Stressor identification

December 2020

North Fork Crow River Watershed Stressor Identification Report

Assessment of stress factors affecting aquatic biological communities and other aspects of streams and rivers

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Cover photo: North Fork Crow River at 328th Street, Meeker County, MN - MPCA photo

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Acronyms and term definitions

AUID	Assessment Unit (Identification Number) MPCA's pre-determined stream segments used as units for stream/river assessment – each has a unique number
AWC	MPCA's Altered Watercourse Project
BMPs	Best management practices
CADDIS	Causal Analysis/Diagnosis Decision Information System, an EPA developed methodology
CR	County Road
CSAH	County State Aid Highway
DO	Dissolved Oxygen
DOC.	Dissolved Organic Carbon
DNR	Minnesota Department of Natural Resources
DS	Downstream
EPT	Three important taxonomic orders of stream macroinvertebrates whose members are typically sensitive to stream degradation - **E**phemeroptera (mayflies), **P**lecoptera (stoneflies), and **T**richoptera (caddisflies)
FIBI	Fish-based lake Index of Biological Integrity; an index developed by the DNR that compares the types and numbers of fish observed in a lake to what is expected for a healthy lake (range from 0–100). More information can be found at the DNR Lake Index of Biological Integrity website
GIS	Geographic Information System
HUC	Hydrologic Unit Code (a multi-level coding system of the U.S. Geological Survey, with levels corresponding to scales of geographic region size)
HSPF	The hydrologic and water quality model **H**ydrologic **S**imulation **P**rogram **F**ortran.
IBI	Index of Biological Integrity – a multi-metric index used to score the condition of a biological community.
Intolerant species	A species whose presence or abundance decreases as human disturbance increases.
IWM	MPCA's Intensive Watershed Monitoring, which includes chemistry, habitat, and biological sampling
m.	The abbreviation for meter
MDA	Minnesota Department of Agriculture
mg/L	Milligrams per liter
µg/L	Micrograms per liter (1 milligram = 1000 micrograms), equivalent to parts per billion (ppb)
Macrophyte	Macro (= large), phyte (= plant). These are the large aquatic plants, such as *Elodea* and Coontail.
MDA	Minnesota Department of Agriculture
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MSHA	Minnesota Stream Habitat Assessment
NFCRW	North Fork Crow River Watershed

NLCD	National Land Cover Database, a GIS layer
NPDES	National Pollutant Discharge Elimination System
Natural background	An amount of a water chemistry parameter coming from natural sources, or a situation caused by natural factors.
OP	Orthophosphorus (a form of phosphorus that is soluble)
P	Phosphorus
SID	Stressor Identification – The process of determining the factors (stressors) responsible for causing a reduction in the health of aquatic biological communities.
SOD	Sediment oxygen demand
Sonde	A deployable, continuous-recording water quality instrument that collects temperature, pH, DO, and conductivity data and stores the values which can be transferred to a computer for analysis
SSTS	Subsurface Sewage Treatment Systems
TALU	Tiered Aquatic Life Uses, a framework of setting biological standards for different categories of streams
Taxa	Plural form - refers to types of organisms; singular is taxon. May refer to any level of the classification hierarchy (species, genus, family, order, etc.). In order to understand the usage, one needs to know the level of biological classification being spoken of. For MPCA fish analyses, taxa/taxon usually refers to the species level, whereas for macroinvertebrates, it usually refers to genus level.
TIV	Tolerance Indicator Value
TMDL	Total Maximum Daily Load
Tolerant species	A species whose presence or absence does not decrease, or may even increase, as human disturbance increases
TP	Total Phosphorus (measurement of all forms of phosphorus combined)
TSS	Total Suspended Solids (i.e. all particulate material in the water column)
TSVS	Total Suspended Volatile Solids (i.e. organic particles)
UAA	Use attainability analysis
US	Upstream
EPA	U.S. Environmental Protection Agency
WRAPS	Major Watershed Restoration and Protection Strategy, with watershed at the 8-digit Hydrological Unit Code scale
10x	IWM chemistry monitoring site that is visited on 10 dates across a growing season

Executive summary

This report documents the efforts that were taken to identify the causes, and to some degree the source(s) of impairments to aquatic biological communities in streams in the North Fork Crow River Watershed (NFCRW). This is the second Stressor Identification (SID) Report for the NFCRW. The first report followed the initial Intensive Watershed Monitoring (IWM) effort in 2007 (MPCA, 2014). A separate SID report was written for Grove Creek following IWM-1 work (MPCA, 2013a). A second round of IWM occurred in the NFCRW in 2017, and is described in a second Intensive Watershed Monitoring and Assessment Report (MPCA, 2020a). The second SID effort began in 2018, and investigated stream segments that were either new biological impairments discovered in IWM-2, or biological impairments that were not included in the IWM-1 NFCRW SID Report. The Minnesota Department of Natural Resources (DNR) conducted geomorphic surveys/assessments at six stream segments in 2017 and 2018 that were assessed as impaired in IWM-1, which are presented in this current report.

Information on the SID process can be found on the U.S. Environmental Protection Agency's (EPA) website http://www.epa.gov/caddis/. Specific information on Minnesota's processes for SID in streams can be found on MPCA's webpage "Is Your Stream Stressed". The DNR has a similar webpage for lakes - "Stressors to Biological Communities in Minnesota's Lakes".

Biological sampling during the IWM resulted in 14 stream reaches being assessed as having impaired fish and/or macroinvertebrate communities. These reaches were brought into the SID process (listed below and shown on Figure 1) because they were determined to have sub-standard biological communities during the 2019 Assessment. Geomorphic survey and assessment was done by DNR at six reaches determined to be impaired in the 2010 Assessment.

Stream impairment investigations

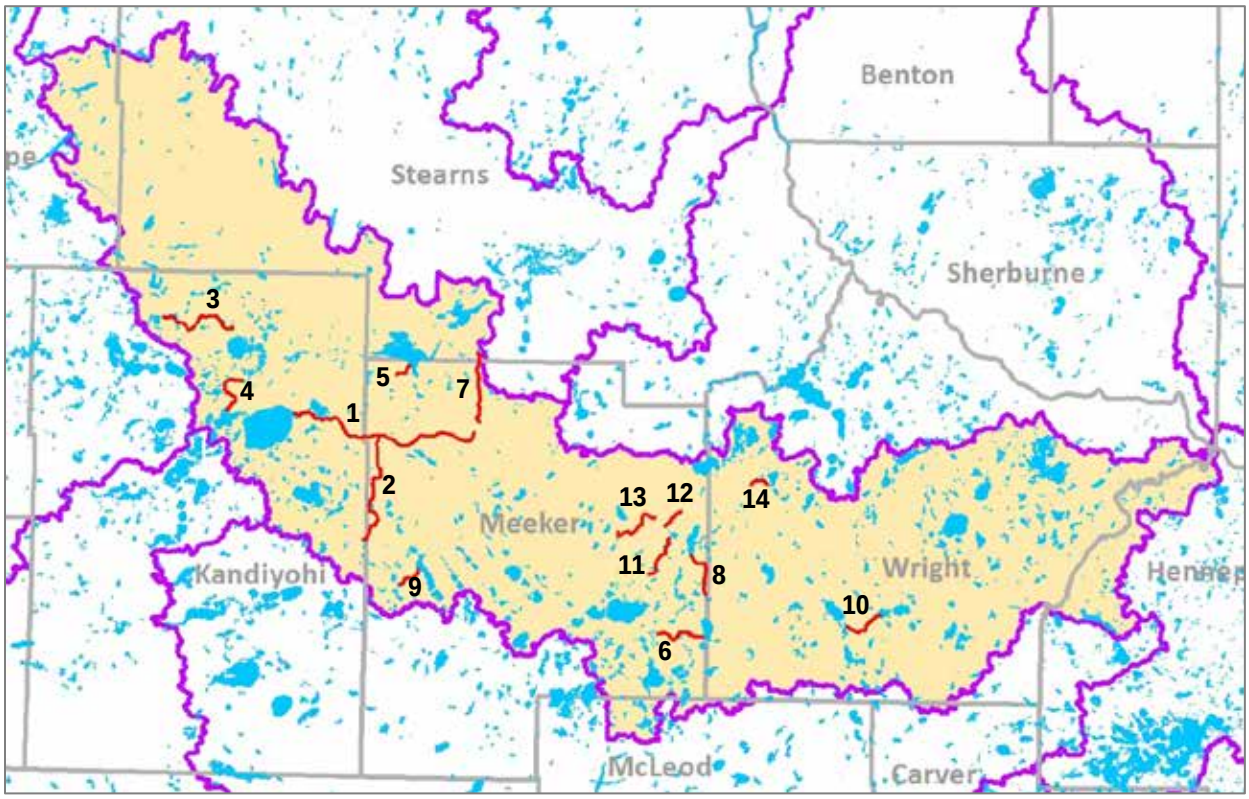
- Middle Fork Crow River (AUID 07010204-511) - Fish
- Judicial Ditch 17 (AUID 07010204-532) - Fish
- County Ditch 37 (AUID 07010204-536) - Fish
- Middle Fork Crow River (AUID 07010204-539) - Fish
- Tributary to Lake Koronis (AUID 07010204-553) - Fish
- Silver Creek (AUID 07010204-557) - Macroinvertebrates
- Stag Brook (AUID 07010204-572) - Fish and Macroinvertebrates
- Collinwood Creek (AUID 07010204-604) - Fish
- County Ditch 26 (AUID 07010204-643) - Fish and Macroinvertebrates
- Twelvemile Creek (AUID 07010204-679) - Fish and Macroinvertebrates
- Washington Creek (AUID 07010204-751) - Macroinvertebrates
- Washington Creek (County Ditch 9, AUID 07010204-753) - Fish
- County Ditch 36 (AUID 07010204-755) - Fish and Macroinvertebrates
- French Creek (AUID 07010204-759) - Fish and Macroinvertebrates

Geomorphology investigations

- North Fork Crow River (AUID 07010204-507)
- Grove Creek (AUID 07010204-514)
- Middle Fork Crow River (AUID 07010204-539)
- Battle Creek (AUID 07010204-552)
- North Fork Crow River (AUID 07010204-685)
- Grove Creek (AUID 07010204-696)

A number of stressors to the stream biological communities were found, and almost all 14 streams had more than one stressor acting on it. These stressors typically involved altered channels, non-point source pollution, infrastructure, or naturally-occurring circumstances. In a few cases, a point source might be contributing to stress, which could be investigated with hydrological modelling. Infrastructure stressors included culverts that were installed such that fish passage is difficult or not possible. Also included in the infrastructure category are legacy ditching projects, which attempted to drain wetland areas throughout much of the NFCRW in the early 1900s. These ditches alter downstream hydrology, and appear to have caused channel damage in some locations, which has led to habitat loss. The ditches also likely contribute to low dissolved oxygen (DO) levels in streams due to the wetland-sourced water they convey to the streams. The natural stressors are low DO, due to the extensive wetlands, and beaver dams, which also can block fish passage, preventing repopulation of streams in spring from downstream overwintering habitat.

Figure 1. Biological impairments in the NFCRW discussed in this report. 1. Middle Fork Crow River (511), 2. Judicial Ditch 17, 3. County Ditch 37, 4. Middle Fork Crow River (539), 5. Tributary to Lake Koronis, 6. Silver Creek, 7. Stag Brook, 8. Collinwood Creek, 9. County Ditch 26, 10. Twelvemile Creek, 11. Washington Creek (751), 12. Washington Creek (753), 13. County Ditch 36, 14. French Creek.



Mechanisms of candidate stressors and applicable standards

A separate document has been developed by MPCA describing the various candidate stressors of aquatic biological communities, including where they are likely to occur, their mechanism of harmful effect, and Minnesota's Standards for those stressors (MPCA, 2019a). Many literature references are cited, which are additional sources of information. The document is titled "Stressors to Biological Communities in Minnesota's Rivers and Streams" and can be found on the web at: https://www.pca.state.mn.us/sites/default/files/wq-ws1-27.pdf. Additional information on Stressor Identification in Minnesota can be found on MPCA's website, "Is Your Stream Stressed?" (MPCA, 2020b).

EPA (2019) has yet more information, conceptual diagrams of sources and causal pathways, and publication references for numerous stressors on their CADDIS website at https://www.epa.gov/caddis.

Notes on analysis of biological data

Biological data (the list of taxa present in the sample and the number of each) form the basis of the assessment of a stream's aquatic life use status. Information on the MPCA's biological monitoring program and protocols can be found on the MPCA website (MPCA, 2020c). Various metrics can be calculated from the fish or macroinvertebrate sample data. An Index of Biological Integrity, a collection of metrics that have been shown to respond to human disturbance, is used in the assessment process (https://www.pca.state.mn.us/water/index-biological-integrity). Similarly, metrics calculated from biological data can be useful in determining more specifically the cause(s) of a biological impairment. Numerous studies have been done to search for particular metrics that link a biological community's characteristics to specific stressors (Hilsenhoff, 1987, Griffith et al., 2009, Álvarez-Cabria et al., 2010). This information can be used to inform situations encountered in impaired streams in Minnesota's Watershed Restoration and Protection Strategy (WRAPS) process. This is a relatively new science, and much is still being learned regarding the best metric/stressor linkages. Use of metrics gets more complicated if multiple stressors are acting in a stream (Statzner and Beche, 2010; Ormerod et. al., 2010, Piggott et. al., 2012).

Staff in MPCA's Standards, Biological Monitoring, and Stressor ID programs have worked to find metrics that link biological communities to stressors, and work continues toward this goal. Much work in this area was recently done to show the impact of nutrients (particularly phosphorus) on biological stream communities when Minnesota's River Nutrient Standards were developed (MPCA, 2013b; MPCA, 2019b). The Biological Monitoring Units of MPCA have worked to develop Tolerance Indicator Values for many water quality parameters and habitat features for species of fish, and genera of macroinvertebrates. This is a take-off on the well-known work of Hilsenhoff (1987; EPA, 2006). For each parameter, a relative score is given to each taxon regarding its sensitivity to that particular parameter by calculating the weighted average of a particular parameter's values collected during the biological sampling for all sampling visits in the MPCA biological monitoring database. Using those scores, a weighted average community score (a community index) can be calculated for each sample. Using logistical regression, the biologists have also determined the probability of the sampled community being found at a site meeting the TSS and/or DO standards, based on a site's community score compared to all MPCA biological sites to date. Such probabilities are only available for parameters that have developed standards, though community-based indices can be created for any parameter for which data exists from sites overlapping the biological sampling sites.

Some of these stressor-linked metrics and/or community indices will be used in this report as contributing evidence of a particular stressor's responsibility in degrading the biological communities in an impaired reach. It is best, when feasible, to also include field observations, water chemistry samples, and physical data from the impaired reach in determining the stressor(s).

Use attainability analysis notes on analysis of physical and hydrological data

Staff of the DNR provide assistance to the SID process by collecting physical data (e.g., Pfankuch assessments and Rosgen geomorphology studies) about the stream channel, and analyzing hydrological data. Summary information about these topics are included in this report. Detailed stream survey data (e.g., channel bed elevations, water slope, etc.) from these efforts is available from DNR Watershed Specialists in the Mankato DNR office.

Biologically-impaired streams

The individual AUIDs assessed as impaired are discussed separately from this point on. The general format will be: 1) a review and discussion of the data and possible stressors that were available at the start of the SID process; 2) a discussion of any additional data that was collected during the SID process; and 3) a discussion of the conclusions for the AUID based on all of the data reviewed.

Note: From this point on, the AUIDs referred to in the text (except main headings) will only include the unique part of the 11-number identifier, which is the last three digits.

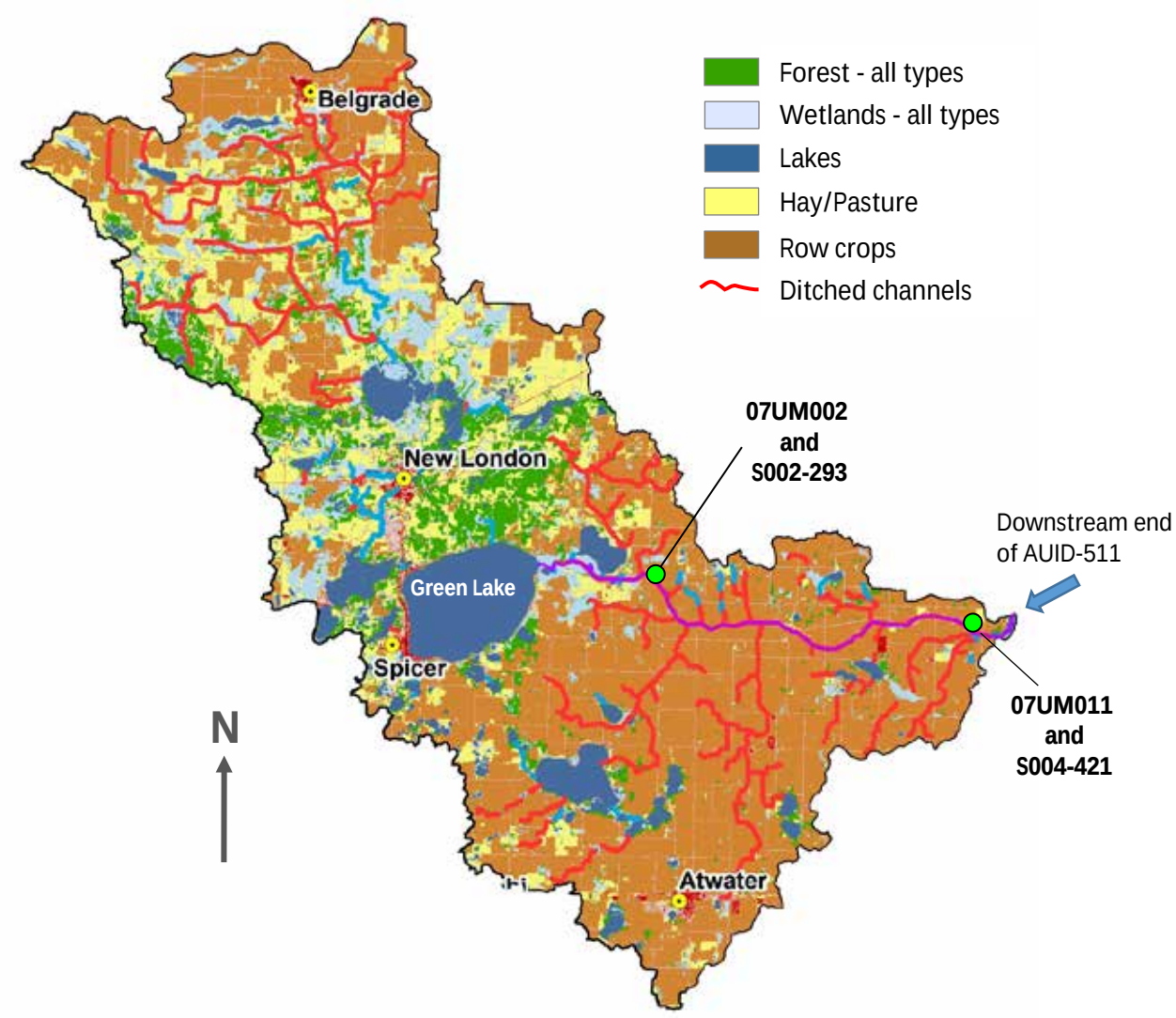
Middle Fork Crow River (AUID 07010204-511)

Impairment: AUID-511 is an approximately 16 mile long reach beginning as outflow of Green Lake. The channel of AUID-511 is mostly altered/ditched with some short reaches that remain in the original, natural channel pattern. There are two biological monitoring stations (07UM002, 07UM011), both of which are within physically altered reaches. Site 07UM002 is in the upstream part of the AUID, while 07UM011 is near the downstream end, which is the confluence of the Middle Fork with the North Fork Crow River. The Use Attainability Analysis (UAA) process determined that the stream should be classed as General Use, despite the ditching/straightening. The AUID was assessed as having an impairment of the fish community. The macroinvertebrate community scored above the Modified and General Use thresholds and is not considered impaired. The Macroinvertebrate Stream Class is 5, the Fish Stream Class is 5. There were no other Aquatic Life Use impairments assigned by the Watershed Assessment Team.

Sub-watershed characteristics

Nearly all of the AUID's length is a straightened channel, though there are a few short natural stretches of unmodified channel. Green Lake's outflow point is the upstream boundary of the AUID. The water exported into AUID-511 is of very good quality. A number of agricultural ditches drain into AUID-511, most prominently Judicial Ditch 17 and County Ditch 28. The land use and land cover of the sub-watershed of AUID-511 is shown in Figure 2. Above Green Lake, the land cover is more varied, with much more perennial vegetation. The land use downstream of Green Lake (associated most directly with AUID-511) is predominantly row crop agriculture. There are several cities/towns in the sub-watershed, including Belgrade, New London, and Spicer upstream of Green Lake, and Atwater downstream of Green Lake. There is little forest land, most of it upstream of the AUID between New London and Green Lake. There is one permitted facility that discharges effluent directly to AUID-511, "Mechanical Facility", permittee MN0052752-SD-2 (data in EQuIS from 2001-2015) as well as the Atwater wastewater treatment plant (WWTP) ponds that discharge seasonally to a tributary of AUID-511, Judicial Ditch 17.

Figure 2. The subwatershed of the Middle Fork Crow River, showing land cover (NLCD 2016). AUID-511 is the purple line from the east end of Green Lake to the arrow on the map.



Data and analyses

Chemistry

A significant data set has been collected from AUID-511 at 07UM002 (S002-293) and 07UM011 (S004-421), including conditions during the biological sampling in 2007 and 2017 (Table 1) and by MPCA/local resource managers (Table 2).

Table 1. AUID-511 water quality measurements from the IWM biological sampling visits and 2018-2019 SID monitoring at 07UM002 (S002-293) and 07UM011 (S004-421). Values in mg/L, temperature in ºC.

Site	Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
07UM002	6/26/2007	15:00	26.5	7.37	--	404	0.142	0.05	0.06	6.68	--	11
07UM002	6/13/2017	12:10	21.1	6.09	69	377	0.045	0.168	< 0.1	7.93	> 100	6.2
07UM002	8/9/2017	16:00	22.3	8.79	101	399	--	--	--	8.18	> 100	--
07UM002	8/9/2017	14:19	22.1	8.10	93	387	--	--	--	8.09	> 100	--
07UM011	7/2/2007	13:30	21.0	7.84	--	538	0.084	0.820	< 0.05	8.20	--	5.6
07UM011	6/21/2007	16:03	22.9	8.49	99	523	0.044	2.40	< 0.1	8.01	> 100	3.0
07UM011	8/15/2017	8:15	18.4	7.97	85	449	--	--	--	7.9	45	--

Table 2. MPCA load monitoring and local government water quality sampling at S004-421 from 2007-2019, in mg/L, during open water season. All parameters in mg/L.

Parameter	Sample count	Average	Minimum	Maximum
TP	179	0.0991	0.021	0.811*
DO	87	7.95	4.52	12.62
Nitrate	117	2.60	0.085	9.84
Ammonia	12 (only 2007)	< 0.06	< 0.05	0.9
TSS	189	17.46	< 1.00	118

* This was an outlier - no other measurement exceeded 0.395 mg/L.

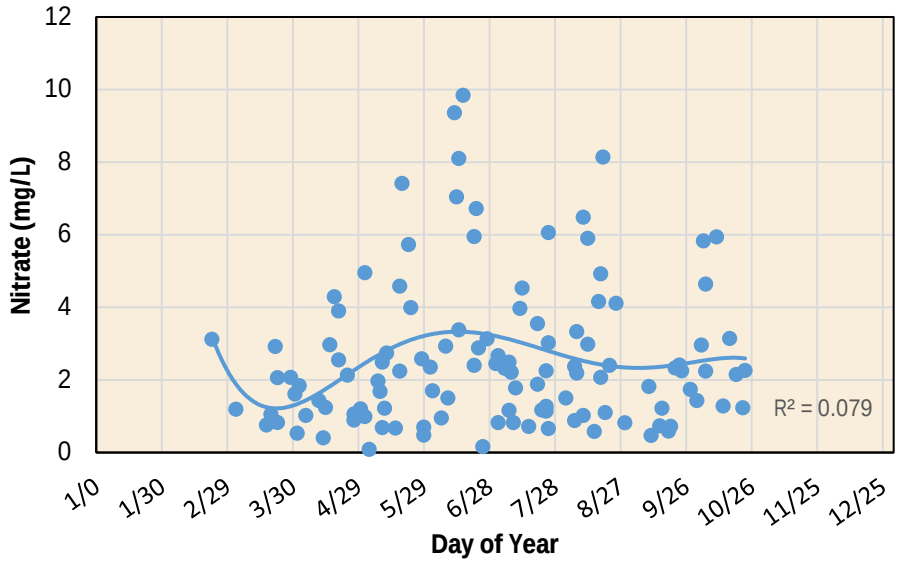
Nutrients - phosphorus

Phosphorus values from the large dataset shown in Table 3 shows that the average total phosphorus (TP) is right at the Central Region River Nutrient standard (0.100 mg/L). This points to a potential for eutrophication to occur.

Nutrients - nitrate and ammonia

Nitrate values are elevated above general Minnesota natural background levels, and may reach levels that are toxic to some aquatic organisms (Figure 3). In fact, there are occasional measurements nearing the Drinking Water standard of 10 mg/L. The time of year when nitrate levels are, on average, the highest is early June, corresponding to the time when crops are very immature, with small root systems for taking up nitrate. Though few samples have been collected at the upstream site, 07UM002, it appears that nitrate levels are lower above the input of Judicial Ditch 17, than at 07UM011, downstream of the input of Judicial Ditch 17. Ammonia values were very low, generally below the lab detection limit, and none were at problematic (toxic) levels.

Figure 3. Nitrate concentrations throughout the year, using data from 2007, 2015-2019. The line is a polynomial regression line. Variability is high, so the R^2 value is low, and factors other than time of year influence the pattern of concentration levels.

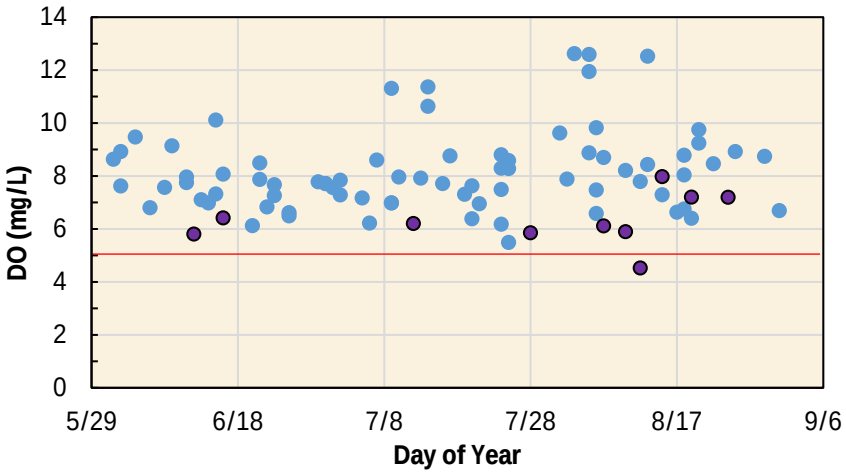


Dissolved oxygen

The DO levels at the historical measurement dates (Figure 4) were essentially always above the standard. However, none of the values were collected at the daily minimum, just after sunrise. So, some mornings may have had substandard DO levels (one did for certain). There is no strong seasonal pattern in the DO levels shown in these measurements. The cluster of high points in early August could be a signal of eutrophication, as these are getting to unnaturally high levels, signaling large amounts of in-stream DO production from photosynthesis. Only a small number of DO percent saturation measurements have been made (Table 1), and they are near 100%, a healthy level, even in mid- to late-afternoon, suggesting that excess plant/algae growth is not occurring, and that eutrophication is not occurring in the river, at least at strongly influential levels.

A Sonde was deployed in 2018 at S004-421 (07UM011) for 13 days, starting on August 14. DO over this period ranged from about 7.7 to 9.6 mg/L. This is a very healthy range, and no day's minimum was even near dropping below the standard. The daily flux of about 1.5 - 2.0 mg/L is also very healthy for fish communities.

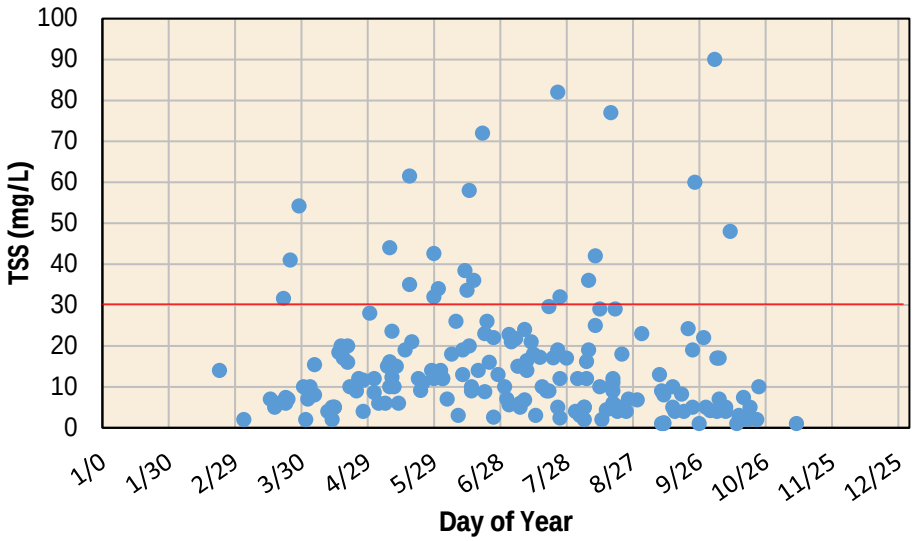
Figure 4. June through August DO measurements from 2007 - 2018 at S004-421. The red line is the DO standard. The dark points are data collected before 9:00 a.m. (mostly between 8:00 a.m. - 9:00 a.m.).



Transparency and suspended solids

Total suspended solids (TSS) most often is better than the Central Region standard, and quite commonly much below it (Figure 5). The standard is however exceeded at times, and can be more than double the standard concentration. These are likely shortly after rain events when runoff enters the river. There are enough samples for a parameter assessment of TSS, and that assessment found the data passes the TSS standard, but there are almost enough exceedances to trip the 10% exceedance standard. A fairly large percentage (66%) of the makeup of the suspended solids (on average) is mineral material (soil) versus organic particulates, based on comparisons of TSS and Total Suspended Volatile Solids (TSVS) from 23 samples collected in 2015 at S004-421.

Figure 5. TSS data from 2007-2019 at S004-421, near the downstream end of AUID-511. The red line is the applicable TSS standard for NFCW streams.



Conductivity

Specific conductivity was in a moderate range, and non-problematic for the biological communities.

Stressor signals from biology

Fish

The 2007 fish community at 07UM002 consisted of 34 species, with four species being most abundant; black bullhead, hybrid sunfish, sand shiner, and bluegill respectively. The June and August 2017 samples had similar numbers of species; 31 and 30 respectively. In June, the three most abundant species were bluegill (particularly), fathead minnow, and black bullhead. In August, the four most abundant species were bluegill (particularly), hornyhead chub, pumpkinseed, and johnny darter, respectively.

The 2007 fish community at 07UM011 consisted of 22 species, with three dominant species; spotfin shiner, black crappie, and common carp being most abundant, respectively. The 2017 sample contained 20 species, with central mudminnow being far dominant, and all other species with 12 or fewer individuals.

The Community TIV Index scores are shown in Table 3. The fish samples show some evidence of the influence of low DO concentrations. The DO Community Index scores were lower than the class average at all visits to both sites, and all were at or below the 32nd percentile of Class 5 streams, with the lowest sample being at only the 2nd percentile. Only one of the five samples had a probability over 45% that the fish communities would come from a DO standard-meeting reach. In terms of the individual TIV metrics for DO (Tables 4 and 5), the fish communities collected at both 07UM002 and 07UM011 are highly

skewed toward low-DO tolerance in terms of both numbers of Tolerant versus Intolerant taxa the percentages of these individuals.

There is slight evidence in the fish data of stress from TSS, less so in the recent sample. The TSS Tolerance Indicator Value (TIV) Index scores are all below (poorer than) average. The communities were, however, fairly likely to come from TSS standard-meeting waters. Few species or individuals of either TSS Tolerance or Intolerance were collected in the 2017 samples, though there were a relatively abundant number of TSS Tolerant individuals in 2007.

There is not convincing evidence from the fish data that nitrate is a stressor. The 2017 samples at both sites had Nitrate TIV Index values that were quite a bit better than the Class 5 average, and at the 64th - 84th percentiles of Class 5 values. The samples are not skewed toward nitrate tolerance in terms of either numbers of Tolerant versus Intolerant species or the percentages of these individuals, though there are fewer Nitrate Intolerant taxa as well as substantially fewer Intolerant individuals at the downstream site. The downstream site, however, had the better Nitrate TIV Index score.

These fish community analyses provide evidence that the fish community is being stressed by inadequate DO levels, but likely not from elevated nitrate nor elevated TSS.

Table 3. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-511 at sites 07UM002 and 07UM011. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Site	Parameter (sample year)	TIV Index	Class avg./median	Percentile within class	Prob. as %
07UM002	DO (2007)	6.59	7.00/7.11	19	39.9
07UM002	DO (2017)	6.64	7.00/7.11	21	43.7
07UM002	DO (2017)	6.64	7.00/7.11	22	44.3
07UM011	DO (2007)	6.87	7.00/7.11	32	60.2
07UM011	DO (2017)	5.76	7.00/7.11	2	5.9
07UM002	TSS (2007)	20.34	13.71/12.96	5	25.8
07UM002	TSS (2017)	17.39	13.71/12.96	21	47.2
07UM002	TSS (2017)	14.64	13.71/12.96	10	69.0
07UM011	TSS (2007)	24.12	13.71/12.96	3	9.3
07UM011	TSS (2017)	14.24	13.71/12.96	27	70.9
07UM002	Nitrate (2007)	2.39	2.06/2.02	33	--
07UM002	Nitrate (2017)	1.70	2.06/2.02	64	--
07UM002	Nitrate (2017)	1.56	2.06/2.02	71	--
07UM011	Nitrate (2007)	2.18	2.06/2.02	43	--
07UM011	Nitrate (2017)	1.28	2.06/2.02	84	--

Table 4. Metrics involving DO tolerance for the sampled fish communities at 07UM002.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	6/26/2007	0	0	18	9	0.0	50.4
Low DO	6/13/2017	1	0	17	11	0.1	38.4
Low DO	8/9/2017	0	0	16	7	0.0	38.2
TSS	6/26/2007	2	1	5	1	0.2	18.8
TSS	6/13/2017	3	2	3	0	0.4	3.6
TSS	8/9/2017	1	0	3	0	0.2	0.6
Nitrate	6/26/2007	6	3	9	3	6.8	31.0
Nitrate	6/13/2017	4	2	7	1	35.2	23.1
Nitrate	8/9/2017	4	1	6	1	30.3	12.7

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Table 5. Metrics involving DO tolerance for the sampled fish communities at 07UM011.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/2/2007	0	0	9	4	0.0	25.4
Low DO	6/21/2017	0	0	9	5	0.0	80.6
TSS	7/2/2007	0	0	3	1	0.0	36.9
TSS	6/21/2017	1	1	3	1	0.3	3.3
Nitrate	7/2/2007	1	0	7	2	7.2	26.2
Nitrate	6/21/2017	2	1	6	0	4.0	15.1

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

The macroinvertebrate community was assessed as not impaired. Since the signal from the fish community was pointing most strongly to low-DO being a stressor, macroinvertebrate DO metrics were reviewed to see if they too were showing evidence of the influence of low-DO.

Three of the four visits found a macroinvertebrate community with an above (better than) Class 5 average DO TIV Index score (Table 6). The one below average was longer ago, in 2007. The probability of the sampled communities of coming from a DO standard-meeting site are fairly good, between 64 and 74%. The community is not skewed toward low DO tolerance in terms of taxa present or percent of individuals (Table 7). It is quite even between low-DO Intolerant and low-DO Tolerant, actually leaning slightly in favor of low-DO intolerance. It does not appear that DO levels are negatively influencing the macroinvertebrate community.

Table 6. Macroinvertebrate Community DO Tolerance Index scores at 07UM002 and 07UM011. For DO, a higher index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO that meets the standard.

Site	Date	TIV Index	Class avg./median	Percentile within class	Prob. as %
07UM002	8/8/2007	7.12	6.94/7.07	54	71
07UM002	8/9/2017	7.19	6.94/7.07	60	73
07UM011	8/9/2007	6.83	6.94/7.07	33	64
07UM011	8/15/2017	7.22	6.94/7.07	63	74

Table 7. Macroinvertebrate metrics related to DO at 07UM002 and 07UM011 utilizing MPCA species tolerance values.

Site	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
07UM002	8/8/2007	6	4	7	1	14.8	9.8
07UM002	8/9/2017	6	2	8	1	10.9	8.5
07UM011	8/9/2007	7	4	9	3	5.1	4.5
07UM011	8/15/2017	7	3	4	2	18.5	4.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, there is contradictory evidence that low DO levels are stressing the communities, with the fish community suggesting it, and the macroinvertebrate community not. TSS may be having a small effect on the fish community, and nitrate does not appear to be a stressor to the fish. One situation that can lead to contradictory findings between fish and macroinvertebrates is when the fish are being negatively impacted by a migration barrier. This will be discussed below.

Temperature

Temperature measurements in Table 1 showed none that would be problematic for the fish community, including those taken in the afternoon of July and August visits.

Habitat

Habitat is mediocre in this channelized AUID, based on Minnesota Stream Habitat Assessment (MSHA) metrics, though the UAA process rated it as sufficient to be placed into the General Use, rather than Modified Use, Tiered Aquatic Life Uses (TALU) category. The total and sub-component scores are shown in Table 8. The poorest-scoring sub-component scores were "Cover" and "Channel Morphology". The latter is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles, and fine particulate substrate. These characteristics were found at 07UM002, with the partial exception that substrate included significant amounts of gravel. Embeddedness of gravel by fine particles was consistently rated as "light", which is good.

The MSHA found somewhat better habitat at the downstream site, 07UM011, which scored 7 points better than 07UM002. The "Channel Morphology" component score was again the lowest, with similar characteristics to 07UM002, again typical of straightened reaches.

Table 8. MSHA scoring for site 07UM002 fish sampling visits.

MSHA Component	6/2007	6/2017	8/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	1.5	2.5	2.5	2.2	5	44.0
Riparian	9	8.5	10.5	9.3	14	66.4
Substrate	18	19	19	18.7	28	66.8
Cover	6	8	12	8.7	18	48.3
Channel Morphology	20	11	8	13.0	35	37.1
Total MSHA Score	54.5	49	52	51.8	100	51.8 = "Fair"

Table 9. MSHA scoring for site 07UM011 sampling visits.

MSHA Component	7/2007	6/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	5	5	5	5	100
Riparian	14	9.5	11.8	14	84.3
Substrate	18.9	17	18.0	28	64.3
Cover	8	12	10.0	18	55.6
Channel Morphology	13	15	14.0	35	40.0
Total MSHA Score	58.9	58.5	58.7	100	58.7 = "Fair"

Hydrology

There has been substantial modification of the natural hydrology of the sub-watershed, both due to large-scale vegetation cover changes (forest to cultivated fields), as well as changes to the channel (straightening) that reduced sinuosity and thus increase channel gradient and water movement through the system. Channel size was also likely increased when the ditching was done originally.

Geomorphology

Nearly the full length of the AUID is straightened channel, and as such does not have a natural river channel pattern that can be assessed for stability. The photos which were taken by the biological monitoring crews were examined for bank condition, and the banks looked healthy (i.e., they appeared stable and erosion problems were not seen). Reviewing aerial photography shows that the pre-settlement channel (the oxbow) was much narrower than the current channel (Figure 6), suggesting that hydrology has been changed after the landscape conversion to agriculture and the associated drainage enhancements (tile, ditches, straightening). The current channel is showing signs that it is receiving excess sediment from either soil erosion off the landscape or un-natural bank erosion. The stream bed appears to be aggrading with fine sediment, which smothers important bed feature habitat important for fish and macroinvertebrates. The high TSS levels that are occasionally found aligns with these signs of excessive sediment loading to the stream. Additional aerial photo review does show locations where in recent years there has been places where fields have almost no buffer, and/or where significant un-natural bank erosion is occurring (Figures 7 and 8). There are also locations where cattle allowed free access to the river have caused bank erosion (Figure 9).

Figure 6. Middle Fork Crow River and old oxbow channel. Arrows point to mid channel bars, deposition of excess sediment that is a sign the river is receiving excessive sediment and is aggrading its channel bed.

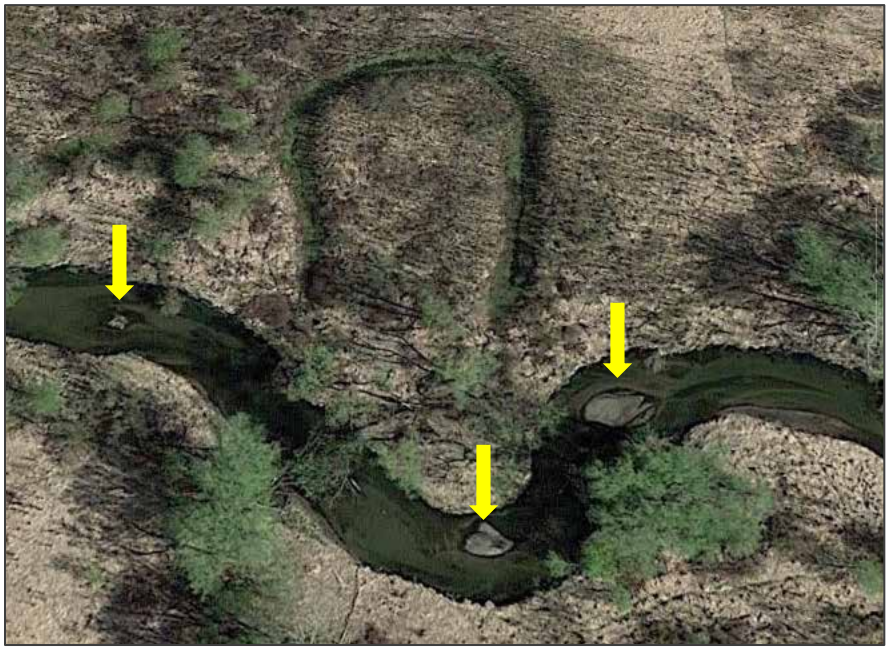
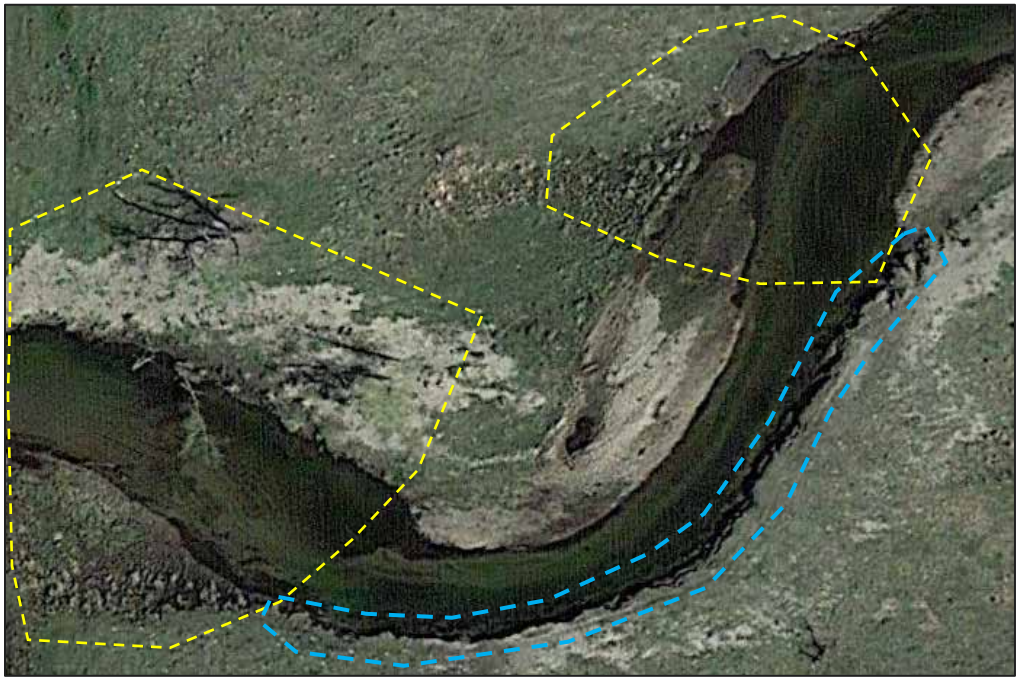


Figure 7. Example of bank erosion along a field edge with almost no buffer (Photo is spring 2015). Such erosion is a source of excess sediment. This erosion is upstream a ways from location shown in Figure 6. The dashed yellow line is the edge of active cultivation.

Figure 8. Erosion from inadequate buffer and armoring vegetation, resulting in field loss, which happened since the previous fall's harvest, as tillage marks can be seen leading to missing land. Photo is from April 2015.

Figure 9. Bank erosion due to cattle access to the channel. Yellow outlines show bare soil and over-widening where pasture animals enter the river; blue outline shows eroding bank caused by inadequate deep-rooted protective vegetation.



There are two road crossings between 07UM011 and the North Fork Crow River, where some species may retreat for winter refuge. One is a bridge (which only very rarely become barriers) while the other is a set of three cement box culverts (CSAH-3). The culverts at CSAH-3 were visited, and determined to be passable for fish. There is a small dam (may be a carp barrier) just across the road upstream of 07UM002. Between 07UM002 and 07UM011 are numerous crossings, with all but one being bridges. The other, a triple box culvert at 560th Avenue, is not a barrier. And so, there are no barriers downstream of 07UM002 and fish migration barriers do not explain the fish impairment.

Conclusions about stressors

Analysis of the fish community gave evidence that low-DO is a stressor. However, similar analysis of the macroinvertebrate community contradicts that finding. A substantial amount of DO sampling has occurred, and has not found low DO levels. Thus, low DO is considered to be inconclusive as a stressor. Nitrate is sometimes quite high, but a signal of nitrate stress did not show up in the analysis of the fish community. TSS also can occasionally be above the state standard, but again, the analysis of the fish data did not show a strong signal of the negative influence of TSS, particularly in the more recent sample.

Review of 2015 aerial photography to analyze geomorphology and channel stability showed definite signs of excessive sediment deposition in the channel, as well as some channel instability as seen in eroding banks at various locations. Bank instability has been caused by cattle trampling of banks while accessing the river, and in other places due to river flows acting on inadequately-protected banks, where protective vegetation has been altered or field buffers are too narrow. In addition, other locations were found to have very narrow stream buffers which may be allowing field runoff to carry sediment into the river. All of these are sources of excess sediment to AUID-511. Though the UAA analysis found habitat should be sufficient to allow for passing biological communities, it is likely that excess bedded sediment has resulted in loss of important stream bed habitat by smothering coarser material, and creating relatively uniform depth by filling pools. Therefore, excess sediment is considered a stressor in AUID-511.

There are two permitted effluent dischargers active in this sub-watershed. It is not currently known how their effluent is influencing the biological communities.

Recommendations

Some stretches of AUID-511 have excellent, wide natural buffers, while some other areas are farmed to within several feet of the stream bank (at least as of 2015). The enactment of the recent Buffer Law may have led some landowners to widen the buffers along the river. Re-establishing some woody vegetation along the banks would also provide additional means of stabilizing the banks against erosion. If areas of inadequate buffering still occur, addressing those would be beneficial. It would also be very beneficial to work with landowners to fence cattle out of the stream and provide off stream watering. This will also help correct the bacterial impairment in AUID-511. These enhancements of the riparian area will also help to reduce nutrient inputs from fields and pastures. It is not known how influential the discharged industrial and municipal wastewater discharges are on the biological communities. Hydrological modeling coupled with records of monitored levels of discharged material would provide some insight. Re-meandering the river would be a way to improve habitat, though there are somewhat limited locations where this would be possible without moving into riparian areas that are currently farm fields.

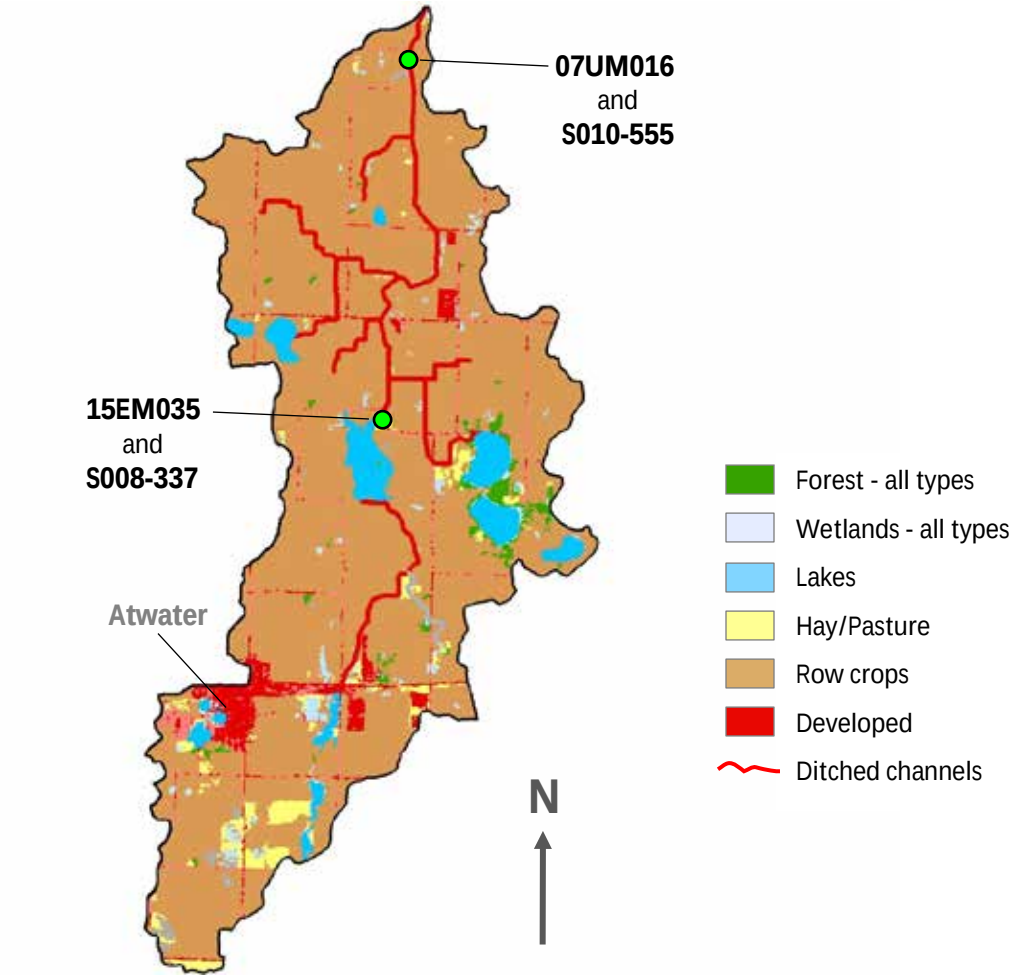
Judicial Ditch 17 (AUID 07010204-532)

Impairment: AUID-532 is the full 9.4 miles long Judicial Ditch 17, beginning just east of Atwater, and ending where it meets the Middle Fork Crow River. The channel of AUID-532 is a straightened channel for its entire length, with a few areas that have somewhat naturalized into a two stage channel with some moderate meandering. The UAA process determined that AUID-532 should be classed as Modified Use. There are two biological monitoring stations, 07UM016 (near the mouth) and 15EM035 (near the midpoint of the reach). AUID-532 has a new (2019) impairment for the fish community. The macroinvertebrate community scored above the Modified Use threshold and is not impaired. The Fish Stream Class at 07UM016 is 7 (Low Gradient) and at 15EM035 is 6 (Northern Streams). The Macroinvertebrate Stream Class is 7 (Prairie Streams - GP) at both sites.

Sub-watershed characteristics

The land use and land cover of the sub-watershed of AUID-532 is highly oriented to row crop agriculture, as well as a number of large poultry farms (Figure 10). One city, Atwater, is found in the sub-watershed, in the southern extent (headwaters area). There is very little wetland or forest area, and much agricultural ditching. The stream system in the sub-watershed is 100% modified/ditch. The "lake" showing up midway along JD-17 is classed in the DNR GIS Lake layer as an intermittent water. Review of historical aerial photography from 1938 does seem to show the outline of a wetland. The ditch channel now runs through this area, and much of it is now farmed. The city of Atwater is permitted to discharge treated municipal wastewater to Judicial Ditch 17. There are three large poultry farms and cow/cattle feedlots along or near the ditch, east of Atwater, which may mean significant manure application on local fields. In 2015 aerial photos, there are fields with less than 16 foot buffers to the ditch. In some areas, the ditch has begun to moderately develop sinuosity, which can improve aquatic habitat if banks are not significantly eroding. Tiling of fields occurs in this subwatershed.

Figure 10. The sub-watershed of Judicial Ditch 17, AUID-532, showing land cover (NLCD 2016).



Data and analyses

Chemistry

A significant data set has been collected over the years from AUID-532 at 07UM016 (S010-555), with lesser amounts from 15EM035 (S008-337), including conditions during the biological sampling visits in

2007, 2015, and 2017 (Table 10), and subsequent SID sampling in 2018-2019 (Table 11). Data are discussed below by parameter.

Table 10. AUID-532 water quality measurements from the IWM biological sampling visits at 07UM016 (S010-555) and 15EM035 (S008-337). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
07UM016											
7/16/2007	15:43	26.3	10.0	--	888	0.184	2.9	< 0.05	8.1	--	27
7/11/2017	8:30	19.6	2.6	28	797	0.069	8.6	0.1	7.3	> 100	8.8
8/14/2017	17:24	21.6	13.5	153	779	--	--	--	7.9	77	--
15EM035											
6/11/2015	11:25	16.0	9.0	95	753	0.099	10	< 0.05	7.1	92	1.2
8/3/2015	11:50	16.0	1.8	19	792	--	--	--	7.2	> 100	--

Table 11. SID monitoring summary for 07UM016 (S010-555), 2018-2019. Values in mg/L.

	07UM016				15EM035			
Parameter	# samples	Avg.	High	Low	# samples	Avg.	High	Low
DO	18	10.4	19.9	5.8	3	8.9	14.1	4.7
DO% sat.	18	107.6	201.6	61.6	3	95.2	149.2	50.0
TP	8	0.181	0.696	0.049	--	--	--	--
Nitrate	8	6.55	9.4	3.3	--	--	--	--
Ammonia	2	< 0.05	< 0.05	< 0.05	--	--	--	--

Nutrients - phosphorus

TP is generally at or above the River Eutrophication Standard (Central), and can sometimes be many times the standard (Table 11).

Nutrients - nitrate and ammonia

Nitrate levels are elevated, and can be very high. Measurements show levels as high as 9-10 mg/L. Such levels don't occur naturally in Minnesota streams. Ammonia levels were very low (good) in all samplings.

Dissolved oxygen

A significant amount of DO data exists from AUID-532, including both instantaneous measurements from across the growing season, and from a continuously-recording deployed instrument (a Sonde, Figures 11 and 12). These measurements show a number of informative characteristics:

- There can be very low DO in the morning, well below the DO standard.
- There are often very high DO levels in mid-to-late afternoon. If fact, the levels the DO has been shown to reach are pretty rare, climbing to almost 20 mg/L. This is far higher than exists in healthy streams, and in this low gradient channel, have to be the result of the photosynthesis of an extreme abundance of plants and/or algae.
- The percent saturation of DO changes greatly each day. Many days have DO percent saturation well above 100%. This only happens with extreme turbulence (not occurring here), or with an un-natural abundance of plants pumping out much oxygen during photosynthesis, faster than it can diffuse into the atmosphere from the water.

