

- **Public Participation, Outreach, Communication**

  Public participation and communication were considered important because stakeholders thought it will take concerted effort of land-owners and land managers to influence the ecological drivers that must be addressed to influence habitat and wildlife outcomes.

- **Habitat, Land Acquisition, Refuges/WMAs**

The importance of natural habitat was recognized in comments about habitat, the need for more natural habitat, and the role of refuges and management areas.

- **Sedimentation, Erosion/Widening/loss of depth, Floodplains**

  Land use impacts driving sedimentation and aquatic habitat degradation were important to stakeholders. Increased precipitation in summer storms drives higher overland runoff, higher river discharge and more stream bed and bank erosion that is forming wider and shallower channels, filling backwater lakes and floodplains.

- **Fish, Wildlife, Mussels**

  Concerns about biological resources focused on large river fish, waterbirds, freshwater mussels, and the habitats and ecological drivers influencing them.

- **Upland Management, Watersheds, Soil Health, BMPs**

  The role of watershed and upland management were recognized because they are critical drivers of river habitat function and quality.

- **Non-consumptive public Use – enjoy nature, access, Kayak/canoe, wildlife watching, boating in Pool**

  While hunting and fishing have been traditional habitat management concerns, there are increased considerations for non-consumptive users.

Miscellaneous issues were mentioned by only one or two stakeholder groups and they were specific to their agency management objectives. They included fish habitat, wildlife habitat, and groundwater levels.

5 Recommendations

Environmental flow recommendations will be determined at an environmental flows workshop in 2021 but some ideas were apparent in the stakeholder meetings

- Downstream

  River flows should be naturalized to the greatest extent possible. Higher flood releases can increase river-floodplain connectivity and reduce the duration of bank full flows maintained by sustained dam releases. Managing for a "fall pulse" would benefit waterfowl habitat.

- Pool

  Coralville Lake habitat can benefit from higher spring water levels to reduce spring drawdown impacts and to augment fish spawning. Water levels can be lowered through the growing season to promote wetland development, but lower water levels can impact boaters. Higher fall water levels increase waterfowl habitat and hunting opportunities and can support reptile overwintering if held high through the winter season.

- Upstream/watershed

  River flow upstream of Coralville Lake cannot be managed by dam operations but stakeholders identified the role of watershed management to influence river flows and water quality.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Bendix, J. and C.R. Hupp. 2000. Hydrological and geomorphic impacts on riparian plant communities. Hydrological Processes 14:2977-2990.

Bettis, E.A. and R.D. Mandel. 2002. The effects of temporal and spatial patterns of Holocene erosion and alluviation on the archaeological record of the Central and Eastern Great Plains, USA. Geoarchaeology 17:141-154.

Bishop, R.A. 1981. Iowa's wetlands. Proceedings of Iowa Academy of Science 88:11-16.

Blann, K., D. DeGeus, and H. Howe. 2016. Identifying Environmental Flow Requirements for the Des Moines River: Background Literature Review and Summary. U.S. Army Corps of Engineers, Rock Island District and The Nature Conservancy, Iowa Chapter. 83 pp.

Blann, K. 2017. Environmental Flows Workshop Summary Des Moines River Sustainable Rivers Project. U.S. Army Corps of Engineers, Rock Island District and The Nature Conservancy, Iowa Chapter. 51 pp.

Bovee, K.D. 1982. 'A guide to stream habitat analysis using the Instream Flow Incremental Methodology', U.S. Fish Wildlife Service, Instream Flow Information Paper 12, FWS/OBS-82/26, Washington, D.C.

Carlander, H.B. 1954. A history of fish and fishing on the Upper Mississippi River. Upper Mississippi River Conservation Committee, Moline, Illinois. 117 pp.

Changnon, S.A., 1983. Trends in floods and related climate conditions in Illinois. Earth and Environmental Science 5:341–363.

Cleary, R.E. 1953. An Annotated Check-List of the Fishes of the Iowa-Cedar River Drainage Basin in Iowa. Proceedings of the Iowa Academy of Science, 60, 626-635. Available at: https://scholarworks.uni.edu/pias/vol60/iss1/86

Dahl, T.E. 1990. Wetland losses in the United States: 1780's to 1980's. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Drury, G.H. 1970. General theory of meandering valleys and underfit streams. Pages 264 – 275 *in* Rivers and River Terraces, G.H. Drury ed., Palgrave Macmillan, London. https://doi.org/10.1007/978-1-349-15382-4

Eash, D.A. 2003. Main-Channel Slopes of Selected Streams in Iowa for Estimation of Flood-Frequency Discharges. U.S. Geological Survey Water-Resources Investigations Report 03-4120. U.S. Geological Survey, Iowa City, Iowa. 236 pp.

Eash, D.A., P.S. O'Shea, J.R. Weber, K.T. Nguyen, N.L. Montgomery, and A.J. Simonson. 2015, Statistical summaries of selected Iowa streamflow data through September 2013: U.S. Geological Survey Open-File Report 2015–1214, 18 p., http://dx.doi.org/10.3133/ofr20151214.

Fredrickson, L.H. and T.S. Taylor 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service Resource Publication 148.

Grumbine, E. 1984. What is Ecosystem Management? Conservation Biology 8: 27-38.

Hansen, E., K.S. Chan, C.S. Jones, and K. Schilling. 2016. Assessing the relative importance of nitrogen-retention processes in a large reservoir using time-series modeling. Journal of Agricultural, Biological, and Environmental Statistics 21:121-169.

Harwell, M.A., V. Meyers, T. Young, A. Bartuska, N. Grassman, J.H. Gentile, C.C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Tamplet, and S. Tosini. (1999). "A framework for an ecosystem integrity report card," *BioSciences* 49(7), 543-556.

Hayashi, M, G. van der Kamp, and D.O. Rosenberry. 2016. Hydrology of prairie wetlands: Understanding the integrated surface-water and groundwater processes. Wetlands 36:237-254.

Heidebrink, L. 2002. Freshwater Mussels of Iowa. Cedar Valley Resource, Conservation, and Development, Inc., Charles City, Iowa. 11 pp.

Hillaker, H.J. 2014. Iowa climate summary. State Climatologist Presentation, Iowa Department of Agriculture and Land Stewardship, Des Moines, Iowa.

Hoogeveen, N. 2010. Solving Dam Problems: Iowa's 2010 Plan for Dam Mitigation. Iowa Department of Natural Resources, Des Moines, Iowa. 59 pp. + appendices.

Iowa Department of Natural Resources. 2015. *Iowa's Wildlife Action Plan: Securing a future for fish and wildlife*. K. Reeder and J. Clymer, eds. Iowa Department of Natural Resources, Des Moines, Iowa, USA.

Iowa Department of Natural Resources. 2015. List of Iowa Mussels Evaluated by the IWAP. Appendix 12 in *Iowa's Wildlife Action Plan: Securing a future for fish and wildlife*. K. Reeder and J. Clymer, eds. Iowa Department of Natural Resources, Des Moines, Iowa, USA.

Johnson, R.R., F.T. Oslund, and D.R. Hertel. 2008. Past, present, and future of prairie potholes in the United States. Journal of Soil and Water Conservation 63:84-87.

Junk, W.J., P.B Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Canadian Special Publication of Fisheries and Aquatic Sciences 106, 110-127.

Kane, K.L., E.E. Klaas, K.L. Andersen, P.D. Brown and R.L. McNeely. 2003. The Iowa Gap Analysis Project Final Report. Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Ames.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Knox, J.C., 1993. Large increases in flood magnitude in response to modest changes in climate. Nature 361: 430–432.

Kofoid, C.A. 1903. The plankton of the Illinois River, 1894-1899: with introductory notes upon the hydrography of the Illinois River and its basin. Illinois Natural History Survey Bulletin VI. 629 pp.

Konrad, C.P., 2010, Monitoring and evaluation of environmental flow prescriptions for five demonstration sites of the Sustainable Rivers Project: U.S. Geological Survey Open-File Report 2010-1065, 22 p.

LaBaugh, J.W.; T.C.Winter, and D.O. Rosenberry. "Hydrologic Functions of Prairie Wetlands" (1998). Great Plains Research: A Journal of Natural and Social Sciences. 361. https://digitalcommons.unl.edu/greatplainsresearch/361.

Leighton, M.M. 2013. Pleistocene history of Iowa River valley north and west of Iowa City in Johnson County, Iowa. University of Iowa dissertation, Iowa City, Iowa. https://doi.org/10.17077/etd.ijudq23p

Lenhart, C.F., E.S. Verry, K.N. Brooks, and J.A. Magner. 2012. Adjustment of prairie pothole streams to land-use, drainage and climate changes and consequences for turbidity impairment. River Research and Applications 28:1609-1619.

Mathews, R. and B.D. Richter. 2007. Application of the indicators of hydrologic alteration software in environmental flow setting. Journal of the American Water Resources Association 43:1400-1413.

McCorvie, M.R. and C.L. Lant. 1993. Drainage district formation and the loss of Midwestern Wetlands, 1850-1930. Agricultural History 67:13-39.

McCully, P. 2001. Silenced Rivers: the ecology and politics of large dams. Zed Books, London.

McDonald, D.B. and R.D.Schmickle. (1965) "Factors Affecting Winter Fish Kills in the Coralville Reservoir, Iowa," Proceedings of the Iowa Academy of Science, 72(1), 243-247.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Orth, D.J. 1986. Ecological considerations in the development and application of instream flow-habitat models. Regulated Rivers: Research and Management 1:171-181.

Plakfkin, J.L., M.T. Barbour, K.D. Porter, K.S. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. Report No. EPA/444/4-89-01.

Parks, T.P., M.C. Quist, and C.L. Pierce. 2016. Anthropological disturbance and environmental associations with fish assemblage structure in two nonwadeable rivers. River Research and Applications 32:66-84.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime. Bioscience 47:769-784.

Postel, S., and B.D. Richter. 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington DC.

Postel, S. and S. Carpenter. 2012. Freshwater Ecosystem Services. Pages 195-214 in Daily, G.C., Nature’s Services: societal dependence on natural ecosystems. Island Press, 412 pages.

Prior, J.C. 1991. Landforms of Iowa. University of Iowa Press, Iowa City, Iowa. 153 pp.

Rahn, M. 1983. A history of wildlife and hunting on the Upper Mississippi River. Upper Mississippi River Conservation Committee, Moline, Illinois. 61 pp.

Richter, B. D., A.T. Warner, J.L. Meyer, and K. Lutz. 2006. A collaborative and adaptive process for developing environmental flow recommendations. River Research and Applications, 22(3), 297–318.

Rhoads, B.L., Q.W. Lewis, and W. Andresen. 2016. Historical changes in channel network extent and channel planform in an intensively managed landscape: natural versus human-induced effects. Geomorphology 252:17-31.

Rosgen, D.L. and H.L. Silvey. 1996. Applied River Morphology. Wildland Hydrology Books, Fort Collins, CO

Ruhe, R.V. 1974. Holocene environments and soil geomorphology in Midwestern United States. Quaternary Research 4:487-495.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications 12:107-123.

Smith, G.D, W.H. Allaway, and F.F. Riecken. 1950. Prairie soils of the upper Mississippi Valley. Advances in Agronomy 2:157-205.

Sparks, R.E., J.C. Nelson, and Y. Yin. 1998. Naturalization of the flood regime in regulated rivers: the case of the Upper Mississippi River. Bioscience 48:706-720.

Stalnaker, C.B. and J.L. Arnette. 1976. Methodologies for the determination of stream resource flow requirements: an assessment. Utah State University, Logan Utah Prepared for U.S. Fish and Wildlife Service, Office of Biological Services, Western Water Allocation. 199 pp.

Sutherland, R. and P. deMaynadier. 2012. Model Criteria and Implementation Guidance for a Priority Amphibian and Reptile Conservation Area (PARCA) System in the USA. Partners in Amphibian and Reptile Conservation, Technical Publication PARCA-1. 28 pp.

Tennant, D.L. 1976. Instream Flow Regimens for Fish, Wildlife, Recreation and Related Environmental Resources, Fisheries, 1, 6-10, DOI: 10.1577/1548-8446(1976)0012.0.CO;2

Transeau, E.N. 1935. The prairie peninsula. Ecology 16:423-437.

U.S. Army Corps of Engineers. 2001. Water Control Manual Coralville Lake, Iowa River Basin, Coralville, Iowa. U.S. Army Corps of Engineers, Rock Island District, Rock Island, Illinois. 145 pp.

U.S. Fish and Wildlife Service. 2013. Iowa River Corridor Project final comprehensive management plan. US Fish and Wildlife Service, Region 3, Bloomington, Minnesota. 230 pp.

U.S. Fish and Wildlife Service. 2004. Mark Twain National Wildlife Refuge Complex Comprehensive Conservation Plan and Environmental Assessment. US Fish and Wildlife Service, Region 3, Bloomington, Minnesota. 435 pp.

Vannote R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37, 130-137.

Ward, J.V. and J.A. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Dynamics of lotic ecosystems (book) ed: TD Fontane & SM Bartell, pp. 29-42.

Ward, J.V., K. Tockner, and F. Scheiemer. 1999. Biodiversity of floodplain river ecosystems: ecotones and connectivity. Regulated Rivers: Research and Management 15:125-139.

Weber, I. 1976. Irving Weber's Iowa City: Historical Stories about Iowa City (Volumes 1 through 8). Iowa City Lions Club.

Williams, J.D., M.L. Warren, K.S. Cumming, J.L. Harris, and R.J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

Zhang, Y.K. and K.E. Schilling, 2006. Increasing streamflow and baseflow in Mississippi River since the 1940s: effect of land use change. Journal of Hydrology 324: 412–422.

Appendix: IHA Summary Plots for Inflow and Outflow

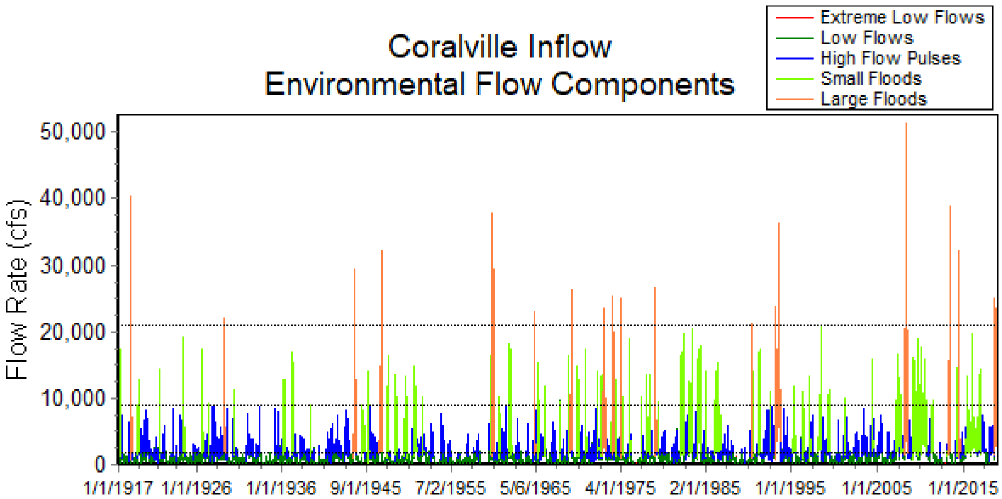
The Indicators of Hydrologic Alteration (IHA) analysis included a Coralville Lake inflow analysis of unregulated flows spanning 1917 – 2018 with the Coralville Dam impact occurring in 1958. The outflow analysis included the unregulated flows for the pre-impact period (1917 – 1958) and the regulated flows for the post-dam period (1960 – 2018).

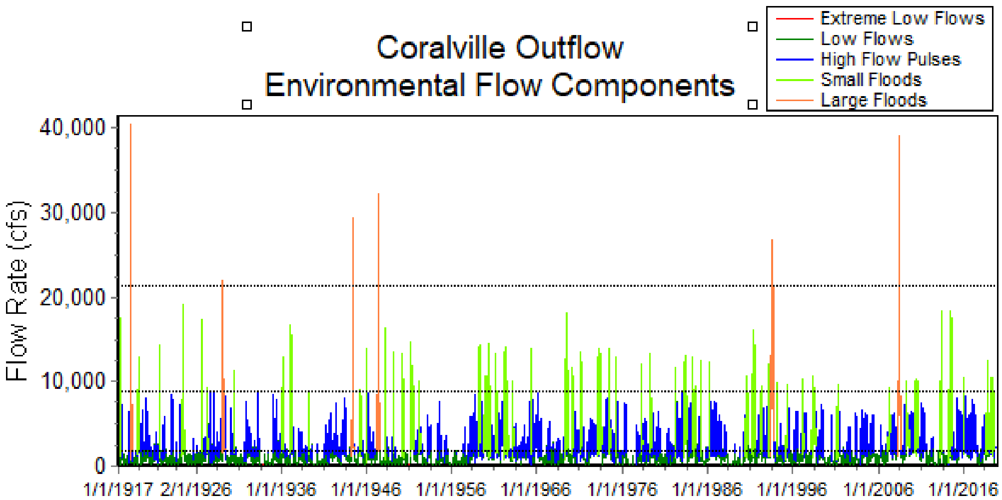
The IHA summary statistics (Table A-1) show very little change in the pattern of flow, but there is higher mean annual flow in the post-dam era.

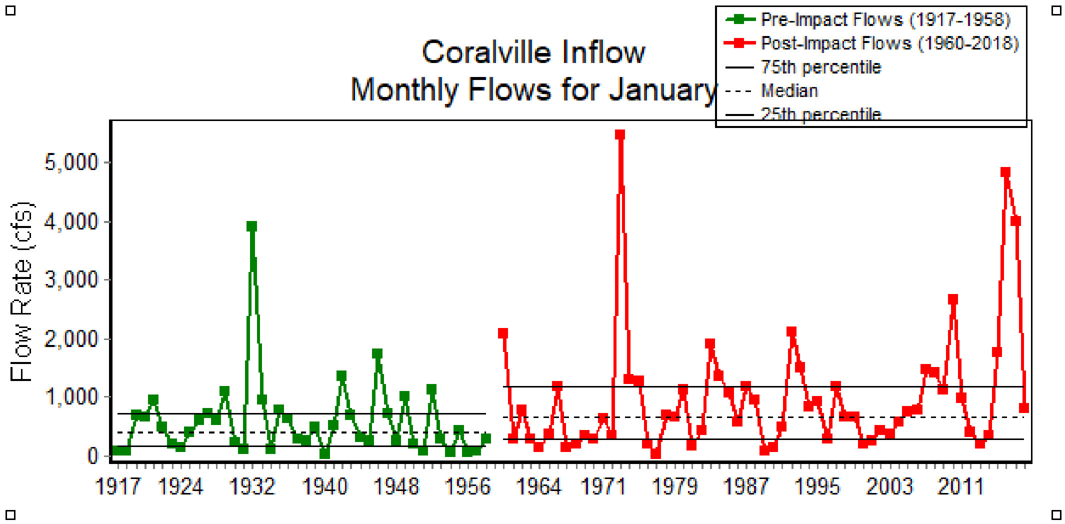
Table A- 1. Indicators of Hydrologic Alteration Coralville Lake outflow analysis summary statistics.

