MEMO

Project name	**MMSD: Nine Springs WWTP WPDES Permit Renewal**
Project no.	**1940109578**
Client	**Madison Metropolitan Sewer District (MMSD)**
To	**Rita Neff, PE**
From	**Michael L. Thompson, PE***
Copy to	**Martin Griffin, Kathy Lake**
Date	**May 2, 2025**

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Approved by	**Robin L. Richards, REM**

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The Madison Metropolitan Sewer District (MMSD) owns and operates the Nine Springs Wastewater Treatment Plant, which has historically discharged treated effluent to: the Badfish Creek, from Outfall 001; and to Badger Mill Creek, from Outfall 005. Authorization was granted to MMSD for these discharges by means of Wisconsin Pollutant Discharge Elimination System (WPDES) Permit No. WI-0024597-09-2, which expired on March 31, 2025 (this permit continues in effect until a new permit is reissued).

MMSD, and Ramboll Americas Engineering Solutions, Inc. (Ramboll) as their consultant, recently participated in a call with the Wisconsin Department of Natural Resources (WDNR) to review the methodologies, assumptions, data inputs, and conditions/scenarios employed by Ramboll in conducting a Modified Streeter-Phelps (MSP) model to predict the impact of the cessation of Outfall 005 discharge on in-stream DO concentrations for Badger Mill Creek.

During the call conducted on April 2, 2025, the WDNR posed a few questions that warranted follow-up and additional clarification. This memorandum provides the requested clarifications.

1. The first item for which we are providing clarification is related to the Dissolved Oxygen (DO) “sag” curve.

   First, it must be noted that the initial stream DO levels utilized for the various model runs were not intended to represent any specific or actual DO levels within Badger Mill Creek, as there are no monitoring points or gages in Badger Mill Creek at the location of or upstream of Outfall 005. Rather, Ramboll’s intent was to conduct a sensitivity analysis using DO levels that were within the range typically observed at the downstream gage (USGS at Verona) to determine what impact, if any, the initial stream DO levels had on downstream DO levels and the Creek’s ability to assimilate the organic load (e.g., biochemical oxygen demand or BOD) in the discharged effluent. The result of the sensitivity analysis showed there was no material impact on downstream DO levels due to the initial DO concentrations, as illustrated in the tables below.

Table 1 – DO Concentrations at River Mile (RM) = 2.5 miles downstream of Outfall 005 for Various Initial DO Concentrations (Initial Stream Dimensions)

	Initial DO 5 mg/L	Initial DO 6 mg/L	Initial DO 8 mg/L	Initial DO 9 mg/L
River Only	7.65 mg/L	7.67 mg/L	7.70 mg/L	7.72 mg/L
River + Source	6.78 mg/L	6.78 mg/L	6.78 mg/L	6.78 mg/L

Table 2 – DO Concentrations at River Mile (RM) = 2.5 miles downstream of Outfall 005 for Various Initial DO Concentrations (Half Stream Dimensions)

	Initial DO 5 mg/L	Initial DO 6 mg/L	Initial DO 8 mg/L	Initial DO 9 mg/L
River Only	8.64 mg/L	8.64 mg/L	8.64 mg/L	8.64 mg/L
River + Source	8.30 mg/L	8.30 mg/L	8.30 mg/L	8.30 mg/L

Second, when DO is assumed to be 5 mg/L, DO held in effluent (DO concentration) is greater than the DO concentration assigned to the Creek. MMSD aerates the Outfall 005 effluent to achieve a DO concentration greater than the 5 mg/L required by the Facility's WPDES (Wisconsin Pollutant Discharge Elimination System) Permit. The starting point of the River+Source graph reflects the average DO level in the effluent of 6.28 mg/L measured at Outfall 005 in August 1-16, 2024. Therefore, the River+Source line graph shows a higher DO concentration at the starting point compared to the River Only line graph. These values are simply the starting assumptions of an average effluent DO assuming the stream was at 5.0 mg/L.

It should be noted thatmaintaining $\geq$ 5 mg/L of DO, however, does not reduce the organic loading or biochemical oxygen demand (BOD) of the effluent. The breakdown of this organic material creates additional oxygen demand as the mix of Creek and effluent travels down the Creek and has an additional oxygen demand beyond the natural sources of oxygen demand (e.g., sediment oxygen demand).

In the River+Source models, the extra organic content is degraded according to the steady-state first-order kinetics for this system impacting DO held in the Creek waters. On the other hand, in the River Only models, DO concentrations increase to and are maintained at higher levels due to the reduced oxygen demand, as there is no additional DO demand beyond natural sources (e.g., no BOD-containing effluent).