- The daily swings of DO are extreme, reaching as much as 13 mg/L (6/19/2019). This much of a daily range of DO is stressful to aquatic organisms.
- In the second half of June (at least in 2019), daily DO minimums do not generally drop below the standard at 07UM016, though they are generally very close to doing so. A Sonde deployed in the second half of July, or first half of August would probably show minimums below the standard, as water temperatures are warmer then, and decomposing bacteria are more active (and use more oxygen).
- In the second half of June (at least in 2019), daily DO minimums **do sometimes drop below** the standard at 15EM035, which is upstream of 07UM016. The readings at this site are similar to downstream at 07UM016, except are typically about 1-2 mg/L lower.

These findings point to a stream experiencing eutrophication, which is driven by excess nutrients in the water. This is verified by site photos that show excessive filamentous algae mats (Photo 1)

Figure 11. DO measurements from deployed Sonde at 07UM016 (S010-555), 6/18/2019 - 7/1/2019.

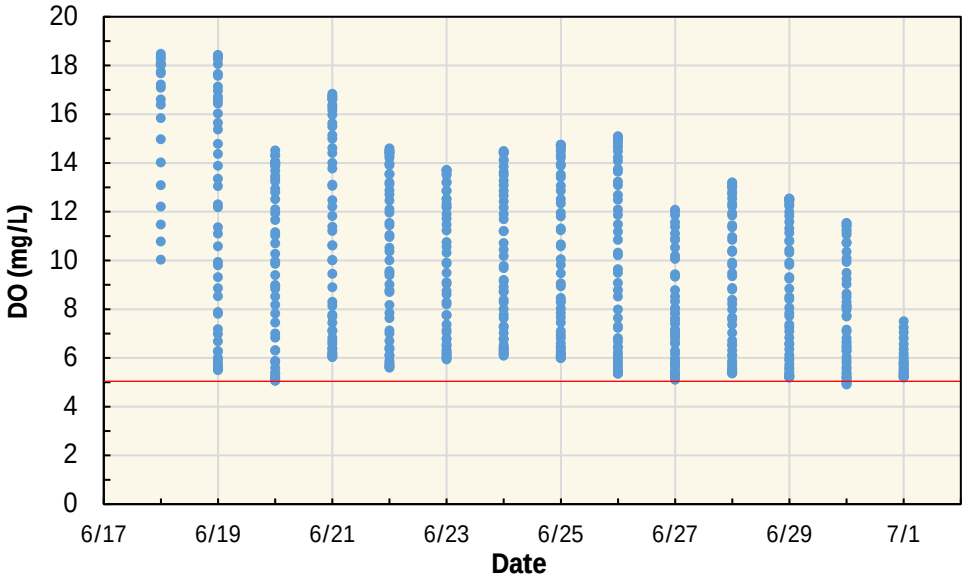


Figure 12. DO measurements from deployed Sonde at 15EM035 (S010-555), June 18, 2019 - July 1, 2019.

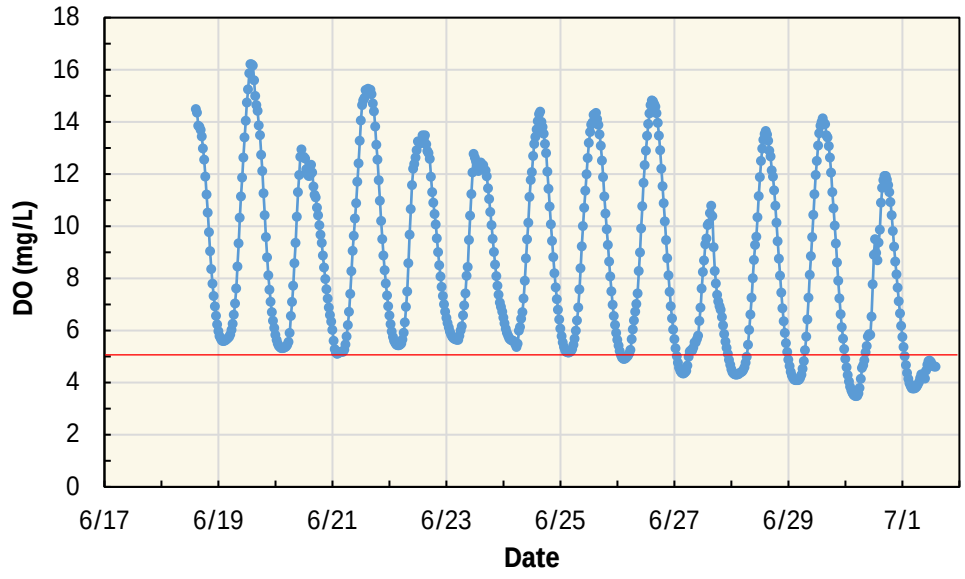


Photo 1. Algae-choked channel at S010-555 on August 6, 2019.

Suspended sediment

Suspended sediment can be very low, but can also get elevated, though the highest of these few measurements is slightly below the regional TSS standard (Table 11). It may be that the 27 mg/L sample contained some decayed organic particles from the excessive plant life in this AUID, and doesn't signify erosion issues.

Stressor signals from biology

Fish

Site 07UM016 - The July 2007 fish community consisted of 9 species, with three species being most abundant: johnny darter, black bullhead, and central mudminnow. A small number of fish were caught, and none were species considered to be sensitive to disturbance. The July 2017 fish community consisted of 13 species, this time with two species being dominant, brook stickleback and central mudminnow. These are both highly ubiquitous species in Minnesota streams. There was a single individual from the lone sensitive species present, blacknose shiner.

Site 15EM035 - The 2015 community consisted of six species, with three species being more abundant: blacknose dace, central mudminnow, and johnny darter. None of the species caught were ones considered sensitive to disturbance.

The Community TIV Index scores are shown in Table 12 and individual TIV metrics Table 13. In the following analyses, the 2015 and 2017 results are here given more weight since they represent recent conditions. The DO Community Index scores show evidence of the influence of low DO concentrations, particularly in the lower end of the AUID. At 07UM016, the DO Community Index score was at only the 26th percentile for Class 7 streams. The probabilities of the fish communities coming from a DO standard-meeting reach were very low at 07UM016 and moderately low at 15EM035. The fish communities are highly skewed toward low-DO tolerance in terms of both the number of Intolerant

versus Tolerant species numbers and the percentage of Tolerant versus Intolerant individuals. Again, this was more strongly seen at 07UM016.

There is little evidence in the fish data of stress from TSS. Only one TSS Tolerant species was collected, and the percentage of TSS Tolerant species was very low. The communities were likely than not to come from TSS standard-meeting waters.

There is some evidence in the fish data of stress from nitrate. Nitrate Tolerant individuals form a large portion of the 2015 and 2017 samples, and there are more Nitrate Tolerant species present than Nitrate Intolerant ones.

These analyses provide evidence that the fish community is likely being stressed by inadequate DO levels and elevated nitrate, but not by elevated TSS.

Table 12. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-532 at 07UM016 and 15EM035. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within the appropriate stream class (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter and site	Date	Stream class	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO 07UM016	7/16/2007	7	6.19	6.21/6.13	51	17.4
DO 07UM016	7/11/2017	7	5.76	6.21/6.13	26	8.8
DO 15EM035	6/11/2015	6	6.91	6.61/6.68	63	43.2
TSS 07UM016	7/16/2007	7	16.26	14.99/13.36	24	66.4
TSS 07UM016	7/11/2017	7	14.47	14.99/13.36	36	75.9
TSS 15EM035	6/11/2015	6	14.08	13.92/13.26	33	77.9
Nitrate 07UM016	7/16/2007	7	2.21	2.22/2.06	44	--
Nitrate 07UM016	7/11/2017	7	2.93	2.22/2.06	28	--
Nitrate 15EM035	6/11/2015	6	3.13	2.45/2.46	23	--

Table 13. Metrics involving DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM016 and 15EM035.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/16/2007	0	0	5	4	0.0	60.7
Low DO	7/11/2017	0	0	9	7	0.0	87.4
Low DO	6/11/2015	0	0	3	2	0.0	35.4
TSS	7/16/2007	0	0	0	0	0.0	0.0
TSS	7/11/2017	0	0	0	0	0.0	0.0
TSS	6/11/2015	0	0	1	0	0.0	3.1
Nitrate	7/16/2007	0	0	3	0	0.0	14.3
Nitrate	7/11/2017	2	0	4	0	0.1	66.6
Nitrate	6/11/2015	0	0	4	0	0.0	58.5

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

During the Sonde deployment (6/18 - 7/1/2019, 13 days), water temperature was very cool. Many days did not reach 20°C. The maximum temperature during the period was 21.6. This period does not represent the warmest period of the summer, but does suggest that water temperatures may be somewhat cool all summer. There is no evidence of temperature stress on the fish community.

Habitat

Numerous MSHA efforts almost always calculated a score in the "Poor" range of the score categories. Many of the symptoms are common to agricultural ditches (uniform bed topography, bed substrate dominance by fine sediments, etc.). The UAA process uses an algorithm based on the MSHA components to determine if habitat conditions would be stressing the biological communities in channelized streams. The UAA analysis did indeed show that habitat limits the biology.

Therefore, the standard in AUID-532 is lower. So, the habitat stressor is at least partially accounted for in the standard this reach is held to. Therefore, other stressors are likely contributing responsibility for the failing IBI score of the fish community.

Geomorphology

No geomorphology studies were conducted on Judicial Ditch 17. A review of photos taken along the two biological sampling reaches did not show any evidence of channel instability. The channel has very high banks, and so is probably entrenched, but either the flow does not frequently get very high, or the gradient is so low that even high flows are not very erosive to the channel boundaries.

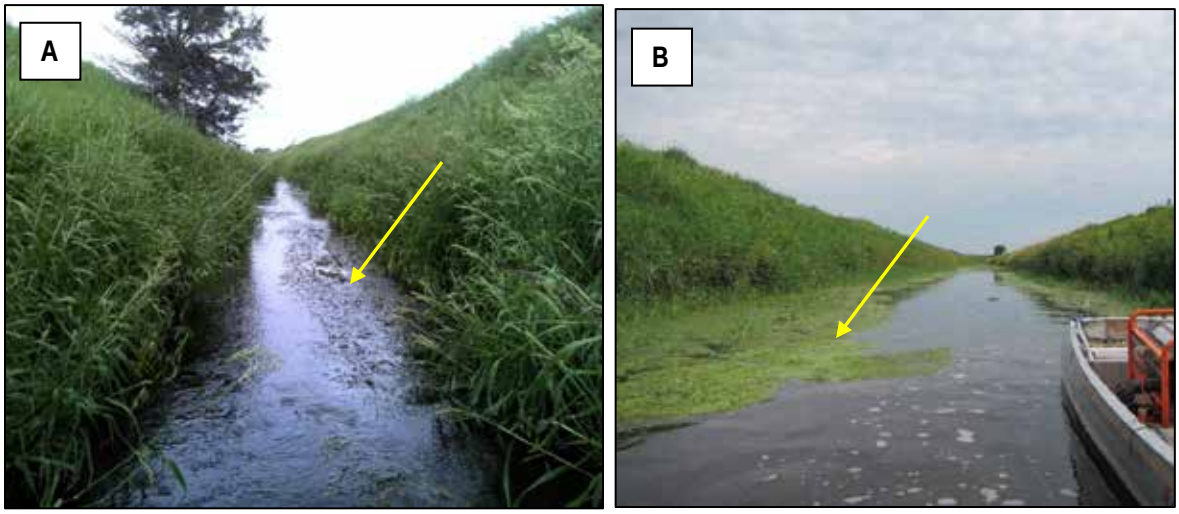
Connectivity

There is one road crossing between biological monitoring site 07UM016 and the North Fork Crow River (at 340th Street). Though not observed from the ground, aerial photos show none of the symptoms that commonly accompany fish barrier culverts (e.g., a downstream scour pool). The culvert on 335th Street, at the upstream end of the biological reach, is nicely passable for fish. Other culverts along the length of the ditch moving upstream to biological site 15EM035 were not observed from the ground to assess fish passability. There are three crossings in that span of stream, at 320th, 310th, and 300th Streets. Aerial photo review of these also show no signs of being barriers. The fish impairment does not appear be explained by a migration barrier.

Conclusions about stressors

The fish community data is signaling that low DO is a stressor in AUID-532, and that nitrate is also likely playing a part in the unhealthy condition of the fish community. The DO data shows instances where the concentration becomes very low in early morning (well under that DO standard), and large daily swings in the change of DO during 24 hour periods. These daily changes in DO are much higher than the value which is part of the River Eutrophication standard. High DO percent saturation levels in late afternoon are evidence that the DO regime is being greatly driven by excessive nutrients in the stream water, which is confirmed by measured phosphorus and nitrate levels, and photos show that even by late spring, there are large amounts of macrophytes growing (Photo 2). Moderate amounts of benthic or filamentous algae were observed by the biological samplers, but algae was not excessive on those dates. However, it was dense in August of 2019 (Photo 2). There is a permitted wastewater effluent discharger (City of Atwater) active in this sub-watershed, which releases phosphorus to the channel, and may be contributing to the nutrient enrichment.

Photo 2. A) At 15EM035, a thick mat of aquatic vegetation, B) Aquatic vegetation and duckweed line the shallow edges of the channel.



Recommendations

There are two likely, potential sources of the excess nutrients in AUID-532, the surrounding agricultural fields and the Atwater treatment ponds. An evaluation could be done of the treatment pond contribution through modelling and review of hydrological and effluent sampling records. MPCA Municipal Division staff could be consulted as a first step. In the 2015 springtime aerial photos, it appears (by using the measuring tool in the photo software) that numerous fields maintained a buffer of less than the required 16 feet width. This may have been corrected during the implementation of the recent Minnesota Buffer Law. If not, buffers should be increased to meet the new state law. Some fields along the ditch have tile drainage that is piped to the ditch. This practice likely delivers significant nitrate to the channel (David et al., 2010). Appropriate best management practices (BMPs) for agricultural field drainage for the reduction of nitrate export would help reduce nitrate (and possibly phosphorus) delivery to the stream.

County Ditch 37 (AUID 07010204-536)

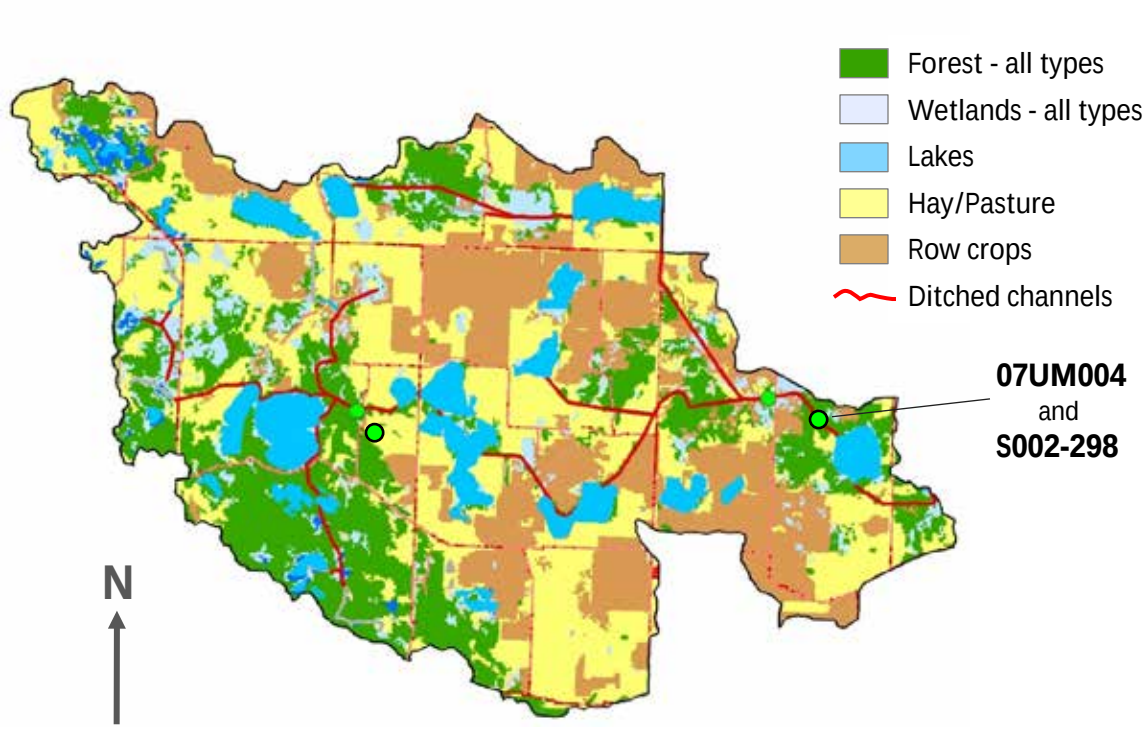
Impairment: AUID-536 is 6.9 miles long, beginning at an unnamed creek (approximately -95.0641, 45.3646 Decimal Degrees) and ending where it meets the Middle Fork Crow River. The channel of AUID-536 is a straightened channel for its entire length, with a few areas that have somewhat naturalized into a two stage channel with some moderate meandering. The UAA process determined that AUID-536 should be classed as General Use. The AUID has one biological monitoring site; 07UM004 at 40th Street NE. AUID-536 has a new (2019) impairment for the fish community. Two fish monitoring visits in 2007 found healthier communities that passed the General Use threshold. The macroinvertebrate community scored above General Use threshold and is not impaired. The Fish Stream Class at 07UM004 is 7 (Low Gradient).

Sub-watershed characteristics

The land use and land cover of the sub-watershed of AUID-536 is much more mixed than the other streams discussed in this report. There is still a fair amount of row crop agriculture, but much higher percentages of wetland, forest, and hay field. There is larger amounts of perennial vegetated cover especially in the channel system upstream of AUID-536, and in the lower part of AUID-536 (Figure 13). In this lower area of the AUID, the fields are quite distant to the channel due either to riparian wetlands or

patches of forested lands. These features give the channel a wide natural buffer for about half of the length of the AUID. No cities, and few residences, are found in the sub-watershed. The channel flows through a number of sizeable wetlands. A desirable (for habitat) two-stage, moderately-sinuous ditch has formed between 25th Street NE and 40th Street NE.

Figure 13. The landscape and land use of the subwatershed of AUID-536 (NLCD 2016).



Data and analyses

Chemistry

The data set for recent years collected from AUID-536 at 07UM004 (S002-298) consists of monitoring during the biological sampling visits in 2007 and 2017 (Table 14), and subsequent SID sampling in 2018-2019 (Table 15). Data are discussed below by parameter.

Table 14. AUID-536 water quality measurements from the IWM biological sampling visits at 07UM004 (S002-298). Values in mg/L, temperature in °C.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
6/25/2007	14:32	24.6	8.0	--	--	0.050	0.59	< 0.05	8.1	--	3.6
7/31/2007	12:10	24.4	10.3	--	615	0.045	0.61	< 0.05	8.3	--	5.8
6/26/2017	14:05	15.0	9.5	94	523	0.030	0.67	0.10	7.9	> 100	3.8
8/8/2017	16:31	19.4	9.1	98	546	--	--	--	8.0	> 100	--

Table 15. SID monitoring summary for 07UM004 (S002-298), 2018-2019. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO	15	7.93	9.1	6.5
DO %	15	79.91	94.5	74.4
TP	8	0.053	0.086	0.019
Nitrate	8	0.85	2.3	0.35
Ammonia	2	< 0.05	< 0.05	< 0.05
Conductivity	15	608.7	639	563

Nutrients - phosphorus

Phosphorus values are very good, all 11 samples in Tables 14 and 15 are well below the River Eutrophication Standard - Central.

Nutrients - nitrogen

Nitrate samples are quite good (low) in 10 of the samples in Tables 14 and 15. One somewhat elevated sample was collected in the SID sampling. The four ammonia samples are all very good. Nitrogen does not appear to be problematic in this AUID. Samples from a Clean Water Partnership Grant collected in 2000-2001 also showed very low levels of nitrate, with the exception of an April sample of 3.53 mg/L.

Dissolved oxygen

Instantaneous DO measurements are all in a good range. Few pre-9 a.m. measurements have been made, so it is not possible to verify that the DO standard is being met. However, mid-afternoon readings are in the range of 9 mg/L, which suggests that eutrophication is not happening in this AUID.

Transparency and suspended solids

TSS concentrations from the three biological visits were very low (good). Clarity measurements were very high.

Conductivity

Specific conductivity was quite similar among all the visits, and similar to other sites in the NFCRW. The measured levels should not be problematic for the fish community.

Stressor signals from biology

Fish

The June 2007 fish community consisted of 10 species, with two species being most abundant: central mudminnow and blacknose shiner. The July 2007 fish community consisted of 12 species, with pumpkinseed being far dominant, and two other species quite abundant; hybrid sunfish and largemouth bass. In both 2007 samples, there were two sensitive species, Iowa darter and blacknose shiner. The July 2017 fish community consisted of fewer species (six), with only central mudminnow being abundant. The same two sensitive species, Iowa darter and blacknose shiner, were again present in 2017.

The Community TIV Index scores are shown in Table 16 and individual TIV metrics in Table 17. The DO Community Index scores, both from the older samples and the 2017 sample show evidence of the influence of low DO concentrations. In 2017, the DO Community Index score was at only the 11th percentile for Class 7 streams. The probabilities of the fish communities coming from a DO standard-meeting reach were very low, at or below 11%, and only at 2.9% in 2017. The fish communities were highly skewed toward low-DO tolerance in terms of both the number of Low-DO Intolerant versus Tolerant species numbers and the percentage of Tolerant versus Intolerant individuals.

There is no evidence in the fish data of stress from TSS. No TSS Tolerant species were collected. The communities were much more likely than not to come from TSS standard-meeting waters.

There is no evidence in the fish data of stress from nitrate. There are some Nitrate Intolerant species present (just one in 2017). There are few Nitrate Tolerant species present, and they make up a small percentage of the individuals in the samples, including in 2017.

These analyses provide evidence that the fish community is likely being stressed by inadequate DO levels and not by either elevated nitrate or elevated TSS.

Table 16. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-536 at 07UM004. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within the appropriate stream class (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	Date	Stream class	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO	6/25/2007	7	5.91	6.21/6.13	35	8.8
DO	7/31/2007	7	6.01	6.21/6.13	40	11.2
DO	6/26/2017	7	5.51	6.21/6.13	11	2.9
TSS	6/25/2007	7	11.41	14.99/13.36	95	85.7
TSS	7/31/2007	7	11.40	14.99/13.36	95	85.8
TSS	6/26/2017	7	12.49	14.99/13.36	71	81.0
Nitrate	6/25/2007	7	0.82	2.22/2.06	93	--
Nitrate	7/31/2007	7	1.42	2.22/2.06	70	--
Nitrate	6/26/2017	7	0.96	2.22/2.06	87	--

Table 17. Metrics involving DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM004.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	6/25/2007	0	0	8	4	0.0	89.6
Low DO	7/31/2007	0	0	10	3	0.0	95.3
Low DO	6/26/2017	0	0	5	3	0.0	92.4
TSS	6/25/2007	1	0	0	0	7.5	0.0
TSS	7/31/2007	0	0	0	0	0.0	0.0
TSS	6/26/2017	0	0	0	0	0.0	0.0
Nitrate	6/25/2007	3	1	1	0	41.8	5.9
Nitrate	7/31/2007	2	0	2	0	1.4	7.1
Nitrate	6/26/2017	1	0	2	0	3.8	8.9

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

The SID visit temperature measurements in mid-summer were in the 16-18^{o}C range, which is quite cool. None of the temperature measurements from biological sampling visits, nor the SID work suggested that water temperature would be stressful for warmwater biological communities.

Habitat

The biological sampling location is a straightened reach which has partially naturalized for a significant distance upstream of 40th Street NE. There is a notable difference in the scores between the 2007 assessments and the 2017 assessments, with the more recent ones being significantly lower (poorer). The more recent assessments put the habitat rating well down into the "Poor" category.

The total and sub-component scores are shown in Table 18. Total MSHA scores from 2007 (two) were averaged as were the two 2017 visits to 07UM004. The 2007 average score is in the "Fair" category. The 2017 average score is much lower, and falls into the "Poor" category. It is not known why the habitat score decreased. There does not appear to have been any ditch maintenance between 2007 and 2017, which can homogenize the habitat present. It was noted by one of the MSHA samplers that there was soft sediment up to shin deep throughout the channel.

The poorest-scoring sub-component scores in both time periods, and particularly the 2017 assessments, were "Substrate" and "Channel Morphology". This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles, and fine particulate substrate. These characteristics were all found at 07UM004. The notable part of the assessment that changed from 2007 to 2017 was the bed topography. Deeper pools were found in 2007, while these were gone in 2017. Depth was very uniform in 2017, with undifferentiated channel features (riffles and pools). Substrate was exclusively fine particulate material (sand and silt) in both 2007 and 2017.

Table 18. MSHA scoring for site 07UM004.

MSHA Component	6/2007	7/2007	6/2017	8/2017	2007 Avg.	2017 Avg.	Max. Poss. Score	2007 % of Maximum	2017 % of Maximum
Land Use	5	5	5	2.5	5	3.8	5	100	76.0
Riparian	12	11.5	10	11	11.8	10.5	14	78.6	75.0
Substrate	8	9	6	6	8.5	6	28	31.5	21.4
Cover	12	8	12	13	10.0	12.5	18	58.8	69.4
Channel Morphology	13	20	5	7	16.5	6	35	45.8	17.1
Total MSHA	50	53.5	38	39.5	51.8	38.8	100	51.8 = "Fair"	38.8 = "Poor"

Geomorphology

A review of the photos taken at the biological sampling visits showed the channel to be physically stable. The banks show no signs of erosion. The channel is in the process of naturalizing, as some sinuosity is forming, and there are areas where new floodplain is being created.

Connectivity

The culvert immediately downstream of the site (40th Street NE) is seated somewhat high, such that flow in the culvert is likely quite shallow during baseflow periods. Based on aerial photo review, the channel immediately downstream of the culvert does not show instability (e.g., scour pool), and so the culvert is sized well so as not to create high velocity flow. It was rated as passable for fish. The culvert a mile upstream (25th Street NE) was also rated passable. The culvert father downstream of the biological site (55th Street NE) was not rated, but review of aerial photos suggest it is sized well, and there is a minimal downstream scour pool, so it is likely passable.

Conclusions about stressors

No conclusive stressor was found for the fish impairment in AUID-536. The fish community data is signaling that low DO is a stressor. The DO dataset is not robust, and is missing the critical early morning

data that is required for assessing whether the DO standard is being met. Daytime data shows adequate DO levels. Poor habitat is also a likely contributing cause of the impaired fish community. There was a significant drop in the MSHA score from the score received in 2007. A ditch cleanout would be a possible explanation for such a drop, but it does not look like a cleanout has occurred between 2007 and 2017 - the same minor sinuosity is present in comparing relevant aerial photographs. Connectivity for fish migration has not been fully investigated. The culvert at 55th Street NE should be visited to ensure that it is not a barrier to fish migration, but unless it is relatively new, it would not likely be one, since in 2007 the fish received a passing IBI score. It did not show some of the obvious signs of being a barrier when recent, high resolution aerial photography was reviewed.

Recommendations

More monitoring work is needed in AUID-536 to pin down the stressor(s) of the fish community, particularly for DO. It would be recommended to collect a number of early morning measurements throughout the growing season to see how low the DO gets in the early morning, around 8:00 or even earlier. Ideally, deployment of a continuously-recording Sonde would be beneficial to capture measurements during the pre-dawn time period. If low DO is confirmed, then investigating for the driver of that situation would be recommended. In this land-use setting, it is likely going to be excess nutrients or sediment oxygen demand due to deposition of organic material in the channel. Again, the culvert at 55th Street NE should be visited to verify that it is not a barrier to fish migration.

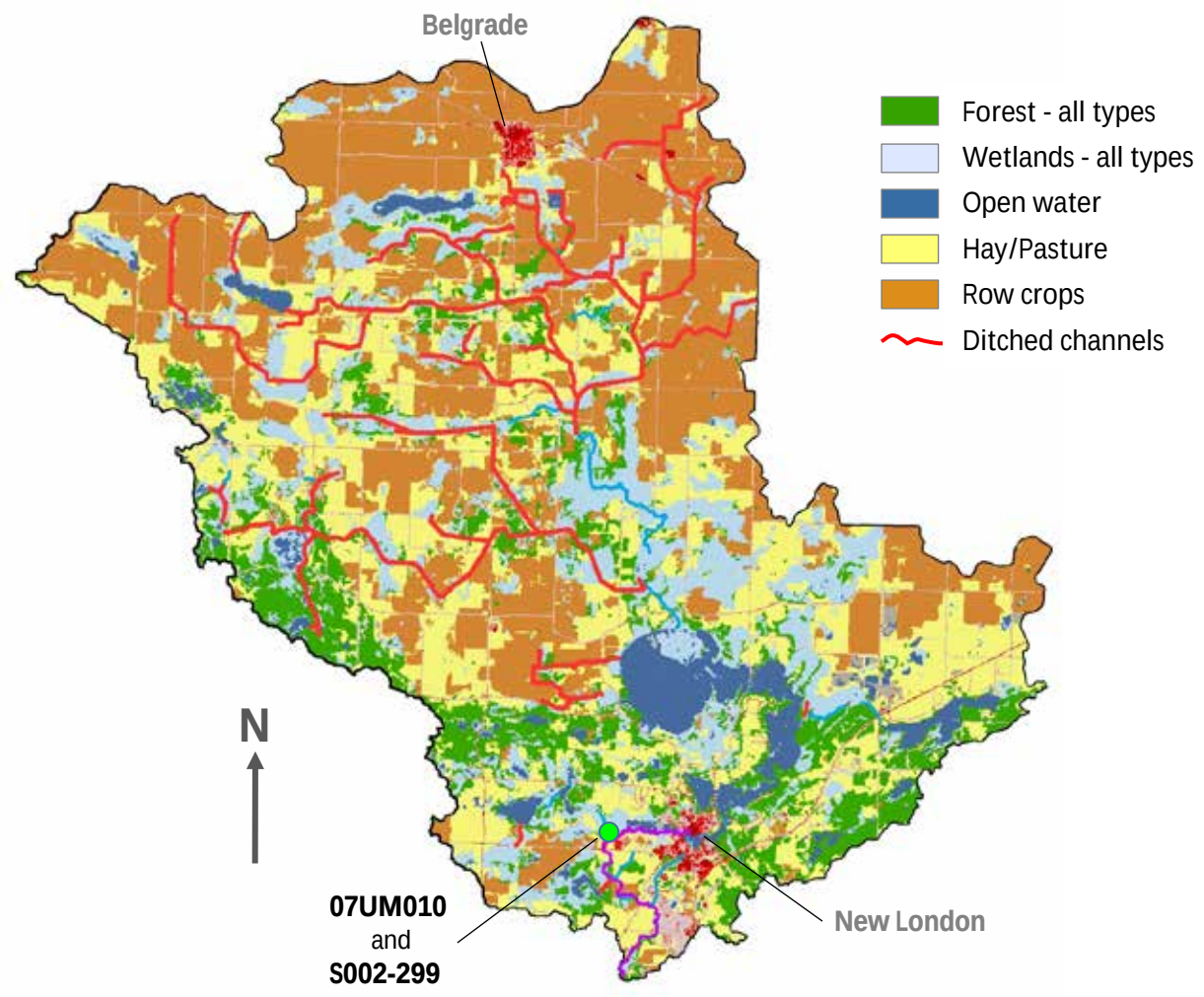
Middle Fork Crow River (AUID 07010204-539)

Impairment: AUID-539 is a fairly short reach, 5.4 miles long, between Monongalia Lake (New London) and Nest Lake. The channel of AUID-539 is an un-altered channel for most of its length, with a short straightened reach in the middle of its run. There is one biological monitoring station (07UM010), which is on a historically-straightened part of the AUID. The UAA process determined that the stream should be classed as General Use, despite the ditching. The AUID was assessed as having an impairment of the fish community. The macroinvertebrate community scored above the Modified and General Use thresholds and is not considered impaired. The Macroinvertebrate Stream Class is 7 (Prairie Streams - GP), the Fish Stream Class is 5 (Northern Streams).

Sub-watershed characteristics

Part of the AUID's length is a natural (un-altered) channel, while some sections were straightened in the early 1900s. Monongalia Lake's outflow point is the upstream boundary of the AUID. One section is the reach containing 07UM010, while there is another historically-straightened section within the reach flowing between 180th Avenue NE and CSAH-9, which can be seen one the 1938 aerial photos. This second section has naturalized to a fair extent, and now has attained some of its meandering pattern over time. Monongalia Lake has too few water quality samples for assessing it with the lake standard. The land use and land cover of the sub-watershed of AUID-539 is shown in Figure 14. Two cities are found in the sub-watershed. In the far headwaters of the Middle Fork Crow River system is Belgrade, and then the city of New London surrounds the upstream end of AUID-539. A golf course and residential area are also found near the channel a bit farther downstream. The majority of the contributing sub-watershed's runoff first passes through Monongalia Lake, prior to entering AUID-539. Upstream of this lake, there are many wetlands, and much agricultural ditching, including through the wetlands. A significant amount of forest is found all along the southern boundary of the sub-watershed. There are no permitted effluent dischargers to the stream system.

Figure 14. Sub-watershed of Middle Fork Crow River AUID-539 showing land use/land cover types (NLCD 2016). AUID-539 is the purple line, in the bottom part of the map.



Data and analyses

Chemistry

A significant data set has been collected over the years from AUID-539 at 07UM010 (S002-299), including conditions during the biological sampling visits in 2007 and 2017, and subsequent SID sampling in 2018 (Table 19). The general conclusion from these data is that these water quality parameters are quite good. The one exception is a single DO measurement that was below the standard. This same conclusion was made for the overall, larger dataset collected by local government staff from S002-299 over the recent years. Nutrients do not appear to be problematic, nor does TSS. The DO data shows good DO levels during the day. The one caveat with the DO assessment is there are almost no early morning measurements, and these are needed to fully assess this parameter, because the daily minimum concentrations of DO occur just after sunrise. So, there is still a possibility that DO issues exist in the AUID.

Table 19. AUID-539 water quality measurements from the IWM biological sampling visits and 2018 SID monitoring at 07UM010 (S002-299). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
6/27/2007	16:09	27.5	12.5	--	404	0.055	< 0.05	< 0.05	7.3	--	3.2
7/26/2007	14:16	26.2	7.0	--	456	0.041	< 0.05	0.07	7.9	--	4.4
6/14/2017	12:20	25.5	9.5	115	392	0.027	--	--	8.1	> 100	8.2
8/9/2017	9:50	21.1	4.61	52	351	--	--	--	7.8	> 100	--
7/12/2018	11:33	27.1	7.27	91.5	392	0.046	< 0.05	--	8.0	--	--

Stressor signals from biology

Fish

The June 2007 fish community consisted of 14 species, with 2 species being highly dominant, bluegill and pumpkinseed. The July 2007 fish community consisted of 13 species, this time with 3 species being dominant, again bluegill and pumpkinseed, with the addition of largemouth bass. The June 2017 community consisted of 21 species, with 2 species being highly dominant, yellow bullhead and yellow perch. Species that are considered "Sensitive" to disturbance were uncommon. In the June 2007 sample only one sensitive individual was caught, a blacknose shiner. No sensitive species were found in the July 2007 sample. More sensitive species were found in the 2017 sample, including; blackchin shiner, hornyhead chub, and a significant number of logperch.

The Community TIV Index scores are shown in Table 20 and individual TIV metrics in Table 21. The fish samples show strong evidence of the influence of low DO concentrations. The DO Community Index scores were lower than the class average at all visits, and all were at or below the 10th percentile of Class 5 streams. The probabilities of the fish communities coming from a DO standard-meeting reach were only between 16 and 21%. The fish communities collected at two 2007 and the June 2017 visits are highly skewed toward low-DO tolerance in terms of both the number of Intolerant versus Tolerant species numbers and the percentage of Tolerant versus Intolerant individuals.

There is little evidence in the fish data of stress from TSS. Few TSS Tolerant species were collected, and two of the community TSS TIV Index scores are better than the Class 5 average. The sampled communities were likely to come from TSS standard-meeting waters.

There is also no evidence in the fish data of stress from nitrate. The Nitrate TIV Index scores for the river are at a high percentile among Class 5 streams. Nitrate Intolerant individuals form a large portion of the sample, and there are more Nitrate Intolerant species present than Nitrate Tolerant ones.

These analyses provide evidence that the fish community is likely being stressed by inadequate DO levels, but not by either elevated TSS or nitrate.

Table 20. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-539 at 07UM010. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter and sample date	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO 6/27/2007	6.32	7.00/7.11	10	21.0
DO 7/26/2007	6.29	7.00/7.11	9	20.1
DO 6/14/2017	6.14	7.00/7.11	6	16.3
TSS 6/27/2007	12.75	13.71/12.96	56	83.4
TSS 7/26/2007	13.17	13.71/12.96	44	81.8
TSS 6/14/2017	14.10	13.71/12.96	29	77.7
Nitrate 6/27/2007	0.95	2.06/2.02	95	--
Nitrate 7/26/2007	0.97	2.06/2.02	95	--
Nitrate 6/14/2017	1.27	2.06/2.02	84	--

Table 21. Metrics involving DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM010.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	6/27/2007	0	0	9	5	0.0	45.6
Low DO	7/26/2007	0	0	10	7	0.0	52.5
Low DO	6/14/2017	0	0	14	9	0.0	76.0
TSS	6/27/2007	1	0	2	1	0.1	0.4
TSS	7/26/2007	1	0	1	1	0.3	0.1
TSS	6/14/2017	3	1	2	2	8.4	0.7
Nitrate	6/27/2007	3	1	2	0	51.3	0.3
Nitrate	7/26/2007	3	1	1	0	43.9	0.6
Nitrate	6/14/2017	5	2	3	0	18.7	12.7

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

The macroinvertebrate community is not assessed as impaired, but a similar analysis was done as for fish regarding oxygen to see if there is some evidence of DO stress in the macroinvertebrate community (Tables 22 and 23). There is little evidence that DO levels are stressful to the macroinvertebrates in 2017. The DO TIV score was well above the class average, and more likely than not that this community would come from a DO standard-meeting site. There is evidence that DO conditions were stressful in 2007, but that was an abnormally dry year with low flow levels.

Table 22. Macroinvertebrate Community DO Tolerance Index scores in AUID-539 at 07UM010. For DO, a higher index score is better. "Percentile" is the rank of the index score within stream Class 7 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO that meets the standard.

Sample date	DO TIV Index	Class avg./median	Percentile in class	Prob. as %
8/7/2007	5.74	6.24/6.36	21	35
8/9/2017	6.90	6.24/6.36	77	66

Table 23. Metrics involving DO tolerance for the sampled macroinvertebrate communities at 07UM010.

Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
8/7/2007	0	0	13	5	0	77.0
8/9/2017	4	2	5	2	3.1	10.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, they show somewhat conflicting signatures for DO stress. The strong signal of DO stress from the fish community is not present in the macroinvertebrate community. The samples were taken about two months apart, and there may have been some factor that changed between these two periods that would explain the differential analyses. There is also the strong influence of lakes in this reach, and it is bookended by lakes, and more likely to have lake fish species, which can have lower DO needs (e.g., the dominance of sunfishes, largemouth bass, bullhead species, and perch, all lake-oriented species) suggests this latter explanation may be correct.

Temperature

Temperature measurements in Table 19 were quite warm. This is likely due to the influence of the lake-sourced water coming from a short distance upstream. It is possible that these warmish temperatures play into the signal of DO stress in the fish community, as their need for oxygen increases as water temperature warms, because of increased metabolism.

Habitat

The biological sampling location is a straightened reach. There is a notable difference in the scores between the 2007 assessments and the 2017 assessments, with the more recent ones being significantly lower (poorer). The more recent assessments put the habitat rating right at the bottom of the scoring range of "Fair".

The total and sub-component scores are shown in table 24. Total MSHA two scores from 2007 were averaged as were the two 2017 visits to 07UM010. The 2007 average score is 66.8, which is essentially at the point of change between the "Fair" and "Good" category ratings. The 2017 average score is much lower, at 45.3, which is essentially right at the point of change from the "Poor" to "Fair" category ratings.

The poorest-scoring sub-component scores in the 2017 assessments were "Substrate" and "Channel Morphology". This is very typical of ditched channels, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles, and fine particulate substrate. These characteristics were all found at 07UM010. Substrate was almost exclusively sand and silt in 2017. A big part of the change in scores over the decade was the apparent change in substrate types to overall finer

material. Gravel was one of the predominant two substrates in 2007, while in 2017, silt had replaced gravel as a predominant substrate.

Table 24. MSHA scoring for site 07UM010.

MSHA Component	6/2007	7/2007	6/2017	8/2017	2007 Avg.	2017 Avg.	Maximum Poss. Score	2007 % of Maximum	2017 % of Maximum
Land Use	5	5	3	3.5	5.0	3.3	5	100	66
Riparian	11	10	9	10	10.5	9.5	14	75	68
Substrate	16.8	17.7	8	6	17.3	7.0	28	62	25
Cover	13	12	12	14	12.5	13.0	18	72	72
Channel	23	20	11	14	21.5	12.5	35	61	36
Total MSHA	68.8	64.7	43	47.5	66.8	45.3	100	66.8 = “Good”	45.3 = “Fair”

Geomorphology

DNR staff conducted a geomorphic assessment of the channel of AUID-539 with the downstream end of the surveyed reach about 925 feet straight-line distance upstream from the old 161st Avenue NE bridge. The survey measurements found that the channel is in stable condition, with low amounts of bank erosion. The channel is slightly incised, but there remains very good access of high waters to spill out onto the floodplain. Stressors due to unstable channel condition (excessive sediment input from bank erosion, unstable and degraded physical habitat, and degraded water quality from suspended bank sediment) are not occurring in AUID-539.

Details from the survey, including measurements, maps, and photos are found in Appendix 3 of this report.

Connectivity

Beginning at the downstream end of the AUID-539, where it enters Nest Lake, there is a set of two former carp barriers immediately above lake. These have been non-functional for a number of years, and DNR has plans to remove them. Due to their non-functioning condition, they should not have been a cause of the impairment in 2017. There are four road crossings between Nest Lake and the biological reach. The lower three are bridges, and thus not barriers. The fourth, at the downstream end of the biological reach (180th Avenue NE) has a pair of box culverts. Photos of the culverts taken during the fish sampling show them to be passable for fish. The Monongalia Lake dam is the top end of the AUID. Upstream dams have a lesser effect on fish communities in downstream reaches than above the dam as long as there is connectivity to larger streams or a lake downstream, and in this case there is. Blockage of connectivity is not a stressor to the fish community in AUID-539.

Conclusions about stressors

The fish community data strongly signals that low DO is a stressor in AUID-539. The 2007 macroinvertebrate sample also showed strong influence of low DO, while the 2017 sample did not. The DO data, while quite extensive, is missing the critical early morning data that is required for assessing whether the DO standard is being met, though the one mid-morning sample showed below-standard DO concentration. Daytime data shows adequate DO levels. It also appears as though habitat has been degraded to some extent, based on comparison of older and recent MSHA surveys, with the addition of bedded sediment. Measured nutrient levels do not appear problematic, however by mid-summer, there are abnormal amounts of filamentous algae (Photo 3).

There are no permitted pollutant dischargers active in this sub-watershed.

Photo 3. August 9, 2017 photo at the downstream end of the biological site reach, showing extensive mats of filamentous algae that develops over the summer in AUID-539.

Recommendations

More monitoring work is needed in AUID-539 to pin down the stressor(s) of the fish community. Data that has been collected suggests that low DO may be the issue, and thus it would be recommended to collect a number of early morning measurements throughout the growing season to see how low the DO gets in the pre-dawn time period. Ideally, a Sonde deployment would be a helpful way to see the round-the-clock fluctuation in the DO concentrations. If low DO is confirmed, then the driver of that situation should be looked for. It is likely going to be excess nutrients or sediment oxygen demand due to deposition in the channel of organic material. The water in the river is quite warm, and encouragement of woody plants, or intentional planting of trees to provide shade to the channel would have some benefit to DO levels, since cooler water holds more oxygen. There is a significant amount of impervious surface near the channel given that the city of New London surrounds part of the AUID. Reduction of urban runoff contributions directly to the river will improve many aspects of the ecological health of the river.

Tributary to Lake Koronis (AUID 07010204-553)

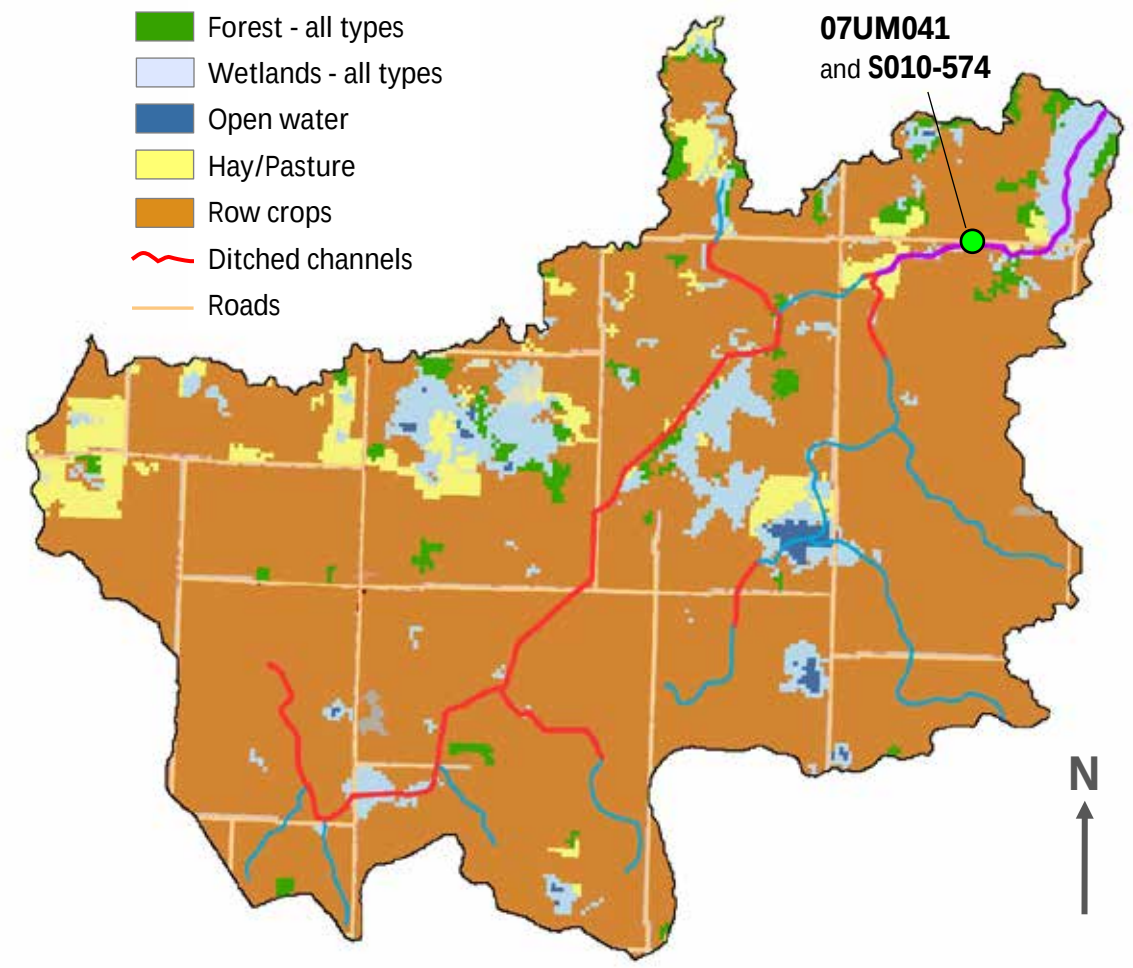
Impairment: AUID-553 is a 1.5 mile long reach, the downstream portion of a creek that flows into the southeastern portion of Lake Koronis. The UAA process determined that the stream should be classed as Modified Use. AUID-553 has one monitoring site, 07UM041. The AUID was assessed as having an impairment to the fish community at site 07UM041, located upstream of CR-20, about 5 miles south of Paynesville. The macroinvertebrate community scored above the Modified and General Use thresholds and is not impaired. The Macroinvertebrate Stream Class is 7, the Fish Stream Class is 7.

Sub-watershed characteristics

About half on the AUID's length is a wetland channel, and the upper half, which is a normal upland stream, is about half ditched/straightened. The rest of the system upstream of the AUID is almost all

agricultural ditch. The land use and land cover of the sub-watershed of AUID-553 is shown in Figure 15. The land use is predominantly row crop agriculture. There are no cities or towns within the sub-watershed. There is little forest land and most of it is associated with lake or wetland shoreland, or residences. There are no permitted effluent dischargers to the stream system.

Figure 15. Sub-watershed of AUID-553 showing land use/land cover types (NLCD 2016). The stream system flows from lower left to upper right. AUID-553 is the purple line.



Data and analyses

Chemistry

A significant data set has been collected from AUID-553 at 07UM041 (S010-574), including conditions during the biological sampling in 2017, and subsequent SID sampling in 2018 and 2019 (Table 25).

Table 25. AUID-553 water quality measurements from the IWM biological sampling visits and 2018-2019 SID monitoring at 07UM041 (S010-574). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS	TSVS
7/16/2007	17:40	24.3	7.3	--	701	0.090	3.4	0.05	8.4	--	14	--
6/26/2017	16:32	17.7	9.0	95.0	713	0.151	7.1	0.10	8.1	38	30	--
8/9/2017	11:48	16.5	9.7	99.0	653	--	--	--	8.1	> 100	--	--
4/26/2019	14:25	--	--	--	--	0.092	3.5	0.05	--	--	14	4.8
5/15/2019	12:30	14.0	11.4	111.0	694	0.064	3.9	0.05	8.1	--	8.8	2.8
5/29/2019	13:45	14.2	10.2	99.6	672	--	--	--	7.7	--	--	--
6/3/2019	12:00	15.4	10.1	100.8	690	--	--	--	8.0	--	--	--
6/10/2019	13:10	16.3	9.3	95.4	701	0.097	4.9	0.05	7.9	--	14	4.4
6/17/2019	12:20	15.7	9.4	94.6	711	--	--	--	7.96	--	--	--
6/24/2019	11:00	15.7	8.8	89.1	652	--	--	--	7.82	--	--	--
6/27/2019	14:00	--	--	--	--	0.496	4.7	0.14	--	--	170	38
7/22/2019	13:15	18.4	8.8	94.4	747	--	--	--	--	--	--	--
8/6/2019	9:20	17.2	9.1	94.5	761	--	--	--	--	--	--	--

Nutrients - phosphorus

Phosphorus values are often just below the Central Region River Nutrient standard, though a sample significantly below, and two samples significantly above that standard were collected. The June 27, 2019, sample that had a much higher TP level than the others was collected on a day where a nearby rain gage recorded approximately 0.75 inches of rainfall a few hours before the sample collection and flow levels were high. Suspended solids also were extremely high (Photo 4), and the additional phosphorus was likely both sediment-bound, and due to the elevated organic particulate concentration measured. It isn't known how much of the suspended material was washed in from the current rain, or if it stirred up sediment already in the river due to increased flow volumes.

Photo 4. Stream conditions in AUID-553 on June 27, 2019, when samples found very high TP and TSS levels.

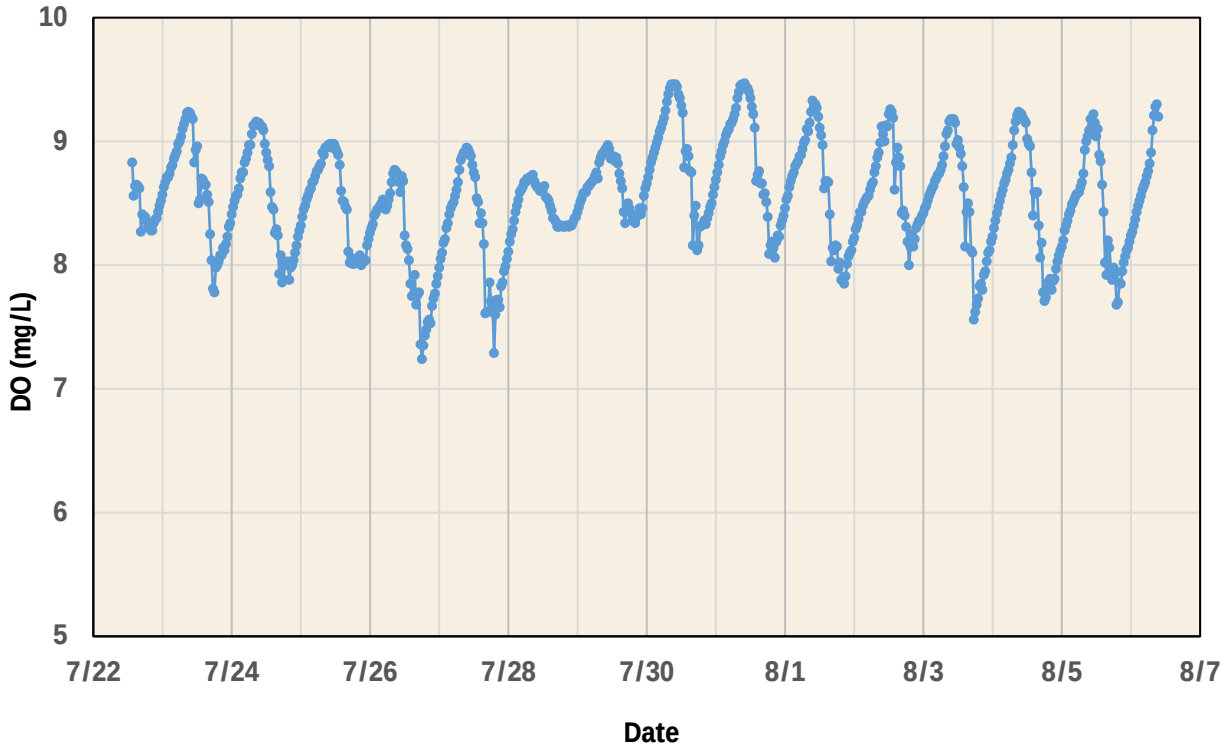
Nutrients - nitrate and ammonia

Nitrate values are elevated above natural levels, and may reach levels that are toxic to some aquatic organisms. Ammonia values were typically very low, and not at problematic levels.

Dissolved oxygen

The DO levels at all sampling visits were well above the standard, though not excessively so, and lower than levels that would indicate eutrophication. DO percent-saturation is generally near 100%, a healthy level, suggesting that excess plant/algae growth is not occurring, and that eutrophication is not occurring in the creek. During late July and early August of 2019, a Sonde was deployed at the biological monitoring site. This date range corresponds to the period of summer when DO is likely to be at its lowest. DO was at a very healthy level at all times of the day, and the daily flux of DO was quite low, less than 1.5 mg/L (Figure 16). Both of those pieces of data are evidence that DO is not a stressor in AUID-553.

Figure 16. DO readings from a Sonde deployment, 7/22/2019 - 8/6/2019 at S010-574 (07UM041). The instrument's time setting was off - the peaks should be occurring in late afternoon, and the minimums at about sunrise.