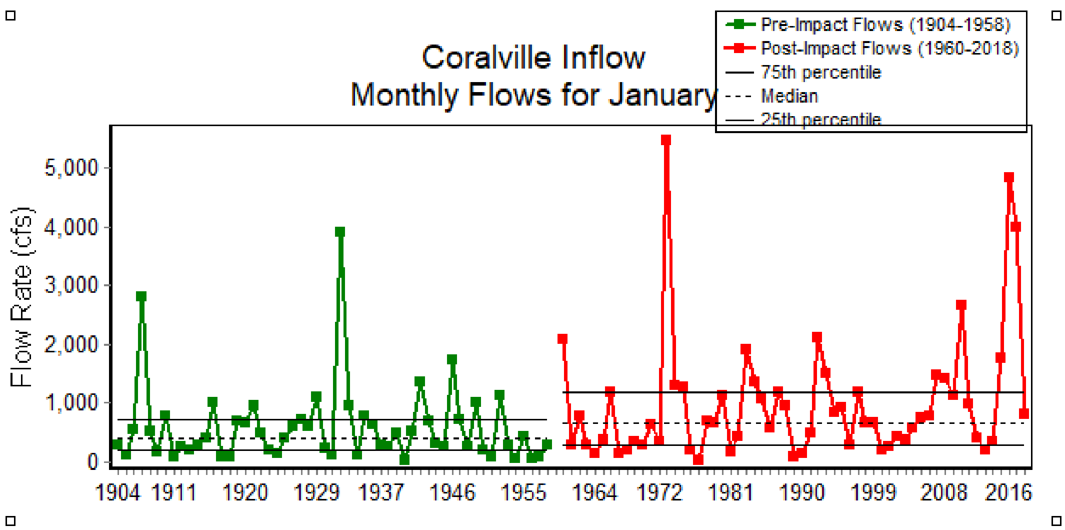
IHA Parameter	Pre-impact period: 1917-1958 (55 years)	Post-impact period: 1960-2018 (59 years)
Mean annual flow	1452	2430
Non-Normalized Mean Flow	1452	2430
Annual C. V.	1.27	1.17
Flow predictability	0.34	0.3
Constancy/predictability	0.72	0.7
% of floods in 60d period	0.33	0.32
Flood-free season	0	0

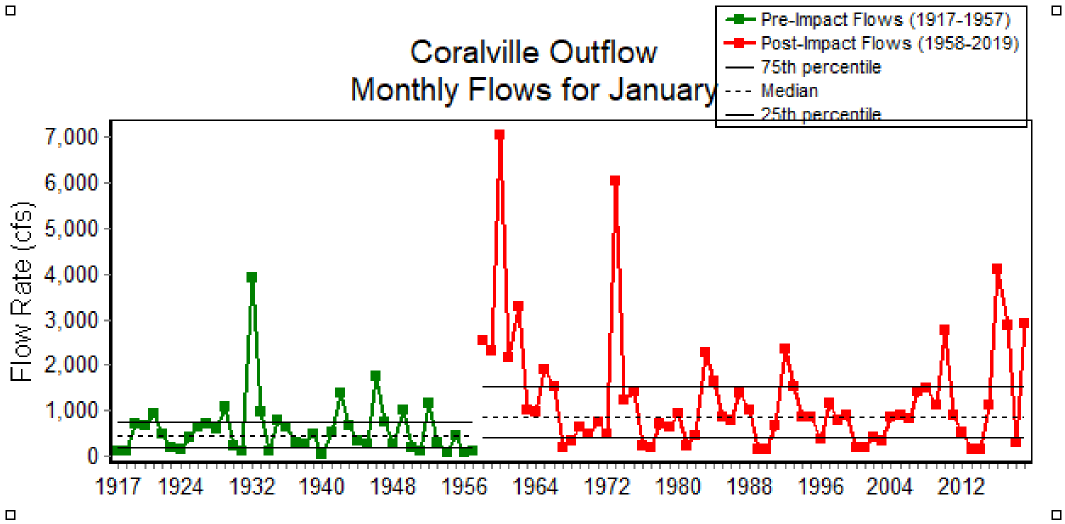
Increase in Coralville Lake inflow magnitude are evident for most months of the year and are consistent across all the minimum and maximum flow parameters which reflects changes in regional land use and climate. The primary difference in the outflow parameters is the decrease in 1, 3, and 7-day maximum flows. The outflow has a lower rise and fall rate with fewer reversals.

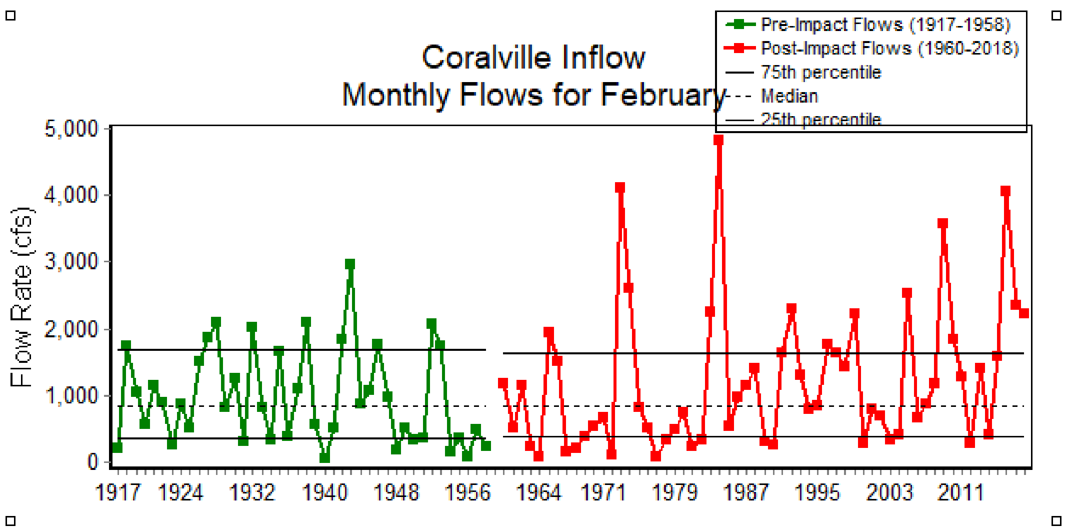

Coralville Inflow
Environmental Flow Components
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods
Flow Rate (cfs)
50,000
40,000
30,000
20,000
10,000
0
1/1/1917 1/1/1926 1/1/1936 9/1/1945 7/2/1955 5/6/1965 4/1/1975 2/1/1985 1/1/1995 1/1/2005 1/1/2015

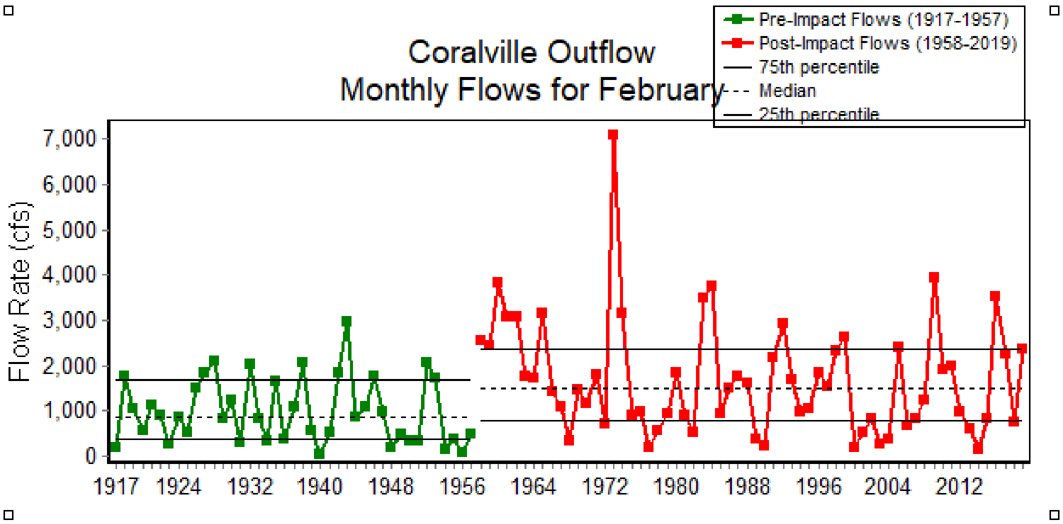

Coralville Outflow
Environmental Flow Components
Extreme Low Flows
Low Flows
High Flow Pulses
Small Floods
Large Floods
Flow Rate (cfs)
40,000
30,000
20,000
10,000
0
1/1/1917 2/1/1926 1/1/1936 1/1/1946 1/1/1956 1/1/1966 1/1/1976 1/1/1986 1/1/1996 1/1/2006 1/1/2016

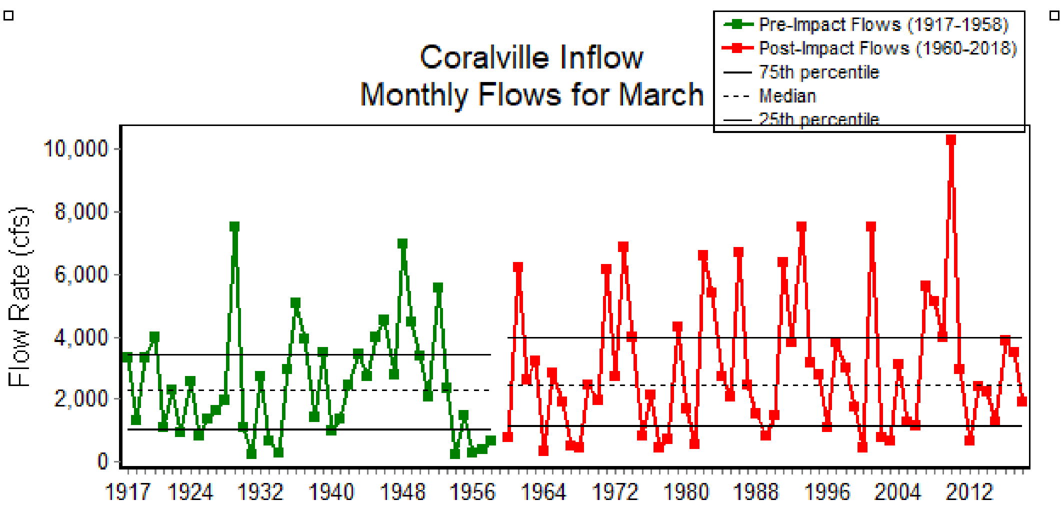

Coralville Inflow
Monthly Flows for January
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

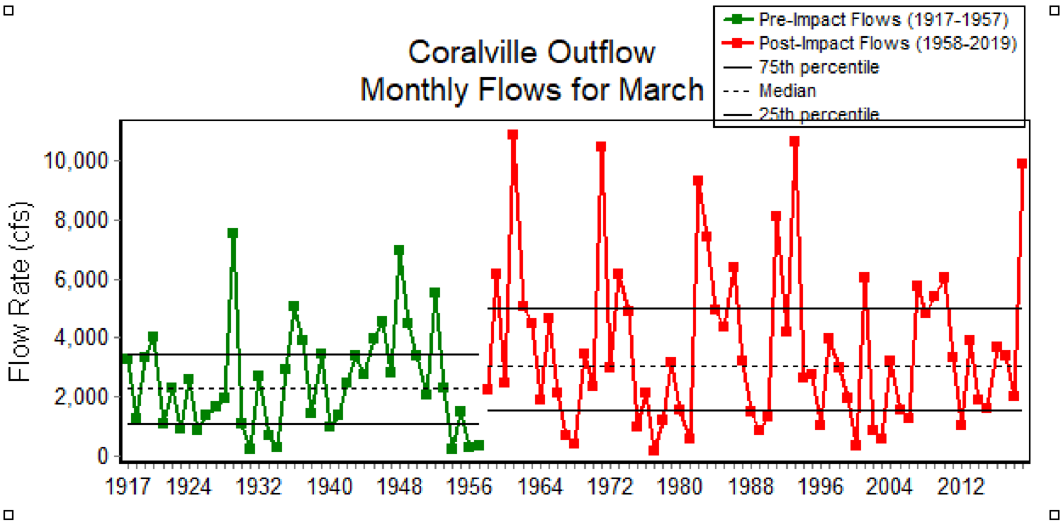

Coralville Inflow
Monthly Flows for January
Pre-Impact Flows (1904-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
5,000
4,000
3,000
2,000
1,000
0
1904 1911 1920 1929 1937 1946 1955 1964 1972 1981 1990 1999 2008 2016

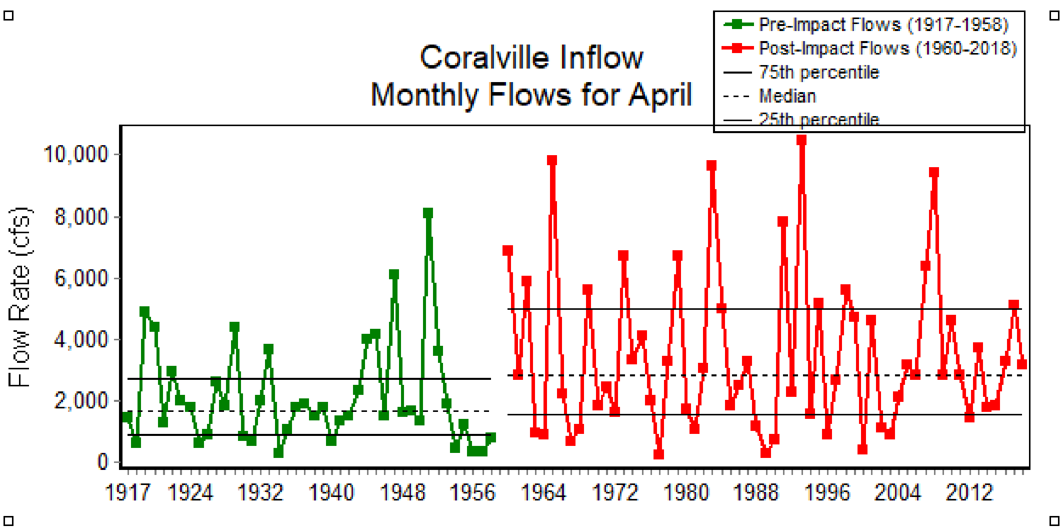

Coralville Outflow
Monthly Flows for January
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

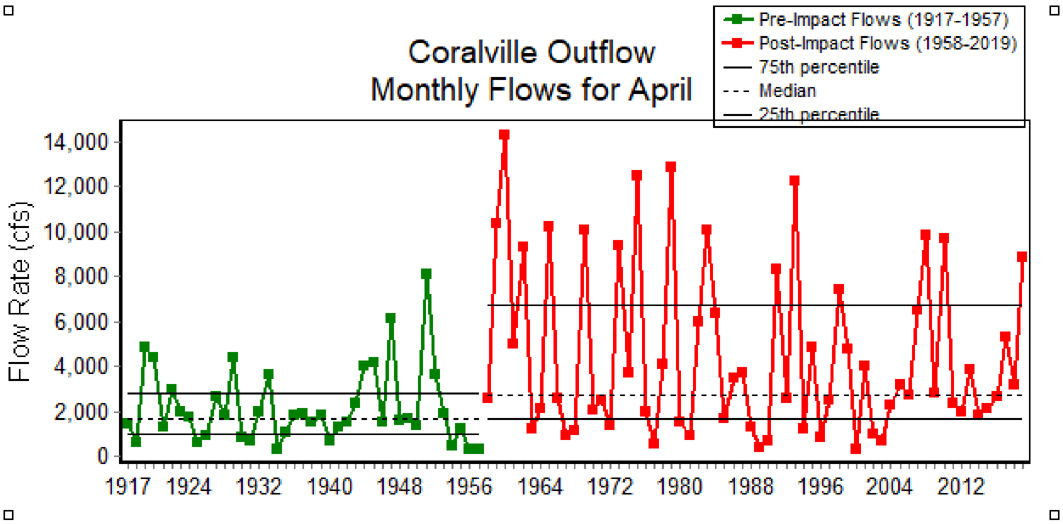

Coralville Inflow
Monthly Flows for February
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

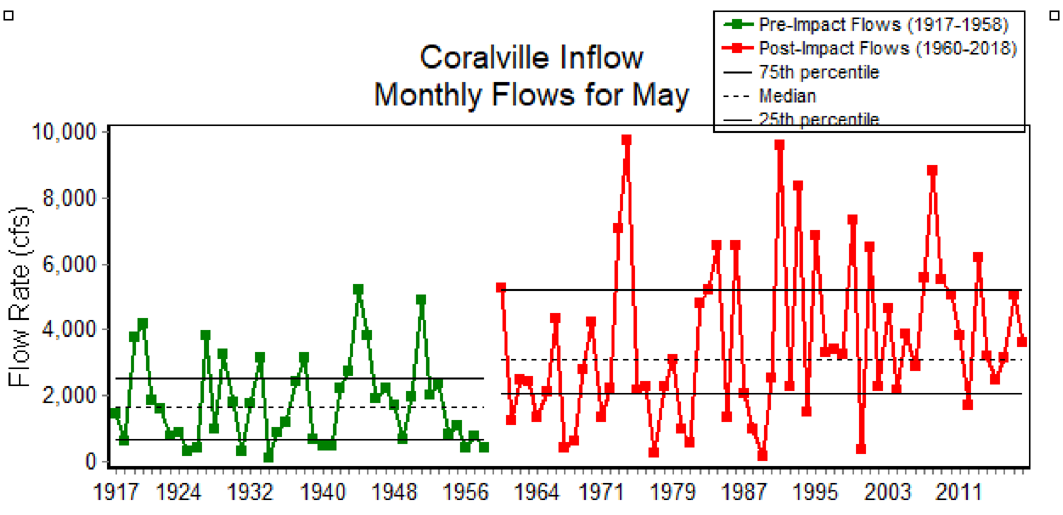

Coralville Outflow
Monthly Flows for February
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

