Becketts Creek 2017 Catchment Report

Watershed Features	
Area	59.8 Square kilometres 1.41% of the Rideau Valley watershed
Land Use	55.28% agriculture 4.59% urban 7.73% rural 24.81% forest 3.87% meadow 0.16% water body 3.55% wetland
Surficial Geology	64.16% clay 7.01% diamicton 0.64% gravel 1.70% organic deposits 5.07% Paleozoic bedrock 21.43% sand
Watercourse Type	2017 thermal conditions cool-warm water system
Invasive Species	Ten invasive species were identified in 2017: banded mystery snail, common and glossy buckthorn, flowering rush, garlic mustard, non-native honey suckle, Japanese knotweed, Manitoba maple, periwinkle, purple loosestrife, and wild/ poison parsnip.
Fish Community	31 species of fish observed from 2006-2017. Game fish species present include: black crappie, brown and yellow bullhead, largemouth and smallmouth bass, northern pike, rock bass, silver and shorthead redhorse, walleye, white sucker and yellow perch.
Wetland Catchment Cover	
0.56% evaluated wetland	
3.00% unevaluated wetland	

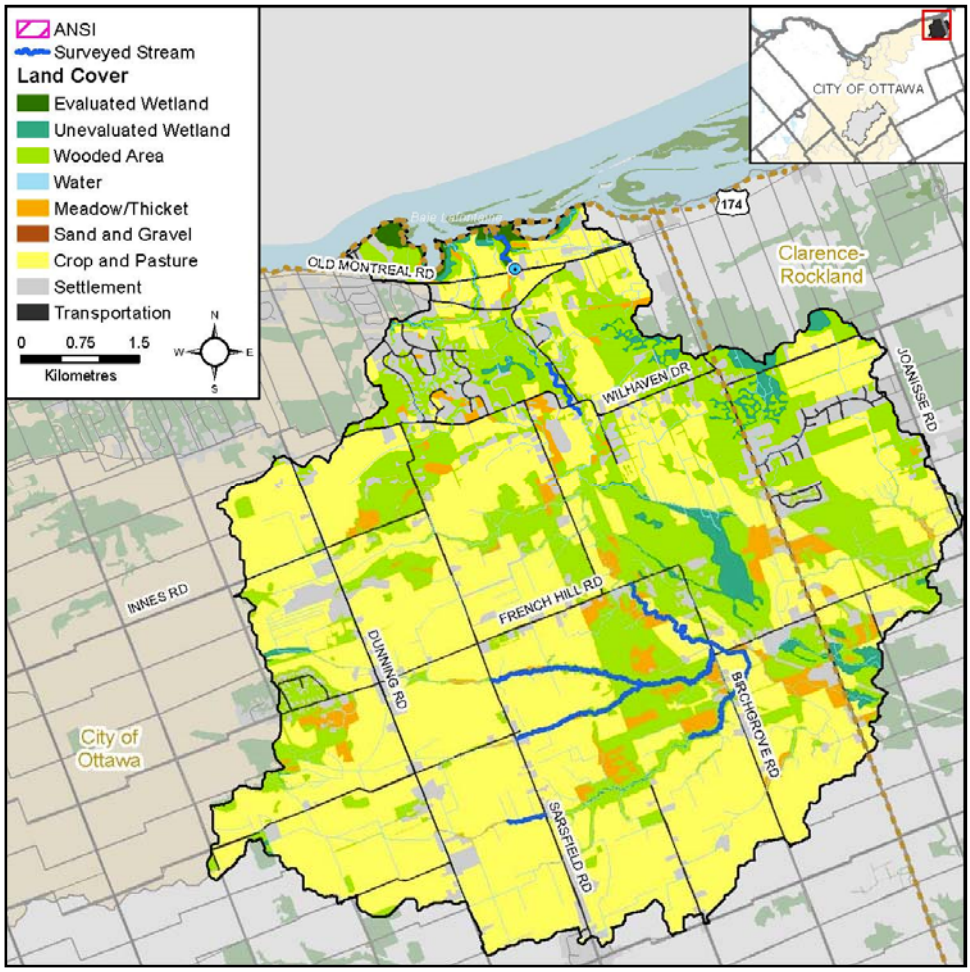


Figure 1 Land cover in the Becketts Creek catchment

Confluence of Becketts Creek on to the Ottawa River

The Rideau Valley Conservation Authority, in partnership with six other agencies in Ottawa: City of Ottawa, Ottawa Flyfishers Society, Ottawa Stewardship Council, Rideau Roundtable, Canadian Forces Fish and Game Club, and the National Capital Commission form the 2017 City Stream Watch Collaborative.

Flood Conditions - Rideau Valley Watershed

Flood Warning Conditions

Heavy rains throughout the summer and into the fall made 2017 the wettest year in Ottawa in recorded history. This year we observed prolonged and significant flooding in parts of the Ottawa River Watershed. RVCA monitors certain areas along the Ottawa River, by mid-April the first flood message was sent and by May 1st the message was upgraded to a Flood Warning.

The Ottawa River peaked on May 7th with a record flow of 5769 cubic meters per second, making it a 1:50 year flood event (RVCA, 2017). The confluence of Becketts Creek with the Ottawa River is situated in Cumberland where flooding was experienced this spring affecting many homes in the area. This year was quite a contrast to 2016, when the city experienced moderate to severe drought conditions throughout most of the year.

Flooded road section in the Stevens Creek catchment near the Rideau River

Flooded section of Pinecrest Creek near the Ottawa River

Flooded agricultural field in the Becketts Creek catchment

Introduction

Becketts Creek is a tributary of the Ottawa River located in the East end of the City of Ottawa. The 28 kilometer stream flows from the southern portion of Sarsfield to its confluence into the River at Baie Lafontaine in Cumberland. Adjacent to the confluence there is also a 184 hectare migratory bird sanctuary.

The sub-watershed of Becketts Creek drains 59.8 square kilometers of land, comprised of mainly forest, agricultural and rural land uses. The vegetation cover is comprised of 87.47 percent wooded areas and 12.53 percent wetland; of the woodlots in the catchment, 55 percent are less than one hectare in size, 40 percent are one to 30 hectares, and five percent have an area over 30 hectares. The majority of the headwaters of this catchment are influenced by agricultural land use. This system is fed mostly by agricultural drains, and portions of itself and many of its tributaries are designated municipal drains.

In 2017 the City Stream Watch program surveyed 130 sections (13 km) of the main stem and branches of Becketts Creek; eight sites were sampled for fish community composition; five temperature loggers were deployed; and 61 headwater drainage feature sites were assessed. Areas that were not surveyed lacked private property access permission. The surveyed sections of the main branch include portions from the mouth to Old Montreal Road, sections near the crossing at Wilhaven Drive, from French Hill Road past Birchgrove Road, and from Sarsfield Road to Dunning Road. Two branches were also surveyed from Birchgrove Road to Sarsfield Road. The following report summarizes findings of the areas surveyed.

Becketts 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 the surveyed sections of Becketts Creek. Buffers greater than 30 meters were present along 71 percent of the left bank and 76 percent of the right bank. A 15 to 30 meter buffer was present along 14 percent of the left bank and 11 percent of the right bank; five to 15 meter buffers were observed along eight percent of the left bank and six percent of the right bank. A five meter buffer or less was present along seven percent of the left banks and five percent of the right bank.

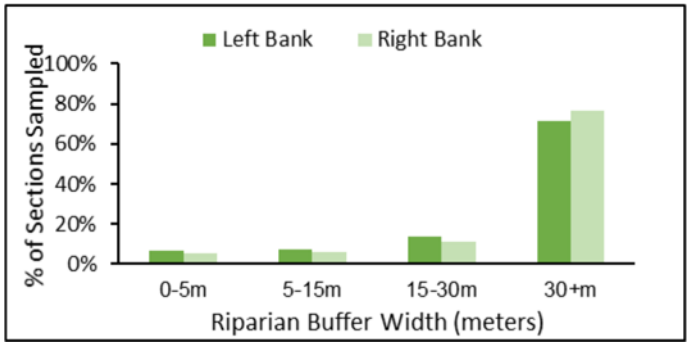


Figure 2 Vegetated buffer width along Becketts Creek

Improvements of buffer are needed, particularly in the agricultural areas and near roadway intersections where buffers are lower than the recommended guidelines.

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. Becketts Creek riparian zones are mostly natural vegetative communities, with alterations associated with municipal infrastructure, including roadways, and agricultural land uses.

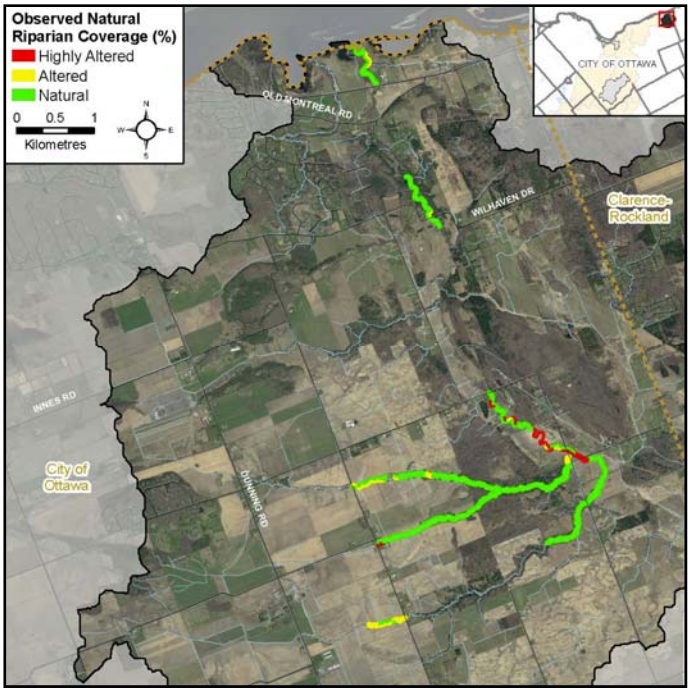


Figure 3 Riparian buffer alterations in Becketts Creek

Adjacent Land Use

Surrounding land use is considered from the beginning to end the 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.

Meadows and forest were present in 80 percent and 82 percent of the sections surveyed, being the most common land use found. Scrubland was present in 52 percent of the surveyed areas, and wetland was present in five percent of sections.

Aside from the natural areas, the most common land use in the catchment was agricultural, with 49 percent of the sections containing active agriculture, eight percent abandoned agriculture and 14 percent of the sections had pasture land present. Other uses observed included 18 percent of surveyed areas with infrastructure (such as roads); residential areas were observed in 14 percent; and industrial or commercial use was identified in two percent of the adjacent lands.

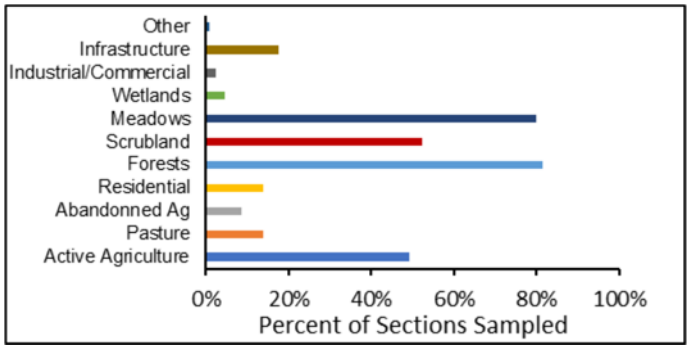


Figure 4 Adjacent land use 100 m from each shoreline and percentage of presence along Becketts Creek

Road crossing altering riparian zones along Becketts Creek

Becketts 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 the 130 sections surveyed in Becketts Creek, with 63 percent remaining without any human alteration. Of the sections surveyed, 25 percent fall 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 five percent of surveyed areas, they may contain diverted or straightened sections and riparian buffers of five to 15 meters. Shoreline alterations also include concrete. One or two storm water outlets could also be present.