Finally, it is worth noting that based on DO data from USGS Gage at Verona (site 05435943) (i.e., the closest gage downstream of Outfall 005), that DO levels in Badger Mill Creek are less than 5 mg/L only for short durations, and is likely due to diurnal fluctuations and certain rainfall events (both of which occur regardless of the presence of Outfall 005). However, the same data indicates that the average DO levels within Badger Mill Creek are usually greater than the assumed 5 mg/L, as the daily average DO concentrations range from 4.9 to 11.6 mg/L during the period evaluated (August, October and December months from 2020 through 2024). It should be noted that for the period evaluated, there was only one daily average DO below 5.0 mg/L (4.9 mg/L from August 7, 2022) and it was associated with significant precipitation (>1.5 inches) on the same date.

2. Another question that was posed during the above referenced call was regarding the reaeration constant (Ka) that was used in the various Streeter-Phelps model runs and whether that constant was varied based on the differing stream conditions (i.e., stream depth and width). Ramboll noted during the call that the Streeter-Phelps model does not utilize a "reaeration

constant" in the strictest terms of a "constant". Rather it is more appropriate to refer to the Ka value used in the Streeter-Phelps model as a "calculated reaeration rate". In the case of the modeling conducted by Ramboll for Badger Mill Creek, the reaeration rate was calculated using the following equation developed by Owens[1] (1964):

$$Ka = 5.32\frac{U^{0.67}}{H^{1.85}}$$

where,

U is the velocity (model calculated)

and H is the depth (model input) of the stream

The Owens equation was selected due to its applicability to small and large rivers with velocities between 0.1 fps and 5 fps, and depths of 0.4 ft to 11 ft.

So, while Ramboll did not directly alter or enter varying reaeration rates, the rates did differ between the initial and the half-dimension model runs- as the width and depth impact the calculated velocity and the depth is a direct input for the reaeration equation.

3. Separate from the Streeter-Phelps model, statistics of actual Badger Mill Creek data from the USGS Gage at Verona (site 05435943) were presented for August, October, and December periods with and without the MMSD discharge occurring. This analysis was done to determine whether the modeling results correlated with observed conditions.

   For comparison of the gage data to the steady-state Streeter-Phelps model, daily averages of the raw 15-min interval data were utilized. While there is variability throughout the day, the overall average is a reasonable statistic to evaluate general trends and is most appropriate for comparison to steady-state model results.

   The DO data from the river gage supports the Streeter-Phelps model results by demonstrating that without MMSD discharge the average dissolved oxygen increases.

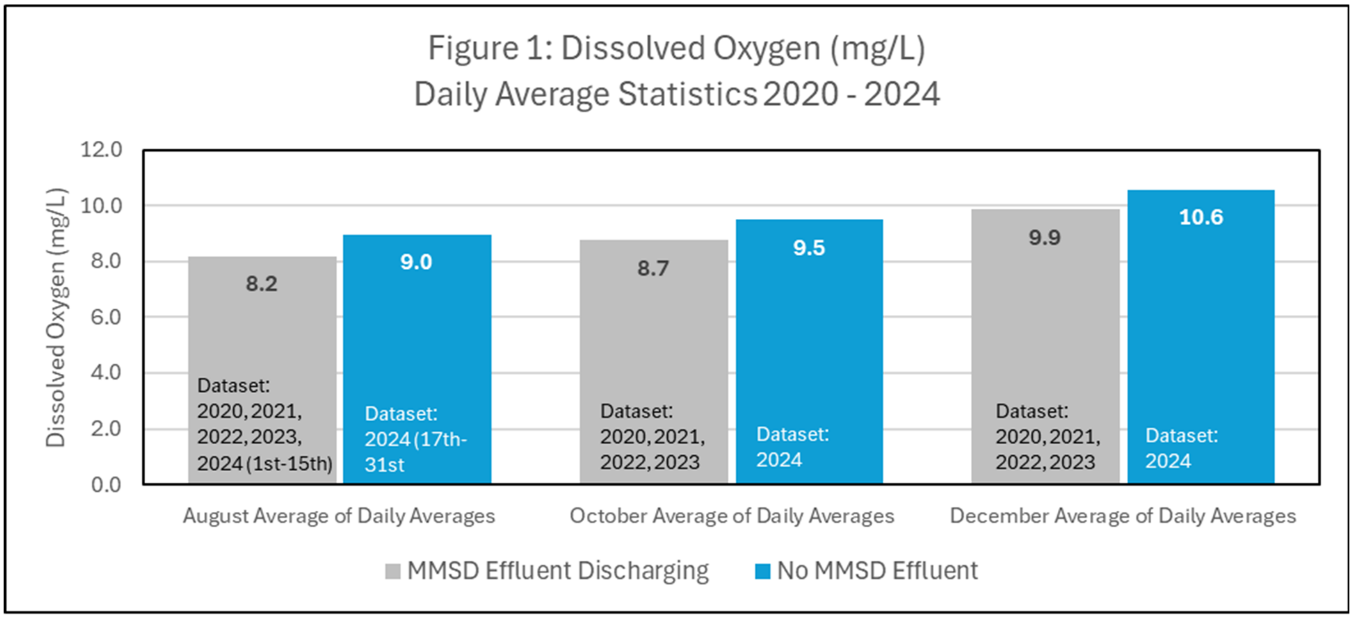
   To supplement the previous tabular presentation of the data (Table 1), several figures are included in Attachment 1. In Figure 1, for each month (August, October, December) the daily average data from 2020-2024 was divided into two categories: "MMSD Effluent Discharging" and "No MMSD Effluent". Then average for each category (i.e., the average of daily averages) was calculated. Without the MMSD effluent, DO averages increase for each month.

