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Midway River Watershed Protection Study

Strategies to protect and restore critical habitats for Brook Trout and other coldwater species

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Executive Summary

The Midway River Watershed Protection Study (MRWPS) is a comprehensive, data-driven strategy to protect and restore habitats for native Brook Trout and other sensitive species in the Midway River Watershed. This effort supports broader state goals under Minnesota's Watershed Restoration and Protection Strategy (WRAPS). The information in this report can be used to guide restoration projects, protection efforts, and additional monitoring work in this watershed for decades to come.

Key Objectives of MRWPS

- Identify and prioritize projects to protect or restore streams under the following focus areas:
    - Connectivity - Fish Passage Restoration
    - Stream Channel Restoration
    - Riparian Corridor Restoration
    - Headwaters Protection and Restoration/Altered Hydrology
    - Unmapped and Unprotected Waters, Trout Streams, Public Waters Designation
- Brook Trout are Minnesota's only native inland salmonid species and a focus of many conservation efforts. This study focused on identifying areas providing refugia (e.g. springs, cold tributaries) for Brook Trout and other native species requiring cold water temperatures
- Movement of Brook Trout and other species is a key adaptation strategy. The MRWPS focuses on improving aquatic connectivity where culverts and development disrupt fish movement between key habitats
- Streams in Northeastern Minnesota are forecasted to warm significantly over the next 30 years. The MRWPS focused on increasing adaptation and resiliency by prioritizing restoration and protection efforts in areas with abundant coldwater refugia, while also identifying streams vulnerable to warming and extirpation of coldwater species

Notable Findings

- 247 restoration and protection projects mapped, categorized, and ranked based on monitoring data and various conservation metrics
- 59 Coldwater Protection Areas (CPA) were identified within the Midway River Watershed based on temperature and fish community data (Figure 19)
- Roughly 70 miles of previously unmapped streams were mapped and many were monitored, resulting in new trout designations and new stream protections for several high-quality streams
- Baseflow Index (BFI) analysis revealed which streams are groundwater-fed and resilient to drought and increased
- 430 stream crossings were mapped; 73 were assessed in the field. Nearly 50% were fish barriers, mostly due to improper culvert design

1.0 Project Objectives and Deliverables

The MRWPS provides a prioritized inventory of projects that can be used to guide conservation actions and future monitoring work. Each year, millions of dollars are spent on watershed restoration and stream habitat improvement projects in the state of Minnesota, highlighting the need for data collection at an adequate scale and level of rigor to ensure these funds are spent effectively. Recommendations provided in this report are data-driven and supported by multiple years of targeted monitoring within the Midway River Watershed.

The impetus for this project stems from broader objectives held by state agencies and local partners. MPCA and other state agencies are charged with developing watershed scale restoration and protection plans based on intensive monitoring data and collaboration with partners. This comprehensive strategy, known as the WRAPS, uses local knowledge of the focus area and robust monitoring data to develop science-based plans for preserving and restoring watershed health. The MRWPS is intended to supplement the broader WRAPS effort by providing specific restoration and protection recommendations that can be referenced as needed for the foreseeable future. Figure 1 provides a basic flow chart of the MRWPS process and specific steps taken to advance conservation planning in the Midway River Watershed.

Final products generated from the MRWPS include this written report, a filterable database of projects organized by category and priority level (available upon request), and an online mapping tool containing spatial datasets of monitoring results, critical habitat features, and locations of prioritized conservation projects throughout the watershed (see screenshot in Appendix D).

A total of 247 individual projects were mapped and prioritized through completion of the MRWPS. Each potential project is grouped into one the following categories; *Connectivity - Fish Passage Restoration*, *Stream Channel Restoration*, *Riparian Restoration*, *Headwaters Protection*, *Headwaters Restoration/Altered Hydrology*, *Gravel Pit Reclamation/Impact*, *Stream Crossing Evaluation Needed*, or *Trout Stream/Public Waters Designation*.

1.1 Basis for Selection of Midway River Watershed as Study Area

The Midway River Watershed was selected for this effort due to the wide range of ecological conditions found within its boundaries, the abundant opportunities for restoration and protection work, and the threat of degradation posed by predicted increases in industrial, commercial, and residential development. Several of the Northeast Minnesota's most productive native Brook Trout streams flow through this mixed landscape of rural, urban, and developing land uses. The schematic in Figure 2 provides a simplified summary of the current ecological condition of the Midway River Watershed and overall approach and mindset used to develop the core objectives of this monitoring effort.

Identifying high-quality aquatic habitats and prioritizing efforts to protect them in their current state is a far more cost-effective and achievable approach than restoring degraded habitats. However, if restoration is required, the best results are often achieved when efforts are applied to slightly degraded habitats with high uplift potential and underlying qualities that will be beneficial to ecosystem recovery (e.g. inputs from cold groundwater springs).

Figure 1: Schematic flow chart of Midway River Protection Study (MRWPS) goals, benchmarks, and strategies

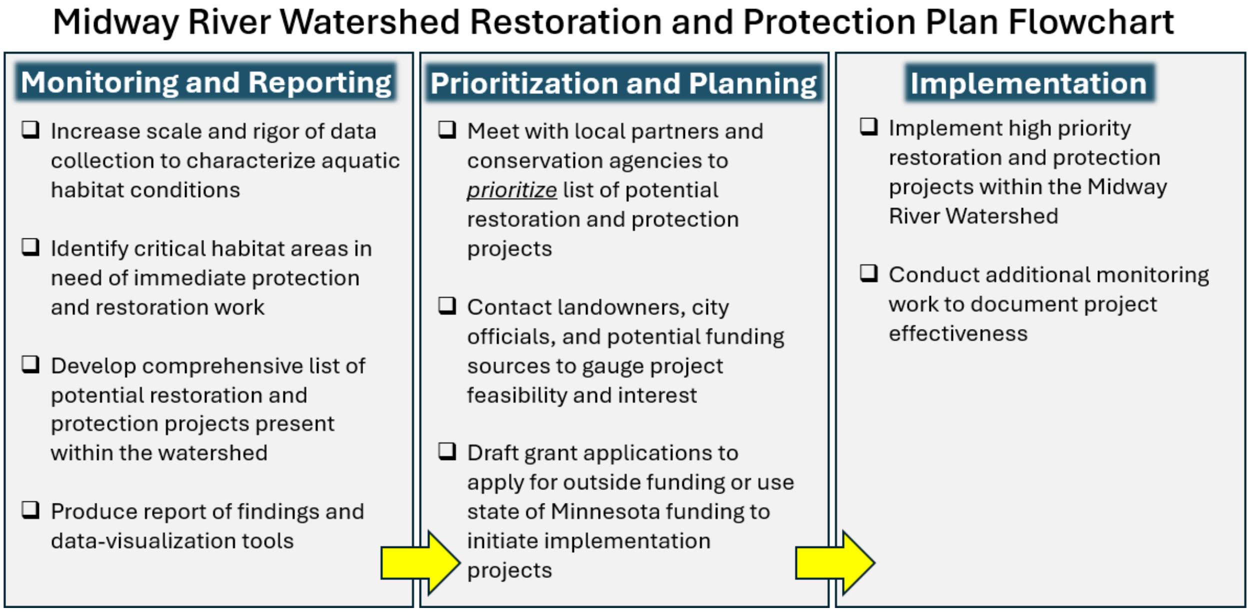
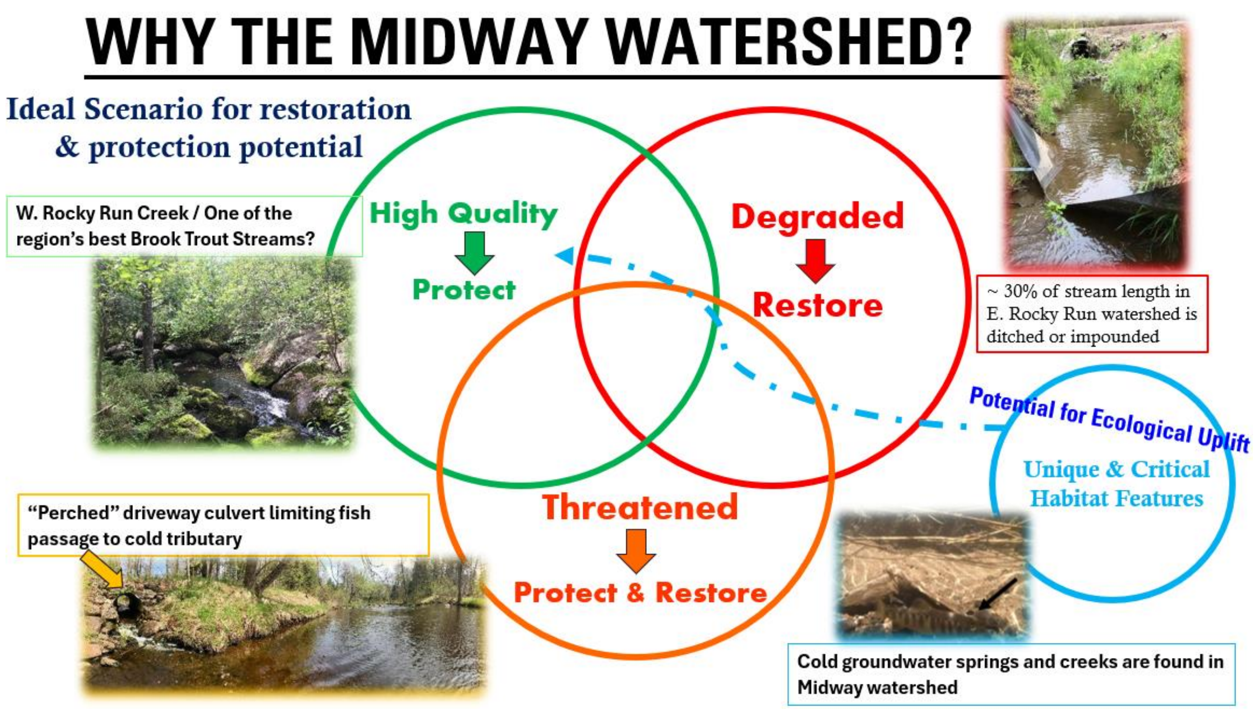


Figure 2: The Midway River Watershed is highly suitable location for restoration and protection work due the wide range of stream conditions within its boundaries. Some watersheds remain highly functioning while others have been degraded or are threatened by various land use practices.



1.2 Brook Trout as a Focus Species for Conservation Planning

The Minnesota Pollution Control Agency (MPCA) operates a biological monitoring program to evaluate stream health using several aquatic life indicators. These include biological metrics related to fish and aquatic macroinvertebrate communities found in rivers, streams, and wetlands. In addition, physical habitat and water quality assessments are completed to document stream conditions and identify resources in need of protection or restoration work. A detailed overview of MPCA's biological monitoring program can be found on MPCA's website (River and stream biological monitoring).

The MRWPS utilized many of the traditional monitoring approaches used by MPCAs monitoring programs, but a specific focus on species requiring cold water temperatures for survival (hereafter referred to as *coldwater* biota), specifically native Brook Trout populations, was used to stimulate stakeholder interest and protect a threatened species. Climate models (Johnson et al. 2013) predict major losses in Brook Trout habitat (estimated at 34%) along the southern half of Lake Superior's North Shore (between cities of Duluth and Silver Bay) by the year 2060. Predicted losses for the northern portion of the shore are lower (11%), as habitat shifts northward in response to increasing regional air temperatures. Preparing for climate change requires action to protect and restore the highest quality remaining habitats to support this threatened species.

Focusing on a single target species also provides an opportunity to simplify and tailor protection activities towards specific and measurable objectives. Developing watershed-wide strategies for protection of all forms of aquatic life inhabiting a watershed is a desirable outcome but requires significantly broader monitoring techniques and resources. The habitat requirements and life-history traits of Brook Trout populations have been extensively studied and are well-understood by resource managers.

In addition, a wide range of conservation grants offered at the Federal, State, and local level have identified the Brook Trout as a target species. Examples of grants used by the MPCA and partners to restore Brook Trout habitats include the National Fish Passage Program (US Fish and Wildlife Service), National Fish and Wildlife Foundation (NFWF), Sustain Our Great Lakes (SOGL), and Conservation Partners Legacy programs. Ultimately, the objective of the MRWPS is to generate funding to restore and protect watershed health through targeted implementation projects. Focusing efforts on high-profile species like the Brook Trout increases the likelihood that projects will be funded and supported by government agencies and public stakeholders.

Finally, any restoration and protection activities focused on Brook Trout conservation will undoubtedly provide ancillary benefits to other organisms co-inhabiting these streams. Desirable native fish species such as Mottled Sculpin, Longnose Dace, Hornyhead Chub, and several others are found in streams throughout the Midway River Watershed and stand to benefit from many of the projects listed in this report. In addition, each of the projects identified in the MRWPS provide ecosystem benefits extending to aquatic macroinvertebrate communities, aquatic and riparian vegetative cover, as well as terrestrial and semi-aquatic species inhabiting the watershed.

2.0 Midway River Watershed Characterization

2.1 Basic Hydrography

The Midway River, a major tributary to the St. Louis River, has a watershed area of just over 66 square miles, covering portions of St. Louis and Carlton counties. The headwaters originate in wooded wetlands and small streams emerging from glacial outwash uplands within the city limits of Hermantown, Minnesota. The headwaters area consists of mixed land uses including residential, commercial, and light industrial development. As a result of this development, a fair portion of headwaters streams are ditched and impacted by urban stormwater runoff. After flowing nearly 20 miles in a southwesterly direction, the Midway River ultimately empties into Thompson Reservoir, an impounded reach of the St. Louis River near the city of Carlton, Minnesota.

The Midway River and its tributary streams flow through a landscape of rolling hills and lacustrine valleys. The average stream gradient (slope) of the Midway River is moderate (1.4%), but bedrock outcroppings at several points along its course result in short sections with steep gradients and small waterfalls. These waterfall features are barriers to fish movement during low flows but are likely passable by larger species in the Midway (Brook Trout, Smallmouth Bass) at higher water levels.

Along its course to Thompson Reservoir, several named tributaries contribute flow to the Midway River. In order from upstream to downstream, named tributaries include East Rocky Run Creek, West Rocky Run Creek, Elm Creek, Anderson Creek, and Hay Creek. In total, 48 tributary streams were identified during this project, 26 of which (54%) were previously unmapped, a distinction that is further explained in Section 4.5. The ecological importance of major and minor tributary streams within the greater Midway River Watershed cannot be overstated. Tributary function, and aquatic connectivity between Midway River main stem and its tributary streams, is a major focus of the MRWPS.

2.2 Midway River Watershed Land Cover

The 2021 National Land Cover Dataset (NLCD) was used to analyze current land cover conditions within the Midway River Watershed (Table 1, Figure 3). Results indicate most of the watershed is under vegetative cover and relatively undeveloped, as over 78% of cover values are classified as a type of vegetation. Woody wetlands (40%), deciduous forest (24%), and mixed forest (7%) account for the largest proportions of vegetative cover by subcategory. Notably, less than 3% of watershed land cover is reported as evergreen forest.

Slightly over 11% watershed land cover is classified as “developed” based on the 2021 NLCD. The majority of the developed land cover is low intensity (4.5%) or open land (4.2%). Areas of high intensity development are visible around the communities of Esko, Hermantown, and Adolph, as well as areas adjacent to major highway corridors that cross portions of the watershed. Agricultural land cover is common in portions of the watershed and accounts for 9.3% of total land cover based on the NLCD 2021 data. Nearly all the agricultural land is categorized as hay/pasture (9.2%) with cultivated crops accounting for 0.1% of total watershed land cover.

Watershed land cover conditions provide important context for framing restoration and protection approaches. The NLCD data were further stratified by *Watershed Zone* for the purpose of evaluating spatial patterns of land cover and land uses within the Midway River drainage (Table 1) (see Section 3.1 for explanation of Watershed Zones). Results can be used as a preliminary gauge of watershed health and potential landscape level stressors, or inversely, a measure of desirable attributes that could increase resiliency to disturbance. The highest rates of developed land are located within the Lower Midway (11.5%), Adolph Creek (10.0%), East Rocky Run (9.7%), and Upper Midway (8.2%) watershed zones. The least-developed watershed zones are Elm Creek (2.6%), Anderson Creek (3.4%), Hay Creek (3.6%), and West Rocky Run (4.1%).

Land cover and development patterns within the Midway River Watershed have been trending towards increased development over the past several decades. The watershed is surrounded by communities with expanding residential, commercial, and industrial developments. Figure 3 shows the watershed boundaries and the proximity of high intensity development land cover pushing towards the area. In a recent development (Spring 2025), roughly 200 acres of land is being proposed for industrial development within the city limits of Hermantown. The site of the proposed project sits adjacent to two of the highest quality trout streams in the Midway River Watershed (West Rocky Run and Elm Creek) and contains many acres of forest, wetlands, and several prominent groundwater springs.

2.3 Midway River Watershed Assessments/Impaired Waters

The MPCA assesses water quality through a watershed-based approach, focusing on biological, chemical, and physical data. This process involves monitoring streams and lakes within a watershed, identifying impaired waters, and developing strategies for restoration and protection. The MPCA maintains an Impaired Waters List 303 (d) list as required by the Federal Clean Water Act, which identifies waters not meeting state water quality standards. Watershed assessment data are also used to document water bodies with exceptional water quality conditions and high biological integrity, which are classified as *Exceptional Use* waters (EU). Management strategies applied to EU waters focus on preservation and protection.

The Midway River Watershed was most recently assessed in 2021 using data collected over the previous decade (2010-2020). Adequate data were available to fully assess 12 stream segments (also referred to as water body ID or WID) within the watershed. Each of the 12 WID assessed met the *General Use* (GU) standard for aquatic life indicators measured via water quality, fish, and aquatic macroinvertebrate community indices. Meeting GU standards implies that measured indicators of water quality, physical habitat, and aquatic biota within the Midway River Watershed are generally in “good” condition. However, none of the WID evaluated achieved EU designation. Several streams have the potential to achieve EU status if restoration and protection activities are implemented, particularly Elm Creek and West Rocky Run.

The only current water quality impairments in the Midway River Watershed are related to *aquatic recreation* and public health designated uses. Portions of Hay Creek and West Rocky Run are listed as impaired for failing to meet the water quality standard for *E. coli* bacteria. Total Maximum Daily Load (TMDL) studies have been completed to identify potential sources of *E. coli* bacteria entering these waters and formulate strategies to reduce contamination levels. The *E. coli* impairments are not a major focus area of the MRWPS, but several projects recommended within this report (e.g. riparian buffers and re-vegetation) would benefit pollutant reduction strategies.

Table 1: 2021 National Land Cover Dataset results summarized by Midway River Watershed zone.

National Land Cover Dataset Categories (2021)	Watershed Zone								
	Adolph Ck.	Anderson Ck.	E. Rocky Run	Elm Creek	Hay Creek	Lower Midway	Middle Midway	Upper Midway	W. Rocky Run
Open Water	0.0%	0.5%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Barren Land	0.2%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.2%	0.5%
Developed, Open Space	3.5%	4.1%	4.6%	2.7%	2.9%	7.2%	4.0%	4.7%	3.1%
Low Intensity Development	5.7%	3.0%	5.3%	2.2%	3.0%	7.6%	3.6%	5.6%	3.0%
Med. Intensity Development	3.5%	0.4%	3.2%	0.4%	0.6%	3.2%	0.7%	2.2%	0.7%
High Intensiy Development	0.9%	0.0%	1.2%	0.0%	0.0%	0.6%	0.1%	0.5%	0.4%
Developed (Cumulative)	***10.0%***	***3.4%***	***9.7%***	***2.6%***	***3.6%***	***11.5%***	***4.5%***	***8.2%***	***4.1%***
Deciduous Forest	33.9%	27.8%	22.0%	43.4%	22.7%	9.2%	22.0%	29.8%	30.2%
Evergreen Forest	1.3%	2.4%	0.9%	0.7%	3.0%	8.5%	2.6%	1.5%	1.3%
Mixed Forest	5.5%	9.8%	7.2%	7.7%	7.1%	9.5%	7.0%	5.8%	5.1%
Shrub/Scrub Forest	1.6%	0.9%	1.1%	2.2%	1.3%	0.5%	0.8%	1.8%	3.3%
Herbaceous Land	2.4%	0.6%	0.8%	1.7%	0.6%	0.3%	0.6%	1.4%	1.8%
Forested (Cumulative)	***44.7%***	***41.5%***	***32.0%***	***55.8%***	***34.8%***	***28.1%***	***33.0%***	***40.3%***	***41.7%***
Hay/Pasture	6.0%	9.5%	2.3%	7.7%	14.3%	14.4%	17.5%	3.7%	8.7%
Culvtivated Crops	0.0%	0.5%	0.0%	0.1%	0.3%	0.1%	0.1%	0.0%	0.3%
Agricultural (Cumulative)	6.0%	10.0%	2.3%	7.9%	14.7%	14.4%	17.6%	3.7%	9.0%
	33.7%	34.3%	50.1%	28.9%	41.1%	33.3%	36.1%	41.2%	40.3%
Emergent Wetlands	1.8%	6.0%	1.1%	1.9%	2.8%	5.4%	4.7%	1.6%	1.4%
Wetlands (Cumulative)	***35.5%***	***40.4%***	***51.2%***	***30.8%***	***44.0%***	***38.7%***	***40.8%***	***42.8%***	***41.7%***

Least Impact — Most Impact

Watershed Zone	Devloped Land Use	Agricultural Land-Use	Developed+Ag Total
Lower Midway	11.5%	14.4%	**25.9%**
Middle Midway	4.5%	17.6%	**22.1%**
Hay Creek	3.6%	14.7%	**18.3%**
Adolph Ck.	10.0%	6.0%	**16.0%**
Anderson Ck.	3.4%	10.0%	**13.5%**
W. Rocky Run	4.1%	9.0%	**13.0%**
E. Rocky Run	9.7%	2.3%	**12.0%**
Upper Midway	8.2%	3.7%	**12.0%**
Elm Creek	2.6%	7.9%	**10.5%**

Figure 3: 2021 National Land Cover Dataset (2021 NLCD) within and surrounding the Midway River Watershed. Note the proximity of numerous High and Medium Intensity Development areas to the watershed boundary. Red arrows indicate potential encroachment of developed land uses towards the Midway River Watershed.

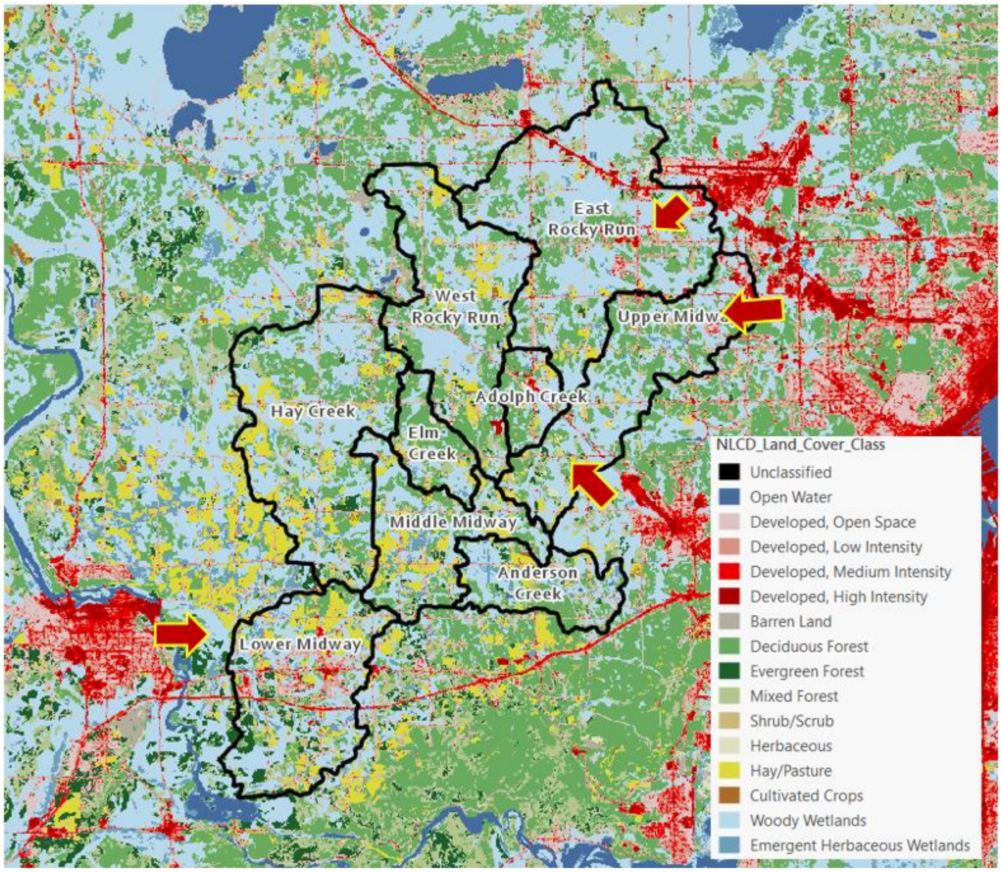


Figure 4: Development of riparian corridor along the Midway River and small tributary stream near Esko, MN. Over the last 20-30 years, areas of the watershed have undergone conversion from forested land → agricultural land → residential subdevelopments.

1992 2021

3.0 Study Design and Organization

3.1 Midway River Watershed Zones

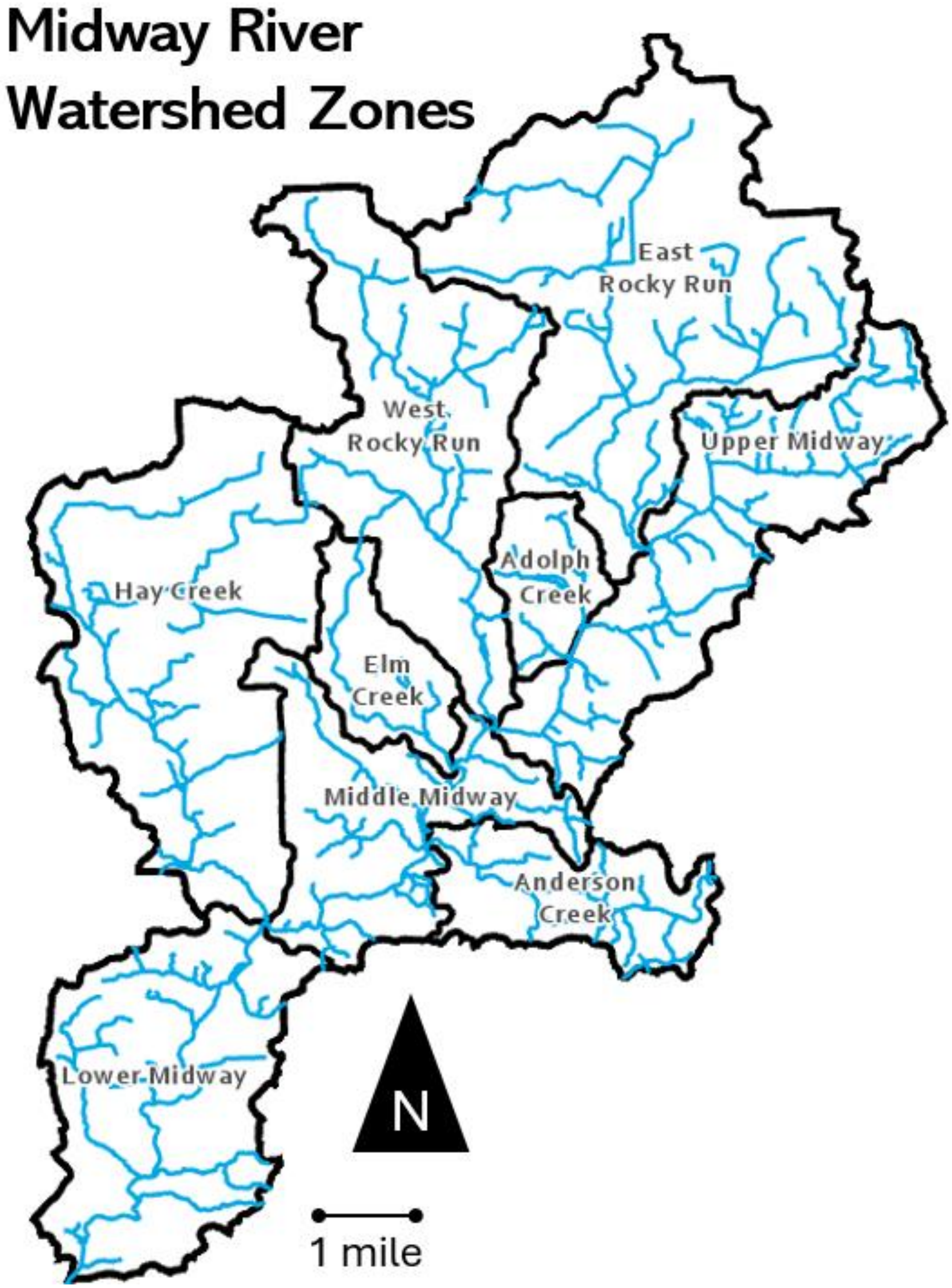
The Midway River Watershed was divided into nine "watershed zones" for the purpose of summarizing monitoring results and project prioritization. Some of these watershed zones follow conventional hydrological watershed boundaries and function as nested drainage networks. These include major tributaries to the Midway River such as West Rocky Run, East Rocky Run, Hay Creek, Elm Creek, and Anderson Creek. Other watershed zones were synthesized for this project based on a combination of geographical, hydrological, and ecological similarities. Watershed Zones are intended to represent a specific region of the greater watershed, but do not exist as nested hydrological drainage networks. The location of the nine watershed zones used throughout this report are shown in Figure 5.

3.2 Stream Reach Delineation and Reach ID Numbers

All flowing water within the Midway River Watershed was mapped and delineated during this project using a combination of leaf-off aerial photography, existing stream linework (e.g. ArcGIS shapefiles), and digital elevation models (DEMs). The resulting stream linework was broken into stream reach scale segments, or "Reach ID", based on a range of characteristics, including stream type (size, pattern, profile), condition (natural or modified -- i.e. channelized/ditched/impounded), major tributary confluences, riparian land use and condition, and geographic location within the watershed. An example of stream reach segmentation and Reach ID naming structure can be found in Appendices B and C.

The Reach ID framework is used throughout this report to organize and report monitoring results, and they also provide geographic reference points for proposed conservation projects. Reach ID were developed specifically for the MRWPS and do not match stream linework data sets frequently used by MPCA or Minnesota Department of Natural Resources (DNR) for water quality assessments, trout stream designations, or Public Waters Inventory (PWI) classifications. A total of 756 unique stream Reach ID were created for use in the MRWPS. Data linked to each Reach ID include a Reach ID number, general channel condition (modified or natural), modification type (e.g. channelized, impounded), flow status (perennial or intermittent), temperature category (see Section 4.1.5), level of wetland influence, reach length, and monitoring stations and proposed projects associated with the reach.

