memo

Project Name |	Stoughton Dam Review (EOR project 01770-0001)	**Date** |	7/7/2022
To / Contact info |	David Pfeiffer (Town of Pleasant Springs)		
Cc / Contact info |			
From / Contact info |	Steve Gaffield, PE; Nick Hayden, PE;		
Regarding |	Review of City of Stoughton Yahara River Park project		

Project Scope and Background

EOR reviewed the City of Stoughton's proposed Yahara River Park project on behalf of the Town of Pleasant Springs, to provide information about potential changes the project would create along the Yahara River in the Town. This memorandum summarizes our observations and conclusions.

Information Sources

We gathered information on the project from the following sources:

- A video conference on April 7, 2022 with Nick Hayden and Steve Gaffield of EOR, Mason Lacy of Recreational Engineering and Planning (REP), Dan Glynn of the City of Stoughton, and David Pfeiffer from the Town of Pleasant Springs;
- Documents on the City's website, including:
    - "Yahara River Hydraulics" video presentation by the City and Recreation Engineering and Planning (REP) dated 8/24/2021;
    - The "Preliminary Design Water Surface Elevation" table dated 9/24/2021;
    - Questions and Answers from Committee of the Whole presentation dated 2/4/2021;
    - Project FAQs dated 11/10/2020;
    - Project Conceptual Design Report dated 5/28/2018;
- Application materials submitted by the City to the Wisconsin Department of Natural Resources (WDNR) for a Waterway Individual Permit to modify the dam, including a Hydraulic Analysis report prepared by REP dated December 20, 2021 and 60% plans and specifications dated March 3, 2022;
- A phone call with John Reimer of the Dane County Land and Water Resources Department on March 10, 2022;
- A visit by Steve Gaffield to the Stoughton Dam, Yahara River, and Lake Kegonsa Dam on May 24, 2022;
- The 1983 WDNR Order 3-SD-83-802 for operation of the Stoughton Dam.

Summary of Proposed Project

Project Details

The City proposes to modify the existing Stoughton Dam to create a river park. The goals of the project stated in the permit application to the WDNR are to provide a recreational amenity, naturalize the river, improve habitat and fish passage, and increase safety of river users.

The project would remove the existing dam gates and replace them with a passive overflow weir at the dam. The new overflow elevation of 836.5 ft is about two feet higher than the base of the existing Tainter gates (834.8 ft); however, the ability to raise the millpond stage by closing the gates will be lost.

The City has submitted a permit application to the WDNR and the U.S. Army Corps of Engineers to modify the dam. The permit application includes 60% design plans and specifications developed by REP.

Design Considerations

Mason Lacy of REP provided information on how the proposed design evolved and the different factors the design attempts to balance. This includes maintaining a water level drop to create the whitewater features, minimizing upstream water level impacts, minimizing flooding impacts, and maintaining / improving public safety.

An earlier design described in REP's 2018 conceptual design report retained the dam's adjustable gates. This would allow closing the gates to maintain the existing millpond stage at low flows and opening the gates to pass floods. It would also provide a larger elevation drop for the river park than the current design. However, the City's steering committee, Dane County, and the WDNR raised concerns that the gates would present a safety hazard to river users. A paddler was rescued from the gates at about this time. Consequently, the City decided to replace the gates with a passive overflow structure.

The elevation of the proposed passive overflow was limited by the desire to avoid raising the 100-year flood elevation shown on Flood Insurance Rate Maps (FIRM) and to avoid an increase in flooding of adjacent properties. The Flood Insurance Study assumes the dam gates are closed to be conservative. The proposed project with a static upstream overflow structure will result in lower elevations on the FIRM. In reality, the City opens the dam gates to pass floods. This will not be an option with the proposed static overflow, so actual flood elevations near the dam will be higher. Minimizing these actual flood impacts is a key reason why the project team is avoiding a static structure upstream of the dam to further increase upstream water levels.

