Diversion and Off-River Storage for Biological Denitrification of Raccoon River Water

for the Purposes of Drinking Water Treatment and
Nitrate, Chloride, and Total Dissolved Solids Load Reductions

Iowa's North Raccoon River Watershed—HUC 07100006

Technical Performance Report
1st Quarter 2006

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I. Overview

On January 2, 2006, staff at Des Moines Water Works (DMWW) began investigation of the flow dynamics, chemistry, and microbiology of the DMWW off-river storage system for the purposes of nitrate mitigation. This report summarizes data accumulated during the 1st quarter period of 2006.

The first three months of the year usually represent a period of relative tranquility in the Raccoon River due to cold temperatures, the river's frequently frozen condition, and minimal precipitation and runoff. Data collected during this time largely represents a "baseline" condition that will be referenced as the year progresses and the flow dynamics of the river and biological activity become more active.

II. River Flow into Off-River Storage Reservoirs

Due to pump failure, river flow into the Water Works Park pond system at the Fleur Drive Treatment Plant did not begin until January 11. At that time, a 0.8 million gallon per day (mgd) pump began delivering Raccoon River water to the ponds. The utility will soon install a 5 mgd pump to increase flow into and through the ponds. DMWW is also aggressively rebuilding the levees separating and the culverts connecting the ponds. All the while, the ponds have remained functional as yield enhancement for the groundwater collection system at Fleur Drive, and as treatment sinks where nitrate is consumed by microorganisms and algae.

At the Maffitt Treatment Plant site, 4 mgd of Raccoon River injection into the gravel pit known as Crystal Lake began on March 16. Due to high turbidity conditions on the river and an increasingly high lake level, this flow was stopped on March 24, but has since been restarted on April 10. No water from Crystal Lake was used for treatment in the plant during the first quarter, but this did begin on April 4, and lake water has been used aggressively since that date.

On March 13, two solar-powered circulators known as Solar Bees were installed on Crystal Lake. These devices draw water up from the lake bottom and distribute it over the lake surface via laminar flow. Their intended purpose is to repress cyanobacteria while enhancing conditions favorable to green algae. DMWW hopes this will enhance denitrification while at the same time repress cyanobacteria.

III. Physical Data

Accumulation of physical data is critical if DMWW staff is to able to identify, characterize, and quantify the various parameters necessary for effective denitrification of river water in the off-river storage reservoirs. These parameters are believed to be total river flow; reservoir acreage, depth, and volume; temperature; river flow volume and rate into the reservoir; and flow out of the reservoir, either back to the river or into the treatment plant. The graphs below depict physical parameters monitored during first quarter.