Highly altered sections (7% of sections) have the highest proportion of alterations. Including riparian buffers less than five meters, shoreline alterations are found on most of the section, and portions of the stream may flow through culverts.

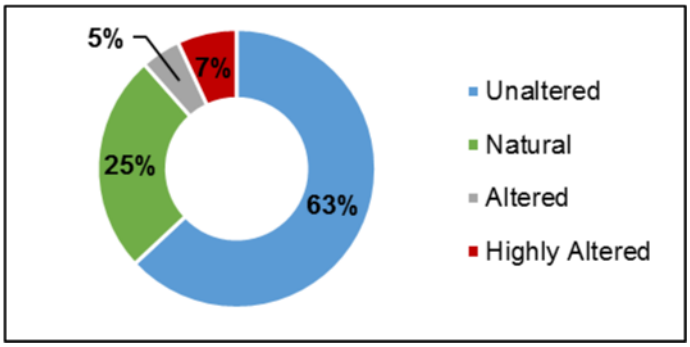


Figure 5 Anthropogenic alterations along Becketts Creek

A highly altered stream section flowing through a culvert

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 Becketts Creek.

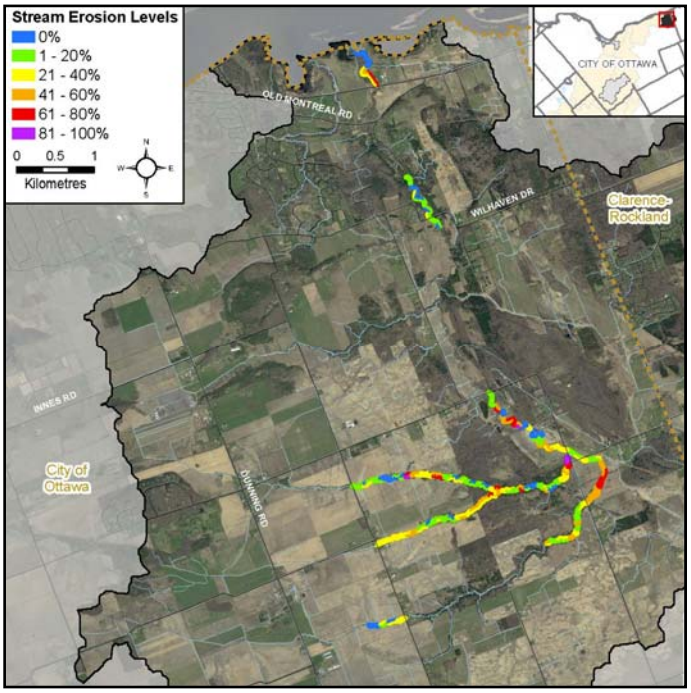


Figure 6 Erosion levels along Becketts Creek

Bank destabilization along a steep slope of Becketts Creek

Near the mouth and in many other reaches of Becketts Creek, the system is dominated by steep forested slopes and leda clay that makes them unstable. In the upper reaches of the system, certain agricultural areas have unstable banks with exposed soils, lack of vegetation and undercutting.

Stream bank erosion with visible soils and lack of vegetation

Undercut Stream Banks

Stream bank undercuts can provide excellent 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 the majority of the sections surveyed in Becketts Creek, 84 percent of the sections had undercutting in the left bank and 80 percent of the right bank.

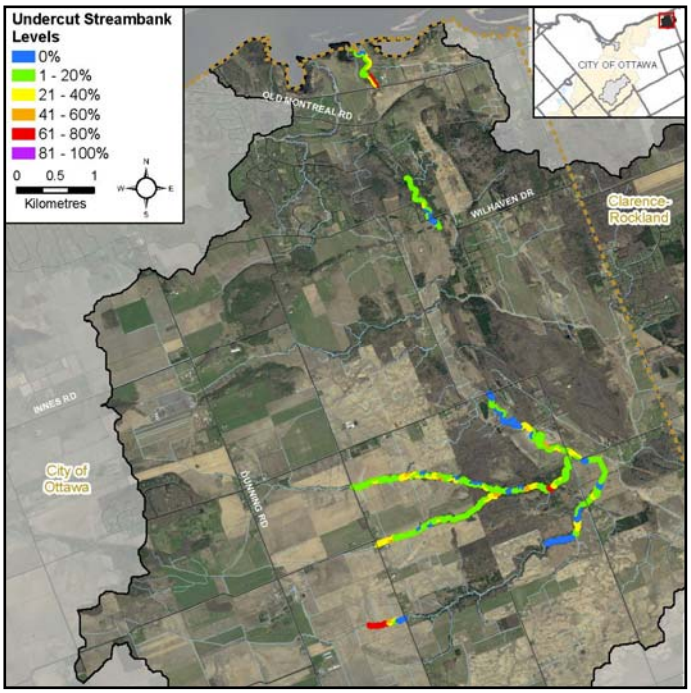


Figure 7 Undercut stream banks along Becketts Creek

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 cover 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 stream shading. The majority of sections (33%) had a shade cover of 61 to 80 percent. The highest shading of 81 to 100 percent was observed in eight percent of the sections. Cover of 41 to 60 percent was present in 18 percent of the sections and 19 percent of the sections had 21 to 40 percent coverage. Minimal shading of one to 20 percent was observed in 18 percent of sections and no cover was observed only in two percent of the sections. Figure 9 shows the distribution of these shading levels along Becketts Creek.

A mix of trees and grasses comprised the majority of shading. Overhanging plants, mainly grasses predominant in agricultural areas were seen in 86 percent of the left bank and 85 percent of the right bank.

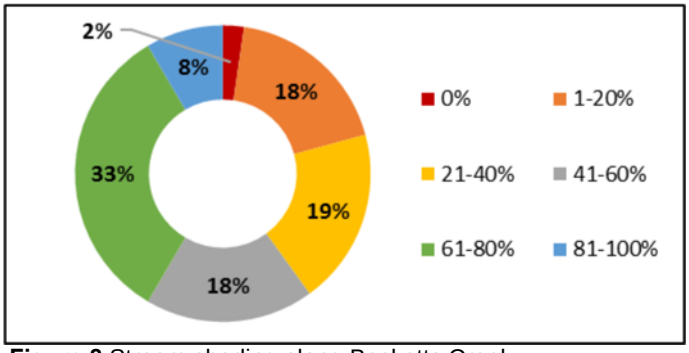


Figure 8 Stream shading along Becketts Creek

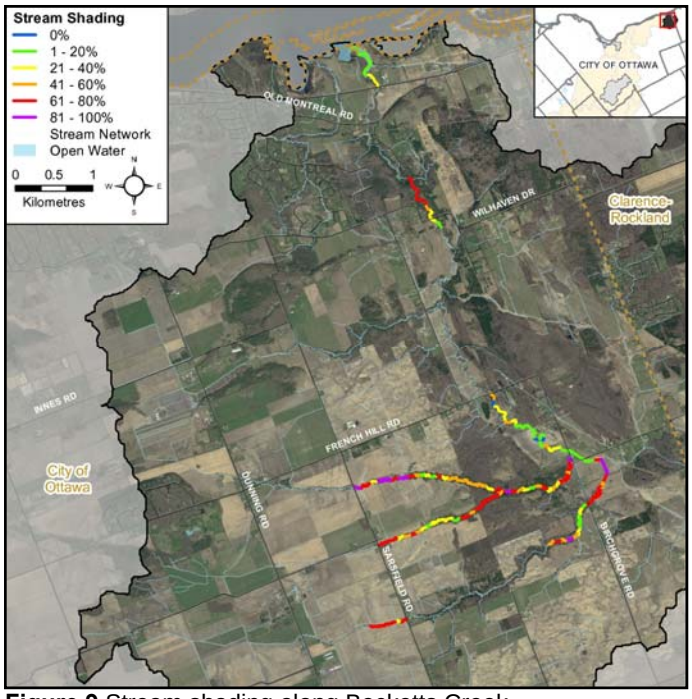


Figure 9 Stream shading along Becketts Creek

Overhanging Trees and Branches

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 trees and branches that were observed along Becketts Creek. In the surveyed portions, 73 percent of the sections had overhanging trees and branches on the left bank, and 70 percent of the sections had overhanging trees on the right banks.

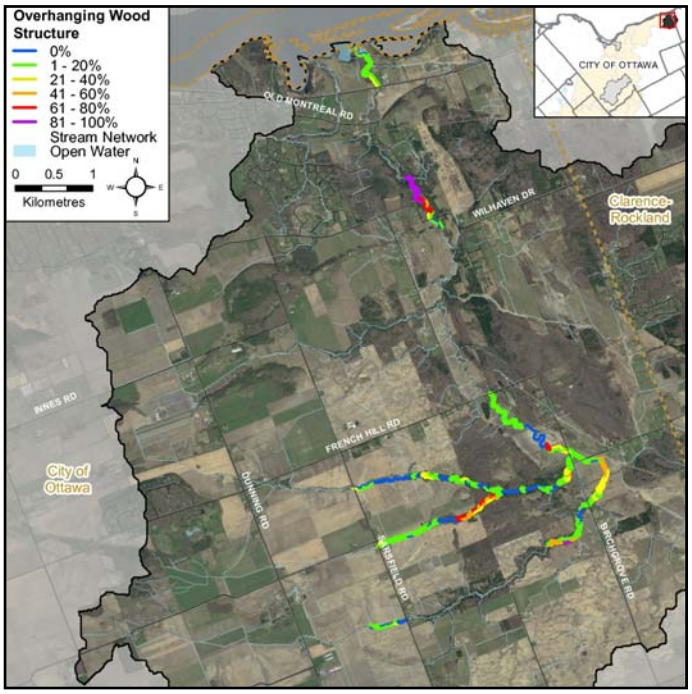


Figure 10 Overhanging trees and branches along Becketts Creek

A natural section with overhanging trees along Becketts Creek

Becketts 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 woody material. A higher score shows greater complexity where a variety of species can be supported. Figure 11 shows habitat complexity of the sections surveyed: five percent had no complexity; 46 percent had a score of one; 19 percent scored two; 15 percent scored three; and 15 percent had the highest habitat diversity.

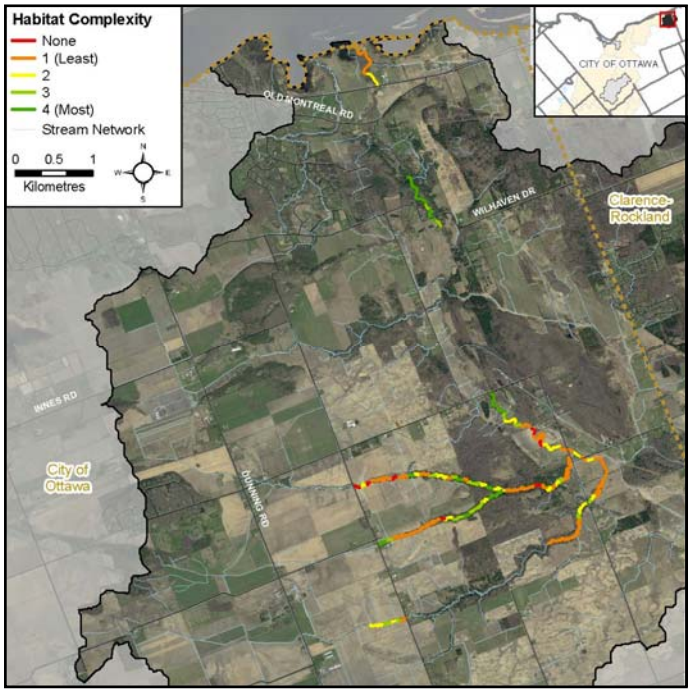


Figure 11 Instream habitat complexity along Becketts Creek

Diverse habitat cover in Becketts Creek

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 surveyed of Becketts Creek. It is a system dominated by clay, with 88 percent of sections containing this type of substrate. It also has bedrock portions; in the locations containing waterfall systems near Old Montreal Road most bedrock portions were not surveyed due to lack of property access.

