technical memo

BADGER MILL CREEK HYDROLOGIC ASSESSMENT

Date |	04/24/2023
To / Contact info |	Kathy Lake, PE, ENV-SP
From / Contact info |	Nick Hayden, Steve Gaffield, and Joe Pallardy
Regarding |	Streamflow & habitat observations during experimental effluent shutdown

Executive Summary

The purpose of this study was to evaluate hydrologic and habitat impacts of a potential shut-down of the Madison Metropolitan Sewerage District effluent return line to Badger Mill Creek. Reducing or eliminating this effluent discharge is under consideration as a means to reduce Total Phosphorus loading to the creek.

Stream baseflow and habitat parameters were measured at several locations on Badger Mill Creek and the Sugar River during low-flow conditions on two dates: one with the effluent discharge operating as normal, and a second with the effluent discharge shut off. Monitoring dates were January 23 and February 13, 2023.

The experimental shut-down reduced the effluent discharge from 4.8 cfs to zero over a period of 1 week. The streams were allowed to adjust to the effluent elimination for another week before the second survey was conducted. Flow at each stream monitoring site dropped by 4.9 to 5.8 cfs between the two monitoring dates, reflecting the effluent elimination and a small regional drop in streamflow between the monitoring dates. Flow at the site farthest upstream on Badger Mill Creek (Old Hwy. PB) dropped from 6.0 cfs to 0.4 cfs between the two surveys. Streamflow increased downstream between monitoring sites at similar rates during each survey, with flow increasing to 5.6 cfs at Bruce Street and 9.3 cfs at the confluence with the Sugar River during the second survey. The discharge reduction caused a decrease in mean velocity, with a change from 0.24 – 0.01 ft/sec at Old Hwy. PB (at the head of pool) and smaller decreases of 0.1 – 0.2 ft/sec farther downstream on Badger Mill Creek (at riffle sites).

Mean water depth at Old Hwy. PB dropped by 0.42 ft between the two surveys, and the decline in depth at the other monitoring sites ranged from 0.08 ft to 0.17 ft. Temperature sensors were installed at 5 sites during the first survey and removed after the second survey, measuring temperature every 5 minutes. Additional temperature data at the USGS gage sites on Badger Mill Creek and the Sugar River were also evaluated. Before the effluent shut-down, the upstream temperature of Badger Mill Creek (at Old PB) was about 10 degrees warmer than the Sugar River sites. After the shut-down, temperatures at this site closely matched the Sugar River sites.

The long-term record of Badger Mill Creek flow at the Bruce St. gage indicates that flows similar to those measured during the experimental shutdown, of approximately 5 cfs at Bruce St. and flow less than 1 cfs at Old PB, would have been common without effluent discharge from 1999 to 2007. However, 3% or fewer days per year would have been at or below these flows during the last 7 years, when regional streamflows have increased.

Background

Emmons and Olivier Resources, Inc. (EOR) performed a hydrologic evaluation of an experimental shutdown of the Madison Metropolitan Sewerage District (MMSD) effluent discharge to Badger Mill Creek in January and February 2023. The purpose of this project is to provide information to MMSD on options to reduce Total Phosphorus loading from its Badger Mill Creek effluent return line to meet Wisconsin Department of Natural Resources (DNR) permit requirements. One option under consideration is reducing or shutting down the effluent return to Badger Mill Creek. This hydrologic assessment addressed questions about the amount of baseflow that could be expected in Badger Mill Creek without the effluent discharge and related changes to in-stream habitat.

Methods

Data Collection

The monitoring activities and timing were coordinated with MMSD and the DNR. The plan was to survey baseflow and habitat measurements at several locations (**Appendix A: Figures**) on Badger Mill Creek and the Sugar River during low-flow conditions when the effluent discharge was operating as normal, then shut down the effluent discharge and repeat the measurements for comparison. The data collection plan for each survey included the following:

- EOR collected discharge measurements at three locations on Badger Mill Creek and one location on the Sugar River, using a Flow Tracker 2 current meter. These measurements were supplemented by data from the United States Geological Survey (USGS) stream gage stations on Badger Mill Creek at Bruce St. and the Sugar River at STH 69. One location (Bruce St.) was chosen to validate EOR's measurements against USGS' gage and long-term record.
- EOR and MMSD established semi-permanent habitat transects at five locations on Badger Mill Creek and one location on the Sugar River (Appendix B). Stakes were placed at each site so that the transect location would be consistent between surveys. Measured water depth and substrate class observations were collected at ten evenly spaced points along the wetted portion of the transect. Additional "dry" measurements were taken on the edges of the transect to quantify the bank position relative to the water surface. The wetted width and taped width were both recorded.
- EOR and MMSD placed temperature sensors at four of the habitat transect sites and one discharge-only site during the first survey. These loggers collected 5-minute temperature readings during and between the two surveys. These data were supplemented by the USGS gage temperature readings at the other two habitat transect sites.

Project Timeline

The study was designed to allow time for streamflow and the groundwater discharge that supplies it to re-equilibrate after the effluent discharge was shut down. EOR evaluated streamflow data from the USGS

gage on Badger Mill Creek at Bruce Street during a previous shutdown in May and June 2021. As shown by the gage hydrograph (**Figure 1)** during that time period, the baseflow prior to the event was close to 14 cubic feet per second (cfs). The effluent discharge was reduced from May 11th to May 18th, with an immediate impact of dropping flows in Badger Mill Creek. The flow dropped further and reached an equilibrium within seven days of the effluent being completely off, with a new baseflow hovering around 9.5 cfs (ignoring short-term impacts from rainfall). This event provided confidence that a similar seven-day gradual reduction to zero followed by a seven-day equilibration period would be ample time for the creek's baseflow to adjust and represent a non-effluent discharge condition.

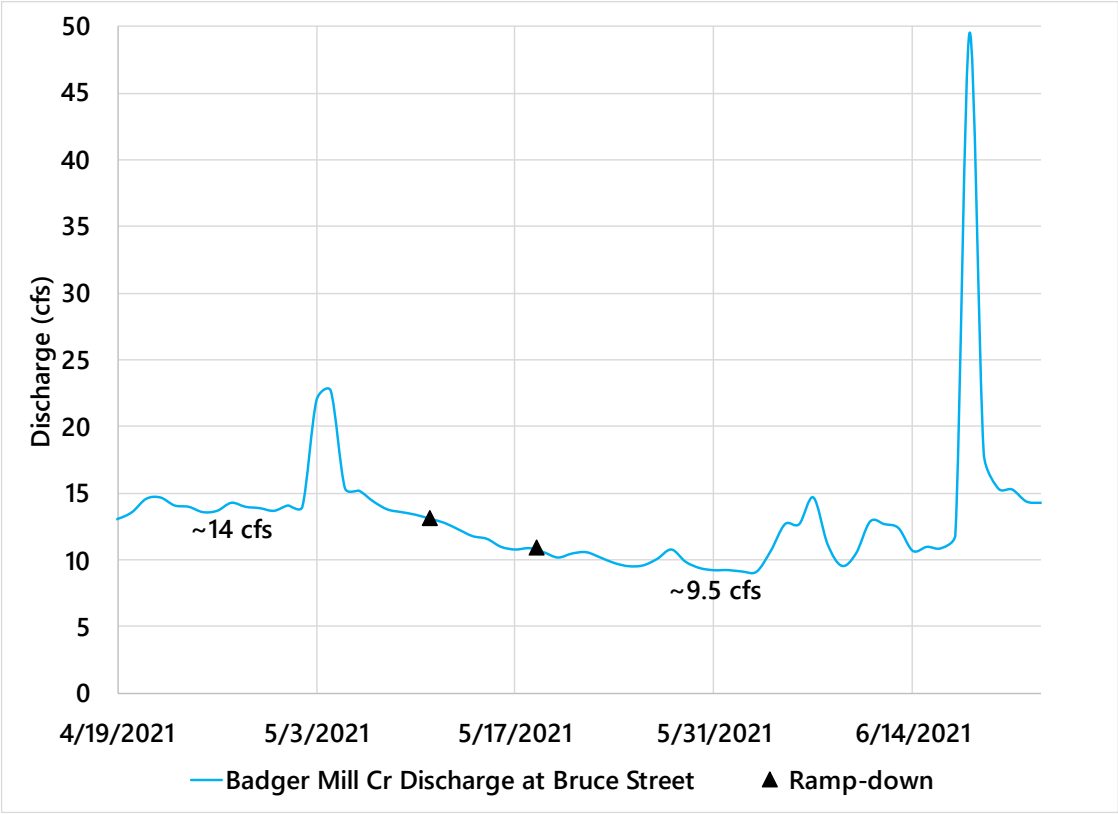


Figure 1. Baseflow Response to May 2021 Effluent Shut-off.

Selecting dates for the shutdown and monitoring required advanced planning, considering current streamflow conditions and the weather forecast. January and February 2023 saw several thaws and precipitation events that led to runoff and streamflow elevated above baseflow conditions. In addition, extreme cold was believed to be a risk to the MMSD pipeline with no discharge. The resulting schedule for the study is summarized in **Table** 1, with the habitat surveys occurring on January 23rd and February 13th, the effluent discharge reduction occurring from January 30th to February 6th, and the effluent remained off for the duration of this study.

Table 1. Project Survey and Effluent Reduction Timeline.