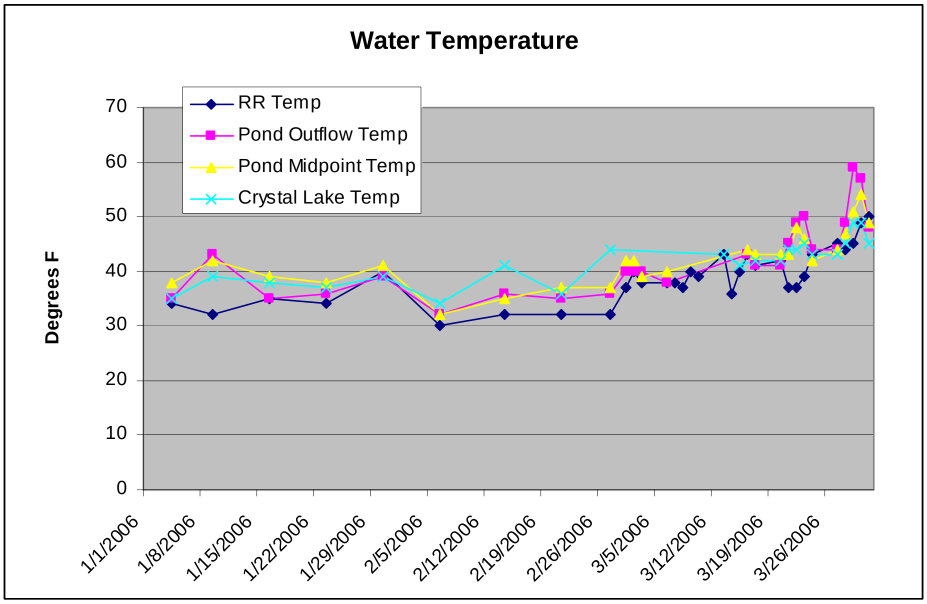

Figure 1: Water Temperature

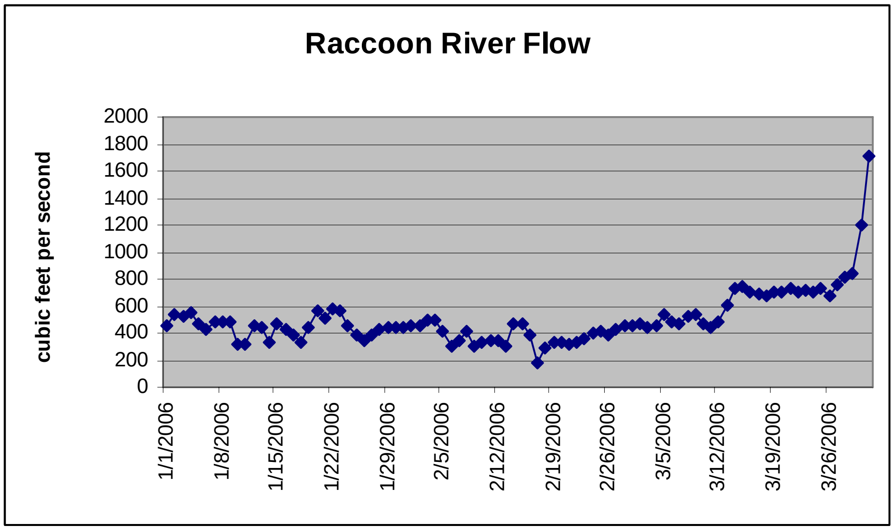

Figure 2: Raccoon River Flow

Nothing in Figures 1 or 2 is particularly surprising. River flow remained near seasonally-low levels throughout the winter, and then began to increase with snow melt and spring rains near the end of March. This time is also of note because it is when the ground thaws and the agricultural drain tiles, which have such a dramatic impact on river water quality, begin to deliver water to the river.

Water temperatures of 35-40^{o}F during the winter were typical, and then began to rise toward the end of March. The water temperatures of near 60^{o} that were recorded at the end of the month were somewhat above normal.

IV. Biological Data

A. Cyanobacteria

Monitoring of cyanobacteria is critical to this project, because blooms of these organisms can have very negative impacts on finished water quality. The utility is also keenly interested in their possible role in denitrification of the off-river storage water, and how they compete with green algae for nutrients. Cyanobacteria counts were monitored weekly throughout the first quarter. Their numbers are depicted in Figure 3 below.

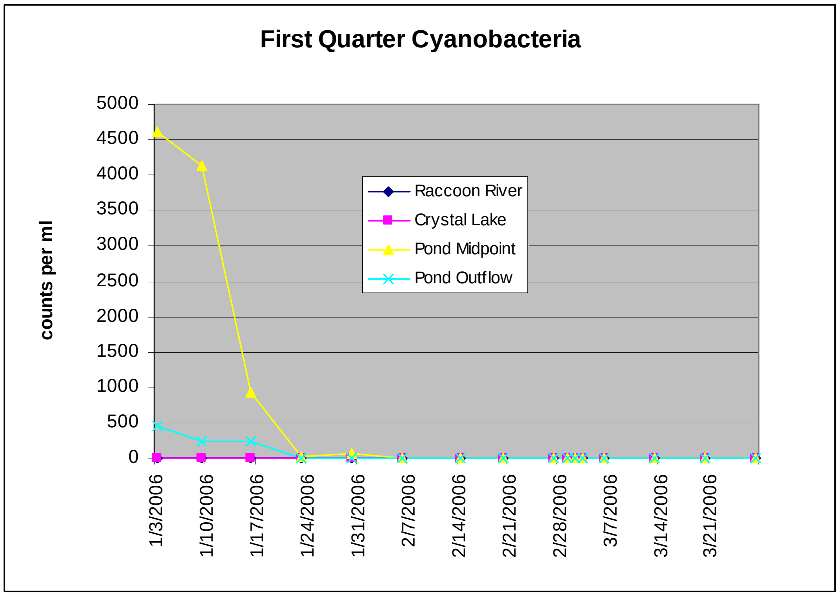

Figure 3: Cyanobacteria

One can see that no cyanobacteria were present in the river or Crystal Lake during the 1st quarter. Some organisms remained in the park ponds during January, but disappeared as winter progressed and have not yet reemerged.