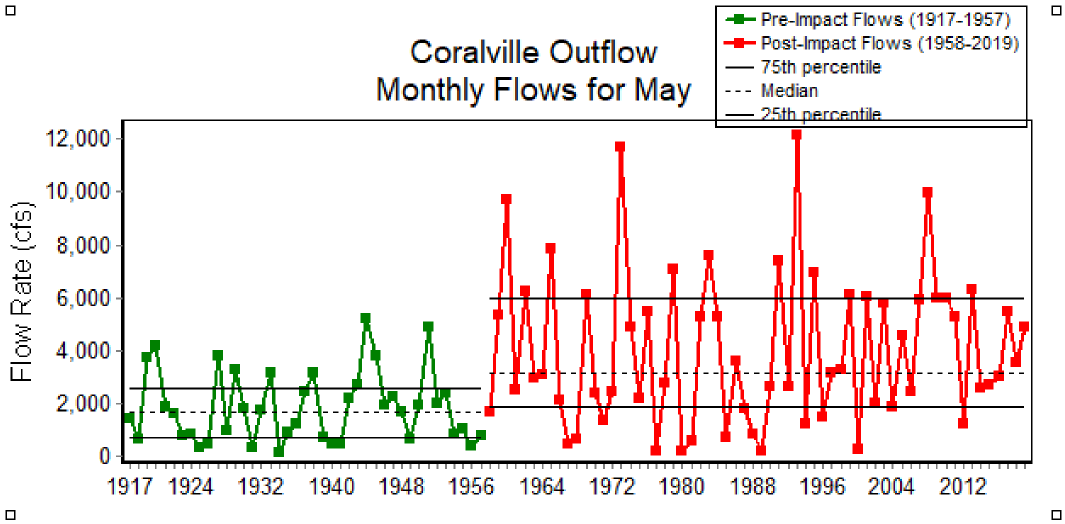

Coralville Inflow
Monthly Flows for March
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

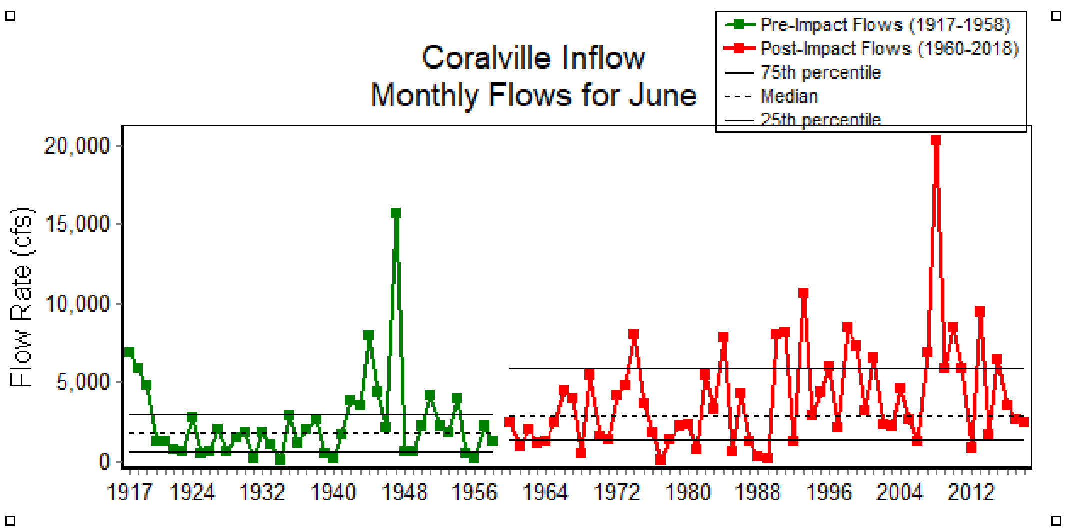

Coralville Outflow
Monthly Flows for March
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

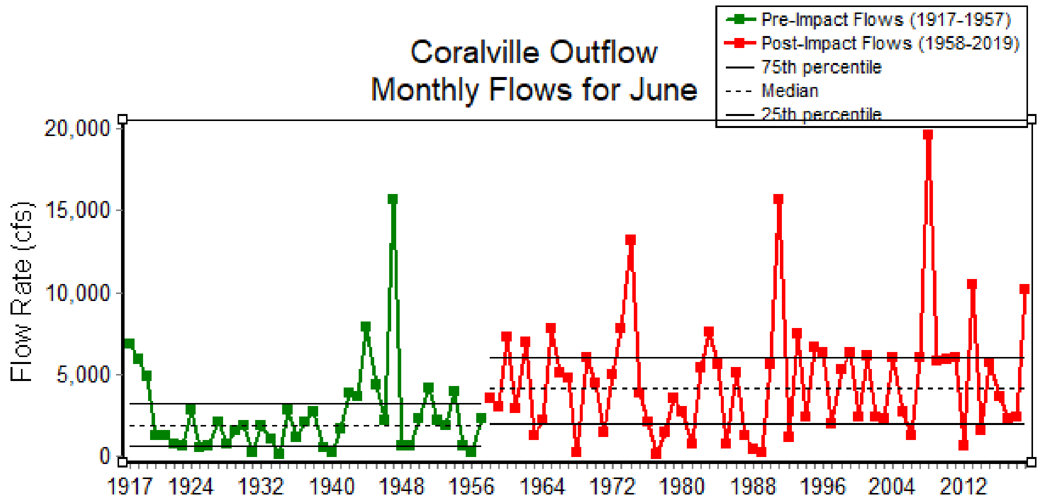

Coralville Inflow
Monthly Flows for April
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

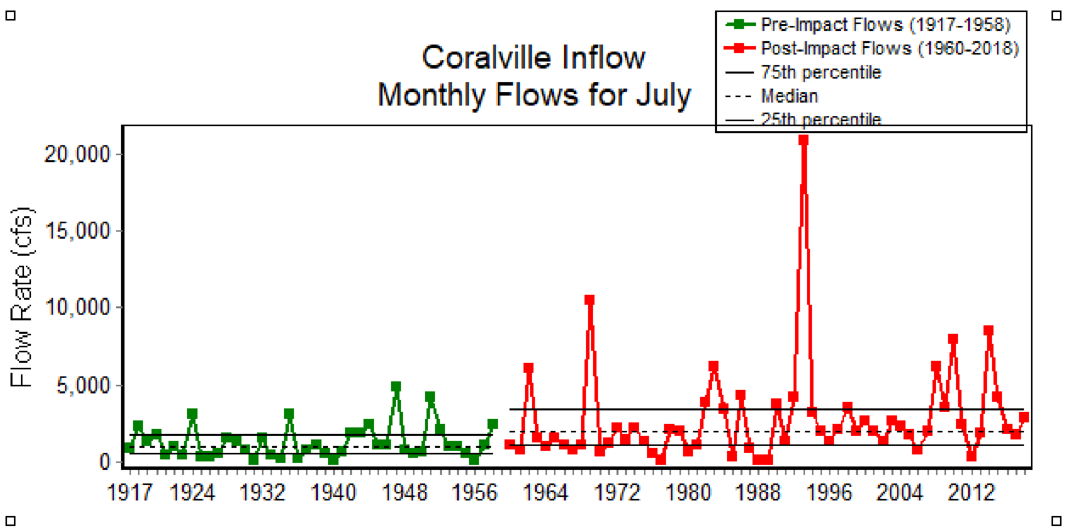

Coralville Outflow
Monthly Flows for April
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

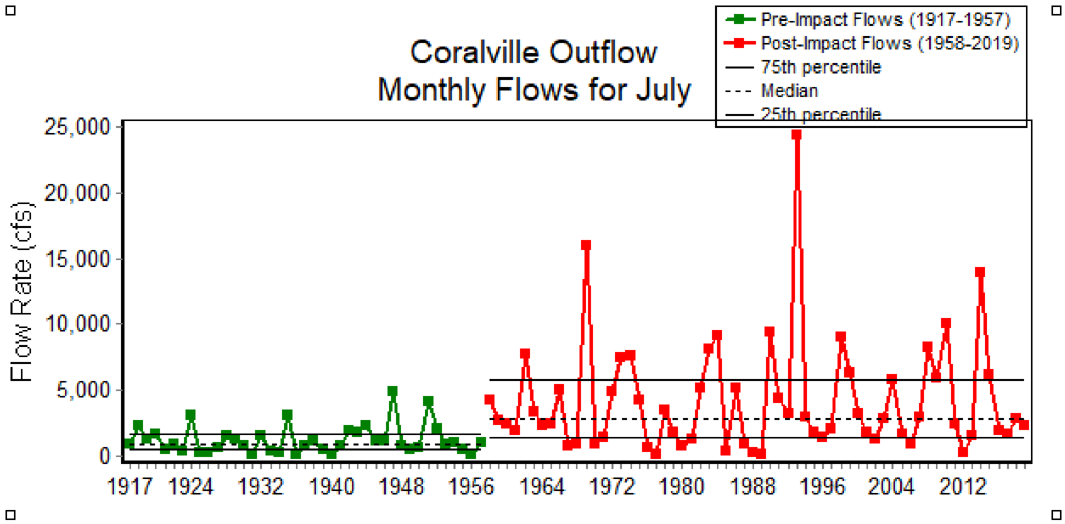

Coralville Inflow
Monthly Flows for May
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1971
1979
1987
1995
2003
2011

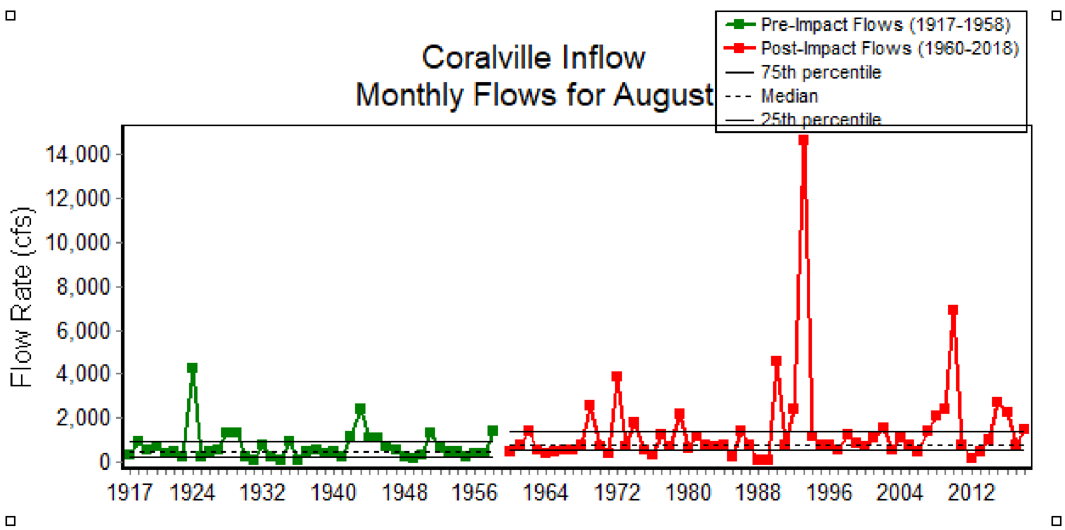

Coralville Outflow
Monthly Flows for May
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

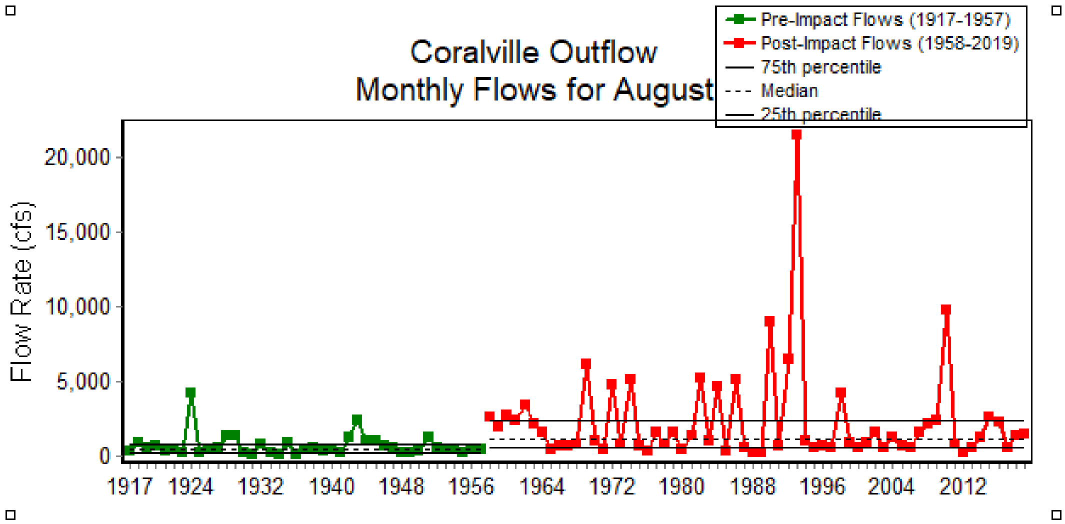

Coralville Inflow
Monthly Flows for June
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

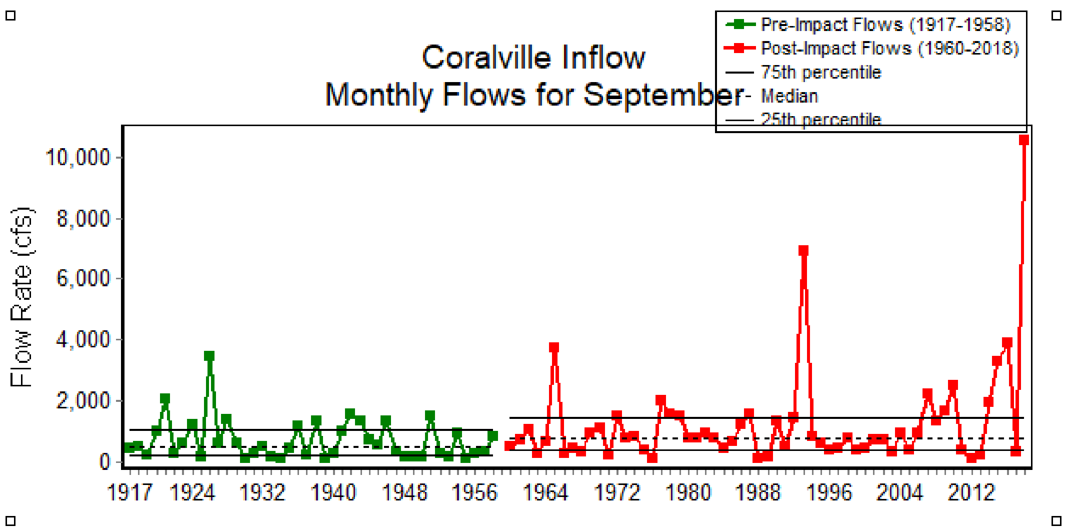

Coralville Outflow
Monthly Flows for June
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

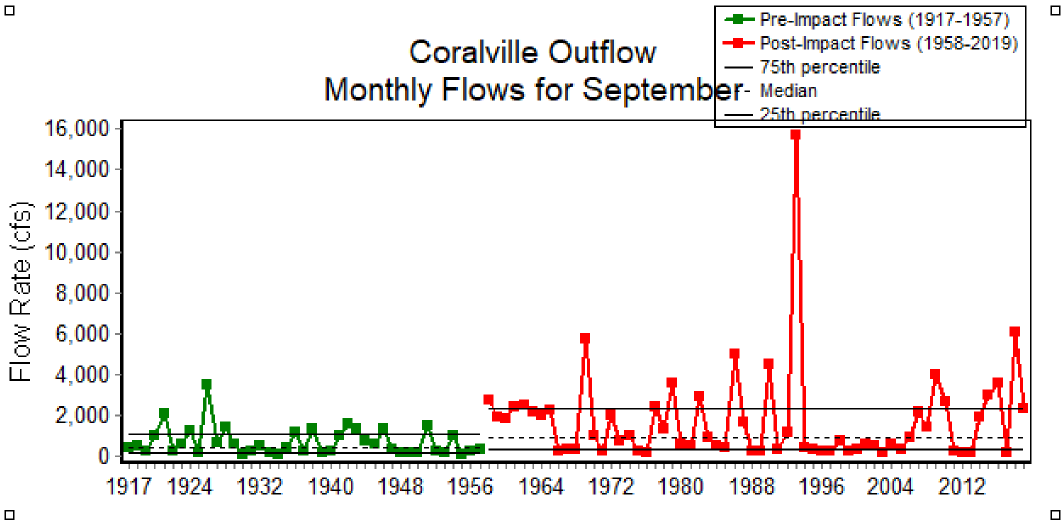

Coralville Inflow
Monthly Flows for July
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

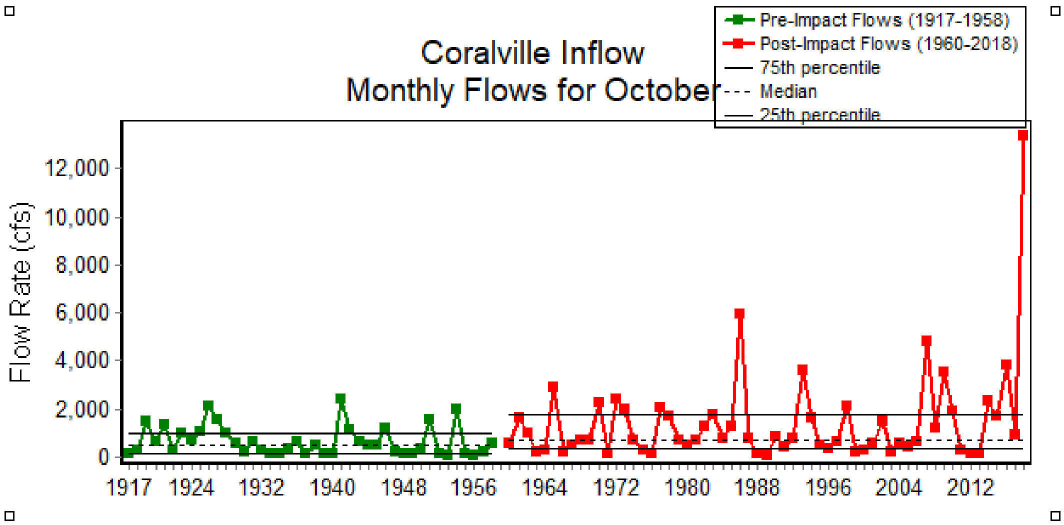

Coralville Outflow
Monthly Flows for July
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
25,000
20,000
15,000
10,000
5,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