Figure 5: Midway River Watershed zone boundaries developed for summarizing results of the MRWPS.



4.0 Monitoring and Assessment Results

4.1 Water Temperature

Water temperature is a critical factor in the distribution of species within aquatic ecosystems. Changes in fish communities can be driven by temperature variability across large geographical areas (e.g. regions of Minnesota), within a subwatershed, or even within an individual stream reach. Water temperature in streams is influenced by many factors, some of which are closely tied to geographic and geologic setting. Examples include the presence or absence of groundwater springs, the type and condition of riparian vegetation, and local climate conditions (air temperature, precipitation). In addition, anthropogenic activities such as surrounding impervious surface cover (e.g. asphalt roads and parking lots), water withdrawals or diversions (surface or groundwater), and the construction of dams and reservoirs can significantly influence water temperature in streams.

Brook Trout, as well as several other fish and macroinvertebrate taxa found within the Midway River Watershed, are considered *"coldwater obligate"* taxa, meaning they are physiologically dependent on cold water temperatures for survival. Optimal water temperatures for Brook Trout survival and growth range between 7.8°C and 20.0°C (46°F and 68°F). Water temperatures between 20.1°C – 25.0°C (68°F – 77°F) are considered "stressful" for Brook Trout and may reduce growth, cause disease or mortality, or provoke movement to more suitable habitats. Temperatures above 25.0°C are considered "lethal" and can cause mortality in Brook Trout populations within hours of exposure.

4.1.1 Temperature Monitoring Methods

Stream temperature data were collected throughout the Midway River Watershed during the open water seasons from 2018 through 2021 using several methods, including continuous logger deployment, synoptic/instantaneous spot measurements, and thermal imaging collected using aerial drones (UAS).

Continuous data loggers were deployed between the months of May and October and set to record at 30-minute intervals. On average, 40 continuous temperature loggers were deployed each year of the study. Deployment locations targeted previously unmapped and unmonitored groundwater springs, small and large tributary streams, and portions of the Midway River main stem. The density and spatial coverage of temperature monitoring stations used in development of the MRWPS far exceeds any previous monitoring efforts undertaken by the MPCA or DNR in this region. This approach was taken to map and characterize cold water habitats at highly localized scales, which ultimately aided the process of prioritizing proposed conversation efforts.

An additional 96 synoptic/instantaneous temperature monitoring locations were added with the goal of increased spatial coverage and resolution. Each synoptic station was visited at least one time, and several were visited two to four times during the four-year study period. Measurements of temperature, pH, dissolved oxygen (DO), and specific conductivity were collected by up to four field crews simultaneously during mid-afternoon hours. All stations were visited within a one to two hour window, helping to produce a synoptic "snapshot" of temperature and water quality conditions throughout the watershed.

The use of UAS equipped with infrared thermal imaging cameras is emerging as a method to more efficiently measure and map stream temperatures within watersheds. At the time of this study, these methods were still being tested by MPCA, and no protocols had been established to survey large watershed areas with this UAS-based monitoring approach. However, several targeted UAS flights were completed over the Midway River and select tributaries to collect imagery and more accurately map and visually depict select thermal refuge areas. See Section 4.1.8 for examples of UAS-based thermal imagery from this study.

4.1.2 Stream Temperature Index Stations/Annual Temperature Variability

Stream temperature can vary significantly from year to year based on snowpack and snowmelt conditions, rainfall totals, and ambient air temperatures. Monitoring this watershed over four-year period offered an opportunity to use continuous stream temperature data to determine which water bodies are more responsive to annual climate variability, which can be used as an indicator of potential climate resiliency.

Nine stations were established as "Water Temperature Index Stations" (WTIS) and were monitored for continuous water temperature each year of the four-year project (Figure 6). Many of the WTIS were located on major tributary streams near their confluence areas with the Midway River. On the other end of the spectrum, several stations were selected to represent cold spring-fed headwaters streams or small tributaries with marginal temperatures for supporting Brook Trout.

Large tributary (drainage area > 10 mi^2) WTIS exhibited the warmest average summer temperatures and highest degree of annual variability (Figure 6). Results from medium-sized tributaries (drainage area between 2 to 3 mi^2) were similar to large tributary streams, but exhibited more intra-group variability, as one station had much colder average summer temperatures than its counterpart. Small tributary WTIS (drainage area between 1 to 2 mi^2) displayed significantly less annual variability in summer mean temperatures than large and medium tributary streams and summer mean temperatures were generally colder. Finally, the single WTIS located on a small headwaters spring within the Elm Creek Watershed had essentially no annual variability and supported extremely cold water temperatures all four years of the study.

WTIS results highlight the connections between seasonal water temperatures and contributing factors such as drainage area size, inputs from groundwater springs, surrounding land use, and ambient conditions (e.g. air temperature, precipitation). Key takeaways from the WTIS data set include;

- Spring-fed headwaters streams monitored near their sources remain extremely cold (10°C to 12°C) and show little to no short-term response to annual variability of ambient conditions.
- As expected, annual stream temperature variability increased in medium and large-sized streams compared to small streams and springs.
- Mean summer temperatures in one medium-sized stream (Elm Creek) were regularly colder than results from smaller streams indicating groundwater presence.
- Summer mean water temperatures varied significantly among the small, medium, and large tributary streams monitored, suggesting that groundwater inputs, land use, shading and other nondrainage area related factors are significant drivers of summer water temperatures.

Figure 6: Range in average summer stream temperatures recorded at nine WITS within the Midway River Waters

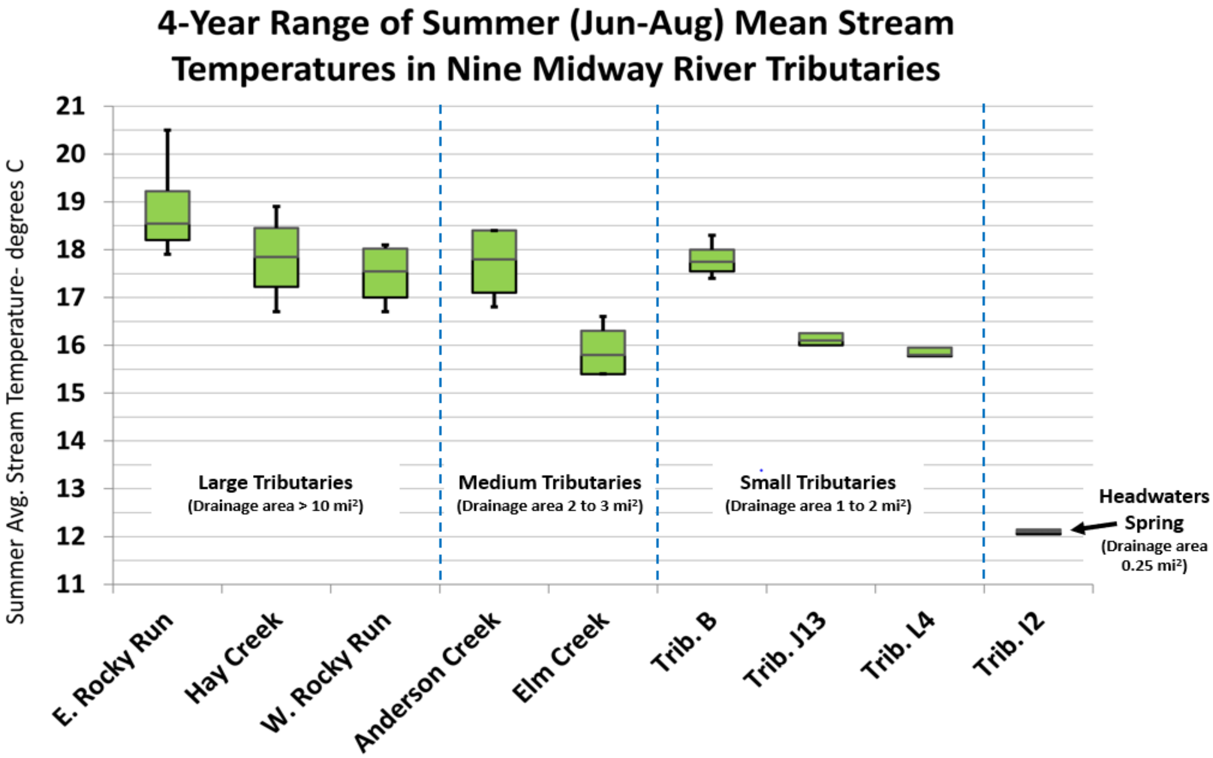


Figure 7: Photos of four WITS within the Midway River Watershed showing the range of stream sizes and conditions.

4.1.3 Stream Temperature Classification

Stream Temperature Area classes have been used by the MPCA in previous reports to summarize continuous data and draw connections between thermal classifications and fish communities. This model is derived from continuous temperature data statistics and the use of three temperature categories adhered to by state agencies and other water resource professionals researching cold water fisheries, GROWTH, STRESS, and LETHAL (Table 2).

Two temperature metrics serving as strong predictors of Brook Trout presence and abundance are percentage of GROWTH (percent of temperature readings in the GROWTH range) and *Summer Average Temperature* (mean temperature recorded (June 1 through August 31). Using statewide temperature data, four "AREA" groupings were defined in the data set (AREA 1 to 4) to develop generalized predictions of Brook Trout presence/absence and abundance (i.e. Brook Trout nearly always present and in high populations) (Table 3, Figure 8). The resulting temperature AREA groupings will be used in the following sections to analyze and communicate stream temperate data for the Midway River Watershed.

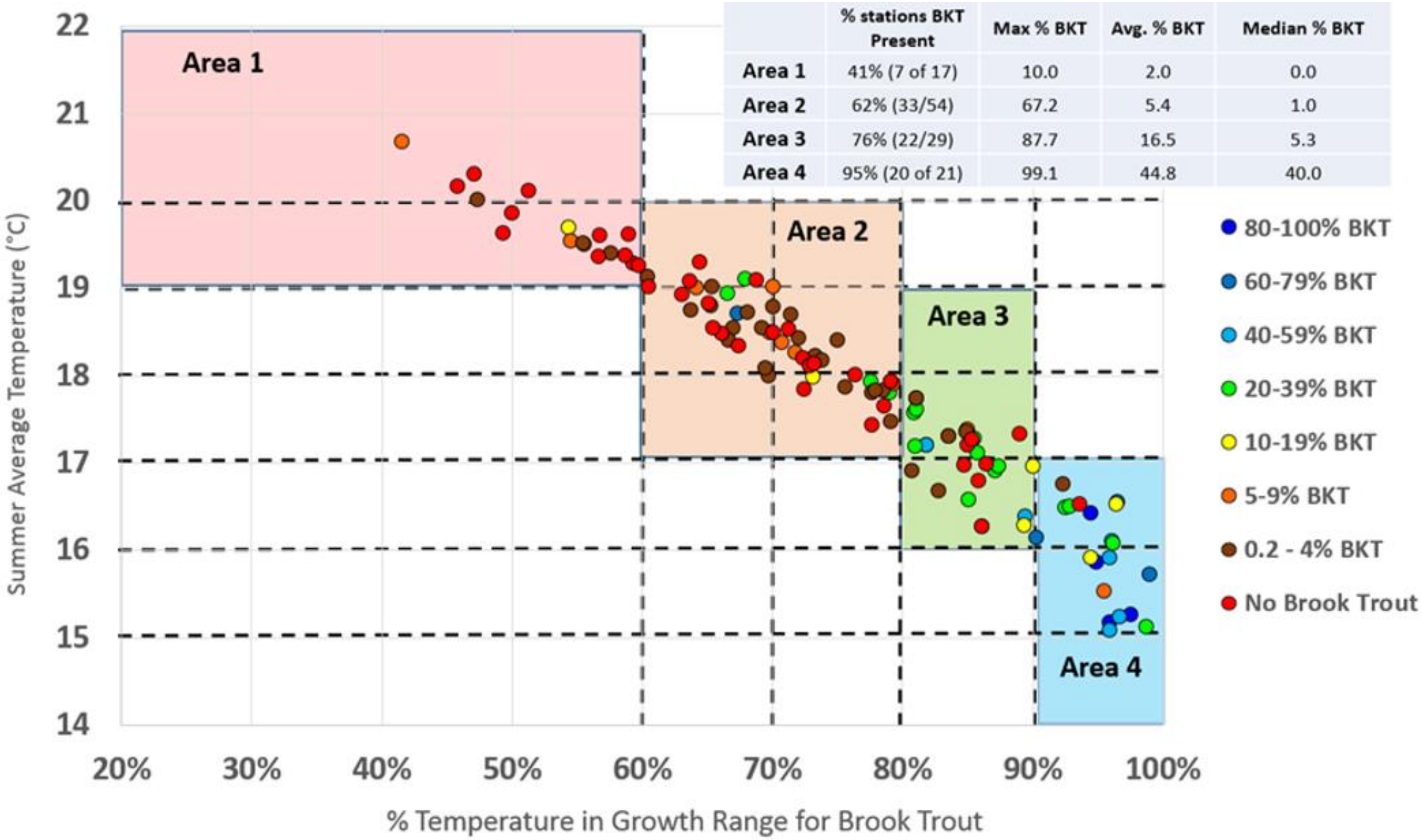
Table 2: Temperature criteria used by DNR and MPCA for determination of Brook Trout Growth, Stress, and Lethal temperature ranges.

Classification	Temperature Range (°C)	Description
Growth	7.8 to 20.0 °C	Temperature range favorable for growth
Stress	>20.0 to 25.0 °C	Stress and avoidance behaviors
Lethal	>25.0 °C	Mortality can be expected at prolonged exposure

Table 3: Criteria used to develop the four temperature AREA (1-4) classifications used in this report.

Area	% Temperature Readings in Brook Trout Growth Range	Summer Average Temperature (C)	Typical Fish Community
Area 1	<60%	>19 C	Brook Trout/Coldwater sp. sometimes present; more often a mix of cool/warmwater taxa
Area 2	60-79%	17 – 20 C	Can support Brook Trout/other Coldwater sp., often a mix of cold, cool, and warmwater taxa
Area 3	80-89%	16 – 18 C	Frequently supports Brook Trout and other Coldwater species, lower relative densities of non-coldwater taxa
Area 4	90 – 100%	<17 C	Almost always support high relative densities of Brook Trout and/or other cold-water species, low taxa richness favoring coldwater species dominance

Figure 8: Scatter-plot of summer average temperature vs percentage of time temperature was within Brook Trout growth range. Marker colors correspond to percent of Brook Trout in the sample. Data include all Lake Superior South and Lake Superior North HUC-8 Watershed stations with biological and temperature data from same season.



	% stations BKT Present	Max % BKT	Avg. % BKT	Median % BKT
Area 1	41% (7 of 17)	10.0	2.0	0.0
Area 2	62% (33/54)	67.2	5.4	1.0
Area 3	76% (22/29)	87.7	16.5	5.3
Area 4	95% (20 of 21)	99.1	44.8	40.0

4.1.4 Stream Temperature Area Analysis by Watershed Zones

Hay Creek Watershed Zone

Most stream temperature data within the Hay Creek Watershed zone fall into temperature AREA 3 and 4, indicating cold water temperatures, and widespread suitability for Brook Trout (Figure 9). Minor perennial tributaries to Hay Creek (blue markers, Figure 9) were consistently very cold (AREA 4) and provide reliable thermal refugia and spawning habitat for Brook Trout moving between the Hay Creek mainstem and these tributary streams. Several small, seasonally intermittent tributaries (green markers, Figure 9) were also quite cold and offer additional habitat during years with adequate precipitation and groundwater recharge.

The Hay Creek main stem exhibited stream temperature variability both longitudinally (from upstream to downstream) and annually. Lower Hay Creek (yellow markers, Figure 9) oscillated between AREA 2 and AREA 4 during this study, indicating susceptibility to changes in ambient conditions (drought, elevated air temperatures). Sections of Hay Creek closer to the geographic mid-point of the watershed were colder and displayed less thermal variability. The stream channel in this portion of the watershed is narrower, heavily shaded, and fed by several spring-fed minor tributaries which help keep temperatures cold and less responsive to ambient conditions.

Overall, Hay Creek and its tributary streams provide an extensive network of high-quality coldwater habitat for Brook Trout and other species. Based on recent data, the lower reaches of Hay Creek can be considered vulnerable to warming, and efforts should be taken to reduce thermal loading and ensure fish have access to cold water refugia within tributary streams and the colder sections of Hay Creek (middle and upper reaches).

Adolph Creek Watershed Zone

The Adolph Creek Watershed zone covers a small drainage area with an abundance of groundwater springs and cold tributary streams. All stream temperature data plotted in AREA 4 (very cold) and displayed very little variability from year to year due to the strong and reliable inputs of groundwater feeding these streams. The lone minor perennial stream in this watershed zone, Adolph Creek (blue markers, Figure 10), provides high quality, reliable coldwater refugia and spawning/rearing habitat for Brook Trout inhabiting this region of the Midway River Watershed. Numerous high priority restoration and protection projects exist within the Adolph Creek Watershed zone, which will be highlighted in greater detail throughout this report.

Anderson Creek Watershed Zone

The Anderson Creek Watershed zone exhibits a high degree of stream temperature variability. Monitoring stations on the main stem of Anderson Creek located in the middle portion of this drainage plot in AREA 4, indicating very cold thermal conditions and high suitability for supporting Brook Trout and other coldwater taxa. This portion of Anderson Creek is narrow and shaded, flowing through a meadow of tall grasses and thick alder brush. Cold, suitable temperatures for Brook Trout (AREA 3, Figure 11) were also observed in the upper portion of the Anderson Creek Watershed near the crossing of Midway River Road.

As Anderson Creek nears its confluence with the Midway River, stream temperatures warm significantly due to channelization (ditching) and stagnant flow velocities resulting from improperly sized and installed culverts. Beaver dams are also common in this area and may exacerbate low streamflow velocities and contribute to temperature increases. Stations in the lower reaches of Anderson Creek Watershed zone routinely fell into AREA 1 and AREA 2 (warm to cool) and tend to support marginal populations of Brook Trout.

The Anderson Creek Watershed zone contains several areas of quality Brook Trout habitat in need of protection measures. In contrast, there are also highly impacted areas in need of restoration work. Failure to remove poor road crossings and restore ditched stream segments in the lower reaches of Anderson Creek will continue to leave Brook Trout populations at risk in this portion of the stream.

Elm Creek Watershed Zone

The Elm Creek Watershed zone contains several of the coldest small and medium-sized tributaries in the entire Midway River Watershed. Stations located along the main stem of Elm Creek (purple markers, Figure 12) plot in AREA 3 and AREA 4, with the coldest of these stations located just upstream of the Elm Creek-Midway River confluence. Unlike many main tributaries to the Midway River, the main stem of Elm Creek becomes colder in its lower reaches, likely due to a prominent spring-fed tributary which provides a constant supply of extremely cold water to this portion of the stream (blue markers, Figure 12). Elm Creek is a prime candidate for protection efforts to preserve high-quality coldwater habitat in the Midway River Watershed.

West Rocky Run Creek Watershed Zone

West Rocky Run (WRR) is one of the largest tributaries to the Midway River and its watershed zone contains many miles of quality habitat for Brook Trout and other coldwater species. Nearly all stream temperature data collected within this watershed zone plotted in AREA 3 (cold) or AREA 4 (very cold), regardless of stream size (Figure 13). Minor tributaries to WRR (blue markers, Figure 13) provide reliable inputs of cold water originating from nearby groundwater springs and wetlands. One minor tributary station plotted in AREA 1 (warm-cool) or AREA 2 (cool-cold) three years in a row due to beaver impoundments near the station, but temperatures remained extremely cold less than one river-mile upstream on this tributary. The lower main stem of West Rocky Run (yellow markers, Figure 13) supports cold to very cold thermal conditions and appears less responsive to changes in precipitation and/or air temperature compared to other large Midway River tributaries.

The WRR Watershed zone is a top priority area for restoration and protection activity due to the abundance of quality coldwater habitat. The warmest stream temperatures observed within this watershed were in areas altered by stream channelization (ditching) or affected by large beaver dams.

East Rocky Run Creek Watershed Zone

The East Rocky Run (ERR) Watershed zone covers a large drainage area encompassing much of the Midway River headwaters. Stream temperature data within the ERR Watershed zone are mixed, with minor streams plotting mostly in AREA 4 (very cold), and intermediate to large perennial streams falling into AREA 2 (cool-cold) or AREA 1 (warm-cool). Several very small or intermittent streams (green markers, Figure 14) remained relatively cold during years with normal to high precipitation levels. Stream temperatures in the lower main stem of East Rocky Run Creek (yellow markers, Figure 14) were warmer and more vulnerable to changes in air temperature and precipitation compared to other major tributaries to the Midway River.

Stream temperature data from the ERR suggest marginal habitat conditions for Brook Trout and other coldwater biota. Some minor tributaries and select areas of the main stem of ERR remain cold enough to support these species but should be considered marginal and vulnerable to warming. Higher rates of developed land use and significant channelization of headwaters streams within the ERR Watershed jeopardize coldwater habitat longevity. Commercial and residential development pressure has been high in this watershed zone over the last several decades and remains a threat to the ecological health of this watershed zone.

Upper Midway River Watershed Zone

This watershed zone constitutes the true headwaters of the Midway River and numerous small tributary streams. In general, stream temperature data in this watershed zone indicate cold to very cold temperatures, with the exception of the main stem of the Midway River, which plotted in AREA 2 (warm-cool) (Figure 15). Most of the minor perennial streams (blue markers, Figure 15) and very small streams (green markers, Figure 15) plotted in AREA 3 and AREA 4, indicating suitable temperatures for Brook Trout. Many of these streams are extremely small and summer baseflow is sustained by small amounts of groundwater entering the stream. Despite cold water temperatures, many of these streams lack adequate flow and DO levels to provide quality Brook Trout habitat.

Middle Midway River Watershed Zone

Water temperature data from the Middle Midway River Watershed zone show distinct groupings by stream size. The main stem of the Midway River (pink markers, Figure 16) plotted in AREA 1 and AREA 2 indicating warm to cool water temperature profiles. Minor perennial streams (blue markers, Figure 16) within this watershed zone were exceptionally cold, plotting well into AREA 1. Several of the small perennial streams within this watershed zone are fed by significant upwellings of groundwater, resulting in consistent stream flow rates and very cold temperatures. During mid-summer periods of excessive heat, large numbers of Brook Trout have been observed seeking refuge near the locations where these tributaries outlet to the main stem of the Midway River. These cold tributary streams and the groundwater springs feeding them are identified as coldwater protection area (CPA) in Section 4.1.7.

Lower Midway River Watershed Zone

Stream temperature data from this watershed zone show a similar pattern to the Middle Midway, with temperature groupings by stream size. The Midway River main stem plotted exclusively in AREA 1 (warm-cool) and can be considered more of a warmwater habitat in this portion of the watershed, although Brook Trout were observed seasonally near several confluence areas with colder tributaries during the MRWPS investigation. Minor perennial streams and very small/intermittent streams were mostly cold within this watershed zone (green and blue markers, Figure 17). However, the rate of stream alteration (ditching, impoundments) and urban land use within this watershed zone is higher compared to other areas of the Midway River Watershed. As a result, many of these minor tributary streams lack reliable stream flow, and physical habitat conditions are poor and highly fragmented in some areas.

Figure 9: Continuous stream temperature results plotted by AREA Class (1-4) Hay Creek Watershed Zone.

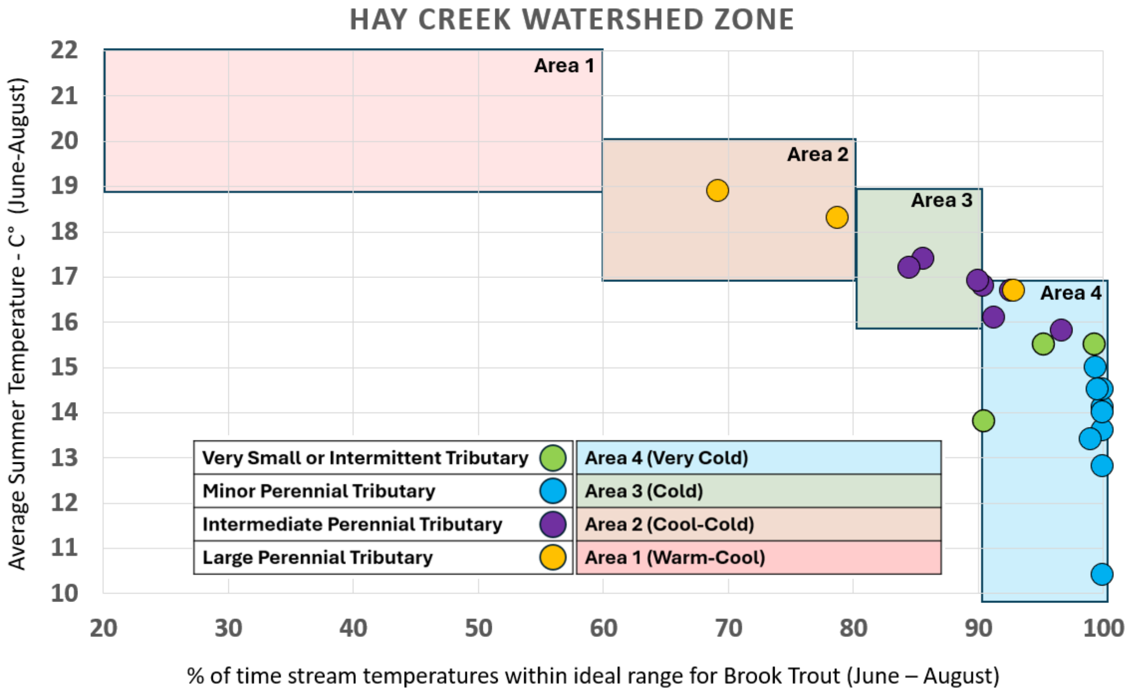


Figure 10: Continuous stream temperature results plotted by AREA Class (1-4) for Adolph Creek Watershed Zone.

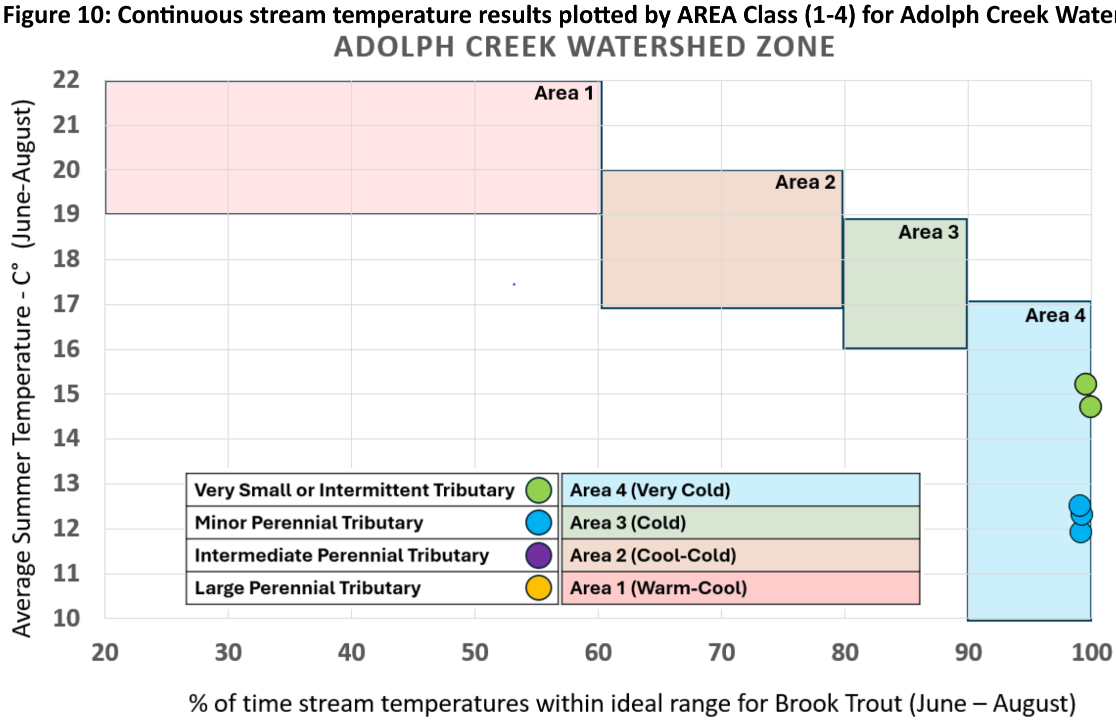


Figure 11: Continuous stream temperature results plotted by AREA Class (1-4) for Anderson Creek Watershed Zone.

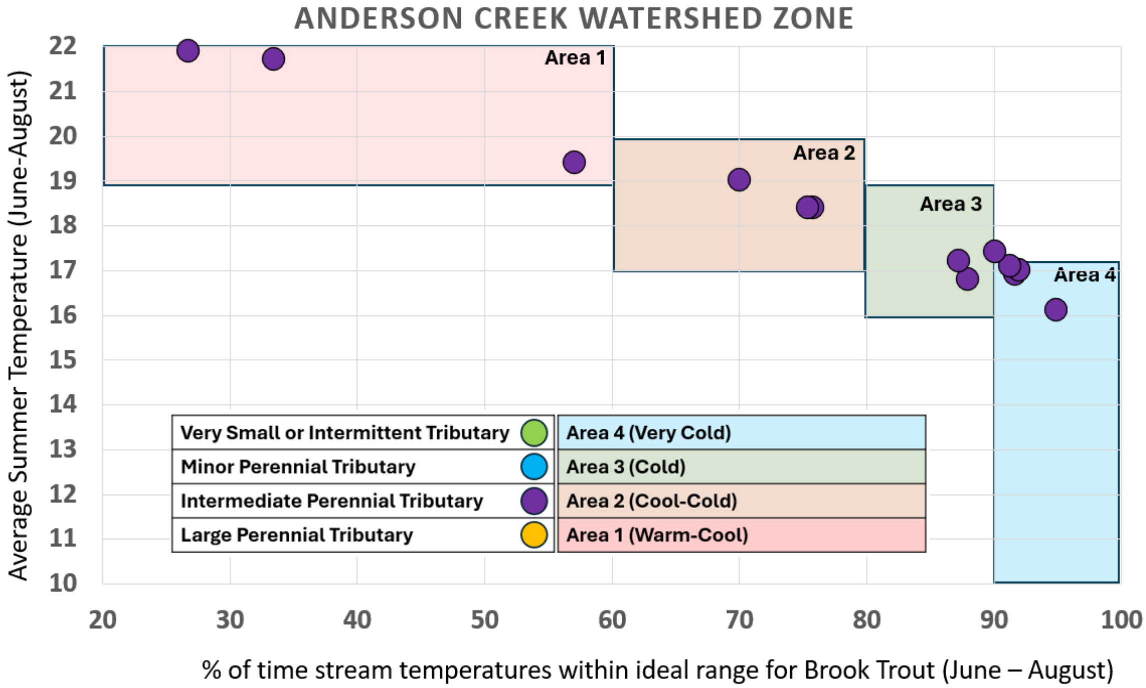


Figure 12: Continuous stream temperature results plotted by AREA Class (1-4) for Elm Creek Watershed Zone.

