Mud Creek 2018 Catchment Report

Watershed Features	
Area	15.54 square kilometres 0.37% of the Rideau Valley watershed
Land Use	17.27% agriculture 27.75% urban 22.52% forest 18.17% meadow 6.59% rural 0.44% waterbody 7.26% wetland
Surficial Geology	44.96% clay 3.18% diamicton 2.10% organic deposits 2.18% Paleozoic bedrock 47.58% sand
Watercourse Type	2018 thermal conditions warmwater system
Invasive Species	Seventeen invasive species were identified in 2018: banded mystery snail, common buckthorn, curly leafed pondweed, dog strangling vine, European frogbit, flowering rush, garlic mustard, glossy buckthorn, Himalayan balsam, Japanese knotweed, Manitoba maples, Norway maples, *Phragmites*, wild parsnip, purple loosestrife, rusty crayfish, yellow iris
Fish Community	19 species of fish have been observed from 2012-2018. Game fish species include: largemouth bass, pumpkinseed

Wetland Catchment Cover
4.89% evaluated wetland
2.36% unevaluated wetland

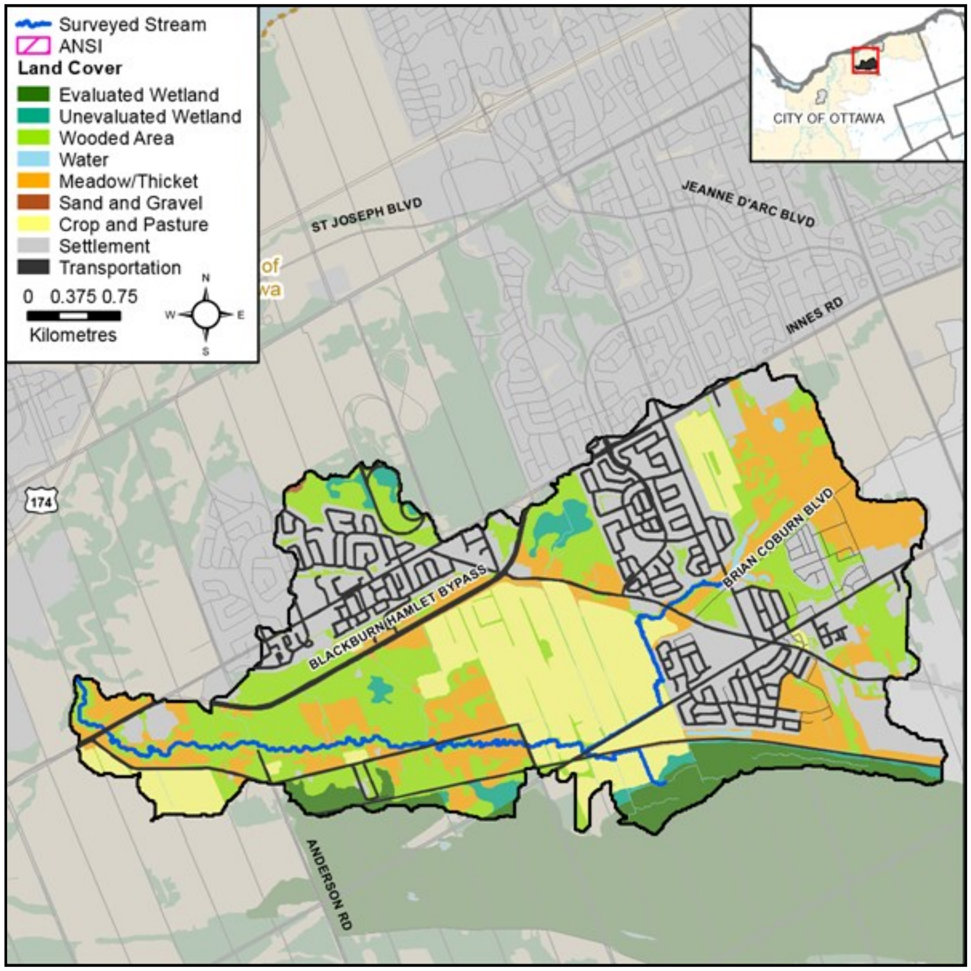


Figure 1 Land cover in the Mud Creek catchment

Mud Creek near the confluence with Greens Creek

The Rideau Valley Conservation Authority, in partnership with eight other agencies in Ottawa, form the 2018 City Stream Watch Collaborative: South Nation Conservation Authority, Mississippi Valley Conservation Authority, City of Ottawa, Ottawa Flyfishers Society, Ottawa Stewardship Council, Rideau Roundtable, Canadian Forces Fish and Game Club, and the National Capital Commission.

Introduction

Mud Creek is approximately six kilometers long and is one of five major tributaries to Greens Creek in the east end of the City of Ottawa. The headwaters of Mud Creek begin in the Mer Bleue Wetland, which is a popular recreation destination as well as being recognized as a Wetland of International Importance by the Ramsar convention, an Area of Natural and Scientific Interest (ANSI) and a Provincially Significant Wetland. From it's headwaters Mud Creek flows through property owned by the National Capital Commission, crossing Renaud road three times and Innes road once before it empties into Greens Creek north of Innes road.

In 2018, the City Stream Watch program surveyed sixty four 100 meter sections of the main channel of Mud Creek and twenty five100 meter sections of a tributary of Mud Creek that originates East of Pagé Road. Three sites were sampled for fish community composition.

Low Water Conditions - Rideau Valley Watershed

Low Water Conditions

Prolonged periods of hot dry weather punctuated by heavy rainfall events characterized 2018. The year began close to normal however March had less than normal precipitation. The spring freshet in early April was significant but the forecasted rain didn't materialize and peak flows were only slightly above average. The dry weather came on through May, continued through June and as of July 10th 2018, the conditions in the Rideau Valley Watershed were declared to be at the minor low water status. At this time, stream flows were below normal but still above critical thresholds. (RVCA, 2018) Twenty five days with temperatures above 30 degrees, 15 of those in July, contributed to the overall drought condition in the watershed. As of July 19th the status within the watershed reached moderate severity.

On August 2nd this status was reduced back to minor severity with significant rainfalls measured through eastern Ontario in late July. Rain in the lower reaches of the watershed continued through August and into September. As of September 27th 2018, the low water status in the lower Rideau River Watershed returned to normal.

Mud Creek Overbank Zone

Riparian Buffer Width Evaluation

The riparian buffer is the adjacent land area surrounding a stream or river. Naturally vegetated buffers are very important to protect the overall health of streams and watersheds. Natural shorelines provide buffering capacity of contaminants and nutrients that would otherwise run off freely into aquatic systems. Well established shoreline plant communities will hold soil particles in place preventing erosion and will also provide the stream with shading and cover. Environment and Climate Change Canada recommends a guideline of 30 meters of natural vegetation on both sides of the stream for at least 75 percent of the stream length (Environment Canada, 2013).

Figure 2 demonstrates buffer conditions along the left and right banks of Mud Creek. Buffers greater than 30 meters were present along 67 percent of the left bank and 68 percent of the right bank. A five meter buffer or less was present along 9 percent of the left banks and 20 percent of the right bank. A fifteen to thirty meter buffer was present along 15 percent of the left banks and four percent of the right bank. A five to fifteen meter buffer was present along nine percent of the left bank and eight percent of the right banks.

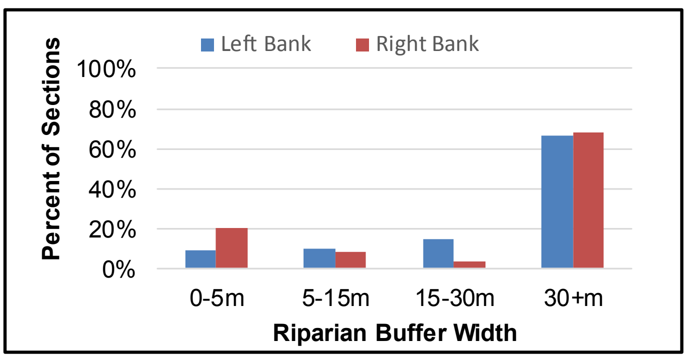


Figure 2 Vegetated buffer width along Mud Creek

Riparian Buffer Alterations

Alterations within the riparian buffer were assessed within three distinct shoreline zones (0-5 m, 5-15 m, 15-30 m), and evaluated based on the dominant vegetative community and/or land cover type. The percentage of anthropogenic alterations to the natural riparian cover are shown in Figure 3.

Mud Creek riparian zones have primarily natural vegetative communities; however there are areas with alterations that are associated with channel straightening and infrastructure such as roadways. Reduced buffers were also observed in residential and agricultural areas.

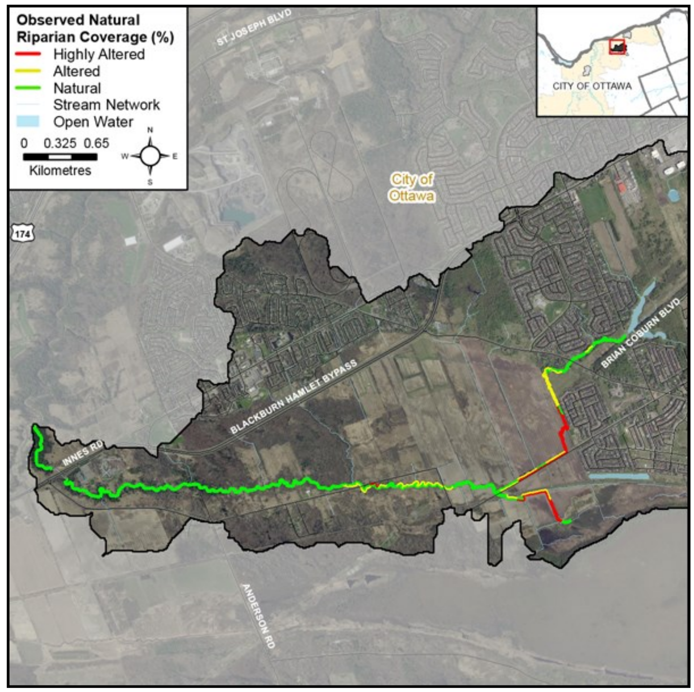


Figure 3 Riparian buffer alterations in Mud Creek

Vegetated buffer along Mud Creek

Infrastructure along Mud Creek at Renaud Road

Adjacent Land Use

Surrounding land use is considered from the beginning to the end of the survey section (100 m) and up to 100 meters on each side of the river. Land use outside of this area is not considered for the surveys but is nonetheless part of the subwatershed and will influence the creek. Figure 4 shows the percent of surveyed sections that contain each type of land use.

The most common land use found was forests, present in 76 percent of sections. Meadows were present in 69 percent of sections. Scrubland was present in 33 percent of sections and wetland was present in two percent of the sections.

Aside from the natural areas, the most common land uses in the catchment were active agriculture and infrastructure land uses, each present in 25 percent of sections. Other uses observed included eight percent of surveyed areas with residential land uses, and industrial/ commercial and recreational uses in one percent of sections each.

Mud Creek Shoreline Zone

Anthropogenic Alterations

Stream alterations are classified based on specific functional criteria associated with the flow conditions, the riparian buffer and potential human influences.

Figure 5 shows the level of anthropogenic alterations for Mud Creek, with 44 percent remaining without any human alteration. Thirty nine percent fell in the classification of natural. Natural sections have not been straightened or diverted, have a riparian buffer greater than 15 meters, contain few lawns, ornamental gardens, beaches, rip rap or constructed wooden structures.

Altered sections account for 12 percent of surveyed areas, they may contain small diverted or straightened sections and riparian buffers of five to 15 meters.

Highly altered sections accounted for four percent of Mud Creek and correspond to sections that flow through a culvert.

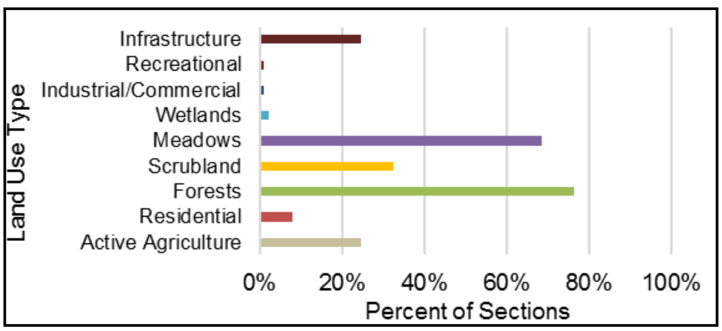


Figure 4 Adjacent land use 100 meters from each shoreline and percentage of presence along Mud Creek

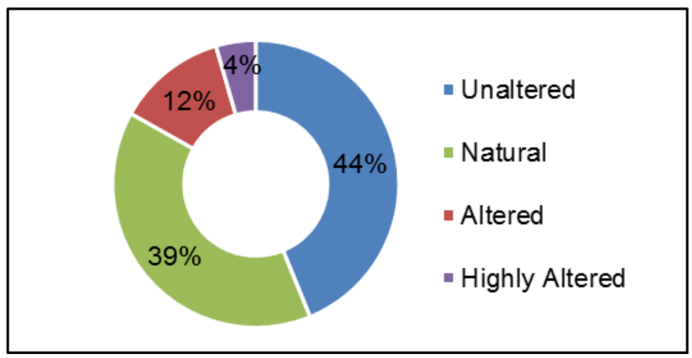


Figure 5 Anthropogenic alterations along Mud Creek

Forested section along Mud Creek

A highly altered section of Mud Creek at Innes Road

Erosion

Stream erosion is the process by which water erodes and transports sediments, resulting in dynamic flows and diverse habitat conditions. Excessive erosion can result in drastic environmental changes, as habitat conditions, water quality and aquatic life are all negatively affected. Bank stability was assessed as the overall extent of each section with "unstable" shoreline conditions. These conditions are defined by the presence of significant exposed soils/roots, minimal bank vegetation, severe undercutting, slumping or scour and potential failed erosion measures (rip rap, gabion baskets, etc.).