Date	Activity

January 11, 2023	Field site reconnaissance
January 23, 2023	Survey #1 – Normal operation
January 30 – February 6, 2023	Gradual reduction of effluent discharge from 3.1 Million Gallons per Day (MGD) [4.8 cfs]
February 6, 2023, 07:00 am	Complete discharge reduction (zero effluent discharge)
February 13, 2023	Survey #2 – Zero effluent discharge condition
February 14 – end of study	Effluent discharge remained at zero

Project Data

Discharge

Figure 2 shows discharge data from the continuous USGS gage station on Badger Mill Creek at Bruce Street, MMSD effluent discharge, and direct discharge measurements made by EOR and USGS. Note that the USGS applied a uniform shift to their site rating curve after their direct discharge measurement on February 13th, which effectively lowered their previous baseflow discharge estimate by 2.5 cfs following the December 15th runoff event's recession. The USGS applies rating curve shifts when their direct discharge measurement does not match their rating curve for a given stage, and this is typically attributed to changes in channel geometry (sediment deposition or scour) following a high flow event. This complicates the use of their data for the period between December 15th and February 13th when they did not have a direct measurement. Prior to the rating shift, EOR's direct measurement on January 23rd (10.43 cfs) was within five percent of the USGS' provisional discharge value at the same time (11.0 cfs), which is relatively good agreement for a natural channel measurement from different operators and equipment. After the shift, EOR's value is 1.9 cfs higher than the revised USGS provisional value. On February 13th, when both EOR and USGS took a measurement on Badger Mill Creek, EOR's value (5.57 cfs) was within seven percent of the USGS value (5.23 cfs). Both EOR and USGS also took a discharge measurement at the STH 69 Sugar River gage on that day, and those measurements were within three percent of each other. Based on these relatively tight concurrent measurements, the following analysis and discussion of discharge data during the effluent reduction period will focus more on the spatially distributed EOR measurements than the shifted USGS Bruce Street gage values.

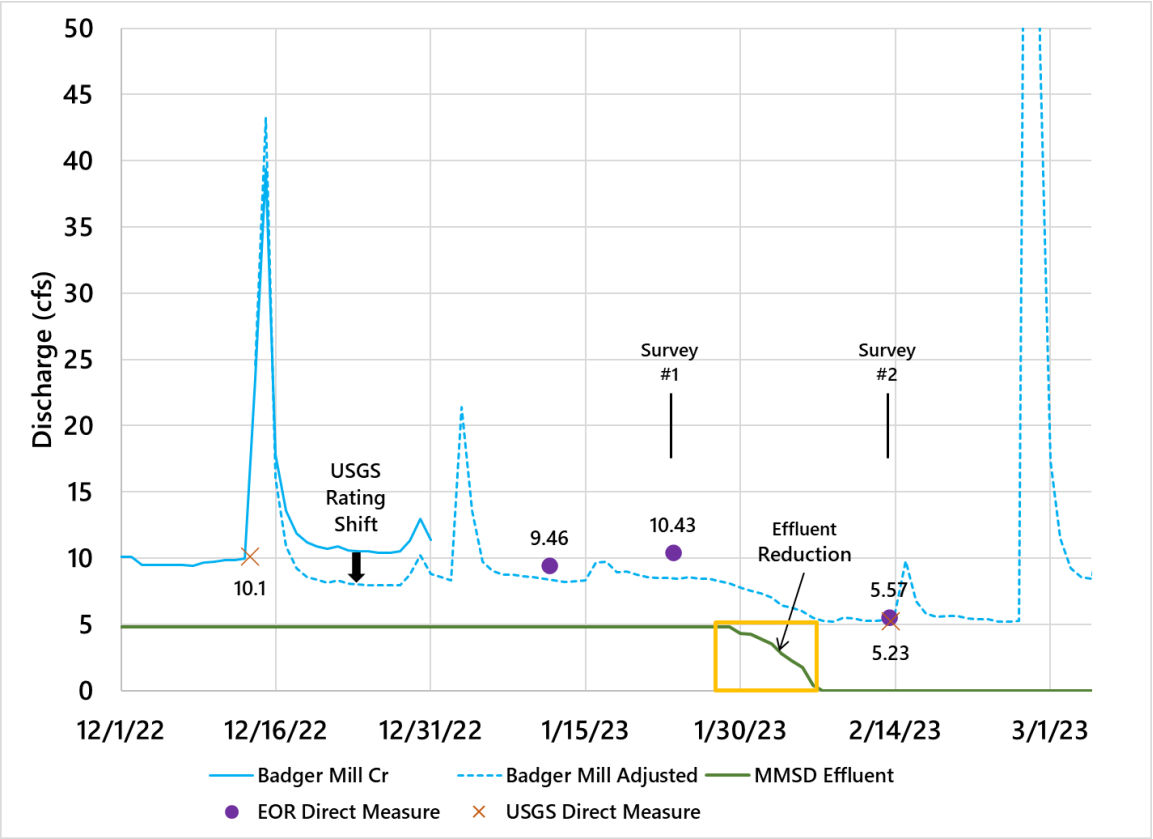


Figure 2. Badger Mill Creek at Bruce Street and Effluent Hydrographs, December 2022 through Feb 2023.

EOR discharge measurements for Survey #1 and Survey #2 are shown in **Table 2**. The change between surveys reflects both the removal of the MMSD effluent discharge (4.8 cfs) and a slight drop in regional baseflow, as demonstrated by an approximately 15% drop at the upstream Sugar River site (SR5).

Table 2. EOR Discharge Measurements during Surveys #1 and #2.

Location	Survey #1 Discharge [Normal Effluent] (cfs)	Survey #2 Discharge [No Effluent] (cfs)	Change (cfs)
BM5 – Old PB	6.0	0.4	-5.6
BM7 – Bruce St.	10.43	5.57	-4.9
BM-AC – above Confluence	14.6	9.3	-5.3
SR5 – Valley Rd.	33.8	28.3	-5.5
SR7 – STH 69[1]	51.0	45.2	-5.8

1 – Values are from USGS gage

Habitat Data

The six habitat transect locations are shown in **Appendix A: Figures** and flow structure, substrate, and other notes are included in **Table 3**. The habitat types ranged from shallow riffles to deeper pools, and except for the upstream-most site (BM5 – muck) there were typically a range of substrate classes present including finer materials (muck-silt-sand) and larger materials (gravel-pebble-cobble). Photos showing both these locations and the discharge-only location (SR5) are included in **Appendix B: Site Photographs**. The photo log documents both survey dates, but unfortunately the "before effluent reduction" condition (Survey #1) is less documented because EOR's field tablet was lost in the deep pool at BM9 and was not able to be recovered. Photos from several individuals present during Survey #1 were combined to document those conditions as best as possible.

Table 3. Habitat Transect Descriptions.

Location	Channel Form	Substate	Other Notes
BM5 – Old PB	Pool	Muck-dominant across entire channel	Steep banks. Habitat surveyed just downstream of pedestrian bridge. Upstream of tributary inflow from spring pond.
BM6 – Lincoln St.	Riffle	Pebble-cobble dominant across main channel, sand/muck present near margins	Shallow riffle. Habitat surveyed downstream of covered bridge.
BM7 – Bruce St.	Riffle / Run	Pebble to boulder substrate dominant across main channel, with pockets of muck and sandy silt near margins	Steep banks. USGS gage site. Habitat surveyed in riffle just downstream of bridge.
BM9 – STH 69	Glide / Head of Pool	Sand-cobble mixture dominant across channel, with boulders present. Muck and boulders near margins.	Near-vertical banks. Habitat surveyed upstream of bridge, just upstream of ditch inflow. Original suggested DNR habitat site (downstream pool) was deep and not wadable.
BM-AC – above Confluence	Riffle	Pebble-cobble dominant with sand/silt pockets across main channel, finer materials near margins.	Wide, shallow riffle.
SR7 – STH 69	Run	Cobble-dominant with sand/silt present across channel, muck near margins.	Steep banks. USGS gage site. Habitat surveyed at USGS discharge transect (large rebar).

Results from the habitat transect surveys are summarized in **Table 4**. Across the sites, discharge decreases ranged between 4.9 to 5.8 cfs, wetted width decreases ranged between 0.0 to 2.1 feet, and mean depth decreases ranged from 0.42 to 0.08 feet. Both the mean and the median statistic were computed but were found to be similar, so only the mean is reported here. Despite the effort to replicate the exact transect and sampling locations, there was some variation in depths at specific points between the surveys due to measurements falling on or near larger substrates (cobbles, boulders). Despite this depth variability in individual measurements, in general Survey #2 depths were shallower than Survey #1.

Table 4. Habitat Transect Results comparing Surveys.

Site Name	Discharge change[1] (cfs)	Wetted Width (ft)			Mean Depth (ft)		
		Survey #1	Survey #2	Change	Before	After	Change
BM5- Old PB	-5.6	21.0	18.9	-2.1	1.20	.78	-0.42
BM6 - Lincoln St.	NA	23.5	21.8	-1.7	0.39	0.23	-0.16
BM7- Bruce St.	-4.9	17.7	15	-2.7	0.59	0.42	-0.16
BM9- STH 69[2]	NA	21.1	21.1	0.0	1.44	1.27	-0.17
BM-AC – above Confluence	-5.3	20.3	20.3	0.0	0.45	0.37	-0.09
SR7 - STH 69	-5.8	35.0	35.0	0.0	1.12	1.04	-0.08

1 – NA signifies no discharge measurement was taken (habitat-only site)

2 – Fence posts were vandalized (removed) so transect location was replicated as best as possible

Temperature Data

MMSD installed HOBO UA-002-64 temperature and light pendants at Sites BM5, BM6, BM9, BM-AC, and SR5 during the first survey. Pendants collected 5-minute temperature readings and were removed following the second survey. These pendant data were supplemented by 15-minute temperature data from the USGS gage sites (BM7, SR7). These data are shown in **Figure 3**.

While the number of temperature sensors, daily air temperature fluctuations, and seasonal groundwater temperature fluctuations complicate data interpretation, the following observations are noted:

- Stream temperatures at BM5 (light blue), the site nearest the MMSD effluent discharge, were always higher than other sites prior to the "zero effluent" period. These temperatures were typically 10 degrees warmer than the Sugar River sites. The higher temperatures at this site reflect input of effluent a short distance upstream, which is warmer than the ambient air temperature in winter and colder in summer.