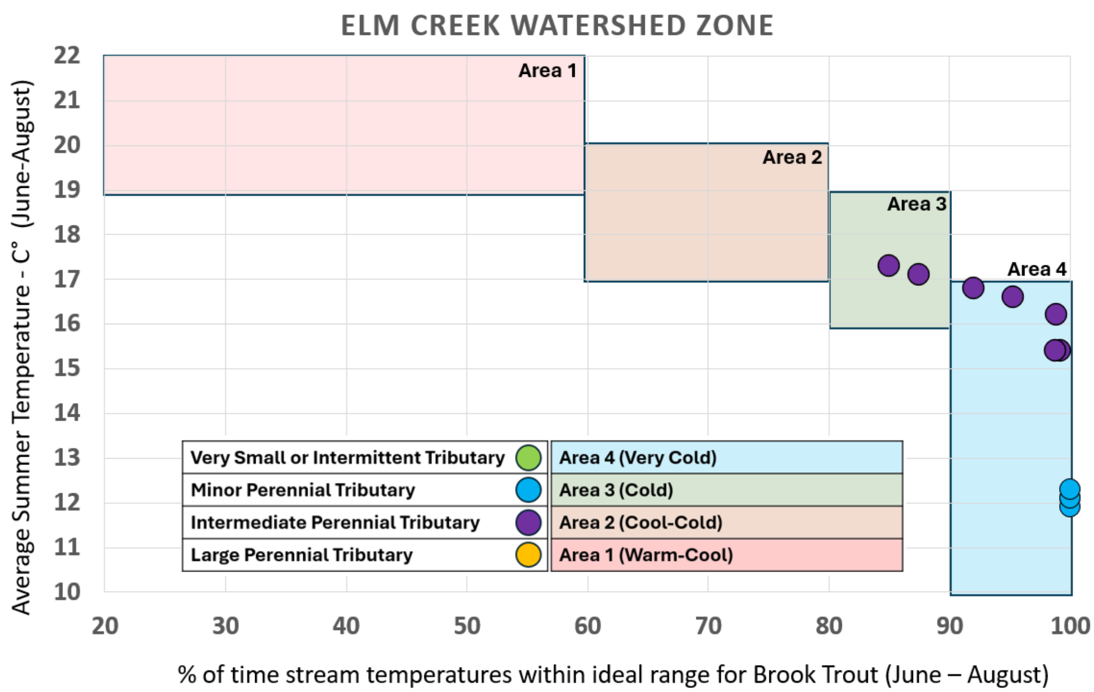


Figure 13: Continuous stream temperature results plotted by AREA Class (1-4) for West Rocky Run Watershed Zone.

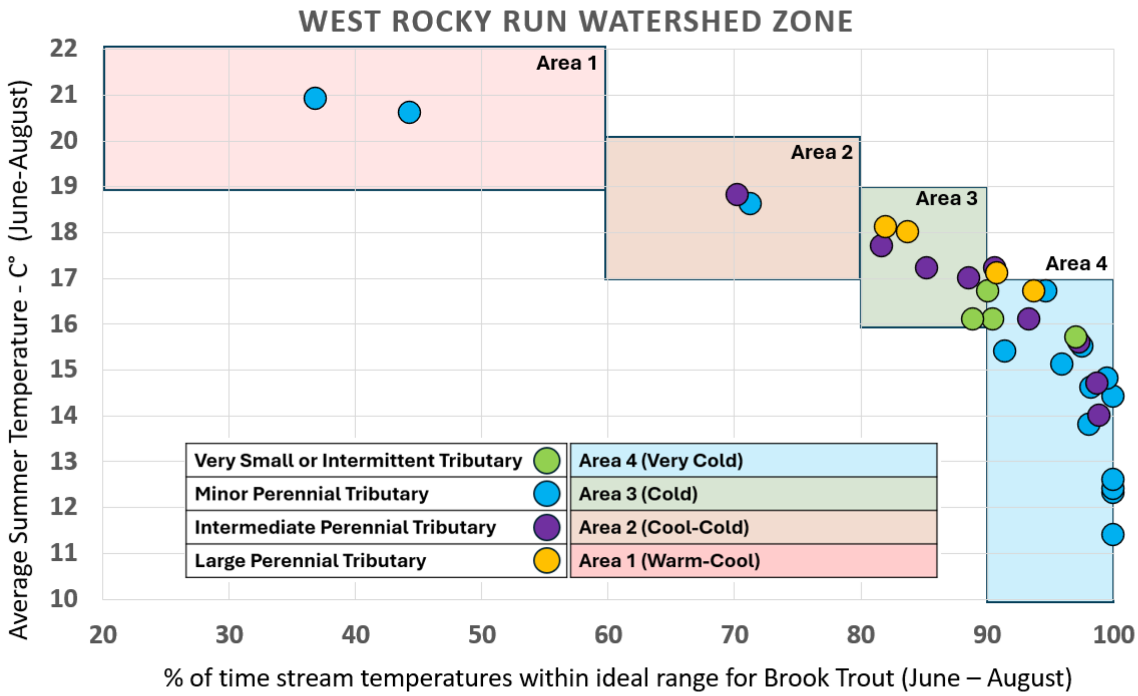


Figure 14: Continuous stream temperature results plotted by AREA Class (1-4) for East Rocky Run Watershed Zone.

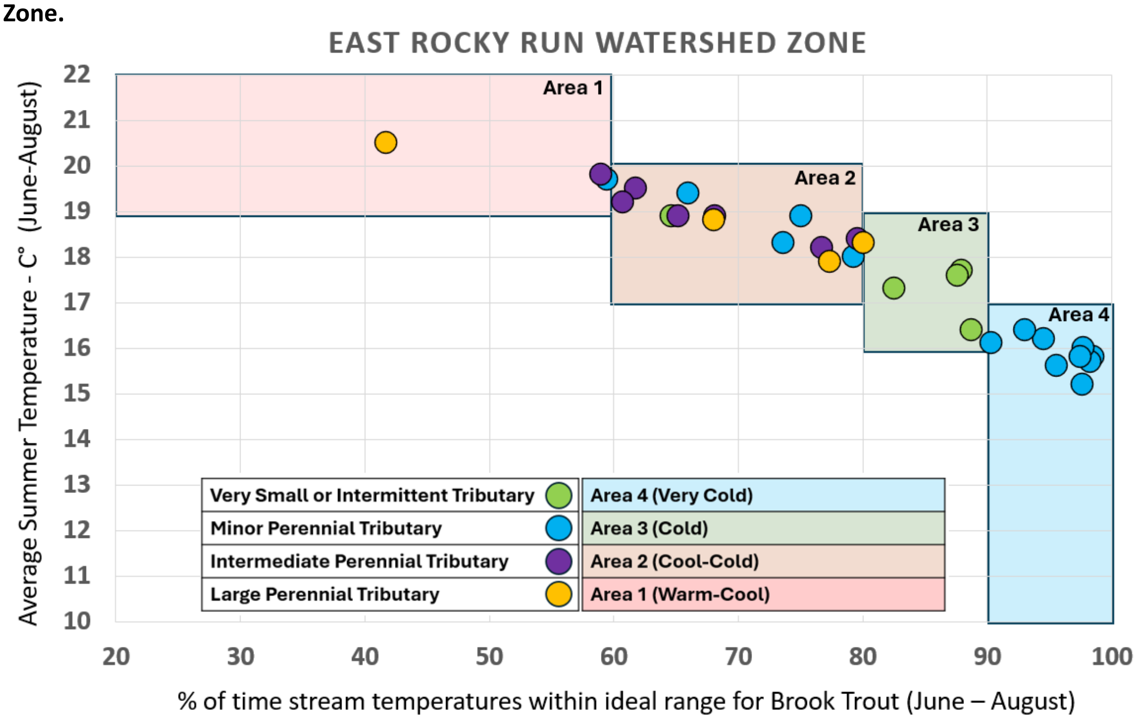


Figure 15: Continuous stream temperature results plotted by AREA Class (1-4) and stream size for the Upper Midway River Watershed Zone.

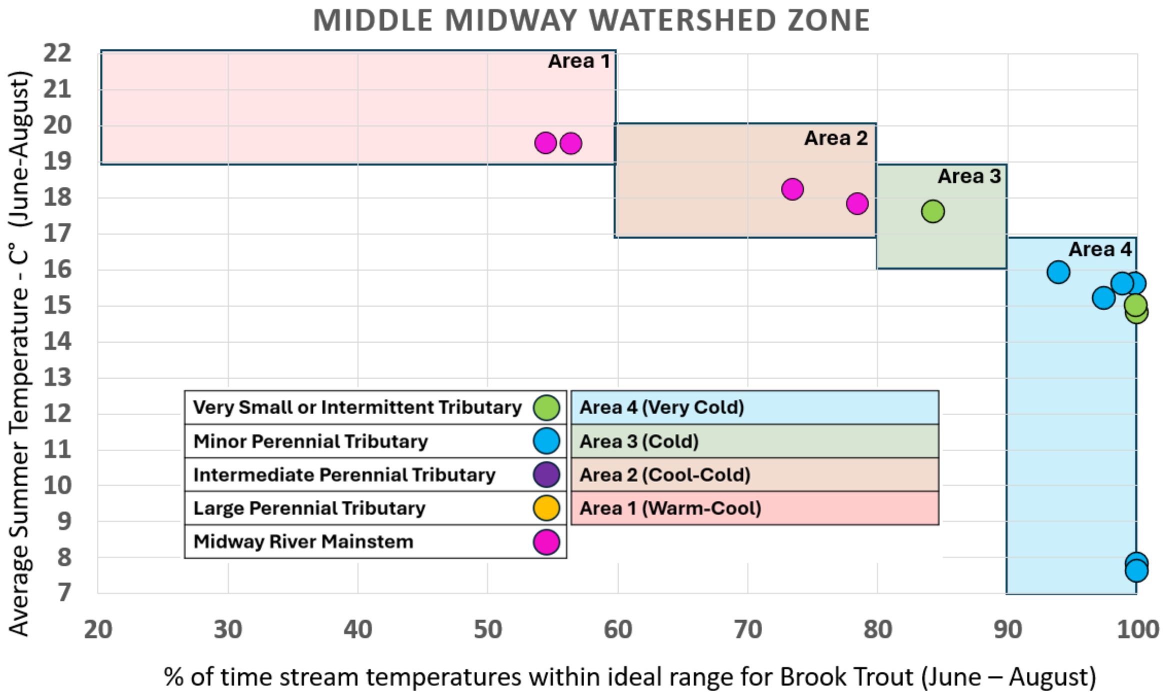


Figure 16: Continuous stream temperature results plotted by AREA Class (1-4) and stream size for the Middle Midway River Watershed Zone.

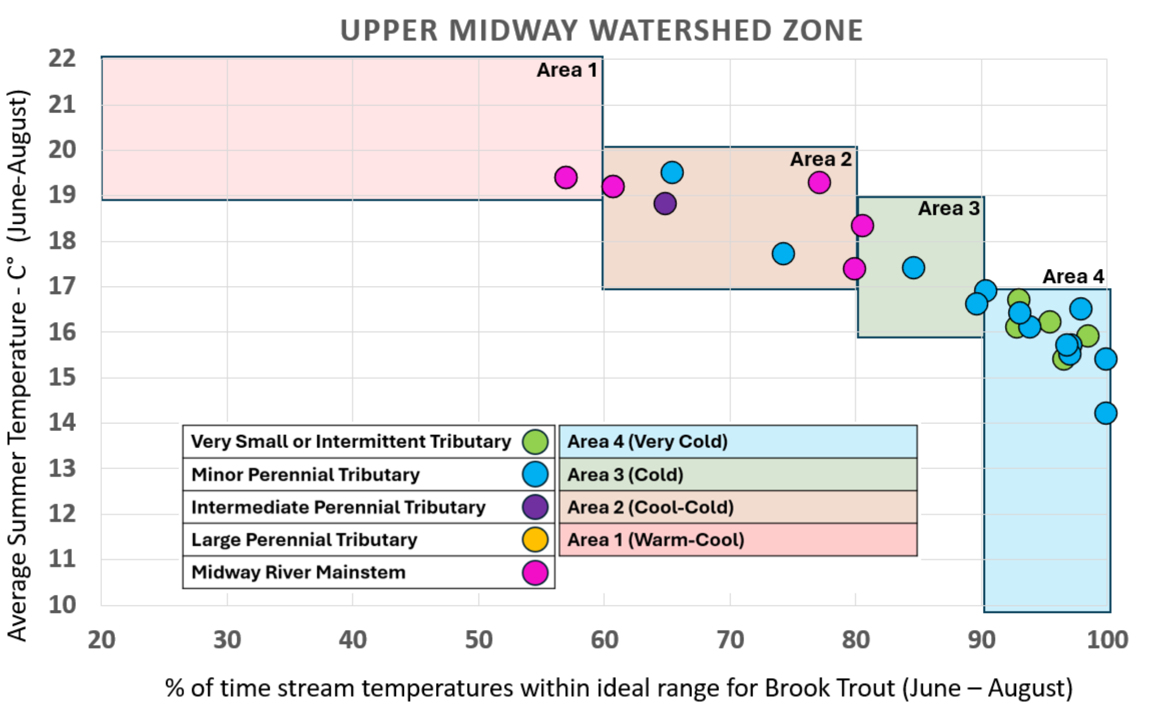
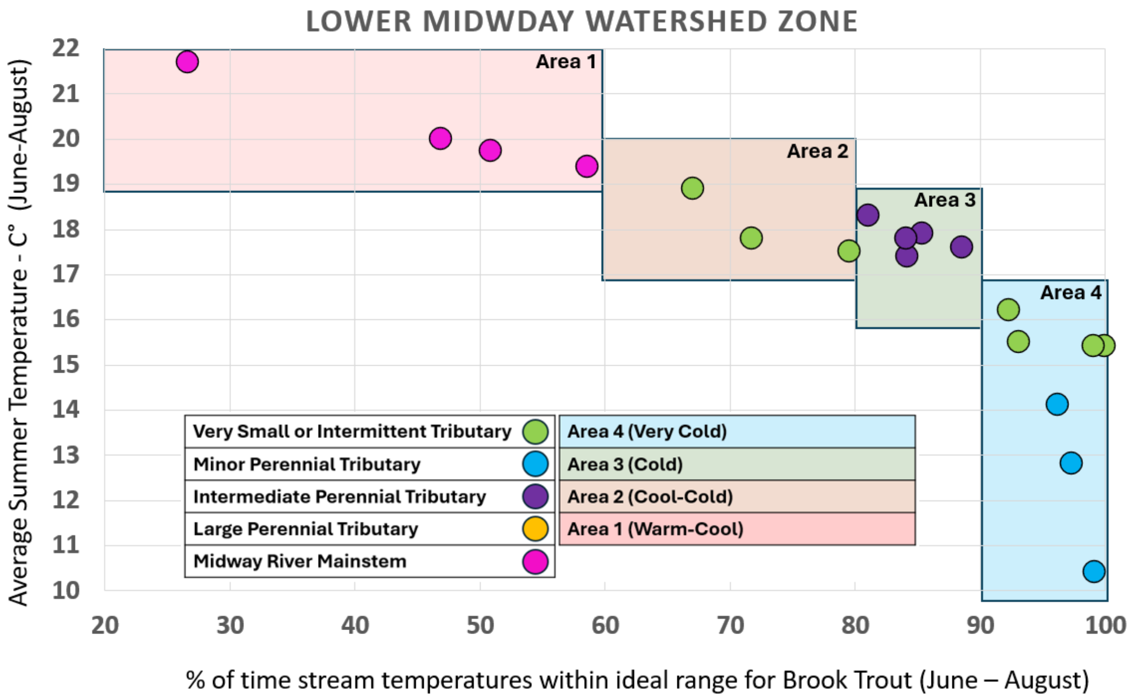


Figure 17: Continuous stream temperature results plotted by AREA Class (1-4) and stream size for the Lower Midway River Watershed Zone.



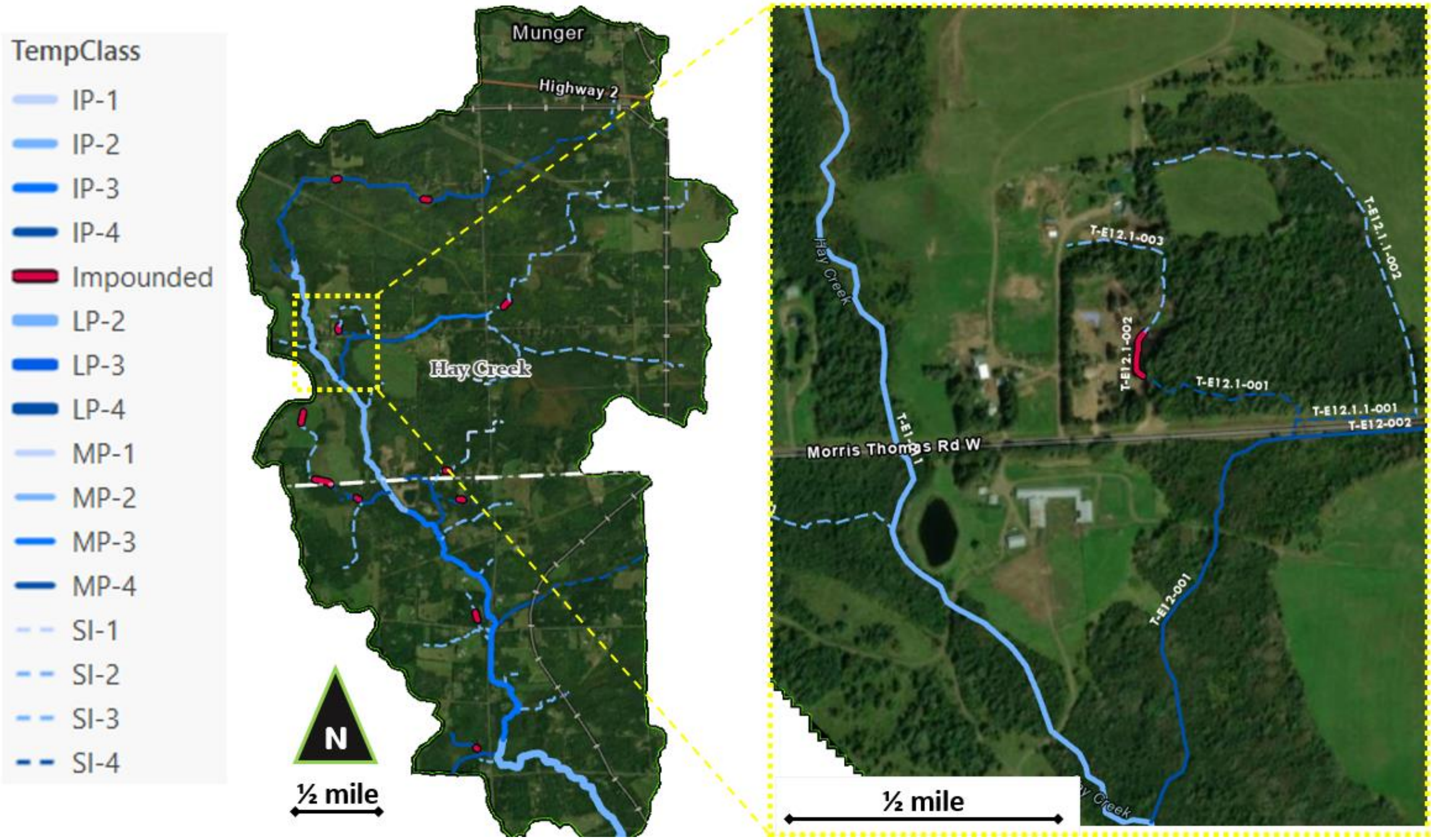
4.1.5 Stream Temperature Linework

Midway River Watershed Stream Temperature Linework (MSTL) was created using data derived from continuous logger deployments and spot measurements. MSTL consists of stream linework (ArcGIS shapefile) with temperature and streamflow attributes provided for individual stream reaches. The goal of MSTL is to display temperature and flow data as a stream network, as opposed to limiting temperature attributes to the single point where the measurement was taken. Monitoring data were extrapolated short distances upstream and downstream of the measurement point based on field measurements and professional judgement gained through extensive time studying this watershed. Confidence levels of high, medium, and low were assigned to data extrapolations based on the quantity and quality of data available for each reach.

Stream segments were assigned MSTL designations based on size (drainage area/flow) and available water temperature data. Size categories, from smallest to largest, include “SI” (very small/intermittent), “MP” (minor perennial), “IP” (intermediate perennial), and “LP” (large perennial). Flow measurements were collected from a selection of these streams (see Section 4.2.1). However, size categories were generally determined by visual field observations or desktop analysis using aerial photos. Temperature designations follow a numerical system from 1-4, with lower numbers indicating colder thermal conditions (**4 = Very Cold, 3 = Cold, 2 = Cold/Cool, 1 = Cool/Warm**). The category assigned to individual stream segments in the mapping tool include a combination of stream size and temperature (e.g. LP-1, MP-4, LP-2, SI-3).

In addition to the stream size and temperature designations, each stream reach has a unique identifier or “Reach ID” (e.g. T-E11-001) based on its location within the Midway Watershed (see Section 3.2 and Appendix B). The Reach ID naming system factors in several hydrography characteristics such as subwatershed, tributary order, and reach position in relation to upstream/downstream placement. The temperature and flow classifications referred to above are mapped by Reach ID delineations with each Reach ID being assigned a temperature and flow category. The example below from the Hay Creek Subwatershed provides an idea of how the Reach ID and associated temperature/flow classes are delineated (Figure 18).

Figure 18: Example of stream temperature and streamflow condition linework developed for the entire Midway River Watershed using monitoring data and extrapolation based on proximity and best professional judgement. See text in Section 4.1.5 for legend info.



4.1.6 Coldwater Habitat Suitability by Watershed Zone

The main objective of the MRWPS is to identify, protect, and restore areas of the Midway River Watershed that provide the highest quality coldwater habitat for Brook Trout. To this end, results derived from the stream temperature mapping tool were used to summarize and rank cold-water habitat suitability by Watershed Zone. These summary statistics were produced using reach ID temperature attributes (see Section 4.1.5) and total stream reach length of each temperature class within the watershed zone. Results were reported as an overall percentage of stream length with a given temperature suitability rating. For these calculations, only temperature and flow delineations with "High" and "Moderate" confidence levels were used.

The tables in Table 4 show the relative percentage of steam mileage in each temperature class and suitability category by Watershed Zone. The "High Quality" thermal habitat class includes all stream mileage rated as class 4 (very cold) or class 3 (cold). See Section 4.1.3 for more information on the Class 1-4 thermal classifications. "Marginal" thermal habitat includes the stream segments rated as class 2 (cool-cold) and "Poor" ratings were given to class 1 (warm) stream reaches. A separate category, "IMP" (abbreviation for "impounded") was developed for stream segments impounded by dams or altered by constructed ponds within the active stream channel.

As an example, the Elm Creek Watershed Zone contains 4,704 linear meters of Class 4 (Very Cold) stream length, and the total linear length of all mapped streams within this watershed zone is 7,628 meters. The percentage of Class 4 stream within this watershed zone is therefore 62% (4,704 m/7,628 m = 0.62). The Elm Creek Watershed Zone contains an additional 1,013 meters of Class 3 (cold) stream length, accounting for 13% of the total stream length within the zone. In total, around 75% of the stream mileage within the Elm Creek Watershed Zone is considered "High Quality" (class 4 or 3) from a stream temperature standpoint.

Watersheds with the highest proportion of "high quality" cold-water stream mileage include West Rocky Run (81%), Elm Creek (75%), Hay Creek (75%), and Adolph Creek (69%). In terms of suitable cold-water habitat availability, a considerable gap exists between these four watershed zones and the five others. The percentage of high-quality stream mileage within the remaining five watershed zones is much lower, ranging from a low of 19% (East Rocky Run) to 46% (Upper Midway). These results indicate an uneven distribution of viable habitat for Brook Trout and other cold-water species within the Midway River Watershed. High-quality habitats are localized, existing in patches where natural background features (e.g. underlying geology, springs) supply cold water to nearby streams and land uses are favorable for maintaining natural stream channels and healthy watershed conditions.

Table 4: (Left) Percent of stream mileage within each temperature class; 4=Very Cold, 3= Cold, 2=Cool/Cold, 1=Warm, IMP=Impounded (Right) Percent of stream mileage within general temperature suitability ranges.

% Mileage within Temperature Class

	4	3	2	1	IMP
Lower Midway	20%	9%	21%	45%	5%
Middle Midway	21%	17%	34%	23%	4%
Upper Midway	19%	27%	46%	2%	5%
Anderson Creek	0%	41%	39%	13%	7%
Hay Creek	40%	35%	22%	0%	3%
Elm Creek	62%	13%	25%	0%	0%
West Rocky Run	45%	35%	14%	3%	3%
East Rocky Run	11%	8%	40%	33%	8%
Adolph Creek	64%	5%	31%	0%	0%

Temperature Suitability - Brook Trout

	High Quality	Marginal	Poor	IMP	Grade
Lower Midway	29%	21%	45%	5%	C
Middle Midway	38%	34%	23%	4%	C
Upper Midway	46%	46%	2%	5%	C+
Anderson Creek	41%	39%	13%	7%	C+
Hay Creek	75%	22%	0%	3%	A
Elm Creek	75%	25%	0%	0%	A
West Rocky Run	81%	14%	3%	3%	A
East Rocky Run	19%	40%	33%	8%	D
Adolph Creek	69%	31%	0%	0%	B+

The wide range of cold-water habitat suitability within the Midway River Watershed underscores the importance prioritizing protection and restoration work in areas with high-quality habitats. Section 4.1.7 of this report features recommendations of specific areas to protect within high-priority watershed zones such as West Rocky Run, Hay Creek, and Elm Creek. Several watershed zones remain candidates for restoration work despite exhibiting poor coldwater suitability based on current conditions. In specific cases, poor temperature conditions are the result of localized stressors which can be eliminated or reduced with specific restoration activities. For example, the lower reach of Anderson Creek is currently ditched an impacted by several poor road crossings, resulting in significant increases in water temperature. If this area were restored, the overall water temperatures would drop, dramatically increasing the overall suitability of this watershed.

4.1.7 Coldwater Protection Areas

Reliable inputs of cold water are critical for the survival of Brook Trout and other fish species with a narrow range of thermal tolerance. Common sources of cold water include groundwater springs, small feeder tributaries, or heavily shaded headwaters streams. These areas of "coldwater refugia" protect against harsh environmental conditions (e.g. elevated water temperature) and are well-documented as one of the key landscape attributes affecting fish population dynamics in streams (Schlosser, 1995; Petty, Hansbarger, & Huntsman, 2012). Efforts to identify and protect *existing* critical habitat and refugia areas as an initial option prior to spending large sums of money to *restore* or *construct* habitat, is recognized as a cost-effective and ecologically sound approach to watershed restoration (Roni, et al., 2002).

Water temperature data, field observations (e.g. verification/mapping of groundwater springs), and landscape features were identified through desktop and field reconnaissance for the purpose of creating CPA for the Midway River Watershed. The CPA represent the most reliable, consistent, and ecologically significant sources of cold water within the watershed based on available data. CPA were mapped as linear stream segments or polygon features that encompass groundwater springs and surrounding groundwater recharge areas (e.g. wetlands, soils with high infiltration rates).

A total of 59 CPA were identified across the Midway River Watershed. Linear stream segments with exceptionally cold water temperatures accounted for 17 of the CPAs, while the remaining 42 CPA define areas with ecologically significant groundwater springs, wetlands, and geological features linked to infiltration and groundwater recharge (e.g. gravel deposits upgradient of known springs). Watershed Zones with the highest number of CPA include West Rocky Run (13), Hay Creek (11), Adolph Creek (7), Elm Creek (6), and Middle Midway (6). Anderson Creek (1) and East Rocky Run (3) Watershed Zones contained the fewest number of CPA identified through this monitoring effort, however, localized areas of excellent coldwater habitat do exist in both subwatershed areas.

Monitoring data (temperature and fish community), as well as anecdotal observations near the CPA, clearly support their important role in sustaining populations of Brook Trout and other coldwater-dependent species in the Midway River Watershed. Large numbers of Brook Trout were frequently observed near many of the CPA features during periods of thermal stress, particularly the summer of 2021, which brought severe drought conditions and elevated summer air temperatures to the region (Figure 19).