REP considered options to avoid or reduce upstream water level impacts during low flows. These included a fixed overflow structure or rock riffle upstream of the dam to maintain the millpond elevation. This would cause a floodplain impact because there would be no gates to open and pass floods. Adjustable weirs at the current dam location and the head of the proposed whitewater feature were also considered. REP's experience and research indicated that adjustable structures at other water parks have presented safety problems, been difficult to operate, and cost millions of dollars. They also become a management challenge when there are competing interests regarding water levels. It would also be challenging to permit a new structure away from the dam itself, such as a riffle or inflatable weir.

Considering these tradeoffs, the proposed overflow elevation was set as high as the design team judged was prudent to maximize the vertical drop of the river park and reduce upstream water

level impacts, while avoiding flooding impacts. One of the consequences of removing the dam gates is that water levels cannot be managed for different flow conditions, and a static upstream control structure will result in more variable upstream water levels.

DNR Dam Operating Orders

The WDNR order for the Stoughton Dam was issued in 1983 and specifies minimum and maximum upstream water levels of 841.00 ft and 842.00 ft, respectively. Stated rationale for the minimum water level include the following.

- "To allow recreational use adjacent to the shoreline, an elevation of at least 841.00 ft, MSL datum, must be maintained during the recreational season." (Findings of Fact, item 5)
- "Water levels below 841.00 ft, MSL datum, will adversely affect recreational use near the shore, lead to drainage of wetlands, expose areas of stream bed which provide aquatic habitat and which would be aesthetically objectionable if exposed." (Findings of Fact, item 8)

The order does not specify the locations of potential impacts identified in Findings of Fact items 5 and 8.

Impact of Project on Water Levels in the Town of Pleasant Springs

Existing Conditions

Water level changes due to the proposed project were evaluated by REP using a hydraulic model of the river and dam. REP started with the Flood Insurance Study model obtained from the WDNR, then modified it to add details of the proposed project. REP adjusted model parameters based on measured water levels in the river. The City's project team surveyed water surface elevations at six locations on Yahara River between the Lake Kegonsa Dam and the Stoughton Dam in November 2020, April 2021, and June 2021 (**Figures 1** and **2**). The data show the effect of summer growth of aquatic vegetation, which increases hydraulic roughness and results in higher water levels for a particular flow during the growing season. Note that upstream of CTH B, water levels were higher in June 2021 at a flow of only 125 cfs than they were in April 2021 and November 2020 when flow was 300 cfs and 530 cfs, respectively. This is consistent with EOR's experience in other Wisconsin streams that summer vegetation growth can have a large effect on water levels. Dane County's efforts to harvest vegetation in the river to improve flow out of Lake Kegonsa reflect this vegetation impact.

Attachment 1 summarizes REP's simulated water levels for flows from 150 cfs to 650 cfs, and for summer and winter conditions. These simulated flows are different than the actual flows on the dates of the water level surveys, but their ranges are similar. For reference, monthly mean flows at the Forton Street gage for 2003 – 2021 range from 261 cfs in August to 447 cfs in November (**Attachment 2**). Simulated water levels appear to reasonably match the measured water levels, and the hydraulic model appears to be a useful tool for evaluating the impacts of the proposed project.

Figure 1. Locations where water levels were surveyed by City team (from REP presentation on August 24, 2021).