Figure 6 shows the levels of stream erosion observed across the surveyed portions of Mud Creek.

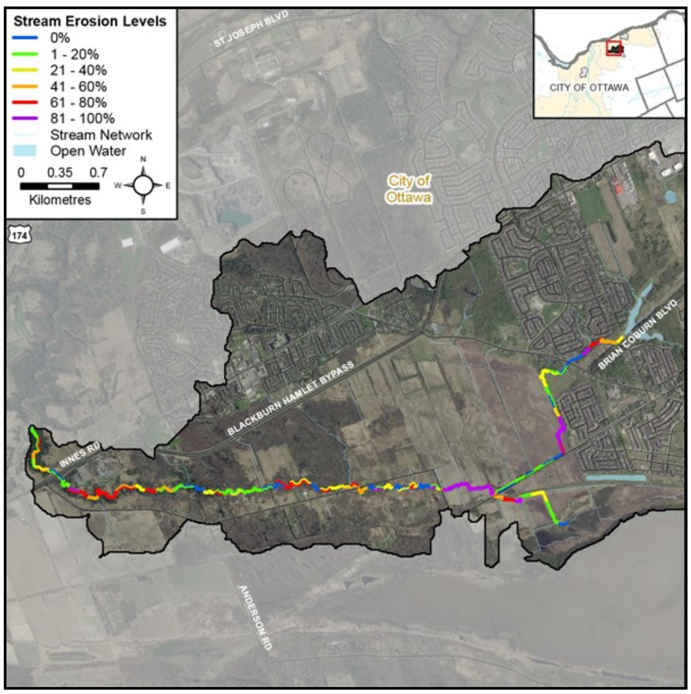


Figure 6 Erosion levels along Mud Creek

Bank erosion observations along Mud Creek

There was erosion present along the majority of the creek which ranged from low to high levels of erosion. There were many areas where CSW staff and volunteers noted highly unstable banks and evidence of recent slope failures.

Unstable banks along Mud Creek

Undercut Stream Banks

Stream bank undercuts can provide important cover habitat for aquatic life, however excessive levels can be an indication of unstable shoreline conditions. Bank undercut was assessed as the overall extent of each surveyed section with overhanging bank cover present.

Figure 7 shows that undercut banks were present in over half of the sections surveyed in Mud Creek. Sixty-six percent of the sections had undercutting in the left bank and 67 percent of the right bank.

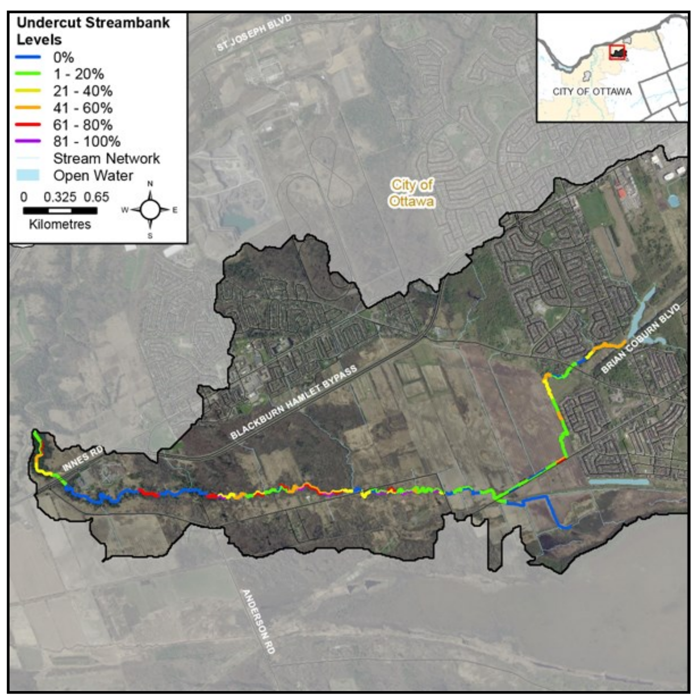


Figure 7 Undercut stream banks along Mud Creek

Stream Shading

Grasses, shrubs and trees all contribute towards shading a stream. Shade is important in moderating stream temperature, contributing to food supply and helping with nutrient reduction within a stream. Stream shading is assessed as the total coverage area in each section that is shaded by overhanging trees/grasses and tree canopy, at greater than one meter above the water surface.

Figure 8 shows the percentage of sections surveyed with various levels of stream shading. The majority of sections, 43 percent, had a shade cover of one to 20 percent. The highest level of shading was observed in 4 percent of the sections. Shading of 61 to 80 percent was present in nine percent of the sections; and 15 percent of the sections had 41 to 60 percent shading. Twenty seven percent of sections had shading of 21 to 40 percent and two percent of sections had no shading. Figure 9 shows the distribution of these shading levels along Mud Creek.

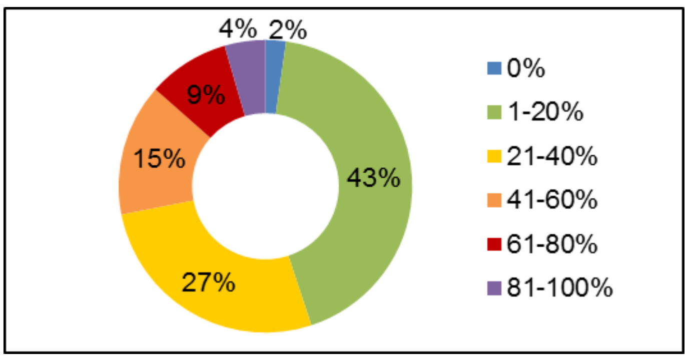


Figure 8 Stream shading along Mud Creek

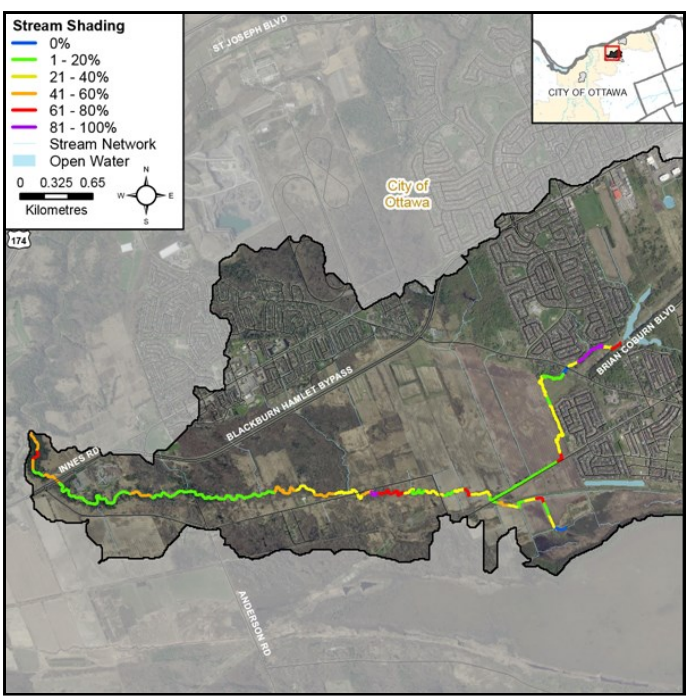


Figure 9 Distribution of stream shading along Mud Creek

A mix of trees, shrubs and grasses comprised the majority of shading along Mud Creek. Overhanging plants were seen in 63 percent of the left bank and 63 percent of the right bank.

Overhanging Wood Structure

Trees and branches that are less than one meter from the surface of the water are defined as overhanging. Overhanging branches and trees provide a food source, nutrients and shade which helps to moderate instream water temperatures.

Figure 10 shows the presence of overhanging wood structure observed along Mud Creek. Ninety four percent of the sections had overhanging trees and branches on the left bank, and 79 percent of the sections had overhanging trees on the right bank.

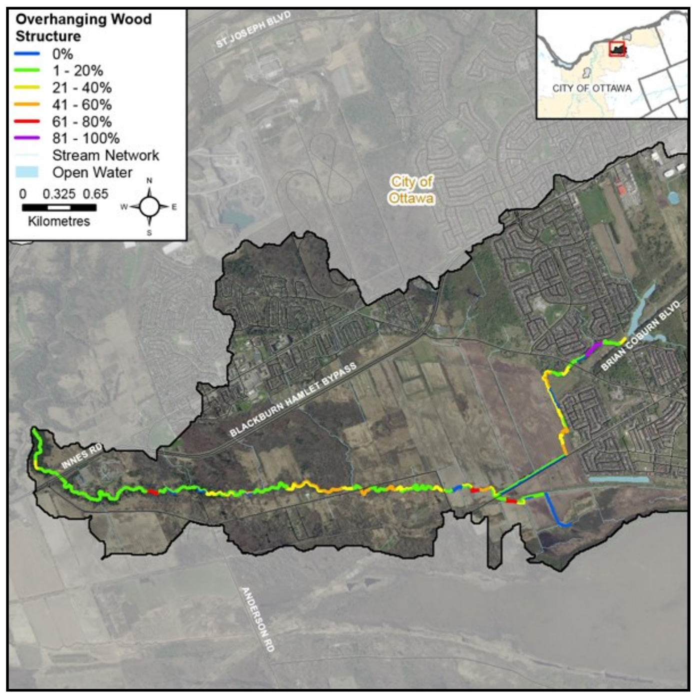


Figure 10 Overhanging wood structure along Mud Creek

Section with overhanging wood structure along Mud Creek

Mud Creek Instream Aquatic Habitat

Habitat Complexity

Habitat complexity is a measure of the overall diversity of habitat types and features within a stream. Streams with high habitat complexity support a greater variety of species niches, and therefore contribute to greater diversity. Factors such as substrate, flow conditions (pools, riffles) and cover material (vegetation, wood structure, etc.) all provide crucial habitat to aquatic life. Habitat complexity is assessed based on the presence of boulder, cobble and gravel substrates, as well as the presence of instream wood structure. A higher score shows greater complexity where a variety of species can be supported.

Figure 11 shows habitat complexity of the sections surveyed: seven percent had no complexity; 44 percent had a score of one; 29 percent scored two; 15 percent scored three; and 6 percent had the highest habitat complexity.

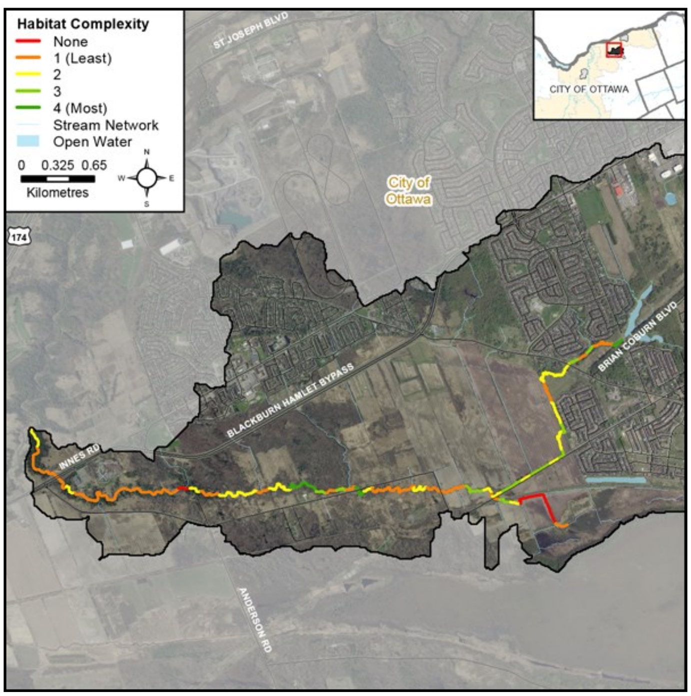


Figure 11 Instream habitat complexity along Mud Creek

Section of Mud Creek featuring riffle and run habitat

Instream Substrate

Diverse substrate is important for fish and benthic invertebrate habitat because some species have specific substrate requirements and for example will only reproduce on certain types of substrate. The absence of diverse substrate types may limit the overall diversity of species within a stream.

Figure 12 shows the substrates present in the sections of Mud Creek. It is a system dominated by clay, with 96 percent of sections containing this type of substrate. It also has substantial amounts of silt. Gravel, sand and cobble were observed in moderate amounts and a small amount of boulders were observed.

Figure 13 shows the dominant substrates along the creek. Clay was the dominant substrate type in 74 percent of sections. Silt was dominant in 21 percent of sections. Gravel was dominant in two percent of sections and sand and cobble were each dominant in one percent of sections.