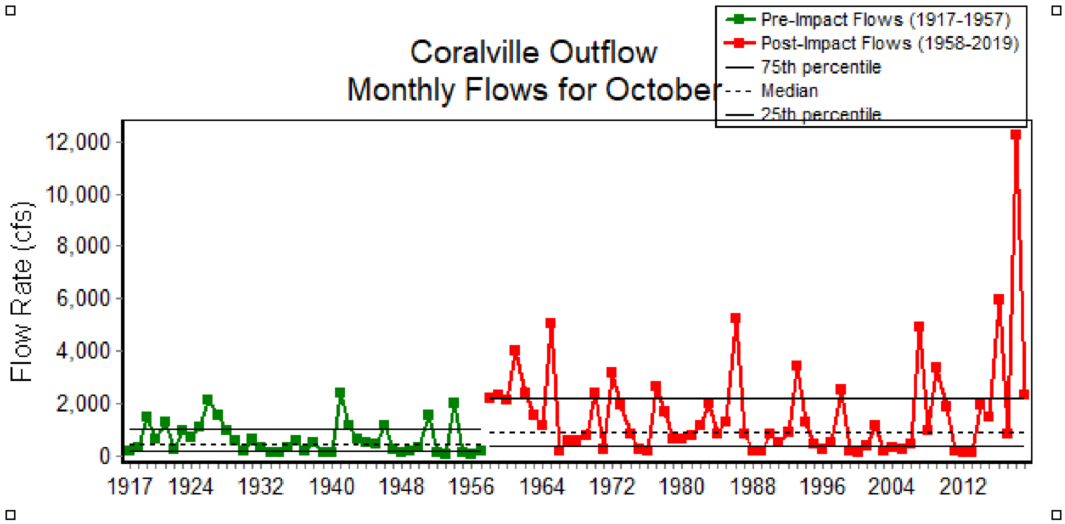

Coralville Inflow
Monthly Flows for August
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

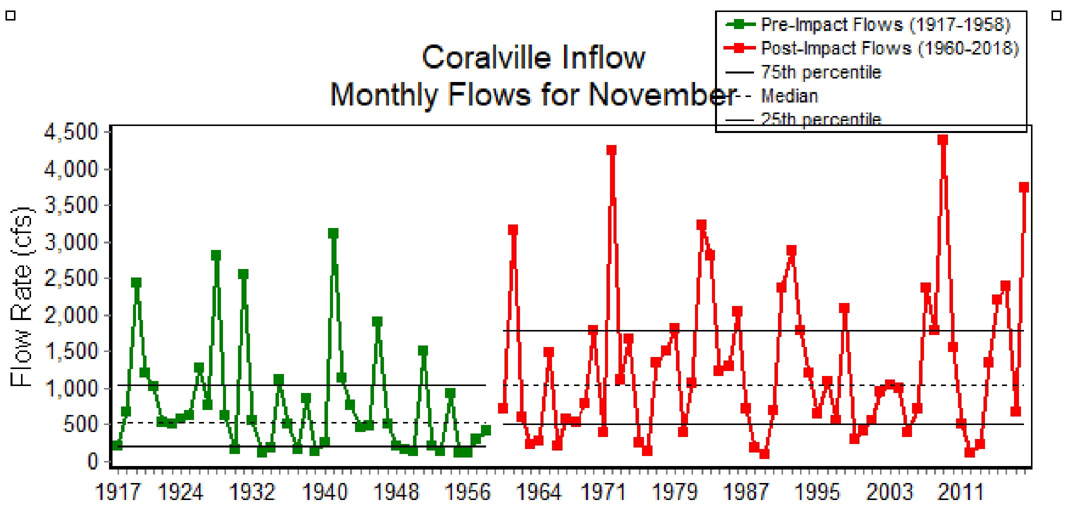

Coralville Outflow
Monthly Flows for August
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

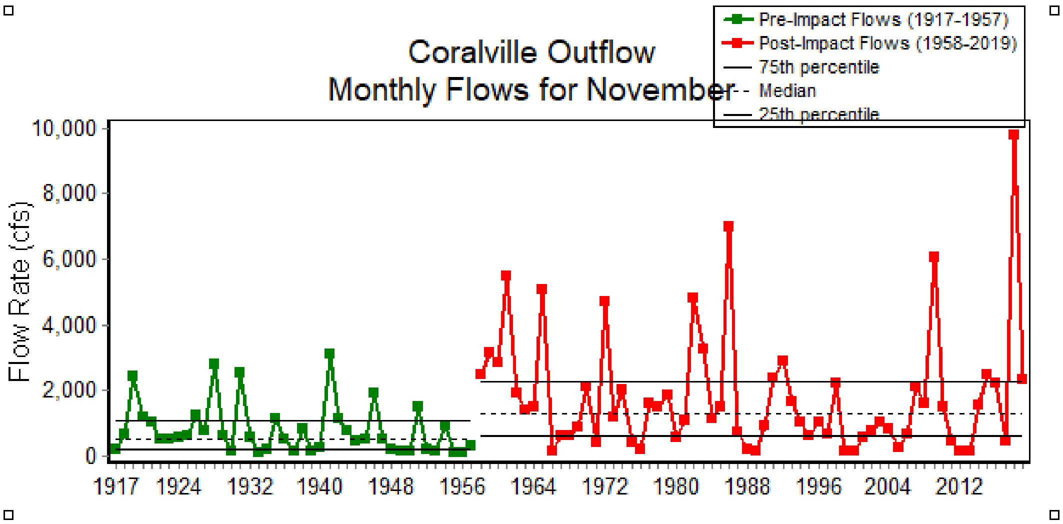

Coralville Inflow
Monthly Flows for September
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

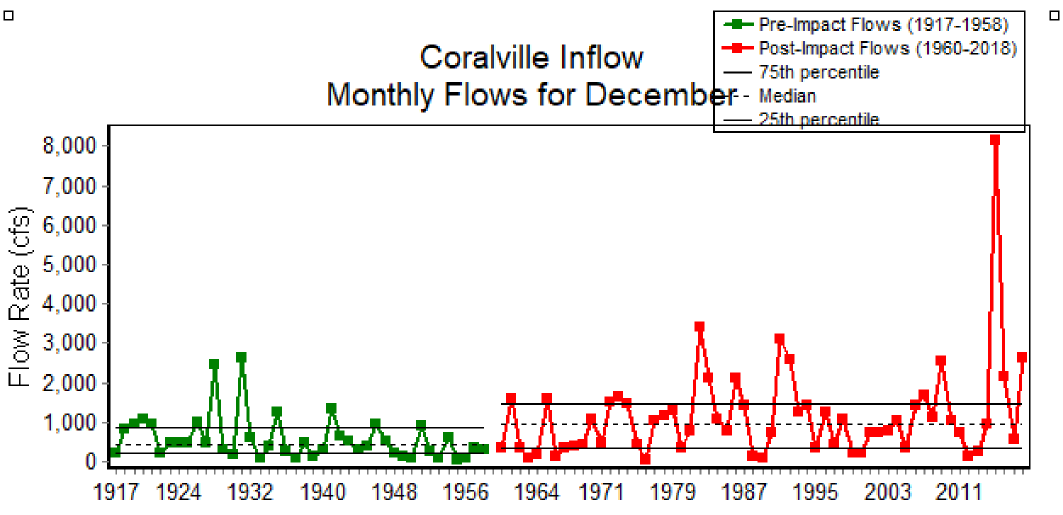

Coralville Outflow
Monthly Flows for September
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

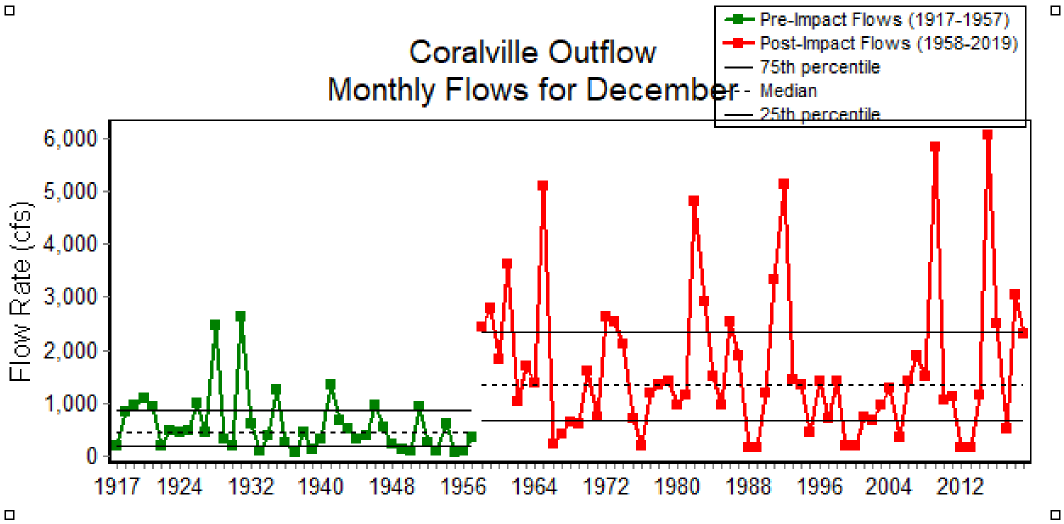

Coralville Inflow
Monthly Flows for October
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

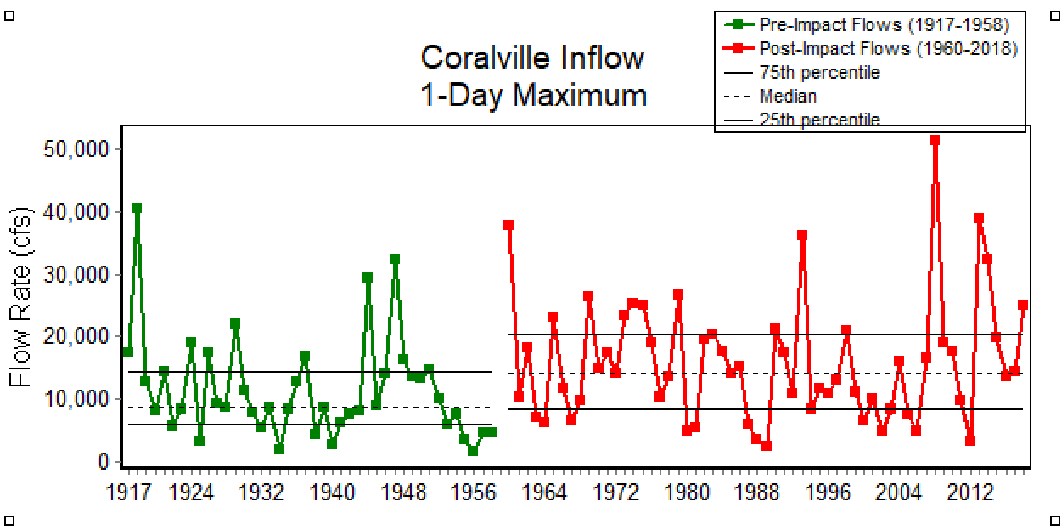

Coralville Outflow
Monthly Flows for October
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
12,000
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

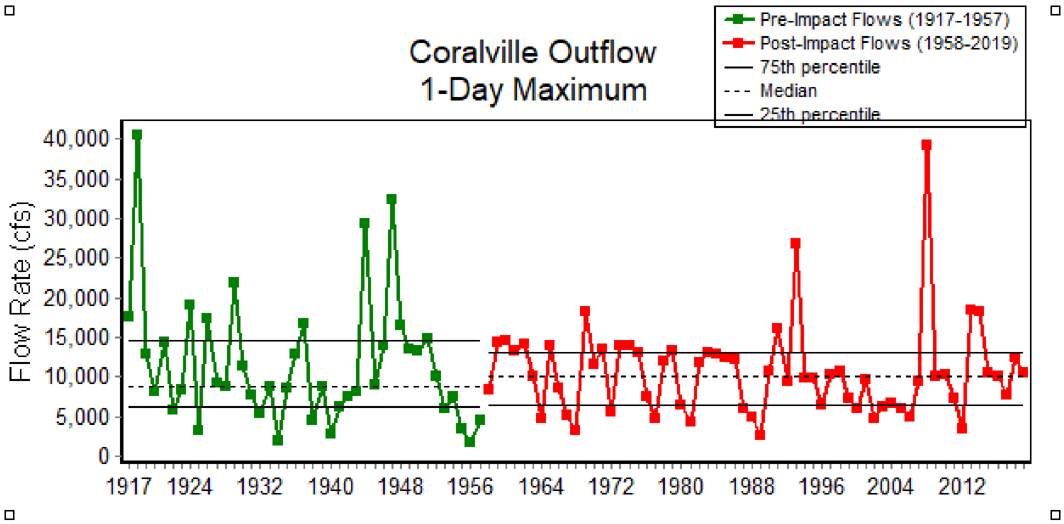

Coralville Inflow
Monthly Flows for November
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

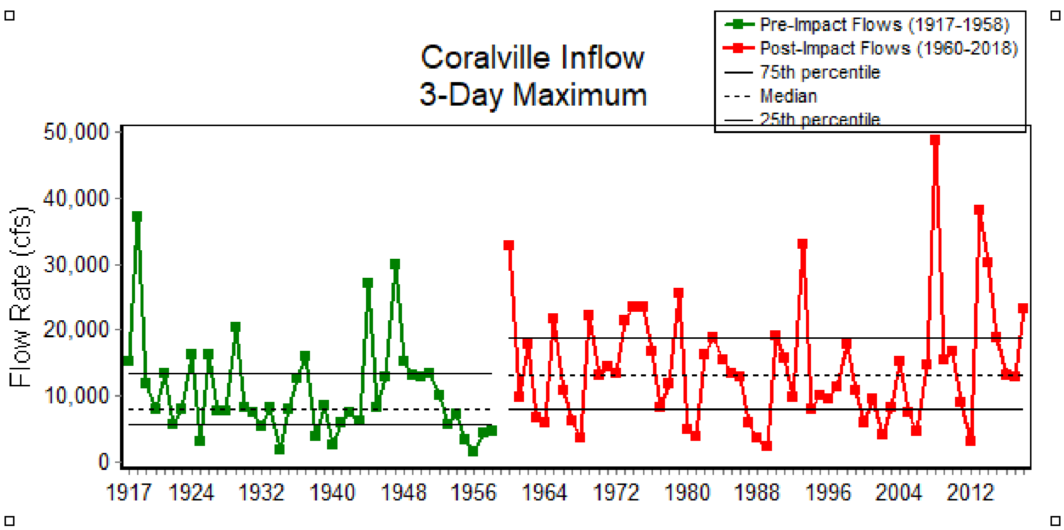

Coralville Outflow
Monthly Flows for November
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

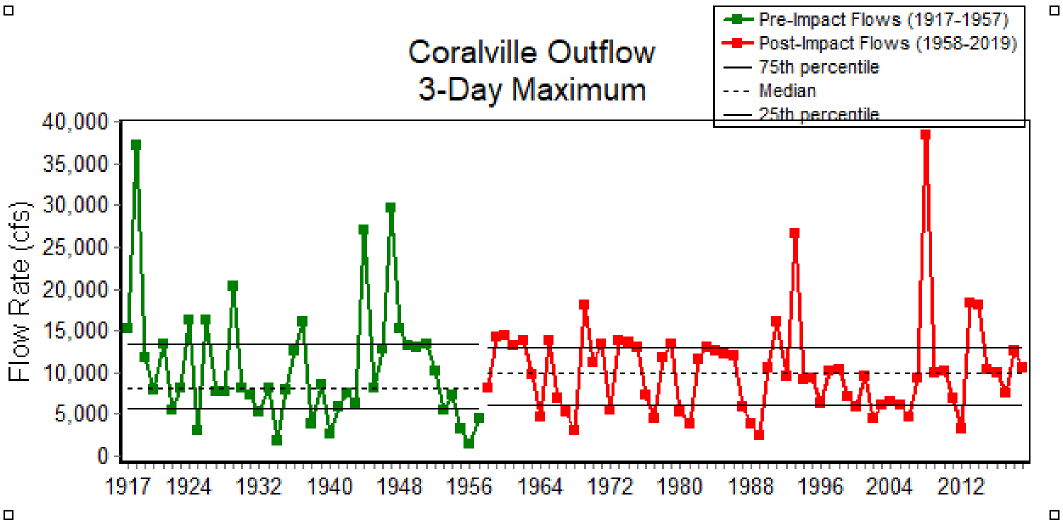

Coralville Inflow
Monthly Flows for December
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

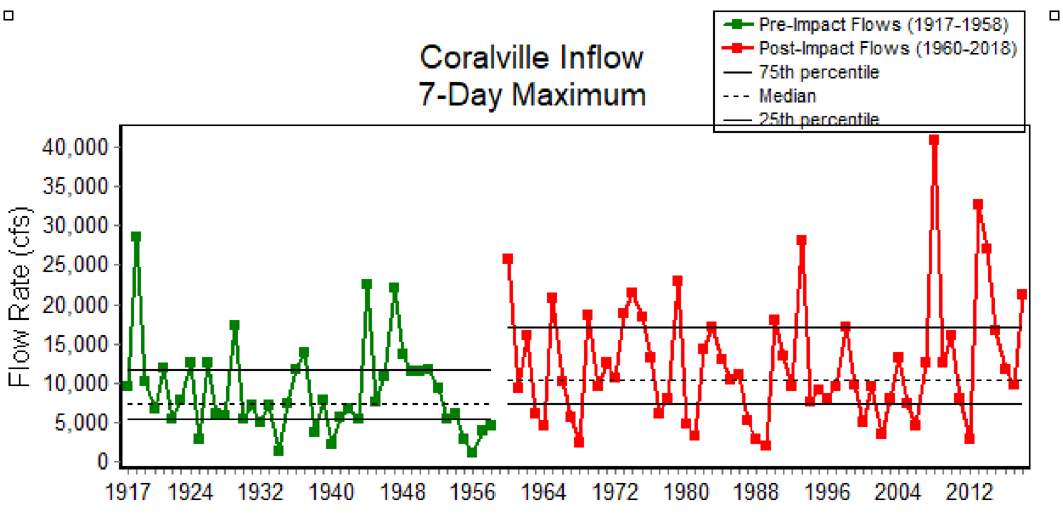

Coralville Outflow
Monthly Flows for December
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

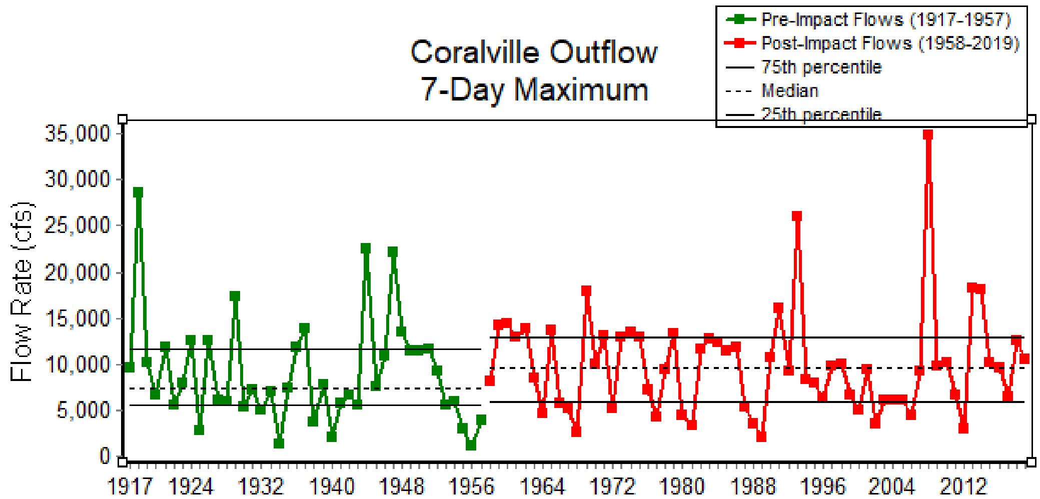

Coralville Inflow
1-Day Maximum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
50,000
40,000
30,000
20,000
10,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