Transparency and suspended solids

TSS appears to often be near the Central Region standard. A large percentage (70%) of the makeup of the suspended solids is mineral material (soil) versus organic particulates. A large TSS dataset has been collected by local resource managers and the large majority of samples meet the standard (Figure 17). Occasional exceedances of the standard do occur, probably related to rain events. The very elevated level on June 27, 2019, was a day significant rain occurred (see Photo 5). Another large dataset has been collected using the Secchi Tube to measure transparency. That data shows the stream to be either very clear, or at least moderately cloudy (Figure 18). Interestingly, there aren't many measurements that showed the clarity to be only slightly cloudy. This might be again explained by the influence of rainfall events. The chemistry data reviewer during the assessment of the NFC streams noted that TSS and Secchi tube measurements were inconclusive as to meeting the standard, and that both are near the impairment threshold.

Figure 17. Numbers of TSS samples in various ranges of concentration, collected from various years between 1991 and 2015 at S001-942 (crossing of 390th Street), a short distance downstream of the biological monitoring site. The red line depicts the Central Region TSS Standard (= 30 mg/L).

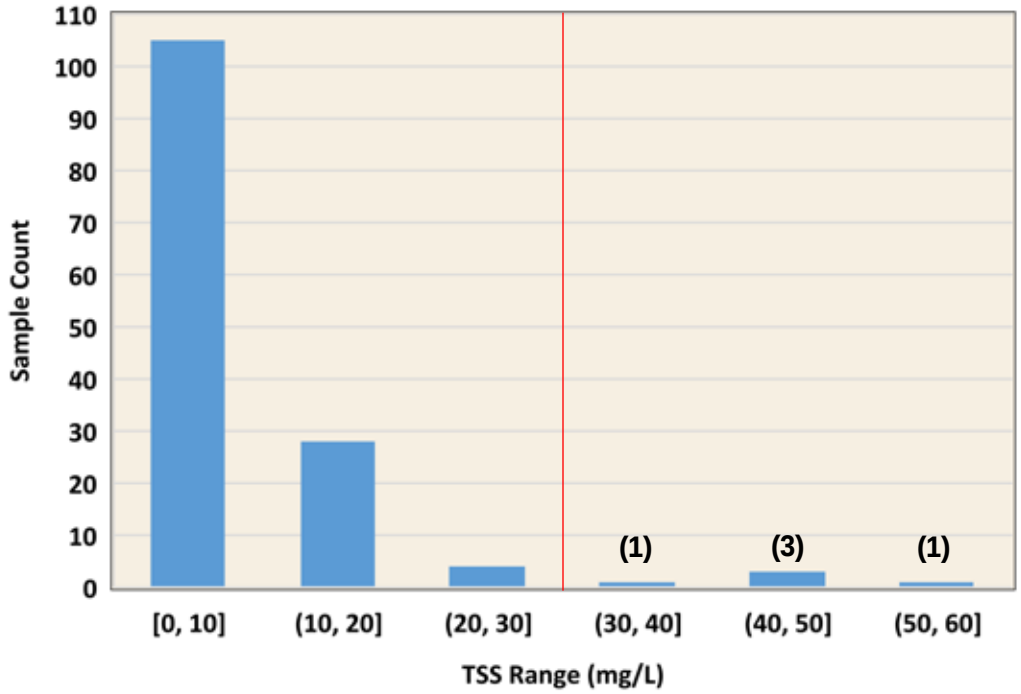
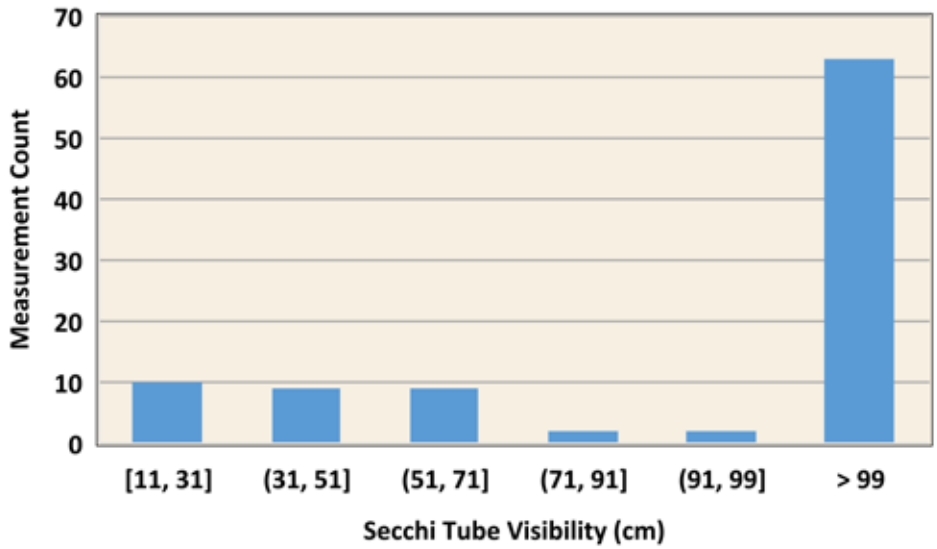


Figure 18. Secchi tube measurements (only including those using the 100 cm tube) from S001-942, from 2008 - 2018.



Conductivity

Specific conductivity was in a moderate range during biological monitoring visits, and non-problematic for the biological communities. The deployed Sonde used for continuous DO measurements also collects specific conductivity. There were numerous very short spikes in single measurements (some above 2000 µS/cm) that may have been due to probe malfunction. These would be very high conductivity levels. Some days had several, some had one, and others none. The non-spike measurements were in the range that were found during the biological measurements (700-730 µS/cm). There are no permitted effluent dischargers to AUID-553. If future monitoring finds similar high levels, this should be investigated further.

Stressor signals from biology

Fish

The 2007 fish community consisted of only four species, with northern pike and central mudminnow being dominant in numbers of individuals. The other species were white sucker and a lone creek chub. The 2017 sample had even fewer species, collecting only central mudminnow and fathead minnow, the former being more numerous. Both of these species are extremely tolerant to habitat conditions. Including both samples, all of the species captured are ubiquitous ones in Minnesota with fairly non-specific habitat needs, and are also able to deal with low DO conditions. Both samples had quite low numbers of individuals relative to the range found in typical stream samples.

The Community TIV Index scores are shown in Table 26 and individual TIV metrics in Table 27. The fish samples show some evidence of the influence of low DO concentrations. The DO Community Index scores were lower than the class average at both visits, and one was at only the 13th percentile of Class 7 streams. The highest probability of the fish communities coming from a DO standard-meeting reach was only 13%. The fish communities collected at the July 2007 and June 2017 visits are highly skewed toward low-DO tolerance in terms of the percentage of Tolerant versus Intolerant individuals.

There is little evidence in the fish data of stress from TSS. No TSS Tolerant species were collected, and the community TSS TIV Index scores are average or better than average, though both are below the class median score. The communities were highly likely to come from TSS standard-meeting waters.

The Community Nitrate TIV score in both 2007 and 2017 were significantly better than average. The analysis of prominence of tolerant and intolerant shows modest evidence that nitrate could be a stressor, as nitrate Tolerant individuals form a moderate portion of the sample, and there are no nitrate Intolerant species present.

These analyses provide evidence that the fish community may be stressed by inadequate DO levels, and elevated nitrate, but probably not by elevated TSS.

Table 26. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-553 at 07UM041. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 7 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter (sample year)	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO (2007)	6.07	6.21/6.16	44	13.2
DO (2017)	5.54	6.21/6.16	13	3.2
TSS (2007)	13.43	14.99/13.36	49	80.0
TSS (2017)	15.01	14.99/13.36	32	65.6
Nitrate (2007)	1.59	2.22/2.06	64	--
Nitrate (2017)	1.52	2.22/2.06	67	--

Table 27. Metrics involving DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM041.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/16/2007	0	0	2	1	0.0	82.6
Low DO	6/26/2017	0	0	2	2	0.0	100
TSS	7/16/2007	0	0	0	0	0.0	0.0
TSS	6/26/2017	0	0	0	0	0.0	0.0
Nitrate	7/16/2007	0	0	2	0	0.0	17.4
Nitrate	6/26/2017	0	0	1	0	0.0	25.8

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

The current assessment is that the macroinvertebrates are not impaired. The newer sample's Index of Biological Integrity (IBI) score was good, while the "expired" sample from 2007 scored quite a bit lower. In the 2007 sample, just over 75% of the taxa present were Tolerant, and no Intolerant taxa were present. The 2017 sample was quite similar, with 70% of the taxa being Tolerant, and again no Intolerant taxa were present. In 2007, the community had three dominant taxa, the amphipod *Hyalella azteca,* the snail *Physa*, and the beetle *Dubiraphia*, in that order. In 2017, there were also three dominant taxa, but all were different than in 2007, with the midge *Polypedilum*, the snail *Physella*, and the mayfly *Iswaeon* the top three. The 2017 sample had almost twice as many Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa as in 2007, likely the cause of the better IBI score in 2017. There were quite a number of wetland-oriented taxa in the 2007 sample, and fewer of these taxa in 2017.

The Community TIV Index scores are shown in Table 28 and individual TIV metrics in Table 29. The two DO TIV Index scores are quite different, with the 2017 sample being much better. Both scores are better than the class average, and the 2017 sample sits at the 84th percentile of Class 7 streams. The probability of the 2017 sampled community coming from a DO-meeting site is fairly good. The 2017 community is somewhat skewed toward taxa that are low-DO Intolerant, both in terms of the Intolerant/Tolerant taxa present and the percentage of individuals in the samples. The more recent macroinvertebrate community does not seem to show stress from inadequate DO concentrations.

The TSS TIV Index scores are better than the class average, though it is still only at the mid percentiles. The probability of the community coming from a standard-meeting site is poor for both 2007 and 2017. The community is quite skewed toward TSS Tolerant taxa, both in terms of the Intolerant/Tolerant taxa present and the percentage of individuals in the samples. With these analyses taken together, it appears that TSS is a contributing stressor to the macroinvertebrate community.

The Nitrate TIV Index scored better than the class average in 2007, but much poorer than that average in 2017, where it is at only the 21st percentile among Class 7 streams. Conditional probability is not available for nitrate. The macroinvertebrate community is highly skewed toward Nitrate Tolerant taxa, both in terms of number of species, as well as percent of individuals. There is some evidence that nitrate concentrations are influencing the macroinvertebrate community, and thus it appears that nitrate is a stressor, even if not to the point of causing impairment.

Table 28. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores at 07UM041 from sample collected on 8/8/2007. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 7 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meets the appropriate standard.

Parameter (sample year)	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO (2007)	6.45	6.24/6.36	56	54
DO (2017)	7.05	6.24/6.36	84	70
TSS (2007)	16.50	16.88/16.55	51	21
TSS (2017)	15.92	16.88/16.55	59	25
Nitrate (2007)	3.17	3.47/3.42	62	--
Nitrate (2017)	4.11	3.47/3.42	21	--

Table 29. Macroinvertebrate metrics related to DO, TSS, and nitrate at 07UM041 utilizing MPCA species tolerance values.

Parameter (sample year)	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
DO (2007)	5	2	11	4	3.6	42.8
DO (2017)	9	4	4	1	7.1	1.9
TSS (2007)	0	0	11	4	0.0	32.5
TSS (2017)	3	0	8	6	8.6	38.3
Nitrate (2007)	2	0	22	12	3.3	50.0
Nitrate (2017)	3	1	27	16	5.2	71.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, among the three parameters shown above, there is contradictory evidence that low DO levels and elevated TSS are stressing the communities. One situation that can lead to contradictory findings between fish and macroinvertebrates is when the fish are being negatively impacted by a migration barrier. This will be discussed below. Nitrate levels show a similar influence (negative) on both communities.

Temperature

Temperature measurements in Table 25 showed none that would be problematic for the fish community. In fact, temperatures are generally quite cool.

Habitat

Habitat is relatively poor in the channelized AUID, based on MSHA metrics, and thus it has been placed into the Modified Use TALU category. The biological sampling location is a straightened reach, and much of the stream system upstream is ditched/straightened.

The total and sub-component scores are shown in Table 30. Total MSHA scores were averaged for the three visits to 07UM041, resulting in a score of 37.5, which is at the well down into the range of the "Poor" category. The poorest-scoring sub-component scores were "Surrounding Land Use", "Channel Morphology" and "Substrate", particularly the first two. This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles, and fine particulate substrate. These characteristics were all found at 07UM041. Substrate was almost exclusively sand and silt (Photo 5).

Table 30. MSHA scoring for site 07UM041.

MSHA Component	7/2007	6/2017	8/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	0	1.5	2.5	1.33	5	26.6
Riparian	10	7	9.5	8.83	14	63.0
Substrate	8	13	15.1	12.03	28	43.0
Cover	14	6	6	8.67	18	48.2
Channel Morphology	12	2	6	6.67	35	19.1
Total MSHA Score	44	29.5	39.1	37.5	100	37.5 = "Poor"

Photo 5. Substrate at 07UM041 is almost exclusively sand. Excess deposition of fine material in the middle of the channel, as here, suggests unnaturally high sediment loading to the stream.

Hydrology

There has been substantial modification of the natural hydrology of the sub-watershed, both due to large-scale vegetation cover changes (forest to cultivated fields), as well as changes to the channel that reduced sinuosity and thus speed flows through the system. Channel size was also likely increased when the ditching was done originally.

Geomorphology

No geomorphology fieldwork was conducted on AUID-553. Some recent new ditching occurred about 2007 just downstream of the biological reach, removing the sinuosity of the previously natural channel (Figure 19).

Figure 19. The channel near 07UM041 was recently straightened (between the yellow squares) as shown in this 2008 aerial photo.

Connectivity

There are two carp barriers downstream of the bio site, one at the head of the wetland that leads to Lake Koronis (390th Street), and one at the downstream end of the wetland immediately upstream of Lake Koronis (CR-20). On the upstream side of 390th Street, there is substantial sediment deposit that leads to the channel being braided in the cattails (Photos 7 (aerial) and 8). These prevent larger species from migrating up into the stream from Lake Koronis in the spring. In addition, the 2015 aerial photography shows a beaver dam about a half mile downstream of 07UM041, which is another barrier, though it is not known if it was functional in 2017 (Photo 7). Lastly, the large wetland near Lake Koronis may be a barrier in itself to some species as there are places in the wetland where a distinct channel disappears.

As the channel of AUID-553 is small, there is likely insufficient overwintering habitat in the stream, with the only available larger downstream habitat being the wetland, where winter DO levels are likely very low. This may well explain why the fish community at 07UM041 is quite low DO tolerant, as these are the only species that can survive winter, as many species are prohibited from re-establishing populations by migrating up from Lake Koronis.

Photo 6. AUID-553 at the 390th Street crossing and upstream wetland. The yellow box is the area photographed in Photo 7. The yellow arrows point to the beaver dam.

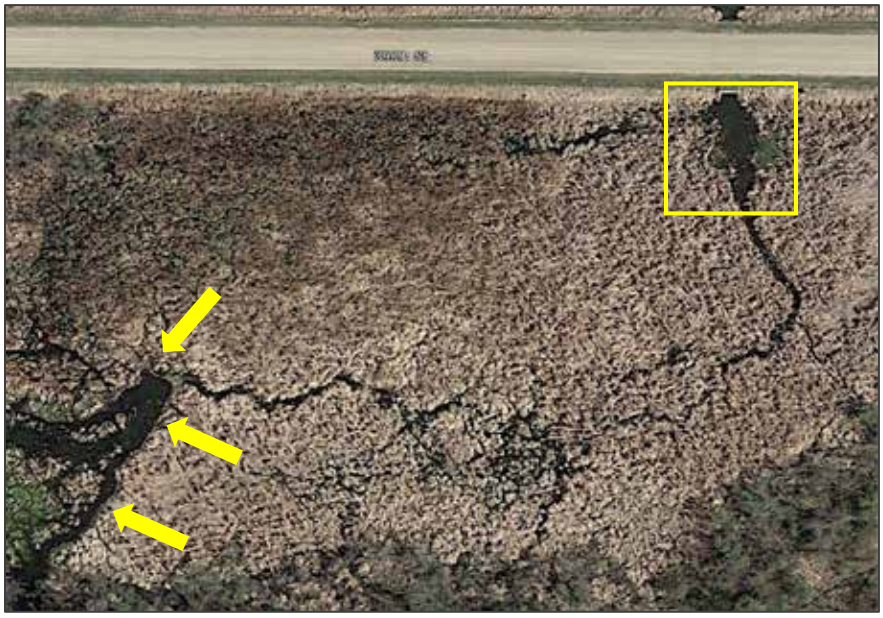


Photo 7. Deep sediment deposit on the upstream side of 390th Street. The water in the center of the photo is only about an inch deep.

Conclusions about stressors

Poor connectivity along AUID-553, particularly in the lower portion, is the apparent stressor creating the fish impairment. This situation confounds the use of assessing the community for stressors. There is some evidence that nitrate could be a stressor. Measured nitrate concentrations are elevated. Though the macroinvertebrates community is not impaired, it shows strong evidence of a negative influence of nitrate. Recent ditching of a natural section of the stream just below the biological reach has harmed habitat. Dissolved oxygen appears to be at relatively healthy concentrations in summer. TSS shows good evidence of being a stressor to the macroinvertebrate community. Measured TSS concentrations are occasionally above the standard.

Recommendations

The primary apparent stressor to AUID-553 is connectivity. Some parts of this stressor are intentional (the carp barriers) and thus there is likely no realistic correction. These barriers are protecting the Lake Koronis ecosystem, and the lake is a much more valued water resource to the local citizenry than is this small ditch system as a recreational resource. It would however be wise to utilize BMPs for water quality in this stream/ditch system's landscape since its water ends up in Lake Koronis.

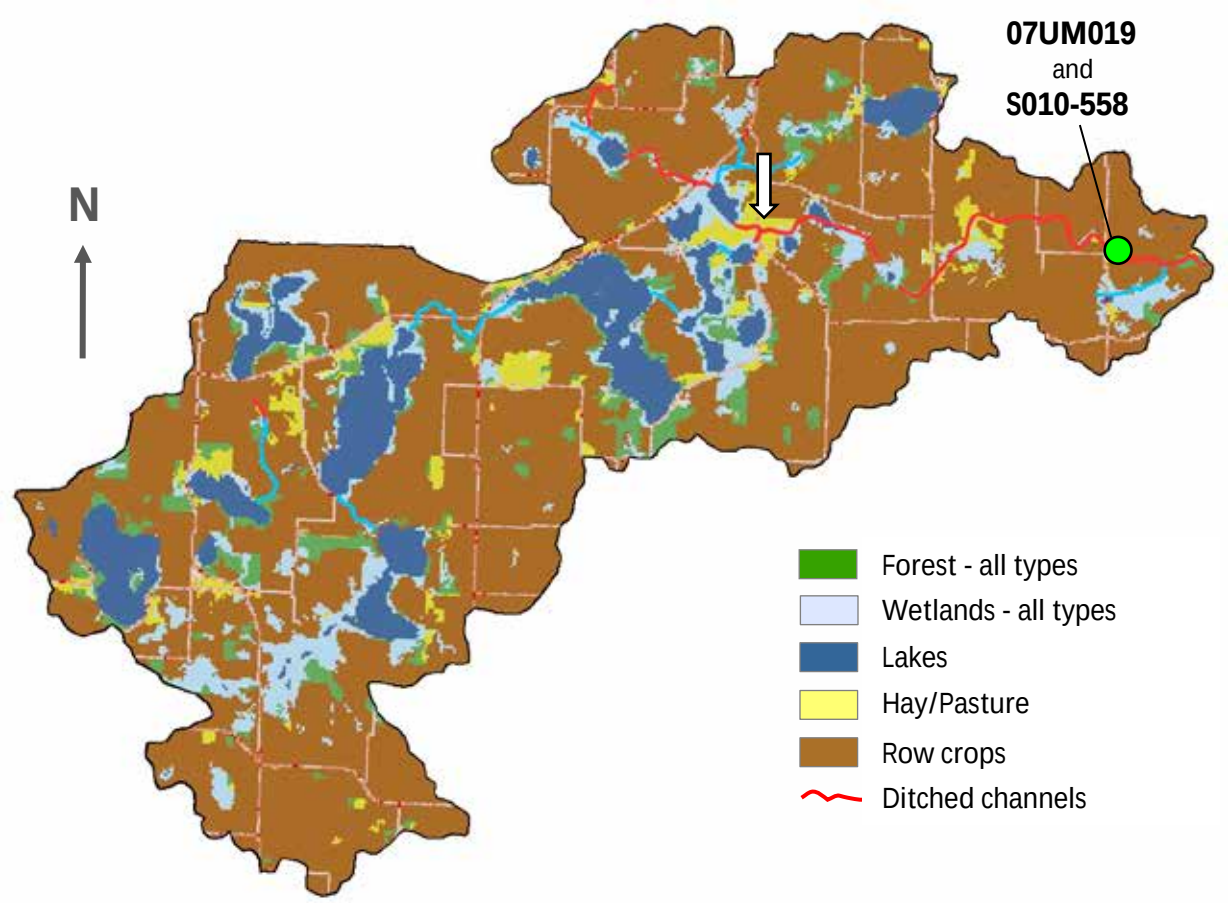
Silver Creek (AUID 07010204-557)

Impairment: The creek is ditched, and the TALU category of the stream is Modified Use. The creek was assessed as having an impaired macroinvertebrate community at site 07UM019, located downstream of the crossing of CR-15, 5 miles southeast of Dassel. The fish community met the passing Modified Use threshold. The Macroinvertebrate Stream Class is 5 (Southern Streams - RR), the Fish Stream Class is 6 (Northern Headwaters).

Sub-watershed characteristics

AUID-557 flows west to east in the northeastern part of the subwatershed. Tributary flow enters from the south east, and flows through several lakes before reaching AUID-557, which begins where this southern tributary ends. The land use and land cover of the sub-watershed of AUID-557 is shown in Figure 20. The land use is predominantly row crop agriculture. A number of lakes and associated wetlands occupy a significant amount of the sub-watershed area. There is little forest land. Most of it is associated with lake or wetland shoreland. There are no cities or towns within the sub-watershed, and there are no permitted wastewater dischargers either directly to AUID-557, or anywhere in the full sub-watershed.

Figure 20. Sub-watershed of AUID-557 showing land use/land cover types (NLCD, 2016). The white arrow points to the upstream end of AUID-557.



Data and analyses

Chemistry

A significant data set has been collected from AUID-557 at 07UM019 (S010-558), including conditions during the biological sampling in 2017, and subsequent SID sampling in 2018 and 2019 (Table 31). In addition to the instantaneous measurements, a continuously-measuring Sonde was deployed in Silver Creek in late July/early August of 2019.

Table 31. AUID-557 water quality measurements from the IWM biological sampling visits and 2018-2019 SID monitoring at 07UM019 (S010-558). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	Turb. (NTU)	TSS
7/18/2007	12:20	21.0	0.85	--	566	0.533	0.05	0.330	7.65	--	8.71	23
6/13/2017	8:46	20.6	3.88	43	394	0.254	0.93	0.347	7.37	79	--	7.7
8/16/2017	15:19	20.3	4.37	48	410	--	--	--	7.45	80	--	--
5/16/2018	11:30	18.6	7.42	79.4	406	0.279	0.28	--	7.67	--	--	--
6/12/2018	9:03	17.0	4.40	45.5	454	0.254	2.80	--	7.42	--	--	--
7/12/2018	11:45	26.5	3.17	39.5	437	--	--	--	7.27	--	--	--
7/17/2018	12:00	24.6	3.04	36.5	394	0.419	0.16	--	7.48	--	--	--
8/8/2018	12:40	23.9	3.38	40.1	357	0.362	0.25	--	7.50	--	--	--
9/27/2018	12:04	13.7	7.76	74.9	383	0.239	0.54	--	7.52	--	--	--
4/26/2019	12:45	--	--	--	--	0.174	0.55	0.09	--	--	--	--
5/15/2019	10:10	16.0	6.18	62.7	399	0.182	0.42	0.05	7.43	--	--	--
5/29/2019	11:15	16.0	6.19	62.8	413	--	--	--	7.28	--	--	--
6/3/2019	14:10	21.5	6.80	77.1	388	--	--	--	7.58	--	--	--
6/10/2019	11:00	19.5	4.72	51.5	385	0.243	0.28	0.05	7.30	--	--	--
6/17/2019	10:15	20.2	4.31	47.5	392	--	--	--	7.33	--	--	--
6/24/2019	13:00	19.4	4.08	44.3	375	--	--	--	7.26	--	--	--
6/27/2019	11:35	--	--	--	--	0.367	0.66	0.09	--	--	--	--
7/18/2019	11:30	26.0	3.89	48.0	434	0.356	0.32	0.21	7.50	--	--	--
8/6/2019	14:25	25.9	6.14	76.1	424	--	--	--	8.00	--	--	--
8/14/2019	12:10	22.0	5.33	61.2	428	0.141	0.05	0.07	7.97	--	--	--
8/20/2019	14:10	21.9	5.61	64.3	432	--	--	--	7.72	--	--	--
8/28/2019	11:10	17.3	5.52	58.1	414	--	--	--	--	--	--	--
9/9/2019	12:20	16.6	5.34	54.7	397	--	--	--	7.90	--	--	--
AVERAGE	**--**	**20.40**	**4.88**	**55.76**	**413.4**	**0.293**	**0.561**	**0.155**	**7.53**	**--**	**--**	**--**

Nutrients - phosphorus

Phosphorus values are very high, much greater than the River Nutrient Standard - Central, often double or triple the standard.

Nutrients - nitrate and ammonia

Nitrate values were extremely low at the 2007 visit, and substantially higher at the June 2017 visit, though the nitrate is still relatively low compared to some other agricultural parts of Minnesota. The SID dataset found relatively low nitrate levels, except for the June 16, 2018, visit. The first half of June is typically when the highest nitrate is found in streams flowing in agricultural landscapes. More early June sampling would be beneficial to determine if high spikes in concentration occur, which could be at levels toxic to especially the macroinvertebrate community. Ammonia values were at levels that would not produce un-ionized ammonia levels above the state standard.

Dissolved oxygen

The DO levels at all three biological sampling visits were below the standard, particularly the 2007 visit, where DO was exceptionally low. Even the afternoon samples are only a bit above the standard. The instantaneous data showed numerous instances of DO well below the standard, even in mid-day periods, and over a three-year period (Table 31).

DO percent-saturation is always well below 100% (Figure 21), which would suggest that excess plant/algae growth is not occurring at significant levels (verified by site photos from biological sampling visits), and that eutrophication is not occurring in the creek. Seventy-five percent of the measurements were below 64% DO saturation, and the maximum was 79.4%. Eutrophic streams are often well above 100% saturation during mid-day periods. However, aerial photos clearly show that there is excessive plant growth (possibly duckweed) in some open-canopy locations of the AUID (Figure 22). There are parts of the riparian corridor which are forested with mature trees that provide much shade, and these might be places where the excessive oxygen produced in the open areas dissipates back into the atmosphere, preventing the high mid-day DO readings typically found in streams experiencing eutrophication. Another possibility is that the sediment oxygen demand (SOD) is very high and decomposition of accumulated organic material is sapping DO from the water column at high rates.

Figure 21. Box and whisker plot showing the distribution of the measurements of DO percent saturation at 07UM019 (S010-558). The horizontal box lines are the 25th, 50th, and 75th percentiles, and the "x" is the mean (55.8% DO saturation).

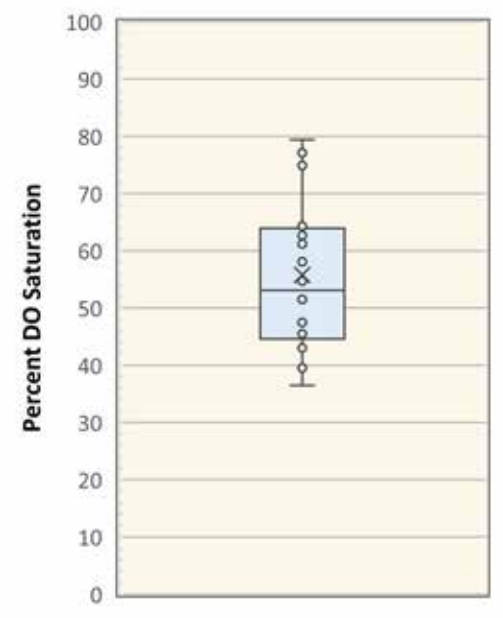


Figure 22. Extremely abundant aquatic plant growth can be seen in the ditched channel about one mile upstream from 07UM019, as it flows through a wetland/grassland area, exacerbated by the wider than natural channel allowing for high sun exposure, along with extra nutrients from landscape runoff.

Transparency and suspended solids

Few TSS samples have been collected. The 2007 sample was high, above the Central Minnesota TSS standard. The 2017 sample was much lower, and below the standard. There have been eight Secchi tube readings in the last 10 years, and all met the standard.

Conductivity

Specific conductivity was in a moderate range (generally 350 - 450 µS/cm), and non-problematic for the biological communities.

Stressor signals from biology

Fish

The 2007 fish community consisted of only tolerant species. The sample was dominated by black bullhead. The second and third most abundant species were green sunfish and common carp. The 2017 fish community again consisted of tolerant species, except spottail shiner, with the sample this time dominated by fathead minnow, followed by green sunfish and central mudminnow. These are ubiquitous species in Minnesota with fairly non-specific habitat needs, and are also able to deal with low DO conditions.

The Community TIV Index scores are shown in Table 32 and individual TIV metrics in Table 33. The fish samples show strong evidence of the influence of low DO concentrations. The DO TIV Index scores were low at both visits, much below the Class 6 average. The probabilities of the fish communities collected from the two visits coming from a DO standard-meeting reach was only 11.4% and 18.3%. The fish communities collected at the July 2007 and June 2017 visits are highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species numbers, and the percentage of Tolerant versus Intolerant individuals. The fish community at 07UM019 is highly unlikely to come from a site with standard-meeting DO.

There is some evidence in the fish data of stress from TSS, though it is somewhat conflicting. The TSS TIV Index score is poor; both samples are at the 5th percentile or worse among Class 6 streams. The probabilities of the fish communities coming from a TSS standard-meeting reach was only 12.8% and 19.7%. However, there was only one TSS Tolerant species present, and the number of TSS Tolerant individuals was quite low, especially in 2017. It is possible that this TSS assessment is confounded by the effect on the community of low DO.

The Nitrate TIV Index score was poorer than the Class 6 average. The community was also fairly skewed toward tolerant species in terms of both the species present and the percentage of individuals. Thus, there is some evidence in the fish data of stress from elevated nitrate levels.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels, nitrate, and possibly TSS.

Table 32. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-557 at 07UM019. For DO, a higher index score is better, while for TSS and Nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile in class	Prob. as %
7/18/2007	DO	6.01	6.61/6.68	20	11.4
6/13/2017	DO	6.21	6.61/6.68	28	18.3
7/18/2007	TSS	23.04	14.44/13.59	2	12.8
6/13/2017	TSS	21.44	14.44/13.59	5	19.7
7/18/2007	Nitrate	2.57	2.45/2.46	46	--
6/13/2017	Nitrate	2.89	2.45/2.46	33	--

Table 33. Metrics involving DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM019.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/18/2007	0	0	8	6	0	86.4
Low DO	6/13/2017	0	0	7	3	0	97.4
TSS	7/18/2007	0	0	1	0	0	9.3
TSS	6/13/2017	0	0	1	0	0	1.9
Nitrate	7/18/2007	1	0	4	0	1.4	35.0
Nitrate	6/13/2017	2	1	5	0	8.3	75.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

There has only been one macroinvertebrate sample collected in AUID-557, on August 16, 2017. The community was dominated by four taxa, in the following order: *Hydropsyche betteni* (a filtering caddisfly), Pisidiidae (fingernail clams), Trepaxonemata (flatworms) and *Polypedilum* (a midge). Aside from the *Hydropsyche* caddisfly, the other taxa should not be dominant in a healthy stream. The taxa list contained few taxa that require higher levels of DO.

The Community TIV Index scores are shown in Table 34 and individual TIV metrics in Table 35. The DO TIV Index is far poorer than average, and is only at the 3rd percentile of Class 5 streams. The probability

of this community coming from a DO standard-meeting site is quite low. There are no low-DO Intolerant taxa present. The number of low-DO Tolerant taxa is small, and the number of individuals were less than 1% of the sample, which is somewhat unexpected given the low DO Index score. This is due to a large number of several taxa that do not have a DO tolerance assignment, which substantially lowers the percentage. Several of these unassigned taxa can tolerate low DO. So, this low percentage should not be considered representative of this sample.

The TSS TIV Index score was better than the Class 5 Central TSS average. Yet, the community is highly skewed toward TSS Tolerant taxa, both in terms of number of species, as well as percent of individuals. Again, with the good Index score, this is somewhat unexpected. However, the probability of this community coming from a TSS standard-meeting site is somewhat low.

The Nitrate TIV Index score was much better than the Class 5 average, and sits at the 95th percentile of Class 5 streams. However, the macroinvertebrate community is quite skewed toward nitrate Tolerant taxa, both in terms of number of species, as well as percent of individuals. Again, this is somewhat curious. Nitrate does not have a state standard yet, so no probability can be calculated.

Table 34. Macroinvertebrate Community DO and TSS Tolerance Index scores at 07UM019. For DO, a higher index score is better, while for TSS, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet those standards.

Parameter	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO	5.60	6.94/7.07	3	31
TSS	13.86	15.07/14.93	76	44
Nitrate	2.18	3.21/3.21	94	--

Table 35. Macroinvertebrate metrics related to DO, TSS, and nitrate at 07UM019 utilizing MPCA species tolerance values.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
DO	0	0	3	1	0	0.91

Habitat

Habitat is relatively poor in the channelized AUID, based on MSHA metrics, and thus it has been placed into the Modified Use TALU category. The full length of the AUID has been straightened. It appears, based on comparing MSHA scores, that habitat has degraded since 2007.

The total and sub-component scores are shown in Table 36. Total MSHA scores were averaged for the two 2017 visits to 07UM019, resulting in a score of 39.2, which is in the range of the "Poor" category. The poorest-scoring sub-component scores were "Substrate" and "Channel Morphology". Poor scores in these two categories are consistent with general findings of ditch habitat. Substrate was predominantly gravel, sand, clay, and silt. Embeddedness of cobble was moderate to severe, depending on the visit date, suggesting excess fine sediment is present and important habitat features are being smothered. The poorest scoring features within "Channel Morphology" were based on lack of riffles, lack of sinuosity, and poor differentiation of channel bed features (riffles, runs, and pools).

Table 36. MSHA scoring for site 07UM019.

MSHA Component	7/2007	6/2017	8/2017	2017 Avg.	Maximum Poss. Score	2007 Percent of Maximum	2017 Percent of Maximum
Land Use	1	1	2.5	1.8	5	20.0	36.0
Riparian	11	7	5	6.0	14	73.3	42.9
Substrate	18	7.8	10	8.9	28	66.7	31.8
Cover	4	16	13	14.5	18	23.5	80.6
Channel Morphology	20	10	6	8.0	35	55.6	22.9
Total MSHA Score	54	41.8	36.5	39.2	100	54 = "Fair"	39.2 = "Poor"

Hydrology

There has been substantial modification of the natural hydrology of the sub-watershed, both due to the historical large-scale vegetation cover changes (perennial vegetation to cultivated fields), as well as changes to the channel that reduced sinuosity and thus water flows through the system at increased speed. Channel size was also likely increased when the ditching was originally done.

Geomorphology

The reach sampled for biology shows significant channel instability. It has and is aggrading with fine sediment, which is smothering habitat and has caused the channel depth to be very shallow (Photo 8). Sediment deposition on the middle of the channel bed is a common sign that excess sediment is depositing.

Photo 8. The channel of AUID-557 in the biological reach is physically very unstable. Excess sediment is a significantly degrading habitat. Arrows point to mid-channel sediment deposition.

Connectivity

Macroinvertebrate communities are not significantly altered by within channel barriers that can impair fish communities, such as perched culverts. Thus, connectivity is not a stressor to the biological impairment in AUID-557.

Conclusions about stressors

There is evidence that several stressors are negatively affecting the fish and macroinvertebrate communities. Low-DO is a stressor. The signal is obvious in the biological data, and measured DO levels are quite low. This may be partly attributed to the numerous wetlands that are in the channels path, including upstream of the AUID. In addition, phosphorus values are very high and are likely contributing to excess plant growth in the wetlands, or in the channel, though none are seen in the biological reach due to extensive shading at that particular location. The normal eutrophication signal of high DO percent saturation during the afternoon was not seen in the data, though it would be very surprising if TP levels seen in the creek were not having some negative effect. TSS and bedded, unstable fine sediment are stressors. This is significantly due to channel instability that likely is caused by a combination of altered hydrology (there is a significant amount of ditching upstream of AUID-557) and the straightening of the channel near to and at the sampling location. Soil input from field soil erosion is another likely source of the bedded sediment. Both the fish and macroinvertebrate communities show some evidence of stress from nitrate, though the nitrate levels that have been measured are not typically high, though periods of elevated concentrations may be relatively short lived (perhaps after runoff events, or in spring before crop growth), and not subject to being found by relatively infrequent sampling. Habitat is very poor, due to the channel instability and unstable, excess sediment.

Recommendations

Re-meandering the creek would be a way to improve habitat, but it appears there are few locations where this would be possible without moving into riparian areas that are currently farm fields. Searching for local field gullies near the creek would help reduce sediment input to the creek (Figure 23). Many

wetlands are present in this subwatershed, most of which have ditches through them. It would be beneficial to the channel's stability to improve wetland storage, perhaps by plugging some of these ditches to help meter out water more slowly.

Figure 23. An un-vegetated field swale that appears to drain field runoff to a gully and into the creek.

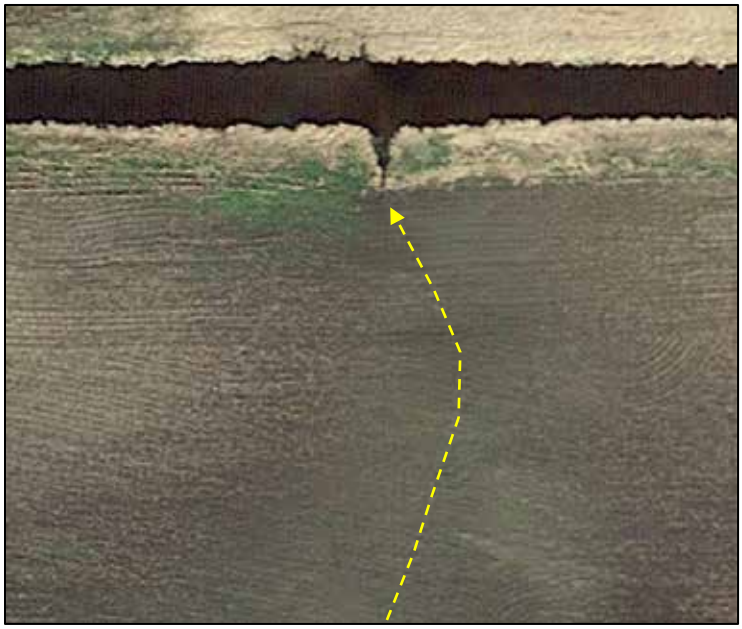


Figure 24. Small direct ditches (perhaps tile line outlets) inputting field runoff directly to the channel.

Stag Brook (AUID 07010204-572)

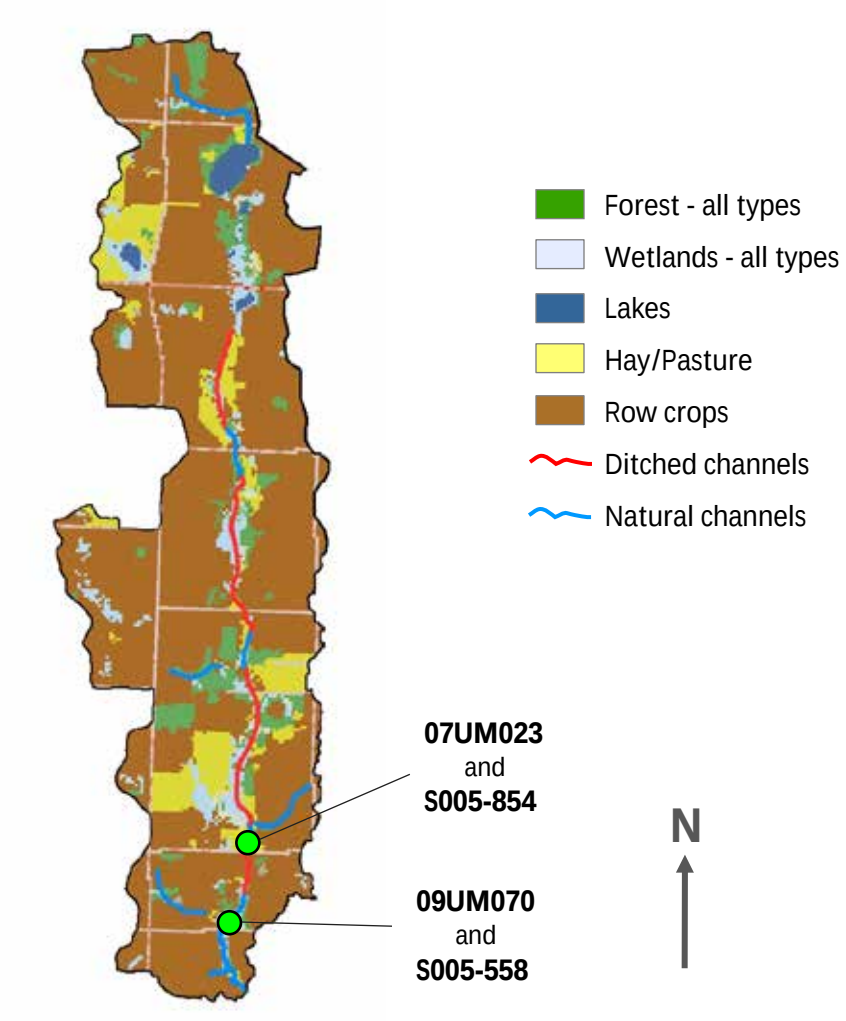
Impairment: Stag Brook is partially a ditched channel, and partly natural, and the TALU category is General Use. The creek was assessed as having both macroinvertebrate and fish community impairments at site 07UM023 and 09UM070, located upstream of the crossing of 365th Street and

upstream of 360th Street, respectively, about 2.5 miles southeast of Manannah. The Macroinvertebrate Stream Class is 6, the Fish Stream Class is 7 (07UM023) and 6 (09UM070). No 2017 samples were collected on Stag Brook in the Cycle 2 IWM monitoring effort.

Sub-watershed characteristics

AUID-572 flows for about 5.7 miles, beginning in an unnamed lake and ending at the Crow River. The land use and land cover of the sub-watershed of AUID-572 is shown in Figure 25. The land use is predominantly row crop agriculture, with some sizeable hay lands. There are no cities or towns within the sub-watershed, nor are there any permitted effluent dischargers. There is little forest land - most of it is associated with lake or wetland shoreland.

Figure 25. Sub-watershed of AUID-572 showing land use/land cover types (NLCD 2016).



Data and analyses

Chemistry

The majority of the chemistry data was collected during 2019, with a few samples collected in 2007 and 2009 (Table 37).

Table 37. AUID-572 water quality measurements from the IWM biological sampling visits and 2019 SID monitoring at 07UM023 (S005-854) and 09UM070 (S005-558). Values in mg/L, temperature in ºC.

Site	Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	Turb. (NTU)	TSS	TSVS
854	6/25/2007	16:50	28	4.03	--	679	0.295	0.19	0.05	7.85	--	--		--
854	8/20/2007	18:15	17.2	5.54	--	780	0.213	0.30	0.05	7.83	--	2.66	2.0	--
854	4/26/2019	16:05	--	--	--	--	0.061	0.09	0.05	--	--	--	--	--
854	5/15/2019	12:00	16.4	8.69	88.9	570	0.076	0.05	0.05	7.68	--	--	8.4	2.4
854	6/4/2019	12:10	20.9	5.90	66.1	618	--	--	--	--	--	--	--	--
854	6/10/2019	12:30	19.7	4.65	51.0	680	0.481	0.05	0.05	7.51	--	--	62	13
854	6/18/2019	12:30	18.9	6.97	75.1	674	--	--	--	7.66	--	--	--	--
854	6/27/2019	13:07	--	--	--	--	0.371	0.38	0.09	--	--	--	76	15
854	7/1/2019	13:00	21.1	4.67	52.9	631	--	--	--	7.59	19	--	--	--
854	7/19/2019	6:45	22.5	2.29	26.5	682	0.528	0.05	0.21	7.44	--	--	19	6.8
854	9/9/2019	13:40	15.1	5.60	55.5	609	--	--	--	7.91	--	--		
558	7/21/2009	10:50	17.6	7.47	--	579	0.370	0.07	1.0	8.07	--	--	34	12
558	4/26/2019	16:15	--	--	--	--	0.067	0.11	0.05	--	--	--	--	--
558	5/15/2019	11:50	15.8	9.86	99.7	590	0.076	0.05	0.05	7.82	--	--	7.2	2.8
558	6/4/2019	12:00	19.9	6.65	73.1	625	--	--	--	--	--	--	--	--
558	6/10/2019	12:20	18.8	6.39	68.7	683	0.132	0.05	0.07	7.64	--	--	6.4	2.8
558	6/18/2019	12:05	19.3	5.00	54.2	667	--	--	--	7.51	--	--	--	--
558	6/27/2019	13:25	--	--	--	--	0.594	1.9	0.12	--	--	--	130	33
558	7/1/2019	12:30	21.9	3.02	34.3	619	--	--	--	7.43	--	--	--	--
558	7/19/2019	6:35	21.62	4.54	51.5		0.244	0.05	0.20	7.67	--	--	--	--
558	8/6/2019	15:40	22.5	6.67	77.5	716	--	--	--	8.09	--	--	--	--
558	8/14/2019	10:45	18.6	6.74	72.5	709	--	--	--	7.95	--	--	--	--
558	8/20/2019	15:25	20.3	6.53	72.4	623	--	--	--	7.82	--	--	--	--
558	8/28/2019	9:20	15.0	6.88	68.6	646	--	--	--	--	--	--	--	--
558	9/9/2019	13:30	14.83	6.92	68.4	625	--	--	--	8.02	--	--	--	--

Nutrients - phosphorus

Phosphorus values are often very high, up to five times the Central River Nutrient Standard. Based on the fairly good association of TSS and TP (Figure 26), it appears that a significant amount of the TP is mineral bound, and may be entering the stream via soil erosion. There are some interesting differences in measurements from the two chemistry monitoring sites (at the two biological monitoring locations). There can be high readings for TP and TSS at one location and not the other, and it is not consistent as to which site has the high values (Figure 27).

Figure 26. Correlation of TSS (A) and mineral SS (B) with TP in AUID-572.

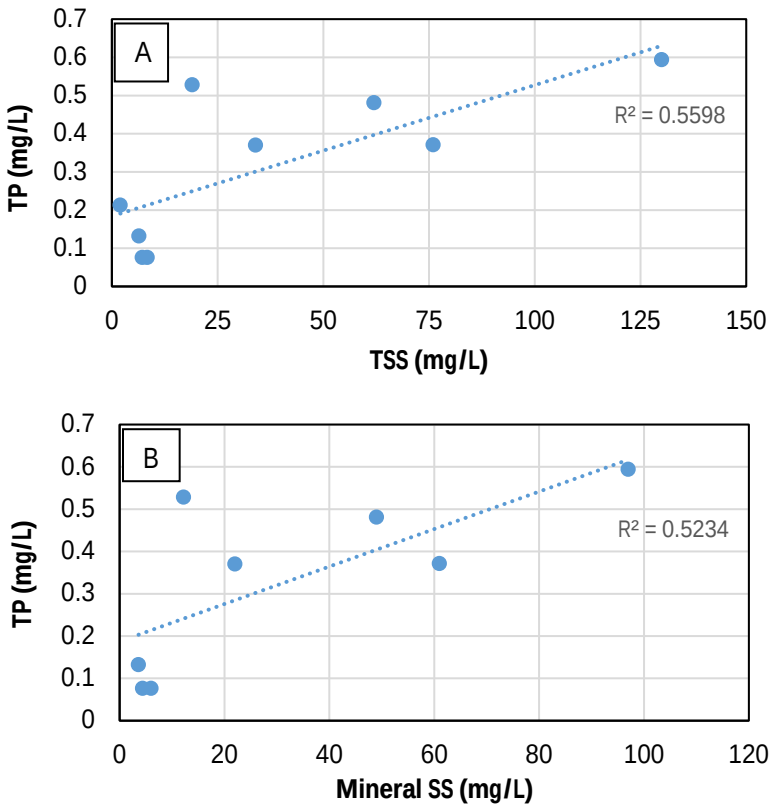
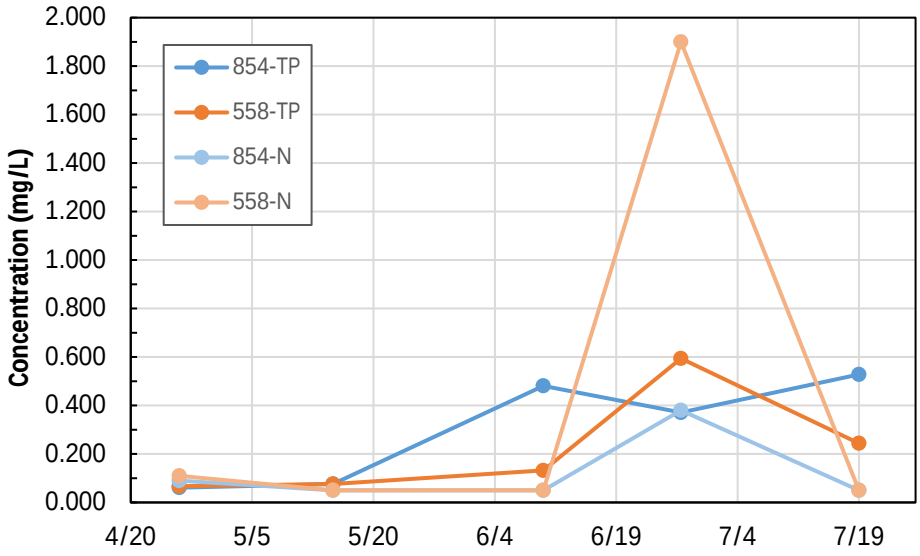


Figure 27. Concentration of TP and Nitrate at S005-558 and S005-854 in 2019. These two sites are only about 0.5 miles apart.



Nutrients - nitrate and ammonia

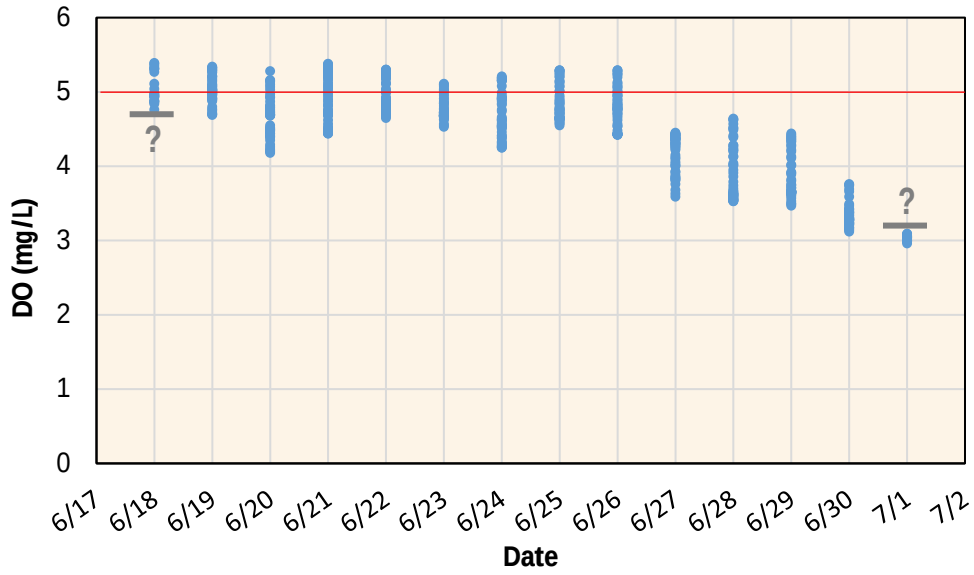
Nitrate values were often extremely low, below the lab's detection limit. A few samples were substantially higher, though still relatively low compared to some other agricultural parts of Minnesota. Ammonia values were generally low, and not at levels that would exceed the standard for unionized ammonia. One ammonia sample was significantly higher. This may have been due to livestock in the upstream area active pasture near the time of the sampling.

Dissolved oxygen

Several measurements of DO were below the standard. Samples around 12:00 were above the standard, but not by a much, and so it is likely that many of these dates would have had early morning DO levels below the standard, such as was found in early morning measurements on July 19, 2019. It does not appear that eutrophication is occurring, however, since mid-day measurements are not high, and the summer DO percent-saturation is always well below 100%, suggesting that excess plant/algae growth is not occurring.

A Sonde was deployed at each of the biological sites on AUID-572 in 2019. Each day of the deployment, DO dropped below the standard, while on a number of days, even the day's high was below the standard (Figure 28). The daily DO flux is quite small as each site's change was only about 1 mg/L from early morning to late afternoon. The low DO flux and the relatively low late-afternoon DO concentrations are evidence against eutrophication. The low DO levels are attributable to something other than excess algal production. The sluggish flow, and organic content of the substrate (noted on the MSHA form) leads to reduced atmospheric exposure, and greater bacterial consumption of oxygen due to decomposition.

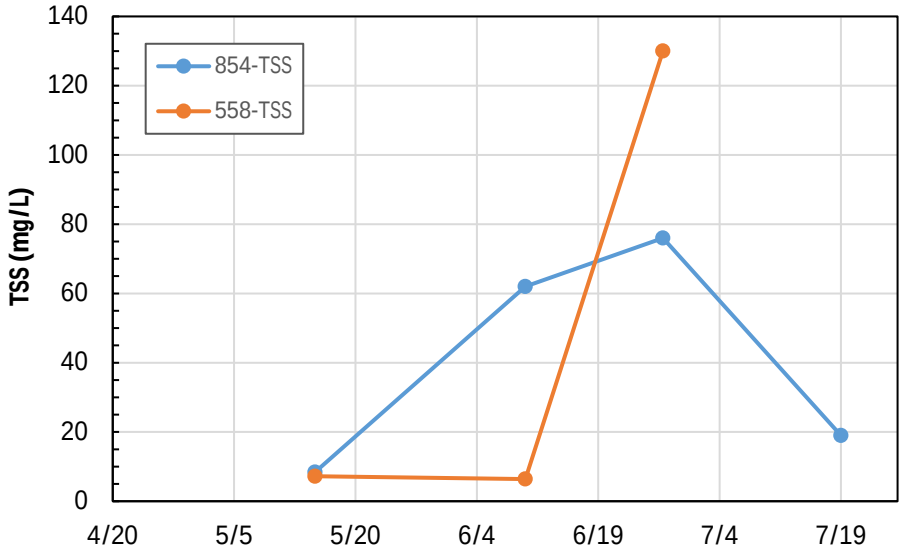
Figure 28. Sonde data for the period of June 17 - July 1, 2019 at 07UM023. The red line is the DO standard. Days 6/18 and 7/1 are partial days.



Transparency and suspended solids

TSS samples showed extreme swings depending on the date, sometimes being much lower than the standard, and sometimes far exceeding the Central Minnesota standard. The suspended particulate material averages 74.4% mineral (soil) and 25.6% organic (plant material). As with TP, there is sometimes a significant difference between the TSS at the two close-proximity sites, and it is not consistent as to which one has the higher concentration (Figure 29).