- Midway through the effluent reduction, BM5 temperatures transitioned to become the lowest of the Badger Mill Creek sites, and closely matched the Sugar River sites for the remainder of the monitoring period.
- Prior to effluent shut-down, the "intermediate" Badger Mill Creek site temperatures (BM6 [purple] and BM7 [grey]) were between BM5 and the "lower" sites (BM9 and BM-AC). After effluent shut-down, those intermediate site temperatures nearly matched those of the lower Badger Mill Creek sites, with all those sites being warmer than BM5 and the Sugar River sites during the final week of data collection leading up to Survey #2.

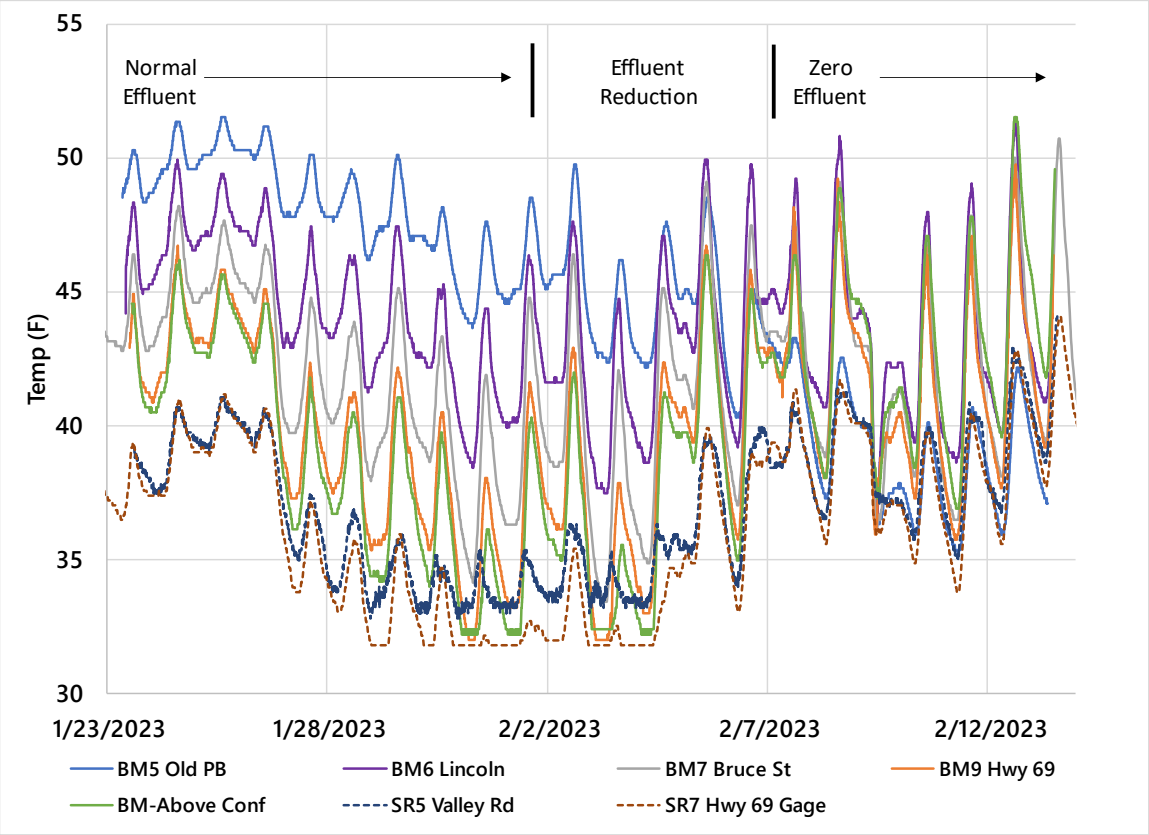


Figure 3. Monitoring Site Temperature Data.

The permanent USGS site temperature data allowed for a longer period of temperature data analysis. These data are compared to mean daily air temperature at the Dane County Regional Airport (MSN) in **Figure 4**. The following observations are noted:

- Temperatures in Badger Mill Creek at the gage site were typically about five degrees warmer than the Sugar River gage site prior to effluent shut-down.

- Following effluent shut-down, Badger Mill Creek temperatures more closely matched the Sugar River, particularly the nighttime (minimum daily) temperatures.
- Both sites experienced larger daily fluctuations towards the end of the period shown, presumably due to increased solar radiation.

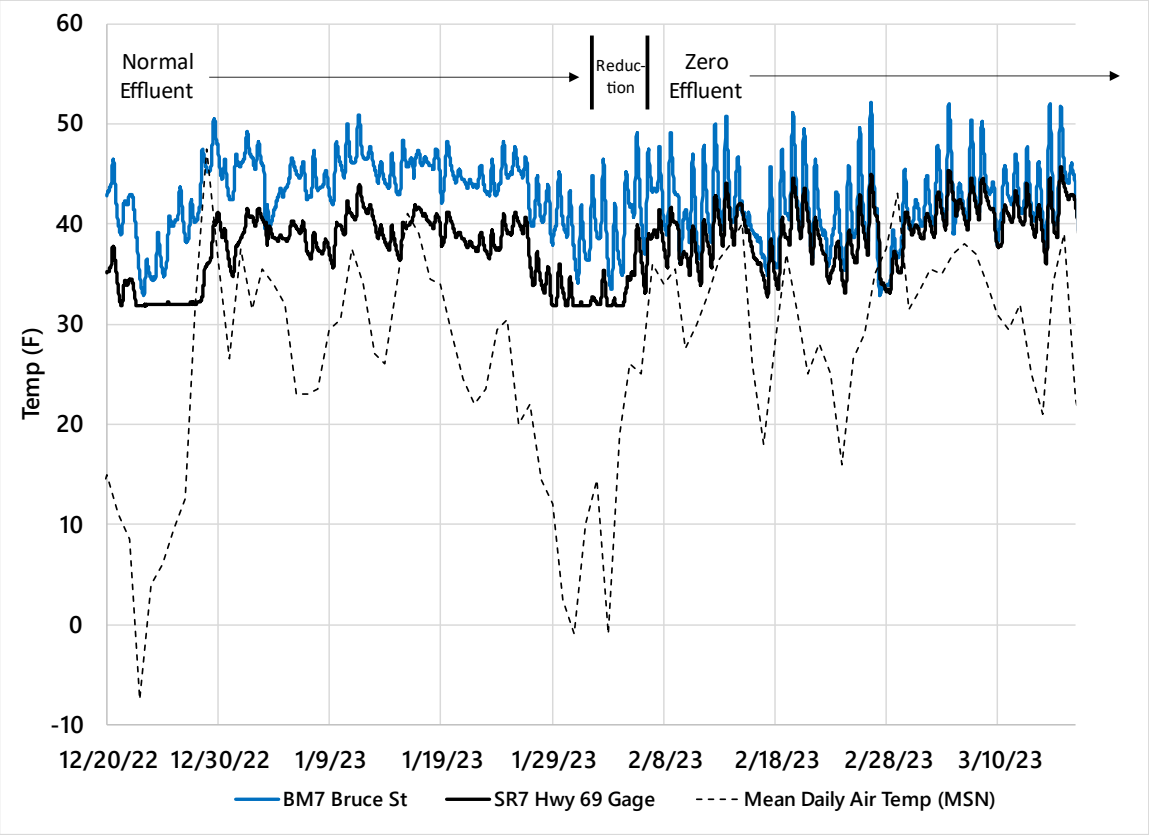


Figure 4. Extended Temperature Data at USGS Gages.

Analysis and Discussion

The DNR classifies Badger Mill Creek as a cool (cold-transition) main stem community.[1] This is defined as a wadeable perennial stream with cold to cool summer temperatures with coldwater and transition fishes. DNR's proposed characteristics for this classification include a maximum daily mean water temperature of 69.3 – 72.5 degrees Fahrenheit and an annual 90% exceedance flow of 3.0 cfs.[2] Implications of shutting down the effluent return flow on these and other habitat characteristics are discussed below.

Discharge, Stage, and Velocity

Badger Mill Creek

The pattern of discharge changes measured by EOR along Badger Mill Creek was mostly as expected given the removal of 4.8 cfs of effluent and dropping regional winter baseflows. The biggest source of measurement uncertainty was the Survey #2 discharge measurement at BM5, which was complicated by low velocities (including backflow) along the stream margins. Without the effluent, Badger Mill Creek continued to gain about 5 cfs between BM5 and BM7 and about 4 cfs between BM7 and BM-AC. This suggests that the sites downstream of BM5 will continue to have perennial flow even if BM5 were to drop to ~0.4 cfs discharge during winter baseflow or substantial drought without the effluent.

The effluent discharge of 4.8 cfs is higher than DNR's 90% exceedance flow of 3.0 cfs for cool-coldwater main stem streams. Without the effluent return, flow at Old PB (site BM5) can be expected to be below 3.0 cfs during most baseflow conditions, so this reach would likely no longer meet the Cool (Cold-Transition) *Main Stem* classification. Whether it would meet the Cool (Cold-Transition) *Headwater* classification would depend on if water temperatures remained cold enough. Lower flows through the wetland upstream of Old PB could lead to increased diurnal fluctuations in dissolved oxygen and potentially higher temperature fluctuations in summer.

The relationship between stream cross-sectional area (wetted width and depth) and discharge is non-linear, as evidenced by the 93% reduction in discharge at BM5 causing only a 10% reduction in wetted width and 35% reduction in mean depth. In addition to stream area, discharge is also a function of water velocity, and in cases where discharge decreases but stream area changes are relatively small, the decrease in velocities will be more pronounced. At BM5, where discharge dropped to approximately 0.4 cfs, mean velocity dropped from 0.24 feet per second (fps) to 0.01 fps between Survey #1 and Survey #2. Note that this 0.01 fps average includes considerable areas along the channel margins where velocity was zero or negative (backwater) at a discharge of 0.4 cfs (**Figure 5)**; velocities in the center of the channel were typically between 0.05 – 0.08 fps during Survey #2.