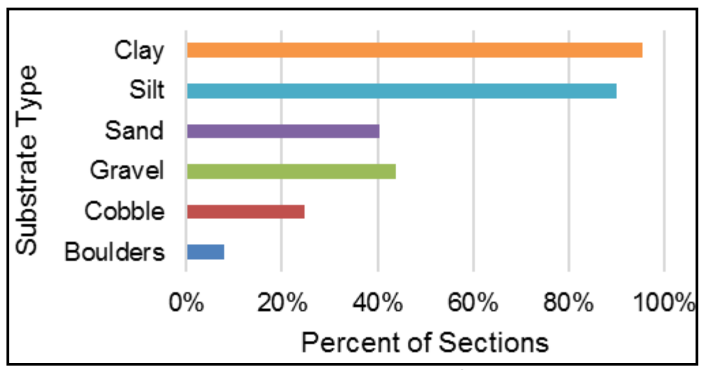


Figure 12 Instream substrate along Mud Creek

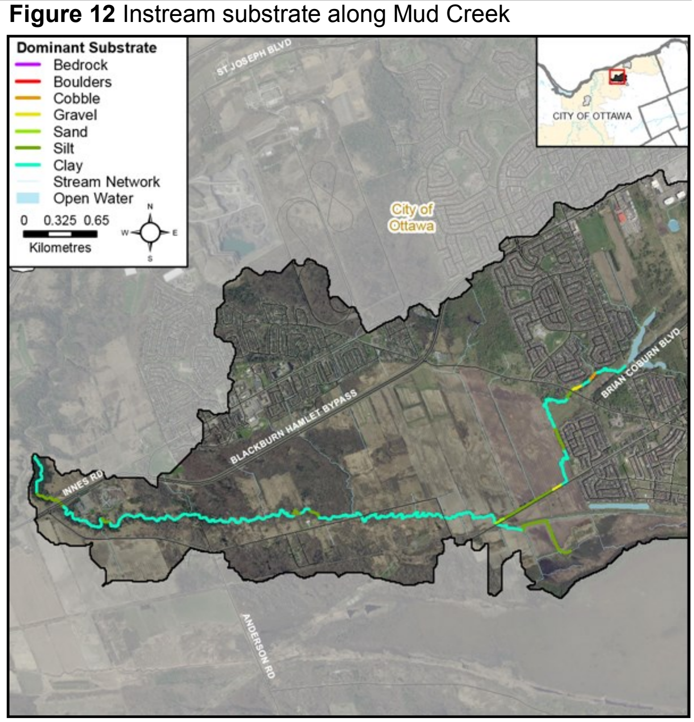


Figure 13 Dominant instream substrate along Mud Creek

Instream Morphology

Pools and riffles are important habitat features for aquatic life. Riffles are fast flowing areas characterized by agitation and overturn of the water surface. Riffles thereby play a crucial role in contributing to dissolved oxygen conditions and directly support spawning for some fish species. They are also areas that support high benthic invertebrate populations which are an important food source for many aquatic species. Pools are characterized by minimal flows, with relatively deep water and winter and summer refuge habitat for aquatic species. Runs are moderately shallow, with unagitated surfaces of water and areas where the thalweg (deepest part of the channel) is in the center of the channel.

Figure 14 shows that Mud Creek has a diversity of morphological conditions, suitable for a variety of aquatic species and life stages; 83 percent of sections contained pools, 78 percent contained riffles and the majority, 93 percent, contained runs. Figure 15 shows the locations of riffle habitat along Mud Creek.

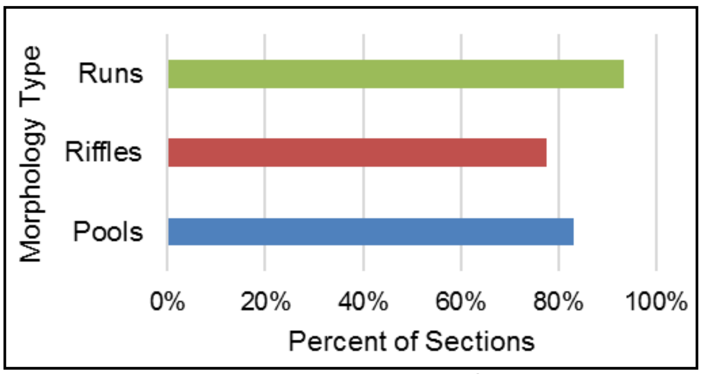


Figure 14 Instream morphology along Mud Creek

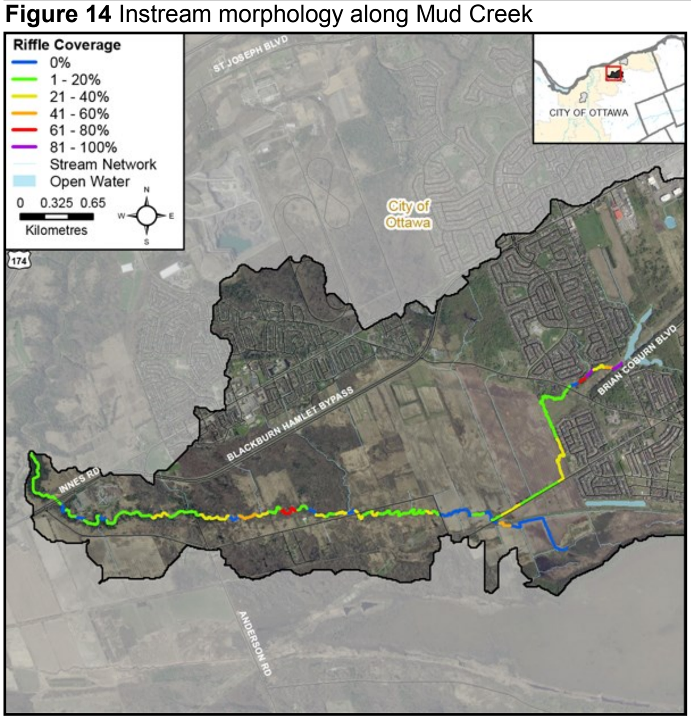


Figure 15 Riffle habitat locations along Mud Creek

Instream Wood Structure

Figure 16 shows that the majority of Mud Creek had low levels of instream wood material in the form of branches and trees with some sections having moderate and high levels of instream wood material. Instream wood structure is important for fish and wildlife habitat, by providing refuge and feeding areas. Excessive amounts can create temporary migration barriers.

Instream wood structure found along Mud Creek

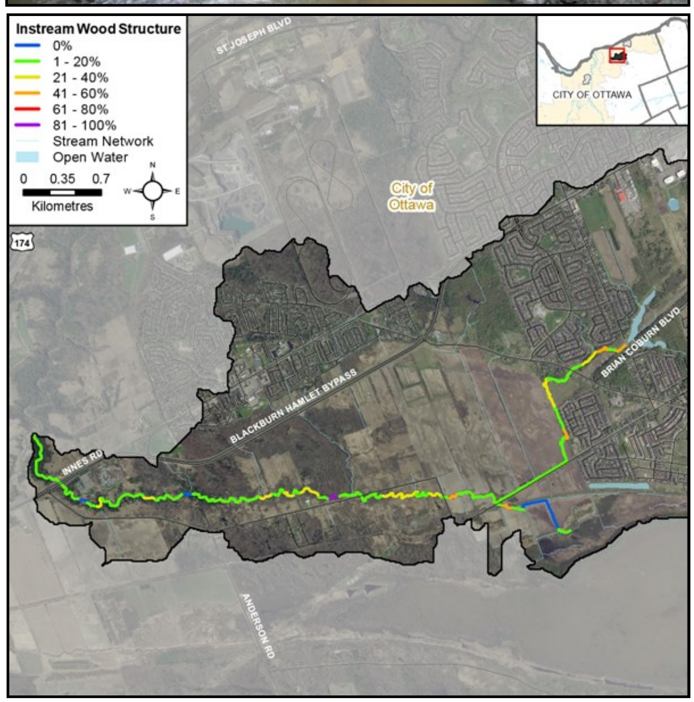


Figure 16 Instream wood structure along Mud Creek

Instream Aquatic Vegetation Type

Instream vegetation is a key component of aquatic ecosystems. It promotes stream health by:

- Providing riparian and instream habitat.
- Maintaining water quality by erosion control, nutrient cycling, and pollutant absorption.
- Stabilizing flows and reducing shoreline erosion.
- Contributing dissolved oxygen via photosynthesis.
- Moderating temperatures through shading.

Figure 17 shows the aquatic vegetation community structure. Surveys showed that Mud Creek had a moderate diversity of aquatic vegetation. Areas with no vegetation were found in 90 percent of sections. The most common type of vegetation was narrow-leaved emergents found in 54 percent of sections. Submerged vegetation was found in 40 percent of sections. Broad-leaved vegetation and algae were each found in 24 percent of sections. Robust vegetation was in 21 percent of sections and free-floating vegetation was in 11 percent. Figure 18 shows dominant vegetation type distribution.

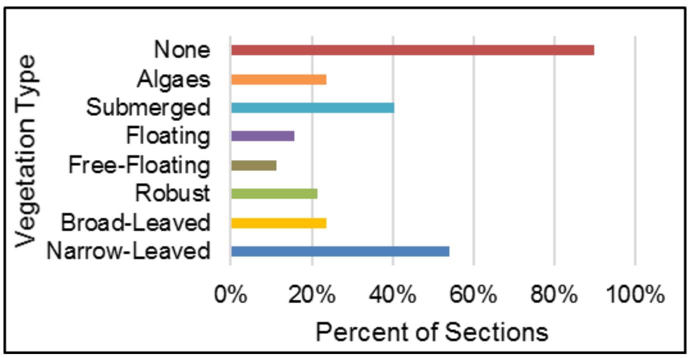


Figure 17 Aquatic vegetation presence along Mud Creek

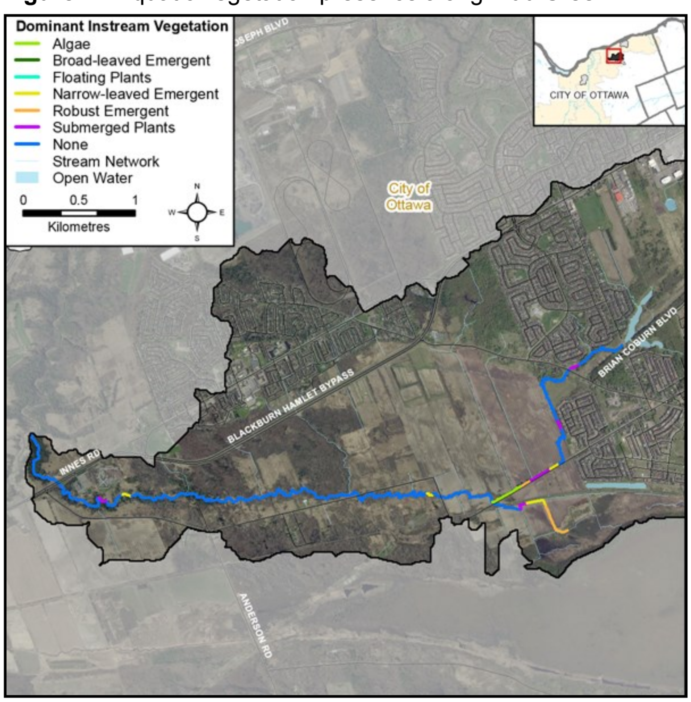


Figure 18 Dominant instream vegetation distribution in Mud Creek

Instream Vegetation Abundance

The abundance of instream vegetation is also crucial for overall aquatic ecosystem health. Lack of vegetation, rare or low abundances can impair the ability of plants to contribute adequately to dissolved oxygen, provide habitat, and remove nutrients and contaminants. Extensive amounts of vegetation can also have negative impacts by lowering dissolved oxygen levels. It can act as a physical barrier for humans and wildlife, and it leads to a reduction in plant diversity. Invasive species in particular tend to have this extensive mode of growth.

As seen in Figure 19, overall, Mud Creek had low levels of vegetation in large part due to the dominance of clay substrates in the stream and the flashy flows that Mud Creek experiences. Areas with no vegetation were seen in 88 percent of sections. Rare and low levels of vegetation were found in 36 and 34 percent of sections. Normal levels were found in 12 percent and common levels were found in seven percent of sections. Finally, two percent of sections had areas with extensive vegetation.

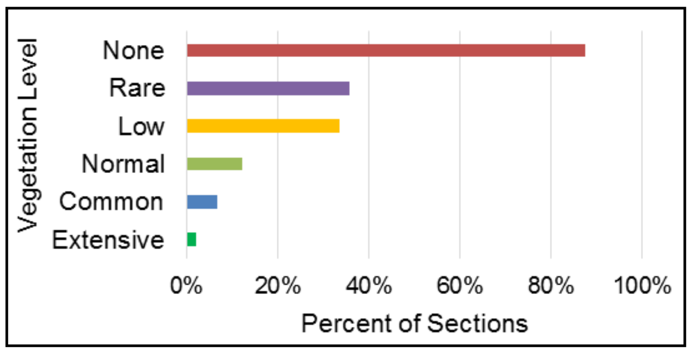


Figure 19 Instream vegetation abundance along Mud Creek

Section of Mud Creek with no instream vegetation observed

Mud Creek Stream Health

Wildlife

The diversity of fish and wildlife populations can be an indicator of water quality and overall stream health (Table 1). Wildlife observations are noted during monitoring and survey activities; they do not represent an extensive evaluation of species presence or absence in the Mud Creek catchment.