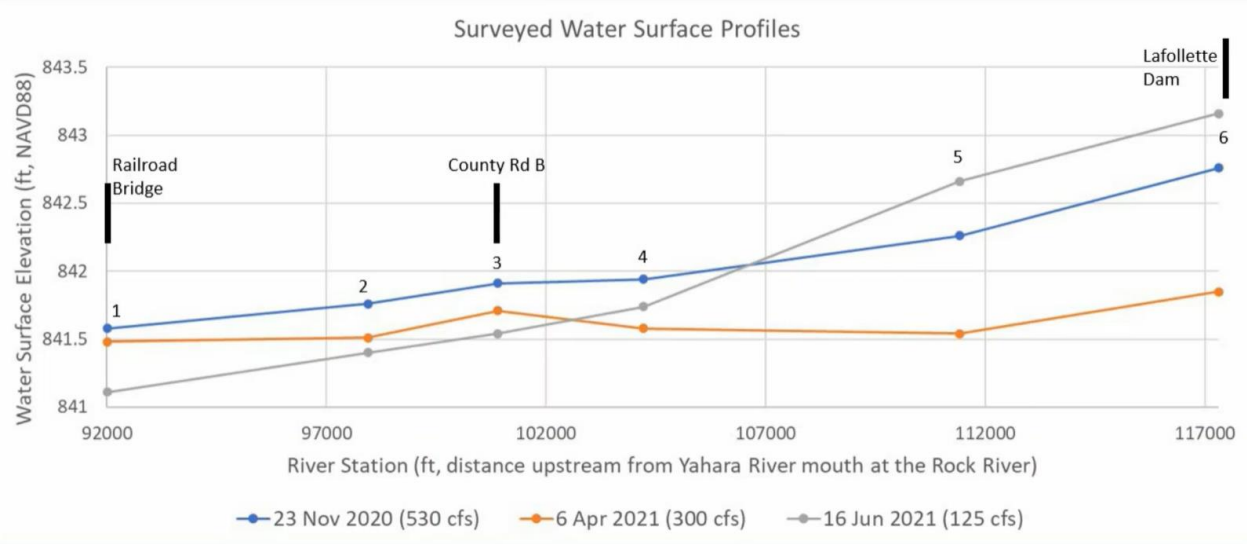

Figure 2. Yahara River profiles from Lake Kegonsa Dam to the railroad bridge upstream of Stoughton surveyed by City team (from REP presentation on August 24, 2021).

Proposed Conditions

The model shows that the proposed project will lower the water level of the Yahara River in the Town of Pleasant Springs (**Attachment 1**). The amount of drop depends on the flow in the river, with greater water level decreases at low flows. The water level change also depends on the season, due to the hydraulic roughness of aquatic vegetation. At the river widening upstream of CTH B, the predicted lowering ranges from 0.3 ft at 650 cfs to 1.6 ft at 150 cfs without vegetation growth. During the growing season, the predicted impacts are reduced to 0.1 ft at 650 cfs to 0.6 ft at 150 cfs.

Note that the City did not collect bathymetric data of the riverbed elevation upstream of the millpond. The only available data on the riverbed elevation is in the cross sections of the 2012 Flood Insurance Study model. Model cross sections are based on 2005 LiDAR data above the water surface, with field surveyed data for the river channel below the water level at many (but not all) cross sections. The cross section in the widening upstream of CTH B (FIS cross section BQ) was surveyed (**Figures 3** and **4**), with riverbed elevations ranging from 839.24 ft to 840.93 ft. For the existing winter conditions water surface elevation of 841.6 ft at 150 cfs predicted by REP, water depths for these surveyed points would range from 2.4 ft to 0.7 ft.

The water level drop predicted by REP for the project upstream of CTH B is very large relative to the existing low-flow depth. More data is needed to accurately map potential changes in the river shoreline position in Pleasant Springs due to the proposed project, but this data was not collected during the City's design process. At FIS cross section BQ in the widening upstream of CTH B, the project would result in shoreline recession of about 500 ft at a flow of 150 cfs during November – April, based on REPs water level predictions and the bathymetric data from the FIS.