Figure 19: Location of Coldwater Protection Zones (pink highlighted areas) identified within the Midway River Watershed

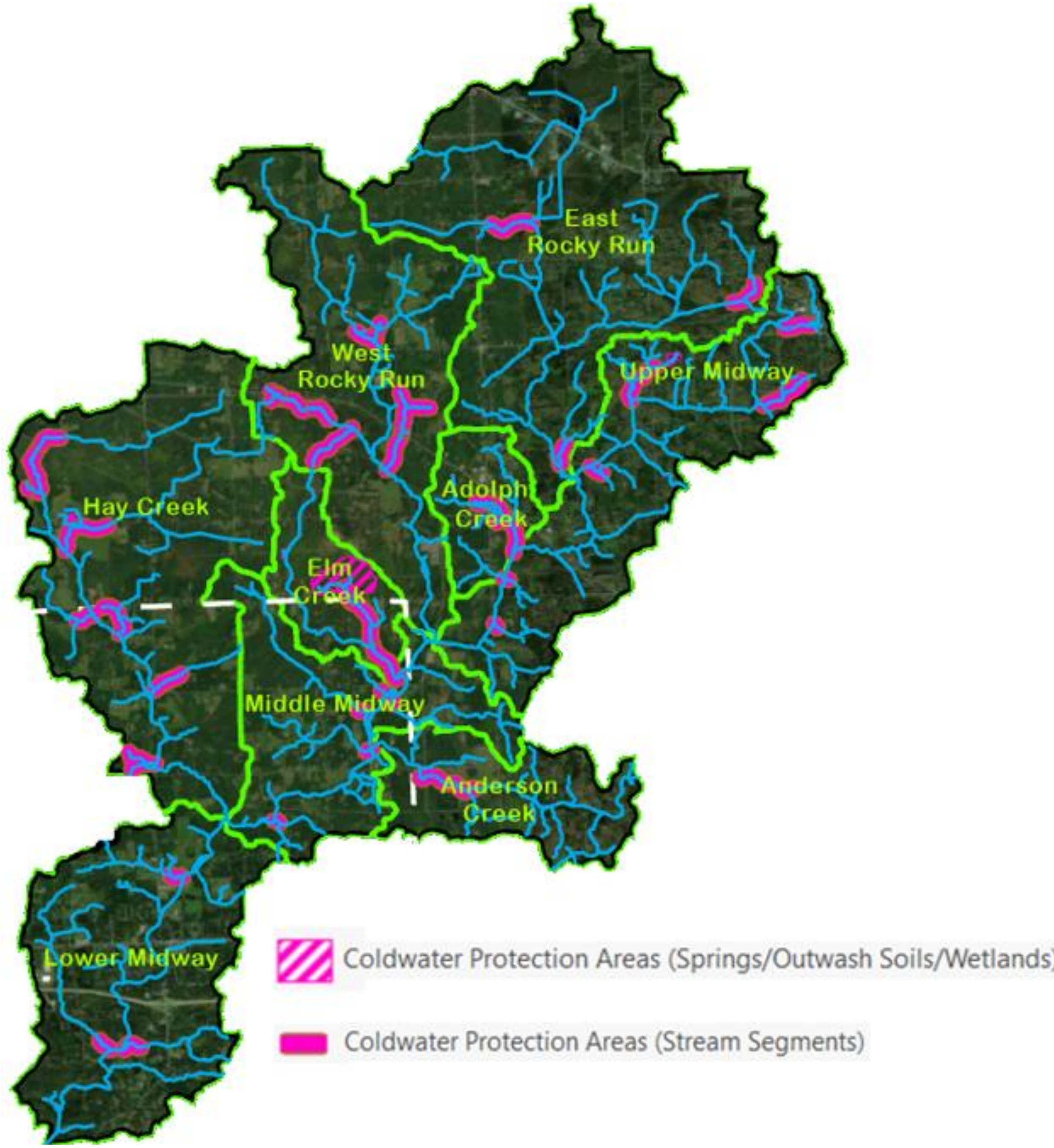


Figure 20: Examples of CPA in the Midway River Watershed. (Left) Reach J1-011 of West Rocky Run is fed by numerous groundwater springs. Note watercress growths in the channel indicating strong groundwater presence. (Right) Reach K2-005 of Adolph Creek. Small spring-fed tributaries like this remain suitable for Brook

Trout year-round and provide thermal refuge during mid-summer months, productive spawning in the fall, and rearing habitat in the winter/spring

Most of the land within the Midway River Watershed falls under private ownership and all CPA identified are located on private property. Many of the tributary streams categorized as CPA are protected as public waters of the state and allow some level of access for fishing access. Currently, DNR and Trout Unlimited are pursuing additional fishing access easements based on some of the information used to map and prioritize CPA. Efforts to foster relationships between local conversation agencies and private landowners and proper land stewardship practices must be adopted to protect these critical habitat features. The following list provides several options for furthering efforts to protect or restore CPA identified in this watershed:

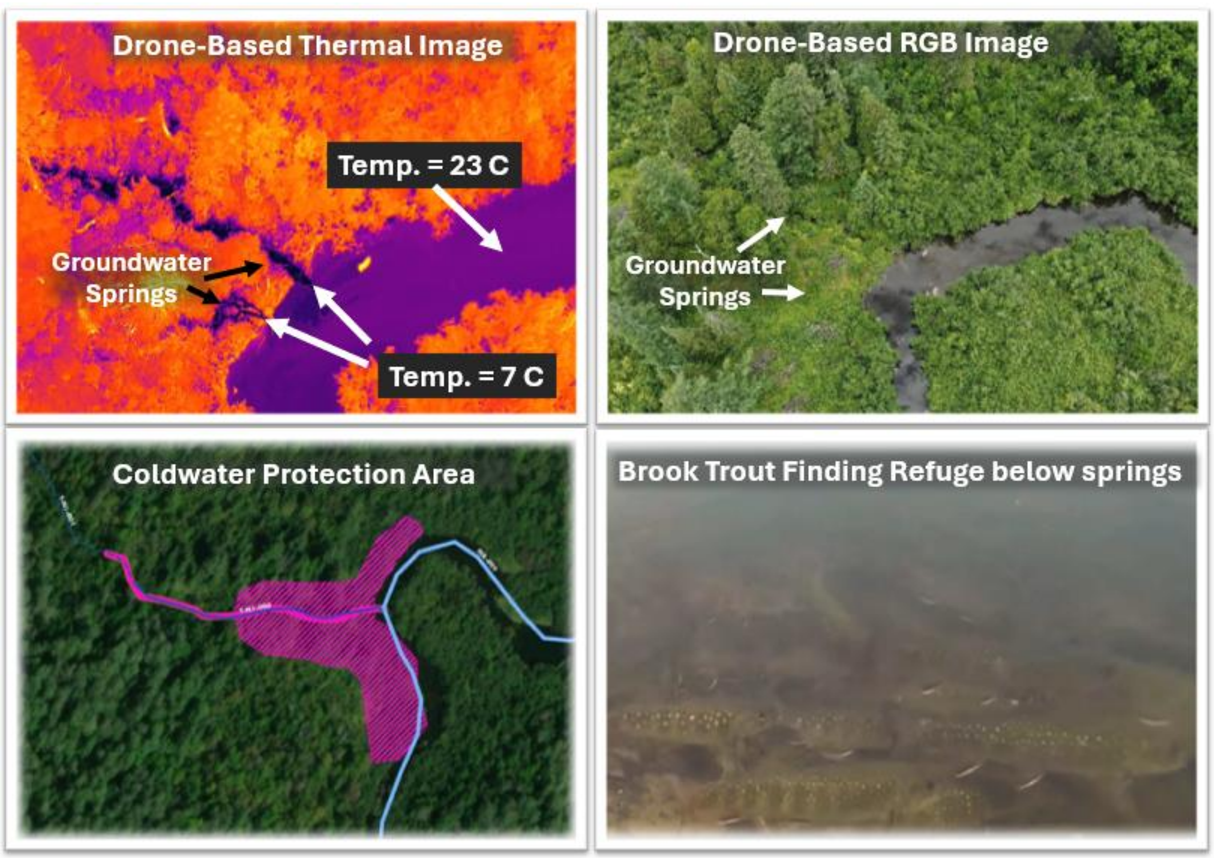
- Establish Fishing Easements and Aquatic Management Areas around CPA's
- Engage with landowners to identify, protect, or restore critical habitats within CPA on private property
- Land acquisition around CPA by government or private conservation organizations (e.g. Minnesota Land Trust)
- Map and protect CPA through local water planning efforts, city planning, and local ordinances
- Continue monitoring efforts to detect and mitigate degradation of CPA and add to CPA inventory

4.1.8 Drone-Based Thermal Imaging

The use of Unmanned Aerial Vehicles (UAV or "drones") equipped with thermal imaging capability is emerging as an efficient means of detecting cold groundwater springs and tributaries. The MPCA started using this technology during the final season of data collection for the MRWPS (2021). On several mid-summer afternoons, pilots targeted specific locations known to contain prominent coldwater features, capturing imagery used to validate and visually depict critical thermal refugia for Brook Trout. Drone-based thermal imagery can offer numerous benefits over collecting temperature data through conventional methods (e.g. hiking in for wading measurements or continuous logger deployment). One of the most useful benefits is the ability to visually portray the spatial extent and magnitude of coldwater refugia in water bodies, an element that is difficult to derive from standard monitoring techniques.

The images in Figure 21 show the Midway River receiving extremely cold groundwater from springs and a spring-fed perennial tributary entering from the river-right side (left-hand side of the images). Water temperature in the Midway River (23°C) was well above the "stress" threshold for Brook Trout (20°C) and approaching "lethal" values (>25°C) at the time of this drone flight in August of 2021. On the contrary, the springs and tributary were delivering cold water to the Midway River at a temperature of 7°C, depicted by the ink-colored plume of water shown entering in the thermal image. Several years of continuous monitoring data from this tributary area confirm that water temperature and flow rates in the spring and spring-fed stream are extremely cold and do not fluctuate. These reliable, constant inputs of extremely cold water are vital for sustaining Brook Trout populations in this portion of the watershed. This is demonstrated by the photo in lower right-hand corner of Figure 21, which shows a large number of trout taking refuge below this spring and tributary stream on a hot afternoon in August 2021.

Figure 20: Drone imagery (thermal and RGB), Coldwater Protection Area (CPA), and underwater footage of Brook Trout collected at a bend of the Midway River fed by numerous groundwater springs. Protection of these areas is paramount for the preservation of Brook Trout and other coldwater species in this river system.



4.1.9 Water Temperature Summary/Recommendations for Protection and Restoration

Streams of the Midway River Watershed support a wide range of water temperature conditions, ranging from extremely cold, climate resilient spring-fed trout streams, to warmwater habitats, which are seasonally unsuitable for Brook Trout and other coldwater obligate species. The temperature data, mapping products, and discussion presented in the MRWPS provide the most robust overview of thermal conditions in the Midway River Watershed to date.

Protection actions should initially focus on the highest quality coldwater habitats identified through the MRWPS. CPAs within the West Rocky Run, Elm Creek, Adolph Creek and upper Hay Creek watershed zones are top priorities for protection (Figure 19). The coldwater habitat found within these watershed zones is top tier both regionally and on a statewide scale. On a more localized scale, the CPA identified along the Midway River mainstem corridor are also critical for sustaining Brook Trout populations moving within the Midway River and confluence areas. Examples include Tributary N1-001, Tributary B1-001, and named tributaries such as Adolph Creek and Elm Creek.

Following efforts to protect the highest quality habitats, attention should shift towards areas trending towards warming and degradation. Anderson Creek, East Rocky Run, Midway River mainstem, and to a lesser extent, localized areas of Hay Creek (extreme lower reaches) were all identified as containing coldwater habitats vulnerable to warming and future extirpation of Brook Trout populations. Maintaining and improving stream connectivity, a topic covered in detail in Section 4.3, will be an important conservation approach near these marginal and vulnerable habitats. Enhancing stream connectivity enables Brook Trout and other coldwater species to freely move throughout the watershed and access reliable thermal refugia.

A detailed discussion of temperature conditions and specific protection strategies for each watershed zone is included in Appendix A1.

4.2 Streamflow and Baseflow Index Calculations

Streamflow, or the amount of water moving within a river channel, is critical for maintaining the physical, chemical, and biological processes needed to support aquatic life. Water flowing in streams is the result of hydrological processes occurring above and below the surface of the landscape. Water entering streams through pathways above the earth's surface is considered *surface runoff* and occurs when water volumes from rain and snowmelt exceed the infiltration and storage capacity of the soils. Precipitation that does not exceed the infiltration capacity penetrates the soil and eventually reaches streams and rivers as subsurface stormflow or as groundwater.

Most rivers and streams continue to flow during periods of no rainfall. These streams are categorized as perennial (i.e. always containing water) as opposed to intermittent (i.e. seasonally/occasionally contain water). Baseflow is the sustained portion of streamflow originating from groundwater discharge. This groundwater discharge from the water table into the stream accounts for baseflow in perennial streams during periods without precipitation. The streams of Northeastern Minnesota are typically regarded as "baseflow limited" or lacking significant groundwater sources. While this is generally the case in comparison to southeast Minnesota heavily groundwater-fed rivers and streams, areas of the Midway

River Watershed support abundant groundwater springs and perennial streams heavily influenced by significant groundwater discharge.

In addition to supplying a source of perennial flow, groundwater discharge to streams are almost always significantly colder than surrounding surface waters and exhibit little to no temperature variation in response to changes in ambient (surrounding) conditions. As a result, groundwater inputs play a critical role in sustaining populations of trout and other stenothermic (organisms that can only survive within a narrow range of temperatures). The importance of groundwater in supporting perennial streamflow and cold water temperatures in the Midway River, particularly within small tributary streams, is discussed in detail in sections 4.2.3 and 4.1.7.

4.2.1 Midway Flow Measurement Methods

Baseflow conditions were measured synoptically (i.e. broad spatial scale, narrow temporal scale) throughout the watershed during critical low flow (i.e. baseflow) periods in 2018 and 2020. Flow measurement transects were established at 35 locations and measurements were collected one to two times at each location using a wading rod and FlowTracker handheld meters. All stations were visited within the shortest time-frame possible (over the course of one to two days) to create a watershed and subwatershed scale “snapshot” of baseflow conditions.

Flow data were collected for the purpose of calculating a BFI for a subset of perennial streams of various sizes throughout the watershed. BFI values were calculated by dividing the measured discharge (ft^3/second) by the contributing surface drainage area (sq. miles) to the flow station. The resulting ratio (i.e. BFI value) provides a coarse means of comparing proportions of groundwater-derived baseflow between the monitoring stations. The BFI values are intended to provide a relative estimate of groundwater contribution. Further flow monitoring, chemical analysis, and mapping of subsurface groundwater basins contributing would be required for more accurate understanding of groundwater-surface water dynamics.

4.2.2 Flow Measurement Results and Baseflow Index Value Calculations

BFI values ranged from a high of 3.985 (station E9-001, Trib. To Hay Creek) to a low of 0.00 (two unnamed tributaries to the Midway River (AB-001 and DD-001). The 0.00 values at lower end of the scale represent streams with no measurable flow velocities or streams with completely dry stream channels during baseflow conditions. Streams listed in the upper range of BFI values in Table 5 can be considered significantly influenced by groundwater discharge, a conclusion corroborated by cold water temperatures measured at all of these locations. For example, station E9-001 is small tributary to Hay Creek fed by prominent groundwater springs (Figure 22).

Flow monitoring stations within the Elm Creek, West Rocky Run, Hay Creek, and Adolph Creek Watershed zones generally produced the highest BFI values. Accordingly, these areas also contain many of the coldest streams and largest populations of Brook Trout observed during the MRWPS investigation. However, select tributary streams within these areas generated lower BFI scores, indicative of much lower groundwater inputs (J13-004, E12-001, K1-005, Table 5). This observation proves groundwater inputs can be localized and highly variable even in areas of the watershed with significant groundwater signals.

BFI values from the 35 stations were used to categorize streams as spring-fed, baseflow-limited, or neutral and by stream drainage area size (headwaters, medium-sized, or large-sized) (Figure 22). Streams plotting in the neutral category exhibited moderate baseflow values but were not outliers in either direction based on the overall trendline for the watershed, suggesting the presence of groundwater discharge in lower volumes proportionate to their drainage area in comparison to spring-fed streams.

4.2.3 Baseflow Index Summary/Recommendations for Protection and Restoration

Protection strategies are recommended near streams with high BFI values to preserve existing groundwater to surface water exchange. Natural groundwater upwellings and spring-fed streams should remain unmodified by dredging, channelization, or impoundments. Additional strategies may include reducing or eliminating development, timber harvest, and/or mineral extraction near these locations. Not coincidentally, many of the streams with high BFI values streams are in areas dominated by gravel-outwash soil types, which tend to promote infiltration and groundwater replenishment and delivery to nearby waters. Gravel extraction operations are clustered around many of the streams with BFI values and may alter processes that sustain groundwater recharge and delivery to surface waters. No specific monitoring studies have been conducted to investigate potential impacts of gravel mining on streamflow or water temperatures in the Midway River Watershed. However, gravel extraction can alter subsurface groundwater flow volume and pathways and therefore have the potential to impact nearby surface waters.

Critical groundwater areas requiring additional protections are listed in Appendix A2. As previously mentioned, many of these areas are geographically linked with the CPA identified in Section 4.1.7 of this report. Streams identified as *baseflow limited* in Table 5 can considered vulnerable to flow related stressors. Further alteration of the drainage areas feeding these water bodies are likely to exacerbate the problem of limited baseflow (e.g. ditching, small impoundments, addition of impervious surfaces). Restoration and protection strategies to increase infiltration rates and surface-water retention are recommended in both baseflow-limited and spring-fed areas. Examples include wetland reclamation and protection, stream channel and floodplain restoration, and green infrastructure projects to reduce stormwater runoff (e.g. rain gardens).

Figure 21: Scatterplot of measured baseflow vs. contributing drainage area at 35 locations throughout the Midway River Watershed. Data points categorized based on relationships between these variables (hash-marked grouping) and location within the watershed (color of markers)

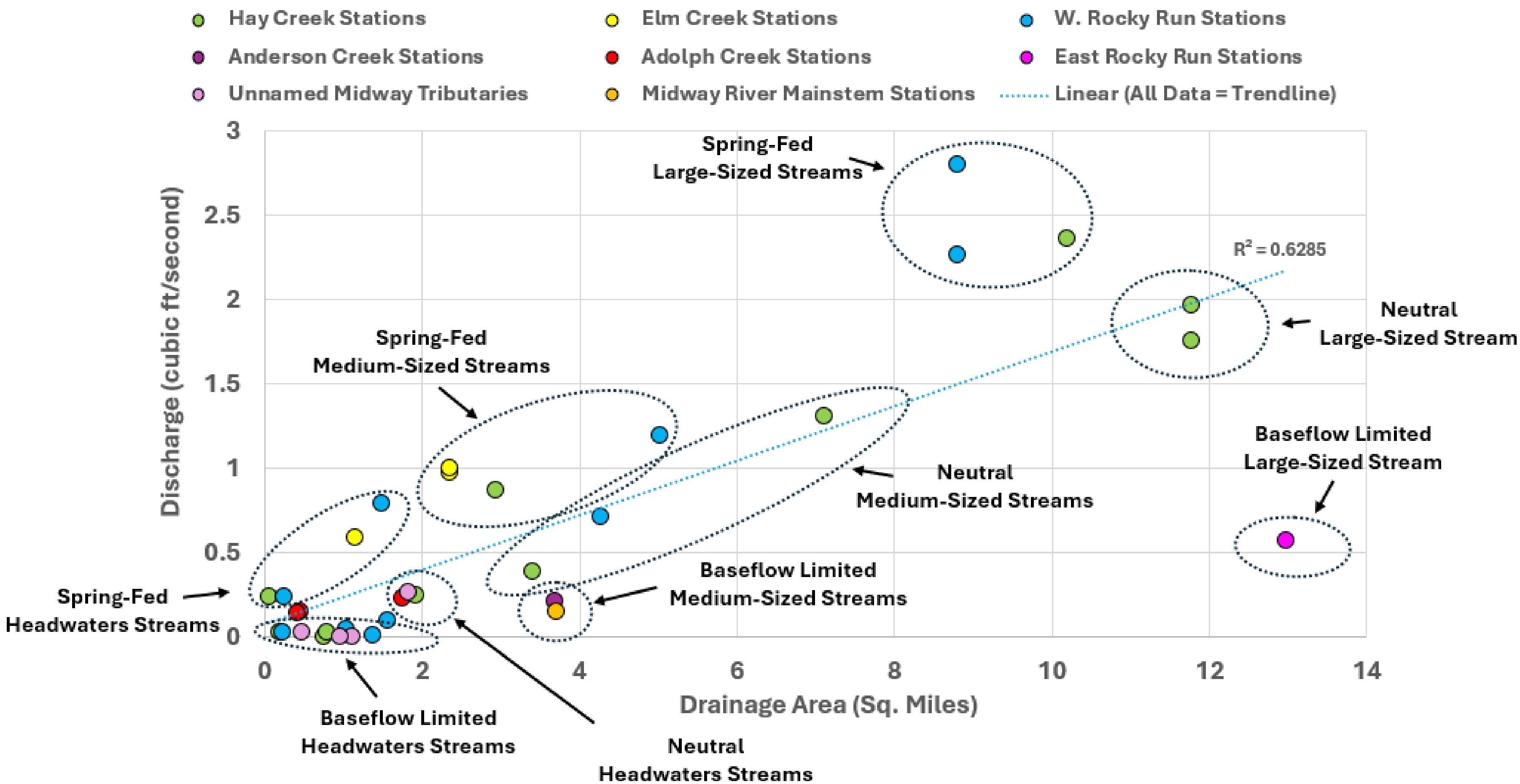


Figure 22: Hay Creek Tributary E9-001 recorded the highest BFI value of the 35 stations monitored. Gravel mining operations near this tributary have the potential to alter groundwater movement and reduce overall groundwater input to this tributary and the main stem of Hay Creek.

Table 5: Baseflow discharges and BFI Values measured at monitoring locations within the Midway River Watershed. Baseflow Index = Measured Discharge/Drainage Area and Baseflow Index Category is based on the data plot show in Figure 22.

Visit Date	Watershed Zone	Stream	Station/Reach	Drainage Area (mi^2)	Total Discharge (ft^3/sec)	Baseflow Index*	Baseflow Index Category
8/18/20	Hay Creek	Tributary E9	E9-001	0.1	0.239	3.985	Spring-Fed Headwaters
9/4/20	W. Rocky Run	Tributary J6	J6-004	0.3	0.241	0.963	Spring-Fed Headwaters
9/4/20	W. Rocky Run	Tributary J6	J6-001	1.5	0.792	0.531	Spring-Fed Headwaters
8/19/20	Elm Creek	Elm Creek	I1-003	1.2	0.586	0.505	Spring-Fed Headwaters
8/20/20	Elm Creek	Elm Creek	I1-001	2.4	1.005	0.428	Spring-Fed Medium Sized Stream
7/29/20	Elm Creek	Elm Creek	I1-001	2.4	0.974	0.414	Spring-Fed Medium Sized Stream
9/4/20	Adolph Creek	Tributary K2	K2-003	0.4	0.146	0.356	Spring-Fed Headwaters
9/4/20	Adolph Creek	Tributary K2	K2-002	0.5	0.152	0.338	Spring-Fed Headwaters
7/29/20	W. Rocky Run	W Rocky Run Ck.	J1-002	8.8	2.800	0.318	Spring-Fed Large Sized Stream
8/18/20	Hay Creek	Hay Creek	E1-011	2.9	0.868	0.295	Spring-Fed Medium Sized Stream
9/4/20	W. Rocky Run	W Rocky Run Ck.	J1-002	8.8	2.264	0.257	Spring-Fed Large Sized Stream
9/4/20	W. Rocky Run	W Rocky Run Ck.	J1-008	5.0	1.198	0.239	Spring-Fed Medium Sized Stream
8/18/20	Hay Creek	Hay Creek	E1-007	10.2	2.363	0.232	Spring-Fed Large Sized Stream
8/18/20	Hay Creek	Hay Creek	E1-009	7.1	1.306	0.183	Neutral Medium-Sized Stream
9/4/20	W. Rocky Run	W Rocky Run Ck.	J1-011	4.3	0.714	0.167	Neutral Medium-Sized Stream
8/18/20	Hay Creek	Hay Creek	E1-002	11.8	1.964	0.167	Neutral Large-Sized Stream
7/29/20	Hay Creek	Hay Creek	E1-002	11.8	1.760	0.149	Neutral Large-Sized Stream
7/29/20	Lower Midway	Tributary B	B1-001	1.8	0.262	0.143	Neutral Headwaters Stream
8/18/20	Hay Creek	Tributary E2	E2-001	0.2	0.026	0.132	Baseflow Limited Headwaters Stream
9/4/20	Adolph Creek	Tributary K1	K1-005	1.8	0.230	0.131	Baseflow Limited Headwaters Stream
9/4/20	W. Rocky Run	Tributary J5	J5-004	0.2	0.030	0.130	Baseflow Limited Headwaters Stream
7/29/20	Adolph Creek	Tributary K	K1-005	1.8	0.229	0.129	Baseflow Limited Headwaters Stream
8/18/20	Hay Creek	Hay Creek	E1-013	1.9	0.246	0.127	Neutral Headwaters Stream
8/18/20	Hay Creek	Tributary E12	E12-001	3.4	0.383	0.112	Neutral Medium-Sized Stream
8/21/20	Anderson Creek	Anderson Creek	G1-001	3.7	0.348	0.094	Baseflow Limited Medium-Sized Stream
8/22/20	Anderson Creek	Anderson Creek	G1-005	1.9	0.134	0.071	Baseflow Limited Headwaters Stream
9/4/20	W. Rocky Run	Tributary J13	J13-001	1.6	0.102	0.065	Baseflow Limited Headwaters Stream
7/29/20	Anderson Creek	Anderson Creek	G1-001	3.7	0.211	0.057	Baseflow Limited Medium-Sized Stream
7/29/20	Upper Midway	Tributary Q	Q1-002	0.5	0.027	0.056	Baseflow Limited Headwaters Stream
8/23/20	Anderson Creek	Anderson Creek	G1-008	0.8	0.042	0.052	Baseflow Limited Headwaters Stream
9/4/20	W. Rocky Run	W Rocky Run Ck.	J1-016	1.0	0.046	0.044	Baseflow Limited Headwaters Stream
7/29/20	E. Rocky Run	Rocky Run East	L1-004	13.0	0.570	0.044	Baseflow Limited Large-Sized Stream
7/29/20	Upper Midway	Midway River	MR-019	3.7	0.150	0.040	Baseflow Limited Medium-Sized Stream
8/18/20	Hay Creek	Tributary E6	E6-001	0.8	0.027	0.034	Baseflow Limited Headwaters Stream
8/18/20	Hay Creek	Tributary E10	E10-001	0.8	0.006	0.008	Baseflow Limited Headwaters Stream
9/4/20	W. Rocky Run	Tributary J13	J13-004	1.4	0.008	0.006	Baseflow Limited Headwaters Stream
7/29/20	Middle Midway	Tributary N	N1-002	1.0	0.001	0.001	Baseflow Limited Headwaters Stream
7/29/20	Middle Midway	Tributary H	H1-001	1.1	0.001	0.001	Baseflow Limited Headwaters Stream
7/29/20	Lower Midway	Tributary DD	DD-001	0.2	no water	0.000	Baseflow Limited Headwaters Stream
7/29/20	Upper Midway	Tributary AB	AB-001	0.5	no flow	0.000	Baseflow Limited Headwaters Stream

4.3 Connectivity and Aquatic Organism Passage (AOP)

Stream connectivity refers to the maintenance of lateral, longitudinal, and vertical pathways required to support biological, hydrological, and physical processes (Annear 2004). Watersheds are complex ecosystems with variety of habitat types and critical features. The ability of fish and other aquatic organisms to move freely within a watershed plays a key role in assuring that all critical habitat needs of a species are met, particularly those that are highly dependent on specific habitat to complete their life cycle (Figure 24). Longitudinal connectivity, or the ability of fish and other aquatic organisms to move within and between streams within a watershed, is a critical component of ecosystem resiliency and a primary area of focus within the MRWPS.

Until recently, researchers believed Brook Trout residing within inland waters (not connected to an ocean or large lake) completed their life cycle without long-range movement (Gerking, 1959; Clapp et al., 1990). However, recent studies demonstrate that long-range movements are relatively common within stream resident Brook Trout populations. Gowan and Fausch (1996) observed that 59% and 66% of marked Brook Trout moved at least 50 meters over several months of monitoring, and movements between 2000 to 3400 m (1.2 to 2.1 miles) were detected. In the upper Cheat River Basin in West Virginia, adult Brook Trout commonly undertake large-scale movements between main stem areas and tributaries for the purposes of spawning, feeding, and refuge from elevated water temperatures (Petty et al., 2012). The DNR observed Brook Trout movements of greater than 1-mile in Hockamin Creek after more than 20-miles of river habitat were reconnected by the removal of three fish passage barrier culverts (DNR 2022).

Stream-dwelling fish move for three primary reasons: to feed, to reproduce, and to seek refuge from stressful or lethal conditions (e.g. drought, flooding, elevated water temperatures). Brook Trout within the Midway River Watershed likely move considerable distances for all three of these purposes, particularly individuals inhabiting the main stem of the Midway River for all or part of their life cycle. The Midway River is warmer and more biologically productive than most of its smaller, colder tributary streams. As a result, it produces an abundance of forage (e.g. small fish, insects, amphibians) which provides ample feeding opportunities for Brook Trout, particularly larger adult fish seeking larger prey. However, these individuals must migrate daily or seasonally to colder tributary streams or springs along the Midway River to avoid lethal water temperatures during the summer. Movements are also expected during the fall spawning period, as small tributary streams typically provide more favorable conditions for spawning and rearing compared to larger rivers.

4.3.1 Common Impacts to Connectivity/Habitat Fragmentation

The degree of stream connectivity with a watershed is influenced by a variety of factors, both natural and anthropogenic (i.e. human-caused). Natural features on the landscape, such as impassable waterfalls or large lakes, can alter or eliminate movement of fish and other aquatic organisms. Examples of anthropogenic influences on connectivity include dams, constructed ponds, and stream crossings with culverts installed under roads, driveways, and trails. As more barriers are introduced into the riverscape, fragmentation of habitats often occurs through the transformation of a single continuous habitat into isolated patches. As a result, natural movement of fish and other wildlife between formerly contiguous habitats is reduced or eliminated.

Road culverts, dams, and constructed ponds are ubiquitous barriers to fish movement and known to disrupt critical ecological processes, especially among salmonid species (i.e. trout, salmon). Brook Trout and other salmonids are highly migratory and have strict habitat requirements. These habitat features can be rare and widely dispersed within a watershed, increasing the importance of barrier-free stream networks. One poorly constructed or undersized culvert acting as a barrier to movement within a watershed can eliminate access to many miles of critical habitat.

The MRWPS set the following action steps and objectives for removing barriers to fish movement within the Midway River Watershed; (1) Map and inventory every stream crossing using aerial imagery, (2) Identify crossings potentially limiting connectivity to critical habitat areas, (3) Conduct field assessments of priority crossings, (4) Prioritize barriers for removal using culvert assessment, water temperature, and biological data (e.g. fish surveys).