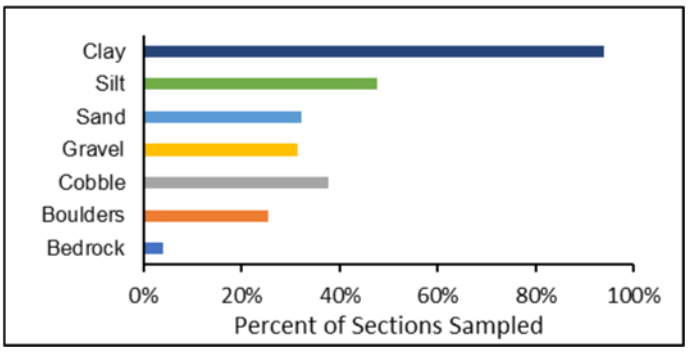


Figure 12 Instream substrates present along Becketts Creek

Figure 13 shows the dominant substrates in the creek. From the areas that were assessed, bedrock was the dominant type in two percent of sections. Gravel and cobble were identified as dominant in eight percent of all surveyed sections; sand and silt dominated only two percent of sections.

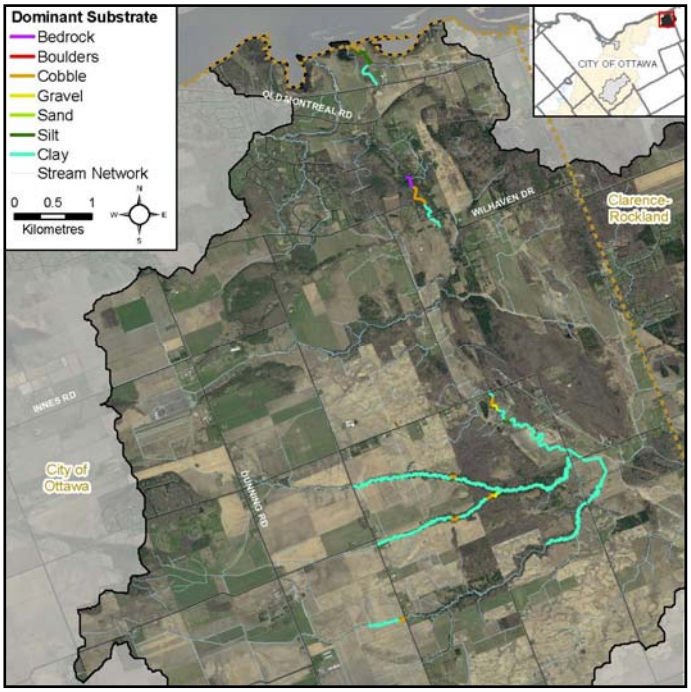


Figure 13 Dominant instream substrates along Becketts Creek

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 diverse 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 Becketts Creek has a diversity of morphological conditions, suitable for a variety of aquatic species and life stages; 78 percent of sections contained pools, 53 percent contained riffles and the majority, 98 percent, contained runs. Figure 15 shows the locations of riffle habitat along Becketts Creek.

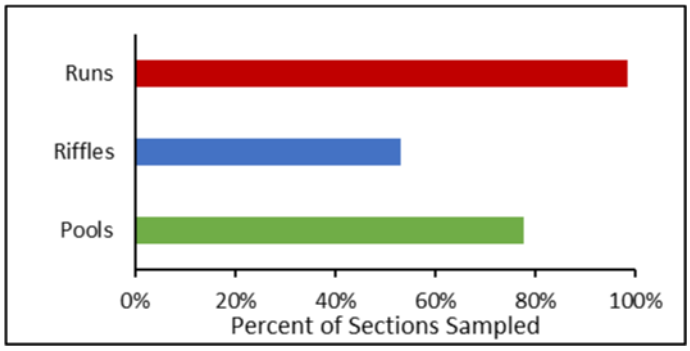


Figure 14 Instream morphology along Becketts Creek

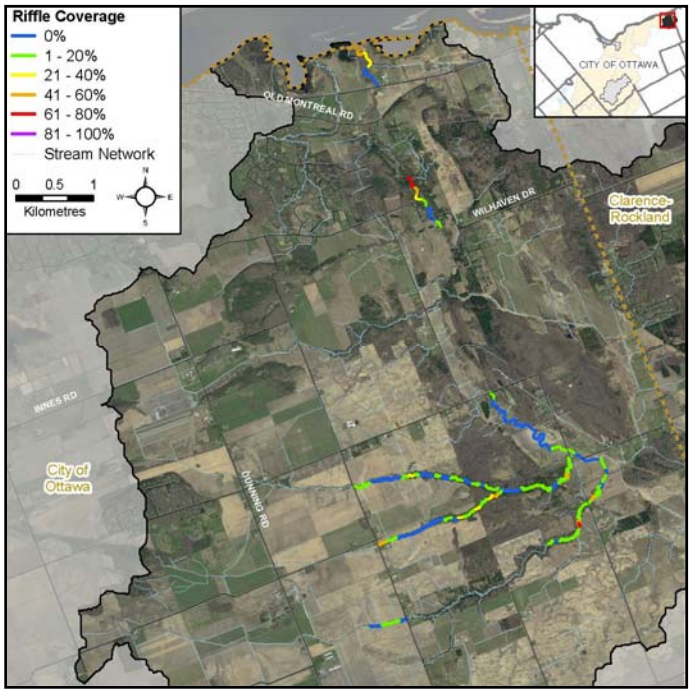


Figure 15 Riffle habitat locations along Becketts Creek

Instream Wood Structure

Figure 16 shows that the majority of Becketts Creek had low levels of instream woody material in the form of branches and trees. Instream wood material is important for fish and wildlife habitat, by providing refuge and feeding areas. Excessive amounts can create barriers.

Instream wood structures found along Becketts Creek

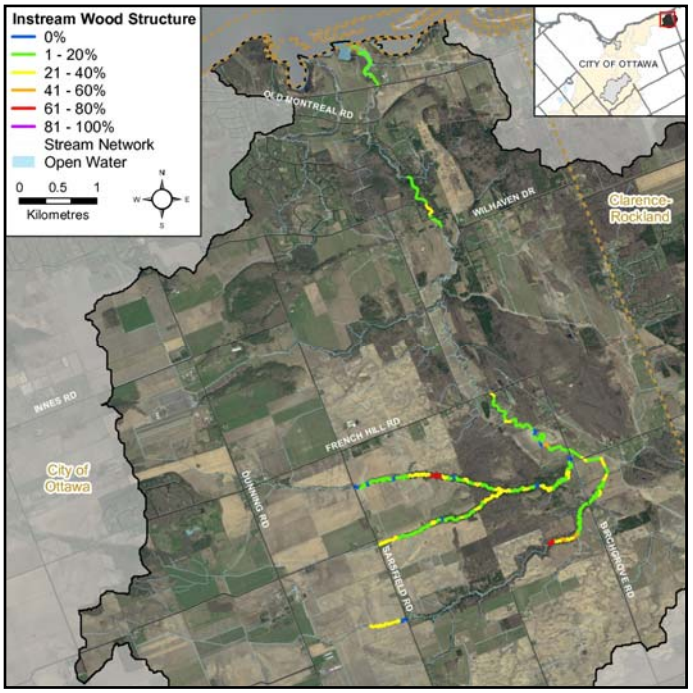


Figure 16 Instream wood structures along Becketts Creek

Instream 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. The two categories most commonly present were none, present in all sections; and narrowed leaved present in 75 percent of sections sampled.

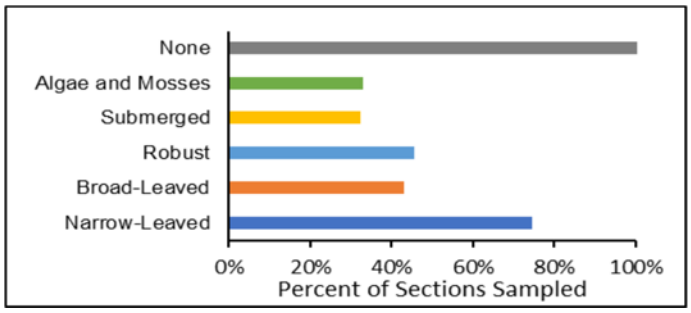


Figure 17 Aquatic vegetation presence along Becketts Creek

Becketts Creek does not have a large diversity of instream vegetation, with 84 percent of sections having no vegetation as the dominant category (Figure 18), due to the types of substrates found such as consolidated clay or bedrock. Narrowed-leaved vegetation was dominant in six percent of sections; robust emergent plants in four percent; and algae and mosses were dominant in three percent. Broad-leaved and submerged vegetation were each dominant in two percent of sections.

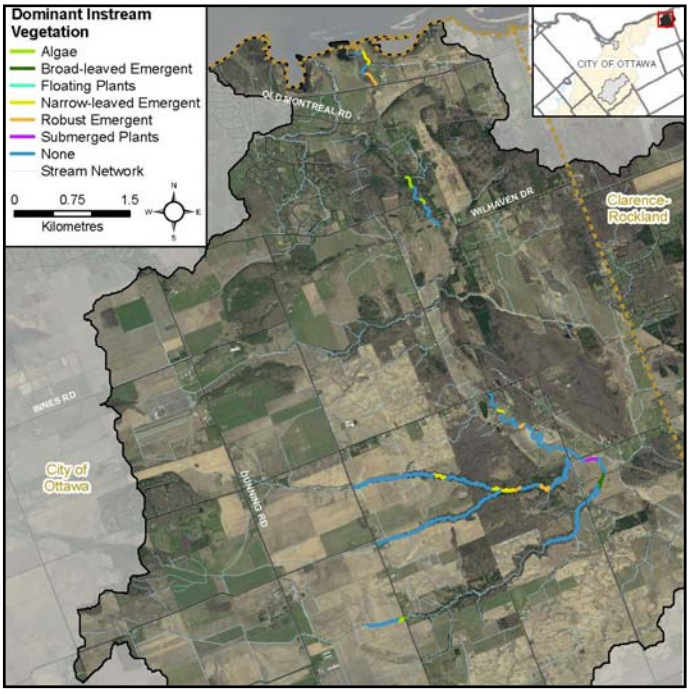


Figure 18 Dominant instream vegetation in Becketts Creek

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, 94 percent of Becketts Creek sections had no vegetation, 25 percent had rare vegetation, and 40 percent had low vegetation levels. Normal abundance levels were observed in 40 percent of sections surveyed and common abundance was observed in 28 percent. Only three percent of sections had extensive abundance levels.