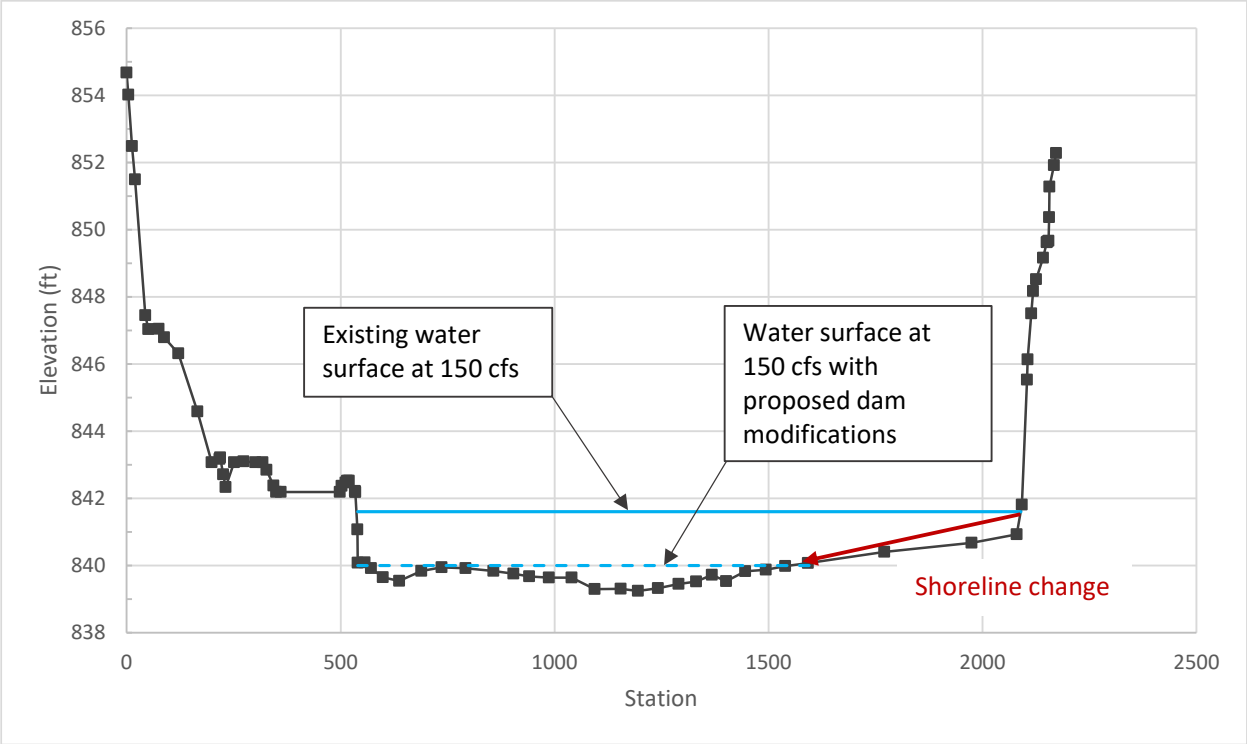

Figure 3. Bathymetric data from FIS model cross section BQ in the widening upstream of CTH B. View is looking downstream with vertical exaggeration. See Figure 4 for cross section location. Water surface elevations are estimated by REP for 150 cfs for existing and proposed winter conditions.

Figure 4. Location of cross section BQ in the widening upstream of CTH B (from WDNR Surface Water Data Viewer). Shaded and hatched patterns show 100-yr floodplain and floodway, respectively.

Proposed Dane County Dredging

The County plans to dredge the Yahara River from the Lake Kegonsa Dam to CTH B[1] to improve the conveyance of floodwaters from the Yahara chain of lakes. According to John Reimer at Dane County, future plans include dredging downstream of CTH B after the final outcome of the proposed dam modification project is determined. The dredging would deepen the river channel by approximately 3 ft over a cross section width of approximately 50 ft.

Increasing conveyance in the river by dredging has potential to lower water levels for any given flow in the reach that is dredged. REP did not evaluate the combination of the proposed dam

[1] Dane County Land and Water Resources Department website, accessed June 13, 2022: https://lwrd.countyofdane.com/LwrdProjects/Detail/Yahara-River-Sediment-Removal-Project

modifications and the County's proposed dredging, so their predictions of water level drop do not reflect the proposed dredging.

EOR conducted a screening analysis to determine if the proposed dredging has potential to further lower the river water level beyond the drop predicted for the dam modifications. This analysis was conducted with the WDNR's Flood Insurance Model because we did not have REP's design model. The intent of this analysis was not to precisely predict water levels after dredging, but to understand the magnitude of changes in water levels that would occur after the proposed dredging project. Main steps in this analysis included:

1. Modifying the dam in the model to represent the proposed dam modifications, setting a static overflow at the proposed design elevation of 836.5 ft;
2. Modifying the cross sections between CTH B and the Lake Kegonsa Dam to simulate dredging, adding a deepened section 50 ft wide and 3 ft deep near the center of the channel;
3. Evaluating simulated water levels for the dam modifications with and without dredging, for both winter and summer vegetation conditions.