B. Green Algae

Green algae are important to this investigation in that they assimilate nitrate into their cells, converting it to organic nitrogen and in the process reduce nitrate concentrations in the surface waters of interest. Prior to this project, DMWW rarely monitored numbers of these organisms during the winter, thinking their numbers were low. However, first quarter data showed that these organisms were surprisingly abundant, even when ice covered the water bodies of interest. Figure 4 on the next page depicts their numbers. Obviously, the pond mid-point location had much higher numbers than the other three sites. The reasons for this are not clear at this time.

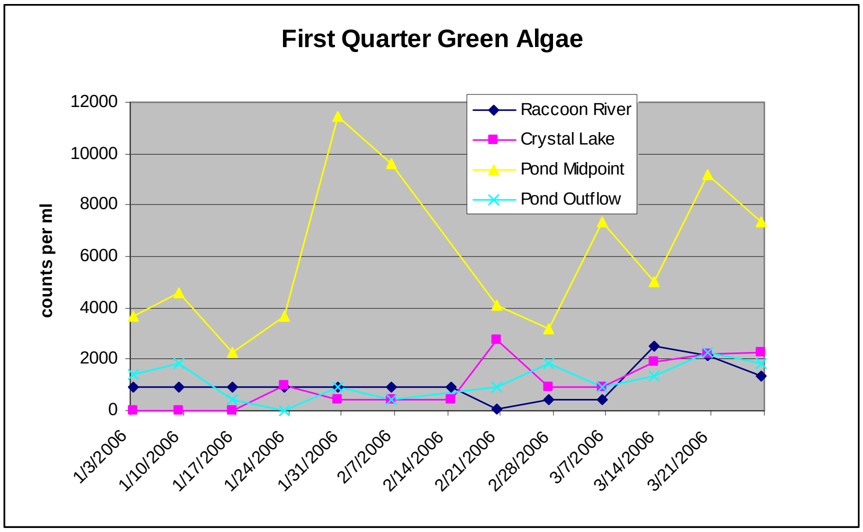

Figure 4: Green Algae

B. *E. coli*

Although *E. coli* likely play little or no role in denitrification, the utility is interested in their fate and numbers as river water is introduced into the off-river storage reservoirs. The Raccoon River is highly impaired by *E. coli*. Figure 5 below depicts their abundance in the four samples.

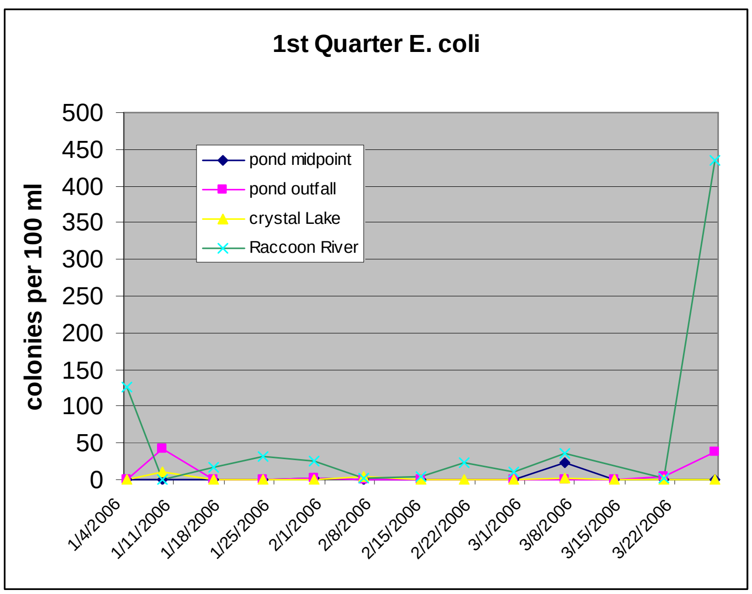

Figure 5: First Quarter *E. coli*

It's apparent that the *E. coli* from the river are dying in the off-river storage reservoirs. Testing in the DMWW laboratory show that *E. coli* die in Raccoon River water after about three days, and evidently they also perish during detention in the off-river storage reservoirs.