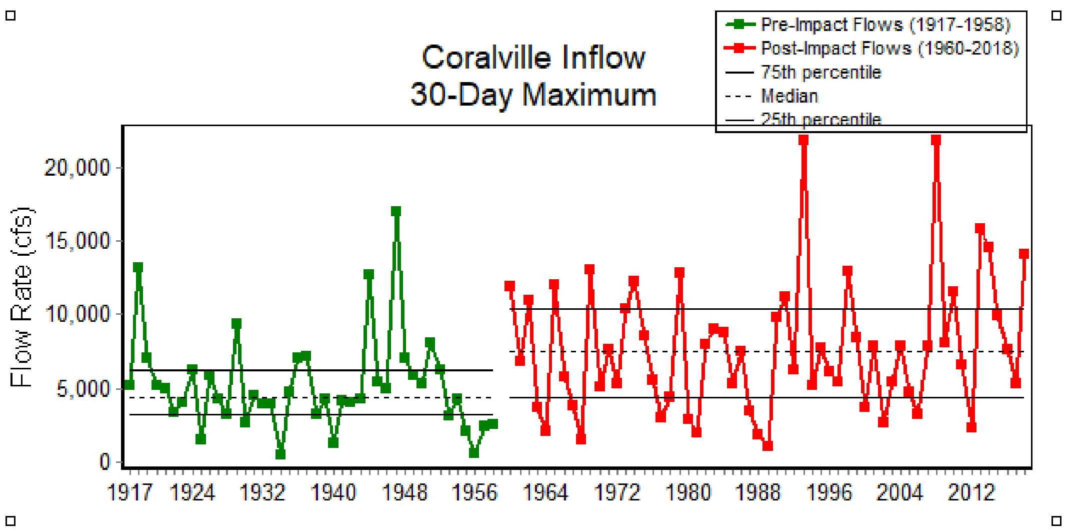

Coralville Outflow
1-Day Maximum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

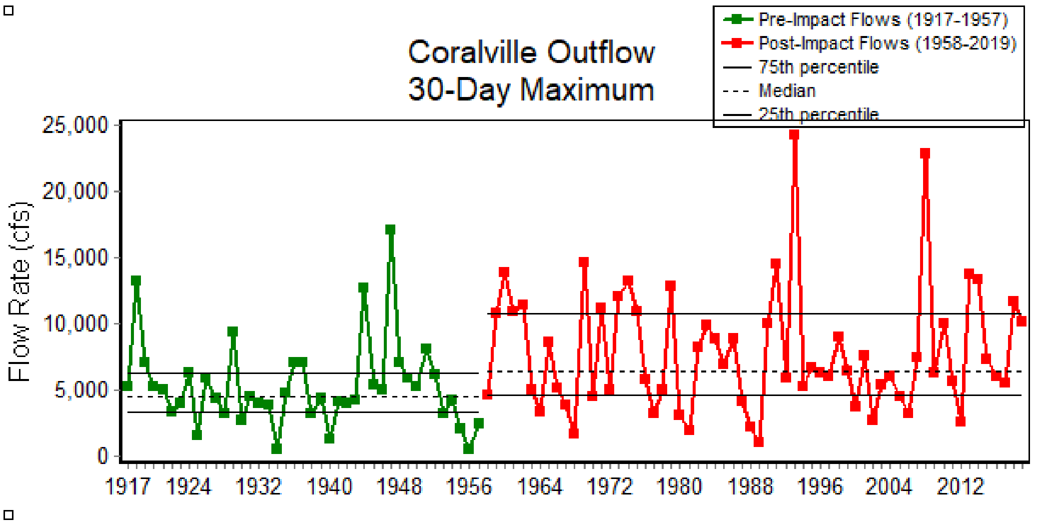

Coralville Inflow
3-Day Maximum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
50,000
40,000
30,000
20,000
10,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

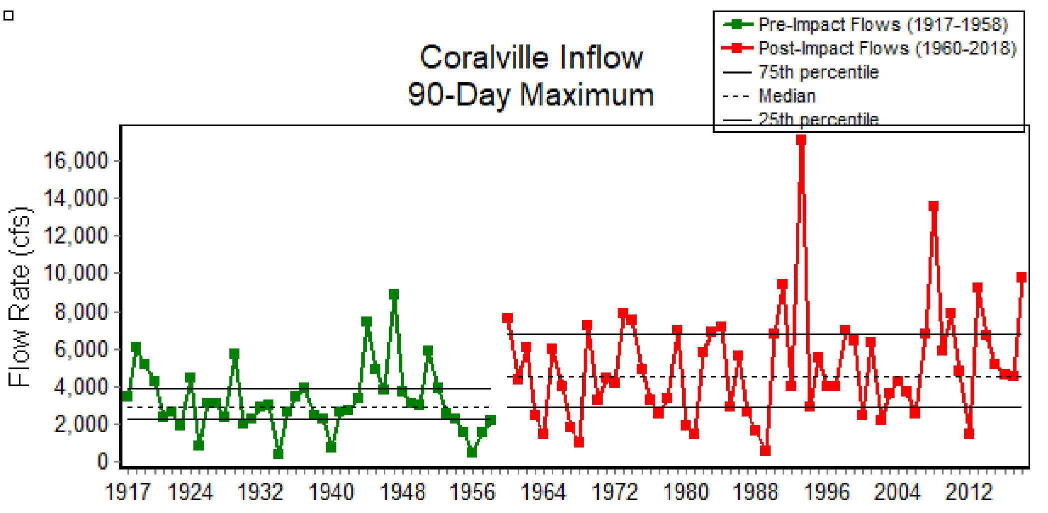

Coralville Outflow
3-Day Maximum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

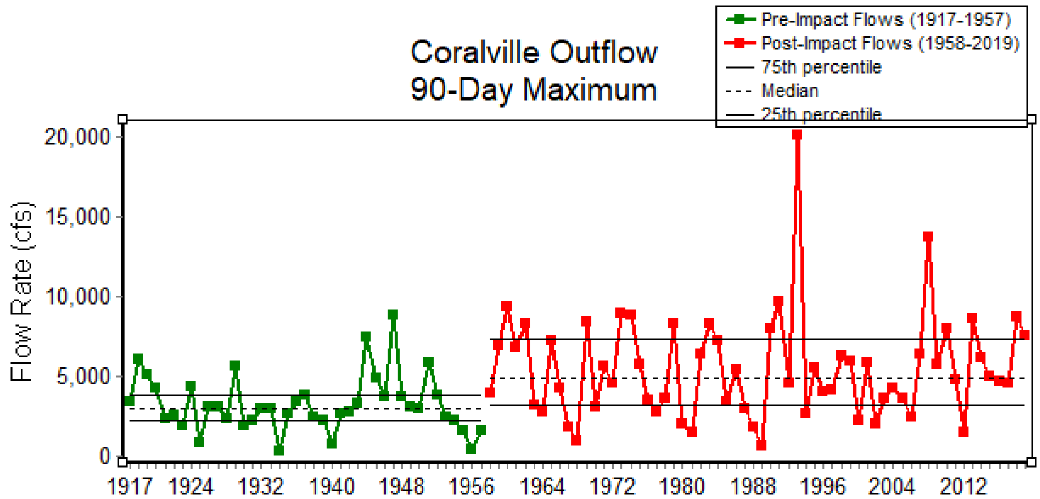

Coralville Inflow
7-Day Maximum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

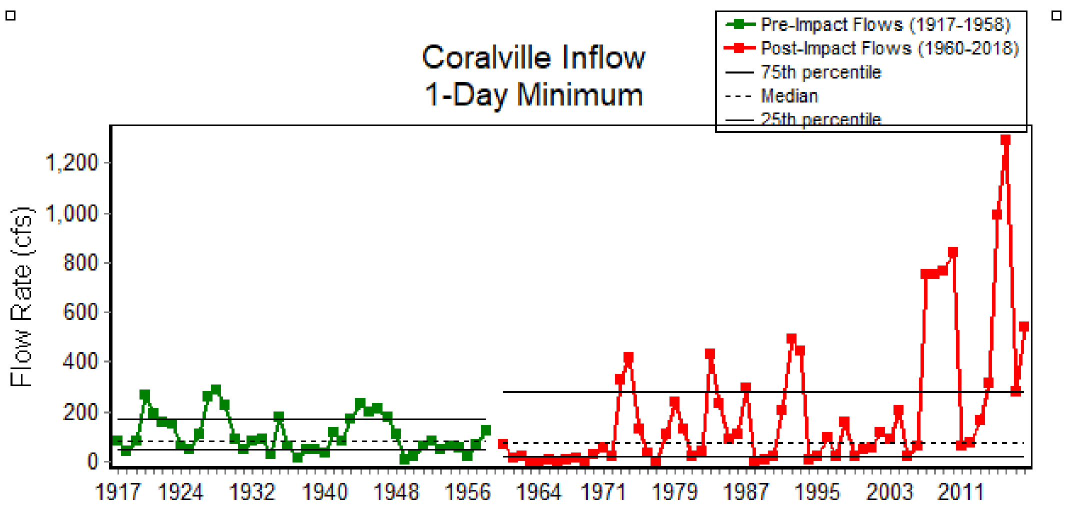

Coralville Outflow
7-Day Maximum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

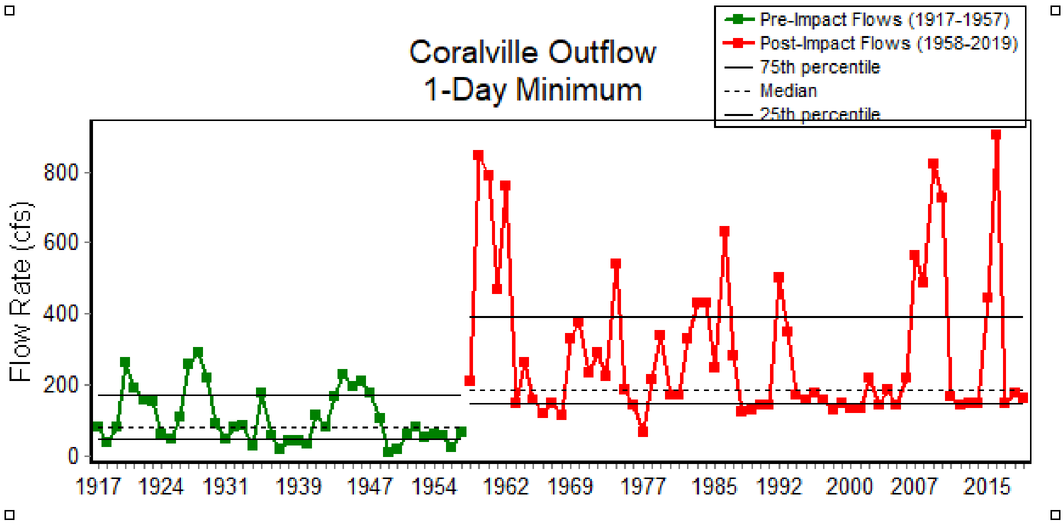

Coralville Inflow
30-Day Maximum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

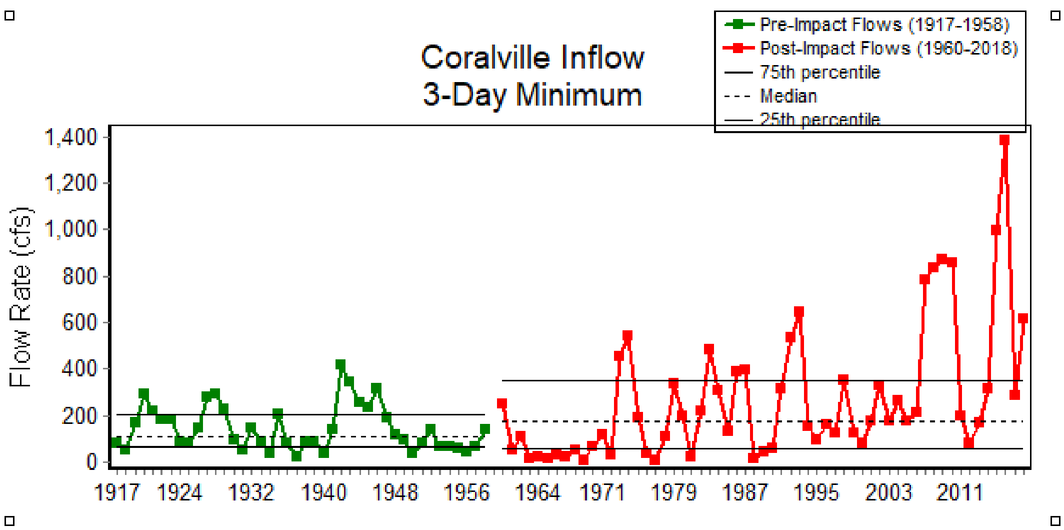

Coralville Outflow
30-Day Maximum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

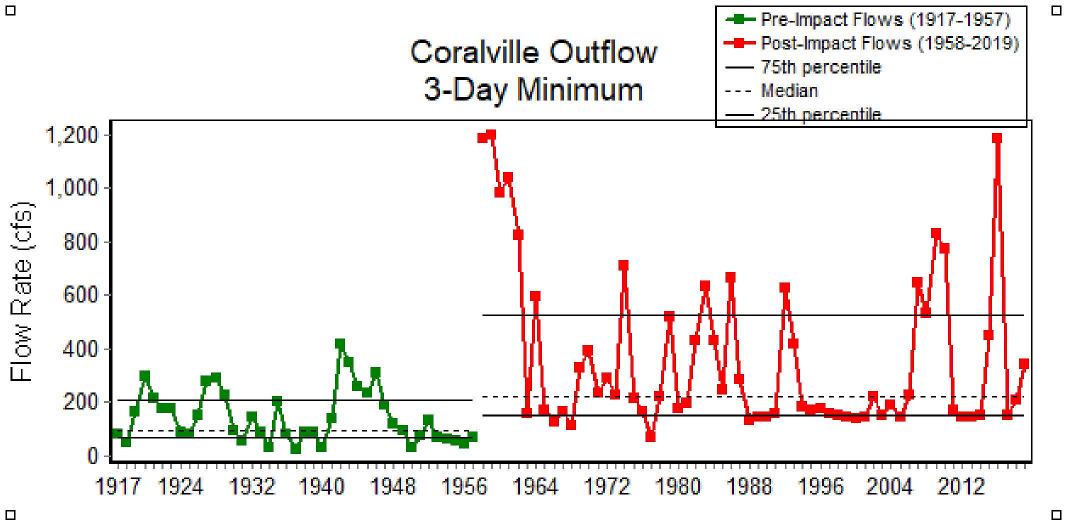

Coralville Inflow
90-Day Maximum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

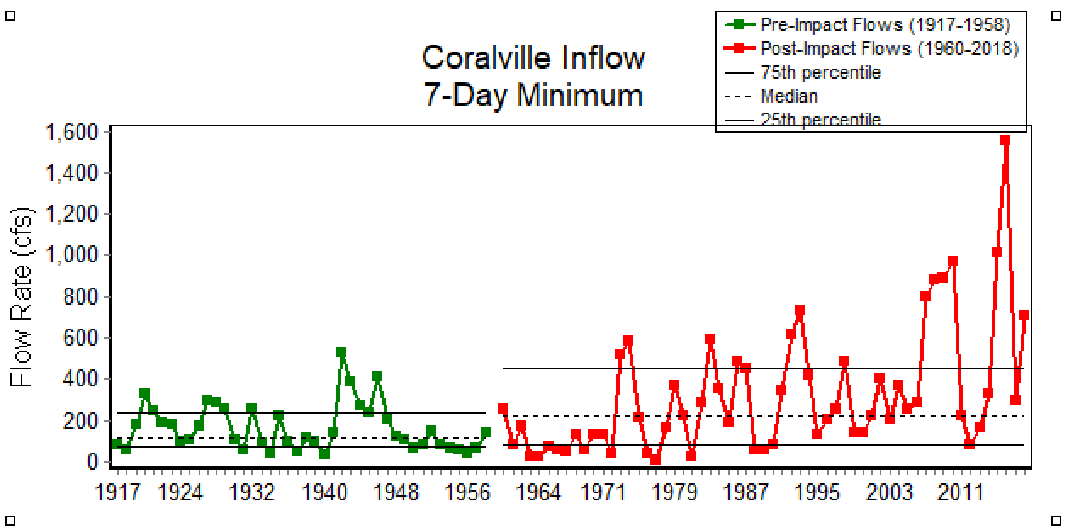

Coralville Outflow
90-Day Maximum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

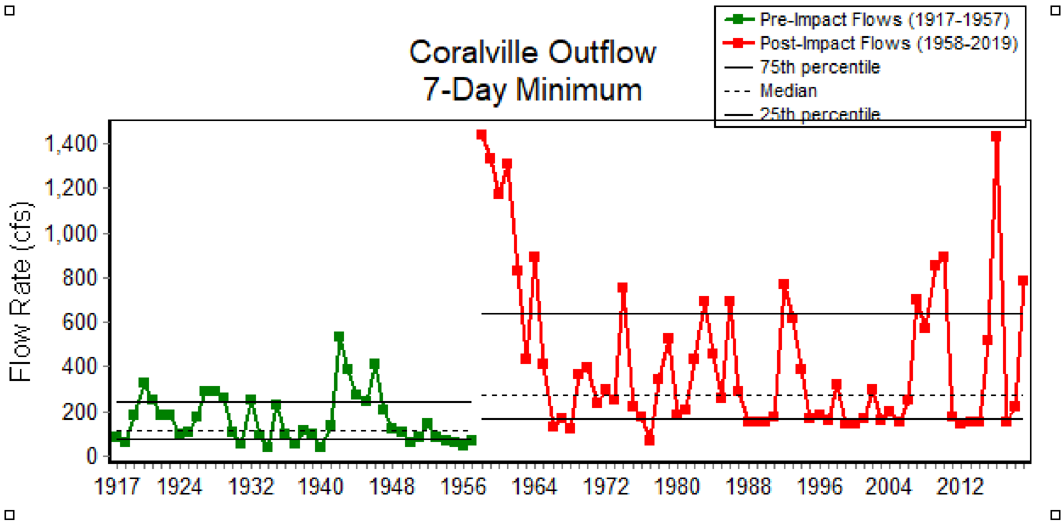

Coralville Inflow
1-Day Minimum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
1,200
1,000
800
600
400
200
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

