HOT SPOT ANALYSIS OF POTENTIAL SANITARY SEWER EXFILTRATION IN CRYSTAL CREEK WATERSHED

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Introduction

- Urban watersheds undergo constant change in both time and space as the result of construction and subsequent infrastructure decay and evolving management decisions. The urban watershed continuum (USS) model describes a set of natural and engineered flow paths that substantially alters hydrologic network connectivity.[1] The USS recognizes four dimensions along which hydrologic connectivity influences downstream water quality.[1,2,3]
- One important dimension is vertical, which describes the connectivity between streams, stormwater, and sanitary infrastructure.[1,2] At the urban-rural interface, septic systems can release bacterial and nutrient pollutants into the soil below the root zone where they can be transmitted to groundwater and streams.[1,2] These systems can degrade, and such sanitary systems are easily disturbed, often poorly sealed, are not tracked well within the regulatory system.
- Sewer pipes flow by gravity and are often located along and beneath streams. Even small leaks from these pipes can impact stream water quality because of the high pollutant loads in sewage.[1]
- This study's purpose was to identify stream reaches where exfiltration leakage from sanitary sewer pipes contaminate a stream in the Crystal Creek Watershed in Davenport, IA, which joins Duck Creek, a tributary of the Mississippi River.

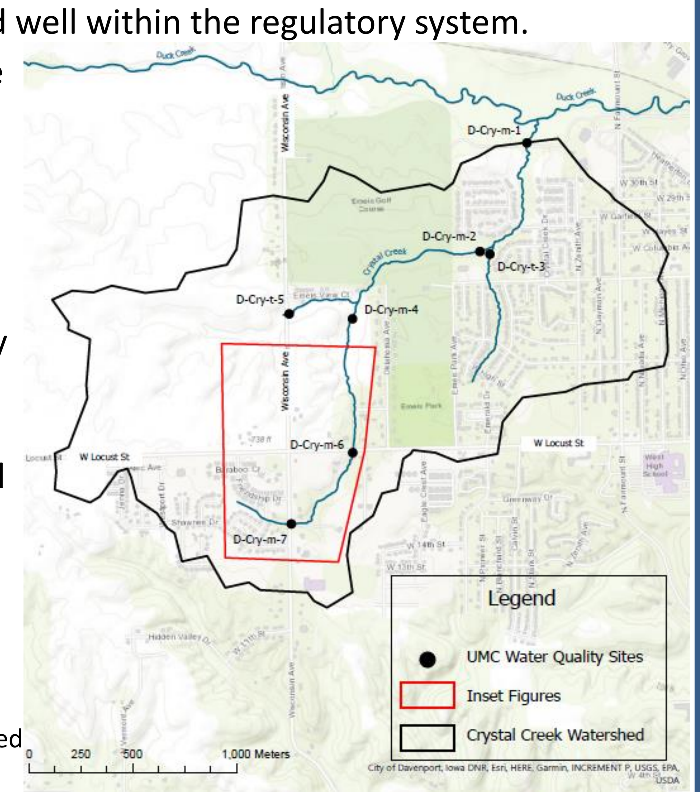

Figure 1. Crystal Creek Watershed and initial sampling sites.

Methods

- We conducted an initial assessment of the watershed on June 21, 2021 at seven sites (Fig. 1). The sites were selected based on data from the City of Davenport indicating potential sewage contamination. We selected five indicators of sewage pollution from the literature 1,2 and established thresholds using historic monitoring data (Table 1).

Table 1. Indicator levels measured during June 21st assessment. Bold numbers indicate exceedancs of the threshold.