[1] https://dnr.wi.gov/water/waterDetail.aspx?key=13654
[2] https://dnr.wisconsin.gov/topic/Rivers/NaturalCommunities.html

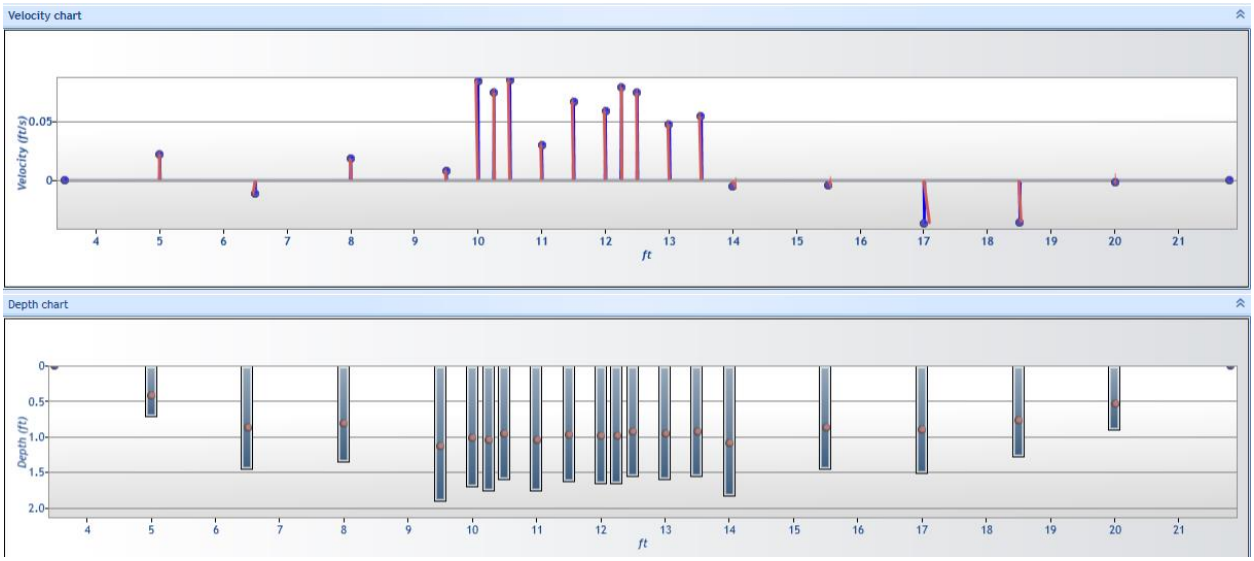


Figure 5. Cross-Section Velocity and Depth Profile at BM5 (Old Pb), Survey #2.

Velocity changes downstream were less pronounced; at BM7 mean velocity dropped from 0.60 fps to 0.47 fps, and at BM-AC mean velocity dropped from 0.95 fps to 0.76 fps. While lower velocity in spawning areas is a potential concern because it can result in less suitable habitat for brown trout[3], at the two sites where EOR discharge measurements coincide with DNR fish survey locations (the confluence and Bruce Street), mean velocity was only reduced by approximately 20% from Survey #1 to Survey #2.

Sugar River

The magnitude of discharge change at the downstream Sugar River site (SR7) was surprising; it was expected that the change would be greater reflecting both the drop in regional baseflow during the time period and the removal of effluent flow in between the two Sugar River sites. One possible explanation for this is the snowpack that was present in rural areas (Sugar River) but not in urban areas (Badger Mill Creek) was observed melting during Survey #2, which could have increased discharges in the Sugar River. Regardless, groundwater dynamics are complicated, and examining the interplay between water table levels, recharge, and surface water inputs on the Sugar River groundwater system would require additional study.

Physical Habitat

The greatest water depth change was observed at the upstream site BM5, where the depth dropped by 0.42 ft or 35%. Water depth at BM 6 (Lincoln Street) and BM7 (Bruce Street) dropped by 0.16 ft, representing reductions of 41% and 27%, respectively at these riffle sites. No sections of the streambed were observed

[3] US Fish and Wildlife Service, 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout. Biological Report 82(10.124) September 1986 Revised.

to be dry on the no-effluent monitoring date, indicating that connectivity between pools would be maintained as long as water depth over riffles was sufficient for fish passage.

The temperature monitoring data indicate thermal changes with effluent elimination. Reduced discharge and a higher width to depth ratio would cause solar radiation and air temperature to have more of a heating effect in summer. Thermal modeling would be needed to quantify expected temperature changes in summer.

Long-Term Implications

A prediction of occurrences of low discharges is possible due to the long-term record of the USGS gage on Badger Mill Creek at Bruce Street (BM7). **Figure 6** shows gage discharge from 1999 to the present (MMSD effluent discharge started in 1998). The red line indicates times when discharge was below 10 cfs at Bruce Street. As discussed above, based on the effluent discharge, current incremental baseflow increases along Badger Mill Creek, and project measurements, it is likely that a historical discharge of 10 cfs or lower at Bruce Street would have corresponded with a discharge < 1 cfs at Old PB (BM5) and the upstream wetlands if effluent discharge was eliminated. The likelihood of this occurring appears to be lower now than during earlier parts of the record. As shown in **Figure 7**, the percentage of time when the gage is below 10 cfs has dropped dramatically, with 3% or fewer of all days being below 10 cfs over the past seven years. Prior to that, there was a period of dryer years (2012-2015) where it does seem that Site BM5 could have experienced < 1 cfs discharge and near-stagnant conditions along channel margins for lengths of time during each year, and flow at Bruce Street likewise could have been around 5 cfs or slightly less, depending on regional baseflow conditions. Note that 5 cfs at Bruce Street would be above the DNR 90% exceedance flow of 3.0 cfs for a Cool (Cold-Transition) Main Stem stream community, but that flow at Old PB would be below this flow threshold during those conditions.

With the caveat that downstream baseflow increases between BM5 and BM7 have likely fluctuated in the past twenty years, which impacts the assumption of this 10 cfs as an indicator, this supports the conclusion that baseflow has increased substantially since MMSD first began discharging effluent into Badger Mill Creek. This is supported by observations at other regional waterways, like the long-term gage record on the Sugar River near Brodhead, and research showing "significant increasing trends" of baseflow in southern Wisconsin[4]. These data suggest if the effluent were discontinued, the likelihood of a discharge < 1 cfs near BM5, or of discharges lower than observed during Survey #2 at other locations during this study, has decreased over time.

[4] Ayers JR, Villarini G, Jones C, Schilling K. Changes in monthly baseflow across the U.S. Midwest. Hydrological Processes. 2019;33:748–758. https://doi.org/10.1002/hyp.13359

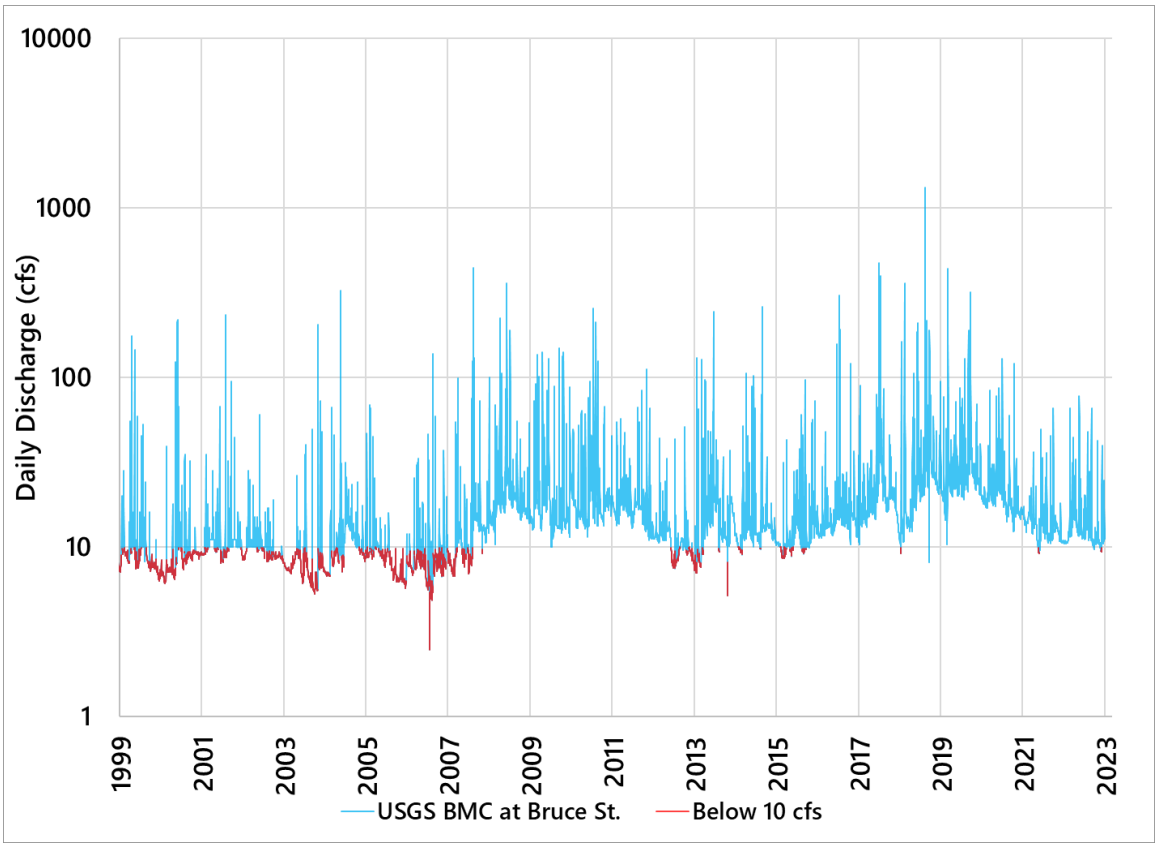


Figure 6. USGS Gage on Badger Mill Creek at Bruce Street, 1999-Present.