Table 1 Wildlife observed along Mud Creek in 2018

Birds	mallard ducks, red-winged blackbird, song birds, American crow, warbler
Reptiles & Amphibians	green frog, bullfrog, American toad, snapping turtle, tadpoles
Mammals	deer tracks, raccoon, beaver, black squirrel, muskrat, chipmunk
Benthic Invertebrates	water striders, leeches, whirligig beetle, mayflies
Other	monarch butterfly, dragonflies, damselflies, mosquitoes, snails, moths, cyprinids, mosquitos, deerflies, pollinators, caterpillars, crayfish, spiders, cicada

Invasive Species

Invasive species are harmful to the environment, the economy and our society. They have high reproduction, quick establishment of dense colonies, tolerate a variety of environmental conditions and lack natural predators. They can have major implications on stream health and reduce species diversity (OMNR 2012). They can be difficult to eradicate, however it is important to continue to research, monitor and manage them.

Figure 20 shows abundance of species observed per section. 17 invasive species were observed in 2018:

- banded mystery snail (*Viviparus georgianus*)
- common buckthorn (*Rhamnus cathartica*)
- curly leafed pondweed (*Potamogeton crispus*)
- dog strangling vine (*Cynanchum rossicum*)
- European frogbit (*Hydrocharis morsus-ranae*)
- flowering rush (*Butomus umbellatus*)
- garlic mustard (*Alliaria petiolate*)
- glossy buckthorn (*Rhamnus frangula*)
- Himalayan balsam (*Impatiens glandulifera*)
- Japanese knotweed (*Fallopia japonica*)
- Manitoba maple (*Acer negundo*)
- Norway maple (*Acer platanoides*)
- Phragmites (*Phragmites autraslis*)
- wild parsnip (*Pastinaca sativa*)
- purple loosestrife (*Lythrum salicaria*)
- rusty crayfish (*Orconectes rusticus*)
- yellow iris (*Iris pseudacorus*)

To report and find information about invasive species visit

http://www.invadingspecies.com

Managed by the Ontario Federation of Anglers and Hunters

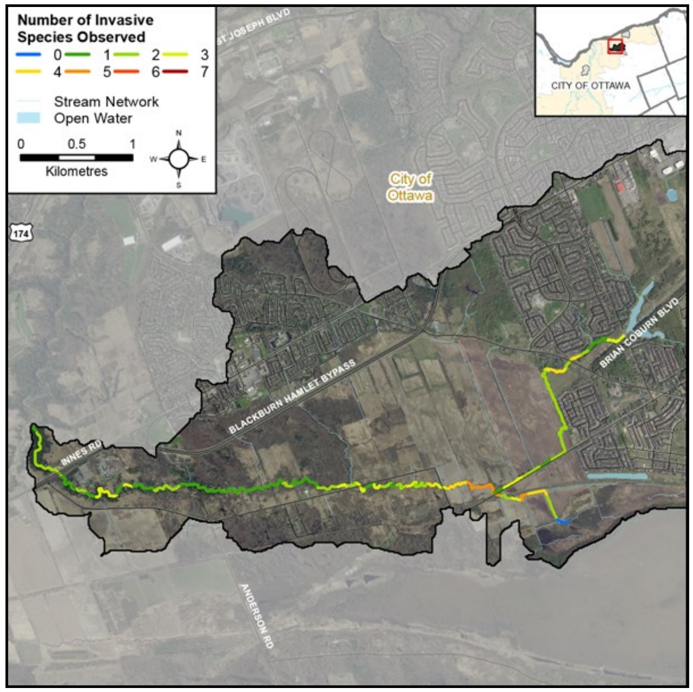


Figure 20 Invasive species abundance along Mud Creek

Japanese knotweed along the right bank of Mud Creek

Pollution

Figure 21 shows the types of pollution observed in Mud Creek. The levels of garbage found in Mud Creek are moderate, with garbage on the stream bottom present in 67 percent of sections and floating garbage present in 30 percent of sections. Eight percent of sections contained other forms of garbage.

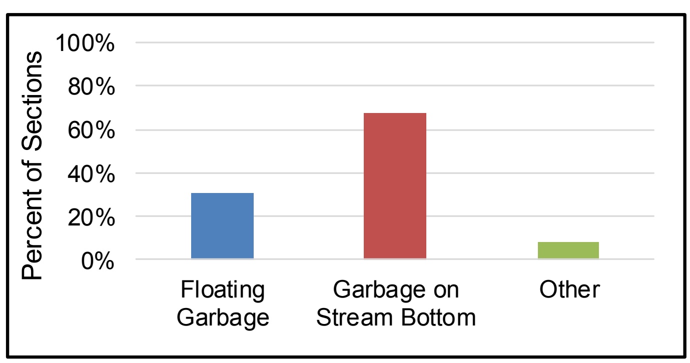


Figure 21 Types of pollution observed in Mud Creek

Mud Creek Water Chemistry

Water Chemistry Assessment

Water chemistry collection is done at the start and end of each 100 meter section with a multiparameter YSI probe. The parameters monitored are: air and water temperature, pH, conductivity, dissolved oxygen concentration and saturation.

RVCA staff and a volunteer measuring water chemistry with a

Dissolved Oxygen

Dissolved oxygen is essential for a healthy aquatic ecosystem, fish and other aquatic organisms need oxygen to survive. The level of oxygen required is dependent on the particular species and life stage. The lowest acceptable concentration for the early and other life stages according to the Canadian water quality guidelines for the protection of aquatic life are: 6.0 milligrams per liter in warm-water biota and 9.5 milligrams per liter for cold-water biota (CCME 1999).

Figure 22 shows the concentration levels found in Mud Creek. The two dashed lines depicted represent the Canadian water quality guidelines. All of the surveyed portions had average oxygen levels adequate to support warm-water aquatic life, with two sections having oxygen levels adequate to support cold-water biota. Average levels across the system were 8.6 milligrams per liter.

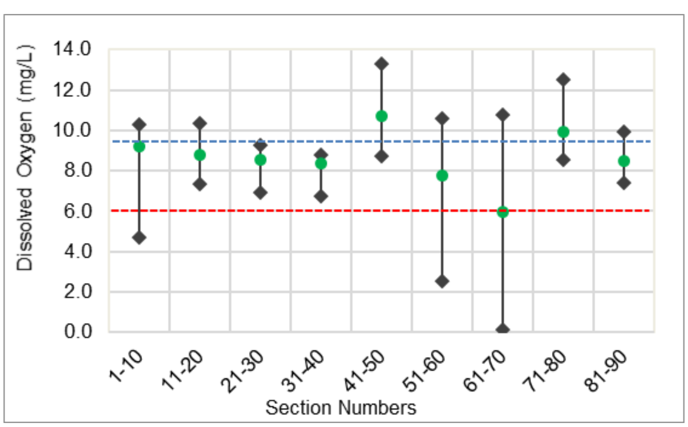


Figure 22 Dissolved oxygen ranges along Mud Creek

Conductivity

Conductivity is a measure of water's capacity to conduct electrical flow. This capacity is dictated by the presence of conductive ions that originate from inorganic materials and dissolved salts. Water conductivity in natural environments is typically dictated by the geology of the area, however anthropogenic inputs also have a profound effect. Currently there is no existing guideline for stream conductivity levels, however conductivity measurements outside of normal range across a system are good indicators of anthropogenic inputs including unmitigated discharges and storm water input.

Figure 23 shows specific conductivity levels in Mud Creek, the average level is depicted by the dashed line (899.3 µS/cm).

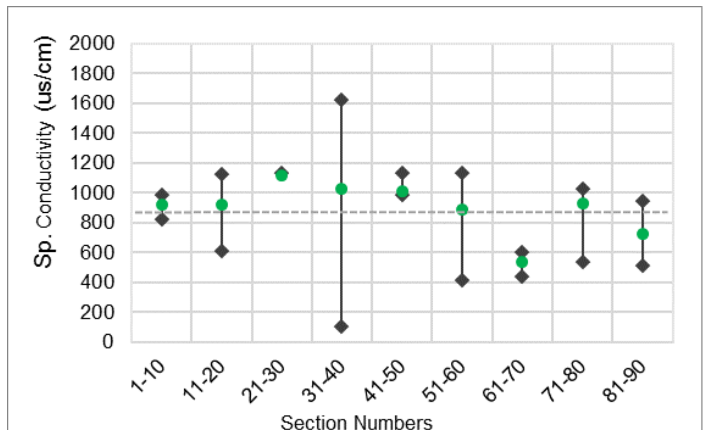


Figure 23 Conductivity ranges along sections of Mud Creek

pH

pH is a measure of alkalinity or acidity. This parameter is also influenced by the geology of the system but can also be influenced by anthropogenic input. For pH, the provincial water quality objective (PWQO) is the range of 6.5 to 8.5 to protect aquatic life (MOEE 1994).

Figure 24 shows that Mud Creek had pH levels that meet the PWQO, depicted by the dashed line. Average levels across the system were pH 7.88.

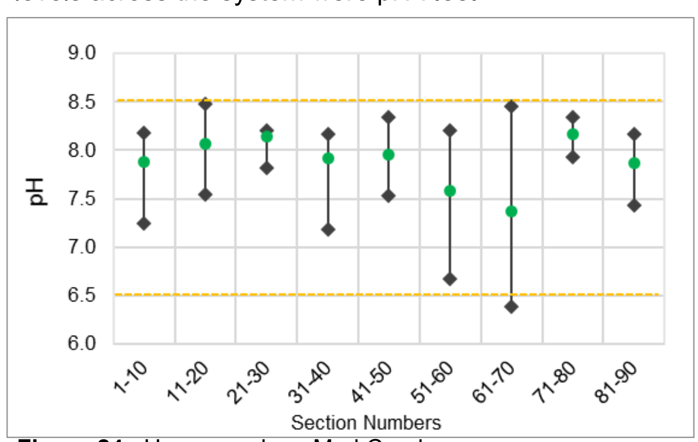


Figure 24 pH ranges along Mud Creek

Oxygen Saturation (%)

Oxygen saturation is measured as the ratio of dissolved oxygen relative to the maximum amount of oxygen that will dissolve based on the temperature and atmospheric pressure. Well oxygenated water will stabilize at or above 100 percent saturation, however the presence of decaying matter/pollutants can drastically reduce these levels. Oxygen input through photosynthesis has the potential to increase saturation above 100 percent to a maximum of 500 percent, depending on the productivity level of the environment. In order to represent the relationship between concentration and saturation, the measured values have been summarized into 6 classes:

1) <100% Saturation / <6.0 mg/L Concentration

Oxygen concentration and saturation are not sufficient to support aquatic life and may represent impairment.

2) >100% Saturation / <6.0 mg/L Concentration

Oxygen concentration is not sufficient to support aquatic life, however saturation levels indicate that the water has stabilized at its estimated maximum. This is indicative of higher water temperatures and stagnant flows.

3) <100% Saturation / 6.0—9.5 mg/L Concentration

Oxygen concentration is sufficient to support warm-water biota, however depletion factors are likely present and are limiting maximum saturation.

4) >100% Saturation / 6.0—9.5 mg/L Concentration

Oxygen concentration and saturation levels are optimal for warm-water biota.

5) <100% Saturation / >9.5 mg/L Concentration

Oxygen concentration is sufficient to support cold-water biota, however depletion factors are likely present and are limiting maximum saturation.

6) >100% Saturation / >9.5 mg/L Concentration

Oxygen concentration and saturation levels are optimal for warm and cold-water biota.

Site on Mud Creek with **impaired** oxygen conditions (Dissolved oxygen levels of 1.96 mg/L and 22.7% saturation)

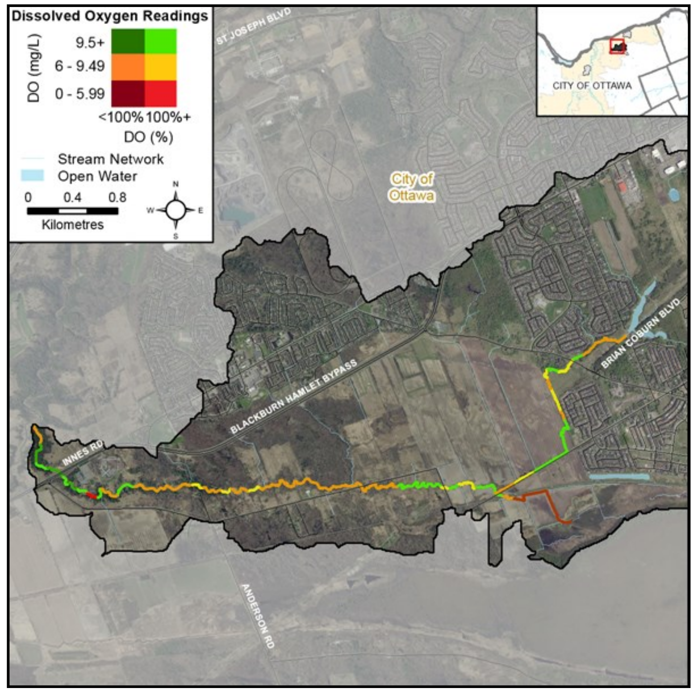


Figure 25 Bivariate assessment of dissolved oxygen concentration (mg/L) and saturation (%) along Mud Creek

Figure 25 shows the oxygen conditions across the areas that were surveyed in 2018. Overall dissolved oxygen conditions in Mud Creek are sufficient to sustain warm-water biota. Sections downstream of the final crossing of Renaud Road, shown in dark red and orange in Figure 25, have significant levels of impairment both in concentration and percent saturation. These areas have wetland features that have naturally lower oxygen levels, however these can be further limited by extensive vegetation growth of invasive species, and anthropogenic nutrient input.