The model simulations predict that dredging upstream of CTH B would lower the water surface in addition to the drop predicted by REP for the proposed dam modifications. At a low flow of 150 cfs, this additional lowering would start at CTH B, be approximately 0.3 ft in the widening upstream of CTH B, and increase to approximately 0.9 ft near the Lake Kegonsa dam (**Figure 5**). Results were similar for both the low and high roughness simulations. Future dredging downstream of CTH B could result in additional water surface decreases in this reach.

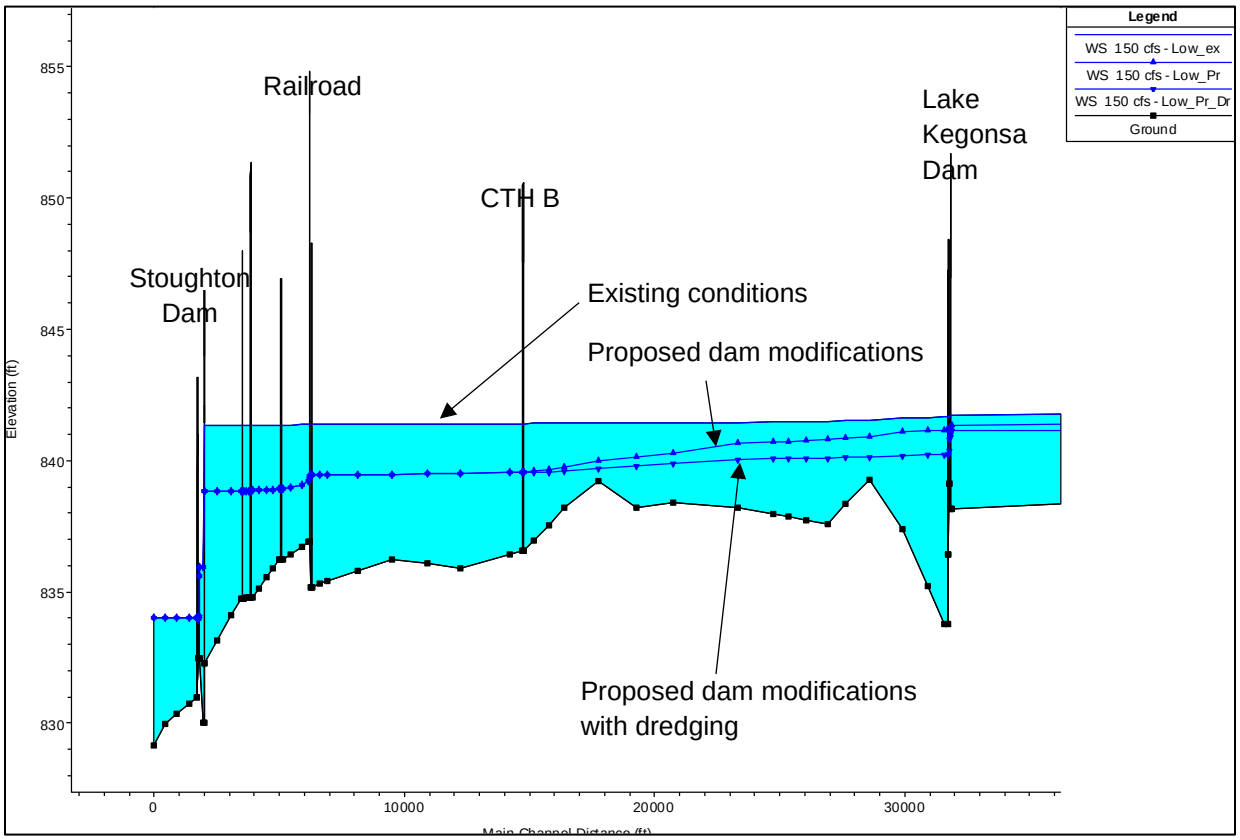

Figure 5. Hydraulic model profile for simulations of existing conditions, the proposed dam modifications, and the proposed dam modifications plus the proposed dredging upstream of CTH B.

Conclusions and Recommendations

Based on our review of the proposed project, we have developed the following conclusions and recommendations.

