Hanlon Creek Business Park Consolidated Monitoring Report 2016

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Aquatic, Terrestrial and Wetland Biologists

Hanlon Creek Business Park
2016 Consolidated Monitoring Report

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Executive Summary

Introduction

A consolidation of the monitoring on the Hanlon Creek Business Park (HCBP) Lands is required as a condition of approval of the *HCBP Environmental Implementation Report 2009* (EIR) prepared by Natural Resource Solutions Inc. Standard Operating Procedures for this monitoring can be found in a report titled *Hanlon Creek Business Park Consolidated Monitoring Program*, prepared by NRSI in 2010.

Pre-construction monitoring began in 2006 and continued for 4 years. Construction-phase monitoring began in 2010. Monitoring occurs either at specific times of the year, and certain components of groundwater and surface water occur year-round. Annual reporting occurs according to the calendar year. A Rapid Assessment and Action Protocol (RAAP) is in place to address immediate monitoring concerns, with a focus on surface water temperature and turbidity.

Construction commenced in late 2009 and has continued each year and through 2016. Construction activity in Phase 1, Stage 2 lands included the operation of one commercial buildings on Hanlon Creek Boulevard. In Stage 3 lands activities included the operation of commercial buildings at 197 – 345 Hanlon Creek Boulevard and 28 Bett Court. Construction in Phase 2 lands in 2016 included operation of one commercial building at 104 Cooper Drive and the building of one structure. The Laird Road overpass was completed in 2014 and has since been in use. Construction inspection in 2016 was conducted by Natural Resource Solutions Inc. (NRSI).

Performance monitoring in 2016 was conducted by Banks Groundwater Engineering Limited, AECOM and NRSI. Monitoring components included groundwater levels, temperature and water quality at 37 monitoring wells and 19 mini-piezometers; stream flow, temperature and water quality at 13 stream stations and within 3 stormwater management ponds; fish and benthic invertebrates at 5 stream stations; and vegetation, breeding birds and amphibians at 11 vegetation plots plus additional bird and amphibian stations.

Results

In 2016, groundwater levels are easily explained by the weather including the patterns of precipitation throughout the year. The highest groundwater levels observed in monitors equipped with data loggers occurred during late-March and early-April with a slight increase also occurring in August. These high levels correspond to thaw events in the winter and precipitation patterns the rest of the year. The lowest groundwater levels occurred in November and December. These periods of low levels were considered normal, as groundwater elevations at all monitoring stations remained within the normal range throughout 2016.

During the months of January, February and March, groundwater levels rose at Core PSW and Downey Road PSW monitoring stations in response to warmer temperatures and rainfall events. Groundwater levels then experienced a decline beginning in early-April, which continued through July, which resulted in the second-lowest late-summer/early-fall levels at some locations. At almost all locations where data loggers had been in place for more than four years, the 2016 summer levels were comparable to 2013 and 2014 summer levels, which were above the low levels observed during the drought in the summer of 2012.

Regarding site-wide patterns in groundwater elevations, the smallest fluctuations occurred in and adjacent to the core wetland and Hanlon Creek Tributary ‘A’. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas. Groundwater elevations varied more widely over the year at perimeter locations where groundwater recharge to the medium- to coarse-grained deposits is most significant.

Altogether, climate had the greatest, if not the only, influence on groundwater levels across the HCBP in 2016. There were no apparent changes in groundwater levels that could be attributed to construction activities during 2016 within the HCBP.

Surface water baseflows in Tributary A in 2016 were lower than those in 2015 and much lower than 2014 at all eight monitoring stations. Annual precipitation in 2016, recorded at both the Hanlon rain gauge and the Waterloo Weather Station, was lower than the climate normal for the years 1971 to 2000 at Guelph Arboretum.

The discharge from Pond 4 was observed to be near continuous again in 2016 causing elevated baseflow levels at HC-A(04), which is located a short distance downstream of Pond 4. The pond interacts with groundwater flowing in a northwesterly direction, and provides a more direct pathway for discharge to Tributary A. The continuous discharge has resulted in the observed elevated baseflows in Tributary A, and has also affected summer water temperatures in Tributary A. The bottom draw outlet ensures that the coolest water in the pond is being discharged, and the cooling trench also receives groundwater directly, further reducing discharge temperatures. Nevertheless, the resulting discharge temperature is greater than the stream temperatures in Tributary A in the summer.

During summer months of 2016, Tributary A stations HC-A(04) and HC-A(06), located downstream of the Pond 4 outlet, recorded high average temperatures and limited daily fluctuation due to the influence of the continuous discharge at Pond 4, as compared to HC-A(03) which is not impacted by pond discharge. Downstream stations on Tributary A which are more exposed such as HC-A(10), HC-A(12), HC-A(13) and HC-A(14), and those with a wider flow channel and shallower depths (HC-A(09)), show the highest daily variation in temperature as there is greater opportunity for solar radiation impact. Station HC-A(08) shows the lowest temperatures and daily temperature variation during the summer, indicating the presence of groundwater inputs in Tributary A1 where this station is located. Altogether, the temperatures in the summer of 2016 were determined to be above the preferred temperatures for Brook Trout.

Groundwater quality in 2016 was generally within the applicable Ontario Drinking Water Quality Standards (ODWQS) criteria for concentrations of the parameters analyzed, with some exceptions for nitrate, metals, sodium and hardness. Colour, turbidity, total dissolved solids and dissolved organic carbon (DOC) generally exceeded the respective ODWQS concentrations, and this is typical for these parameters in monitoring wells.

For surface water quality in 2016, the majority of the stream sites were within the ranges of the Provincial Water Quality Objectives (PWQO). The dissolved oxygen (DO) was below the PWQO minimum level at only one station; HC-A(04), compared to four in 2015, which may be attributable to a below-average flow rate due to high temperatures and an extended period of no precipitation. The pH levels were more acidic than the

PWQO guideline range at one of the stations and were more basic at two stations. Monitoring of turbidity at four stations occurred in 2016. It appears that none of the stations experienced a dramatic increase from their respective baseflow (background) turbidity levels. Sediment accumulation and biofouling resulted in inaccurate readings for extended periods at two stations; HC-A(11) and HC-A(14).

Benthic invertebrate monitoring in 2016 showed increases in Ephemeroptera, Plecoptera and Trichoptera (EPT) richness at two of five stations and generally showed average values when compared to previous years. Taxonomic richness increased at all five stations with a second consecutive year of increasing taxa richness at four stations. One station (BTH-002) resulted in a sequential “Impact” determination, a result that is a fairly regular occurrence at BTH-002. The continued occurrence of ‘impact’ at this station suggests a change in the quality of the benthic community. This may be attributable to natural changes in habitat conditions at the station.

Fish monitoring in 2016 resulted in the capture of a total of 448 individual fish representing nine different species. The total catch in 2016 represents a slight decrease in the total numbers of fish from 2015 but an increase in species captured. Population estimates remain relatively high for four of the five stations, with EMS-003 remaining relatively low, which is typical for this monitoring station. The fish species captured in 2016 are known previously from the monitoring program and generally exhibit a cool-water thermal regime. No Brook Trout were captured during electrofishing monitoring and no evidence of Brook Trout spawning was observed during spawning surveys.

Vegetation monitoring in 2016 showed largely stable vegetation conditions with only a few exceptions. A total of 127 vascular flora species were recorded in 2016 – slightly lower than what was observed in 2015. Four species were recorded for the first time in 2016; Cleavers (*Galium aparine*), Woodland Horsetail (*Equisetum sylvaticum*), Bearded Shorthusk (*Brachyelytrum erectum*), and Bristle-stalked Sedge (*Carex leptalea*). In 2016, Woodland Horsetail, Meadow Horsetail (*Equisetum pretense*), Rough Avens (*Geum laciniatum*) and Clearweed (*Pilea pumila*) were observed and are considered rare within Wellington County. None of the species observed are federally or provincially significant.

The coefficient of wetness continued to show that two plots (Plots 3 and 5) are upland sites while the remaining nine plots are in wetlands. Plot 1 continued to be the wettest plot, and Plot 3 continued to be the driest. In 2014, Plot 7 had exhibited a positive CW value (0.16) which is not indicative of White Cedar-Hardwood Swamp conditions. It is noted that the plot contains hummocks with upland plant species as well as a portion of watercourse. In 2016 this plot showed a much wetter CW value (-0.10), more typical of what has been observed at Plot 7. Plots 16 and Plot 18 had shown a steady drying trend between 2011 and 2015. In 2016, both plots showed a marked drop in average CW values (i.e. indicative of wetter conditions). This is considered to be a positive change which reverses the drying trend previously being observed.

The coefficient of conservatism (CC) values at five of the plots (Plots 3, 4, 5 and 18) had average results between 4 and 5, which are consistently the highest values from year to year and can be interpreted as having plant species that are associated with a specific plant community but can tolerate moderate disturbance. Plot 7 has consistently maintained the highest values for most years and showed a CC value over 5 in 2016. Plot 9 had a value between 2 and 3, while Plot 6 had a value between 1 and 2. These are the lowest values observed between the plots which indicate the presence of plant species that are more tolerant of disturbance.

The Natural Area Index (NAI) combines the CC with native species to provide a more stable assessment of the vegetation. In total 5 of 11 vegetation monitoring plots were equal to or showed slight increases in NAI over 2015 values; however overall values are still generally lower than in previous years at most stations. There are a variety of explanations, including the potential for the addition or subtraction of one species to have a substantial effect on the NAI value at a station with low diversity. It is also believed that the drought conditions in 2012 are likely to have a lingering effect on the NAI values for most of the stations.

The numbers of non-native species have remained relatively stable throughout monitoring from 2006 to 2015, with 20 recorded within vegetation plots in 2016. For total numbers of species by category of plants, observations were made of 89 herbaceous plant species and 22 shrub species. The number and composition of trees was unchanged. Following monitoring in 2014 the scope of tree inventory work was reduced to collect only canopy closure data. No tree species are present within Plots 1, 6 and 9. Signs of Emerald Ash Borer (*Agrilus planipennis*) were observed among Ash (*Fraxinus* spp.) trees within the larger natural feature, including those within monitoring Plot 1 and Plot 18.

A total of 58 bird species were observed during breeding bird monitoring in 2016, with 55 species documented during the formal point counts. Of the 55 species, 23 exhibited possible breeding evidence, 19 exhibited probable, six were confirmed, and four did not show breeding evidence. The most abundant species observed during 2016 surveys were American Goldfinch (*Spinus tristis*) and Red-winged Blackbird (*Agelaius phoeniceus*) followed by Song Sparrow (*Melospiza melodia*). These species are consistently the most abundant within the point counts.

In general, the diversity of bird species at each plot in 2016 was similar to those numbers documented between 2006 and 2011, with 2012 and 2013 appearing as exceptional years of high diversity across the study area. In 2016, Great Horned Owl (*Bubo virginianus*) was recorded within the subject property for the first time at Plot 19. In 2016, notable increases in bird diversity (over 2015 values) were observed at Plots 3, 5, and 11. The highest bird species diversity in 2016 was recorded at Plot 6 with 19 species while the lowest diversity was recorded at Plot 2 with 10 species. An increasing trend is observed at Plot 6 while decreasing trends are noted at Plots 2, 8, 19 and 20. At Plots 2 and 8 these appear to be a return to what was observed during pre-construction monitoring years.

NRSI observed four species that are considered Threatened federally and provincially: Bobolink (*Dolichonyx oryzivorus*), Eastern Meadowlark (*Sturnella magna*), Barn Swallow (*Hirundo rustica*) and Bank Swallow (*Riparia riparia*). Eastern Wood-pewee (*Contopus* virens), a species listed as Special Concern federally and provincially, was also documented in 2016. Bobolink has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2016. In 2016, Bobolink was observed at (or adjacent to) Plots 9, 11, and 20. Eastern Meadowlark was observed at (or adjacent to) Plots 1, 9, 11, and 20 and was observed showing possible breeding evidence at Plot 20. Barn Swallow was observed only as an incidental species during the 2016 breeding bird surveys. Individuals were observed adjacent to Plot 3 and 11 showing possible breeding evidence. Suitable nesting habitat for this species is present at the Crawley farmhouse within Phase 3 and birds may also now be utilizing business park structures to nest. Adjacent barns may also provide suitable nesting habitat. A single Bank Swallow was observed at Plot 6 in 2016. Topsoil piles associated with the development had been present in 2015, however this potentially suitable habitat was no longer present in 2016. The SWM ponds may present may provide suitable foraging habitat for this species. A single Eastern Wood-pewee was documented showing possible breeding evidence at Plots 2 and 3 in 2016. Incidental observations were also documented at Plots 6 and 20. The open understorey habitat present at Plot 3 provides ideal habitat for this species which may also utilize other treed and edge habitats throughout the study area.

Five amphibian species were recorded during evening call count surveys in 2016; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), American Toad (*Anaxyrus americanus*), Green Frog (*Rana clamitans melanota*) and Gray Treefrog (*Hyla versicolor*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The five amphibian species recorded calling in 2016 is above the annual average of 3.8 species recorded in previous years. Species recorded during surveys have fluctuated over the eight-year monitoring period, with as many as six species recorded during 2009 surveys and none recorded during the first preconstruction monitoring year (2006).

Issues

Water temperatures during summer months of 2016 continued to be elevated as a result of the effects of SWM Pond 4. While higher than average air temperatures and lower precipitation levels were noted in 2016 compared to 2015, which contributed to these elevated water temperatures, the influence of SWM Pond 4 continued to be evident in 2016. The evidence is focused on the stations on Tributary A that are the nearest to the SWM Pond 4 outlet. Water temperatures exceeded both 22°C and 24°C at the stations downstream of the SWM Pond 4 outlet while the station upstream of the outlet did not exceed 22°C or 24°C in 2016. Thermal effects are evident in the proportion of the summer that the temperature was above 19°C, and by the thermal regime classifications in 2016 compared to pre-construction data. These elevated water temperatures are of concern based on the goal of maintaining a suitable thermal regime for Brook Trout, a cold water fish species that inhabit the Hanlon Creek system.

Two potential modes of impact by SWM Pond 4 were previously discussed in the 2013, 2014 and 2015 consolidated monitoring reports. The first mode is the water that is discharging to Tributary A through the SWM Pond 4 outlet; the second is the pond's effects on adjacent groundwater that may eventually discharge to Tributary A as groundwater.

One benthic monitoring station experienced a threshold exceedance in 2016. Station BTH-005 produced an exceedance of the third benthic invertebrate threshold.

Station BTH-002 had an 'Impact' determination for the fifth consecutive year, which resulted in another exceedance of the first threshold in 2015. Station BTH-005 exhibited a 63% decline in the number of EPT taxa as compared to the averaged results from 2014 and 2015. This exceedance results from the averaging of a very low proportion of EPT observed in 2014 (1.4%) and an uncharacteristically high proportion of EPT in 2015 (35.3%), which raised the averaged result for 2014 and 2015. The EPT richness in 2016, which was 6.7%, appears to be more 'typical' for this station when compared to the results between 2009 and 2013.

None of the fish monitoring thresholds were exceeded in 2016.

Multiple vegetation plots had threshold exceedances in 2016. Herbaceous cover exceeded the lower reach of this threshold in Plot 3 in 2016. While increases in herbaceous species in Plot 2 reflect a positive change in recent years the cover in 2016 is still well below the pre-construction average. Herbaceous cover in this plot is primarily influenced by the presence of Ostrich Fern which, which experienced a reduction during extremely dry monitoring years in 2011 and 2012. It is anticipated that if the site continues to receive higher levels of precipitation during the spring months, herbaceous cover at Plot 3 will continue to increase.

Herbaceous species diversity negatively exceeded the pre-construction threshold at Plot 7. Plot 7 has consistently exhibited some of the highest species diversity at any of the plots, however many species observed at Plot 7 in previous years consisted of one or several individual plants. As the plot is relatively intact and there is a high likelihood that those species present in low numbers in past years remain present in the larger ELC community surrounding the plot the decrease in 2016 is not considered reason for concern.

Although Coefficient of Wetness (CW) is not used as a specific threshold for the vegetation monitoring, it is noteworthy that, prior to 2016, the CW values at Plots 16 and 18 were showing a drying trend between 2011 and 2015. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. It appears that fluctuations in groundwater levels would have little to no effect on the soil wetness in the wetlands because their elevations have never been above the ground surface of the wetlands. Groundwater levels in the vicinity of Plots 16 and 18 do not show a trend that matches the declining trend in CW values. Monitoring results show a marked increase in CW values at both Plot 16 and Plot 18 in 2016 suggesting a return to the conditions observed in 2011 and 2012.

An associated threshold exceedance is the decline in amphibian abundance at seven stations in 2016. A decrease of two calling codes was observed for American Toad at four plots, Gray Treefrog at four plots, and Spring Peeper at two plots. American Toad has been limited in numbers and distribution throughout the study area and the reduction in 2016 can be attributed to natural variation following a year of greater abundance in 2015. In spite of the reduction in Gray Treefrog and Spring Peeper at several plots it should be noted that both species remain widespread and abundant within the subject property. Several increases were also noted at a number of plots where conditions within the plots were more suitable for early-season breeding anurans. Further, the use of SWM ponds by Spring Peepers, as well as American Toads, has increased notably since their creation. The continued establishment of riparian and aquatic vegetation within SWM ponds will likely continue to provide suitable foraging and breeding habitat for some anuran species.

Thresholds were reached for breeding bird abundance in 2016. Plots 4, 6, 7, 8 and 9 were all below the threshold for breeding bird abundances. None of these are of immediate concern. Breeding bird abundance was generally on average with the during-construction data set despite the threshold exceedances which were documented.

Corrective Measures Undertaken

No corrective measures were undertaken in 2016. The RAAP group met on several occasions regarding temperature exceedances, including an additional visit by AECOM to confirm site conditions following exceedances at Stations HC-A(03) and HC-A(11).

The temperature effects continued at SWM Pond 4, and the corrective measures undertaken in 2012 were again monitored for effectiveness in 2016. The corrective measures undertaken in 2012 included:

1) raising the outlet of the cooling trench at Pond 4 (removed in early 2013),
2) raising the weir level at the pond outlet at Pond 4, and
3) planting of aquatic vegetation throughout the shallow areas of the pond as well as planting vines and herbaceous species in and around the cooling trench at Pond 4.

As these measures have proven to be insufficient to correct the temperature effects of SWM Pond 4, the RAAP team discussed additional mitigation strategies to be considered for implementation that focus primarily on the management of groundwater in the vicinity of SWM Pond 4. By the end of 2016 these mitigation measures were still under consideration and review and it is expected that decisions regarding this will be made in 2017.

While other issues have been identified through review of the monitoring results, there were no other clear cause-and-effect relationships that constituted problems to be rectified through corrective measures.

Recommendations

Based on the 2016 monitoring results, it is recommended that additional corrective measures be developed to address the effects of SWM Pond 4 on water temperatures in Tributary A. The need for additional monitoring requirements should be considered in conjunction with the development and implementation of the corrective measures.

It is also recommended that existing monitoring continue with diligent attention given to stream temperatures and the SWM Pond 4 mitigation measures put in place to date, using the RAAP as prompted by any stream temperature or turbidity exceedances.

The long-term groundwater monitoring program at the HCBP site should continue in 2017 on a quarterly basis as previously recommended. The surface water monitoring program during and post construction should also continue in 2017 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010) to ensure temperature targets are met and water temperatures are suitable for Brook Trout.

Surface water should continue to be monitored at Plots 16 and 18 and adjacent roads, swales and development blocks in order to determine whether surface hydrology has been altered in a manner that is affecting Plots 16 and 18.

It was determined following the 2016 monitoring season that the frequency of fish and benthic invertebrate monitoring should be adjusted. The biological components are end points that are functions of the physical surface water and groundwater conditions, and they tend to be slower to respond. It is therefore common practice to undertake biological monitoring every two or three years, while physical parameters are measured more frequently. Therefore, beginning in 2017, fish and benthic monitoring will be completed every second year at the existing five benthic and five fish monitoring stations

Terrestrial monitoring, including vegetation, breeding bird, and amphibian monitoring is also recommended to be adjusted to every 2 years, with 2018 being the next year of monitoring. Monitoring of the aquatic and riparian vegetation within the SWM Pond 4 and herbaceous plants along the cooling trench should also continue in order to monitor the survival and establishment of the vegetation planted in the fall of 2012.

Conclusions

Monitoring at the Hanlon Creek Business Park in 2016 was successful in providing useful information to describe environmental conditions on site, detect issues and develop solutions.

Elevated stream temperatures and the contributing temperature impacts from SWM Pond 4 continued to be the most prominent issue in 2016. As such, monitoring in 2017 and 2018 should give particular attention to this issue through the continued monitoring of nearby wells and the effectiveness of the planted vines and aquatic vegetation. The RAAP group should carefully review any stream temperature threshold exceedances. Additional corrective measures should also be developed to mitigate the effects on stream temperatures, including additional monitoring as required to inform such measures.

1.0 Introduction

Pre-construction monitoring for the Hanlon Creek Business Park (HCBP) began in 2006 and occurred annually for four consecutive years to establish baseline conditions. Some additional groundwater monitoring began in 1999. Limited construction activity occurred in 2009 associated with service installation under the Hanlon Expressway and borrow-pit operations. In 2010, more substantial grading and servicing construction activities began, marking the beginning of the construction-phase monitoring period that has continued annually from 2010 to 2016. The monitoring includes groundwater, surface water, aquatic biology, terrestrial biology, and construction inspection, all of which are summarized and discussed in this consolidated monitoring report.

The monitoring program associated with the HCBP is an integration of a series of monitoring requirements arising from recommendations made in the Consolidated Environmental Impact Study (NRSI 2004), the Draft Plan Conditions (OMB 2006), and review comments from agencies during the various stages of the planning process. A consolidation of the monitoring on the HCBP Lands was required as a condition of approval of the *HCBP Environmental Implementation Report 2009* (EIR) prepared by Natural Resource Solutions Inc. (NRSI 2009). The City of Guelph Environmental Advisory Committee (EAC) recommended approval of the EIR, with a list of conditions that should be met prior to registration of the plans for Phases 1 and 2. Condition 8 states:

> *That a comprehensive and consolidated monitoring program, which specifies frequency, location, protocols, timing, thresholds, and specific contingency measures be submitted and approved by the City of Guelph and the GRCA [Grand River Conservation Authority].*

To meet the above condition, a document titled *Hanlon Creek Business Park Consolidated Monitoring Program* (NRSI 2010) was created as a reference document containing the standards that are to be followed in carrying out the Consolidated Monitoring Program. Refer to that document for detailed information on the framework of the monitoring program and the Standard Operating Procedures for each monitoring component. The Standard Operating Procedures provide detailed methodologies such that the performance monitoring can be carried out consistently over the years of monitoring.

This report integrates the information from all monitoring components for the 2016 calendar year. Monitoring in 2016 occurred at specific times of the year according to seasonal requirements, with the exception of continuous groundwater and surface water monitoring that occurs year round. Separate reporting for each discipline occurs following the end of the calendar year, and this consolidated report is prepared based on those reports. A Rapid Assessment and Action Protocol (RAAP) is in place to address immediate monitoring concerns, with a focus on surface water temperature and turbidity, and this consolidated report also summarizes the RAAP activity.

Individual reports from each discipline are appended, and the results are summarized in Section 2.0. Natural Resource Solutions Inc. (NRSI) has prepared this consolidated report each year since 2009 with support from Banks Groundwater Engineering Limited (hydrogeology), and AECOM (surface water).

1.1 Study Area

The Hanlon Creek Business Park comprises the lands between Downey Road and the Hanlon Expressway, and between Forestell Road and the south end of the Kortright subdivision along Teal Drive (Map 1). Prior to development, lands within Phases 1 and 2 were a mix of agricultural fields, meadow, woodland, forest and Provincially Significant Wetlands (PSW) consisting of swamp, marsh and thicket, while Phase 3 was primarily agricultural field and cultural meadow, with small wetlands. The core area of natural features was designated as natural heritage lands to be retained in their pre-development state. The agricultural fields and associated hedgerows, and small isolated habitats were designated for roads and development blocks.

The creek, wetlands and forested uplands in the HCBP are part of the much larger Hanlon Creek watershed. The central wetlands in the HCBP are part of the Hanlon Swamp Wetland Complex and therefore are considered provincially significant. In addition, a small wetland in the southwestern portion of the HCBP, next to Downey Road, is part of the provincially significant Speed River Wetland Complex.

This area encompasses a headwater tributary of Hanlon Creek. The tributary within the HCBP was designated as Tributary A in the Hanlon Creek Watershed Study (Marshall Macklin Monaghan Limited 1993). All of Hanlon Creek is designated as a cold-water stream to be managed for Brook Trout (*Salvelinus fontinalis*) (GRCA and MNR 1998).

1.1.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2016. Construction activity in 2016 within Phases 1 and 2 is outlined below and highlighted on Map 2. No construction activity occurred within Phase 3 in 2016.

Phase 1, Stage 2

- Operation of commercial building – 500 Hanlon Creek Boulevard (Fusion Homes)
- Operation of commercial building – 501 Hanlon Creek Boulevard (Compass)

Phase 1, Stage 3

- Operation of commercial buildings – 197-345 Hanlon Creek Boulevard (Wurth Canada, Graniteworx, etc.)
- Operation of commercial building – 28 Bett Court (MF Property Management Inc.)

Phase 2

- Operation of commercial building – 104 Cooper Drive (Ontario One Call)
- Preliminary grading of Blocks 8, 9 and 26 was completed in 2014 with a structure being built in fall 2016
- Laird Road overpass has been in-use since 2014

1.2 Monitoring Requirements and Components

The City of Guelph, as the developer representative, is responsible for the monitoring. The duration of the responsibility to monitor has been defined for each of Phases 1 and 2 as the time when 75% of the area of the individual phase is built, plus an additional two years. It is anticipated that this timeframe will also apply to Phase 3.

A total of seven discrete monitoring requirements were identified during the planning process for the HCBP. The requirements are each rooted in one or more of the various stages of the process, including the Consolidated EIS (NRSI 2004), the Draft Plan Conditions (OMB 2006), the Environmental Implementation Report, and review comments from agencies pertaining to the design, mitigation and restoration of features in the Business Park.

The seven discrete monitoring requirements are as follows:

1. **Performance of Stormwater Management Systems:** Monitoring of hydrogeology, creek flows and temperatures, aquatic biota and wetlands, arising from the Draft Plan Condition #12 to provide baseline information on interactions and as input to the design of stormwater management facilities that discharge to Tributary A, as well as post construction monitoring of performance of the ponds (especially thermal impacts).
2. **Groundwater and Wetlands for the HCBP:** Monitoring arising from the Draft Plan Condition #12 of hydrogeology and wetlands at strategic locations to provide baseline information on spatial distribution and interactions of groundwater/wetlands such that block-level infiltration targets can be assessed.
3. **Groundwater and Wetlands for the Mast-Snyder Gravel Pit:** Monitoring of hydrogeology and wetlands in the western portion of lands south of Laird Road (Speed River PSW) to monitor changes in groundwater and wetlands stemming from concerns over potential impacts of the proposed neighbouring Mast-Snyder Gravel Pit.
4. **Permit Conditions and EIR Recommendations:** Monitoring arising as conditions from permit applications/review as well as impact predictions specifically arising from recommendations out of the EIR process.
5. **Success and Naturalization of Restoration Areas:** Monitoring of success and naturalization processes of restoration areas within buffers, swales and stormwater management areas, arising from agency comments and restoration planting warranty.
6. **Wildlife Movement:** Monitoring of wildlife movement throughout the Business Park, with a focus on movement and mortality associated with Laird Road and Hanlon Creek Boulevard (Road ‘A’).
7. **Construction Monitoring:** Monitoring arising from the Draft Plan Condition #10, which states that an environmental inspector is to carry out the construction monitoring during grading, servicing, and building construction.

There are eight performance monitoring components and two construction monitoring components that occur on the HCBP property, and they are each being conducted to serve one or more of the requirements listed above.

1.2.1 Performance Monitoring

The performance monitoring components are indicated as follows, with the past years of monitoring indicated in parentheses.

- Groundwater (most years from 1999 to 2016; quarterly from 2006 to 2016)
- Stream Temperature and Flow (annually from 2006 to 2016)
- Fish (annually from 2006 to 2016)
- Benthic Invertebrates (annually from 2006 to 2016)
- Vegetation and Soils (annually from 2006 to 2016)
- Breeding Birds (annually from 2006 to 2016)
- Amphibians (annually from 2006 to 2016)
- Salamanders (2009 and 2010 only)

1.2.2 Construction Monitoring

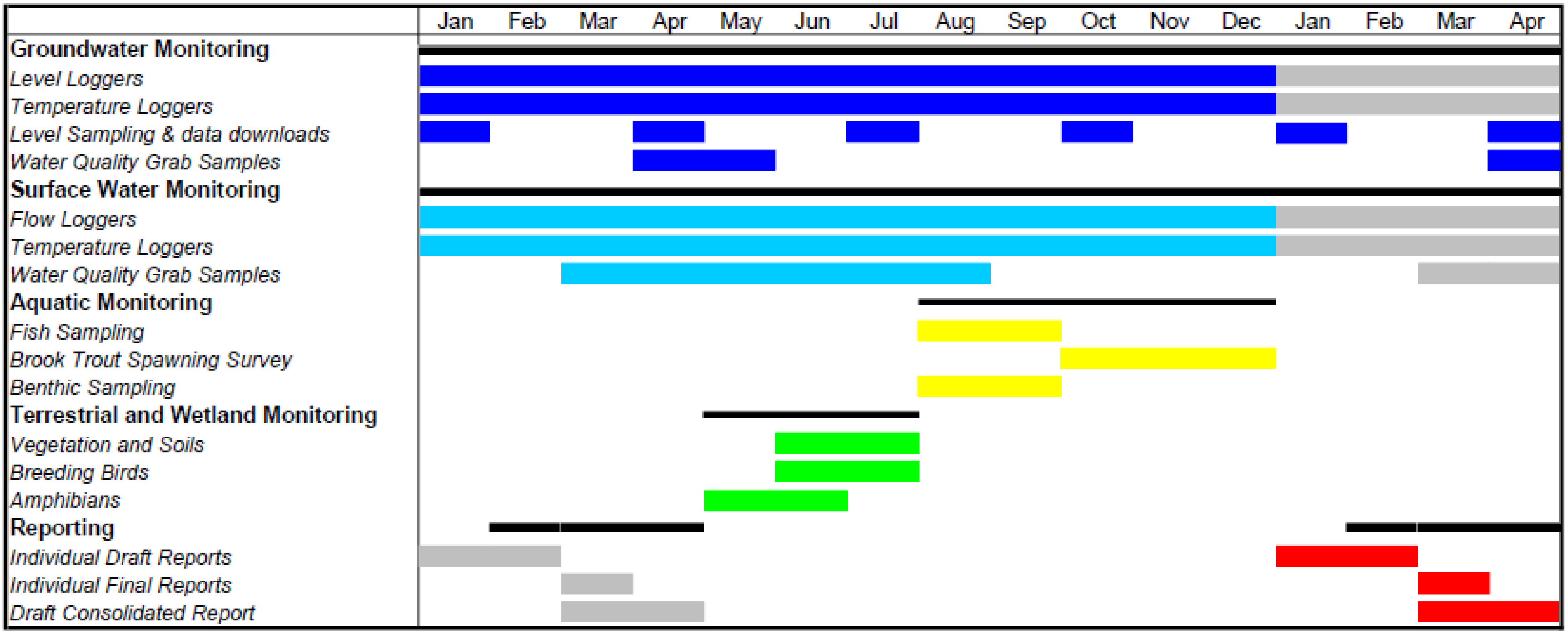
Construction monitoring is tied to the specific undertaking. Generally, construction monitoring must occur to ensure compliance with the conditions of various permits, including permit(s) from the Grand River Conservation Authority (GRCA) under Ontario Regulation 150/06 and the Letter of Advice from GRCA that constitutes approval under Section 35 of the *Fisheries Act*. Construction monitoring also serves as a means to avoid contravention of other regulations, such as Section 36 of the federal *Fisheries Act* pertaining to deleterious substances. In the specific case of the HCBP, the need for construction monitoring also stems from Condition 10 from the Ontario Municipal Board (OMB) hearing for the HCBP Draft Plan (June 2006). The condition states that an environmental inspector is to carry out the construction monitoring during grading, servicing, and building construction.

Construction inspection reports from 2016 are found in Appendix I.

1.3 Annual Schedule of Activities

Table 1 provides the general annual timeline of performance monitoring activities, which approximates the schedule of the 2016 monitoring. The specific dates of monitoring activities in 2016 are provided in the appended individual reports. Each colour represents an individual monitoring component (Groundwater Monitoring – dark blue, Surface Water Monitoring – light blue, Aquatic Monitoring – yellow, Terrestrial and Wetland Monitoring – green). The timeline for Reporting is represented by red.

Table 1. General Annual Schedule of Performance Monitoring Activities



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Groundwater Monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Level Loggers	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	▨	▨	▨
Temperature Loggers	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	▨	▨	▨
Level Sampling & data downloads	🟦			🟦			🟦			🟦			🟦			🟦
Water Quality Grab Samples				🟦	🟦											🟦
Surface Water Monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Flow Loggers	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	▨	▨	▨
Temperature Loggers	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	▨	▨	▨	▨
Water Quality Grab Samples			🟦	🟦	🟦	🟦	🟦	🟦							▨	▨
Aquatic Monitoring								■	■	■	■	■				
Fish Sampling								🟨	🟨							
Brook Trout Spawning Survey										🟨	🟨	🟨				
Benthic Sampling								🟨	🟨							
Terrestrial and Wetland Monitoring					■	■	■									
Vegetation and Soils						🟩	🟩									
Breeding Birds						🟩	🟩									
Amphibians					🟩	🟩										
Reporting		■	■	■										■	■	■
Individual Draft Reports	▨	▨											🟥	🟥		
Individual Final Reports			▨												🟥	
Draft Consolidated Report			▨	▨											🟥	🟥

2.0 Monitoring Results

2.1 Climate Data

Climate data provided by the Waterloo International Airport Station (WMO ID 71368) was utilized for groundwater monitoring due to its proximity to the HCBP site and availability of total daily precipitation and maximum daily air temperature data. For assessment of surface water monitoring data, climate information was used from the Guelph Turfgrass Institute.

In 2015, at the request of the City of Guelph, a tipping bucket rain gauge (model TB3) was installed by AECOM on the roof of the Clair Road Emergency Services Centre near the Hanlon Creek Business Park. This rain gauge was in place for all of 2016 and data was used in the interpretation of results for 2016. The precipitation is important for reporting and interpreting both the groundwater and surface water monitoring results. This includes trends preceding the monitoring year, and patterns during the monitoring year.

From 2003 to 2016, there has generally been lower-than-normal precipitation resulting in a cumulative negative departure from monthly normals. Fluctuations have occurred during this time, including an increase from July 2013 to January 2015, but the overall trend is a negative departure from normal. This does not necessarily translate into analogous reductions in groundwater or streamflow. Instead, groundwater levels are strongly correlated with precipitation during the previous 18 months. During the same period, cumulative departure from the average of the preceding 18 months illustrates periods of decrease and increase in precipitation. The year 2007 stands out as a year of substantial decrease in precipitation, followed by an increase in precipitation from mid-2008 to early 2010. Smaller fluctuations have occurred since that time followed by a significant rise from July 2013 to January 2015. This 18-month increase represents the second highest level since monitoring began in 2003. Through the rest of 2015 and 2016 the trend has been downward due to a less-than-normal amount of precipitation

Precipitation recorded using the Hanlon rain gauge in 2016 was 910.2 mm, which is slightly below the Canadian Climate Normal (1971-2000) of 923.3 mm at the Guelph

Arboretum. The precipitation measured with the Hanlon rain gauge was lower than what was observed at the Elora Research Station (927.7 mm) but much higher than what was observed at the Waterloo Weather Station (814.2 mm). Prior to the installation of the Hanlon rain gauge precipitation levels were recorded at the Elora Research Station, beginning in 2008.

Substantial variation in monthly precipitation occurred during 2016, beginning with precipitation levels well below normal for January and February and then well above normal for March. In April the precipitation once again fell below monthly normal and remained below normal through May, June, and July. August exhibited precipitation levels above normal followed by below-normal levels once again through September, October and November. In December the precipitation was noted to be only slightly above the observed normals. Overall, in 2016 the cumulative precipitation levels were below cumulative monthly normals for the site.

The air temperatures from May to September were noted to be typical during the spring and warm during the summer months. The average air temperatures in May and June were identical to the Canadian Climate Normals from 1971 to 2000 at the Guelph Arboretum at 12.3 and 16.9°C, respectively. In July, August and September the daily average air temperatures were noted to be above the climate normals by roughly 1 degree in July and 2 degrees in both August and September. The average temperatures in August and September were also among the highest average air temperatures documented for those months during the monitoring period since 2007. In August the daily average temperature of 20.8°C was the highest that has been observed at the site for the month with the second highest occurring in 2010 at 19.8°C. The daily average temperature of 16.2°C in September is the second highest that has been observed for this month, with the highest of 17.0°C occurring in 2015.

2.2 Groundwater Levels and Flow

During the 2016 monitoring period there were 37 functioning monitoring wells and 19 mini-piezometers located across the HCBP site. Two of the mini-piezometers (13D and 14D) were installed along Hanlon Creek Tributary A immediately downstream of stormwater management (SWM) Pond 4 in June 2013. These were required to provide additional monitoring data related to the effects of SWM Pond 4 on Tributary A, and they have remained in place through 2016. To evaluate the response to spring thaw and precipitation at selected groundwater monitors, data loggers were installed to record groundwater levels on a more frequent basis, with installation at some stations beginning in 2007. In the year 2016, groundwater elevations were recorded using data loggers in 38 of the 56 groundwater monitoring stations. Table 2 in the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II) lists the monitoring wells and mini-piezometers where the 38 data loggers were in operation for all or part of 2016. In addition, groundwater quality samples were collected from a total of 36 monitoring wells that were available for sampling in 2016. These were the same wells that were sampled in 2015. The locations of the groundwater monitoring stations are shown on Map 3 (of the consolidated report) including new, existing, proposed, and abandoned stations as of December 2013.

The resulting groundwater level monitoring data is tabulated and plotted on graphs in the appendices of the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II). Those results are summarized and discussed below.

Long-Term and Medium-Term Observations of Groundwater Levels

Groundwater levels are interpreted to have been elevated in the early to mid-1990s, followed by a decline from 1997 to 2007. These trends are based on climate data beginning in 1971. On-site groundwater monitoring began in 2003, and since that time precipitation has varied on an annual basis.

In 2007, the effects of below-average precipitation were expressed in groundwater levels in July and November, when total precipitation was well below average, and also the lowest observed from 1971 to 2016.

In late 2010 and early 2011, groundwater levels declined and approached the low levels observed in 2007. This is attributable to below-average annual precipitation in late 2009, through most of 2010, and into February 2011. Then in 2012, groundwater levels at many monitored locations on-site during the summer and fall were the lowest recorded since monitoring began in 2003.

The total precipitation in 2016 was 722 mm, which was the seventh lowest recorded amount from 1971 to 2016 while the total precipitation in 2015 was 667 mm, which was the third lowest recorded amount for the summer-fall time period. In spite of the low precipitation in 2015 and 2016, groundwater levels at many monitored locations on-site during the summer and fall of 2016 remained above the low levels recorded in the summer and fall of 2012.

The periods of low groundwater levels are contrasted by higher levels during the intervening periods. Annual precipitation in 2003, 2006, 2008, 2011, and 2013 was above average. This appears to have influenced groundwater levels in the spring of 2004 and 2007, the spring and fall of 2008, in the last five months of 2011, and from spring to fall in 2013.

General Observations in 2016

In 2016, groundwater levels are easily explained by the weather including the patterns of precipitation throughout the year. The highest groundwater levels observed in monitors equipped with data loggers occurred during late-March and early-April. The high levels during this time were in direct response to a combination of warm temperatures in January and February in addition to above-average precipitation throughout the month of March. A slight increase in groundwater levels was also noted in August due to above-normal precipitation, however in general the site observed a downward trend in levels between April and December.

The lowest groundwater levels occurred in November and December resulting from the lower-than-normal precipitation levels that occurred throughout most of 2016 that resulted in a downward trend that began in April. These periods of low groundwater levels were considered normal, as groundwater elevations at all monitoring stations remained within the normal range throughout 2016 as indicated by the respective graphs for each of the monitoring stations.

Site-Wide Patterns in 2016

The groundwater elevation data from the 38 groundwater monitoring stations throughout 2016 continued to exhibit the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Groundwater discharge conditions have also been confirmed at the Downey Road PSW.

The greatest range in groundwater elevations occurred around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. The smallest fluctuations occurred in and adjacent to the core wetland and Hanlon Creek Tributary ‘A’. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas.

Graphs illustrating hydraulic gradients and groundwater elevations are included in the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II).

2016 Monitoring of Groundwater Levels in the Core PSW

Groundwater levels in 2016 were monitored at 14 monitoring wells and 10 mini-piezometer stations within or near the Core PSW (Table 2, Map 3).

Table 2. Monitoring Wells and Mini-Piezometers Within or Near the Core PSW

Monitoring Wells		Mini-Piezometers	
MW103	MW119A	PZ-1	PZ-12
MW104	MW121A	PZ-2	PZ-13
MW105	MW122A	PZ-4	PZ-14
MW111	MW127	PZ-7	
MW116A	MW129	PZ-8	
MW117A	MW130A	PZ-10	
MW118A	MW131	PZ-11	

In 2016, the observed groundwater levels and temperatures in the monitoring wells and mini-piezometers responded to precipitation and maximum daily air temperatures. This confirms the inherent relationship of the wetlands to the shallow groundwater system. The hourly recording of groundwater levels at mini-piezometer locations also indicates subtle fluctuations during each 24-hour period, likely associated with diurnal cycles of evapotranspiration in the wetland. While responsiveness is apparent, the range of groundwater levels in mini-piezometers is more subdued than in those at other locations on the HCBP site. This reflects the relatively constant groundwater elevations in the wetland area, usually with only minor perturbations observed relative to precipitation and/or temperature changes.

During the months of January, February and March 2016, groundwater levels rose sharply in response to warmer temperatures and rainfall events. As noted previously, combined snow and rainfall through January, February and March was about 177 mm, just short of the 181 mm normal amount of precipitation for this period. Groundwater levels began a sharp decline in early-April, which is earlier than most years, and continued to decline through July. August rainfall caused levels to rise again briefly before declining through December. Groundwater levels rose again in response to precipitation events in late-December.

The graphs of each of the Core PSW groundwater monitors listed in Table 2 (see Appendix II for graphs) show that below-normal precipitation during 2016 caused groundwater levels to decline to the second-lowest late-summer/early-fall levels at some locations. The lowest levels observed in 2016 varied from location to location, but most occurred during July and August. At almost all locations where data loggers had been in place for more than four years, the 2016 summer levels were comparable to 2013 and 2014 summer levels, which were above the low levels observed during the drought in the summer of 2012. At many Core PSW monitoring stations, groundwater levels rose in response to precipitation in December.

Groundwater levels in the three mini-piezometer monitoring locations (i.e. from north to south PZ-4D, PZ-2D, and PZ-1D) that are located in the Core PSW, were below the normal range for most of 2012. During 2013 through 2016, groundwater levels were within the range of prior years. The recorded groundwater elevations for PZ-4D, PZ-2D, and PZ-1D are presented in Graphs G13, G20, and G22 within the appendices of the groundwater technical memorandum prepared by Banks Groundwater Engineering Limited (Appendix II).

Similarly, groundwater levels recorded in streambed mini-piezometers (i.e. from north to south PZ-10D, PZ-8D, PZ-11D, PZ-7D) were below the level of the creek and the streambed for part, if not most, of 2012. Groundwater levels during 2013 through 2016 were within the range observed in prior years, where data is available (Appendix II).

Altogether, climate had the greatest, if not only, influence on groundwater levels within the Core PSW in 2016. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to development or construction activities during 2016 within the HCBP (i.e. there were no abnormal changes in groundwater elevations that would have suggested otherwise). As of the end of 2016, 10 lots in Phase 1 had been developed and another two were at various stages of development. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during March, August and late-December, it is evident that infiltration was occurring across the site.

2016 Monitoring of Groundwater Levels in the Downey Road PSW

Groundwater levels in 2016 were monitored at two stations at the Downey Road PSW. These include monitoring well MW003, which is located on the north edge of the PSW, and mini-piezometer nest PZ-9, which is located in the centre of the PSW (Map 3).

During the months of January, February and March 2016, groundwater levels rose sharply in response to warmer temperatures and rainfall events. Combined snow and rainfall through January, February and March was about 177 mm, which is just short of the 181 mm normal amount of precipitation for this period. Groundwater levels began a sharp decline in early-April, which is earlier than most years, and continued to decline through July. August rainfall caused levels to rise again briefly, before declining through December. Groundwater levels rose in response to precipitation events in late-December.

The responses to precipitation events and spring thaw, or lack thereof, observed in this monitor during the period 2007 to 2016, have demonstrated the local sensitivity of the shallow groundwater system, which is associated with the coarse-grained nature of the overburden deposits within and above the uppermost aquifer. The below-normal precipitation during 2016 caused groundwater levels to decline to the third-lowest fall levels at this location since data logger monitoring began in 2007.

As noted above, two mini-piezometers were installed in the Downey Road PSW. PZ-9S was installed to a depth of about 0.5 m and PZ-9D to a depth of about 1.0 m below ground level. Groundwater levels for this pair of shallow and deeper mini-piezometers have illustrated the upward hydraulic gradient that exists in this PSW.

It is noted that responses to precipitation and temperature are apparent in PZ-9D, similar to MW003, confirming the infiltrative capacity of the medium- to coarse-grained deposits on this site and the inherent relationship of the wetlands to the shallow groundwater system. Each year, groundwater levels decline to an elevation that is below ground level in the wetland, typically during June or July.

A small upward hydraulic gradient is also evident at various times when groundwater levels in MW003 are higher when compared with levels in the adjacent PZ-9D.

2016 Monitoring at Perimeter Locations

Groundwater levels in 2016 were monitored at nine monitoring wells around the perimeter of the site. These included stations MW125, MW126, MW128, MW124, MW107, MW132, MW135, MW133, and MW134 (Map 3).

Groundwater elevations vary more widely over the year at perimeter locations in comparison to the Core PSW locations. The perimeter groundwater monitoring stations responded to spring thaw and the above-normal precipitation during March, August and late-December of 2016, similar to the monitoring stations at the Core PSW and the Downey Road PSW. There were no apparent short-term and/or long-term changes in groundwater levels at perimeter monitoring stations that could be attributed to development or HCBP construction activities in 2016.

2.3 Surface Water Levels and Flow

As part of the surface water monitoring program in 2016, water depth (level) was measured at 8 stations on Tributary A and Tributary A1. The station names are HC-A: 03, 04, 06, 10, 11, 12, 13 and 14. In addition, one station (SR-01) was located on an unnamed tributary on the west side of Downey Road across from the Downey Road PSW. In addition to the continuous level monitoring, seven baseflow and three high flow measurements were taken at each of the stations between May 31 and December 1, 2016. Rating curves were developed using these data as a mean to convert continuous level to flow data. The resulting surface water data is presented in the tables and figures in the surface water monitoring report prepared by AECOM (Appendix III). Those results are summarized and discussed below.

As per GRCA requirements, monitoring was also completed at each of the stormwater management facilities, which included SWM Ponds 1, 2, and 4. Monitoring of these locations included three components: inflow and discharge flow rates, water temperature, and water quality sampling. Inflow and discharge are discussed below while water temperature and water quality are discussed in Sections 2.4 and 2.5, respectively. Inflow and discharge flow rates were computed based on water level loggers placed in each facility's inlet and outlet structures and the rating curves established for each location. The locations of loggers within each SWM Pond are provided in Table 3. Refer to Map 4 for all monitoring station locations.

Table 3. Stormwater Management Pond Monitoring Stations

SWMF	Station	Data Collected	Date installed	Location
Pond 1	HC-P1(01)	Temperature	September 2011	In pond close to bottom
	HC-P1(02)	Temperature	September 2011	In pond near mid-depth
	HC-P1(03)	Temperature	September 2011	In pond at surface
	HC-P1(04)	Temperature, Depth	September 2011	Inlet
	HC-P1(05)	Temperature, Depth	September 2011	Inlet
	HC-P1(06)	Temperature, Depth	June 2011	Outlet
	HC-P1(07)	Temperature	June 2011	Cooling trench outlet
	HC-P1(08)	Temperature	June 2011	Cooling trench outlet
Pond 2	HC-P2(01)	Temperature	April 2011	In pond close to bottom
	HC-P2(02)	Temperature	April 2011	In pond near mid-depth
	HC-P2(03)	Temperature	April 2011	In pond at surface
	HC-P2(04)	Temperature, Depth	April 2011	Inlet
	HC-P2(05)	Temperature, Depth	August 2012	Inlet
	HC-P2(06)	Temperature, Depth	June 2011	Inlet
	HC-P2(07)	Temperature, Depth	April 2011	Outlet
Pond 4	HC-P4(01)	Temperature	October 2011	In pond close to bottom
	HC-P4(02)	Temperature	November 2011	In pond near mid-depth
	HC-P4(03)	Temperature	November 2011	In pond at surface
	HC-P4(04)	Temperature, Depth	August 2012	Inlet
	HC-P4(05)	Temperature, Depth	October 2011	Outlet
	HC-P4(06)	Temperature	October 2011	Cooling trench outlet

Operational issues were experienced in 2016 at several surface water monitoring stations. Equipment theft and malfunctions produced data gaps in the continuous monitoring data at eight stations. The most substantial gap occurs between January and April, resulting from the theft of a laptop computer containing monitoring data for the first four months of 2016. The resulting data gaps in logger files are given in detail in the surface water monitoring report prepared by AECOM (Appendix III).

A plot showing the creek flow at eight surface water stations as well as precipitation data collected at the Hanlon Creek rain gauge station for the 2016 monitoring period (May 1 to November 27) is shown in Figure 1. Baseflow measurements for 2016 are shown in Figure 2, and a summary of baseflow monitoring from 2008 to 2016 is provided in Table 4.

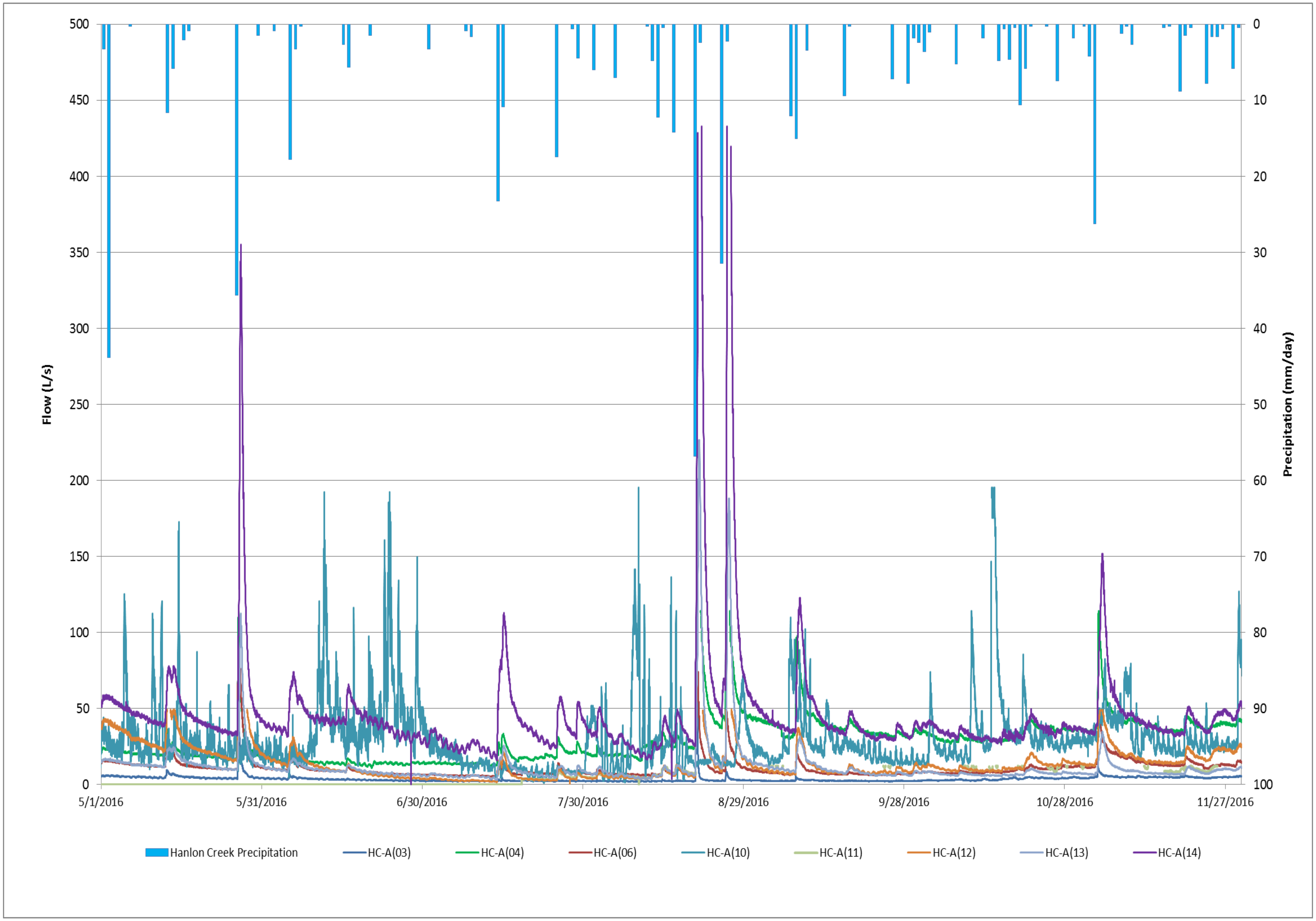


Figure 1. Tributary A and A1 Estimated Flow and Measured Precipitation– Continuous for Eight Stations, May to November 2016

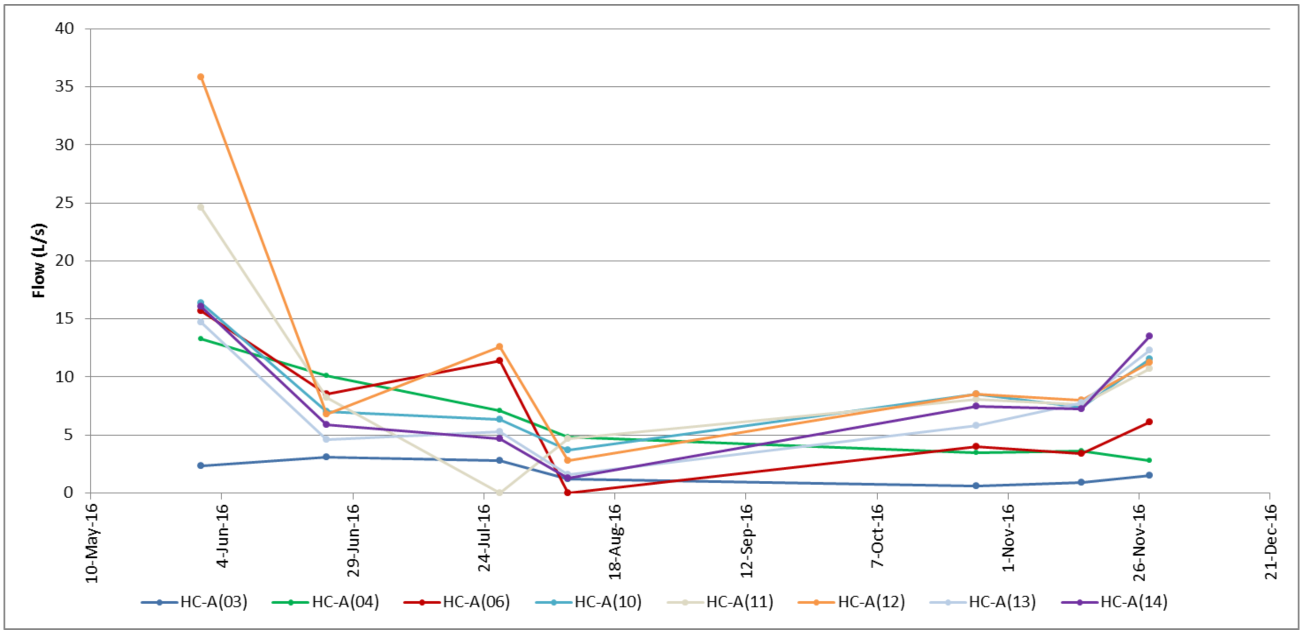


Figure 2. 2016 Hanlon Creek Tributary A Baseflow Measurements

Table 4. Hanlon Creek Baseflow Monitoring – 2008 to 2016 Summary (L/s)

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08) Tributary	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
2008 Min	n/a	3.5	2.7	2.1	3.8	7.7	n/a	n/a	n/a	0.9
2009 Min	n/a	3.9	1.2	3.0	4.2	5.0	n/a	n/a	n/a	1.8
2010 Min	n/a	0.4	0.4	-7.3	1.1	0.8	n/a	n/a	n/a	0.9
2011 Min[2]	2.8	5.5	0.8	1.5	n/a	2.4	4.6	5.0	2.8	1.5
2012 Min	0.1	3.2	3.1	0.5	n/a	1.3	0.7	1.7[1]	0.6[1]	0.7[1]
2013 Min	1.2	8.2	5.5	n/a	n/a	6.4	2.7	12.5	3.4	3.4
2008 Max	n/a	11.3	10.7	10.0	9.4	16.8	n/a	n/a	n/a	12.1
2009 Max	n/a	14.9	25.6	22.1	18.7	56.3	n/a	n/a	n/a	53.8
2010 Max	n/a	2.9	4.9	12.3	6.7	22.2	n/a	n/a	n/a	1.2
2011 Max[2]	47.4	56.6	50.0	5.9	n/a	31.5	46.0	31.9	18.2	48.0
2012 Max	2.5	10.5	14.6	7.4	n/a	13.2	45.6	17.6	36.6	20.7
2013 Max	4.4	16.8	10.3	n/a	n/a	16.9	16.0	21.7	15.8	15.7
2014 Max	3.6	15.4	16.9	n/a	n/a	27.7	27.3	33.1	30.0	28.2
2015 Max	4.2	11.9	11.9	n/a	n/a	17.4	18.9	18.6	17.2	19.7
2016 Max	3.1	13.3	15.7			16.4	24.6	35.8	14.7	16.1
2008 Average	n/a	6.0	9.3	9.0	8.5	20.5	n/a	n/a	n/a	15.8
2009 Average	n/a	7.8	10.7	9.3	10.6	21.3	n/a	n/a	n/a	19.7
2010 Average	n/a	1.6	2.0	2.4	3.6	7.1	n/a	n/a	n/a	5.0
2011 Average[2]	14.6	21.7	20.2	2.7	n/a	19.3	20.6	18.0	20.5	17.2
2012 Average	1.1	6.1	7.5	3.1	n/a	8.0	14.4	10.6	10.9	9.1
2013 Average	2.7	11.2	7.9	n/a	n/a	10.4	10.4	16.1	8.0	9.9
2014 Average	2.6	12.3	14.0	n/a	n/a	19.3	21.1	26.1	21.0	17.2
2015 Average	2.2	9.0	8.7	n/a	n/a	12.6	14.9	14.4	12.9	14.5
2016 Average	1.8	6.5	8.2	n/a	n/a	8.7	10.7	12.2	7.4	8.0
Notes	[1] Hanlon Creek was noted to be dry or flows were below the measurement threshold flow at stations HC-A(03),HC-A(12), HC-A(13) and HC-A(14) [2] Baseflows were influenced by construction activities									

Baseflows in Tributary A in 2016 were lower than those in 2015 and much lower than those in 2014 at all 8 monitoring stations. It is expected that these low numbers are a result of the higher average air temperatures and below-normal precipitation that were experienced in 2016. The annual precipitation was both lower than was what observed in 2015 (910.2 mm in 2016 compared to 927.7 mm in 2015) and lower than the Canadian Climate Normal (1971-2000) at the Guelph Arboretum (923.3 mm).