IV. Chemistry Data

A. Nitrate

Because it is the primary treatment challenge for DMWW, and because the Raccoon River is one of the most nitrate-impaired streams in the U.S., this contaminant is the primary focus of this investigation. Figure 6 below shows 1st Quarter nitrate results for the four sample locations.

Data from Figure 6 are very encouraging because this shows, at least in the park pond system, that denitrification/algal assimilation is occurring even at low water temperatures.

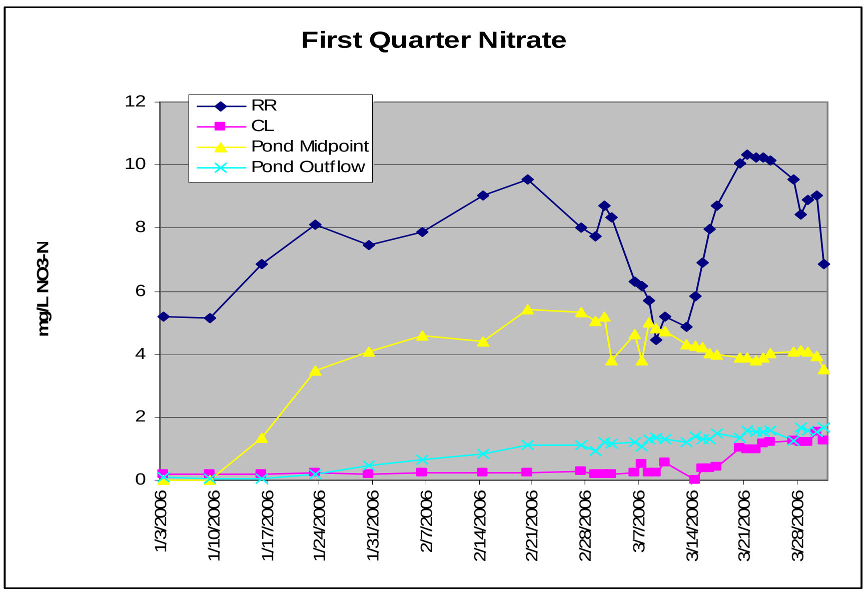

Figure 6: First Quarter Nitrate

About 64 million gallons of river water was introduced to the park ponds during the first quarter. This water had an average nitrate concentration of 7.7 mg/L. Yet the highest concentration measured at the pond system midpoint was 5.4 mg/L and the highest at the pond system terminus was 1.66 mg/L. The averages were 4.2 and 1.1, respectively, also indicating that as the water winds its way through the pond system, nitrate is consumed.

This is confirmation that biological activity is consuming and/or assimilating nitrate even during the cold winter months.

Because introduction of river water into Crystal Lake did not begin until March 16, no conclusions can be made yet about the denitrifying capacity of this former gravel pit. DMWW remains confident that this system will also perform as expected during the second quarter, and staff is anxious to assess the affect the solar-powered circulators will have on denitrification in the lake.

B. Total and Organic Nitrogen

Organic nitrogen was assessed weekly in the four samples. This parameter is important because it indicates the fate of the nitrate nitrogen—denitrification to the atmosphere, or assimilation into plant protein. Figure 7 below depicts total nitrogen data.