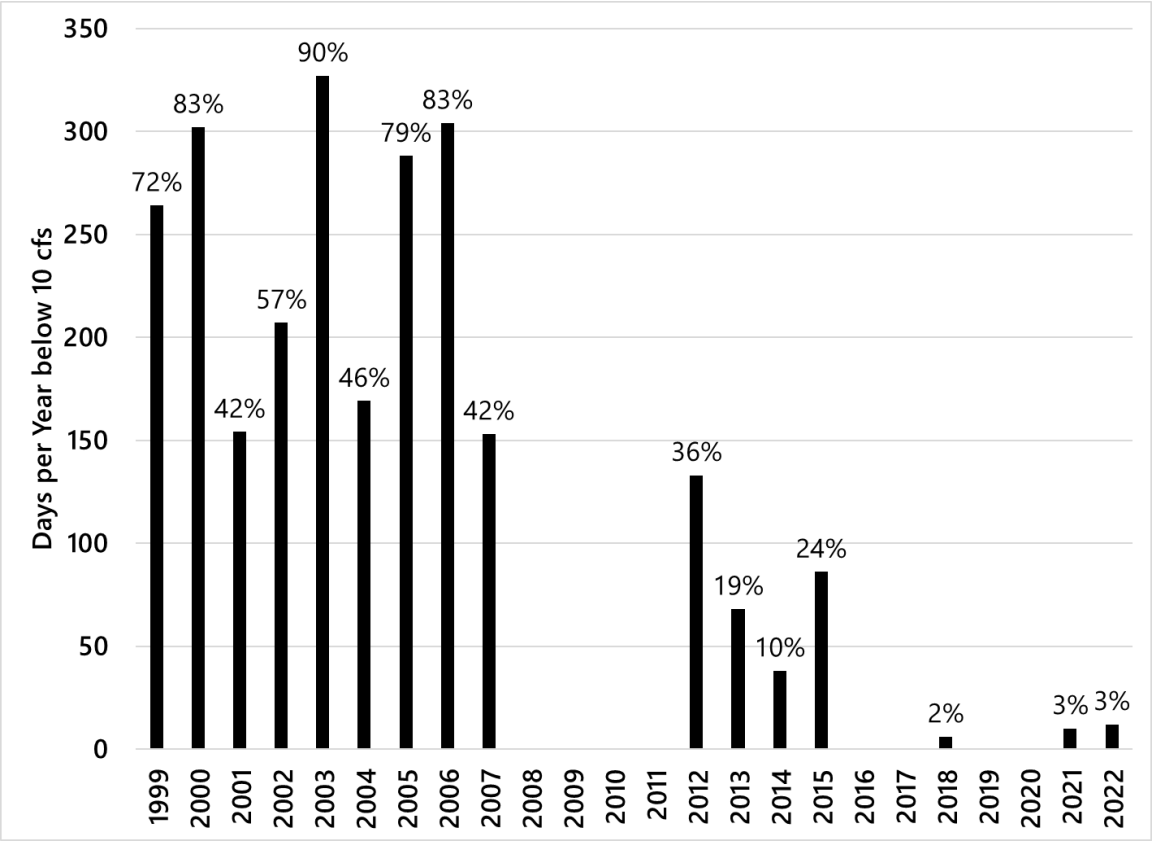


Figure 7. Percent of Days Below 10 cfs at Bruce Street, 1999- Present.

Conclusions

1. During the experimental effluent discharge shutdown, streamflow in Badger Mill Creek dropped by approximately 5 cfs at each of the measurement sites from Old PB downstream to the confluence with the Sugar River. This corresponds to elimination of 4.8 cfs of effluent plus an approximate 15% regional baseflow decline between the two measurement dates in January and February 2023. Decreases in the flow of the Sugar River flow upstream and downstream of Badger Mill Creek were of a similar magnitude.
2. Site BM5 at Old PB had a flow of 0.4 cfs without the effluent discharge, below the threshold of 3.0 cfs for the 90% exceedance flow of a Cool (Cold-Transition) Main Stem stream community which DNR has applied to Badger Mill Creek. All other sites had measured flow above this threshold.
3. Water depth dropped by 0.42 ft at BM5 and 0.08 – 0.17 ft at the other sites. No stream reaches were observed to dry completely during the shutdown.
4. Water velocity change was most pronounced at BM5, where mean velocity dropped from 0.24 fps to 0.01 fps due in part to channel margin areas with zero flow or backwater. Center channel velocities there were higher (approximately 0.05-0.08) during that survey. Smaller changes in mean

velocity were measured farther downstream on Badger Mill Creek (0.60 fps to 0.47 fps at BM7 and 0.95 fps to 0.76 fps at BM-AC).

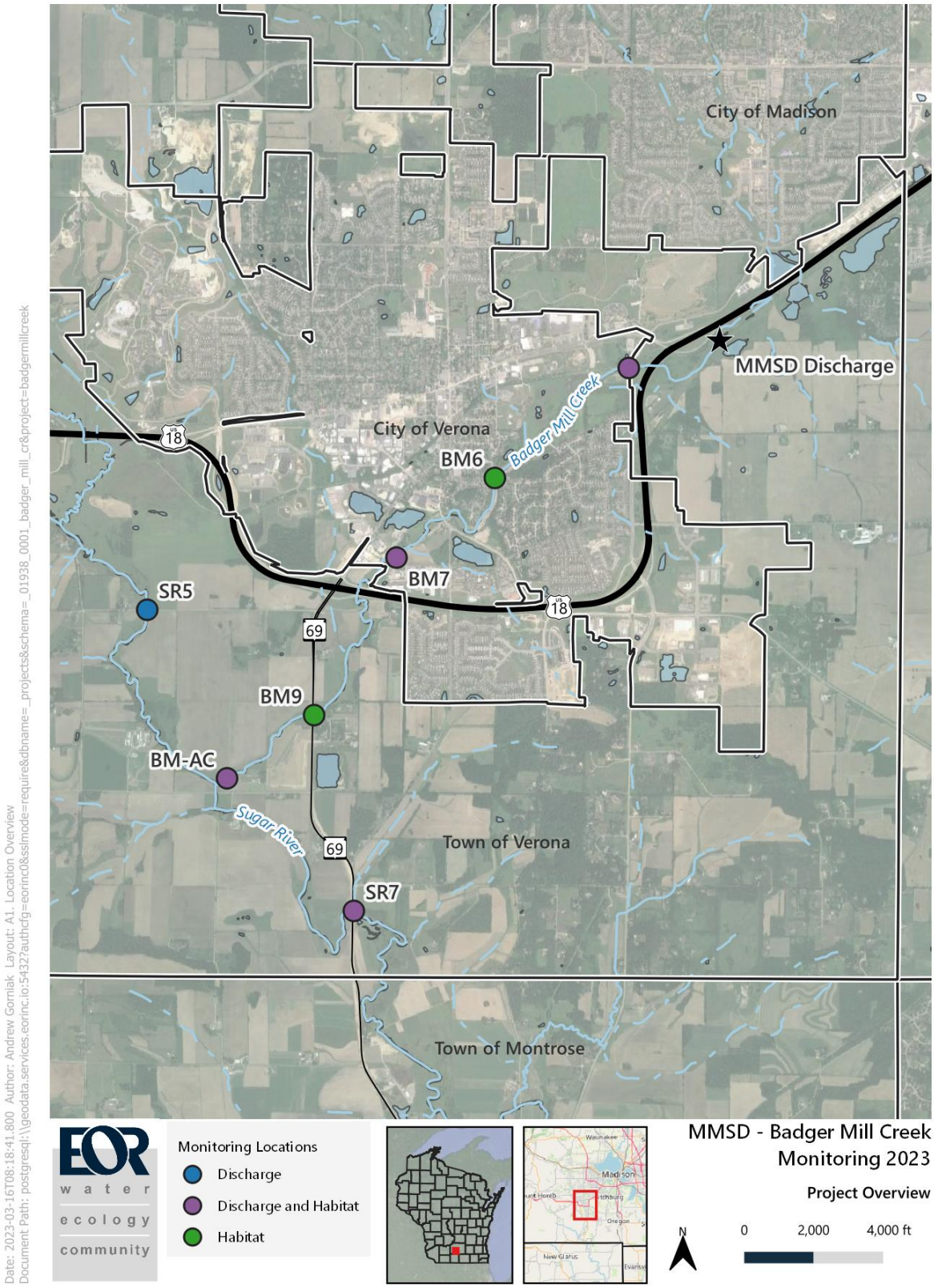
5. Stream temperature at BM5 dropped by approximately 10 degrees after the shutdown, going from the warmest of the monitoring sites to matching the Sugar River temperature. The effect on downstream sites on Badger Mill Creek was less pronounced. This indicates that higher summer temperatures would be expected in Badger Mill Creek, especially at upstream site BM5. Quantifying this increase was beyond the scope of this study.
6. The long-term record of Badger Mill Creek flow at the Bruce St. gage indicates that flows similar to those measured during the experimental shutdown, with approximately 5 cfs at Bruce St. and flow less than 1 cfs at Old Hwy. PB, would have been common without effluent discharge from 1999 to 2007. However, 3% of fewer days per year would have been at or below these flows during the last 7 years, when regional streamflows have increased.