The discharge from Pond 4 was observed to be near continuous again in 2016 causing elevated baseflow levels at HC-A(04), which is located a short distance downstream of Pond 4. The pond interacts with groundwater flowing in a northwesterly direction, and provides a more direct pathway for discharge to Tributary A. It remains the understanding that groundwater is the predominant source of the pond's continuous discharge. The continuous discharge has resulted in the observed elevated baseflows in Tributary A, and has also affected summer water temperatures in Tributary A. The effect on water temperatures is discussed in Section 2.4.

Baseflow levels at station HC-A(04) were slightly higher than those at HC-A(06) in 2016 (on average 0.3 L/s higher). Prior to construction of Pond 4 in 2011, average baseflows from 2008 to 2010 ranged from 1.6 to 7.8 L/s at HC-A(04). In 2014, 2015 and 2016, average baseflows were 12.3, 9.0 and 6.5 L/s (Table 4), reflecting the increase in baseflow that is attributed to continuous discharge of water from Pond 4.

The continuous discharge from Pond 4 has occurred since the construction of its outlet in late 2011. The average baseflows during the years 2011 and 2012 did not reflect the continuous discharge from Pond 4, for a different reason in each of those years. The SWM Pond 4 outlet was constructed in late 2011. Prior to the outlet construction, the average baseflows at HC-A(04) were already elevated throughout most of 2011 due to dewatering for the construction of the outlet and cooling trench for Pond 4, which was a unique condition for that year. In 2012 there were drought conditions, causing the average baseflows at HC-A(04) to be consistent with pre-2011 baseflows in spite of the continuous discharge that occurred that year. Without the continuous discharge, the baseflows in 2012 would have been much lower.

Farther downstream, the reach between HC-A(09) and HC-A(10) receives input from a small groundwater-fed tributary (Tributary A1) that flows through a cedar-hardwood mixed, swamp which helped it remain a gaining reach. HC-A(10) and HC-A(11) have historically been groundwater discharge areas and this was the case for 2016. HC-A(12), HC-A(13) and HC-A(14) were all areas of ground water recharge or losing reaches again in 2016.

2.4 Water Temperature

2.4.1 Groundwater Temperature

Groundwater temperatures were recorded using data loggers in 38 groundwater monitoring stations across the Hanlon Creek Business Park during 2016. Temperature monitoring has been conducted since 2007 at four PSW monitoring locations (MW003, PZ-9D, PZ-2D, and PZ-7D), all of which are representative of shallow groundwater conditions within the site. The groundwater temperature results are given in the 2016 technical memorandum prepared by Banks Groundwater Engineering (Appendix II) and discussed as follows.

Temperature ranges for each of the four PSW locations were as follows:

- MW003 – similar to previous years ranging from a low of 6.6°C in late-March to a high of 12.2°C in mid-October
- PZ-9D – ranged from a low of 3.5°C in mid-March to a high of 16.1°C in mid-September
- PZ-2D – ranged from a low of 4.6°C in mid-April to a high of 13.3°C in mid-September
- PZ-7D – ranged from a low of 5.4°C in early-March to a high of 11.7°C in early- to mid- September.

The temperature range of groundwater at greater depths in this general area tends to fluctuate in a narrower range, typically between 5 and 10°C. It is therefore apparent that the temperatures in the shallower groundwater regime in the vicinity of these four monitors are influenced by seasonal variations in air temperature and solar radiation. These data are interpreted to be representative of the temperature of groundwater discharging to the wetlands and creeks in these locations.

Monitoring well MW119A is located adjacent to and down-gradient from SWM Pond 4. Groundwater temperatures recorded in monitoring well MW119A during 2016 ranged from a low of 6.4°C in mid-April to a high of 15.7°C in the second half of September, similar to 2015. This is also comparable to the ranges observed from 2008 to 2010, prior to the construction of SWM Pond 4 in late 2010. The high temperature of 15.7°C in 2016 was below the highest temperature recorded, which was 17.5°C on September 5, 2012. Prior to construction of SWM Pond 4 in late 2010, the highest groundwater temperature at this monitor was 15.0°C in early-September 2010. Prior to that, the years 2008 and 2009 had reached a maximum of approximately 13°C in September.

The bottom of SWM Pond 4 is below the shallow groundwater surface and as a result the un-lined pond is in direct contact with the local groundwater system. A portion of the water in the pond is interpreted to discharge from the pond as groundwater in a north-westerly direction, flowing into the ground adjacent to the pond. Therefore, water in the pond warmed by solar radiation during the summer months in 2016 appears to have increased the late-summer groundwater temperature by as much as 3°C in the area down-gradient (north-west) of the pond. This was evident at monitor MW119A, which had late-summer temperatures that were 3-5°C warmer than concurrent temperatures up-gradient of Pond 4 at MW131.

Additional monitoring of groundwater temperatures down-gradient of SWM Pond 4 was initiated in June 2013 to better understand the interactions between the groundwater system, Tributary A and Pond 4. A pair of shallow mini-piezometers (PZ-13D and PZ-14D) were installed on the east and west bank of Tributary 'A', respectively, and equipped with data loggers (refer to Figure 1). The piezometers were located a short distance down-stream from surface water monitoring station HC-A(04). In 2016 the groundwater temperatures at PZ-13D and PZ-14D reached maximums of just less than 14°C in August with PZ-13D slightly higher than PZ-14D. Based on this it is likely that these monitors were influenced by the warmer shallow groundwater flow affected by SWM Pond 4. Graph 24a (Appendix II) shows that temperatures in PZ-13D and PZ-14D returned to below those recorded in MW131 (up-gradient of Pond 4) by late-October each year, indicating that these two piezometers are reacting in response to solar heating of the pond and subsequent warming of the groundwater. In contrast, MW131 is not influenced by the warmed groundwater from Pond 4 and therefore, exhibits cooler summer temperatures and less variability overall as a result of the more consistent groundwater temperatures. This issue is discussed further in Section 5.1.2.

2.4.2 Surface Water Temperature

Surface water temperatures were measured in Tributary A and Tributary A1 using data loggers at 13 stream stations and in numerous locations within SWM Ponds 1, 2 and 4. The results are given in the surface water monitoring report prepared by AECOM (Appendix III), and are summarized and discussed as follows.

A plot of the continuous temperature monitoring throughout the year 2016 is provided in Figure 3. In previous years, during the winter months (January to March), water temperatures at all stations are at or around freezing (0°C) for most of the winter indicating that a large portion of Tributary A periodically experienced frozen conditions. Additionally, stations HC-A(03), HC-A(04), HC-A(06), HC-A(08), HC-A(10), HC-A(11) and SR-1 exhibit temperatures that fluctuate below zero degrees indicating that loggers may be exposed to air temperatures during the winter months. This is likely to have continued in 2016, however due to the data gap between January and April this cannot be confirmed.

Stations HC-A(08), HC-A(03), HC-A(04), and HC-A(06) have historically shown trends of consistent temperatures above 0° during sub 0° air temperature conditions. This indicates these stations are likely most influenced by groundwater input. Conversely stations HC-A(14) and HC-A(09) record the coldest temperatures and are least influenced by groundwater inputs. These trends are consistent with over-winter observations made since the implementation of the monitoring program before the construction of the SWM ponds.

During summer months, stations HC-A(04) and HC-A(06), located downstream of the SWM Pond 4 outlet, recorded high average temperatures and little daily fluctuation due to the influence of SWM Pond 4's continuous discharge compared to HC-A(03), which is not impacted by pond discharge. Downstream stations which are more exposed such as HC-A(10), HC-A(12), HC-A(13) and HC-A(14); and those with a wider flow channel and shallower depths (HC-A(09)) show the highest daily variation in temperature as there is greater opportunity for solar radiation impact. Station HC-A(08) shows the lowest temperatures and daily temperature variation during the summer, indicating the presence of groundwater inputs in Tributary A1 where this station is located.

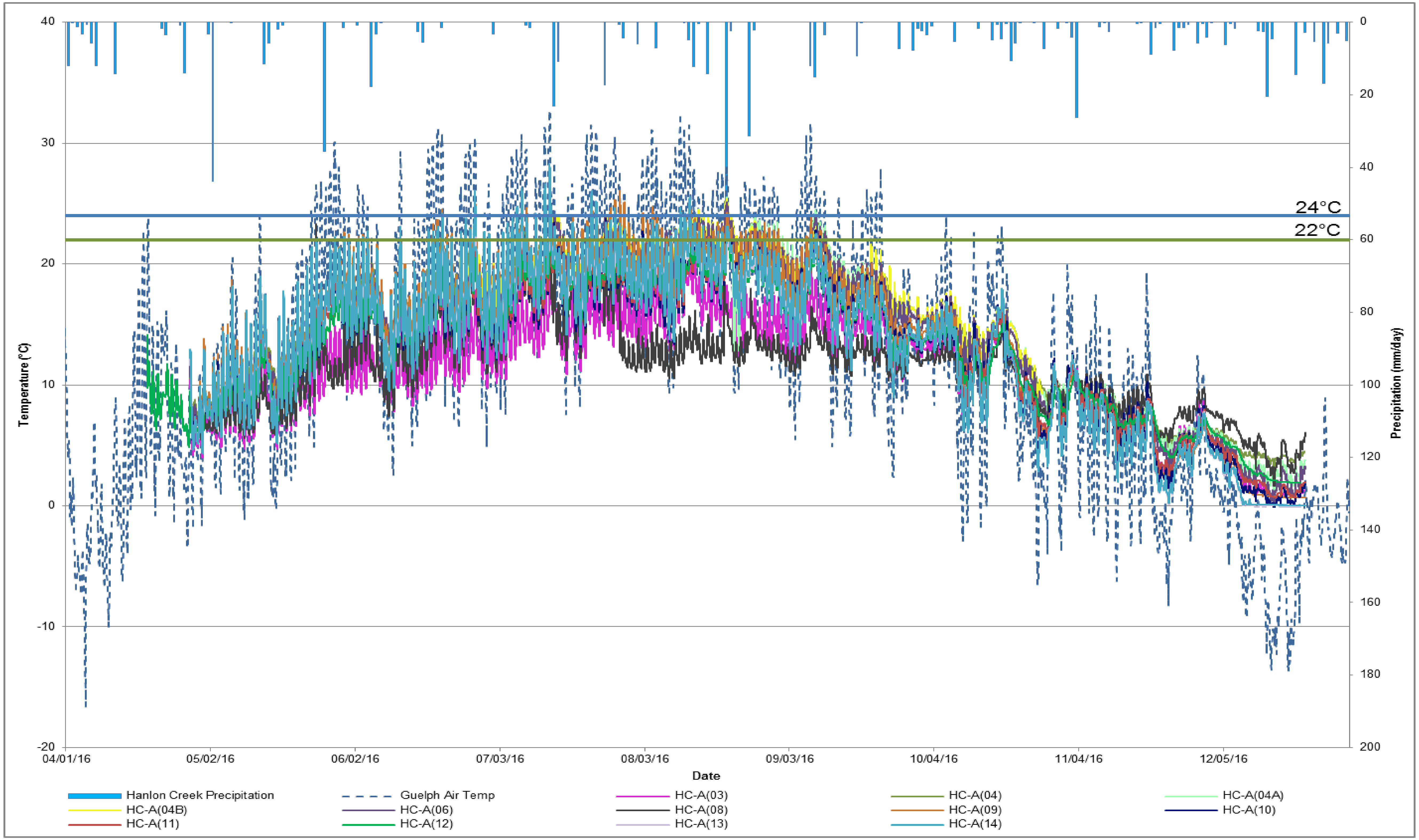


Figure 3. Tributary A and A1 Temperature Monitoring – Continuous Temperature for 13 Stations, April to December 2016

The surface water temperatures in 2016 were notably higher compared to 2015, and somewhat warmer compared to other years of monitoring. This is evidenced by the thermal regime classifications for Tributaries A and A1, and the analysis of temperature suitability for Brook Trout, each discussed below. Elevated air temperatures from May to September 2016 largely explain the warm water temperatures. In addition, the continuous discharge from SWM Pond 4 continues to increase the water temperatures, particularly at Stations HC-A(04) and HC-A(06).

Table 5 shows the thermal regime classifications for Tributaries A and A1 from 2006 to 2016 using the methods developed by Stoneman and Jones (1996) and revised by Chu (2009). The 2016 classifications show similar conditions to those in 2015 and other previous years. Three stations shifted thermal regimes from 2015 to 2016. Station HC-A(03) shifted from cool to cool-cold, and stations HC-A(10) and HC-A(13) shifted from cool to cool-warm. The other stations remained the same from 2015 to 2016. Also, two stations were new for 2016: HC-A(04A) and HC-A(04B).

Table 5. Temperature Classification Summary

	Based on C. Chu et al. (2009)									Based on Stoneman and Jones (1996)		Overall Change in Thermal Regime
Station	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	
HC-A(03)	Cool-Cold	Cool	Cool-Cold	Cool-Cold	Cool	Cool	n/a	n/a	n/a	n/a	n/a	None
HC-A(04)	Cool-Warm	Cool-Warm	Cool	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cold	Cold	Cold-Cool to Cool-Warm
HC-A(04A)	Cool-Warm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	None
HC-A(04B)	Cool-Warm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	None
HC-A(06)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cool	Cool	Cool to Cool-Warm
HC-A(08)	**Cold**	Cold	Cold	Cold	Cool-Cold	Cold	Cold	Cold	Cold	Cold	Cold	None
HC-A(09)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	n/a	Cool	Cold	Cool	Cool to Cool-Warm
HC-A(10)	Cool-Warm	Cool	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Cold	n/a	Cool-Cold	Cool	Cool	Cool to Cool-Warm
HC-A(11)	Cool	Cool	Cool	Cool	Cool-Warm	Cool	Cool	Cool-Warm	Cool	Warm	Warm	Cool-Warm to Cool
HC-A(12)	Cool	Cool	Cool	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a	Cool-Warm to Cool
HC-A(13)	Cool-Warm	Cool	Cool-Warm	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a	None
HC-A(14)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	Cool	Cool	n/a	n/a	None

Comparing 2016 results to pre-construction years (2006 to 2010), it is evident that there is some warming that is likely attributable to the effects of SMW Pond 4. Stations HC-A(04), HC-A(06), HC-A(09) and HC-A(10) were warmer again in 2016. Further downstream, station HC-A(11) was cooler in 2016 compared to pre-construction condition, which may reflect the cooling effect of the removal of the online pond in conjunction with building the Hanlon Creek Blvd crossing of Tributary A in 2009. Station HC-A(14) was one category warmer in 2016 compared to pre-construction conditions (i.e. cool-warm in 2016 as opposed to cool in 2008 and 2009). Stations HC-A(12) and HC-A(13) did not exist prior to construction. Beginning in 2011, the results for those stations suggest that the only influence has been the warmer climate conditions in 2012. Altogether, the majority of the stations with warmer thermal regimes occur in the section of Tributary A that is most likely to be influenced by SWM Pond 4. Stations HC-A(04A) and HC-A(04B) were installed in 2016 and have no previous data to compare against.

2.4.2.1 Suitability of Temperature for Brook Trout

Studies suggest that the upper temperature tolerance limits for Brook Trout are in the range of 22.3°C (Eaton et al 1995) to 25.4°C (Wehrly et al 2007). Optimum water temperature for growth during the summer is suggested to be in the range of 10 to 19°C (Hokanson et al 1973). In general, water temperatures observed throughout the summer months in 2016 were above the preferred temperatures documented for Brook Trout in the *Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F* (AECOM, 2009). Water temperatures were noted to exceed 19°C and threshold exceedances of 22 and 24°C were also observed between May and September. Temperature exceedances of 19°C and up to 24°C may limit Brook Trout presence within certain areas of the creek during the summer months where water temperatures are elevated above their preferred range. However, these exceedances are not likely to eliminate the potential presence of Brook Trout altogether since fish are mobile and will move upstream or downstream in search of cooler water temperatures to use as refugia (Power 1980). Further, although no Brook Trout have been captured at the HCBP fish monitoring stations, the presence of other coolwater and coldwater species such as White Sucker (*Catostomus commersonii*) and Mottled Sculpin (*Cottus bairdii*) indicate that species preferring those thermal regimes are able to persist.

Similar to previous years, stream temperatures in 2016 exceeded the preferred summer temperature range for Brook Trout of 10 to 19°C. Table 6 shows that all stations, with the exception of HC-A(08), had periods of time when temperatures were above 19°C in July and August. Stations HC-A(04) and HC-A(06) were influenced by the continuous outflow from SWM Pond 4, and for the majority of the time in July and August had temperatures above 19°C. In contrast, station HC-A(03) is located immediately upstream of the SWM Pond 4 outflow, and had significantly less time when the stream temperature was above 19°C. Station HC-A(09) also had substantial time when the temperature was above 19°C. Station HC-A(08) is located on Tributary A1 which is typically colder, and its temperature never went above 19°C. Downstream of the confluence of Tributary A and Tributary A1 at HC-A(10) and HC-A(11), the combined flows had some time above 19°C, but the results were clearly influenced by the colder water from Tributary A1. Moving downstream through stations HC-A(12), HC-A(13) and HC-A(14), the time above 19°C increased, reflecting the loss of water to the ground known to occur in this reach, and exposure to the sun that occurs early in the summer before the herbaceous vegetation is fully grown in this area. In 2016, every monitoring station along Tributary A experienced at least some time when temperatures were above the preferred summer temperature range for Brook Trout. Only two stations, HC-A(03) and HC-A(08) experienced values, specifically hours and percent of time over 19°C, that were within the modeled values.

Autumn temperatures are also important to Brook Trout as they relate to spawning, which typically occurs between the middle of October and the end of November in southern Ontario. Witzel and MacCrimmon (1983) observed that stream temperatures were most commonly between 6 and 8°C while Brook Trout were spawning in the fall in southern Ontario streams. During the spawning period water temperatures were within the 6 to 8°C preferred range at the HCBP, indicating that water temperatures were suitable for Brook Trout spawning.

Table 6. Summer (July to August) 2016 Temperature Summary

Station	Modeled Values[1]	HC-A(03)	HC-A(04)	HC-A(04A)	HC-A(04B)	HC-A(06)	HC-A(08)[2]	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
Summer (July-August) average maximum (ºC)	14.5 - 19.9	17.87	22.47	22.77	22.83	22.77	8.24	23.37	21.37	20.36	19.83	21.63	22.68
Summer (July-August) average (ºC)	12.5 - 14.5	15.59	21.28	21.33	21.44	20.97	13.07	20.79	18.67	18.51	18.58	19.49	19.69
Summer (July-August) average minimum (ºC)	9.0 - 12.0	13.25	18.70	18.90	18.48	17.11	6.53	18.68	16.50	16.95	17.43	17.53	16.74
Maximum 3-day mean (ºC)	14.0 - 19.0	18.75	23.40	23.40	23.36	22.90	14.36	22.81	20.60	20.31	20.34	21.54	21.90
Maximum 7-day mean (ºC)	13.0 - 17.0	17.93	22.87	22.99	22.94	22.46	13.97	22.02	19.79	19.61	19.70	20.64	20.99
Maximum 7-day mean of daily maximums (ºC)	15.0 - 23.5	19.84	23.54	23.91	24.02	23.76	15.59	24.69	22.65	21.23	20.66	23.66	24.70
	Temperature Exceedance over 19°C for July and August												
Hours over 19°C	0 - 130	76	1330	1313	1338	1263	0	1200	692	611	615	930	927
Percent of Time over 19°C	0 - 9%	5%	90%	89%	91%	86%	0%	81%	47%	41%	41%	63%	62%
Frequency of Exceedance over 19°C (Days)	0 - 27	13	61	62	62	61	0	62	61	55	48	61	62
Average Duration of Event Over 19°C (h)	3 - 6	5	74	66	64	53	0	38	13	12	17	20	19
Maximum duration of event over 19ºC (h)	<<130	13	580	322	544	416	0	188	83	82	86	89	86
	Temperature Exceedance over 22°C for July and August												
Hours over 22°C		0	564	604	601	474	0	449	84	15	0	143	260
Percent of Time over 22°C		0%	38%	41%	41%	32%	0%	30%	6%	1%	0%	10%	17%
Frequency of Exceedance over 22°C (Days)		0	41	47	50	49	0	57	20	6	0	22	37
Average Duration of Event Over 22°C (h)		0	16	24	24	10	0	6	3	2	0	4	5
Maximum duration of event over 22ºC (h)	<<130	0	62	139	138	47	0	43	13	7	0	14	15
	Temperature Exceedance over 24°C for July and August												
Hours over 24°C	0 -3.2	0	21	29	30	17	0	81	0	0	0	24	59
Percent of Time over 24°C	0 - 0.21%	0%	1%	2%	2%	1%	0%	5%	0%	0%	0%	2%	4%
Frequency of 24°C Exceedance (Days)		0	2	3	4	1	0	17	0	0	0	4	12
Average Duration of Event Over 24°C (h)		0	21	15	10	17	0	5	0	0	0	6	5
Maximum duration of event over 24ºC (h)	<3.2	0	21	20	21	17	0	9	0	0	0	9	10

[1] Modeled range referees to the results of the Hanlon Creek Business Park Stream Temperate Impact Report Continuous Modeling with HSP-F (AECOM, 2009)

[2] Due to low ground water and precipitation levels, Station HC-A(08) experienced low flow conditions which caused the stations temperature logger to be exposed to air temperatures from approximately July 1st to July 24th This data was not included in the analysis for the table above as it does not represent true in-stream conditions.

Note: Red text denotes exceedances of the modeled range

Maximum temperatures were also reviewed and provide further evidence that the temperatures in 2016 were not suitable for Brook Trout. The HCBP Consolidated Monitoring Plan established two thresholds for Brook Trout; the first is a single temperature exceedance of 22.0°C, and the second is any single temperature exceedance of 24.0°C. The highest number of exceedances of these thresholds since monitoring began occurred in the year 2012. Comparatively fewer exceedance events occurred in 2016, yet exceedances of both thresholds were still observed (Table 6).

Temperatures in excess of 22°C are not suitable for Brook Trout. In 2016 a total of nine stations exceeded 22°C for at least some of the time in July and August at the HCBP. The stations with the highest numbers of hours exceeding 22°C were located at two locations: downstream of SWM Pond 4, and just upstream from the confluence of Tributary A and Tributary A1. Downstream from Pond 4 the highest durations of the 22°C exceedance were observed at HC-A(04A) and HC-A(04B), which both exceeded the threshold for approximately 600 hours, or 41% of the July and August time period (Table 6). HC-A(04), located closer to SWM Pond 4, exceeded 22°C for 564 hours, or 38% of the time. Station HC-A(06), located downstream from these stations and further from SWM Pond 4, exceeded 22°C for 474 hours, or 32% of the time. HC-A(09), which is located farther downstream from these monitoring stations exceeded the 22°C threshold for 449 hours, or 30% of the time.

Some of the 22°C threshold results in 2016 were comparable to those in the year 2012, which had highest observed exceedances in the construction phase monitoring. The stations with similarly high exceedances were HC-A(04A), HC-A(04B), and HC-A(09). Stations HC-A(04A) and HC-A(04B) were in operation for the first time in 2016 and have no additional years of data to compare against. Nevertheless, they demonstrated particularly high frequencies of exceedance of 22°C. Station HC-A(09) has generally exhibited the largest exceedances, resulting from the wide channel and shallow water depths that characterize the site. Overall, stations HC-A(09), HC-A(06) and HC-A(04) have had greater number of hours above 22°C since the construction of SWM Pond 4, and these stations continued to demonstrate a substantial number of hours above 22°C in 2016. Improving the thermal conditions of the upstream areas of Tributary A (by addressing the SWM Pond 4 issues) will likely result in a reduction in water temperature at these downstream stations.

At the other stations, HC-A(03), located just upstream of the outflow from SWM Pond 4, did not experience any exceedance of 22°C in 2016 and has only experienced minor exceedances in previous years due to climatic factors. Station HC-A(14) also exceeded 22°C for a total of 260 hours or 17% of the time period. HC-A(14) is the most downstream stations at the HCBP and it has been typical for it to exceed both thresholds of 22°C and 24°C because of naturally occurring loss of water and exposure to the sun in this part of Tributary A. Other stations on Tributary A had fewer periods of time above 22°C in July and August. While the resulting time periods for those stations are a modest proportion of July and August, temperatures above 22°C are not suitable for Brook Trout, and adverse effects can occur even if the temperatures are not lethal. Only Stations HC-A(03), HC-A(08), and HC-A(12) had water temperatures that remained below 22°C in 2016.

Temperatures above 24°C can be lethal for Brook Trout, and seven stations had temperatures above 24°C during July and August 2016. Only three stations exhibited this exceedance in 2016 including HC-A(09), Station HC-A(06), and Station HC-A(14). The highest number of exceedances were observed at Station HC-A(09), which exceeded 24°C on 17 occasions, with an average of 5 hours and totaling 81 hours, or 5% of the time (Table 6). The second highest number of exceedances were observed at Station HC-A(14), which exceeded 24°C on 12 occasions, with an average of 5 hours and totaling 59 hours, or 4% of the time. Other stations that exceeded 24°C in 2016 included HC-A(04), HC-A(04A), HC-A(04B), HC-A(06), HC-A(09), and HC-A(13). These stations exceeded 24°C for between 1 and 4 days, with total exceedances between 21 and 30 hours, or 1 to 2% of the time. The RAAP team normally meets whenever temperatures exceeded 24°C at telemetry stations to discern the cause and try to address it. A discussion of the RAAP team's activity in 2016 is provided in Section 4.0.

2.4.2.2 Stormwater Management Pond Temperature

In addition to the monitoring of stream temperatures, monitoring was conducted at the constructed stormwater management facilities, which included SWM Pond 1, SWM Pond 2, and SWM Pond 4 (Map 4). Temperature was measured at each pond's inlet, at three depths near the bottom-draw outlet, at the outlet of the pond, and at the outlet of the cooling trench (where applicable).

SWM Pond 1

Outflows from Pond 1 were not recorded for 2016 due to low water levels that persisted throughout the monitoring season (Figure 5). Therefore, the function of the cooling trenches at SWM Pond 1 cannot be determined for 2016. In 2014, the cooling trenches demonstrated steady to declining temperatures through the storm event with cooling trench 1 generally maintaining lower temperatures than cooling trench 2.

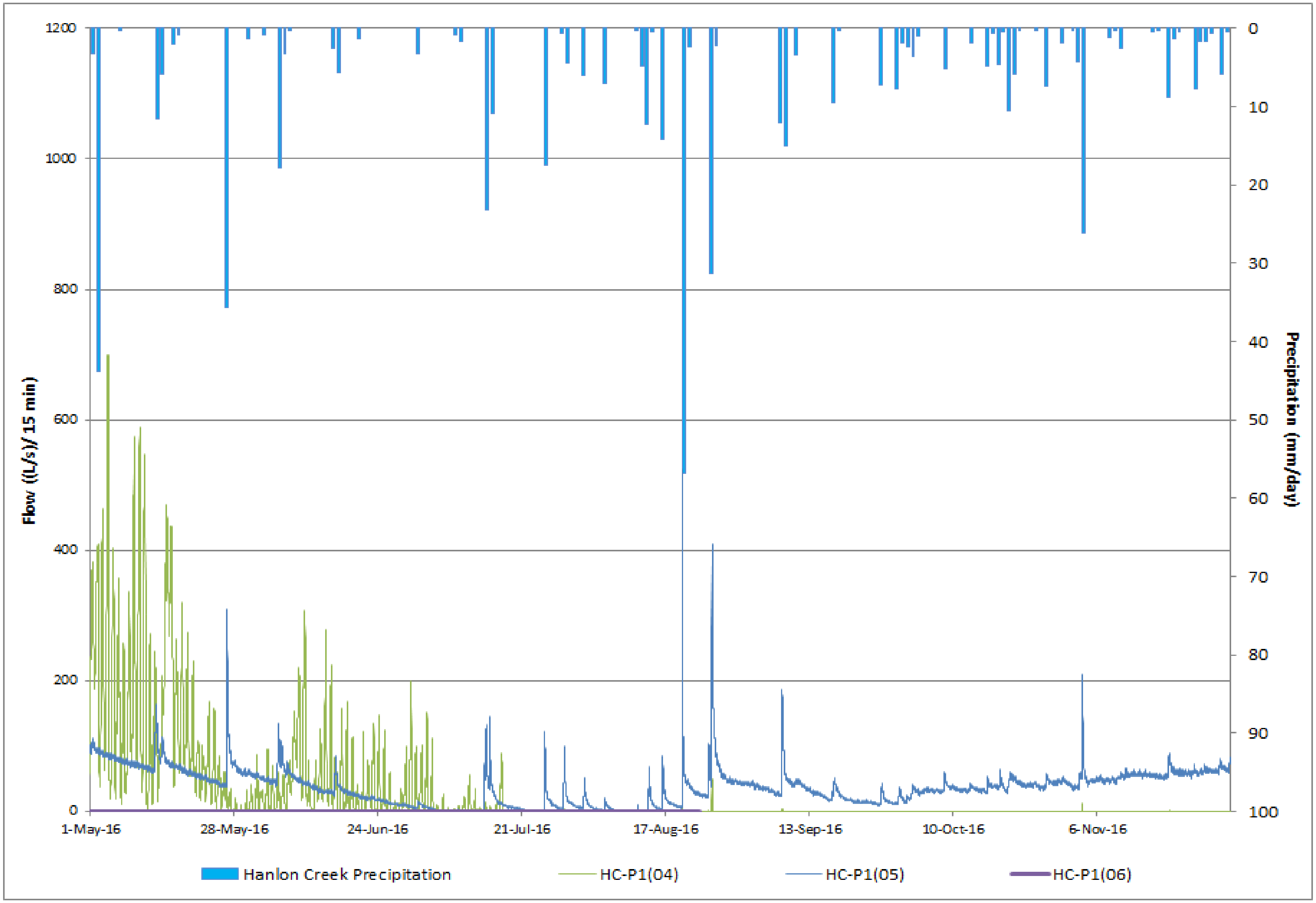


Figure 4. Estimated flow and precipitation data for Pond 1.

SWM Pond 2

Outflows from Pond 2 were not recorded for 2016 due to low water levels that persisted throughout the monitoring season (Figure 6). Therefore, the function of the cooling trenches at SWM Pond 2 cannot be determined for 2016.

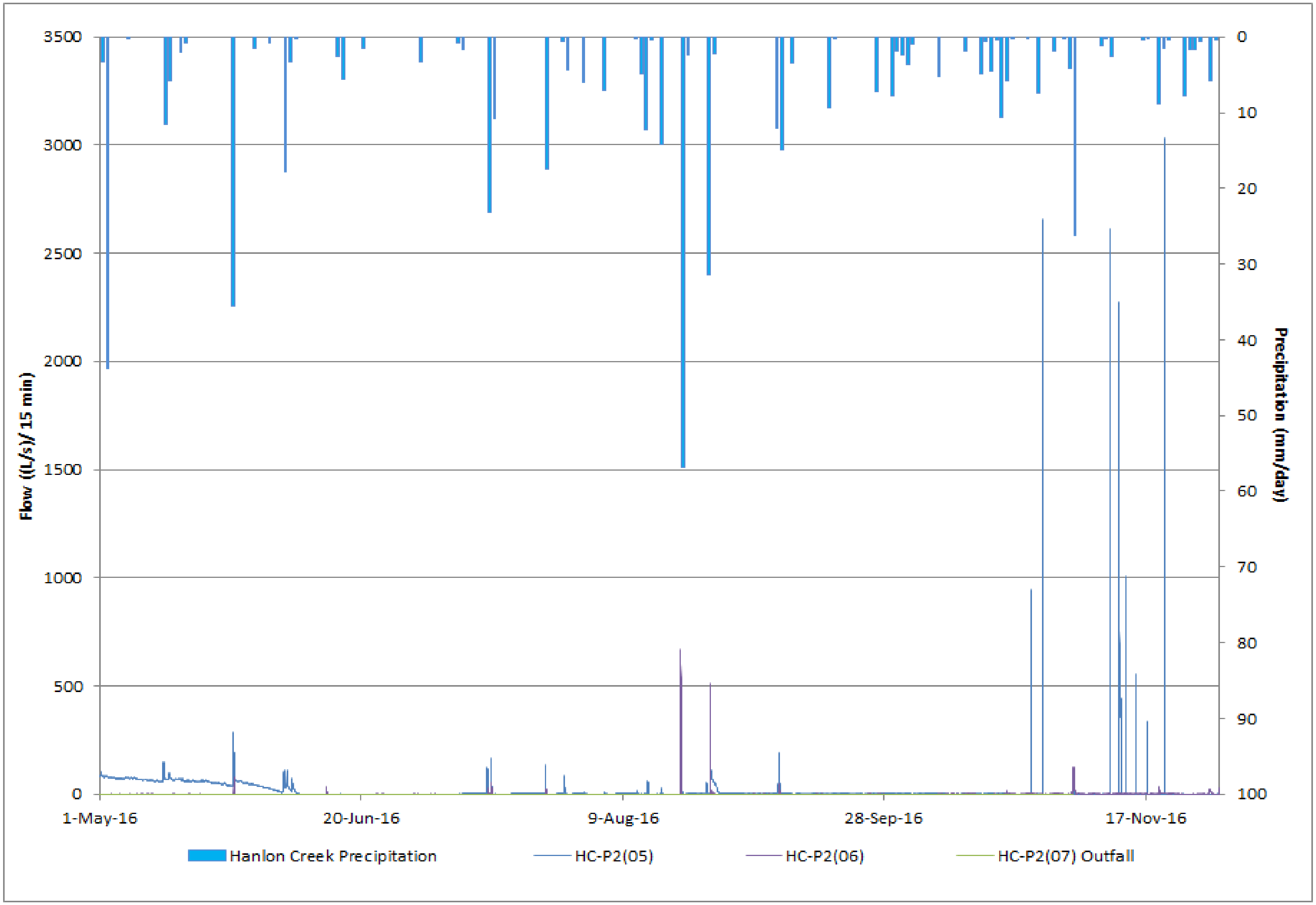


Figure 5. Estimated flow and precipitation data for Pond 2.

SWM Pond 4

As discussed in Section 2.3, SWM Pond 4 continued to discharge continuously, augmenting flow in Tributary A. This is also shown on Figure 6.

It is evident that in 2016 the water temperatures within Pond 4 were strongly stratified during the summer, with bottom temperatures that had much less temperature fluctuation than surface temperatures. The bottom temperatures and mid-level temperatures remained similar in August with bottom temperatures elevating slightly above mid-level temperatures daily. Figures 7 and 8 demonstrate how the cooling trench maintained lower temperatures than the pond throughout the spring and summer, yet were higher than upstream water temperatures in Tributary A at station HC-A(03). The resulting water temperatures downstream in Tributary A at station HC-A(04) are strongly influenced by the pond's discharge through the cooling trench. During the summer, the maximum daily temperatures recorded at HC-A(04) were typically several degrees cooler than temperatures recorded at the pond's outlet. This demonstrates that the cooling trench is generally functioning as intended, although the continuous discharge is nevertheless increasing stream temperatures in Tributary A.

It appears that during dry periods the cooling trench was receiving water as outflows from the pond (outflow) combined with direct reception of groundwater (Figure 6). This explains why, during a dry period, the cooling trench water temperatures were midway between the pond outflow temperature and the upstream Tributary A temperatures at station HC-A(03) (Figure 8). The upstream temperatures in Tributary A appear to have been strongly influenced by groundwater. The daily minimum temperatures were consistent with groundwater temperatures at up-gradient monitoring wells MW 131 and MW 122A, which reached a maximum of nearly 14°C in the summer of 2016. The diurnal fluctuation in stream temperatures is interpreted to represent solar radiation and warm air temperatures that increased stream temperatures above groundwater temperatures during daylight hours. The pond outflow temperatures were considerably higher than the stream and groundwater temperatures. The fact that the cooling trench temperatures were in between suggests that they were a result of a mixture of pond outflow water and groundwater.

Cooling trench performance during a storm event further demonstrates how the mixing of SWM Pond 4 outflow (the water entering the cooling trench from the pond) and groundwater occurs. In response to a storm, the cooling trench temperatures were closer to pond outflow temperatures (Figure 8). This can be attributed to the greater volume of pond outflow, which has the greater influence on cooling trench temperature. Following the storm event, the cooling trench temperature gradually returned to a more balanced blend of groundwater and pond outflow, trending in a manner consistent with the pond outflow volumes.

With the possible exception of a few hours after a storm, it appears that the cooling trench performed largely as a mixing chamber, with the rock doing only a little to absorb heat from the outflow water. The cooling trench temperature responded very quickly to the inundation of outflow (Figure 7). It appears that while the cooling trench at SWM Pond 4 did have a generally cooling effect on the continuous flow discharged to Hanlon Creek Tributary A, it had a limited ability to mitigate outflow temperatures during storm events.

In September 2012, aquatic vegetation was planted in the pond and the outlet weir was raised to reduce the constant discharge from SWM Pond 4. Raising the weir height did not stop SWM Pond 4 from continuously discharging from 2013 to 2016. Plantings of vines and other flora was completed at the end of 2012 on the cooling trench in an attempt to shade the exposed rock. The plants did not mature sufficiently from 2013 to 2016 to cover the cooling trench. Minor improvement in the amount of vegetation taking root along the cooling trench has been noted, although the affect remains minor. These design features may provide additional cooling to the ponds discharge in future summer seasons. However, it will be necessary to implement other measures to further mitigate the effects on stream temperatures. Options for other mitigation measures are being discussed with the City and the GRCA.

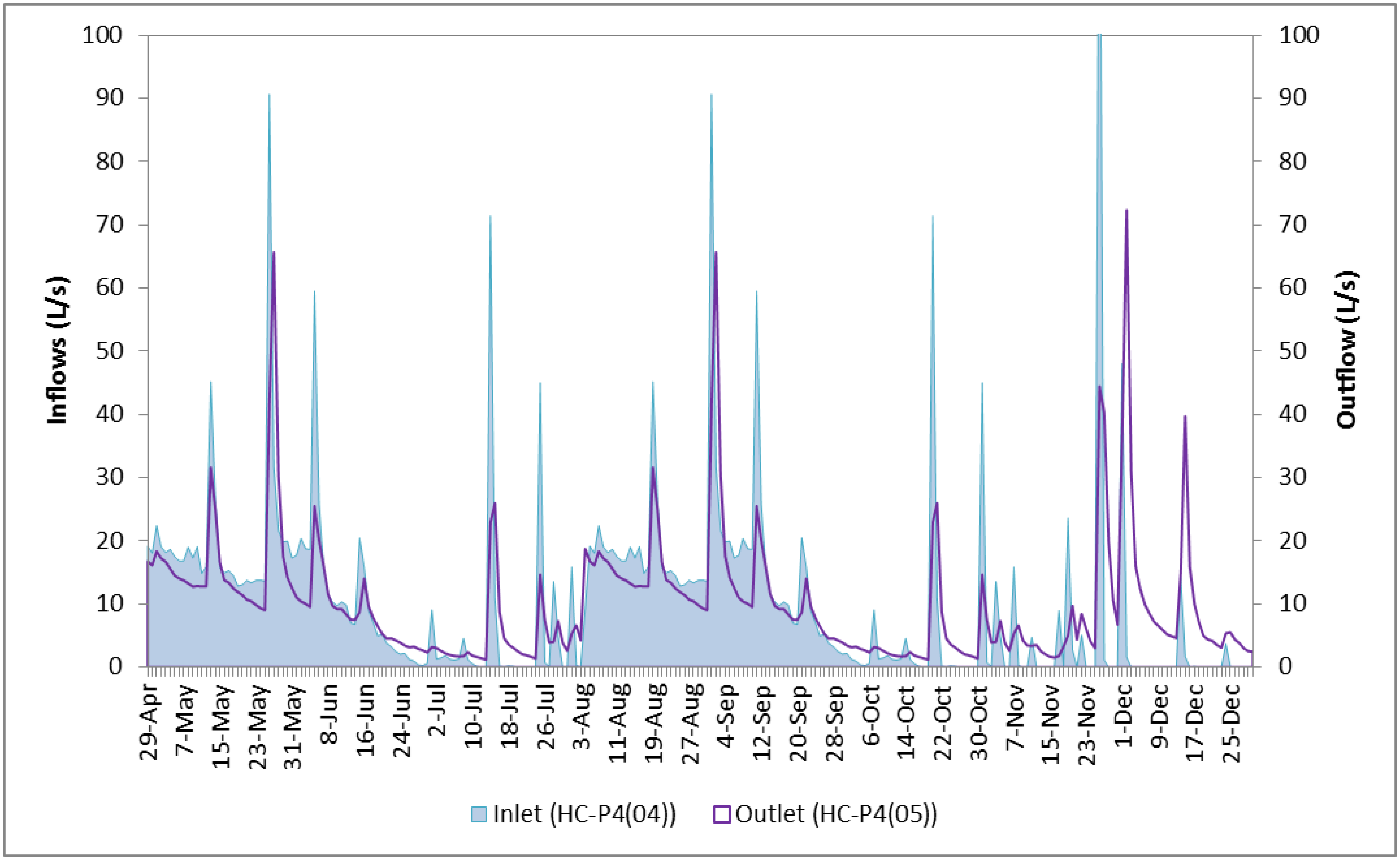


Figure 6. Average daily flows at inlet and outlet of Pond 4.

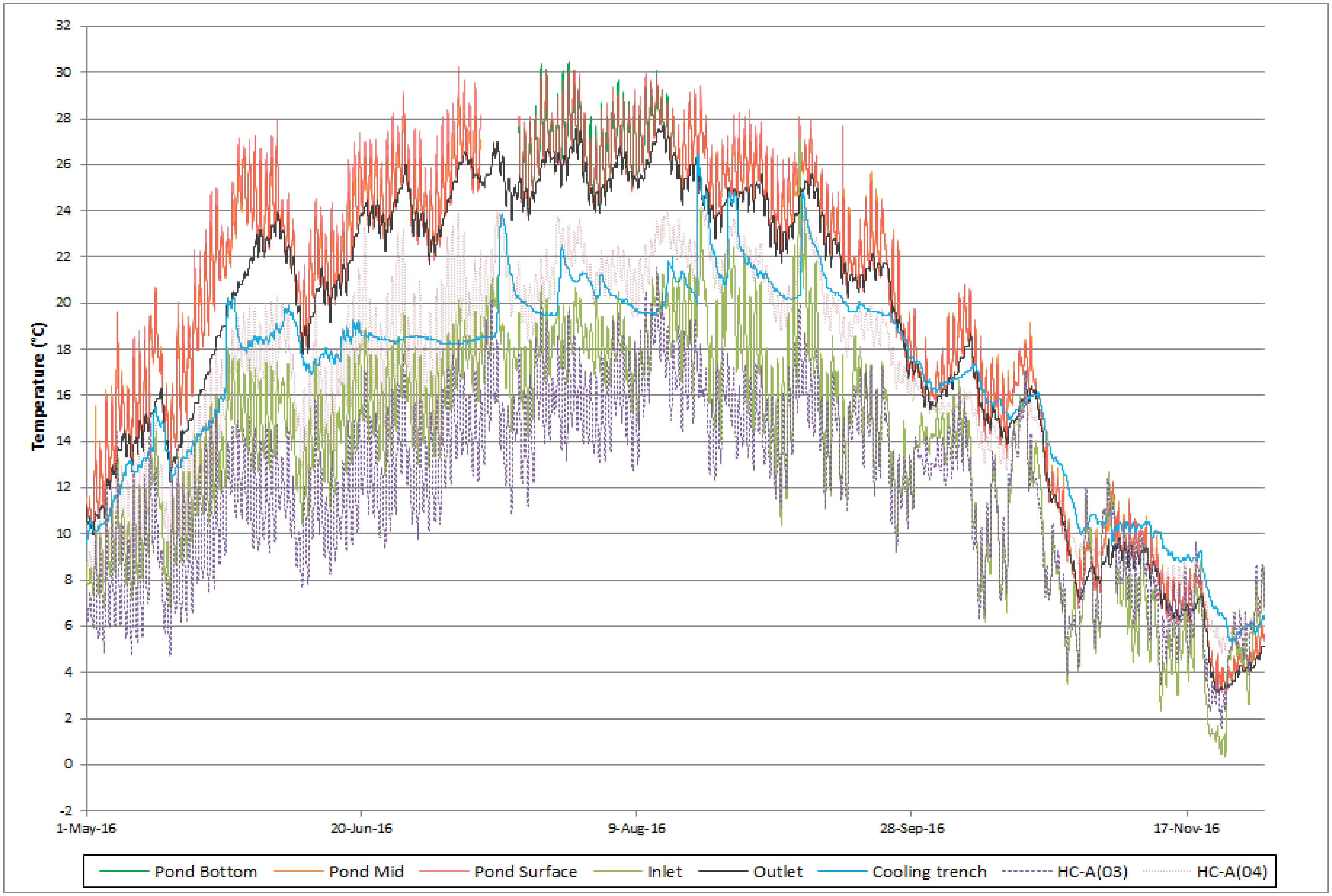


Figure 7. Measured water temperatures through Pond 4 and directly upstream and downstream of the Pond 4 outlet.

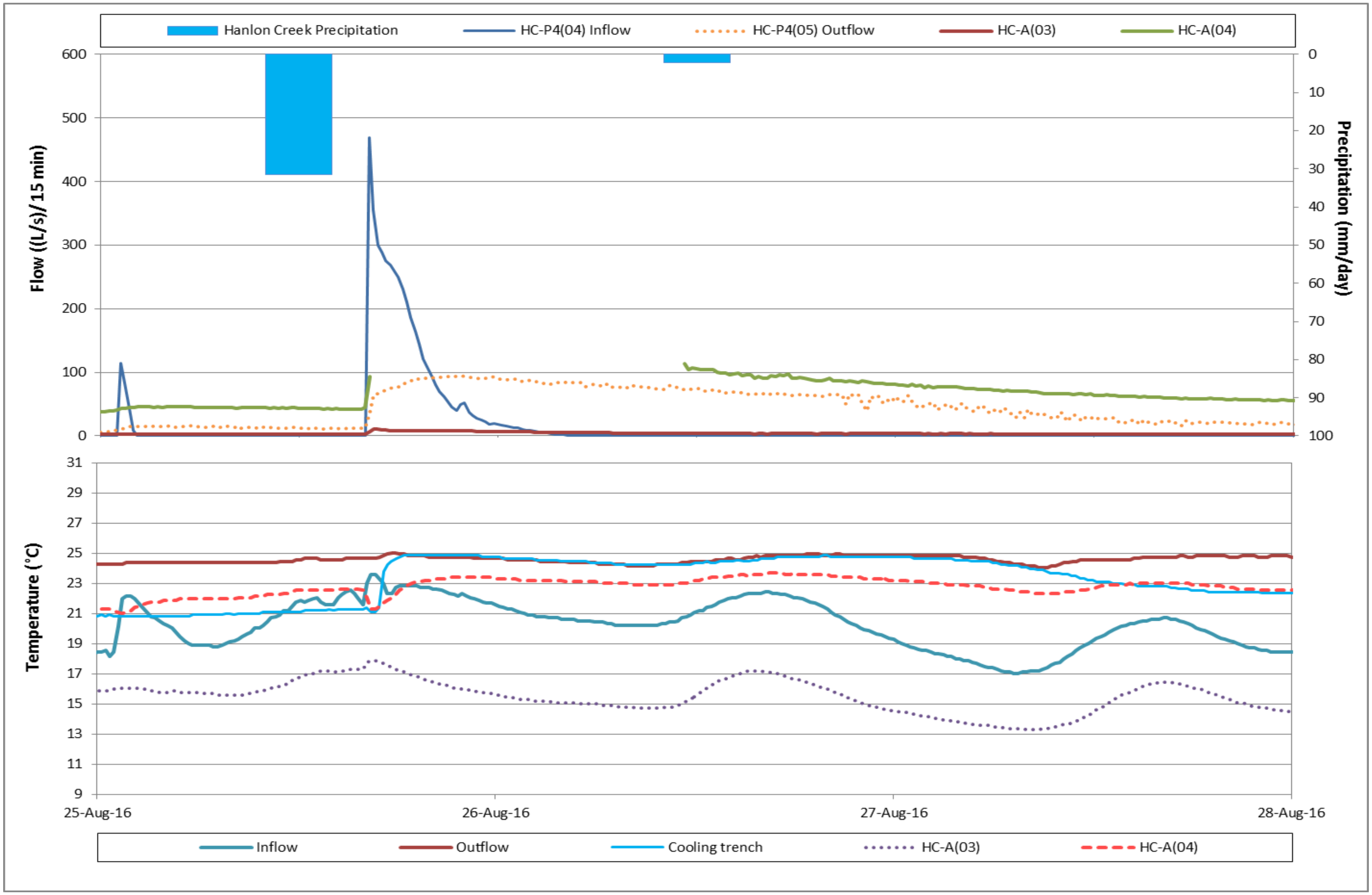


Figure 8. Flow and water temperature during a precipitation event for Pond 4 as well as directly upstream and downstream of the Pond 4 outlet.

2.5 Water Quality

2.5.1 Groundwater Quality

The groundwater quality results are given in the 2016 technical memorandum prepared by Banks Groundwater Engineering (Appendix II) and discussed as follows.

Water samples were taken from 36 monitoring wells in April 2015. Each sampling period the wells are purged prior to sampling the equivalent of three casing volumes. The samples are also field-filtered with a 45 micron in-line filter. The groundwater at the HCBP can be characterized as basic (pH>7) and, based on the reported calcium and magnesium concentrations, as hard. Since 2003, the concentrations of the parameters analyzed have generally been below the applicable Ontario Drinking Water Quality Standards (ODWQS) criteria, with the following exceptions during the 2016 monitoring period (refer to Appendix II for specific exceedances):

- Nitrate (as N) concentrations exceeded the ODWQS of 10.0 mg/L on at least one occasion in six monitoring wells
- Aluminum concentrations exceeded the ODWQS of 0.1 mg/L on at least one occasion in 24 monitoring wells
- Cadmium concentrations exceeded the ODWQS of 0.005 mg/L on at least one occasion in 11 monitoring wells
- Iron concentrations exceeded the ODWQS of 0.3 mg/L on at least one occasion in 32 monitoring wells
- Lead concentrations exceeded the ODWQS of 0.010 mg/L on at least one occasion in 22 monitoring wells
- Manganese concentrations exceeded the ODWQS of 0.05 mg/L on at least one occasion in 37 monitoring wells
- Sodium concentrations exceeded the ODWQS of 20 mg/L on at least one occasion in 37 monitoring wells
- Hardness concentrations exceeded the ODWQS of 100 mg/L in all monitoring wells.

Colour, turbidity, total dissolved solids, and DOC exceeded the respective ODWQS concentrations in most of the monitoring wells. This observation is typical for monitoring wells that cannot be developed to a sediment-free condition. Therefore, it cannot be concluded that these four parameters are naturally above the respective ODWQS. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels of some parameters.

2.5.2 Surface Water Quality

2.5.2.1 In-Stream Water Quality

During each field visit an YSI multi-parameter probe (556R) was used to collect dissolved oxygen, pH, and specific conductivity conditions at each site. These results are shown graphically in Figures 9, 11 and 13, respectively. The majority of the sites were within the ranges of the Provincial Water Quality Objectives (PWQO). In the event that water quality samples were collected and the pH probe was not functioning, then the pH was determined by lab analysis.

During one of the baseflow monitoring events, dissolved oxygen (DO) was found to be below PWQO guidelines. This occurred at station HC-A(04) on August 16, 2016. Lower DO levels observed on this date could be attributed to below average flow rates, high temperatures and an extended period of no precipitation. The average annual dissolved oxygen levels show DO levels have been fairly consistent since 2010, with the exception of 2012 which was noted to be a particularly warm summer (Figure 10).

Stations HC-A(13) and HC-A(14) recorded pH levels above the PWQO guidelines on September 26, 2016. Station HC-A(03) also recorded pH levels below PWQO standards on November 28. Overall the pH levels to have been decreasing since 2012. However, overall averages have increased between 2015 and 2016 (Figure 12).

There is no PWQO for conductivity; however conductivity is related to the concentration of ions, e.g., chloride and can provide an estimate of trend in ions levels. Overall, in 2016 the upstream reaches had lower conductivity results with higher results progressing downstream. Values ranged from 400 to 1300 µS/cm (Table 13). Throughout the years of monitoring, the specific conductivity appears to be consistent at most stations. Exceptions include HC-A(03), which appears to be trending to lower levels, and HC-A(12) and HC-A(14) which appear to be trending to higher levels (Figure 14), leading to the spatial pattern of low conductivity upstream and high conductivity downstream observed in the 2016 results.