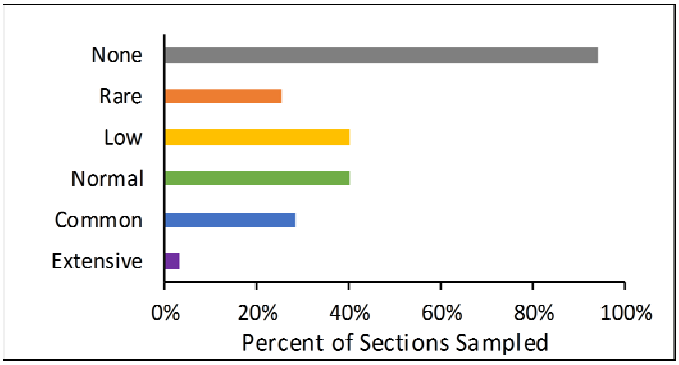


Figure 19 Instream vegetation abundance in Becketts Creek

Instream floating yellow water lily on Becketts Creek

Section of Becketts Creek without aquatic vegetation

Becketts Creek Stream Health

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 manage or eradicate, however it is important to continue to research, monitor and manage them.

Figure 20 shows abundance of species observed per section. Ten invasive species present in 2017 were:

- banded mystery snail (*Viviparus georgianus)*
- common & glossy buckthorn (*Rhamnus cathartica* & *R. frangula*)
- flowering rush (*Butomus umbellatus*)
- garlic mustard (*Alliaria petiolata*)
- non-native honey suckle (*Lonicer sp.*)
- Japanese knotweed (*Reynoutria japonica var. japonica*)
- Manitoba maple (*Acer negundo*)
- periwinkle (*Vinca minor*)
- poison/wild parsnip (*Pastinaca sativa*)
- purple loosestrife (*Lythrum salicaria*)

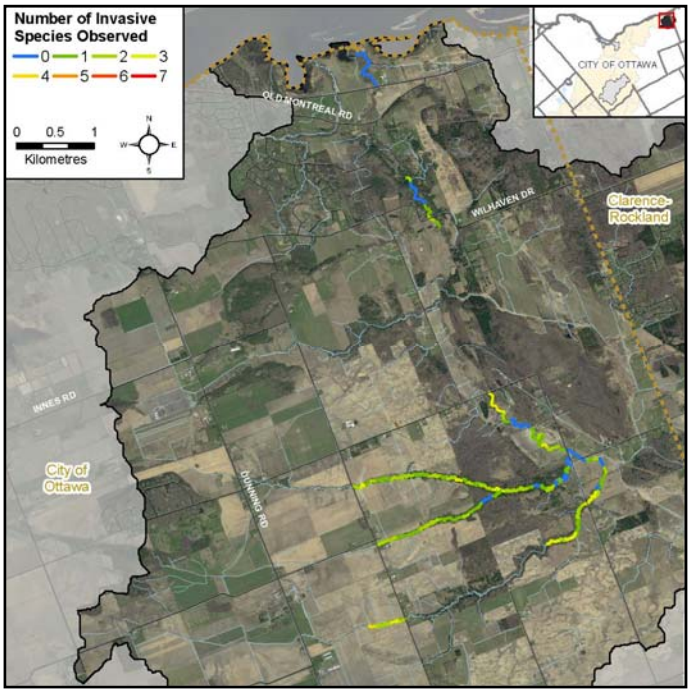


Figure 20 invasive species abundance along Becketts Creek

Invasive Japanese knotweed along the bank of Becketts Creek

To report and find information about invasive species visit

http://www.invadingspecies.com

Managed by the Ontario Federation of Anglers and Hunters

Pollution

Figure 21 shows the types of pollution observed in Becketts Creek. The levels of garbage found in the main portion of the stream were low, with 84 percent of sections surveyed containing no garbage. In the 16 percent of sections that were polluted, most garbage observed were styrofoam, plastics, cans, and tires.

In the headwater portions of the catchment garbage and dumping was also observed. The images below show examples of dumping and oil spills near roads.

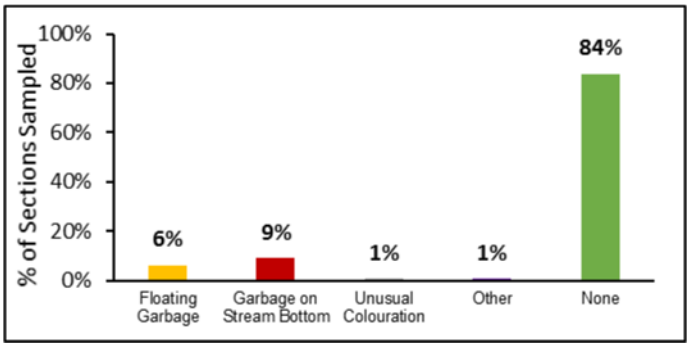


Figure 21 Pollution observed within Becketts Creek

Pollution observed along headwater areas of Becketts Creek: metal drums and pails of unknown fluids

Wildlife

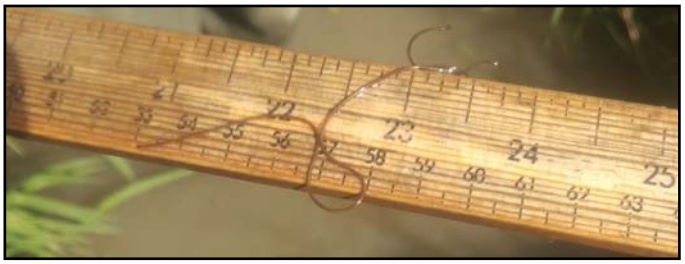
The diversity of fish and wildlife populations can be an indicator of water quality and overall stream health (Table 1). Wildlife observations are noted during standard monitoring and survey activities; they do not represent an extensive evaluation of species presence or absence in the Becketts Creek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

Wasp hive (top) and pearl dace (bottom) found along Becketts Creek

Ebony jewelwing damselflies (top) and fingernail clams (bottom) are found throughout the Becketts Creek catchment

Table 1 Wildlife observations along Becketts Creek in 2017

Birds	American crow, American goldfinch, American robin, black-capped chickadee, blue jay, Canada goose, common merganser, downy woodpecker, ducks, finches, gray catbird, great blue heron, mourning dove, red-winged blackbird, ruffed grouse, song sparrow, sparrows, turkey vulture, wild turkey, woodpeckers
Reptiles & Amphibians	American bullfrog, common garter snake, frogs, gray treefrog, green frog, leopard frog, painted turtle, snapping turtle, tadpoles, wood frog
Mammals	American beaver, American mink, American red squirrel, chipmunks, eastern grey squirrel, muskrat, northern river otter, raccoon tracks, white-tailed deer
Aquatic Insects & Benthic Invertebrates	aquatics sow bugs, banded mystery snail, beetles, caddisflies, crayfishes, damselflies, eastern floater, fingernail clams, mayflies, stoneflies, giant floater, horsehair worm, unionid mussels, water boatman, water strider, whirligig beetle
Other	*Argiope* spider, bees, bumblebees, butterflies, caddisflies, cicadas, crane flies, crickets, damselflies, deerflies, dragonflies, ebony jewel wing, horseflies, midges, monarch butterfly, mosquitoes, moths, mud dauber, red meadow-hawk, spiders, wasps



Horsehair worm (above) and painted turtle basking on a log (below) in Becketts Creek

Becketts 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.

A volunteer collecting water chemistry measurements with a multiparameter YSI probe on Becketts Creek

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 the surveyed portions of Becketts Creek. The two dashed lines depicted represent the Canadian water quality guidelines. Most of the surveyed portions had adequate oxygen levels to support warm-water aquatic life. Levels below the Canadian water quality guideline were found in agricultural areas and at road crossings (sec. 51-63; 11-23 SB). Average levels across the system were 8.4 milligrams per liter.

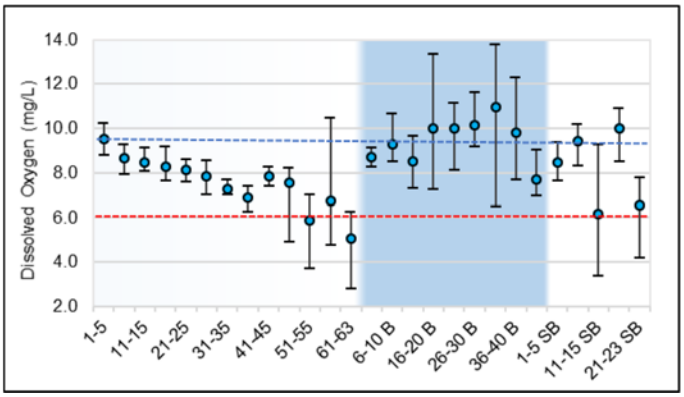


Figure 22 Dissolved oxygen ranges in surveyed sections of Becketts Creek: 1-63 main stem, 1-44 branch (B) in blue, 1-23 south branch (SB)

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 Becketts Creek, the average level is depicted by the dashed line (720 µS/cm). Notable variability was observed at the mouth, (sec. 1-5) likely influenced by the Ottawa River; and by drainage in agricultural zones and runoff from roadway crossings (sec. 56-60, 6-10 SB, 16-20 SB).

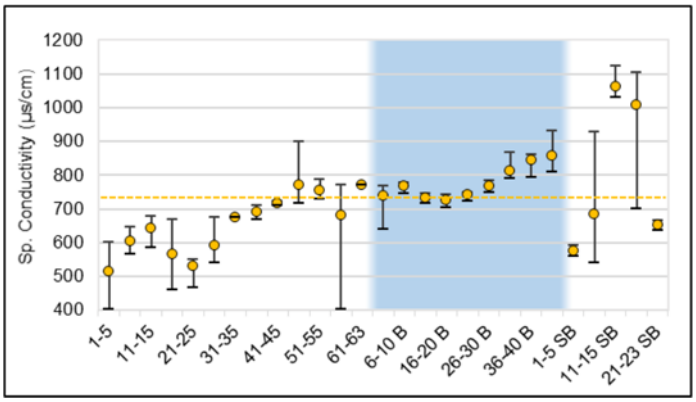


Figure 23 Conductivity ranges in sections of Becketts Creek: 1-63 main stem, 1-44 branch (B) in blue, 1-23 south branch (SB)

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 Becketts Creek had mostly pH levels that meet the PWQO, depicted by the dashed line. Average levels across were pH 7.95; and sections above 8.5 were found in agricultural land use areas.

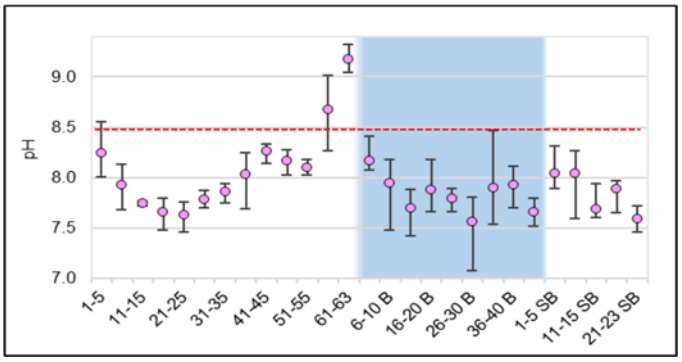


Figure 24 pH ranges in surveyed sections of Becketts Creek: 1 -63 main stem, 1-44 branch (B) in blue, 1-23 south branch (SB)

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 Becketts Creek with **optimal** oxygen conditions

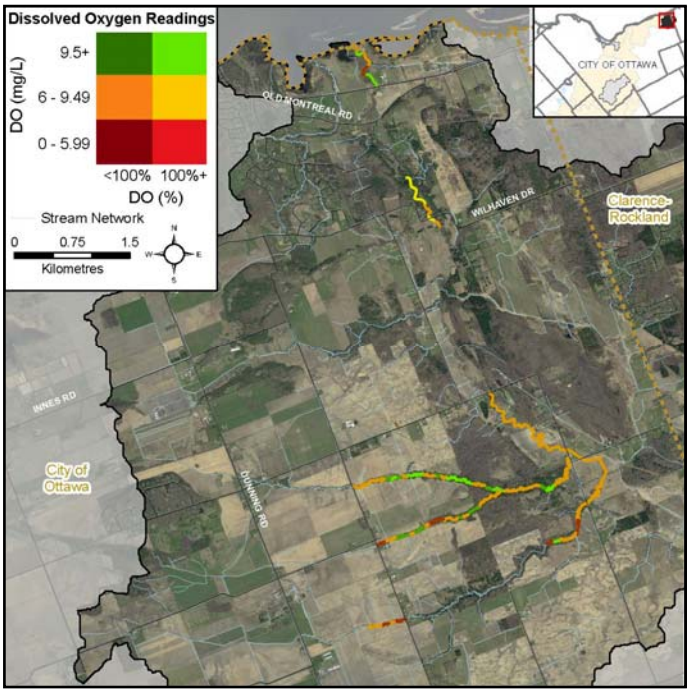


Figure 25 Bivariate assessment of dissolved oxygen concentration (mg/L) and saturation (%) along Becketts Creek

Figure 25 shows the oxygen conditions across the areas that were surveyed in 2017. Overall dissolved oxygen conditions in Becketts Creek are sufficient to sustain warm-water biota.