Figure 23: (Left) The basic life cycle of stream fish with emphasis on patterns of habitat use and migration (from Schlosser, 1991) (Right) Underwater image of Brook Trout on spawning near nest (or redd) dug from clean, coarse gravel substrate

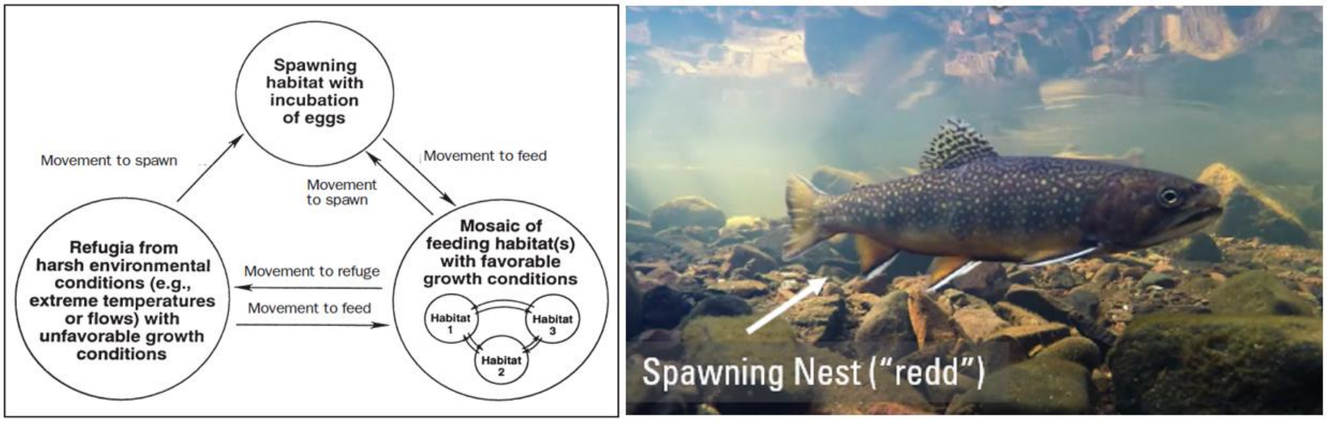


Figure 24: Perched driveway culvert limits fish passage between Midway River and cold tributary stream

Figure 25: Examples of impacts to stream connectivity and aquatic organism passage within the Midway River Watershed. 1) impoundment of Tributary B4-001; 2) impoundment of Tributary AG-005; 3) impoundment of Tributary AI1-002

4.3.2 Crossing Assessment Methodology

After mapping every visible stream crossing in the entire watershed using leaf-off aerial imagery, priority culverts were selected by MPCA and Soil and Water Conservation District staff for further assessment in the field. Priority culverts generally fit one or more of the following characteristics: (1) located on a perennial stream; (2) located on a public road or private property with a public waterway; and (3) located within a subwatershed with high quality habitat conditions. Additional priority culverts located deep within private property parcels were mapped but not assessed due to lack of access. These specific crossings were mapped and flagged as high priorities for future assessment and must be factored into decision-making process for culvert replacement efforts.

Field evaluations of priority stream crossings were completed using the DNR Stream Crossing Basic Assessment Form. This assessment form covers a wide range of parameters related to the condition and potential impacts of stream crossings. For this report, the focus will be on the specific variables most likely to limit fish passage through the crossing. These include culvert sizing and slope, outlet drop height (i.e. outlet “perch height”), alignment, and the physical conditions observed within the culvert (e.g. substrate type, lack of substate, water depth). The following sections describe each of these variables in greater detail.

Culvert Sizing

Proper culvert sizing requires the identification and measurement of a river’s bankfull width, or the width of a river or stream channel measured at the point where the water level reaches the top of the banks and begins to overflow onto the floodplain (Gordon et al. 1992; U.S. Forest Service 2003) (Dunne and Leopold 1978). Bankfull dimensions are typically determined through a combination of field measurements of physical indicators (e.g. depositional flats), hydrological records, or empirical models based on available data for the region of interest. More information on the identification of bankfull dimensions can be found here.

Culverts assessed for this project were assigned one of three ratings based on field measurements of bankfull and culvert dimensions: “appropriately sized”, “undersized”, or “oversized”. Culverts with a total span (width) between 0.8 and 1.5 times the bankfull width of the stream were classified as appropriately sized. For example, an appropriate culvert sizing for a stream with a 10 foot bankfull width could range from 8 feet to 15 feet in width. Appropriately sized crossings have a reduced chance of negatively impacting fish passage, physical habitat, and infrastructure integrity. A crossing with these dimensions relative to bankfull width is unlikely to impede the ability of a stream to move water, sediment, and woody debris (trees, logs) through the crossing at all flow stages, which ultimately preserves the integrity of the stream channel and its ecological function.

Undersized culverts possess a total span less than 0.8 times the bankfull stream width and are typically the most problematic from a fish passage standpoint. During periods of high flow (e.g. bankfull events or larger floods), water passing through undersized culverts is constricted, resulting in unnaturally high current velocities within the culvert. The high current velocities generated inhibit or eliminate fish movement in the upstream direction and often prevent the retention of natural substrates like sand, rock, or silt on the culvert bottom. Additionally, the elevated flow velocities generated by this constriction of flow often create a scouring effect on the downstream side of the crossing, which can cause bank erosion and eventually lead to a culvert outlet becoming perched above the water surface.

Culverts with a total span greater than 1.5 times the bankfull stream width were classified as oversized. Oversized culverts are less common than undersized culverts because the cost of materials and installation is often a limiting factor. Oversized culverts produce excessive channel widths and unnaturally low current velocities, which often results in excess sediment deposition within the culvert and upstream and downstream of the crossing – a process known as stream bed aggradation. Aggradation within oversized culverts can increase physical stress on the culvert and lead to higher maintenance costs due to frequent clean outs. Aggradation of the streambed can also create low-flow fish passage barriers if the flow is too shallow, or the water flows subsurface through the aggraded material.

Outlet Drop/Perch Height

Culvert outlet drop, also referred to as a "perched" culvert, occurs when the structure's outlet is elevated above the water surface on the downstream side of the crossing. This drop can create a turbulent rapid or "freefall" of water depending on the height of the perch and the amount of flow passing through the culvert. A perch is likely to develop if a culvert is installed directly on the surface of the streambed without being "countersunk" or buried properly. The installation of undersized culverts is another common cause of outlet perch. If the structure is sized too small for high streamflow or flooding events, the water passes through at unnaturally high velocities and causes scouring of the channel bed and banks on the downstream side of the crossing. Ultimately, this scouring lowers the elevation of the streambed, leaving the culvert outlet perched above the water surface.

The height of the outlet drop or perch is a key factor in evaluating the degree to which a given crossing restricts upstream fish movement. Additional factors to consider include culvert slope, depth of the pool on the downstream side of the crossing, and the species or age-class of the fish attempting to pass upstream. Swimming and leaping abilities vary widely by fish species and age-class, and functional culvert crossings will fully account for this variability.

A significant body of research and methodologies are available to define relationships between outlet drop height and fish barrier degree (e.g. partial barrier, complete barrier, nonbarrier). For this project, the decision was made to simplify the categorization process. Any culvert outlet with a perch or outlet-drop greater than 0.0 ft was classified as a barrier to fish passage. For the purposes of this report, no distinction was made between partial barrier, complete barrier, seasonal barrier. However, the height of culvert outlet drops were measured in the field and can be factored into decision making processes related to the prioritization of culvert replacements.

Substrate

Proper amounts of natural stream bottom substrate (e.g. gravel, cobble, sand, silt) within a culvert facilitates fish passage and promotes overall stability of the structure. Substrate provides the "roughness" necessary to reduce water velocities within the culvert and provides hydraulic relief that can be used by fish to rest and recover while progressing upstream. Culverts with appropriate slope and sizing to accommodate both high and low flow conditions are more likely to contain proper amounts of substrate to facilitate fish passage year-round.

Substrate conditions within Midway River stream culvert crossings were evaluated using a "Yes" or "No" criteria based on field determinations of whether the culvert contained adequate substrate to promote fish passage. Crossings with no substrate were deemed barriers to fish passage if the following criteria were met: (1) No substrate observed on culvert bottom and (2) culvert width to bankfull width ratio is less than 0.5.

Culvert Alignment

Culvert alignment refers to the spatial positioning of a culvert relative to the stream or river channel it is crossing. Ideally, culverts should be aligned with the stream channel and its floodplain to maintain natural river hydraulics, sediment transport, and the stability and longevity of the infrastructure in place. Culverts are frequently installed with improper alignment for the purpose of cost-savings or to route a stream away from a developed area. Field investigations and aerial photos were used to evaluate alignment of stream crossings within the Midway River. Although not directly related to fish passage, proper alignment is an important consideration for reducing impacts to aquatic habitat and road infrastructure.

4.3.3 Stream Crossing Assessment Results

A total of 430 stream crossings were identified in the Midway River Watershed using leaf-off aerial imagery and field reconnaissance. Proportionally, based on crossing structure type, 309 (72%) crossings were classified as culvert structures, 26 (6%) crossings were bridges, 93 (22%) were classified as "unknown," and 2 (<1%) were classified as no crossing ("fords"). Crossings under Public Roadways (e.g. state, county, township, city) accounted for 199 (46%) of the crossings identified, followed by Private Access Roads (n=96, 22%), Private Driveways (n=79, 18%), Private Trail (n=23, 5%), Private Railroad (n=22, 5%), and Private-Old Railroad or Road Grade (n=11, 3%).

Of the 430 stream crossings mapped in the Midway River Watershed, 73 crossings were considered both high priorities for assessment and accessible for field evaluation using the DNR crossing assessment form. An additional 39 crossings were identified as a high priority for field evaluations, but access was limited due to private property. Future monitoring efforts in this watershed will prioritize engagement with landowners in the interest of adding these private crossings into the inventory of assessed stream crossings.

Slightly under half of the stream crossings assessed (n=36, 49.3%) were determined to be either partial or full barriers to fish passage. Partial barriers were significantly more common than full barriers, accounting for 78% of the total number of barriers identified. Fish passage barriers were identified on streams crossing under public roadways, private driveways, railroads, and abandoned road grades located on private land. Of these categories, driveway crossings were least likely to be fish barriers (27%) and railroad crossings were the most likely to limit fish passage (60%). Most of the culvert assessments were completed on public roadways (n=56) and just over half of these structures were classified as fish barriers, either partial or full (52%).

Lack of natural substrate (i.e. rock, sand, silt) within the culvert was cited most frequently as a limiting factor to fish passage. Out of the 36 culverts identified as barriers, 33 (92%) of these lacked natural substrate through the length of the crossing. Velocity barriers caused by undersized culverts were cited as a limiting factor in 56% of the fish barriers identified, followed by outlet drop or perched culvert outlet (44%).

Figure 26: Examples of culverts with perched outlets (e.g. outlet drop) within the Midway River Watershed.

Table 6: Criteria used for assessing culvert sizing, water depth and substrate, and outlet drop and fish passage barrier status.

Fish Barrier?	Sizing	Water Depth/Substrate	Outlet Drop
Fish Passage Barrier	**Undersized Culvert** *(Stream* - Culvert Width Ratio <0.80)*	• **Water Depth <0.2 ft** • **No natural substrate present on culvert bottom**	**Outlet Perch Height/Barrier Degree:** • >2.0 ft = Complete Barrier • 0.5 - 2.0 ft = Significant Barrier • <0.5 ft = Partial/Seasonal Barrier
Passable / No Barrier	**Appropriately Sized Culvert** *(Stream* - Culvert Width Ratio 0.80 to 1.5)*	• **Water Depth >0.2 ft** • **Natural substrate present on culvert bottom**	**No Outlet Perch**
Passable / No Barrier**	**Oversized Culvert** *(Stream* - Culvert Width Ratio > 1.5)*		

* Stream width is measured as "Bankfull" stream width (equivalent to the 1.5-year recurrence flood event)
** Oversized culverts often result in sediment accumulation within and around crossing, negatively impacting physical habitat

4.3.4 Prioritization of Culvert Replacements

Potential culvert replacement projects were prioritized using stream crossing assessment results and relevant water quality and habitat data. The overarching goal of replacing fish barrier culvert with passable structures is to eliminate the most significant barriers (e.g. full barriers, significant outlet drop) and reconnect the longest contiguous segments of currently fragmented high-quality aquatic habitat. Variables selected for prioritization scoring included culvert outlet drop, number of upstream miles reconnected, percentage of culvert plugged, culvert width ratio, and flow rating. These variables were weighted differently based on expected impact to fish passage and potential restoration gains that may be achieved through culvert replacement (Table 7).

An initial or base culvert replacement score was calculated using the variables and formula shown in Table 7. A higher score represents a higher priority for replacement. A total of 35 fish passage barriers were scored using these criteria, producing replacement prioritization scores ranging from 2.3 to 711.9. The results were grouped into three tiers to simplify the results and aid in restoration planning. "Tier 1" sites represent stream crossings considered high priorities for replacement. In general, Tier 1 crossings are structures with an outlet perch and a significant number of stream miles upstream available for re-connection. Tier 2 crossings are also likely to have an outlet drop but less overall mileage fragmented by the fish passage barrier. Most Tier 3 crossings do not have an outlet drop, but instead limit fish passage due to being undersized, plugged by debris, or a lack of natural substrate present within the culvert. Tier 3 crossings also generally cause fragmentation of fewer stream miles than Tier 1 or Tier 2 crossings.

The three-tier approach provides a starting point for prioritization based on simple metrics related to culvert condition and stream mileage, but several key factors are not accounted for in the base scoring criteria. In addition to basic crossing assessment data, water temperature, streamflow, and biological monitoring data were also factored in for the purpose of prioritizing implementation work (e.g. culvert replacements). This was accomplished by applying a "stream quality adjustment" to the prioritization score. To calculate the final replacement prioritization score, the base prioritization score was multiplied by factors of 1 (low stream quality), 1.5 (moderate stream quality), 2 (high stream quality), and 3 (very high stream quality). Key attributes of streams adjusted for high and very high quality include cold water temperatures, healthy populations of naturally reproducing Brook Trout, consistent baseflow (e.g. drought-resistance), and quality physical habitat.

The examples shown in Figure 28 highlight the importance of stream quality adjustments on the overall stream crossing prioritization scoring. The culvert crossing on Tributary H1 at Larson Road is extremely undersized (low culvert/Bankfull ratio), perched by 0.50 ft, and blocks access to 2.51 miles of upstream habitat. The crossing is a full barrier to fish passage and initially ranked in the upper 50th percentile of priority replacements (15th of 35). However, this tributary has limited baseflow and functions as an intermittent stream during periods of limited precipitation. As a result, the stream quality adjustment assigned to this stream was "low" and the score was multiplied by a factor of 1, with no change to the overall score. In contrast, the overall prioritization scores and rank of the other two examples included in Figure 28 increased due to a Stream Quality Adjustment Factor of "Very High" and base scores were multiplied by a factor of "3." These two crossings are located on high quality streams with cold water temperature, quality physical habitat, and healthy populations of naturally reproducing Brook Trout.

A complete list of stream crossing replacement prioritization scores is included in Appendices A3 and A4. Most priority culverts for replacement are located on tributary streams to the Midway River, however, the highest ranked crossing overall is located on the main stem of the Midway River at Midway Road (see photo in Figure 27). This crossing blocks access to 60.2 miles of upstream habitat when factoring in Midway River main steam and tributary mileage. Tributary streams with multiple priority culvert replacements listed in the top 10 of the overall rankings include Elm Creek, West Rocky Run Creek, and Hay Creek. An additional 16 stream crossings were identified as high priorities for assessment but were not evaluated as part of this study due to lack of access to private property. Landowner engagement and field evaluation of these crossings is recommended to obtain a complete picture of priority culvert replacements in areas of the Midway River Watershed with high restoration potential. A table of the remaining high priority crossings in need of field evaluation are listed in Appendix A5.

Table 7: Culvert assessment variables, weighting criteria, and prioritization formula

Variable	Definition	Priority Weighting
Outlet Drop	Culvert outlet drop or perch (feet)	50
Upstream Miles Re-Connected	Number of stream miles re-connected	10
% Plugged	% of culvert plugged by debris or sediment	10
Culvert Width Ratio	Culvert Width / Stream Bankfull Width	Denominator
Flow Rating	Perennial Stream or Intermittent Stream	Denominator
Prioritization Formula: (50 x *Outlet Drop (ft)* + 10 x *Upstream Miles Re-Connected* + 10 x *% Plugged*) ÷ **Culvert Width Ratio** ÷ **Flow Rating**		

Table 8: Descriptions of criteria used to develop Stream Quality Adjustment factor score

Stream Quality Adjustment	Definition	Adjustment Factor *
Very High	Very cold water temperature, consistent streamflow, high quality habitat, Brook Trout and other cold water fish species abundant and sustained by natural reproduction	**3**
High	Cold water temperature, consistent streamflow, quality habitat, Brook Trout and other cold water fish present and sustained by natural reproduction	**2**
Medium	Cool or warm water temperature, perennial streamflow but very low flow rate, habitat limited or slightly degraded, Brook Trout or other cold water fish species may be present but in very low populations	**1.5**
Low	Warm or cool water temperature, limited or intermittent/ephemeral streamflow, habitat limited or slightly degraded, Brook Trout and other cold water fish species mostly absent	**1**
*** Adjustment factor is multiplied by crossing replacement prioritization score**		

Figure 27: Culvert assessment variables, base prioritization rank, and adjusted prioritization rank (Stream Quality Adjustment) for three Midway River Watershed stream crossings

	Tributary H1 @ Larson Rd.	Tributary J6.1 – US HWY 2	Elm Creek (Trib. I1) @ Private Drive
Outlet Drop (Ft.)	0.50	0.25	0.00
Upstream Mileage Reconnected	2.51	0.91	5.79
% Plugged	5%	10%	50%
Culvert Width/Bankfull	0.48	0.75	0.35
Flow Rating	2	1	1
Prioritization Base Score (Rank)	52.6 (15^{th} of 35)	30.1 (24^{th} of 35)	180.8 (5^{th} of 35)
Stream Quality Adjustment Factor	1	3	3
Final Score (Rank)	52.6 (21^{st} of 35)	60.2 (11^{th} of 35)	543 (3^{rd} of 35)

4.3.5 Stream Impoundments and Artificial Ponds

Artificial impoundments (e.g. dams, berms) and ponds constructed in lotic (flowing) riverine habitats have the potential to cause increases in water temperature, alter sediment transport process, decrease habitat quality, and reduce or eliminate aquatic connectivity (Ebel and Lowe, 2013; Maxted et al 200). In addition, the transformation stream habitats into pond has been linked to significant disruption of native fish and macroinvertebrate communities, often increasing the abundance of "invader" species which are more tolerant of modified or disturbed habitat conditions (Didham et al 2007). Unless proper permits are obtained, modifications of public waterways, such as dam construction, ditching, or pond creation, is an illegal activity and grounds for financial penalty and mandatory restoration of the impacted habitat. Despite these regulations, modifications of this type are a common impact to watershed health, particularly in semi-rural and rapidly developing areas.

Impoundments and ponds were inventoried throughout the Midway River Watershed using leaf-off aerial imagery and Light Detection and Ranging (LIDAR) DEMs. The ponds and impoundments inventoried for this project were determined to be "in-line" with a visible stream or river (see examples in Figure 26). Many more "off-line" or land locked ponds are present in this watershed, excavated to a depth designed to intercept the subsurface groundwater table to attain standing water. These features do not directly alter the path of surface waters but can impact the quantity and temperature of water in nearby creeks and rivers as groundwater is intercepted before reaching surface waters.

A total of 81 in-line stream impoundments or ponds were identified along the Midway River and its tributary streams. Based on the rate of newly constructed ponds over the past few decades, the overall number has likely increased since the writing of this report. Constructed ponds or impoundments were observed on streams in most of the Midway River Watershed Zones apart from Elm Creek and Adolph

Creek (Table 9). The highest number of these features were documented in the Lower Midway Watershed zone (n=20), Upper Midway Watershed zone (n=18), and East Rocky Run Creek Watershed zone (n=10). East Rocky Run and Anderson Creek Watershed zones had the highest percentage of stream miles impacted by impoundments or ponds (Table 9).

Table 9: Summary of stream impoundments and ponds by Midway River Watershed Zone

Watershed Zone	Watershed ZoneArea (Sq. Miles)	Number of Impoundments/Ponds	Number of Impoundments/Ponds per Sq. Mile	Impounded Stream Length (m)	Total Stream Length (m)	% Impounded/Pond
East Rocky Run	14.25	10	0.7	2186	48859	4.5%
Anderson Creek	3.74	6	1.6	787	19169	4.1%
Lower Midway	8.72	20	2.3	1363	36732	3.7%
Upper Midway	8.37	18	2.2	1234	46238	2.7%
Middle Midway	5.77	5	0.9	683	28187	2.4%
Hay Creek	12.13	9	0.7	830	38831	2.1%
West Rocky Run	9.30	3	0.3	589	31069	1.9%
Adolph Creek	1.82	0	0.0	0	8976	0.0%
Elm Creek	2.35	0	0.0	0	9414	0.0%

As a conservative estimate, roughly 50% the ponds and impoundments identified are located on ephemeral or intermittent streams. Streams of this variety usually do not flow all year round and may only support flowing water when groundwater levels are elevated or after periods of snowmelt or sustained rainfall. These estimates are based on general field observations and/or analysis of aerial imagery, since many of these streams were not assessed using streamflow or water level measurements. The impact of impoundments and ponds on small headwaters streams, even those with ephemeral or intermittent flow, can still be ecologically significant by worsening low or no flow conditions.

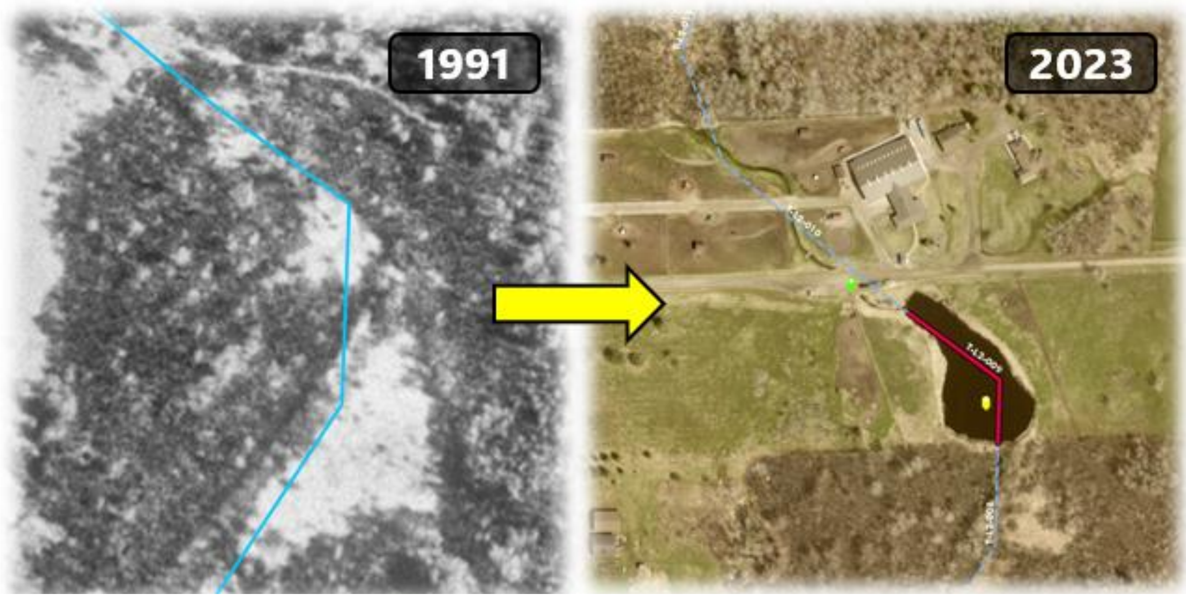
Many of the constructed ponds in the Midway River Watershed occupy areas that were formerly fully functional wetlands and/or groundwater infiltration areas. Natural wetlands and infiltration areas (e.g. forested uplands) are geographically linked to reliable sources of cold water delivered to the Midway River and its many tributary streams. Most of the CPA discussed in Section 4.1.7 are fed by headwaters streams, wetlands, and forested corridors. Disturbing or altering a headwaters stream or adjacent wetlands can seem benign compared to activities that directly impact larger perennial streams and rivers. However, the cumulative impact of removing or altering headwaters stream mileage can have significant consequences for aquatic habitats downstream and overall watershed health. Headwater streams are the smallest parts of river and stream networks but make up the majority of river miles in the United States.

Out of the 81 total impoundments or ponds documented in the Midway River Watershed, 61 were selected for further prioritization as potential restoration projects. Of the total 61 prioritized projects, 6 were given a "high" priority rating for removal via stream channel restoration work. The high priority projects are located on perennial streams (flowing water year-round) and the impoundment was found to be contributing to physical habitat and/or water quality degradation. The remaining projects were given priority ratings of "moderate" (n=19), "low" (n=29), or "very low" (n=11). Most of the projects receiving a low or very low priority ranking are located on extremely small streams with ephemeral or intermittent flow and limited habitat.

The headwaters of the Hay Creek Watershed zone emerged as one priority area for removing impoundments and ponds. This watershed supports many miles of high-quality Brook Trout habitat in large part due to cold water temperatures in its headwaters and numerous tributary streams. The landscape of this watershed is a mix of woodlands, wetlands, private residences, and agricultural land. Ponds and impoundments were identified on numerous private parcels in this watershed zone. Working with landowners to remove these unnatural features will improve water quality, lower stream temperatures, improve streamflow, and eliminate barriers to fish movement. In addition, Hay Creek is listed as an impaired water for elevated *E. coli* bacteria concentrations and several these ponds were identified as potential contributing factors to this impairment.

Projects to remove these unnatural features while restoring altered habitats back to fully functioning streams and wetlands is a cost-effective, low-risk approach to restoring ecosystem health and resiliency. A complete list of impoundments and ponds along with coordinates, restoration priority rankings, and site-specific comments can be provided upon request or viewed in the MRWPS online map (still in development).

Figure 28: Example of an ephemeral/intermittent stream channel converted to a pond (East Rocky Run Tributary L2-009)



4.4 Restoring Channelized (Ditched) Streams

Approximately 41,204 miles of streams in Minnesota (49.6% of the total) have been altered in some manner by humankind. Channelization or ditching is one of the most common forms of stream alteration, a process that reduces overall stream length by removing bends (i.e. meanders) and straightening its course. Streams are often ditched in urban and agricultural areas to reduce flooding potential, facilitate various forms of development within the riparian zone, or minimize infrastructure complexity and cost (see example in Figure 30). The ecological consequences of channelized riverine habitats are numerous. Common impacts include the alteration of natural hydrological processes, higher levels of pollutants entering waterways, degraded habitat conditions, and reduced connectivity. Specific impacts to cold water trout habitats include increased water temperatures, degraded spawning habitat, and reduced cover for adult and juvenile trout.

4.4.1 Quantification of Channelized Streams in the Midway River Watershed

As part of this study, all visible streams in the Midway River Watershed were mapped and categorized as either natural or modified (Figure 31). Stream segments categorized as natural exhibited no sign of historic or recent modification, and retain a pattern, dimension, and profile similar to its pre-settlement condition. On the other hand, stream segments categorized as modified were either channelized at the time of this assessment or exhibited signs of historic alteration, and some level of progression towards re-establishing as a natural channel. Generally, if channelized streams are not routinely maintained, cleaned out, and straightened, the processes of erosion and deposition will begin to reform meander bends, allowing the stream to gradually regain its natural pattern over time.

Further classification of Midway River Watershed streams as perennial or ephemeral (intermittent) was completed to refine the overall impact assessment of channelized stream segments. Although streams of all sizes are frequently channelized, these modifications are more commonly carried out on small headwaters streams, many of which do not support flow year-round. Fully functioning headwaters streams are critical to watershed health, including those with ephemeral stream flow. However, for the purpose of prioritizing potential restoration projects it is important to forecast the underlying ecological potential of channelized streams. The restoration potential of perennially flowing channelized streams will likely be greater, or at least more visible to the public. As a result, channelized segments of perennial streams generally received a higher priority ranking for restoration compared to ephemeral streams.

A total of 271 distinct stream segments were classified as *modified* (channelized) during the desktop evaluation process. Slightly over 80% (218 of 271) of the channelized stream segments identified were located on small headwaters streams either predicted or verified to be ephemeral or intermittent. On the other end of the spectrum, portions of some of the largest perennial streams in the watershed are also channelized. Examples include the lower 0.9 river miles of Anderson Creek (Project ID# 21), Hay Creek adjacent to Canosia Road (Project ID# 29, Figure 30), West Rocky Run Creek upstream of Morris Thomas Road (Project FID# 249 and 250), and Midway River along the railroad tracks near Adolph (Project ID# 44). See Appendix A6 for a complete list of stream channel restoration projects with High and Very High priority ratings.

Channelized streams were observed in all nine Midway River Watershed Zones, but the proportion of natural vs modified channel length within each zone varied widely. Watershed Zones with the highest ratio of perennial (flowing year-round) channelized stream mileage included Anderson Creek (37%), Adolph Creek (34%), and Hay Creek (24%). Lower Midway (1%), Elm Creek (7%), and Middle Midway (7%) were the watershed zones with the lowest percentage of channelized *perennial* stream length. The results change dramatically when including ephemeral and intermittent streams into the analysis. The East Rocky Run Creek Watershed zone contains the highest overall percentage of channelized stream mileage at 48.2% if both perennial and ephemeral stream mileage is factored into the analysis. A significant portion of small headwaters streams in the East Rocky Run Watershed have been channelized to accommodate the rapid rate and scale of residential and commercial development in the city of Hermantown.

Figure 29: These photos show a reach of Hay Creek before (1940) and after (2025) it was ditched for construction of County Rd 1 (Canosia Rd). The stream was straightened and ditched to reduce the number of stream crossings and reduce the active floodplain

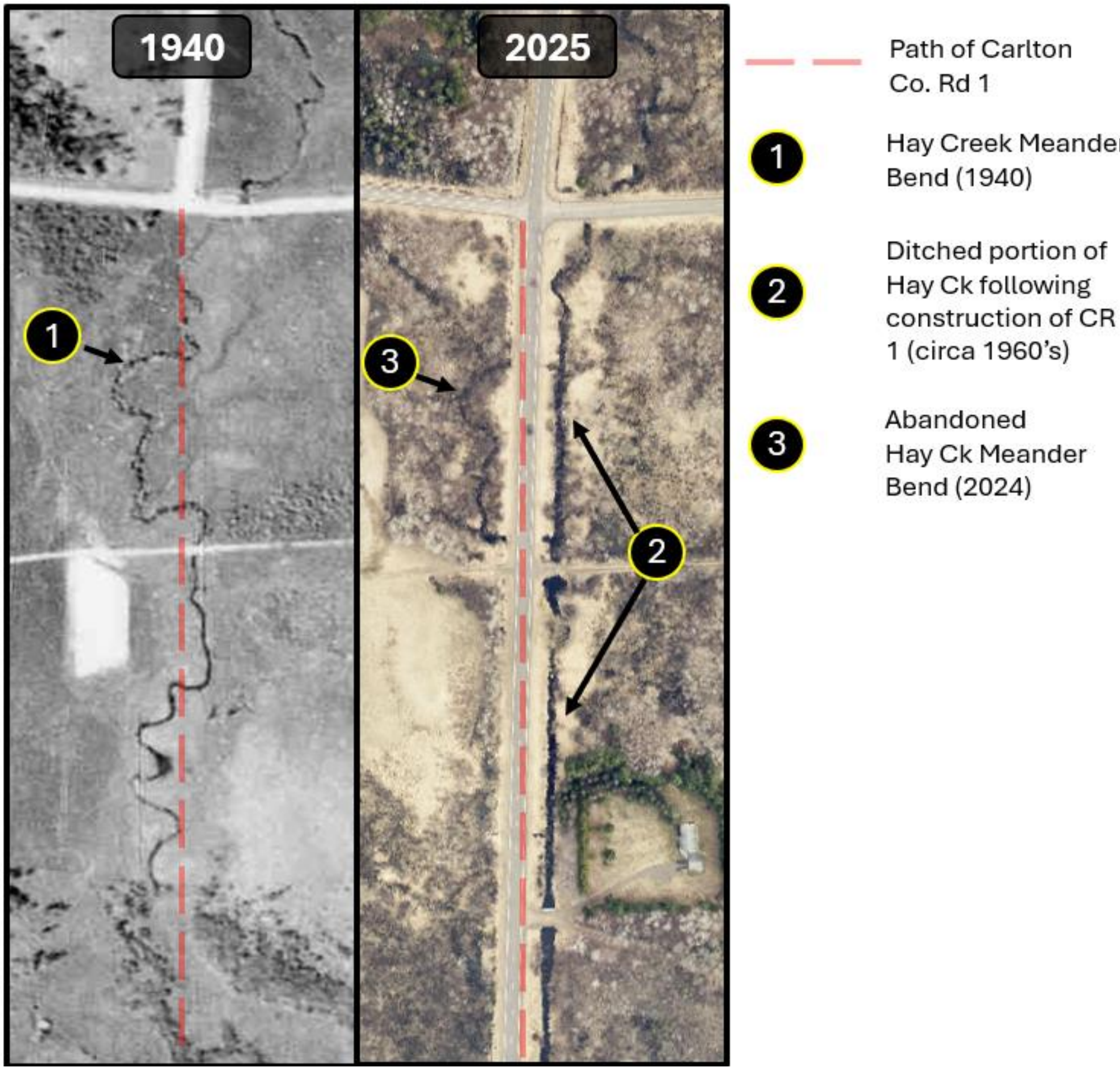


Table 10: Total length of channelized streams and relative percentage (PCT) of channelized (ditched) vs natural stream channel by Midway River Watershed zone.