1. The City proposes to modify the Stoughton Dam, not remove it. The design includes a fixed overflow at an elevation of 836.5 ft. This is approximately 2 ft higher than the bottom of the existing gate openings. For the flows evaluated by the City ranging from 150 cfs to 650 cfs, the resulting water levels immediately upstream of the dam will therefore be higher than if the dam were removed or if the existing gates remained fully open. Predicted water surface elevations for the proposed project and full dam removal are within 0.1 ft of each other upstream of CTH B for the same range of flows.
2. The proposed fixed overflow elevation at the dam will result in lower water levels upstream of the dam compared to existing conditions, especially at low flows, because there will be no gates to close to maintain the millpond level. At a low flow of 150 cfs, the City's designer, REP, predicts that the water level upstream of CTH B will be 0.6 to 1.6 ft lower, with the smaller end of this impact range occurring during the growing season due to the hydraulic roughness of aquatic vegetation. At a flow of 380 cfs, which is in the range of monthly mean flows, REP estimates a water surface drop upstream of CTH B of 0.3 – 0.8 ft.

3. The change in the position of the edge of water cannot be mapped precisely due to the lack of available bathymetric data. However, the scale of the predicted water level drop is large relative to the water depth upstream of CTH B.
4. Given the lowering of water levels at low and mean flows, we expect that emergent vegetation would encroach farther into the water from the shoreline. The scale of this change cannot be estimated without additional data on water depths.
5. The DNR operating order for the Stoughton Dam states that water levels below 841.00 ft will adversely affect recreational use and aesthetics, drain wetlands, and affect river habitat. Therefore, the DNR should evaluate these impacts as part of the permit review process.
6. Our screening analysis indicates that the proposed Dane County dredging would further lower water levels upstream of CTH B in addition to the lowering due to the proposed dam modifications. In the widening upstream of CTH B, this additional lowering would be approximately 0.3 ft. Further evaluation of the combined effects of the proposed dam modifications and dredging by the City and/or County is recommended.
7. Additional bathymetric data could be collected by volunteers. If this is undertaken, we recommend that the river flow at the Forton Street gage and the river stage at CTH B or another location be recorded on the measurement date. Measuring stage is important because seasonal vegetation growth affects the relationship between flow and water level. A temporary or permanent stage gage would need to be established for this purpose. A challenge in these measurements would be accurately measuring the depth to the top of the soft muck.

Attachments

Attachment 1. Modeled water surface elevations during winter and summer aquatic growth conditions (from REP).

Attachment 2. Monthly mean flows at USGS gage on the Yahara River at Forton Street.

Table 1. Modeled Water Surface Elevation Comparisons with winter aquatic plant growth conditions (roughness coefficients calibrated to November & April measurements)

		Water Surface Elevation (ft)									Water Surface Difference between Existing and Proposed (ft)					
		Existing Conditions			with Proposed Project			with full Dam Removal			with Proposed Project			with full Dam Removal		
River Station (ft)	**LOCATION**	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs
88236	Stoughton Mill Pond	841.2	841.4	841.5	840.1	839.4	838.6	837.0	836.1	835.1	-1.1	-2.0	-2.9	-4.2	-5.3	-6.4
89646	Main St	841.3	841.4	841.5	840.3	839.6	838.6	839.0	838.2	837.1	-1.0	-1.9	-2.9	-2.4	-3.3	-4.4
93817	Widening between RR bridge & County Rd B	842.1	841.7	841.5	841.6	840.7	839.5	841.4	840.5	839.4	-0.4	-1.0	-2.1	-0.6	-1.2	-2.2
103439	Widening north of County Rd B	842.4	841.9	841.6	842.1	841.1	840.0	842.0	841.0	840.0	-0.3	-0.8	-1.5	-0.4	-0.9	-1.6
117303	Immediately downstream of Lafollette Dam	843.3	842.6	841.8	843.2	842.3	841.2	843.2	842.3	841.2	-0.1	-0.3	-0.5	-0.1	-0.3	-0.5

Table 2. Modeled Water Surface Elevation Comparisons with peak aquatic plant growth conditions (roughness coefficients calibrated to June measurements)