There are forested areas in the headwater reaches where conditions would be optimal for warm and cold-water biota. Impairment of dissolved oxygen levels, shown in red in Figure 25, were observed near agricultural areas and road crossings.

Site on Becketts Creek with **impaired** oxygen conditions

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 Becketts Creek (720 µS/cm) exceed the water quality parameter (500 µS/cm) used for the Canadian Environmental Performance Index (Environment Canada 2011).

Figure 26 shows relative specific conductivity levels in Becketts Creek. Normal levels were maintained near Wilhaven Drive, and throughout many portions upstream of Birchgrove Road. Moderately elevated conditions were observed in the main stem of Becketts Creek between French Hill Road and Birchgrove Road. Highly elevated conditions were present in the South Branch portion, where there is agricultural activity. Other areas with highly elevated conditions are near the confluence with the Ottawa River, and agricultural areas East of Sarsfield Road.

Section of Becketts Creek upstream of Sarsfield Road with highly elevated conductivity levels

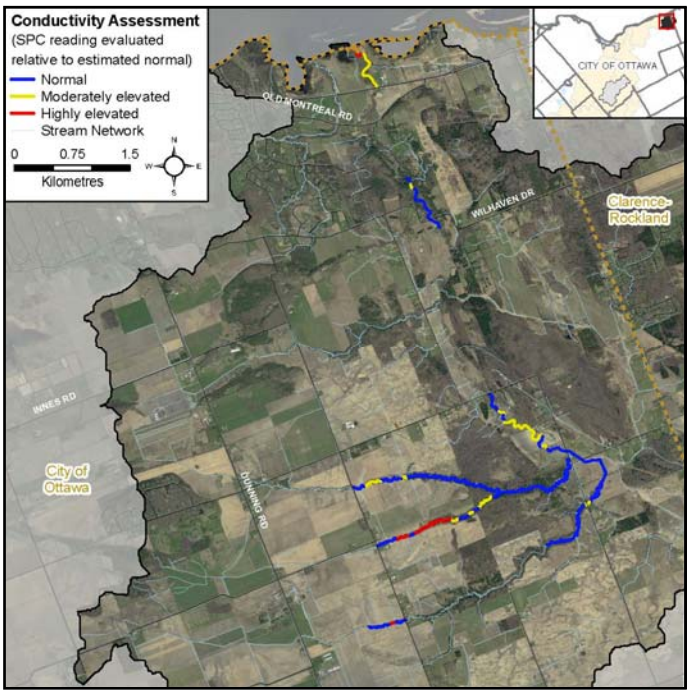


Figure 26 Relative specific conductivity levels along Becketts Creek

Section of Becketts Creek upstream of Birchgrove Road that would benefit from buffer enhancement to improve shoreline conditions and water quality.

Becketts 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 Becketts Creek, five temperature loggers were placed; four were retrieved, one was missing in its location (#5), and one was compromised out of water.

Figure 27 shows where thermal sampling sites were located. Analysis of data from three loggers (using the Stoneman and Jones, 1996, method adapted by Chu et al., 2009), Becketts Creek is classified as **Cool-warm water** (Figure 28).

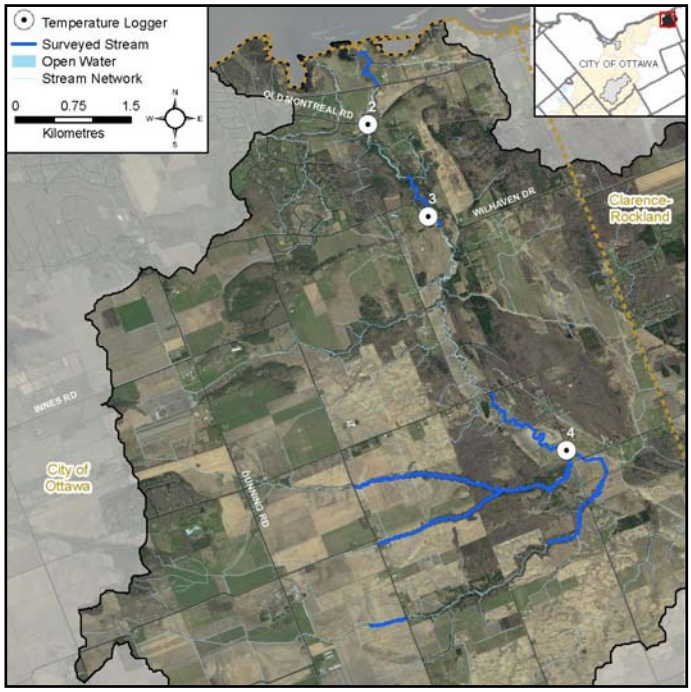


Figure 27 Temperature logger locations on Becketts Creek

Within those three 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.

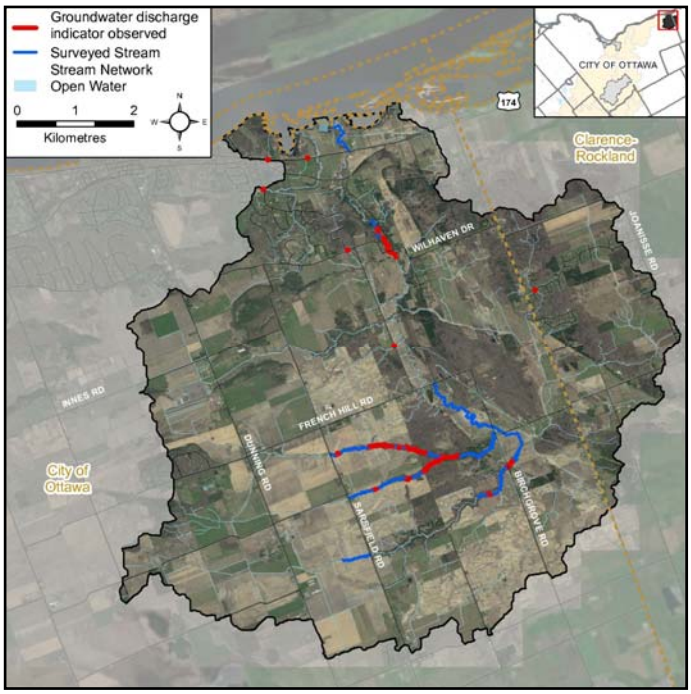


Figure 29 Groundwater indicators observed in Becketts Creek

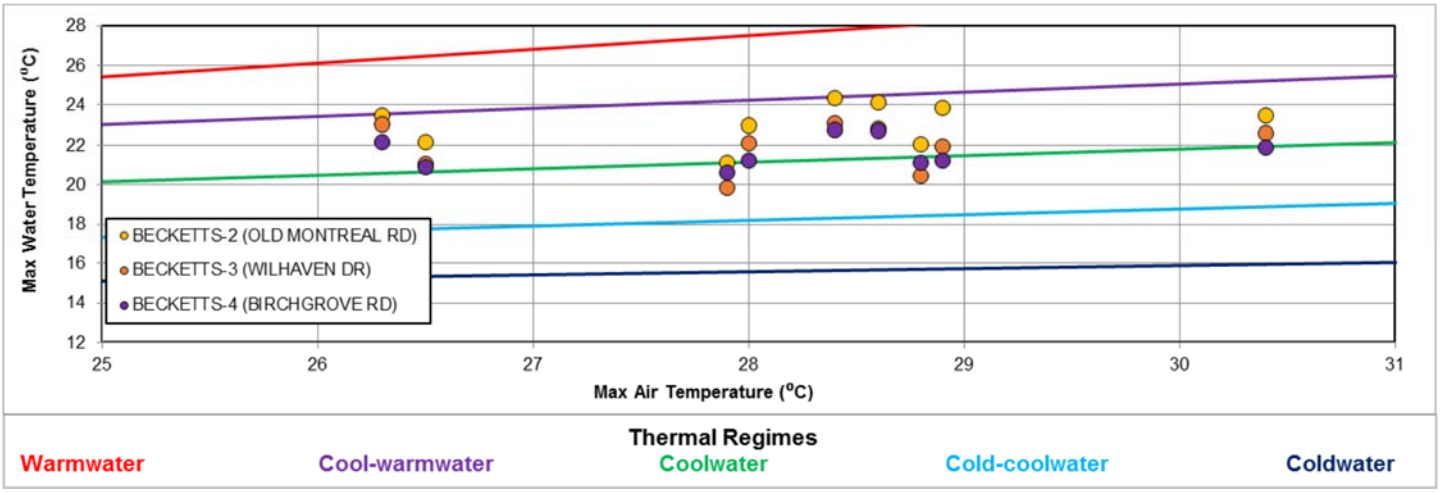


Figure 28 Thermal Classification for Becketts Creek with the five thermal regimes adapted from Stoneman and Jones (1996) by Chu et al. (2009): **cool-warm water** category for all three sites sampled on Becketts Creek

Becketts Creek Fish Community

Fish Community Summary

Eight fish sampling sites were evaluated between May and October 2017. Two sites located near the confluence with the Ottawa River were sampled daily for four days with a large fyke net. The two sites near Wilhaven Drive and French Hill Road crossings were sampled with a seine net. The four most upstream sites, one near Birchgrove Road and three near Sarsfield Road, were sampled using a back pack electro-fisher.

Table 2 Fish species observed along Becketts Creek in 2017

Species	Thermal Class	MNR Species Code
black crappie *Pomoxis nigromaculatus*	Cool	BlCra
bluegill *Lepomis macrochirus*	Warm	Blueg
bluntnose minnow *Pimephales notatus*	Warm	BnMin
brook stickleback *Culaea inconstans*	Cool	BrSti
brown bullhead *Ameiurus nebulosus*	Warm	BrBul
central mudminnow *Umbra limi*	Cool-warm	CeMud
Cyprinid *spp.*	Variable	Ca_MI
common shiner *Luxilus cornutus*	Cool	CoShi
creek chub *Semotilus atromaculatus*	Cool	CrChu
johnny/tessalated darter *Etherostoma spp.*	Cool	EthSp
fathead minnow *Pimephales promelas*	Warm	FhMin
golden shiner *Notemigonus crysoleucas*	Cool	GoShi
northern pearl dace *Margariscus nachtriebi*	Cold-cool	PeDac
northern pike *Esox lucius*	Cool	NoPik
pumpkinseed *Lepomis gibbosus*	Warm	Pumpk
silver redhorse *Moxostoma anisurum*	Cool	SiRed
spottail shiner *Notropis hudsonius*	Cold-cool	SpShi
walleye *Sander vitreus*	Cool	Walle
white sucker *Catostomus commersonii*	Cool	WhSuc
Total Species		**19**

Nineteen species were captured in 2017, they are listed in Table 2 along with their thermal classification preferences (Coker et al., 2001) and MNR species codes. Becketts 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 MNR codes provided in Table 2.