Areas in the lower reaches near the confluence with Greens Creek and in the upper reaches near Renaud Road showed optimal conditions for cold-water biota. These areas are shaded and contain riffle habitat that is conducive to oxygenation.

Site on Mud Creek with **optimal** oxygen conditions (Dissolved oxygen levels of 10.26 mg/L and 103.1% saturation)

Specific Conductivity Assessment

Specific conductivity (SPC) is a standardized measure of electrical conductance, collected at or corrected to a water temperature of 25°C. SPC is directly related to the concentration of ions in water, and is influenced by the area geology and anthropogenic input as it contributes to the presence of dissolved salts, alkalis, chlorides, sulfides and carbonate compounds. The higher the concentration of these compounds, the higher the conductivity. Common sources of elevated conductivity include storm water, agricultural inputs as well as commercial and industrial effluents.

In order to summarize the conditions observed, levels were evaluated as either normal, moderately elevated or highly elevated. These categories are defined by the amount of variation (standard deviation) at each section compared to the system's average.

Average levels of conductivity in Mud Creek (899.3 µS/cm) are higher than the federal guidelines for freshwater (500 µS/cm) used for the Canadian Environmental Performance Index (Environment Canada 2011). Figure 26 shows relative specific conductivity levels in Mud Creek. Normal levels were maintained for most of the surveyed portions. Moderately elevated conditions were observed in the upper reaches of the creek where water flows downstream from Mer Bleue and along Renaud Road. Wetland features can have an increased level of conducting ions being discharged from groundwater. This area also receives road runoff influences, and has adjacent agricultural land uses; which can lead to elevated conductivity levels.

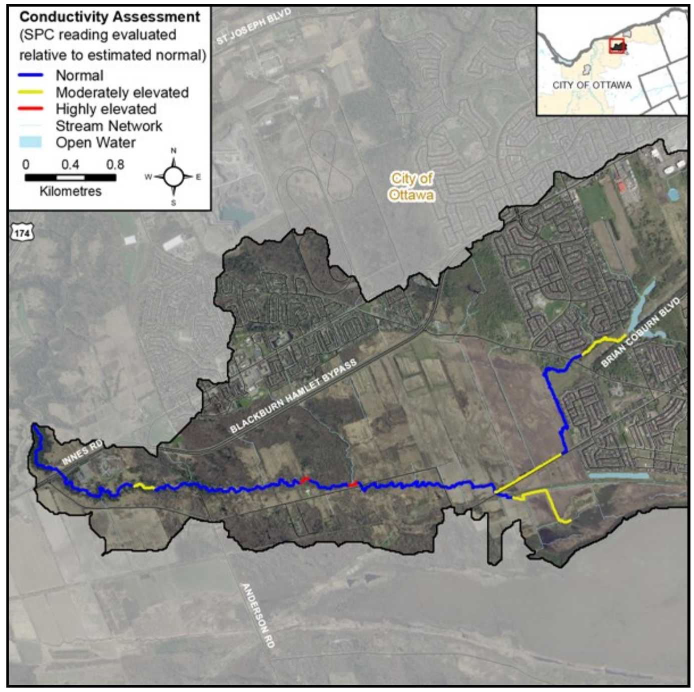


Figure 26 Relative specific conductivity levels along Mud Creek

Section of Mud Creek downstream of Mer Bleue with moderately elevated levels of specific conductivity

Section of Mud Creek along Renaud Road with moderately elevated levels of specific conductivity

Mud Creek Thermal Classification

Thermal Classification

Instream water temperatures are influenced by various factors including, season, time of day, precipitation, storm water run off, springs, tributaries, drains, discharge pipes, stream shading from riparian vegetation and artificial shade created by infrastructure. To monitor water temperatures in Mud Creek, two temperature loggers were placed in April and retrieved in October.

Figure 27 shows where thermal sampling sites were located. Analysis of data from two loggers (using the Stoneman and Jones, 1996, method adapted by Chu et al., 2009), Mud Creek is classified as **warmwater** with cool-warmwater reaches. (Figure 28).

Within those two sites, cool, cool-warm water and warm water fish species were present, with fish thermal preferences indicated by Cocker at al. (2001).

Groundwater

Groundwater discharge areas can influence stream temperature, contribute nutrients, and provide important stream habitat for fish and other biota. During stream surveys, indicators of groundwater discharge are noted when observed. Indicators include: springs/ seeps, watercress, iron staining, significant temperature change and rainbow mineral film. Figure 29 shows areas were one or more groundwater indicators were observed during stream surveys and headwater assessments.

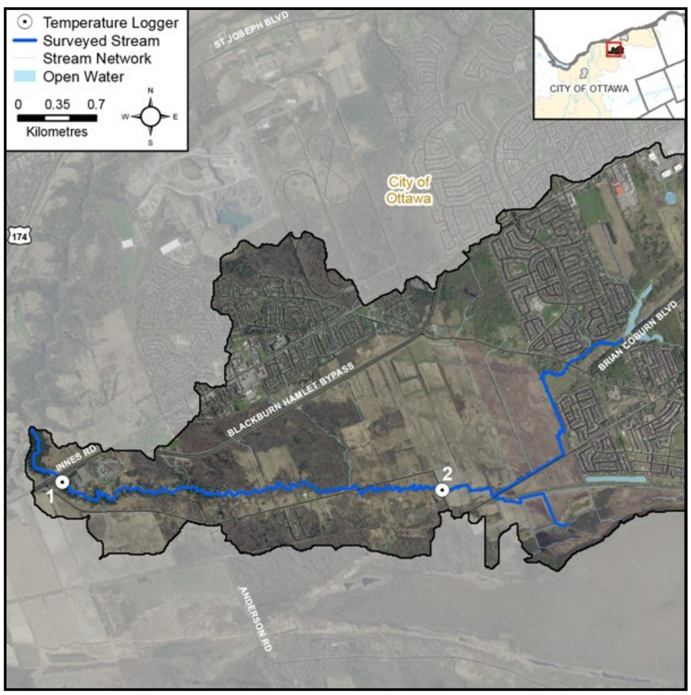


Figure 27 Temperature logger locations on Mud Creek

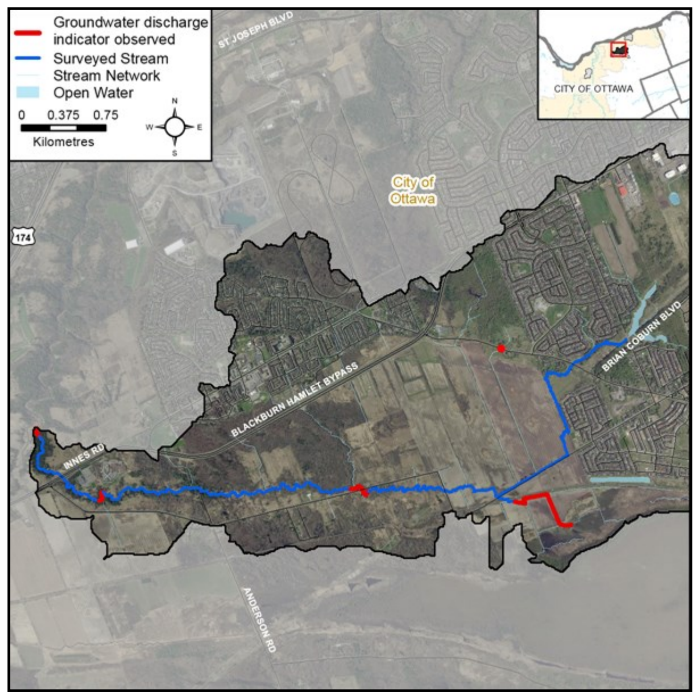
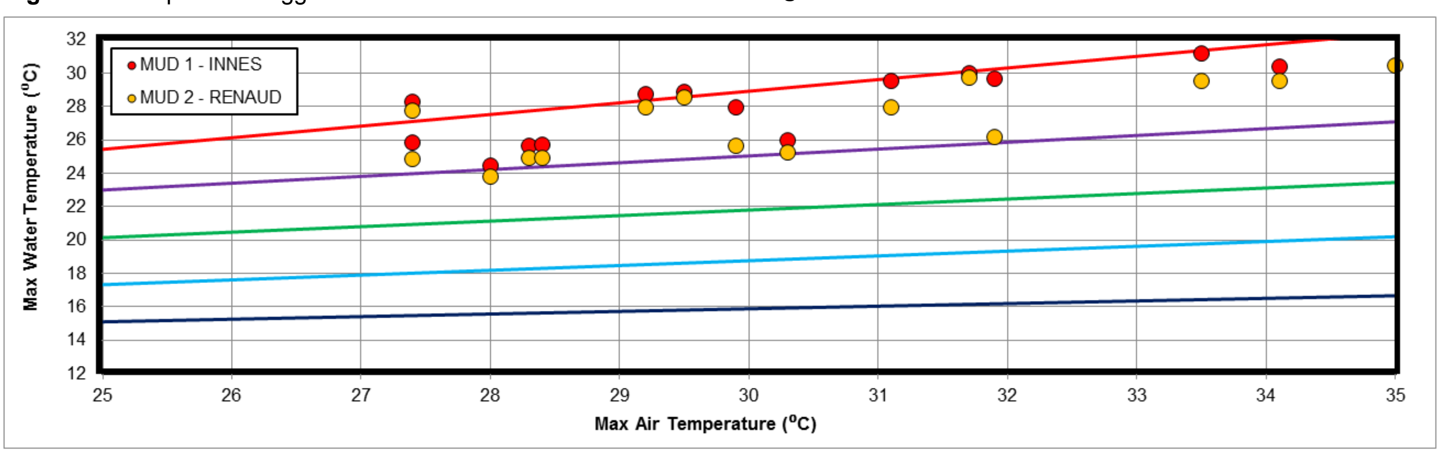


Figure 29 Groundwater indicators observed in Mud Creek



Thermal Regimes

Warmwater **Cool-warmwater** **Coolwater** **Cold-coolwater** **Coldwater**

Figure 28 Thermal Classification for Mud Creek with the five thermal regimes adapted from Stoneman and Jones (1996) by Chu et al. (2009): **warmwater** category for both sites sampled on Mud Creek

Mud Creek Fish Community

Fish Community Summary

Three fish sampling sites were evaluated between May and July 2018. There was one site near Innes Road that was sampled by seine net in June and then by backpack electrofishing in July. Another site near Renaud Road was also sampled twice, both times by backpack electrofishing. The third site off Pagé Road was sampled once by backpack electrofishing in May.

Table 2 Fish species observed in Mud Creek

Species	Thermal Class	MNRF Species Code
bluegill *Lepomis macrochirus*	Warm	Blueg
bluntnose minnow *Pimephales notatus*	Warm	BnMin
brassy minnow *Hybognathus hankinsoni*	Cool	BrMin
brook stickleback *Culaea inconstans*	Cool	BrSti
central mudminnow *Umbra limi*	Cool-warm	CeMud
Chrosomus spp.	Cool	PhoSp
common shiner *Luxilus cornutus*	Cool	CoShi
creek chub *Semotilus atromaculatus*	Cool	CrChu
johnny/tessalated darter *Etheostoma spp.*	Cool	EthSp
fathead minnow *Pimephales promelas*	Warm	FhMin
largemouth bass *Micropterus salmoides*	Warm	LmBas
longnose dace *Rhinichthys cataractae*	Cool	LnDac
northern pearl dace *Margariscus nachtriebi*	Cool	PeDac
northern redbelly dace Chrosomus eos	Cool	NRDac
pumpkinseed *Lepomis gibbosus*	Warm	Pumpk
white sucker *Catostomus commersonii*	Cool	WhSuc
Total Species		**16**

Sixteen species were captured in 2018, they are listed in Table 2 along with their thermal classification preferences (Coker et al., 2001) and MNRF species codes. Mud Creek has a mixed fish community ranging from cool to warm water species. The sampling locations where these species were observed, as well as RVCA historical sites, are depicted in Figure 30. The codes used in the figure are the MNRF codes provided in Table 2. For comparisons across sampling years and a complete list of RVCA historical fish records from Mud Creek refer to page 21 of this report.