All Streams (Perennial and Ephemeral)

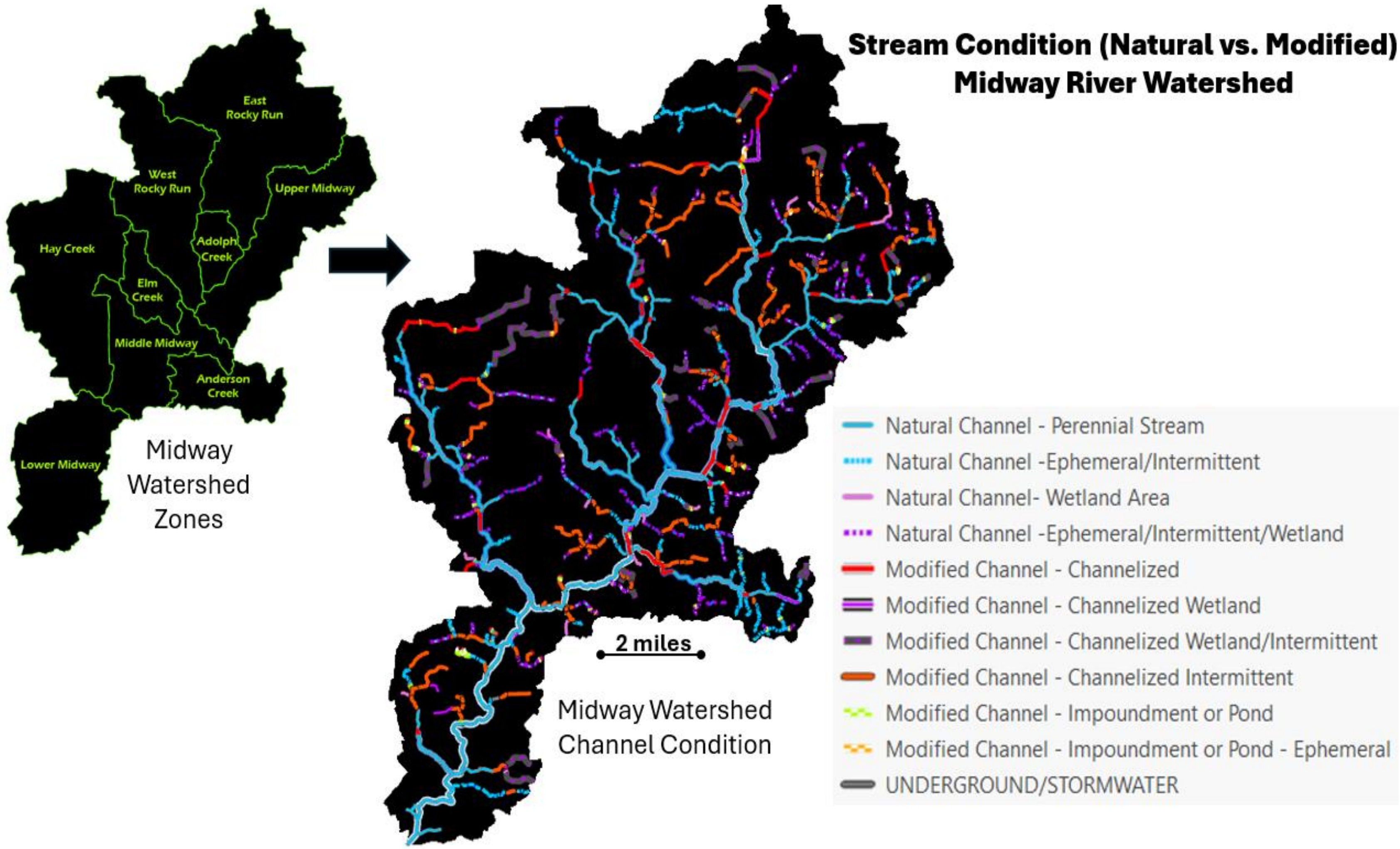
Watershed Zone	Total Length (m)	Natural Length (m)	Pct Natural (Length)	Modified Length (m)	Pct Modified (Length)	Channelized Length (m)	Pct Channelized (Length)	Pct Impounded
Lower Midway	36731	24933	67.9%	11799	32.1%	10390	28.3%	3.2%
Middle Midway	28186	19562	69.4%	8624	30.6%	8108	28.8%	1.8%
Upper Midway	46238	31169	67.4%	15069	32.6%	14017	30.3%	2.3%
Anderson Creek	19168	13533	70.6%	5634	29.4%	4847	25.3%	4.1%
Hay Creek	38832	23322	60.1%	15510	39.9%	14575	37.5%	2.4%
Elm Creek	9415	8919	94.7%	495	5.3%	495	5.3%	0.0%
West Rocky Run	31070	20642	66.4%	10427	33.6%	10188	32.8%	0.0%
East Rocky Run	48859	25315	51.8%	23544	48.2%	21176	43.3%	4.8%
Adolph Creek	8976	5557	61.9%	3419	38.1%	3389	37.8%	0.3%

Perennial Streams Only

Watershed Zone	Total Length (m)	Natural Length (m)	Pct Natural (Length)	Modified Length (m)	Pct Modified_(Length)	Channelized Length (m)	Pct Channelized	Pct Impounded
Lower Midway	16159	16003	99.0%	156	1.0%	156	1.0%	0.0%
Middle Midway	9121	7869	86.3%	1252	13.7%	826	9.1%	4.7%
Upper Midway	17028	12393	72.8%	4635	27.2%	3681	21.6%	5.6%
Anderson Creek	5843	3672	62.8%	2171	37.2%	2171	37.2%	0.0%
Hay Creek	18456	13119	71.1%	5337	28.9%	4507	24.4%	4.5%
Elm Creek	6660	6166	92.6%	495	7.4%	495	7.4%	0.0%
West Rocky Run	17976	15029	83.6%	2947	16.4%	2773	15.4%	1.0%
East Rocky Run	17694	12133	68.6%	5561	31.4%	4165	23.5%	7.9%
Adolph Creek	2062	1363	66.1%	699	33.9%	699	33.9%	0.0%

Least Impact — Most Impact

Figure 30: Stream channel condition (Natural vs. Modified) and type (Ephemeral, Perennial, Wetland) within the Midway River Watershed (data sources circa 2015-2022)



4.4.2 Prioritization of Restoration Projects – Channelized Streams

Stream restoration projects adhering to Natural Channel Design (NCD) principles provide an opportunity to uplift the ecological and physical function of channelized streams. NCD relies upon the principles of fluvial geomorphology and the use of unimpacted "reference reaches" to restore impacted stream channels to a stable pattern, profile, and dimension. If properly designed and constructed, NCD restorations result in a natural, self-sustaining stream channel that provides valuable hydraulic (water transport), geomorphic (sediment erosion and transport) and ecological (habitat, water quality) function back to the project area. NCD projects have restored previously channelized segments of several trout streams near the Midway River Watershed. As part of this investigation, channelized stream segments were evaluated and prioritized for potential NCD restoration work.

Out of 271 channelized stream segments identified in the Midway River Watershed, 34 potential locations were reviewed and prioritized for possible restoration work. Potential projects were ranked based on ecological uplift potential, factoring in a range of underlying site conditions likely to support or hinder restoration outcomes. High priority locations generally supported cold water temperatures, Brook Trout within or near the stream reach, perennial flow, and fair physical habitat conditions that would likely support sensitive fish and macroinvertebrate species after restoration. Low priority locations were predicted to have little to no uplift potential due to natural background factors such as low streamflow and/or limited physical habitat (e.g. complete lack of coarse stream substrate, naturally limited oxygen levels due to wetland influence).

High priority ranking for NCD restoration were assigned to 14 channelized stream segments. The majority of the high priority projects are in areas with excellent cold water fish habitat upstream or downstream of the proposed location, which will facilitate re-population of the restored reach with desirable native species such as Brook Trout, Mottled Sculpin, and sensitive minnow species typically found in high-quality habitats (e.g. Longnose Dace). High priority projects are weighted heavily towards the following watershed zones due to high uplift potential; Hay Creek, West Rocky Run Creek, Adolph Creek, and the Upper Midway River. Final prioritization rankings for all potential stream channel restoration projects can be found in Appendix A6.

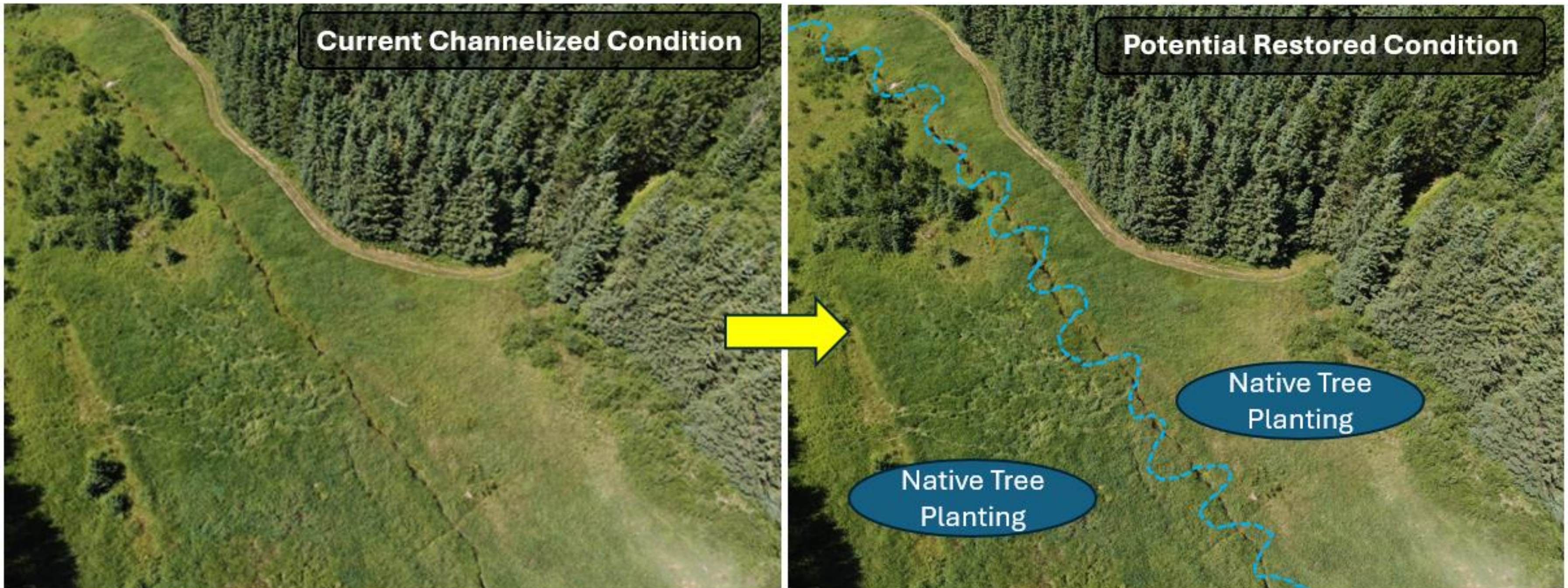
In some cases, Brook Trout and other favorable cold water species were observed in channelized stream segments receiving high prioritization rankings for restoration. However, populations were lower than expected, and tolerant or unfavorable fish species were often found co-inhabiting these impacted areas along with Brook Trout. For example, Brook Trout were sampled in moderate numbers within a channelized headwaters reach of Hay Creek, but several tolerant species such as Central Mudminnow, Fathead Minnow, Creek Chub, and Brook Stickleback were also present in high numbers, indicating a departure from the potential reference condition (e.g. undisturbed condition, natural or nonchannelized stream channel). Figure 32 depicts a hypothetical stream restoration project to re-meander this channelized portion of Hay Creek and the predicted response within the fish community. As habitat conditions are improved through restoration work, the number of Brook Trout present would likely increase, coupled with a decrease in the relative abundance of tolerant species and individuals.

4.4.3 Restoring Channelized Streams/Recommendations for Protection and Restoration

Stream channel restoration can be financially expensive and involves considerable ecological risk, as engineers and biologists are tasked with the responsibility of re-constructing natural watershed processes governed by complex hydrological, geomorphological, and biological factors. Directing these efforts towards channelized streams removes some of the uncertainty in deciding whether stream restoration is warranted or if projected outcomes will be worth the investment. Channelized streams represent the most degraded lotic (flowing water) habitats within a watershed, altered by direct human intervention to modify them from their original state, in the process removing most of the natural processes integral to sustaining high quality aquatic communities.

A complete list of high priority restoration projects focused on restoring channelized streams using NCD principles is presented in Appendix A6. Project construction costs, feasibility, complexity, and landowner relations are important considerations in deciding which to fund and implement. These considerations were factored into the priority ranking process, but additional work will be required to finalize local priorities and the overall feasibility of the recommended projects.

Figure 31: Hypothetical and simplified restoration schematic for a ditched headwaters reach of Hay Creek. Re-meandering this channelized section adds stream length and would improve habitat conditions by increasing the quantity and quality of pools, riffles, runs, fish cover, and coarse stream substrates. In response, the fish community would shift towards supporting larger populations of sensitive coldwater species and fewer tolerant species.



Hay Creek – Station 19LS141 (Sampled June 20, 2019)

Common Name	Number	Length Min (mm)	Length Max (mm)
pearl dace	4	45	57
northern redbelly dace	4	34	40
creek chub	20	65	145
central mudminnow	36	44	84
brook trout	11	38	220
brook stickleback	8	54	64
fathead minnow	2	35	46

Potential Fish Community Post Restoration? - Hay Creek – Station 19LS141

Common Name	Number	Length Min (mm)	Length Max (mm)
pearl dace	4	45	57
northern redbelly dace	4	34	40
creek chub	8	65	145
central mudminnow	1	44	44
brook trout	50	38	220
brook stickleback	1	54	54
~~fathead minnow~~	~~2~~	~~35~~	~~46~~

Blue = Neutral Species   Green = Sensitive Coldwater Species   Red = Tolerant Species

4.5 Protecting Unmapped Streams and Seasonal Habitats

Minnesota contains an abundance of water in the form of lakes, open water wetlands, rivers, and small streams. Over the years, considerable efforts have been taken to map, inventory, and monitor waterways across the state. Various stream mapping data sets exist among federal, state, and local government entities which are used to manage water quality data and protect water bodies from encroaching development, discharges from municipal and industrial wastewater, among other forms of possible degradation. Despite these efforts and regular improvements made in identifying waterways on the landscape, many small streams remain unmapped, unmonitored, and therefore, unprotected.

A concerted effort was undertaken during MRWPS to identify and ultimately protect unmapped streams within the Midway River Watershed. The goals of this effort were guided by the following core objectives: (1) accurately map the path of all flowing waters within the Midway River Watershed; (2) establish targeted monitoring stations that can be used to help characterize the condition and ecological services provided by these unmapped streams; and (3) process these new data sources through existing regulations to increase protection of the unmapped streams.

Most mapped streams and rivers of Minnesota are protected under several rules. A designation of "public waterway" is given to all waters identified on the PWI maps authorized by Minn. Stat. § 103G.201. The law requires PWI maps to be developed for each county of Minnesota, which are regularly updated as new data become available. Waterways listed under the PWI are protected such that a Public Waters Permit (PWP) is required to alter their course and condition. For example, structures built to cross streams protected under the PWI, such as road culverts or bridges, require a PWP before construction can occur.

Stream segments identified as Designated Trout Streams in Minnesota are classified as public waterways and by default are protected under the PWI rule. The MCPA considered the above PWI rules and trout stream designation procedures to devise a monitoring approach with the goal of adding critical stream habitats to the PWI and designated trout stream program. The following sections outline this monitoring approach and several of the outcomes achieved.

4.5.1 Methods for Identifying Unmapped Waters

To identify current gaps in mapped stream networks, existing stream mapping data sets produced by DNR and MPCA, along with the Public Land Survey section boundaries, were overlain recent spring season "leaf-off" aerial imagery. Available stream mapping data sets are represented through geospatial "linework" (stream lines) and include MPCA's WID linework as well as the DNR's PWI and Designated Trout Streams linework. In most cases these three data sets were in general agreement with one another in terms of geographic location, coverage, and accuracy. Unmapped streams were identified in instances where visible stream channels were not accounted for in the current linework data sets (see Figure 33). A combination of tools within Google Earth and ESRI ArcGIS Pro were used to draw in and digitize unmapped streams and add them to the project inventory of Midway River Watershed stream segments, and the unmapped waters were assigned Reach ID (see Section 3.2).

Nearly 70 miles of previously unmapped streams were mapped within the Midway River Watershed during this study (Figure 33). This total includes perennial streams (9.31 miles; 13% of total) and ephemeral or intermittent tributaries (60.27 miles, 87% of total). The MPCA and partners completed broad-scale, targeted monitoring of most of the unmapped streams throughout the watershed to characterize water quality conditions and ecological services provided by these water bodies. This effort was an initial step towards establishing data records on unmapped streams and means of prioritizing specific unmapped segments for additional monitoring. The data requirements for establishing new Designated Trout Streams and PWI listings are data-intensive, requiring continuous water temperature and fish community data to verify the capability of the proposed segment to support a self-sustaining trout population (i.e. natural reproduction - no fish stocking required). In addition, private landowners within the PLS section (640 acre) must agree to the proposed designation.

Unfortunately, most of the additional stream mileage mapped through this project will remain unlisted under the PWI (i.e. protected waters) or Designated Trout Streams list due to a lack of sufficient monitoring data needed for classification or an inability to support resident populations of Brook Trout. Until additional data are collected, there are no legal protections in place to protect these streams from direct alteration (e.g. ditching, ponding, impoundments) or development within their floodplain or riparian zone. The MPCA plans to share the additional stream mileage mapped with state and local governments, as well as city and county officials involved with planning and local ordinances to increase awareness of these waters and promote voluntary protection strategies and/or additional monitoring efforts.

4.5.2 Quantifying Unmapped Waters/Establishing New Protected Waters

Monitoring plans were developed to target specific locations that could prove conducive to adding new PWI and/or Designated Trout Stream designations. Two monitoring approaches were used in this effort due to the scale of the watershed and the abundance of unmapped streams discovered during the initial mapping effort. Instantaneous or “spot” measurements of water quality (temperature, DO, specific conductance, and pH) were collected at 96 locations throughout the Midway River Watershed as a broad-based effort to characterize conditions at locations considered unlikely to be eventual candidates for PWI/Designated Trout Stream additions. These locations were largely intermittent or ephemeral streams, water bodies with wetland characteristics, or small tributaries to sections of the watershed with limited potential to support cold water trout habitat. In areas with high potential for PWI/Designated Trout Stream designation, a more intensive monitoring approach was employed using continuous temperature data loggers and biological monitoring (fish surveys), since these data sets are required during the process of designate new stream segments as trout streams.

Ultimately, four unmapped stream segments were selected to receive the full monitoring effort required to establish new designated trout stream listings and additions to the state of Minnesota’s PWI. Fish community and continuous water quality data were collected from unmapped tributaries to Hay Creek (Station 19LS147 - reach E2-001) and West Rocky Run (Station 19LS134 - reach J6-004), as well as two unmapped tributaries to the main stem of the Midway River (Station 21LS006 - reach K2-004; Station 21LS011 - reach AB-001). Continuous water temperature data were collected for a minimum of two years and up to four years in the case of several sites. Fish community sampling was completed one time at each site using MPCA biological monitoring protocols (Figure 34).

Cold water temperatures, suitable physical habitat, and naturally reproducing Brook Trout populations were observed at all four of the unmapped stream locations sampled. Stations 19LS134 (Trib. to West Rocky Run), 21LS006 (Adolph Creek), and 19LS147 tributary (Hay Creek) supported large populations of Brook Trout and appear to be critical spawning and rearing areas for this species based on overall productivity and relative abundance of young-of-year (YOY) Brook Trout. Extremely cold water temperatures and consistent baseflows were observed at these stations due to sustained inputs from groundwater springs. On the other hand, station 21LS011 supported far fewer Brook Trout than the other three stations and appeared to be streamflow-limited during dry or drought periods, despite water temperatures remaining cold throughout the summer. The presence of channelized streams abandoned gravel mining operations, and residential development in the headwaters of this tributary may contribute to the limited baseflow.

4.5.3 New Trout Designations/Protected Waters within the Midway River Watershed

Seven new trout stream designations were proposed to DNR based on monitoring work completed by MPCA and project partners. Four proposals were located on previously unmapped water bodies, while the other three targeted portions of mapped waters currently included in the PWI but not designated individually as trout streams. Data summaries, maps, and drafts of the proposals can be provided upon request.

Ultimately, the MPCA's efforts led to the establishment of four new trout stream designations within the Midway River Watershed. **These designations are not yet completed but are in the process of being finalized and written into statute as of July 2025**. In Carlton County, 0.33 miles of Tributary B1 ("Korby Creek") is now designated as a protected trout stream. In St Louis County, three new trout stream designations were established; 1.4 miles of Midway River Tributary K2 ("Adolph Creek"), 3.5 miles of West Rocky Run Tributary J6 ("Jeffrey Creek"), and 1.4 miles of West Rocky Run Tributary J5 ("Solway Creek"). As designated trout streams, these stream segments are now legally protected under the PWI. Any stream channel modifications, new road or driveway culverts, or development within the floodplain of these streams will now require a PWP.

Figure 32: Pink colored stream lines in map represent the 70 miles of unmapped streams identified in the Midway River Watershed. Photos on right show examples of these waterways, several of which support naturally reproducing populations of Brook Trout

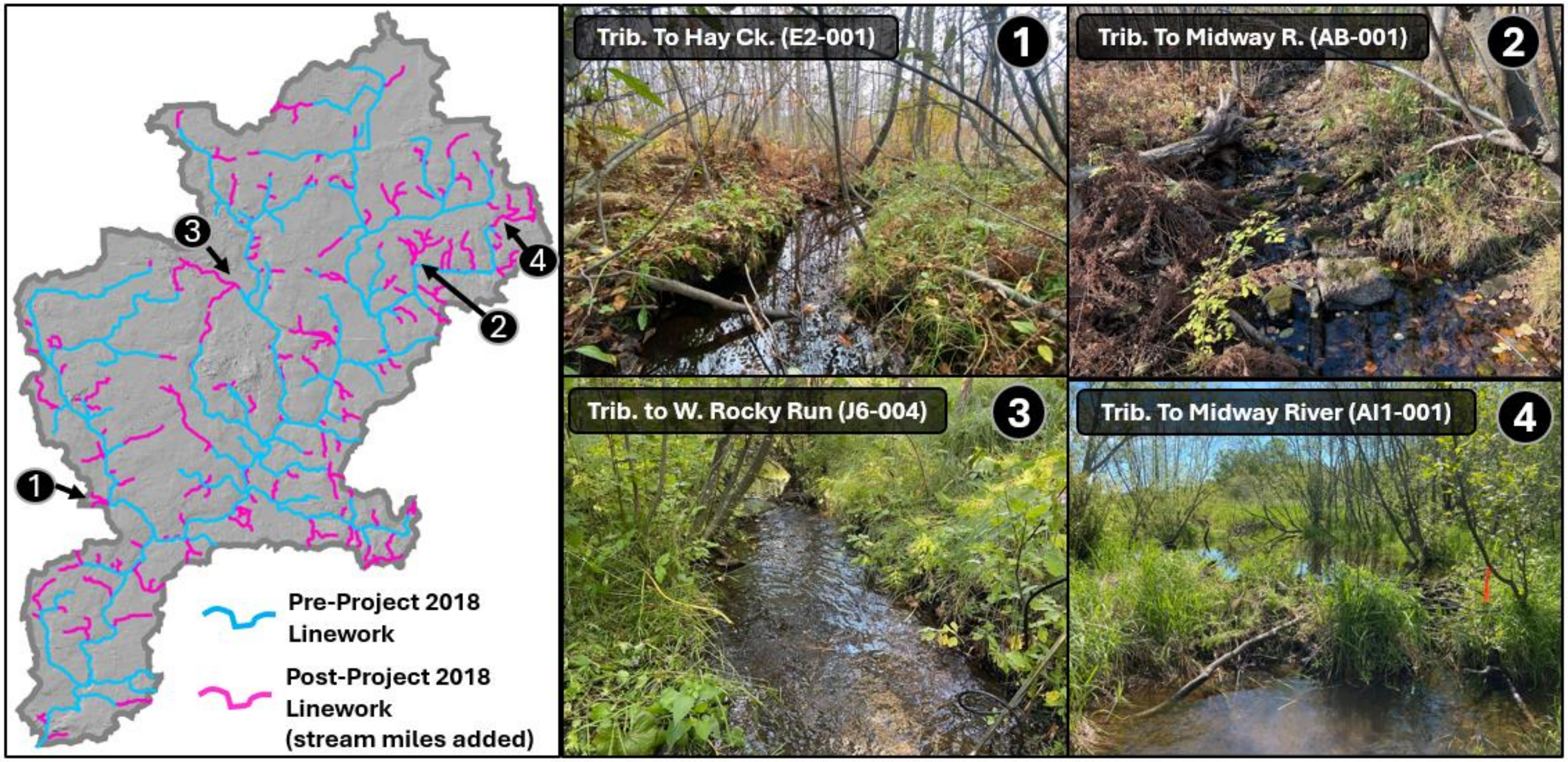
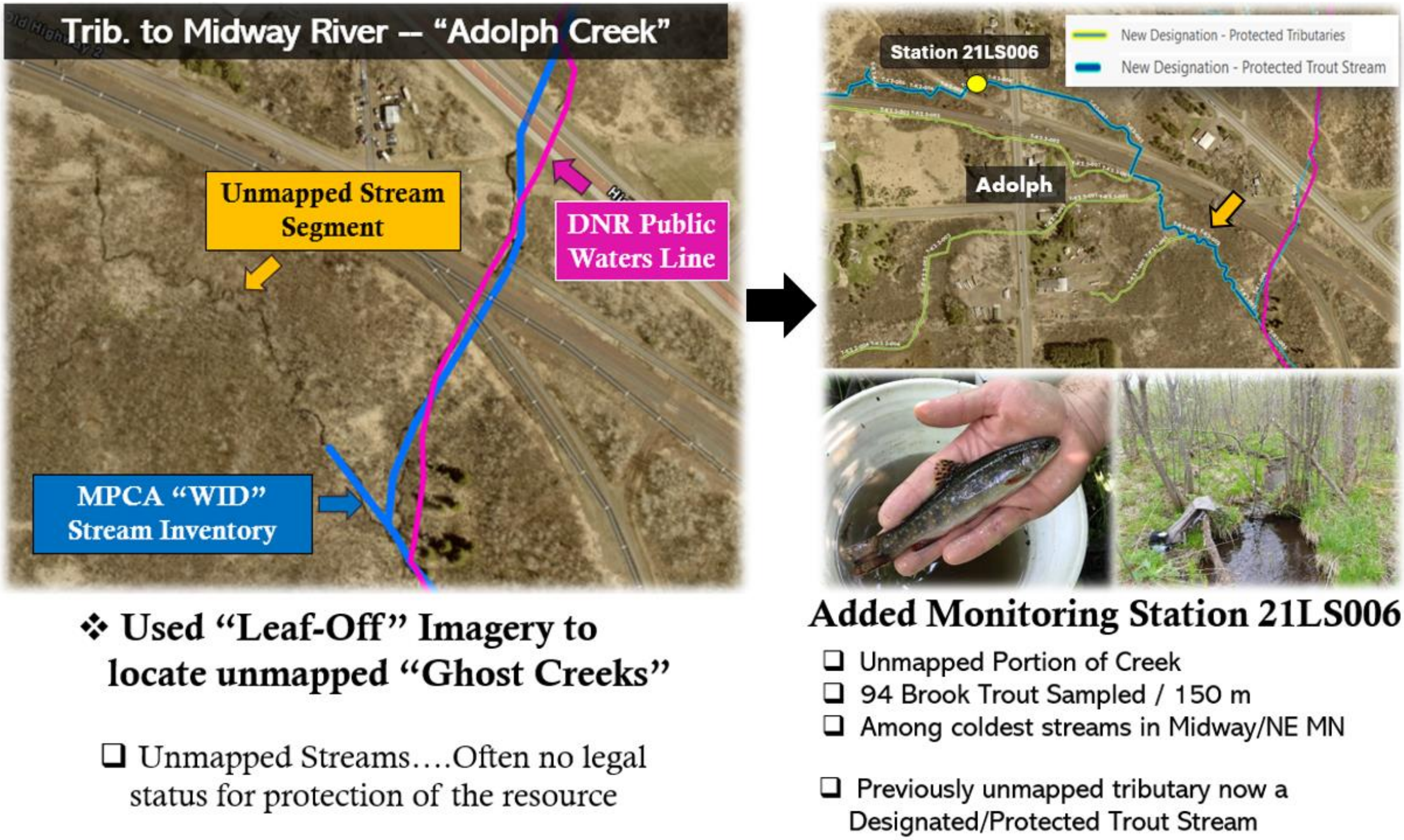


Figure 33: Process of identifying unmapped streams using existing stream linework and leaf-off aerial imagery (left), and example of field data collection required for designation of formerly unmapped section of Adolph Creek (right)



4.6 Riparian Zone Restoration

The riparian zone or riparian area includes the terrestrial lands along the edges of water bodies, such as streambanks, bluffs, and floodplains. These areas are unique from surrounding uplands in that their soils and vegetation are shaped by recurring interaction with water. Riparian zones provide important ecological services to the water bodies they lie adjacent to. Examples include providing physical habitat for a wide range of semi-aquatic and terrestrial species, improving water quality by removing excess nutrients from overland runoff, stabilizing streambanks and bluffs, reducing water temperatures due to shading from overhead forest canopy, and providing forage for fish in the form of terrestrial insects regularly deposited into nearby waters. Some studies indicate terrestrial organisms (e.g. ants, grasshoppers) are more important for sustaining nourishment and survival in stream resident Brook Trout than aquatic prey items (Utz and Hartman, 2006).