For comparisons across sampling years and a complete list of RVCA historical fish records from Becketts Creek refer to page 22 of this report.

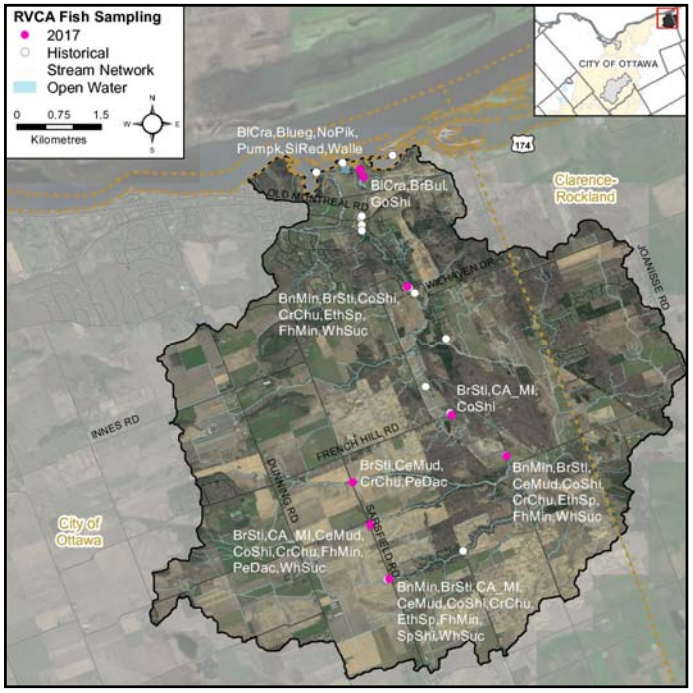


Figure 30 Becketts Creek fish sampling locations and 2017 fish species observations

Retrieving a fyke net (above) and measuring a northern pike (below) in Becketts Creek near the Ottawa River

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 most notorious obstructions along Becketts Creek are a natural series of bedrock ledges/waterfalls upstream of Old Montreal Road, as well as a weir under Old Montreal Road. Additionally, in the sections that were surveyed in 2017, 14 woody material dams were observed. These were resulting form beaver activity in the area. The locations of the obstructions observed in 2017 are shown in Figure 31.

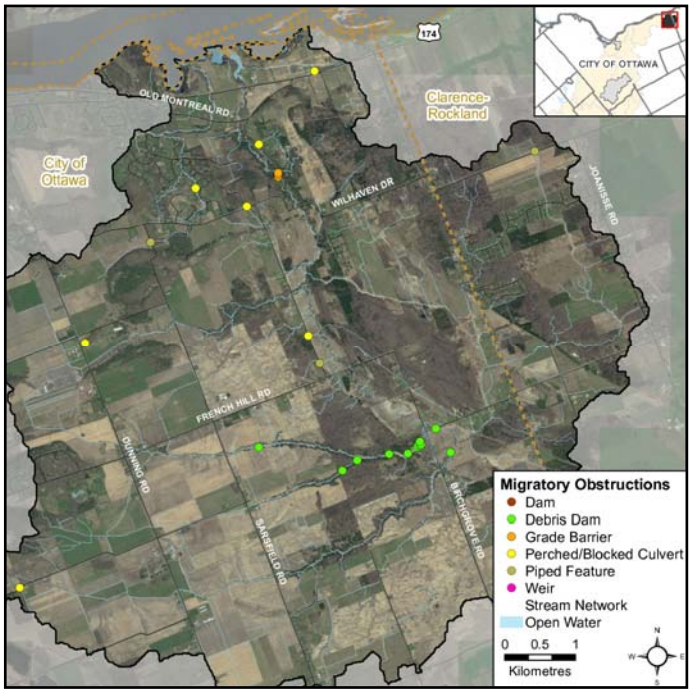


Figure 31 Migratory obstructions along Becketts Creek

One of several bedrock water falls found along Becketts 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.

In 2017, a total of 25 beaver dams were observed; their locations and condition are shown in Figure 32.

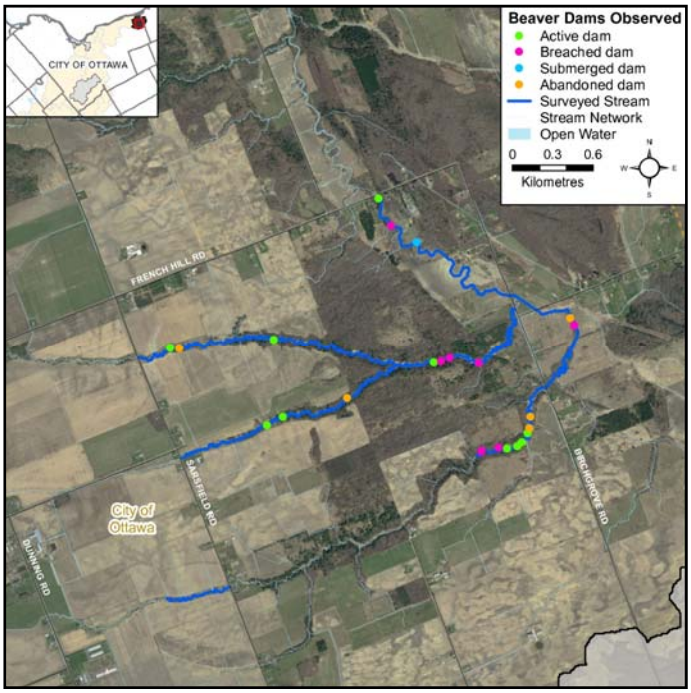


Figure 32 Beaver Dam locations along Becketts Creek

Active beaver dam found on Becketts 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 2017 the City Stream Watch program assessed 61 HDF sites in the Becketts Creek Catchment (Figure 33).

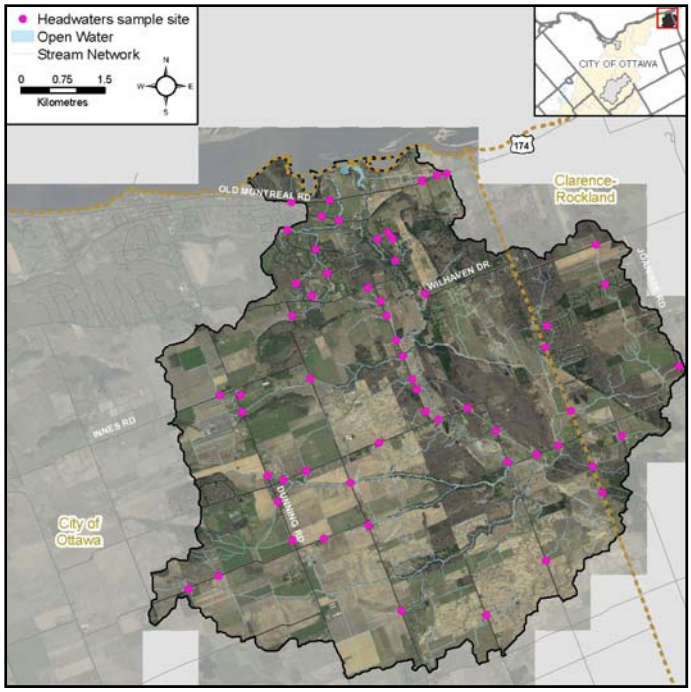


Figure 33 Locations of HDF sampling sites in the Becketts Creek catchment

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. Channelized features were overall dominant, observed in 32 sites. Seven features were roadside ditches, two were tiled, and one pond outlet was observed. The natural features present included 15 natural channels and two wetlands. Two features were no longer present.

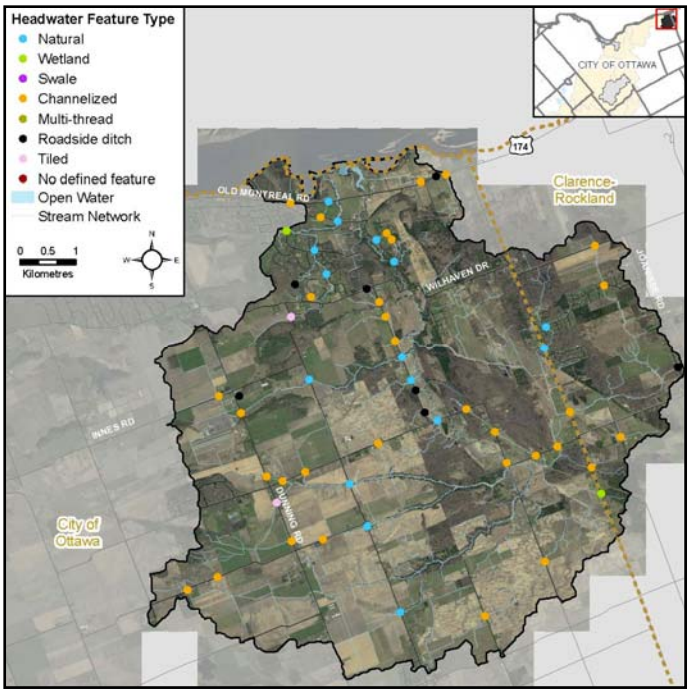


Figure 34 Headwater feature types in the Becketts Creek catchment

Channelized drainage feature on Regimbald 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 Becketts Creek catchment area are shown in Figure 35.

Intermittent feature with summer and spring conditions along Dunning Road

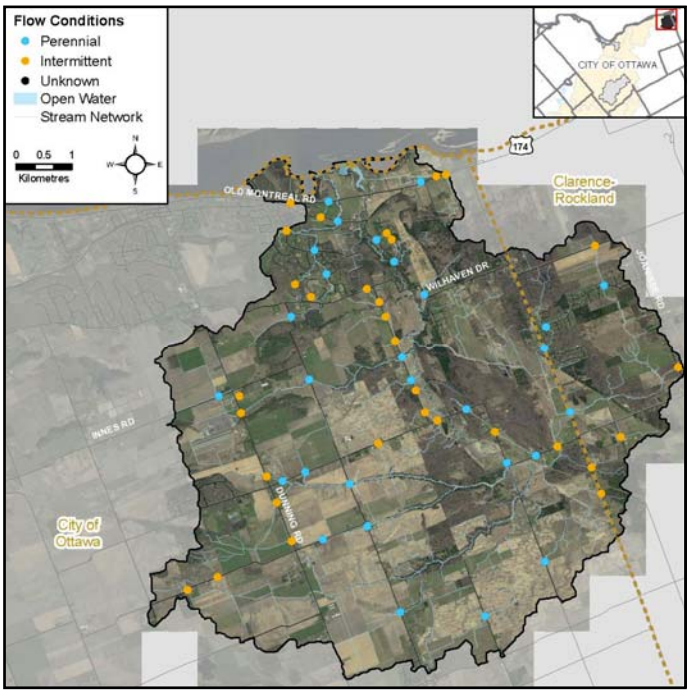


Figure 35 Headwater feature flow conditions in the Becketts Creek catchment

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 Becketts Creek headwater drainage features. Most modifications in this catchment for headwater drainage features are dredging or straightening.