Site Name	pH	Dissolved Oxygen (%)	Conductivity	Ammonia	Phosphate	Biologial Oxygen Demand (BOD)	Total Fecal Coliforms (CFU/mL)	Total *E. coli* (CFU/mL)
D-Cry-m-1	8	84.1	710	0.021	**0.21**	**1.04**		
D-Cry-m-3	7.9	82.7	688	0.012	0.13	**1.2**	**3282**	**1110**
D-Cry-m-4	**7.5**	**47.3**	844	**0.046**	**0.25**	**2.03**	**740**	**620**
D-Cry-m-6	**7.2**	**59.3**	755	**0.101**	**0.23**	**1.08**	**750**	**2495**
D-Cry-m-7	**6.6**	**46.6**	**1380**	**0.075**	0.12	0.89	100	100
D-Cry-t-2	8	80	**1192**	0.000	0.13	0.94		
D-Cry-t-5	8	96.4	680	0.000	0.06	0.7		

- We conducted intensive, 25 m increment, sampling within the reaches upstream of the sites where at least 4 of the indicators exceeded the thresholds (Fig. 2, red rectangles).
- pH, specific conductance (SPC), and dissolved oxygen (DO) levels were taken using YSI Pro-Plus Multi-parameter sondes.
- Ammonia and phosphate were measured using EPA colorimetric methods.
- Biological Oxygen Demand (BOD) was assessed using a modified USGS method.[4]
- *Escherichia coli* (*E. coli*) and fecal coliforms analysis was performed using IDEXX Colilert™ and Quantitray ™.

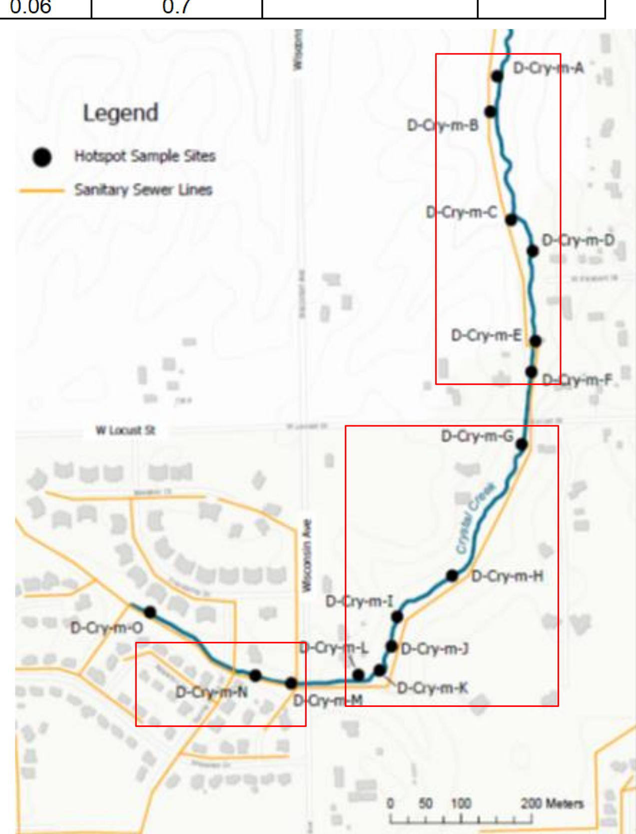

Figure 2. Crystal Creek Watershed stream reaches assessed with intensive sampling.

Results

There were strong correlations among six of the eight indicators (Table 2). Dissolved oxygen levels strongly correlated with all five other water chemistry-related indicators, while ammonia and BOD were strongly correlated with four of the water chemistry-related indicators. Fecal coliform levels and Specific Conductance levels were uniformly high across all the assessed reaches (Figs. 3-4).