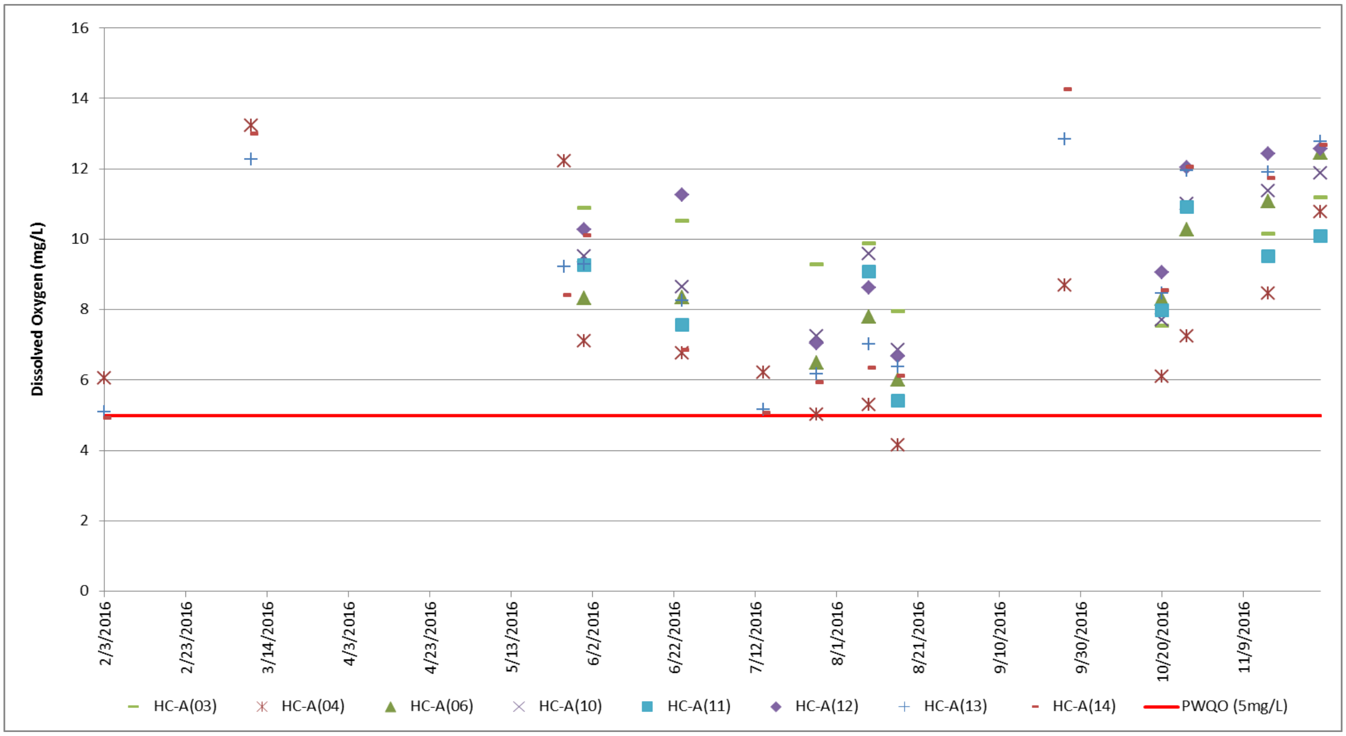


Figure 9. YSI Dissolved Oxygen Readings from 8 Monitoring Stations on Tributary A

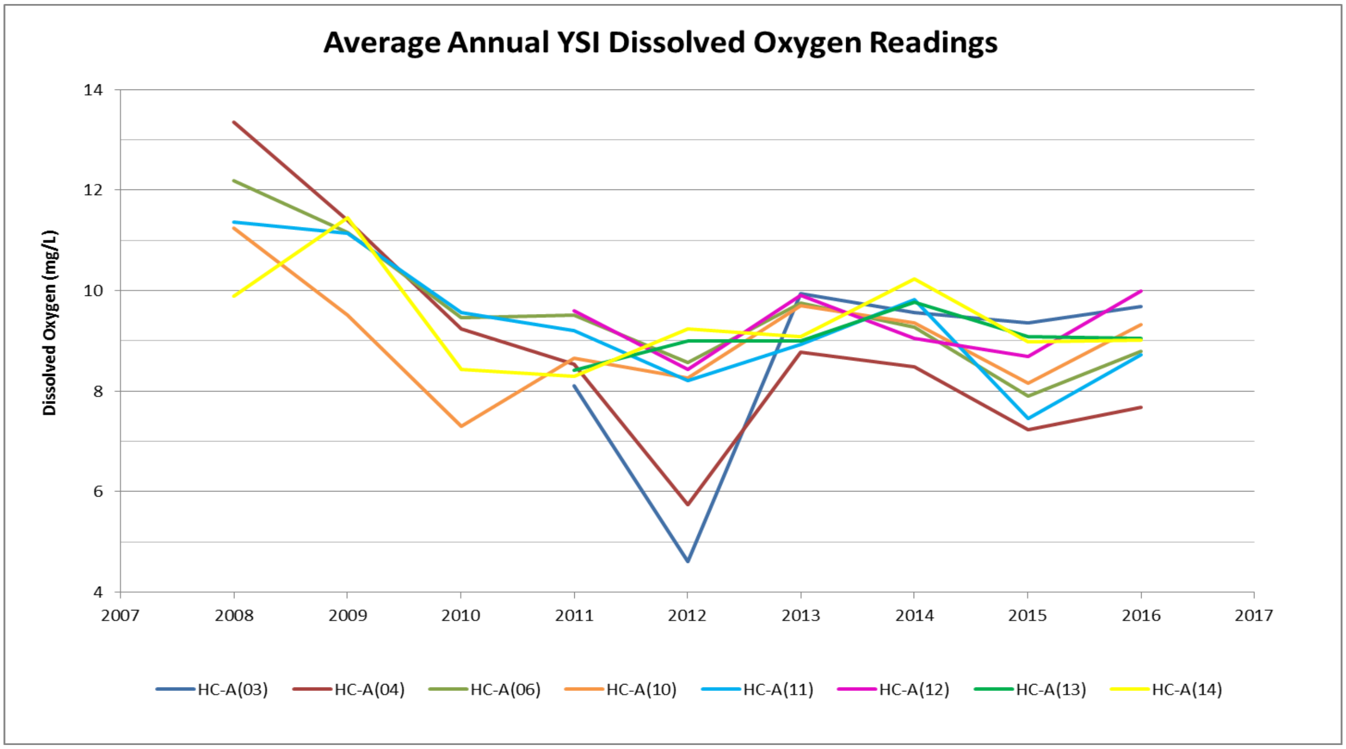


Figure 10. Average Annual YSI Dissolved Oxygen Readings from 2008 to 2016

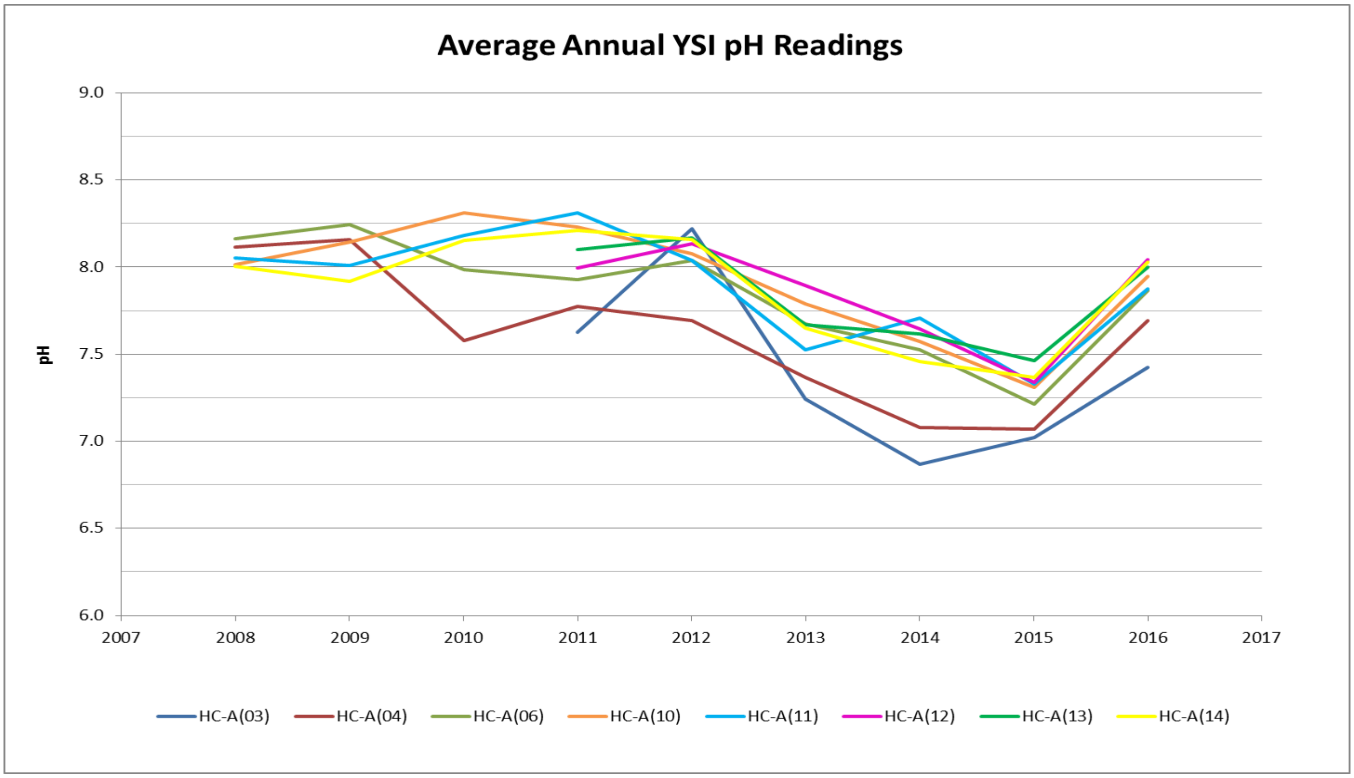


Figure 11. YSI pH Readings from 8 Monitoring Stations on Tributary A

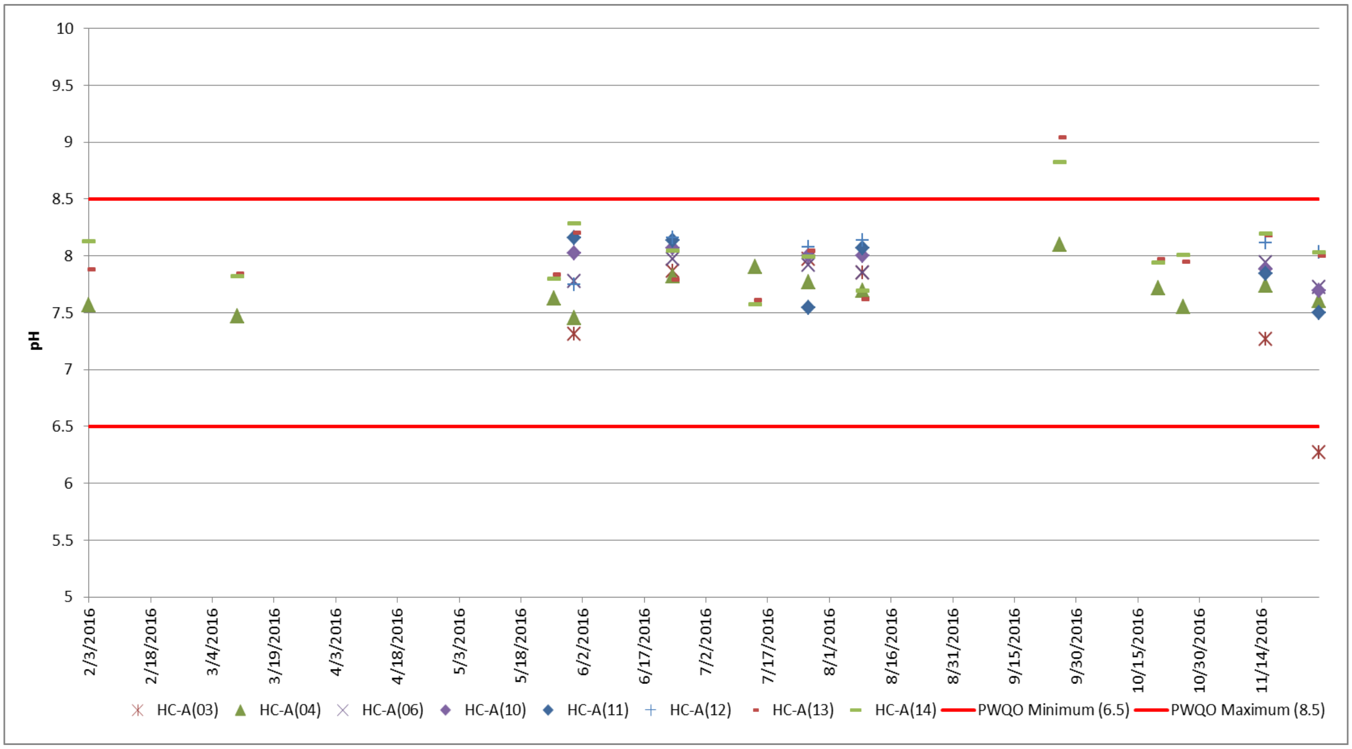


Figure 12. Average Annual YSI pH Readings from 2008 to 2016

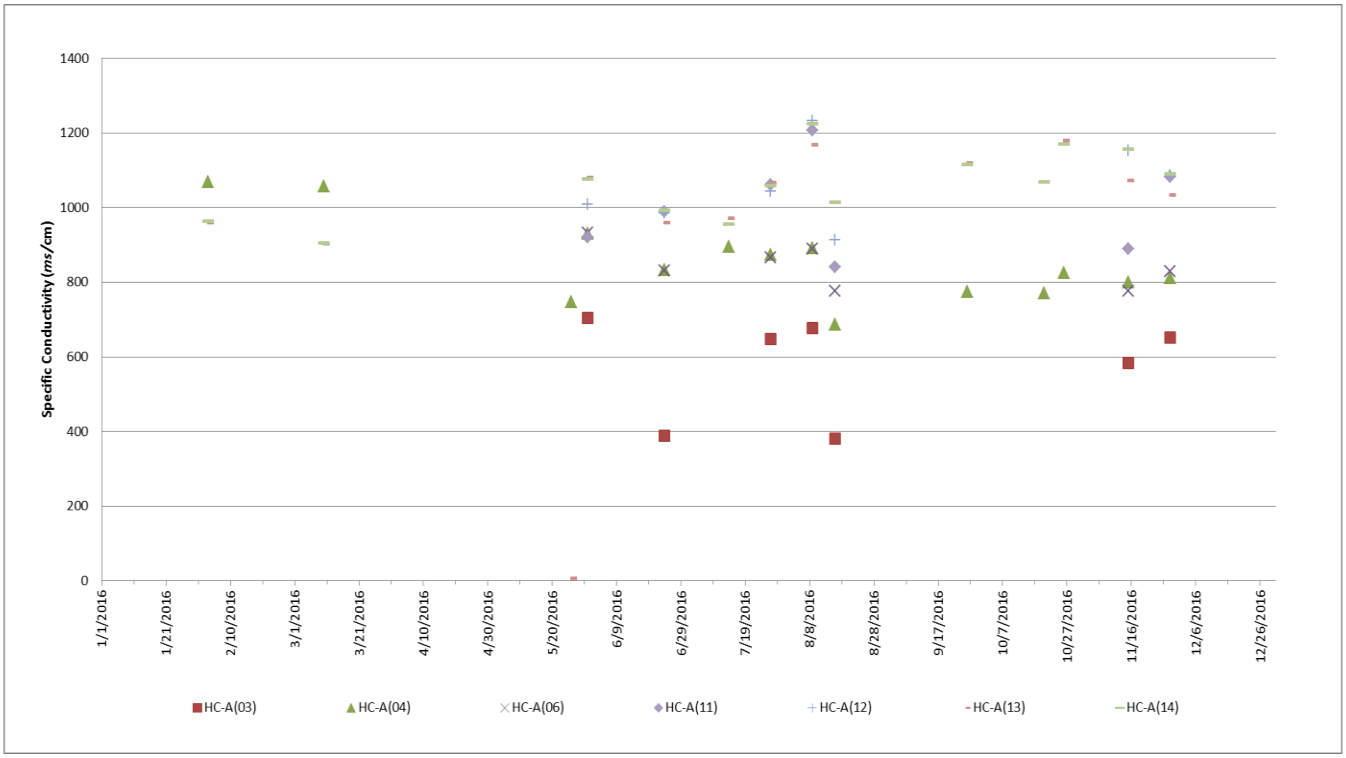


Figure 13. YSI Specific Conductivity Readings from 8 Monitoring Stations on Tributary A

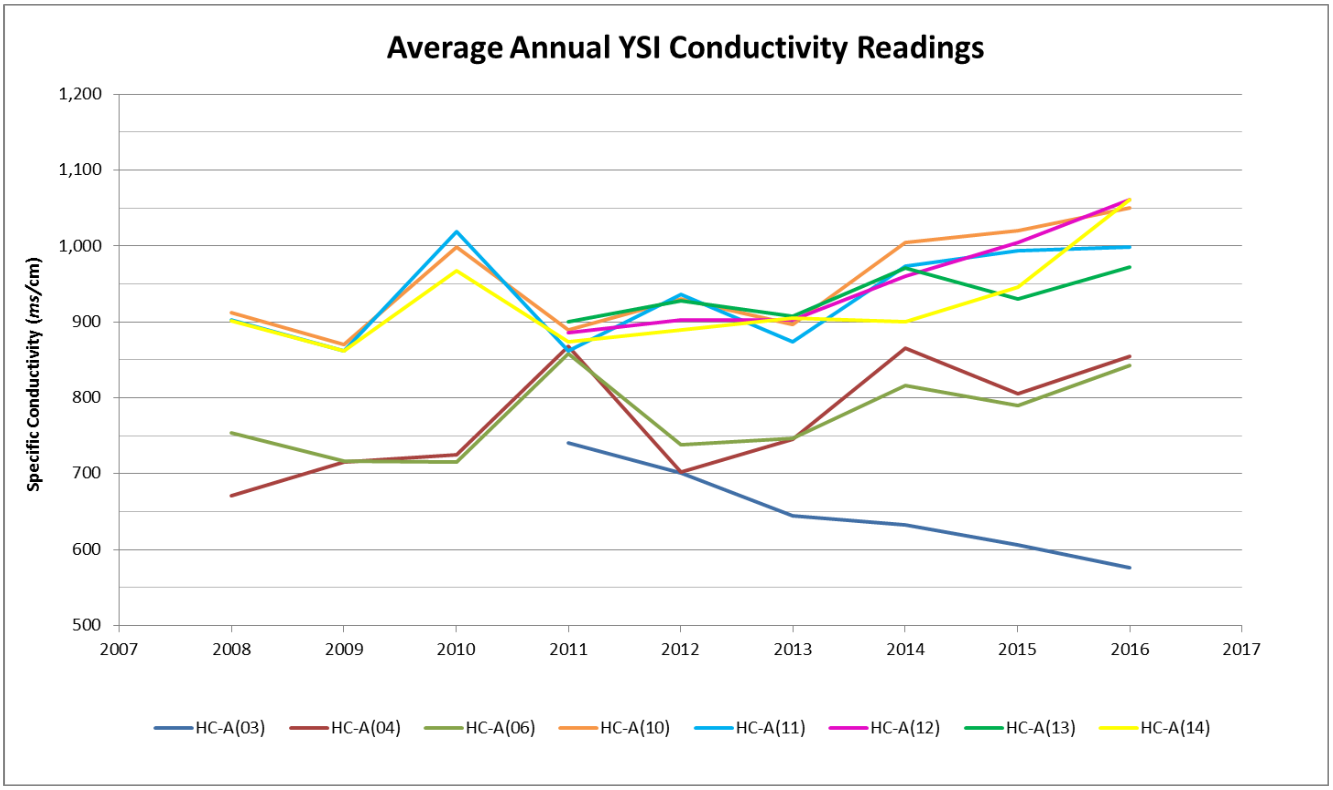


Figure 14. Average Annual YSI Conductivity Readings from 2008 to 2016

In 2016, four turbidity monitoring stations were installed along Hanlon Creek at stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14). Average and maximum turbidity at all stations appear to be approximately 6.3 and 27.9 NTU (in response to rainfall events), respectively. The PWQO for turbidity is based on Secchi depth readings not decreasing more than 10% due to the addition of suspended matter. Based on the CCME Guidelines for the Protection of Aquatic Life, it allows for a maximum increase of 8 NTUs from background levels for a short-term exposure and of 2 NTUs for long-term exposure. It appears that none of the stations experienced a dramatic increase from their respective baseflow (background) turbidity levels.

Some issues were encountered with the turbidity data. It appears that loggers at HC-A(11) and HC-A(14) were buried under sediment for extended periods causing the sensor to record maximum turbidity levels. During site visits turbidity sensors were checked and cleaned however sediment buildup in between visits occurred. There is also potential that biofouling and vegetation growth in the stream interfered with the sensor readings. Due to fouling occurring at stations HC-A(11) and HC-A(14) no conclusions can be made regarding turbidity conditions at these locations.

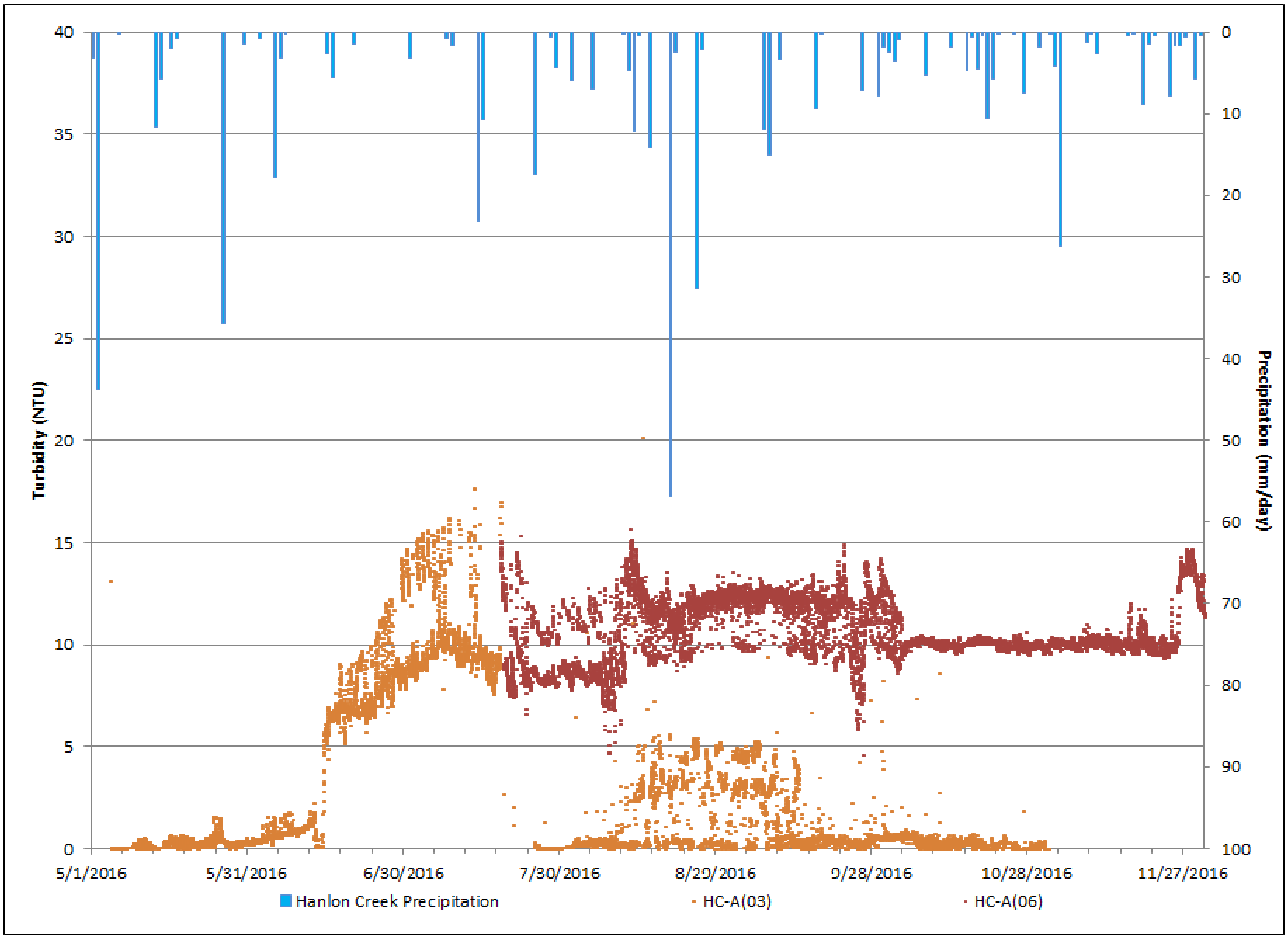


Figure 15. In-stream Turbidity Measurements for 2016

2.5.2.2 Stormwater Management Pond Water Quality

To establish the performance efficiency of the SWM facilities and to satisfy the MOECC Certificate of Approval, the water quality sampling program consists of grab samples at the inlet, outlet and downstream of each pond. Parameters that were analyzed in 2016 included:

- CBOD5
- Total Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Metals (total and dissolved, lead, zinc and copper)
- Escherichia coli
- Nitrate as N
- Chloride

The Consolidated Monitoring Program included the following water quality sampling requirements:

- One sample per season (Winter and Fall) within one hour commencement of a storm event;
- Five wet weather samples collected during summer months (June-September);
- One sample collected during the snowmelt freshets (Spring);
- Three dry samples taken 72 hours after a wet weather event

Eight wet weather samples were collected over the course of the 2016 monitoring season. Both the winter and spring freshet samples were collected. Five wet weather samples were collected between May and October 2016. The remaining wet weather sample was taken during the month of November. One dry sample was taken during the spring, summer and fall (three in total). From May to October, water levels at Pond 1 and 2 were too low prior to a rainfall event to result in stormwater being discharged from the outlet into Hanlon Creek Tributary A. Therefore, samples taken at Pond 1 and 2 were not taken during discharge events. As a result, the only interactions between these SWM facilities and Hanlon Creek Tributary A would have occurred though ground water interactions. Samples collected during non-discharge periods in the summer months were taken directly from the SWM facilities. As such, the water samples did not necessarily represent the water flowing into Hanlon Creek Tributary A. Pond 4 was discharging during the summer months and stormwater samples were collected from the pond outlet. The tabular results of the water quality sampling have been included in Appendix E of the surface water report (Appendix III of this report).

Water quality sampling results are presented as a number of exceedances as compared to the PWQO in Table K of the surface water report (Appendix III). A number of water quality parameters were typically higher in the SWM facilities with lower concentration in Hanlon Creek. E.Coli concentrations exceeded the recommended PWQO guidelines for recreational use for both wet weather and dry weather sampling events. Total phosphorus showed an overall reduction as the water moved though the pond. The instream phosphorus levels exceeded the PWQO during both wet and dry weather sampling events. However; this is not uncommon for streams in the Grand River watershed (GRCA, 2012). Nitrate, total suspended solids, copper and lead all showed higher concentrations entering the SWM facilities than the outlet samples. Aluminum, cadmium, copper, iron, lead, vanadium and zinc exceeded PWQO in the SWM facilities. However, instream levels did not exceed PWQO guidelines for aluminum or vanadium. Copper, iron, lead and zinc exceeded PWQO guidelines for both wet weather and dry weather sampling events at various inlet, outlet and instream stations (see Table 7). Zinc concentration both in the SWM facilities and instream exceeded the PWQO.

In 2011, the Canadian Council of Ministers of the Environment (CCME) set standards for Chloride exposure indicating increased risk of harm to aquatic life after long term exposure to concentrations above 120 mg/L and short term exposure to concentrations above 640 mg/L (CCME 2011). Chloride concentrations were typically higher at pond outlets and in-stream locations, compared to samples taken at pond inlets. However, inlet chloride levels sharply increased during winter sampling. All samples were below the short term exposure target of 640 mg/L. All ponds and stream locations recorded chloride level exceedances above the long term exposure target of 120 mg/L during the monitoring season.

Table 7. Number of Guideline Exceedances per Water Quality Sampling Location

			PWQO		**CCME**		**Number of Exceedances for Wet Weather Sampling Events**												**Number of Exceedances for Dry Weather Sampling Events**			**Total**
Analyte	**Units**	**LOR[1]**	**Lower Limit**	**Upper Limit**	**Short Term**	**Long Term**	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4 (04)	HC-P4 (05)	HC-A (04)	HC-A (13)	HC-A (14)	HC-A(04)	HC-A(13)	HC-A(14)	
Dissolved Oxygen(DO)	mg/L	0.05	5	-	-	-	2	1	2	1	2	2	1	1	0	0	0	1	1	0	0	14
pH	pH units	0.1	6.5	8.5	-	-	1	1	2	0	1	1	2	0	1	0	1	1	0	0	0	11
Chloride	mg/L	2	-	-	120	640	4	3	7	2	2	3	2	3	6	5	7	7	3	3	3	60
Total Phosphorus	mg/L	0.003	-	0.03	-	-	6	6	4	7	7	7	6	5	1	3	5	5	0	1	2	65
E. Coli	CFU/100mL	10	-	100	-	-	5	5	5	7	5	3	4	5	2	4	5	5	1	1	1	58
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	7	7	7	7	7	7	7	7	5	7	6	6	3	3	3	89
Arsenic (As) - Total	Mg/L	0.001	-	0.005	-	-	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	-	0	3	0	0	3	0	1	0	0	2	1	1	0	1	0	12
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	1	4	0	0	1	0	1	0	0	0	1	0	0	0	0	8
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	-	6	6	1	7	7	3	6	6	1	1	2	2	0	0	0	48
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	2	7	2	7	5	4	5	4	1	4	1	1	0	1	1	45
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	-	0	4	2	7	6	3	5	4	1	1	1	1	0	1	1	37
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0	2	0	0	0	0	4	0	0	0	1	0	0	0	0	7
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	-	1	4	2	6	5	0	1	4	1	7	1	1	3	1	1	38
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015*	-	-	4	6	3	7	7	6	6	6	1	0	0	0	0	0	0	46
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001*	-	-	7	7	5	7	7	7	6	6	2	6	4	4	1	1	1	71
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001*	-	-	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02*	-	-	0	0	0	0	0	0	0	0	0	7	0	0	2	0	1	10

Notes: [1] Limit of reporting (LOR)
- 8 Wet weather grab samples and 2 dry weather grab samples were collected
- Exceedances based upon the PWQO limits, Chloride exceedances were based upon the CCME short term level.
* Objectives for total metals.

2.6 Aquatic Habitat and Biota

Aquatic monitoring was conducted for the benthic invertebrate and fish community within Tributary A and Tributary A1 of Hanlon Creek. Monitoring in 2016 was conducted at five different sites, each with a benthic invertebrate sampling station and a quantitative fish sampling station. Aquatic habitat information was collected at each station. Brook Trout spawning surveys were conducted on three separate occasions in fall 2016 along sections of Tributary A and Tributary A1. Locations of the ten sampling stations are shown on Map 5, along with the Brook Trout spawning search area.

To assess the benthic invertebrate community, several indices were calculated to provide a characterization of the community at each station and to allow for comparisons across years. The indices calculated for 2016 include the Percent Model Affinity (PMA) index, which generates Percent Similar Community (PSC) values. Values that are higher than the critical PSC value indicate no impact, while values that are lower than the critical PSC value indicate impact at that station. Other indices were taxonomic richness, Ephemeroptera, Plecoptera and Trichoptera (EPT) richness, and percent dominant taxon.

To assess the fish community, multi-pass electrofishing surveys were conducted. This involved isolating a section of stream using nets and electrofishing that section multiple times until there was a decline in the number of fish captured in subsequent passes with the electrofisher. Following the identification and enumeration of the catches, population estimates were calculated for the five monitoring stations using a maximum likelihood constant P method (Schnute 1983).

Detailed results from the aquatic monitoring program are provided in the 2016 aquatic monitoring report prepared by NRSI (Appendix IV) and are summarized and discussed in Sections 2.6.1 and Section 2.6.2 below.

2.6.1 Benthic Community

The benthic invertebrate index results are shown on Figures 16 (taxa richness), 17 (EPT Taxa Richness) and 18 (Proportion of dominant taxon), and in Table 8 (PMA analysis).

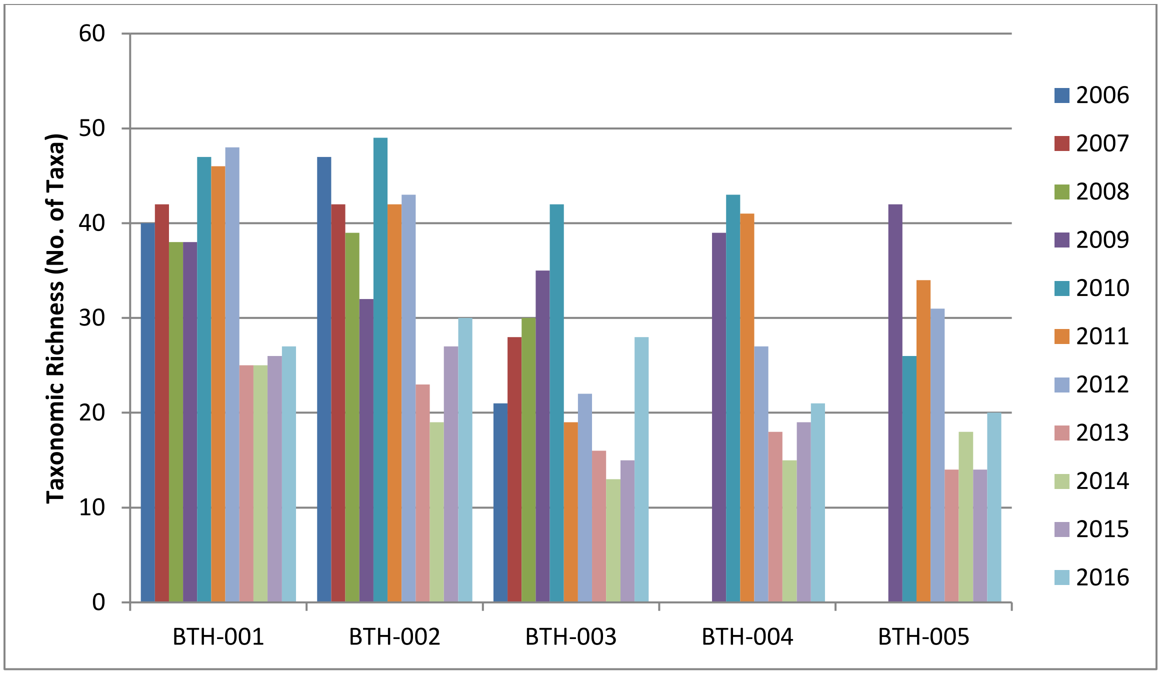


Figure 16. Benthic Invertebrate Taxonomic Richness for the Years 2006 to 2016

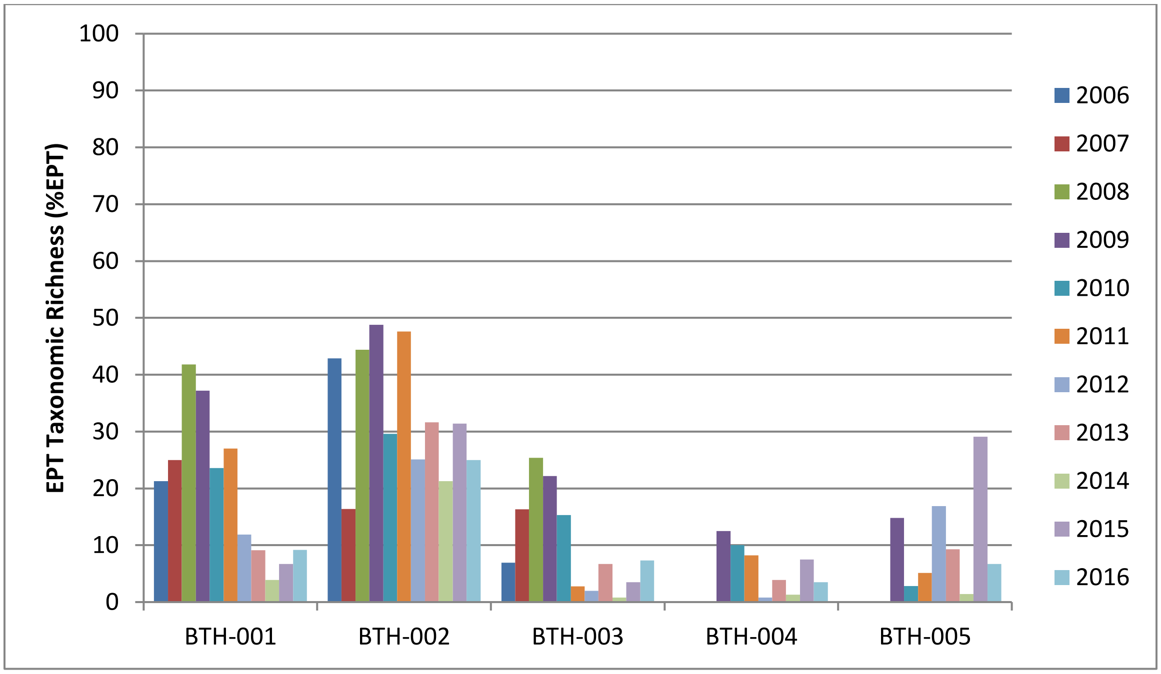


Figure 17. Benthic Invertebrate EPT Taxa Richness for the Years 2006 to 2016

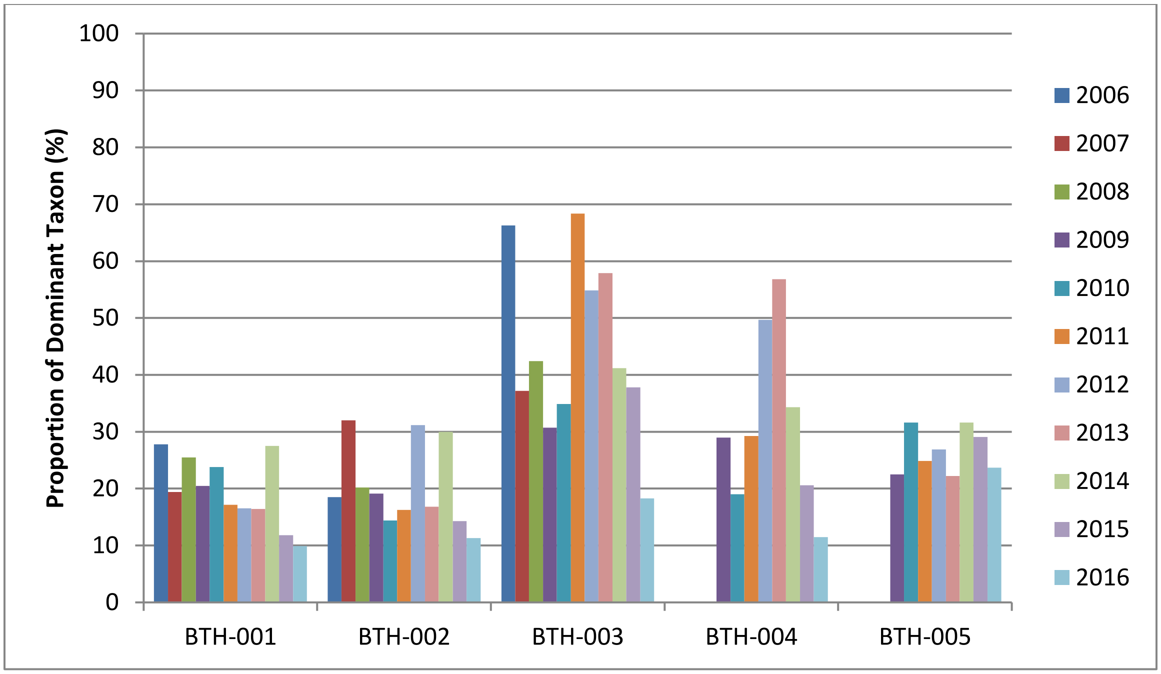


Figure 18. Benthic Invertebrate Proportion of Dominant Taxa for the Years 2006 to 2016

Table 8. Percent Similar Community Values and Impact Determination

Station	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 Critical PSC	2016 Sample PSC	2016 Result
BTH – 001	NI	NI	NI	NI	NI	NI	NI	NI	NI	I	42.12	47.60	NI
BTH – 002	I	NI	I	I	NI	I	I	I	I	I	50.7	29.6	I
BTH – 003	NI	NI	NI	NI	NI	NI	I	I	NI	NI	42.12	59.42	NI
BTH – 004	-	-	-	NI	NI	NI	I	I	I	NI	42.12	57.36	NI
BTH – 005	-	-	-	NI	NI	NI	NI	NI	I	I	42.12	56.17	NI

NI – No Impact
I – Impact

Station BTH-001

Taxonomic richness at station BTH-001 has varied from 25 to 48 over the 11 years of monitoring. Between 2006 and 2012 the taxa richness at this station remained fairly consistent with an increase observed in 2010. The highest taxa richness occurred in 2012 with a high of 48 (Figure 16). In 2013 and 2014, taxonomic richness was 25 for each of those years. These values were lower due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. In 2015 and 2016, taxa richness remained relatively low for station BTH-

001, with only a slight increasing trend in spite of the genus-level identification of all specimens. The years 2015 and 2016 have notably lower taxa richness compared to other years of monitoring, although not low enough to trigger a threshold exceedance at any point in time.

The EPT richness at BTH-001 has varied greatly between 2006 and 2016. Pre-construction values ranged from a low of 21.3% in 2006 to a high of 48.1% in 2008, which appeared to be uncharacteristically high for this station (Figure 17). Following 2008 the EPT richness has declined to below 10% with the lowest EPT richness (3.9%) occurring in 2014. The EPT richness increased slightly in 2015 and then again to 9.2% in 2016, but overall remains lower than what had been observed during pre-construction monitoring.

The dominant taxon in 2016 was *Chironomus*, belonging to the family Chironomidae (midges) and sub-family Chironominae of the order Diptera (true flies). Species belonging to this sub-family may be associated with a variety of habitats but can generally be found in the littoral and profundal areas of lentic systems as well as the depositional areas of lotic systems (Merritt et al. 2008), typically associated with finer substrates including silt and sand. The conditions at station BTH-001 are consistent with this generalized habitat description providing silt, sand and gravel substrates, as well as moderately abundant detritus and woody debris. *Chironomus* can occur in systems with poor water quality and severe organic pollution (Mandaville 2002). This species represented 9.9% of the total number of individuals within the sample in 2016 (Figure 18). Species of Dipterans (true flies) have also previously comprised large proportions of the samples at BTH-001, and did again in 2016 with approximately 68% of the sample contributed to Dipteran species. Dipteran species previously dominated the samples in 2006, 2007, 2013, and 2014. Previously observed dominant taxa have also included a species of caddisfly (Trichopteran) of the family Hydropsychidae in 2008 and 2009. Families that have also historically been found at BTH-001 include Amphipods (*Gammarus pseudolimnaeus*), Isopods (*Caecidotea intermedius*), and Coleopterans (*Optioservus fastiditus*). These species have all historically comprised a large proportion of the samples at this station and have dominated the samples during different years from 2010 to 2012. A species of Megalopteran of the family Sialidae dominated the sample in 2015.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 47.6 was higher than the critical PSC value of 42.12 (Table 8). The PMA index has consistently shown ‘no impact at BTH-001 with the exception of 2015, which was the first year the results have shown an ‘impact’ determination. A decrease in EPT species at this site between 2012 and 2014 indicated a potential change in conditions, and continued low EPT richness combined with the PMA impact determination in 2015 suggests that conditions may be changing.

Station BTH-002

Taxonomic richness at station BTH-002 was 30 in 2016 Figure 16. Results show an increase trend following two consecutive years of decreasing taxa richness in 2013 and 2014. In 2013 and 2014, taxonomic richness was 23 and 19, respectively for each of those years. These values were lower than previous years due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. An increasing trend is noted for 2015 and 2016 with the taxa richness in 2016 approaching a similar number to what was observed during pre-construction monitoring in 2009. Generally, it appears that taxonomic richness has continued to be fairly consistent at BTH-002.

The EPT richness was 25% in 2016, a decrease from 31.4% in 2015 but generally similar to what has been observed since 2012 (Figure 17). This metric has shown no obvious increasing or declining trends. EPT richness has frequently been high (above 40%) with large declines noted in 2007 (16.4%), 2010 (29.6%), and most recently in 2012. Further to this, it has never experienced declining richness values over consecutive years. The lowest levels in EPT richness at BTH-002 were seen during a pre-construction year in 2007 indicating that the observed declines in EPT taxa are within the natural variations of the station. Station BTH-002 has consistently shown the highest EPT richness values of the five monitoring stations.

The dominant taxa at station BTH-002 in 2016 belonged to the family Sialidae of the order Megaloptera (Alderfly). Species belonging to this family may be associated with a variety of substrates and current types and are exclusively predatory (Merritt *et al*. 2008). The conditions at station BTH-001 are consistent with this generalized habitat description providing substrates that include gravel and cobble, as well as moderately abundant detritus and woody debris. Sialidae are considered to be indicative of very good water quality with only slight organic pollution (Mandaville 2002). This species represented 11.3% of the total number of individuals within the sample (Figure 18) and has also dominated the sample in 2006. Species belonging to the family Elmidae (riffle beetle) from the order Coleoptera dominated the sample in 2015 and represented a large proportion of the sample again in 2016. Prior to 2015 *Gammarus pseudolimnaeus* had been the dominant taxa at this station between 2012 and 2014. The result for % dominant taxon has generally been lower at this station over the years of monitoring with 2007, 2012 and 2014 being relatively high (32.0%, 31.2% and 30.0%, respectively). The dominant taxonomic group has changed several times at BTH-002 including *Micropsectra sp.* (Diptera) in 2007 and 2008, *Cheumatopsyche spp.* (Trichoptera) in 2009, and *Leuctra spp.* (Plecoptera) in 2010 and 2011. In 2013 two species dominated the sample including *G. pseudolimnaeus* and *Diplectrona modesta*, a species of Trichoptera. EPT species, and specifically Trichopteran species, have typically been well represented within the sample at BTH-002 over the years and were again in 2016 including species of Hydropsychidae and Philopotamidae. The site characteristics associated with BTH-002 are well suited for EPT including gravel and cobble riffles. In 2016, a large branch had fallen across the channel approximately halfway up the site and created a slight backwater effect, leading to an accumulation of silt and detritus upstream. This may affect the proportion of EPT species over time.

The PMA index in 2016 showed ‘impact’ for the sixth consecutive year. Results since pre-construction monitoring began in 2006 have been inconsistent up until 2011 with results showing no reliable trend of ‘impact’ or ‘no impact’. Since 2011 results have consistently indicated ‘impact’, which has been the most common result, with ‘no impact’ observed only two out of ten years of monitoring (2007 and 2010) (Table 8). Continuation of the ‘impact’ determinations suggests that some change has occurred, although it may not be a major change. Taxonomic richness and % EPT are somewhat lower in recent years, corroborating the PMA results. Monitoring using the PMA analysis should continue with the intention of determining whether or not a ‘no impact’ determination is observed again. The other metrics should also be considered along with the results of the PMA analysis.

Lastly, the predominance of the ‘impact’ result should not be construed to mean that station BTH-002 is in poorer condition than the other stations. This station is the only station that uses the cobble/gravel model community for PMA index, and it was chosen based on the habitat characteristics of the station. Because of this difference, comparisons among the other four stations using the PMA index are not valid. The monitoring program is intended to provide temporal comparison within stations.

Station BTH-003

Taxonomic richness at station BTH-003 was 28 in 2016. This is a substantial increase from 15 in 2015 (Figure 16) and higher than has been observed annually since 2011. Taxa richness has experienced a general decrease that began in 2011, which followed an exceptionally high year in 2010 where the richness was 42. The lowest result occurred in 2014 with a value of 13. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. Over the 5 years of monitoring prior to 2011 species richness had increased steadily by 50%, beginning in 2006 with a measure of 21 and increasing to 42 in 2010. The results observed in 2011 and 2012 appeared to be a return to the degree of taxonomic richness that was observed during pre-construction monitoring. In 2016 taxa richness was noted to increase substantially with numbers similar to pre-development values.

The EPT richness was 7.3% in 2016, an increase from 3.5% in 2015 and 0.8% in 2014 (Figure 17). Results have varied throughout the years with an increasing trend observed during the first three years of monitoring and a decreasing trend between 2008 and 2014. The EPT richness values seen between 2011 and 2015 generally show levels that were lower than results from pre-construction monitoring, with the exception of 2013 which saw an increase to pre-construction levels. The result from 2016 marks the second consecutive increase in EPT at BTH-003 and a value that is the highest that has been observed since 2010 and slightly higher than the preconstruction value of 6.9%, observed in 2006.

The dominant taxon in 2016 was *Gammarus pseudolimnaeus*, which comprised 18.3% of the total sample (Figure 18). This marks the fifth consecutive year that *G.*

pseudolimnaeus has been the dominant species at BTH-003 comprising between 37.8% and 68.4% of the samples since 2012. *G. pseudolimnaeus* prefers soft substrates and the shallow areas of both lotic and lentic environments. The preference of this species for depositional areas explains its abundance at station BTH-003 as this station occurs in a slow-flowing, groundwater-fed headwater tributary with abundant detritus and underlying substrates dominated by silt and clay. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). Prior to 2012, the dominant taxon was *Micropsectra* spp., a Dipteran species that had previously been the dominant taxon throughout all six years of pre-construction monitoring. In 2015 a variety of Chironomid species comprised the majority of the subdominant groups including several species belonging to the *Prodiamesinae* and *Orthocladiinae* subfamilies. The 2016 dominant taxa value marks the lowest that has been observed since sampling began. The dominant taxa values at BTH-003 has typically been the highest observed across the site with *G. pseudolimnaeus* comprising the majority of samples. The low value in 2016 indicates a potential shift in the dominant taxa as the subdominant taxa comprised larger proportions of the sample.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 59.4 was higher than the critical PSC value of 42.12 (Table 8). The result of ‘no impact’ is consistent with the results from 2014 and 2015. This is a change from 2012 and 2013, both of which showed ‘impact’. Prior to 2011 the results suggested that habitat and/or water quality conditions at station BTH-003 were generally improving as evidenced by a consistent increase in species diversity (taxonomic richness) and a similarly consistent result of ‘no impact’. Results in 2011 and 2012, however, suggested a change in the habitat conditions at this site leading to results that are similar to those observed in 2006. This was demonstrated through a decrease in taxonomic richness and EPT taxa richness, and a large increase in the proportion of the dominant taxon, *Micropsectra* spp in 2011, and *G. pseudolimnaeus* in 2012 and 2013. However, since this change was consistent with pre-construction monitoring results in 2006, it was attributed to natural variation. Results in 2015 and 2016 show increases in taxa richness and EPT richness, which suggest an improvement in water quality.

Station BTH-004

This was the eighth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-004 was 21 in 2016, a slight increase from 19, which was observed in 2015 and 15 in 2014, was the lowest taxa richness observed to date (Figure 16). The highest taxa richness at BTH-004 was 43 in 2010 although results in 2009 and 2011 were similarly high. A decrease in taxa richness at BTH-004 began in 2010 and continued to 2014. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae, compared to genus-level identification for all other years. In 2015 and 2016 taxa richness was noted to remain relatively low overall with a slight increase between years.

The EPT richness was 3.5% in 2016, a decrease from 7.5% in 2015 (Figure 17). Since 2012 the EPT richness values have been up and down but have overall been relatively low in relation to the other four monitoring stations. The highest proportion of EPT taxa (12.5%) occurred in 2009 while the lowest occurred in 2012 with a value of 0.78%. A trend of decreasing EPT richness was observed between 2009 and 2012, however since then no consistent trends have been observed.

The dominant taxon at BTH-004 in 2016 was *Prodiamesa sp.*, a species of Diptera belonging to the sub-family *Prodiamesinae*. Species belonging to this sub-family are generally associated with the erosional and depositional areas of lotic systems (Merritt et al. 2008). The conditions at station BTH-004 are consistent with this generalized habitat preference providing silt and sand substrates, as well as moderately abundant detritus and woody debris. *Chironomus* can occur in systems with poor water quality and severe organic pollution (Mandaville 2002). This species represented 11.5% of the total number of individuals within the sample in 2016 (Figure 18). *Gammarus pseudolimnaeus* was the dominant taxa at this site for the four consecutive year (between 2012 and 2015), although its proportion within the sample had decreased by over 35.0% since 2013. In 2016 *G. pseudolimnaeus* maintained a relatively high abundance and was the subdominant family, representing 11.2% of the sample. Prior to 2012, the dominant taxa was identified as *Caecidotea intermedius*, a species of aquatic sowbug, which dominated the sample in 2010 and 2011. Both *C. intermedius* and *G. pseudolimnaeus* inhabit shallow waters where detritus is present and are likely to coexist in such habitat.

Several other species of Chironomid also comprised large proportions of the sample at BTH-004 in 2016 including *Chironomus sp.* and *Polypedilum sp.*, both taxa belonging to the subfamily Chironominae.

The PMA index showed 'no impact' in 2016 as the calculated PSC value of 57.36 was higher than the critical PSC value of 42.12 (Table 8). This is the second consecutive year of a 'no impact' determination following three consecutive years of 'impact' (2012, 2013, and 2014) which resulted in two years of threshold exceedances at this station. Prior to 2012 the PMA analysis had shown 'no impact', which is the most consistent determination for BTH-004.

Station BTH-005

This was the eighth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-005 was 20 in 2016, an increase from 14 in 2015 (Figure 16). This is the highest value that has been seen since the substantial decline from 31 in 2012 to 14 in 2013. These results continue to be considerably lower than what was generally observed at this station prior to 2013. A threshold exceedance was observed in 2013 following a decrease from 42, the highest value that has been noted at this site, to 14, the lowest that has been observed. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae, compared to genus-level identification for all other years. In 2015 and 2016 taxa richness remained relatively low overall with an increase observed in 2016.

In 2016 the EPT taxonomic richness experienced a decrease at BTH-005 following a substantial increase between 2014 and 2015 (1.4% to 29.1%). In 2016 the richness decreased from 29.1%, the highest observed at this station, to 6.7%. The EPT richness values at BTH-005 have fluctuated since 2006 with no obvious trends observed (Figure 17). The highest results have been observed in 2009, 2012 and 2015 while low results were observed in 2010, 2011, and 2014. The 2016 value is roughly average for the station.

The dominant taxon at BTH-005 was *Gammarus pseudolimnaeus* in 2016, similar to what was observed at BTH-003 and BTH-004. *G. pseudolimnaeus* represented 23.7%

of the total sample in 2016 (Figure 18). The habitat preferences of this species are consistent with the habitat characteristics of BTH-005, which is largely comprised of silt and sand along with detritus and some woody debris. This was the dominant species in 2014 and 2015 at this station as well. Prior to 2014 the dominant taxa had been *Caecidotea* sp., which includes a variety of sowbug species (Asellidae spp.). In 2014 and 2015 this species continued to comprise a large proportion of the sample. In 2015 the subdominant species was a species of Trichoptera (caddisfly) belonging to the family *Hydropsychidae*. Both the dominant and subdominant species observed at BTH-005 in 2015 are indicative of very good water quality (Mandaville 2002). Several species of Chironomid comprised a large proportion of the sample at BTH-005 in 2016 as well, including species of the subfamilies Chironominae and Prodiamesinae.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 56.17 was higher than the critical PSC value of 42.12 (Table 8). Results from 2014 and 2015 showed ‘impact’ for two consecutive years, which resulted in a threshold exceedance in 2015. Between 2009 and 2013 results had consistently shown ‘no impact’, which was again seen in 2016. Overall the results suggest an improvement in the conditions at BTH-005.

2.6.2 Fish Community

During 2016 construction-phase aquatic monitoring a total of 448 individual fish were captured representing nine different species: Blacknose Dace (*Rhinichthys obtusus*), Brook Stickleback (*Culaea inconstans*), Central Mudminnow (*Umbra limi*), Creek Chub (*Semotilus atromaculatus*), White Sucker (*Catostomus commersonii*), Fathead Minnow (*Pimephales promelas*), Northern Redbelly Dace (*Chrosomus eos*), Pumpkinseed (*Lepomis gibbosus*), and Mottled Sculpin (*Cottus bairdii*). The total catch in 2016 was slightly lower than the 481 fish captured in 2015 but was almost identical to 2014 sampling when 451 fish were captured. It appears that the numbers of fish across the Hanlon site have stabilized over the past three years following an uncharacteristically high catch of 735 fish in 2013. Prior to 2013 the total catches ranged from 92 in 2006 to 260 in 2012. All nine fish species captured in 2016 are known previously from the monitoring program and have been captured frequently over the years, with the exception of Pumpkinseed, which was only captured previously in 2014. The majority of the species exhibit a cool-water thermal regime with Fathead Minnow and Pumpkinseed exhibiting a warmwater thermal regime and Mottled Sculpin exhibiting a coldwater thermal regime (Eakins 2017). Population estimates are provided in Figure 19, and results are discussed below. Similar to previous years, no Brook Trout were captured during 2016 fish community sampling.

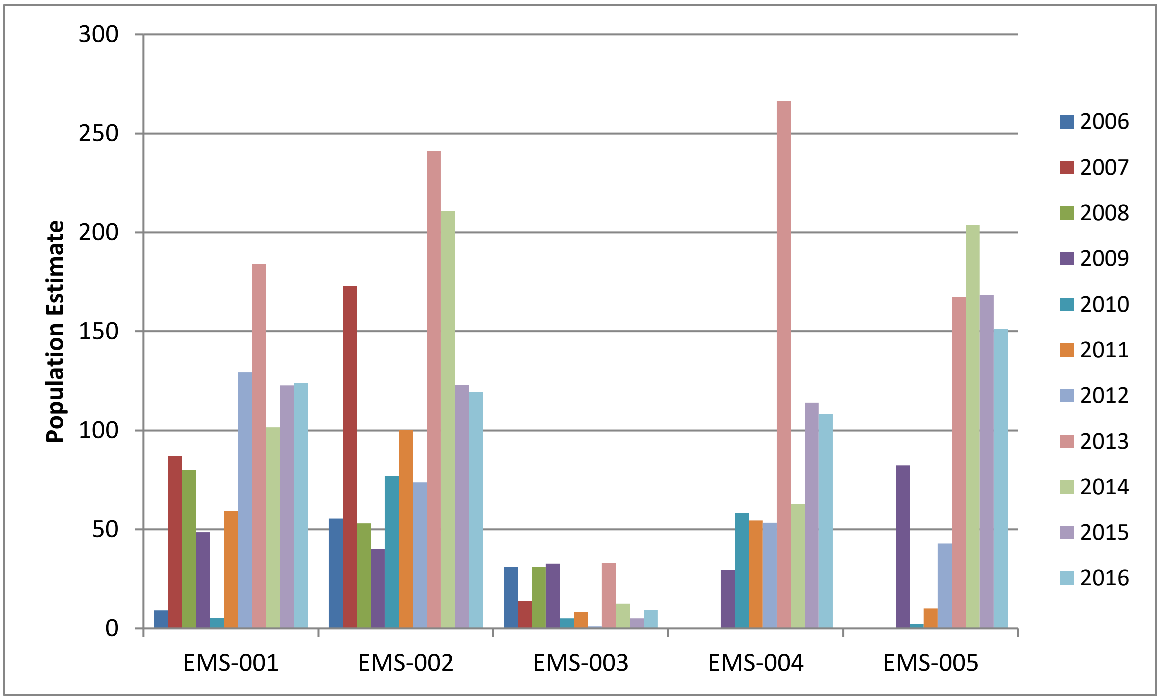


Figure 19. Population Estimates at Electrofishing Stations for the Years 2006 to 2016

Station EMS-001

Electrofishing in 2016 resulted in the capture of five species; Blacknose Dace, White Sucker, Brook Stickleback, Northern Redbelly Dace, and Creek Chub. A combined total of 118 individual fish were captured through a total of three passes, slightly higher than 116 from 2015. All species have been captured previously at EMS-001 with Blacknose Dace being the only species captured every year since sampling began in 2006. Fathead Minnow has also been previously captured at this station but was absent in 2016. This site has typically seen between three and five species with only two species being captured in 2015.

Fish population estimates at this station have varied greatly between 2006 and 2016, and have generally been higher during construction-phase monitoring beginning in 2010 than they were during pre-construction monitoring prior to 2010. The lowest population estimate was observed in 2010, which was estimated at 5. This result was similar to the low population estimate observed in 2006. In 2013 the population was estimated at 184, the highest that has been observed at the site. This was attributed to increased baseflows following a year of above-average precipitation. Following 2013 the population estimates have remained between 100 and 125 and appear to be relatively stable.

Station EMS-002

Electrofishing in 2016 resulted in the capture of seven fish species and combined for a total of 101 individual fish over three passes. The species captured were Blacknose Dace, Brook Stickleback, Mottled Sculpin, Fathead Minnow, White Sucker, Central Mudminnow and Creek Chub. Blacknose Dace and Brook Stickleback have been captured at this station every year while Creek Chub have been captured sporadically. Central Mudminnow and White Sucker have also been previously captured throughout the years at this station. Mottled Sculpin (*Cottus bairdii*), a coldwater species was also captured at this site in 2011. This is the first year that Fathead Minnow, a warmwater species, has been captured at this monitoring station. However, Pumpkinseed, also a warmwater species, was captured here in in 2014. Fathead Minnow have also been captured on site in the past at EMS-001 and EMS-005 in 2011 and 2013, respectively. The detailed results are provided in Table 14. This site has typically seen between three or four species with five species being captured in 2013 and six species captured in 2014.

The estimated fish population at EMS-002 has exhibited no obvious trend since sampling began in 2006. The estimated numbers have experienced a great deal of variation with the lowest estimate occurring in 2009 (approximately 40) and the highest estimate of approximately 241 occurring in 2013. The estimate observed in 2016 is similar to what was seen in 2015, which followed a decrease from 2013 and 2014 numbers but continue to remain above most of the previous years.

Station EMS-003

Electrofishing in 2016 resulted in the capture of three fish species and a combined total of 9 fish over three passes. The species captured were Blacknose Dace, Creek Chub and Brook Stickleback. Electrofishing results at this station continue to indicate a low diversity of species relative to the other stations as only the three species captured in 2016 have been captured here since 2006. Blacknose Dace and Brook Stickleback have been captured consistently while Creek Chub has only been captured at this station previously in 2006.

Population estimates at EMS-003 have been consistently low relative to the other stations within the HCBP study area. The estimate calculated in 2016 shows a slight increase from 2015 but a similarly low estimate to what has been observed at this station since 2010, with the exception of a high year in 2013. Overall, the pre-construction population estimates have been generally higher than during-construction.

Station EMS-004

Electrofishing took place at this site for the first time in 2009 and it has been sampled every year since. Electrofishing in 2016 resulted in the capture of three fish species and a combined total of 93 fish over three passes. The species captured included Blacknose Dace, White Sucker, and Creek Chub. Blacknose Dace and Creek Chub have been consistently captured over the previous years of monitoring. White Sucker has also been previously captured at this station in 2013. This site has typically seen three or four species with five species being captured in 2013.

Fish population estimates remained relatively consistent at EMS-004 between 2009 and 2012 ranging from approximately 29 to 58. In 2013 the population estimate increased substantially to 266, the highest estimate recorded at any of the five stations since sampling began in 2006. In 2014 the numbers decreased to more typical levels before increasing again to 114 in 2015. The population estimate of 108 is similar to what was observed in 2015 and is generally higher than previous results.