Despite their critical role in protecting watershed health, riparian zones are frequently degraded in areas with high rates of development or agricultural activity. Land availability is often limited and at a premium in areas with these land uses, and the value of protecting riparian zones is often overshadowed by development and industrial pressures. Estimates have placed riparian habitat loss at greater than 95% in most western united states (Krueper 1993). On average, this rate is much lower in Minnesota, and particularly within the Midway River Watershed, which still retains many miles of densely vegetated riparian corridors and riparian wetlands.

Historic farming practices and wildfires significantly altered the landscape and current riparian corridor of the Midway River from its pre-settlement or early settlement condition (Figure 34). Currently, few corridors of old-growth forest line the banks of the Midway. Instead, undeveloped sections of the river course through riparian corridors dominated by younger stands of aspen or birch, and more commonly shrub species like tag alder, willow, and dogwood, mixed in with native and invasive herbaceous vegetation. These buffers provide considerable protection from streambank erosion and overland runoff, but do not offer significant canopy shading or inputs of large woody debris (e.g. fallen trees or limbs), which provide important fish cover and habitat complexity. Over the last 30 to 40 years, landscapes within the Midway River have transitioned from agricultural (grassland/pasture) to residential or suburban, further altering riparian corridors, wetlands, and stream networks (Figure 35). Long term restoration and protection goals for the Midway River Watershed should focus on preserving remaining riparian old growth forests and working to re-establish corridors of mature trees within riparian zones.

4.6.1 State of Minnesota Buffer Law

In the state of Minnesota, a “buffer law” was enacted to establish riparian buffers for the protection and enhancement of water quality and biological integrity. This law requires landowners owning property adjacent to “public waters” (i.e. water body listed on the PWI) to maintain a vegetated buffer with an average width of 50-feet and a minimum width of 30-feet. In addition, the buffer must be continuous along shoreline of the water body and consist of perennially rooted vegetation. Several variations and adaptations of the law can be applied in instances when riparian lands are used for agricultural purposes, but the buffer law still applies. Based on the buffer-law map maintained by state agencies, all of the public waters in the Midway River Watershed appear to require the 50-foot average buffer (Minnesota Buffer Law Map).

4.6.2 Riparian Restoration Projects Prioritization/ Potential Buffer Law Violations

Recent aerial imagery was used to identify degraded riparian areas within the Midway River Watershed to provide a roadmap for potential riparian restoration work. Imagery spanning the years of 2015 through 2023 was used for this desktop review process, meaning historic or very recent (i.e. post 2023) riparian impacts were not accounted for in this assessment. In general, disturbed or degraded riparian areas within this watershed were due to small livestock operations, housing developments, and expansive turf-grass lawns with frontage to the Midway River, and to a lesser extent, major and minor tributary streams.

A total of 32 potential riparian restoration projects were mapped and prioritized based on degree and scale of perceived impact, quality of the resources affected, and connection to waters listed on the impaired waters list. All projects identified were located on privately owned parcels of land. Nearly half of the projects identified (14/32; 44%) were impacted riparian corridors along the main stem of the Midway River, predominantly large turf-grass residential lawns or fields with limited shoreline in a condition that could be classified as a high-quality riparian buffer (e.g. trees, native perennial grasses). Although turf-grass technically qualifies as perennial vegetation under the mandatory buffer-law, a “no-mow” buffer of native plant and tree species is recommended, as this type of buffer is much more effective at preventing erosion and contributing to high quality aquatic and terrestrial habitat.

The 32 potential riparian restoration projects were evaluated and prioritized collectively by the MPCA, Carlton County SWCD, and South St. Louis County SWCD staff. Projects were assigned a priority rating scale of 1 to 4, with 4 being the highest priority and 1 serving as the lowest priority score. A total of 14 projects were assigned a rating of “3” or “4” and are considered top priorities for restoration of riparian habitat. Many of the high priority projects are located along the Midway River main stem due to a higher rate of developed shoreline and vegetation clearing along this water body. Sections of the Midway River with poor riparian corridors were found to lack cover habitat for fish along the streambanks and within the river channel, as shown in the upper two photographs in Figure 36. These areas also lack the overhead forest canopy required to shade the river during the hottest periods of the day, likely resulting in significant water temperature increases and less suitable conditions for species requiring cold water temperatures.

High priority riparian restoration projects were also identified on smaller Midway River tributary streams. Riparian corridors along several high-quality trout streams were found to be cleared and mowed to the stream edge, leading to bank erosion, habitat loss, and increased thermal loading from sun exposure. For example, Project ID #2 on reach I1-003 of Elm Creek received a prioritization rating of “4” or “Very High” for riparian restoration (Figure 36). In this case, the impact severity is very high (short turf grass eroding banks, no tall/deep-rooted/native vegetation), but the scale of the impact is relatively small (approximately 80 ft). The priority status of this project was also elevated since Elm Creek is a very high-quality trout stream, and this stream reach exhibits warmer water temperatures compared to other areas of this water body. Restoring a high-quality riparian corridor at this location would reduce bank erosion, improve in-stream habitat, and reduce water temperature.

Potential buffer law violations were documented at 5 locations in the Midway River Watershed (Table 11). All potential violations are relatively minor in severity and are the result of small animal livestock operations within the riparian corridor of a public water. Several of the affected streams are likely ephemeral or intermittent, yet they are listed on the PWI and state buffer law map. Field inspections are recommended to further evaluate these areas for compliance with state buffer law and potentially provide financial and technical assistance for installing proper buffers. Two of the locations on Hay Creek (E1-011 and E1-008) have been identified as high priority projects to reduce loading of *E. coli* bacteria to this water body. Currently, Hay Creek is listed as an impaired water for elevated *E. coli* concentrations.

Table 11: Potential Minnesota buffer-law violations in the Midway River Watershed. Field visits are needed for verification

** The locations listed below may be in violation of State of Minnesota's Buffer Law. Site inspections and further evaluation is recommended.

Watershed Zone	Steram Name	Project ID	Reach	DNR Kittle #	Latitude	Longitude	Description
Adolph Creek	Unnamed Trib. to Midway River	97	KK1-003	S-002-010-003.4-001	46.769617	-92.28134	Small livestock lot without perennial vegetation
West Rocky Run	Unnamed Trib. to West Rocky Run	90	J13-003	S-002-010-003-003	46.811683	-92.303844	Small livestock lot without perennial vegetation
Hay Creek	Hay Creek	76	E1-011	S-002-010-002	46.779853	-92.389618	Small livestock lot without perennial vegetation
Hay Creek	Hay Creek	75	E1-008	S-002-010-002	46.755713	-92.368153	Small livestock lot. Small area lacks perennial vegetation
Lower Midway	Unnamed Trib. to Midway River	83	D1-002	S-002-010-001.7	46.720664	-92.369607	Small livestock lot. Small area lacks perennial vegetation

** The locations listed below ***would*** be in violation of the buffer law if the waterbody within this riparian zone was a Public Water (i.e. listed on the Public Waters Inventory)

Watershed Zone	Steram Name	Project ID	Reach	DNR Kittle #	Latitude	Longitude	Description
Middle Midway	Unnamed Trib. to Midway River	105	O1-004	N/A	46.744986	-92.295631	Small livestock lot without perennial vegetation

Figure 34: (Left) Farmhouse of Alex and Georgina Esko on the banks of the Midway River circa 1900. Note the lack of trees and other vegetation within the riparian corridor. (Right) Drone-based imagery representative of present-day riparian corridor conditions along much of the Midway River

4.6.3 Riparian Restoration Summary/Recommendations for Protection and Restoration

While many riparian areas in the Midway River Watershed are still in good condition, others have been degraded due to practices that reduce their quality and function, including turf lawns mowed to the water's edge, livestock access to streams, removal or die-off of trees and native plants, and development pressure near headwaters tributaries and along the main stem of the Midway River. Degraded riparian corridors lead to warmer water, poor fish habitat, and increased erosion.

High priority riparian restoration projects in the Midway River Watershed are listed in Appendix A7. This list provides a project inventory and starting point for local conservation groups to pursue conservation funding, establish working relationships with private landowners, and ultimately restore riparian habitats throughout the watershed. Attention must also be directed towards preserving existing high quality riparian habitat through outreach and education and enforcement of the Minnesota Buffer Law and PWI /trout stream regulations.

Figure 35: Examples of high quality and degraded riparian corridors observed along the mainstem of the Midway River.

Figure 36: Examples of poor riparian management (left and center) and high quality/unimpacted riparian conditions (right) within the same reach of Elm Creek (I1-010). This is a good example of a high priority candidate for small-scale riparian corridor restoration.

5.0 Conclusions and Next Steps

The MRWPS offers a comprehensive, data-driven roadmap to safeguard and restore critical coldwater habitats within a watershed increasingly threatened by development, climate change, and habitat fragmentation. Over a four-year monitoring period (2018 through 2021), the project identified and assessed key ecological features across the Midway River Watershed using rigorous stream temperature monitoring, streamflow measurements, biological assessments, and mapping and field assessments of previously undocumented watercourses.

Key findings demonstrate the importance of specific tributaries—namely West Rocky Run, Elm Creek, Hay Creek, and Adolph Creek and numerous unnamed tributaries—as strongholds of high-quality coldwater habitat for Brook Trout and other sensitive aquatic species. These streams exhibited stable, very cold thermal regimes, high BFI values indicative of strong groundwater inputs, and biological indicators supporting exceptional aquatic life.

The analysis also identified significant threats:

- Nearly 50% of evaluated stream crossings are barriers to fish movement due to undersized or perched culverts.
- Headwater areas and cold tributaries are under pressure from urban development, particularly in Hermantown and near the East Rocky Run Watershed.
- Groundwater springs and stream segments with thermal refugia are largely on private lands, requiring collaboration for long-term protection.

The MRWPS has successfully produced:

- A prioritized list of 247 restoration and protection projects.
- A robust geospatial database and mapping tool to inform local and state conservation planning.
- A framework to guide targeted culvert replacements, riparian restoration, channel re-naturalization, and land use policy decisions.

Going forward, conservation efforts should:

1. Protect the highest quality coldwater habitats, especially in CPA.
2. Restore vulnerable areas where stream connectivity is impaired or stream temperatures are warming
3. Incorporate MRWPS findings into local planning, permitting, and ordinance decisions.
4. Engage private landowners through easements, conservation incentives, and stewardship programs.

Ultimately, the MRWPS provides a replicable model for watershed-scale conservation planning. Its emphasis on scientific rigor, spatial precision, and actionable priorities offers a powerful tool to ensure the long-term health and resilience of one of Minnesota’s most ecologically valuable coldwater systems.

Appendix A – Data Summaries/Project Recommendations

❖ Appendix A1 – Stream Temperature Summaries and Project Recommendations

Watershed Zone	General Conditions/Comments	Restoration/Protection Priorities (Temperature)
East Rocky Run	Stream temperature data indicate much of the East Rocky Run Watershed zone is marginal for supporting Brook Trout and other cold water species. Natural features associated with cold water habitat, such as groundwater springs and elevated woody wetlands, are sparse in East Rocky Run in comparison to other areas of the Midway River drainage. Brook Trout were still observed in localized areas, but sampling efforts were cut short due to severe drought conditions throughout the 2021 monitoring season. Development (residential/commercial) has altered the landscape and hydrology in much of this watershed zone. The ability of Brook Trout to inhabit this watershed zone long-term is questionable.	▪ Restore wetlands and natural stream channels in heavily developed/ditched/modified headwaters tributaries to East Rocky Run with cold water temperatures (See Project ID #132; #133; #179) ▪ Install green infrastructure projects in developed areas (Arrowhead Rd./Ugstad Rd. Intersection) and current/future subdivisions (Project ID #202) ▪ Protect existing wetlands and headwaters tributaries (particularly Tributaries L2, L4, L9)
West Rocky Run	The West Rocky Run Watershed zone is a stronghold for native Brook Trout within the Midway River drainage. Several tributaries (upper reaches of J6, J5) deliver cold, spring-fed water and offer excellent habitat for adult Brook Trout and natural reproduction. Prominent groundwater springs along the main stem of W. Rocky Run also keep temperatures cold (Reach J1-012, J1-010). However, several areas are at risk to increased warming due to ditching, loss of forest and wetlands, and gravel mining. These areas include Tributary J13, Tributary J8 (gravel pit ditch), and Tributary J5 downstream of HWY 2. The lower half of W. Rocky Run Creek remains cold enough to support excellent numbers of Brook Trout largely due to cold groundwater springs and tributaries located in the upper half of the watershed.	▪ Restore wetlands and natural stream channels in heavily developed/ditched/modified headwaters tributaries to West Rocky Run with cold water temperatures (See Project ID #90, #115, #133, #66, #112) ▪ Protect prominent groundwater springs and the tributaries that emerge from these areas (see CPA table in Appendix A2). Also protect W. Rocky Run headwaters which remains largely undeveloped (J1-013 through J1-020) ▪ Remove road/trail berms that create small impoundments of cold stream reaches (Project #12) and disconnect/fill ditch from gravel pit to W. Rocky Run at Tributary J8 (Project ID #66)

Watershed Zone	General Conditions/Comments	Restoration/Protection Priorities (Temperature)
Anderson Creek	The upper half of the Anderson Creek Watershed zone supports cold water temperatures and healthy populations of wild Brook Trout. Several poor road crossings and areas of ditching/channel re-alignment have contributed to significant increases in water temperature in the lower portion of Anderson Creek from N. Cloquet Rd to its confluence with the Midway River. Stream temperatures in lower Anderson Creek frequently exceed stress and lethal thresholds for Brook Trout, and DO concentrations are below optimal levels for survival and growth. Protection strategies should be implemented in the upper half of the watershed, while restoration strategies to restore natural channel conditions and fish passage are a better fit for the lower portion.	▪ Correct stream alignment and restore natural stream channel pattern upstream of North Cloquet Rd. The creek is ditched and impounded by several poorly designed culverts (Project ID # 115) ▪ Improve connectivity to colder sections of Anderson Creek by replacing barrier culverts at Paso Fino Ln (Project ID #3), Old Trail crossing downstream of Midway Rd (Project #14), Midway Rd (Project ID #9) and railroad crossing just east of Midway Rd (Project ID #8) ▪ Remove impoundments on headwaters tributaries (Project ID #153, #152, #154, #176)
Adolph Creek	The Adolph Creek drainage is relatively small in acreage but contains an abundance of high-quality cold water habitat. The lower portion remains unaltered (i.e. not ditched), flows through a riparian corridor of alder swamp and forest, and supports good populations of Brook Trout. The area around Adolph (US HWY 2/Midway Rd intersection) remains cold and supports trout populations despite habitat degradation and fragmentation resulting from numerous road and RR crossings. In addition, several parking lots and dumping areas are infringing on wetlands and springs east of Midway Road. The western branch of Adolph Creek emerges from large groundwater springs and supplies most of the flow and habitat.	▪ Protect land around CPA from further development and contamination (gas stations, railroad, dumping areas). Maintain/improve forested buffers. See list of CPA in Appendix A2. ▪ Re-meander ditched portion of reach K2-003 to prevent warming (Project ID #114) ▪ Replace road culverts to restore full connectivity to the coldest portions of Adolph Creek (Project ID #7, Project ID #23)
Elm Creek	Cold water temperatures and wild Brook Trout populations are present throughout the Elm Creek Watershed zone. The coldest temperatures were observed in the lower portion of Elm Creek and tributary I2, which flows into Elm Creek about 0.7 river miles upstream of the Elm Ck-Midway R confluence. Compared to other areas of the Midway River Watershed, the Elm Creek drainage is significantly less altered by development (residential/commercial) and contains large areas of in-tact forest lands and wetlands. A prominent topographical feature underlain by deposit of gravel/outwash soils, centrally located in the watershed, is the source of many springs that feed cold groundwater to Elm Creek. This watershed zone is one of	▪ Protect headwaters of tributary I2 from development and gravel mine expansion (Project FID #51). This is one of the coldest tributaries in the entire Midway River Watershed. It originates from springs below a large gravel deposit which is actively being mined on its north facing slope. ▪ Maintain corridors of mature forest and wetlands along Elm Creek and tributary streams. ▪ Replace several road and driveway culverts to restore full connectivity to the coldest portions of Elm Creek (Project FID #2, Project ID #6). The driveway culvert just upstream of the Elm Ck – Midway R. confluence (Project FID# 2) is one of the highest priority projects in the entire Midway River Watershed.

Watershed Zone	General Conditions/Comments	Restoration/Protection Priorities (Temperature)
	the most resistant to drought and increases in ambient air temperatures due to the prominent groundwater features and lack of development.	
Hay Creek	Hay Creek is one of the largest tributaries to the Midway River. Stream temperatures in the headwaters of this watershed zone are very cold and remain stable during periods of warming or drought. On the contrary, water temperatures in lower Hay Creek near N. Cloquet Rd are more variable and responsive to ambient air temperature and water levels. Water temperatures are suitable for Brook Trout survival and growth along the entire length of Hay Creek, but some areas may be trending towards marginal conditions. Numerous spring-fed tributaries supply cold, well oxygenated water to Hay Creek along its path to the Midway River. These tributaries provide critical refugia and spawning/rearing habitat.	▪ Minimize impacts to headwaters region and cold tributaries identified as CPA in this watershed zone. See complete list in Appendix A2. ▪ Evaluate impacts/risk associated with large gravel mining operations along St. Louis River Road (Project ID# 68). These operations are adjacent to Hay Creek and one of its coldest tributary streams (Tributary E9). Expansion of existing mines or creation of new mines need to consider impacts to nearby streams. ▪ Replace several road and driveway culverts to restore full connectivity to cold tributary streams (Project ID #4, FID #18). Inspect culverts on priority cold water streams located on private land to determine if fish passage barriers are present (Project ID# 220, 216, 212, 213)
Upper Midway	The Upper Midway River Watershed zone contains the headwaters of the Midway River as well as numerous small tributary streams. Most of the streams in this area support cool to cold water temperatures, but streamflow and DO limit biological productivity in some waters. Small populations of Brook Trout inhabit the upper Midway River and were also observed in the lower reaches of several tributary streams in this watershed zone. Many of the small tributaries have been modified by ditching and/or small impoundments or ponds on private land. These stream modifications are likely altering hydrology, increasing water temperatures, and fragmenting fish populations. Curbing the impacts of increasing residential and commercial development will be a challenge in this watershed zone. Tributary streams with cold water temperatures are fed by undeveloped areas with wetlands and forested uplands, but many of these are adjacent to housing developments and/or commercial districts. Proper planning and setbacks will be needed to protect these resources.	▪ Remove small impoundments/ponds on cold Midway River tributary streams and restore natural stream channel (Project ID # 159, 167, 126, 147, 159) ▪ Protect wetlands, forested land, and riparian corridors within and adjacent to the CPA in this watershed zone (see Appendix A2 for details on CPA) ▪ Restore stream channel, adjacent wetlands, and forest within subwatershed of Tributary AB which was impacted by gravel mining (Project ID # 117, 116, 130). This tributary supports cold water temperatures and a small Brook Trout population in addition to providing thermal refuge for fish moving in from the Midway River.

Watershed Zone	General Conditions/Comments	Restoration/Protection Priorities (Temperature)
Middle Midway	The Middle Midway Watershed zone combines a larger, warmer main stem of the Midway River with very cold small to medium-sized tributary streams. This combination results in healthy numbers of Brook Trout in both the Midway River and several of the tributary streams. Access to thermal refugia (springs, tributaries) is a vital component to survival of Brook Trout in this portion of the Midway River main stem, as water temperatures are frequently too warm in areas where thermal refugia is lacking or inaccessible. Critical cold water refuge areas in this watershed zone include the Midway R. - Elm Ck confluence area, Midway R. -Tributary N confluence area, and the Midway R. – Hay Ck confluence area.	▪ Protect wetlands, forested land, and riparian corridors within and adjacent to the CPA in this watershed zone (see Appendix A2 for details on CPA) ▪ Install green infrastructure to decrease impact of stormwater runoff along busy roadway corridors and subdivision housing areas (Riverwood Subdivision around Tributary H and Tributary N) ▪ Maintain/increase the ability of Brook Trout and other cold water species to move throughout this watershed zone to find cold water refugia. All new culverts/bridges should allow full fish passage. Remove existing fish passage barriers reducing movement between Midway River main stem and tributary streams (Project ID# 4, Project ID# 3)
Lower Midway	The Lower Midway Watershed zone includes the downstream-most section of the Midway River, one medium-sized tributary (Tributary B), and numerous small tributary streams. Water temperatures in this section of the Midway River are marginal for Brook Trout and tend to be more suitable for Smallmouth Bass and cool/warm water species. However, Brook Trout were sampled in the lower reaches of Tributary B and from the confluence areas with minor tributary streams with cold temperatures. Aside from the Midway River, Tributary B is the only water body large enough to support resident Brook Trout population in this watershed zone. Water temperatures recorded in this tributary are cold enough to support Brook Trout, but upstream land uses make it vulnerable to warming (gravel mining, commercial/residential development). In addition, this tributary outlets to the Midway River directly through a driveway culvert with a 0.6’ perch height, which prevents fish passage into this water body from the Midway River during low flow. The extreme lower reaches of Tributary C and Tributary D may also provide some localized cold water refugia where they merge with the Midway River, but habitat and connectivity issues limit upstream habitat in these drainages.	▪ Replace driveway culvert on Tributary B at confluence with Midway River (Hautaluoma Rd; Project ID# 10) to restore full fish passage to this cold tributary. ▪ Investigate/monitor land use practices in Tributary B that could contribute to thermal loading (i.e. warming) of this stream. Examples include perched/undersized culverts (Project ID# 15, 37), private impoundments (Project ID# 149), gravel mining adjacent to the stream corridor (south of I-35). ▪ Conduct suitability/feasibility studies for installing green infrastructure projects to treat stormwater runoff within subdevelopments bordering the Midway River in Esko, Minnesota ▪ Tributary D watershed restoration (Project ID# 244). Cold water temperatures observed in lower reaches of this tributary, but land conversion to farms and residential properties has resulted in extensive ditching and numerous constructed ponds, both of which are contributing to streamflow alterations and possible temperature increases.

Appendix A – Data Summaries/Project Recommendations

❖ Appendix A2 – Midway River Watershed Coldwater Protection Areas

Watershed Zone	ID	Latitude	Longitude	Priority	Comment
Adolph Creek	ADP-2	46.7755	-92.2739	Very High	Very cold tributary to Midway River with good numbers of Brook Trout. Land owned by Wisconsin Central Railroad.
Adolph Creek	ADP-3	46.7803	-92.2786	Very High	Very cold tributary to Adolph Creek. Much of this reach is channelized and the culvert under Midway Road is a partial barrier to fish passage. Abundant groundwater springs and wetlands in the vicinity,
Adolph Creek	ADP-5	46.7809	-92.2835	Very High	Large groundwater springs feeding the headwaters of Adolph Creek. Extremely cold water below these springs and an important spawning and rearing area for Brook Trout.
Adolph Creek	ADP-4	46.7805	-92.2817	Very High	Extremely cold tributary to Adolph Creek emerging from large springs. Many Brook Trout present, predominantly young of year. Appears to be key spawning and rearing reach for Brook Trout.
Elm Creek	ELM-4	46.769	-92.3174	Very High	Area of high topographical relief underlain by gravel/sand outwash soils. Prominent groundwater springs seep from the south facing slope creating several cold tributaries to Elm Creek.
Elm Creek	ELM-1	46.7625	-92.3118	Very High	Extremely cold tributary to Elm Creek. Prominent groundwater springs feed this tributary from elevated wetlands and gravel deposits. Threatened by gravel mining.
Elm Creek	ELM-2	46.7657	-92.3162	Very High	Extremely cold tributary to Elm Creek. Prominent groundwater springs feed this tributary from elevated wetlands and gravel deposits. Threatened by gravel mining.
Elm Creek	ELM-3	46.7518	-92.3055	Very High	Very cold section of Elm Creek near confluence with the Midway River. Driveway culvert near the Elm-Midway confluence is undersized and a partial barrier to fish passage.
Hay Creek	HAY-9	46.765	-92.3782	Very High	Groundwater springs in this area feed a cold perennial tributary to Hay Creek. Much of this area has been disturbed or destroyed by gravel mining.
Hay Creek	HAY-6	46.762	-92.3723	Very High	One of the coldest tributaries monitored in the entire Midway River Watershed. Emerges from a large gravel deposit that has been heavily mined. Protections are needed to ensure flow rates and temperatures remain unchanged.
Hay Creek	HAY-8	46.738	-92.3674	Very High	Very cold tributary to Hay Creek. Brook Trout sampled in this tributary in 2019 despite partial barrier culvert at CSAH 1. Culvert should be replaced to increase access to this tributary which offers refugia and spawning/rearing habitat.
Middle Midway	MMD-6	46.7453	-92.3132	Very High	Significant groundwater springs in this zone produce one of the most critical thermal refuge areas for Brook Trout in the entire Midway River Watershed. Extremely high priority for protection.
Middle Midway	MMD-5	46.7455	-92.313	Very High	Extremely cold tributary, significant groundwater spring inputs just upstream from the confluence with Midway River. This tributary provides critical coldwater refuge for Brook Trout in this portion of the Midway. Very high protection priority.
West Rocky Run	WWR-8	46.8018	-92.3339	Very High	Area contains groundwater springs that feed a cold tributary to West Rocky Run. Measures should be taken to preserve the integrity and ecological function of this area and the surrounding landscapes that infiltrate precipitation to this upwelling.
West Rocky Run	WWR-9	46.7977	-92.3204	Very High	Area contains groundwater springs that feed a cold tributary to West Rocky Run. Measures should be taken to preserve the integrity and ecological function of this area and the surrounding landscapes that infiltrate precipitation to this upwelling.
West Rocky Run	WWR-11	46.8106	-92.3112	Very High	Prominent groundwater springs emerging from a hillside slope and entering West Rocky Run. This section of the creek is extremely cold due to these groundwater inputs.
Adolph Creek	ADP-7	46.7776	-92.2777	High	Small area of springs and wetlands below a steep slope. Monitoring data indicates very cold temperatures with several small spring-fed tributaries originating from this area. Upslope of these groundwater springs is a lot with runoff concerns.
Adolph Creek	ADP-1	46.7777	-92.2773	High	Cold tributary stream to Adolph Creek fed by springs and wetlands in the vicinity
Anderson Creek	ADC-1	46.732	-92.2903	High	Cold reach flowing through meadow and alder. Heavily shaded. Provides coldwater refuge for fish moving between warmer sections of the creek upstream and downstream of this area.
East Rocky Run	ERR-1	46.7884	-92.262	High	Cold tributary to East Rocky Run. Small populations of Brook Trout have been sampled in East Rocky Run despite comparatively warmer temperatures. Thermal refugia like this are critical for preventing Brook Trout extirpations from East Rocky Run.
Elm Creek	ELM-5	46.7727	-92.3317	High	Area of groundwater springs within a beaver meadow. No monitoring data available but features of this tupe hese have been identified as sources of cold water in other areas of the Midway River Watershed.
Hay Creek	HAY-11	46.7867	-92.3946	High	Prominent spring emerging from forested area develops into a tributary to Hay Creek. No monitoring data available from this location, but aerial photos suggest this is a significant spring and source of cold water to Hay Creek.
Hay Creek	HAY-1	46.7926	-92.3919	High	Cold headwaters reach of Hay Creek that includes several springs. Narrow stream channel with good shading.
Hay Creek	HAY-2	46.7948	-92.3888	High	Cold headwaters reach of Hay Creek. Brook Trout present in 2019 despite degraded habitat from ditching. Restoration candidate.
Hay Creek	HAY-3	46.7861	-92.3934	High	No data for this tributary, but it originates from a large groundwater spring and very likely that it is cold.
Hay Creek	HAY-4	46.7768	-92.3855	High	Cold tributary to Hay Creek with a healthy population of Brook Trout. This tributary is a priority for protection and restoration as much of it is channelized.
Hay Creek	HAY-5	46.7639	-92.3803	High	Cold tributary to Hay Creek in an area of the watershed with significant gravel mining activity.
Hay Creek	HAY-7	46.7512	-92.3637	High	Cold tributary to Hay Creek providing approximately 0.5 miles of spawning and rearing habitat.
Lower Midway	LMD-2	46.6892	-92.3797	High	Moderately cold tributary with a small to moderate population of Brook Trout in the lower reaches. Marked as a Coldwater Protection Area since there are very few streams of this size and temperature class in the Lower Midway. Driveway culvert is perched.
Upper Midway	UMD-7	46.803	-92.2356	High	Brook Trout present in lower reaches of this drainage, but upper portions are ditched in some areas and the surrounding landscape is highly developed or impacted by legacy gravel mining. Protection and restoration recommended
West Rocky Run	WWR-10	46.8119	-92.3054	High	Area contains groundwater springs that feed a tributary to West Rocky Run. Portions of the springs have been excavated into a pond, and cattle grazing and ditching have degraded he stream corridor. Restoration and protection activities recommended.
West Rocky Run	WRR-1	46.7994	-92.3276	High	Very cold tributary (previously unmapped) originating from groundwater springs just upstream. High numbers of Brook Trout sampled, particularly smaller young-of-year, indicating importance as spawning and rearing habitat.
West Rocky Run	WRR-3	46.7976	-92.3206	High	Continuation of this cold tributary (previously unmapped) to West Rocky Run. Large groundwater spring on private property.