		Water Surface Elevation (ft)									Water Surface Difference between Existing and Proposed (ft)					
		Existing Conditions			with Proposed Project			with full Dam Removal			with Proposed Project			with full Dam Removal		
River Station (ft)	**LOCATION**	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs	650 cfs	380 cfs	150 cfs
88236	Stoughton Mill Pond	841.2	841.4	841.5	840.1	839.4	838.6	837.0	836.1	835.1	-1.1	-2.0	-2.9	-4.2	-5.3	-6.4
89646	Main St	841.3	841.4	841.5	840.3	839.6	838.6	839.0	838.2	837.1	-1.0	-1.9	-2.9	-2.4	-3.3	-4.4
93817	Widening between RR bridge & County Rd B	842.2	841.8	841.7	841.8	840.8	840.3	841.6	840.6	840.2	-0.4	-1.0	-1.4	-0.6	-1.2	-1.4
103439	Widening north of County Rd B	844.3	843.1	842.3	844.2	842.9	841.7	844.2	842.8	841.7	-0.1	-0.3	-0.6	-0.1	-0.3	-0.6
117303	Immediately downstream of Lafollette Dam	845.4	844.3	843.5	845.4	844.2	843.4	845.4	844.2	843.4	0.0	-0.1	-0.1	0.0	-0.1	-0.1

Attachment 2. Monthly mean flows at USGS gage 05429700 on the Yahara River at Forton Street.

00060, Discharge, cubic feet per second												
YEAR	Monthly mean in ft3/s (Calculation Period: 2003-12-01 -> 2021-09-30)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003												412.9
2004	225.7	235.9	303.4	316.9	401	659.2	517.1	355	253.7	181.2	280.3	299.3
2005	261.6	341.4	394.9	363.7	291.7	72.6	56.5	33.2	27.1	49.5	248.5	259.6
2006	182.1	110	124.9	223.3	344.4	191.4	244.1	203.6	300.1	318	408.4	373.6
2007	217.2	166.2	327.7	555.8	306.2	191.5	69.5	373.3	591.7	462.8	339.2	383.1
2008	436.2	341.1	503.8	820	725.8	966.9	716.4	421.3	436.6	387.9	353.7	411.8
2009	417.4	352.4	716.1	772.6	704.5	380.8	271.1	179.7	224	408.6	500.3	518.9
2010	480.6	308	337.1	248.5	329.5	450.3	560	472.3	451.3	461.5	411.3	351.4
2011	306.8	316.3	467.5	477.1	444	272.1	171.2	100.6	130	194.7	371.7	382.4
2012	330.4	247.2	201.2	102.3	261.2	82.5	43.6	41.7	23.2	51.3	278.5	260.1
2013	232.4	302.1	436.5	827.7	623.6	463.1	733.1	327.9	117.8	243.3	384.6	318.7
2014	244.9	187.1	297.1	337.4	423.5	349	363	200.9	287.2	290.7	336.8	338.9
2015	209.4	189.1	145.8	167.3	164.7	264.4	160.7	78.7	192.6	361	420	554.1
2016	463.6	340.9	328.4	257	314.9	202.7	211.4	222	372	543.2	574.8	498.5
2017	448.8	453.7	500.5	563.2	526.5	416.7	562.8	431.9	350.2	416	392.7	329
2018	354.5	495.3	467.2	366.7	549.8	572.5	529.9	461.9	1,067	1,082	873.7	617.8
2019	550.7	542.2	774.2	772.1	697.1	440.5	507.6	353.8	519.2	962.7	879.7	729.2
2020	568	434.3	514.8	527.5	466.6	358.2	442.5	283.8	382.1	492.9	552.3	517.9
2021	373.5	257.9	330.8	165.1	241.7	163.6	174.3	163.4	177.9			
Mean of monthly Discharge	350	312	398	437	434	361	352	261	328	406	447	420

** No Incomplete data have been used for statistical calculation

Downloaded on June 15, 2022 from:
https://waterdata.usgs.gov/nwis/monthly/?referred_module=sw&site_no=05429700&por_05429700_155096=2181559,00060,155096,2003-11,2021-10&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list