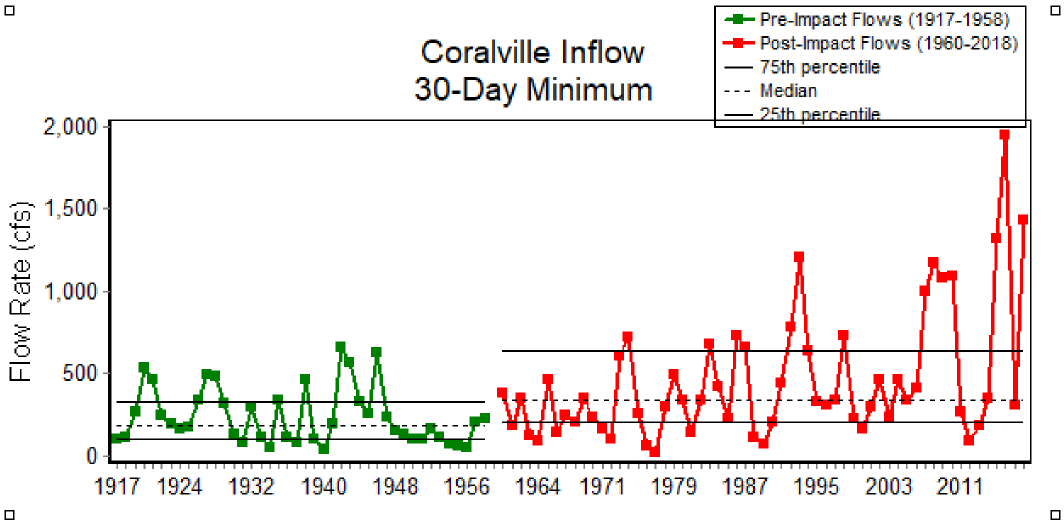

Coralville Outflow
1-Day Minimum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
0
200
400
600
800
1917
1924
1931
1939
1947
1954
1962
1969
1977
1985
1992
2000
2007
2015

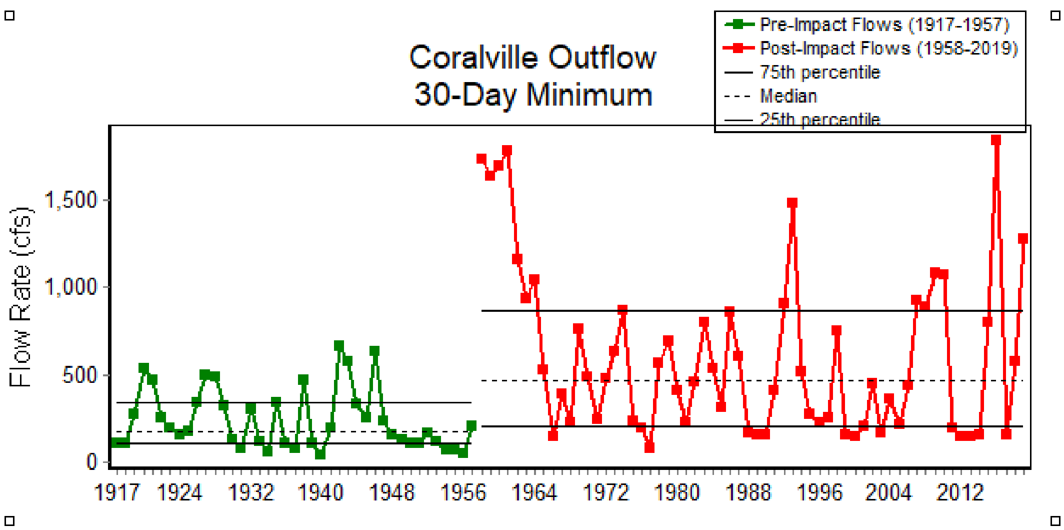

Coralville Inflow
3-Day Minimum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
0
200
400
600
800
1,000
1,200
1,400
1917
1924
1932
1940
1948
1956
1964
1971
1979
1987
1995
2003
2011

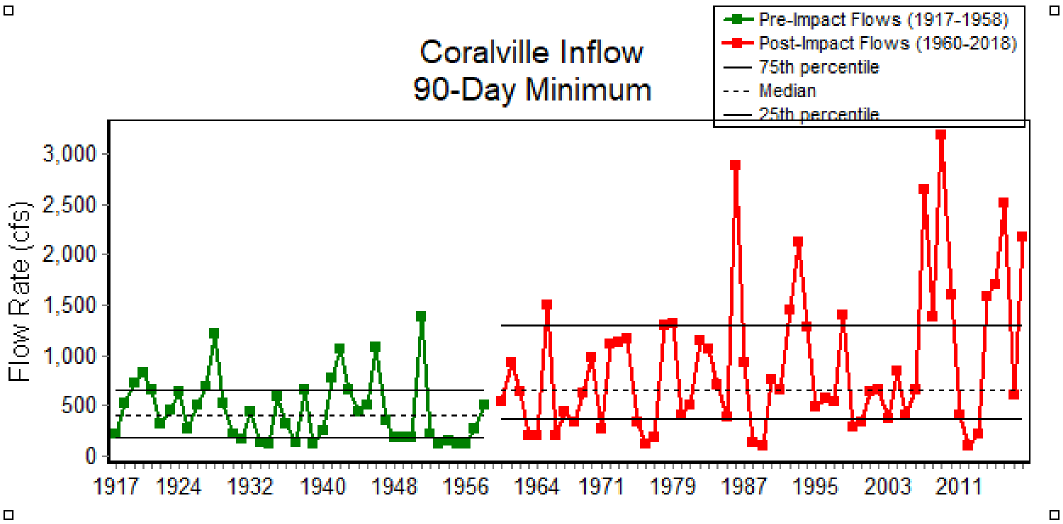

Coralville Outflow
3-Day Minimum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
1,200
1,000
800
600
400
200
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

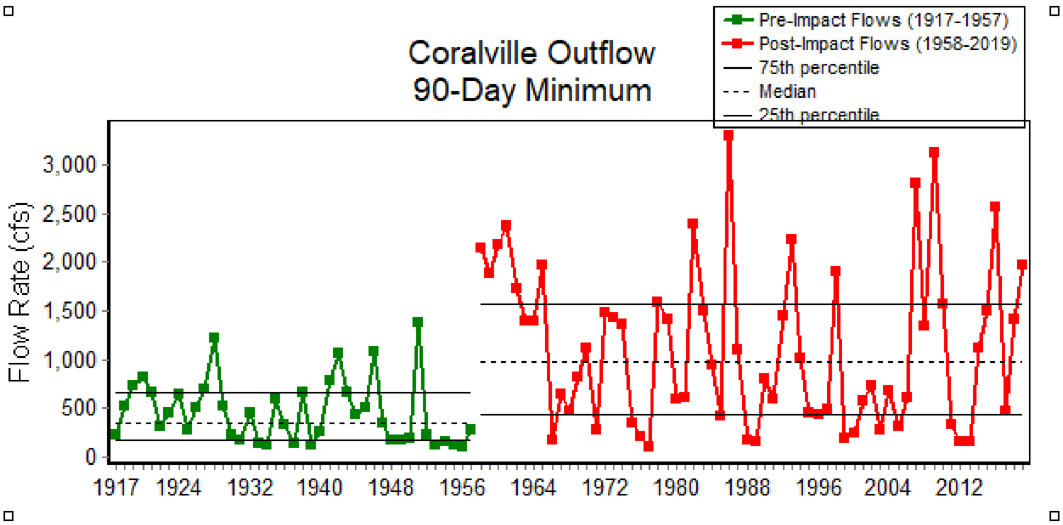

Coralville Inflow
7-Day Minimum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
1,600
1,400
1,200
1,000
800
600
400
200
0
1917
1924
1932
1940
1948
1956
1964
1971
1979
1987
1995
2003
2011

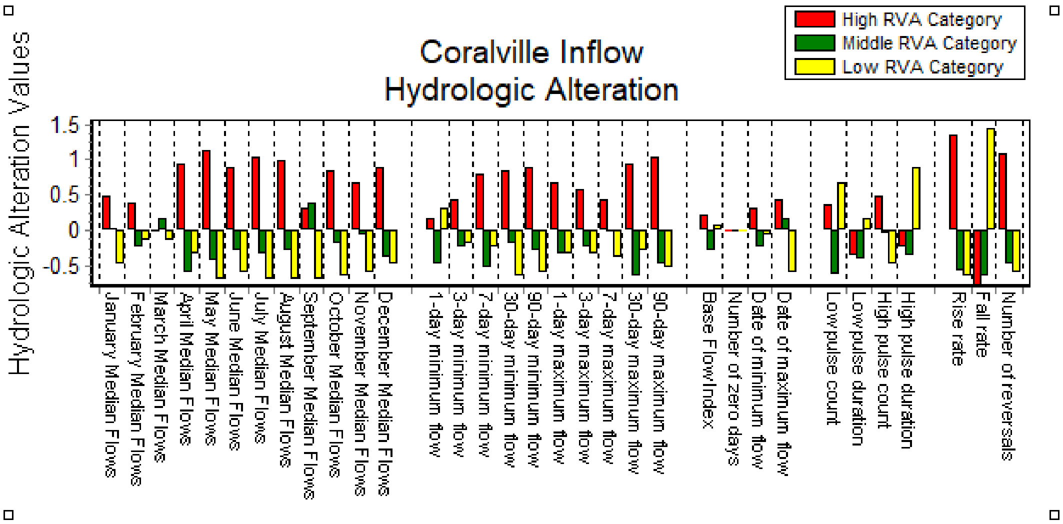

Coralville Outflow
7-Day Minimum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
1,400
1,200
1,000
800
600
400
200
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

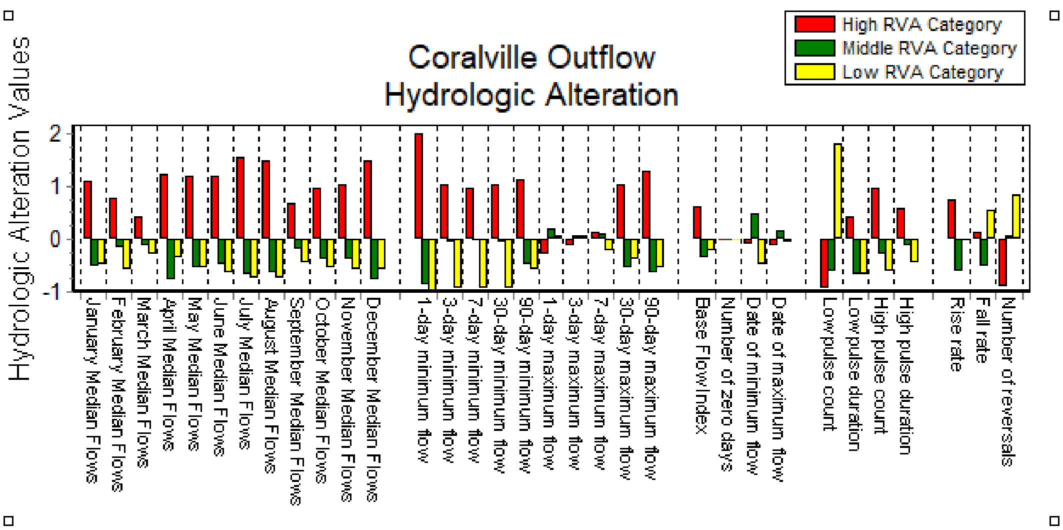

Coralville Inflow
30-Day Minimum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
2,000
1,500
1,000
500
0
1917
1924
1932
1940
1948
1956
1964
1971
1979
1987
1995
2003
2011

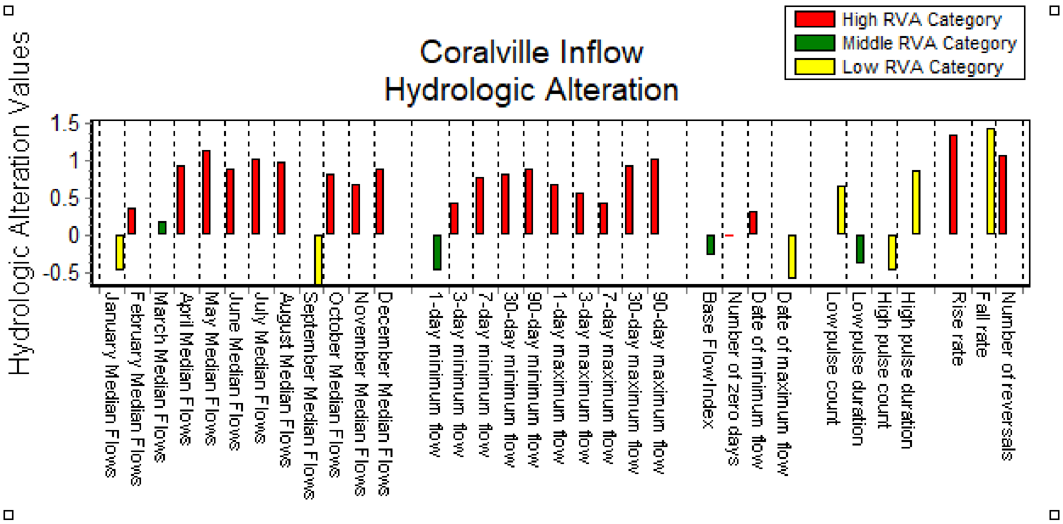

Coralville Outflow
30-Day Minimum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
1,500
1,000
500
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

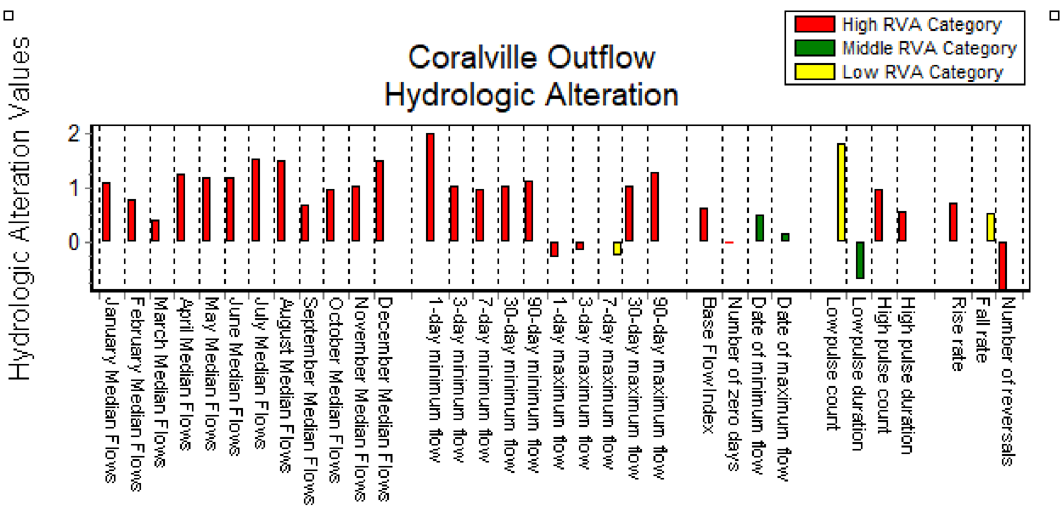

Coralville Inflow
90-Day Minimum
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
3,000
2,500
2,000
1,500
1,000
500
0
1917
1924
1932
1940
1948
1956
1964
1971
1979
1987
1995
2003
2011

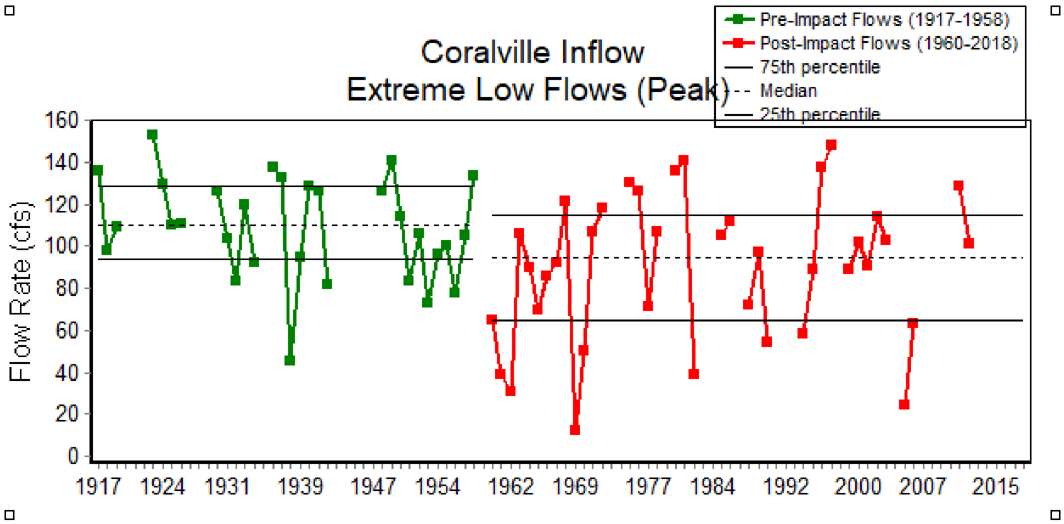

Coralville Outflow
90-Day Minimum
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
3,000
2,500
2,000
1,500
1,000
500
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

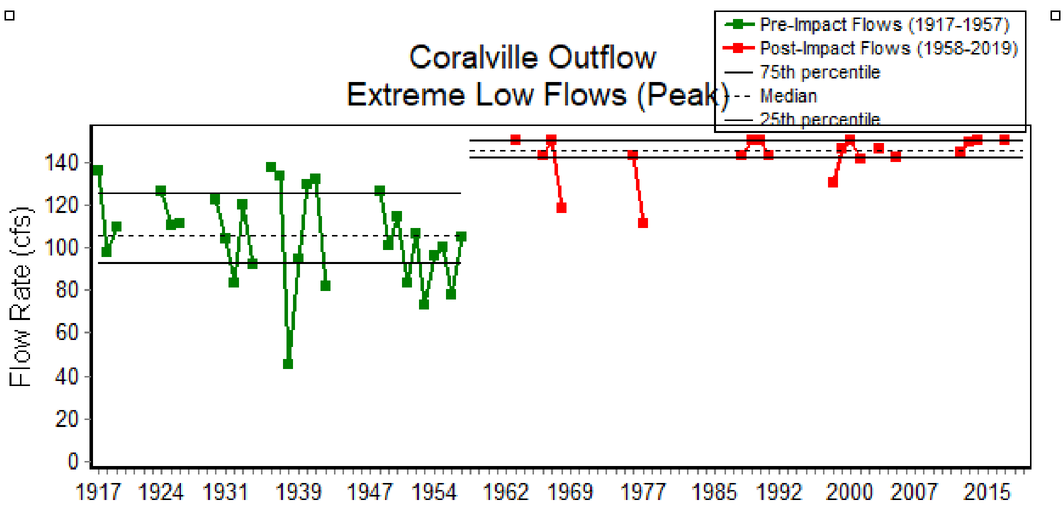

Coralville Inflow
Hydrologic Alteration
High RVA Category
Middle RVA Category
Low RVA Category
Hydrologic Alteration Values
1.5
1
0.5
0
-0.5
January Median Flows
February Median Flows
March Median Flows
April Median Flows
May Median Flows
June Median Flows
July Median Flows
August Median Flows
September Median Flows
October Median Flows
November Median Flows
December 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