Station EMS-005

Electrofishing took place at this site for the first time in 2009 and has been sampled every year since. Electrofishing in 2016 resulted in the capture of six fish species and a combined total of 127 individual fish over four passes. The species captured included Blacknose Dace, Central Mudminnow, Creek Chub, Northern Redbelly Dace, Pumpkinseed, and White Sucker. Prior to 2013, this station typically contained between two and three species. In 2013, seven species were captured here including Fathead Minnow, Northern Redbelly Dace and White Sucker. White Sucker has been captured at this site every year since 2013 while Fathead Minnow and Northern Redbelly Dace have been absent. Blacknose Dace has been captured during every year of sampling at this station. Brook Stickleback, Central Mudminnow and Creek Chub have also been captured regularly throughout previous years of monitoring.

The population estimate at station EMS-005 in 2016 was 151, a slight decrease from 2015 and a second consecutive year of decrease following 2014, which has the highest estimate that has been observed at EMS-005 (204). This marks a continued decline following four consecutive years of increasing estimates that started in 2010 with a low of approximately 2. The population estimate at EMS-005 in 2016 was the highest observed across any of the five monitoring stations within the HCBP.

Brook Trout Spawning Survey

During the fall of 2016 Brook Trout spawning surveys were conducted along a section of Tributary A and along Tributary A1 (refer to Map 5) to document Brook Trout spawning activity. Throughout the surveyed reaches the habitat was variable from silt and muck to cobble and gravel. The majority of the site, and particularly along Tributary A1 and at the downstream extent of Tributary A was deemed to be unsuitable for Brook Trout spawning due to the presence of silt and muck. The most suitable areas for Brook Trout spawning were observed upstream and downstream of the Hanlon Creek Boulevard crossing. At this location, substrates were predominantly gravel and small cobble and the presence of groundwater infiltration was noted. Three spawning surveys were conducted throughout October and November and no evidence of spawning activity was observed, which is consistent with previous years.

2.7 Terrestrial Habitat and Biota

Since 2006, the terrestrial and wetland monitoring program has focused on plot-based surveys to document breeding amphibians, breeding birds and vascular flora (herbaceous, shrubs and trees) as well as incidental wildlife throughout the property. Soils information was collected from each of the monitoring plots between 2006 and 2014.

For plot set-up and annual monitoring survey methods, the reader is referred to the HCBP Terrestrial and Wetland Monitoring Report (Appendix V). In addition, the Standard Operating Procedures for the vegetation, breeding birds and amphibians are found in the *HCBP Consolidated Monitoring Program* (NRSI 2010). The monitoring stations are shown on Map 6 of this report.

Detailed results for the terrestrial habitat and biota are given in the 2016 terrestrial and wetland monitoring report prepared by NRSI (Appendix V). The results are summarized and discussed below.

2.7.1 Vascular Flora

In 2016, a total of 127 vascular flora species were documented during the plot-based monitoring. Overall, 262 different species have been observed in the vegetation monitoring plots. In 2016, vegetation surveys documented 4 species not previously recorded (Table 9).

Table 9. Vegetation Species Not Previously Recorded at the HCBP

Common Name	Scientific Name	Plot Occurrence
Cleavers	*Galium aparine*	1
Woodland Horsetail	*Equisetum sylvaticum*	2
Bearded Shorthusk	*Brachyelytrum erectum*	4
Bristle-stalked Sedge	*Carex leptalea*	4

A total of 14 regionally significant species have been observed in the plots between 2006 and 2016. In 2016, Woodland Horsetail, Meadow Horsetail (*Equisetum pratense*), Rough Avens (*Geum laciniatum*) and Clearweed (*Pilea pumila*) were observed and are considered rare within Wellington County. None of the species observed are federally or provincially significant.

Refer to Map 6 for locations of vegetation monitoring stations, and the 2016 terrestrial and wetland monitoring report (Appendix V) for a comprehensive list of the vegetation species observed from 2006 to 2016.

2.7.1.1 Floristic Indices

A common method for evaluating and assessing natural areas is using floristic composition. This method is based on the character of a region's flora. There are several floristic indices which can be used to describe the character of the vegetation in the plot. These include the Coefficient of Wetness (CW), the Coefficient of Conservatism (CC), and the Natural Area Index (NAI). All species (herbs, shrubs, and trees) from each plot are considered in these equations.

Coefficient of Wetness

The CW is based on wetland values given to each individual plant species. Values range from -5 to +5, where -5 indicates an obligate wetland species, and +5 indicates an obligate upland species. "0" is assigned to facultative species, those that are just as likely to be found in wetland or upland habitats. The CW values used are based on Oldham et al. (1995). Figure 20 shows the average wetness per plot, based on the wetness coefficients of all species found within a plot. All except two of the monitoring plots are located within wetland areas.

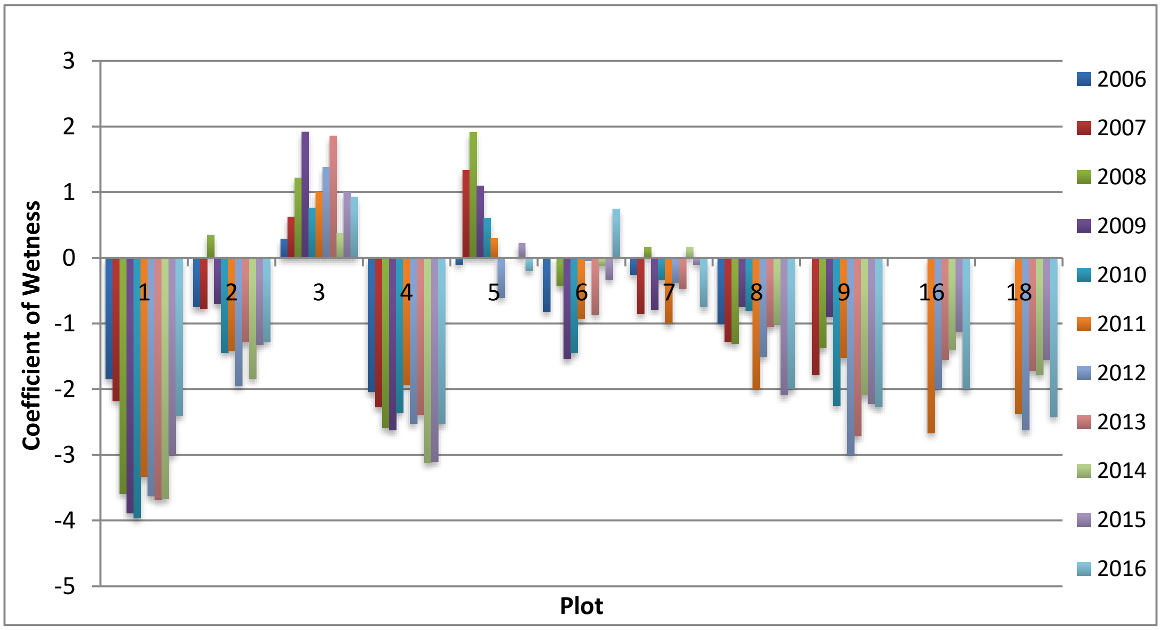


Figure 20. Coefficient of Wetness by Plot 2006 - 2016

Overall, 5 of 11 vegetation monitoring plots exhibited a drier CW value in 2016 over 2015 value. In many cases these plots have shown a slight drying trend over the past several monitoring years, although 2016 results show that in several cases this trend may no longer be occurring.

Plot 1 has previously been documented as the wettest site during most years of monitoring. In 2016 Plot 4 was slightly wetter than Plot 1 with a CW score of -2.53, compared to -2.40 at Plot 1. Shallow, pooled water is regularly present throughout much of Plot 1 at the time of the vegetation survey and Plot 4 is comprised of saturated organic soils. Plot 3 (Sugar Maple forest) continued to exhibit the driest average CW value (0.93). Plot 5 exhibited the lowest average CW value which has been recorded in the plot since monitoring began at -0.60. In 2015 this plot experienced a positive CW value (0.22). Plot 5 is situated within a Fresh-Moist Forest community which nears wetland conditions. Plot 3 and Plot 5 are the only two vegetation monitoring plots to occur within upland ELC communities. In 2016 Plot 6 experienced a positive CW value for the first time at this station with a value of 0.75. Average CW values have been variable at this plot between -0.04 and -1.54. This plot occurs within a transition area between wetland and upland conditions, where some degree of data fluctuation is expected. In 2016 the three most abundant species observed exhibited a positive CW value of +3 while several species with low CW values (-5) that are typically observed at Plot 6 were absent. In 2014, Plot 7 had exhibited a positive CW value (0.16) which is not indicative of White Cedar-Hardwood Swamp conditions. It is noted that the plot contains hummocks with upland plant species as well as a portion of watercourse. In 2015 this plot had a slightly wetter CW value (-0.10) with 2016 results showing a much wetter CW value of -0.75. This plot showed the wettest CW value in 2011 at -1.00 and has generally been between 0.00 and -1.00 during most monitoring years, with the exception of 2009 and 2014. Plot 8, which is situated almost entirely within Tributary A (to the north of Hanlon Creek Boulevard) had an average CW value of -2.00 in 2016 which is the second wettest value recorded in this plot to date (and identical to 2011), with the wettest observed in 2015 (-2.09). The remaining plots are located within swamp or marsh habitat.

At Plot 16 and Plot 18, CW values had shown a steady drying trend between 2011 and 2015, with the most pronounced decrease in CW values occurring between 2011 and 2013. These plots are located in close proximity to recent development (Block 9 and Block 10) and the Hanlon Creek Boulevard (Maps 2 and 6 in Appendix V). Both of these plots were added in 2011 to monitor any changes within the wetland community due to the potential dewatering required as part of the City of Guelph SW Quadrant Class EA. In 2016, both plots showed a marked drop in average CW values (i.e. indicative of wetter conditions), Plot 16 dropping to -2.00 from -1.13 in 2015 and Plot 18 dropping to -2.42 from -1.55 in 2015. As both plots are located within Silver Maple (*Acer saccharinum*) swamp, this return to wetter conditions (as indicated through average CW values) is considered to be a positive change which reverses the drying trend previously being observed.

Plot 16 has consistently contained limited herbaceous vegetation, and is located in a wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. Vegetation coverage within Plot 16 appears to be somewhat influenced by the amount of seasonal standing water within the plot which results in a large proportion of un-vegetated substrates and can influence the various floristic indices which are analyzed. Given that soils within the plot remained saturated into the July, 2016 vegetation monitoring period, and the presence of facultative wetland species, it appears that the plot is maintaining a hydrological balance which supports herbaceous wetland flora. Groundwater levels had been investigated in the vicinity of Plot 16 in 2015 to try and explain the drying trend that was being observed. It was determined that groundwater levels did not correspond to the drying trend in CW values.

Plot 18 has contained a diversity of species with good coverage of the 10x10m plot. It too is located in a small wetland that is physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. The swamp within which Plot 18 is located does not contain the same well-defined topographical depression that Plot 16 does. During monitoring conducted between April and July, standing water is rarely observed within this plot. The continued presence of species with low CW values indicates that wetland conditions are being maintained within this feature. It is also noted that the presence of hummocks within the plot allows for the persistence of upland species with higher CW values. Similar to Plot 16, It was determined that groundwater levels did not correspond to the drying trend that had been observed in CW values between 2012 and 2015.

Previous monitoring reports had inferred that, to some extent, the seasonal standing water may inundate Plot 16 to a degree which excludes some wetland species periodically thus giving the impression of a drying trend from the data set. Analysis of groundwater levels in recent years indicates that the water table is generally below the elevation of the plot and larger wetland feature. Observations of standing water noted during calling anuran surveys indicate that in some years Plot 16 may contain standing water into June, while other years the plot may only contain saturated detritus. Based upon discussions with the monitoring team, it is now suspected that altered surface water inputs may be contributing to the changes in herbaceous vegetation within this plot and perhaps others such as Plot 18 and Plot 6. Site drainage is designed in a manner which directs all surface water flows from the adjacent developable land into conveyance swales that then flow into the SWM ponds. Therefore the wetland features only receive surface water flows from their own blocks (Map 2). Regardless of whether vegetation fluctuates as a result of inundation or as a result of drier conditions brought about by reduced surface flow contributions, at least several years would be required for those species to recolonize the plot once soil moisture returns to favourable conditions.

Coefficient of Conservatism

Species conservatism is the degree of faithfulness a plant displays to a set of environmental conditions. The quality of a natural area is reflected in the number of conservative species found within a certain habitat (Wilhem and Ladd 1988 *In* Oldham et al. 1995). For the CC, each species is given a rank between 0 and 10, based on its degree of fidelity to a range of synecological parameters (Oldham et al. 1995). Synecology is the study of the structure, development, and distribution of ecological communities. Species ranked between 0 and 3 are found in a variety of plant communities, including disturbed sites. Species ranked between 4 and 6 are those associated with a specific plant community, but which can tolerate moderate disturbance. Species ranked from 7 to 8 are found in plant communities in an advanced stage of succession with minor disturbance. Plants with a ranking of 9 or 10 have high degrees of fidelity to a narrow range of synecological factors.

The average CC per plot is shown on Figure 21. The highest CC value in 2015 was found in Plot 7 (5.27), which is located at the transition between Fresh-Moist Sugar Maple Deciduous Forest and White Cedar-Hardwood Mineral Mixed Swamp habitats.

Plot 7 has consistently maintained the highest values for most years. Plot 3, Plot 4, Plot 5 and Plot 18 all exhibited average CC values between 4 and 5 in 2016. While Plot 3 and Plot 4 are consistently among the highest values from year to year Plot 5 and Plot 18 exhibit a good deal of variability. Plot 5 has a consistently low average CC value due to the low diversity of species which can grow among the conifer-dominated canopy. In 2016 the CC value increased slightly with the addition of White Trillium (*Trillium grandiflorum*) (CC 5) to the plot. The lowest average CC values have consistently been found within Plot 6 between 2010 and 2016. The low values at Plot 6 are due to the old field conditions and the dominance of non-native cool season grasses, which comprised 8 of the 20 species recorded in 2016 (no CC value is assigned for these species). The average CC value for the Reed Canary Grass meadow marsh (MAMM1-3) in 2016 was 1.58 followed by Plot 9 (2.67), a Cattail shallow marsh (MASM2-1) which is also dominated by low CC plant species. Neither of these plots contain trees and are likely to have been cleared and farmed historically given the abundance of early successional and non-native species as well as their proximity to existing (or previously existing) farm fields. These plots are dominated by species which have a low CC value or no CC value for those species considered non-native to Ontario.

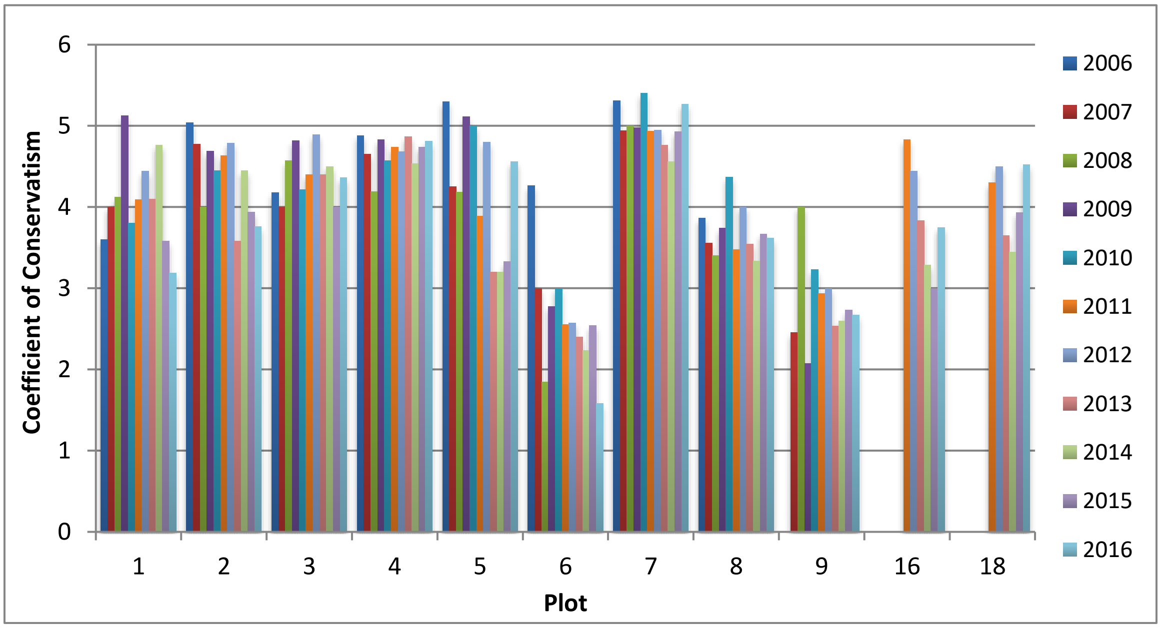


Figure 21. Coefficient of Conservatism by Plot 2006- 2016

In most plots, the average CC value fluctuates from one year to the next but the overall trend between 2006 and 2016 is that values have remained steady. As applicable to other parameters such as average CW, the species diversity in Plot 5 is prone to producing fluctuations in average CC as some species are noted within the plot some monitoring years but not others.

The values continue to decline at Plot 6 and remain the lowest across all monitoring stations. The species within this plot are noted to include a high proportion of non-native species. These species aren't assigned CC values, which works to drive the average CC down. Plot 6 is likely to exhibit low CC values for many years as natural succession occurs and the balance of native to non-native species shifts as tree and shrub species become established and the presence of cool season grass species decreases.

Plot 16 has demonstrated a trend of decreasing average CC between 2011 and 2015. This has been largely attributed to the seasonal standing water levels within the swamp feature and the influence this has on vegetation diversity. The increase in 2016 marks a positive rebound most likely due to recolonization of the plot by higher CC species which were not recorded in the last couple of years due to unsuitable soil moisture conditions.

Natural Area Index

The NAI, or floristic quality index, allows the objective comparison of two or more natural areas or vegetation types (Oldham et al. 1995). The NAI is calculated by multiplying the average CC value by the square root of the total number of native species. Whereas the abundance and frequency of species can fluctuate greatly by season and year, the NAI is more stable and offers a more accurate picture. The NAI for each plot is shown on Figure 18.

The Ministry of Natural Resources and Forestry (MNRF) reports that natural areas with NAI values of over 35 are considered significant at the provincial level (Wilhelm and Ladd 1988 in MNR 1994). For comparison, an old successional field may score as low as <5 (Andreas et al. 2002). None of the plots within the HCBP score a value of 35 or higher. In 2016, Plot 6 showed a marked decrease in NAI values from the previous 10 year average. As an old field, NAI values here are always among the lowest for all monitoring plots and this drop (from 9.50 to 5.47) is not a concern at this time. In total 5 of 11 vegetation monitoring plots were equal to or showed slight increases in NAI over 2015 values; however overall values are still generally lower than in previous years at most stations. Figure 22 shows that NAI values peaked in the during-construction monitoring years 2010 and 2011).

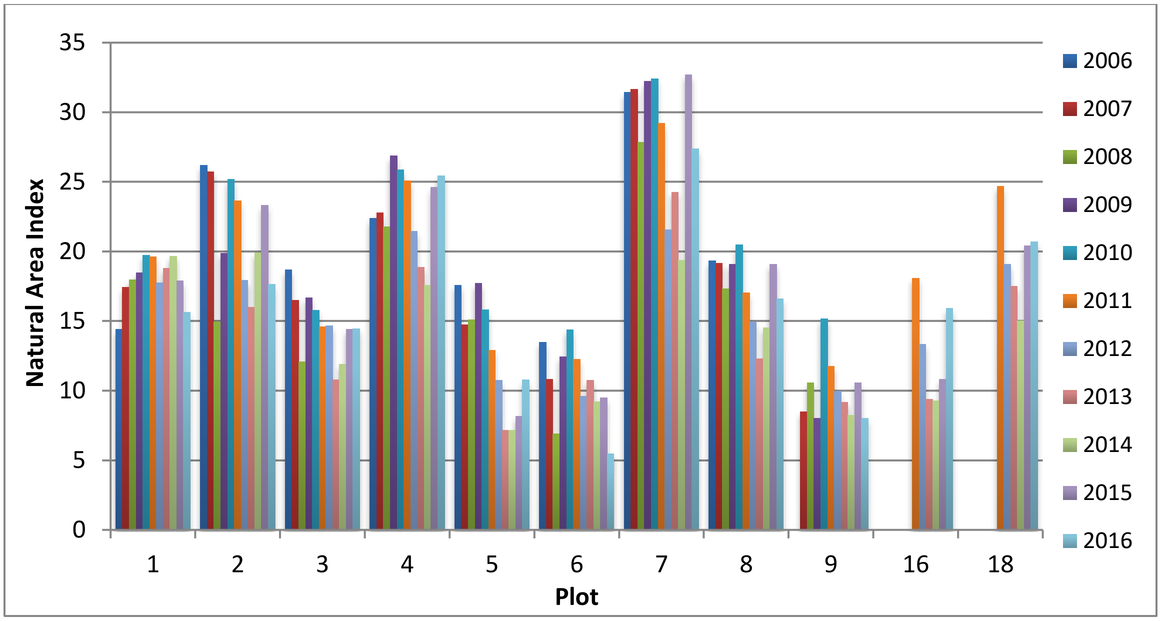


Figure 22. Natural Area Index by Plot 2006 – 2016

None of the plots within the HCBP score a value of 35 or higher. In 2016, notable decreases in NAI values occurred at a number of plots including Plots 1, 2, 6 and 7 and in total 6 of 11 plots experienced decreases in NAI values over 2015 results. A notable increase in NAI occurred at Plot 16. Plot 7 maintained the highest NAI value, even though it decreased in 2016 following an all-time high of 32.70 (up from 19.36 in 2014) in 2015. The complex micro-topography within Plot 7 which includes wetland, upland hummocks and a watercourse provides a diversity of habitat within the 10x10m plot and in turn a high number of plant species, many with higher CC values.

The lowest NAI values in 2016 were observed in Plot 6 (5.47), and Plot 9 (8.01). Plot 6 exists within an old field meadow which contains a number of non-native species and early successional species. The absence of high CC species in the plot maintains a low NAI value. This plot is unlikely to undergo notable changes in NAI for a number of years until woody species cover establishes which will subsequently lead to significant changes in the composition of the community and the herbaceous species present. Plot 9 is dominated by Reed Canary Grass (CC 0), with abundant Broad-leaved Cattail (*Typha latifolia*) (CC3). Both species are highly aggressive and limit the ability of other herbaceous species to establish thus a consistently low NAI value is documented in this plot. Similar to Plot 6, until woody species establish canopy and change the structure of the vegetation community within the plot (to a swamp thicket or treed swamp), the plot will continue to show low species diversity and a low NAI value.

As noted in previous reports, the effects of the extremely dry spring in 2012 are likely to have lingering effects on the diversity of plants throughout the site. Given that most of the vegetation monitoring plots are located within wetlands, it is likely that the dry conditions in recent years, 2012 in particular, had a lingering effect on vegetation composition. Long term data indicates that between 1997 and 2006, 14 of the 20 years were below the 46-year average precipitation (Appendix II). This drying trend is also evident in that 19 of the 24 months leading up to the end of 2016 recorded a less-than-normal amount of precipitation (Appendix II). Some species may re-appear in time through the seed bank or colonization from areas adjacent to the plot. Further monitoring will determine to what degree the plot vegetation rebounds.

2.7.1.2 Non-Native Species

A total of 20 non-native species were recorded within the vegetation plots in 2016. The number of non-native species found in each plot is compared on Figure 23. In general, non-native species have been present in all plots over the course of monitoring with the exception of Plot 5 which periodically contains a low number of invasive species but in very low numbers and not present every year. The greatest number of non-native species was recorded in Plot 6, with 8 species documented. In 2010, 15 non-native species were documented within this plot, a number which has declined every year since. In general, the same dominant non-native species have been observed between 2006 and 2016. Situated within a successional reed canary grass meadow marsh, Plot 6 has consistently contained a high number of non-native species due to historic disturbance (human disturbance from ATV’s/machinery during pre-construction monitoring year) and close proximity to the previous agricultural land use. All species which were documented in Plot 6 in 2016 are unlikely to spread into the treed natural features as they require full sunlight and prefer disturbance. Many of the species, however, are clonal, somewhat aggressive and will likely continue to exclude higher quality plant species from establishing until tree canopy develops and the area is in an advanced state of succession.

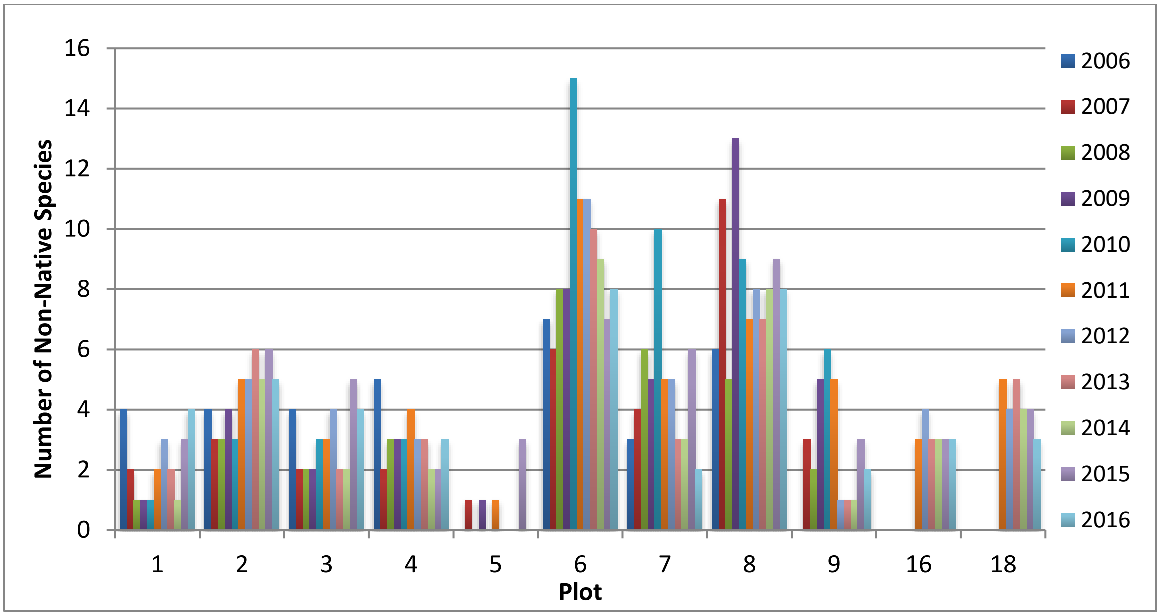


Figure 23. Non-Native Species by Plot 2006 - 2016

Between 2006 and 2015, 25 other non-native species were recorded that were not observed during the 2016 surveys. This fluctuation suggests that some non-native species may only establish for a single season before ecosystem resilience, site conditions (including drought or flooding), or a combination of both suppress the species from establishing within the plots permanently.

Certain non-native species are considered particularly invasive, and are given a score of ‘-3’ on a weediness scale ranging from ‘-1’ to ‘-3’. The invasive species found within the HCBP vegetation monitoring plots include 4 shrub species (3 species with a weediness value of -3) and 12 herbaceous species (all species with a weediness value of -2 or -1).

Garlic Mustard (*Alliaria petiolata*) was only recorded in Plot 18 during the 2011 monitoring year. This species is very common and invasive and it is rare to find areas that do not contain this plant. Most of the non-native species present within the monitoring plots are common agricultural weeds or shrub species which produce prolific amounts of berries that are distributed by deer, birds and other wildlife.

Common Buckthorn is the most widely dispersed non-native plant within the monitoring plots, with Glossy Buckthorn (*Rhamnus frangula*) also found in a number of plots with mesic to wet soils. Both species are tolerant of shading and fruiting specimens tend to be most common at the edge of wooded features where they receive ample sunlight. Due to the ability of these species to grow beneath a dense canopy, a groundcover of herbaceous vegetation is often interspersed with many young seedlings which germinate from the seedbank. Common Buckthorn is widespread throughout southern Ontario; it is often found on calcium-rich soils and occurs in a range of soil moisture and sunlight conditions (Anderson 2012).

One significant non-native species observation was noted for the first time in 2016. A small stand of Common Reed (*Phragmites australis* ssp. *australis*) was observed to the east of Plot 6 in addition to several small stands that were noted at the fringe of SWM Pond 4. This aggressive non-native species has the potential to spread into adjacent wetlands and meadows and create monocultures which compromise native species diversity. It is imperative that these populations of Common Reed be managed and removed. Given that the species occurs in a recently engineered ditch feature and SWM pond associated with the development, the introduction of this species is likely a result of recent grading activities during the construction of Phase 1 and Phase 2. To control the spread of this species the full removal of all live rootstock is required or the species will re-establish and continue to spread.

2.7.1.3 Herbaceous Inventory

A total of 89 species of herbaceous plants were observed during the plot-based vegetation monitoring that was conducted in 2016. All herbaceous species documented within vegetation monitoring plots had been noted in previous years with no new species additions in 2016.

2.7.1.4 Shrub Inventory

In 2016, 22 shrub species were recorded. This number has varied over the monitoring years with low values of 15 species recorded in 2007, 2008, and 2009. All shrub species documented within vegetation monitoring plots had been noted in previous years with no new species additions in 2016.

2.7.1.5 Tree Inventory

Following monitoring in 2014 the scope of tree inventory work was reduced to collect only canopy closure data. Data pertaining to tree health is not conducive to quantitative analysis and DBH measurements were determined to be of little value for comparison from one year to the next and was thus discontinued.

Measures of canopy closure continue to provide insight into regeneration and the establishment of naturalization plantings at Plot 8. Comparison of these values from one year to the next provide insight into the resilience of the ecosystem as naturalization plantings have yet to reach heights which would influence canopy cover readings. The filling in of canopy provides benefits to the site, including the maintenance of microhabitat conditions for riparian vegetation and helping to regulate water temperatures within Hanlon Creek. No tree species are present within Plots 1, 6 and 9.

Signs of Emerald Ash Borer (*Agrilus planipennis*) (EAB) were observed among Ash (*Fraxinus* spp.) trees within the larger natural feature, including those within monitoring Plot 1 and Plot 18. A loss of canopy cover due to Ash decline is likely to make for a temporary increase in herbaceous species both in numbers and in vigour. In time the canopies of existing trees including White Cedar, Red Maple (*Acer rubrum*) and Yellow Birch (*Betula alleghaniensis*) will fill in those areas where Ash was once present. Canopy openings will also spur the growth of shrub and tree saplings.

2.7.2 Breeding Birds

2.7.2.1 Breeding Bird Species Diversity

During 2016 monitoring, a total of 55 species of birds were observed during the point counts at the monitoring plots. Including those species which were noted outside of point counts or incidentally during other surveys, a total of 58 bird species were documented within the study area in 2016. Of the 55 species observed during the formal point counts, 23 exhibited possible breeding evidence, 19 exhibited probable, six were confirmed, and four did not show breeding evidence.

The most abundant bird species observed were American Goldfinch (*Spinus tristis*), and Red-winged Blackbird (*Agelaius phoeniceus*), comprising 13% and 11% of the observations during breeding bird point counts respectively. These were followed by Song Sparrow (*Melospiza melodia*) at 8%. These species are consistently the most abundant within the point counts largely due to the presence of suitable habitat and the large populations of these species within Southern Ontario. Figure 24 represents the 12 most abundant species observed in 2016, with all other birds observed less frequently compiled as 'other'.

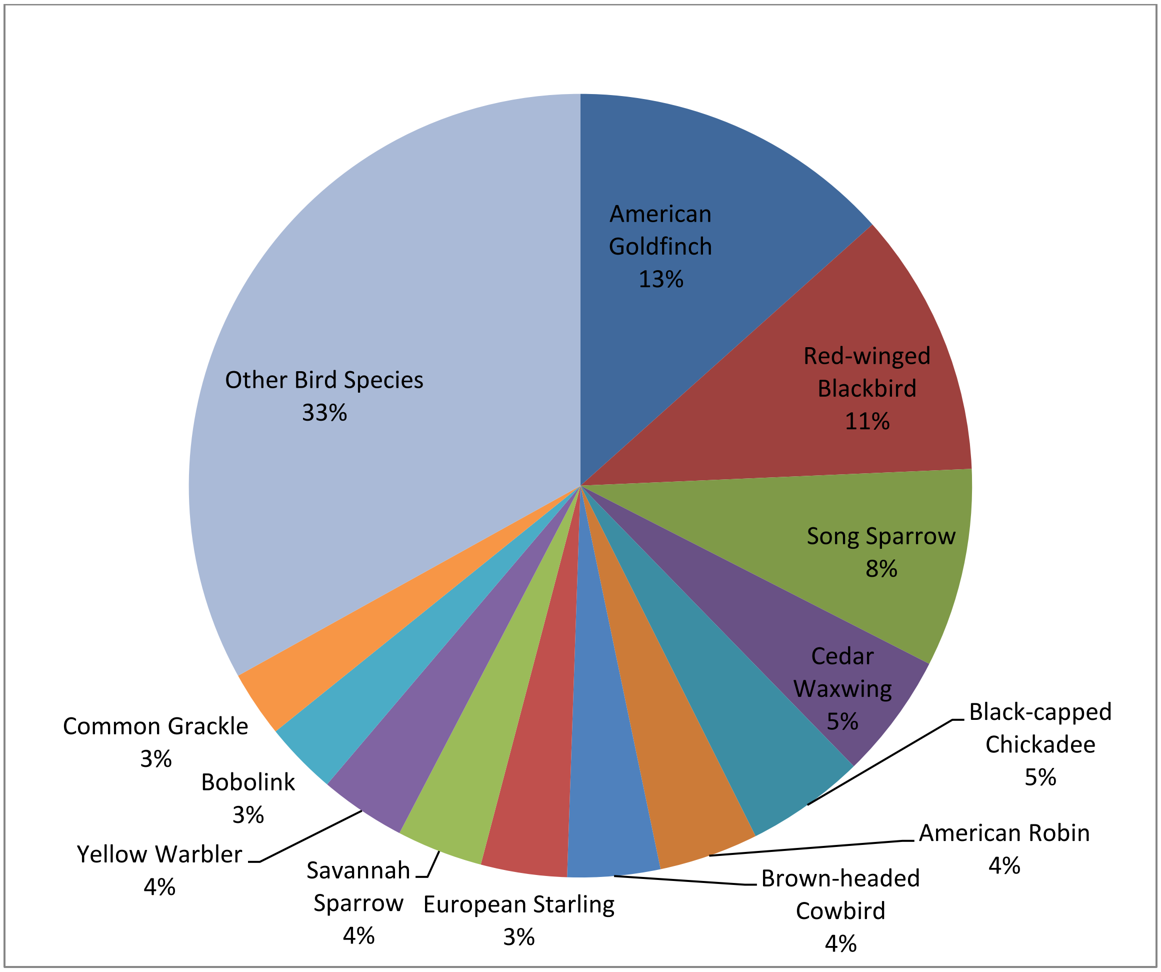


Figure 24. Most Abundant Bird Species Observed in 2016

In general, the diversity of bird species at each plot in 2016 was similar to those numbers documented between 2006 and 2011, with 2012 and 2013 appearing as exceptional years of high diversity across the study area (Figure 25). In 2016, Great

Horned Owl (*Bubo virginianus*) was recorded within the subject property for the first time at Plot 19. The conifer-dominated swamps and open meadow habitats (including SWM areas) within the Hanlon Creek Business Park provide suitable foraging and breeding habitat for this species.

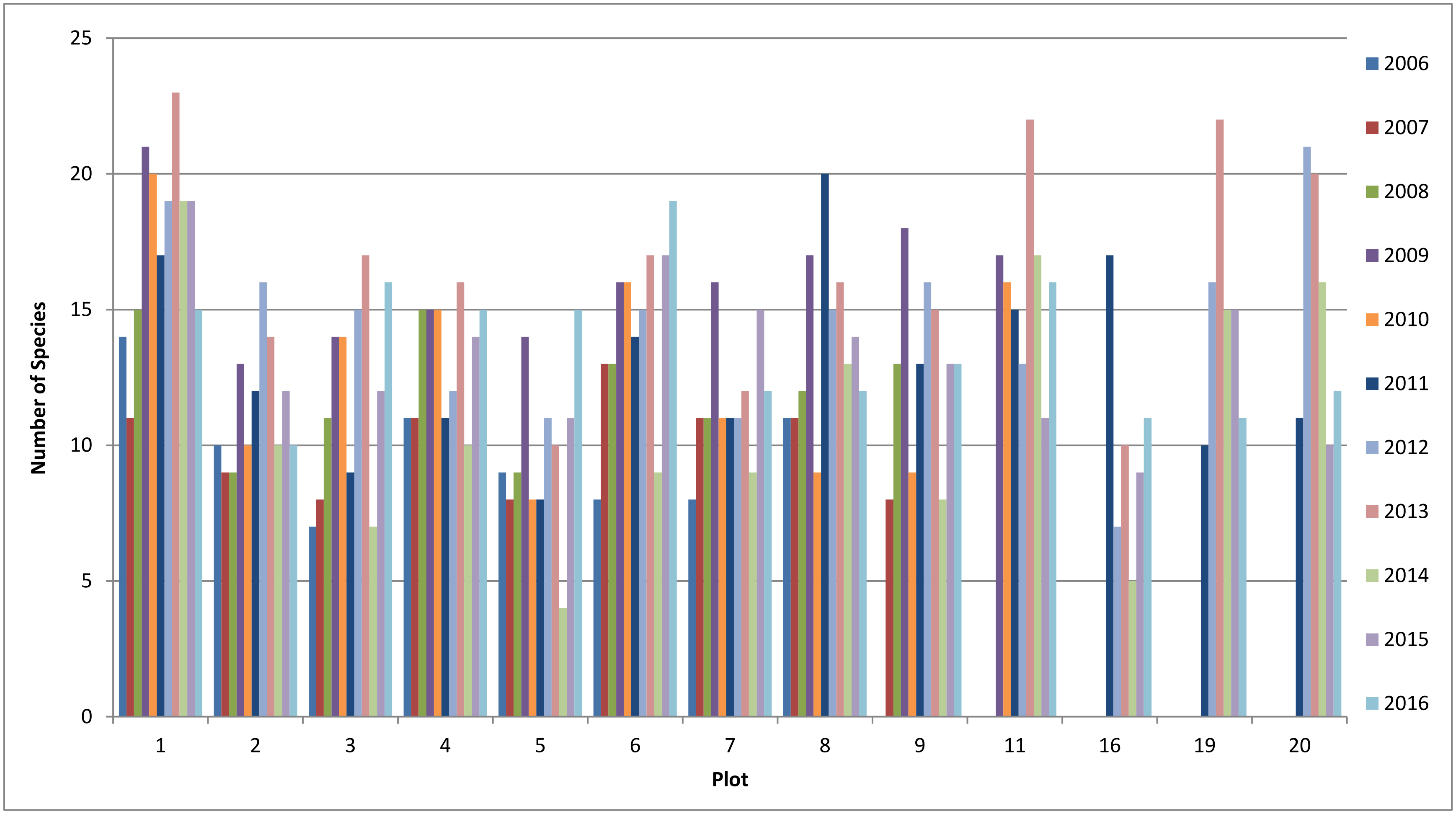


Figure 25. Breeding Bird Species Diversity 2006 – 2016

In 2016, notable increases in bird diversity (over 2015 values) were observed at Plots 3, 5, and 11. The highest bird species diversity in 2016 was recorded at Plot 6 with 19 species while the lowest diversity was recorded at Plot 2 with 10 species. An increasing trend is observed at Plot 6 while decreasing trends are noted at Plots 2, 8, 19 and 20. At Plots 2 and 8 these appear to be a return to what was observed during pre-construction monitoring years.

Bird species diversity in Plots 19 and 20 have exhibited continuous declines following years of high diversity in 2012 and 2013. A cause for this trend is not clear given that the plot is situated among agricultural fields which have gone fallow and support a variety of grassland bird species. As in years prior to 2016, grassland species including Eastern Meadowlark (*Sturnella magna*), Bobolink (*Dolichonyx oryzivorus*) and Savannah Sparrow (*Passerculus sandwichensis*) all utilize the fallow field habitat present within Phase 3 (Plot 19 and Plot 20) for foraging and nesting. No construction has occurred in this area to date. Bird species diversity has decreased within these plots over the last several years which may simply be a result of point-in-time observations of species during the breeding bird surveys. Previous years had recorded species including Black-capped Chickadee (*Poecile atricapillus*), American Crow (*Corvus brachyrhynchos*), Blue Jay (*Cyanocitta cristata*), Ring-billed Gull (*Larus delawarensis*) and Downy Woodpecker (*Picoides pubescens*), none of which would typically utilize the open country habitat for breeding. Despite the reduction in diversity recorded within these plots, the maintained presence of grassland birds from one year to the next supports that the plot continues to provide functional habitat for those species which would require grassland for foraging and breeding.

2.7.2.2 Breeding Bird Abundance

The breeding bird abundance (the number of individual birds) since 2006 is shown on Figure 26. In general the 2016 abundance reflects the overall average since monitoring began in 2006. Similar to species diversity, breeding bird abundance showed a notable spike during the 2012 and 2013 monitoring years and 2016 data generally reflects abundance data observed between 2006 and 2011. Those species which have tended to comprise much of the abundance value for each plot including Red-winged Blackbird, American Goldfinch, Song Sparrow, Black-capped Chickadee and American Robin continue to comprise the bulk of individuals observed. Spikes in bird abundance have been observed in past monitoring years due to large flocks of a single species which have included Red-winged Blackbirds in Plot 6 in 2006 and Canada Goose (*Branta canadensis*) in Plot 9 in 2007.

Abundance data recorded during 2016 breeding bird surveys indicates that Plot 1, 6 and 9 all continue to have the highest bird abundance annually. All 3 plots are situated within or adjacent to open country which allows for good sight lines of nearby features. Bird abundance for a given breeding bird survey in 2016 ranged from 7 individuals at Plots 6, 7 and 8 to as many as 32 individuals at Plot 6.

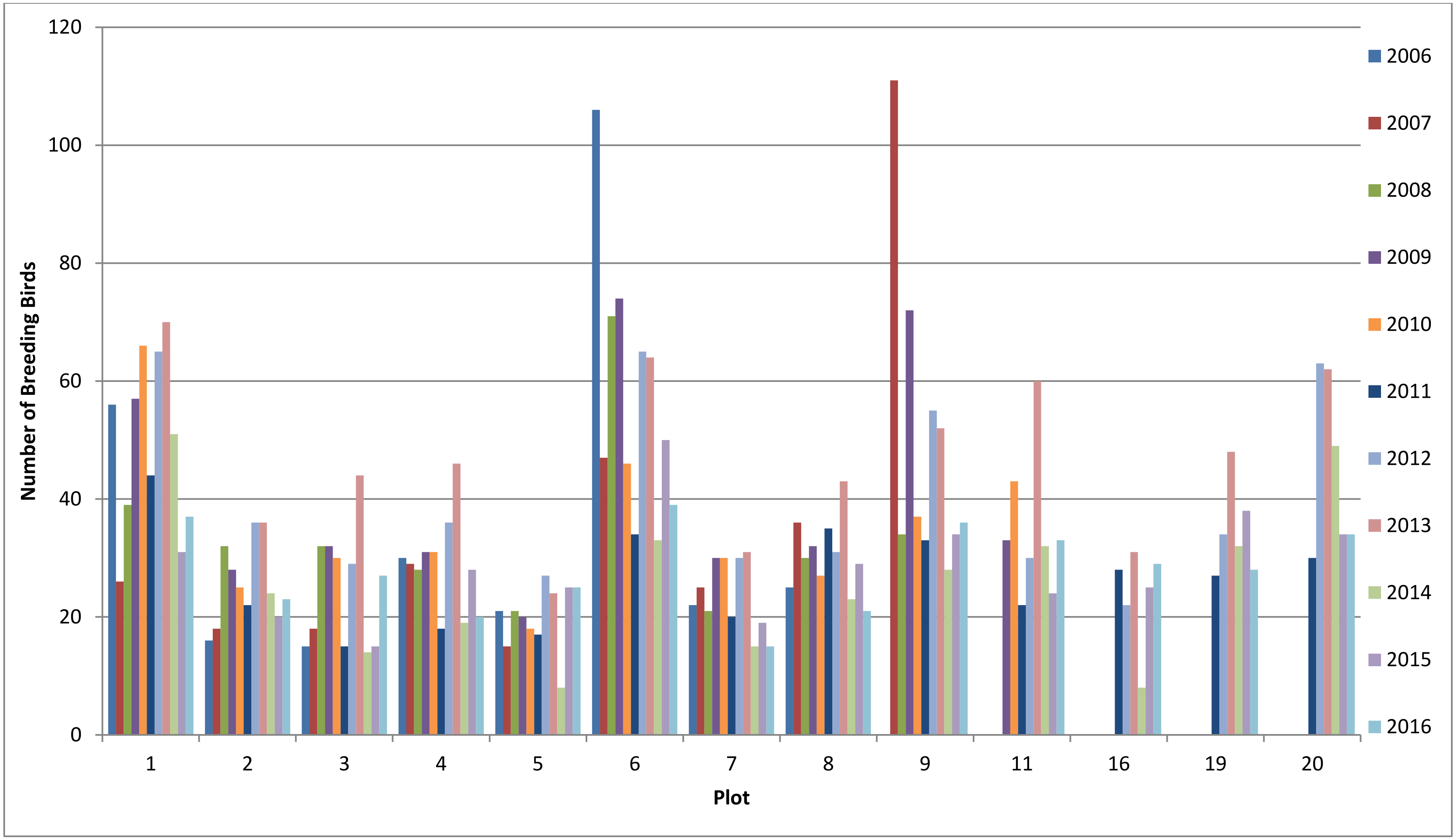


Figure 26. Breeding Bird Abundance 2006 - 2016

2.7.2.3 Significant Species

In 2016, NRSI observed 4 species that are considered Threatened federally and provincially (COSEWIC 2016, MNRF 2016b): Bobolink, Eastern Meadowlark, Barn Swallow (*Hirundo rustica*), and Bank Swallow (*Riparia riparia*). Additionally, Eastern Wood-pewee (*Contopus virens*), a species listed as Special Concern federally and provincially (COSEWIC 2016, MNRF 2016b) was documented during 2016 breeding bird surveys.

Bobolink and Eastern Meadowlark share a similar habitat requirement and both were recorded at (or adjacent to) Plot 9, 11 and 20. Additionally a single Eastern Meadowlark was observed at Plot 1 in 2016. Bobolink showed probable breeding evidence at Plot 20 with as many as 6 individuals observed during a survey on June 3, 2016. Eastern Meadowlark showed possible breeding evidence with as many as 2 individuals observed during a survey on June 21, 2016. Bobolink requires large, open expansive grasslands (>50ha) with dense ground cover; hayfields, meadows or fallow fields; marshes (OMNR 2000). This species has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2016. Eastern Meadowlark requires grassy meadows, farmland, pastures or hayfields at least 10ha in size (OMNR 2000). Suitable habitat is found within the southwest portion of the subject property (Phase 3) as well as within the retained open meadow habitat associated with Plot 19 (Map 6).

Barn Swallow was observed only as an incidental species during the 2016 breeding bird surveys. Individuals were observed adjacent to Plot 3 and 11 showing possible breeding evidence. Barn Swallows are found in farmlands and rural areas, and generally use buildings (such as barns) or other man-made structures for nesting. They are often found foraging in open country near water (Brown and Bomberger-Brown 1999, OMNR 2000). Suitable nesting habitat for this species is present at the Crawley farmhouse within Phase 3 and birds may also now be utilizing business park structures to nest. Birds may also be nesting outside of the subject property in barns along Forestell Road or Downey Road and utilizing the subject property as nearby foraging habitat.

A single Bank Swallow was observed at Plot 6 during a survey on June 21, 2016. This species nests within eroding banks of streams and rivers and forages within open and water-associated habitats (Garrison 1999). Although topsoil piles associated had been present in 2015, this potentially suitable habitat was no longer present in 2016. The SWM ponds may present may provide suitable foraging habitat for this species.

A single Eastern Wood-pewee was documented showing possible breeding evidence at Plots 2 and 3 during the 2016 surveys. Incidental observations of this species were also documented at Plot 6 and 20, beyond the point count radius and within adjacent woodlots. Eastern Wood-pewee prefers open forest (deciduous, coniferous or mixed) often predominated by oak with little understory or forest clearings, edges, farm woodlots or parks (OMNR 2000). The open understory habitat present at Plot 3 provides ideal habitat for this species which may also utilize other treed and edge habitats throughout the subject property.

A total of 19 bird species were observed which are considered significant within the City of Guelph (Dougan & Associates 2009). Of these 19 species, 2 showed confirmed breeding evidence; Red-bellied Woodpecker (*Melanerpes carolinus*) (Plot 3) and Eastern Kingbird (*Tyrannus tyrannus*) (Plot 20). A total of 4 species showed probable breeding evidence, including American Redstart (*Setophaga ruticilla*) (Plot 11), Savannah Sparrow (Plot 19), and Willow Flycatcher (*Empidonax traillii*) (Plot 9). Additionally, 12 species showed possible breeding evidence and 4 did not show any breeding evidence (i.e. flying over habitat). Turkey Vulture (*Cathartes aura*), Bobolink, and Eastern Meadowlark are considered significant in Wellington County.

2.7.3 Amphibians

Calling anuran species were recorded at 11 of the 16 plots in 2016. Plots 1 and 15 recorded 3 species of anuran. No calling anurans were recorded in 2016 at Plots 4, 6, 7, 9, and 14. These plots often lack standing water and do not always provide ideal anuran breeding habitat.

Five amphibian species were recorded during evening call count surveys in 2016; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), Green Frog (*Rana clamitans melanota*), Gray Treefrog (*Hyla versicolor*) and American Toad (*Anaxyrus americanus*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The 5 anuran species recorded calling in 2016 is slightly above average (4.0) among species numbers recorded in previous years. Species recorded during surveys have fluctuated over the ten-year monitoring period, with as many as six species recorded during 2009 surveys and none recorded during the first preconstruction monitoring year (2006).

Spring Peeper has consistently been one of the most abundant calling anurans with the species widely distributed and somewhat abundant in 2016. A full chorus of many individuals was recorded at Plots 15, 16, and 18. At Plot 18 this species was last recorded (in full chorus) in 2011. No individuals were recorded at Plot 6, 9, 11, and 12, which have had Spring Peeper documented most years since monitoring began at the respective plots.

Green Frog was documented sporadically and in low numbers in 2016, similar to previous years. An estimated two individuals were noted calling at Plot 13 in 2016, which is the first time this species has been recorded at this plot. Since 2007 this species has been documented at 9 of the 16 plots.

Gray Treefrog was the most widely distributed and most abundant calling species in 2016. It was recorded at eight of the 16 anuran monitoring stations with an estimated 24 individuals recorded as well as two full chorus plots. In recent monitoring years, Plot 1 and Plot 16 have shown high numbers of Treefrogs calling. Plot 1 exists within Willow thicket swamp and is regularly subject to seasonal flooding. Plot 16 is located within an area of seasonal standing water surrounded by mature Silver Maples.

Wood Frog has shown a pattern of higher numbers in one season followed by lower numbers (or none calling) in the next. The data from 2016 reflects a year of higher Wood frog abundance with an estimated 3 individuals calling, and one full chorus.

American Toad has been limited in numbers and distribution throughout the study area between 2006 and 2015. This continued in 2016 with a pair of toads documented during calling anuran surveys at Plot 12.

No Leopard Frog (*Lithobates pipiens*), Pickerel Frog (Lithobates *palustris*) or Western Chorus Frog (*Pseudacris triseriata*) were observed in 2016, either during call counts or incidentally. All of these species have been recorded intermittently within the subject property in previous years, with a call code of 1 or 2 and in low numbers. Pickerel Frog and Western Chorus Frog have not been documented since 2012.

The 2016 terrestrial and wetland monitoring report (Appendix V) provides detailed information on the ambient air temperature, water temperature, and pH ranges for each of the field visits in 2016.

3.0 Summary of Thresholds

Thresholds have been developed for each component of the HCBP Monitoring Program. Each threshold is described within the *HCBP Consolidated Monitoring Program* (NRSI 2010) and is listed in Table 10.

Table 10. Summary of Thresholds by Monitoring Component

Component	Threshold	Exceedance in 2016 (Yes/No, stations)	Exceedances from 2009 to 2015
Groundwater	A specific quantitative threshold is not used. However, groundwater elevations that increase above previously observed seasonal high levels or decline below previously observed seasonal low levels, without an obvious relationship to precipitation, will be identified as observations of concern. Similarly, groundwater quality that differs from previous ranges in parameters, and/or indicates an upward trend, will be identified as observations of concern.	No	Yes, in 2010, 2011 and 2012
Surface Water	1. Any single temperature exceedance of 22°C requires analysis in the annual consolidated monitoring report.	Yes, at HC-A(04), HC-A(04A), HC-A(04B), HC-A(06), HC-A(09), HC-A(10), HC-A(11), HC-A(13), HC-A(14)	Yes, in 2009, 2010, 2011, 2012, 2013, 2014 and 2015
	2. Any single temperature exceedance of 24°C triggers the Rapid Assessment and Action Protocol.	Yes, at HC-A(04), HC-A(04A), HC-A(04B), HC-A(06), HC-A(09), HC-A(13), HC-A(14)	Yes, in 2010, 2011, 2012, 2013, 2014 and 2015
Fish	1. A 50% change in the number of taxa represents a potential decline in the suitability of the habitat for Brook Trout. Because coldwater fish communities typically have a lower species diversity, an increase in species diversity may represent a negative change in relation to the Brook Trout management objective. Specifically, the warm-water fish community may increase in species	No	Yes, in 2011 and 2015

Component	Threshold	Exceedance in 2016 (Yes/No, stations)	Exceedances from 2009 to 2015
	richness as a result of warmer water temperatures, which indicates that the habitat is becoming less suitable for Brook Trout. A decrease in species diversity may also represent a negative change in the suitability of the habitat for Brook Trout, likely attributable to some cause other than water temperature.		
	2. A 50% reduction in the number of fish captured represents a potential decline in the fish community resulting from habitat impacts. However, it may also represent an improvement in habitat suitability for Brook Trout based on temperature changes.	No	Yes, in 2010, 2012, 2014 and 2015
Benthic Invertebrates	1. For the Percent Model Affinity (PMA) analysis, the threshold is an "Impact" determination at a station for 2 consecutive years following 2 consecutive years where the determination was "No Impact" at that station.	No	Yes, in 2013, 2014 and 2015
	2. For Total Taxonomic Richness, the threshold is a 50% decline in the total number of taxa at a station, as compared to the results from the previous year.	No	Yes, in 2011 and 2013
	3. For EPT Taxonomic Richness, the threshold is a 50% decline in the number of EPT taxa at a station, as compared to the average results from the previous 2 years.	Yes, at BTH-005	Yes, in 2011, 2012, 2013 and 2014
Vegetation and Soils	1. A change in herbaceous cover by more than 25%.	Yes, at Plot 3	Yes, in 2011, 2012, 2013, 2014 and 2015
	2. A change in species diversity by more than 25%.	Yes, at Plot 7	Yes, in 2010, 2011, 2013, 2014 and 2015
	3. A change in canopy cover by more than 25%.	No	Yes, in 2010, 2011, 2014 and 2015
Breeding Birds	1. A negative change in species diversity (number of species) by more than 25%.	No	Yes, in 2010, 2014 and 2015

Component	**Threshold**	**Exceedance in 2016 (Yes/No, stations)**	**Exceedances from 2009 to 2015**
	2. A negative change in the breeding bird abundance (number of individuals birds) by more than 25%.	Yes, at Plot 4, Plot 6, Plot 7, Plot 8 and Plot 9	Yes, in 2010, 2011, 2014 and 2015
Amphibians	1. A decrease in species diversity (number of species) by more than 2 species.	Yes, at Plot 6 and Plot 9	Yes, in 2010 and 2012
	2. A change in species abundance measured by a decrease in two call codes.	Yes, at Plot 1, Plot 6, Plot 7, Plot 9, Plot 10, Plot 11 and Plot 16	Yes, in 2010, 2011, 2012, 2013, 2014 and 2015

4.0 Rapid Assessment and Action Protocol

In 2011 a Rapid Assessment and Action Protocol (RAAP) was implemented as a response protocol for when thresholds are exceeded or when other unexpected environmental issues arise. A six-person committee was set which included a primary and an alternate designated for each represented group (City of Guelph, GRCA, and Monitoring Team). Whenever there was a RAAP event, all six people were contacted via email, and a meeting was scheduled. The list of designated persons for 2016 is shown in Table 11.

Table 11. List of RAPP Designated Persons for 2016

Affiliation	Name
Monitoring Team (AECOM)	Zahra Parhizgari
Monitoring Team (NRSI)	Andrew Schiedel
City of Guelph	Prasoon Adhikari
City of Guelph	Adele Labbe
GRCA	John Palmer
GRCA	Tony Zammit

The specific thresholds that require rapid response are the 22.0°C and 24.0°C stream temperature thresholds, and the turbidity threshold which was initially set at 10 NTU in the HCBP Consolidated Monitoring Program guidance document (NRSI 2010). These targets were set with the primary goal of maintaining Brook Trout habitat within the Hanlon Creek tributaries. To determine when temperatures or turbidity exceed these thresholds, a telemetry system was implemented at four stations within the site to monitor temperature, turbidity and depth. This system notified the monitoring staff when there was an exceedance, triggering the RAAP. In addition, any on-site observations of immediate problems, such as sediment observed entering a wetland or watercourse during a rainfall event, one or more of the designated persons should be contacted. If a RAAP is triggered, the basic steps are:

1. After the exceedance/event occurs the monitoring staff member, inspector or notified person will contact the designated persons immediately.
2. The designated persons must meet/conference call within 48 hrs.
3. Notification and corrective actions must be proposed within three business days.
4. Report should be produced.

5. This report should be included in the consolidated monitoring report.

Section 4.1 provides an account of the meetings that occurred as a result of threshold exceedances in 2016.

4.1 Chronology of Events

The following summary is based on the correspondence and meeting minutes of the RAAP committee found in Appendix VI.

A RAAP meeting was called in late June to discuss a recorded temperature exceedance at HC-A(14), which was the first for 2016. It was determined that high recorded air temperatures with limited vegetation cover and low recorded groundwater conditions contributed to the exceedance. In the past, thermal exceedances at this location have been attributed to weather conditions and no mitigation measures have been recommended to improve thermal conditions at this location. It was also decided that exceedances at this location be communicated via an e-mail to RAAP members.

A RAAP meeting was called in late July concerning two exceedance events that occurred at station HC-A(06). It was found that a combination of high ambient air temperatures and low water levels attributed to an increase in in-stream water temperatures. It was noted that high water temperatures were recorded upstream at stations HC-A(04), HC-A(04A) and HC-A(04B) with temperatures increasing between HC-A(04) and HC-A(04A).