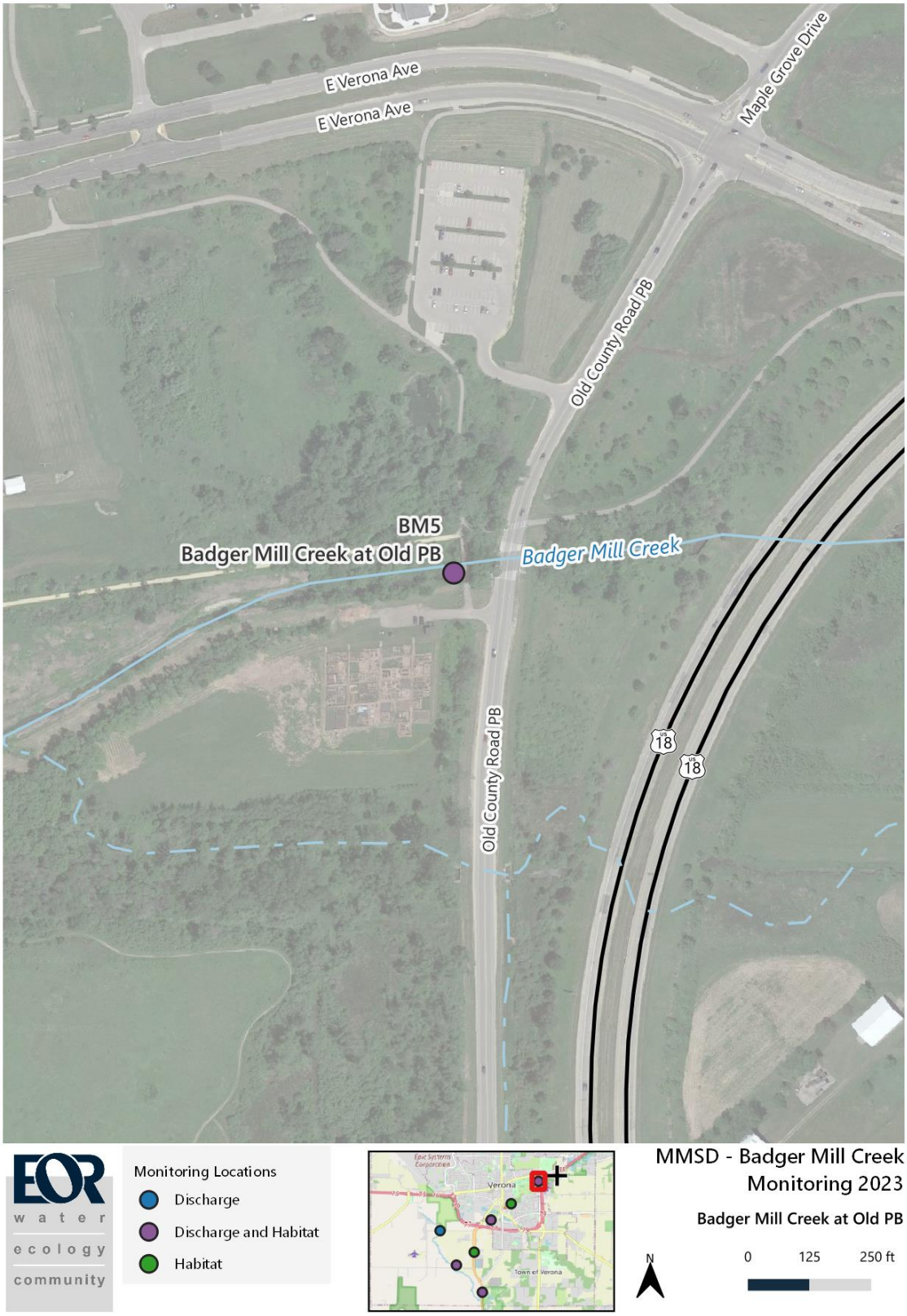
Attachments

Appendix A: Figures

Appendix B: Photographs

APPENDIX A: FIGURES

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Monitoring Locations
Discharge
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Habitat
Verona
Town of Verona
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MMSD - Badger Mill Creek
Monitoring 2023
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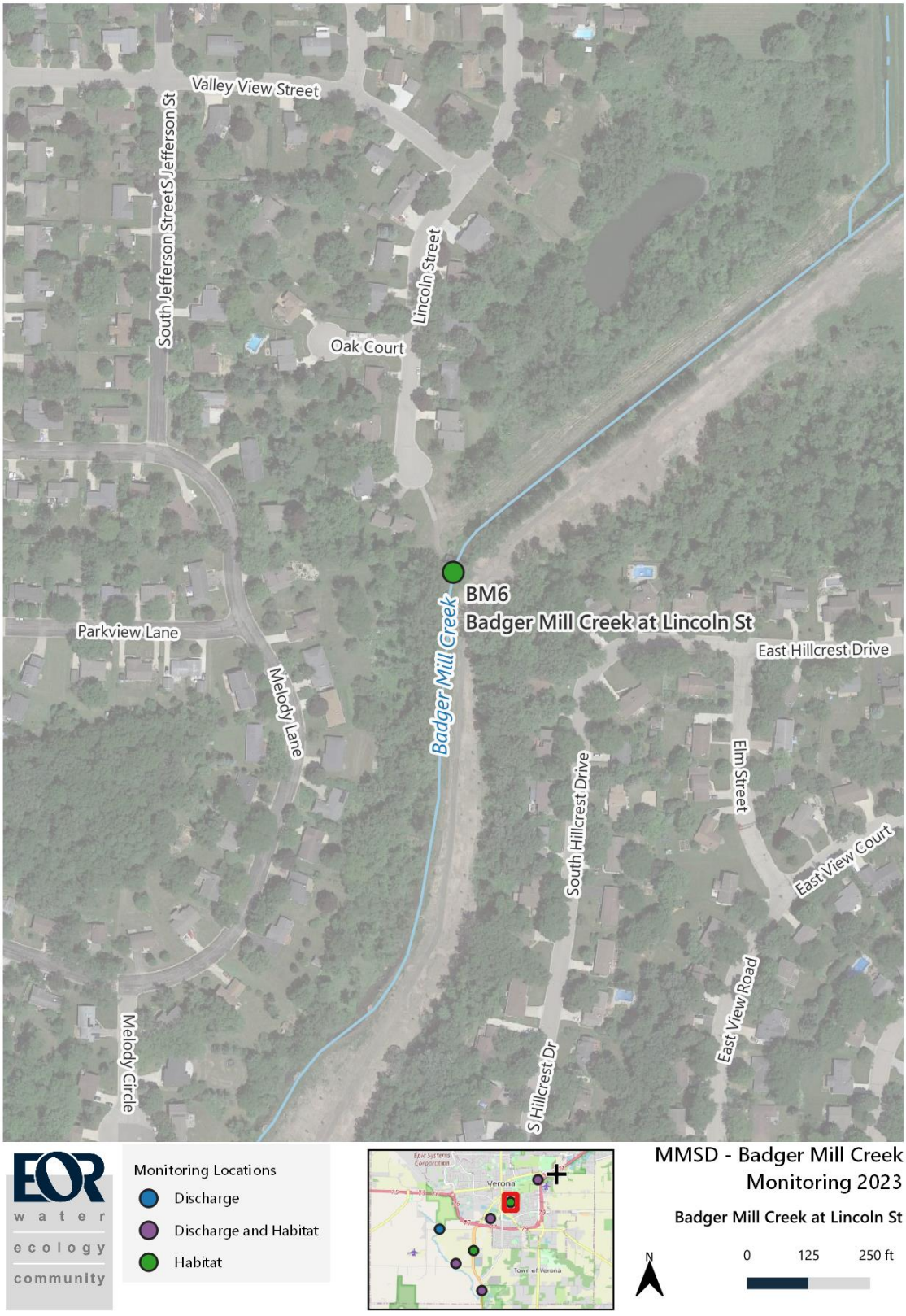