Table 2. Indicator Spearman's correlations

Indicators	% Dissolved Oxygen	Biological Oxygen Demand	Ammonia	Orthophosphate	pH	Specific Conductance	E. coli	Fecal coliforms
% Dissolved Oxygen	-	-0.46 (p-value = 0.04)	-0.74 (p-value = 0.01)	-0.39 (p-value = 0.08)	0.51 (p-value = 0.002)	0.43 (p-value = 0.01)	NS	NS
Biological Oxygen Demand	-0.46 (p-value = 0.04)	-	0.79 (p-value < 0.001)	0.53 (p-value < 0.02)	NS	NS	NS	NS
Ammonia	-0.75 (p-value < 0.01)	0.79 (p-value < 0.001)	-	0.73 (p-value < 0.01)	NS	-0.42 (p-value = 0.06)	NS	NS
Orthophosphate	-0.39 (p-value = 0.08)	0.56 (p-value = 0.04)	0.73 (p-value < 0.01)	-	NS	NS	0.65 (p-value < 0.01)	NS
pH	0.51 (p-value = 0.002)	NS	NS	NS	-	NS	NS	NS
Specific Conductance	0.43 (p-value = 0.01)	NS	-0.36 (p-value = 0.09)	-0.42 (p-value = 0.06)	NS	-	NS	NS
E. coli	NS	NS	0.39 (p-value = 0.07)	0.65 (p-value < 0.01)	NS	NS	-	NS
Fecal coliforms	NS	NS	NS	NS	NS	NS	NS	-

Figure 3. Fecal coliform levels (color) at sampling locations (circles) along Crystal Creek.

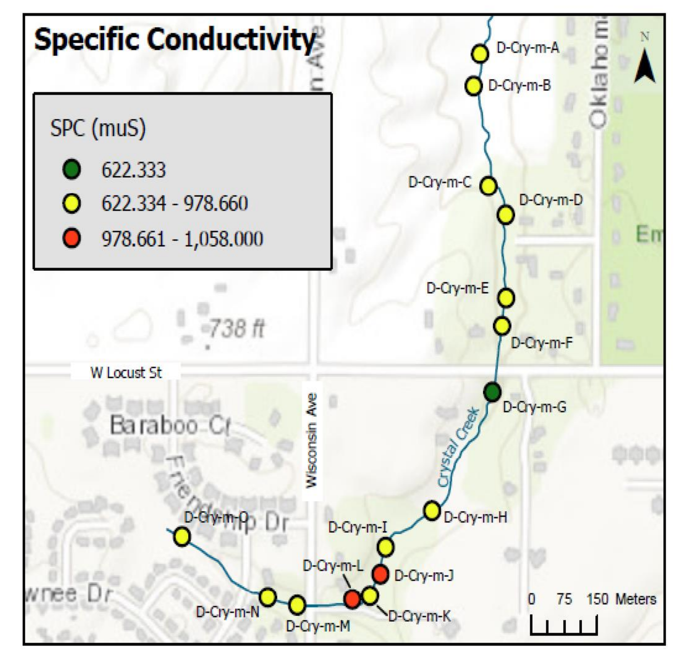

Figure 4. Specific conductivity levels (color) at sampling locations (circles) along Crystal Creek.

The stream reach between D-Cry-m-D and D-Cry-m-F was characterized by lower dissolved oxygen levels (Fig. 5) and higher BOD (Fig. 6) and ammonia (Fig. 7), and to a lesser degree orthophosphate (Fig. 8) levels. E. coli levels also spiked in this stream reach (Fig. 9). The stream reach between D-Cry-m-G and D-Cry-m-J was also characterized by lower dissolved oxygen levels (although they were extremely variable over short intervals) and higher BOD and ammonia levels. Although there are no stream crossing, the sanitary sewer line is in close proximity to the stream along this entire reach.