On August 12, 2016 AECOM noted an threshold exceedance at two stations that do not typically see exceedances; HC-A(03) and HC-A(11). A call was held on August 15 to discuss the exceedance, which included representatives from AECOM, the City of Guelph, and the GRCA. Prior to the call AECOM discussed the exceedance with Banks Groundwater Engineering, who indicated that there was likely no groundwater input to HC-A(11) at the time of the exceedance as a result of low groundwater levels recorded near the site. It was also noted that groundwater levels were not quite as low as they were in 2012. AECOM visited the site on August 15 to determine if low water levels had caused temperature gauges to record temperatures reflective of the water's surface.

The field visit noted discrepancies in the water temperature readings between telemetry station sensors and back-up loggers at both HC-A(03) and HC-A(11). Telemetry sensors were observed to be closer to the surface of the water, which resulted in readings that were several degrees warmer than readings from backup loggers, which were closer to the bottom. During this trip backup loggers were also downloaded from HC-A(04) and HC-A(06). These results showed slight exceedances at both stations that had not been recorded by the telemetry stations. It was determined that City of Guelph staff would discuss potential remediation of SWM Pond 4 and AECOM would provide a summary of all exceedances for the site in 2016 to aid in discussion.

On August 20, 2016 AECOM observed a maximum water temperature of 24.73°C at Station HC-A(06) between 11:00 AM and 10:00 PM. A meeting of the RAAP team was initiated to discuss this due to its exceedance of the 24°C threshold. A call was held on August 22, 2016 that included representatives from AECOM, NRSI and the City of Guelph. During the call AECOM staff were asked to download other relevant temperature loggers to help verify the cause of the exceedance. AECOM staff visited the site on August 23 to download all loggers within SWM Pond 4 and between the Pond 4 outlet to Hanlon Creek and HC-A(06). A graph and summary of the data was provided to the team by AECOM. The data indicated that following a rainfall event of approximately 50 mm the cooling trench was no longer able to provide the cooling effect noted prior to the rainfall. Initially it was determined that this was likely due to the large volume of runoff water reaching the cooling trench, which caused the rocks within the cooling trench to warm, reducing the trench’s overall effectiveness. It was also noted that higher than normal daily minimum air temperatures and above-average nightly air temperatures may have prevented the cooling trench from cooling down, reducing its capacity to cool out-letting water. GRCA provided a response to this determination via email on August 29 indicating that following heavy rainfall the cooling trench outlet was observed to equalize with the pond discharge temperature at 25°C. GRCA interpreted that this was not because the rocks warmed resulting in a loss in cooling capacity but because pond discharge flow rate and temperature overwhelmed any benefit to be gained by mixing with groundwater in the cooling trench. NRSI provided further input via email on August 30 postulating that the diversion of the cooling trench temperature from the bottom draw temperature after the storm was a result of a reduction in pond outflow. Previously NRSI had determined that resulting water temperatures at the cooling trench outlet reflect the proportion of pond outflow versus groundwater intercepted by the cooling trench. Action items were discussed, which included the City of Guelph considering returning the Pond 4 water level to its original design level in addition to introducing more plantings as per the original design.

As a follow-up to the RAAP call on August 22, GRCA provided additional perspective and thoughts on the exceedance and stressed that preventing or greatly reducing the flow of groundwater into Pond 4 should be a priority along with diverting the groundwater to the cooling trench, either to the trench inlet or its outlet.

A meeting was held on November 4, 2017 with staff from the City of Guelph, NRSI, Banks Groundwater Engineering, and AECOM. This meeting included a discussion of mitigation measures that could be implemented to address SWM Pond 4, which included: the construction of a Pond 4 shade structure, lowering the pond water level to allow for vegetation to establish further, and installing tile drainage to divert groundwater to the cooling trench. AECOM was tasked with preparing a memo outlining the options discussed and indicating the required information and design to move forward toward a solution.

5.0 Discussion of Thresholds and Issues

Several issues were identified during the 2016 monitoring season. These were identified based on the exceedances of the various monitoring component thresholds that have been described within the *Hanlon Creek Business Park Consolidated Monitoring Program* (NRSI 2010). Threshold exceedances are identified in Section 3.0. The following is a discussion of the issues that were identified or ongoing in 2016.

5.1 Water Temperature Impacts from Stormwater Management Pond 4

As discussed in Section 2.4.2, water temperatures during summer months of 2016 continued to be elevated as a result of the effects of SWM Pond 4. While higher than average air temperatures and lower precipitation levels were again noted in 2016, which contributed to these elevated water temperatures, the influence of SWM Pond 4 continued to be evident in 2016. The evidence is focused on the stations on Tributary A that are the nearest to the SWM Pond 4 outlet. Water temperatures exceeded both 22°C and 24°C at the stations downstream of the SWM Pond 4 outlet while the station upstream of the outlet did not exceed 22°C or 24°C in 2016. Thermal effects are evident in the proportion of the summer that the temperature was above 19°C, and by the thermal regime classifications in 2016 compared to pre-construction data.

Looking at the temporal evidence, the 2016 thermal regime classifications continued to be warmer than pre-construction years (2009/2010 and earlier) at stations HC-A(04), HC-A(06), HC-A(09) and HC-A(10). In addition, the proportion of time that the temperature was above 19°C at stations HC-A(04) and HC-A(06) was greater in 2016 compared to pre-construction conditions, being 90% and 86% in 2016 versus 9% and 18% in 2010, respectively. Further, newly installed stations HC-A(04A) and HC-A(04B), located between HC-A(04) and HC-A(06), also showed significant amounts of time over 19°C in 2016 (89% and 91%, respectively). In 2009, the summer temperature data demonstrated no time (0%) above 19°C at stations HC-A(04) and HC-A(06). It is clear that SWM Pond 4 has changed the conditions at these stations.

Looking at the spatial evidence, stations HC-A(04), HC-A(04A), HC-A(04B) and HC-A(06), located in Tributary A downstream of the SWM Pond 4 outlet, recorded higher average temperatures and little daily fluctuation compared to station HC-A(03), located upstream of the SWM Pond 4 outlet. The subdued daily fluctuation resulted from the very constant temperature of water that continuously discharges from the SWM Pond 4 outlet. Furthermore, the temperatures at the two of these stations that are downstream in Tributary A were consistently in between the upstream temperatures and the SWM Pond 4 outlet temperatures, providing evidence of the mixing of the two sources of flow.

Further downstream at station HC-A(09), it is difficult to discern how much SWM Pond 4 is affecting the temperatures. In 2009, the temperature at this station was at times above 19°C, with a proportion of 2.1% of the 21 days of data that was available that summer. In 2010, station HC-A(09) exceeded 19°C for 34% of the time. This indicates that there has been a history of higher water temperatures at station HC-A(09). The data for 2016 shows that the water temperature was above 19°C for 81% of the time. This could be a result of the influence of SWM Pond 4, although the greater distance from the pond and the lesser temporal difference in this statistic makes the relationship less certain. The high ambient air temperatures and lower than normal precipitation levels experienced in 2016 would have also acted to increase the water temperatures in Tributary A.

Downstream from station HC(A)-09 it is unlikely that SWM Pond 4 is affecting the temperatures, as evidenced by the thermal regime classification at station HC-A(11) which was cooler in 2016 compared to pre-construction condition. This cooler thermal regime at station HC-A(11) may reflect the cooling effect of the removal of the online pond in conjunction with building the Hanlon Creek Blvd crossing of Tributary A in 2009. In spite of the cooling in that location, station HC-A(14), which is farthest downstream on the site, was one category warmer in 2016 compared to pre-construction conditions. Therefore, the warmer classification at station HC-A(14) was largely due to factors beyond the potential influence by SWM Pond 4.

As another effect to consider for the stations further downstream of the four stations nearest to SWM Pond 4, stations HC-A(09), HC-A(13) and HC-A(14) experienced exceedances of the 24°C threshold. Station HC-A(09) may have been influenced by SWM Pond 4 and, based on review of the groundwater and surface water information, it is unlikely that the warm temperatures at that station were caused by other development-related effects. The exceedances at station HC-A(14) are not unusual, so are less likely to be related to warming from SWM Pond 4. In 2016 nine of 12 surface water monitoring stations had some time with temperatures over 22°C ranging from 1% at HC-A(11) to 41% at HC-A(04A). While the stations located downstream from HC-A(09) were most likely affected by higher ambient air temperatures and lower-than-normal precipitation levels, it appears that the main issue with stream temperatures in 2016 was the effects of SWM Pond 4. There is no clear evidence that other aspects of the development are contributing to the exceedances of 22°C and 24°C. Thus, it is appropriate to focus on the stream temperature impacts of SWM Pond 4, and consider whether there are possible restoration activities for station HC-A(09), in order to reduce the potential for exceedances of 22°C and 24°C.

Further analysis of the spatial and temporal characteristics of the stream temperatures in Tributary A and Tributary A1 is provided in Section 2.4.2, and a discussion on the suitability of the temperatures for Brook Trout is provided in Section 2.4.2.1. Analysis of stormwater management pond temperatures is provided in Section 2.4.2.2, and analysis of the modes of impact of SWM Pond 4 is provided as follows.

Two potential modes of impact by SWM Pond 4 were previously discussed in consolidated monitoring reports for the years 2012 through 2015. The first mode is the water that is discharging to Tributary A through the SWM Pond 4 outlet; the second is the pond’s effects on adjacent groundwater that eventually discharges to Tributary A as groundwater. They are outlined again as follows.

5.1.1 Warm Water Discharging Through SWM Pond 4 Outlet

In 2016, the continuous outflows from the SWM Pond 4 cooling trench continued to be approximately 3 to 6°C warmer than the upstream water temperatures at station HC-A(03) in Tributary A. The resulting temperature in Tributary A immediately downstream at station HC-A(04) is closer to the SWM Pond 4 outflow temperatures. However, in general, outflow temperatures were still up to 8 degrees cooler than pond temperatures, indicating that the cooling trench is functioning to mitigate and cool water from SWM Pond 4 to some degree.

As discussed in Section 2.4.2.2, the cooling trench at SWM Pond 4 has limited performance during storm events. The HCPB Stream Temperature Impact (AECOM 2009) indicated that there was little information on performance of the outlet trenches in terms of reducing temperature; however it refers to the Max Becker Subdivision Pond, at which the outlet temperature exceeded 22°C only once during a storm event. At SWM Pond 4 the cooling trench is noted to lower the pond outflow temperatures in between storm events, but only mitigates temperatures for a few hours after a storm event begins. Therefore, the temperature is largely driven by the pond outflow temperature during a storm. This is understood to be a potential limitation of cooling trenches, with the understanding that the first flush of water has the greatest potential for thermal impact. Nevertheless, it is important to understand that the cooling trench is most likely functioning to mix groundwater with the outflow from SWM Pond 4, and its perceived performance under current conditions may not reflect extensive absorption of heat by the rock in the cooling trench. If the continuous discharge from the SWM Pond 4 outlet were not occurring, there may be additional heat capacity in the rock and surrounding groundwater to facilitate additional cooling of the first flush of a storm event. Refer to Section 2.4.2.2 for further explanation of the current function of the cooling trench at SWM Pond 4.

In order to improve the performance of the cooling trench and mitigate the effects of the continuous discharge from the pond, herbaceous species and vines were planted along the cooling trench in the fall of 2012. These were installed as an additional mitigation feature with the hope that they would grow over the rock lined cooling trench and reduce the impacts from solar radiation. It was determined that they provided little benefit during their first year as they covered only a small area of the trench, and this continued to be the case in 2016. It may be necessary to augment these plantings, or to pursue additional measures. Several strategies for mitigation of the SWM Pond 4 temperatures were discussed by the RAAP team in 2016 with the primary focus of preventing or greatly reducing the flow of groundwater into Pond 4 along with diverting the groundwater to the cooling trench, either to the trench inlet or its outlet, and these are listed in Section 4.1. Although discussion surrounding mitigation occurred in 2016 no additional mitigation measures were implemented.

5.1.2 Warming of Groundwater Adjacent to SWM Pond 4

The warming of the groundwater adjacent to and down-gradient from SWM Pond 4 continued in 2016. In 2012 it was determined that surface water from SWM Pond 4 could be migrating toward Tributary A through the ground as another pathway from SWM Pond 4 to Tributary A. This was evidenced by elevated groundwater temperatures compared to pre-2012 monitoring and compared to groundwater temperatures up-gradient from SWM Pond 4 in the same year. This effect has continued through 2013, 2014, and 2015, and is again evident in 2016.

In July and August, 2016, the water temperatures at monitoring well MW119A, located down-gradient from SWM Pond 4, were again approximately 3 to 5°C higher than those at monitoring well MW 131, located up-gradient of SWM Pond 4. This is a clear indication that an effect is occurring, and it is clearly illustrated on Graph G24a in Appendix G of the groundwater monitoring report (see Appendix II of this report). In addition, groundwater temperatures at monitoring well MW119A and piezometers PZ-13D and PZ-14D demonstrated potentially-elevated temperatures (Section 2.4.1).

Mitigation of this mode of effect would need to either lower the temperature of the water in SWM Pond 4, curtail the flow of groundwater out of this part of the pond, or augment the continuous outflow with additional cool groundwater. Such measures were discussed in 2016; however none have been implemented to date.

5.2 Change in Benthic Invertebrate Community at One Station

5.2.1 Decline in the Number of EPT Taxa by 50% (Compared to the Average Results from the Previous 2 years) at One Station

One station, BTH-005, produced an exceedance of the third benthic invertebrate threshold in 2016.

Station BTH-005 exhibited a 63% decline in the number of EPT taxa as compared to the averaged results from 2014 and 2015. This exceedance results from the averaging of a very low proportion of EPT observed in 2014 (1.4%) and an uncharacteristically high proportion of EPT in 2015 (35.3%). The 2014 result is the lowest that has been observed to date at BTH-005 while the result in 2015 is the highest. The low proportion in 2014 is more typical to what has been in previous years at this monitoring station while the high in 2015 appears uncharacteristic. Although the threshold was exceeded in 2016 it is mainly a function of the very high proportion in 2015, which acted to raise the averaged result for 2014 and 2015. The EPT richness in 2016, which was 6.7%, appears to be more ‘typical’ for this station when compared to the results between 2009 and 2013.

Prior to 2015 there appeared to be a trend of decreasing EPT richness across the five benthic monitoring stations starting in 2008 and 2009 when the EPT richness values were generally at their highest. This decrease followed a trend of increasing EPT richness that was observed during pre-construction monitoring from 2006 to 2008. Known potential stressors include the drought conditions in 2012, and the continuous discharge from SWM Pond 4 beginning in late 2011. However, EPT values were noted to increase at all stations in 2015 and at two of three stations in 2016 even though there was continued discharge from SWM Pond 4 into Tributary A. It is important to note that the change in level of identification that affected the overall taxonomic richness in 2013 did not apply to the EPT richness, because Ephemeroptera, Plecoptera and Trichoptera groups were identified to the same taxonomic resolution (genus) throughout all years of monitoring.

5.3 Changes in Vegetation

5.3.1 Change in Herbaceous Cover by 25% at One Station

Herbaceous cover exceeded the lower reach of this threshold in Plot 3 in 2016.

While increases in herbaceous species in Plot 3 (7.2% between 2013 and 2014, 19.1% between 2014 and 2015 and 19.5% between 2015 and 2016) reflect a positive change in recent years, the 28.6% cover in 2016 is still well below the pre-construction average of 57.83%. Herbaceous cover in this plot is primarily influenced by the presence of Ostrich Fern (*Matteuccia struthiopteris*) which, prior to 2011 had comprised a significant portion of herbaceous cover within the plot before values dropped significantly. It should be considered that the mortality of Ostrich Fern during the driest monitoring years would require time for the population to rebound (assuming conditions are suitable for the species) to pre-construction numbers. Should the site receive abundant precipitation during the spring of 2017, vegetation monitoring may find that herbaceous cover continues to build on the 2016 figures.

5.3.2 Change in Herbaceous Species Diversity by 25% at One Station

Plot 7 fell below the threshold in 2016. Species diversity negatively exceeded the pre-construction threshold in Plot 7 in 2016. This plot contained 29 species, 2 of which were non-native, whereas the pre-construction average for the plot was 42 species.

Plot 7 has consistently exhibited some of the highest species diversity at any of the plots, typically above 40 species. In 2014 a decrease in diversity was observed to the same number of species that has caused the exceedance in 2016 (29 species). However, the 2015 results showed a large increase to the highest diversity that has been observed at any station since monitoring began. A review of monitoring data from previous years indicates that many species observed at Plot 7 consisted of one or several individual plants. As the plot is relatively intact (few non-native species and with a complex, natural microtopography) this decrease in species is not considered reason for concern. It is also likely that many of those species present in low numbers in past years remain present in the larger ELC community surrounding the plot. On-going monitoring will continue to document species diversity at this plot and provide further analysis of this trend.

5.3.3 Decreasing Coefficient of Wetness at Two Stations

Although Coefficient of Wetness (CW) is not used as a specific threshold for the vegetation monitoring, it is noteworthy that, prior to 2016, the CW values at Plots 16 and 18 were showing a drying trend between 2011 and 2015. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. Groundwater levels at adjacent monitoring wells have been analyzed for temporal patterns and compared to the ground elevations (Section 2.7.1.1). However, the drought year in 2012 is the only obvious groundwater effect. Furthermore, it appears that fluctuations in groundwater levels would have little to no effect on the soil wetness in the wetlands because their elevations have never been above the ground surface of the wetlands. Groundwater levels in the vicinity of Plots 16 and 18 do not show a trend that matches the declining trend in CW values. Monitoring results show a marked increase in CW values at both Plot 16 and Plot 18 in 2016 suggesting a return to the conditions observed in 2011 and 2012. As another possibility, a prolonged seasonal inundation by surface water may also be impacting some plant species such that the lower CW value is more of an artifact rather than a direct indication of drier conditions. Monitoring of vegetation and groundwater should continue at these plots in order to better understand the impacts which may be occurring within these features.

5.4 Change in Breeding Bird Abundance by 25% at Five Stations

Plots 4, 6, 7, 8 and 9 were all below the 25% threshold in 2016. Breeding bird abundance was generally average to below average for the majority of plots in 2015, although bird numbers experienced an increase at the majority of plots between 2014 and 2015. As mentioned in previous monitoring reports, observations of flocks can have a notable impact on bird abundance figures. The threshold set within Plots 6 and 9 for pre-construction (2006-2009) both include very large numbers of Red-winged Blackbird or Canada Geese which inflated the threshold substantially. In 2016, small flocks of certain species such as Red-winged Blackbird and European Starling were noted occasionally, but no exceptionally large flocks were observed. As both 2012 and 2013 constitute years of high bird abundance, and the presence of flocks within pre-construction threshold calculations, 2016 data is generally on average with the during-construction data set despite the threshold exceedances which were documented.

Monitoring should continue to assess breeding bird abundance to determine if bird abundance is being maintained across the site and within the different vegetation communities.

5.5 Decline in Amphibian Species Diversity at Two Stations

A decline in amphibian species number by more than 2 (between the preconstruction average and 2015 as well as between 2015 and 2016) was observed at Plot 6 and Plot 9 in 2016.

Plots 6 and 9 both showed decreases greater than 2 species with a drop from 4 to 0 species recorded at Plot 6 and from 3 to 0 species recorded at Plot 9. Each of these plots had a minimal amount of standing water between April and June with much of the plot area comprised of damp matted grasses on saturated soils. These conditions are not considered ideal, particularly as it relates to amphibian breeding. It is notable that species diversity in Plot 6 shows a regular pattern of fluctuating; between 2009 and 2014 diversity alternated annually between 3 species and 1 species with 2015 (4 species) and 2016 (0 species) complementing this trend. To some degree the data for Plot 9 reflects this pattern as well with years of higher diversity alternating with years of lower diversity. To a large extent it is likely that these fluctuations are a reflection of climatic conditions (temperature and precipitation).

5.6 Decline in Species Abundance for Three Species at Seven Stations

A decrease in two calling codes was established as the threshold in the HCBP Consolidated Monitoring Program (NRSI 2010). Ten of these decreases were observed in 2016 including:

- American Toad in Plots 1, 10, 11 and 16 – no individuals recorded in 2016, down from a call code of 3 at Plot 11 in 2015 and 2 at the other plots. American Toad was only recorded at Plot 12 during the 2016 surveys,
- Gray Treefrog in Plots 6, 7, 9, and 10 – no individuals recorded in 2016 after call codes of 2 were recorded at all of these plots in 2015,
- Spring Peeper in Plots 6 and 9 – no individuals recorded in 2016, down from a call code 2 recorded at Plot 6, and a call code of 3 recorded at Plot 9 in 2015.

American Toad has been limited in numbers and distribution throughout the study area between 2006 and 2016, and therefore it is understood that 2015 was a year of greater abundance followed by less abundance in 2016. Based on past result, this can be attributed to natural variation that occurs in the habitats in the HCBP.

It should be noted that both Gray Treefrog and Spring Peeper remain widespread and abundant within the subject property. In 2016, increases in Gray Treefrog call codes from 0 to 2 were documented at Plots 8, 15, and 17. Increases in Spring Peeper call codes from 0 to 3 were observed in Plots 16 and 18 between 2015 and 2016.

As noted in previous monitoring reports, the use of SWM ponds by Spring Peepers, as well as American Toads, has increased notably since their creation. The continued establishment of riparian and aquatic vegetation within SWM ponds will likely continue to provide suitable foraging and breeding habitat for some anuran species.

During 2016 calling anuran surveys, a full chorus of both Gray Treefrog and Spring Peeper was recorded at Plot 16. This plot was flagged in previous monitoring reports for decreases in herbaceous vegetation and bird species diversity. The presence of a full chorus of Spring Peeper provides good indication that conditions within the plot were suitable for early-season breeding anurans. During the April survey it was noted that water within the plot was up to 15cm deep with shallow standing water still present during the May survey. By the June survey, water within Plot 16 was limited to small, fragmented puddles and saturated detritus.

6.0 Summary of Corrective Measures Undertaken

No corrective measures were undertaken in 2016. The RAAP group met on several occasions regarding temperature exceedances, including an additional visit by AECOM to confirm site conditions following exceedances at Stations HC-A(03) and HC-A(11).

The temperature effects continued at SWM Pond 4, and the corrective measures undertaken in 2012 were again monitored for effectiveness in 2016. The corrective measures undertaken in 2012 included:

4) raising the outlet of the cooling trench at Pond 4 (this was removed in early 2013),
5) raising the weir level at the pond outlet at Pond 4, and
6) planting of aquatic vegetation throughout the shallow areas of the pond as well as planting vines and herbaceous species in and around the cooling trench at Pond 4.

As these measures have proven to be insufficient to correct the temperature effects of SWM Pond 4, the RAAP team discussed additional mitigation strategies to be considered for implementation that focus primarily on the management of groundwater in the vicinity of SWM Pond 4. Specifically, mitigating the temperature impacts of Pond 4 should include diverting additional groundwater towards the cooling trench, either at its inlet or outlet. It is anticipated that diverting additional colder groundwater directly to the cooling trench will lower the water temperature of the outflow reaching to the creek. By the end of 2016 these mitigation measures were still under consideration and review and it is expected that decisions regarding this will be made in 2017.

While other issues have been identified through review of the monitoring results, there were no other clear cause-and-effect relationships that constituted problems to be rectified through corrective measures.

7.0 Recommendations

7.1 Actions for 2017

Based on the 2016 monitoring results, it is recommended that additional corrective measures be developed to address the effects of SWM Pond 4 on water temperatures in Tributary A. The need for additional monitoring requirements should be considered in conjunction with the development and implementation of the corrective measures.

Vegetation surveys in 2016 identified an aggressive non-native species, Common Reed, for the first time at the HCBP east of Plot 6 in Phase 1 as well as along the edges of SWM Pond 4. This species has the potential to spread into adjacent wetlands and meadows and create monocultures which compromise native species diversity. It is imperative that these populations of Common Reed be managed and removed. Given that the species occurs in a recently engineered ditch feature and SWM pond associated with the development, the introduction of this species is likely a result of recent grading activities during the construction of Phase 1 and Phase 2. It is recommended that this species be controlled through repeated herbicide application by a licensed professional. It is further recommended that a full site inspection be conducted to document all stands of Common Reed, focusing on SWM ponds. Monitoring of the effectiveness of management efforts should also be continued annually until the species is no longer present. The full removal of all live rootstock is required or the species will re-establish and continue to spread.

While other issues were identified as a result of threshold exceedances or other occurrences, none of the issues were clearly linked to impacts from development. Therefore, no further actions are recommended at this time based on the monitoring results.

7.2 Future Monitoring

2016 marked the seventh year of construction-phase monitoring at the HCBP. The following recommendations for monitoring are made with this in mind.

It is recommended that monitoring continue with diligent attention given to stream temperatures and the SWM Pond 4 mitigation measures put in place to date, using the RAAP as prompted by any stream temperature or turbidity exceedances. This will ensure that attention is given to any ongoing patterns in stream temperature, and actions can be taken if deemed necessary. Additional monitoring may also be required to inform the development and implementation of measures to mitigate the effects on stream temperatures.

The long-term groundwater monitoring program at the HCBP site should continue in 2017 on a quarterly basis as previously recommended. Particular attention should be given to monitoring wells MW119A, PZ-13D and PZ-14D regarding the temperature effects of SWM Pond 4, and to monitoring wells MW103 and MW118A regarding the declining CW values at vegetation Plots 16 and 18. Surface water should continue to be monitored at Plots 16 and 18 and adjacent roads, swales and development blocks in order to determine whether surface hydrology has been altered in a manner that is affecting Plots 16 and 18. Groundwater samples should continue to be collected from selected monitoring wells and analyzed for the established water quality parameters. The improved filtering of water samples should be continued as standard practise.

The surface water monitoring program during and post construction should continue in 2017 as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010) to ensure temperature targets are met and water temperatures are suitable for Brook Trout. Temperature monitoring of stormwater management ponds should also continue in 2017 to monitor their effectiveness, including the bottom draw outlet and cooling trench performance. Water quality in Tributary A should be monitored using grab samples as per MOECC CofA requirements.

It was determined following the 2016 monitoring season that the frequency of fish and benthic invertebrate monitoring should be adjusted. The biological components are end points that are functions of the physical surface water and groundwater conditions, and they tend to be slower to respond. It is therefore common practice to undertake biological monitoring every two or three years, while physical parameters are measured more frequently. Therefore, beginning in 2017, fish and benthic monitoring will be completed every second year at the existing five benthic and five fish monitoring stations. The reduced frequency of aquatic biology monitoring is appropriate at the HCBP, even though aquatic metrics can be responsive to the physical conditions. Extensive baseline and during-construction benthic and fish data have been collected that provide a comprehensive understanding of the nature of the fish and benthic invertebrate communities on site. Furthermore, the management objective is to improve the habitat such that it can support Brook Trout (*Salvenlinus fontinalis*), and to date no Brook Trout have been captured during regular monitoring.

Vegetation monitoring should also be reduced in frequency to every two years, with the next monitoring year being 2018. In that year, vegetation monitoring should continue as per the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010), with the following notes for 2018. Special attention should continue to be given to Plots 16 and 18 to determine if there is a continued decline in CW values.

Monitoring of the aquatic and riparian vegetation within the SWM Pond 4 and herbaceous plants along the cooling trench should also continue in order to monitor the survival and establishment of the vegetation planted in the fall of 2012.

Breeding bird and amphibian monitoring frequency should be adjusted to every 2 years, with 2018 being the next year of monitoring. Breeding birds and amphibians should be monitored in 2018 according to the Standard Operating Procedures for the Consolidated Monitoring Program (NRSI 2010).

Monitoring of all anuran plots should continue with a particular focus on changes observed within Plot 16. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends. As with the other biological monitoring components, the frequency should be adjusted to every 2 years, with 2018 being the next year of monitoring.

8.0 Conclusions

Monitoring at the Hanlon Creek Business Park in 2016 was successful in providing useful information to describe environmental conditions on site, detect issues and develop solutions. Elevated stream temperatures and the contributing temperature impacts from SWM Pond 4 continued to be the most prominent issue in 2016. As such, monitoring in 2017 and 2018 should give particular attention to this issue through the continued monitoring of nearby wells and the effectiveness of the planted vines and aquatic vegetation. The RAAP group should carefully review any stream temperature threshold exceedances. Additional corrective measures should also be developed to mitigate the effects on stream temperatures, including additional monitoring as required to inform such measures.

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MAPS

Map 1

Hanlon Creek Business Park

Study Area and Natural Features

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Date: March 7, 2017
Project: NRSI-1035F
Scale: 1:9,000 (11 x 17")
UTM Zone 17 NAD83

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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1035F_Map1_StudyArea_9K_2017_03_07_LEH.mxd

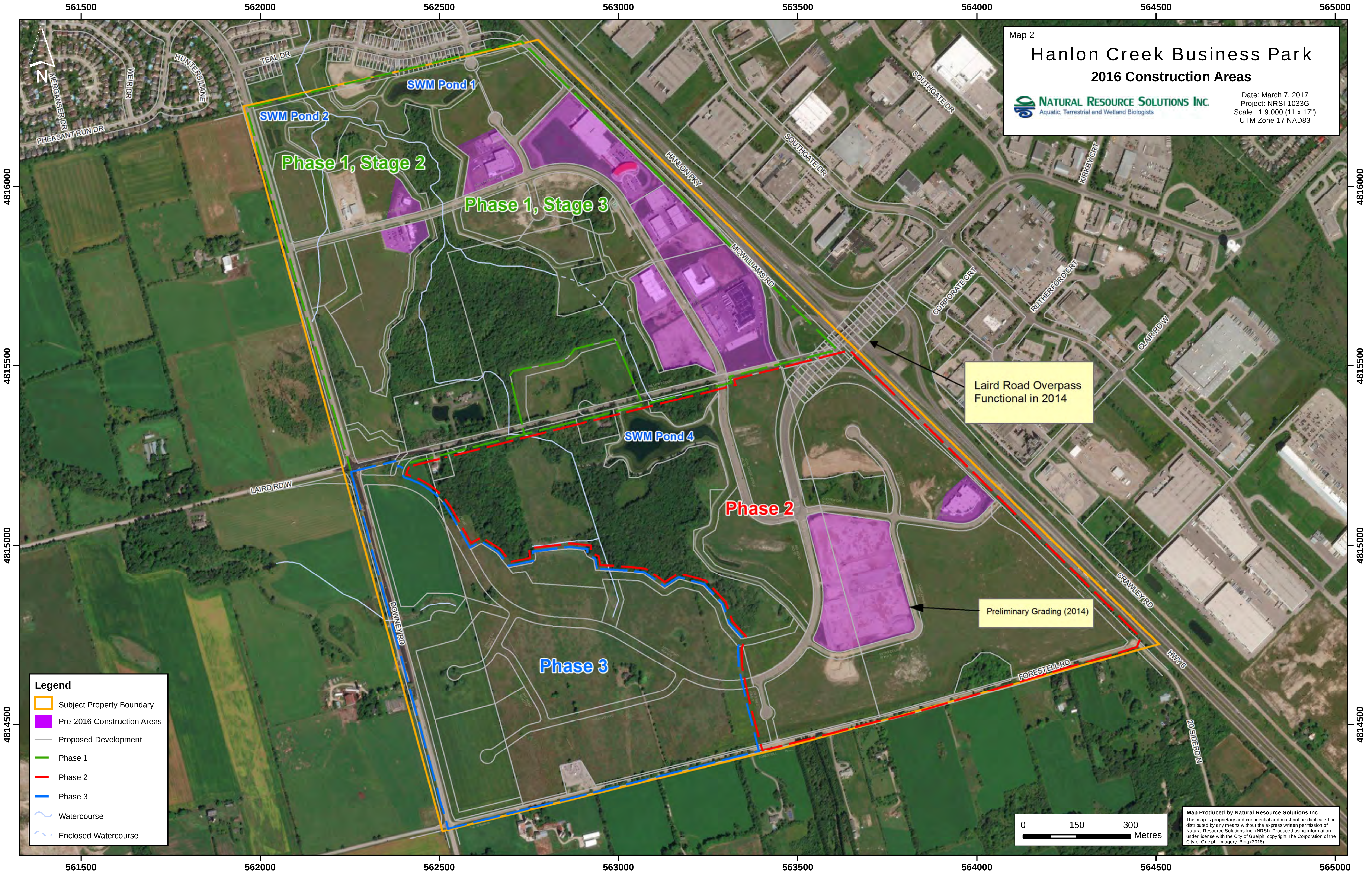
Map 2

Hanlon Creek Business Park

2016 Construction Areas

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Date: March 7, 2017
Project: NRSI-1033G
Scale : 1:9,000 (11 x 17")
UTM Zone 17 NAD83



Laird Road Overpass Functional in 2014

Preliminary Grading (2014)

Legend

▭	Subject Property Boundary
■	Pre-2016 Construction Areas
—	Proposed Development
—	Phase 1
—	Phase 2
—	Phase 3
∼	Watercourse
- -	Enclosed Watercourse

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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1033F_Map2_2016ConstructionAreas_9K_2017_03_07_LEH.mxd

Map 3

Hanlon Creek Business Park

Groundwater Monitoring Stations

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

January 31, 2012
Project: NRSI-1035F
Scale: 1:8,500 (11 x 17")
UTM Zone 17 NAD83

Legend

- ● Monitoring Well
- ● Monitoring Well (New)
- ⊗ Abandoned Monitoring Well
- ⊗ Monitoring Well (Phase 3 To Be Abandoned)
- ● Monitoring Well (Proposed)
- ☆ Mini-Piezometer Pair (Existing)
- ☆ Mini-Piezometer Pair (New)
- ★ Mini-Piezometer Pair (Proposed)
- — Development Block Boundary
- — Watercourse
- - - Enclosed Watercourse

Note: Monitoring Wells and Mini-Piezometers are current as of January 2012

Map Produced by Natural Resource Solutions Inc.
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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1035F_Map3_GroundWaterMonitoring_8K_2017_03_07_LEH.mxd

Map 4

Hanlon Creek Business Park

Surface Water Monitoring Stations

AECOM

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

March 7, 2017
Project: NRSI-1035f
Scale: 1:8,500 (11 x 17")
UTM Zone 17 NAD83

Legend

●	Temperature Monitoring Station
●	Temperature and Depth Monitoring Station
●	Temperature, Turbidity and Depth
—	Development Block Boundary
—	Watercourse
- -	Enclosed Watercourse

Map Produced by Natural Resource Solutions Inc.

Document Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1035F_Map4_SurfaceWaterMonitoring_8K_2017_03_06_LEH.mxd

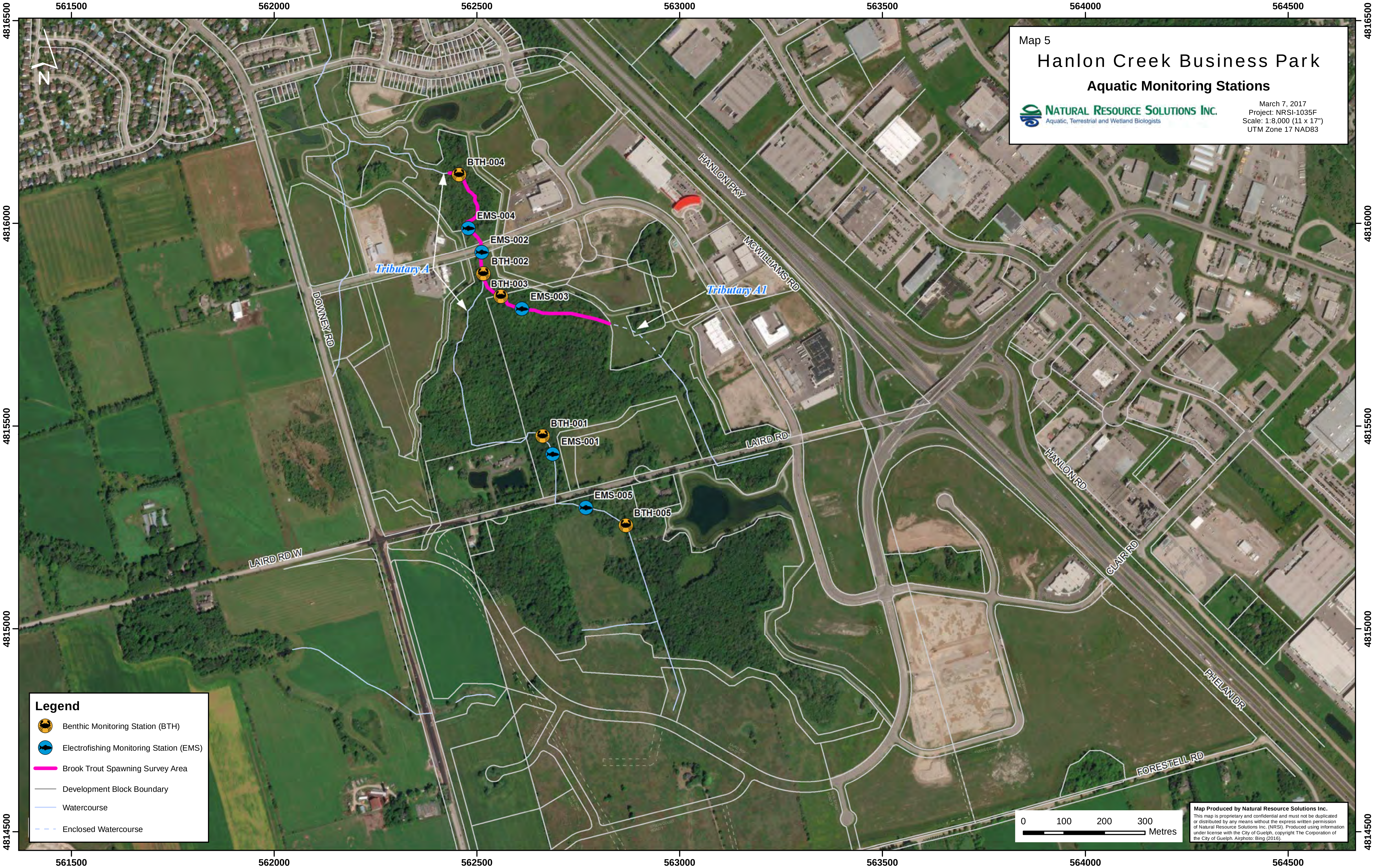
Map 5

Hanlon Creek Business Park

Aquatic Monitoring Stations

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

March 7, 2017
Project: NRSI-1035F
Scale: 1:8,000 (11 x 17")
UTM Zone 17 NAD83



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Document Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1035F_Map5_AquaticMonitoring_8K_2017_03_07_LEH.mxd

Map 6

Hanlon Creek Business Park

Terrestrial Monitoring Stations

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

March 7, 2017
Project: NRSI-1035F
Scale: 1:9,000 (11 x 17")
UTM Zone 17 NAD83

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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1035F_Map6_TerrestrialMonitoringStations_9K_2017_03_07_LEH.mxd

APPENDIX I

CONSTRUCTION INSPECTION REPORTS

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Environmental Inspection Report

Project Number:	1041
Construction Project:	HCBP Phase 2
Date of Inspection:	April 29, 2016
Location:	Hanlon Creek Business Park – Phase 2
Works inspected:	Slope failures along north side of isolated PSW
Activity:	No on-site activity
Weather Conditions at time of Inspection:	8°C, overcast, windy, no precipitation
Weather Conditions 24 hrs prior to Inspection:	9°C, overcast, slightly windy, no precipitation

Comments:
By way of email correspondence with Carmen Sframeli (Husson Engineering + Management), NRSI was made aware that there had been a slope failure along the north side of the isolated PSW within the Hanlon Phase 2 lands. Bill Luffman (Cooper Construction) requested that NRSI take a look at the site.

The slope along the north side of the isolated PSW has failed in numerous locations (approximately 4 larger areas as shown in the attached photos). The slope material has overwhelmed the heavy-duty silt fence along the bottom of the slope in these failure areas and has migrated into the wetland area. During the site visit, it did not appear that any of the material had travelled further into the wetland than extent visibly obvious (i.e. no siltation into wet areas). As there is no active construction in the area, the heavy-duty silt fence that was installed along the top of slope is no longer keyed in or functioning.

The south, east and west slopes around the isolated PSW are still fully vegetated, with no slope or fence failures noted.

The northern slope has failed previously; however, has typically been isolated to 1 or 2 failure areas. In March 2013, LVM was contracted by Husson engineering to inspect the site, determine cause of slope failures and provide an approach for long-term stability. It was determined that groundwater travelling laterally was the cause of the failures; therefore, LVM recommended installation of a sub-drain at the location of the failure. I have attached a copy of LVM's report for reference. To my knowledge, the plan was reviewed and approved in concept by a GRCA engineer on April 3, 2013 and a final approved plan was implemented (see email correspondence attached).

It was identified that the slope did not fail in the location where the sub-drain was installed in 2013. Husson has contracted a geotechnical company to drill boreholes along the top of slope to determine where porous soils are present. The new information from the geotechnical investigation will help determine the proper elevation of sub-drain installation along the entire northern slope to prevent any future failures.

It is recommended that the findings from the geotechnical investigation and rectification approach be reviewed and discussed with the City and GRCA prior to implementation in spring 2016.

As material has migrated into the wetland area beyond the heavy-duty silt fence, it is recommended that material be pulled out of the wetland without further disruption to surrounding vegetation. Care should be taken to ensure that only migrated material is removed from the wetland, and that wetland soils are left undisturbed.

Upon completion of site clean-up and implementation of the agreed upon rectification measures, any exposed soils are to be treated with clean topsoil and seeded with a native seed mix. It is recommended that the slope be treated with terraseed to provide for a thicker, faster growing groundcover. Once material has been pulled out of the wetland, heavy-duty silt fence should be erected along the wetland boundary limit (toe of slope) to ensure that no additional material migrates into the PSW.

Follow-up Requirements:

- Discuss remedial measures with landowner, GRCA and City,
- Remove excess material from wetland area,
- Erect heavy-duty silt fence along wetland boundary (toe of slope),
- Implement remedial measures in spring 2016,
- Topsoil and seed (terraseed) northern slope immediately upon completion of remedial measures with the already approved native seed mix,
- NRSI to conduct follow-up inspections to ensure remedial measures effective and exposed soils stabilized

Inspection Report Distribution List

Organization / Title	**Name**
Cooper Construction – Director of Development	Bill Luffman
Husson Engineering + Management	Carmen Sframeli
City of Guelph, Environmental Planner	Adèle Labbè
City of Guelph, Manager of Technical Services	Joe deKoning
City of Guelph, Environmental Engineer	Prasoon Adhikari
GRCA, Resource Planner	Nathan Garland
GRCA, Supervisor of Resource Planning	Fred Natolochny

Prepared By: Tara Brenton **Date: May 5, 2016**

Photo 1: Northern slope – view west

Photo 2: Failure at top of slope, closest to east side

Photo 3: Material migration at most eastern failure location

Photo 4: View of most central failure area

Photo 5: Failure closer to west side of isolated PSW

Photo 6: Failure in northwest corner

Appendix I

LVM Slope Failure Report, April 4, 2013

LVM

LVM inc

353 Bridge Street East
Kitchener (Ontario) Canada N2K 2Y5
Telephone: 519.741.1313
Fax: 519.741.5422
www.lvm.ca
kitchener@lvm.ca

EMAIL TRANSMISSION

April 4, 2013

Guelph Land Holdings Inc.
c/o Husson Engineering
1725 16th Avenue, Suite 103
Richmond Hill, Ontario L4B 4C6

Attention: Mr. Carmen Sframeli, P.Eng

Subject: Slope Failure – North Side of Part 15 ESA
Hanlon Creek Business Park, Phase 2 – Grading and Servicing
Guelph, Ontario
160-P035567-0500-IM-L004-00

Dear Sir:

LVM inc. is pleased to provide this letter with discussion on the slope failure that occurred on the north side of the Part 15 ESA, about 90 m west of Road N at Phase 2 of the Hanlon Creek Business Park.

LVM first inspected the slope failure during a site visit on March 26, 2013. During the inspection it was determined that the likely cause of the failure was groundwater seepage. It was recommended that the soil that slid down the slope be removed, and the slope re-inspected to identify the area where seepage was occurring.

The contractor began removal of the soil on April 3, 2013, and LVM returned to site to conduct additional inspection and provide recommendations on the slope repair. Site Visit Report 160-P-0035567-1-01-001-IM-I-0007-00 was issued with the results of our inspection. A copy of this report is attached.

The recommended repair detail is provided in the attached Drawing 1.

Based on our inspection, it appears that the cause of the failure is seepage. The most likely cause of the seepage is rainwater infiltrating into the ground in the area to the north of the slope, and then travelling laterally south in the sand and gravel fill over a less permeable (siltier) layer of fill.

The recommended slope repair will act to capture the groundwater travelling laterally through the ground and outlet it to the bottom of the slope. This repair is intended to be a permanent solution for the area of the failure.

As the area that failed appears to be the preferential pathway for lateral travel of groundwater, it is expected that providing subdrain drainage at the location of the failure will help to prevent similar failures in adjacent areas of the slope.

I trust that this information meets your present requirements. If you have any questions, please do not hesitate to contact our office.

Yours very truly,

Jeff Dietz, P.Eng.
Consulting Engineer
lm

LICENSED PROFESSIONAL ENGINEER
J.W. DIETZ
2013-04-04
PROVINCE OF ONTARIO

Encl. Site Visit Report 160-P035567-1-01-001-IM-I-0007-00
Encl. Drawing 1 – Slope Repair Detail

1ec: Husson Engineering, Mr. Paul Husson
1ec: Cooper Construction, Mr. Bill Luffman

LVM inc.

353 Bridge Street East
Kitchener (Ontario) Canada N2K 2Y5
Telephone: 519.741.1313
Fax: 519.741.5422
www.lvm.ca
kitchener@lvm.ca

SITE VISIT REPORT

No. 7

Project: Hanlon Creek Business Park – Phase 2 – Area Grading

Location: Guelph, Ontario

Job No.: 160-P-0035567-1-01-001-IM-I-0007-00
(formerly P035567-0500)

Contractor: Tacc

Reported By: V. Billeci

Date: April 3, 2013

Time: 12:00 P.M.

Purpose of Site Visit:

Recommendation for slope failure off Elsegood Court (approximately Sta 0+080).

Comments:

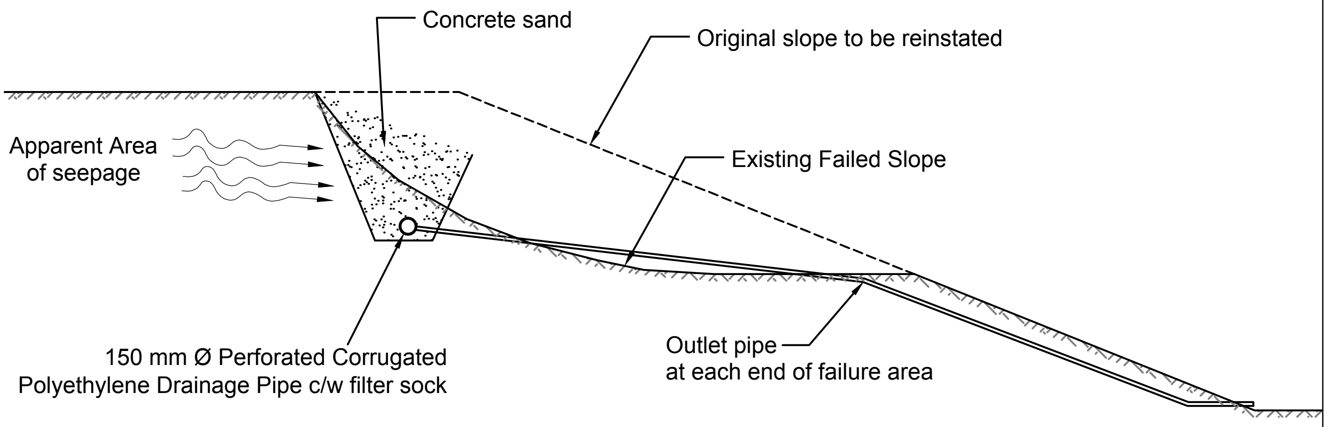
1. LVM was contacted by Hussen to assess the slope failure in the area noted-above.
2. It appears the upper portion of the slope had failed and slid down the hill.
3. Water seepage was visible at the upper east portion of the failed area.
4. The area of failure was approximately 8 m wide and 6 m from the top of the slope.
5. Prior to slope rehabilitation, the contractor was instructed to install subdrains along the top and down the side of the failed area.
6. The subdrains should consist of 150 mm diameter perforated pipe, trenched in the subgrade, and backfilled with concrete sand.

Distribution:

1ec: Cooper Construction Limited,
c/o Husson Engineery + Management,
Mr. Carmen Sframeli, P. Eng. and Ms. Jennifer Hzelton, C.Tech
1ec: City of Guelph, Mr. Colin Baker, P. Eng
sm

Vince Billeci

Jeff Dietz, P.Eng



NOTES:

1. Perforated corrugated polyethylene drainage pipe shall meet the requirements of OPSS 1840.

2. Pipe filter fabric conforming to OPSS 1860 for geotextile Class 1 with a filtration opening size of 150 to 450 microns shall be supplied on all sections of perforated pipe.

3. Subdrain pipes to be set on at least 1% grade draining to a positive outlet. If the pipe is outletted to a ditch then the last 1.5 m should consist of a corrugated galvanized steel pipe equipped with a rodent gate.

4. Bedding and backfill material shall be concrete sand meeting the gradation requirements of OPSS 1002 (Fine Aggregate for Concrete).

5. Slope to be re-topsoiled and re-seeded.

Project

Hanlon Creek Business Park
Phase II

Guelph, Ontario

Title

SLOPE REPAIR DETAIL

LVM inc.
353, Bridge Street East
Kitchener (Ontario) N2K 2Y5
Telephone : 519.741.1313
Fax : 519.741.5422

Prepared **A.Higgins**
Drawn **A.Higgins**
Checked **J.Dietz**

Discipline **MATERIALS ENG.**
Scale **NTS**
Date **2013-04-04**

Project manager **J.Dietz**
Sequence no. **01 of 01**

M. dept.	Project	Disc.	Dwg no.	Rev.
160	**P-035567-001**	**IM**	**001**	**00**

G:\160\P0035567 (FORMERLY P035567)\Z5_CAD\001\160-P035567-001-IM-DWG-01.DWG

Appendix II

GRCA Correspondence

From: Craig Bolton
Subject: Wednesday Afternoon – Hanlon Creek Business Park slope failure
Date: 2013-04-03
To: Tara Brenton, Jay Dharmadurai

Hi Tara and Jay,

It was good meeting you both this afternoon. I have now reviewed my findings on site with staff in our office.

I have spoken with one of our engineers (Gus Rungis) and he is conceptually accepting the recommended solution of pipes being installed to move the water from the top of the slope to the wetland subject to the proposed works being designed and the works installed under the supervision of an engineer. Any works undertaken would be done at the applicant's risk. We have not reviewed the plan proposed but we are in agreement that this will be a temporary solution due to the emergent situation and the forecasted precipitation. We recognize that this work can proceed without submitting a permit at this time due to the limited time constraints.

We would anticipate submission of a final solution in the near future, and we will examine the final solution proposed by an engineer and address permit requirements at that time. We would anticipate a geotechnical report to address the reasons for the current failure and a stamped engineers plans for the long term solution as soon as possible. I spoke with Fred Natolochny (Supervisor of Resource Planning) and he has asked me to look at the previous permits to determine any additional permit requirements for the proposed works. I will be able to look at this tomorrow and have an answer for you before the weekend.

Thank you,

Craig

Craig Bolton B.A (Geog), M.Ed., OCT
Regulations Officer
Grand River Conservation Authority
400 Clyde Road
P.O. Box 729
Cambridge, ON N1R 5W6
(519) 621-2763 x2323 Office
(519) 240-7457 Cell
(519) 621-4945 Fax
www.grandriver.ca
cbolton@grandriver.ca

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Environmental Inspection Report

Project Number:	1041
Construction Project:	HCBP Phase 2
Date of Inspection:	November 1, 2016
Location:	Hanlon Creek Business Park – Phase 2
Works inspected:	Slope repairs along north side of isolated PSW
Activity:	No on-site activity
Weather Conditions at time of Inspection:	10^{o}C, overcast, low winds, no precipitation
Weather Conditions 24 hrs prior to Inspection:	12^{o}C, partly cloudy, no precipitation

Comments:
A follow-up inspection of the northern slope along the isolated PSW was conducted on November 1, 2016. The slope stabilization methods as recommended in the Geotechnical Investigation Report prepared by Englobe (2016), follow-up recommendations provided in NRSI's April 2016 inspection report (NRSI) and the City's recommendation for a 3:1 slope have been implemented.

The following items were noted during the inspection:

1) The sub-drain has been installed and the northern slope has been repaired and regraded to provide a 3:1 slope (attached Drawing),
2) The excess site material that had migrated into the PSW has been removed from the PSW, with no disturbance observed to adjacent wetland vegetation,
3) A new layer of heavy-duty sediment and erosion control fencing has been installed along the toe of slope to discourage the migration of any site material into the PSW,
4) A seed mix has been applied to the northern slope, in 2 small areas within the PSW that were lacking vegetation cover and along the top of the slope within the future development block.
5) Seed along the northern slope is well established with little to no bare ground exposed.

Following the inspection conducted on November 1, 2016, NRSI confirmed with Copper Construction that the seed mix applied to the slope is comprised of a turfgrass mixture (White Clover, Tuft Type Perennial Ryegrass, Creeping Red Fescue and Kentucky Blue Grass). The isolated wetland is considered Provincially Significant; therefore, the original intent of the approved landscape plans in the EIR was to naturalize the slope / wetland buffer area. To ensure that the slope continues to be stable, while also providing a naturalized buffer to the wetland, the following naturalization efforts as recommended by NRSI will be undertaken the week of November 7, 2016:

1) In the 2 areas where seed mix has been applied to exposed soils directly within the wetland, grass will be raked off to expose soils. Seeds will be collected from the adjacent natural area and broadcast over the exposed wetland soils to encourage generation of native / naturally occurring species

2) Small nodes along the slope will be raked to remove the grass and expose the topsoil layer. Native seeds will be broadcast onto the exposed areas to encourage naturalization patches. The small nodes will help encourage / disperse native seeds along the slope and over the course of a couple of years, will provide a more naturalized buffer in place of non-native lawn. The exposed nodes will be randomly placed along the slope and kept to a small size so that the slope continues to be stable.

Photos are provided below that compare the condition of the failed slope as documented in April 2016 to the repaired slope in November 2016. Repairs are compliant with the City's recommendation for a less steep slope, follow-up requirements outlined in the previous inspection report and the Englobe geotechnical investigation report (2016).

Follow-up Requirements:

- If deemed necessary, NRSI to conduct follow-up inspection in early spring 2017 to confirm that stabilization measures still in place following winter and spring thaw

Inspection Report Distribution List

Organization / Title	**Name**
Cooper Construction – Director of Development	Bill Luffman
Husson Engineering + Management	Carmen Sframeli
City of Guelph, Environmental Planner	Adèle Labbè
City of Guelph, Manager of Technical Services	Joe deKoning
City of Guelph, Environmental Engineer	Prasoon Adhikari
GRCA, Resource Planner	Nathan Garland
GRCA, Supervisor of Resource Planning	Fred Natolochny

Prepared By: Tara Brenton **Date: November 3, 2016**


April 29, 2016


November 1, 2016

April 29, 2016

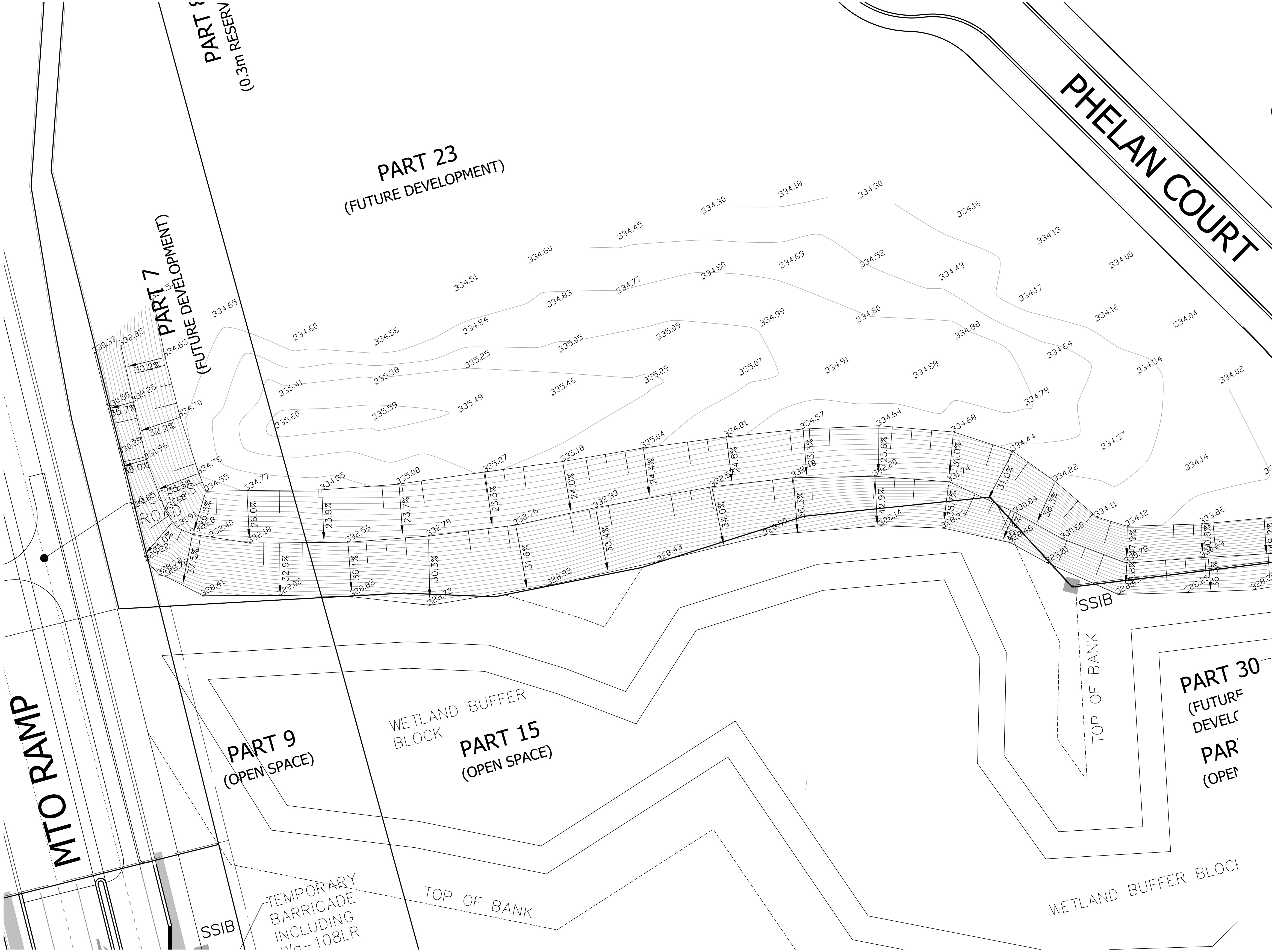
November 1, 2016

April 29, 2016

November 1, 2016

April 29, 2016

November 1, 2016



HUSSON

ENGINEERING + MANAGEMENT

P 905.709.5825
1725 16TH AVENUE, SUITE 103
RICHMOND HILL, ON L4B 4C6
HUSSON.CA

FIGURE 1
HANLON CREEK
SLOPE GRADING

DATE: OCTOBER 2016 SCALE: 1:750 PROJECT: 12600

APPENDIX II

GROUNDWATER MONITORING REPORT

Annual Technical Memorandum
2016 Groundwater Monitoring Program
Hanlon Creek Business Park
City of Guelph

April 2017

Prepared for:

City of Guelph
Economic Development
1 Carden Street
Guelph, ON N1H 3A1

Prepared by:

Banks Groundwater Engineering Limited
940 Watson Road South, RR 1 Puslinch, Ontario N0B 2J0
519.829.4808 www.banksgroundwater.ca

Technical Memorandum

Banks Groundwater Engineering Limited
940 Watson Road South, RR 1 Puslinch, Ontario N0B 2J0
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10 April 2017

Hanlon Creek Business Park
2016 Groundwater Monitoring Program

---

1 Introduction

This Technical Memorandum presents the results of the ninth year of a long-term groundwater monitoring program for the Hanlon Creek Business Park (HCBP). The results of the first eight years were presented in Technical Memoranda completed in 2009 through 2016 respectively. A Hydrogeology Report was completed by Banks Groundwater Engineering Limited in May 2008, as part of the Environmental Implementation Report (EIR), in support of the proposed HCBP. The Hydrogeology Report presented a recommended long-term groundwater monitoring program. This program was developed in recognition of the importance of establishing baseline groundwater conditions and to assess any changes in groundwater elevations and groundwater quality during and following development of the site. The monitoring program is also required to assess the performance of the stormwater management facilities as they are constructed and to observe seasonal trends in water levels in the core wetland. This monitoring program is consistent with the recommendations of the Hanlon Creek State-of-the-Watershed Study Report (2003).