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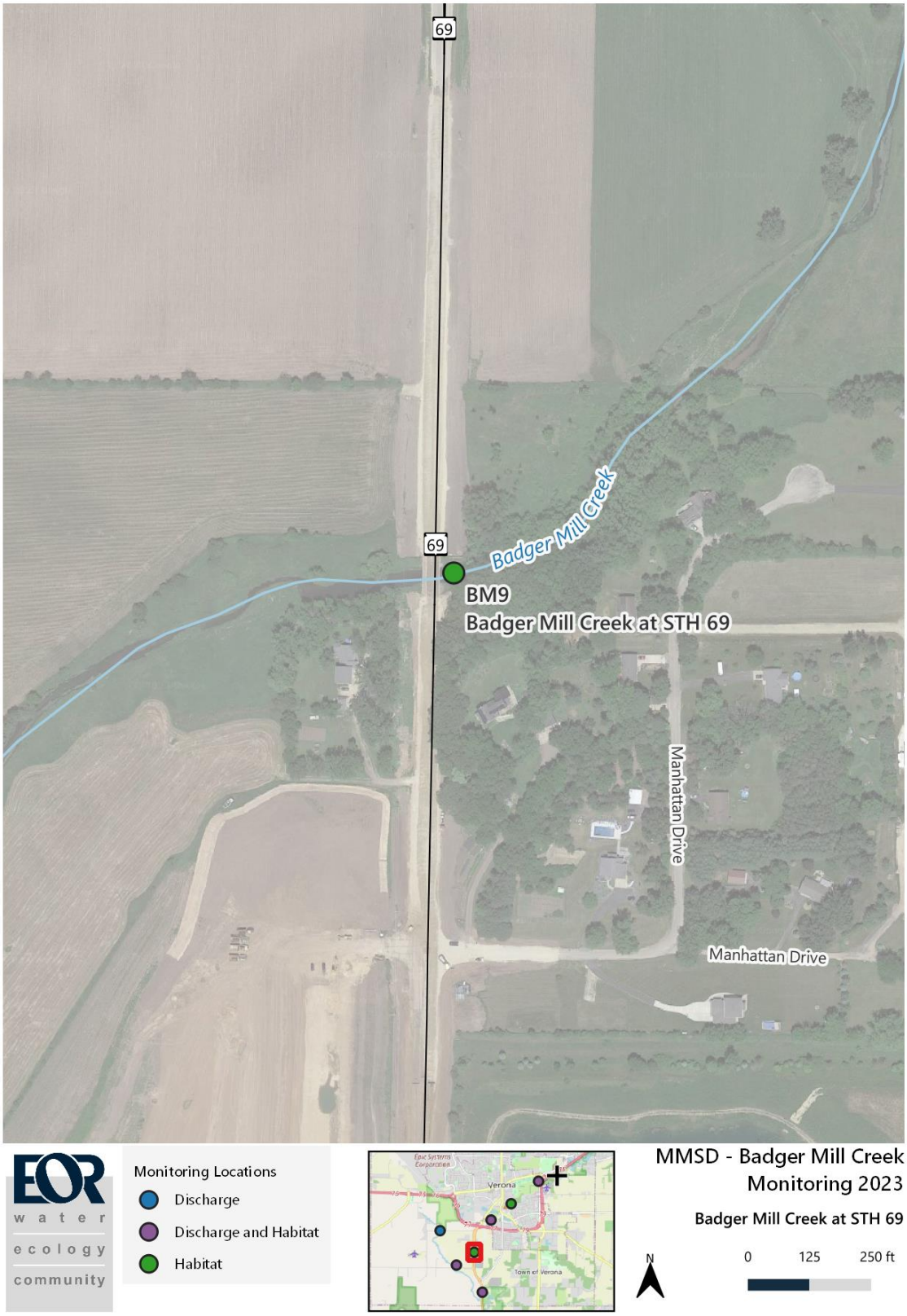
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Badger Mill Creek
BM9
Badger Mill Creek at STH 69
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Monitoring Locations
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Discharge and Habitat
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community
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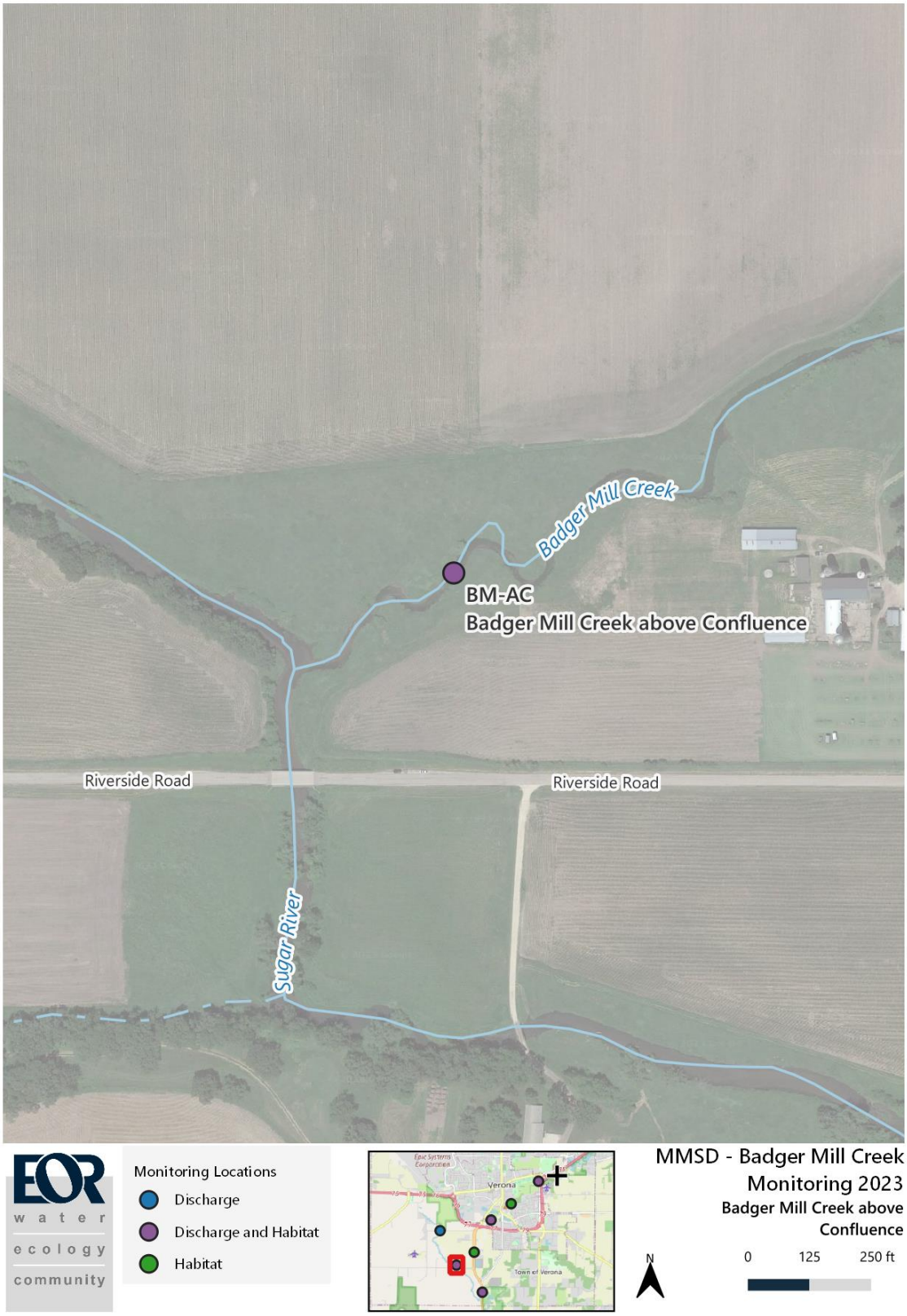
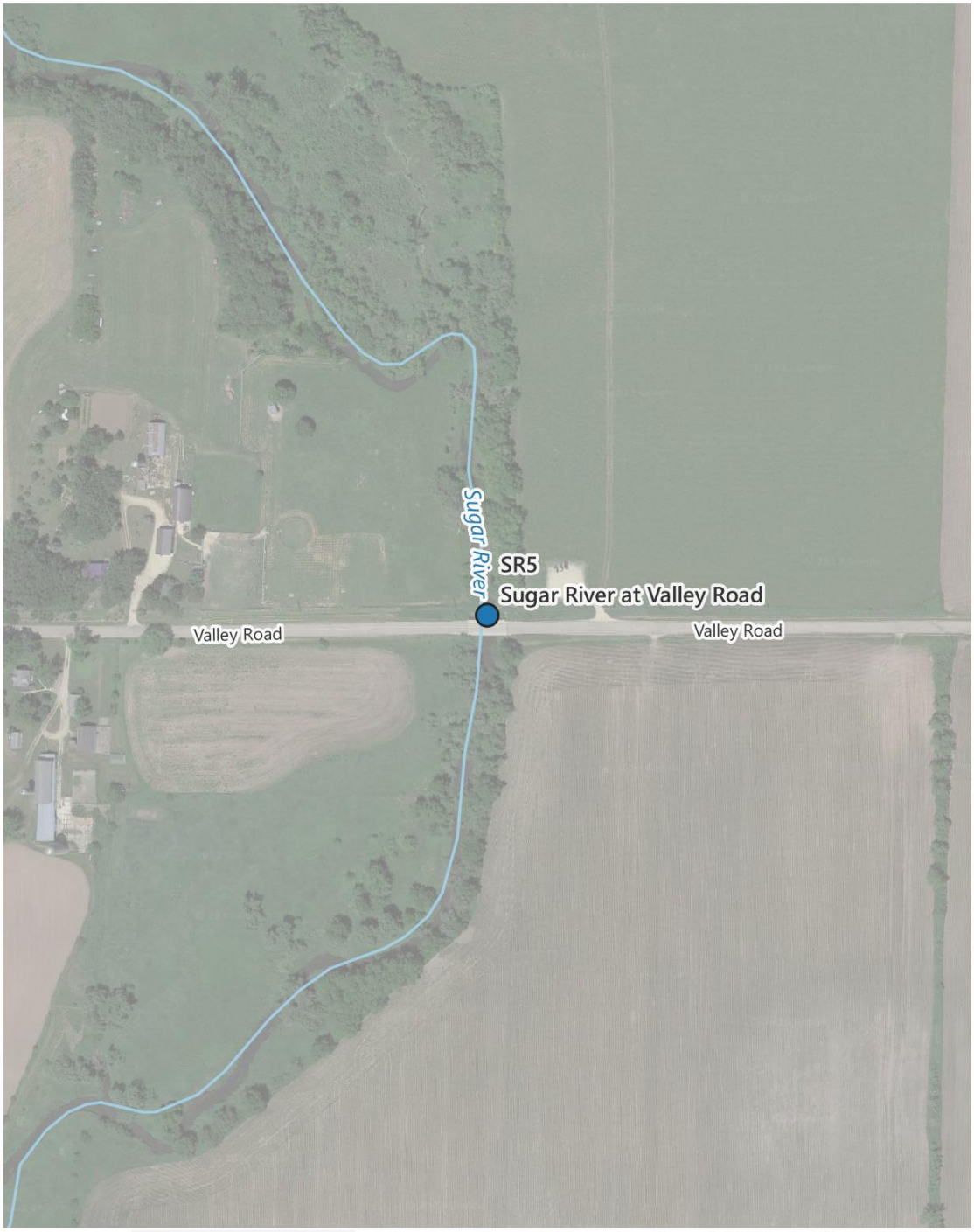
Document Path: postgresql:\\gecdata.services.eorinc.io:5432?authcfg=eorinc08&sslmode=require&dbname=_projects&schema=_01938_0001_badger_mill_cr&project=badgermillcreek