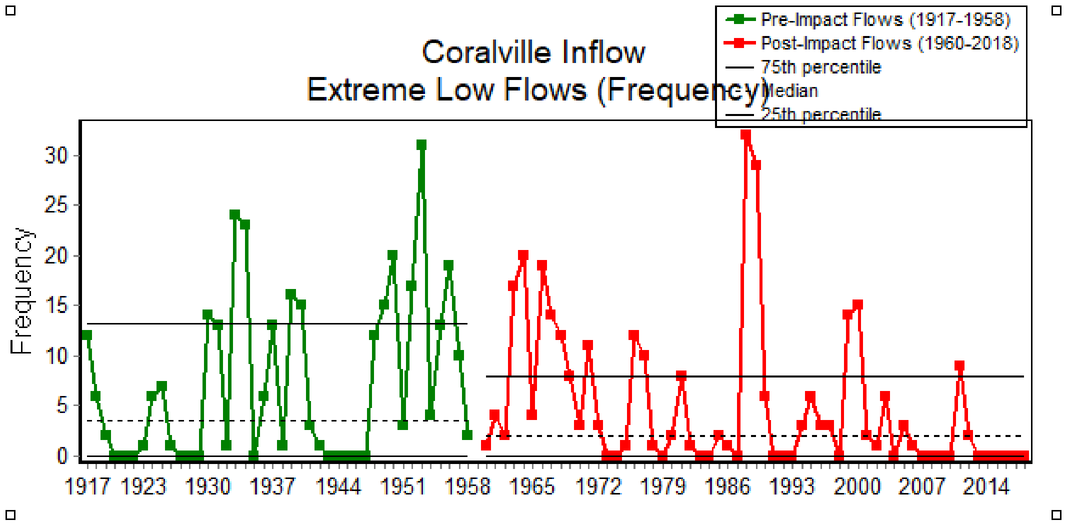

Coralville Outflow
Hydrologic Alteration
High RVA Category
Middle RVA Category
Low RVA Category
Hydrologic Alteration Values
2
1
0
-1
January Median Flows
February Median Flows
March Median Flows
April Median Flows
May Median Flows
June Median Flows
July Median Flows
August Median Flows
September Median Flows
October Median Flows
November Median Flows
December 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

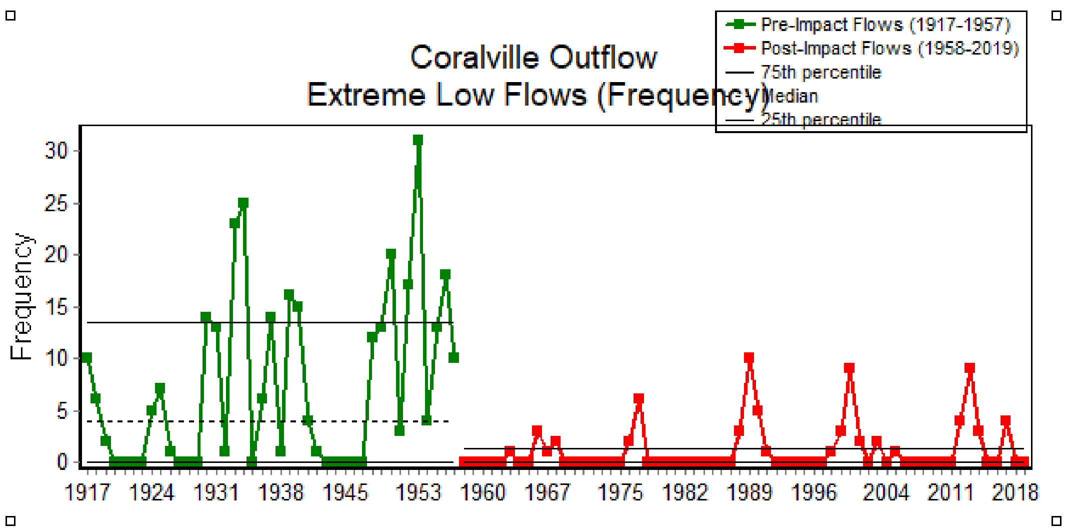

Coralville Inflow
Hydrologic Alteration
High RVA Category
Middle RVA Category
Low RVA Category
Hydrologic Alteration Values
1.5
1
0.5
0
-0.5
January Median Flows
February Median Flows
March Median Flows
April Median Flows
May Median Flows
June Median Flows
July Median Flows
August Median Flows
September Median Flows
October Median Flows
November Median Flows
December 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

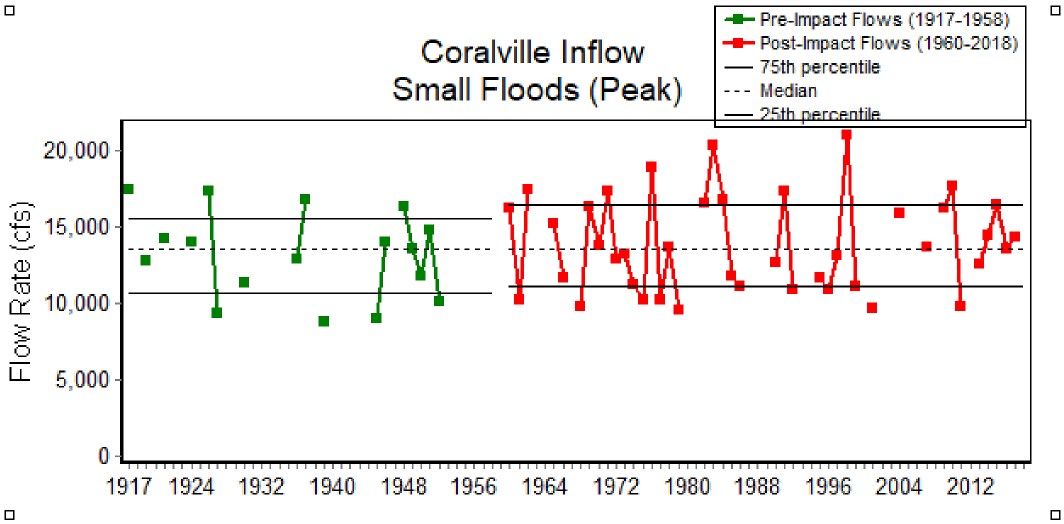

Coralville Outflow
Hydrologic Alteration
High RVA Category
Middle RVA Category
Low RVA Category
Hydrologic Alteration Values
2
1
0
January Median Flows
February Median Flows
March Median Flows
April Median Flows
May Median Flows
June Median Flows
July Median Flows
August Median Flows
September Median Flows
October Median Flows
November Median Flows
December 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

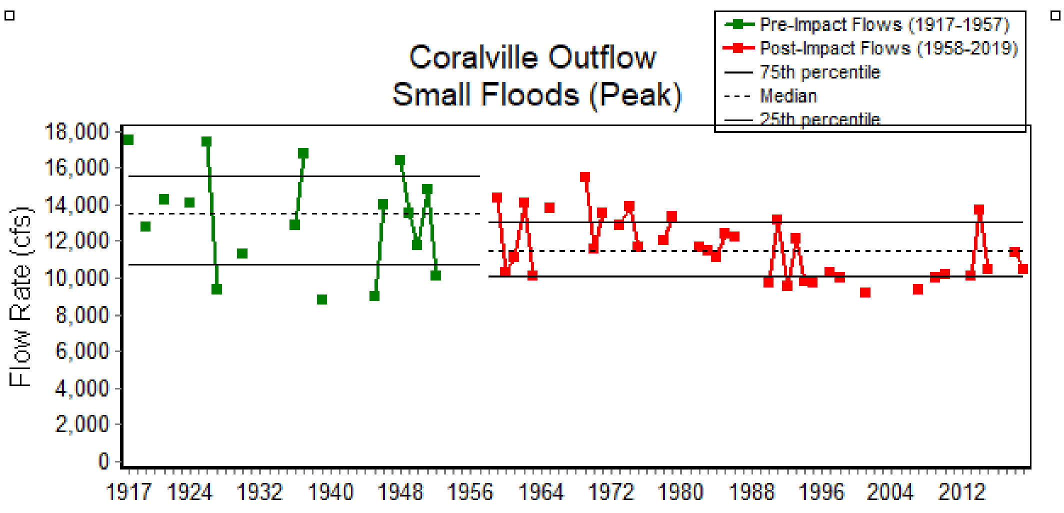

Coralville Inflow
Extreme Low Flows (Peak)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
160
140
120
100
80
60
40
20
0
1917
1924
1931
1939
1947
1954
1962
1969
1977
1984
1992
2000
2007
2015

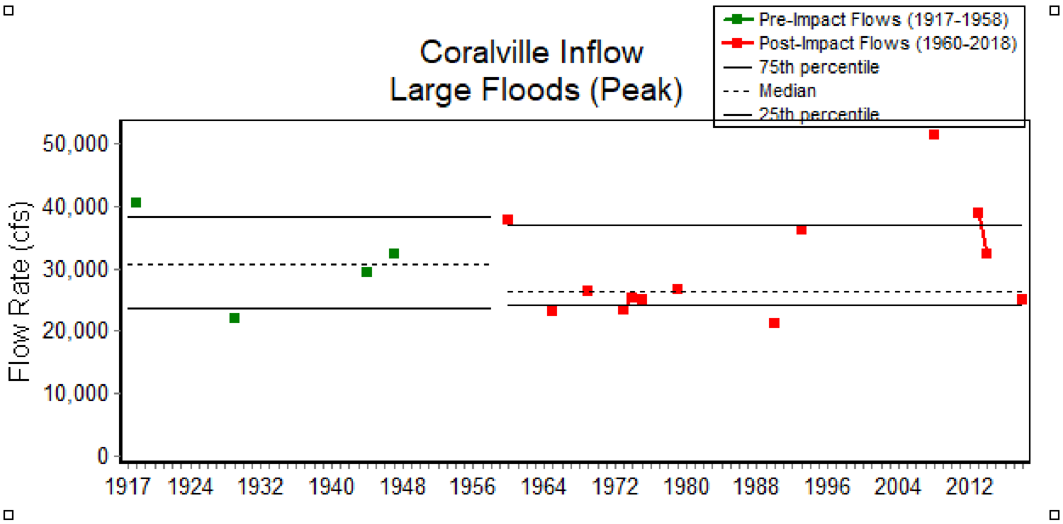

Coralville Outflow
Extreme Low Flows (Peak)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
140
120
100
80
60
40
20
0
1917
1924
1931
1939
1947
1954
1962
1969
1977
1985
1992
2000
2007
2015

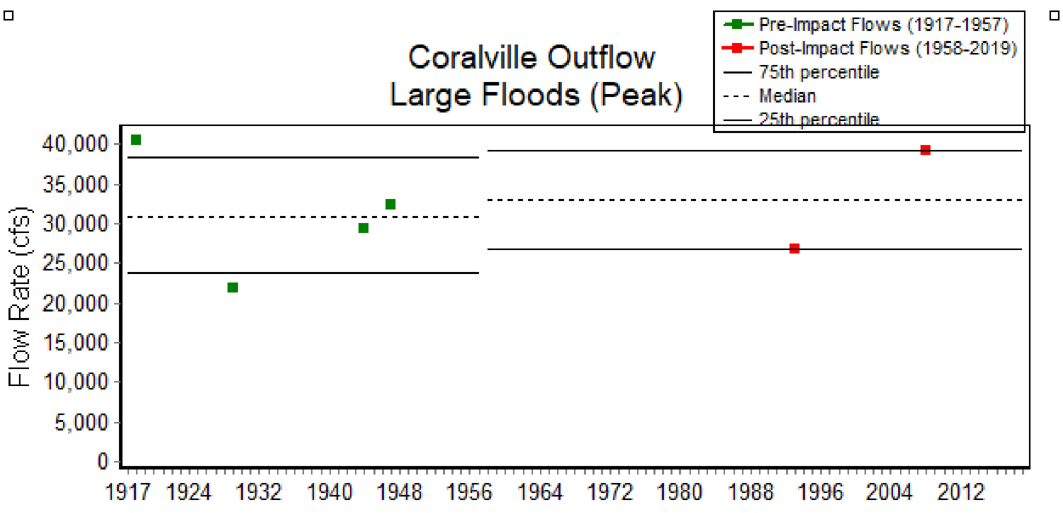

Coralville Inflow
Extreme Low Flows (Frequency)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Frequency
0
5
10
15
20
25
30
1917
1923
1930
1937
1944
1951
1958
1965
1972
1979
1986
1993
2000
2007
2014

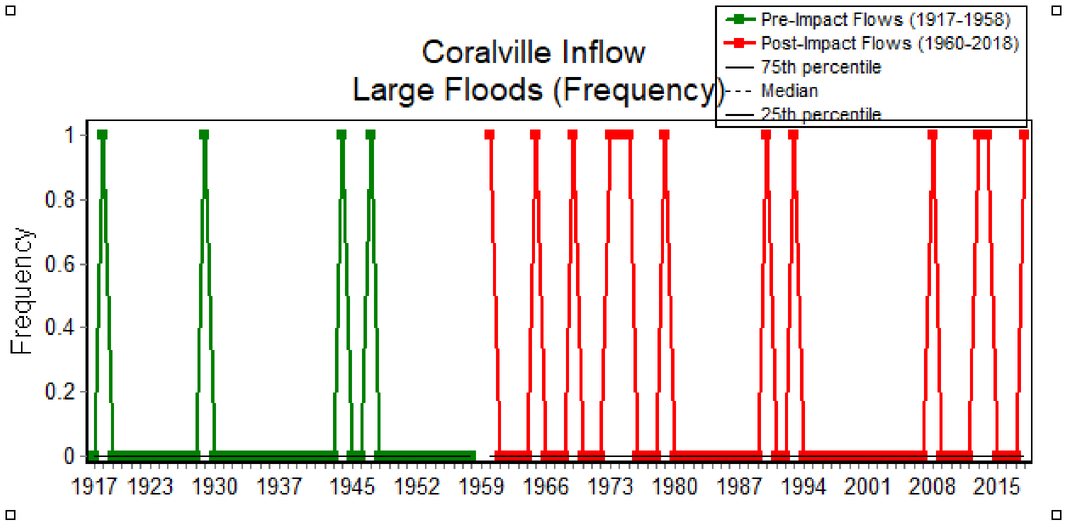

Coralville Outflow
Extreme Low Flows (Frequency)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Frequency
0
5
10
15
20
25
30
1917
1924
1931
1938
1945
1953
1960
1967
1975
1982
1989
1996
2004
2011
2018

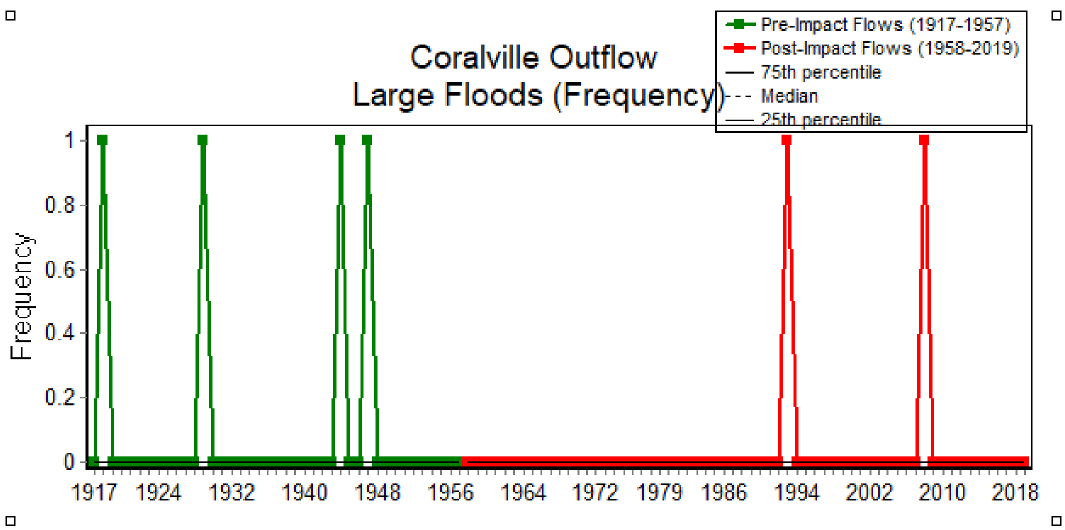

Coralville Inflow
Small Floods (Peak)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
20,000
15,000
10,000
5,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

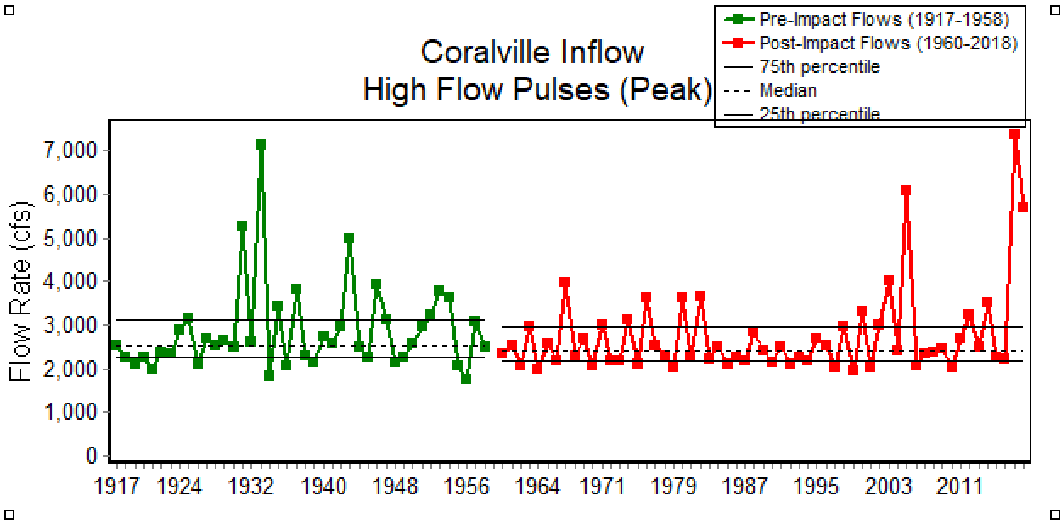

Coralville Outflow
Small Floods (Peak)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