Baseline groundwater conditions were established during five years of on-site monitoring. The detailed results for the period spring 2003 to spring 2008 were presented in the Hydrogeology Report. Banks Groundwater Engineering is continuing to monitor groundwater in on-site monitoring wells and in wetland and streambed mini-piezometers on a quarterly basis. To correspond to previous monitoring, the preferred monitoring periods are January, April, July and October. Data loggers have been installed to measure and record groundwater levels and temperatures on a more frequent basis in selected monitoring wells and mini-piezometers. Groundwater samples are being collected from selected monitoring wells on an annual basis and analyzed for a representative list of groundwater quality parameters to augment the existing background water quality data.

It is not expected that development of this site will have any effect on local private water wells. It is expected that if any changes in groundwater elevations and groundwater quality occur during and following development of the site, as a result of construction and post-construction activities, they will become apparent first in the on-site monitoring wells. Therefore, it was concluded that monitoring of local private wells was not required.

It is also noted that selected monitoring wells and mini-piezometers are currently being monitored for the purpose of establishing baseline data in advance of proposed adjacent land use activities (e.g. Mast-Snyder Gravel Pit). Changes related to climatic conditions are being observed in the on-site monitoring wells and mini-piezometers.

Site grading began in 2010 in Phases 1 and 2. This necessitated decommissioning of selected monitoring stations located within the grading areas, in accordance with Ontario Regulation 903 (as recently amended) of the Ontario Water Resources Act by a licensed Water Well Technician. Records of well decommissioning are required by this Regulation to be completed and submitted to the Owner and the Ministry of the Environment and Climate Change (MOECC).

A total of 12 monitoring wells had been decommissioned by the end of 2011, three monitors were located in Phase 1 and the remaining nine monitors were located in Phase 2. One active monitoring well (MW135) located in Phase 2 was decommissioned in the late summer of 2016 while lot grading was being completed. This monitor will be replaced in early 2017.

Many existing monitoring wells have been maintained, with minor modifications or improvements, for continued monitoring. Six additional monitors were installed within Phase 1 in October 2011, and five additional monitors were installed within Phase 2 in January 2012. Monitoring of the eleven additional wells began in January 2012.

The monitoring data has been compiled, plotted, and analyzed and the results are presented in this Technical Memorandum. Conclusions and recommendations related to the monitoring program are summarized.

2 Groundwater Monitoring

2.1 Groundwater Monitoring Background

Groundwater level monitoring was conducted at this site for more than five years in support of the evaluation of local hydrogeological conditions. The various stages of monitoring that have been completed are summarized in the EIR Hydrogeology Report. Since January 2007, groundwater levels have been monitored at the HCBP site on a quarterly basis.

The locations of the current groundwater monitoring stations are shown in Figure 1. As noted above, some stations have been decommissioned and new stations were installed as of January 2012.

2.2 Groundwater Monitoring Stations Status

The status of each groundwater monitoring station is determined during each monitoring round. This includes all monitoring wells and mini-piezometers. The current condition of each station and other relevant attributes are described in Appendix A. Monitoring wells decommissioned during 2010 and 2011 are identified. Additional monitoring wells and mini-piezometers in Phases 1 and 2 are also included.

2.3 Groundwater Monitoring Data Collection and Compilation

The establishment of baseline groundwater conditions continued until grading of the site was initiated. This included monitoring of groundwater levels in selected monitoring wells and mini-piezometers (listed in Appendix A). In most cases this monitoring will continue to occur on a seasonal basis to establish variations in groundwater levels for each season at each station. In a selected number of monitors, groundwater levels and temperatures will also continue to be recorded on a frequent basis using data loggers. This will assist in determining the relationships of groundwater levels, wetland levels, surface water flow, and precipitation. Groundwater samples were collected from selected monitoring wells and analyzed for general chemical parameters in 2016. Sampling and analysis is to continue on an annual basis, although a reduced scope is planned for 2017, recognizing the minimal changes in water quality and the state of development in parts of the site.

During the 2016 monitoring period, there were 37 functioning monitoring wells and 19 mini-piezometers located across the HCBP site. Two of the mini-piezometers were installed in June 2013 on a temporary basis, and remained in-place at the end of 2016 (details below). The data obtained from all groundwater monitoring locations during 2016 were compiled for the purpose of the analyses presented below.

Following each seasonal monitoring period, the data was recorded and entered into the groundwater level and temperature monitoring dataset. Data downloaded from each data logger was corrected for barometric pressure and then incorporated into the respective records within the groundwater level monitoring dataset. As the dataset is updated, tables and graphs are also updated to support on-going analysis of the groundwater monitoring results.

2.4 Groundwater Monitoring Results

The results of manual groundwater level measurements at the HCBP site up to October 2016 are summarized in tabular format in Appendix B. Selected monitoring station details are included with the monitoring data, which is presented as depth (in metres) to groundwater below current ground level and groundwater elevation (metres above mean sea level).

The groundwater elevation data for each monitoring station, based on the manual measurements, are presented in graphical format in Appendix C. The groundwater elevations from April 2003 to October 2016 presented in these graphs illustrate seasonal levels for most locations. The range of groundwater elevations varies with each monitoring location, ranging from as little as 0.45 m, to as much as 2.62 m over this 13.5-year monitoring period. Monitoring well MW123 is excluded from this comparison as it is completed in the deep bedrock aquifer and the groundwater levels are influenced by municipal well production.

Presented in Appendix D is a summary of vertical hydraulic gradient calculations, based on comparisons of shallow, intermediate and deep monitoring intervals, on selected dates. Graphs illustrating groundwater elevations and hydraulic gradients are included, with monitoring stations grouped in seven west-to-east profiles. These data and graphs confirm the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Groundwater discharge conditions have also been confirmed at the wetland adjacent to Downey Road, situated between Laird and Forestell Roads.

Given that climate is one of the most significant factors influencing groundwater elevations, available local climate data was compiled and is presented in graphical format in Appendix E. During 2016, groundwater elevations and temperatures were recorded using data loggers in 37 groundwater monitoring stations. These data are presented with the climate data in Appendixes F, G, and H.

The hourly groundwater elevation data presented in Appendixes F, G, and H has been further assessed by reducing the data into graphs of the quarterly (i.e. seasonal) range in hourly groundwater elevations for each of the currently-existing monitors that are equipped with data loggers for part or all of the period from 2007 to 2016. This format is intended to assist in illustrating any significant changes and/or trends in the data when compared year-over-year for each quarter. This is the third annual report to include such graphs, which are presented in Appendix I.

Groundwater samples have been collected from selected monitoring wells in July 2003 and each April from 2008 to 2016. The samples were submitted to an accredited laboratory for analysis of selected chemical parameters. As indicated previously, this will provide a baseline of groundwater quality data prior to and during development of the site. The water quality data are presented in Appendix J.

3 Groundwater Characterization Update

3.1 Factors Influencing Fluctuations in Groundwater Elevations

There are a number of factors that influence groundwater levels at any given time and location, including:

- Precipitation
- Ambient air temperature and solar radiation (influencing snowmelt, evaporation and evapotranspiration)
- Vegetation
- Soils
- Geology
- Topography and associated drainage characteristics

- Land cover
- Local groundwater withdrawals and uses (e.g. construction dewatering).

Each of these factors can influence the rate and spatial distribution of groundwater recharge. As such, it was important to account for these factors under the pre-development conditions in order to appreciate the causes of observed groundwater elevation changes. These changes also need to be evaluated relative to long-, medium-, and short-term influences. For the purposes of this evaluation, a <u>long-term influence</u> is considered for example to be lower-than-normal precipitation over several years, which have caused drought conditions in this area of Ontario historically and recently. For the purposes of this evaluation, <u>medium-term influences</u> are considered seasonal. <u>Short-term influences</u> are considered event-related, such as spring thaw and periods of above-normal or sustained rainfall.

Given that climate is one of the most significant factors influencing groundwater elevations, available local climate data was compiled and plotted to evaluate short-, medium-, and long-term variations and trends in precipitation and air temperature. A detailed evaluation of climate and fluctuations in groundwater elevations was presented in the EIR Hydrogeology Report.

Updated climate data is presented in graphical format in Appendix E. Graph E1 presents the total annual precipitation recorded at the Region of Waterloo International Airport Station (WMO ID 71368), for the period 1971 to 2016 inclusive. This station was selected due to its' proximity to the HCBP site and availability of total daily precipitation and maximum daily air temperature data. Also illustrated in Graph E1 is a trend line depicting the annual cumulative departure from the average annual precipitation for this 46-year period, which is estimated to be 875 mm/year. This technique is helpful in illustrating periods of above- and below-average annual precipitation. An upward trend indicates sequential years of above-average precipitation (e.g. 1982 to 1988). A downward trend indicates a period of below-average precipitation (e.g. 1997 to 2007), possibly resulting in drought conditions. These longer-term trends can have a notable influence on groundwater levels. They need to be considered in the context of past, present, and future groundwater levels on-site due to the relatively shorter period (i.e. less than 14 years) of groundwater monitoring that has been conducted at the HCBP site.

The data presented in Graph E1 indicates that during the period 1997 to 2016 inclusive, the total annual precipitation for 14 out of 20 years was below the 46-year average of 875 mm/year. It is therefore interpreted that groundwater levels would have been elevated during the early to mid-1990's and likely declined from 1997 to 2007. Since groundwater monitoring began on-site in 2003, the total annual precipitation has only been above the longer-term annual average in the years 2003, 2006, 2008, 2011, and 2013. The varying annual precipitation during this period has caused groundwater levels to continue to fluctuate.

As indicated above, the groundwater monitoring program on-site began in April 2003. It is therefore useful to consider total monthly precipitation during this period (and shortly before) to evaluate medium-term influences on groundwater levels. Graph E2 presents the total monthly precipitation recorded at the Region of Waterloo International Airport Station, for the period January 2003 to December 2016 inclusive. Also illustrated in Graph E2 is a trend line depicting the monthly cumulative departure from the average monthly precipitation for this period. <u>The average monthly precipitation for the period 2003 to 2016 has been calculated to be about 68 mm/month.</u> Similar to the annual data, an upward trend indicates sequential months of above-average precipitation, which may cause increases in groundwater levels. A downward trend indicates a period of below-average precipitation, possibly resulting in a reduction in groundwater levels. On the basis of Graph E2, it would be expected that groundwater levels would be higher following months of above average precipitation.

The monthly observed precipitation from January 2003 to December 2016, the monthly normals, and the cumulative departure from the normal monthly precipitation are presented in Graph E3. This plot suggests that, due to a declining trend in precipitation from the spring of 2004 to the spring of 2008, groundwater levels would have declined during the same period, followed by an increase from the summer of 2008 to the summer of 2009, when monthly precipitation was greater. Increases in groundwater levels would also be expected in the spring of 2010, the fall of 2011, the fall of 2012, the spring and fall of 2013, the summer and fall of 2014 and 2015, and the spring of 2016.

An alternative method to evaluate fluctuations in groundwater levels relative to monthly precipitation trends is to consider the monthly cumulative departure from normal monthly amounts. The normal amounts are based on the updated 30-year record (i.e. from 1981 to 2010), which was published in 2013 by Environment Canada. The updated record was applied in preparation of Graph E3.

These observations are further illustrated in Graph E4, which presents the preceding 18-month average monthly precipitation for the period from January 2003 to December 2016. This graph was developed with the understanding that the preceding 18 months of precipitation are likely the most influential on observed groundwater elevation trends. The cumulative departure from the 18-month average precipitation over this period also emphasizes the trends observed in Graph E2. One of the most notable recent trends is the increase in average precipitation beginning late-2008 and continuing to January 2010. This was followed by fluctuations up to about October 2014, including a declining trend from January to August 2011, and then somewhat of a rebound from September 2011 to April 2012. A significant rise is observed from July 2013 to January 2015, and this 18-month increase represents the second highest level since monitoring began in 2003. Since then the trend has been downward due to the less-than-normal amount of precipitation in 19 of 24 months up to the end of 2016.

Short-term influences related to events are depicted by daily precipitation totals and ambient air temperature (i.e. maximum daily temperature). These data are presented in Graph E5, for the March 2007 to December 2016 monitoring period, and in Graph E6 for the January to December 2016 period. To determine which events have an immediate influence on groundwater levels, total daily precipitation and air temperature are plotted together and compared with groundwater levels. Based on available data, the relationship of the above factors to observed fluctuations in groundwater elevations within the HCBP site was evaluated with direct reference to Graphs E1 to E6 and graphs of groundwater elevations observed at each monitoring station. This analysis is presented in the following sub-sections.

3.2 Observed Groundwater Elevations and Depths to Groundwater

The manually-recorded groundwater elevations for each monitoring station are summarized in tabular form in Appendix B, and presented as graphs in Appendix C. Groundwater elevations recorded by data loggers installed in 36 of the active monitoring locations are presented as graphs in Appendixes F, G, and H. Graphs for monitoring stations that have been decommissioned are also included for reference in Appendixes C, G and H. The observed groundwater elevations can be associated with the long-, medium-, and short-term factors discussed previously. To assist with the direct comparison of groundwater elevations and precipitation, the total monthly precipitation has been included in each of the graphs in Appendixes F, G, and H. The interpreted relationships are discussed below.

3.2.1 Long-Term

Analyses presented in the eight previous Technical Memoranda and the EIR Hydrogeology Report showed that it is likely groundwater levels declined from the spring of 1997 to the fall of 2007, based on the recorded precipitation for this period. Evidence of the effects of the longer trend of below-average precipitation is shown by the groundwater levels in July and November 2007, which prior to 2012 were the lowest observed groundwater elevations on-site. Precipitation in 2007 was well below average and was the lowest observed from 1971 to 2016 (refer to Graph E1). Below-average annual precipitation in 2009 and 2010 also influenced groundwater elevations through the summer and fall of 2010.

The total precipitation in 2016 was 722 mm, which was the seventh lowest recorded amount from 1971 to 2016. This was attributed to below-average precipitation in nine of twelve months in 2016. However, by comparison groundwater levels at many monitored locations on-site during the summer and fall of 2016 were not as low as those recorded in the summer and fall of 2012, which were the lowest recorded since monitoring began in 2003.

In contrast, annual precipitation in 2003, 2006, 2008, 2011, and 2013 was above average. This appears to have influenced groundwater levels in the spring of 2004 and 2007, the spring and fall of 2008, in the last five months of 2011, and from spring to fall in 2013.

3.2.2 Medium-Term

Analyses presented in the eight previous Technical Memoranda and the EIR Hydrogeology Report showed that monthly total precipitation and trends (depicted in Graphs E2 and E3) provide additional insight related to the observed seasonal fluctuations in groundwater elevations. Following below-average precipitation in late 2009, through most of 2010, and into February 2011, groundwater elevations declined and approached the low levels observed in 2007. Above-average precipitation from March to December 2011 (with the exception of July), reversed the declining groundwater levels at many locations. But then the below-average precipitation through seven of the first eight months of 2012 caused groundwater levels to decline, and at many locations to the lowest recorded since monitoring began in 2003. These effects were reversed following above-average monthly precipitation in September and October 2012, and the following spring and fall of 2013.

Throughout 2016, maximum daily temperatures fluctuated within typical seasonal ranges. However, from the start of January to the end of February there were 32 days where the maximum temperature equalled or exceeded 0^0C. Precipitation events on some of the days would have been rainfall, an estimated combined total of 57 mm. This is interpreted to have resulted in the observed sharp increase in groundwater elevations at many stations across the site, which continued through to the beginning of April. Maximum daily temperatures rose above freezing during the first week of March and remained above freezing until the first week in December 2016.

Combined snow and rainfall through January, February and March was about 177 mm, which is just short of the 181 mm normal amount of precipitation for this period. Further comparisons of 2016 monthly precipitation amounts versus normal monthly amounts are presented in Table 1.

Table 1: 2016 Monthly Precipitation versus Monthly Normals

Month	2016 Total Monthly Precipitation (mm)	Normal Monthly Precipitation (mm)	Difference (mm)
January	27.8	65.2	-37.4
February	35.7	54.9	-19.2
March	113.6	61.0	52.6
April	56.6	74.5	-17.9
May	68.0	82.3	-14.3
June	41.3	82.4	-41.1
July	49.7	98.6	-48.9
August	103.5	83.9	19.6
September	49.3	87.8	-38.5
October	42.4	67.4	-25.0
November	61.4	87.1	-25.7
December	72.4	71.2	1.2
Total	721.7	916.5	- 194.8

The data presented above in Table 1 illustrates there were only three months in 2016 where precipitation was at, or above, normal monthly amounts (i.e. March, August and December). During March, the warm temperatures combined with a total of almost 53 mm of rain caused a continued sharp increase in groundwater levels. Groundwater levels began to decline in early-April, which typically does not occur until May. Lower-than-normal precipitation from April through July resulted in a sharp decline in groundwater levels across the site. August precipitation events resulted in the second wettest month of 2016. The warm days and rainfall in late-December also contributed to a rise in groundwater levels at the end of 2016.

3.2.3 Short-Term

The manual measuring and recording of groundwater levels across the HCBP site has been conducted on 49 occasions, during various months and seasons, from April 2003 to October 2016. As a result, monitoring of groundwater levels may not have occurred at precisely the best time to observe the highest and lowest annual elevations. Fortunately however, groundwater levels were observed in selected monitors in the spring of 2003, in most monitors in the springs of 2004 and 2006, and in all available monitors during the spring from 2007 to 2016 inclusive. Therefore, it is expected that these observations represent the influence of spring thaw and precipitation events, and as such are reasonably close to the highest annual levels for this monitoring period.

To evaluate the response to spring thaw and precipitation at selected groundwater monitors, data loggers were installed to record groundwater levels on a more frequent basis. Table 2 below lists the monitoring wells and mini-piezometers where 36 data loggers were in operation for all of 2016 (refer to Figure 1 for locations). A number of locations were selected to evaluate groundwater levels and to establish baseline conditions relative to various climate effects prior to development of the HCBP.

The EIR Hydrogeology Report presented a detailed evaluation of daily influences from March 2007 to April 2008. The previous eight Technical Memoranda presented a detailed evaluation of climate influences on groundwater levels for January through December for each year from 2008 to 2015 respectively. For reference, the total daily precipitation and maximum daily air temperature recorded at the Region of Waterloo International Airport Station are presented in Graph E5, for the period March 2007 to December 2016.

The following is noted for January through December 2016 in Graphs E2 to E6:

- As noted above, from the start of January to the end of February there were 32 days where the maximum temperature equalled or exceeded 0^0C. Precipitation events on some of the days would have been rainfall, an estimated combined total of 57 mm. Maximum daily temperatures rose above freezing during the first week of March and remained above freezing until the first week in December 2016. A short period of warm, wet weather occurred during the last 10 days of December.
- Combined snow and rainfall through January, February and March was about 177 mm, which is just short of the 181 mm normal amount of precipitation for this period. The warm temperatures combined with rainfall during the first quarter of 2016 is interpreted to have resulted in the observed sharp increase in groundwater elevations at many stations across the site, which continued through to the beginning of April.
- Rainfall continued to be below normal for the months of April through July (refer to Table 1), resulting in a decline in groundwater levels at many monitoring locations from early-April through early-August.
- August rainfall was almost 20 mm above normal, causing groundwater levels to rise temporarily. Groundwater levels then tended downwards until the last week in December.
- The total precipitation through 2016 was about 722 mm, as compared to a 46-year average of about 875 mm and a normal of 916.5 mm.

These are considered to be the main climatic factors influencing groundwater levels on-site during the 2016 interval. The highest groundwater levels observed in monitors equipped with data loggers occurred during late-March and early-April. The lowest groundwater levels occurred in November and December.

Table 2: Monitoring Stations Equipped With Data Loggers as of December 2016

Monitoring Well	Data Logger Installed	Monitoring Well	Data Logger Installed
003	March 2007	121A	July 2008
004	August 2009	122A	July 2008
103	June 2010	124	January 2012
104	January 2008	125	January 2012
105	January 2008	126	January 2012
107	July 2008	127	January 2012
109	April 2009	128	January 2012
111	October 2010	129	January 2012
112	October 2010	130A	January 2012
116A	January 2008	131	January 2012
117A	January 2008	132	January 2012
118A	July 2008	133	January 2012
119A	July 2008	134	January 2012

Mini-Piezometer	Data Logger Installed	Mini-Piezometer	Data Logger Installed
1D	April 2009	9D	March 2007
2D	January 2007	10D	April 2012
4D	April 2009	11D	June 2010
7D	November 2007	12D	January 2012
8D	June 2010	13D	July 2016

2016 Groundwater Level Monitoring at Downey Road PSW

Groundwater levels and temperatures are monitored at two stations at the Downey Road PSW. These include monitoring well MW003, which is located on the north edge of the PSW, and mini-piezometer nest PZ-9, which is located in the centre of the PSW. The groundwater level and temperature observations for MW003 and PZ-9D are presented in graphical format in Appendix F.

Graph F1 presents the daily groundwater elevations (with occasional manual readings) recorded in monitor MW003, from March 2007 to January 2008. In late January 2008, the data logger was re-set to record groundwater levels and temperatures on an hourly basis. The EIR Hydrogeology Report presented a detailed evaluation of groundwater levels from March 2007 to April 2008, and the eight previous Technical Memoranda presented a detailed evaluation for each respective year from 2008 through 2015. The following is a summary of 2016 observations at this location.

During the months of January, February and March 2016, groundwater levels rose sharply in response to warmer temperatures and rainfall events. As noted previously, combined snow and rainfall through January, February and March was about 177 mm, which is just short of the 181 mm normal amount of precipitation for this period.

Groundwater levels began a sharp decline in early-April, which is earlier than most years, and continued to decline through July. August rainfall caused levels to rise again briefly, before declining through December. Groundwater levels rose in response to precipitation events in late-December.

The responses to precipitation events and spring thaw, or lack thereof, observed in this monitor during the period 2007 to 2016, have demonstrated the local sensitivity of the shallow groundwater system, which is associated with the coarse-grained nature of the overburden deposits within and above the uppermost aquifer. The below-normal precipitation during 2016 caused groundwater levels to decline to the third-lowest fall levels at this location since data logger monitoring began in 2007.

As noted above, two mini-piezometers were installed in the Downey Road PSW. PZ-9S was installed to a depth of about 0.5 m and PZ-9D to a depth of about 1.0 m below ground level. Graph F2 presents the groundwater elevations recorded in mini-piezometer PZ-9D, for the period March 2007 to December 2016. Groundwater levels for this pair of shallow and deeper mini-piezometers have illustrated the upward hydraulic gradient that exists in this PSW.

It is noted that responses to precipitation and temperature are apparent in PZ-9D in Graph F2, similar to MW003, confirming the infiltrative capacity of the medium- to coarse-grained deposits on this site and the inherent relationship of the wetlands to the shallow groundwater system. Each year, groundwater levels decline to an elevation that is below ground level in the wetland, typically during June or July.

The groundwater elevations for MW003 and PZ-9D are combined in Graph F3, indicating similar trends in each monitor. A small upward hydraulic gradient is also evident at various times when groundwater levels in MW003 are higher when compared with levels in the adjacent PZ-9D.

2016 Groundwater Level Monitoring in the Core PSW

Groundwater level and temperature observations, for monitoring wells and mini-piezometers that are located in and adjacent to the Core PSW of the HCBP, are presented in graphical format in Appendix G. The total monthly precipitation has been included for comparison in the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in the groundwater temperature graphs. The graphs in Appendix G are presented in an order that corresponds to the north-to-south locations of the monitoring stations (refer to Figure 1).

The responses to maximum daily air temperatures and precipitation are apparent in these plots. This confirms the infiltrative capacity of the medium- to coarse-grained deposits adjacent to the Core PSW and the inherent relationship of the wetlands to the shallow groundwater system. The hourly recording of groundwater levels at mini-piezometer locations also indicates subtle fluctuations during each 24-hour period, likely associated with diurnal cycles of evapotranspiration in the wetland. The range of groundwater levels in mini-piezometers is more subdued than other plots, which reflects the relatively constant groundwater elevations in the wetland area, usually with only minor perturbations observed relative to precipitation and/or temperature changes.

The observed relationship of total daily rainfall and maximum daily temperature, recorded at the Region of Waterloo International Airport Station, to the groundwater levels and temperatures recorded on-site from 2003 to 2016 inclusive, has validated the use of this station’s data for these analyses. A rain gauge has been installed at the City of Guelph Clair Road Emergency Services Centre. It is expected that the data from this gauge will be incorporated into the analyses for the 2017 monitoring program.

Groundwater levels at Core PSW monitoring stations during 2016 responded to climatic factors similar to the Downey Road PSW monitors described in the previous section. During the months of January, February and March 2016, groundwater levels rose sharply in response to warmer temperatures and rainfall events. As noted previously, combined snow and rainfall through January, February and March was about 177 mm, which is just short of the 181 mm normal amount of precipitation for this period.

Groundwater levels began a sharp decline in early-April, which is earlier than most years, and continued to decline through July. August rainfall caused levels to rise again briefly, before declining through December. Groundwater levels rose in response to precipitation events in late-December.

The below-normal precipitation during 2016 caused groundwater levels to decline to the third-lowest late-summer/early-fall levels at some locations. The lowest levels observed in 2016 varied from location to location, but most occurred during late-July and August. At many Core PSW monitoring stations, groundwater levels rose in response to precipitation in August for a brief period and then later in December.

Groundwater levels in the three mini-piezometer monitoring locations (i.e. from north to south PZ-4D, PZ-2D, and PZ-1D) that are located in the Core PSW, were below the normal range for most of 2012. During 2013 through 2016, groundwater levels were within the range of previous years. The recorded groundwater elevations for PZ-4D, PZ-2D, and PZ-1D are presented in Graphs G13, G20, and G22 respectively. These graphs show groundwater levels that are typically at, or above, ground level during spring months and reduced levels during late-summer months.

Similarly, groundwater levels recorded in streambed mini-piezometers (i.e. from north to south PZ-10D, PZ-8D, PZ-11D, PZ-7D) were below the level of the creek and the streambed for part, if not most, of 2012. Groundwater levels during 2013 through 2016 were within the range observed in previous years, where data is available. The recorded groundwater elevations for PZ-10D, PZ-8D, PZ-11D, and PZ-7D are presented in Graphs G2, G4, G6, and G8 respectively. These graphs show groundwater levels at, or above, the streambed during spring months and reduced levels during late-summer months.

Climate had the greatest, if not only, influence on groundwater levels within the Core PSW in 2016. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to construction activities during 2016 within the HCBP (i.e. there were no abnormal changes in groundwater elevations that would have suggested otherwise). As of the end of 2016, ten lots in Phase 1 had been developed and another two were at various stages of development. One lot had been developed in Phase 2 and a second lot was being developed. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during March, August and late-December, it is evident that infiltration was occurring across the site.

2016 Groundwater Level Monitoring at Perimeter Locations

Groundwater level and temperature observations, for monitoring wells that are located at perimeter locations around the HCBP site, are presented in graphical format in Appendix H. The total monthly precipitation has been included for comparison in the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in the groundwater temperature graphs. The graphs in Appendix H are presented in an order that corresponds to the north-to-south locations of the monitoring stations (refer to Figure 1).

The responses to precipitation and maximum daily air temperatures are also apparent in these plots. Groundwater elevations vary more widely over the year at perimeter locations in comparison to the Core PSW locations. The perimeter groundwater monitoring stations responded to spring thaw and the above-normal precipitation during March, August and late-December 2016, similar to the monitoring stations described in the previous two sections. There were no apparent short-term and/or longer-term changes in groundwater levels at perimeter monitoring stations that could be attributed to construction activities during 2016 within the HCBP.

3.2.4 Site-Wide Observations

Groundwater Elevations

It is noted that, as expected, the greatest range in groundwater elevations occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. The smallest fluctuations occur in and adjacent to the core wetland and Hanlon Creek Tributary ‘A’. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range of groundwater elevations in these areas.

The hourly groundwater elevation data presented in Appendixes F, G, and H has been further assessed by reducing the data into graphs of the quarterly (i.e. seasonal) range in hourly groundwater elevations for each of the currently-existing monitors that are equipped with data loggers for part or all of the period from 2007 to 2016. This format is intended to assist in illustrating any significant changes and/or trends in the data when compared year-over-year for each quarter/season. This is the third annual report to include such graphs, which are presented in Appendix I.

The graphs in Appendix I are presented in numerical order, with monitoring wells presented first and then followed by piezometers (refer to Figure 1). The responses to short-, medium- and longer-term precipitation amounts are apparent in these plots. There are no apparent changes in groundwater levels at these monitoring stations that could be attributed to construction activities within the HCBP, with the exception of those monitors affected by short-term construction dewatering events in 2010, 2011, and 2012. Therefore, it is recommended that this format continue to be utilized to track fluctuations in groundwater elevation trends as part of the long-term monitoring program.

Depth to Groundwater

The smallest fluctuations in depth to groundwater occur in and adjacent to the core wetland and Hanlon Creek Tributary 'A'. Shallow depths to groundwater and the occurrence of groundwater discharge to these surface water features naturally limit the range in depths to groundwater in these areas. The greatest range in depths to groundwater occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant.

Groundwater Flow

The EIR Hydrogeology Report illustrated the horizontal direction of shallow groundwater flow is from southeast of the site, arcing towards the northern boundary of the site. The horizontal direction of groundwater flow coincides with the wetlands and creek, indicating that a portion of groundwater is discharging to this surface water system.

Also of interest is the vertical direction of groundwater flow. Presented in Appendix D is a summary of vertical hydraulic gradient calculations, based on comparisons of shallow, intermediate and deep monitoring intervals, on selected dates. Graphs illustrating groundwater elevations and hydraulic gradients are included, with monitoring stations grouped in seven west-to-east profiles. These data and graphs confirm the downward hydraulic gradients (i.e. groundwater recharge conditions) in the upland portions of the site, and upward hydraulic gradients in the vicinity of, and within, the core wetland complex (i.e. groundwater discharge conditions). Seasonal variations in vertical directions of groundwater flow are also observed in some monitoring well pairs. Groundwater discharge conditions have also been confirmed at the Downey Road PSW.

3.2.5 Groundwater Temperatures

Data loggers installed in either a monitoring well or mini-piezometer also record groundwater temperature. These data are illustrated in graphical format in Appendixes F, G, and H, following the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in these groundwater temperature graphs. Seasonal variations and associated time lags in groundwater temperatures are illustrated by these graphs.

PSW Groundwater Temperature Monitoring

As noted previously, groundwater level and temperature monitoring has been conducted using data loggers since 2007 at four PSW monitoring locations (i.e. MW003, PZ-9D, PZ-2D, and PZ-7D). These locations are representative of shallow groundwater conditions, although each location has somewhat different characteristics. The characteristics and factors that may influence groundwater temperatures are described as follows:

- MW003 – completed in the shallow water table aquifer; groundwater levels have ranged from 0.3 m above grade to 1.3 m below grade; located at the edge of an open agricultural field, adjacent to a provincially significant wetland (PSW); shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and by sunlight and standing water in the wetland during summer months (Graphs F 1 and F 1a, Appendix F)

- PZ-9D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.62 m above grade to 0.88 m below grade; located in the PSW close to MW003; shallow groundwater temperature recorded is potentially influenced by cold air temperatures and frozen wetland during winter months and by sunlight and standing water in the wetland during summer months (Graphs F 2 and F 2a, Appendix F)
- PZ-2D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.04 m above grade to 0.80 m below grade; located in a core wetland complex about 50 m east of Hanlon Creek Tributary ‘A’; shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and moderated by trees providing shade during summer months (Graphs G 20 and G 20a, Appendix G)
- PZ-7D – relatively shallow (i.e. 1.0 m deep) mini-piezometer; groundwater levels have ranged from 0.25 m above grade to 0.05 m below grade; located in a core wetland complex in the eastern tributary of Hanlon Creek Tributary ‘A’; shallow groundwater temperature recorded is potentially influenced by cold air temperatures during winter months and moderated by trees providing shade during summer months (Graphs G 8 and G 8a, Appendix G)

Groundwater temperatures recorded from March 2007 to December 2016 at these locations range from a low of just below 3^0C to a high of almost 16^0C. The 2016 temperature ranges for each location were as follows:

- MW003 – similar to previous years ranging from a low of 6.1^0C in late-March to a high of 12.3^0C in early-November
- PZ-9D – ranged from a low of 3.5^0C in the mid-March to a high of 15.9^0C in late-August and early-September
- PZ-2D – ranged from a low of 4.6^0C in mid-April to a high in late-August of 13.0^0C
- PZ-7D – ranged from a low of 5.4^0C in early-March to an estimated high of about 13.0^0C in late-August (note: the data logger failed in late-July when the temperature was 12.1^0C).

The temperature range of groundwater at greater depths in this general area tends to fluctuate in a narrower range, typically between 5 and 10^0C. It is therefore apparent that the temperatures in the shallower groundwater regime in the vicinity of these four monitors are influenced by seasonal variations in air temperature and solar radiation. These data are interpreted to be representative of the temperature of groundwater discharging to the wetlands and creeks in these locations.

Monitoring Well MW119A

This monitor is located adjacent to the northwest edge of stormwater management pond 4. The principal groundwater flow direction in this part of the HCBP site is north-westerly towards Tributary 'A' of Hanlon Creek. This monitor location is therefore down-gradient of pond 4. Groundwater temperatures recorded in monitoring well MW119A during 2016 ranged from a low of 6.4^0C in mid-April, to a high of 15.7^0C in second-half of September (Graph G 18a, Appendix G). This is comparable to the ranges observed from 2008 to 2010. The highest temperature recorded to-date at this location was 17.5^0C on 5 September 2012. Prior to construction of pond 4 in late 2010, the highest groundwater temperature at this monitor was 15^0C in early-September 2010. The previous two years had reached a maximum of about 13^0C in September.

The pond bottom is below the shallow groundwater surface and as a result the un-lined pond is in direct contact with the local groundwater system. A portion of the water in the pond is interpreted to discharge from the pond as groundwater and flow in a north-westerly direction. Therefore, water in the pond warmed by solar radiation during summer months appears to have increased the groundwater temperature marginally in the area down-gradient of the pond. It was noted previously that the groundwater temperature at monitoring well MW119A at the end of December 2012 was 10^0C, compared to about 7 to 8^0C on the same date the preceding four years.

Additional monitoring of groundwater temperatures down-gradient of pond 4 was initiated in June 2013. A pair of shallow mini-piezometers (PZ-13D and PZ-14D) were installed on the east and west bank of Tributary 'A', and equipped with data loggers (refer to Figure 1). The piezometers were located a short distance down-stream from surface water monitoring station HC-A(04). The groundwater temperatures recorded in PZ-13D and PZ-14D up to the end of October 2016 are presented in Graph G24a. Also included in this graph are the groundwater temperatures recorded in MW119A and MW131. MW131 is located about 130 m up-gradient of pond 4. It is apparent from comparison with the MW131 graph that the groundwater temperatures at PZ-13D and possibly PZ-14D, which reached a maximum of just less than 14^0C in August, was likely influenced by the warmer shallow groundwater flow affected by pond 4. The groundwater temperature at PZ-13D may have been influenced by solar radiation during summer months on the adjacent, up-gradient field. Graph 24a also shows that temperatures in PZ-13D and PZ-14D returned to below those recorded in MW131 by late-October each previous year.

The temperatures recorded in the remaining monitoring stations also reflect shallow groundwater temperatures near the central wetland complex and around the perimeter of the site. Temperature ranges and the timing of higher and lower temperatures are similar in most monitors. The highest observed groundwater temperatures are evident in monitors where the groundwater elevation is close to surface during summer months, particularly the monitors located in open fields. These monitors also exhibit the lowest groundwater temperatures during the late winter and early spring, when melting snow and frost infiltrate to the shallow groundwater system.

3.3 Relevance to Site Development and Stormwater Management

The observed minimum and maximum depths to shallow groundwater (i.e. water table) are presented in Appendix B for the 2003 to 2016 monitoring period. These observations indicate specific locations where there may be limitations to lot-level stormwater infiltration facilities. As noted previously, the greatest range in depths to groundwater occurs around the perimeter locations of the site where groundwater recharge to the medium- to coarse-grained deposits is most significant. It is interpreted that it is in these areas where the groundwater elevations in the spring of 1997 would have been up to 0.5 m above those observed in April 2004, April 2007, and April 2008. Therefore, allowance should be made for this potential high groundwater elevation during the design of stormwater infiltration facilities, at the Site Plan Approval stage. The design should be in accordance with accepted MOECC stormwater management planning and design procedures, thus allowing adequate separation between the bottom of the infiltration system and the high water table elevation.

The business park has been partially-graded for development purposes. It will be necessary to consider the estimated depth to groundwater based on proposed site grading to further evaluate potential locations for lot-level stormwater infiltration facilities. Continued monitoring of groundwater levels at all functioning monitoring well locations is required to support these evaluations, which will be required as part of the Site Plan Approval process.

3.4 Groundwater Quality

Groundwater samples were first collected in 2003 from 23 selected monitoring wells, and then from 33 selected monitoring wells in 2008, 2009, and 2010, and 25 available monitoring wells in 2011. A total of 36 monitoring wells were available for sampling in 2012 through 2015, including the 11 additional monitoring wells. These wells were sampled again in 2016. The groundwater quality data are summarized in Appendix J. The data were compared to the Ontario Drinking Water Quality Standards (ODWQS), Ontario Regulation 169/03. Concentrations that exceeded the ODWQS are indicated on the tables. The groundwater can be characterized as basic (i.e. pH>7) and, based on the reported calcium and magnesium concentrations, as hard.

There were no notable changes in water quality at any of the monitored locations in 2016. In general, the concentrations of the parameters analyzed were below the applicable ODWQS criteria, with the following exceptions (refer to Appendix J for specific exceedances and Figure 1 for well locations):

- Nitrate (as N) concentrations exceeded the ODWQS of 10.0 mg/L on at least one occasion in six monitoring wells
- Aluminum concentrations exceeded the ODWQS of 0.1 mg/L on at least one occasion in 24 monitoring wells
- Cadmium concentrations exceeded the ODWQS of 0.005 mg/L on at least one occasion in 11 monitoring wells
- Iron concentrations exceeded the ODWQS of 0.3 mg/L on at least one occasion in 32 monitoring wells
- Lead concentrations exceeded the ODWQS of 0.010 mg/L on at least one occasion in 22 monitoring wells
- Manganese concentrations exceeded the ODWQS of 0.05 mg/L on at least one occasion in 37 monitoring wells
- Sodium concentrations exceeded the ODWQS of 20 mg/L on at least one occasion in 37 monitoring wells
- Hardness concentrations exceeded the ODWQS of 100 mg/L in all monitoring wells.

The ODWQS for nitrate is health-related and the concentrations above this level in five monitoring wells can be attributed to the agricultural use of this site and the application of nutrients. Nitrate was also elevated above normal levels in five other monitoring wells. The elimination of nutrients applied to crops would be expected to reduce levels of nitrate. Such changes have been observed in other areas of Guelph.

The ODWQS for aluminum is an operational guideline for drinking water supplies and the elevated levels detected may be attributed to monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for lead is a standard for drinking water supplies and the elevated levels detected may be attributed to monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for iron and manganese is an aesthetic objective and the elevated levels are typical of groundwater in this area of Ontario. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels in all monitors.

The ODWQS for sodium is a health-related parameter for people on sodium-restricted diets. Elevated levels of sodium and chloride are often associated with the application of road salt for de-icing purposes. The levels of chloride do not exceed the ODWQS of 250 mg/L in any of the monitors; however, the level of chloride was elevated above normal levels in many of the monitors where sodium was elevated. The source of the elevated sodium and chloride occurring in some of the monitoring wells, including one of the bedrock wells, can likely be attributed to road salting along the Hanlon Expressway, Downey Road, and possibly Forestell Road.

The ODWQS for hardness is an aesthetic objective and the elevated levels observed in all monitoring wells are typical of groundwater in this area of Ontario.

Colour, turbidity, total dissolved solids, and DOC exceeded the respective ODWQS concentrations in most of the monitoring wells. This observation is typical for monitoring wells that are not developed to a sediment-free condition. Improved filtering of samples at the time of collection since 2009 has resulted in reduced levels of some parameters.

3.5 Thresholds 2016

3.5.1 Groundwater Elevations

The manually-recorded groundwater elevations for each existing and decommissioned monitoring station are summarized in tabular form in Appendix B, and presented as graphs in Appendix C. Groundwater elevations recorded by data loggers currently installed in 36 of the monitoring locations are presented as graphs in Appendixes F, G, and H. Decommissioned monitoring stations that had been equipped with data loggers are also included in Appendixes G and H for reference. These graphs also include the total monthly precipitation to assist with the direct comparison of groundwater elevations and precipitation.

As described previously, groundwater elevations across the HCBP were affected by the warm first quarter of 2016, with normal precipitation amounts. Groundwater levels rose sharply until early-April and then declined just as sharply through to early-August. Despite these notable changes, groundwater elevations at almost all monitoring stations during 2016 remained within the respective ranges observed in previous years, and as a result, there were no thresholds observed during this monitoring period. This is further illustrated by the quarterly/seasonal range in hourly groundwater elevation graphs presented in Appendix I.

In summary, climate had the greatest, if not only, influence on groundwater elevations across the HCBP in 2016. There were no apparent short-term and/or longer-term changes in groundwater levels that could be attributed to construction activities during 2016 within the HCBP. Construction dewatering occurred on two lots in Phase 1 during 2014, and there was no effect on groundwater levels in any of the nearby HCBP monitoring wells and piezometers. As of the end of 2016, ten lots in Phase 1 had been developed and another two were at various stages of development. One lot had been developed in Phase 2 and a second lot was being developed. The remainder of the graded portion of the site consisted of paved roadways, vegetated stormwater management swales and ponds, gravel-surfaced trails, and barren soils across most vacant lots. Based on the observed responses of groundwater levels to rainfall events and above-normal total monthly precipitation during March, August and December, it is evident that infiltration was occurring across the site.

3.5.2 Groundwater Temperatures

As described in sub-section 3.2.5, data loggers installed in either a monitoring well or mini-piezometer also record groundwater temperature. These data for 38 monitoring locations are illustrated in graphical format in Appendixes F, G, and H, following the groundwater elevation graphs. The maximum daily air temperature trend has been included for comparison in these groundwater temperature graphs. Seasonal variations and associated time lags in groundwater temperatures are illustrated by these graphs.

Despite the influence of climate on groundwater elevations during 2016, groundwater temperatures fluctuated within the typical ranges at most of the 38 monitoring stations where data loggers are installed. Groundwater temperatures at monitoring stations MW119A and PZ13-D, which are located down-gradient of pond 4, were likely influenced by the warmer water in this stormwater management pond in late summer. High temperatures in the second-half of September were 16.0^{0}C in MW119A, and in mid-August at PZ-13D were about 14^{0}C. Further comparison also shows that groundwater temperatures at PZ-13D returned to below those recorded in up-gradient monitor MW131 by late-October each year, whereas MW119A was similar to MW131 beginning in December both years.

3.6 Long-Term Groundwater Monitoring Program

The long-term groundwater monitoring program at the HCBP site should continue as previously recommended on a quarterly basis. As the site is graded and blocks prepared for development, new monitoring wells are installed to replace decommissioned wells. This has been completed as soon as practically possible, such that the effects of development on groundwater levels, if any, can be identified without delay. If required, mitigative measures can then be developed and implemented. A map illustrating these locations is presented on Figure 1, in the Hanlon Creek Business Park 2016 Consolidated Monitoring Report, prepared by Natural Resource Solutions Inc., AECOM, and Banks Groundwater Engineering Limited.

Data loggers have been installed in monitoring wells and mini-piezometers that are expected to remain during and following site grading. Additional data loggers are being installed in new monitoring wells as they are installed. This will improve the groundwater monitoring dataset and the establishment of the influences of climate on groundwater elevations over the short-, medium-, and long-term. Groundwater samples should continue to be collected on an annual basis from selected monitoring wells. Improvements to filtering of water samples have been successful in reducing the amount of sediment and should be continued as a standard practise.

4 Summary

The on-going monitoring of groundwater levels has provided an updated characterization of the hydrogeological conditions across the HCBP site and surrounding area, including the local occurrence and movement of groundwater in relation to the on-site wetlands and Hanlon Creek Tributary ‘A’. The following is a summary of conclusions and recommendations related to the groundwater monitoring program.

- A long-term groundwater monitoring program is required to assess any changes in groundwater elevations and groundwater quality during and following development of the site. The monitoring program is also required to assess the performance of the stormwater management facilities once they are constructed and to observe seasonal trends in water levels in the core wetland. It is therefore recommended that groundwater levels continue to be monitored on a quarterly basis at a minimum in all available monitoring wells and mini-piezometers, before and where possible during grading of the site. To correspond to previous monitoring, the preferred monitoring periods would continue to be January, April, July and October.
- In 2017, groundwater samples should just be collected from selected monitoring wells and only be analyzed for sodium and chloride to assess the increasing trend of these two parameters. All other parameters have shown little to no change over the past several years and continued sampling and analysis should resume in specific locations/areas as further development occurs in the business park.
- Any monitoring stations located within grading areas must be properly decommissioned, in advance of grading, in accordance with Ontario Regulation 903, as recently amended, of the Ontario Water Resources Act, by a licensed Water Well Technician.
- In some cases, existing monitoring wells can be maintained, with minor modifications or improvements, for continued monitoring. Several monitors have been replaced following grading and development of selected blocks. The locations for long-term monitoring of groundwater levels and quality are identified, including existing and new monitors that are expected to be maintained and proposed future monitoring locations (refer to Figure 1, Hanlon Creek Business Park 2016 Consolidated Monitoring Report, prepared by Natural Resource Solutions Inc., AECOM, and Banks Groundwater Engineering Limited).

- Groundwater level and temperature monitoring using data loggers should continue for many, if not all, of the groundwater monitoring stations over the long-term. By utilizing this technology, the frequency of monitoring can be increased significantly and trends in groundwater level changes (e.g. related to construction) can be detected sooner and with improved accuracy.
- It is recommended that the monitoring data continue to be compiled, plotted, and analyzed on an annual basis by a qualified professional engineer or geoscientist. The results should be presented in a Technical Memorandum that is submitted as an Appendix to the Consolidated Monitoring Report to the City of Guelph, for the purpose of review, acceptance, and response to recommendations. Recommendations related to the monitoring program, including any proposed modifications, would be included. The GRCA should also receive a copy for review and comment in relation to maintenance of groundwater levels across the site, but with particular emphasis on the Provincially Significant Wetlands and Hanlon Creek Tributary 'A'. In the event of unexpected changes in groundwater elevations or quality, the frequency of monitoring, sampling, and reporting would be evaluated and revised as required.

Respectfully submitted,
Banks Groundwater Engineering Limited

Original signed by:

William D. Banks, P.Eng.
Principal Hydrogeologist

The Figure, Tables and Graphs referenced in this Technical Memorandum are appended under the following headings:

Figure 1: Groundwater Monitoring Stations December 2016

Appendix A: Current Groundwater Monitoring Network December 2016

Appendix B: Groundwater Level Monitoring Data 2003 – 2016

Appendix C: Groundwater Monitoring Graphs 2003 – 2016

Appendix D: Vertical Hydraulic Gradient Data and Graphs 2003 – 2016

Appendix E: Climate Monitoring Graphs 1971 – 2016

Appendix F: Downey Road PSW Groundwater Monitoring Graphs 2007 – 2016

Appendix G: HCBP Core PSW Groundwater Monitoring Graphs 2007 – 2016

Appendix H: HCBP Perimeter Groundwater Monitoring Graphs 2007 – 2016

Appendix I: HCBP Quarterly Groundwater Elevation Range Graphs 2007 – 2016

Appendix J: Groundwater Quality Monitoring Data 2003 – 2016

APPENDIX III

SURFACE WATER MONITORING REPORT

City of Guelph

2016 Hanlon Creek Tributary A Surface Water Monitoring Report

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February, 2017

Project Number: 60265453

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March 01, 2017

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Dear Mr. Schidel:

Project No: 60265453
Regarding: 2016

We are pleased to provide a pdf and MS Word copy of our 2016 Hanlon Creek Tributary A Surface Water Monitoring Report. If you have any questions or comments regarding this report, please contact the undersigned.

Sincerely,
AECOM Canada Ltd.

Zahra Parhizgari, M.Sc., P.Eng.
Senior Water Quality Specialist

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Encl.

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1. Background

In 2003 AECOM was retained by the City of Guelph (City) to establish and carry out a surface water monitoring program at Hanlon Creek Tributary A in anticipation of construction at the Hanlon Creek Business Park. The purpose of this program was to identify pre-construction flow and temperature characteristics. The surface water program has evolved since 2003 and is now included as the surface water monitoring component of the Consolidated Monitoring Program established for the Hanlon Creek Business Park (HCBP). Other components of this monitoring program include groundwater (completed by Banks Groundwater); and aquatic and terrestrial ecology (by NRSI).

In 2003-2004 monitoring data was reported in separate memoranda to the City and a consolidated Environmental Impact Study (EIS) prepared by NRSI for the Hanlon Creek Business Park in 2004. Monitoring continued in 2006 and 2007 with continuous temperature measurements at 6 stations between the outlet of the online pond (Road A) and 150 m upstream of Laird Road. Depth and velocity were continuously measured at the Laird Road culvert (HC-A(05)) and periodic depth measurements were also recorded at this location. Sampling completed in 2006-2007 was summarized in a technical memorandum, submitted to the City of Guelph in February 2008.

The 2008 monitoring plan included temperature monitoring at the previous 6 stations along Tributary A and an additional temperature monitoring station (HC-A(14)) located downstream of the existing SWM pond (Pond 2) outlet. This additional station provided background information to identify the temperature impacts of proposed Ponds 1 and 2. Depth and velocity were monitored at the Laird Road culvert (HC-A(05)) and water depth was monitored at station HC-A(10). High flow measurements were collected to establish a rating curve for HC-A(10). Through June-September 2008, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all stations. Monitoring results from 2008 were presented in a memorandum to the City of Guelph, dated February 3, 2009.

The 2009 monitoring plan included temperature monitoring at the 7 stations monitored in 2008. Temperature monitoring consisted of logging temperature readings every 15 or 30 minutes at the 7 site locations. Temperature loggers deployed during winter months were set at a 30 minute interval to ensure adequate memory would be available throughout the winter months. Loggers re-deployed during later months were set at a 15 minute interval. A continuous level/temp logger (HC-A(10)) and the depth and velocity monitoring equipment at HC-A(05) were used to monitor flow during 2009. During May-October 2009, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity). The flow/velocity instrument stopped logging data November 22nd due to battery failure and was removed from the culvert December 14, 2009. The remainder of the data loggers continued to collect continuous data at 30 minute intervals throughout the winter.

The 2010 monitoring plan included temperature monitoring at the 7 stations monitored in 2009, a new station depth and temperature monitoring station at SR-1(01), the existing station HC-A(14) being supplemented with the installation of a level logger, and continuous depth/velocity monitoring at the Laird Road culvert (HC-A(05)). Temperature monitoring consisted of logging temperature readings every 15 minutes from April until December and every 30 minutes during the winter months at the eight site locations. During May-October 2010, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity). High flow measurements were collected to develop rating curves for HC-A(10) and HC-A(14).

In 2011 a number of additional stations were installed in Tributary A at the beginning of the monitoring season. Monitoring in the stormwater management facilities (SWMFs) was initiated as Ponds 1, 2 and 4 were functioning as SWMFs. Herein this report SWMF and ponds are used interchangeably. The same surface water monitoring program completed in 2011 as also carried out in 2012 and 2013.

In August 2010, the Hanlon Creek Business Park Consolidated Monitoring Program (NRSI, AECOM, Banks Groundwater) was submitted to the City of Guelph. This monitoring plan included the location, parameters and naming convention for all surface monitoring works to be completed as part of the implementation of servicing and construction at the HCBP.

The 2015 monitoring program followed the stations used during the 2012, 2013 and 2014 monitoring years as no new stations were deemed necessary. A small number of stations were relocated based on recommendations from the 2012 monitoring report to improve data collection. Additionally, a tipping bucket rain gauge (Model TB3) was installed for the 2015 monitoring season. The rain gauge was installed on the roof of the Clair Road Emergency Services Centre, located approximately 2 km west of the Hanlon Creek Business Park.

2. 2016 Surface Water Monitoring Program

2.1 Program Components

Table A: Tributary A Continuous Monitoring Stations and **Table B**: Continuous Pond Monitoring Stations summarize the continuous monitoring program completed at each of the sites during the 2016 monitoring season. Monitoring station locations are illustrated in **Figure 2-1**: Monitoring Station locations.

The program is consistent with the 2015 program with the addition of two stations. There are currently 13 stations for the Halon Creek Tributary A, 8 stations for Pond 1, 7 stations for Pond 2 and 6 stations for Pond 4.

Station HC-A(03) is located in the upper reaches of Hanlon Creek Tributary A1 (Trib. A1) within the site, about 10 m upstream of Pond 4 in a partially forested area. Station HC-A(04) is located approximately 75 m downstream of Pond 4 and 150 m upstream of Laird Road in a partially forested area. Tributary A then passes through an open area low lying/wetland.

Following the recommendations made by 2015 Hanlon Creek Tributary A Surface Water Monitoring Report, two new continuous temperature monitoring stations were included in the 2016 surface water monitoring program. Station HC-A(04A) was installed in Tributary A upstream of the Laird Rd. culvert and station HC-A(04B) was installed directly downstream of the Laird Rd. culvert. The stations were installed to aid in the understanding of the temperature characteristics of Tributary A between stations HC-A(04) and HC-A(06). Station HC-A(04A) is located approximately 100m downstream of Station HC-A(04) and approximately 50m upstream of the Laird Road Crossing. Tributary A then passes under Laird Road. Station HC-A(04B) is located directly downstream of the Laird Road culvert.

Station HC-A(06) is located approximately 100 m downstream of Laird Road. Along this stretch the stream passes through a cedar wetland in which HC-A(09) is located. Station HC-A(08) is located in the same cedar wetland on a tributary of the main branch of Tributary A1. Station HC-A(10) is located approximately 50 m downstream of the confluence of the main branch and the tributary and just upstream of the Hanlon Creek Boulevard crossing. Station HC-A(11) is located at the downstream end of Hanlon Creek Boulevard culvert. From the culvert, the stream passes through another cedar wetland area. Station HC-A(12) is located in an open wetland area at the outlet of cedar wetland and upstream of Pond 1. Station HC-A(13) is located approximately 200 m downstream of HC-A(12) and immediately downstream of the outlet of Pond 1 in an open field. Station HC-A(14) is located at the downstream end of the study site, approximately 150 m upstream of Teal Drive.

During the winter months, the telemetry stations were removed and replaced with temperature/depth loggers set to record at 30 minute intervals. Telemetry stations at stations HC-A(03) and HC-A(14) were reinstalled in May 2016. Telemetry stations HC-A(06) and HC-A(11) required replacement sensors for turbidity and depth which resulted in telemetry stations being installed later in the year The telemetry station at HC-A(06) was installed in May and the telemetry station at HC-(11) was installed in July. Temperature/depth loggers were removed during the winter months from stations where the flow is intermittent. This was done to prevent damage from occurring to the logger.

Influent and effluent water quality monitoring of SWM pond inlets and outlets and Tributary A downstream of the SWM ponds was also monitored as per MOE Certificate of Approval (CofA) 1384-7QFPZQ requirements. Ponds 1, 2 and 4 were sampled during the 2016 monitoring program.

During May-December 2016, sites were visited monthly to download data, perform maintenance, and collect baseflow measurements and water quality parameters (DO, pH, specific conductivity) at all in-stream stations. High flow measurements were collected for HC-A(03), HC-A(04), HC-A(06), HC-A(10), HC-A(11), HC-A(12), HC-A(13), and HC-A(14) to develop a rating curve. Monitoring reports from 2016 site visits are included in **Appendix A**.