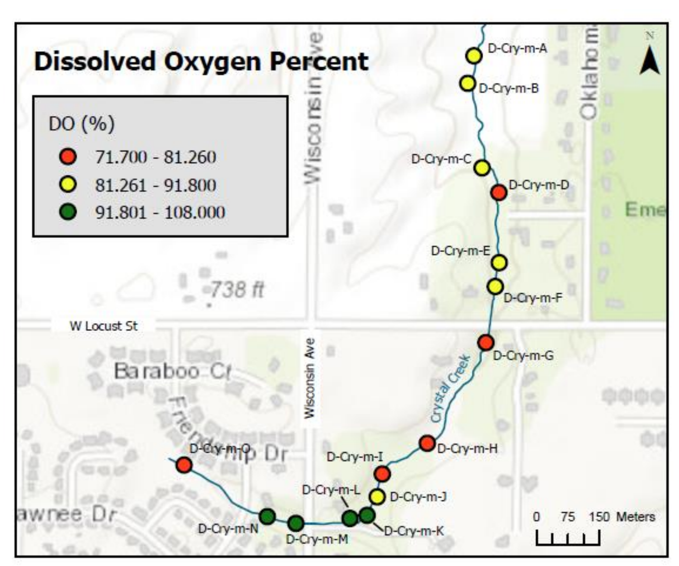

Figure 5. Dissolved Oxygen levels (color) at sampling locations along Crystal Creek.

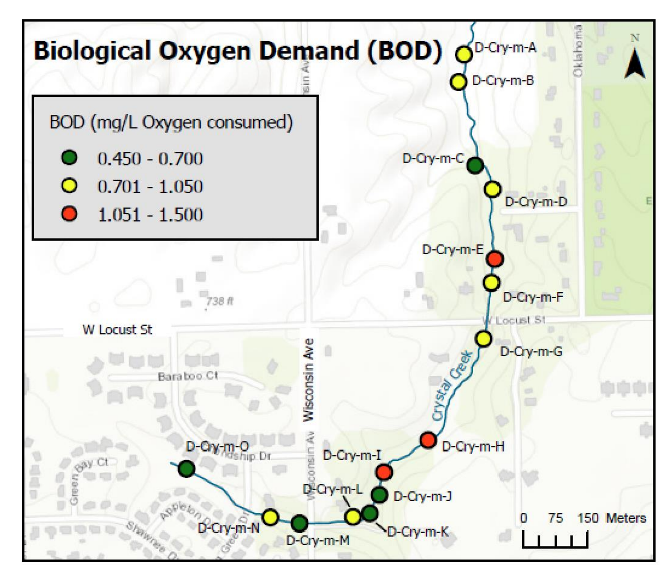

Figure 6. BOD levels (color) at sampling locations along Crystal Creek.

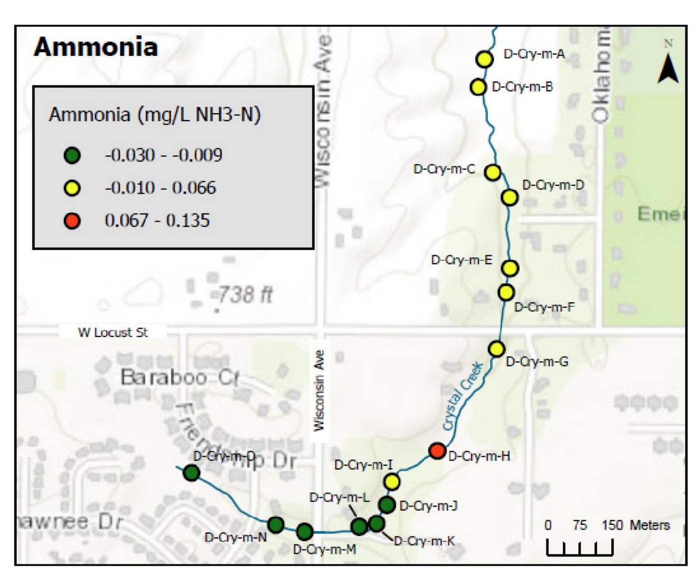

Figure 7. Ammonia Levels (color) at sampling locations along Crystal Creek.