Figure 29. Concentration of TSS at S005-558 and S005-854 in 2019. These two sites are only about 0.5 miles apart.



Conductivity

Specific conductivity was in a moderate range, and non-problematic for the biological communities.

Stressor signals from biology

Fish

The first 2007 fish community sample at 07UM023 was dominated by creek chub, followed by brook stickleback and central mudminnow. The second 2007 sample was even more dominated by creek chub, followed by northern redbelly dace and blacknose dace. The 2009 fish community just downstream, at 09UM070, was dominated by fathead minnow, followed by creek chub and white sucker. Many of the species collected are ubiquitous ones in Minnesota with fairly non-specific habitat needs, and are also able to deal with low DO conditions.

The Community TIV Index scores are shown in Table 38 and individual TIV metrics in Table 39. The fish samples show evidence of the influence of low DO concentrations. The DO Community Index scores were better than the class average at 07UM023, and right at average at 09UM070. The probability of the fish communities collect from those visits coming from a DO standard-meeting reach was relatively good at site 07UM023, but somewhat low at 09UM070. The fish communities collected at both sites were highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species numbers, and the percentage of Tolerant versus Intolerant individuals.

There is some evidence in the fish data of stress from TSS, though the analysis is somewhat conflicting. No TSS Tolerant species were collected, yet the TSS TIV Index score at 09UM070 was somewhat poor, relative to the Class 7 average, and the score percentiles among same-class streams were quite low. The communities at site 07UM023 were a bit more likely than not to come from a TSS-standard meeting site, while the community at 09UM070 was less likely than not to come from a TSS-standard meeting site. So, it is somewhat ambiguous as to whether TSS is a significant stressor of the fish community in AUID-572.

The Nitrate TIV Index was much higher than the class averages at all three visits, and also at very low percentiles for the appropriate class. The community was quite skewed toward nitrate Tolerant species and individuals.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels and elevated nitrate, while stress from elevated TSS is uncertain.

Table 38. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-572 at 07UM023 and 09UM070. For DO, a higher index score is better, while for TSS, a lower index score is better. "Percentile" is the rank of the index score within either stream Class 6 or 7 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Site	Date	Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
07UM023	6/25/2007	DO	6.55	6.21/6.16	72	37.8
07UM023	8/20/2007	DO	6.87	6.21/6.16	85	59.7
09UM070	7/1/2009	DO	6.62	6.61/6.68	46	42.2
07UM023	6/25/2007	TSS	15.19	14.99/13.36	29	64.3
07UM023	8/20/2007	TSS	15.21	14.99/13.36	29	64.1
09UM070	7/1/2009	TSS	18.08	13.92/13.26	8	40.0
07UM023	6/25/2007	Nitrate	3.25	2.22/2.06	22	--
07UM023	8/20/2007	Nitrate	3.39	2.22/2.06	20	--
09UM070	7/1/2009	Nitrate	3.48	2.45/2.46	12	--

Table 39. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM023 and 09UM070.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	6/25/2007	0	0	5	4	0.0	45.4
Low DO	8/20/2007	0	0	4	3	0.0	31.6
Low DO	7/1/2009	0	0	3	3	0.0	57.3
TSS	6/25/2007	1	0	0	0	11.0	0.0
TSS	8/20/2007	1	0	0	0	13.7	0.0
TSS	7/1/2009	1	0	0	0	7.6	0.0
Nitrate	6/25/2007	1	0	5	0	11.0	76.1
Nitrate	8/20/2007	1	0	4	0	13.7	72.9
Nitrate	7/1/2009	1	0	4	0	7.6	85.4

Macroinvertebrates

There has only been one macroinvertebrate sample collected in AUID-572, in 2007 at 07UM023. The community was dominated by two taxa, the mayfly *Caenis* and the amphipod *Hyalella azteca* in that order. *Caenis* was the only EPT taxa found in the sample. A stream sample with only one EPT taxa (a grouping of insect orders with genera typically being sensitive), is very uncommon. There were a number of taxa, all in low numbers, which are often found in wetland habitat, including a planorbid snail, fingernail clam, two Hemipteran taxa, dytiscid beetle, and stratiomyid fly.

The Community TIV Index scores are shown in Table 40 and individual TIV metrics in Table 41. The DO TIV Index scores a bit low relative to the class average, and sits at the 34th percentile of Class 6 streams. The probability of the sampled community coming from a DO-meeting site is neither good nor poor. The community is skewed toward taxa that are low-DO Tolerant, and the percentage of individuals in the sample that are low-DO Tolerant was quite large. The macroinvertebrate community does seem to show some stress from inadequate DO concentrations.

The TSS TIV Index scores well relative to the class average, though it is still only at the 56th percentile. The probability of the community coming from a standard-meeting site is fairly good. The community is quite skewed toward TSS Tolerant taxa, but the percent of individuals that are TSS Tolerant is quite low. With all of these analyses taken together, it does not appear that TSS is a main stressor to the macroinvertebrate community.

The Nitrate TIV Index scored poorer than the class average, and at the 42nd percentile among Class 6 streams. Conditional probability is not available for nitrate. The macroinvertebrate community is highly skewed toward Nitrate Tolerant taxa, both in terms of number of species, as well as percent of individuals. There is some evidence that nitrate concentrations are influencing the macroinvertebrate community, and thus it appears that nitrate is a stressor.

Table 40. Macroinvertebrate Community DO, TSS, and nitrate Tolerance Index scores at 07UM023 from sample collected on 8/8/2007. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability (ver.2018) a community with this score would come from a stream reach with DO or TSS that the appropriate standard.

Parameter	TIV Index	Class avg./median	Percentile in class	Prob. as %
DO	6.32	6.40/6.60	34	50
TSS	14.95	15.12/15.17	56	67
Nitrate	3.27	3.08/3.13	42	--

Table 41. Macroinvertebrate metrics related to DO, TSS, and nitrate at 07UM023 utilizing MPCA species tolerance values.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
DO	2	0	9	3	1.3	55.4
TSS	0	0	7	4	0.0	6.0
Nitrate	0	0	18	13	0.0	62.0

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, among the three parameters shown above, there is strong evidence that low DO levels and nitrate are stressors of the biology. Nitrate levels are often very low, but appear to occasionally be high during runoff events. TSS can also be very high at times, but it does not seem to be having a strong influence on the biological communities.

Temperature

Temperature measurements in Table 37 showed none that would be problematic for the fish community; most of the measurements are relatively cool even.

Habitat

Habitat is within the "Poor" scoring range of the MSHA. The total and sub-component scores are shown in Table 42. MSHA scores were averaged for the three visits to 07UM023 and 09UM070, resulting in a score of 40.0. Nearly all of the five main subcomponents of the MSHA scored poorly, with the poorest-scoring sub-component score being "Substrate". Substrate was either sand, clay, silt, or detritus. No coarse substrate was found.

Table 42. MSHA scoring for site 07UM023.

MSHA Component	07UM023 6/2007	07UM023 8/2007	09UM070 7/2009	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	2	2.5	0	1.5	5	30.0
Riparian	7	6	12.5	8.5	14	60.7
Substrate	8	8	7	7.7	28	27.5
Cover	7	11	8	8.7	18	48.3
Channel Morphology	14	17	10	13.7	35	39.1
Total MSHA Score	38	44.5	37.5	40	100	40 = "Poor"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest to cultivated fields), as well as straightening of more than half the channel length, that reduced sinuosity and thus speed flows through the system. Channel size was also likely increased when the ditching was done originally. Based on recent aerial photography, it appears that some formerly cropped acres are currently in CRP enrollment. This AUID appears to experience very low flow volumes. At 09UM070, the 2009 macroinvertebrate sample was deemed non-assessable due to very low water at the time of collection, and at the 07UM023 recon in October 2017, the stream was nearly dry. The 2007 macroinvertebrate sampling comments say the upstream area is dry.

Geomorphology

Several parts of this AUID were channelized/straightened decades ago. No on-the-ground geomorphology studies were conducted on this AUID. The biological sampling photos seem to show evidence of overwidening, due to altered hydrology. It would be unusual if this were not the case given the proportion of the stream system has been ditched. However, this would need to have on-the-ground survey work to determine this conclusively.

Connectivity

There is a perched culvert on 365th Street (07UM019, Photo 9). In low water, it backs up flow upstream of 365th Street. Since 07UM019 is on the upstream side of 365th Street, this migration barrier likely played a part in the failing fish community in 2007. This barrier is likely not the only issue however, as a site a mile downstream (09UM070, just upstream of 360th Street) also found a failing fish community. The culvert at 360th Street is also at least a partial fish migration barrier. It is set high, and at a higher angle that the stream gradient, and the water picks up speed in the culvert (Photo 10).

Photo 9. The upstream side of the culvert at 365th Street (07UM019). The lip of the culvert is up off the bottom of the stream bed and velocity can be seen picking up immediately upon reaching the culvert.

Photo 10. The downstream end of the culvert at 360th Street (09UM070) showing the fast water emerging from the culvert.

Conclusions about stressors

AUID-572 has numerous stressors contributing to the biological impairment. There is evidence of inadequate DO levels, both from the biological data, and from direct measurements of DO. Both the fish and macroinvertebrate communities are skewed toward low-DO Tolerant species as well as much higher percentages of low-DO Tolerant individuals than low-DO Intolerant ones. Both the instantaneous DO measurements, as well as the deployed Sonde found significantly sub-standard levels of DO. These same tolerance patterns were also found for both fish and macroinvertebrates regarding nitrate. Direct nitrate measurements were typically very low (good), and so it may be that there are spikes in nitrate concentration that are short lived, but influential. Phosphorus levels are often very high, sometimes as much as five times the River Eutrophication Standard - Central. The very narrow daily flux of DO suggests eutrophication is not the cause of the low DO.

In addition to water quality stressors, there are some physical issues that are stressors. First, there is in general poor habitat, which is common for agricultural ditches, particularly if they are periodically maintained. There are also two culverts that are at least partial barriers to fish migration. Many of the fish in smaller sized streams, such as this AUID move downstream to find suitable overwintering habitat. If culverts are not designed with fish passage in mind, they can prevent fish from recolonizing smaller streams in spring. This stream seems to have relatively common conditions of very low flow volume. The alteration of hydrology by enhancing drainage of the landscape likely reduces the amount of water in mid- and late-summer. This makes it more stressful for the fish that do manage to reside in the stream, as water gets more stagnant, warmer, and habitat area is reduced.

There are no permitted effluent dischargers in this sub-watershed.

Recommendations

Due to the number of stressors in AUID-572, it would probably be difficult to restore conditions for biological communities to thrive, particularly if this ditch system is periodically maintained. It would be best to start with work that addresses the water chemistry/quality problems for a couple reasons. First, physical changes, such as improving connectivity by re-installing culverts, are expensive, and if other

conditions upstream of those changes are poor, the improved connectivity will probably not be well utilized if other factors preclude good living conditions. Second, addressing the water chemistry issues also helps improve conditions in streams/rivers that receive the water from Stag Creek, making those waters healthier and better suited for thriving biological communities. It would be useful to do additional nitrate monitoring, since the available data did not normally find elevated nitrate. It would be good to target some early season monitoring for nitrate (mid-April to early June) when crops are not utilizing crop field nitrogen, as well as rain events and days immediately following larger rain events, when field drain tile may be delivering significant water to the creek. Addressing the intermittency issue is likely going to be very difficult, due to the very high percentage of row crop agriculture within this sub-watershed.

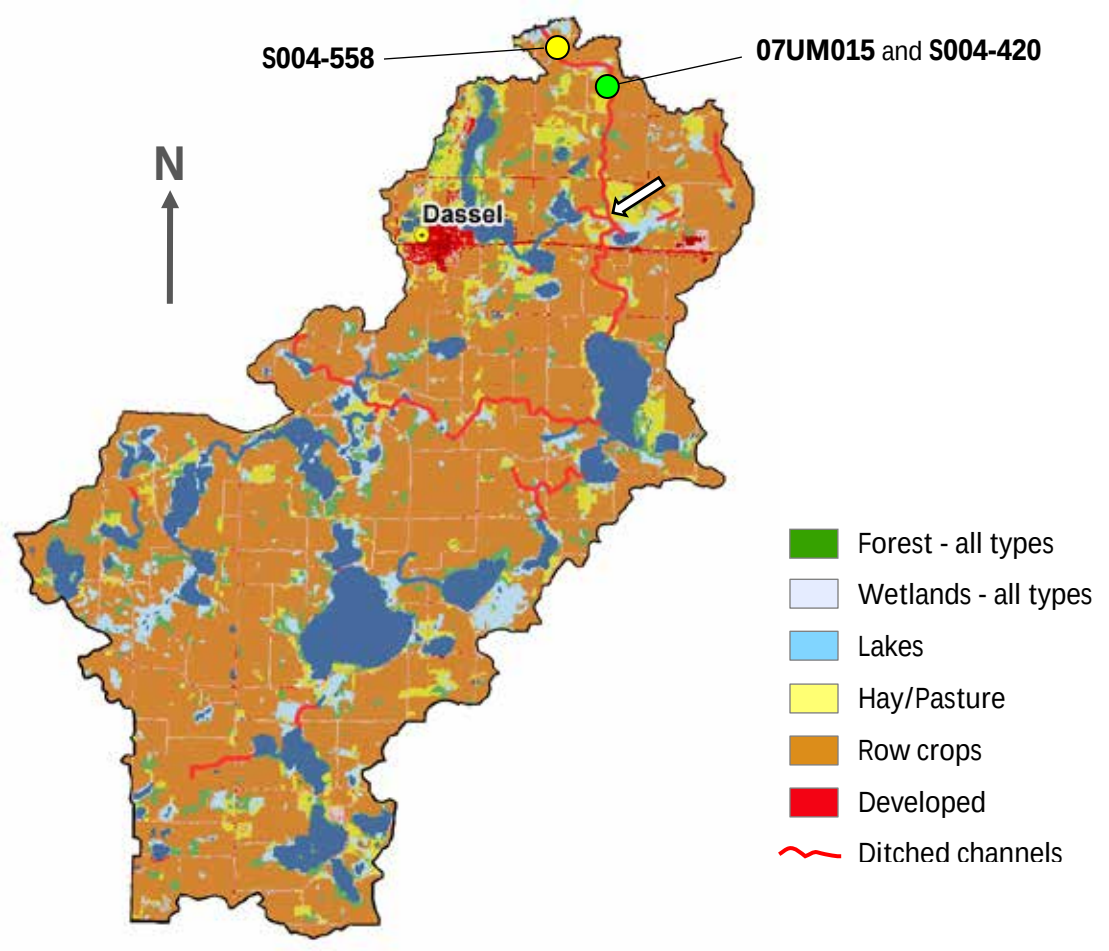
Collinwood Creek (AUID 07010204-604)

Impairment: AUID-604 is an approximately 3.8 mile long reach beginning about a half mile north of U.S. Highway 12. The full length of the channel of AUID-604 is altered/ditched. There was one biological monitoring station (07UM015). There was a sufficient dataset of DO and TSS measurements to assess these parameters. DO was assessed as failing to meet the standard, while TSS was assessed as meeting the standard, though exceedances do occur among the TSS dataset. The UAA process determined that the stream should be classed as General Use, despite the ditching. The AUID was assessed as having impairments of both the fish and macroinvertebrate communities. The Macroinvertebrate Stream Class is 6, the Fish Stream Class is 5.

Sub-watershed characteristics

The full length of AUID-604 channel has been straightened. The Collinwood Creek sub-watershed contains the smaller Silver Creek sub-watershed (also discussed in this report). The land use and land cover of the sub-watershed of AUID-604 is shown in Figure 28. The land use is predominantly row crop agriculture. There is relatively little areal coverage of perennial vegetation. In the lower parts of the AUID, there is wet meadow along the riparian corridor. The town of Dassel is within the sub-watershed, upstream of AUID-604. The parts of the drainage system upstream of AUID-604 flow through several lakes. Just upstream of the top of AUID-604 are two large marshes which contribute some flow to AUID-604. There is some evidence that the stream goes dry in some years (at least 2007, 2009, and 2012). There are no permitted effluent dischargers to AUID-604.

Figure 30. The Collinwood Creek subwatershed and its land use/cover (NLCD 2016). The arrow points to the upstream end of AUID-604, which flows north.



Data and analyses

Chemistry

The chemistry sampled at the biological monitoring visits is presented in Table 43. The sample site for AUID-604 was also a 10x chemistry site sampled by the Middle Fork Crow Watershed District. As such, there is a fairly large data set from 3 years of this monitoring. Some of this data is summarized in Table 44. There has also been sampling a bit farther downstream, still within AUID-604, by local citizens (Table 45). Fewer parameters have been collected at this latter site.

Table 43. IWM chemistry results from 2009 and 2017 at 07UM015 (S004-420). Values in mg/L, temperature in °C.

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS	TSVS
8/4/2009	13:53	19.6	7.36	--	519	0.207	< 0.05	< 0.1	8.11	--	16.6	4.0
6/15/2017	8:50	21.5	4.03	46	424	--	--	--	7.9	--	--	--
8/16/2017	12:42	20.1	7.07	78	373	--	--	--	7.8	> 100	--	--

Table 44. Summary of several chemistry parameters collected at S004-420 (07UM015). Values in mg/L.

Parameter	# Samples	Average	Minimum	Maximum
TP	22	0.156	0.064	0.278
Nitrate	11	< 0.28	< 0.05	0.91
TSS	23	19.1	< 2	110
Chloride	13	19.1	5.6	27

Table 45. Summary of TP and TSS samples collected at S004-558 in 2010-2018. Values in mg/L.

Parameter	# Samples	Average	Minimum	Maximum
TP	61	0.136	0.054	0.285
TSS	61	13.2	1	50

Nutrients - phosphorus

TP values averaged above the Central Minnesota River Nutrient standard by a fair amount, with the maximum value almost three times the Central Region standard.

Nutrients - nitrate and ammonia

Nitrate values were often extremely low, sometimes below the lab's detection limit. A few samples were substantially higher, though still very low compared to some other agricultural parts of Minnesota. No measurements exceeded 1 mg/L. Ammonia values were never at levels that would produce un-ionized ammonia levels that exceed the standard.

Dissolved oxygen

AUID-604 has been assessed as not meeting the DO standard, and is listed on the 303(d) list as impaired for dissolved oxygen. One DO reading during biological sampling was below the standard. The other two biological visits were later in the day, and don't represent the daily minimum DO levels.

Transparency and suspended solids

The average of TSS samples at 07UM015 was significantly better than the standard, though 4 of the 23 samples exceeded the standard, with two of those being only slightly over. The only visit that included TSVS (8/4/09) found that the suspended particulate material was 75.9% mineral (soil) and 24.1% organic (plant material). The second sample site, downstream farther, averaged somewhat lower TSS, and had a lower maximum, and six of the 61 samples were above the standard.

Chloride

All chloride samples were far below the state chloride standard, and thus chloride concentrations in AUID-604 are not stressing aquatic life.

Conductivity

Specific conductivity was in a moderate range, and non-problematic for the biological communities.

Stressor signals from biology

Fish

The fish community at 07UM015 was dominated by bluegill, and secondarily dominated by spottail shiner and white sucker.

The Community TIV Index scores are shown in Table 46 and individual TIV metrics in Table 47. The fish samples show evidence of the influence of low DO concentrations. The DO Community Index score was

poorer than the Class 5 average. The probability of the fish communities collected from those visits coming from a DO standard-meeting reach was quite low. The fish community was highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and the percentage of Tolerant versus Intolerant individuals.

There is some evidence in the fish data of stress from TSS, though the analysis is somewhat conflicting. Few TSS Tolerant species were collected, yet the TSS TIV Index score at 07UM015 was somewhat poor, relative to the Class 5 average, and the score percentile among Class 5 streams was also quite low. However, the community is quite likely to come from a TSS-standard meeting site. Given that few TSS Tolerant species were present, and in very low numbers, this suggests that TSS levels are at most a light stressor.

Nitrate does not show evidence of being a stressor. The Nitrate TIV Index score was much better than the class average, and the percentage of Nitrate Intolerant individuals was much higher than for Nitrate Tolerant ones.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels, and possibly to a minor extent by TSS, while nitrate does not show evidence of being a stressor.

Table 46. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-604 at 07UM015. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
6/15/2017	DO	6.70	7.00/7.11	24	33.9
6/15/2017	TSS	14.72	13.71/12.96	21	79.5
6/15/2017	Nitrate	1.09	2.06/2.02	91	--

Table 47. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM015.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	6/15/2017	0	0	13	8	0.0	40.5
TSS	6/15/2017	2	1	2	0	1.2	3.2
Nitrate	6/15/2017	4	1	4	0	65.3	19.2

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

Two assessable macroinvertebrate samples have been collected, in 2009 and 2017. The most abundant taxa differed each year. In 2009, one taxon was dominant, the amphipod *Hyallela azteca*. In 2017, again one taxon was dominant, the midge *Polypedilum*.

The Community TIV Index scores are shown in Table 48 and individual TIV metrics in Table 49. The DO TIV Index scores were poorer than the class average for one of the two samples. The percentiles and probabilities of the sampled community coming from a DO-meeting site are quite varied between the two years, though taken together they lean toward having only a moderate chance of coming from a DO-meeting site. The community is skewed toward taxa that are low-DO Tolerant, though again, this varied substantially between the two years, showing much stronger signal of low-DO conditions in 2009 than 2017. Given that the Intolerant versus Tolerant taxa presence and percent of individuals are quite

skewed toward low-DO tolerance, the macroinvertebrate community does seem to show stress from inadequate DO concentrations. That there is considerable variation in these metrics may reflect the fact that in some years, the flow gets very low, and likely eliminates more sensitive taxa from surviving in this system.

The TSS TIV Index scores were both poorer than the Class 6 average, and their percentiles were quite low relative to Class 6 streams. The probability of the community coming from a standard-meeting site is quite low. The community is highly skewed toward TSS Tolerant taxa, and the percent of individuals that are TSS Tolerant was quite high in two of the samples. No TSS Intolerant taxa were present in any of the samples. This analysis does provide some evidence that TSS is a stressor to the macroinvertebrate community.

The Nitrate TIV Index scored better than the class average for one sample, and worse for the other (2017), and the percentiles among Class 6 streams differed by a sizeable amount. Conditional probability is not available for nitrate. Though the Index scores looked fairly good, the macroinvertebrate community is extremely skewed toward nitrate Tolerant taxa, both in terms of number of species present, as well as percent of individuals. Just one nitrate Intolerant taxa was present in each of the samples. There is strong evidence that elevated nitrate concentrations are stressing the macroinvertebrate community.

Table 48. Macroinvertebrate Community DO, TSS and Nitrate Tolerance Index scores at 07UM015. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that the appropriate standard.

Date	Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
8/6/2009	DO	6.05	6.40/6.60	23	43
8/16/2017	DO	6.87	6.40/6.60	69	65
8/6/2009	TSS	15.87	15.12/15.17	36	26
8/16/2017	TSS	16.84	15.12/15.17	21	19
8/6/2009	Nitrate	2.45	3.08/3.13	77	--
8/16/2017	Nitrate	3.50	3.08/3.13	30	--

Table 49. Macroinvertebrate metrics related to DO, TSS, and nitrate at 07UM015 utilizing MPCA species tolerance values.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
DO	0	0	12	4	0.0	68.3
DO	1	1	5	2	7.6	12.4
TSS	0	0	14	7	0.0	17.7
TSS	0	0	10	2	0.0	62.5
Nitrate	1	0	21	16	0.6	22.7
Nitrate	1	0	14	10	3.5	57.5

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, among the three parameters discussed above, there is good evidence that low DO levels are a stressor to the aquatic life in the creek. TSS showed weak evidence of stressing the fish community, but quite strong evidence that macroinvertebrates are stressed by TSS levels. The latter response might be due to the substrate being nearly completely fine particulate material, rather than a true influence of suspended particles. The influence of elevated TSS is likely at least a secondary stressor of the macroinvertebrate community. Nitrate levels do appear to be stressing the macroinvertebrates, but not the fish. Work in other southern Minnesota watersheds have also found macroinvertebrates being affected by nitrate at lower levels than for fish.

Temperature

Temperature measurements in Table 44 showed none that would be problematic for the fish community; most of the measurements are relatively cool even.

Habitat

MSHA scores were averaged for the three visits to 07UM015 resulting in an average score of 46.0, which is at the very bottom of the "Fair" scoring range of the MSHA. The total and sub-component scores are shown in Table 50. Of the 5 main subcomponents of the MSHA, "Channel Morphology" scored poorest, followed by "Land Use". The other score that was less than 50% of its maximum was "Substrate". Substrate was almost exclusively sand and silt.

Table 50. MSHA scoring for site 07UM015.

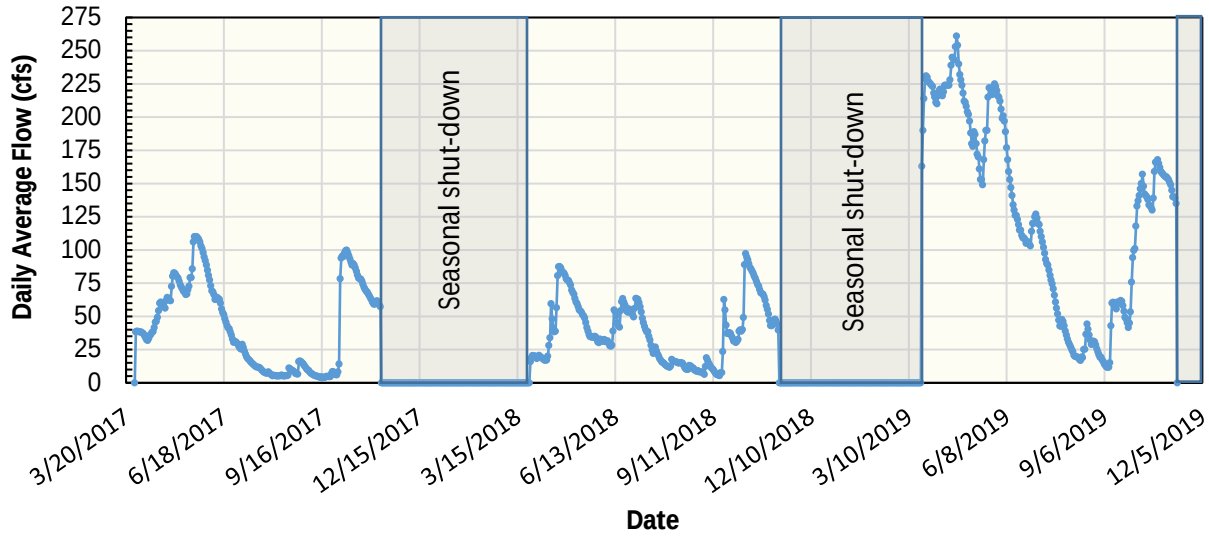
MSHA Component	8/2009	6/2017	8/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	0	2.5	2.5	1.7	5	34.0
Riparian	13.5	7.5	7.5	9.5	14	67.9
Substrate	10	10	16.4	12.1	28	43.2
Cover	10	15	13	12.7	18	70.6
Channel Morphology	13	6	11	10.0	35	28.6
Total MSHA Score	46.5	41.0	50.4	46.0	100	46 = "Fair"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (perennial vegetation to cultivated fields), as well as straightening of the full length of the AUID, which reduced sinuosity and thus water moves through the system more quickly. Channel size was also likely increased when the ditching was done originally. This speeding of the water movement through the landscape may have an influence on the relatively frequent intermittency of the creek (Photo 11). A short term flow gage (three years) was established on Collinwood Creek during 2017-2019 just upstream of 07UM015. There were no flows as low as 2009, but there were prolonged periods in mid-late summer when flow levels were down to the 5-6 cfs range in 2017 and 2018 (Figure 31).

Photo 11. There are times that water levels get extremely low in Collinwood Creek, as in this photo from August 4, 2009, taken at the upper end of the biological monitoring reach (07UM015).

Figure 31. Record of daily average flow in cfs for 2017 - 2019 near 07UM015.



Geomorphology

This AUID was channelized/straightened decades ago. Straight channels typically have homogenous habitat, lacking variety of the features that sinuosity creates (depth and velocity variability, riffles and pools, etc.). Generally ditches have higher than normal banks, which prevents higher flows from spilling out onto a floodplain. This was observed in the photos that were taken along the channel during the fish monitoring. High water access to the floodplain contributes to better stream stability and habitat. No on-the-ground geomorphology studies were conducted on this AUID.

Connectivity

There are two road crossings between Big Swan Lake and the biological reach. The culvert at 250th Street, which is the downstream end of the biological sample reach, is not passable by fish in times of lower flow volumes (Photo 12). Given the water line marks in the culvert, there are times that the flow is high enough to allow fish passage. The farther downstream crossing, evaluated only by reviewing aerial photography, appears to be a nicely-passable crossing. The occasional drying of the channel is also a

potential migration barrier due to places that become too shallow for fish to traverse (Photo 12). In 2017, there was good flow in June, but flow volumes got pretty low again in August. Macroinvertebrate communities are not significantly altered by barrier features (such as perched culverts) that can impair fish communities.

Photo 12. The culvert on 250th Street, at the downstream end of 07UM015 sits at too high an elevation to allow for fish passage at lower water levels. Date of photo is August 4, 2009.

Conclusions about stressors

The most evident stressor is low DO. The direct DO measurements revealed below-standard levels (the AUID is now on the proposed 303(d) list for DO impairment), and the analysis of the fish and macroinvertebrate communities also clearly showed the community to be skewed toward taxa that tolerate low DO conditions. TP is often above the river standard, but it is not clear whether the creek is experiencing eutrophication as a cause of the low DO. The biological reach has mature forest riparian vegetation, which shades the channel and photos show almost no plant growth in the creek. The macroinvertebrates show a strong signal of stress from nitrate (fish do not), though none of the measured nitrate concentrations were at levels thought to be toxic to aquatic organisms. There may be occasional elevated nitrate levels that haven't been captured in the relatively small dataset. Again, the macroinvertebrates showed influence of elevated TSS, while evidence for the fish community was weak. TSS levels above the standard are occasionally found in the creek. There is clearly a problem culvert at the downstream end of the biological reach (250th Street), which at lower flow volumes is not passable for fish. Lastly, it appears that the creek becomes intermittent on a fairly frequent basis (i.e., every few years). This may be somewhat confounding the community analyses particularly for the macroinvertebrates. Some taxa may be missing simply due to the relatively routine drying up of the channel. Fish are less affected on a long-term basis, because they migrate back into the channel when water returns, provided there is not a barrier to doing so.

There are no permitted pollutant dischargers active in this sub-watershed. There is potential for non-point nutrient pollution due to agricultural activity, both from row crop fields, as well as animal production (feedlots and pastures). There are some pastures that appear to allow animal access to the channel, and a couple small feedlots/barnyards that are also close to the channel. There is also potential influence of non-point pollution from urban land use (city of Dassel is upstream of AUID-604), though this is buffered from the AUID by the fact that runoff from the Dassel area flows into a tributary (Silver Creek - which has a section in this report) that flows through several lakes before reaching AUID-604,

which processes that water significantly. In many other places along the AUID, there is a very nice, wide channel buffer of permanent vegetation, often being mature forest, which is a positive influence on habitat and water quality.

Other negative in-channel habitat conditions typical of ditches (i.e., fine sediment substrate, homogeneous velocity and reduced stream-bed contour) were found in the MSHA protocol conducted in Collinwood Creek. In addition to being poor habitat, uniform stream channels create less-turbulent flows and reduce water interaction with the atmosphere (i.e., reduce aeration). Reduced habitat compounds the low DO as an additional stressor.

Signs of physical channel instability were occasionally seen in reach photographs (occasional scoured banks). It appeared this was due to the channel trying to develop some sinuosity. Straight channels aren't natural, and natural factors work to re-meander straight channels over time. The issues of altered hydrology is not of strong concern for bank erosion reasons, though the altered flow may contribute to periodic low flows due to reduced upstream storage. During these periods, DO levels may become especially problematic as stream flow becomes fairly stagnant.

Recommendations

It would be helpful to make observations of stream flow over several years to determine how often the stream is intermittent. This would provide more context to interpreting samples of the biological community. If intermittency occurs relatively frequently (e.g., every few years), replacing the culvert is less of a priority, unless roadwork is being conducted. Re-establishing connectivity to a reach with poor habitat is not all that productive, and there are probably higher priority projects that will be more beneficial for that investment. It would be helpful to do a thorough reconnaissance of the length of the creek to see if open canopy areas have large amounts of macrophytes or algae that could help confirm whether eutrophication might be the cause of low DO. Regarding the farm animal impacts, minimizing runoff from these areas, and fencing cows/cattle from the stream would be beneficial.

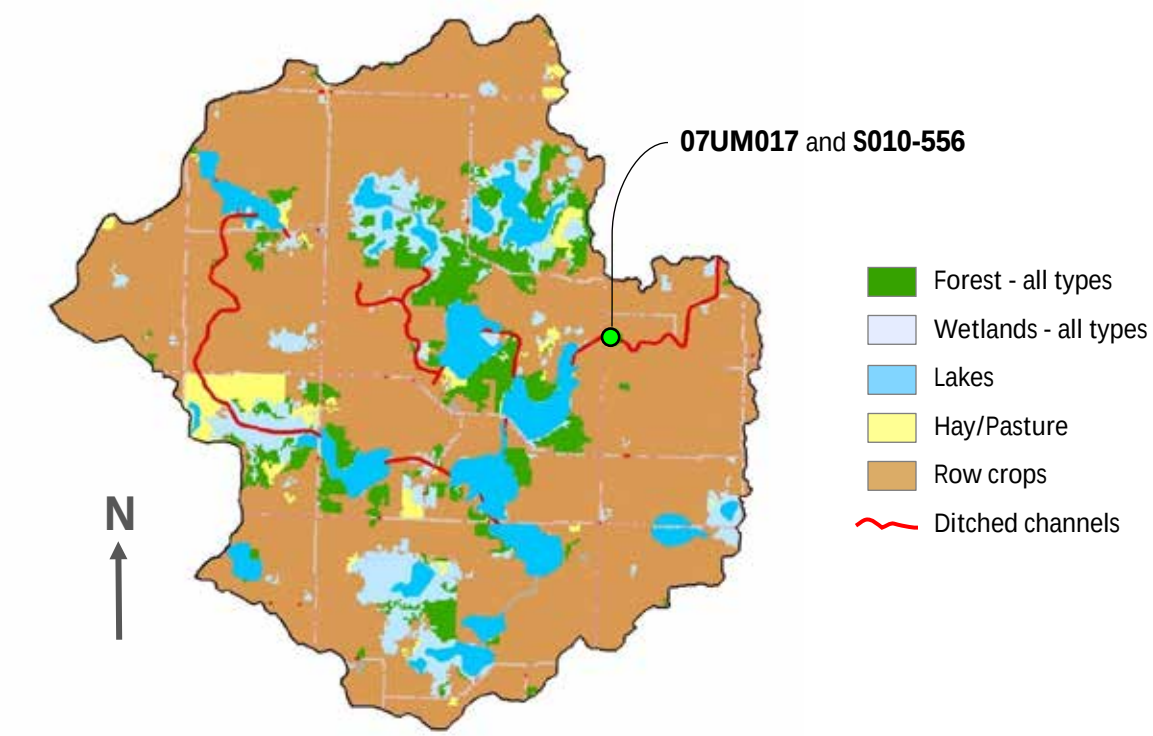
County Ditch 26 (AUID 07010204-643)

Impairment: AUID-643 is a short, 2.3 miles long reach, beginning as the outlet of an unnamed lake and ending where it enters Long Lake. The channel of AUID-643 is a straightened channel for its entire length. The UAA process determined that AUID-643 is habitat-limited, and should be classed as Modified Use. The AUID has one biological monitoring station, 07UM017 at CR-4. AUID-643 has new (2019) impairments for both the fish and macroinvertebrate communities. The Fish Stream Class at 07UM020 is 6 (Northern Headwaters), and the Macroinvertebrate Stream Class is 7 (Prairie Streams - GP).

Sub-watershed characteristics

The land use and land cover of the sub-watershed of AUID-643 is highly oriented to row crop agriculture (Figure 29). There are also numerous small lakes and wetlands, with accompanying forested patches in the sub-watershed upstream of where AUID-643 starts. The lower part of the sub-watershed, which is adjacent to AUID-643, is nearly 100% row crop agriculture, with just the required ditch buffer in perennial vegetation. There are no cities/towns found in the sub-watershed, so urbanization-related stressors are not present, nor are there any permitted effluent dischargers to AUID-643.

Figure 32. The landscape and land use of the subwatershed of AUID-643 (NLCD 2016).



Data and analyses

Chemistry

The data set collected from AUID-643 at 07UM017 (S010-556) consists of monitoring during the biological sampling visits in 2017 (Table 51), and subsequent SID sampling in 2018-2019 (Table 52). No other monitoring by other organizations has occurred in AUID-643. Data are discussed below by parameter.

Table 51. AUID-643 water quality measurements from the IWM biological sampling visits at 07UM017 (S010-556). Values in mg/L, temperature in ºC.

Date	Time	Water Temp. ºC	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
6/27/2017	14:58	18.3	5.46	58	541	0.99	0.12	< 0.10	7.2	> 100	< 1
8/14/2017	19:24	20.0	2.07	23	613	--	--	--	7.1	> 100	--

Table 52. SID monitoring summary for 07UM017 (S010-556), June - September 2018 - 2019. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO*	19	2.83	10.1	0.71
DO % saturation*	18	31.69	103.1	8.5
Conductivity*	20	548.3	690	353
Temperature*	20	19.16	24.0	12.3
TP	12	0.273	0.620	0.073
Nitrate	12	0.414	1.2	< 0.05
TSS	3	7.93	11	4.4
TSVS	3	3.73	5.2	2.0

*May 15 - Sept. 27, only one pre-9 a.m. measurement.

Nutrients - phosphorus

While TP is sometimes below the River Eutrophication Standard - Central, generally it exceeds the standard. The average concentration of the samples collected is nearly three times the standard, and one reading was over six times the standard. It is likely that excess phosphorus is fueling the oxygen stressed condition of the stream.

Nutrients - nitrate and ammonia

Sampling has shown nitrate to be relatively low. Agricultural landscapes farther south in Minnesota often have nitrate levels much higher than what was found in AUID-643. It is often somewhat elevated, as shown by the fact that nitrate can be at levels below the detection limit. This nitrate is likely mostly from agricultural fertilizer, which can be seen by the sample from April 26, which was much higher than later spring and summer samples. At this time, soil is exposed and no crops are growing and utilizing nitrate (which is soluble in water), and so it can be carried by runoff to the channel.

Dissolved oxygen

DO concentrations are often below the standard. The average of numerous 2018 and 2019 samples was just over 50% of the standard, and included a low measurement of less than 1 mg/L.

Transparency and suspended solids

The four available TSS samples found low concentrations of suspended particulates, all below the regional TSS standard. The Secchi tube transparency measurements at the two biological monitoring visit were excellent. The citizen monitoring volunteer who tracks conditions at the downstream end of the AUID has said that the stream is typically clear.

Conductivity

Specific conductivity was in a range similar to other NFCW streams. The measured levels should not be problematic for the fish community.

Stressor signals from biology

Fish

The fish community in AUID-643 has been sampled once, in 2017. Only three species were caught. Central mudminnow was far dominant. The two other species present were brook stickleback and black bullhead. No sensitive species were present.

The Community TIV Index scores are shown in Table 53 and individual TIV metrics in Table 54. The DO Community Index score was much worse than the Class 6 average and the fish community was highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and the percentage of Tolerant versus Intolerant individuals.

The TSS TIV Index score was much better than the Class 6 average. The probabilities the sample could come from a TSS standard-meeting site are very high. There were no TSS Intolerant nor Tolerant species found, which would suggest that TSS is not a stressor.

Nitrate does not show evidence of being a stressor. The Nitrate TIV Index score was much better than the class average, and though there were no Nitrate Intolerant individuals, there were almost no Nitrate Tolerant ones either.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels, but not due to elevated TSS or nitrate levels.

Table 53. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-643 at 07UM017 on 6/27/2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
DO	5.31	6.61/6.68	1	1.7
TSS	12.11	13.92/13.26	80	82.8
Nitrate	0.77	2.45/2.46	99	--

Table 54. Metrics involving low-DO, TSS, and nitrate tolerance for the 6/27/2017 sampled fish community at 07UM017.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	0	0	3	3	0.0	100
TSS	0	0	0	0	0.0	0.0
Nitrate	0	0	1	0	0.0	1.8

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

One macroinvertebrate sample has been collected at 07UM017, in 2017. The most abundant taxa by a substantial amount was the midge *Chironomus*. Three other abundant taxa were Oligochaeta (worms), *Physella* (a snail), and *Hyalella azteca* (an amphipod). *Chironomus* is notorious for being able to tolerate low DO waters. Oligochaeta and *Physella* also can tolerate very low DO waters. No EPT taxa were present in the sample, a very unusual situation for a stream. EPT taxa in general require good DO concentrations.

The Community TIV Index scores are shown in Table 55 and individual TIV metrics in Table 56. The DO TIV Index score was far poorer than the class average, and the score is near the bottom of DO TIV Index scores for stream Class 7. The probability of the sampled community coming from a DO-meeting site is extremely low. The community is highly skewed toward taxa that are low-DO Tolerant in terms of the number of species that were present versus low-DO Intolerant (none), and there was a high percentage of low-DO Tolerant individuals comprising the sample.

The TSS TIV Index score was far better than the Class 7 average, and the percentile within Class 7 streams was extremely high. The probability of the community coming from a standard-meeting site is moderately strong. The community is skewed toward TSS Tolerant, in terms of the taxa present, but the number of individuals from these TSS Tolerant taxa is fairly low.

As with TSS, the Nitrate TIV Index scored much better than the Class 7 average, and at a high percentile among Class 7 streams. Conditional probability is not available for nitrate. Though the Index score is very good, the macroinvertebrate community is somewhat skewed toward Nitrate Tolerant taxa, both in terms of number of species present, and the percent of individuals, though the percentage, like with TSS, is not high. No Nitrate Intolerant taxa were present in the sample.

Given that the DO TIV Index score is extremely poor, and that the Intolerant versus Tolerant taxa presence and percent of individuals are somewhat skewed toward low-DO tolerance, the macroinvertebrate community does show stress from inadequate DO concentrations. This analysis does not provide consistent evidence that either TSS or nitrate is a stressor to the macroinvertebrate community.

Table 55. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores in AUID-643 at 07UM017 on August 14, 2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 7 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
DO	3.67	6.24/6.36	2	5.0
TSS	12.08	16.88/16.55	95	61
Nitrate	2.36	3.47/3.43	89	--

Table 56. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled macroinvertebrate community at 07UM017 on August 14, 2017.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	0	0	6	4	0.0	59.3
TSS	0	0	6	4	0.0	14.2
Nitrate	0	0	5	5	0.0	14.2

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, there is strong evidence that low DO levels are stressing both communities. There is a weak signal that TSS is a stressor to the macroinvertebrate community, but not to fish. Again for nitrate, there is a similar weak signal that nitrate may be a stressor to the macroinvertebrates, but not the fish.

Temperature

The water temperature at both biological sampling visits was quite cool. Other temperature measurements show the stream typically has very moderate temperatures, with the highest measurement being 24.0°C. Based on these data, temperature should not be a stressor to the biological communities.

Habitat

Habitat is very poor in this channelized AUID, based on MSHA metrics, and the UAA process rated it as insufficient to be placed into the General Use TALU category, so it was placed into the Modified Use category. The total MSHA score in 2007 was the same as the averaged 2017 observations, well below the threshold at which it is considered "Poor". The total and sub-component scores are shown in Table 57. In the 2017 observation, the poorest-scoring sub-component scores by far were "Surrounding Land Use" and "Channel Morphology". The latter is very typical of ditches, which typically have little sinuosity, uniform bed topography, and lack of distinct channel features like pools or riffles. These characteristics were indeed responsible for the poor score for this MSHA component. The largest substrate type present was gravel, though the observers noted that it was significantly embedded by the predominant substrates of sand, clay, and silt. It was also noted that the lateral margins of the channel were quite "mucky". The samplers also noted at the June 27, 2017 visit that there was extensive aquatic vegetation, to the point of terming it "choking" (Photo 13). Based on such low MSHA scores, poor habitat is a stressor in AUID-643.

Table 57. MSHA scoring for site 07UM017.

MSHA Component	7/2007	6/2017	8/2017	2017 Avg.	Maximum Poss. Score	2007 % of Maximum	2017 % of Maximum
Land Use	0	0	0	0	5	0.0	0.0
Riparian	8	7	7	7	14	53.3	50.0
Substrate	9	7	7	7	28	33.3	25.0
Cover	2	11	10	10.5	18	11.8	58.3
Channel Morphology	10	0	7	3.5	35	27.8	10.0
Total MSHA Score	29	25	33	29	100	29 = "Poor"	29 = "Poor"

Photo 13. The channel within the biological sampling reach on June 27, 2017 showing the extensive vegetation and filamentous algae mats growing upon it.

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, as essentially all of the channels in this stream system are ditches. These connect numerous wetland areas. It is not known how much of the channel system that exists now existed naturally. There are no stream channels denoted on the original public land survey map within this sub-watershed. Not knowing how the original land drainage occurred, it is difficult to say how differently the hydrology of the watershed functions differently now. Generally, we speak of the influence of alteration of hydrology on natural stream channels, as it can physically damage them when flow patterns are changed. This situation does not exist for AUID-643, as essentially the whole system is modified.

Geomorphology

No geomorphology studies were conducted on AUID-643. Photos along the channel of the biological sampling reach do not show bank instability.

Connectivity

There are two culverts downstream of site 07UM017. One is at the very end of the AUID where it meets Long Lake. This culvert at 545th Avenue appears passable based on aerial photos. The second culvert is at the 245th Street crossing. The road appears to be abandoned for a section, including this crossing, and seems to be only used as a field access for the adjacent farmstead. The culvert has not been visited, and therefore it is unknown as to its level of passability for fish. The culvert just upstream of 07UM017 was

determined to be passable. Problems with connectivity cannot be ruled out as potential locations include private property, but where crossings were able to be checked, they are passable.

Conclusions about stressors

There are two main stressors to aquatic biology in AUID-643; low-DO concentration and poor physical habitat. A small data set found little evidence that either elevated TSS or nitrate (via toxicity) are stressors. There was a minor signal that TSS and nitrate were influencing the macroinvertebrate community, but not the fish. The root cause of the DO impairment is elevated nutrients, which stimulate excessive plant growth (eutrophication). There is a lack in diversity of habitat features which contributes to the poor biological communities. As a constructed ditch, habitat is not necessarily degraded, but in many ways is limited by design.

Recommendations

Addressing the poor physical habitat will be difficult, because the characteristics found are typical of ditches, especially if they are maintained. Allowing ditches to develop some habitat features by reducing maintenance/clean-outs will improve biological community health.

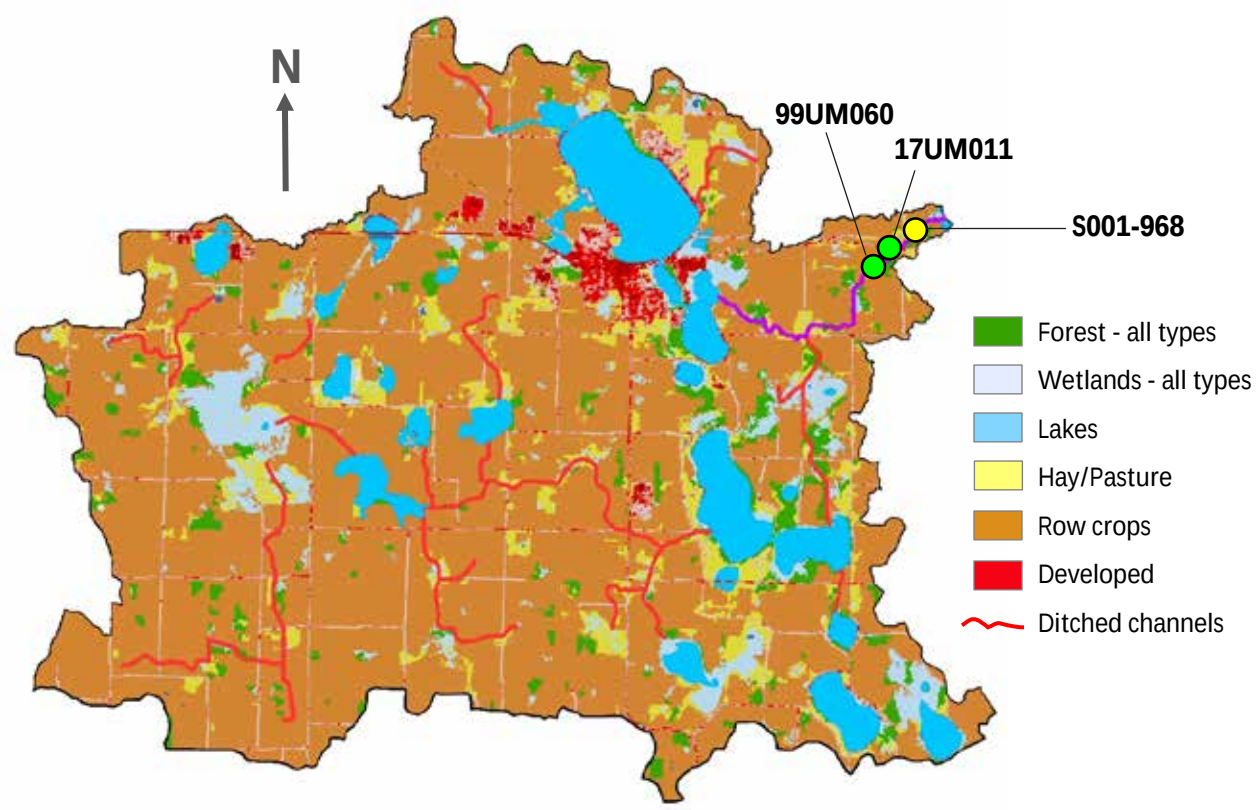
Twelvemile Creek (AUID 07010204-679)

Impairment: AUID-679 is an approximately 3.7 mile long reach beginning as the outflow of Dutch Lake and ending at the entrance to Little Waverly Lake. There have been two biological monitoring sites on this reach. An older site, 99UM060, was sampled in 1999, while a new site, 17UM011, was sampled in 2017. The sites are quite close to each other, just upstream of U.S. Highway 12. Part of the AUID-679 channel has been straightened. The new site is on a natural part of the channel, and therefore, the site is held to the General Use standard. The AUID was assessed as having impairments of both the fish and macroinvertebrate communities. The Macroinvertebrate Stream Class is 5 (Southern Streams - RR), the Fish Stream Class is 6 (Northern Streams).

Sub-watershed characteristics

The middle portion of AUID-679 has been straightened, while the upper and lower parts have a natural, unmodified channel. Howard, Mallard Pass, and Dutch Lakes are the headwaters of Twelvemile Creek. Numerous other smaller lakes spread throughout the subwatershed are connected via a ditch system that is tributary to Twelvemile Creek, though are not surficially connected to Twelvemile Creek. The land use/cover of the sub-watershed of AUID-679 is shown in Figure 29. The land use is predominantly row crop agriculture with lesser amounts of grassland/pasture and very little forest cover. The City of Howard Lake is just upstream of AUID-679, across Dutch Lake. There are no permitted effluent dischargers to AUID-679.

Figure 33. The sub-watershed and land use/cover (NLCD 2016) for Twelvemile Creek and AUID-679 (the purple line).



Data and analyses

Chemistry

The chemistry sampled at biological monitoring visits and 2019 work SID is presented in Table 58. The 2019 data was collected a short distance downstream of the biological sample sites, at S001-968 on Gowan Avenue SW. The Middle Fork Crow Watershed District collected water chemistry data a total of 10 times in May - September of 2017 and 2018 (Table 59). Data are discussed below by parameter.

Table 58. IWM chemistry results from 1999 (at 99UM060) and 2017 (at 17UM011), and at S001-968 in 2019 by SID staff. Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS	TSVS
7/7/1999	11:20	21.6	3.50	--	528	0.257	0.360	0.07	7.5	--	< 4.0	--
6/20/2017	14:10	20.7	6.72	75	522	0.179	0.244	< 0.1	7.5	> 100	3.2	--
9/13/2017	10:54	20.7	6.01	67	384	--	--	--	7.7	> 100	--	--
6/3/2019	15:45	20.4	6.92	76.5	509	--	--	--	--	--	--	--
6/4/2019	9:15	19.9	5.24	57.6	508	--	--	--	--	--	--	--
6/19/2019	9:00	19.2	6.30	68.2	493	--	--	--	7.6	--	--	--
7/2/2019	9:25	21.3	4.50	50.7	508	--	--	--	7.5	--	--	--
7/18/2019	12:00	25.8	3.13	38.1	473	--	--	--	7.5	--	--	--

Table 59. IWM 10x chemistry results from 2017 and 2018 at S001-968 (a short distance downstream of 17UM011) collected by the Middle Fork Crow Watershed District. Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS
5/16/2017	14:00	20.3	7.84	--	490	0.135	--	--	--	49	41
6/5/2017	13:30	20.5	7.46	--	494	0.142	--	--	--	77	7
7/10/2017	12:45	23.6	7.64	--	480	0.224	--	--	7.9	> 100	2
8/10/2017	11:10	18.5	8.23	--	410	0.225	--	--	7.9	> 100	3
9/11/2017	11:15	18.9	9.02	--	--	0.182	--	--	7.8	> 100	2
5/10/2018	11:00	13.0	8.23	--	480	0.155	--	--	7.8	89	12.4
6/11/2018	11:25	19.8	6.95	--	448	0.389	--	--	7.7	72	53.2
7/9/2018	13:15	25.6	3.59	--	471	0.25	--	--	7.4	80	8.2
8/7/2018	11:50	22.1	6.40	--	427	0.27	--	--	7.9	50	14.2
9/6/2018	12:35	17.9	7.35	--	487	0.251	--	--	7.7	55	9.2

Nutrients - phosphorus

All 11 of the samples that have been collected in 2017-2018 were above the River Eutrophication Standard - Central. Six of the samples were more than two times the standard. This finding points to a possible eutrophication situation in AUID-679.

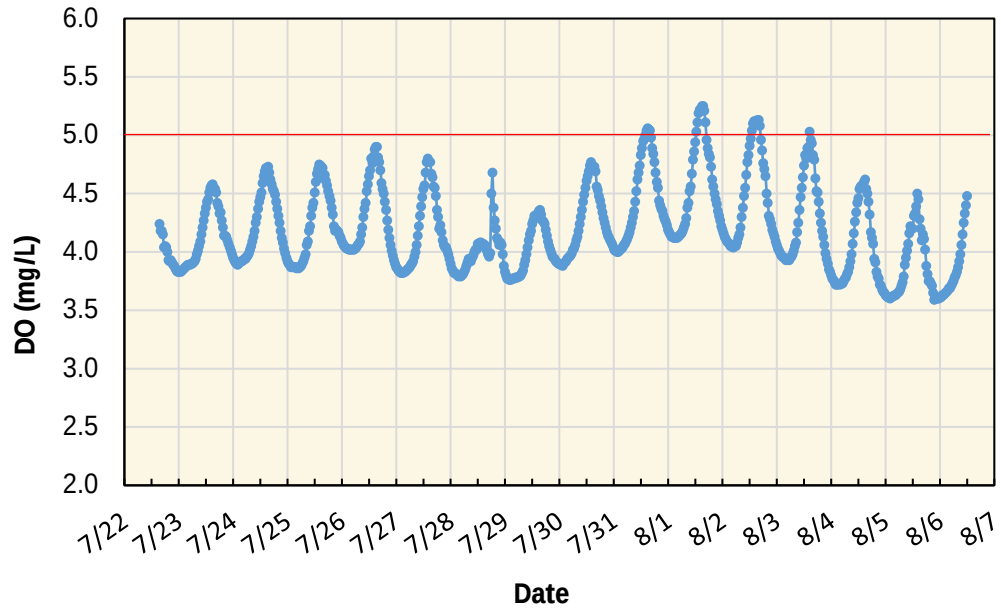
Nutrients - nitrogen

Only one recent nitrate sample has been collected in recent years, at 17UM011. It was quite low for an agricultural landscape. Ammonia was at very low concentration. The 1999 sample was quite similar to the 2017 sample. With such few samples, it is hard to describe the nitrate dynamics in the creek. Additional information will be gleaned from the biological communities, below.