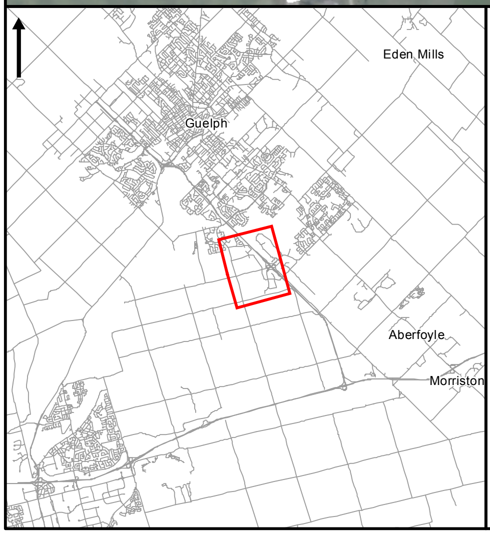
Table A: Tributary A Continuous Monitoring Stations

Station ID	Station ID Prior to 2010	Data Collected*	Date installed	Notes
HC-A(03)		Temperature, Depth, Turbidity	March 2011	
HC-A(04)	**1**	Temperature, Depth	March 2011	
HC-A(04A)		Temperature	July 2016	
HC-A(04B)		Temperature	July 2016	
HC-A(05)	**"FLOW"**	Area/velocity	--	Area/velocity meter was not installed to do issues with sedimentation in the culvert during the 2010 monitoring year.
HC-A(06)	**2**	Temperate, Depth, Turbidity	March 2011	Depth senor and turbidity senor replaced for 2016
HC-A(08)	**3**	Temperature	May 2006	
HC-A(09)	**4**	Temperature	May 2006	
HC-A(10)	**5**	Temperature, Depth	May 2006	
HC-A(11)	**6**	Temperate, Depth, Turbidity	March 2011	Turbidity sensor replaced for 2016
HC-A(12)	**7**	Temperature, Depth	April 2011	
HC-A(13)		Temperature, Depth	March 2011	
HC-A(14)		Temperate, Depth, Turbidity	March 2011	Temperature sensor replaced for 2015
SR-1(01)		Temperature, Depth	June 2010	

*Note: prior to 2010, only Station HC-A(10) (or Station #5) was monitored for level in addition to temperature. The HC-A(05) ("FLOW") station was monitored for flow. All other stations collected only temperature data prior to 2010.

Table B: Continuous Pond Monitoring Stations

SWMF	Station	Data Collected	Date installed	Location
Pond 1	HC-P1(01)	Temperature	September 2011	In pond close to bottom
	HC-P1(02)	Temperature	September 2011	In pond near mid-depth
	HC-P1(03)	Temperature	September 2011	In pond at surface
	HC-P1(04)	Temperature, Depth	September 2011	Inlet
	HC-P1(05)	Temperature, Depth	September 2011	Inlet
	HC-P1(06)	Temperature, Depth	June 2011	Outlet
	HC-P1(07)	Temperature	June 2011	Cooling trench outlet
	HC-P1(08)	Temperature	June 2011	Cooling trench outlet
Pond 2	HC-P2(01)	Temperature	April 2011	In pond close to bottom
	HC-P2(02)	Temperature	April 2011	In pond near mid-depth
	HC-P2(03)	Temperature	April 2011	In pond at surface
	HC-P2(04)	Temperature, Depth	April 2011	Inlet
	HC-P2(05)	Temperature, Depth	August 2012	Inlet
	HC-P2(06)	Temperature, Depth	June 2011	Inlet
	HC-P2(07)	Temperature, Depth	April 2011	Outlet
Pond 4	HC-P4(01)	Temperature	October 2011	In pond close to bottom
	HC-P4(02)	Temperature	November 2011	In pond near mid-depth
	HC-P4(03)	Temperature	November 2011	In pond at surface
	HC-P4(04)	Temperature, Depth	August 2012	Inlet
	HC-P4(05)	Temperature, Depth	October 2011	Outlet
	HC-P4(06)	Temperature	October 2011	Cooling trench outlet



Legend

●	Temp
●	Temp/Level
●	Temp/Level/Water Qaulity
●	Temp/Turbidity/Level
●	Temp/Turbidity/Level/Water Quality
—	Watercourses
—	Property
■	Ponds
■	Access Paths
■	Multi-Use Trails
■	Cooling Trench
▨	Wetlands

N

Hanlon Creek Business Park

2018 Surface Water Monitoring Sites

November 2016	1:8,000	Datum: NAD '83 Zone 17 Source: AECOM, GRCA
P#: 60265453	V#: 001	

AECOM

Figure 1

0 250 500
Meters

Map location: \\CAKCN1FP001\Data\Projects\60265453\000-CADD\050 GIS WIP\Design\Hanlon_SurfaceWaterMonitoring 2017(02.04.2016) Vertical.mxd
Date Saved: 11/2/2016 12:00:53 PM

2.2 Data Gaps

During the 2016 sampling year, equipment theft and malfunctions produced data gaps in the continuous monitoring data. A laptop which contained monitoring data from January to the end of April was stolen causing a 4 month data gap for all stations. **Table C** outlines time periods and monitoring parameters unavailable for the associated station.

Table C: Data Gaps in Logger Files - 2016

Location	Station	Parameter	Data Gaps
Tributary A	**HC-A(03)**	Temperature/ Water Level/Turbidity	Jan 1 – Apr 27
	HC-A(04)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-A(04A)	Temperature	Jan 1 – Jul 14
	HC-A(04B)	Temperature	Jan 1 – Jul 14
	HC-A(06)	Temperature/ Water Level/Turbidity	Jan 1 – Apr 27
	HC-A(08)	Temperature	Jan 1 – Apr 29
	HC-A(09)	Temperature	Jan 1 – Apr 29
	HC-A(10)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-A(11)	Temperature/Water Level/Turbidity	Jan 1 – Apr 28
	HC-A(12)	Temperature/ Water Level	Jan 1 – Apr 18
	HC-A(13)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-A(14)	Temperature/ Water Level/Turbidity	Jan 1 – Apr 27
	SR-1(1)	Temperature/Water Level	Jan 1 – Dec 31
Pond 1	**HC-P1(01)**	Temperature	Jan 1 - Sept 15
	HC-P1(02)	Temperature	Jan 1 – Apr 28
	HC-P1(03)	Temperature	Jan 1 – Apr 28
	HC-P1(04)	Temperature/ Water Level	Jan 1 – Apr 18
	HC-P1(05)	Temperature/ Water Level	Jan 1 – Apr 18
	HC-P1(06)	Temperature/ Water Level	Jan 1 – Apr 29
	HC-P1(07)	Temperature	Jan 1 – Apr 18
	HC-P1(08)	Temperature	Jan 1 – Apr 18
Pond 2	**HC-P2(01)**	Temperature	Jan 1 – Apr 28, Sept 15 – Dec 31
	HC-P2(02)	Temperature	Jan 1 – Dec 31
	HC-P2(03)	Temperature	Jan 1 – Dec 31
	HC-P2(04)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-P2(05)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-P2(06)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-P2(07)	Temperature/ Water Level	Jan 1 – Apr 27
Pond 4	**HC-P4(01)**	Temperature	Jan 1 – Jul 18, Aug 15 – Dec 31
	HC-P4(02)	Temperature	Jan 1 – Apr 28, Jul 11 – Jul 18
	HC-P4(03)	Temperature	Jan 1 – Apr 28, Jul 11 – Jul 18
	HC-P4(04)	Temperature/ Water Level	Jan 1 – Apr 27
	HC-P4(05)	Temperature/ Water Level	Jan 1 – Apr 28
	HC-P4(06)	Temperature	Jan 1 – Apr 27

2.3 Site Construction

In July 2009 tree cover upstream of stations HC-A(11) and HC-A(14) was removed as part of the initial clearing for the Hanlon Creek Boulevard culvert construction. In the summer of 2010 construction of the site began with the works being completed at the culvert crossing in August. During 2011, construction of the Phase 1 site was completed with construction and construction of Phase 2 was completed by early 2012. The first lot level development began in Phase 1 in May 2012 and no developments were constructed in Phase 2 during 2012. Development continued in 2013, 2014, 2015 and 2016 with construction of some buildings and related parking areas occurring in Phase 1. Construction of the Laird Road overpass occurred in the Phase 2 lands in 2013.

3. In-stream Temperature Monitoring

The locations of the temperature monitoring stations for 2016 are shown in **Figure 2-1** and station descriptions are included in **Section 2**. The temperature loggers (HOBO Pendant Temperature/Light Logger and HOBO 12-bit Temperature Smart Sensors) and level/temperature loggers (HOBO U20 Water Level Data Logger) were placed in the creek secured to steel stakes driven into the substrate. Data was collected in 30 minute intervals during the winter months and 15 minute intervals for the remainder of the year.

3.1 In-Stream Thermal Conditions

A plot of the continuous temperature monitoring throughout the period of monitoring in 2016 is included in **Figure 3-1**: Hanlon Creek Temperature Monitoring –April –December 2016 and highlighting conditions during the summer is shown in **Figure 3-2**: Hanlon Creek Temperature Monitoring – June – September 2016. Monthly plots of stream temperature and hourly air temperature data from the Guelph Turfgrass Institute Station are included in **Appendix B** and show a clearer comparison of thermal conditions observed at each station. These plots show the daily diurnal pattern of temperature variation, with temperatures increasing during the day and decreasing at night.

Temperature data for the winter of 2016 was not available; however, historically, during the winter months (January to March), temperatures at all stations appear to have been at or around freezing (0°C) for most of the winter indicating that a large portion of Tributary A periodically experienced frozen conditions. Stations HC-A(08), HC-A(03), HC-A(04), and HC-A(06) showed trends of consistent temperatures above 0° during sub 0° air temperature conditions. This indicates these stations are likely most impacted by groundwater input. Conversely stations HC-A(14) and HC-A(09) recorded the coldest temperatures and are least impacted by groundwater inputs.

During the 2016 monitoring period, station HC-A(04), located just downstream of the Pond 4 outlet showed that daily fluctuations in temperatures at this station were moderate throughout the year even in comparison to fluctuations noted at upstream station HC-A(03) and downstream station HC-A(06). Station HC-A(06) shows a similar trend but experiences greater increases on days with high ambient air temperatures. During the summer months, stations HC-A(04), HC-A(04A), HC-A(04B) and HC-A(06), recorded high average temperatures and little daily fluctuation compared to the upstream station HC-A(03). This demonstrates that in-stream thermal conditions at HC-A(04) are impacted from the continual discharge from Pond 4. Additionally, stations HC-A(04A) and HC-A(04B) recorded higher temperatures than HC-A(04), indicating that warming is occurring between sites. This is potentially due to warmer runoff from Laird Road and/ or warmer input from the upstream wetland area.

Downstream stations which are more exposed (HC-A(10), HC-A(12), HC-A(13) and HC-A(14)) and those with a wider flow channel and shallower depths (HC-A(09)) are stations that show the highest daily variation in temperature as they are located in areas where there is greater opportunity for solar radiation impact and there is little indication of groundwater inputs.

A comparison between the numbers of 24°C exceedance events per monitoring site to the average summer temperatures for 2016 has been provided in **Figure 3-3**: Comparison between the number of 24°C exceedance events per monitoring site to the average summer temperatures for 2016. In addition, a comparison between the recorded number of hours in stream temperatures exceeding 19°C to the average summer temperatures at each site is shown in **Figure 3-4**: Comparison between the recorded number of hours in stream temperatures exceeded 19°C to the average summer temperatures for 2016. These two figures also illustrate stations HC-(A)09, HC-A(06) and HC-A(04/4A/4B) and HC-A(14) as having the greatest exceedances of 19ºC and/or 24ºC. Information regarding Pond 4 and it's observed thermal conditions are included in Section 6.2.3

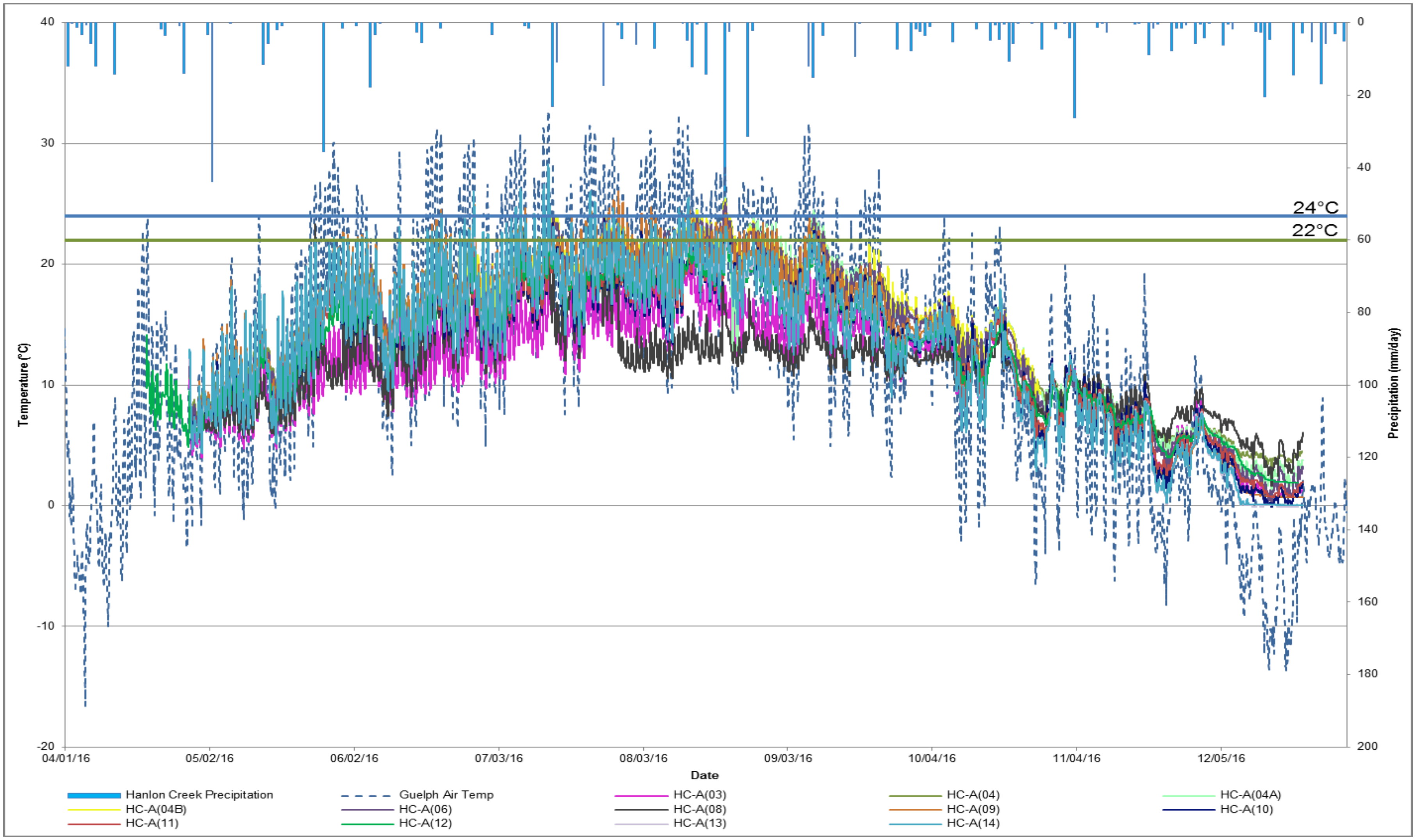


Figure 3-1: Hanlon Creek Temperature Monitoring –April –December 2016

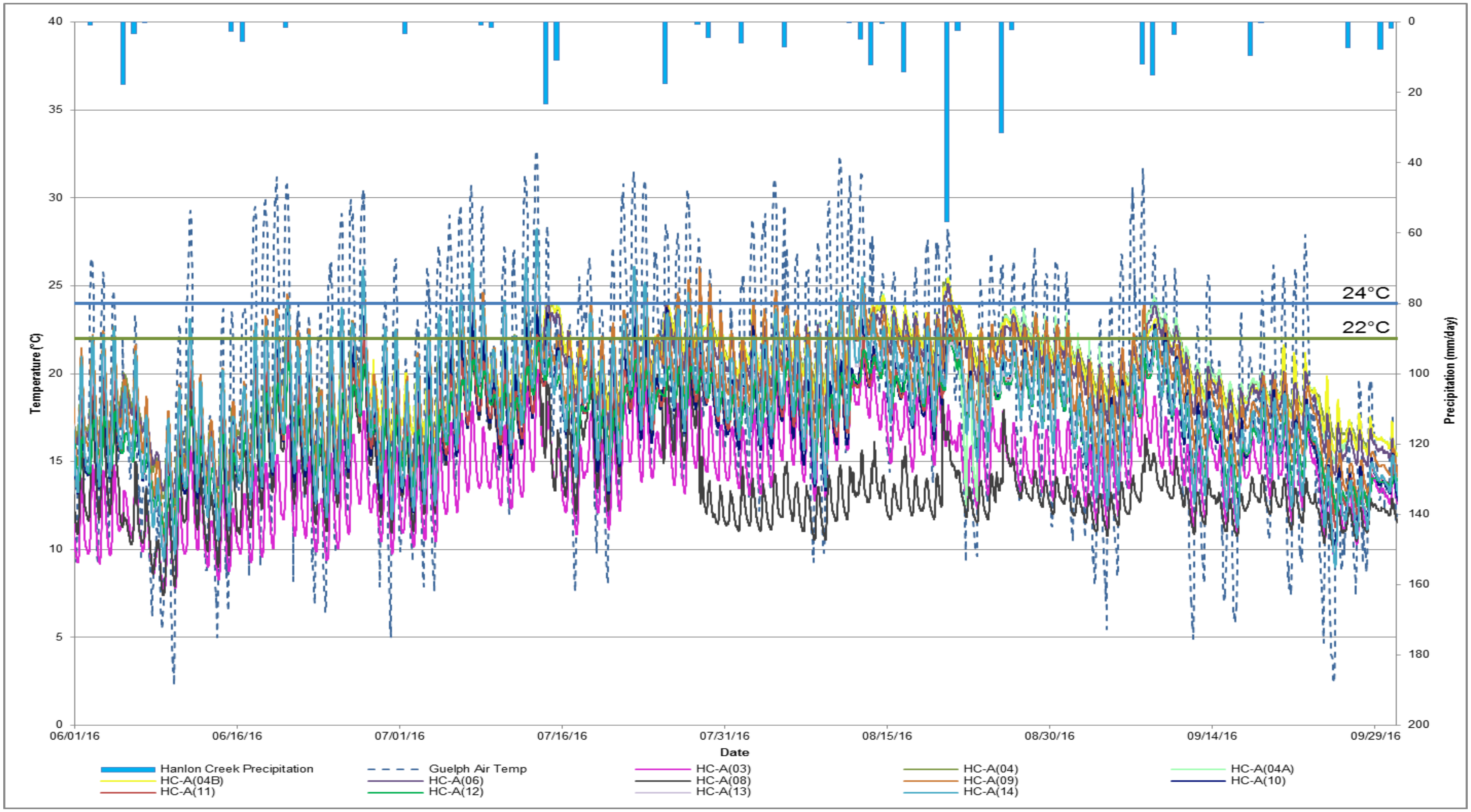


Figure 3-2: Hanlon Creek Temperature Monitoring – June – September 2016

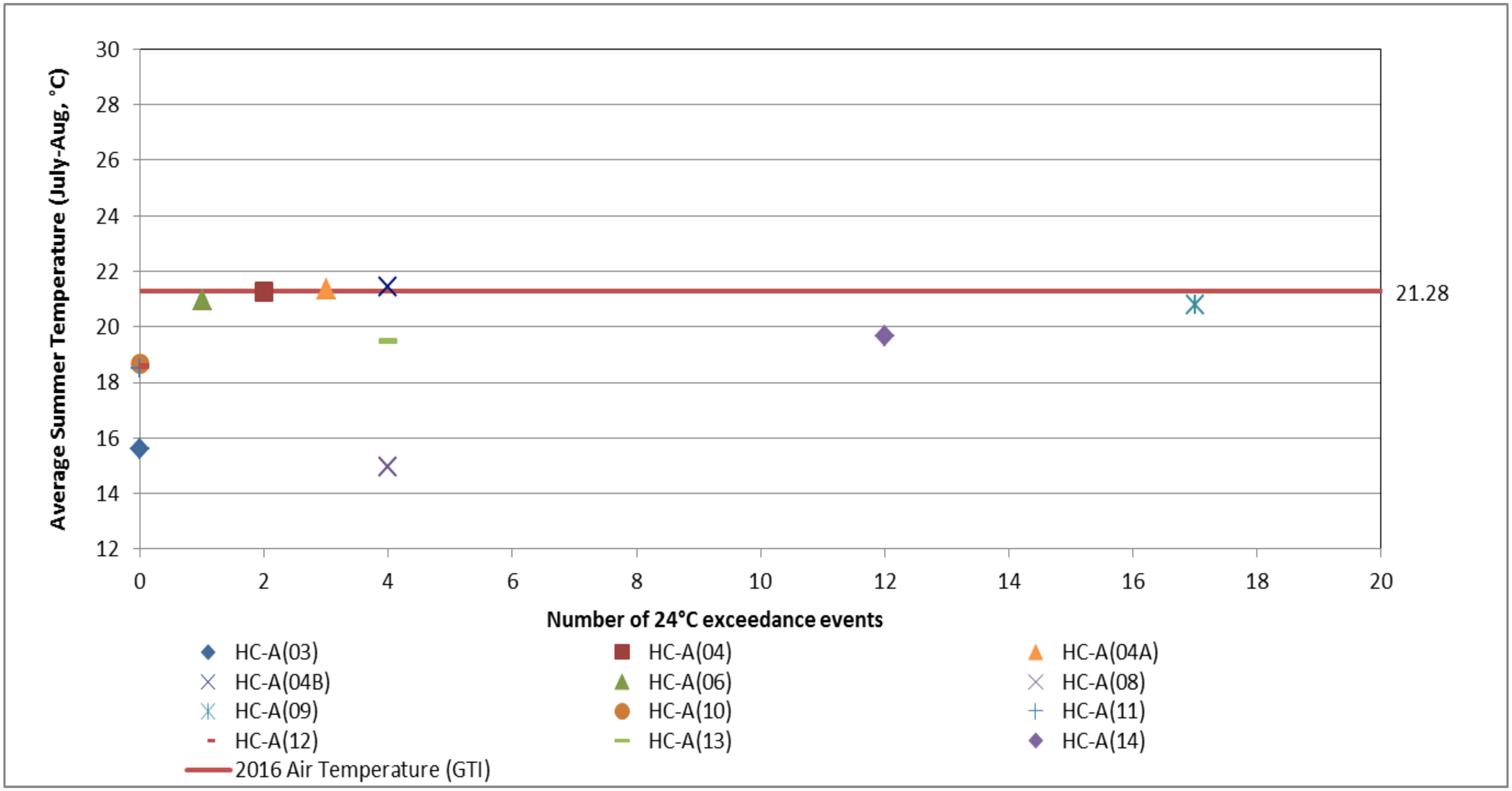


Figure 3-3: Comparison between the number of 24°C exceedance events per monitoring site to the average summer temperatures for 2016

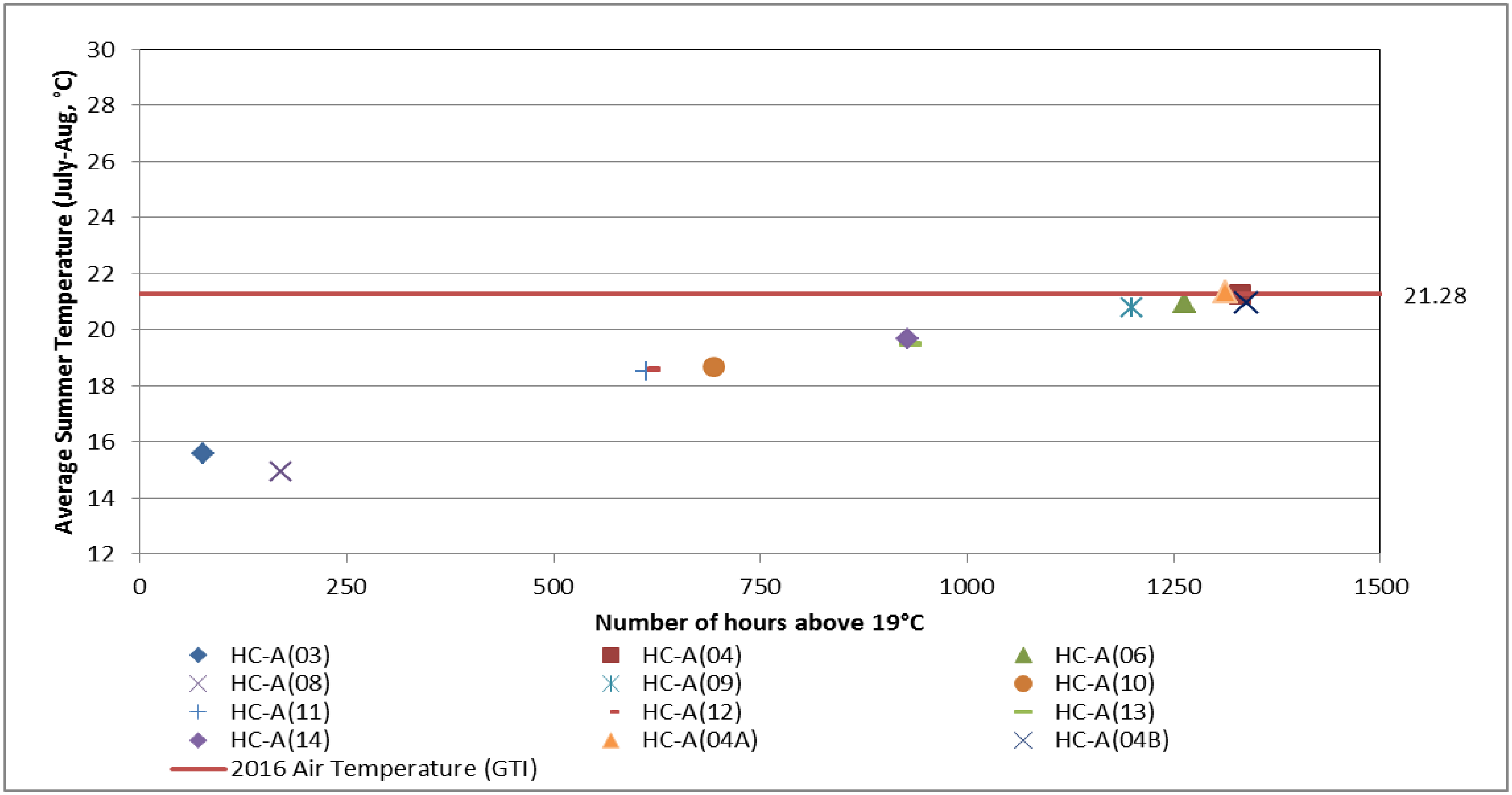


Figure 3-4: Comparison between the recorded number of hours in stream temperatures exceeded 19°C to the average summer temperatures for 2016

3.2 In-stream Thermal Conditions in Comparison to Thermal Modeling Prediction

The ability of a stream to support a cold-water fish species is often defined by the temperatures throughout the summer (July and August) and autumn (mid October – end of November) months. The 2009 Hanlon Business Park Stream Temperature Impact Report (AECOM, 2009) provided a summary of reach based statistical stream temperature modeling results for future mitigated site conditions. This summary included target daily averages, maximums, minimums, the number of hours target temperatures were exceeded and exceedance frequencies during both the summer and autumn.

The Hanlon Creek Business Park Consolidated Monitoring Plan recommends:

1. Any single temperature exceedance of 22°C is analyzed in an annual temperature and flow monitoring report, including an investigation of the cause of the exceedance and recommendations for contingency measures as warranted. The investigation should consider the frequency, duration and spatial distribution of the exceedance.
2. Any single temperature exceedance of 24°C triggers an investigation commencing within 2 days of acquiring the information. This investigation should consider the frequency, duration and spatial distribution of the exceedance, seek to identify the cause of the temperature exceedance, and provide recommendations for adaptive management measures as warranted. If contingency measures are warranted, the design and implementation of selected measures should be completed as soon as possible. At the latest, the selected measures should be implemented in the year following the exceedance of 24°C.

A summary comparison of overall modeled existing and future mitigated conditions of average temperature conditions throughout the creek were included in the modeling report. The same statistical analysis applied to the modeling results has been applied to the 2016 data and is included in **Table D** and **Table E** where sufficient data are available. To monitor the changes to Hanlon Creek over time, a comparison of 2016 data to historical conditions has been included in **Appendix C,** and **Table F** includes a comparison of monthly ambient air temperatures and Canadian climate normals.

The comparison shows higher recorded in stream temperatures than recent years with temperature levels and exceedance event totals comparable to those observed in 2012. This has led to an increased amount of exceedance events above 19°C and 22°C at all stations with the exception of HC-A(03) and HC-A(08). Stations HC-A(04), HC-A(04A), HC-A(04B), HC-A(06), HC-A(09), HC-A(13) and HC-A(14) all recorded temperatures above 24°C during 2016. Average in-stream temperatures for Trib A for July and August increased by 2.1°C from 17.02 °C recorded in 2015 to 19.12°C recorded in 2016. A combination of higher than average air temperatures shown in **Table F**: Comparison of Monthly Ambient Air Temperatures to the Canadian Climate Normals, lower in-stream baseflow levels displayed in **Figure 4-10**: Average annual baseflow and precipitation from 2008 to 2016 and below average annual precipitation shown in **Table H**: Observed Precipitation Trends for 2015 Compared to Canadian Climate Normalsmay have contributed to the increase in in-stream temperatures and in-stream temperature exceedance events.

Table D: 2016 Summer (July-August) Temperature Summary

Station	Modeled Values[1]	HC-A(03)	HC-A(04)	HC-A(04A)	HC-A(04B)	HC-A(06)	HC-A(08)[2]	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
Summer (July-August) average maximum (ºC)	14.5 - 19.9	17.87	22.47	22.77	22.83	22.77	8.24	23.37	21.37	20.36	19.83	21.63	22.68
Summer (July-August) average (ºC)	12.5 - 14.5	15.59	21.28	21.33	21.44	20.97	13.07	20.79	18.67	18.51	18.58	19.49	19.69
Summer (July-August) average minimum (ºC)	9.0 - 12.0	13.25	18.70	18.90	18.48	17.11	6.53	18.68	16.50	16.95	17.43	17.53	16.74
Maximum 3-day mean (ºC)	14.0 - 19.0	18.75	23.40	23.40	23.36	22.90	14.36	22.81	20.60	20.31	20.34	21.54	21.90
Maximum 7-day mean (ºC)	13.0 - 17.0	17.93	22.87	22.99	22.94	22.46	13.97	22.02	19.79	19.61	19.70	20.64	20.99
Maximum 7-day mean of daily maximums (ºC)	15.0 - 23.5	19.84	23.54	23.91	24.02	23.76	15.59	24.69	22.65	21.23	20.66	23.66	24.70
	Temperature Exceedance over 19°C for July and August												
Hours over 19°C	0 - 130	76	1330	1313	1338	1263	0	1200	692	611	615	930	927
Percent of Time over 19°C	0 - 9%	5%	90%	89%	91%	86%	0%	81%	47%	41%	41%	63%	62%
Frequency of Exceedance over 19°C (Days)	0 - 27	13	61	62	62	61	0	62	61	55	48	61	62
Average Duration of Event Over 19°C (h)	3 - 6	5	74	66	64	53	0	38	13	12	17	20	19
Maximum duration of event over 19ºC (h)	<<130	13	580	322	544	416	0	188	83	82	86	89	86
	Temperature Exceedance over 22°C for July and August												
Hours over 22°C		0	564	604	601	474	0	449	84	15	0	143	260
Percent of Time over 22°C		0%	38%	41%	41%	32%	0%	30%	6%	1%	0%	10%	17%
Frequency of Exceedance over 22°C (Days)		0	41	47	50	49	0	57	20	6	0	22	37
Average Duration of Event Over 22°C (h)		0	16	24	24	10	0	6	3	2	0	4	5
Maximum duration of event over 22ºC (h)	<<130	0	62	139	138	47	0	43	13	7	0	14	15
	Temperature Exceedance over 24°C for July and August												
Hours over 24°C	0 -3.2	0	21	29	30	17	0	81	0	0	0	24	59
Percent of Time over 24°C	0 - 0.21%	0%	1%	2%	2%	1%	0%	5%	0%	0%	0%	2%	4%
Frequency of 24°C Exceedance (Days)		0	2	3	4	1	0	17	0	0	0	4	12
Average Duration of Event Over 24°C (h)		0	21	15	10	17	0	5	0	0	0	6	5
Maximum duration of event over 24ºC (h)	<3.2	0	21	20	21	17	0	9	0	0	0	9	10

[1] Modeled range refers to the results of the Hanlon Creek Business Park Stream Temperate Impact Report Continuous Modeling with HSP-F (AECOM, 2009)

[2] Due to low ground water and precipitation levels, Station HC-A(08) experienced low flow conditions which caused the stations temperature logger to be exposed to air temperatures from approximately July 1st to July 24th This data was not included in the analysis for the table above as it does not represent true in-stream conditions.

Table E: Fall Temperature Summary

Station	Modeled Range	HC-A(03)	HC-A(04)	HC-A(04A)	HC-A(04B)	HC-A(06)	HC-A(08)	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
	Mid October to End of November												
Max Temp. (°C)	11.9 - 13.0	17	16	17	17	17	15	17	18	17	15	18	18
Frequency of 11°C Exceedance (days)	2.1 - 5.6	12	12	16	11	15	13	9	13	11	8	11	11
Hours Over 11°C	16 - 27	176	259	271	246	238	198	167	193	175	152	175	175
Average Hrs. Over 11°C per Event	4.8 - 5.9	29	65	39	123	30	40	83	39	44	152	44	44
Maximum duration of event over 11°C (h)	5.9	140	248	235	242	179	142	152	143	149	152	143	144
	November Only												
Max Temp. (°C)	9.3 - 11.3	12	11	12	0	12	12	12	13	11	11	13	13
Frequency of 11°C Exceedance (days)	0.4 - 2.0	3	1	3	0	2	3	2	3	2	0	2	2
Hours Over 11°C	0.4 - 11.3	28	2	24	0	13	43	15	40	23	0	25	24
Average Hrs. Over 11°C per Event	1.0 - 10.8	7	2	12	0	6	21	15	20	11	0	12	12
Maximum duration of event over 11°C (h)	10.8	18	2	20	0	10	38	15	36	19	0	20	19

Table F: Comparison of Monthly Ambient Air Temperatures to the Canadian Climate Normals

	Daily Average (°C)					Average Daily Maximum (°C)					Average Daily Minimum (°C)				
	May	**Jun**	**Jul**	**Aug**	**Sep**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Climate Normals[1]	12.3	16.9	19.7	18.6	14.1	18.6	23.3	25.9	24.5	19.8	6.0	10.6	13.5	12.6	8.4
2007	12.7	18.3	18.5	19.3	15.8	20.5	25.9	26	26.5	23.7	4.9	10.6	10.9	12.1	7.8
2008	10.1	17.9	19.7	17.5	14.9	16.3	23.3	25.7	23.7	21.1	3.9	12.5	13.6	11.2	8.7
2009	11.2	15.9	16.5	17.4	13.5	18	21.7	22.1	23.7	20	4.2	10	10.8	11	7
2010	n/a	n/a	20.3	19.8	14.1	n/a	n/a	26.4	26.1	19.6	n/a	n/a	14.2	13.3	8.5
2011	12.7	16.7	21.4	19.3	15.2	17.7	22.7	28.6	25.8	20.9	7.8	10.6	14.1	12.6	9.6
2012	15.2	18.6	22	19.3	14.4	22.8	25.2	30.1	26.6	21.1	7.5	12	13.9	11.9	7.6
2013	13.5	16.9	19.9	18	13.7	20.4	22.3	25.3	24.5	20.2	6.2	11.4	14.5	11.4	7.1
2014	12.3	17.8	17.6	17.6	14.1	18.5	24.6	23.6	23.6	20.5	5.9	10.9	11.5	11.4	7.7
2015	15.1	16.0	18.7	18.0	17.0	22.7	22.0	25.6	23.7	23.7	7.3	9.8	11.7	12.2	10.3
2016	12.3	16.9	20.6	20.8	16.2	19.5	24.8	27.7	27.6	23.2	5.2	9.1	13.4	14.1	9.2

[1] Data is taken from Canadian Climate Normals 1971-2000 for the Guelph Arboretum, 2007 to 2016 data was collected at the Guelph Turfgrass station

Temperatures highlighted in blue represent temperatures lower than Climate Normals and temperatures highlighted in red represents temperatures higher than the Climate Normals.

3.3 Summary of Historical Thermal Exceedances

A comparison of monthly Canadian climate normal air temperatures from May through September for 2009 to 2016 is shown in above **Table F**: Comparison of Monthly Ambient Air Temperatures to the Canadian Climate Normals. No exceedances of 24°C were recorded in 2010, in comparison a single occurrence of 22°C was recorded at station HC-A(14) in 2009. In 2011, exceedances above 24°C were observed, with eight of ten stations experiencing temperature exceedances. The 2012 summer recorded the highest number of exceedances to date within the main branch of Hanlon Creek. It was noted that, unlike previous years, 24°C was exceeded in the headwater reaches of the creek, downstream of Pond 4 as opposed to the exceedances occurring in the furthest downstream reaches. These issues were noted in July of 2012 and the RAAP team was assembled to investigate the cause of the exceedances. It was determined that the cause of the temperature exceedances was the continuous discharge of Pond 4. Mitigation measures were put into place with a goal to decrease the quantity and temperature of water entering Tributary A via Pond 4. The weir in Pond 4 was raised during the summer in attempt to decrease continuous outflow from the SWMF into Tributary A. Vegetation along the cooling trench was installed during the fall 2012 with hopes it would act as a cooling agent once it became established.

Water temperature exceedances decreased in 2013 from 2012; however temperatures were still above the ideal habitat conditions documented for brook trout in the Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F (AECOM, 2009). The greatest contributor to stream temperature increases was the continuous discharge of warm water into the headwater of the creek from Pond 4. An exceedance of 24ºC at station HC-A(14) led to a RAAP meeting been called. It was determined that cooling trench discharge from Pond 1 combined with high air temperatures could have factored into the exceedance. Further monitoring of cooling trench temperatures was suggested in order to determine the true effectiveness of the Pond 1 cooling trenches.

In 2014, overall climate conditions were cooler than in 2013 and Canadian climate normals. Higher than average precipitation levels were recorded in 2014 than 2013 and the Canadian climate normals. As a result, fewer exceedance events occurred in 2014. Temperatures remained higher at stations found farthest downstream while the trend of increasing temperatures at reaches downstream of Pond 4, observed in 2012, also continued.

Higher average air temperatures during the summer months and lower precipitation levels compared to 2014 were observed in 2015. The combination of higher air temperatures and lower precipitation levels led to higher in-stream temperatures and an increase in the number of temperature exceedances in 2015. Even though average air temperatures were still below the Canadian climate normal as shown in **Table F**: Comparison of Monthly Ambient Air Temperatures to the Canadian Climate Normals, station’s HC-A(06), HC-A(09) and HC-A(14) recorded in stream temperatures higher than 24ºC. A RAAP meeting was called in late July to discuss the temperature exceedances recorded at HC-A(06). It was found that the temperature exceedance was not a direct result of Pond 4’s continuous discharge as an increase in stream temperature between HC-A(04) and HC-A(06) was observed. It was suggested that a cut-off drain could be installed along the south side of Pond 4 to intercept groundwater prior to entering the pond and discharge the groundwater directly to Trib A. It was noted that this retrofit may not directly address the 24°C exceedance however, it would help to decrease overall temperatures in Trib A. Alternatively it was discussed that temperature monitors be placed between the two stations to determine whether the cause of the temperature discrepancy was a result of groundwater discharge or exposure to solar radiation.

In 2016, higher average air temperatures during the summer months and low precipitation levels in June and July compared to the Canadian climate normal were observed. Precipitation levels for 2016 compared to previous years and the Canadian climate normal are provided in **Table H**: Observed Precipitation Trends for 2015 Compared to Canadian Climate Normals. The combination of higher air temperatures and lower precipitation levels led to higher in-stream temperatures and an increase in the number of temperature exceedances in 2016. Recorded average daily mean temperatures and recorded average daily maximum temperatures provided in **Table F** were either at or above the Canadian climate normal for the months of June, July and August. Stations HC-A(04), HC-A(04A), HC-A(04B), HC-A(06), HC-A(09), HC-A(10), HC-A(11), HC-A(13), and HC-A(14) recorded in stream temperatures higher than 24ºC.

A RAAP meeting was called in late June to discuss a recorded temperature exceedance at HC-A(14). It was determined that high recorded air temperatures with limited vegetation cover and low recorded groundwater conditions contributed to the exceedance. In the past, thermal exceedances at this location have been attributed to weather conditions and no mitigation measures have been recommended to improve thermal conditions at this location. It was also decided that exceedances at this location be communicated via an e-mail to RAAP members.

A RAAP meeting was called in late July concerning two exceedance events that occurred at station HC-A(06). It was found that a combination of high ambient air temperatures and low water levels attributed to an increase in in stream water temperatures. It was noted that high water temperatures were recorded upstream at stations HC-A(04), HC-A(04A) and HC-A(04B) with temperatures increasing between HC-A(04) and HC-A(04A). A similar exceedance event at HC-A(06) on August 20 led to another RAAP call in late August. A storm event had caused an increased discharge from Pond 4 resulting in higher recorded water temperatures at stations HC-A(04), HC-A(04A), HC-A(04B) and HC-A(06). Discussions that followed this event emphasized the impact of groundwater input on lowering temperature at the cooling trench outfall, and suggested merits in diverting groundwater from the pond to downstream of the cooling trench.

Appendix C includes a comparison of historical conditions at each station. This summary shows that overall stations HC-(A)09, HC-A(06) and HC-A(04) have had greater number of hours above 22°C since the construction of Pond 4 and HC-(A)09 has also had a greater number of hours above 24°C.

3.4 In-stream Thermal Regime Classification

The method described in Stoneman and Jones (1996) later revised by C. Chu *et al.*(2009) was used to determine the temperature regime. Classification for each station was based on a comparison of daily maximum air temperature and maximum in-stream water temperature measured between 16:00 and 18:00 during summer months (July 1 – August 31) when maximum daily air temperatures exceed 24.5°C. A nomograph is then used to classify results based upon water thermal characteristics of coldwater, cold-coolwater, coolwater, cool-warmwater and warmwater. **Appendix D** includes graphical representation of this analysis. **Table G** summarizes the thermal regime classification associated with each station within the study area. Noted trend changes in the thermal classification of each site are also included in **Table G** below. These noted changes are based upon trends in the thermal regime. These are generalized trends that could be modified as more years of data is available.

The comparison included in **Table G** indicates station HC-A(04) shows the greatest change in thermal regime from cold-cool to cool-warm. This trend is noted to occur since 2012. Other stations that show signs of increases to thermal regimes are located in the middle reaches and include HC-A(06), HC-A(09), HC-A(10). These observations are generally consistent with the observation that stations HC-A(04), HC-A(06), and HC-A(09) appear to have the greatest number of hours exceeding 22°C and 24°C as discussed in **Section 3.3**.

Overall stations HC-A(03), HC-A(08), HC-A(13) and HC-A(14) have not experience a noted change in thermal regime. Stations HC-A(03) and HC-A(08) are highly influenced by groundwater inputs which may contribute to the static nature of the thermal regime. Stations HC-A(13) and HC-A(14) are located in open areas in the downstream reach and are generally the warmest stations.

Lastly, stations which show signs of decreased thermal regimes are located in the downstream reaches; however upstream of Pond 1 and Pond 2 and include HC-A(11) and HC-A(12).

Overall these trends provide further evidence that the creek reach from the Pond 4 outlet to Hanlon Creek Boulevard appears to be thermally impacted by the continuous discharge from Pond 4 during the later summer months and early autumn.

Table G: Temperature Classification Summary

Station	**Based on C. Chu *et al.* (2009)**									**Based on Stoneman and Jones (1996)**		**Overall Change in Thermal Regime**
	2016	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**	**2008**	**2007**	**2006**	
HC-A(03)	Cool-Cold	Cool	Cool-Cold	Cool-Cold	Cool	Cool	n/a	n/a	n/a	n/a	n/a	None
HC-A(04)	Cool-Warm	Cool-Warm	Cool	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cold	Cold	Cold-Cool to Cool-Warm
HC-A(04A)	Cool-Warm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	None
HC-A(04B)	Cool-Warm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	None
HC-A(06)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool	Cool	Cool-Cold	Cool-Cold	Cool	Cool	Cool to Cool-Warm
HC-A(08)	Cold	Cold	Cold	Cold	Cool-Cold	Cold	Cold	Cold	Cold	Cold	Cold	None
HC-A(09)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	n/a	Cool	Cold	Cool	Cool to Cool-Warm
HC-A(10)	Cool-Warm	Cool	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Cold	n/a	Cool-Cold	Cool	Cool	Cool to Cool-Warm
HC-A(11)	Cool	Cool	Cool	Cool	Cool-Warm	Cool	Cool	Cool-Warm	Cool	Warm	Warm	Cool-Warm to Cool
HC-A(12)	Cool	Cool	Cool	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a	Cool-Warm to Cool
HC-A(13)	Cool-Warm	Cool	Cool-Warm	Cool	Warm	Cool-Warm	n/a	n/a	n/a	n/a	n/a	None
HC-A(14)	Cool-Warm	Cool-Warm	Cool-Warm	Cool-Warm	Warm	Cool-Warm	Cool-Warm	Cool	Cool	n/a	n/a	None

4. In-stream Flow Monitoring

4.1 Continuous Depth and High Flow Monitoring

Nine flow monitoring stations were installed along Hanlon Creek. The depth/velocity meter (ISCO 2100) has not been installed since 2010 due to high sedimentation at HC-A(05) producing unreliable data.

A depth logger (HOBO U20-001-001 Water Level logger) was used to monitor water levels at HC-A(04), HC-A(10), HC-A(12), HC-A(13) and SR-1(01) throughout 2015. Depth measurements were also collected at telemetry monitoring (Instrumentation Northwest, PS9800) stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14).

Seven baseflow and three high flow measurements were taken between May 31st and December 1st 2016 at each station using a FlowTracker Handheld-ADV® (Acoustic Doppler Velocimeter). The measured flow values from 2016 and previous years were used to develop stage (level) - discharge relationships (rating curves) for each station as shown in **Appendix E.**

The following issues were experienced over the course of the 2016 monitoring year:

- Flow measurements were not collected at SR-1(01) due to on site construction of a new culvert and ditch.
- No flow measurement was taken at HC-A(06) on August 9th due to insufficient flow.
- Flow data is unavailable at station HC-A(11) for July 27th due to a corrupt data file.
- Stream cross-sections for stations HC-A(10), HC-A(13) and HC-A(14) were adjusted at the beginning of the 2016 monitoring program to avoid watercress growth affecting station flow measurements. Increased watercress growth downstream was noted during the monitoring season at stations HC-A(10), HC-A(11) and HC-A(13). Watercress growth was also observed within the adjusted cross-sectional area at HC-A(10) later in the monitoring season. **Figure 4-1**: Watercress growth at Station HC-A(10). Photo taken looking downstream while standing upstream from the stations cross section (10/26/2016) through **Figure** 4-5: Watercress growth downstream of adjusted cross-section for station HC-A(13). Photo taken looking downstream of station cross-section (10/20/2016) shows the extent of growth downstream of each cross-section.

The creek flow at stations HC-A(03), HC-A(04), HC-A(06), HC-A(10), HC-A(11), HC-A(12) , HC-A(13) and HC-A(14), for the 2016 monitoring period is shown in **Figure 4-6**. This figure also includes recorded precipitation from the Hanlon Creek rain gauge station. It should be noted rating curves for stations HC-A(11) and HC-A(12) have been developed in the absence of high peak flow values and therefore peak flow values estimated for these stations are associated with a lower level of accuracy than the other stations. **Figure 4-6** shows flows generally increasing as stations move farther downstream.

Figure 4-1: Watercress growth at Station HC-A(10). Photo taken looking downstream while standing upstream from the stations cross section (10/26/2016)

Figure 4-2: Watercress growth at the cross section of Station HC-A(10). Some watercress growth occurred at the adjusted cross section site. (10/26/2016)

Figure 4-3: Watercress growth at Station HC-A(11). Photo taken looking cross stream while standing on the left bank (10/20/2016)

Figure 4-4: Watercress growth at Station HC-A(14). Photo taken looking downstream of station cross-section (10/20/2016)

Figure 4-5: Watercress growth downstream of adjusted cross-section for station HC-A(13). Photo taken looking downstream of station cross-section (10/20/2016)

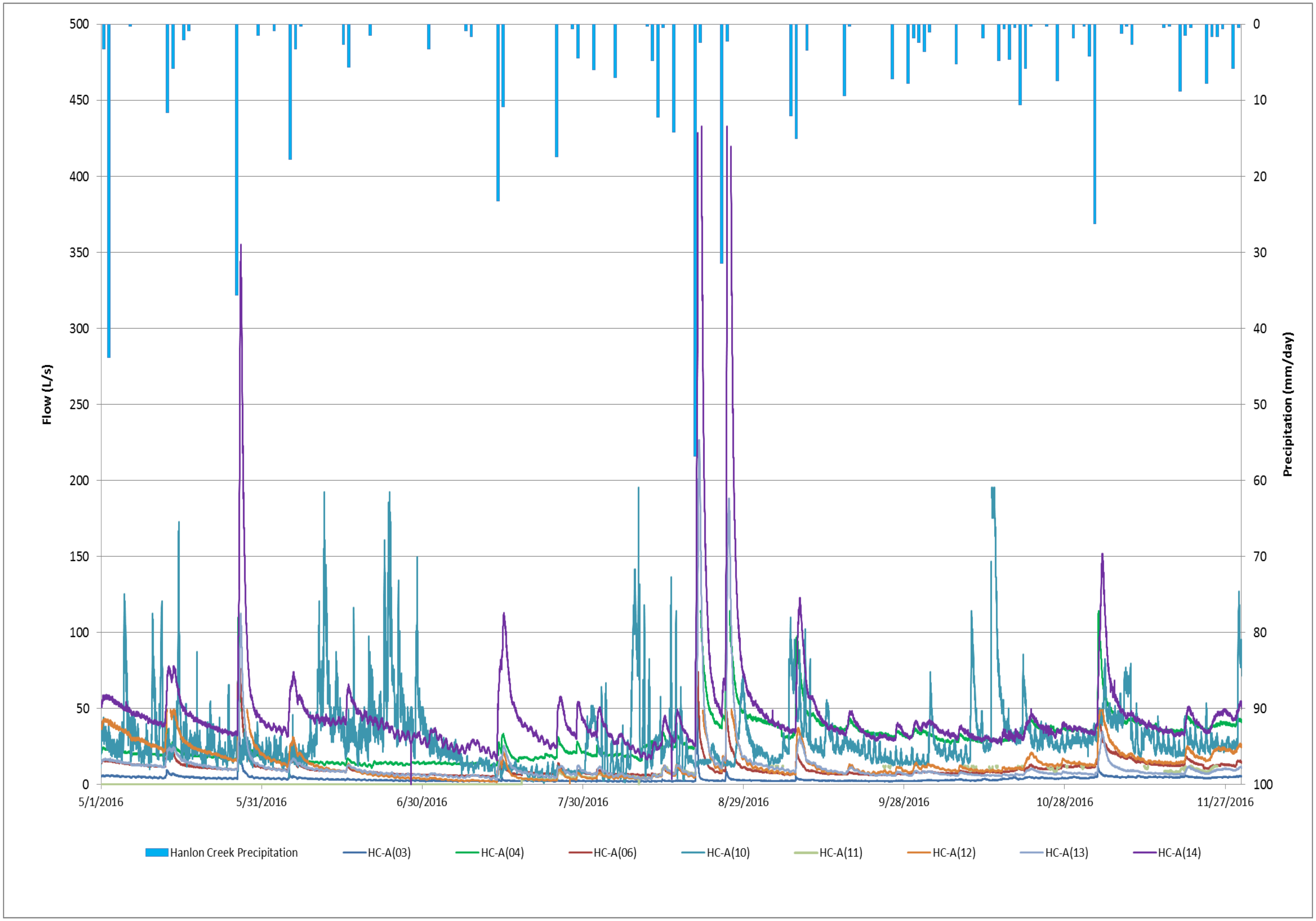


Figure 4-6: 2016 Flow Monitoring for Hanlon Creek

4.2 Precipitation

Comparisons between 2016 precipitation totals to previous years and the Canadian Climate Normals are shown in **Table H.** Precipitation data from the Hanlon creek rain gauge was used. 2016 is the first year a complete set of data is available for the Hanlon creek rain gauge.

Compared to the Canadian climate normals, the Hanlon creek rain gauge recorded below average precipitation totals for 2016. Only 4 months measured precipitation higher than the Canadian climate monthly normals. Most of the precipitation in 2016 fell in March (140.8mm), May (104.4mm) and August (137.6mm). Lower precipitation values during the summer and fall, with the exception of August, contributed to below average baseflow levels as all stations recorded lower baseflow averages than averages recorded in 2015. Lower precipitation levels during the summer season also contributed to decreases in water levels at Pond 1 and Pond 2 which are shown below.

Table H: Observed Precipitation Trends for 2015 Compared to Canadian Climate Normals

	Units	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Canadian Climate Normals (1971-2000) Guelph Arboretum	mm	56.4	50.8	72.1	78.3	79.9	76	88.5	95.9	92.1	69.2	86.3	77.7	**923.3**
Observed Elora Research Station 2008	mm	98.5	57.4	85.5	64.6	86.1	81.6	131.3	120.7	119.3	68.4	103.1	100.4	**1116.9**
Observed Elora Research Station 2009	mm	66.1	82.0	72.7	106.2	79.3	69.2	79.5	92.1	53.7	91.5	37.3	65.8	**895.4**
Observed Elora Research Station 2010	mm	27.2	24.4	41.3	47.5	99.9	184.1	89.4	12.1	117.8	52.6	50.8	21.1	**768.2**
Observed Elora Research Station 2011	mm	47.6	58.2	86.1	100.7	113.3	87.0	31.9	158.6	76.1	128.9	90.5	85.5	**1064.4**
Observed Guelph Turf Grass Institute 2011	mm	20	23.8	89.6	92.8	147.4	100.4	26.8	51.2	71.4	93.4	84.6	59.2	**860.6**
Observed Elora Research Station 2012	mm	46.8	32.0	31.0	30.0	28.2	64.6	30.4	62.6	106.2	127.3	40.2	79.9	**679.2**
Observed Guelph Turf Grass Institute 2012	mm	39.2	17.0	28.4	31.0	32.2	90.0	54.6	98.4	127.0	129.0	11.6	57.8	**716.2**
Observed Elora Research Station 2013	mm	80.5	71.2	40.6	123.8	102.0	122.3	130.9	69.5	142.9	133.6	33.7	43.2	**1094.2**
Observed Guelph Turf Grass Institute 2013	mm	72.4	41.4	25.2	98.6	70.8	82.4	173.6	54.8	79.4	116.4	26.4	44.0	**885.8**
Observed Elora Research Station 2014	mm	51.2	58.1	46.7	101.7	54.1	68.8	133.7	51.1	27.9	74.3	63.3	45.8	**776.7**
University of Waterloo Weather Station 2014	mm	74.2	30.7	17.5	90.9	63.6	52.4	165.9	91.5	159.8	79.6	90.6	33.3	**950**
Observed Elora Research Station 2015*	mm	77.0	58.2	34.4	77.3	48.0	175.9	66.8	80.6	53.1	111.5	78.2	66.7	**927.7**
University of Waterloo Weather Station 2015	mm	49.6	48.2	23.9	77	61.6	117.9	60	78.2	53.8	109.6	68.2	66.2	**814.2**
Hanlon Creek Rain Gauge 2016	mm	46.6	67.4	124.6	69.2	104.4	31.6	62	137.6	56.8	50.4	63.6	96	**910.2**

*Precipitation data gaps for the Elora RCS: Jan 17, Jun 28, Jul 23, Jul 31, Aug 2, Sept 4, Spet 30, Dec 8, Dec, 23, Dec 25 – 26, Dec 28 – 29

Figure 4-7: Low water levels observed in the main cell of Pond 1. (8/9/2016)

Figure 4-8: Low water levels observed in the main cell of Pond 2. (10/20/2016)

4.3 Baseflow

In addition to the continuous flow monitoring, baseflow measurements for each station HC-A(03), HC-A(04), HC-A(06), HC-A(08), HC-A(10), HC-A(11), HC-A(12), HC-A(13) and HC-A(14) were taken on between April 29th and December 1st, 2016, using a Flow Tracker 6300 - Acoustic Doppler Velocity Meter. These results are shown in **Figure 4-9** and presented in **Table I.**

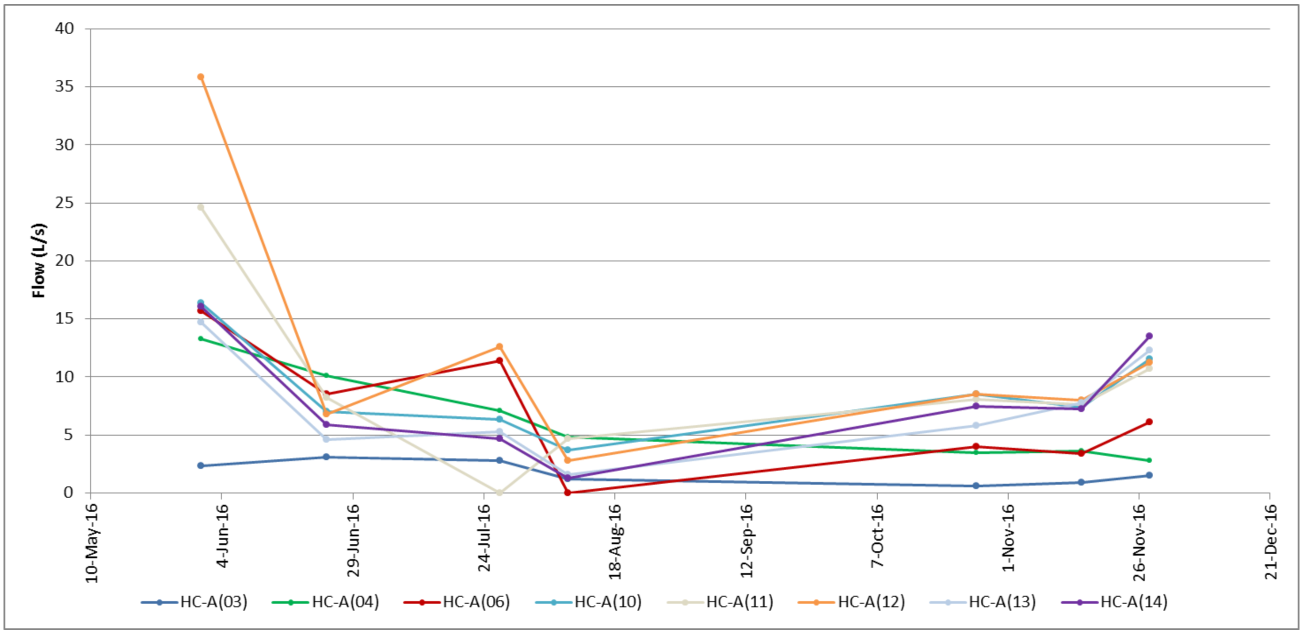


Figure 4-9: Hanlon Tributary A Baseflow Measurements – 2016

Table I: Hanlon Creek Baseflow Monitoring (L/s) – April 2016 to November 2016

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
5/31/2016	0.0023	0.0133	0.0157	0.0164	0.0246	0.0358	0.0147	0.0161
6/24/2016	0.0031	0.0101	0.0085	0.007	0.0082	0.0068	0.0046	0.0059
7/27/2016	0.0028	0.0071	0.0114	0.0063	n/a[1]	0.0126	0.0053	0.0047
8/9/2016	0.0012	0.0048	n/a[2]	0.0037	0.0047	0.0028	0.0016	0.0013
10/26/2016	0.0006	0.0035	0.004	0.0085	0.0081	0.0085	0.0058	0.0075
11/15/2016	0.0009	0.0036	0.0034	0.0074	0.0076	0.008	0.0078	0.0072
11/28/2016	0.0015	0.0028	0.0061	0.0115	0.0107	0.0112	0.0123	0.0135

1. Missing data due to corrupt data files
2. Missing data due to insufficient flow

A comparison of 2008 -2016 average baseflow measurements are shown in **Figure 4-10** and presented in **Table J.** Baseflows were influenced only in 2011 by construction impacts such as dewatering activities.