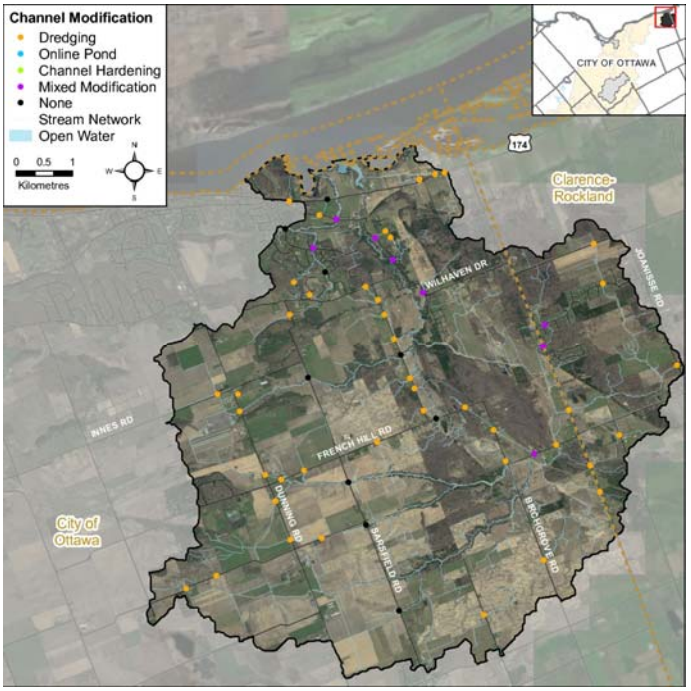


Figure 36 Headwater feature channel modifications in the Becketts Creek Catchment

An example of mixed modifications: channel straightening and hardening with gabion baskets on Birchgrove 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 Becketts Creek catchment. No vegetation was the most common condition in springtime (27 features); flows and sediment transport are unmitigated by the lack of vegetative material. Of the remaining features: 17 were dominated by meadow, 14 by wetland vegetation and one was lawn.

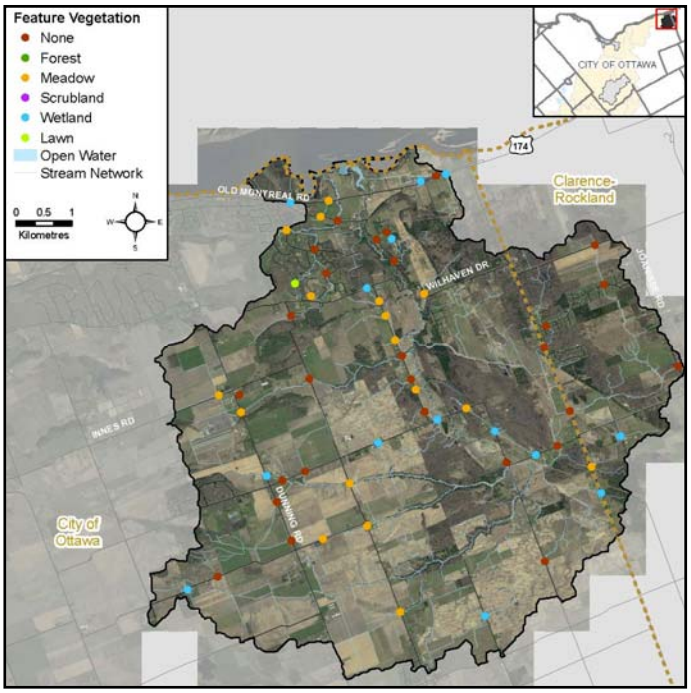


Figure 37 Headwater feature vegetation in the Beckets Creek catchment

Instream meadow vegetation in HDF along Kinsella Drive

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 Becketts Creek catchment. These riparian zones have anthropogenic influences from agricultural areas as well as road infrastructure.

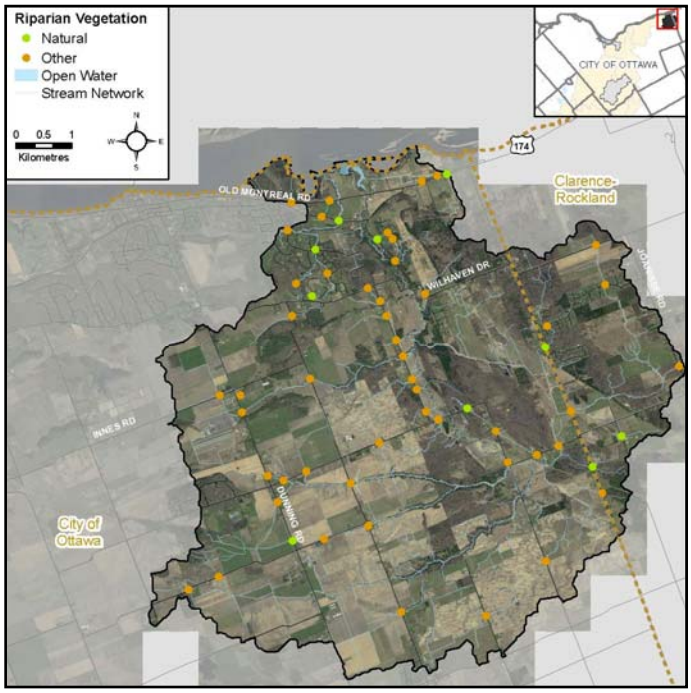


Figure 38 Riparian vegetation types along headwater features in the Becketts Creek catchment

HDF with natural forest riparian vegetation along Becketts Creek 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 extensive. Seven features had evidence of extensive deposition and six had substantial levels. Nine features had moderate amounts of deposits, 23 had minimal levels and 13 had no evidence of sediment deposition. Figure 39 shows the levels of sediment deposition in the catchment.

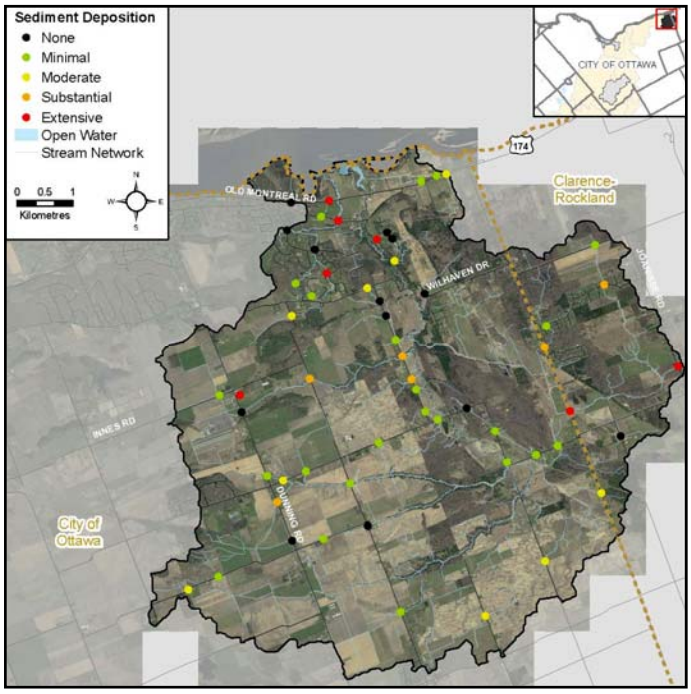


Figure 39 Headwater feature sediment deposition in the Becketts Creek catchment

Extensive sediment deposition observed on Joannise 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 Becketts Creek catchment, 29 of the sites had minimal roughness, 15 had moderate, 11 had high, and four had extreme coverage. Figure 40 shows the various feature roughness across the area.

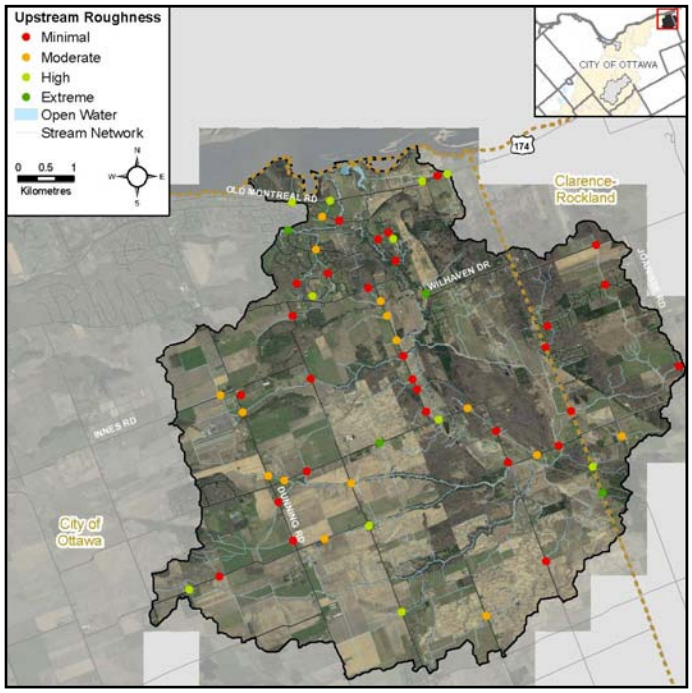


Figure 40 Headwater feature roughness in the Becketts Creek catchment

High feature roughness in springtime provided by cattails within feature on French Hill Road

Stream Comparison Between 2006, 2011 and 2017

The following tables provide a comparison of observations on Becketts Creek between the 2006, 2011 and 2017 survey years (RVCA 2006, RVCA 2011). Monitoring protocols from 2006 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 2006, 2011 and 2017. Average summer water temperatures range from cooler water in 2017 (17.7°C) to warmer values in 2011 (19.1°C), with 1.4 degrees centigrade of variation. In 2017 cooler temperatures than the two previous reporting years are possibly due to cooler air temperatures and higher precipitation experienced in 2017. 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 0.05°C for every degree of air temperature from 2011 to 2017.

Average dissolved oxygen levels were found to be increasing by 0.44 milligrams per liter from 2011 to 2017. These changes can also be attributed to weather patterns and cooler temperatures which are conducive to the stream's ability to hold more oxygen.

Average specific conductivity increased from 2011 to 2017 by 39.2 µS/cm and pH decreased by 0.07 units from 2011 to 2017. These slight changes may be indicative of increased anthropogenic input, specifically ionic compounds including road salts and fertilizers.

Table 3 Water chemistry comparison (2006/2011/2017)

Water Chemistry (2006—2017)				
YEAR	**PARAMETER**	**UNIT**	**AVERAGE**	**STND ERROR**
2011	pH	-	8.10	± 0.02
2017	pH	-	8.03	± 0.04
2011	Sp. Conductivity	us/cm	627.1	± 15.2
2017	Sp. Conductivity	us/cm	666.3	± 10.7
2011	Dissolved Oxygen	mg/L	7.92	± 0.16
2017	Dissolved Oxygen	mg/L	8.37	± 0.16
2006	Water Temperature	ºC	18.9	± 0.2
2011	Water Temperature	ºC	19.1	± 0.4
2017	Water Temperature	ºC	17.7	± 0.3
2011	Standardized Stream Temperature[1]	ºC Water / 1ºC Air	0.84	± 0.01
2017	Standardized Stream Temperature[1]	ºC Water / 1ºC Air	0.79	± 0.02

[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 3 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

Invasive Species

The overall percentage of sections surveyed where invasive species were observed had a significant reduction of 23 percent (Table 4). Purple loosestrife had a drastic reduction of observations by 72 percent, this decline may be associated to management efforts for this species (OMNR 2012). Decreases in observations of Manitoba maple may be due to increased beaver activity observed. Other invasive species have expanded their range, most notably poison parsnip. There are also other species that were not previously reported in the system that are now present including banded mystery snail, invasive buckthorn, invasive honey suckle, Japanese knotweed and periwinkle.