Dissolved oxygen

All of the instantaneous DO measurements are relatively low, regardless of the time of day. The afternoon measurements are above the standard, but are lower than is typical of healthy streams for the afternoon period. Several morning samples are below the DO standard, particularly as the season moves to mid-summer. A continuously-measuring Sonde was deployed in 2019 in late July - early August, and found that over the 15 day period of deployment, the DO almost never met the DO standard (Figure 31). The DO percent saturation can provide insight into the DO dynamics, and is also data collected by the Sonde. Measurements much over 100% confirm there is an abnormal amount of plants and/or algae in the stream. From the instantaneous measurements, the saturation ranged from 38 - 76%. From the 15 days long Sonde data, the DO saturation averaged 49.7%, and ranged from 43.0 - 62.7%. This maximum is quite low, especially for a stream with elevated nutrients to fuel plant growth. It means that even when photosynthesis is occurring in the daytime, more oxygen is being used by decay bacteria working on organic material than is being produced by photosynthesis or diffusion of oxygen into the water from the atmosphere. These data suggest that there is not eutrophication occurring in AUID-679.

Figure 34. Sonde DO measurements in Twelvemile Creek at S001-968 in 2019. The red line is the DO standard.



Transparency and suspended solids

The TSS and/or Secchi tube readings at the biological sampling visits were excellent. The 10 samples collected by the District in 2017-2018 showed that TSS is often extremely low, with 6 of the samples below 10 mg/L, and as low as < 2 mg/L. However, TSS can get high, as two of the samples were 41 and 53 mg/L. This same pattern was found in the citizen monitoring transparency data collected in the early 2000s.

Conductivity

Specific conductivity was quite similar among the sampling visits, and similar to other sites in the NFCW. The level generally hovered around the 500 µS/cm. The measured levels should not be problematic for the fish or macroinvertebrate communities.

Stressor signals from biology

Fish

The fish community in AUID-679 has been sampled once, on June 20, 2017. A total of 10 species were caught, with bluegill being far dominant. The next two most abundant species were largemouth bass and crappie. All three are lake-oriented species. No sensitive species were present.

The Community TIV Index scores are shown in Table 60 and individual TIV metrics in Table 61. The DO Community Index score was slightly better than the Class 6 average and just under the median. There is a less than 50% chance that this community would be found in a DO standard-meeting stream. The fish community was skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and skewed for the percentage of Tolerant versus Intolerant individuals.

The sample's TSS TIV Index was somewhat better than the class average, and slightly worse than the median. The sample has a fairly high probability that it would be found in a TSS standard-meeting site. There were no TSS Tolerant species present in the recent sample, which suggests that TSS is not a stressor. There is minimal evidence in the 2017 fish data of the influence TSS.

The sample's nitrate TIV Index was far better than the class average. There are more nitrate Tolerant species present, but they form a small percentage of the community. The percentage of nitrate

Intolerant individuals was much higher than for nitrate Tolerant ones in the recent sample (due to the large abundance of bluegill in the sample). Nitrate does not show evidence of being a stressor.

These analyses provide some evidence that the fish community is being stressed by inadequate DO levels, but little to no evidence that elevated TSS or nitrate levels are stressors.

Table 60. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-679 at 17UM011, June 20, 2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
DO	6.7	6.61/6.68	49	45.2
TSS	13.4	13.92/13.26	46	75.9
Nitrate	0.75	2.45/2.46	99	--

Table 61. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish community at 17UM011.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	0	0	7	2	0.0	16.5
TSS	0	0	0	0	0.0	0.0
Nitrate	1	0	3	0	74.1	5.2

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

One macroinvertebrate sample has been collected at 17UM011, on September 13, 2017. The three most abundant taxa in the sample were the caddisfly *Hydropsyche betteni*, the mayfly *Baetis brunneicolor*, and immatures of caddisfly family Hydropsychidae (possibly more *H. betteni*).

The Community TIV Index scores are shown in Table 61 and individual TIV metrics in Table 62. The DO TIV Index score was better than the class average, and the score is at a fairly high percentile of DO TIV Index scores for stream Class 5. The probability of the sampled community coming from a DO-meeting site is fairly good. The community is somewhat skewed toward taxa that are low-DO Intolerant in terms of the species that were present, and low-DO Intolerant individuals comprised a relatively high percentage of the sample.

The TSS TIV Index score was poorer than the Class 5 (Central TSS) average, and the percentile within Class 5 Central TSS streams is quite low. The probability of the community coming from a standard-meeting site is quite poor. The community is strongly skewed toward TSS Tolerant taxa in terms of both the taxa present and the percent of TSS Tolerant individuals. There are no TSS Intolerant taxa present.

The Nitrate TIV Index scored somewhat better than the Class 5 average. Conditional probability is not available for nitrate. Though the Index score is better than the class average, and at a fairly high percentile among Class 5 streams, the macroinvertebrate community is strongly skewed toward Nitrate Tolerant taxa, especially in terms of number of species present, and to a lesser extent, the percent of individuals. Zero Nitrate Intolerant taxa were present in the sample.

Given that the DO TIV Index score is good, and that the Intolerant versus Tolerant taxa presence and percent of individuals are skewed toward low-DO intolerance, the macroinvertebrate community shows no evidence of stress from inadequate DO concentrations. There is moderate evidence that TSS is a

stressor to the macroinvertebrate community. There is also good evidence for nitrate stress to macroinvertebrates.

Table 62. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores in AUID-679 at 17UM011 on 9/13/2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
DO	7.37	6.94/7.07	75	77
TSS	16.49	15.07/14.93	21	21
Nitrate	2.78	3.21/3.21	78	--

Table 63. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled macroinvertebrate community at 17UM011 on 9/13/2017.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	3	2	1	0	21.1	5.9
TSS	0	0	8	3	0.0	48.3
Nitrate	0	0	10	9	0.0	31.3

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, there is conflicting evidence that low DO levels are stressful, with the fish suggesting that possibility, and the macroinvertebrates suggesting not. Also conflicting is the evidence for elevated TSS as stressor, this time with macroinvertebrates suggesting yes, while fish suggest no. There is also a signal, again from the macroinvertebrates only, that elevated nitrate is a stressor. That the fish don't show the nitrate influence at these nitrate levels is not surprising as other MPCA work has suggested that macroinvertebrates in general are affected by lower levels of nitrate than most fish. Invertebrates have been found to be sensitive to nitrate beginning at about 4 mg/L (Camargo et al. 2005).

Temperature

A number of temperature measurements have been taken at 17UM011 and none showed any that would be problematic for the fish community.

Habitat

Habitat as measured by the MSHA was at the high end of the scoring range considered "Fair" in 2017. The total and sub-component scores are shown in Table 63. The poorest-scoring sub-component scores were "Surrounding Land Use" and "Channel Morphology". Surrounding land use scored poorly due to the small amount of perennial cover in the landscape surrounding the AUID. The subcomponents of Channel morphology most responsible for the reduced score are lack of deep pools, and channel instability. Both of these are related to hydrological patterns of the streamflow. Both can be negatively affected by flashy or excessive flow. These cause banks to fail, and excess sediment in the channel, filling deeper pools. Channels that formed based on one pattern of hydrology will be damaged if the land area that contributes runoff is enlarged. Hydrology is discussed next. The speed of flow in the biological reach appears to be swift enough to prevent sedimentation by fine particulate material in the riffles and runs, as embeddedness of large substrates was considered "Light" at both visits.

Table 64. MSHA scoring for site 17UM011.

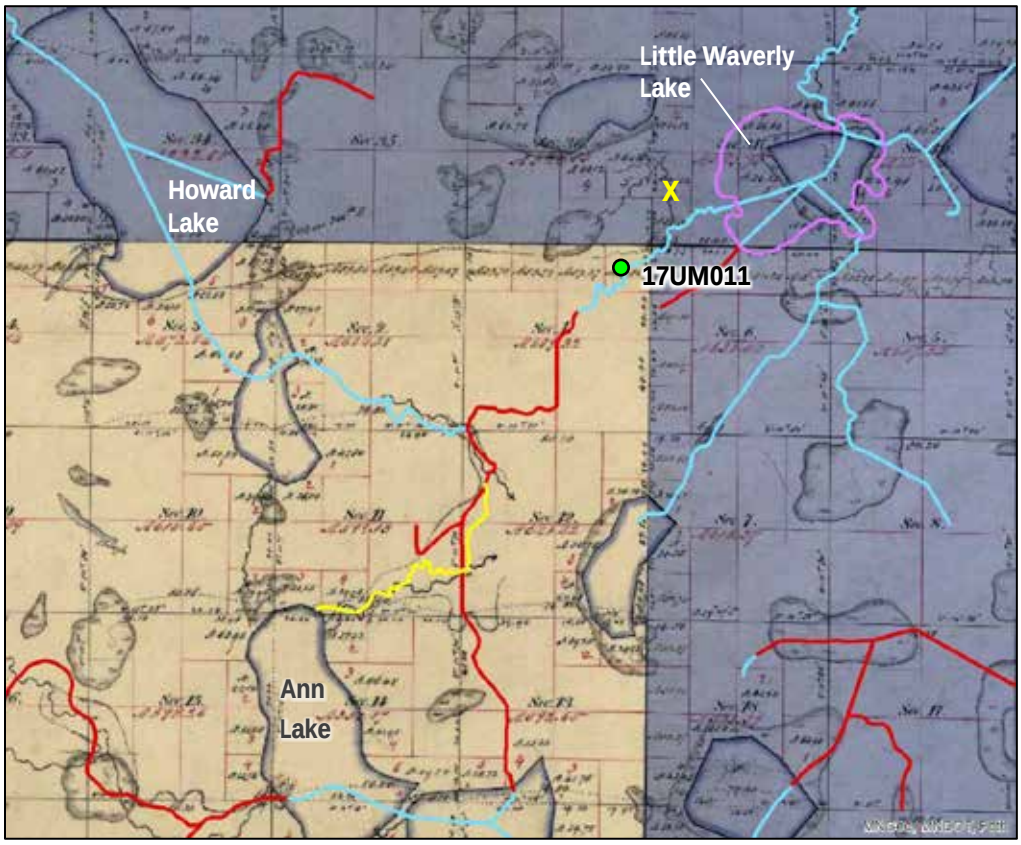
MSHA Component	6/2017	9/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	0	0	0	5	0.0
Riparian	12.5	10.5	11.5	14	82.1
Substrate	19.2	19.6	19.4	28	69.3
Cover	16	12	14	18	77.8
Channel Morphology	18	19	18.5	35	52.9
Total MSHA Score	65.7	61.1	63.4	100	63.4 = "Fair"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest/prairie to cultivated fields), as well as straightening of portions of the channel that reduced sinuosity and thus speeds movement of water through the landscape and stream system. A tributary ditch system entering the AUID from the south has added flow that was not originally connected surficially to Twelvemile Creek. The channel width was also likely increased when the ditching was done on a portion of Twelvemile Creek. These changes have made Twelvemile Creek a more flashy system than it was pre-modification, with quicker, stronger pulses of water moving through the system following sizeable rain events.

A number of changes to the hydrology have occurred on the landscape since settlement. The following comments regard Figure 31. The size of Little Waverly Lake, the receiving water of AUID-679 flow, has doubled in size from the time of the original land survey, according to the tracing of the 2017 Little Waverly Lake's shoreline (done in GIS). Some streams were drawn on the survey map and can be used to see how humans have changed flow patterns. On the original drawings, the headwaters of Twelvemile Creek is shown, as is a creek exiting Ann Lake. These lines aren't continued on the drawing, but aerial photography shows the remnant channel. The arrow point at the ends of these survey map channels are about at the western edge of a large wetland that still exists (perhaps the reason the lines end here). In some cases, these survey map streams appear incorrect. Using LiDAR, the channel near Little Waverly Lake appears to have been mapped incorrectly (Figure 31). There is no evidence on the LiDAR coverage that a channel ever travelled north there.

Figure 35. Original land survey map in the Twelvemile Creek subwatershed, with current streams overlain. There seem to have been some hydrological alterations made to the Twelvemile Creek system. The yellow line is an original outflow channel from Ann Lake that seems to no longer have flow. The survey map channel with the yellow "x" appears to have been incorrectly mapped in that location, rather it flowed into Little Waverly Lake.



Geomorphology

The physical channel is highly related to the hydrology of the sub-watershed's landscape. As mentioned above, hydrology has be substantially changed from its original flow paths and amounts. The added water burden in the channel has caused channel instability in places. Significant bank erosion was noted and photographed by the biological crews (Photo 14). The cobble substrate in this section of stream has prevented significant downcutting of the channel, but pressure has been put onto the banks, and this has caused instability, and the resulting input of sediment into the stream and downstream into the lake (Photo 15). Additional areas of bank erosion can be seen in aerial photos, both upstream and downstream of the biological site, particularly where riparian woody vegetation has been changed to grass.

Photo 14. Two bank sections in the biological sampling reach are examples of bank instability and sediment input to the creek and Little Waverly Lake downstream.

Photo 15. A sediment delta (within the yellow box) has formed where Twelvemile Creek enters Little Waverly Lake. Turbid stream water can also be seen in the lake.

Connectivity

There are three road crossings downstream of the biological monitoring site and above Little Waverly Lake that could potentially be barriers to fish migration and influence the fish community where sampled. These are, from downstream to upstream, 60th Street SW, Gowan Avenue SW, and U.S. Highway 12. These crossings were visited, and all appear to allow for fish passage. Among these, one factor that can lead to a culvert being a barrier is culvert length applies to the culvert under U.S. Highway 12. It was measured with a computer tool to be approximately 168 feet in length. The gradient of the culvert is very low, so water velocity, at least at baseflow conditions, is quite slow and should allow fish passage despite the length. No other barriers, such as beaver dams, could be seen in aerial photos in this section of stream. Road crossing infrastructure is not a barrier to fish migration, and thus not a stressor to the fish community at 17UM011.

There are some crossing upstream of the biological monitoring site that also have potential to be barriers based on aerial photo review, particularly a structure associated with a private driveway bridge at approximately 45.052556, 94.025017. These would not affect the fish community at 17UM011, but could affect the fish community upstream of their location. One mitigating factor for upstream areas is that fish can migrate from upstream overwintering refuge areas; the large wetland complex on the tributary to Twelvemile Creek and Dutch Lake.

Conclusions about stressors

Investigation to uncover biological stressors did not reveal any for which there was strong evidence. There was some evidence of low-DO stress in the fish community, but not in the invertebrate community. The opposite was found for TSS, where the macroinvertebrate community analysis suggested stress from elevated TSS, while the fish community analysis did not. Neither the fish nor macroinvertebrates showed signs of stress from nitrate. Measurement of DO did find common occurrences of concentrations below the standard. Macroinvertebrates are perhaps not showing this as a stressor due to other macroinvertebrate habitat features (particularly substrate and flow velocity) being relatively favorable.

Phosphorus concentrations in the stream are sometimes well above the River Eutrophication - Central standard. There are several livestock feedlots in the sub-watershed, some very close to the channel. There could be runoff from these areas reaching the channel. The fact that there is an *E. coli* impairment for AUID-679 suggests this could be the case. In addition, there exists pasture land along the AUID at which animals have access to the creek. Manure from the feedlots is also likely spread on fields that are within the sub-watershed. Additionally, there is significant wetland area hydrologically connected to the tributary ditch that enters AUID-679, which also supplies phosphorus from plant material decay. BMPs addressing the E coli issue should also decrease the TP levels in the stream. It is unclear how influential the elevated TP is on the DO dynamics of the stream; the measurements at the biological monitoring site does not show the typical daily pattern found in streams experiencing eutrophication. Primarily, there is not the high DO in afternoon hours. Even if TP is not strongly influential in Twelvemile Creek, reduction would benefit Little Waverly Lake.

Physical habitat assessment found the habitat to almost reach the scoring range of “Good”, and therefore habitat is not considered a stressor. Potential barriers to fish migration were checked and found to be passable, thus connectivity is good and barriers cannot explain the fish impairment.

There are no permitted pollutant dischargers active in this sub-watershed. There is one urban area upstream of AUID-679, the City of Howard Lake. Runoff from the impervious surfaces of Howard Lake reaches either Howard Lake, Mallard Pass Lake, or Dutch Lake, and materials carried in the runoff is

somewhat processed by these lakes, providing a buffer for Twelvemile Creek, though potentially causing water quality deterioration in the lakes.

Recommendations

Additional phosphorus monitoring would be helpful to determine source locations, including the input from the tributary ditch entering from the south. More DO monitoring, also at more locations along the AUID would be helpful to determine whether eutrophic conditions exist in some parts of Twelvemile Creek. Again it would be helpful to measure DO levels in the tributary ditch and how influential that is to DO levels in Twelvemile Creek, due to the abundant wetland habitat along that channel. A draft TSS TMDL has been completed in 2020. Wright County SWCD has received a long-term grant from EPA (through MPCA) for the Twelvemile Creek subwatershed, which will allow for more intensive water quality BMP implementation than it likely would receive otherwise.

Washington Creek (AUIDs 07010204-751)

Impairments: AUID-751 is a 3.52 mile long reach beginning as the outlet of Washington Lake and ending at -94.342, 45.108. The sampled portion of the AUID is channelized, and the UAA placed the AUID in the Modified Use class. The AUID has one biological monitoring station, 07UM030 at 273rd Street. AUID-751 has a new (2019) impairment for the macroinvertebrate community, while the fish met the IBI standard for the modified threshold. The macroinvertebrate stream Class is 5 (Southern Streams - RR) and the fish stream Class is 7 (Low Gradient).

Sub-watershed characteristics

The land use and land cover of the lower portion of the sub-watershed of AUID-751 is somewhat evenly mixed between row crop agriculture, hay and pasture, and forest/wetland (Figure 33). Several small lakes are found in the sub-watershed. The land cover of the part of the upper sub-watershed that first feeds runoff to Washington Lake is much more homogeneously devoted to row crop agriculture. Essentially all of the stream channels in the sub-watershed are created or straightened stream channels. Almost the full length of AUID-751 flows through wetland habitat (Figures 34 and 35). The City of Dassel's wastewater treatment ponds are permitted to discharge the treated water to Washington Creek, a short ways downstream of the Washington Lake outlet.

Figure 36. The sub-watershed of Washington Creek, AUID-751 and its land use/cover (NLCD 2016). The left two-thirds of the image, which is partly opaque, is land area that drains first to Washington Lake, before becoming streamflow in AUID-751. The non-opaque area in the upper right is the land area that drains to AUID-751 without first draining to Washington Lake.

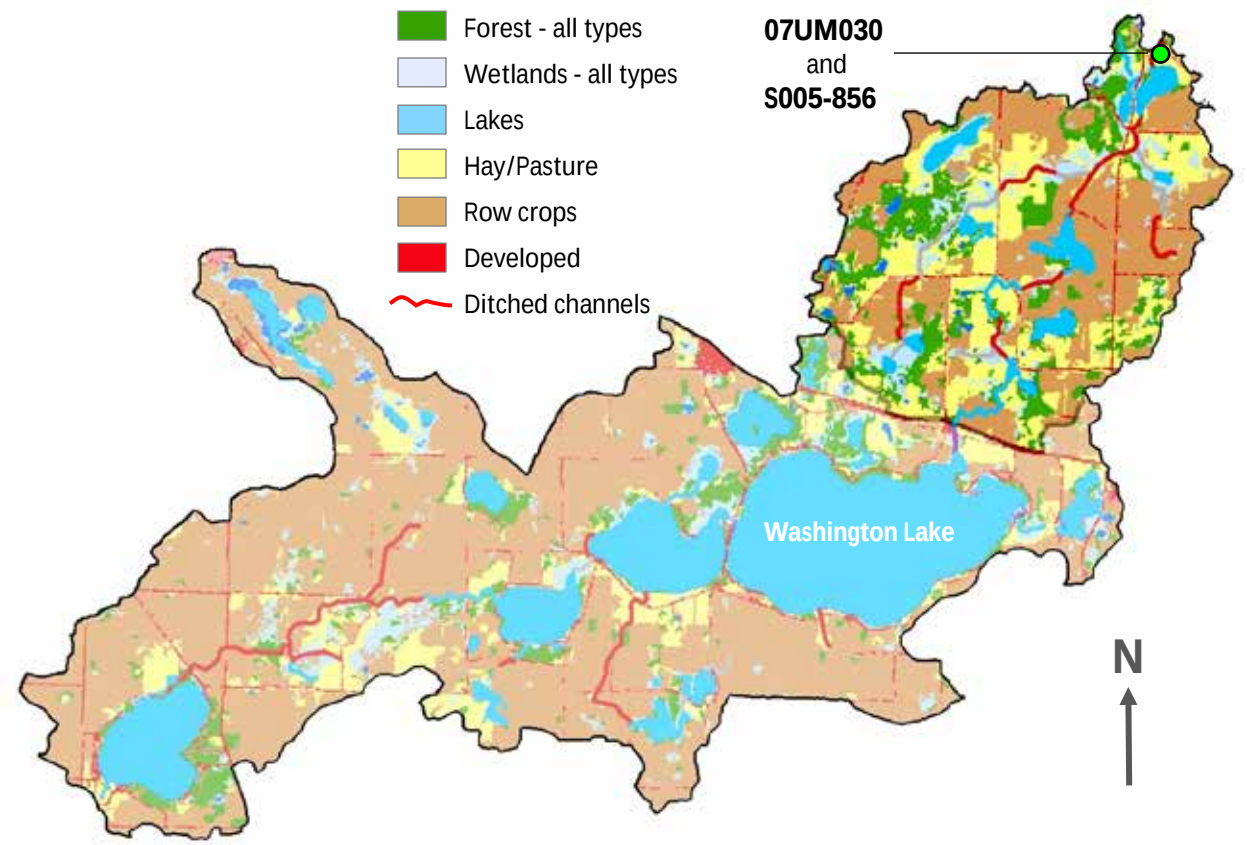


Figure 37. The direct subwatershed of AUID-751 showing National Wetland Inventory wetlands.

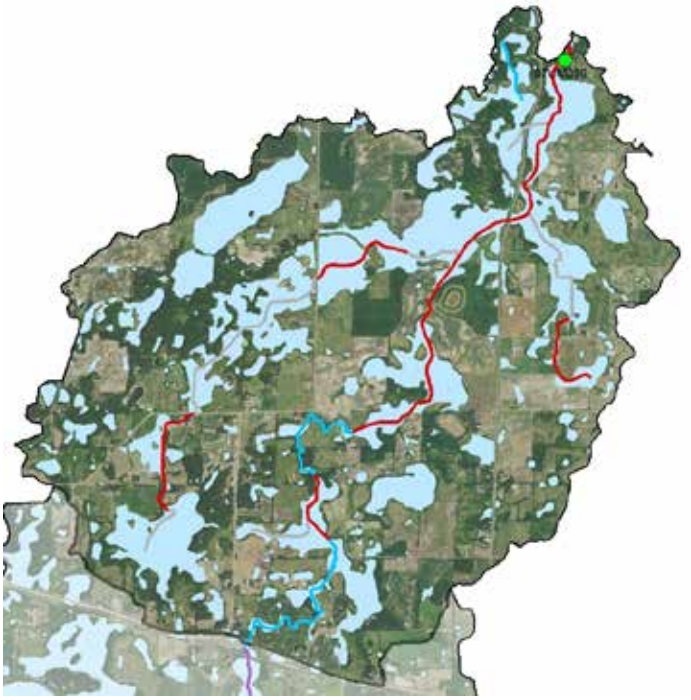


Figure 38. Aerial photography of the reach leading to and including the biological sample site 07UM030 near the top of the image, showing very large wetland that the channel flows through. Riparian habitat upstream within AUID-751 is similar.

Data and analyses

Chemistry

The data set for recent years collected from AUID-751 at 07UM030 (S005-856) consists of monitoring during the biological sampling visits in 2009 and 2017 (Table 64), and subsequent SID sampling in 2019 (Table 65).

Table 65. AUID-751 water quality measurements from the IWM biological sampling visits at 07UM030 (S005-856). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
6/20/2017	9:30	18.3	1.9	20	401	0.093	< 0.02	0.27	7.15	> 100	1.4
8/4/2009	?:??	21.5	--	--	--	0.148	< 0.05	< 0.1	--	--	< 4.0
8/15/2017	15:24	24.6	1.9	23	633	--	--	--	7.22	> 100	--

Table 66. SID monitoring summary for 07UM030 (S005-856) in 2019, 10:00 a.m. to 2:00 p.m. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO	7	3.56	5.0	2.1
DO % saturation	6	39.9	59.8	26.3
TP	1	--	0.131	--
Nitrate	1	--	0.07	--
Temperature	6	22.7	25.9	19.4

Nutrients - phosphorus

Of the three samples shown above, two were over the River Eutrophication Standard - Central, and one was just under, pointing to a potential for a eutrophication situation in AUID-751.

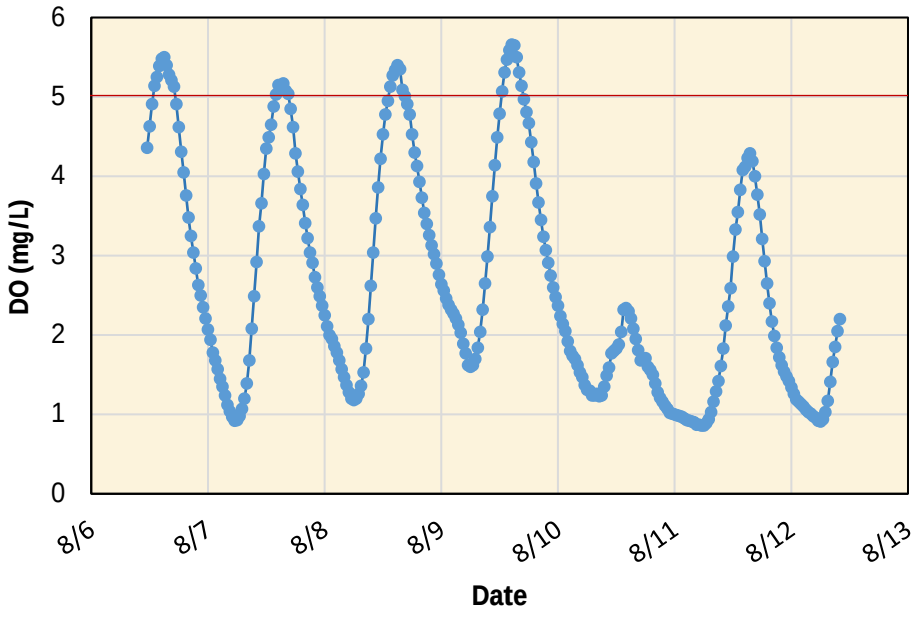
Nutrients - nitrogen

The few nitrate samples available showed extremely low concentrations, which is not surprising since denitrification (nitrate conversion to nitrogen gas) occurs well in wetland environments, and the AUID flows through wetlands along almost its full length. One of the two ammonia samples was somewhat elevated, but was not at a concentration high enough to have had an un-ionized fraction above the state standard.

Dissolved oxygen

The two instantaneous DO measurements taken at biological sampling visits are both far below the standard. Additional instantaneous DO measurements taken at SID visits averaged only mid-3mg/L, with the highest reading exactly at the standard. Further insight comes from a Sonde deployment done from August 6, 2019 - August 12, 2019. This data shows that the daily minimum in early morning can drop to slightly below 1.0 mg/L which is extremely poor (Figure 36). DO only reached an afternoon high of about 5.75 mg/L, and some days did not reach 5.0 (the standard). These data suggest that there is much organic material decaying in the channel, either deposited from upstream, or due to excessive plant growth within the site. The Sonde also collects the DO percent saturation, which can be useful in evaluating whether eutrophication is occurring (if DO percent saturation is above 100%). DO percent saturation data never reached 70% during the six days, and typically dropped to 10 - 20% overnight, which is extremely low. These numbers suggest there is very high SOD in the sediments of the channel.

Figure 39. Continuous monitoring Sonde DO data collected in 2019 at 07UM030 (S005-856). The red line is the state standard.



Transparency and suspended solids

The recent biological sampling visit showed a low TSS concentration. A monitoring site within AUID-751 (S005-857) about two miles upstream of the bio site has 2010 and 2011 Secchi tube data, and clarity is always at > 100, or in the high 90s cm.

Conductivity

Specific conductivity was in the range of many other streams in the NFRCW. The measured levels should not be problematic for the biological communities.

Stressor signals from biology

Macroinvertebrates

Two macroinvertebrate samples have been collected at 07UM030, in 2009 and 2017. Three taxa were relatively dominant in the sample, the amphipod *Hyalella azteca*, leeches (Hirudinea), and the snail *Valvata*. This is a very poor trio of taxa to dominate a stream sample. Many of the other taxa present are those common in wetlands, which often naturally have low DO. Only two EPT taxa were present, the tolerant mayfly *Caenis diminuta*, and a single individual caddisfly *Oecetis testacea*. This few EPT taxa is very uncommon for a stream sample. EPT taxa in general require good levels of DO.

The Community TIV Index scores are shown in Table 66 and individual TIV metrics in Table 67. The DO TIV Index score was far poorer than the class average, and the score is at a low percentile of DO TIV Index scores for stream Class 5. The probability of the sampled community coming from a DO-meeting site is low, extremely so with the 2017 sample. The community is highly skewed toward taxa that are low-DO Tolerant in terms of the species that were present, and low-DO Tolerant individuals comprised a high percentage of the sample.

The TSS TIV Index score was better than the Class 5 average, particularly so in 2017, and the percentile within Class 5 streams for the 2017 sample was extremely high. The probability of the community coming from a standard-meeting site is very high. The community is somewhat skewed toward TSS Tolerant taxa in terms of the taxa present and the percent of individuals. However, there are some TSS Intolerant taxa present.

The Nitrate TIV Index scored much better than the Class 5 average, and the percentiles within class were extremely high. Conditional probability is not available for nitrate. Similar to the situation with TSS, the 2009 macroinvertebrate community was somewhat skewed toward Nitrate Tolerant taxa, especially in terms of number of species present, and to a lesser extent, the percent of individuals. The 2017 was more balanced between Nitrate Tolerant and Intolerant taxa, and this time, more individuals were Intolerant.

Given that the DO TIV Index score is very poor, and that the Intolerant versus Tolerant taxa presence and percent of individuals are highly skewed toward low-DO tolerance, and that no low-DO Intolerant taxa were present either year, the macroinvertebrate community shows extremely strong evidence of stress from inadequate DO concentrations. There is mixed evidence that TSS and nitrate are stressors. Given that many of the taxa present are in general tolerant ones, this may explain the presence of numerous taxa that are also tolerant to these latter parameters.

Table 67. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores in AUID-751 at 07UM030 on 8/15/2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2018) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	Date	TIV Index score	Class avg./median	Percentile in class	Prob. as %
DO	8/4/2009	5.73	6.94/7.07	4	34
DO	8/15/2017	4.02	6.94/7.07	1	7
TSS	8/4/2009	15.87	16.36/16.08	55	76
TSS	8/15/2017	11.87	16.36/16.08	98	91
Nitrate	8/4/2009	2.47	3.21/3.21	87	--
Nitrate	8/15/2017	1.39	3.21/3.21	99	--

Table 68. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled macroinvertebrate community at 07UM030 on 8/4/2009 and 8/15/2017.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	2009	0	0	16	8	0.0	64.2
Low DO	2017	0	0	15	8	0.0	60.5
TSS	2009	3	0	9	5	2.1	25.5
TSS	2017	1	0	7	5	0.9	18.5
Nitrate	2009	3	0	15	9	2.1	32.1
Nitrate	2017	2	1	7	5	15.4	8.8

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

The temperature measurements taken at the three visits to 07UM030 (including an afternoon visit, see Table 64 and 65) were moderate to cool, not at stressful levels. The Sonde discussed above also measures temperature, and the deployment was during the warmest part of the summer. The temperatures measured by the Sonde found that the great majority of the time, temperatures were below 25°C. A few days had measurements in the 26-27°C range for a few hours. These short durations at this temperature level should not be problematic.

Habitat

Habitat is mediocre in this channelized AUID, based on MSHA metrics, and the UAA process rated it as insufficient to be placed into the General Use TALU category, so it was placed into the Modified Use category. The total and sub-component scores are shown in Table 69. In the 2017 observation, the poorest-scoring sub-component scores were "Substrate" and "Channel Morphology". This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles. These characteristics were indeed responsible for the poor score for this MSHA component. Gravel and cobble were recorded as being present, but the predominant substrates were sand and silt. In one of the 2017 visits, siltation was recorded as "Heavy". Channel bed features (e.g., riffles and pools) were not well defined. The scorers noted that embeddedness of the cobble was moderate. Samplers noted extensive macrophyte vegetation.

Table 69. MSHA scoring for site 07UM030.

MSHA Component	8/2009	6/2017	8/2017	2017 Average	Maximum Poss. Score	2009 % of Maximum	2017 % of Maximum
Land Use	5	5	2.5	3.8	5	100	76.0
Riparian	9.5	11	10.5	10.8	14	63.3	77.1
Substrate	12.8	13	11	12.0	28	47.4	42.9
Cover	12	15	14	14.5	18	70.6	80.6
Channel Morphology	18	10	5	7.5	35	50.0	21.4
Total MSHA Score	57.3	54	43	48.6	100	57.3 = "Fair"	48.6 = "Fair"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest to cultivated fields), as well as straightening of the channel that reduced sinuosity and thus speeds movement of water through the landscape/stream

system. There are still significant amounts of wetlands, which help in storing runoff. The general enhanced drainage of the sub-watershed probably creates low flow conditions more commonly than before modification. Water levels were very low in 2007 and precluded collecting acceptable fish and macroinvertebrate samples. The latter sample in 2017 also found somewhat low stream stage, but it was still deemed sufficient to sample. The outlet of Washington Lake appears to be controlled, and during drier times, may not be providing the channel much water. Functioning of this control structure is not familiar to the author.

Connectivity

Even though only macroinvertebrates (and not fish) were impaired in AUID-751, culverts were visited to assess their ability to allow fish passage. These culverts were at crossings of CSAH-24, Minnesota (MN) Highway 15, and at the western endpoint of 255th Street. The CSAH-24 culvert is passable, the MN Highway 15 may be a barrier at low flows due to the rock riffle at the downstream end of the culvert, and the culvert at the end of 255th Street is a barrier, as the culvert is perched. The two road crossings downstream of 07UM030 are both bridges, which do not create barriers as culverts can, and so connectivity to nearby Lake Arvilla is good for fish overwintering needs and spring re-entry into the stream.

Geomorphology

No geomorphology study was conducted for AUID-751. Channel stability was observed to be good per the MSHA work, and photos show low banks that allow higher flows to easily spill out into the floodplain. Much of the AUID does not have a real stream bank, but instead very wide riparian wetland habitat. This characteristic is one factor that contributes to the clear water typically found, as there is not much soil bank which could erode into the stream.

Conclusions about stressors

Analysis of both the macroinvertebrate community makeup, as well as actual DO measurements show that dissolved oxygen is the primary stressor to the macroinvertebrate community in AUID-751. DO concentrations can be below the standard for long periods of time, and minimum daily levels get very low, down to about 1 mg/L, which is only 20% of the state DO standard. The large amount of aquatic macrophytes that develop in the stream cannot make up for the amount of oxygen usage that decay bacteria are using in the wetlands breaking down accumulations of dead organic material. Afternoon DO levels barely achieve the standard some days, and other days do not even get that high. These same macrophytes contribute to the daily minimums as they respire (use DO) during night hours.

Phosphorus loads in the stream are sometimes above the River Eutrophication - Central standard, though not by extreme amount. It is difficult to know how much of this phosphorus is originating from the land, and how much from the organic material breakdown in the extensive riparian wetlands found along most of the length of the AUID. There may be legacy phosphorus accumulations in the wetlands from 100+ years of farming the landscape and the development around Washington Lake.

Physical habitat diversity is lacking, and is probably a contributing factor to the impairment. The habitat limitations found are typical of ditches in agricultural areas. In addition to being poor habitat, uniform stream channels create less-turbulent flows and reduce water interaction with the atmosphere (i.e., reduce aeration). Reduced habitat compounds the low DO as an additional stressor. The control of Washington Lake's outflow, and the artificial drainage (ditches) throughout this sub-watershed may also have some negative influence on habitat via potentially exacerbating low flow volumes in the stream during drier periods.

There are no permitted effluent dischargers to AUID-751, but the city of Dassel's WWTP effluent is discharged a relatively short distance upstream (about 1 mile upstream, in a riparian wetland of AUID-750). There is hydrologic connectivity to AUID-751, and phosphorus in the effluent may be raising the

phosphorus downstream (in AUID-751), but a more detailed study would be required to determine the degree of influence. There also are no urban areas or cities/towns from which runoff is enhanced by large areas of impervious surfaces. U.S. Highway 12 does cross the next-upstream AUID of Washington Creek, which may be a source of chloride, though it has not been measured.

Recommendations

Additional phosphorus monitoring would be helpful to determine whether phosphorus is at levels that are triggering eutrophication. It would give additional insight to do longitudinal sampling for TP, starting with the outlet of Washington Lake, and also sample the two tributary ditches to see what levels those are contributing to AUID-751. Reducing quantities of phosphorus arising from land runoff, faulty septic systems, etc., would likely benefit the stream, since it appears that phosphorus is elevated to some degree. Habitat cannot be reasonably enhanced other than to try to improve the water quality component. It will likely be quite difficult to improve the DO, due to the extent of the wetlands that are directly connected hydrologically to the channel. Improvement of water quality in Washington Lake would provide some benefit to AUID-751. It would be helpful to collect some chloride samples to see if U.S. Highway 12's runoff is a source of stress to the biological communities.

Washington Creek (County Ditch 9) (AUID 07010204-753)

Impairment: AUID-753 is a 1.8 mile long reach beginning about 2 miles downstream of the end of AUID-751, at County Ditch 36 and ending at T120 R29W S27, east line. The sampled portion of the AUID is channelized, and the UAA placed the AUID in the Modified Use class. The AUID has one biological monitoring station, 07UM014 at CR-21. AUID-753 has a new (2019) impairment for the fish community. The macroinvertebrate sample was not collected due to a new beaver dam that flooded the site. The fish stream Class is 5 (Northern Streams).

Sub-watershed characteristics

The sub-watershed is comprised mostly of two other sub-watersheds discussed in this report, County Ditch 36 (AUID-755) and an upstream section of Washington Creek (AUID-751). A relatively small third land area adjacent to the AUID-753 channel is the additional land area that contributes flow to AUID-753 (Figure 40). This third area is quite similar in its land use/cover as the other two parts; row crop acreage is the primary land cover, along with a significant amount of hay/pasture, and a smaller amount for forest (Figure 41). A significant amount of riparian wetland is found along the channel corridor of all three of the sub-watershed pieces, and is in direct hydrological connection with the channel. The great majority of the stream channels in the sub-watershed are created or straightened stream channels.

Figure 40. The sub-watershed of Washington Creek (County Ditch 9), AUID-753. Piece 1 is the sub-watershed of County Ditch 36, part of which is AUID-755, discussed next. Piece 2 is the subwatershed of Washington Creek, AUID-751, discussed prior. Piece 3 is the land area that contributes runoff to AUID-753 separately from pieces 1 and 2. All three together contribute water to AUID-753, the lower part of Washington Creek (County Ditch 9).

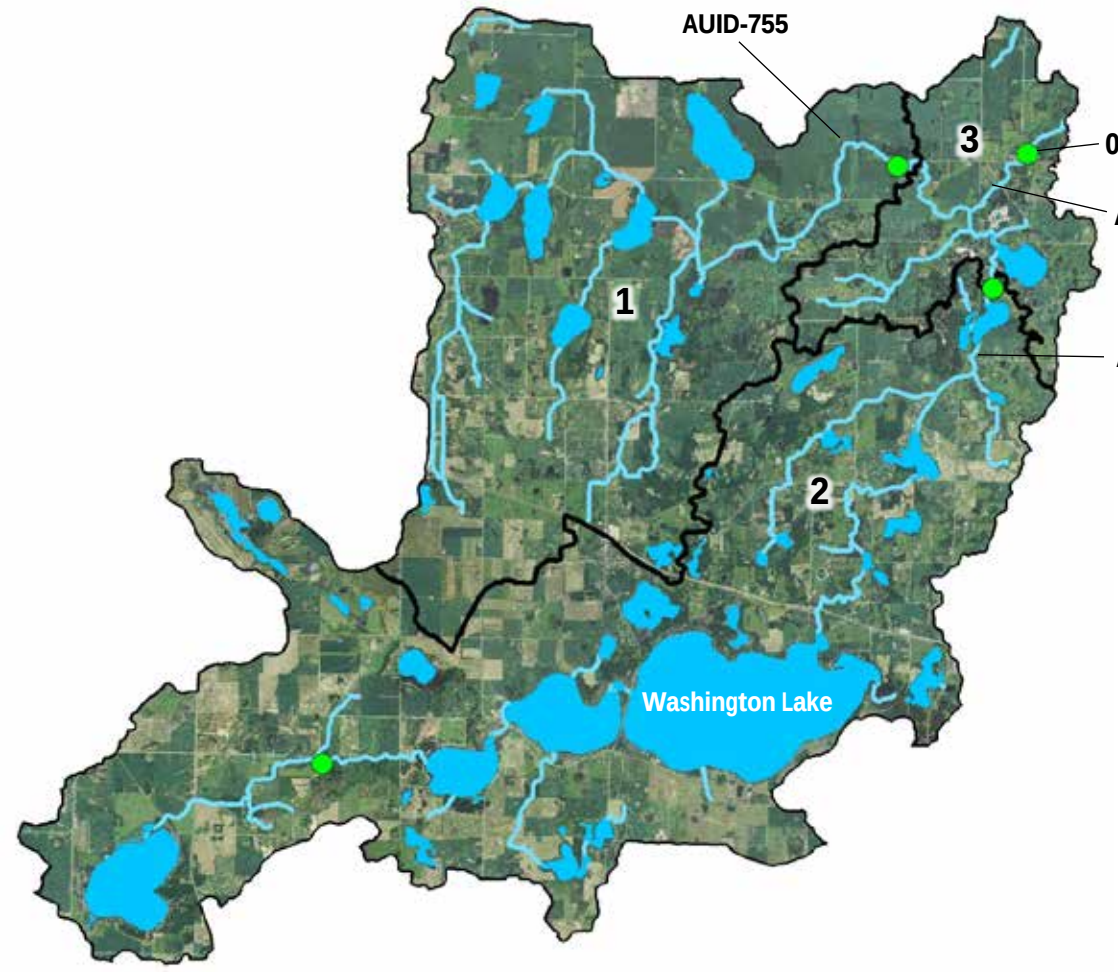
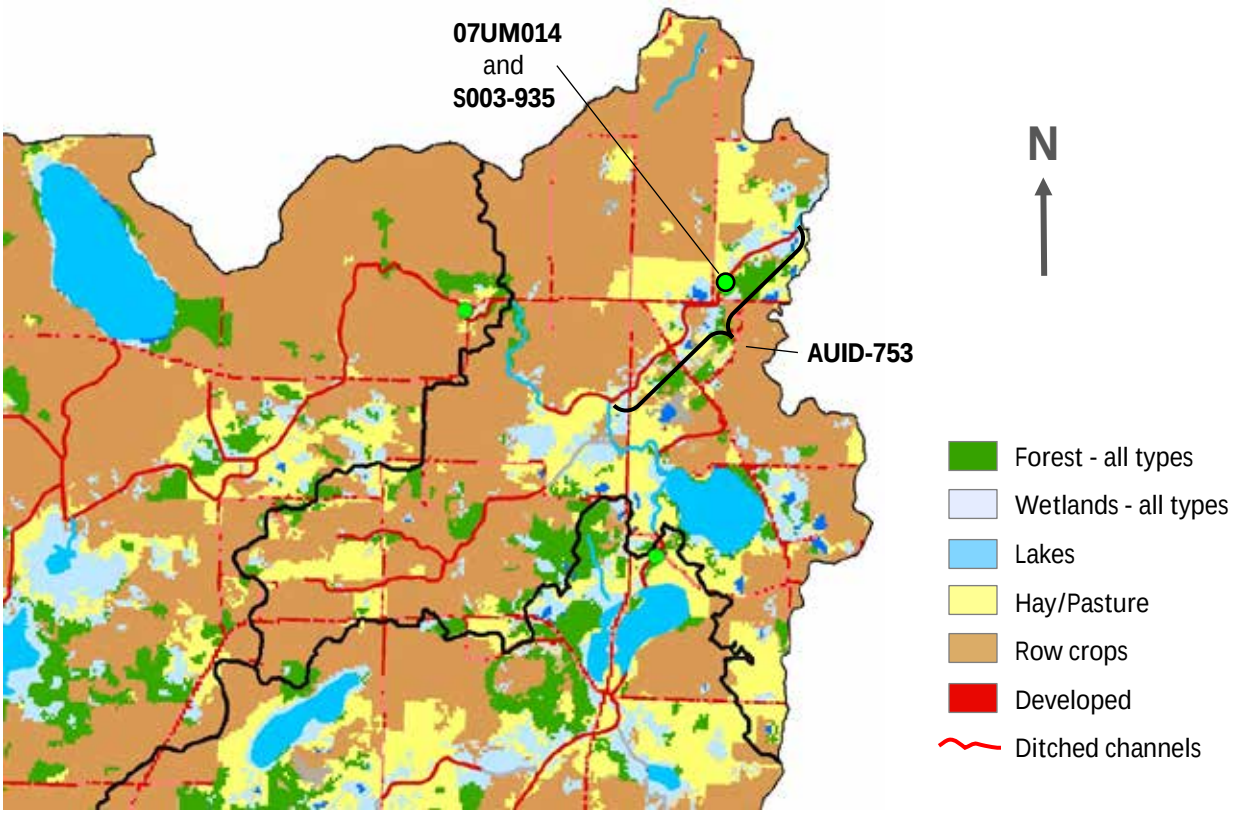


Figure 41. Land use (NLCD, 2016) in the AUID-753 part of Washington Creek (piece 3 in Figure 40).



Data and analyses

Chemistry

The data set for recent years collected from AUID-753 at 07UM014 (S003-935) consists of monitoring during the biological sampling visits in 2017 (Table 70), and subsequent SID sampling in 2019 (Table 71). A significant dataset also exists from 2009, 2017 and 2018 (Table 72). Data are discussed below by parameter.

Table 70. AUID-753 water quality measurements from the IWM biological sampling visits at 07UM014 (S003-935). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
6/29/2017	9:00	18.6	5.5	58	439	--	--	--	7.6	60	--
8/15/2017*	18:57	21.5	4.4	50	454	--	--	--	7.5	31	--

*Data is influenced by a beaver dam at site.

Table 71. SID monitoring summary for 07UM014 (S003-935) in 2019, 10:00 a.m. to 2:00 p.m. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO	6	5.66	7.9	4.1
DO % saturation	5	68.5	92.8	47.6

Table 72. AUID-753 water quality measurements from the IWM visits at 07UM014 (S003-935) in 2017 and 2018, and a dataset from 2007 and/or 2009. Samples are from May - September, mostly in late morning. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO	41	5.37	9.32	0.64
DO % saturation	2 (2017)	54.4	58.5	50.2
TP	22	0.178	0.373	0.071
Nitrate	12 (2007)	0.151	0.41	< 0.05
Ammonia	12 (2007)	0.08	0.24	< 0.05
TSS	22	19.3	59.2	6.0
Chloride	13	11.9	16.4	5.9
Conductivity	38	500.4	604	435
Temperature (ºC)	41	20.8	31.9	13.5

Nutrients - phosphorus

TP concentrations generally were over the River Eutrophication Standard - Central, with the highest measurement almost four times the standard. This presents the potential for eutrophication.

Nutrients - nitrogen

The most recent data is a set of 2007 samples (Table 72). These nitrate samples showed extremely low concentrations, which is not surprising since denitrification (nitrate conversion to nitrogen gas) occurs well in wetland environments, and the AUID flows through wetlands along almost its full length. The only ammonia samples are again from 2007, and almost all were very low; the one somewhat elevated sample was not at a concentration high enough to have had an un-ionized fraction above the state standard.

Dissolved oxygen

The two instantaneous DO measurements taken at biological sampling visits are both relatively close to the standard, one above it and one below. Many of the additional instantaneous DO measurements are somewhat suspect for quality, due to conditions at the site. The dataset from 2007 is from a dry year when stream flow was low. Many of these measurements show below-standard DO concentrations. Then, sometime in mid-summer 2017, a beaver built a dam downstream of the site, impounding the water to some degree at the site. Again, many of these measurements showed below-standard DO levels. This leaves the 2009 and 2019 measurements being from more normal conditions. Most of the 2009 samples were below the standard, including two readings of 2.6 mg/L. The six measurements from 2019 found three that were moderately below the standard. However, all of these measurements were taken in late morning or early afternoon, and thus do not represent that day's minimum DO levels. Sub-standard DO levels were found under multiple flow conditions, in four different years, suggesting that low-DO is a common phenomenon in AUID-753. This is not surprising, due to the fact that waters coming into AUID-753 from upstream (AUID-751 and AUID-755) also have low DO concentrations. DO percent saturation can be useful in evaluating whether eutrophication is occurring (if DO percent saturation is above 100%). Of the nine DO percent saturation measurements, none were as high as 100%. They were most often in the 55-65% range, which is low, and suggests that there is much microbial activity decaying dead organic material. Having continuous DO percent saturation readings for several days would add ability to better determine how decay is influencing DO levels. It is likely that

much of this decay is happening in the riparian wetlands that are hydrologically connected to the channel.

Transparency and suspended solids

The concentration of TSS is generally lower than the state standard, but does sometimes exceed it. Three of 10 samples collected in 2017-2018 were significantly above the standard (30 mg/L); 49.6, 49.8, 59.2 mg/L. No recent TSVS have been collected in recent year. A set of samples collected in 2001 found concentrations between 2 - 5 mg/L. Therefore, it is not known what percentage of the TSS is mineral vs organic particles.

Chloride

Chloride has been collected in 2017-2018 and all samples were far below Minnesota's chloride standard.

Conductivity

Specific conductivity was in typical range of many other streams in the NFCRW. The measured levels should not be problematic for the biological communities.

Stressor signals from biology

Fish

The fish community in AUID-753 has been sampled twice, in 2007 and 2017. In 2007, 25 species were caught, with three species being dominant: bluegill, black bullhead, and bluntnose minnow. Three sensitive species were present in 2007; five brook silverside, one rock bass, and one spottail shiner. Due to abnormally low water in 2007, the fish sample was determined to be "not assessable". In the 2017 sample, there were 19 species present, with one far dominant species, central mudminnow. No sensitive species were present in 2017.

The Community TIV Index scores for the 2017 sample are shown in Table 73 and individual TIV metrics in Table 74. The DO Community Index score was much poorer than the Class 5 average, and the probability of this community coming from a DO standard-meeting stream is extremely low. The community was highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and highly skewed for the percentage of Tolerant versus Intolerant individuals.

There is mixed evidence in the 2017 fish data of the influence TSS. The TSS TIV Index was poorer than the class average, at only the 24th percentile of this class. However, this community does still have a relatively good chance that it could be found in a TSS standard-meeting site. There were modestly more TSS Tolerant species than Intolerant ones present in the sample, which suggests that TSS might be a moderate stressor.

Nitrate does not show evidence of being a stressor. The TIV score was much better than the Class 5 average. There are equal numbers of Nitrate Tolerant and Intolerant species present, and they comprise nearly the same percentage of individuals.

These analyses provide strong evidence that the fish community is being stressed by inadequate DO levels, moderate evidence that elevated TSS might be a secondary stressor, and no evidence that nitrate is a stressor.

Table 73. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-753 at 07UM014. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile in class	Prob. as %
6/13/2017	DO	5.7	7.00/7.11	2	4.3
6/13/2017	TSS	14.4	13.70/12.96	24	69.7
6/13/2017	Nitrate	1.16	2.06/2.02	88	--

Table 74. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish community at 07UM014.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	0	0	13	9	0.0	85.4
TSS	1	0	3	0	0.6	5.9
Nitrate	4	1	4	0	12.8	14.6

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Temperature

The temperature measurements taken at the two visits to 07UM014 (one morning and one early evening) were quite cool, and not near stressful levels. The temperatures measured in other monitoring at S003-935 (07UM014) also generally found cool temperatures (Table above). One date found a high temperature that would be stressful to fish (31.5°C), but that was an anomaly among the rest of the data. Measured temperatures do not show common stressful conditions.

Habitat

Habitat is mediocre in this channelized AUID, based on MSHA metrics, and the UAA process rated it as insufficient to be placed into the General Use TALU category, resulting in placement into the Modified Use category. The total MSHA score has declined between 2007 and 2017 observations, and now is well below the threshold at which it is considered "Poor". The total and sub-component scores are shown in Table 74. In the 2017 observation, the poorest-scoring sub-component scores by far were "Substrate" and "Channel Morphology". This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles. These characteristics were indeed responsible for the poor score for this MSHA component. In the 2007 observation, gravel was the coarsest substrate recorded being present, and only found in a small area of riffle habitat. Otherwise, the substrate was all sand and silt. In 2017, gravel was recorded as being present in small quantity, but the predominant substrates were silt and detritus. The scorers noted that embeddedness of the gravel was moderate. In 2017, the fish samplers noted extensive fish cover, including macrophyte vegetation, logs, and one deep pool. It is not clear why the MSHA score dropped substantially between 2007 and 2017. Aerial photos do not seem to indicate ditch maintenance was conducted between years. The biggest scoring differences are a decline in substrate quality and a more uniform bed topography. The MPCA lead biologist for the NFCRW, who did the 2017 sampling, believes the difference may be due to the very different flow levels between 2007 and 2017. Flow volumes were extremely low in 2007, making interpretation of channel habitat more difficult. It is believed that the 2017 assessment is more accurate.

Table 75. MSHA scoring for site 07UM014.

MSHA Component	7/2007	6/2017	2007 Maximum Poss. Score	2017 Maximum Poss. Score	2007 % of Maximum	2017 % of Maximum
Land Use	5	2.5	5	5	100	50.0
Riparian	11	11	15	14	73.3	78.6
Substrate	12.35	4	27	28	45.7	14.3
Cover	9	14	17	18	52.9	77.8
Channel Morphology	24	5	36	35	66.7	14.3
Total MSHA Score	61.35	36.5	100	100	61.4 = "Fair"	36.5 = "Poor"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest to cultivated fields), as well as straightening of the channel that reduced sinuosity and thus speeds movement of water through the landscape/stream system. A review of the photos taken during biological sampling indicates the hydrological regime does not appear to be flashy to the point of damaging the channel causing bank erosion/bed substrate instability). The landscape may still have enough depressional area storage to reduce flashiness of precipitation runoff relative to ditched areas where wetlands have been eliminated. There are some large wet meadow/wetland areas that are adjacent to the ditch system that probably slow a significant amount of the runoff from quickly reaching the ditch.