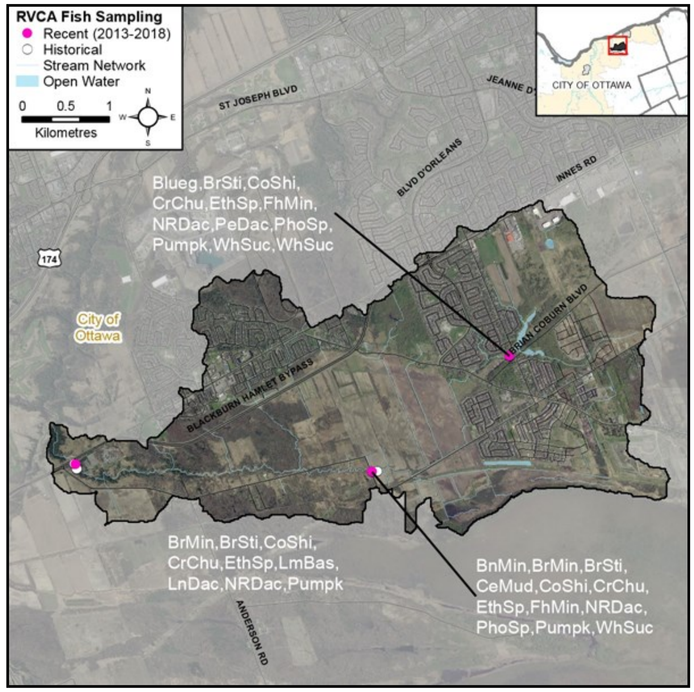


Figure 30 Mud Creek fish sampling locations and 2018 fish species observations

Back pack electrofishing (above) and a brassy minnow captured (below) in Mud Creek near Innes Road

Migratory Obstructions

It is important to know locations of migratory obstructions because these can prevent fish from accessing important spawning and rearing habitat. Migratory obstructions can be natural or manmade, and they can be permanent or seasonal.

The majority of migratory obstructions observed on Mud Creek were debris dams. This debris accumulated from naturally fallen trees and branches. There were also seven perched culverts observed. The locations of migratory obstructions observed during headwater drainage feature assessment and stream surveys in 2018 are shown in Figure 31.

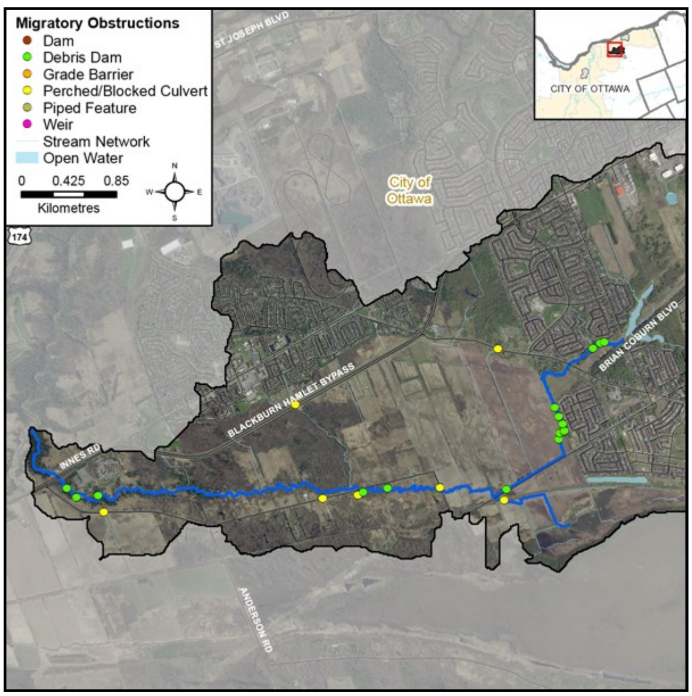


Figure 31 Locations of migratory obstructions along Mud-Creek

Debris dam observed along Mud Creek

Beaver Dams

Overall, beaver dams create natural changes in the environment. Some of the benefits include providing habitat for wildlife, flood control, and silt retention. Additional benefits come from bacterial decomposition of woody material used in the dams which removes excess nutrient and toxins. Beaver dams are also considered potential barriers to fish migration.

Nine beaver dams were observed along Mud Creek. This included four abandoned dams, one breached dam, one submerged dam and three active dams. The locations of beaver dams observed during stream surveys in 2018 are shown in Figure 32.

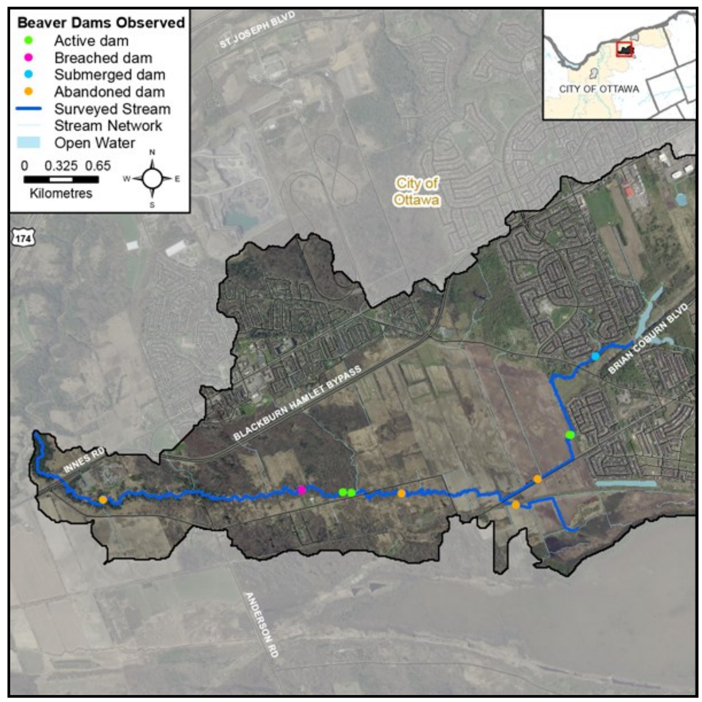


Figure 32 Locations of beaver dams along Mud Creek

Active beaver dam observed along Mud Creek

Headwater Drainage Feature Assessment

Headwater drainage features (HDF) represent the origin from which water enters a watershed. These are small depressions, stream and wetland features that capture flows from groundwater discharge, rain and snow melt water and transport it to larger streams and rivers. In their natural state, they provide (OSAP, 2017):

- Flood mitigation as water storage capacity.
- Water purification and groundwater discharge.
- Seasonal and permanent habitat refuge for fish, including spawning and nursery areas.
- Wildlife migration corridors/breeding areas.
- Storage and conveyance of sediment, nutrients and food sources for fish and wildlife.

Headwaters Sampling

RVCA is working with other Conservation Authorities and the Ministry of Natural Resources and Forestry to implement the protocol with the goal of providing standard datasets to support science development and monitoring of headwater drainage features.

Features are evaluated as per the Ontario Stream Assessment Protocol (OSAP, 2017). This protocol measures zero, first and second order headwater drainage features. It is a rapid assessment method characterizing the amount of water, sediment transport, and storage capacity within headwater drainage features. In 2018 the City Stream Watch program assessed 9 HDF sites in the Mud Creek Catchment (Figure 33).

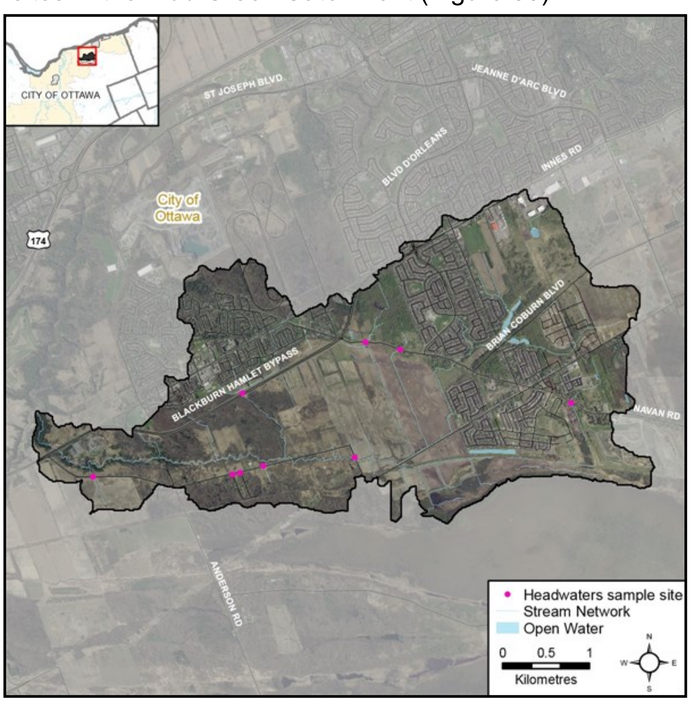


Figure 33 Location of HDF sampling sites in the Mud Creek catchment

Feature Type

The headwater sampling protocol assesses the feature type in order to understand the function of each feature. The evaluation includes the following classifications: defined natural channel, channelized or constrained, multi-thread, no defined feature, tiled, wetland, swale, roadside ditch and pond outlet. By assessing the values associated with the headwater drainage features in the catchment area we can understand the ecosystem services that they provide to the watershed in the form of hydrology, sediment transport, and aquatic and terrestrial functions.

Figure 34 shows the feature type of the primary feature at the sampling locations. Natural features were overall dominant, observed at four sites. One feature was classified as a swale, one tiled and one was channelized. There were also two features that were roadside ditches.

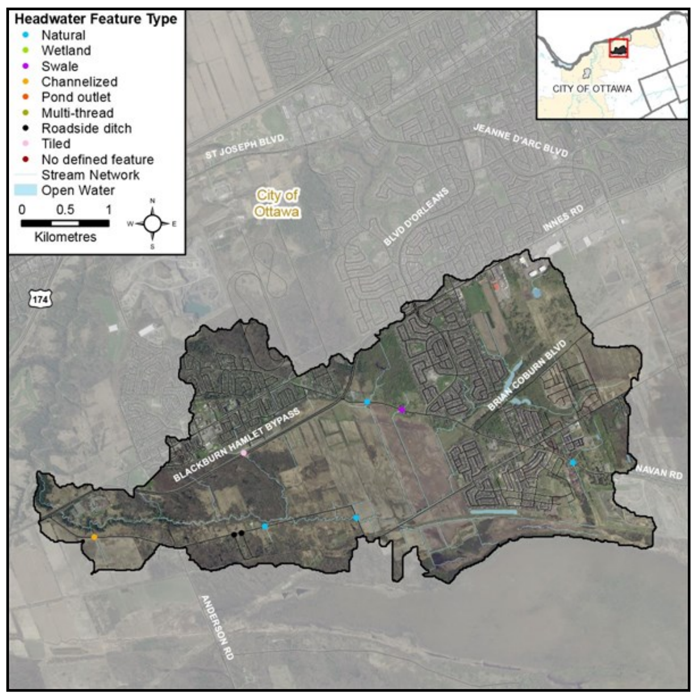


Figure 34 Map of Mud Creek HDF feature types

Natural headwater drainage feature on Navan Road

Headwater Feature Flow

Flow conditions in headwater features can be variable throughout the year in response to yearly seasonal weather conditions. This protocol targets features that are perennial, or intermittent. Intermittent flow conditions are those where water typically flows at least six months of the year. Perennial systems flow year round. Sites were observed in the spring and summer; flow conditions were compared.

Flow conditions in the Mud Creek catchment area are shown in Figure 35.

Intermittent feature with spring and summer conditions in the Mud Creek catchment

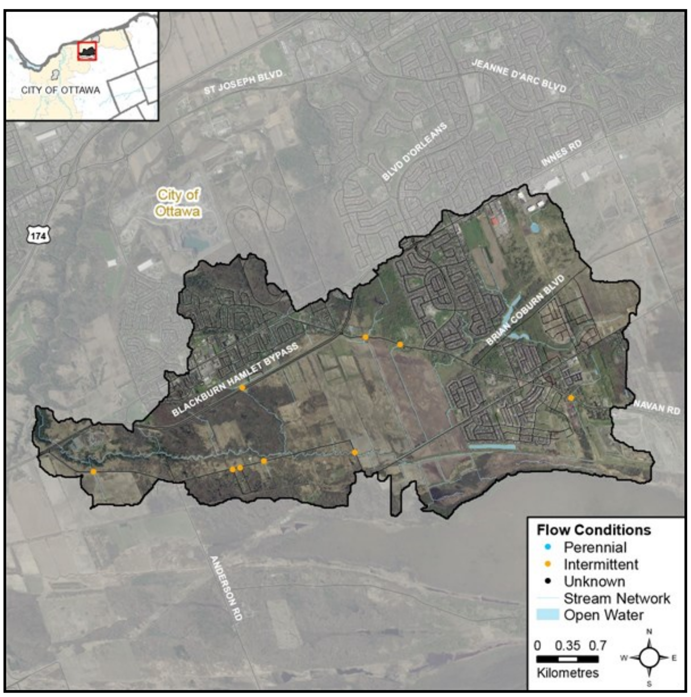


Figure 35 Headwater feature flow conditions in the Mud Creek catchment

Feature Channel Modifications

Channel modifications can influence HDF conditions and function. Modifications that were of focus included channel straightening (or re-alignments), dredging, hardening (e.g. rip-rap, armourstone, gabion baskets) or on-line ponds.

Figure 36 shows channel modifications observed in Mud Creek headwater drainage features. Most modifications observed in this catchment for headwater drainage features are dredging and channel hardening.