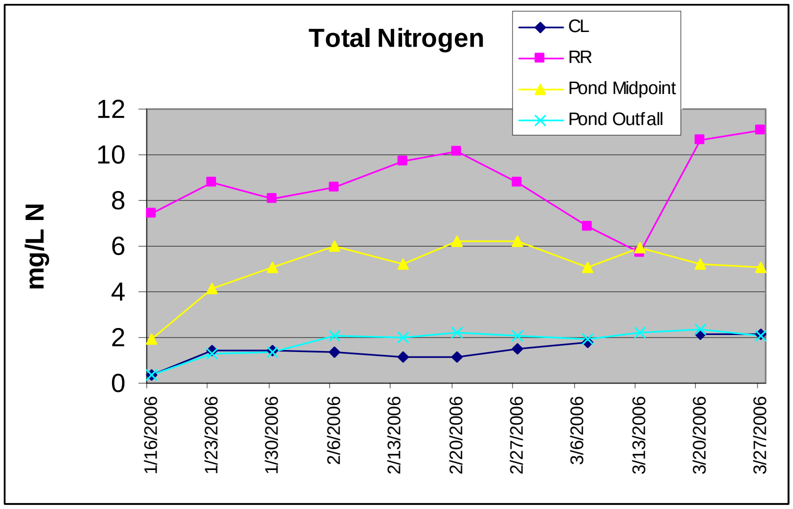

Figure 7: Total Nitrogen

Perhaps more interesting than the total nitrogen data is the average percentage of nitrogen that is organic nitrogen. This is shown in Figure 8 on the next page. Data in Figure 8 show that as nitrate-nitrogen is introduced into the off-river storage reservoirs from the river, some amount of this is converted to organic N. This will have important implications as this investigation proceeds throughout the year, and for the design of the off-river storage reservoirs. It will also be important to identify the primary mechanism of nitrate reductions—either assimilative or dissimilative—occurring in each body of water, so that the process can be optimized.

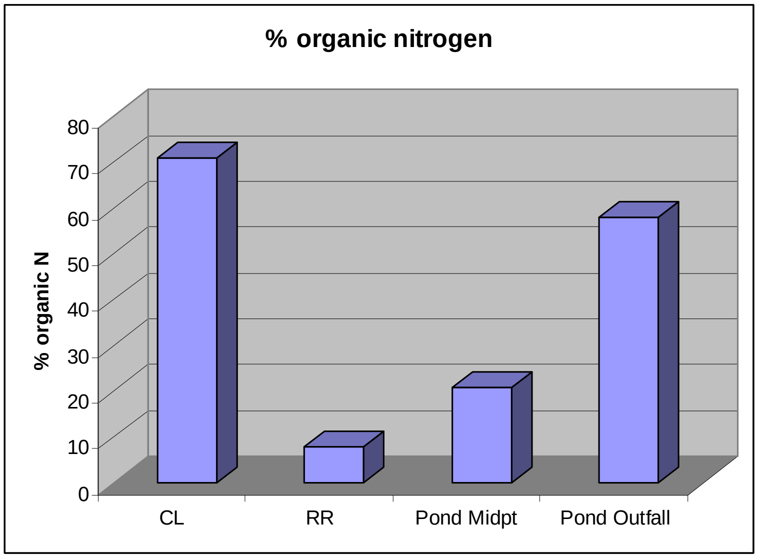

Figure 8: % Organic Nitrogen

C. Other Chemistry Data

Other parameters that have been analyzed during first quarter include Total Organic Carbon (TOC), total phosphorous (TP), ortho phosphorous (OP), turbidity, nitrite-nitrogen, and chloride. Extensive textual analysis of this data is not warranted at this time, but will be important as the project progresses. For instance, TOC, phosphorous, and turbidity levels may prove important as cyanobacteria and green algae become more numerous as summer approaches. One goal of this project is to reduce chloride inputs into the Raccoon River from DMWW's nitrate removal facility discharge. Because the nitrate removal facility was not used during 1st quarter, no assessment of this discharge on river chloride levels can be made. All the data discussed above is included with this report.

V. Other Data Considerations

A. Data Related to the Nitrate Removal Facility

The DMWW nitrate removal facility was not operated during the first quarter, so no data related to its discharge is included in this quarterly report.

B. Cyanotoxin Data

No cyanobacteria blooms were observed during the first quarter, so no samples were evaluated for cyanotoxins.

C. Data Completeness

1. Laboratory Measurements

The first quarter sampling plan called for a total of 1022 sample measurements. Actual measurements successfully completed totaled 1007, for a completion rate of 98.5%. Eight analyses were rescheduled and run on the next calendar day.

2. Field Measurements

Sample temperature was scheduled each sampling day on-site at the four sample locations. Due to a labeling problem on the sample bottles, several of the measurements were lost several days after sampling. A total of 128 temperature measurements were scheduled; 104 were recorded successfully (81.3%). The missing measurements occurred during a period of little temperature change, and these should not affect the outcome or success of the project. Steps have been taken to eliminate this possibility during future sampling.

VI. Second Quarter Plans

Daily monitoring will continue for the Raccoon River, the Park Pond system, and Crystal Lake. The nitrate removal facility was not operated during the first quarter, but it was operated in the first part of April, and Raccoon River monitoring downstream from the effluent was performed. Results of this monitoring will be summarized in the second quarter report. If a bloom of cyanobacteria is observed, samples will be collected that will be evaluated for cyanotoxins. Finally, monitoring results obtained during the second quarter should enable DMWW to begin calculating off-river storage requirements necessary for effective nitrate mitigation for the purposes of drinking water treatment.