Connectivity

There is an outlet structure on Lake Arvilla that, from aerial photography, appears to be high enough to be a fish barrier to migration from AUID-753 into the Lake. This likely does not have much effect of the fish community in AUID-753, as it is generally access to downstream, larger riverine or lake habitat that is important for overwintering refuge. Aerial photography indicates that the two sets of culverts on the AUID are passable to fish, while two other crossings are bridges, which rarely cause migration issues. Therefore, fish are readily able to find refuge in the much larger North Fork Crow River, into which the AUID directly flows. A few beaver dams could be seen in photos, but they appeared to be breached since they were not backing up water, and turbulent flow could be seen around them. Migration barriers are not a cause of the fish impairment.

Geomorphology

No study relating to geomorphology was done on AUID-753. The characteristics of the channel, being a low gradient system is not one that typically experiences channel instability. A large portion of the stream corridor is bordered by wetland, and so there is much ability of high stream flows to spill out of the main channel onto a floodplain and dissipate energy.

Conclusions about stressors

The SID analysis has found strong evidence of two primary stressors of the impaired fish community; low DO and poor physical habitat. There is a small amount of evidence that elevated TSS might be a secondary stressor, but that finding is inconclusive. High TSS levels are occasionally present. The low DO is likely a combination between the natural influence of the abundant wetlands (microbial use of oxygen during decay of accumulated wetland vegetation), and nutrient enrichment due to 100+ years of relatively heavy amounts of farming the surrounding landscape. It is unknown how much of an effect the permitted effluent releases of the Dassel wastewater ponds have on the nutrient dynamics in the stream. The poor habitat is reflective of the straightened, ditched condition of the channel. The homogenous habitat found in the MSHA observations in AUID-753 is common in agricultural ditches.

Recommendations

Additional TSS samples would be beneficial, taken especially during higher flow levels to better determine the conditions when TSS is likely to be significantly elevated, and how often this occurs. Habitat will be difficult to enhance, due to the fact that such a high percentage of the overall stream system is manipulated for drainage. Ideally putting the channel back into its original, sinuous pattern would create better habitat, though this may be extremely difficult due to current land management for farming. Phosphorus may also be quite difficult to bring down due to probably legacy accumulations above normal in the wetland habitats that are hydrologically connected to the stream. Opportunities to reduce phosphorus input to the stream would benefit the system, gradually bringing down phosphorus levels, and improving DO levels.

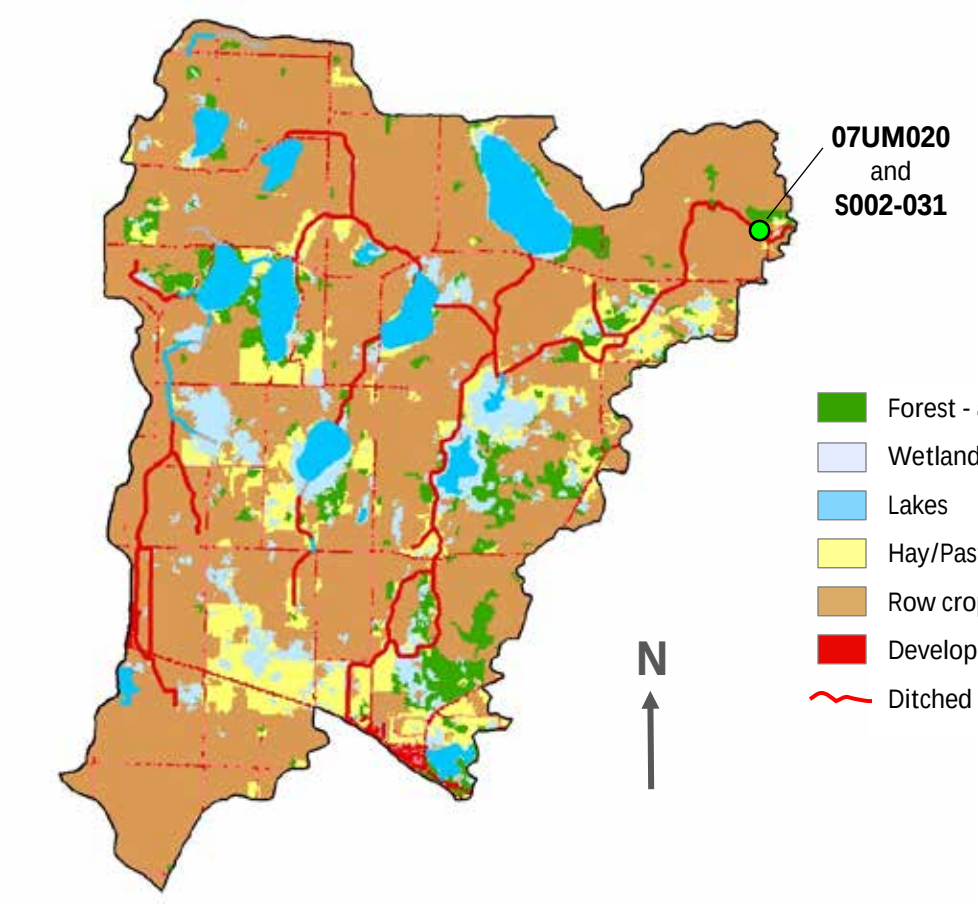
County Ditch 36 (AUID 07010204-755)

Impairment: AUID-755 is an approximately 4.6 mile long reach beginning as the outlet of Powers Lake and ending a short distance downstream of the biological site, where it runs briefly along the east-west section of CSAH-21. This reach is a straightened channel for its entire length, with a relatively short stretch that has somewhat naturalized into a moderately sinuous channel. Downstream of AUID-755, the channel returns to a natural, unmodified stream. The UAA process determined that AUID-755 is habitat-limited, and should be classed as Modified Use. The AUID has one biological monitoring station, 07UM020 at CSAH-21. AUID-755 has new (2019) impairments for both the fish and macroinvertebrate communities. The Fish Stream Class at 07UM020 is 6 (Northern Headwaters), and the macroinvertebrate Stream Class is 6 (Southern Forest Streams - GP).

Sub-watershed characteristics

The land use and land cover of the sub-watershed of AUID-755 is highly oriented to agriculture (Figure 42). A number of small lakes are found in the sub-watershed. Smaller patches of forest are found within the sub-watershed, typically adjacent to the lakes. There are some wetland patches, and these too are typically adjacent to the lakes and/or forest patches. Most of the channel network contributing flow to AUID-755 either originates from lakes, or moves through lakes. Almost all of the channel network in the sub-watershed is either created, or is straightened stream channel, including the full length of AUID-755. Part of the city of Darwin (the portion north of U.S. Highway 12) is in the sub-watershed, at the extreme southern edge. A nice 2-stage ditch channel has formed naturally in the part of the reach just upstream of site 07UM020.

Figure 42. The landscape and land use of the subwatershed of County Ditch 36, AUID-755 (NLCD, 2016).



Data and analyses

Chemistry

The data set for recent years collected from AUID-755 at 07UM020 (S002-031) consists of monitoring during the biological sampling visits in 2007 and 2017 (Table 76), and subsequent SID sampling in 2018-2019 (Table 77). A small dataset also exists from 2001. Data are discussed below by parameter.

Table 76. AUID-755 water quality measurements from the IWM biological sampling visits at 07UM020 (S002-031). Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO % Sat.	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi Tube (cm)	TSS
7/17/2007	8:30	19.9	0.22	--	558	0.152	< 0.05	< 0.1	7.42	--	8.0
6/13/2017	13:09	20.0	8.2	90	246	0.260	3.66	0.318	7.73	81	6.4
8/15/2017	17:11	23.3	8.5	100	552	--	--	--	7.81	36	--

Table 77. SID monitoring summary for 07UM020 (S002-031) in 2018. Values in mg/L.

Parameter	# samples	Avg.	High	Low
DO	6	9.5	15.7	7.5
DO % saturation	6	103.3	160	77
TP	5	0.188	0.285	0.107
Nitrate	5	1.62	4.2	0.34
TSS	3	NA	860*	6.8
Conductivity	6	579	605	554

*This value is extremely high.

Nutrients - phosphorus

All seven samples in Tables 76 and 77 are above the River Eutrophication Standard - Central, some by a small amount, and some by over two times, pointing to a possible eutrophication situation in AUID-755.

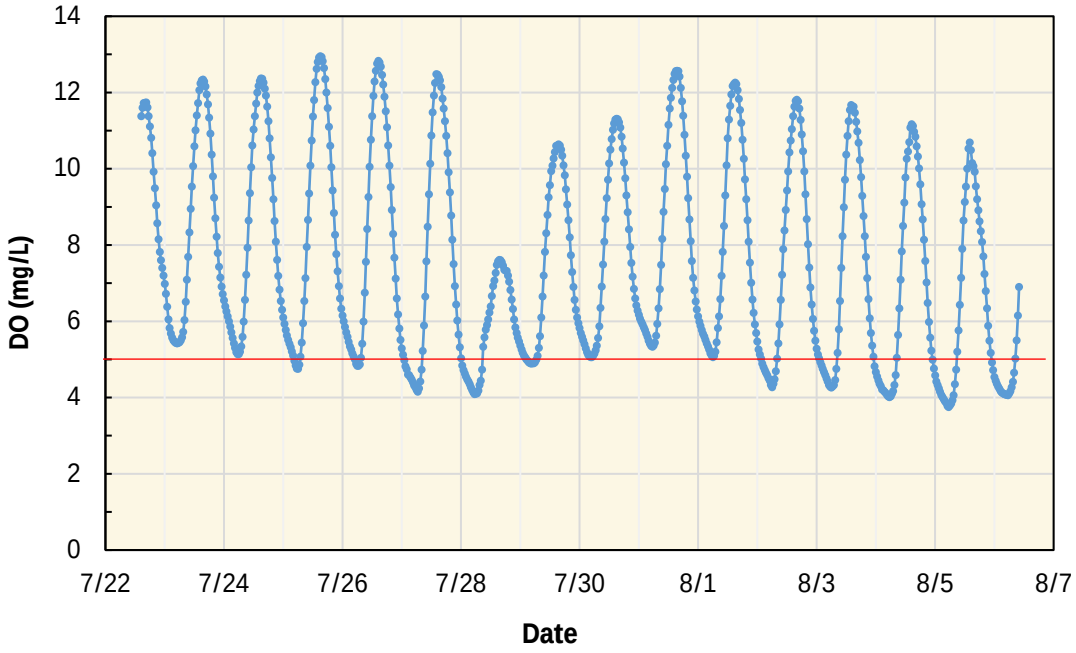
Nutrients - nitrogen

Both nitrate and ammonia samples have mixed results, at times very low (good), and at times fairly high. The only recent ammonia sample was not at a concentration high enough to have had an un-ionized fraction above the state standard. Based on the small set of recent samples, nitrogen may at times be problematic in this AUID from a biological toxicity standpoint. An older dataset at S002-031 collected from May 23 to July 10, 2001 found nitrate levels ranging from 2.22 - 7.07 mg/L. The upper part of this range likely harmful to macroinvertebrates. The nitrate levels from both new and older datasets are high enough to be contributing to eutrophication.

Dissolved oxygen

Though instantaneous DO measurements are all above the standard in the recent data, there are no early morning samples. The one very high reading came in May, when there isn't typically the large influence of algae yet. More insight comes from a Sonde deployment done from July 22, 2019 - August 6, 2019. This data shows that the daily minimum in early morning dropped below the standard (by about 1 mg/L) on 10 of 15 mornings, and most other days dips right to the standard (Figure 43). The mid-afternoon readings on many of the days are high (above 11 mg/L), and the daily change of 7 - 8 mg/L is also considered high (i.e., problematic for biological communities). These data suggest that there is some eutrophication occurring in AUID-755. The Sonde also collects the DO percent saturation, and measurements much over 100% confirm there is an abnormal amount of plants and/or algae in the stream. A number of days had maximum measurements in the 130 - 150% range, with the maximum over the whole period being 160.2%. These numbers confirm that there is a large amount of plant life in the stream, likely fueled by the elevated nutrients discussed above.

Figure 43. DO measurements from a deployed Sonde at minute intervals, from 7/22/2019 - 8/6/2019 at 07UM020 (S002-031). The red line is the state DO standard.



Transparency and suspended solids

The recent biological sampling visit showed a low TSS concentration. The second visit in 2017 had a quite low transparency measurement. Of five available TSS measurements, four were 10 mg/l or less, which is quite good. The fifth sample, taken during a significant rainfall event, was vastly higher, at 860 mg/L. This same sample had the mineral and organic components being 740 and 120 mg/L, respectively, so the majority is from erosion, either within channel or from the landscape.

Conductivity

Specific conductivity was quite similar among all the visits, and similar to other sites in the NFCW. The measured levels should not be problematic for the fish community.

Stressor signals from biology

Fish

The fish community in AUID-755 has been sampled twice, in 2007 and 2017. In 2007, only four species were caught, with black bullhead being far dominant. Only 10 individual fish were not black bullhead. No sensitive species were present. In the 2017 sample, there were again four species present, but even fewer individuals caught. The most abundant species was central mudminnow. No black bullhead were caught and again, no sensitive species were present.

The Community TIV Index scores are shown in Table 78 and individual TIV metrics in Table 79. *With so few fish caught, these numbers should be viewed with less emphasis than similar analyses with data from a more robustly populated stream.* The DO Community Index score for both samples was much poorer than the Class 6 average and the fish community was skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and highly skewed for the percentage of Tolerant versus Intolerant individuals. The 2007 and 2017 samples were quite similar regarding these metrics.

There is no evidence in the 2017 fish data of the influence TSS. The recent sample's TSS TIV Index was better than the class average, though the 2007 sample's was much poorer than average. The 2017

sample has a good chance that it could be found in a TSS standard-meeting site. There were no TSS Tolerant species present in the recent sample, which suggests that TSS is not a stressor.

Nitrate does not show evidence of being a stressor in either sample. There are a couple Nitrate Tolerant species present, but they form a small percentage of the community. The Nitrate TIV Index scores were both better than the class average, particularly the 2017 sample. There were no Nitrate Intolerant taxa present, but also very few Nitrate Tolerant taxa or individuals.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels, but not due to elevated TSS or nitrate levels.

Table 78. Fish Community DO, TSS, and nitrate Tolerance Index scores in AUID-755 at 07UM020. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability (ver. 2020) a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
7/17/2007	DO	5.41	6.61/6.68	2	2.2
6/13/2017	DO	5.49	6.61/6.68	4	2.8
7/17/2007	TSS	25.42	13.92/13.26	1	6.5
6/13/2017	TSS	13.61	13.92/13.26	40	74.9
7/17/2007	Nitrate	2.32	2.45/2.46	57	--
6/13/2017	Nitrate	1.08	2.45/2.46	93	--

Table 79. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM020.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/17/2007	0	0	3	2	0.0	99.3
Low DO	6/13/2017	0	0	3	2	0.0	96.3
TSS	7/17/2007	0	0	1	0	0.0	1.4
TSS	6/13/2017	0	0	0	0	0.0	0.0
Nitrate	7/17/2007	0	0	1	0	0.0	1.4
Nitrate	6/13/2017	0	0	2	0	0.0	7.4

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

One macroinvertebrate sample has been collected at 07UM020, in 2017. One taxon, the amphipod *Hyalella azteca*, was highly dominant in the sample. The two other taxa that were relatively numerous were the snail *Physella*, and an unknown genus of the damselfly family Coenagrionidae. A number of the other taxa found were those frequently found in wetlands, which often naturally have low DO. There were only three EPT taxa, and these among the more tolerant of this otherwise sensitive group of insect orders. EPT taxa in general require good levels of DO.

The Community TIV Index scores are shown in Table 80 and individual TIV metrics in Table 81. The DO TIV Index score was poorer than the class average, and the score is at a low percentile of DO TIV Index scores for stream Class 6. The probability of the sampled community coming from a DO-meeting site is

fairly low. The community is highly skewed toward taxa that are low-DO Tolerant in terms of the species that were present, and low-DO Tolerant individuals comprised a high percentage of the sample.

The TSS TIV Index score was moderately poorer than the Class 6 average, and the percentile within Class 6 streams was low. The probability of the community coming from a standard-meeting site is quite poor. The community is strongly skewed toward TSS Tolerant taxa in terms of the taxa present and to a lesser degree, the percent of individuals. There are no TSS Intolerant taxa present.

The Nitrate TIV Index scored moderately better than the Class 6 average. Conditional probability is not available for nitrate. Though the Index score is slightly better than the class average, the macroinvertebrate community is strongly skewed toward Nitrate Tolerant taxa, especially in terms of number of species present, and to a lesser extent, the percent of individuals. Zero Nitrate Intolerant taxa were present in the sample.

Given that the DO TIV Index score is very poor, and that the Intolerant versus Tolerant taxa presence and percent of individuals are highly skewed toward low-DO tolerance, the macroinvertebrate community shows strong evidence of stress from inadequate DO concentrations. There is moderate evidence that TSS is a stressor to the macroinvertebrate community. There is also good evidence for nitrate stress to macroinvertebrates.

Table 80. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores in AUID-755 at 07UM020 on 8/15/2017. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version). "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards.

Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
DO	5.88	6.40/6.60	19	38
TSS	15.74	15.12/15.17	39	27
Nitrate	2.79	3.08/3.12	65	--

Table 81. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled macroinvertebrate community at 07UM020 on 8/15/2017.

Parameter	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	1	0	11	5	0.3	73.3
TSS	0	0	10	6	0.0	21.3
Nitrate	0	0	12	10	0.0	19.1

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, there is solid evidence that low DO levels are stressing both communities. There is a moderate signal from the macroinvertebrates (but not from fish), that elevated TSS could be a stressor. There is also a signal, again from the macroinvertebrates only, that elevated nitrate is a stressor. That the fish don't show the nitrate influence at these nitrate levels is not surprising as other MPCA work has suggested that macroinvertebrates are affected by lower levels of nitrate than most fish.

Temperature

The temperature measurements taken at the two visits to 07UM020 (both afternoon, see Table 76) were moderate to cool, not at stressful levels. The temperatures measured by the Sonde found that the great amount of the time, temperatures were very moderate. A few days had measurements in the 26-27^{o}C range for a few hours. These short durations at this temperature level should not be problematic.

Habitat

Habitat is mediocre in this channelized AUID, based on MSHA metrics, and the UAA process rated it as insufficient to be placed into the General Use TALU category, so it was placed into the Modified Use category. The total MSHA score has declined between 2007 and 2017 observations, and now is slightly below the threshold separating "Fair" and "Poor". The total and sub-component scores are shown in Table 81. In the 2017 observation, the poorest-scoring sub-component scores by far was "Channel Morphology". This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles. These characteristics were indeed responsible for the poor score for this MSHA component. Cobble was recorded as being present, but the predominant substrates were sand and gravel. The scorers noted that embeddedness of the cobble was moderate to severe. In 2007, the fish samplers noted extensive macrophyte vegetation, while macrophytes were less abundant based on comments in 2017.

Table 82. MSHA scoring for site 07UM048.

MSHA Component	7/2007	6/2017	8/2017	2017 Avg.	Maximum Poss. Score	2007 % of Maximum	2017 % of Maximum
Land Use	2.5	1.75	2.5	2.1	5	50.0	42.0
Riparian	9	8.5	10.5	9.5	14	60.0	67.9
Substrate	14	16	16	16	28	51.9	57.1
Cover	13	10	11	10.5	18	76.4	58.3
Channel Morphology	18	3	8	5.5	35	50.0	15.7
Total MSHA Score	56.5	39.3	48	42.6	100	56.5 = "Fair"	42.6 = "Poor"

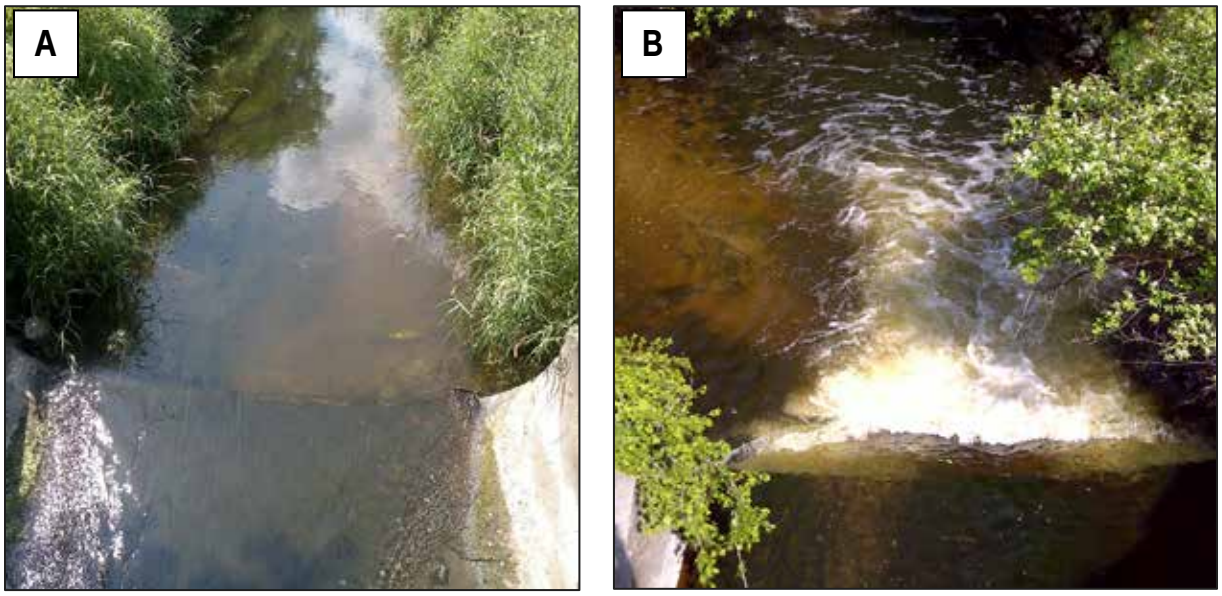
Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest to cultivated fields), as well as straightening of the channel that reduced sinuosity and thus speeds movement of water through the landscape/stream system. Looking at the photos taken during biological sampling, the hydrological regime does not appear to be flashy to the point of damaging the channel causing bank erosion/bed substrate instability). The landscape may still have enough depressional area storage to reduce flashiness of precipitation runoff. There are some large wet meadow/wetland areas that are within the ditch system that probably slow a significant amount of the runoff from quickly reaching the ditch.

Connectivity

The culvert under CR-21 just downstream of the biological monitoring site is a fish migration barrier. It is set with too high a gradient, causing the water to increase significantly in the culvert, and is set too elevated at the upstream side (Photo 16A). The culvert is perched at the downstream end, forming a small waterfall (Photo 16B). These culvert characteristics prevent fish from migrating up into AUID-755 from the North Fork of the Crow River, which is a relatively short distance downstream this road crossing. This culvert is acting as a grade control and setting the bed elevation upstream, so removal would need careful design in order to prevent destabilization of the upstream channel, including down-cutting of the channel bed, bank erosion, and a large movement of sediment downstream.

Photo 16. The culvert under CR-21; (A) upstream side, and (B) downstream side.



Geomorphology

In addition to the photos mentioned above that showed healthy banks, the MSHA team recorded "Little" with regard to bank erosion.

Conclusions about stressors

Four situations have strong evidence of being stressors; low-DO concentrations and poor physical habitat for both fish and macroinvertebrates, a migration barrier (perched culvert at CR-21) for fish and nitrate levels for macroinvertebrates. Elevated TSS as a stressor is inconclusive, with low influence apparent in the biological samples and several low TSS sample results. One extremely high TSS measurement, given its great deviation from other samples, when it was not collected after a large rain event, seems to be of questionable quality.

Recommendations

Additional nitrate and TSS samples would be beneficial, in order to better determine if these are at stressful levels. Because nitrate is highest in spring, April and May samples would be helpful as would probably be the maximum concentrations for the year. Some TSS samples should target rain events, as baseflow concentrations meet the standard. If/when the culvert is replaced on CR-51, design should allow for fish passage. Since this may involve dropping the elevation of the culvert, careful design will be required to prevent down-cutting and channel destabilization in the reach upstream of the culvert. Addressing the poor physical habitat will be difficult, because the characteristics found are typical of ditches. Reducing sediment inputs to the ditch would be one way to improve bed material habitat.

French Creek (Wright County Ditch 19) (AUID 07010204-759)

Impairment: AUID-759 is an approximately 1.7 mile long reach beginning as the outflow of French Lake. There was one biological monitoring station (07UM048). The full length of the channel of AUID-759 is altered/ditched. The UAA process determined that the stream should be classed as Modified Use. The AUID was assessed as having impairments of both the fish and macroinvertebrate communities. The Macroinvertebrate Stream Class is 5, the Fish Stream Class is 6. There was not a sufficient dataset of DO and TSS measurements to assess these parameters.

Sub-watershed characteristics

The full length of AUID-759 channel has been straightened. The land use and land cover of the sub-watershed of AUID-759 is shown in Figure 44. Immediately upstream of the biological site is a large wet-meadow. The land use is predominantly row crop agriculture or grassland/pasture. There is a relatively small amount of forested land. There are no towns in the AUID-759 sub-watershed. There is a very large impervious area adjacent to the AUID, part of an auto salvage company, which has an industrial stormwater permit. Recently, aerial photos show that stored cars which were close to the stream channel have been moved farther away from the channel, and it appears that a stormwater pond was created in approximately 2015 to intercept runoff from the large lot that is moving toward the creek. Also, another area along the riparian corridor appears to have been allowed to reforest over the last 25 years or so (Photo 17). There are no permitted effluent dischargers to the stream system.

Figure 44. The French Creek subwatershed and its land use/cover (NLCD, 2016). The opaque area that covers most of the sub-watershed is the area from where runoff flows into French Lake, then into AUID-759. The non-opaque area on the west side is the area where runoff flows into AUID-759.

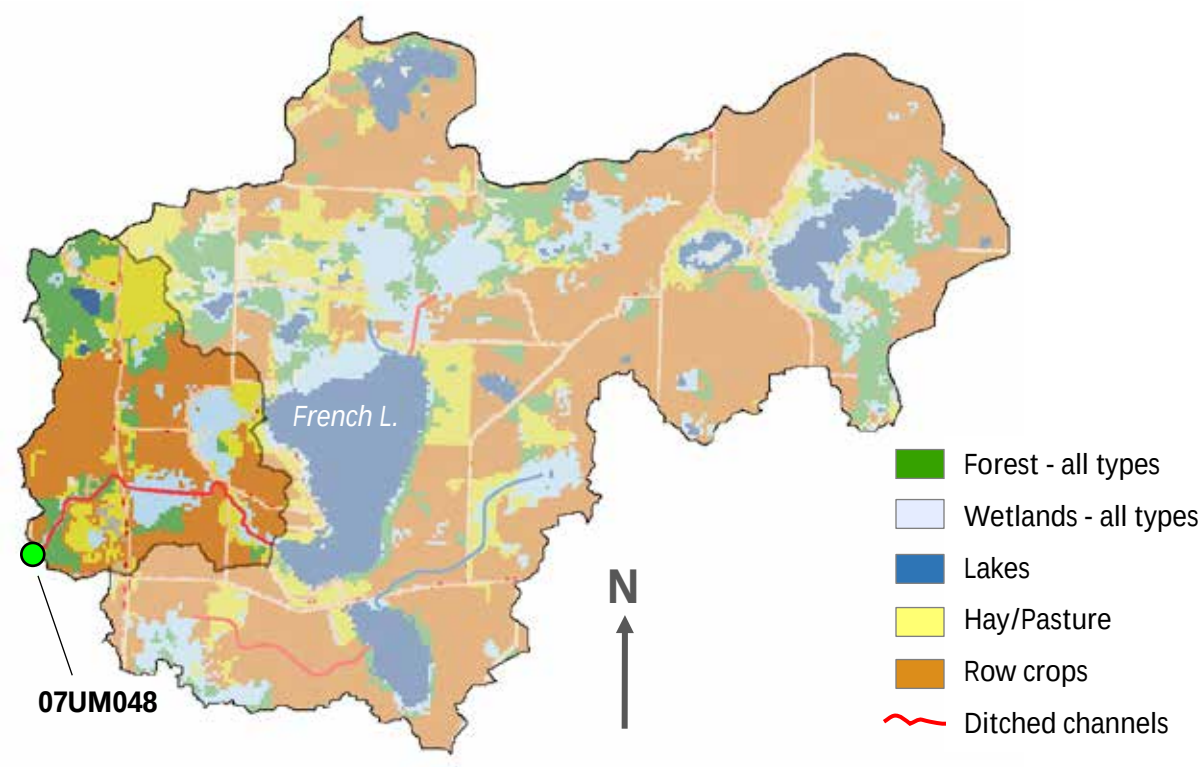
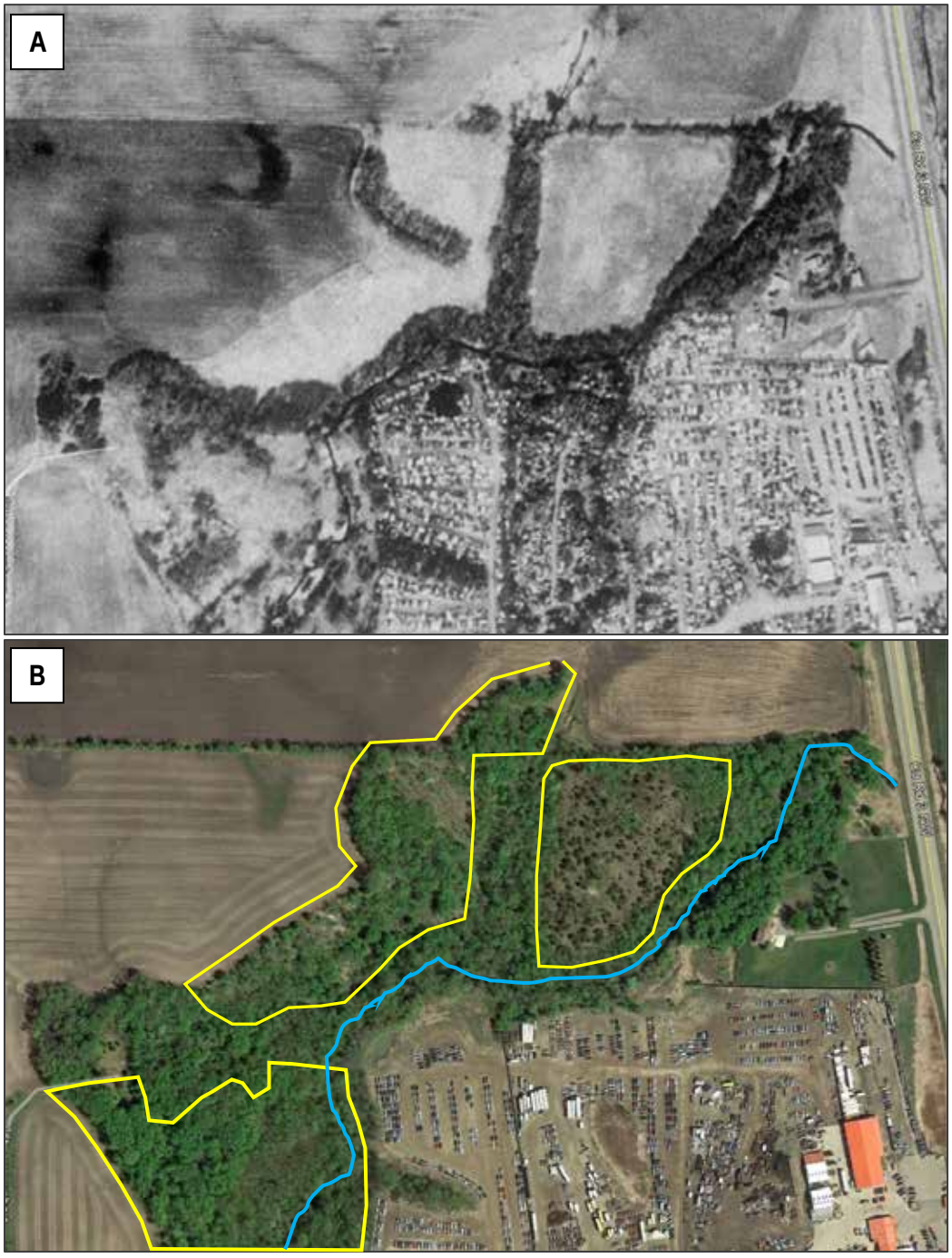


Photo 17. A. 1991 aerial photo, B. 2019 aerial photo, with yellow areas being naturalized between the two photo dates. The blue line in B is the creek channel.



Data and analyses

Chemistry

The chemistry sampled at the biological monitoring visits is presented in Table 83. No other chemistry data exists for stream assessment purposes.

Table 83. IWM chemistry results from 2009 and 2017 at 07UM048. Values in mg/L, temperature in ºC.

Date	Time	Water Temp.	DO	DO %	Spec. Cond.	TP	Nitrate	Amm.	pH	Secchi (cm)	TSS
7/18/2007	8:20	23.1	0.57	--	381	0.074	< 0.05	0.09	7.39	--	2.8
6/26/2017	16:58	19.0	3.39	37	384	0.065	0.08	< 0.1	7.19	> 100	1.6
8/16/2017	8:13	20.5	2.09	23	371	--	--	--	7.2	> 100	--

Nutrients - phosphorus

TP values were below (better than) the Central Minnesota River Nutrient standard by a fair amount.

Nutrients - nitrate and ammonia

Nitrate values were extremely low, very near and below the lab's detection limit. This is to be expected since most of AUID-759's water is sourced from French Lake. Ammonia values were correspondingly very low, again as expected due to the lake's influence.

Dissolved oxygen

All three of the biological sampling visits found DO levels significantly below the standard. A continuous recording Sonde was deployed from 6/19 - 7/2/2019 and results are shown in figure 45. The minimum DO each day was below 2.0 mg/L, sometimes at or near 1.0 mg/L. This is an extremely low DO level and this data shows that low DO is highly likely a stressor in AUID-759. DO percent saturation levels were rarely above 60% and often in the 20 - 30% range.

Also in 2019, a few nearly-simultaneous measurements were made near the French Lake outlet (Oliver Avenue NW) and at 07UM048, which are approximately 0.72 stream-miles apart. Between them is a wet meadow that the channel moves through. The comparative DO and temperature measurements are shown in Table 84. The DO level drops substantially over this relatively short distance at each set of measurements, dropping by at least half or more. The percent saturation also drops substantially as water moves through the wetland. It is likely that the substrate in the wetland is deep, organic material with a high SOD. Deep silt was encountered by the fish sampling crew monitoring just downstream of the wetland.

Figure 45. Sonde DO data for French Creek (07UM048), from 6/19/2019 - 7/2/2019. The red line is the DO standard.

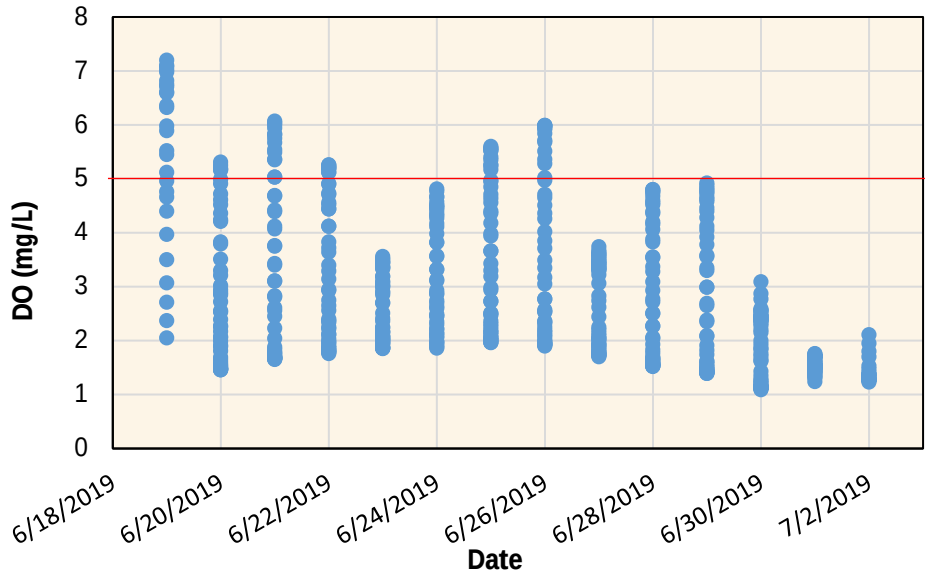


Table 84. Comparative DO and temperature data bracketing the wetland between the lake outlet and the biological monitoring site (07UM048).

Date	Location	Time	DO	DO % saturation	Temperature (ºC)
6/3/2019	S002-521	15:03	13.65	158.9	22.5
6/3/2019	07UM048	14:55	7.83	89.1	21.7
6/19/2019	S002-521	9:35	9.81	112.0	22.8
6/19/2019	07UM048	9:45	4.30	47.6	20.4
7/2/2019	S002-521	9:55	6.90	81.6	23.7
7/2/2019	07UM048	10:10	2.49	28.4	21.9

Transparency and suspended solids

The two TSS samples were very low, as might be expected since most of the water at the biological site is water fresh out of French Lake. The channel is very low gradient between the lake and the biological site, so there is minimal likelihood of erosion along the channel or a stirring up of sediment from the stream bottom. TSS is highly likely not a stressor in AUID-579.

Chloride

No chloride samples have been collected in AUID-579, but it is unlikely they would be high here as the roadways crossing the stream are not highways.

Conductivity

Specific conductivity was in a moderate range, and non-problematic for the biological communities.

Stressor signals from biology

Fish

The fish community in AUID-759 has been sampled twice, in 2007 and 2017. In 2007, no fish species was dominant, as very few fish were caught at 07UM048. The number of individuals caught was abnormally small, at 17 individuals. In the 2017 sample, there were even fewer individuals caught (11), and only from three species, most of which were central mudminnow.

The Community TIV Index scores are shown in table 85 and individual TIV metrics in table 86. With so few fish caught, these numbers should be viewed with less emphasis than similar analyses with data from a more robustly populated stream. Probabilities for table 85 were not calculated because of this. The DO Community Index score for both samples was much worse than the Class 6 average and the fish community was highly skewed toward low-DO tolerance in terms of the Tolerant versus Intolerant species present, and the percentage of Tolerant versus Intolerant individuals. Fewer low-DO Tolerant species were present in the recent sample compared to the 2007 sample, but there were also fewer species present in the 2017 sample.

The two samples, which occurred 10 years apart, show very different signals as to the influence TSS may be having on the fish community. The recent sample's TSS TIV Index was much better than the class average, while the decade older sample's was much poorer than average. As with DO, the TSS probabilities were not calculated due to the small number of individuals. In both samples, there were no TSS Tolerant species found, which would suggest that TSS is not a stressor.

Nitrate does not show evidence of being a stressor, particularly in the recent sample. The Nitrate TIV Index scores were both much better than the class average, and the percentage of Nitrate Intolerant individuals was much higher than for Nitrate Tolerant ones in the recent sample.

These analyses provide evidence that the fish community is being stressed by inadequate DO levels, but not due to elevated TSS or nitrate levels.

Table 85. Fish Community DO, TSS, and Nitrate Tolerance Index scores in AUID-759 at 07UM048. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 6 (2019 version).

Date	Parameter	TIV Index score	Class avg./median	Percentile within class
7/18/2007	DO	6.07	6.61/6.68	22
6/26/2017	DO	5.88	6.61/6.68	16
7/18/2007	TSS	15.86	13.92/13.26	13
6/26/2017	TSS	12.56	13.92/13.26	70
7/18/2007	Nitrate	1.85	2.45/2.46	75
6/26/2017	Nitrate	0.87	2.45/2.46	97

Table 86. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled fish communities at 07UM048.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	7/18/2007	0	0	6	2	0.0	64.8
Low DO	6/26/2017	0	0	1	1	0.0	63.6
TSS	7/18/2007	0	0	0	0	0.0	0.0
TSS	6/26/2017	0	0	0	0	0.0	0.0
Nitrate	7/18/2007	1	0	1	0	5.9	29.4
Nitrate	6/26/2017	1	0	1	0	27.2	9.1

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Macroinvertebrates

One macroinvertebrate sample has been collected at 07UM048, in 2017. The most abundant taxa by a substantial amount was the midge *Rheotanytarsus*. The other abundant taxon was the flatworm *Trepaxonemata*. Only one EPT taxon was present in the sample, a quite tolerant species, the fine sediment-preferring mayfly *Caenis diminuta*. Gathering only one mayfly taxon is highly unusual for a Riffle/Run classed stream.

The Community TIV Index scores are shown in Table 86 and individual TIV metrics in Table 87. The DO TIV Index score was far poorer than the class average, and the score is at the extreme bottom of DO TIV Index scores for stream Class 5. The probability of the sampled community coming from a DO-meeting site is very low. The community is skewed toward taxa that are low-DO Tolerant in terms of the species that were present, but low-DO Tolerant individuals comprised only a small percentage of the sample.

The TSS TIV Index score was far better than the Class 5 average, and the percentile within Class 5 streams was extremely high. The probability of the community coming from a standard-meeting site is good. The community is not skewed toward either TSS Tolerant or Intolerant taxa, in terms of both the taxa present and the percent of individuals.

As with TSS, the Nitrate TIV Index scored far better than the Class 5 average, and at an extremely high percentile among Class 5 streams. Conditional probability is not available for nitrate. Though the Index score is extremely good, the macroinvertebrate community is somewhat skewed toward Nitrate Tolerant taxa, both in terms of number of species present, and to a lesser extent, the percent of individuals. Just one Nitrate Intolerant taxa was present in the sample.

Given that the DO TIV Index score is extremely poor, and that the Intolerant versus Tolerant taxa presence and percent of individuals are somewhat skewed toward low-DO tolerance, the macroinvertebrate community does seem to show stress from inadequate DO concentrations. This analysis does not provide any evidence that TSS is a stressor to the macroinvertebrate community. The evidence for nitrate stress is somewhat conflicting, though a moderate signal exists that elevated nitrate might be a stressor to the macroinvertebrates.

Table 87. Macroinvertebrate Community DO, TSS, and Nitrate Tolerance Index scores in AUID-579 at 07UM048. For DO, a higher index score is better, while for TSS and nitrate, a lower index score is better. "Percentile" is the rank of the index score within stream Class 5 (2019 version). "Prob." is the probability a community with this score would come from a stream reach with DO or TSS that meet the standards.

Date	Parameter	TIV Index score	Class avg./median	Percentile within class	Prob. as %
8/16/2017	DO	4.98	6.96/7.09	2	19
8/16/2017	TSS	9.54	16.36/16.08	99	82
8/16/2017	Nitrate	1.78	3.21/3.21	99	--

Table 88. Metrics involving low-DO, TSS, and nitrate tolerance for the sampled macroinvertebrate community at 07UM048.

Parameter	Date	# Intolerant Taxa*	# Very Intolerant Taxa	# Tolerant Taxa*	# Very Tolerant Taxa	% Intolerant Individuals	% Tolerant Individuals
Low DO	8/16/2017	0	0	4	1	0.0	6.7
TSS	8/16/2017	0	0	1	0	0.0	0.3
Nitrate	8/16/2017	1	0	6	5	0.3	9.5

*Includes # of Very Intolerant or Very Tolerant taxa as part of the count.

Composite conclusion from biology

Bringing together the fish and macroinvertebrate community analyses, there is solid evidence that low DO levels are stressing both communities. The macroinvertebrate community should probably be given more weight, because the fish sample contained an abnormally small number of individuals, which can make some analyses less reliable. There isn't a signal among either community that elevated TSS is a stressor, and there is a weak signal that elevated nitrate levels may be a minor stressor to the macroinvertebrate community. Another situation that can lead to a depauperate fish community is the presence of a migration barrier - this will be discussed below.

Temperature

A number of temperature measurements have been taken at 07UM048 (see Tables 82 and 83) and none showed any that would be problematic for the fish community, though no afternoon mid-summer measurements are available. The deployed Sonde (6/19 - 7/2/2019, 13 days) recorded a maximum temperature of 25.8°C. The majority of the time the temperature was between 19°C - 24°C. These temperatures are not stressful for warmwater fish species. Temperature in mid-late July and early August is probably a few degrees higher in general, however, the 2017 fish sample was in late June.

Habitat

Habitat is mediocre in this channelized AUID, based on MSHA metrics, and the UAA process rated it as insufficient to be placed into the General Use TALU category, so it was placed into the Modified Use category. The total MSHA score is well below the threshold at which it is considered "Poor". The total and sub-component scores are shown in Table 88. The poorest-scoring sub-component scores were

"Substrate" and "Channel Morphology". This is very typical of ditches, which typically have little sinuosity, uniform bed topography, lack of distinct channel features like pools or riffles, and fine particulate substrate. Sand and silt were indeed the predominant substrates found by the crew. The limited larger substrate was noted as being moderately to severely embedded by fine particulates.

Notes from the fish sampling visit in 2017 say that there is very deep silt and stagnant areas in the reach, and that the last 40m of the reach had silt deep enough to preclude fish sampling as the backpack would get partially submerged due to the crew sinking deeply into the substrate.

Table 89. MSHA scoring for site 07UM048.

MSHA Component	7/2007	6/2017	8/2017	Avg.	Maximum Poss. Score	Percent of Maximum
Land Use	5	2.5	2.5	3.3	5	66.7
Riparian	14	8.5	12	11.5	14	82.1
Substrate	8	5.3	9.2	7.5	28	26.8
Cover	2	10	10	7.3	18	40.6
Channel Morphology	9	4	8	7.7	35	22.0
Total MSHA Score	38.0	30.3	41.7	36.7	100	36.7 = "Poor"

Hydrology

There has been significant modification of the natural hydrology of the sub-watershed, both due to historical large-scale vegetation cover changes (forest to cultivated fields), as well as straightening of the channel that reduced sinuosity and thus speeds movement of water through the landscape/stream system. This AUID may not have been a contiguous channel in pre-settlement times (Figure 43). There is no evidence from viewing the LiDAR elevation data that a natural, sinuous channel existed through the wetland just upstream of 07UM048, which confirms the original survey drawings shown in Figure 43. Channel size was also likely increased when the ditching was done originally (Figure 44). These changes have very likely made French Creek a more flashy system, with quicker, stronger pulses of water moving through the system following sizeable rain events, and may result in lower baseflow volumes during drier times.

Figure 46. The original survey plat sketch shows that there may not have been a channel through the wet meadow where there now is a ditch (area circled in red). Outflows from the lake may have dissipated throughout the meadow, and then coalesced again to form the downstream part of the channel, which on this original map is named Frenchmans Cr. The green dot is the center point of the biological sampling reach.

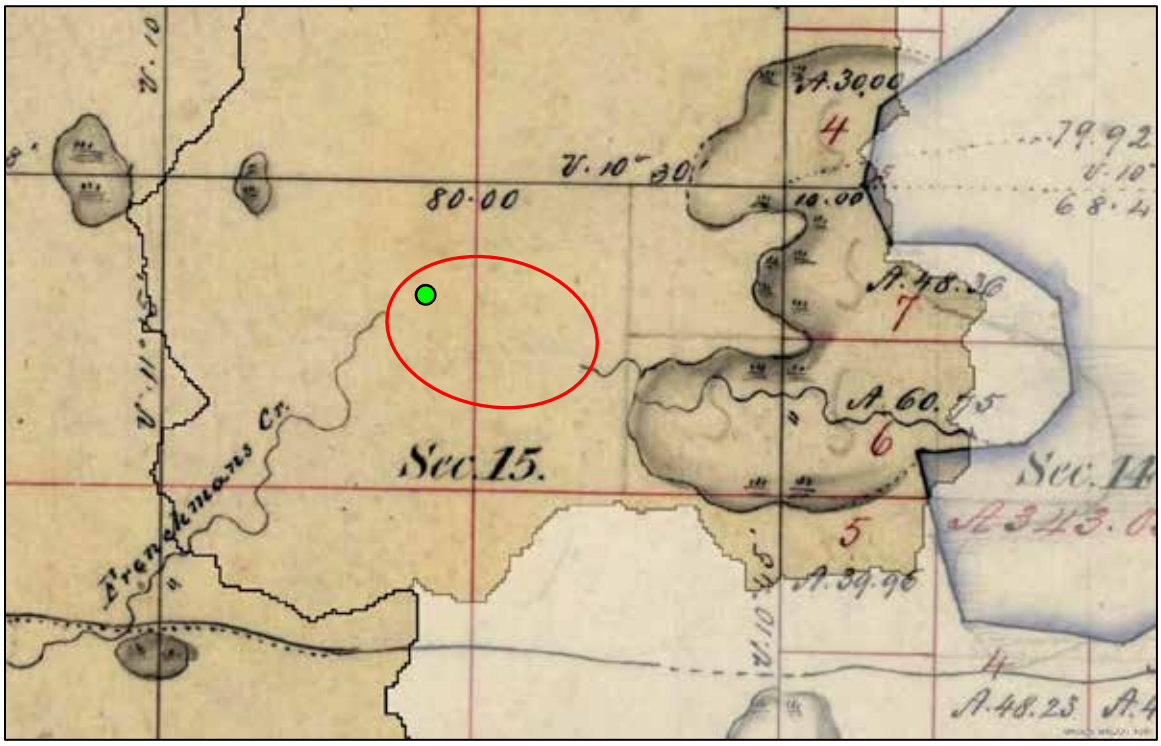
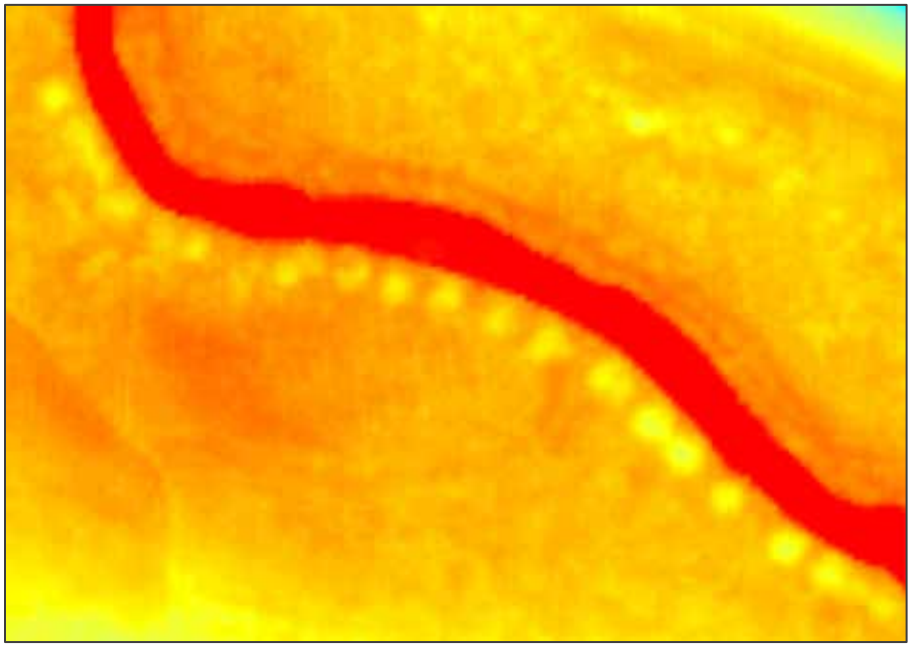


Figure 47. LiDAR derived ground surface elevation of the channel immediately downstream of French Lake shows how the channel has been enlarged by ditching. The red band is the stream channel, and the yellow dots along the edge are spoil piles of soil from the digging of a larger channel.



Geomorphology

Much of this AUID was channelized/straightened decades ago. Straight channels typically have homogenous habitat, lacking variety of the features that sinuosity creates (depth and velocity variability, riffles and pools, etc.). The ditching likely altered the general bed elevation of the channel system, and if lower than natural, prevents higher flows from spilling out onto a floodplain, which can lead to bank instability. Ditches also commonly have higher banks than natural stream channels, which also prevents high flows from dissipating on the floodplain. Though there are areas where ditch banks are high, they do not appear to be unstable - little abnormal erosion was seen in the photos that were taken along the channel during the fish monitoring. No on-the-ground geomorphology studies were conducted on this AUID. Some bank instability/erosion can be seen on aerial photography in the lower parts of the AUID where cattle pasture surrounds the channel and the animals have access to the stream.

Connectivity

There are four culvert crossings between the North Fork Crow River and the biological site on the downstream AUID-760. Two of the crossings are on public roads (CR-37 and Peloquin Avenue NW), and two are on private drives. From aerial photography, both of the private drive culverts appear to have scour pools on the downstream side, suggesting that culvert sizing is not correct, and thus these may be fish migration barriers. The culvert at CR-37 is passable, while the Peloquin Avenue NW culvert is somewhat suspect of being a partial barrier. It is undersized and set at too high an elevation per guidance by MnDOT (2019). At lower flows, it is passable (Photo 18). There is also a private crossing within the biological reach and road crossing at the upstream end of the biological reach on CSAH-3. From crew photos, the private culvert does not appear to be a barrier. The CSAH-3 crossing was visited and is not a migration barrier. A third upstream culvert crossing is near French Lake on Oliver Avenue. While not visited on the ground, aerial photos show it is likely passable, though this crossing is not that likely to influence the fish community at the biological site even if it were a barrier.

Photo 18. Downstream end of the culvert at Peloquin Avenue NW.

Conclusions about stressors

There are two stressors with strong evidence of being stressors, low DO and poor habitat. A third, fish migration barrier(s) may be a stressor also. The direct DO measurements revealed daily minimum concentrations routinely dropped far below-standard levels, and the analysis of the fish and macroinvertebrate communities also showed the community to be skewed toward taxa that tolerate

low DO conditions, particularly the macroinvertebrates. The artificial drainage (ditches) throughout this sub-watershed are very likely a negative influence on DO levels in the river, due to physical changes in the ditched channel that change the physics of water movement within the channel, and can reduce the exposure of the full water column to the atmospheric contact that can move oxygen into the water from the air (i.e., reduced water mixing). Longitudinal DO monitoring along AUID-759 shows the decline in DO occurs especially within the section of the AUID just upstream of the biological monitoring site, where the channel is a ditch through a large wet meadow. This wetland does not appear to have had a channel prior to arrival of homesteaders. Enlargement of the natural channel leaving French Lake also has likely created a more stagnant flow susceptible to losing DO.

There are no permitted effluent dischargers active in this sub-watershed. There is significant potential for non-point nutrient pollution due to cultivation for agricultural activity. This may be somewhat mitigated by the two large wetlands within the landscape that directly drains to the AUID (i.e., the runoff that doesn't first move through French Lake). There are no urban areas or cities/towns from which runoff is enhanced by large areas of impervious surfaces, though a business adjacent to the AUID has a very large impervious area. Depending on how the runoff moves, it is possible it has some significant effects of hydrology of the stream, though it appears a sedimentation basin collects runoff.

Poor in-channel habitat conditions typical of ditches (i.e., fine sediment substrate, homogeneous velocity and reduced stream-bed contour) are found in this AUID. In addition to being poor habitat, uniform stream channels create less-turbulent flows and reduce water interaction with the atmosphere (i.e., reduce aeration). Reduced habitat compounds the low DO as an additional stressor.

Signs of physical channel instability due to altered hydrology were not present, though bank instability/erosion can be seen where livestock are allowed access to the stream. Though issues of altered hydrology are not of strong concern here for bank erosion reasons, the altered flow may contribute to periodic low flows due to reduced upstream storage. During these periods, DO levels may become especially problematic as stream flow becomes more stagnant. Connectivity may be problematic at times, with the Peloquin Avenue NW culvert not meeting MnDOT design standards for fish passage. Two private culverts may be problematic for fish passage as well, but were not verified via a ground observation.