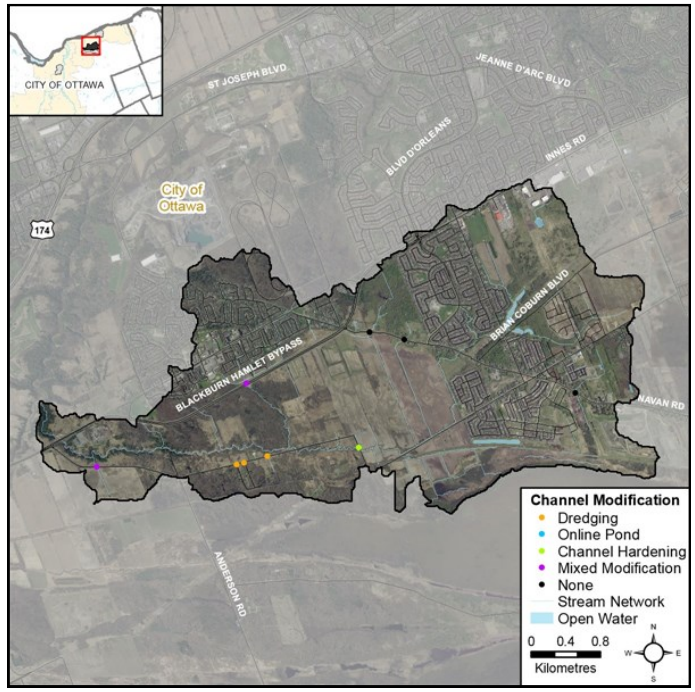


Figure 36 Headwater feature channel modifications in the

Channel hardening with gabion baskets along Renaud Road

Headwater Feature Vegetation

Headwater feature vegetation evaluates the type of vegetation that is found within the drainage feature. The type of vegetation within the channel influences the aquatic and terrestrial ecosystem values that the feature provides. For some types of headwater features the vegetation within the feature plays a very important role in flow, sediment movement and provides wildlife habitat. The following classifications are evaluated: no vegetation, lawn, wetland, meadow, scrubland and forest.

Figure 37 depicts the dominant vegetation observed at the sampled sites in the Mud Creek catchment. Meadow vegetation was the most common type (6 features); followed by forest vegetation (2 features) and one feature had scrubland as its dominant vegetation type.

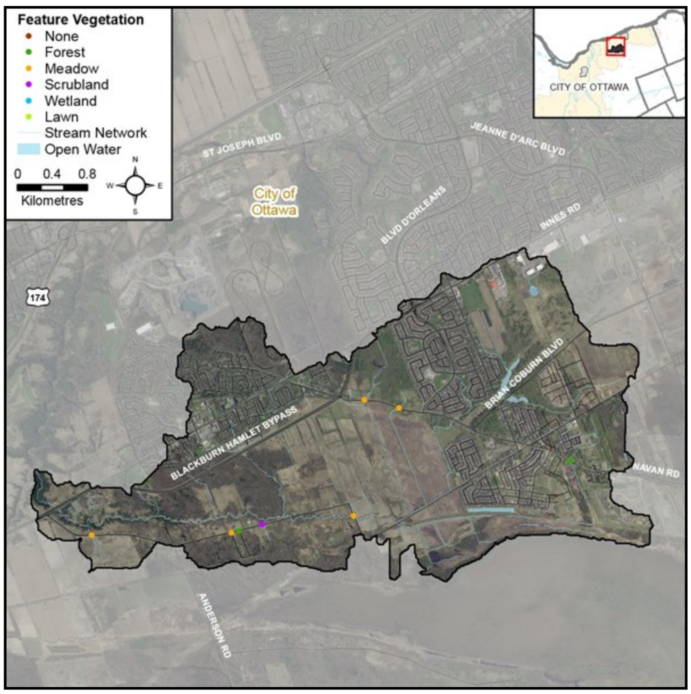


Figure 37 Headwater feature vegetation in the Mud Creek catchment

HDF site dominated by forest vegetation along Navan Road

Headwater Feature Riparian Vegetation

Headwater riparian vegetation evaluates the type of vegetation that is found along the adjacent lands of a headwater drainage feature. The type of vegetation within the riparian corridor influences the aquatic and terrestrial ecosystem values that the feature provides to the watershed.

Figure 38 shows the type of riparian vegetation observed at the sampled headwater sites in the Mud Creek catchment. These riparian zones have anthropogenic influences from agricultural areas as well as road infrastructure.

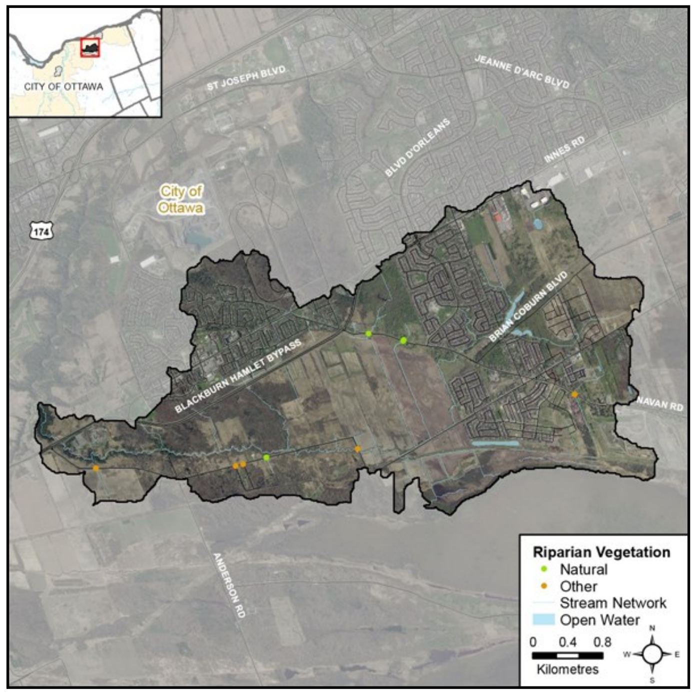


Figure 38 Riparian vegetation types along headwater features in the Mud Creek catchment

HDF with other, non-natural cropped, riparian vegetation along Renaud Road

Headwater Feature Sediment Deposition

Assessing the amount of recent sediment deposition in a channel provides an index of the degree to which the feature could be transporting sediment downstream (OSAP, 2017). Sediment transport is a natural process, however, excessive sedimentation can be indicative of higher erosion than a natural system can accommodate. High sediment deposition can indicate the need for further assessment and potential implementation of best management practices.

From the upstream features assessed, sediment deposition ranged from none to substantial. Two features had evidence of substantial deposition and one had moderate levels. Four features had minimal amounts of deposits, and one feature had no evidence of sediment deposition. Figure 39 shows the levels of sediment deposition in the Mud Creek catchment.

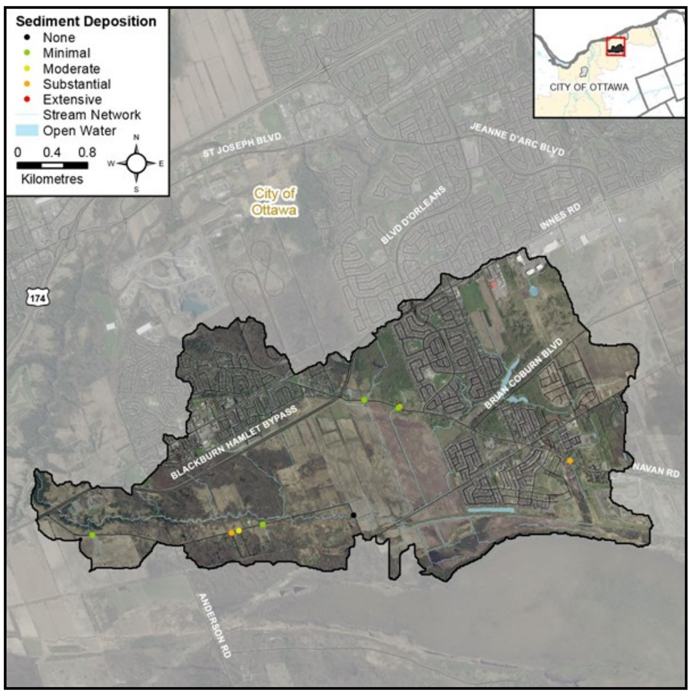


Figure 39 Headwater feature sediment deposition in the Mud Creek catchment

Substantial sediment deposition observed on Navan Road

Headwater Feature Upstream Roughness

Feature roughness is a relative measure of the amount of material within the feature that diffuses flows (OSAP, 2017). Materials on the channel bottom that provide roughness include vegetation, wood material as well as boulders and cobble substrates. Roughness can reduce erosion downstream of the feature, as well as providing important habitat to a variety of aquatic organisms, and producing food sources.

This parameter is categorized depending on the amount of roughness coverage in a channel: minimal (less than 10 %), moderate (10-40 %), high (40-60 %), and extreme (more than 60 %). In the Mud Creek catchment, one site had moderate upstream roughness, five sites had high levels of roughness and two had extreme coverage. Figure 40 shows the various feature roughness across the area.

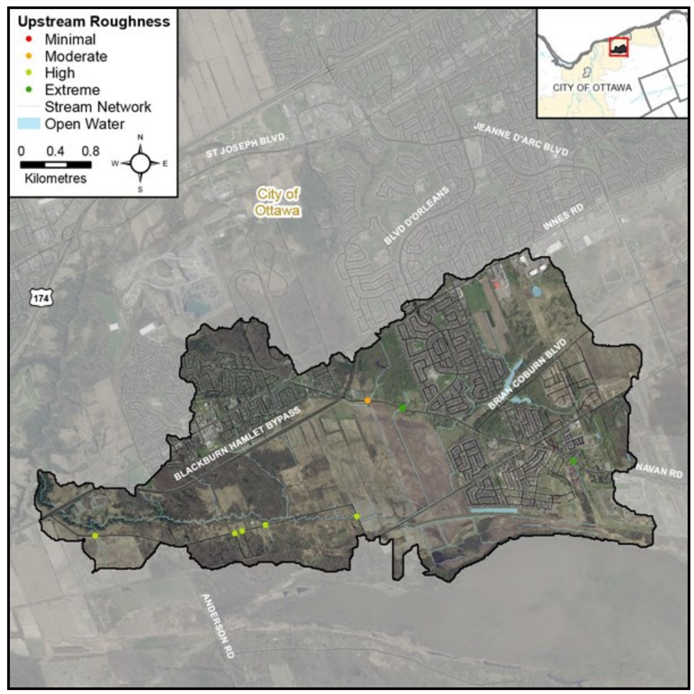


Figure 40 Headwater feature roughness in the Mud Creek catchment

High feature roughness at Navan Road

Stream Comparison Between 2007, 2012 and 2018

The following tables provide a comparison of observations on Mud Creek between the 2007, 2012 and 2018 survey years (RVCA 2007, RVCA 2012). Monitoring protocols from 2007 were modified and enhanced, so data from that year cannot be compared to the later years (there are some exceptions). In order to accurately represent current and historical information, the site data was only compared for those sections which were surveyed in both reporting periods. This resulted in changes to our overall summary information, averages presented here differ from ones in this report. This information is therefore only a comparative evaluation and does not represent the entirety of our assessment.

Water Chemistry

Water chemistry parameters are collected throughout all the sections surveyed in the stream. This criteria reflects the overall conditions and changes in the environment. Variation in these conditions can be attributed to environmental and ecological changes. Some can be in part due to natural variability within the system from various weather, seasonal and annual conditions.

Table 3 shows a comparison of these parameters between 2012 and 2018. Average summer water temperatures range from cooler water in 2018 (20.0°C) to warmer values in 2012 (22.4°C), with 2.4 degrees centigrade of variation. Aside from these general temperature observations, loggers provide a detailed summary of stream thermal conditions.

Standardizing stream temperature accounts for climatic factors including air temperatures and precipitation. With the data collected from temperature loggers, standardized stream temperatures are calculated and summarized in Table 3. These values decreased by 0.03°C for every degree of air temperature from 2012 to 2018.

Table 3 Water chemistry comparison (2012/2018)

Water Chemistry (2012—2018)				
YEAR	**PARAMETER**	**UNIT**	**AVERAGE**	**STND**
2012	pH	-	8.26	± 0.06
2018	pH	-	7.88	± 0.05
2012	Sp. Conductivity	us/cm	-	-
2018	Sp. Conductivity	us/cm	899.3	± 25.7
2012	Dissolved Oxygen	mg/L	9.3	± 0.21
2018	Dissolved Oxygen	mg/L	8.6	± 0.25
2012	Water Temperature	ºC	22.4	± 0.25
2018	Water Temperature	ºC	20.0	± 0.24
2012	Standardized Stream Temperature[1]	ºC Water /	0.95	± 0.76
2018	Standardized Stream Temperature[1]	ºC Water /	0.92	± 0.64

[1] ***Standardized Stream Temperature:*** Temperature data is collected via logger and standardized based on the following conditions:

- Daily maximum air temperatures must exceed 24.5 ºC
- No precipitation for 2 days preceding measurement
- Measurements to be taken between 4:00PM—6:00PM
- All temperatures points to be collected in July/August
- Logger must be deployed in flowing waters

Average dissolved oxygen levels were found to be decreasing by 0.7 milligrams per liter from 2012 to 2018. These changes can also be attributed to weather patterns and warmer temperatures which are conducive to the stream's ability to hold less oxygen.