Watershed Zone	ID	Latitude	Longitude	Priority	Comment
West Rocky Run	WRR-5	46.7957	-92.3004	High	Cold tributary with good numbers of Brook Trout and significant wetlands and gravel deposits.
West Rocky Run	WRR-5	46.7926	-92.3014	High	Cold tributary with good numbers of Brook Trout and significant wetlands and gravel deposits. This tributary is fragmented by a fish migration barrier culvert at US HWY 2
West Rocky Run	WRR-7	46.8102	-92.3096	High	Cold reach of West Rocky Run with many prominent groundwater springs entering within a beaver meadow.
Adolph Creek	ADP-6	46.7782	-92.2819	Medium	Area of apparent springs and wetlands but limited data to gauge their importance as a source of cold water. Worth protection efforts in this developed/developing subwatershed with significant numbers of Brook Trout.
East Rocky Run	ERR-2	46.7984	-92.2028	Medium	Cold tributary with limited baseflow. Originates from elevated topography like many of the cold tributaries in the Midway area. Getchell Road appears to impound this tributary to some degree and it is channelized downstream of Getchell Rd
East Rocky Run	ERR-3	46.829	-92.2684	Medium	Cold tributary to East Rocky Run. Small populations of Brook Trout have been sampled in East Rocky Run despite comparatively warmer temperatures. Thermal refugia like this are critical for preventing Brook Trout extirpations from East Rocky Run.
Elm Creek	ELM-6	46.7689	-92.3296	Medium	Area of groundwater springs within a beaver meadow. No monitoring data available but features of this tupe hese have been identified as sources of cold water in other areas of the Midway River Watershed.
Hay Creek	HAY-10	46.78	-92.3831	Medium	Cold tributary in ditch on north side of this road originates from wetland and springs on several private land parcels. Ditching and recent wetland impacts threaten this source of cold water to Hay Creek.
Lower Midway	LMD-1	46.7183	-92.3604	Medium	Cold tributary with low baseflow and some water quality limitations (DO). Adult and juvenile Brook Trout have been observed in the lower reaches of this tributary - confirming use as spawning and rearing habitat.
Middle Midway	MMD-1	46.7479	-92.3063	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Middle Midway	MMD-2	46.7488	-92.3084	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Middle Midway	MMD-3	46.739	-92.3121	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Middle Midway	MMD-4	46.7273	-92.3356	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Upper Midway	UMD-8	46.7984	-92.2028	Medium	A small tributary with cold water temperature emerges from this expansive area of elevated wetlands and possible groundwater springs. Development pressure in this area is high.
Upper Midway	UMD-9	46.8091	-92.2009	Medium	This area forms the headwaters of the Midway River and contains wetlands and spring features. The stream segment running through this area is cold but there are connectivity issues downstream that may prevent or reduce movement of fish into this area
Upper Midway	UMD-1	46.7674	-92.2768	Medium	Very small but cold tributary to the Midway River. Likely provides thermal refugia and some limited spawning/rearing habitat for Brook Trout.
Upper Midway	UMD-2	46.7597	-92.2799	Medium	Cold tributary with very limited flow and connectivity to the Midway. Fish do not have access to this tributary due to steep gradients and much of it is ditched along Midway Rd, but temps are cold and it provides some thermal refugia at confluence
Upper Midway	UMD-3	46.7984	-92.2442	Medium	Cold tributary with Brook Trout present in 2021 survey. Low baseflows, potentially due to development and ditching upstream. Protection and restoration candidate as one of the only cold tributaries in this area.
Upper Midway	UMD-4	46.7859	-92.2536	Medium	Cold tributary to Midway River with limited baseflow and stream length. Added to the list of CPA based on the lack of cold tributary streams in this area.
Upper Midway	UMD-5	46.8086	-92.20318	Medium	Cold reach of the Midway River headwaters with healthy riparian corridor that is surrounded by high intensity commercial and residential development. Several connectivity issues along this reach likely limit potential for fish moving into this reach.
Upper Midway	UMD-6	46.7987	-92.2026	Medium	Cold tributary with limited flow. Appears Getchell Rd impedes flow and creates a blockage/impoundment and stream is ditched below road crossing. Proper culvert and some channel restoration would increase ecological function. Also impoundment in headwaters
West Rocky Run	WRR-2	46.8004	-92.3326	Medium	Smaller branch of tributary (previously unmapped) that includes longer CPA downstream. Cold water temperatures and Brook Trout present. Driveway culvert and road ditch degrade habitat and connectivity.
West Rocky Run	WRR-4	46.7912	-92.3188	Medium	Very cold tributary (previously unmapped) originating from large wetland complex with gravel deposits near its headwaters to facilitate infiltration and groundwater recharge.
Middle Midway	MMD-3	46.739	-92.3121	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Middle Midway	MMD-4	46.7273	-92.3356	Medium	Cold tributary to the Midway River. Upper reaches are intermittent but near the confluence with the Midway, this tributary is cold and provides thermal refugia and a short distance of spawning/rearing habitat for coldwater species.
Upper Midway	UMD-8	46.7984	-92.2028	Medium	A small tributary with cold water temperature emerges from this expansive area of elevated wetlands and possible groundwater springs. Development pressure in this area is high.
Upper Midway	UMD-9	46.8091	-92.2009	Medium	This area forms the headwaters of the Midway River and contains wetlands and spring features. The stream segment running through this area is cold but there are connectivity issues downstream that may prevent or reduce movement of fish into this area

Appendix A – Data Summaries/Project Recommendations

❖ Appendix A3 – Midway River Watershed Culvert Replacement Scores and Rank

ReachID	Stream Name	Location	Road Authority	Lat	Long	Base Replacement Score	Stream Quality Adjustment Factor	Adjusted Replacement Score	Rank	Upstream Miles
MR-012	Midway River	Midway River @ Midway Rd	St. Louis County	46.759641	-92.280035	711.9	712	1424	1	60.22
T-B1-001	Tributary B	Tributary B @ Hautaluoma Rd	Private	46.688832	-92.379443	327.5	328	655	2	4.05
T-I1-001	Elm Creek	Elm Creek @ Private Rd	Private	46.750941	-92.305081	180.8	362	543	3	5.79
T-J1-011	Rocky Run Creek	Rocky Run Creek @ Maple Grove Rd	St. Louis County	46.807601	-92.305852	146.6	293	440	4	9.16
T-E1-009	Hay Creek	Hay Creek @ St. Louis River Rd	St. Louis County	46.764936	-92.380173	219.2	219	438	5	12.40
T-J6-004	Tributary to Rocky Run Creek	Tributary to Rocky Run Creek @ Private Rd	Private	46.799889	-92.330543	113.3	227	340	6	1.13
T-G1-005	Anderson Creek	Anderson Creek @ Midway Rd	St. Louis County	46.731784	-92.280066	191.1	96	287	7	7.30
T-E12-004	Tributary to Hay Creek	Tributary to Hay Creek @ Canosia Rd	St. Louis County	46.780913	-92.364694	122.5	61	184	8	4.56
T-E12-004	Tributary to Hay Creek	Tributary to Hay Creek @ Mattson Rd	Township	46.779081	-92.375029	59.6	119	179	9	5.09
T-B1-002	Tributary B	Tributary B @ Korby Rd	Township	46.693441	-92.386272	116.1	58	174	10	3.56
T-Q1-001	Tributary Q	Tributary Q @ Midway Rd	St. Louis County	46.754217	-92.280114	120.8	0	121	11	1.04
T-G6-003	Tributary to Anderson Creek	Tributary to Anderson Creek @ North Cloquet Rd	St. Louis County	46.734227	-92.271319	77.2	39	116	12	0.36
T-E2-001	Tributary to Hay Creek	Tributary to Hay Creek @ County Road 1	Carlton County	46.737936	-92.366481	38.2	76	114	13	0.62
T-J5-005	Tributary to Rocky Run Creek	Tributary to Rocky Run Creek @ Hwy 2	State of MN	46.793126	-92.30118	30.1	60	90	14	0.91
T-K2-003	Tributary K	Tributary K @ Midway Rd	St. Louis County	46.780553	-92.280169	27.4	55	82	15	0.99
T-J6.1-002	Tributary to Rocky Run Creek	Tributary to Rocky Run Creek @ Jeffrey Rd	Township	46.801315	-92.333204	37.8	38	76	16	0.08
T-AB2-001	Tributary AB	Tributary AB @ Ugstad Rd	Hermantown	46.802852	-92.238285	63.9	0	64	17	0.37
T-L4.2-004	Tributary to East Rocky Run	Tributary to East Rocky Run @ Lavaque Junction	Hermantown	46.818461	-92.237005	63.7	0	64	18	1.91
T-I1-005	Elm Creek	Elm Creek @ St. Louis River Rd	St. Louis County	46.765065	-92.327967	38.2	19	57	19	1.91
T-I3-003	Elm Creek	Elm Creek @ Erickson Rd	Township	46.75949	-92.322454	35.6	18	53	20	2.54
T-H1-002	Tributary H	Tributary H @ Larson Ln	Private	46.740451	-92.316111	52.6	0	53	21	2.51
T-L4.2.1-002	Tributary to East Rocky Run	Tributary to East Rocky Run @ Lavaque Junction	Hermantown	46.818493	-92.228611	47.6	0	48	22	1.85
T-K1-006	Tributary K	Tributary K @ Railroad	Railroad	46.777961	-92.274139	30.9	15	46	23	1.47
T-E1-016	Hay Creek	Hay Creek @ Canosia Rd	St. Louis County	46.79255	-92.364566	29.7	15	45	24	1.33
T-K1-001	Tributary K	Tributary K @ Railroad	Railroad	46.767661	-92.277449	42.6	0	43	25	5.87
T-K2-004	Tributary to Tributary K	Tributary to Tributary K @ Old Hwy 2	Hermantown	46.780479	-92.281342	14.0	28	42	26	0.93
T-D1-001	Tributary D	Tributary D @ County Road 1	Carlton County	46.719544	-92.365903	27.0	13	40	27	1.75
T-K1-007	Tributary K	Tributary K @ Morris Thomas/Old Hwy 2	Hermantown	46.778595	-92.27383	26.8	13	40	28	1.41
T-G6-004	Tributary to Anderson Creek	Tributary to Anderson Creek @ Lilac Hill Rd	Township	46.734943	-92.271861	25.6	13	38	29	0.28
T-R1-002	Tributary R	Tributary R @ Private Rd	Private	46.759517	-92.279726	37.6	0	38	30	1.02
T-B1-003	Tributary B	Tributary B @ I35	State of MN	46.699399	-92.391355	29.6	0	30	31	2.96
T-C1-002	Tributary C	Tributary C @ Thompson Rd	Carlton County	46.689074	-92.364845	27.9	0	28	32	1.58
T-L4.2-0051	Tributary to East Rocky Run	Tributary to East Rocky Run @ Private Rd	Private	46.820198	-92.238237	26.7	0	27	33	1.77
T-L3-001	Tributary to East Rocky Run	Tributary to East Rocky Run @ Five Corners Rd	Hermantown	46.793877	-92.270229	19.0	0	19	34	1.15
T-J6.1-001	Tributary to Rocky Run Creek	Tributary to Rocky Run Creek @ Hwy 2	State of MN	46.800546	-92.331032	2.3	5	7	35	0.22

Appendix A – Data Summaries/Project Recommendations

❖ Appendix A4 – Top Priority (High/Very High) Culvert Replacement Projects

The table below includes potential Stream Connectivity and Fish Passage Projects that were given a ranking of **High/Very High** during the prioritization process completed by MPCA and local Soil and Water Conservation District staff. A complete spreadsheet database of all projects evaluated is available upon request.

High/Very High Priority Culvert Replacement Projects -- Connectivity and Fish Passage

Project_ID	Watershed Zone	Stream	Crossing Location/Road Name	Reach_ID	County	Lat	Long	Priority Level
6	Anderson Creek	Anderson Ck.	Paso Fino Lane	G1-001	Carlton	46.738785	-92.306992	Very High (4)
7	Elm Creek	Elm Ck	Private Driveway	I1-001	Carlton	46.750951	-92.305074	Very High (4)
8	West Rocky Run	W. Rocky Run Trib.	Private Trail (Inactive)	J6.2-001	Saint Louis	46.800546	-92.331032	Very High (4)
131	Anderson Creek	Anderson Ck.	Railroad (Active)	G1-004	Saint Louis	46.731565	-92.286680	High (3)
133	Anderson Creek	Anderson Ck.	Midway Road	G1-005	Saint Louis	46.731788	-92.280214	High (3)
155	Elm Creek	Elm Ck	Northwoods Trail/Road	I1-002.5	Carlton	46.757632	-92.316932	High (3)
156	Adolph Creek	Tributary K2	Midway Road	K2-003	Saint Louis	46.780537	-92.280176	High (3)
198	Hay Creek	Trib. to Hay Creek (E2)	Canosia Rd	E2-001	Carlton	46.737872	-92.366373	High (3)
234	West Rocky Run	Trib. to West Rocky Run (J5)	US HWY 2	J5-005	Saint Louis	46.793107	-92.301190	High (3)
247	Lower Midway	Tributary B (B1)	Hautaluoma Rd	B1-001	Carlton	46.688840	-92.379384	High (3)

Appendix A – Data Summaries/Project Recommendations

❖ Appendix A5 – High Priority Culvert Assessment Data Gaps

The table below includes stream crossing assessment data gaps that were given a ranking of **High/Very High** during the prioritization process completed by MPCA and local Soil and Water Conservation District staff. These crossing were not assessed during this study due to private property access issues. A complete spreadsheet database of all projects evaluated is available upon request.

High/Very High Priority Culvert Assessment Data Gaps -- Connectivity and Fish Passage

Project_ID	Watershed Zone	Stream	Crossing Location/Road Name	Reach_ID	County	Lat	Long	Priority Level
22	Hay Creek	Hay Ck	Private Access Rd	E1-005	Carlton	46.743680	-92.363264	Very High (4)
23	Hay Creek	Hay Ck	Private Access Rd	E1-015	Saint Louis	46.792352	-92.373031	Very High (4)
24	Hay Creek	Hay Ck	Private Access Rd	E1-012	Saint Louis	46.787556	-92.391908	Very High (4)
25	Hay Creek	Hay Ck	Private Access Rd	E1-011	Saint Louis	46.779755	-92.389509	Very High (4)
26	Hay Creek	Hay Ck	Private Access Rd	E1-011	Saint Louis	46.777373	-92.388730	Very High (4)
85	Hay Creek	Trib. to Hay Creek (E12)	Private Access Rd	E12-004	Saint Louis	46.780820	-92.369768	Very High (4)
86	Hay Creek	Trib. to Hay Creek (E12)	Private Access Rd	E12-004	Saint Louis	46.780478	-92.371647	Very High (4)
89	Hay Creek	Trib. to Hay Creek (E12)	Private Access Rd	E12-001	Saint Louis	46.778151	-92.384586	High (3)
100	Hay Creek	Trib. to Hay Creek (E9)	Private Access Rd	E9-001	Carlton	46.761582	-92.371853	Very High (4)
248	West Rocky Run	West Rocky Run	Private Access Rd	J1-012	Saint Louis	46.814329	-92.314461	Very High (4)

Appendix A –Data Summaries/Project Recommendations

❖ Appendix A6 – Top Priority (High/Very High) Stream Channel Restoration Projects

The table below includes potential Stream Habitat Restoration Projects that were given a ranking of **High/Very High** during the project prioritization process completed by MPCA and local Soil and Water Conservation District staff. A complete spreadsheet database of all projects evaluated is available upon request.

Project_ID	Watershed Zone	Stream	Reach_ID	County	Lat	Long	Priority Level
1	Hay Creek	Hay Ck	E1-014	Saint Louis	46.794670	-92.385174	Very High (4)
9	Adolph Creek	Adolph Ck.	K1-001	Saint Louis	46.773334	-92.273667	High (3)
21	Anderson Creek	Anderson Ck.	G1-002	Saint Louis / Cartlon	46.735267	-92.299707	High (3)
28	Hay Creek	Hay Ck	E1-013	Saint Louis	46.794708	-92.387710	High (3)
29	Hay Creek	Hay Ck	E1-006	Carlton	46.747552	-92.365787	High (3)
30	Hay Creek	Hay Ck	E1-014	Saint Louis	46.794580	-92.382171	High (3)
31	Hay Creek	Hay Ck	E1-015	Saint Louis	46.792346	-92.372973	High (3)
44	Upper Midway	Midway R.	MR-014	Saint Louis	46.769889	-92.275468	High (3)
45	Middle Midway	Midway R.	MR-007 and MR-008	Carlton	46.742106	-92.312291	High (3)
69	Adolph Creek	Tributary K2	K2-003	Saint Louis	46.780332	-92.278858	High (3)
82	Hay Creek	Trib. to Hay Creek (E10.1)	E10.1-002	Carlton	46.763321	-92.383780	High (3)
87	Hay Creek	Trib. to Hay Creek (E12)	E12-003	Saint Louis	46.779211	-92.381412	High (3)
88	Hay Creek	Trib. to Hay Creek (E12)	E12-004	Saint Louis	46.780903	-92.367525	High (3)
93	Hay Creek	Trib. to Hay Creek (E12.2)	E12.2-002	Saint Louis	46.781860	-92.361893	High (3)
105	Upper Midway	Trib. to Tributary AB (AB2)	AB2-001	Saint Louis	46.799685	-92.242999	High (3)
126	West Rocky Run	Trib. to West Rocky Run (J13)	J13-003	Saint Louis	46.812597	-92.302295	High (3)
141	Upper Midway	Tributary AB (AB1)	AB1-002	Saint Louis	46.800339	-92.243536	High (3)
146	Upper Midway	Tributary AF	AF1-002	Saint Louis	46.796635	-92.220249	High (3)
152	Upper Midway	Tributary AI1	AI-002	Saint Louis	46.807347	-92.211612	High (3)
249	West Rocky Run	West Rocky Run	J1-007	Saint Louis	46.787558	-92.306207	High (3)

Appendix A –Data Summaries/Project Recommendations

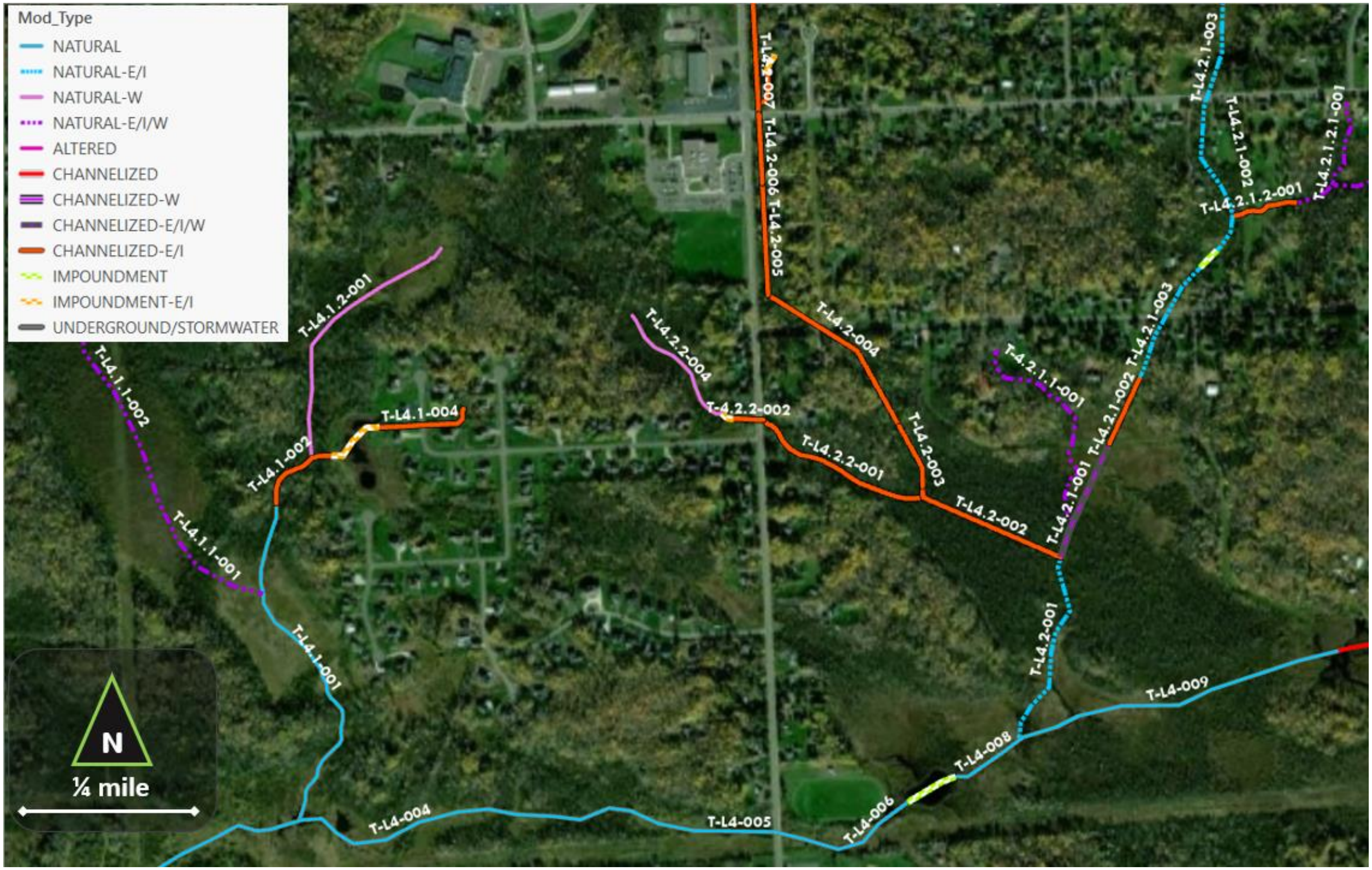
❖ Appendix A7 – Top Priority (High/Very High) Riparian Corridor Restoration Projects

The table below includes potential Riparian Corridor Restoration Projects that were given a ranking of **High/Very High** during the project prioritization process completed by MPCA and local Soil and Water Conservation District staff. A complete spreadsheet database of all projects evaluated is available upon request.

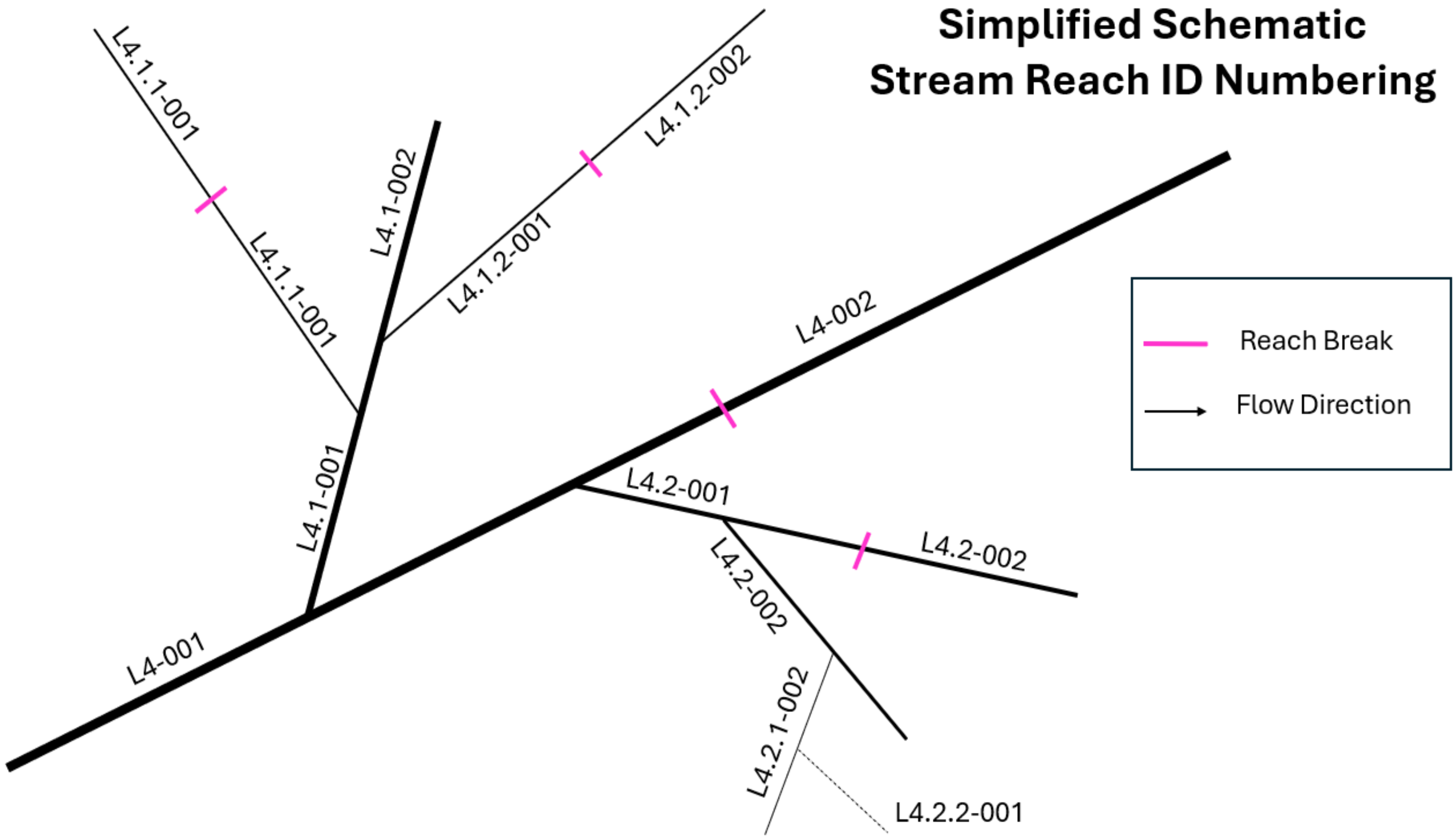
Project_ID	Watershed Zone	Stream	Reach_ID	County	Lat	Long	Priority Level
2	Elm Creek	Elm Ck	I1-003	Carlton	46.759285	-92.323038	Very High (4)
13	Hay Creek	Hay Ck	E1-008	Carlton	46.755467	-92.367787	Very High (4)
15	Hay Creek	Hay Ck	E1-011	Saint Louis	46.779853	-92.389618	Very High (4)
19	Lower Midway	Midway R.	MR-006	Carlton	46.718363	-92.359063	Very High (4)
20	Middle Midway	Midway R.	MR-007	Carlton	46.730858	-92.335767	Very High (4)
27	Middle Midway	Midway R.	MR-009	Carlton	46.750213	-92.302051	Very High (4)
37	Middle Midway	Midway R.	MR-010	Saint Louis	46.754998	-92.299808	Very High (4)
38	West Rocky Run	Tributary J13	J13.3-004	Saint Louis	46.819810	-92.298382	Very High (4)
39	Hay Creek	Trib. to Hay Creek (E12)	E12-003	Saint Louis	46.778735	-92.379481	Very High (4)
40	Elm Creek	Elm Ck	I1-003	Carlton	46.759710	-92.322078	High (3)
42	Hay Creek	Hay Ck	E1-014	Saint Louis	46.794670	-92.385174	High (3)
43	Lower Midway	Midway R.	MR-006	Carlton	46.710901	-92.366179	High (3)
64	Lower Midway	Midway R.	MR-007	Carlton	46.724515	-92.353044	High (3)
84	Lower Midway	Tributary D	D1-002	Carlton	46.720036	-92.367874	High (3)

Appendix B – Example of Stream Reach Delineation and Condition

This image is a screenshot of the online mapping tool showing stream reach delineation and general condition (channelized, natural channel, impoundment, etc.).

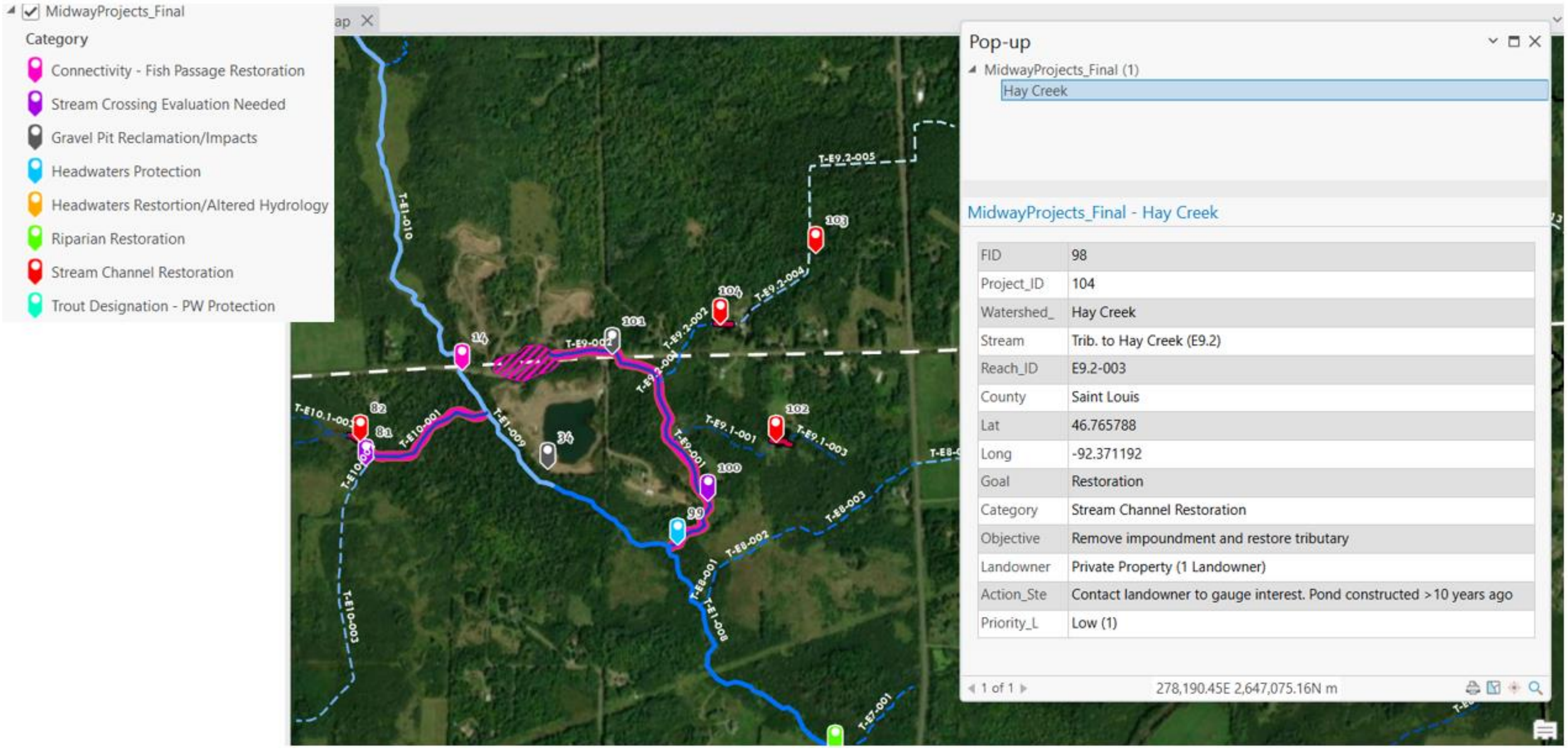


Appendix C – Schematic Example of Stream Reach ID Numbering System



Appendix D – Schematic Example of Stream Reach ID Numbering System

This image below is a screenshot of the MRWPS online mapping tool that is in development.



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