Monitoring Locations
- Discharge
- Discharge and Habitat
- Habitat

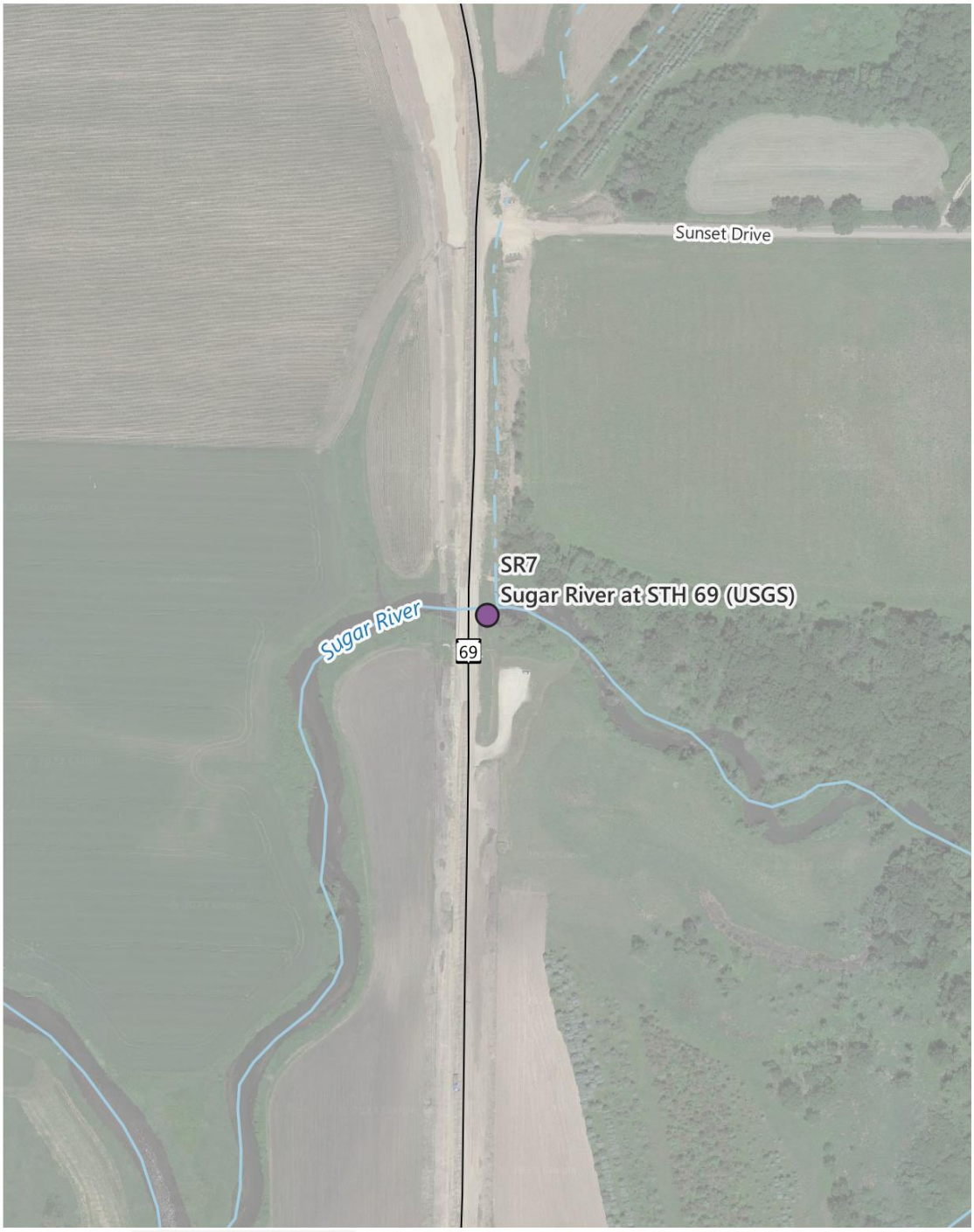
MMSD - Badger Mill Creek Monitoring 2023

Sugar River at Valley Road

N

0 125 250 ft

Date: 2023-03-16T08:25:44.904 Author: Andrew Gorniak Layout: A2: Site Maps.
Document Path: postgresql:\\geodata.services.eorinc.io:5432?authcfg=eorinc08&sslmode=require&dbname=_projects&schema=_01938_0001_badger_mill_cr&project=badgermillcreek



Date: 2023-03-16T08:25:55.774 Author: Andrew Gorniak Layout: A2: Site Maps.
Document Path: postgresql:\\geodata.services.eorinc.io:5432?authcfg=eorinc08&sslmode=require&dbname=_projects&schema=_01938_0001_badger_mill_cr&project=badgermillcreek

water ecology community

Monitoring Locations
- Discharge
- Discharge and Habitat
- Habitat

MMSD - Badger Mill Creek Monitoring 2023

Sugar River at STH 69 (USGS)

N

0 125 250 ft

APPENDIX B: SITE PHOTOGRAPHS

BM5 – Old PB

Before effluent shutdown

Photo 1: Looking downstream.

Photo 2: Looking at right bank.

After effluent shutdown

Photo 3: Looking upstream.

Photo 4: Looking at left stream bank.

Photo 5: Looking at right stream bank.

Photo 6: Looking downstream.

BM6 – Lincoln St.

Before effluent shutdown

Photo 7: Looking downstream.

Photo 8: Looking upstream.

After effluent shutdown

Photo 9: Looking upstream.

Photo 10: Looking downstream.

Photo 11: Looking at right stream bank.

BM7 – Bruce St. (USGS Gage)

Before effluent shutdown

Photo 12: Looking at right stream bank.

Photo 13: Discharge measurement.

After effluent shutdown

Photo 14: Looking upstream.

Photo 15: Looking at right stream bank.

Photo 16: Looking at left stream bank.

Photo 17: Looking downstream.

BM9 – STH 69

Before effluent shutdown

Photo 18: Looking at left stream bank.

Photo 19: Looking upstream.

Photo 20: Looking at right stream bank.

After effluent shutdown

Photo 21: Looking at left stream bank.

Photo 22: Looking upstream.

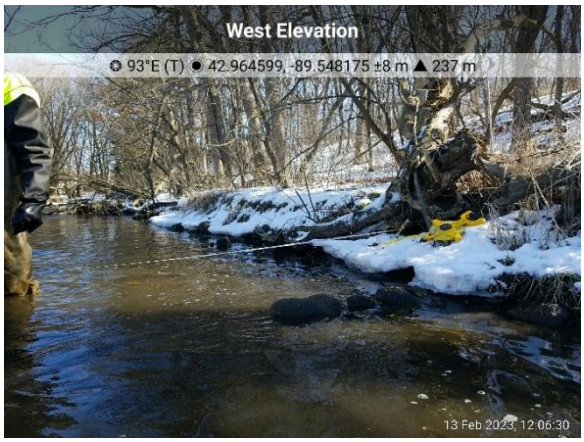


Photo 23: Looking at right stream bank.

Photo 24: Looking downstream.

BM-AC – above Confluence

Before effluent shutdown

Photo 25: Looking downstream.

Photo 26: Looking upstream.

After effluent shutdown

Photo 27: Looking downstream.

Photo 28: Looking upstream.

Photo 29: Looking at left stream bank.

Photo 30: Looking at right stream bank.

SR5 – Valley Rd

Before effluent shutdown

Photo 29: Looking upstream.

Photo 30. Looking downstream.

After effluent shutdown

Photo 31: Looking upstream.

Photo 32: Looking downstream.

Photo 31: Looking at right stream bank.

Photo 32: Looking at left stream bank.

SR7 – STH 69 (USGS Gage)

Before effluent shutdown

Photo 33: Looking upstream.

Photo 34: Looking downstream.

Photo 35: Looking at right stream bank.

Photo 36: Looking at left stream bank.

After effluent shutdown

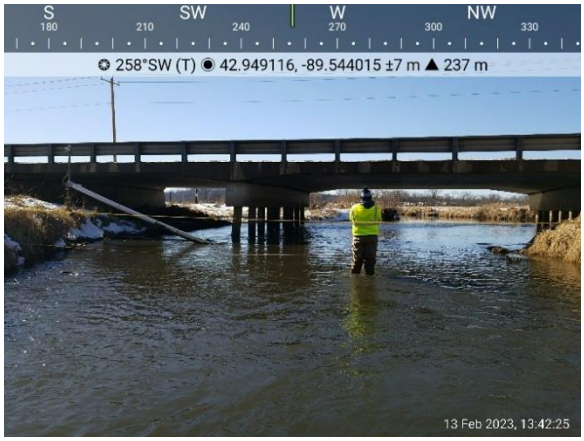


Photo 37. Looking upstream.

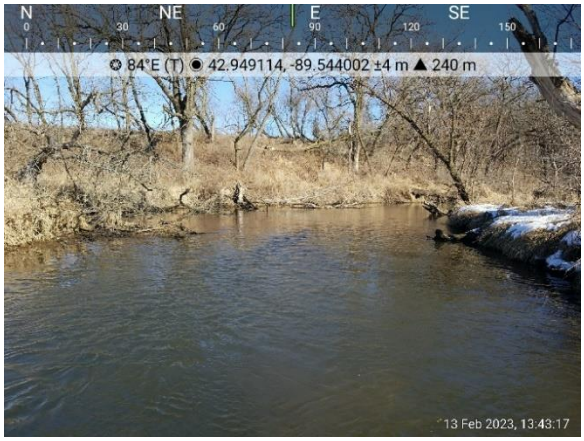


Photo 38. Looking downstream.

Photo 39: Looking at right stream bank.

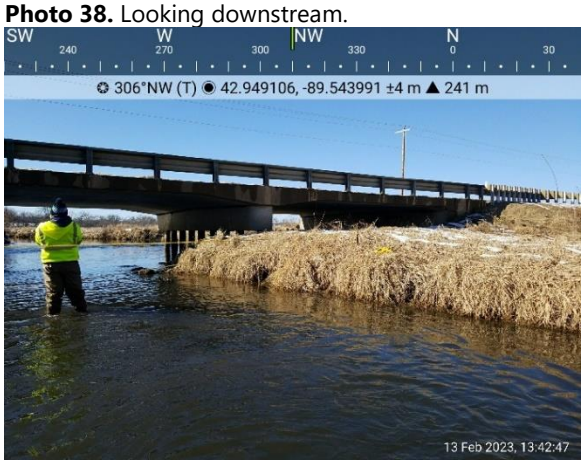


Photo 40: Looking at left stream bank.