Invasive Species

The overall percentage of sections surveyed where invasive species were observed had a increase of 17 percent (Table 4). Purple loosestrife had a reduction of observations by 14 percent, this decline may be associated to management efforts (OMNR 2012). European frog-bit and dog strangling vine also had a reduction in observations. Other invasive species have expanded their range, more notably Manitoba maple and flowering rush which increased by 62 and 19 percent, respectively. There were also eight invasive species newly reported in 2018

Table 4 Invasive species presence observed in 2012 and 2018 (NR are Not Reported species)

Invasive Species	2012	2018	+/-
banded mystery snail	NR	8%	▲
common buckthorn	1%	3%	▲
curly leafed pondweed	NR	8%	▲
dog strangling vine	6%	4%	▼
European frog-bit	16%	7%	▼
flowering rush	1%	20%	▲
garlic mustard	2%	2%	-
glossy buckthorn	NR	2%	▲
Himalayan balsam	NR	7%	▲
Japanese knotweed	2%	6%	▲
Manitoba maple	16%	78%	▲
Norway maple	NR	1%	▲
Phragmites	NR	3%	▲
poison/wild parsnip	NR	1%	▲
purple loosestrife	72%	58%	▼
rusty crayfish	1%	2%	▲
yellow iris	NR	2%	▲
Total	**82%**	**99%**	▲

Pollution

Garbage accumulation on Mud Creek was found to decrease from 2012 to 2018. In 2018 the polluted sections contained garbage, such as plastics, cans, bottles, and included other large items (tires, furniture and traffic signs).

Table 5 Pollution levels (presence in % of sections)

Pollution/Garbage	2012	2018	+/-
floating garbage	46%	30%	▼
garbage on stream bottom	79%	67%	▼
other	89%	8%	▼
Total	**90%**	**84%**	▼

Instream Aquatic Vegetation

Table 6 shows the diversity of instream aquatic vegetation increases from 2012-2018. Narrow-leaved emergent plants (e.g. sedges), broad leaved emergent plants (e.g. arrowhead), robust emergent plants (e.g. cattails), submerged plants (e.g. pondweed) and floating plants (e.g. water lilies) were all were shown to have higher observations in the number of sections surveyed. A drastic decline was observed for algae which decreased by 70 percent.

Table 6 Instream aquatic vegetation (presence in % of sections)

Instream Vegetation	2012	2018	+/-
narrow-leaved emergent plants	32%	54%	▲
broad-leaved emergent plants	21%	24%	▲
robust emergent plants	13%	21%	▲
free-floating plants	1%	11%	▲
floating plants	1%	16%	▲
submerged plants	23%	40%	▲
algae	94%	24%	▼
none	15%	90%	▲

Fish Community

Fish sampling was carried out by the City Stream Watch program in 2012 and 2018 to evaluate fish community composition in Mud Creek (see Table 7). In total 19 species have been observed in Mud Creek. In 2012, sixteen species were captured at seven sites and 16 species were also found at 3 sites in 2018. The majority of species observed in 2018 had been captured in 2012, with the exception of northern pearl dace and bluegill as new records.

Table 7 Comparison of fish species caught between 2012-2018

Species	2012	2018
banded killifish *Fundulus diaphanus*	X	
bluegill *Lepomis macrochirus*		X
bluntnose minnow *Pimephales notatus*	X	X
brassy minnow *Hybognathus hankinsoni*	X	X
brook stickleback *Culaea inconstans*	X	X
central mudminnow *Umbra limi*	X	X
Chrosomus spp.		X
common shiner *Luxilus cornutus*	X	X
creek chub *Semotilus atromaculatus*	X	X
Etheostoma spp.	X	X
fathead Minnow *Pimephales promelas*	X	X
golden shiner *Notemigonus crysoleucas*	X	
largemouth bass *Micropterus salmoides*	X	X
longnose Dace *Rhinichthys cataractae*	X	X
northern pearl dace *Margariscus nachtriebi*		X
northern redbelly dace *Chrosomus eos*	X	X
pumpkinseed *Lepomis gibbosus*	X	X
trout-perch *Percopsis omiscomaycus*	X	
white sucker *Catostomus commersonii*	X	X
Total Species 19	**16**	**16**

Electrofishing downstream of Innes Road

Monitoring and Restoration

Monitoring and Restoration Projects on Mud Creek

Table 8 highlights recent and past monitoring that has been done on Mud Creek by the City Stream Watch program. Monitoring activities and efforts have changed over the years. Potential restoration opportunities are listed on the following page.

Table 8 City Stream Watch monitoring and restoration on Mud Creek

Accomplishment	Year	Description
City Stream Watch Stream Monitoring	2007	6.2 km of stream was surveyed
	2012	8.7 km of stream was surveyed
	2018	8.9 km of stream was surveyed
City Stream Watch Fish Sampling	2012	7 fish community sites were sampled
	2018	3 fish community sites were sampled
City Stream Watch Thermal Classification	2012	two temperature probes were deployed
	2018	two temperature probes were deployed
City Stream Watch Headwater Drainage Feature Assessment	2018	9 headwater drainage feature sites were sampled in the Mud Creek catchment
National Capital Commission Green's Creek Restoration	2012	Identification of high level watershed goals and restoration opportunities , design and development of three projects. Covers middle and lower Greens Creek, Mud Creek and McEwan Creek.
National Capital Commission Erosion Threshold Analysis	2012	Analysis covers Mud Creek and part of McEwan Creek
City Stream Watch Stream Cleanups	2018	Cleared 400m of shoreline along Mud Creek

Cleaning up garbage along Mud Creek upstream of Renaud Road

Temperature probe installation on Mud Creek upstream of Innes Road

Potential Riparian Restoration Opportunities

Riparian restoration opportunities were assessed in the field and include potential enhancement through riparian planting, erosion control, invasive species management and/or wildlife habitat creation (Figure 41).

Erosion control

Erosion issues are common throughout the catchment, with key areas identified for potential enhancement. These regions included instances of outflow/deposition from adjacent land use, and destabilization in proximity to infrastructure and agriculture.

Riparian Planting

Riparian planting locations were identified in regions of low relative diversity. There is one section north of Anderson Road where a landslide had previously occurred that could benefit from enhanced riparian cover.

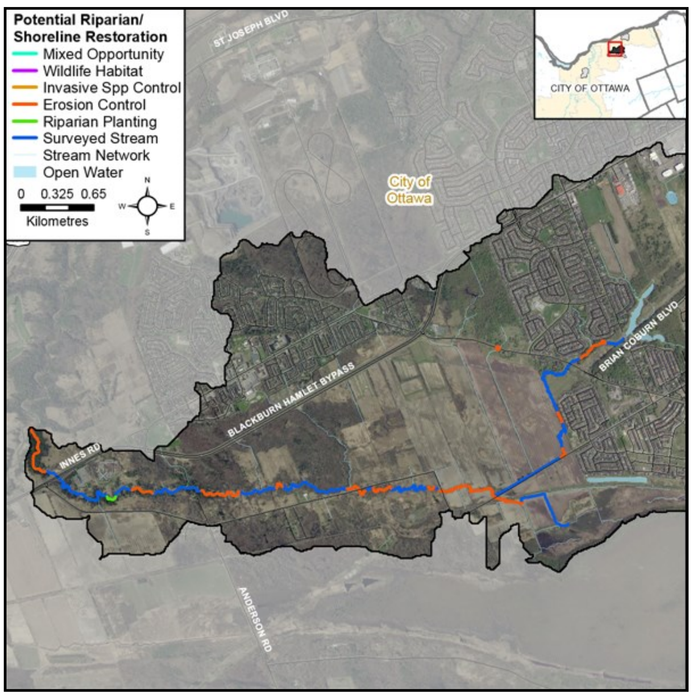


Figure 41 Potential riparian/shoreline restoration opportunities along Mud Creek

Scoured banks that could benefit from erosion control along Mud Creek.

Potential Instream Restoration Opportunities

Garbage clean up

Pollution was observed in many sections surveyed along Mud Creek. In particular, garbage was more concentrated near both crossings at Renaud Road, in an area where the creek runs behind a residential neighborhood, and downstream of a stormwater management pond. Mud Creek would benefit from clean ups in any of the areas shown in Figure 42.

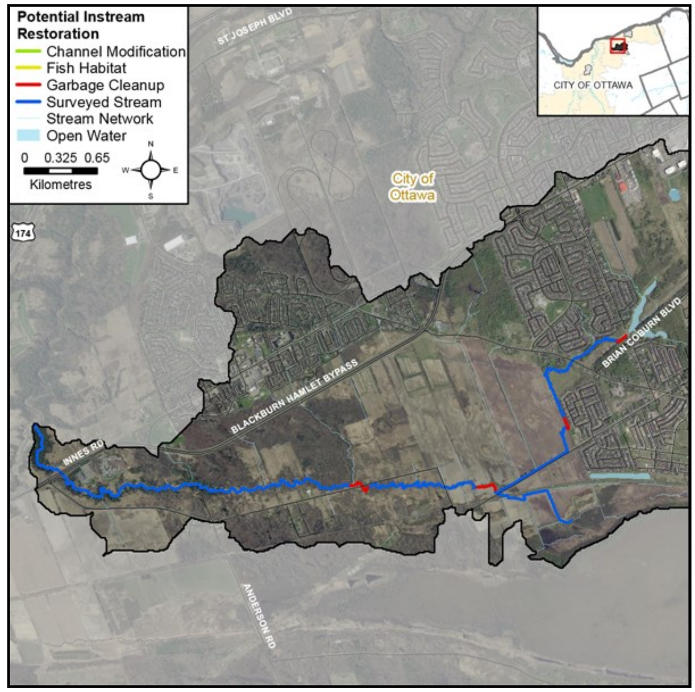


Figure 42 Potential instream restoration opportunities in Mud Creek

Area with accumulation of garbage that could benefit from a stream clean up.

References

1. Canadian Council of Ministers of the Environment (CCME), 1999. Canadian water quality guidelines for the protection of aquatic life: Dissolved oxygen (freshwater). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.
2. Environment Canada, 2011. Canada's Freshwater Quality in a Global Context Indicator. Data sources and methods. ISBN: 978-1-100-17978-0 . Available online: http://publications.gc.ca/collections/collection_2011/ec/En4-144-3-2011-eng.pdf
3. Environment Canada, 2013. *How Much Habitat is Enough? Third Edition*. Environment Canada, Toronto, Ontario. Accessed online: https://www.ec.gc.ca/nature/default.asp?lang=En&n=E33B007C-1.
4. Chu, C., Jones, N.E., Piggott, A.R. and Buttle, J.M., 2009. Evaluation of a simple method to classify the thermal characteristics of streams using a nomogram of daily maximum air and water temperatures. *North American Journal of Fisheries Management*, *29* (6), pp.1605-1619.
5. Coker, G.A., Portt, C.B. and Minns, C.K., 2001. *Morphological and ecological characteristics of Canadian freshwater fishes*. Burlington, Ontario: Fisheries and Oceans Canada.
6. Ministry of Environment and Energy (MOEE), 1994. Water management policies, guidelines, provincial water quality objectives of the Ministry of Environment and Energy. Copyright: Queens Printer for Ontario, 1994.
7. Ontario Ministry of Natural Resources (OMNR), 2012. Ontario Invasive Species Strategic Plan. Toronto: Queens Printer for Ontario. Accessed online: https://dr6j45jk9xcmk.cloudfront.net/documents/2679/stdprod-097634.pdf.
8. Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications Ltd, Oakville pp.1-966.
9. Stanfield, L. (editor) 2017. Ontario Stream Assessment Protocol (OSAP). Version 10.0. Fish and Wildlife Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario.
10. Stoneman, C.L. and Jones, M.L., 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. *North American Journal of Fisheries Management*, *16*(4), pp.728-737.
11. Stuart, V., Harker, D.B. and Clearwater, R.L., 2010. *Watershed Evaluation of Beneficial Management Practices (WEBs): Towards Enhanced Agricultural Landscape Planning-Four-Year Review (2004/5-2007/8)*. Agriculture and Agri-Food Canada, Ottawa, Ont.
12. Walker, H.J.W. and Walker, O., 1968. *Carleton Saga: By Harry and Olive Walker*. Carleton County Council.
13. Rideau Valley Conservation Authority (RVCA), 2018. Watershed Condition Statements. Manotick, ON. Available online:

    https://www.rvca.ca/watershed-conditions-statements

For more information on the overall 2018 City Stream Watch Program and the volunteer activities, please refer to the City Stream Watch 2018 Summary Report: https://www.rvca.ca/rvca-publications/city-stream-watch-reports

RVCA City Stream Watch would like to thank all the **volunteers** who assisted in the collection of information; as well as the many **landowners** who gave us property access to portions of the stream; and to our **City Stream Watch Collaborative members**: South Nation Conservation Authority, Mississippi Valley Conservation Authority, City of Ottawa, Ottawa Flyfishers Society, Ottawa Stewardship Council, Rideau Roundtable, Canadian Forces Fish and Game Club, and the National Capital Commission