Table 4 Invasive species presence observed in 2011 and 2017 (NPR are Not Previously Reported species)

Invasive Species	2011	2017	+/-
banded mystery snail	NPR	1%	▲
common & glossy buckthorn	NPR	9%	▲
flowering rush	8%	4%	▼
garlic mustard	0%	7%	▲
honey suckle	NPR	9%	▲
Japanese knotweed	NPR	1%	▲
Manitoba maple	70%	40%	▼
periwinkle	NPR	1%	▲
poison/wild parsnip	24%	51%	▲
purple loosestrife	81%	9%	▼
Total	**94%**	**71%**	▼

Pollution

Garbage accumulation on Becketts Creek was found to increase from 2006 to 2011 and then decreased significantly in 2017. Frequent precipitation events in 2017 may have flushed garbage downstream. In 2017 the polluted sections contained mostly garbage, such as tires, lodged in the stream bottom. During the headwater drainage feature assessments, dumping and garbage associated with the roadside was observed (see p. 9) and one case was reported to the Ministry of Environment.

Table 5 Pollution levels (presence in % of sections)

Pollution/Garbage	2006	2011	2017	+/-
floating garbage	14%	27%	8%	▼
garbage on stream bottom	19%	17%	7%	▼
unusual Coloration	0%	0%	1%	▲
other	1%	37%	1%	▼
Total presence in % of sections	**24%**	**39%**	**16%**	▼

Instream Aquatic Vegetation

Table 6 shows instream aquatic vegetation changes from 2011-2017. Broad leaved emergent plants (e.g. arrowhead), robust emergent plants (e.g. cattails) and submerged plants (e.g. pondweed) had increased presence in the number of sections surveyed. Other types of aquatic vegetation had decreased incidence, possibly associated to heavy rainfall which can make it difficult for certain plants to establish.

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

Instream Vegetation	2011	2017	+/-
narrow-leaved emergent plants	86%	64%	▼
broad-leaved emergent plants	36%	53%	▲
robust emergent plants	33%	39%	▲
free-floating plants	34%	1%	▼
floating plants	9%	6%	▼
submerged plants	37%	43%	▲
algae and mosses	100%	32%	▼

Fish Community

Fish sampling was carried out in 2007, 2011 and 2017 to evaluate fish community composition in Becketts Creek (see Table 7). In total 31 species have been observed by City Stream Watch. In 2006 19 species were captured at two sites; 26 species were found at 11 sites in 2011; and in 19 species were observed in eight sites in 2017. Deep water levels due to significant precipitation events in 2017 limited the type and effort of sampling. The majority of species observed in 2017 had been captured in previous years, with the spottail shiner as a new record. It is also important to note one invasive species, the common carp (Scott and Crossman 1998).

Table 7 Comparison of fish species caught between 2007-2017

Species	2007	2011	2017
black crappie *Pomoxis nigromaculatus*		X	X
blacknose dace *Rhinichthys atratulus*	X		
bluegill *Lepmois macrochirus*		X	X
bluntnose minnow *Pimephales notatus*	X	X	X
brook stickleback *Culaea inconstans*	X	X	X
brown bullhead *Ameiurus nebulosus*	X	X	X
central mudminnow *Umbra limi*	X	X	X
cyprinid *spp.*	X	X	X
common carp *Cyprinus carpio*		X	
common shiner *Luxilus cornutus*	X	X	X
creek chub *Semotilus atromaculatus*	X		X
Etherostoma spp.	X	X	X
fathead minnow *Pimephales promelas*	X	X	X
golden shiner *Notemigonus crysoleucas*		X	X
largemouth bass *Micropterus salmoides*	X		
logperch *Percina caprodes*	X	X	
longnose dace *Rhinichthys cataractae*	X	X	
northern pearl dace *Margariscus nachtriebi*		X	X
northern pike *Esox Lucius*		X	X
northern redbelly dace *Chrosomus eos*	X		
pumpkinseed *Lepomis gibbosus*	X	X	X
rock bass *Ambloplites rupestris*	X	X	
Rhinichthys spp.		X	
shorthead redhorse *Moxostoma macrolepidotum*		X	
silver redhorse *Moxostoma anisurum*		X	X
spottail shiner *Notropis hudsonius*			X
tadpole madtom *Noturus gyrinus*		X	
walleye *Sander vitreus*		X	X
white sucker *Catostomus commersonii*	X	X	X
yellow bullhead *Ameiurus natalis*		X	
yellow perch *Perca flavescens*	X	X	
Total Species 31	**18**	**26**	**19**

Assessing bulk weights of fish captured by electrofishing in Becketts Creek

Beaver Activity and Dams

The total number of beaver dams observed in 2017, compared to 2011 increased by two, lodges decreased by two (Table 8). More notably, the total beaver activity in the area has increased in 26 percent of sections.

Table 8 Number of beaver dams observed (2011/2017)

Metric	2011	2017	+/-
Number of lodges	6	4	▼
Percent of sections with beaver cropping	8 %	34 %	▲
Total number of dams	**12**	**14**	▲

Bank Erosion

Bank stability has decreased since 2011, Table 9 shows the average proportion of sections surveyed which had bank erosion observed. Bank erosion is observed in more areas. This increase in process may be in part due to high precipitation and increased erosive forces experienced in 2017.

Table 9 Left and right bank erosion levels (2011/2017)

Level of Erosion	2011	2017	+/-
Left Bank	26%	30%	▲
Right Bank	25%	31%	▲

Monitoring and Restoration Projects on Becketts Creek

Table 8 highlights recent and past monitoring that has been done on Becketts 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 10 City Stream Watch monitoring efforts on Becketts Creek

Accomplishment	Year	Description
City Stream Watch Stream Monitoring	2006	11.6 km of stream was surveyed
	2011	15.8 km of stream was surveyed
	2017	13.0 km of stream was surveyed
City Stream Watch Fish Sampling	2007	two fish community sites were sampled
	2011	11 fish community sites were sampled
	2017	eight fish community sites were sampled
City Stream Watch Thermal Classification	2011	five temperature probes were deployed
	2017	five temperature probes were deployed
City Stream Watch Headwater Drainage Feature Assessment	2017	61 headwater drainage feature sites were sampled in the Becketts Creek catchment

Active beaver dam on Becketts Creek in 2011 (left) and 2017 (right)

Temperature probe installation in Becketts Creek near Old Montreal 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).

Invasive Species Control

Invasive species management is recommended especially in areas where new invasive species were observed in single instances, these include Japanese knotweed and Periwinkle.

Riparian Planting

Various sections of Becketts Creek riparian area can benefit from riparian planting. Many sections had unstable banks and signs of erosion, planting would counter these negative effects on the system. Runoff and anthropogenic impacts would also be mitigated.

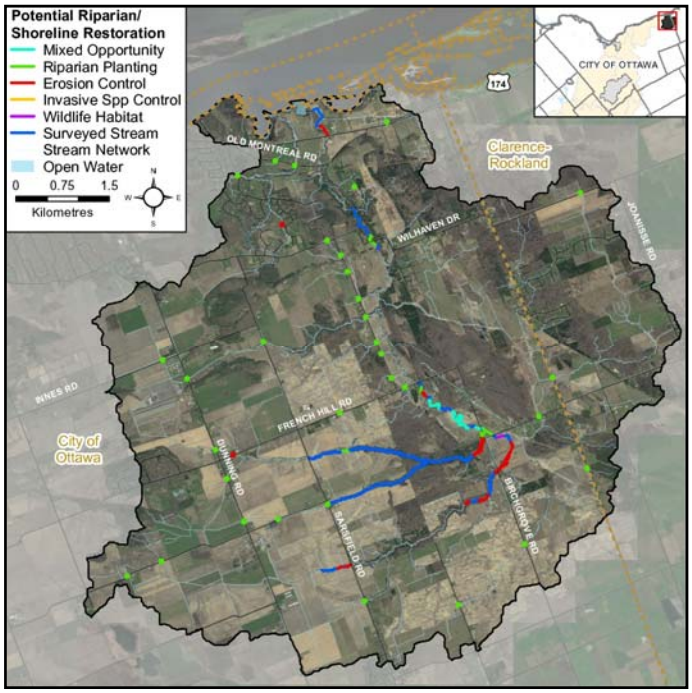


Figure 41 Potential riparian/shoreline restoration opportunities along Becketts Creek

Shoreline of Becketts Creek with potential for riparian planting and bioengineering

Potential Instream Restoration Opportunities

Fish Habitat Enhancement

Fish habitat restoration potential was assessed in a single area shown in Figure 42. Potential habitat enhancement work could include the installation of rock (cover and riffle creation) and instream woody structure.

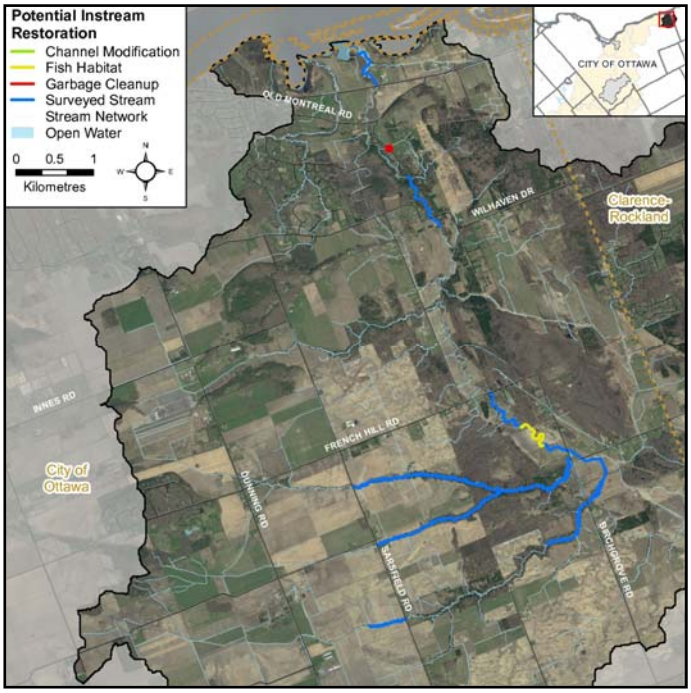


Figure 42 Potential instream restoration opportunities in Becketts Creek

Tile Outlet Control

Due to the high agricultural land use in the Becketts Creek catchment, many areas could benefit from tile outlet control. This involves placing structures at the head of tile drains to retain water and nutrients in the field during growing season. It has been demonstrated through research that water quality and crop yields increase with the use of these structures. On average fields of corn see a three percent yield increase and soy can have up to four percent (Agriculture & Agri-food Canada, 2011).

Headwater drainage feature that could benefit from tile outlet control in the Becketts Creek catchment



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. Rideau Valley Conservation Authority (RVCA), 2006. *City Stream Watch 2006 Annual Report.* Manotick, ON: Grant Nichol.
9. Rideau Valley Conservation Authority (RVCA), 2011. *Becketts Creek 2011 Summary Report.* Manotick, ON: Julia Sutton.
10. Rideau Valley Conservation Authority (RVCA), 2017. Around the Rideau May/June 2017. Manotick, ON. Available online: https://www.rvca.ca/media/k2/attachments/ATR_May-June_2017.pdf
11. Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications Ltd, Oakville pp.1-966.
12. Stanfield, L. (editor) 2017. Ontario Stream Assessment Protocol (OSAP). Version 10.0. Fish and Wildlife Branch, Ontario Ministry of Natural Resources, Peterborough, Ontario.
13. 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.
14. 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.

For more information on the overall 2017 City Stream Watch Program and the volunteer activities, please refer to the City Stream Watch 2017 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**: City of Ottawa, Ottawa Flyfishers Society, Ottawa Stewardship Council, Rideau Roundtable, Canadian Forces Fish and Game Club, and the National Capital Commission