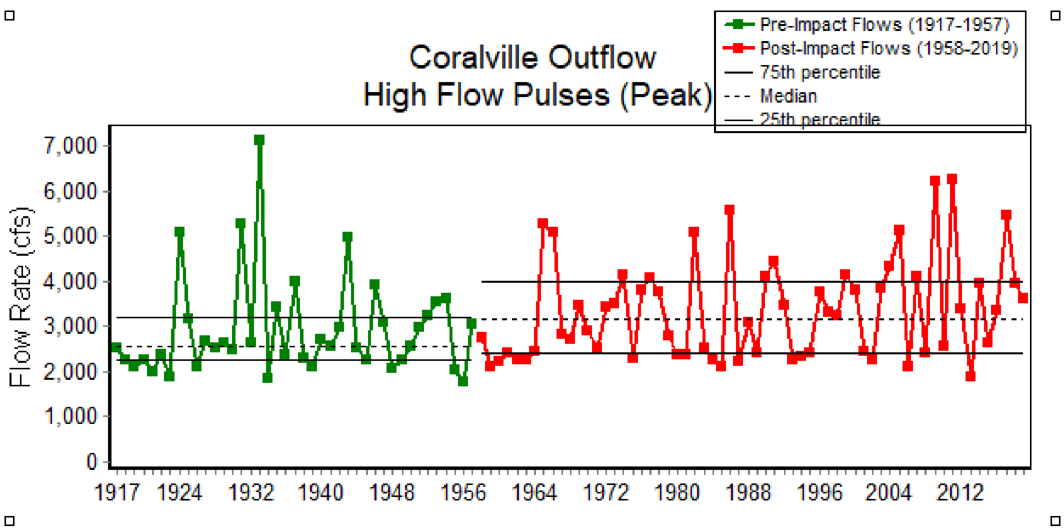

Coralville Inflow
Large Floods (Peak)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
50,000
40,000
30,000
20,000
10,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

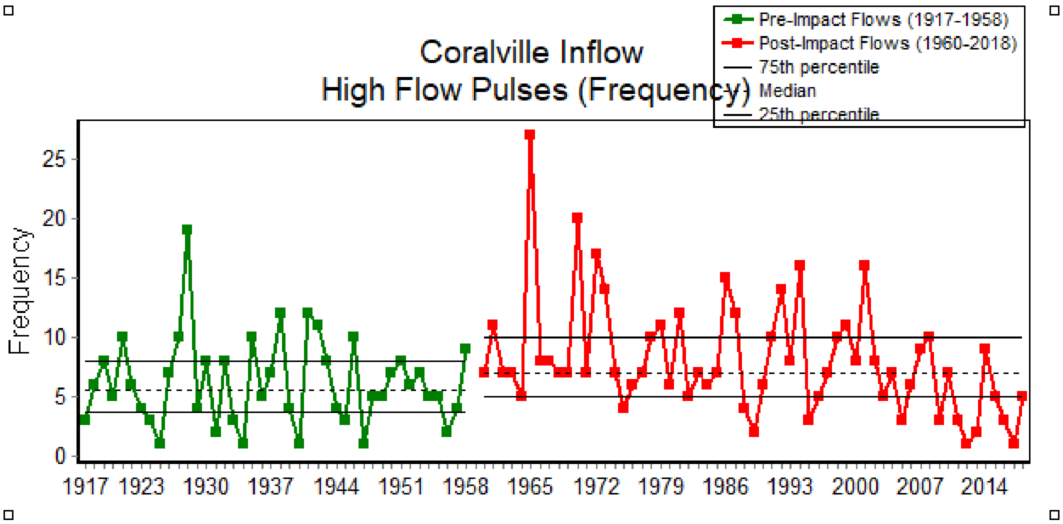

Coralville Outflow
Large Floods (Peak)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
1917
1924
1932
1940
1948
1956
1964
1972
1980
1988
1996
2004
2012

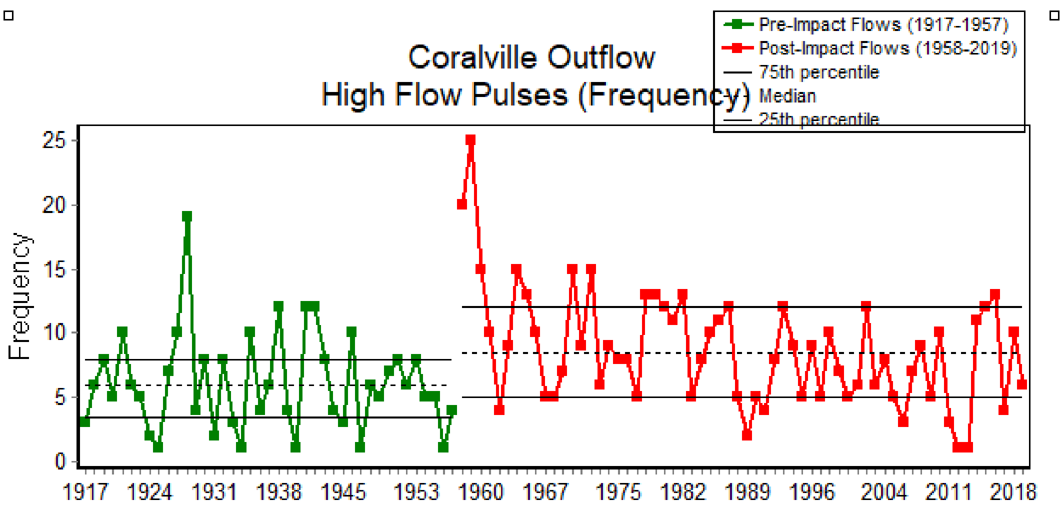

Coralville Inflow
Large Floods (Frequency)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Frequency
1
0.8
0.6
0.4
0.2
0
1917 1923 1930 1937 1945 1952 1959 1966 1973 1980 1987 1994 2001 2008 2015

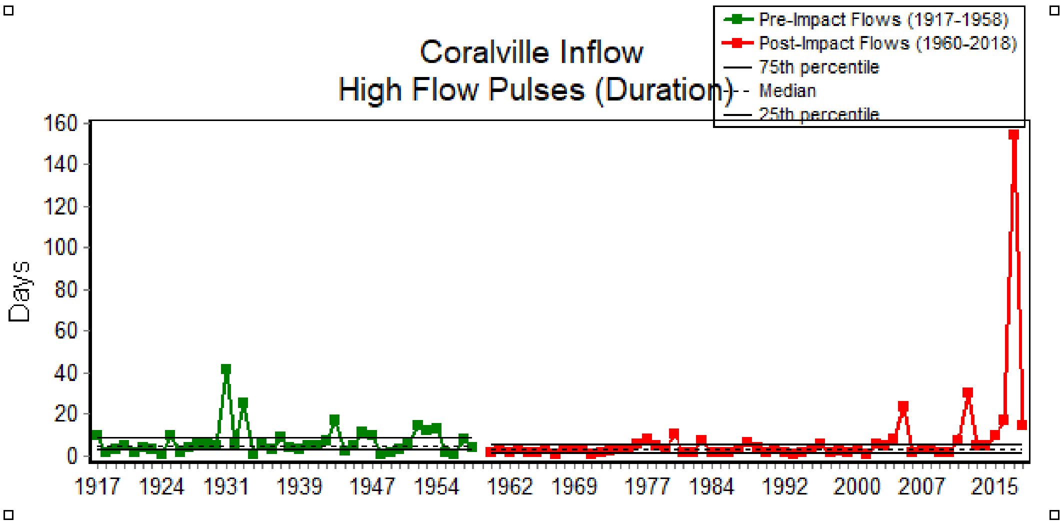

Coralville Outflow
Large Floods (Frequency)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Frequency
1
0.8
0.6
0.4
0.2
0
1917 1924 1932 1940 1948 1956 1964 1972 1979 1986 1994 2002 2010 2018

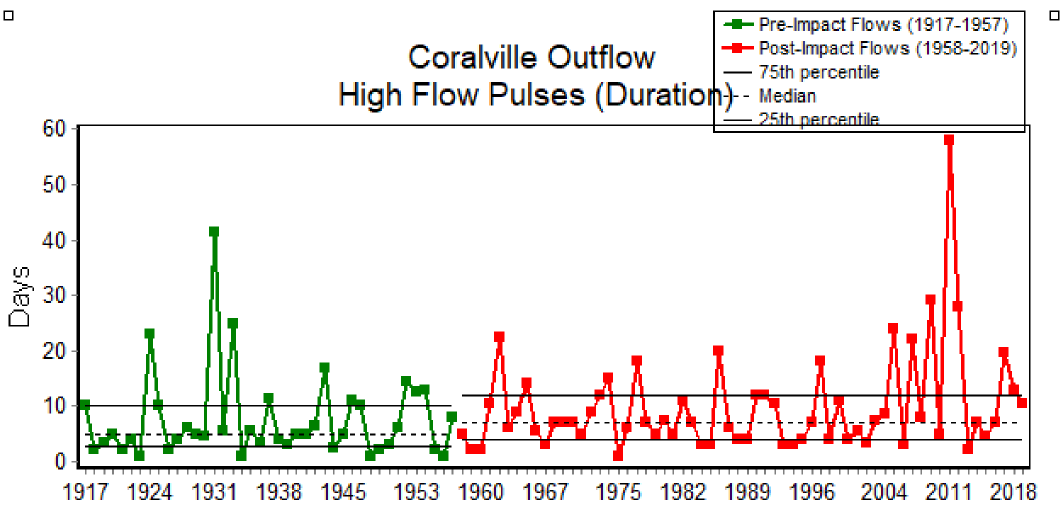

Coralville Inflow
High Flow Pulses (Peak)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Flow Rate (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1971 1979 1987 1995 2003 2011

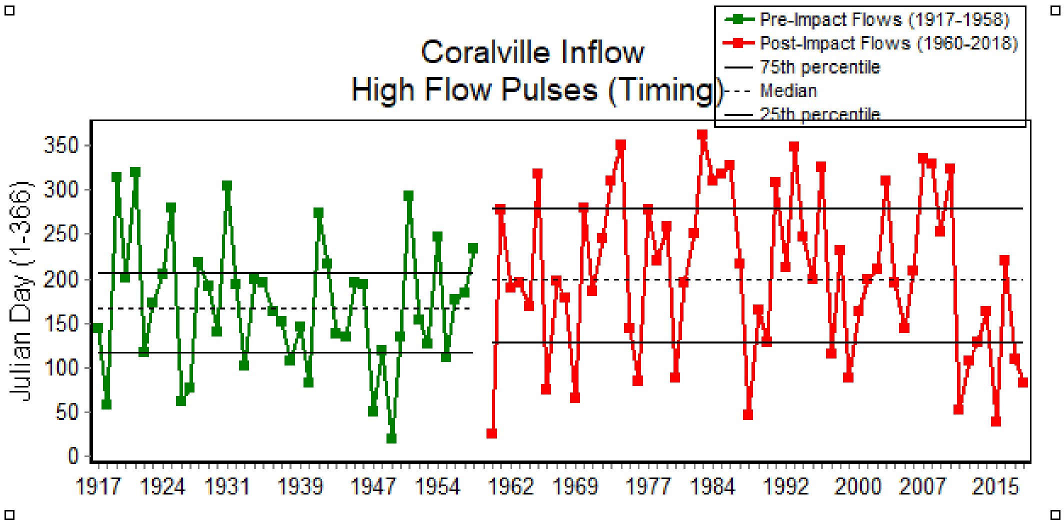

Coralville Outflow
High Flow Pulses (Peak)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Flow Rate (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1917 1924 1932 1940 1948 1956 1964 1972 1980 1988 1996 2004 2012

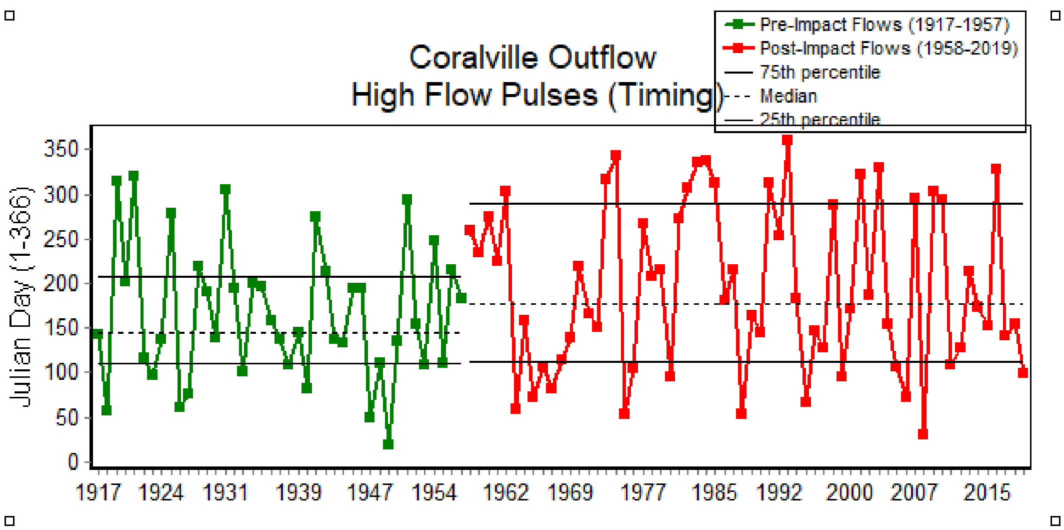

Coralville Inflow
High Flow Pulses (Frequency)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Frequency
0
5
10
15
20
25
1917 1923 1930 1937 1944 1951 1958 1965 1972 1979 1986 1993 2000 2007 2014

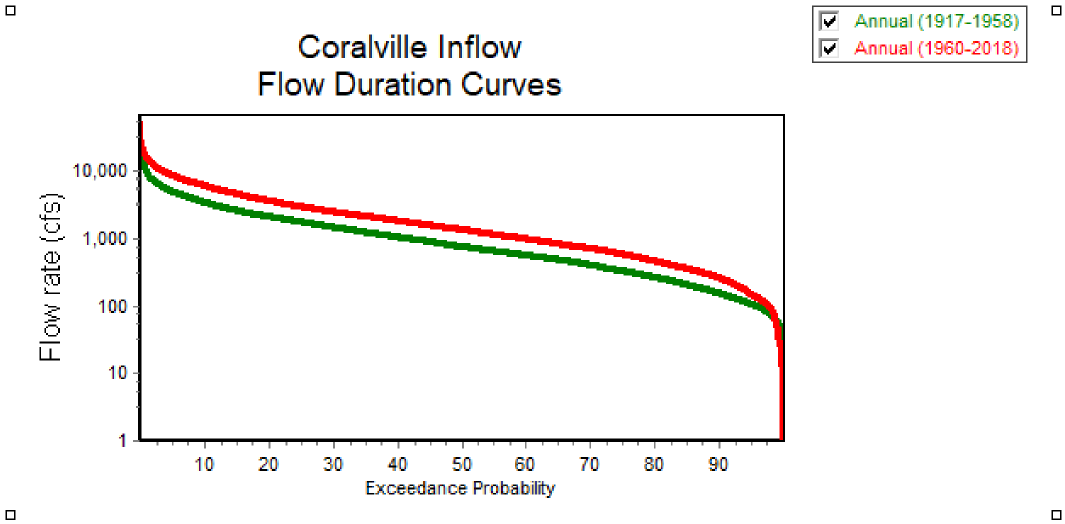

Coralville Outflow
High Flow Pulses (Frequency)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Frequency
0
5
10
15
20
25
1917 1924 1931 1938 1945 1953 1960 1967 1975 1982 1989 1996 2004 2011 2018

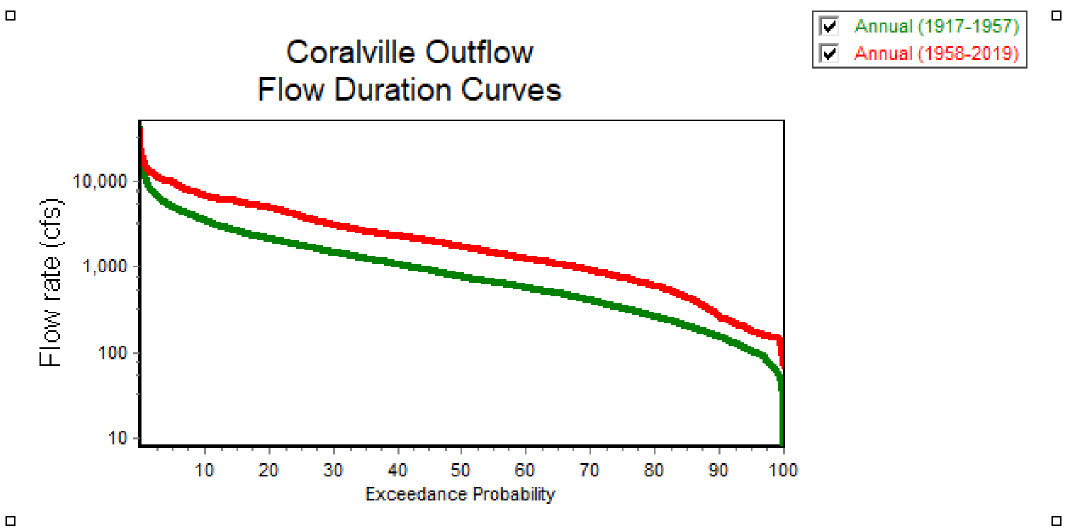

Coralville Inflow
High Flow Pulses (Duration)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Days
160
140
120
100
80
60
40
20
0
1917 1924 1931 1939 1947 1954 1962 1969 1977 1984 1992 2000 2007 2015


Coralville Outflow
High Flow Pulses (Duration)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Days
60
50
40
30
20
10
0
1917 1924 1931 1938 1945 1953 1960 1967 1975 1982 1989 1996 2004 2011 2018


Coralville Inflow
High Flow Pulses (Timing)
Pre-Impact Flows (1917-1958)
Post-Impact Flows (1960-2018)
75th percentile
Median
25th percentile
Julian Day (1-366)
350
300
250
200
150
100
50
0
1917 1924 1931 1939 1947 1954 1962 1969 1977 1984 1992 2000 2007 2015


Coralville Outflow
High Flow Pulses (Timing)
Pre-Impact Flows (1917-1957)
Post-Impact Flows (1958-2019)
75th percentile
Median
25th percentile
Julian Day (1-366)
350
300
250
200
150
100
50
0
1917 1924 1931 1939 1947 1954 1962 1969 1977 1985 1992 2000 2007 2015


Coralville Inflow
Flow Duration Curves
Annual (1917-1958)
Annual (1960-2018)
Flow rate (cfs)
10,000
1,000
100
10
1
10 20 30 40 50 60 70 80 90
Exceedance Probability


Coralville Outflow
Flow Duration Curves
Annual (1917-1957)
Annual (1958-2019)
Flow rate (cfs)
10,000
1,000
100
10
10 20 30 40 50 60 70 80 90 100
Exceedance Probability