Recommendations

It may be difficult to do much to correct the conditions impairing the stream, due to the large wetland encompassing a large section of the AUID, the channelized nature of the creek that removed important habitat features created by a meandering stream, and the likely connectivity issues. Replacing the culvert at Peloquin Avenue NW with a properly-sized culvert partially embedded in the stream bed should be considered when replacement is scheduled. There is probably not enough benefit to replace it as a special project, because the other habitat needs to create a healthy fish community are not present upstream, and the length of the stream between Peloquin Avenue and French Lake is not very long. There are probably other culvert replacements elsewhere in the NFCRW that would have greater benefit due to better habitat presence, or a longer length of stream above the replaced culvert. Additional sampling for nitrate would be beneficial, particularly in April, May, and early June, when field sourced nitrate tends to be higher, prior to crop growth. This would be best done at Peloquin Avenue or CSAH-37, farther away from French Lake.

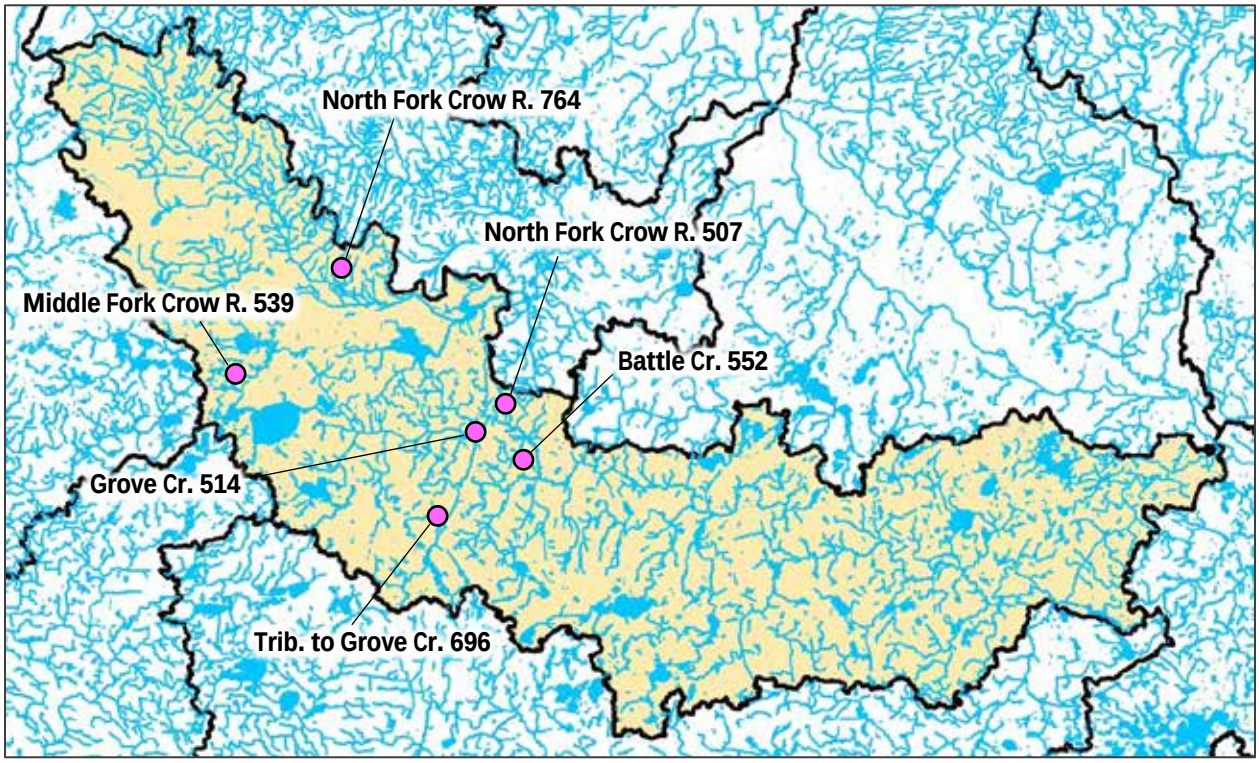
There is another section of French Creek, beginning just downstream of the biological site to the confluence with the North Fork Crow River. A substantial length of that AUID flows within a pasture with animals having full access to the creek. Bank erosion due to trampling can be seen in aerial photography, and the riparian vegetation changes to shallow-rooted grass due to foraging both have negative

influence on water chemistry and habitat. Fencing livestock from the stream would benefit habitat in this lower section of French Creek and may improve the fish community upstream in AUID-759. This would also benefit water quality in the North Fork Crow River.

Stream geomorphology investigations

Minnesota DNR Watershed Specialists conducted studies of six locations (Figure 44) on five NFC streams in 2018 and 2019. All of the six AUIDs studied were streams that were assessed as impaired for fish and/or macroinvertebrates in the 2010 Watershed Assessments. Two geomorphic methods were used, those of Rosgen (1996) and Pfankuch (1975). Summaries of the work are presented below for five of the six locations. The Middle Fork Crow River was discussed above in the Middle Fork Crow River AUID-539 section. These summaries are taken from DNR write-ups of the findings of each stream. These full DNR documents are attached in this report as Appendices 1 - 6, for those seeking finer detail.

Figure 48. Locations of DNR Geomorphology surveys in the NFCRW, 2017-2019.



North Fork Crow River - AUID 07010204-507

This AUID was assessed in 2010 as failing to meet its aquatic life use as measured by the fish community sampled in 2007 at site 07UM021. The 2007 macroinvertebrate community did meet its aquatic life use standard. The 2017 monitoring effort again found the macroinvertebrate community quite healthy, and the fish community was improved over 2007, and did barely meet the passing threshold. Additional fish data is needed to remove the fish impairment and delist the site, but the fish community seems to be improving.

This AUID begins where the Middle Fork Crow River enters, and ends where Jewitt's Creek enters. The reach within AUID-507 where geomorphic measurements were made is from just upstream of 592nd Avenue to just downstream of MN Highway 22. This reach is about 2.7 miles upstream of 07UM021. The Pfankuch assessment found the channel to be stable. The Rosgen protocol found the physical channel to be very healthy, with dimensions and bank heights that are natural, allowing high flow events to spill out

onto a wide floodplain to dissipate the water's energy so as not to tear apart the channel. Indeed, bank observations also found little erosion. Such channels typically provide good and stable habitat for aquatic organisms. The findings correlate well with the healthy macroinvertebrate community, and the recent improved score of the fish community. The results strongly suggest that altered hydrology is not a root cause of stressor(s) to the fish community in AUID-507.

Grove Creek - AUID 07010204-749 (split from previous AUID-514)

AUID-514 was assessed over several years as having numerous impairments: Fish (2002), DO (2004), macroinvertebrates (2006), *E. coli* (2010), and turbidity (2010). AUID-514's length was broken into two new AUIDs after TALU was instituted, with AUID-749 being the lower 9.12 miles of Grove Creek. Data collected from AUID-749 in IWM-2 (in 2017 and 2018) confirm that the DO, E. coli, and TSS are still impairments. Also, biological sampling results from 2009 and 2017 were determined to support the original impairment decisions for both fish and macroinvertebrates.

The geomorphology reach is located in this new AUID-749, at the same location as biological monitoring site 07UM026. The geomorphology reach was immediately downstream of the biological sample reach. The Pfankuch assessment scored in the range considered "Fair" for stability. Sand was the dominant substrate type, with gravel being the largest substrate type present. The Rosgen protocol found the physical channel to be fairly healthy, with slight incision, allowing much of the high flow events to spill out onto a wide floodplain to dissipate the water's energy so as not to tear apart the channel. Such channels typically provide good and stable habitat for aquatic organisms. However, bed materials were judged to be moving and re-depositing more than is natural, which detracts from habitat quality. This could be the result of the incision mentioned above, as there is more energy working against the stream bottom, having greater ability to move especially the finer particles like sand. The results suggest that altered hydrology from upstream ditching is possibly leading to moderate problems in AUID-749 (Photo 19).

Photo 19. The biological monitoring staff documented that there are periodic locations where bank failure is occurring along the 07UM026 reach, depositing sediment into the stream and leading to vertical raw banks that are not protected from additional erosion.

Grove Creek findings from the earlier SID work that followed the first IWM effort are found in another report (MPCA 2013).

Battle Creek - AUID 07010204-552

This AUID was assessed in 2010 as failing to meet its aquatic life use as measured by the fish and macroinvertebrate communities sampled in 2007 at site 07UM027. Resampling in 2017 also found both the fish and macroinvertebrate communities to be impaired. The reach where geomorphic measurements were made is immediately downstream of 07UM027, on the east side of MN Highway 22. The Pfankuch assessment found the channel to be in the "Fair" category regarding channel stability. The Rosgen protocol found the physical channel to be slightly incised, meaning that some of the high waters remain in the channel instead of out on the floodplain. The result is more energy remaining in the channel to cause instability of the channel (potential for more bank erosion and bed scour). Channel incision is typically initiated by an alteration of the hydrology of the system (increased runoff and greater frequency of higher flow events. The surveyors found that the bed materials seem more mobile than expected, leading to an unstable habitat for aquatic organisms. The results strongly suggest that altered hydrology may be a contributing stressor to the fish and macroinvertebrate communities in AUID-552.

The macroinvertebrate crew found areas where the stream bed was knee deep (and deeper) in silt.

North Fork Crow River - AUID 07010204-764 (split from previous AUID-685)

This AUID was assessed in 2010 as failing to meet its aquatic life use as measured by the fish community, sampled at several sites in 2007. This AUID's length was broken into two new AUIDs after TALU was instituted, the predominant one in terms of length is now identified as AUID-764 (it is 38.9 miles long). The geomorphology reach is located in this new AUID-764. Per results from biological monitoring at five sites in 2015 or 2017, all of which scored above (better than) the health threshold for both fish and macroinvertebrates, this reach is no longer considered to be impaired. In fact, the farthest downstream site (15UM203) in AUID-764 scored above the exceptional use threshold for both fish and macroinvertebrates. Numerous BMPs have been applied to the stream banks and landscape along this AUID and appear to have contributed to its healthiness.

The reach where geomorphic measurements were made is at about the midway point of the length of the North Fork Crow River, and about 0.6 miles upstream of 07UM009. The Pfankuch assessment found the channel to be stable. The Rosgen protocol found the physical channel to be very healthy, with dimensions that are natural, allowing high flow events to spill out onto a wide floodplain to dissipate the water's energy so as not to tear apart the channel. Such channels typically provide good and stable habitat for aquatic organisms. The results strongly suggest that altered hydrology is not leading to problems in AUID-764. The positive findings of the DNR geomorphology work undoubtedly contribute to the healthy biological communities found throughout this upper reach of the North Fork Crow River.

Unnamed Tributary to Grove Creek - AUID 07010204-696

This AUID was assessed in 2019 as failing to meet its aquatic life use as measured by the fish and macroinvertebrate communities sampled in 2009 at site 09UM080. The section of the creek that was the focus of the geomorphic survey is somewhat of an anomaly within AUID-696, as it is a section that was created (i.e., dug) to re-route the creek, sometime between 1979 and 1981. There are other parts of the AUID that are also ditched, though have been so for a much longer period and may have naturalized to some extent. The reach where geomorphic measurements were made immediately downstream of 09UM080, and a part of the stream reach for biological sampling may have overlapped a small part of the geomorphology reach. The Pfankuch assessment found the channel to be in the "Fair"

range for channel stability. The Rosgen protocol found the physical channel to be fairly healthy for stability, with a slightly incised channel, meaning that some of the higher flows that would have spilled onto the floodplain remain in the channel, creating conditions that could lead to channel instability. The incision is probably not due to altered hydrology effects, but rather to how the channel was constructed in approximately 1980. The surveyors not that the channel was also created wider than it would be naturally. The survey crew noted signs that the channel is naturally narrowing itself over time. Since this situation is an anomaly for just this relatively small section of the stream, it is not possible to extrapolate the findings to the rest of the stream for determining stressors that apply more broadly to this AUID. Grove Creek findings from the earlier SID work that followed the first IWM effort are found in another report (MPCA 2013).

Overall conclusions and stressor summary table

A variety of stressors were found during the SID process for streams that MPCA and partners assessed in 2019 as having impairments to their fish and/or macroinvertebrate communities. These impairments were found in the second IWM process begun in 2017. These are similar to the list of stressors found in the first IWM effort in 2007. Stressors included those that are common to landscapes with much land devoted to agriculture. These included elevated nitrate levels, elevated phosphorus levels and the low-DO concentrations it can cause, channel instability due to altered hydrology, excessive suspended and bedded sediment, alterations of channels by ditching/straightening leading to habitat homogenization, and livestock trampling damage to stream channels and banks leading to sediment input. A common infrastructure stressor was also found that occurs all throughout Minnesota and the United States, that being road crossing culverts that are undersized or installed such that they create barriers to fish migration. The results of the SID work for the individual stream impairments recently found in the NFCRW are presented in Table 90.

Most of the stressors found in this project are those that are related to land runoff. These include elevated amounts of runoff due to landscape vegetation changes, and contaminants that are carried in this runoff (nutrients nitrate and phosphorus, eroded soil particles. Efforts (i.e., BMPs) that focus on reduction of runoff (various tillage practices, building of soil health, vegetated buffers along water resources) and efforts to store water on the landscape and allow it to more slowly move to streams will help reduce many of these stressors and improve water quality and stream habitat in the NFCRW. For problems associated with road crossing infrastructure (fish passage), it is helpful to make road authorities aware of the issues, so that when planned road projects associated with the roadway occur, they can also accomplish correction of the culvert problems. Replacement culverts should be designed with organism passage in mind (MnDOT, 2019). An excellent example is the recent culvert design and installation project on Sucker Creek at the 650th Avenue crossing (Photo 20).

Table 90. Summary of stressors causing biological impairments in NFCRW streams by location (AUID). An empty cell means there is no evidence to suspect that particular stressor.

Stream	AUID Last 3 digits	Biological Impairment	Stressor								
			Dissolved Oxygen	Phosphorus	Nitrate toxicity	TSS	Connectivity	Altered Hydrology	Channel alteration	Habitat	Toxic chemicals
Middle Fork Crow R.	511	Fish	?			?		•	¨	•	?
Judicial Ditch 17	532	Fish	•	¨	•				¨	•	
County Ditch 37	536	Fish	?						¨	•	
Middle Fork Crow R.	539	Fish	•	?						•	
Trib. to Lake Koronis	553	Fish			?	•	•				
Silver Creek	559	M-invert	•		•	•		•	¨	•	
Stag Brook	572	Fish, M-invert	•		•		•	?		•	
Collinwood Cr.	604	Fish, M-invert	•	?	•	?	•	?		•	
County Ditch 26	643	Fish, M-invert	•	¨					¨	•	
Twelvemile Cr.	679	Fish, M-invert	?			?					
Washington Creek	751	M-invert	•						¨	•	
Washington Creek	753	Fish	•			?			¨	•	
County Ditch 36	755	Fish, M-invert	•	¨	•	?	•		¨	•	
French Cr.	759	Fish, M-invert	•		?		•		¨	•	

¨ A "root cause" stressor, which leads to consequences that become the direct stressors. Possible contributing root cause.

• Determined to be a direct stressor.

o A stressor, but anthropogenic contribution, if any, not quantified. Includes beaver dams as a natural stressor.

X A secondary stressor.

? Inconclusive

Photo 20. Downstream side of new culverts on Sucker Creek at 650th Avenue, southeast of Litchfield. The main culvert is properly sized and set at the appropriate elevation to allow natural continuity of the stream through the culvert. The floodplain culvert allows for high streamflow to pass and protect the roadway.

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Appendices

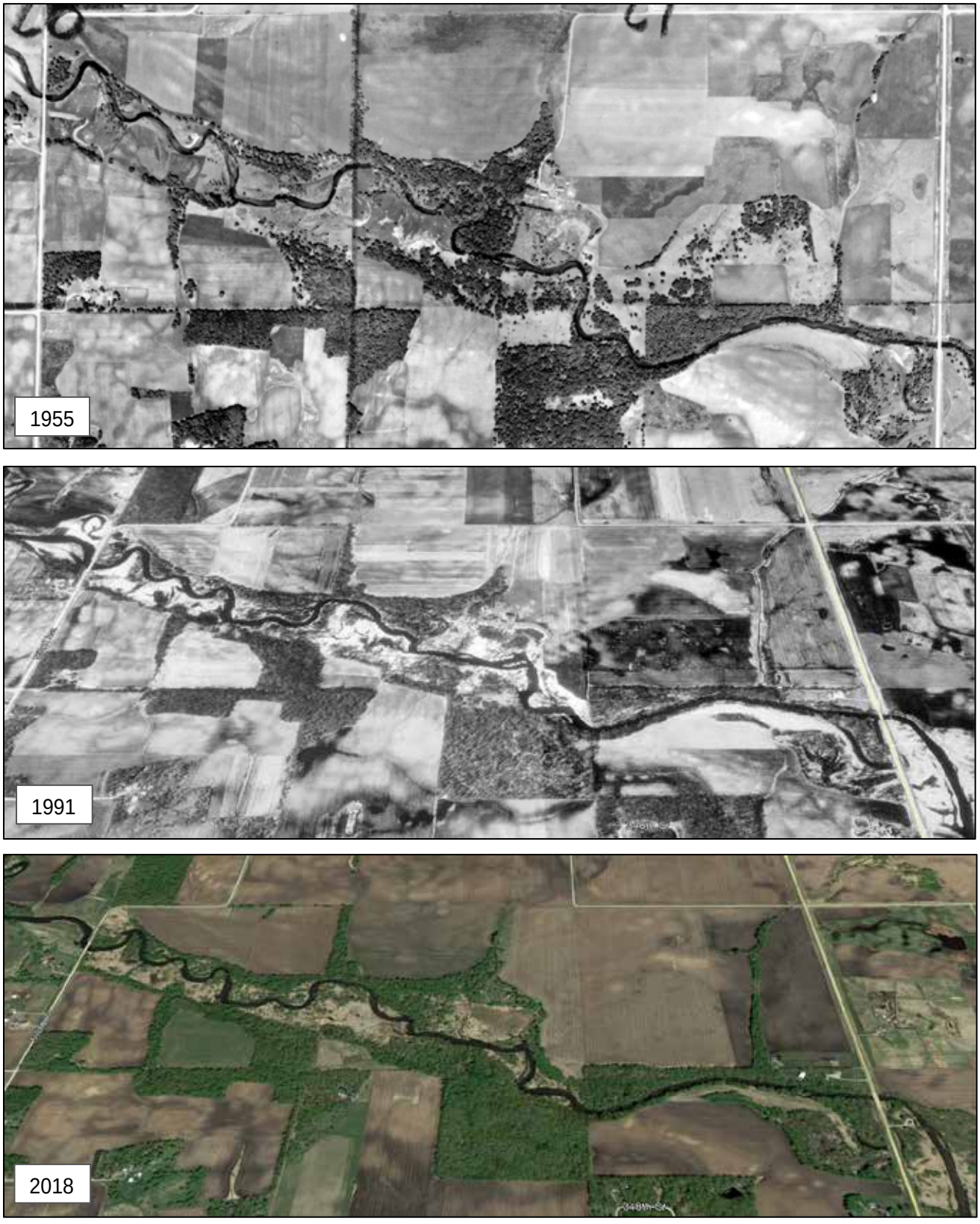
Appendix 1. North Fork Crow River (07010204-507)

Geomorphic Reach Information			
Stream Name	North Fork Crow River	**Drainage Area**	658.75 mi^2
MPCA AUID	07010204-507	**Stream Type**	C5c-
County	Meeker	**Valley Type**	Unconfined Alluvial U-AL-FD
Section, Township, Range	Sec 27, 28, 34, T121N, R31W	**Water Slope**	0.0006 ft/ft
Entrenchment Ratio	10.65 (slightly entrenched)	**Sinuosity**	1.36
Width/Depth Ratio	17.24 (moderate to high)	**Pfankuch Stability Rating**	74 (good)
Bank Height Ratio	1.0 (stable)	**Particle size (D50)**	1.06 mm (sand)

The North Fork Crow River geomorphic survey consisted of 2.25-mile reach from 592nd Avenue to MN Highway 22 in Meeker County. The survey was completed in late-July 2018 at moderate to high flow volume. The data were collected utilizing a SonTek RiverSurveyor in combination with a Trimble R10 GPS to collect longitudinal profile and cross-sectional data. Three riffle cross-sections and two pool cross-sections were surveyed and riffle and full reach particle size data were collected. The purpose of the survey was to document the unaltered, natural stretch of low-gradient river with floodplain connectivity, minimal bank erosion, high quality riparian conditions, and diverse habitat to document potential reference conditions.

The North Fork Crow River through this mid-mainstem reach meanders through a wide, alluvial valley with an intact riparian corridor. The pattern and riparian conditions have remained constant over the last approximately 30-years. There is no sign of past channelization based on aerial photograph review (Figure 49).

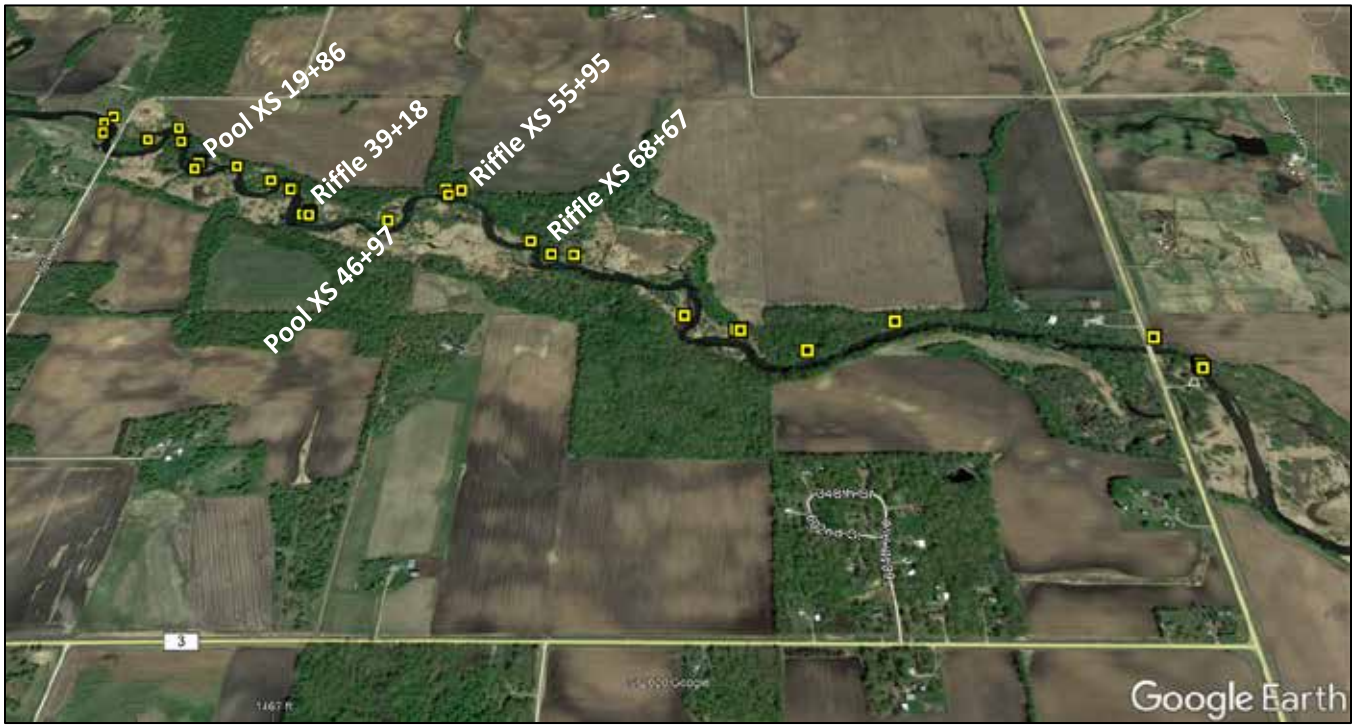
Figure 49. The surveyed reach; 1955 photo on the top, 1991 in the middle, and 2018 photo on bottom. 1991 and 2018 images courtesy of Google Earth.



Locations of cross-section surveys are shown in Figures 50 and 51. The middle riffle at station 55+95 was used as the classification riffle because riffle pebble count data were collected at this location and it was consistent with the downstream riffle. The classification riffle had a reasonable width-to-depth ratio of 17.24, given the sandy materials identified (Figure 52). The upper riffle at station 39+18 was more like a run in a compound pool. However, that was not determined until after returning to the office and reviewing the data. There was no evidence of excess deposition or aggradation at the time of the survey and this width-to-depth condition appears adequate for sediment transport. The site has excellent floodplain connectivity at flood flows with a bank height ratio of 1.01, providing a "Stable" rating for this very low degree of channel incision. The water surface slope was relatively flat (i.e., low slope) with an overall drop of 0.0006 ft/ft (0.06%) throughout the entire 2.25-mile stretch. However, in the defined reach near the classification riffle, a measured slope of 0.0008 ft/ft was used for the data analysis and discharge calculations. This resulted in an estimated bankfull discharge of 865.59 cubic feet per second (cfs) and a velocity of 3.45 feet per second using the U/U* methodology. This matches up with regional curve and USGS Stream Stats tool estimates. The stream flow gage at MN Highway 22 is for flood warning purposes and lacked long-term data to determine the 1.5 to 2-yr return interval flows. The flow measurement collected during the geomorphic survey indicated flow was 369 cfs on July 31, 2018.

Sand was the dominant streambed material. The particle size D50 of the reach was 1.06 mm with 64% of the reach pebble count consisting of sand. Other substrate documented in the pebble counts included cobble, silt and clay. Parent materials were generally mapped as coarse loamy alluvium, according to the NRCS web soil survey. The overall stream type classification is C4c-, based on the Rosgen classification system. It is a low gradient, meandering channel with point bars, riffle/pool streambed sequences with a well-defined floodplain. The Pfankuch stability rating was 74, resulting in a "Good" condition rating.

Figure 50. Location of North Fork Crow River geomorphic survey reach upstream of State Highway 22, near Manannah. Yellow points indicate GPS survey shots. 2018 image courtesy of Google Earth.



The longitudinal profile indicated the mean riffle depth was 4.16 ft and the maximum riffle depth was 5.17 ft (Figure 51). The mean pool depth to bankfull elevation was 6.58 ft and the maximum was 8.95 ft over the 2.29-mile longitudinal profile. The downstream riffle and pool cross-sectional surveys are shown in figures 53 and 54. The SonTek RiverSurveyor may result in less accurate riffle and pool depths when compared to the typical survey grade equipment. The longitudinal profile revealed continuous floodplain connectivity and minor channel incision. There was little evidence of streambank erosion, based on visual observations and photographs captured during kayak reconnaissance and survey. Actual bank erosion measurements were not collected. The kayak reconnaissance included an additional four-mile reach downstream. In the reach from MN Highway 22 to 328th Street, the valley is mapped with outwash materials. Adequate floodplain and high quality riparian conditions existed in this reach too. However, there were more wetlands, oxbows, and side channels observed throughout the downstream stretch. A key strategy for this area of the North Fork Crow River will be maintaining and protecting the wide, perennial vegetated buffer and floodplain to help sustain stream stability, ecological functions, and diverse habitat. This reach of the North Fork Crow River has been identified as a priority for stream protection, according to Stream Protection Priorities for Watershed Restoration and Protection Strategies (WRAPS) data set available within the Watershed Health Assessment Framework (WHAF) interactive map. It is currently fully supporting for the aquatic life assessment, and designated with a higher risk of becoming impaired in the future. Photos of this section of the North Fork Crow River in shown in Figures 55 and 56.

Figure 51. The longitudinal survey profile within AUID-507 with cross-section survey locations.

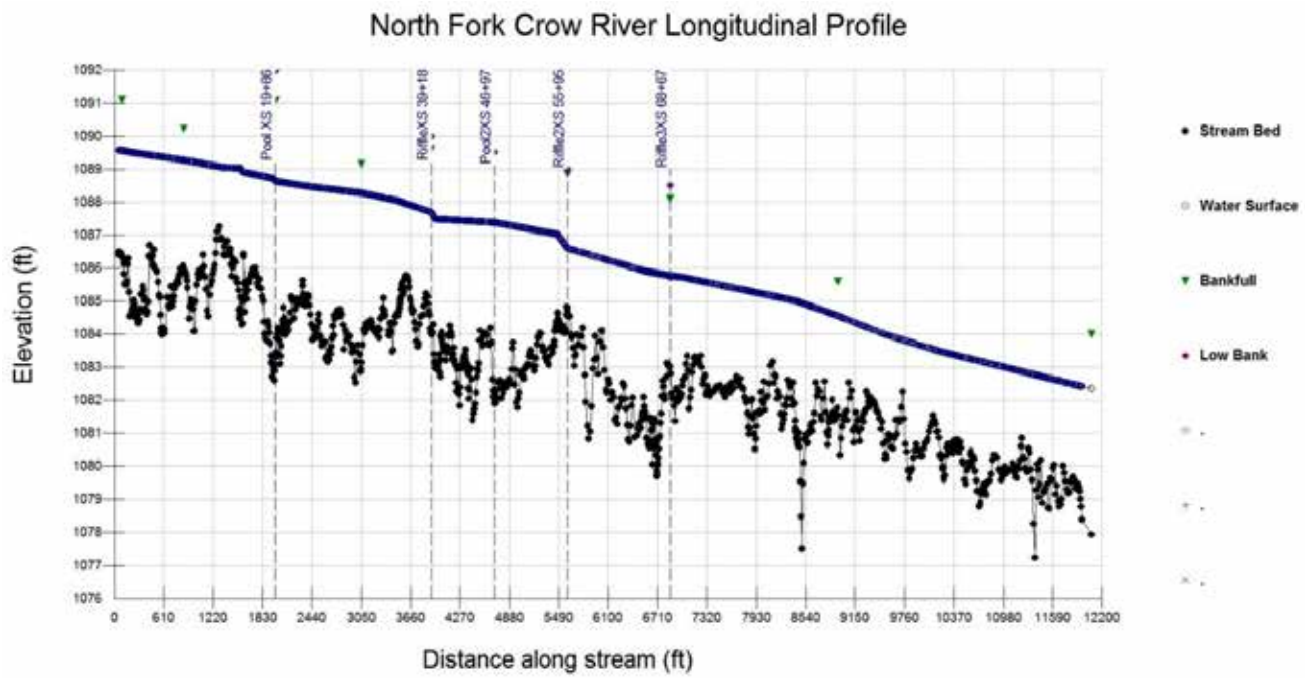


Figure 52. Riffle cross-section utilized for stream classification.

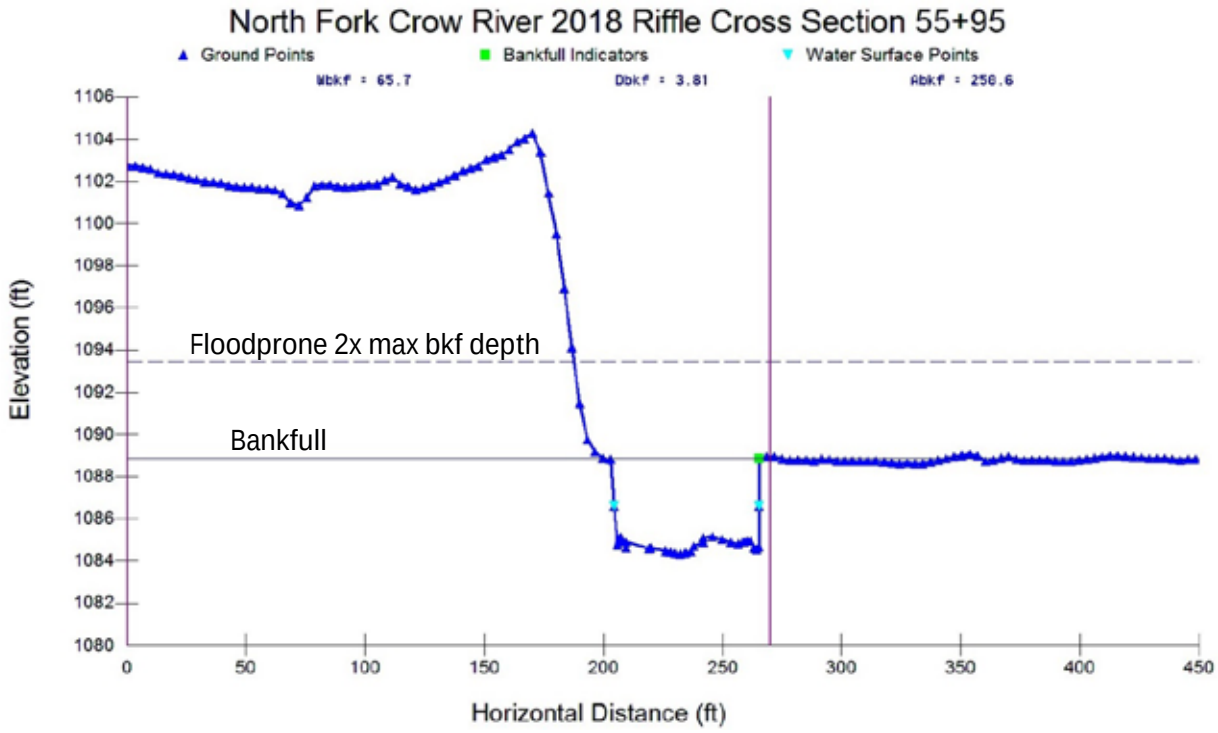


Figure 53. Downstream riffle cross-section at station 68+67.

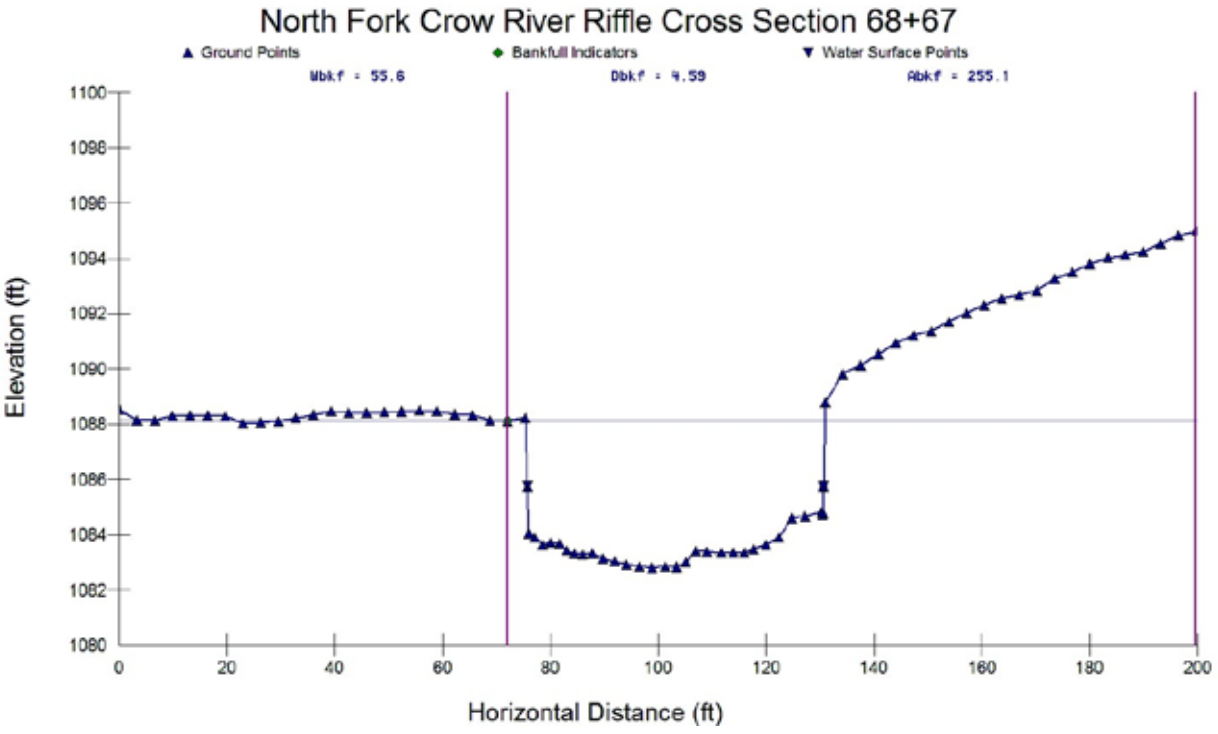


Figure 54. Pool cross-section surveyed at station 19+86. Mean depth to bankfull elevation is 4.94 ft and maximum depth equals 8.45 ft.

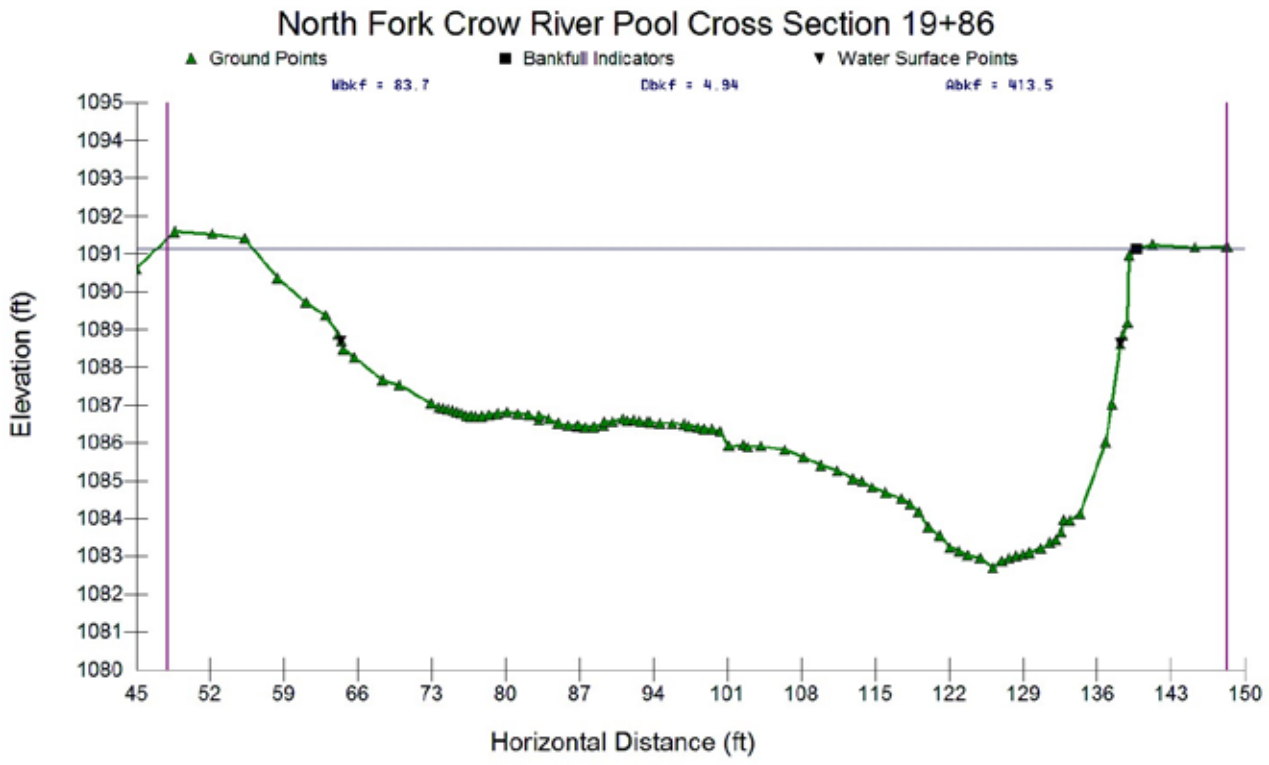


Figure 55. Image of typical channel width and riparian conditions throughout the survey reach.

Figure 56. An image of a riffle feature in a straight section as the thalweg crosses over toward the outside bend flowing to the pool downstream.

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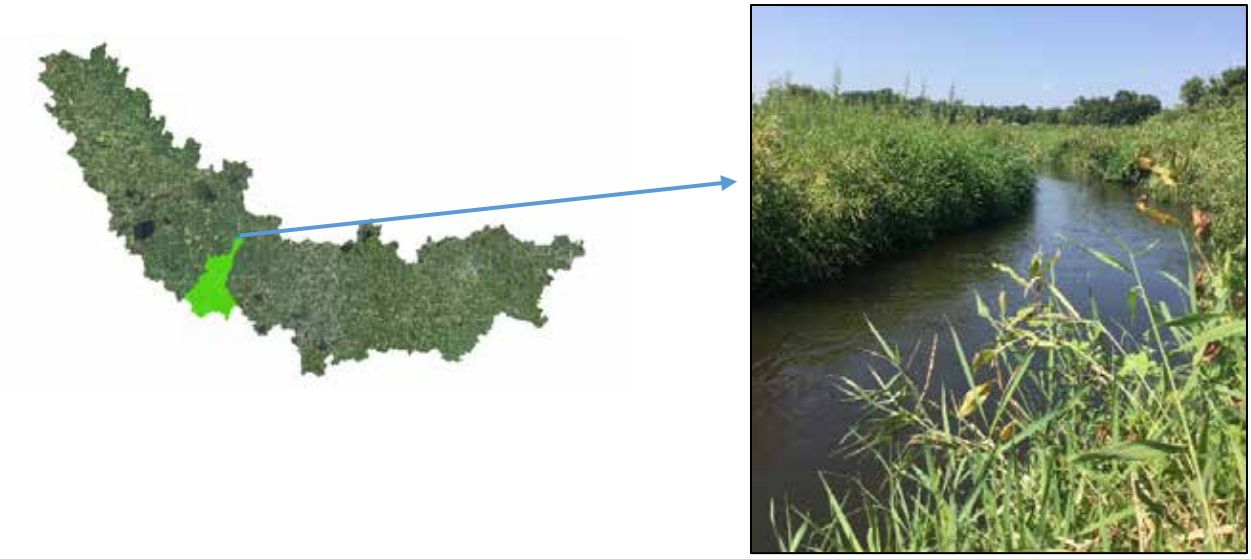
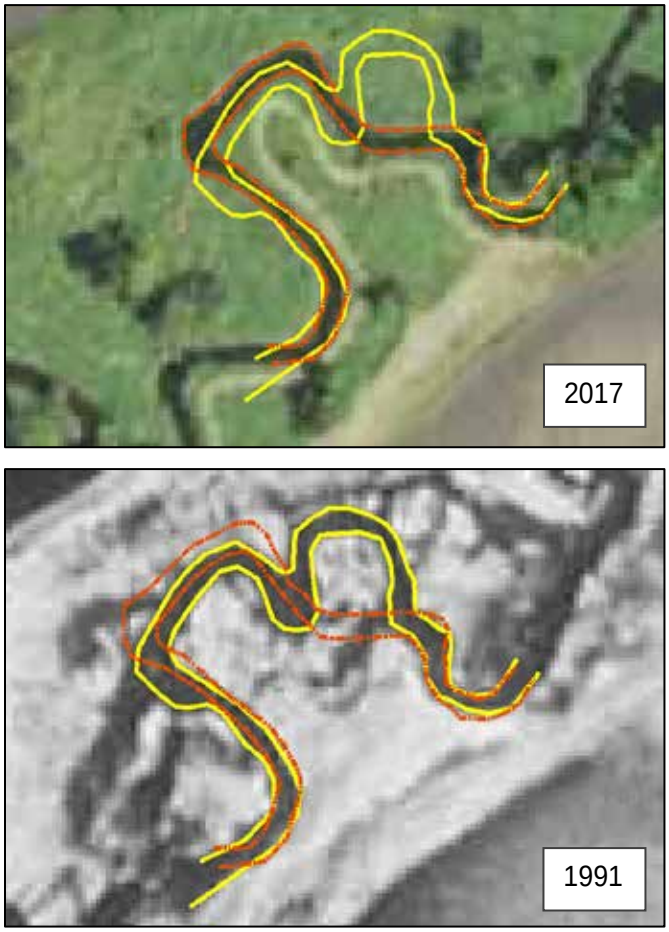
Appendix 2. Lower Grove Creek (07010204-514)

Geomorphic Reach Information			
Stream Name	Grove Creek	Drainage Area	50.58 mi^2
MPCA AUID	07010204-514	Stream Type	E5
County	Meeker	Valley Type	Unconfined Alluvial U-AL-FD
Section, Township, Range	Sec 32, T121N, R31W	Water Slope	0.00075 ft/ft
Entrenchment Ratio	33 (slightly entrenched)	Sinuosity	2.42
Width/Depth Ratio	5.9 (low)	Est. Reach Erosion Rate	3.54 tons/yr
Bank Height Ratio	1.21 (slightly incised)	Pfankuch Stability Rating	78 (fair)



The Lower Grove site is a sinuous E5 stream with a 200-300 foot (ft) wide buffer, dominated by reed canary grass. There is no sign of past channelization based on air photo review. However, the stream was more sinuous in the past with irregular meanders scrolls (Figure 57). The Lower Grove Creek geomorphic survey reach is downstream of 340th Street and consisted of a longitudinal profile, two riffle cross sections, one pool cross section (Figure 58), pebble count, and bank erosion estimates and validation.

Figure 57. 2017 vs. 1991 streamlines for the survey reach. The yellow streamline is 1991 and red streamline is 2017.

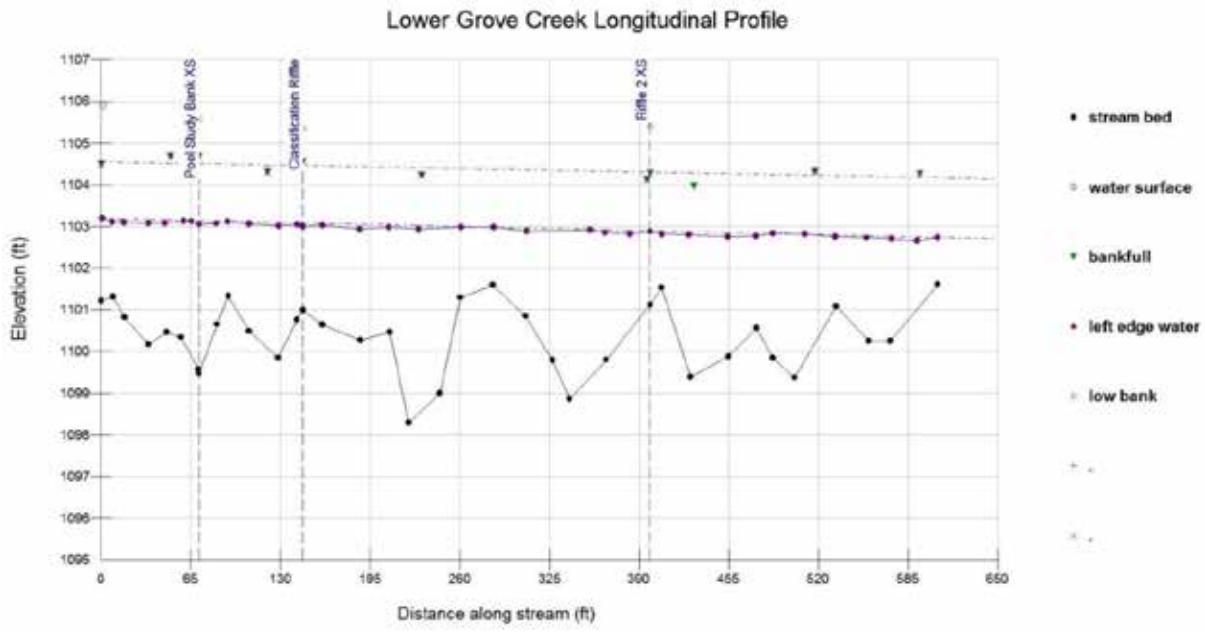


The classification riffle had a low width-to-depth ratio; 5.9 is an optimal w/d ratio for E channels to allow them to transport sediment most efficiently. The channel had only a slight degree of incision and had overall floodplain connectivity at flows above bankfull stage, an attribute not common in southern Minnesota streams, as most are more deeply incised. The study reach is within a few miles of the confluence with the North Fork Crow River and the valley is wide and unconfined. Soils are mapped as coarse loamy alluvium, according to the online web soil survey. There was evidence of recent substantial sand movement and deposition along the streambed. The D50 of the reach was 0.48 mm with 50% consisting of sand. Other substrate documented in the pebble counts include gravel, silts and clay.

Figure 58. Location of Lower Grove Creek geomorphic site; 2018 image courtesy of Google Earth. Riffle XS 1+46 is the classification riffle.

The longitudinal profile (Figure 59) indicated the mean riffle depth was 3.05 ft and the maximum riffle depth was 3.51 ft. The mean pool depth to bankfull elevation was 4.85 ft and the maximum was 6.10 ft, over the 600 ft longitudinal profile. The stream was low gradient with a slope of 0.00075 ft/ft. The Pfankuch stability rating was a 78, a "Fair" stability rating.

Figure 59. Longitudinal profile for Lower Grove Creek, 2017.



The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model estimated stream banks within the reach contribute 3.54 tons of sediment annually for the 600 ft reach using the Colorado curve. The pool cross section (Figure 60) at station 0+76 was surveyed in 2017 and 2018 to document changes and validate predicted stream erosion rates. The right study bank erosion estimate was 0.036 ft/yr in 2017. The 2018 re-survey revealed the measured bank erosion rate was 0.564 ft/yr.

The pool cross section resurvey also indicated changes in the channel bed. The 2017 mean pool depth was 4.29 ft and the maximum equaled 5.21 ft. In 2018, the mean depth was 3.1 ft and the maximum was 3.3 ft. The toe pin was not located because it was buried in bed sediments at the time of the 2018 re-survey.

Figure 60. Pool study cross section in 2017 and 2018. A deposition of sediment of 1.4 feet deep in the middle of the cross-section was measured.

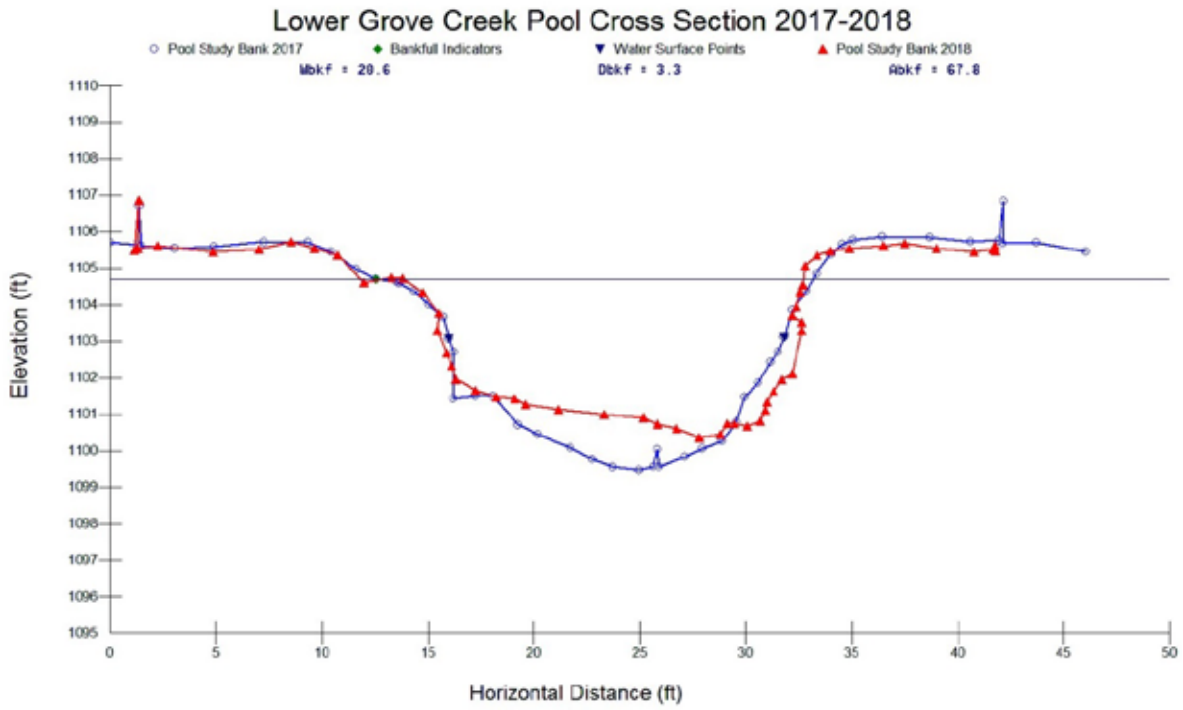
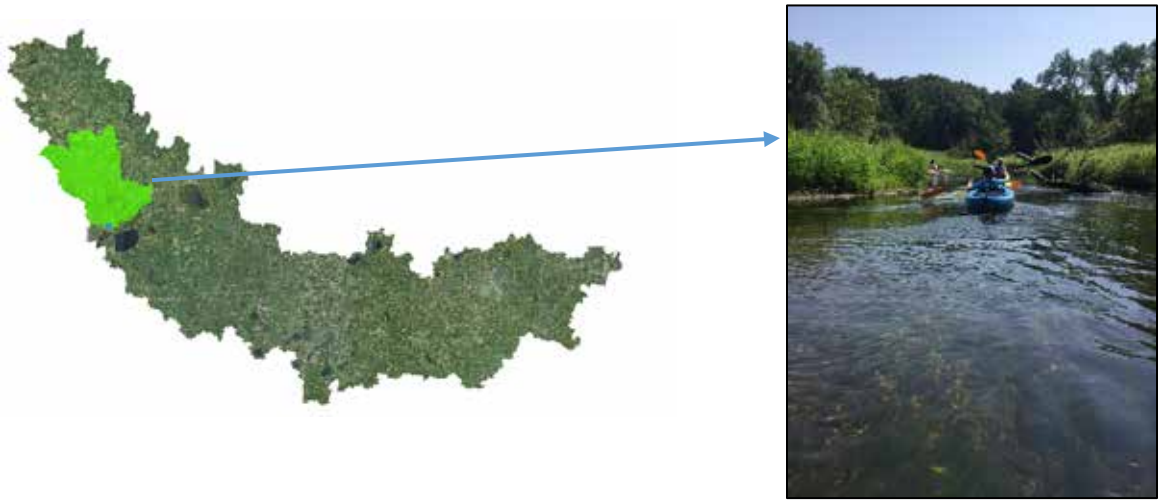


Figure 61. Images captured on June 5, 2017, during the longitudinal profile survey.

Appendix 3. Middle Fork Crow River (07010204-539)

Geomorphic Reach Information			
Stream Name	Middle Fork Crow River	Drainage Area	113.76 mi^2
MPCA AUID	07010204-539	Stream Type	C4c-
County	Kandiyohi	Valley Type	Unconfined Lacustrine U-LA-LD
Section, Township, Range	Sec 21, T121N, R34W	Water Slope	0.00088 ft/ft
Entrenchment Ratio	14.75 (slightly entrenched)	Sinuosity	1.64
Width/Depth Ratio	15.47 (moderate to high)	Particle size (D50)	3.69 mm (fine gravel)
Bank Height Ratio	1.15 (slightly incised)	Pfankuch Stability Rating	77 (good)



The Middle Fork Crow River geomorphic survey reach is located upstream of the old Town Hall Road, near the inlet of Nest Lake, and three miles north-northwest of Spicer. Collaborative monitoring between the MPCA, DNR, and Middle Fork Crow River Watershed District occurs to assess water quality, stream flow, fish and macroinvertebrates in the vicinity. However, the geomorphic survey was completed upstream of the other monitoring sites through a meandering reach with an open area, without a hardwood forest canopy to acquire accurate and adequate GPS satellite coverage. In 2018, the geomorphic survey consisted of a longitudinal profile, riffle and pool cross sections, pebble counts, and bank erosion estimates. A follow-up survey was conducted in 2019 to re-survey the pool cross section and validate streambank erosion predictions.