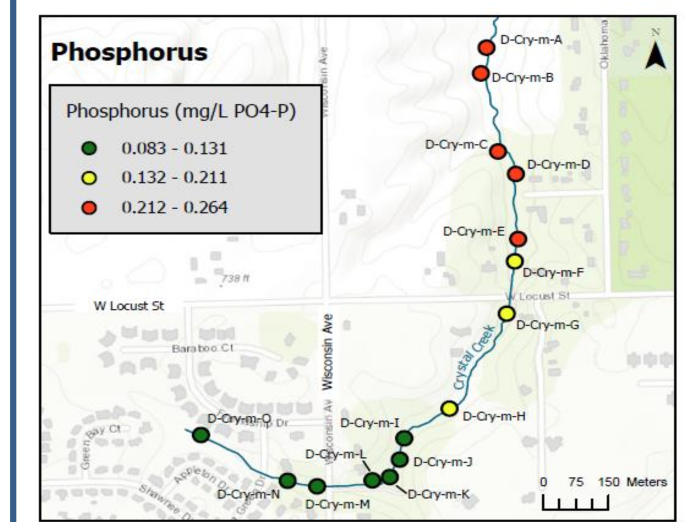

Figure 8. Phosphate levels (color) at sampling locations (circles) along Crystal Creek.

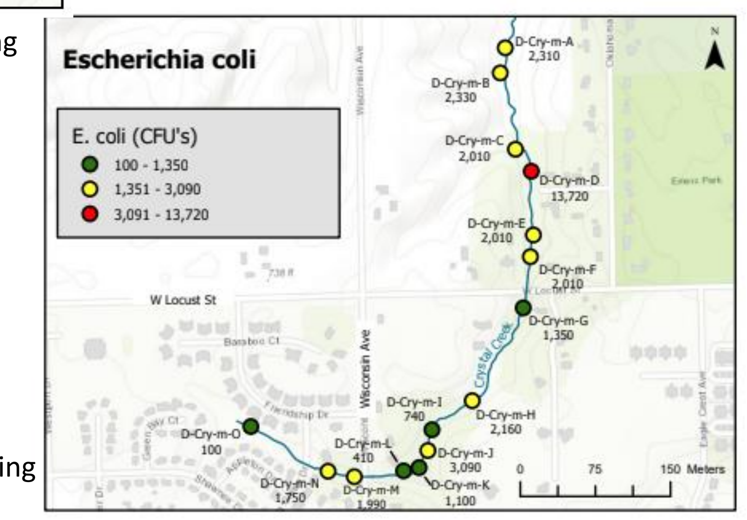

Figure 9. *E. coli* Levels (color) at sampling locations (circles) along Crystal Creek.

Discussion

- The combination of reduced pH, increased ammonia, BOD, fecal coliforms, and to a lesser extent, reduced dissolved oxygen in the sampling sites downstream of the sanitary sewer crossing argue for an exfiltration event at or near that crossing upstream of D-Cry-m-4 (Figs. 1-2). Impacts of such exfiltration are being observed at D-Cry-m-E and D-Cry-m-C (Figs 3-9). However, there are a series of residences with older septic systems on the east side of stream between D-Cry-m-4 and D-Cry-m-6 that could also be the source.
- A second area is worth highlighting, although the evidence is less conclusive concerning an exfiltration event. A cluster of several upstream sites (D-Cry-m-G and D-Cry-m-J show a combination of extremely high fecal coliforms and *E.coli*, increased BOD, a small dip in pH, and a small peak in ammonia, which is elevated throughout this reach. The sewer line runs parallel to the stream in this area (Fig. 2). A leak in this area may be less localized, or alternatively the transient storage of sewage in groundwater this far upstream may be really different that that seen downstream. Thee are no septic systems in proximity to this stream reach.
- Overall, the selected indicators of sanitary sewage performed well with the exception of Fecal coliform. Fecal coliform levels were elevated throughout the watershed, and these elevated background levels limited its usefulness as an indicator at the stream reach scale.
- The City of Davenport sanitary sewage program is currently using dye and smoke testing to identify leaking segments a sewer line along these reaches.

Literature Cited

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We thank Izzy Seten, Moreen Akomea-Ampeh, and Ben Ford who contributed substantially to the field and lab work, and GIS analyses for this project.