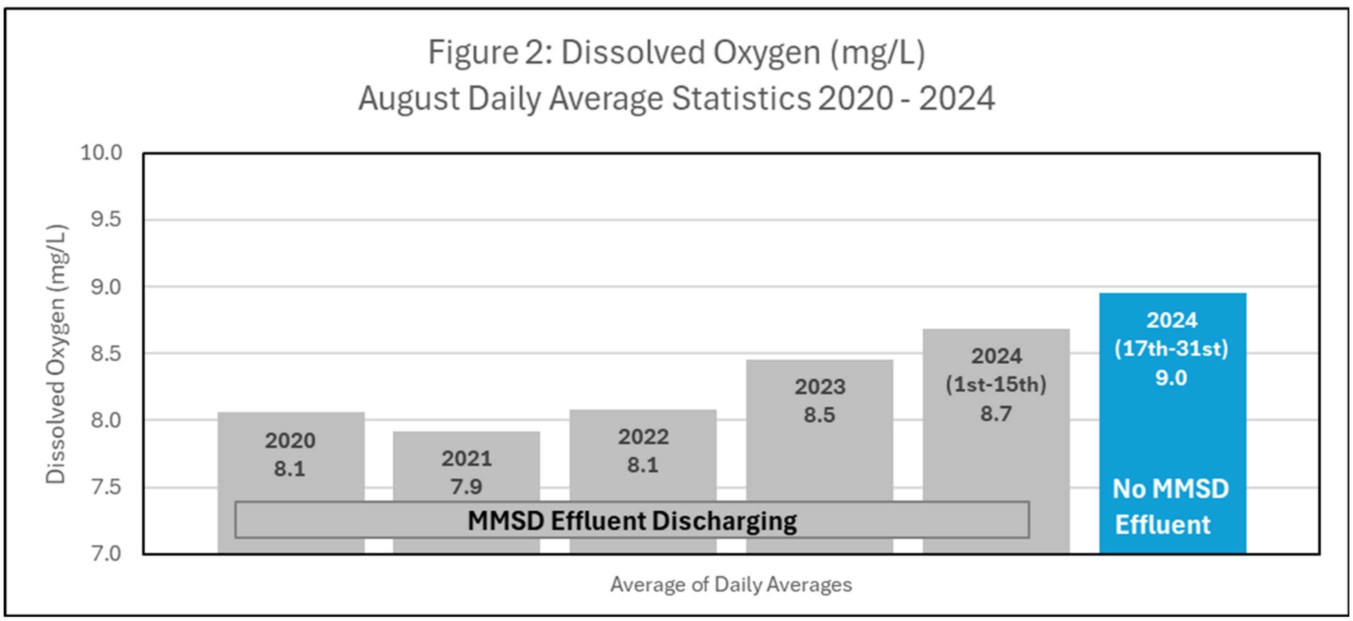
   The dataset for "MMSD Effluent Discharging" was further categorized by year for comparison to the "No MMSD Effluent" periods to get a more detailed picture for each calendar month. Figures 2 through 4 demonstrate the same overall conclusions but more clearly. For example, for DO, for each month the "No MMSD Effluent" dataset average is equal to or above the average of each of the periods with "MMSD Effluent Discharging".

   In short, the steady-state Streeter-Phelps model projections of DO trends (positive net effect without the MMSD effluent discharging) are supported by the downstream gage data for Badger Mill Creek.

[1] Owens, M., Edwards, RW & Gibbs, JW 1964 "Some Reaeration Studies in Streams', International Journal of Air & Water Pollution, Vol. 8, P. 469-486.

Attachment 1
Badger Mill Creek (USGS Gage at Verona) Data Figures





Attachment 1
Badger Mill Creek (USGS Gage at Verona) Data Figures