The Middle Fork Town Hall site is a sinuous C4c- stream with a 300-600 foot (ft) wide buffer and a frequently connected floodplain dominated by reed canary grass and other perennial vegetation. There is no sign of past channelization based on air photo review. However, the stream was historically more sinuous with irregular and tortuous meander scrolls (Figure 62). The Middle Fork Crow River reach flows through an unconfined, depressional basin with parent soil materials consisting of an organic layer over sandy and loamy outwash. The predominant soil types near the channel are very poorly drained and the soil profile typically consists of muck, loam, and sand, according to the NRCS web soil survey. The D50 of the reach's substrate particle size was 3.69 mm with 61% consisting of gravel. Other substrate

documented in the pebble counts included sand, silt, and clay. The Pfankuch stability rating was 77 indicating the channel is in “Good” or stable condition.

Figure 62. 1991 versus 2019 streamlines for the survey reach. The yellow streamline is 1991 and red represents 2019.

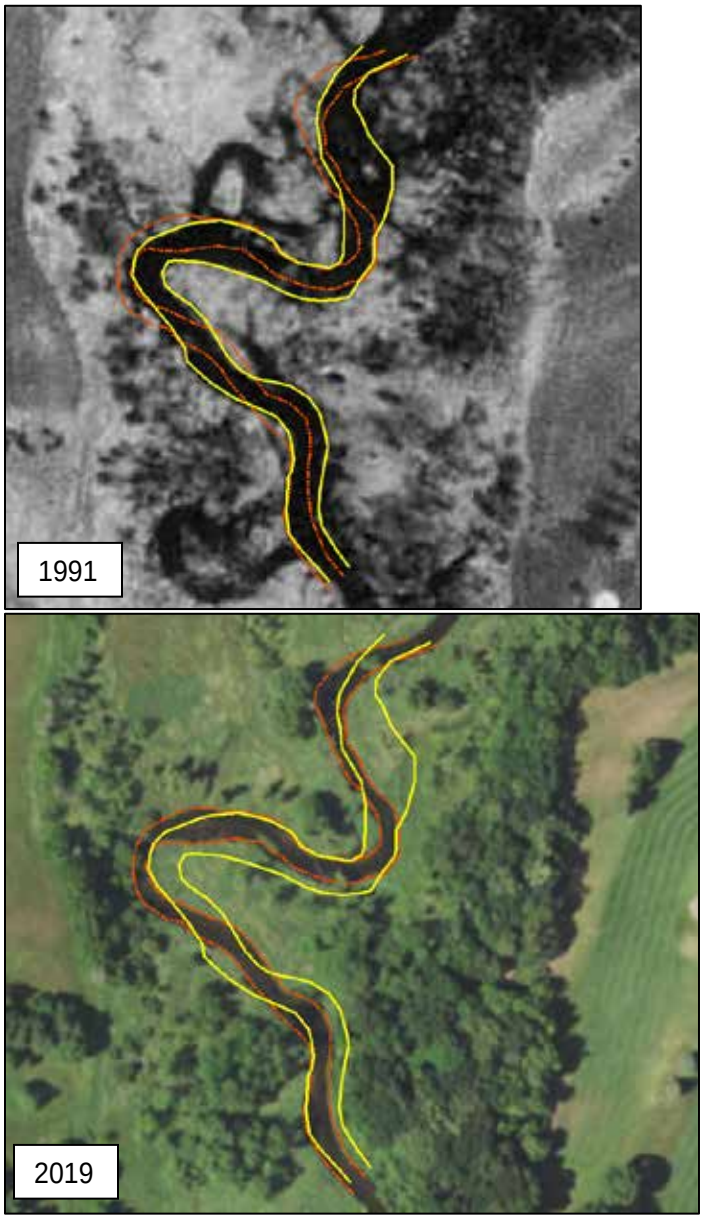
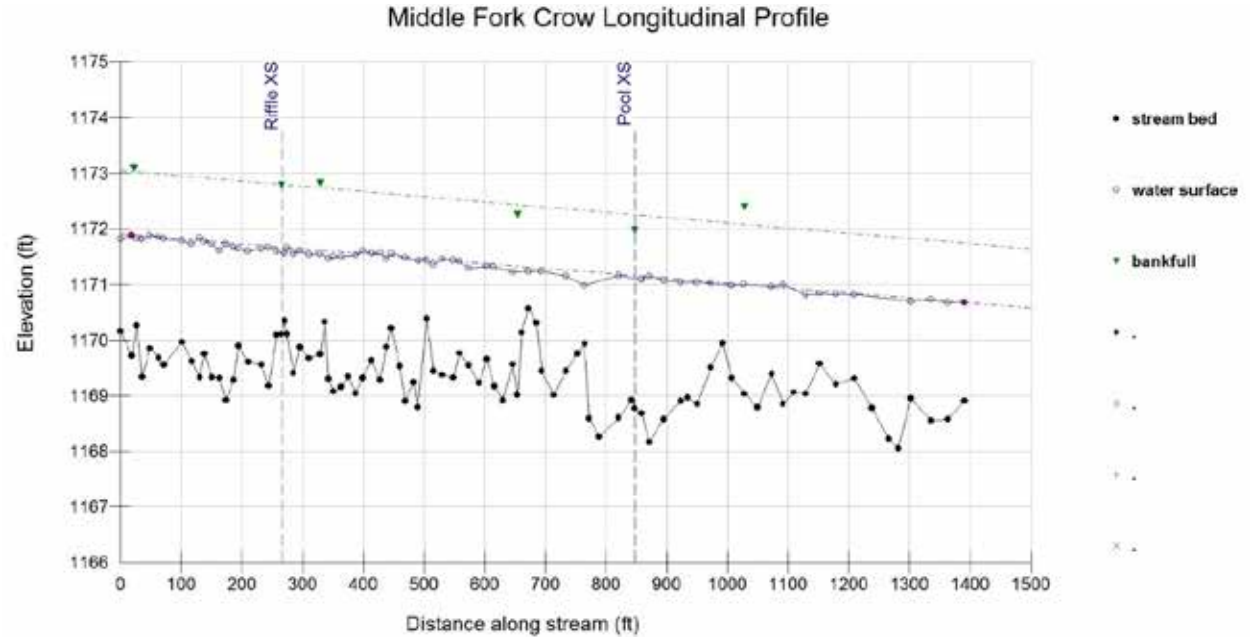


Figure 63. Location of the Middle Fork Crow geomorphic survey site; 2015 image courtesy of Google Earth.

The riffle cross section had a bankfull width of 33.57 feet (ft) and mean depth of 2.17 ft, resulting in a moderate-high, but relatively stable width-to-depth ratio of 15.47 for a C channel. The water slope was relatively low at 0.00088 ft/ft (i.e., 0.088%), resulting in the low gradient C4c- classification. There was only a slight degree of channel incision and the stream had good overall floodplain connectivity at flows above bankfull stage. The longitudinal profile (Figure 64) indicated the mean riffle depth was 2.46 ft and the maximum riffle depth was 2.51 ft. The mean pool depth to bankfull elevation was 3.57 ft and the maximum was 4.06 ft over the 1,390 ft longitudinal profile.

Figure 64. Longitudinal profile for Middle Fork Crow near Town Hall Road, 2018. Bankfull elevation was similar to low bank height (LBH) elevations. However, LBHs were not captured on the profile.



The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model estimated stream banks within the reach contribute 3.09 tons of sediment annually for the 1,390 ft reach using the Colorado curve. The pool cross section (Figure 65) at station 8+47 was surveyed in 2018 and 2019 to document changes and validate predicted stream erosion rates. The right bank, or outside bend, erosion estimate was 0.073 ft/yr in 2018. The 2019 resurvey was lower than the predicted amount with a measurement of 0.0046 ft/yr. Maintaining and protecting the wide riparian buffer and floodplain will help sustain stream stability, ecological functions, and diverse habitat.

Figure 65. Pool study cross section 2018-2019. There were not substantial changes measured to the bed, bank, or floodplain.

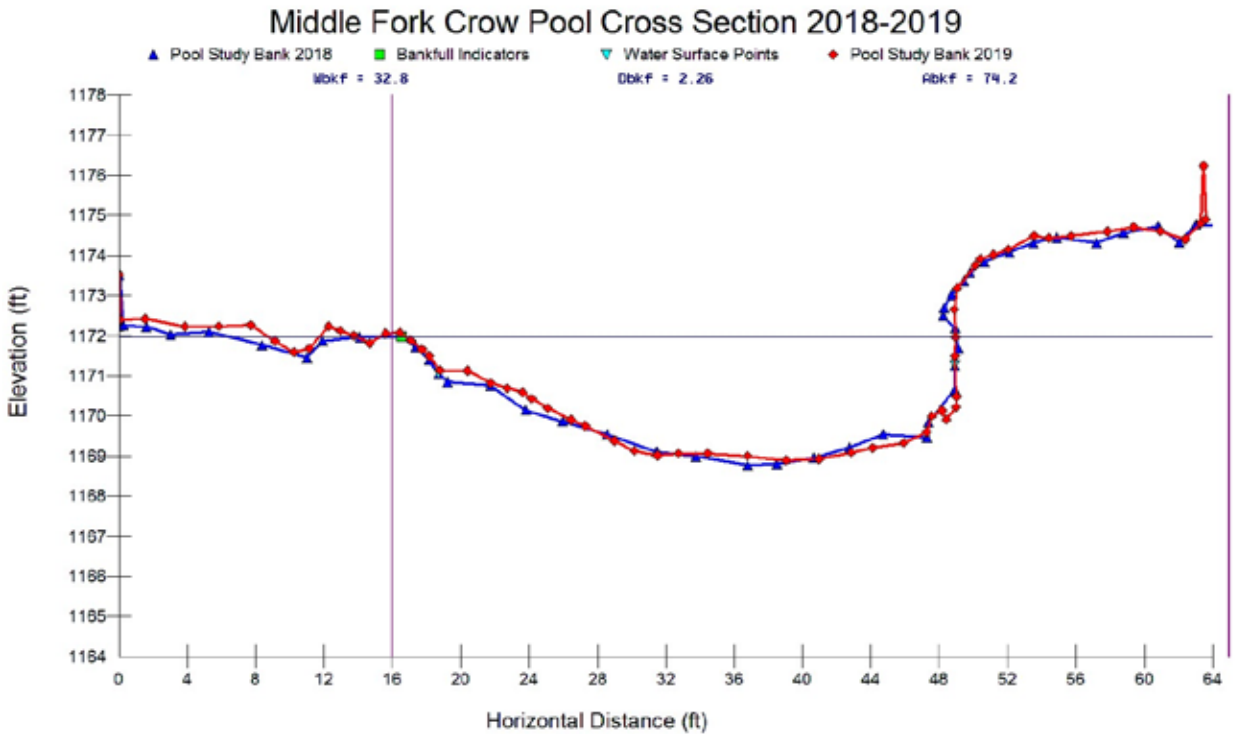


Figure 66. Images captured on August 23, 2018, during the longitudinal profile survey.

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Appendix 4. Battle Creek (07010204-552)

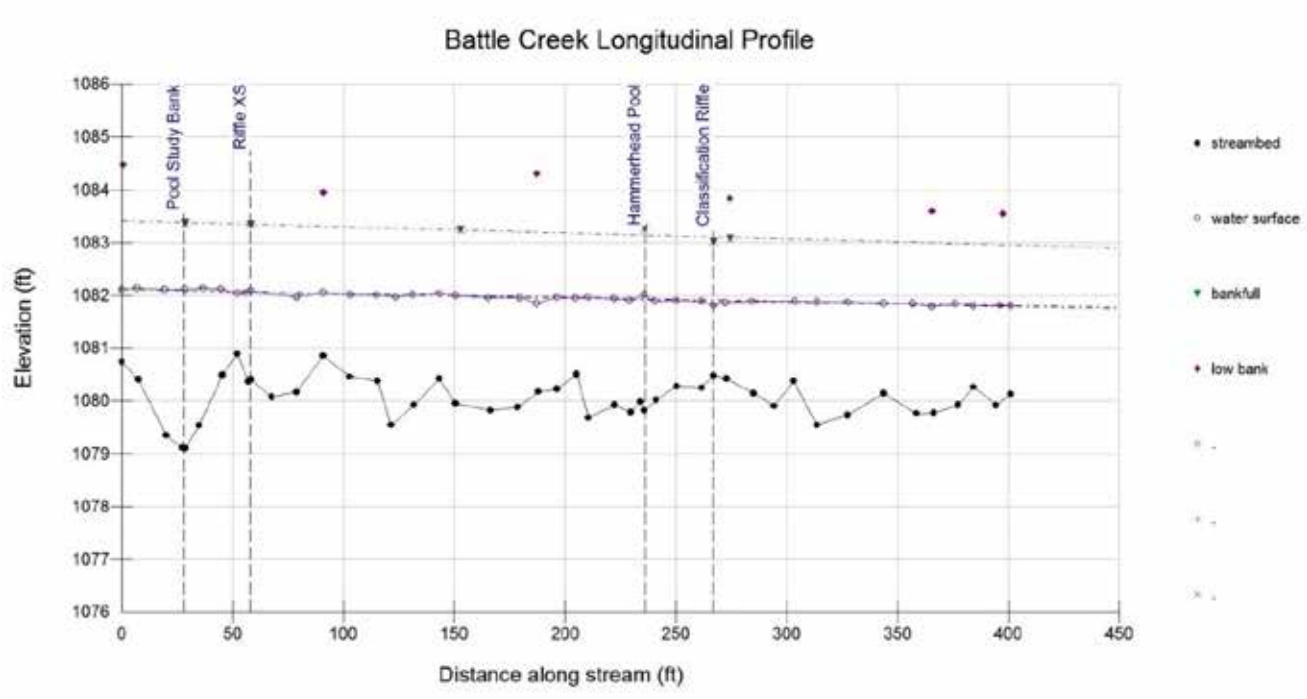
Geomorphic Reach Information			
Stream Name	Battle Creek	Drainage Area	21.3 mi^2
MPCA AUID	07010204-552	Stream Type	E5
County	Meeker	Valley Type	Unconfined Alluvial U-AL-FD
Section, Township, Range	Sec 14, T120N, R31W	Water Slope	0.0007 ft/ft
Entrenchment Ratio	16.38 (slightly entrenched)	Sinuosity	2.36
Width/Depth Ratio	5.41 (low)	Est. Reach Erosion Rate	2.44 tons/yr
Bank Height Ratio	1.26 (slightly incised)	Pfankuch Stability Rating	86 (fair)

The Battle Creek geomorphic survey reach downstream of Minnesota State Highway 22 consisted of two riffle cross sections, two pool cross sections (Figure 67), a longitudinal profile (Figure 68), pebble count, and bank erosion estimates. Upstream of MN Highway 22, the stream was channelized in the past. However, throughout the survey reach the channel is a naturally meandering E channel with a relatively wide (i.e., 200-300 feet (ft)), and had a dense reed canary grass dominated buffer strip and floodplain connectivity. The Battle Creek survey site has a narrow and deep channel with a predominately sand streambed. The substrate particle size D50 for the reach equals 1.85mm, or very coarse sand. The riffle cross section at station 2+66 was most representative and used as the classification riffle. This classification riffle indicated a low width-to-depth E channel with a slight degree of incision. The longitudinal profile indicated the mean riffle depths are 2.60 ft and the maximum riffle depths are 2.83 ft. The mean pool depths to bankfull stage are 3.62 ft and the maximum is 4.29 ft over the 401 ft longitudinal profile.

The Pfankuch stability rating was 79, indicating a “Fair” rating for an E5 channel. E5 streams have a very high sensitivity to disturbance, good recovery potential, moderate sediment supply, high streambank erosion potential, and are very dependent on vegetation to maintain stability (Rosgen 1994).

Figure 67. Location of Battle Creek geomorphic survey site; 2018 image courtesy of Google Earth. 2+66 is the classification riffle.

Figure 68. Battle Creek Longitudinal Profile, June 2017.



The Bank Assessment for Non-point source Consequences of Sediment (BANCS) model estimated stream banks within the reach contribute 2.44 tons of sediment annually for the 401 ft reach using the Colorado curve. The pool cross section at station 0+28 was monumented and re-surveyed in August 2018 to validate bank erosion estimates (Figures 69 and 70, and Table 91). The study bank estimate was 0.036 ft/yr at the time of the initial survey. The actual measured erosion rate equaled 0.361 ft/yr when 2017 and 2018 cross sections were overlaid. The pool study cross section narrowed from 2017 to 2018 as part of the width got much shallower, resulting in the cross-sectional area decreasing by approximately 10 sq ft. A sandy depositional feature was developing on the right side of the cross section (see Figures 2 and 4). The toe pin was not located in 2018, even after searching with a metal detector. It likely moved as the bed eroded approximately 0.3 ft. The sand dominated, loosely packed streambed materials appear to be easily moved at bankfull and higher flows. This maybe an indicator of some channel bed instability, because E channels are typically very efficient with little bed deposition when they have a low width/depth ratio.

Figure 69. Pool study surveyed cross-section in 2017 and 2018.

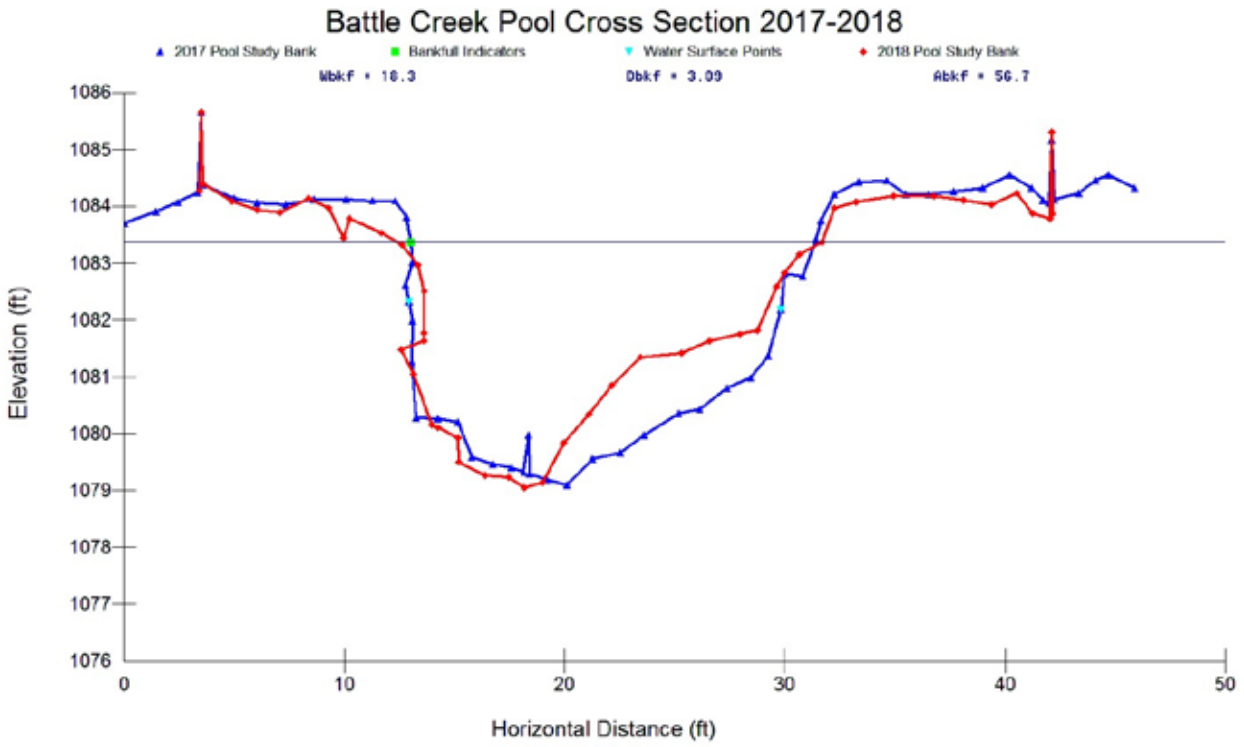


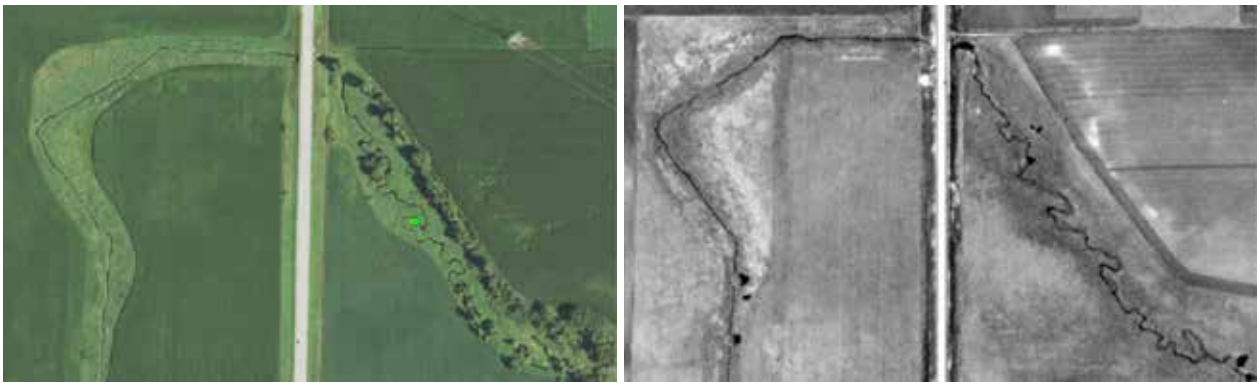
Table 91. Changes in the Pool Study cross-section from 2017 to 2018.

Cross Section and Year	Bankfull Area (sq ft)	Width Bankfull (ft)	Mean Depth (ft)	Max Depth (ft)
Pool Study XS 2017	56.7	18.3	3.09	4.27
Pool Study XS 2018	46.3	19.3	2.4	4.32

Figure 70. Pool Study XS resurvey, August 22, 2018. Sandy deposition and point bar development.

An aerial photo investigation indicates the pattern and belt width of Battle Creek remained constant over 62 years; see Figure 71 comparing 1955 to 2017 aerial photos. Perennial vegetation with thick root masses and access to a floodplain prevent bank erosion from becoming excessive, especially in E channels.

Figure 71. 2017 FSA image on left and 1955 on the right. Past channelization was done upstream of MN Highway 22, but the study reach has maintained its belt width and sinuous pattern.



Appendix 5. North Fork Crow River – Regal Flats Wildlife Management Area

Geomorphic Reach Information			
Stream Name	North Fork Crow River	Drainage Area	202.62 mi^2
MPCA AUID	07010204-685	Stream Type	C4c-
County	Kandiyohi	Valley Type	Unconfined Glacial Outwash U-GL-GO
Section, Township, Range	Sec 10, T122N, R33W	Water Slope	0.00071 ft/ft
Entrenchment Ratio	37.9 (slightly entrenched)	Sinuosity	1.8
Width/Depth Ratio	13.99 (moderate)	Pfankuch Stability Rating	52 (good)
Bank Height Ratio	1.01 (stable)	Particle size (D50)	6.85 mm (fine gravel)

The North Fork Crow River geomorphic survey reach lies within the Regal Flats Wildlife Management Area, located approximately four miles west of Paynesville, and upstream of Rice Lake and Lake Koronis. The river through this area is sinuous with an intact riparian corridor with continuous, connected tracts of naturally vegetated land dominated by native prairie, woodlands, and wetlands (Figure 72). There is no sign of past channelization based on aerial photograph review. This site is within the alluvium outwash headwaters region of the North Fork Crow River watershed. The geomorphic survey consisted of a longitudinal profile, riffle and pool cross-section, and pebble count. The pool cross-section was monumented and surveyed in 2018 and 2019 to measure the annual bank erosion rate.

The classification riffle (Figure 73) had a moderate width-to-depth ratio; 13.99 is close to a reference condition for a C channel. The site has excellent floodplain connectivity at flood flows with a bank height ratio of 1.01, providing a “Stable” rating for the degree of channel incision. The water surface slope was relatively flat (i.e., low slope) with an overall drop of 0.00071 ft/ft (0.07%) (Figure 74). A common signature of C channels are the riffle and pool sequences and point bars within the active channel. The longitudinal profile indicated the mean riffle depth was 3.29 feet (ft) and the maximum riffle depth was 4.0 ft. The mean pool depth was 5.2 ft and the maximum was 6.47 ft over the 2,107 ft longitudinal profile.

Figure 72. Location of Regal Flats Wildlife Management Area, North Fork Crow geomorphic site; 2016 image courtesy of Google Earth.

Figure 73. Riffle cross section 2018.

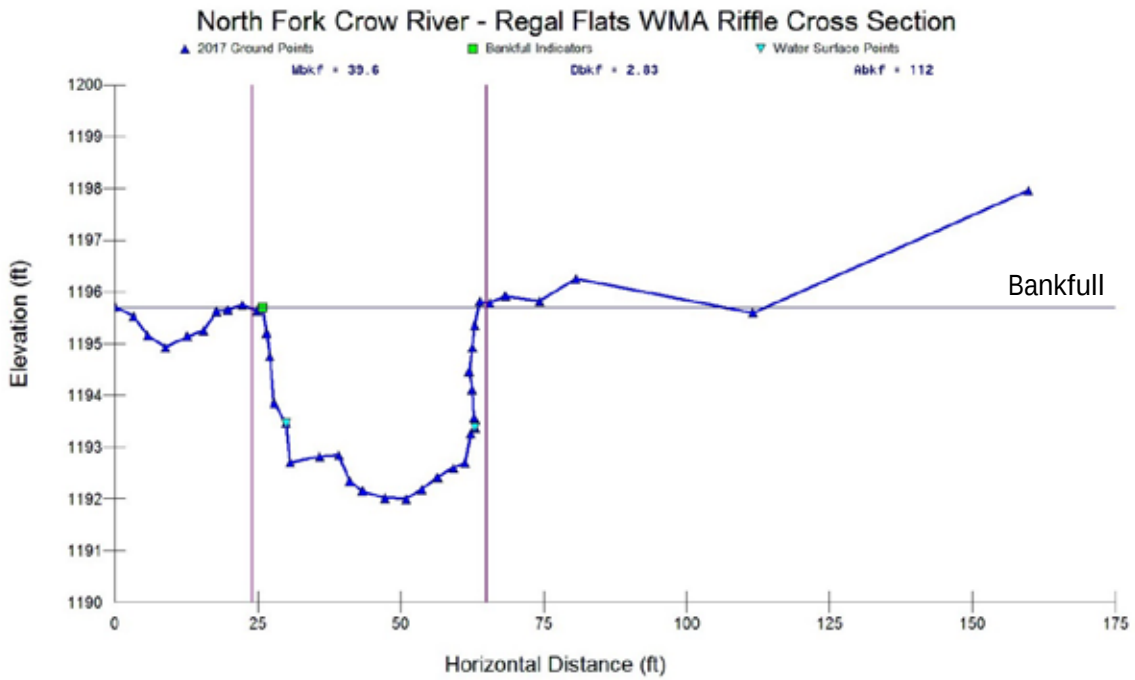
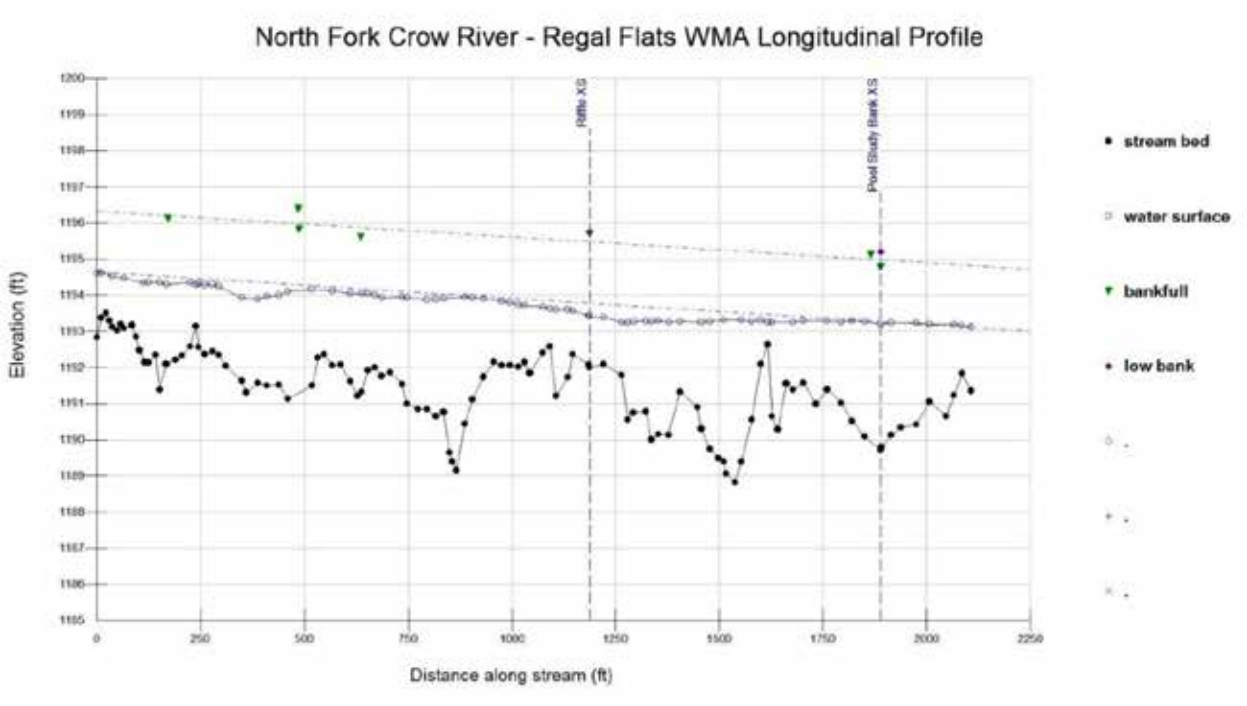


Figure 74. Longitudinal Profile for North Fork Crow River, 2018.



Gravel was the dominant streambed material. The D50 of the reach was 6.85 mm with 59% of the reach pebble count consisting of gravel. Other substrate documented in the pebble counts include cobble, sand, silt and clay. This results in an overall stream classification of C4c-. The Pfankuch stability rating was 52 resulting in a "Good" condition rating.

The pool cross section at station 18+89 was surveyed in 2018 and 2019 to document changes and validate predicted streambank erosion rates (Figure 75). The right bank, or outside bend, erosion estimate was 0.42 ft/yr in 2018. The sandy bank materials were noted and a bank material adjustment of five was given. At this time, the Colorado curve is utilized within the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model to estimate annual erosion. The 2019 resurvey was higher than the predicted amount with a measurement of 1.797 ft/yr (Figure 76). When comparing the 2019 photo to the 1991 historic air photo, the bank retreated 26 feet over the 28-year timespan (Figure 77). There were no additional banks scored for an overall estimated bank erosion reach contribution. In general, there was thick reed canary grass, willow saplings, and other herbaceous vegetation overlapping the banks and the bank height ratio was nearly one throughout the surveyed reach (Figure 78). Additional photos of the geomorphic study reach are shown below (Figure 79).

This reach of the Nork Fork is identified as a priority for stream protection, according to the Stream Protection Priorities for Watershed Restoration and Protection Strategies (WRAPS) data set within the Watershed Health and Assessment Framework (WHAF) mapping system. The reach is currently fully supporting for aquatic life use and designated in a higher risk category for future impairment status.

Figure 75. Pool study bank cross-section 2018 and 2019. The right bank eroded 1-2 ft, but the remainder of the cross section displayed minimal change.

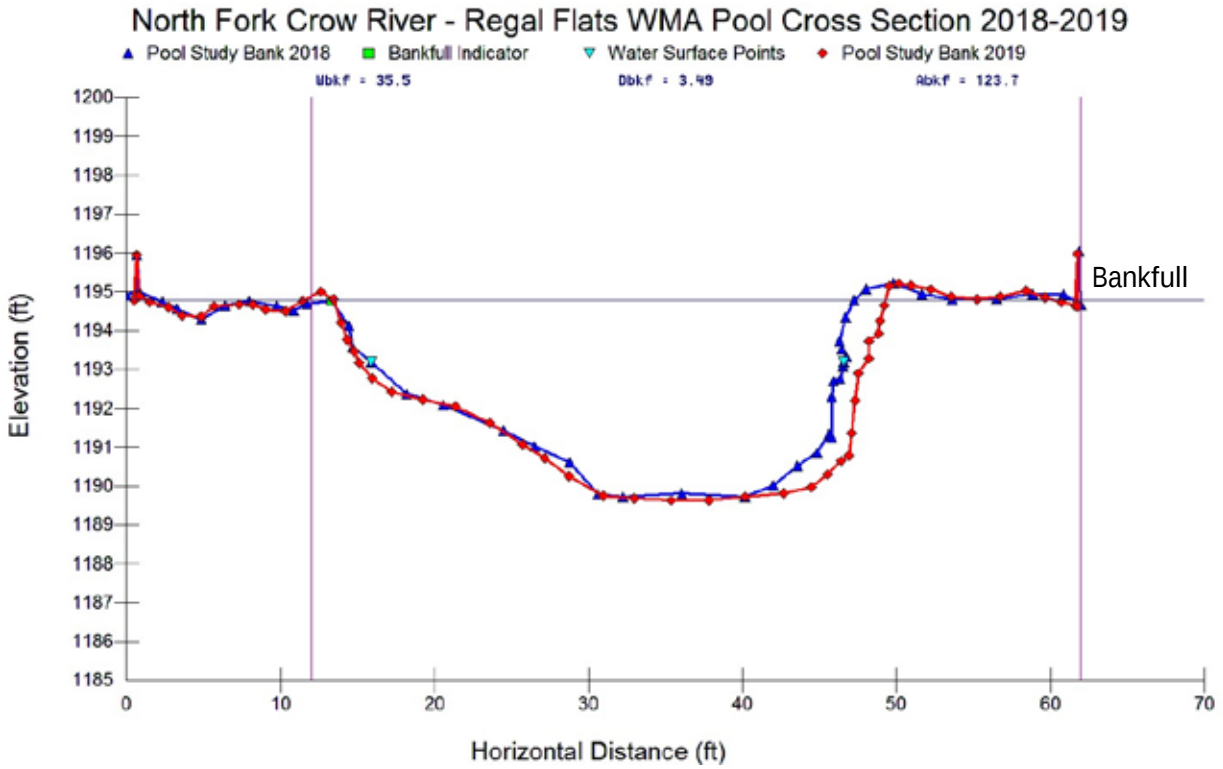


Figure 76. Right bank overlay for pool cross-section revealed an overall annual erosion rate of 1.80 ft.

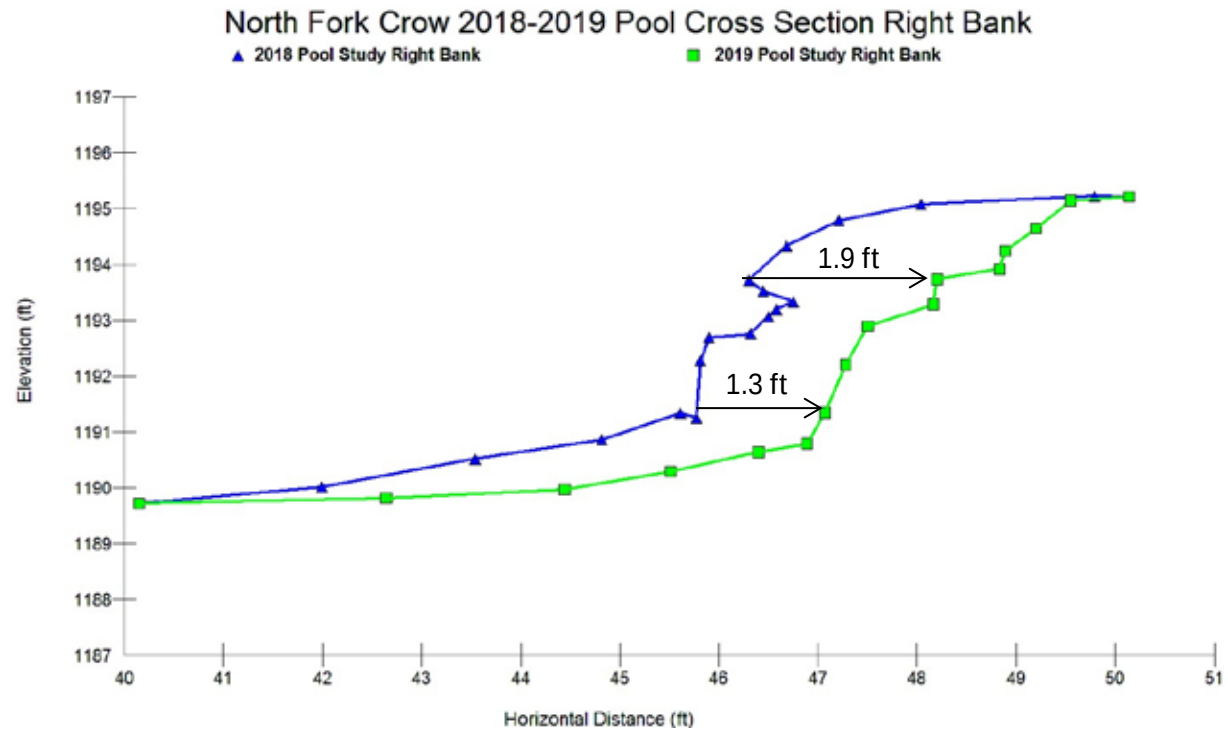


Figure 77. 1991 streamlines compared to 2019 for the survey reach. The yellow streamline is 1991 and red streamline is 2019.

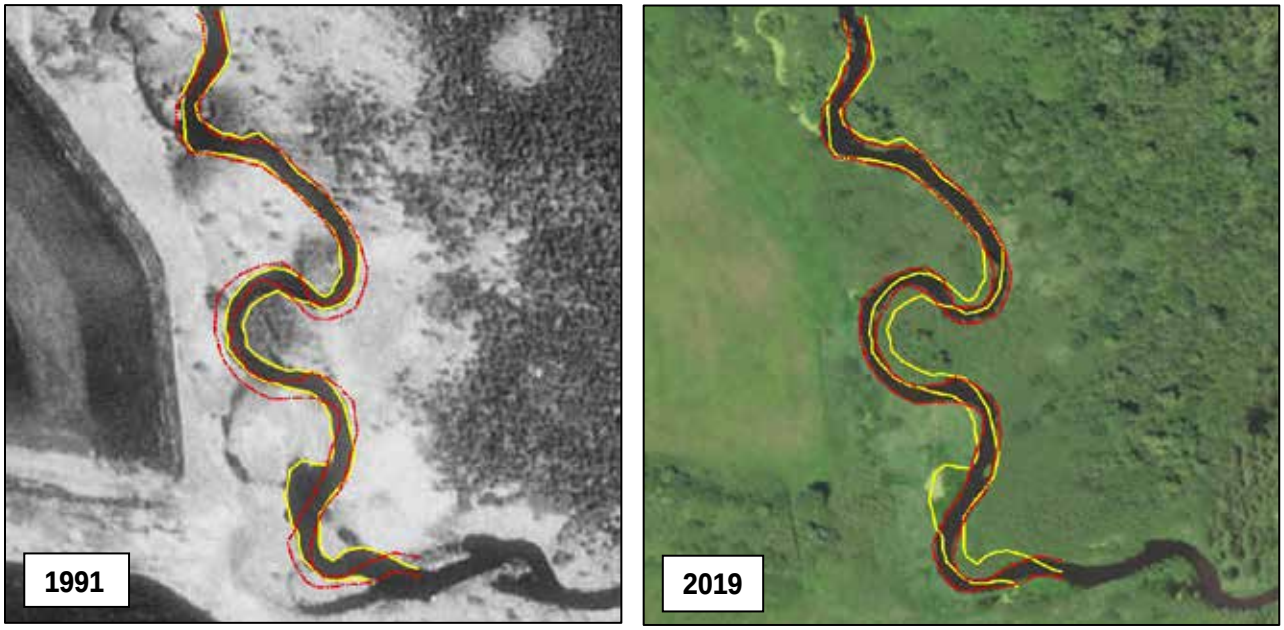


Figure 78. 2019 pool cross section, right bank.

Figure 79. Images captured on July 17, 2018 during the longitudinal profile survey.

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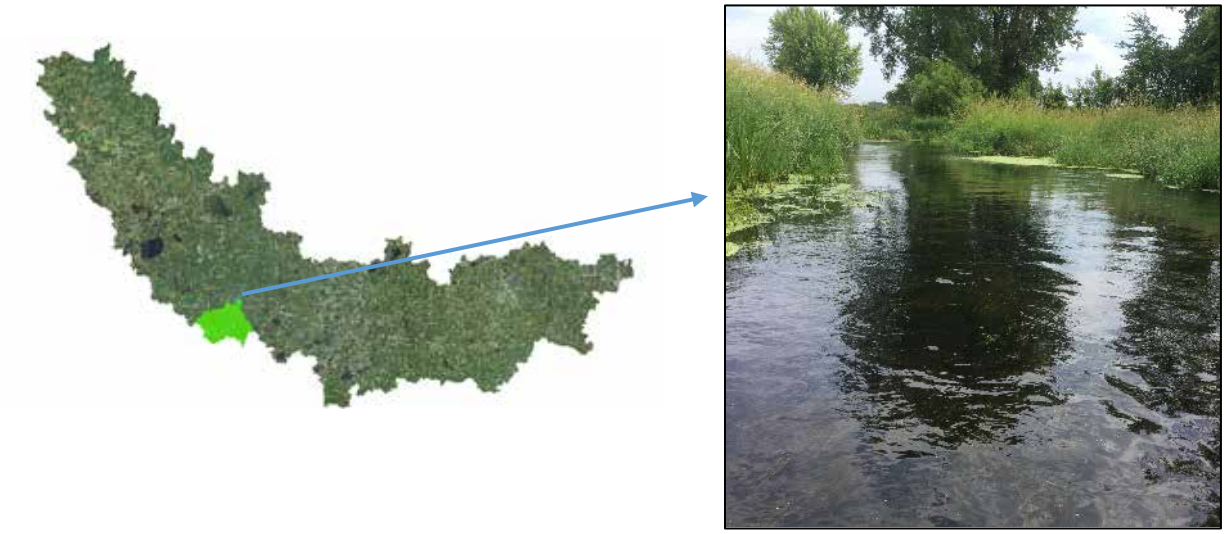
Rosgen, D. L. 2014. River Stability Field Guide. Second Edition. Wildland Hydrology, Fort Collins, CO.

Appendix 6. Grove Creek – upstream U.S. Highway 12

Geomorphic Reach Information			
Stream Name	Grove Creek	Drainage Area	30.98 mi^2
MPCA AUID	07010204-696	Stream Type	Currently C5 D Reference Condition E
County	Meeker	Valley Type	Unconfined Lacustrine U-LA-LD
Section, Township, Range	Sec 1, T119N, R32W	Water Slope	0.00105 ft/ft
Entrenchment Ratio	2.4 (slightly entrenched)	Sinuosity	1.83
Width/Depth Ratio	57.23 (very high)	Pfankuch Stability Rating	101 (fair)
Bank Height Ratio	1.01 (not incised)	Particle size (D50)	0.38 mm (medium sand)



A historically altered reach upstream of U.S. Highway 12 was surveyed in July 2017. The Grove Creek geomorphic survey near the speedway consisted of a 1,680 foot (ft) longitudinal profile, riffle and pool cross section, and pebble count. Before surveying, an initial stream walk-over confirmed a perched culvert at the railroad tracks (Figure 80).

Figure 80. Perched culvert below the railroad grade, located 0.5 miles upstream of U.S. Highway 12 on Grove Creek, creating a fish passage barrier.

The geomorphic survey was conducted just south of U.S. Highway 12. At a time between 1979 and 1991 major channel and floodplain alterations occurred creating unstable channel conditions, backwater effects, and excess sedimentation over time (Figures 81 and 82). The alterations resulted in an over wide, shallow stream channel lacking habitat and natural streambed features. However, since the changes that occurred over 30 years ago, the stream is beginning to evolve with natural bed features as the channel is narrowing up, forming subtle meanders and a series of riffles and pools. However, the channel is far from reaching equilibrium or stability. The survey started downstream of a private crossing and followed the perennial, primary flow channel toward the west and north (Figures 83).

Figure 81. Historical aerial images from 1955, 1979, and 1981.

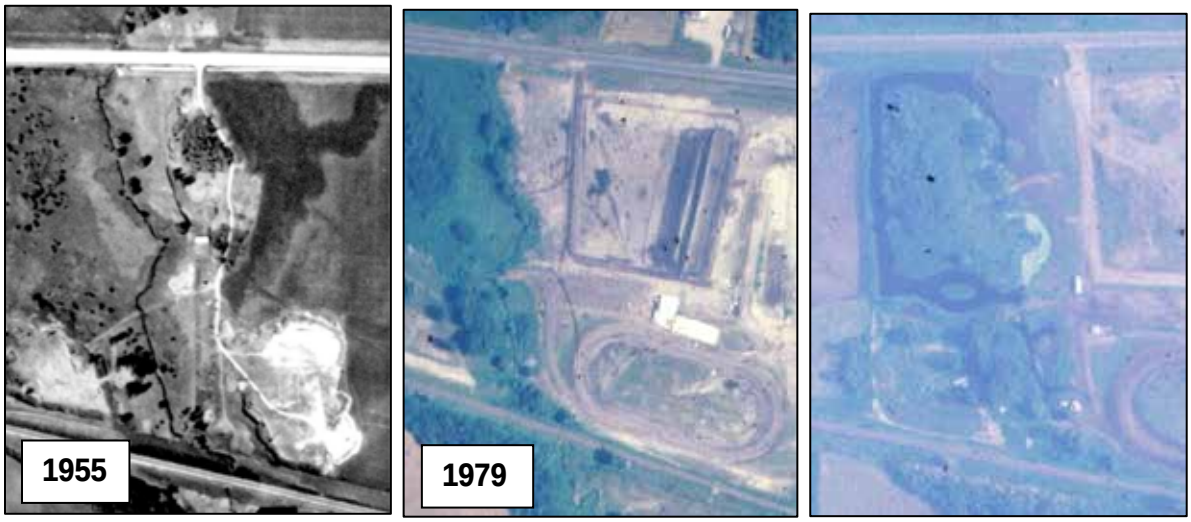


Figure 82. Yellow lines outline 1991 channel and 2017 is the red dashed line.

Figure 83. Yellow dots pinpoint the longitudinal profile and cross sectional survey data collected. Image courtesy of Google Earth, 2015.

In order to accurately classify, document and understand the stream, the longitudinal profile (Figure 84) two different segments. The first ~1,200 ft, the upstream portion of the surveyed reach had lower slope (0.00105 ft/ft or 0.1%) and greater stream width, ranging from 15-60 ft in bankfull width. Both cross sections and the pebble count were collected in the upper reach. Therefore, this site summary will primarily focus on the upper reach. The lower reach, or last 480 ft of the longitudinal profile was located primarily in the road right-of-way. In the lower reach the boundary conditions are more confined, the channel was narrower at approximately 8-10 ft in bankfull width, and water slope was steeper at 0.00263 ft/ft.

There was generally an adequate floodplain connection as the stream flowed through a wetland basin, with exception of where spoil piles were in certain areas of the floodplain. The upper reach longitudinal profile indicated the mean riffle depth was 1.75 ft and the maximum riffle depth was 2.26 ft. The mean pool depth to bankfull height was 3.16 ft and the maximum was 3.74 ft throughout the upper reach 1,200 ft longitudinal profile. The 3+69 riffle cross section was the only surveyed riffle, and therefore, used as the classification riffle (Figure 85). After the survey and desktop review, it was discovered the riffle cross section was surveyed in an area that was 110 ft wide and included a small island in the middle in the 1991 photo. This classification riffle had a very high width-to-depth ratio with a bankfull channel width of 62.4 ft and an average of depth of 1.09 ft. The stream channel is over-wide compared to the standard range typical for the drainage area and likely aggrading over time. There appears to be evidence of a bankfull bench depositional feature in development. The channel was classified as a C stream type but almost demonstrates D channel features.

The Grove Creek survey site has a wide and shallow channel with a predominately sand streambed. The D50 for the reach equaled 0.38 mm. The thalweg consisted of mainly stand particles, but the stream bed was soft and mucky in many places. Wetland vegetation surrounded the channel and there was no evidence of streambank erosion due to dense vegetation on the edges of the channel, low bank heights, and features more characteristic of a wetland basin. Bank erosion estimates were not collected and there were no monumented cross-sections.

Figure 84. Grove Creek upstream U.S. Highway 212 longitudinal profile, July 2017.

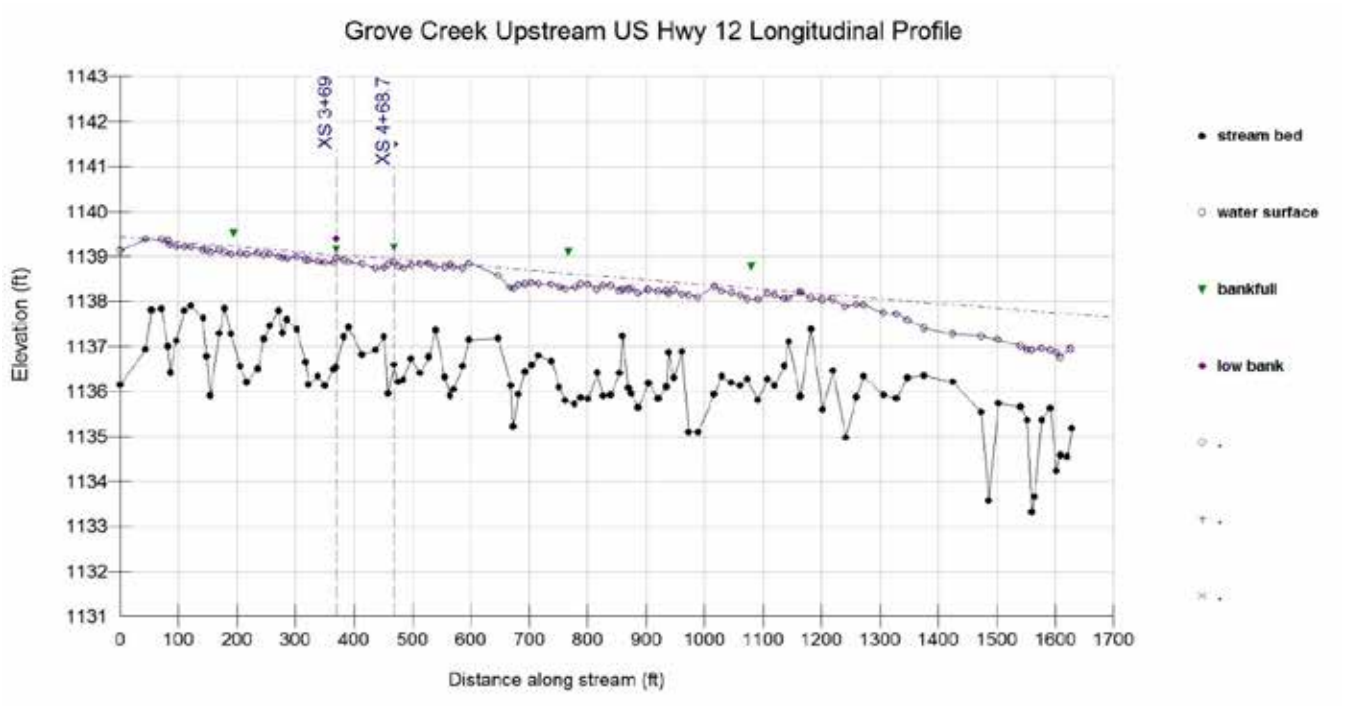
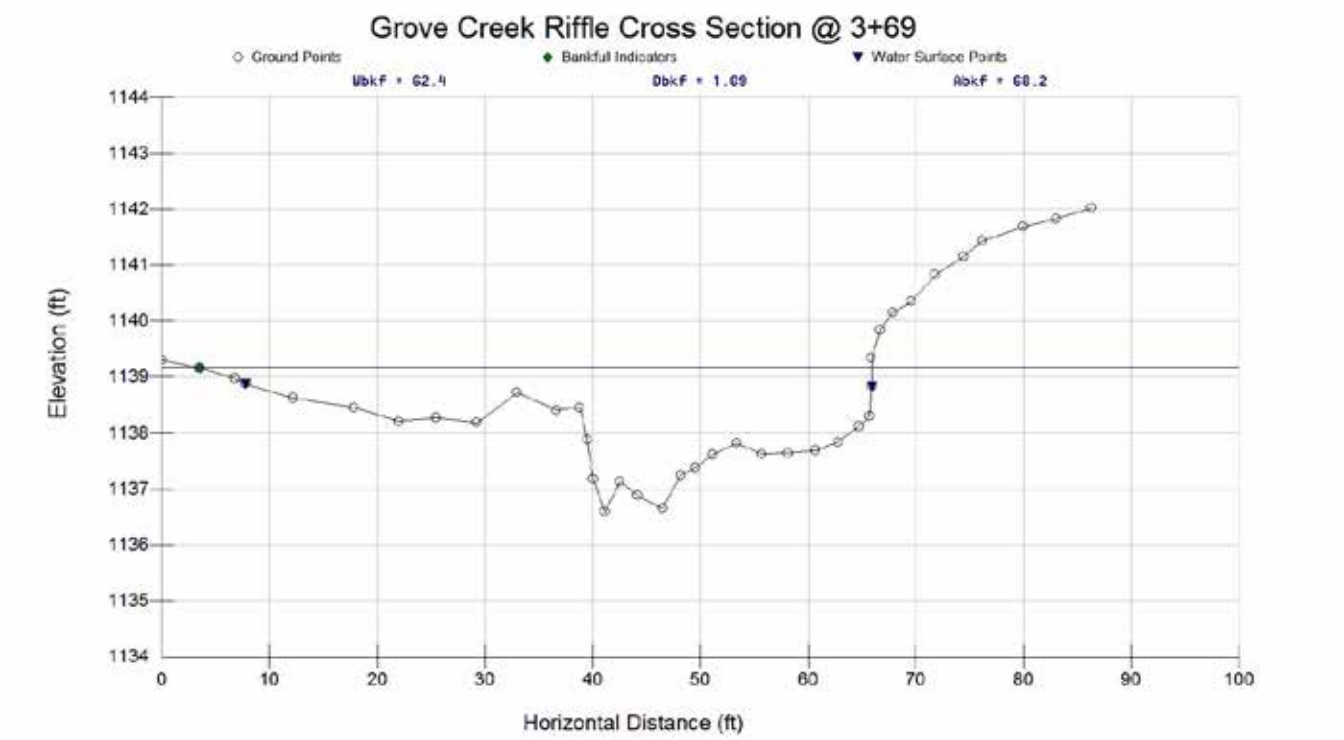


Figure 85. Grove Creek riffle cross section at 3+69. The stream is too wide, but appears to be narrowing over time.



The Pfankuch stability rating was a 101, indicating a "Fair" rating for a C5 channel. However, the reference stream condition and the majority of Grove Creek is an E channel. It should be narrower, deeper, and meandering. If the opportunity arises, this site would be a good candidate for stream restoration. Not only would there be the opportunity to improve stream stability and habitat, but also moving the stream out of the U.S. Highway 12 right-of-way would improve safety conditions. Photos of several locations of the reach are shown below (Figures 86 and 87).

Figure 86. Grove Creek wetland and backwater area. Photo taken looking north at the start of the longitudinal profile survey.

Figure 87. Along the upper reach survey, collecting a bankfull survey elevation point (left) and lower reach survey in right-of-way with narrower channel (right).