Average baseflow measurements in 2016 were similar to the overall averages recorded in 2012 and 2013. Recorded baseflow discharge from all stations was slightly lower than 2015 values.

Historical and recent baseflow measurements have been used to classify which reaches are losing (contributing groundwater) or gaining (receiving groundwater) reaches. These conclusions are corroborated with temperature data.

In 2013, measures were taken to reduce the outflow from Pond 4 in 2013, however pond discharge was still observed to be near continuous causing high baseflow levels at HC-A(04) compared to recorded upstream baseflow at station HC-A(03). Station HC-A(06) exhibited slightly higher baseflow levels compared to station HC-A(04). The reach between HC-A(09) and HC-A(10) receives input from a small groundwater-fed tributary in the cedar swamp which contributes to the increased baseflow between HC-A(06) and HC-A(10). Stations HC-A(10) and HC-A(11) have historically been groundwater discharge areas and this was the case for 2016. HC-A(12) and HC-A(13) were both areas of groundwater recharge/ losing reaches in 2016 while the reach between HC-(13) and HC-A(14) recorded an increase in average baseflow.

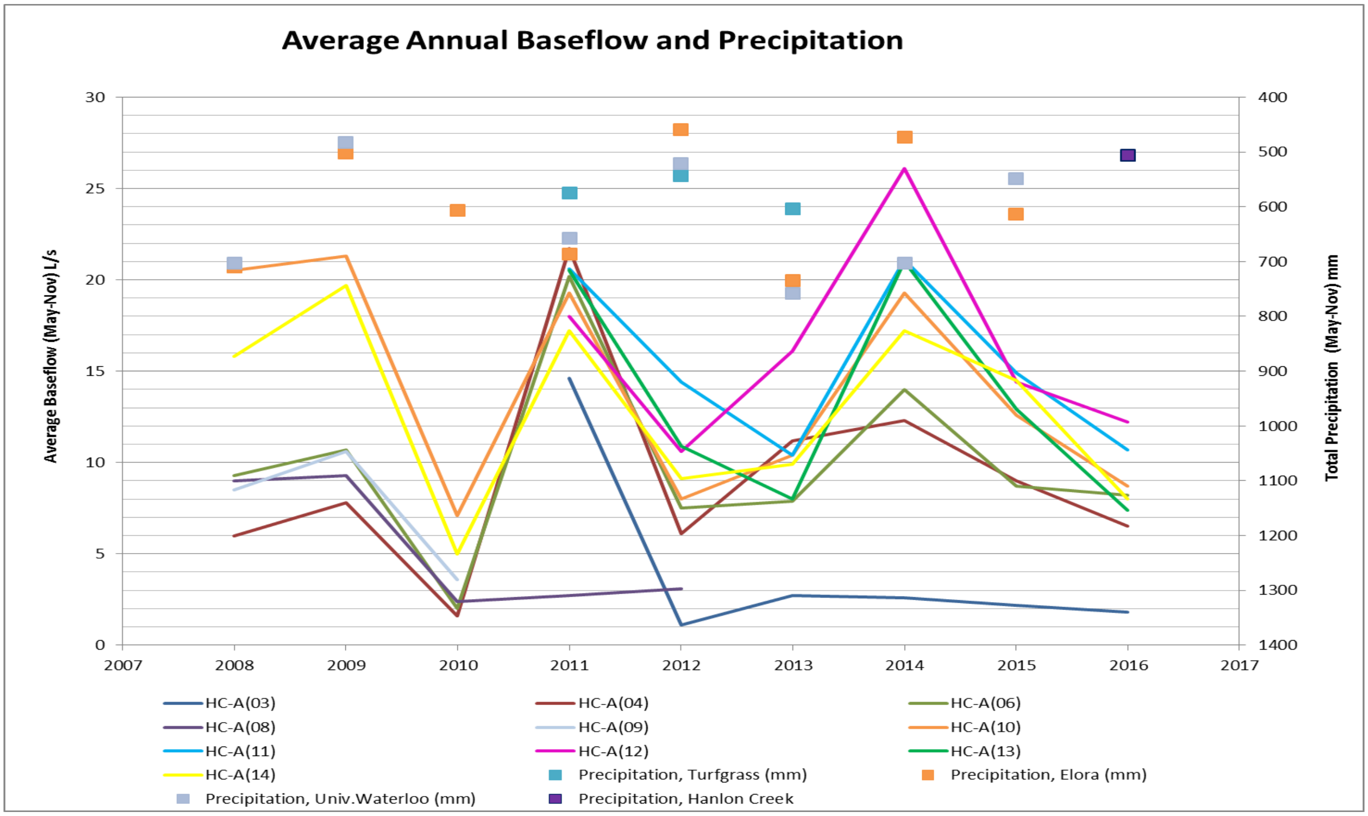


Figure 4-10: Average annual baseflow and precipitation from 2008 to 2016

Table J: Hanlon Creek Baseflow Monitoring – 2008-2015 Summary (L/s)

Station	HC-A(03)	HC-A(04)	HC-A(06)	HC-A(08) Tributary	HC-A(09)	HC-A(10)	HC-A(11)	HC-A(12)	HC-A(13)	HC-A(14)
2008 Min	n/a	3.5	2.7	2.1	3.8	7.7	n/a	n/a	n/a	0.9
2009 Min	n/a	3.9	1.2	3.0	4.2	5.0	n/a	n/a	n/a	1.8
2010 Min	n/a	0.4	0.4	-7.3	1.1	0.8	n/a	n/a	n/a	0.9
2011 Min[2]	2.8	5.5	0.8	1.5	n/a	2.4	4.6	5.0	2.8	1.5
2012 Min	0.1	3.2	3.1	0.5	n/a	1.3	0.7	1.7[1]	0.6[1]	0.7[1]
2013 Min	1.2	8.2	5.5	n/a	n/a	6.4	2.7	12.5	3.4	3.4
2008 Max	n/a	11.3	10.7	10.0	9.4	16.8	n/a	n/a	n/a	12.1
2009 Max	n/a	14.9	25.6	22.1	18.7	56.3	n/a	n/a	n/a	53.8
2010 Max	n/a	2.9	4.9	12.3	6.7	22.2	n/a	n/a	n/a	1.2
2011 Max[2]	47.4	56.6	50.0	5.9	n/a	31.5	46.0	31.9	18.2	48.0
2012 Max	2.5	10.5	14.6	7.4	n/a	13.2	45.6	17.6	36.6	20.7
2013 Max	4.4	16.8	10.3	n/a	n/a	16.9	16.0	21.7	15.8	15.7
2014 Max	3.6	15.4	16.9	n/a	n/a	27.7	27.3	33.1	30.0	28.2
2015 Max	4.2	11.9	11.9	n/a	n/a	17.4	18.9	18.6	17.2	19.7
2016 Max	3.1	13.3	15.7			16.4	24.6	35.8	14.7	16.1
2008 Average	n/a	6.0	9.3	9.0	8.5	20.5	n/a	n/a	n/a	15.8
2009 Average	n/a	7.8	10.7	9.3	10.6	21.3	n/a	n/a	n/a	19.7
2010 Average	n/a	1.6	2.0	2.4	3.6	7.1	n/a	n/a	n/a	5.0
2011 Average[2]	14.6	21.7	20.2	2.7	n/a	19.3	20.6	18.0	20.5	17.2
2012 Average	1.1	6.1	7.5	3.1	n/a	8.0	14.4	10.6	10.9	9.1
2013 Average	2.7	11.2	7.9	n/a	n/a	10.4	10.4	16.1	8.0	9.9
2014 Average	2.6	12.3	14.0	n/a	n/a	19.3	21.1	26.1	21.0	17.2
2015 Average	2.2	9.0	8.7	n/a	n/a	12.6	14.9	14.4	12.9	14.5
2016 Average	1.8	6.5	8.2	n/a	n/a	8.7	10.7	12.2	7.4	8.0
Notes	[1] Hanlon Creek was noted to be dry or flows were below the measurement threshold flow at stations HC-A(03),HC-A(12), HC-A(13) and HC-A(14) [2] Baseflows were influenced by construction activities									

5. In-stream Water Quality Data

During each field visit a YSI multi-parameter probe (556R) was used to collect dissolved oxygen, pH, and specific conductivity conditions at each site. The 2016 results and historic site comparisons are shown in **Figure 5-1**: 2016 YSI Dissolved Oxygen Readings to **Figure 5-6**: Average Annual YSI Conductivity Readings from 2008 to 2016 . The majority of the sites were within the ranges of the Provincial Water Quality Objectives (PWQO). It should be noted that the average annual comparisons provided show general trends of water quality parameters measured during baseflow conditions and do not provide a definite representation of stream conditions.

During the 2016 baseflow monitoring events, there was one occurrence where dissolved oxygen (DO) was found to be below PWQO guidelines. This occurred at station HC-A(04) on August 16th.Lower DO levels observed on this date could be attributed to below average flow rates, high temperatures and below average precipitation. The average annual dissolved oxygen levels shown in **Figure 5-2** show DO levels have been fairly consistent since 2010, with the exception of 2012 which was noted to be a particularly warm summer.

The number of days where pH levels were above PWQO guidelines was also recorded. Stations HC-A(13) and (14), recorded pH levels above the PWQO guidelines on September 26th. Station HC-A(03) recorded pH levels below PWQO standards on November 28th. Overall the annual trend in **Figure 5-4** shows pH levels to have been decreasing since 2012. However, overall averages increased from 2015 to 2016.

The is no PWQO for conductivity. Overall in 2016 the upstream reaches had lower conductivity readings and greater results in the downstream reaches with values ranging from 400 to 1300 µS/cm. Overall specific conductivity appears to be consistent throughout the system with the exception of HC-A(03) which appears to be trending to lower levels.

In 2016, four turbidity monitoring stations were installed along Hanlon Creek at stations HC-A(03), HC-A(06), HC-A(11) and HC-A(14). A Turner Designs Cyclops turbidity sensor uses an optical scattered light method to determine turbidity. **Figure 5-7**: In stream Turbidity Measurements for 2016 presents the turbidity monitoring results observed for the 2016. Average and max turbidity at all stations are about 6.3 and 27.9 NTU (in response to rainfall events), respectively. The PWQO for turbidity is based on Secchi depth reading not decreasing more than 10% due to the addition of suspended matter. Based on the CCME Guidelines for the Protection of Aquatic Life, allow for a maximum increase of 8 NTUs from background levels for a short-term exposure and of 2 NTUs for long-term exposure. It appears that none of the stations experienced a dramatic increase from their respective baseflow (background) turbidity

Some issues were encountered with the turbidity data. It appears that loggers at HC-A(11) and HC-A(14) were buried under sediment for extended periods causing the sensor to record maximum turbidity levels. During site visits turbidity sensors were checked and cleaned however sediment buildup in between visits occurred. There is also potential that biofouling and vegetation growth in the stream interfered with the sensor readings. Due to fouling occurring at stations HC-A(11) and HC-A(14) no conclusions can be made regarding turbidity conditions at these locations.

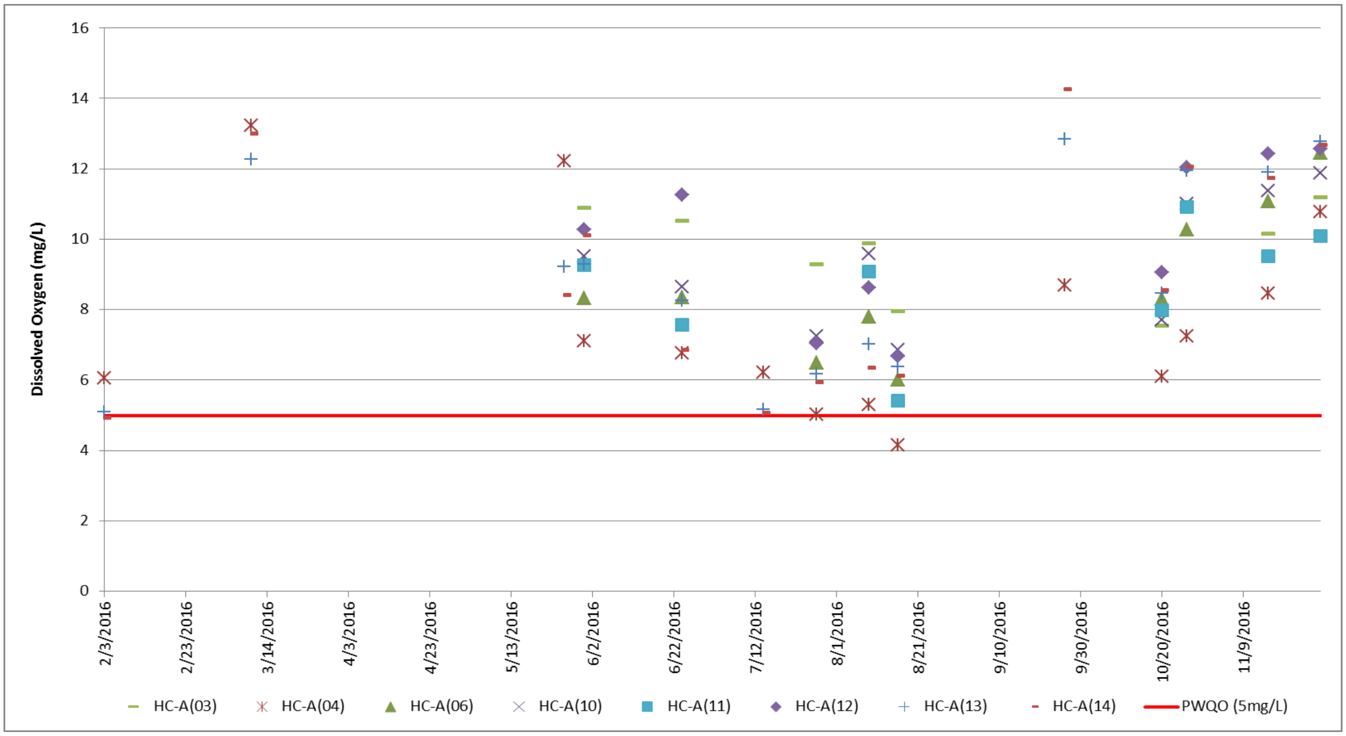


Figure 5-1: 2016 YSI Dissolved Oxygen Readings

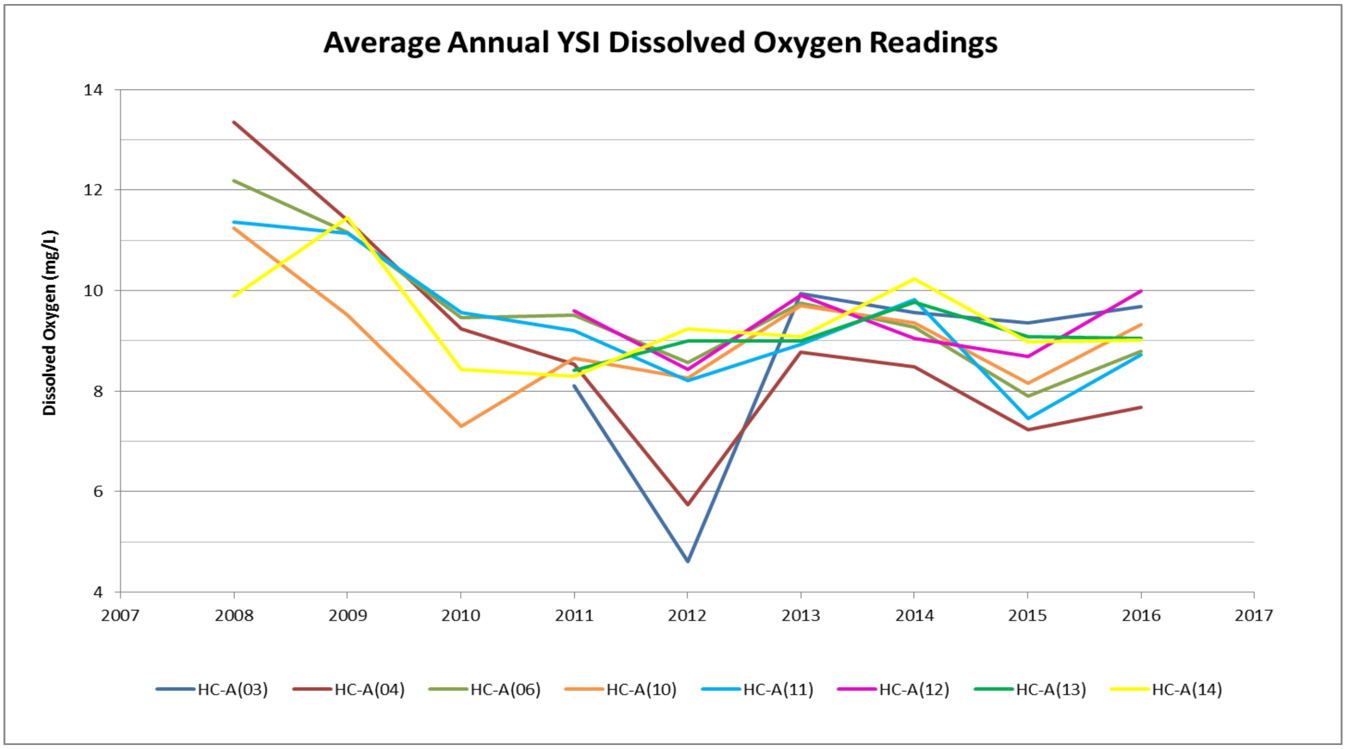


Figure 5-2: Average Annual YSI Dissolved Oxygen Readings from 2008 to 2016

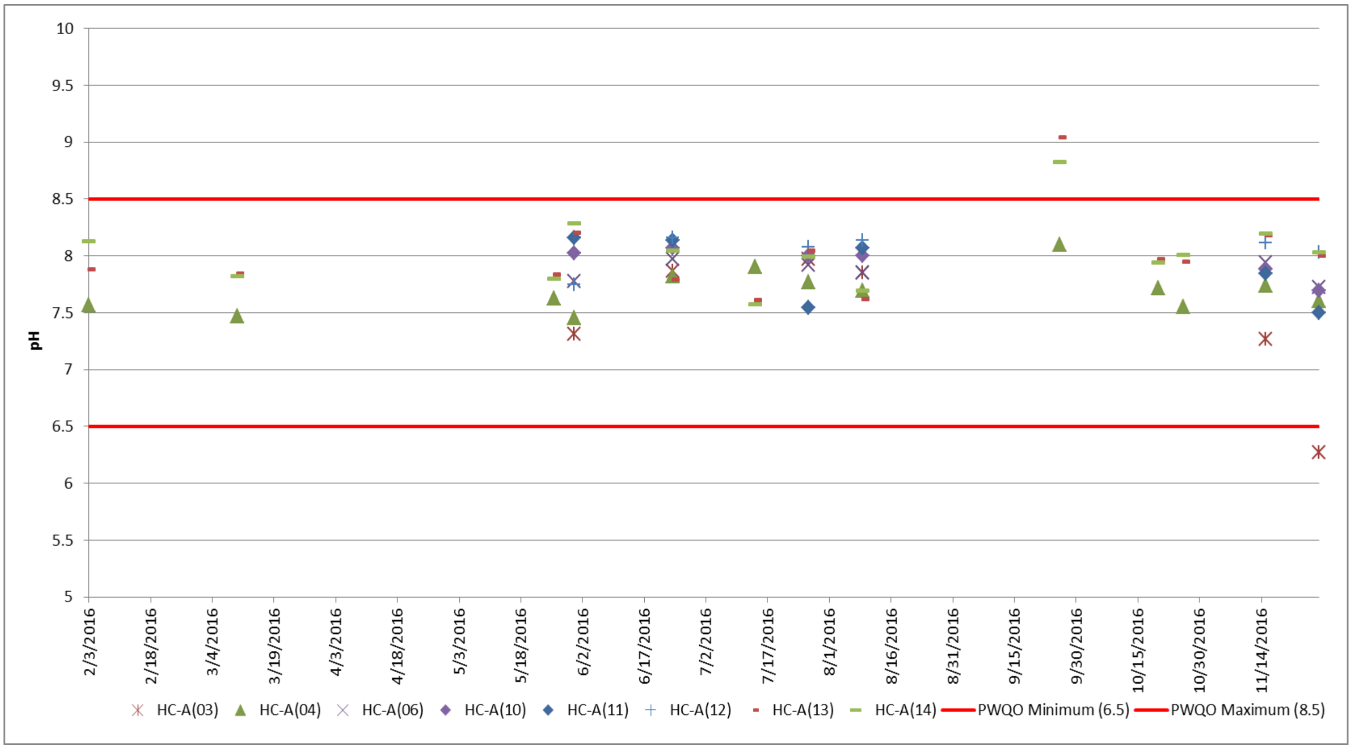


Figure 5-3: 2016 YSI pH Readings

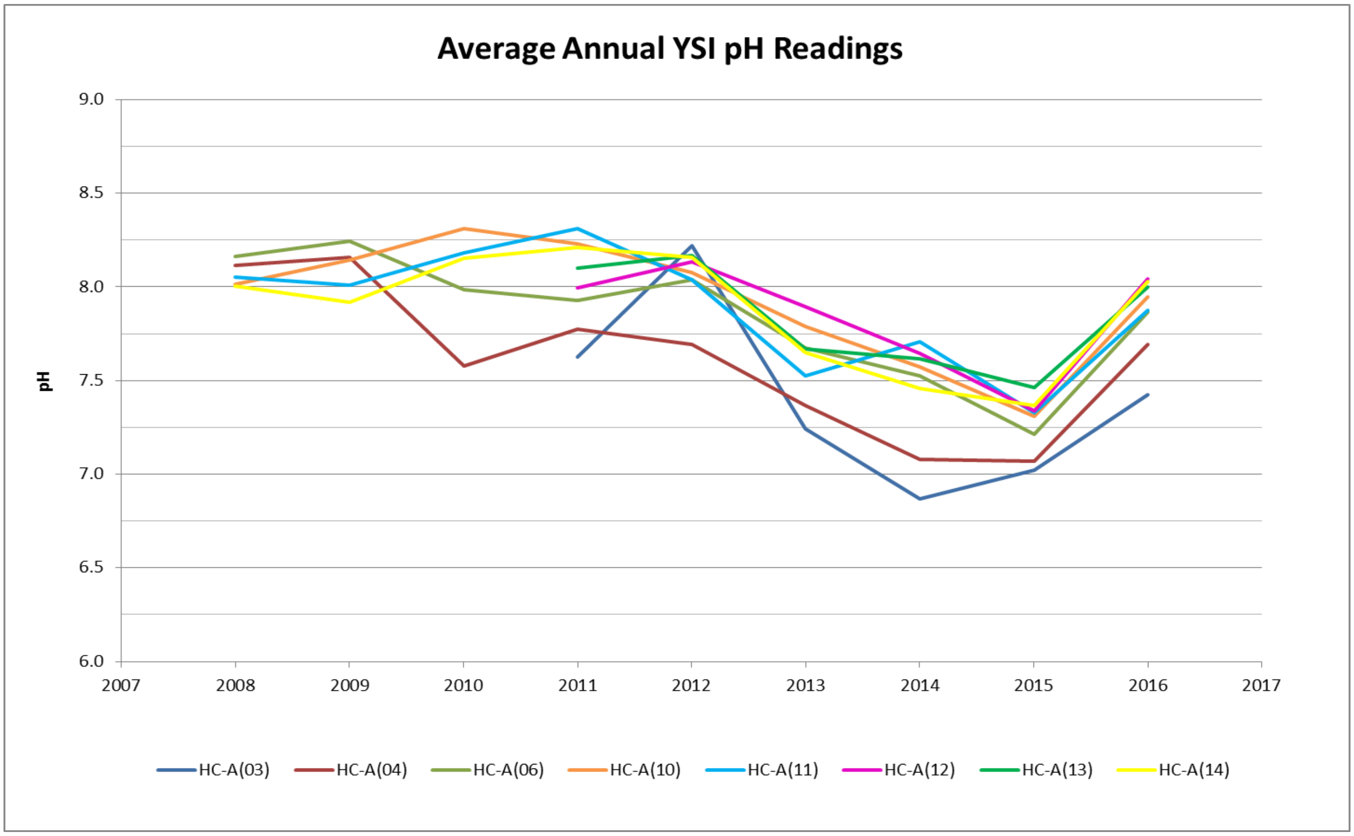


Figure 5-4: Average Annual YSI pH Readings from 2008 to 2016

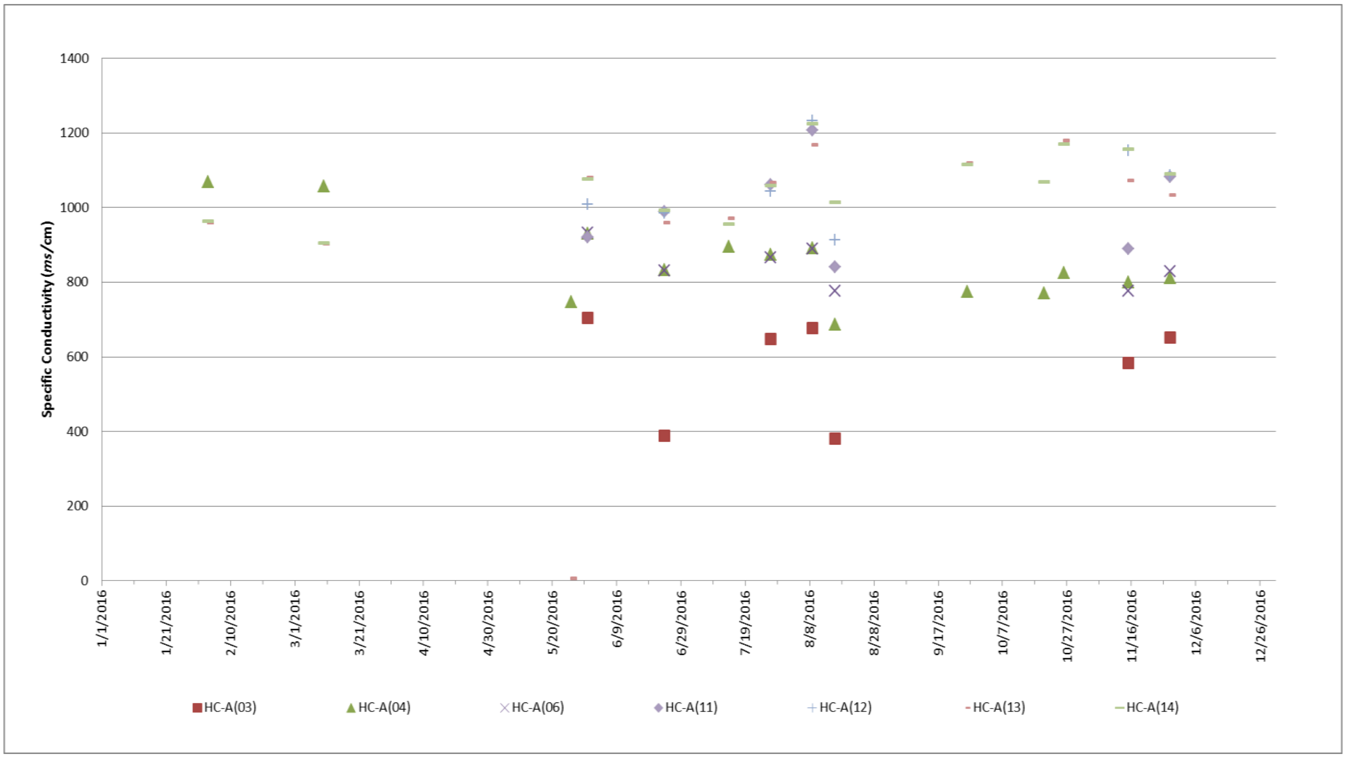


Figure 5-5: 2016 YSI Conductivity Reading

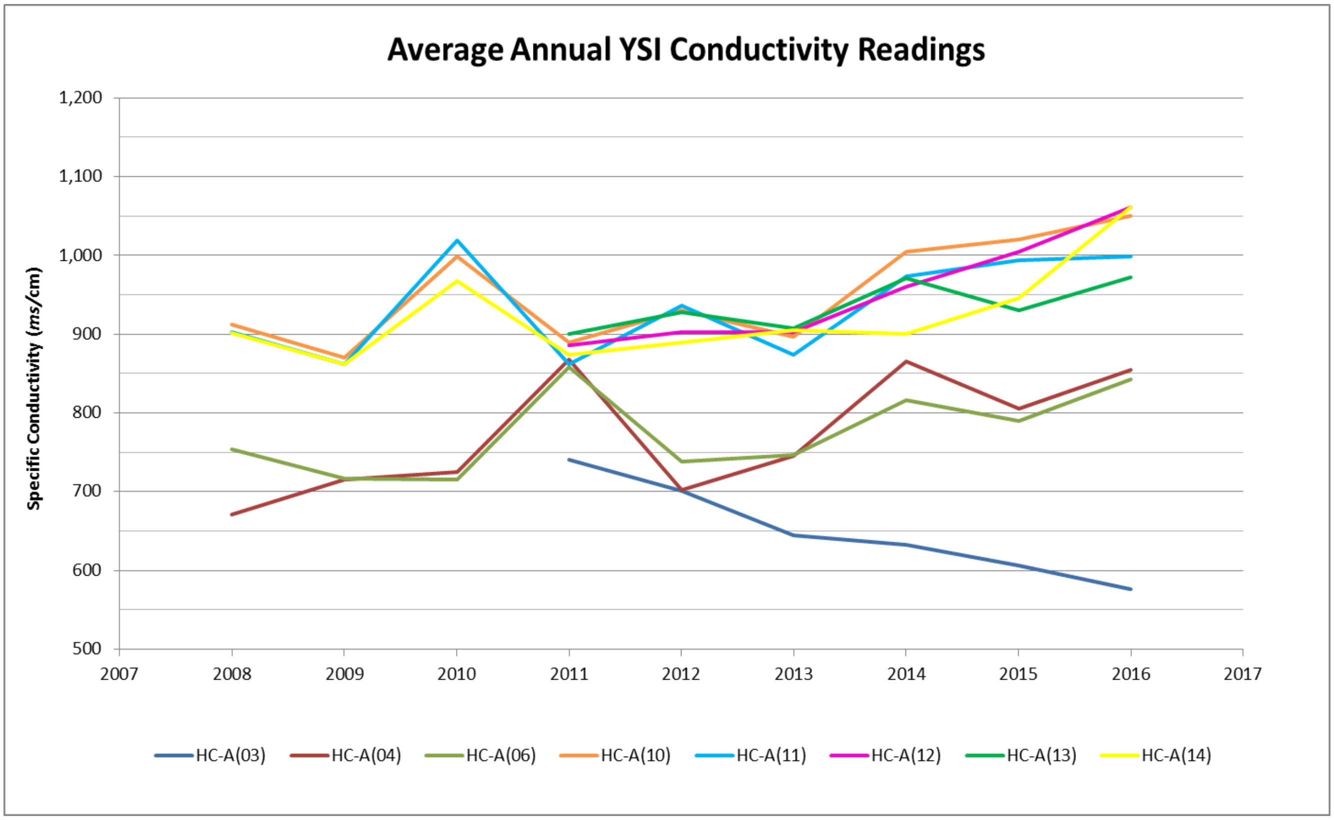


Figure 5-6: Average Annual YSI Conductivity Readings from 2008 to 2016

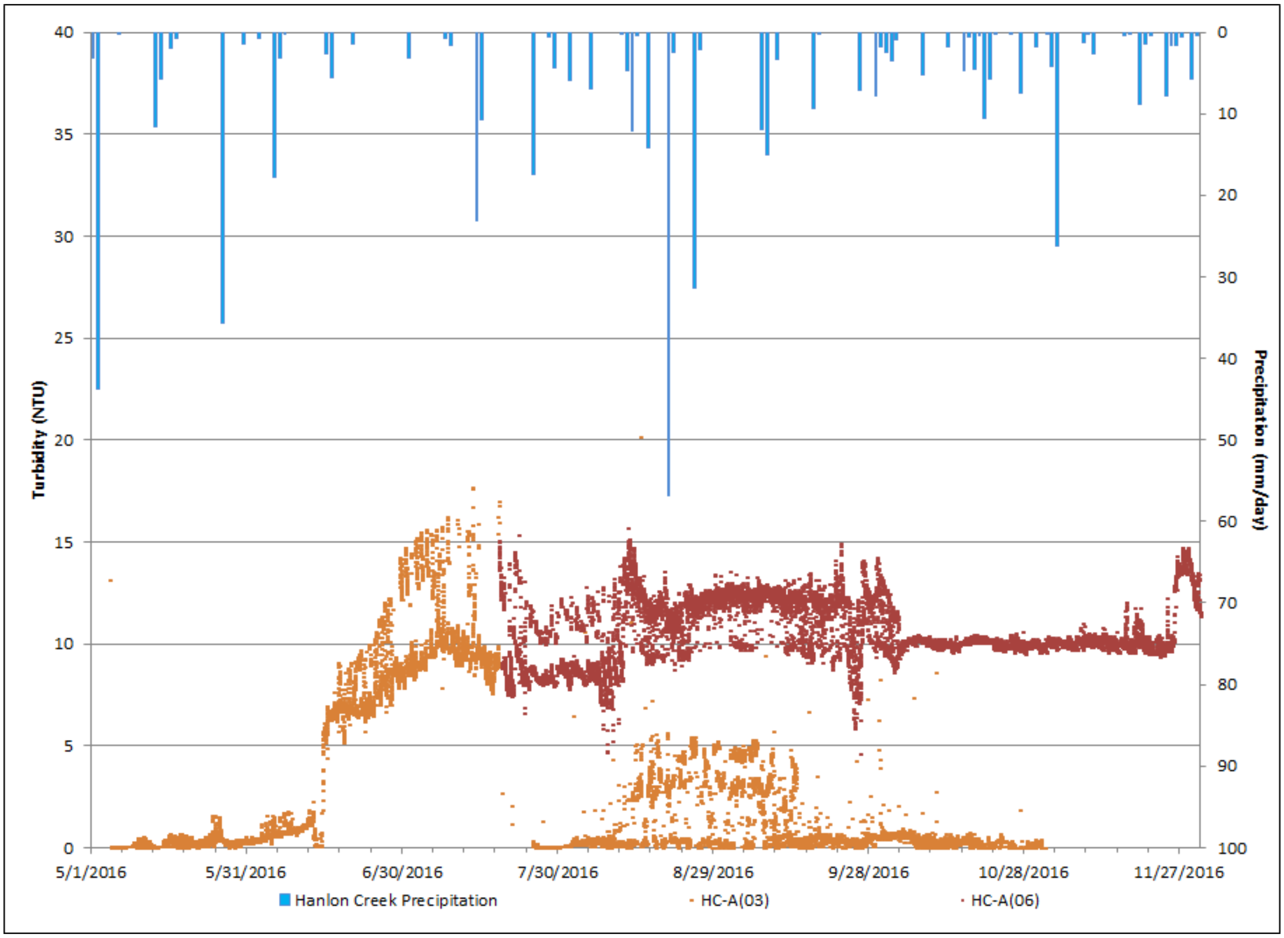


Figure 5-7: In stream Turbidity Measurements for 2016

6. Stormwater Management Facility Monitoring

As part of the Ministry of Environments CofA 1384-7QFPZQ and the Grand River Conservation Authorities (GRCA) requirements, monitoring was completed at each of the stormwater management (SWM) facilities (Pond 1, 2 and 4). The monitoring included three components, inflow and discharge flow rates, water temperature, and water quality sampling.

6.1 Flow

Water level loggers were located at each facility's inlet and outlet structures. This continuous depth data was used to estimate inflows and outflows of the facilities.

For Pond 1, flow was calculated for the two inlet structures (HC-P1(04) and HC-P1(05)) using Manning's equation for flow through a partially full concrete pipe Estimated flows for Pond 1's inlet structure and outlet structure are shown in **Figure 6-1**: Estimated Flow for Pond 1

Figure 6-2: Estimated flow for Pond 2. Pond water levels were not high enough in 2016 to trigger a pond discharge event.

For Pond 2, flows were calculated at the inlet structure HC-P2(06)) and the outlet structure (HC-P2(07)). At HC-P2(04), inflow rates to the pond at the 655 mm inlet pipe could not be estimated as the logger is significantly influenced by tail water conditions throughout the monitoring season. Inflows were calculated at HC-P2(06) using Manning's equation for a grass lined trapezoidal swale. Due to an impediment to flow in the upstream channel, flow in this drainage swale only occurred during large storm events. Flows at Pond 2 are illustrated in **Figure 6-2**. Pond water levels were not high enough in 2016 to trigger a pond discharge event.

For Pond 4, flow was calculated for both the inlet (HC-P4(04)) and the outlet (HC-P4(05)) structures. Inflows were calculated at HC-P4(04) using Manning's equation for a grass lined trapezoidal swale. The outflow from Pond 4 was calculated using the orifice equation based on the water level recorded by a level logger that was placed inside the outlet control structure (P4-(05)). Pond 4 continuously discharged water throughout the majority of the 2016 monitoring season. Flows for Pond 4 are illustrated in **Figure 6-3**.

Figure 6-4 provides a summary of average daily flows at the inlet (HC-P4(04)) and outlet (HC-P4(05)) of Pond 4. The difference is an indication of the exchange of flow between Pond 4 and the aquifer.

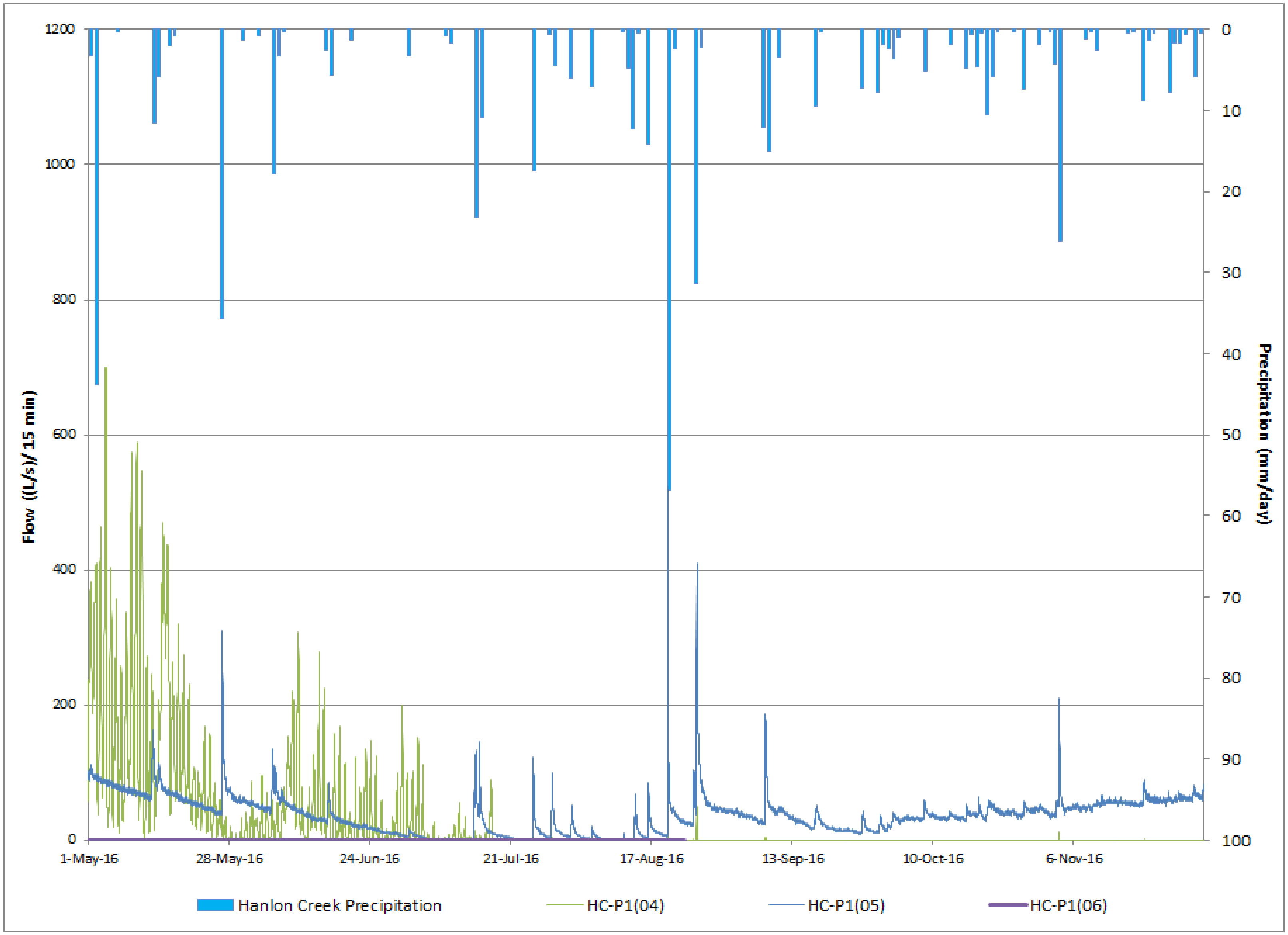


Figure 6-1: Estimated Flow for Pond 1

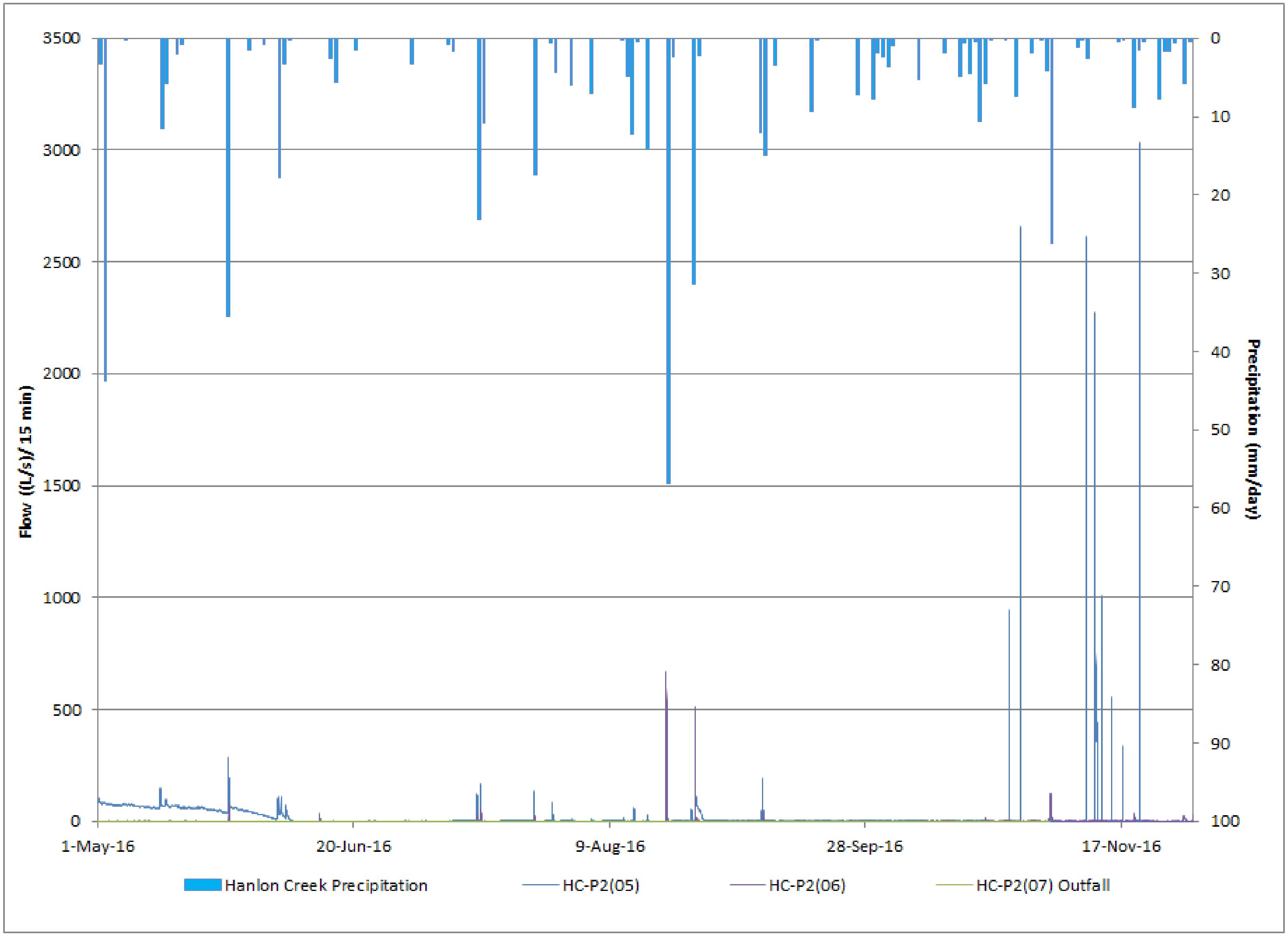


Figure 6-2: Estimated flow for Pond 2

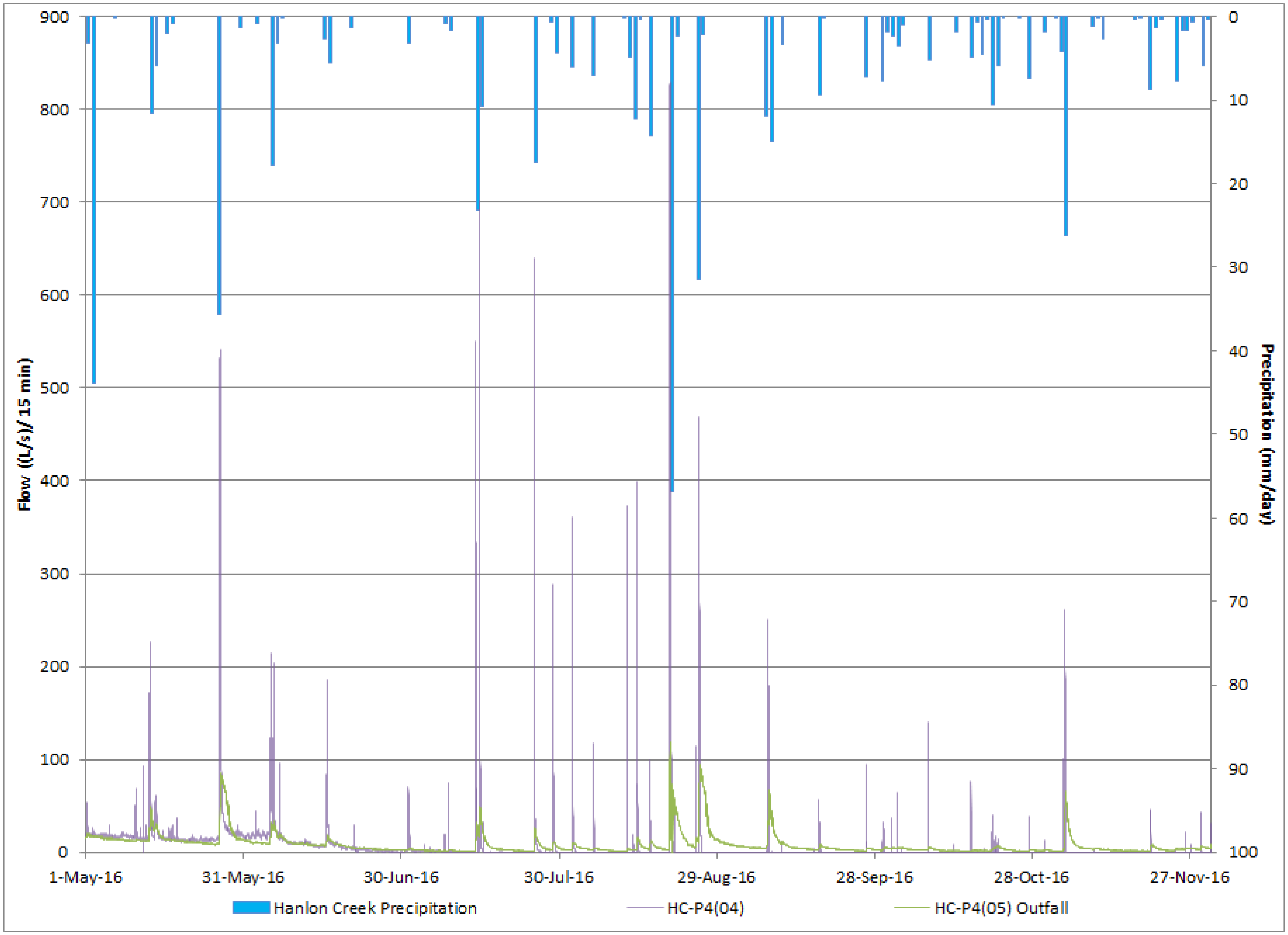


Figure 6-3: Estimated flow for Pond 4

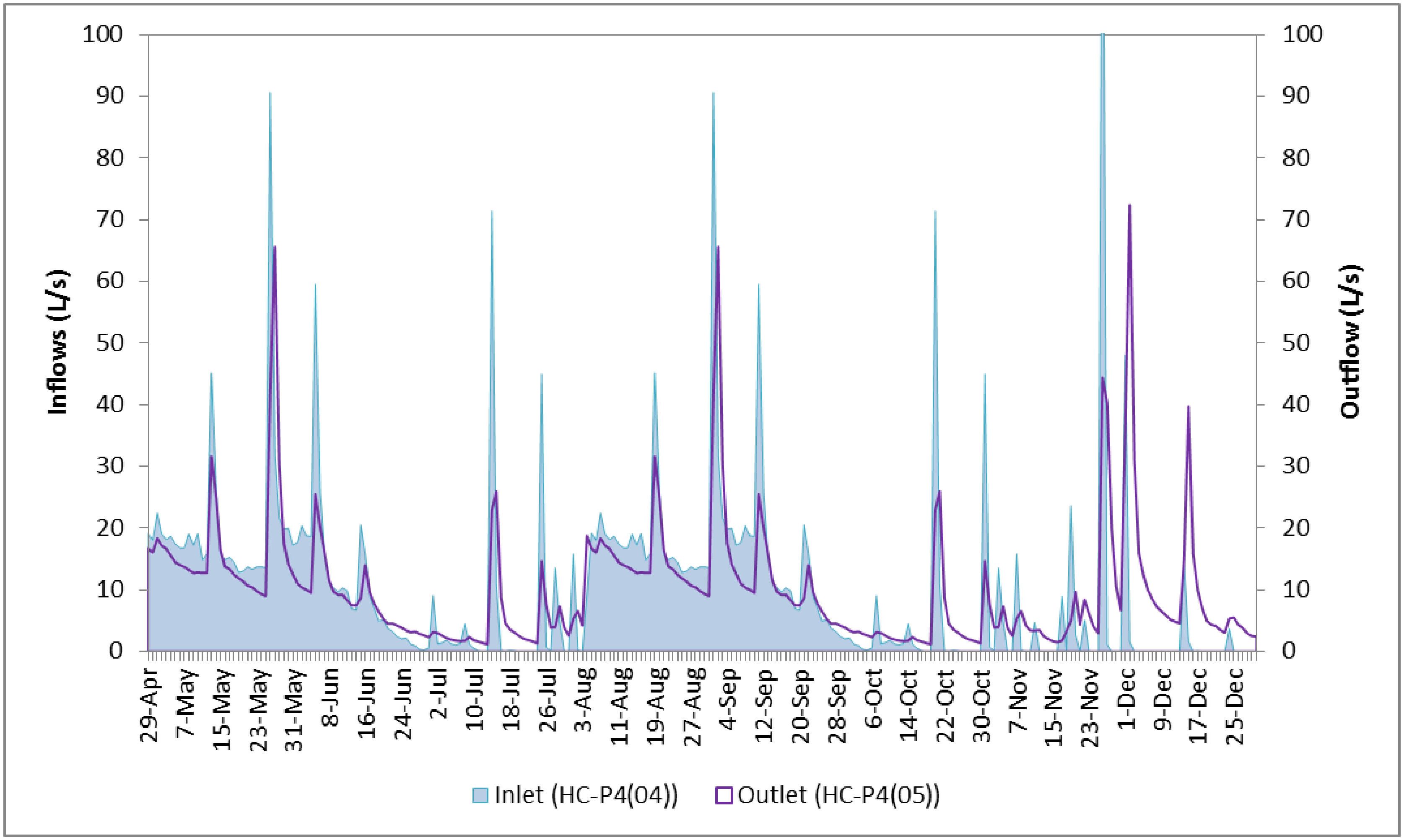


Figure 6-4: Average Daily Flows at Inlet and Outlet of Pond 4

6.2 Temperature

Water temperature was monitored at the following locations at each of the SWM facilities:

- inflow structures;
- cooling trench outlets;
- outflow structures; and
- pond stratification temperate monitoring clusters.

The purpose of monitoring temperature in the SWM facilities is to illustrate that the mitigation measures that were incorporated into Hanlon Creek Tributary A are effective and that the water being discharged to the creek will not contribute to the warming of the steam.

6.2.1 Pond 1

Pond 1 was designed with multiple mitigation features. Stormwater is conveyed to the SWM facility via two grass drainage swales that discharge into the settling forbays. Before water can pass though to the main body of the pond, the flow must pass though a planted wetland area. The water is discharged via a bottom draw structure into one of two cooling trenches prior to being discharged into the wetland areas. These measures allow for maximum infiltratration, and minimize the amount of water directly discharged from the SWMF to the creek.

Water temperatures were monitored in the inlet channels (HC-P1(04,05)), at the pond outflow catchbasin structure (HC-P1(06)) and at the cooling trench outflows (HC-P1(07,08)). The thermal profile in the pond was also measured (HC-P1(01), HC-P1(02), HC-P1(03) - in order of deepest to shallowest placement, with HC-P1(03) located closest to the surface.

No discharge was recorded at the outlet of Pond 1 during the 2016 monitoring season**.** Therefore conclusions regarding the function of Pond 1’s cooling trench cannot be determined based on the 2016 data.

6.2.2 Pond 2

The design of Pond 2 was a retrofit of an existing SWM facility. There are three inlets to the SWM facility, two storm sewer outlets (HC-P2(04,05)) and one grass drainage swale (HC-P2(06)). Each inlet discharges into its own sediment forebay. Before the water can pass through to the main body of the pond, the flow must pass through a planted wetland area; the water is discharged via a bottom draw structure into an infiltration gallery that was constructed as part of the pond design for the original SWM facility. Similar to Pond 1, depth loggers were placed at each inlet as well as the at the Pond 2 outlet (HC-P2(07)). Temperature loggers were also installed in the ponds main cell to record the ponds temperature profile (HC-P2(01,02,03)). Outflow from the Pond was not recorded during the 2016 monitoring season.

6.2.3 Pond 4

Pond 4 was designed with mutiple mitigation features. Stormwater is first conveyed to the SWM facility via a grass drainage swale and discharged into a settling forebay. Before the water can pass though to the main body of the pond, the flow must pass though a wetland area (see below). The water is discharged via a bottom draw structure into a cooling trench prior to being discharged into Hanlon Creek Tributary A.

While the outflows were often more than 5ºC less than the surface temperatures, the cooling trench outflows were still typically 3-6ºC warmer than the upstream station. In September 2012, the outlet weir was raised to stop Pond 4 from continuously discharging. This has not been achieved however, due to high levels of groundwater input to the pond. .

Additionally, vegetation was planted in the pond, and vines and other fauna were installed on the cooling trench to shade the exposed rock. The plantings have not yet matured to cover the cooling trench yet. However, in 2016, improvements were noted in the amount of vegetation taking root along the cooling trench as shown in **Figure 6-7**: Vegetation along Pond 4's cooling trench looking towards Pond 4. (2016/8/9) Although the current impact is minor, these features are anticipated to provide additional cooling to the ponds discharge in future summer seasons.

Water temperatures were monitored in the inlet channel (HC-P4(04)), at the pond outflow structure (HC-P4(05)) and at the cooling trench outflow (HC-P4(06)). Temperature loggers were installed in the pond's main cell to record the pond's temperature profile. The complete temperature monitoring records at the Pond 4 stations for 2016 are shown in **Figure 6-5**: Measured temperatures through Pond 4 and directly upstream and downstream of the Pond 4 outletThe temperature monitoring during a storm event in August is shown in **Figure 6-6**: Flow and Temperature during a precipitation event for Pond 4 as well as directly upstream and downstream of the Pond 4 outlet to more clearly illustrate the general pattern of the thermal regime throughout the pond before and after a precipitation event. The temperature records from the creek stations upstream (HC-A(03)) and downstream (HC-A(04) and HC-A(06)) as well as precipitation and inflows are shown **in Figure 6-5**: Measured temperatures through Pond 4 and directly upstream and downstream of the Pond 4 outlet

Recorded temperature at the bottom-draw outlet (HC-P4(05)) was generally lower (during summer months) than the in-pond loggers (HC-P4(01-03)); it appears that the bottom draw outlet successfully allows for the discharge of the coldest (deepest) water first. The temperature recorded at the outlet of the cooling trench tended to have the least variation: it appears that the cooling trench did have a moderating, and generally cooling, effect on the flow discharged to Hanlon Creek Tributary A. Despite the cooling effects of the trench and bottom draw outlet (as well as the cooling impact of groundwater input), temperatures leaving the pond were still higher than in-stream water temperatures upstream of Pond 4. The temperatures recorded at the creek station HC-A(04) downstream of Pond 4 were higher than those recorded upstream of the pond outlet (HC-A(03)). This highlights the pond's thermal impacts on HC-A(04), which has a much smaller magnitude of diurnal temperature fluctuations than those observed in the creek sites upstream (HC-A(03)) and downstream (HC-A(06)). At station HC-A(06), daily peak temperatures remain (at 25.13 ºC) as high as those of HC-A(04) at 25.32 ºC , but atmospheric cooling at night exerts a greater impact on the daily minima observed at HC-A(06), which is 0.01ºC C versus 3.05 ºC at HC-A(04).

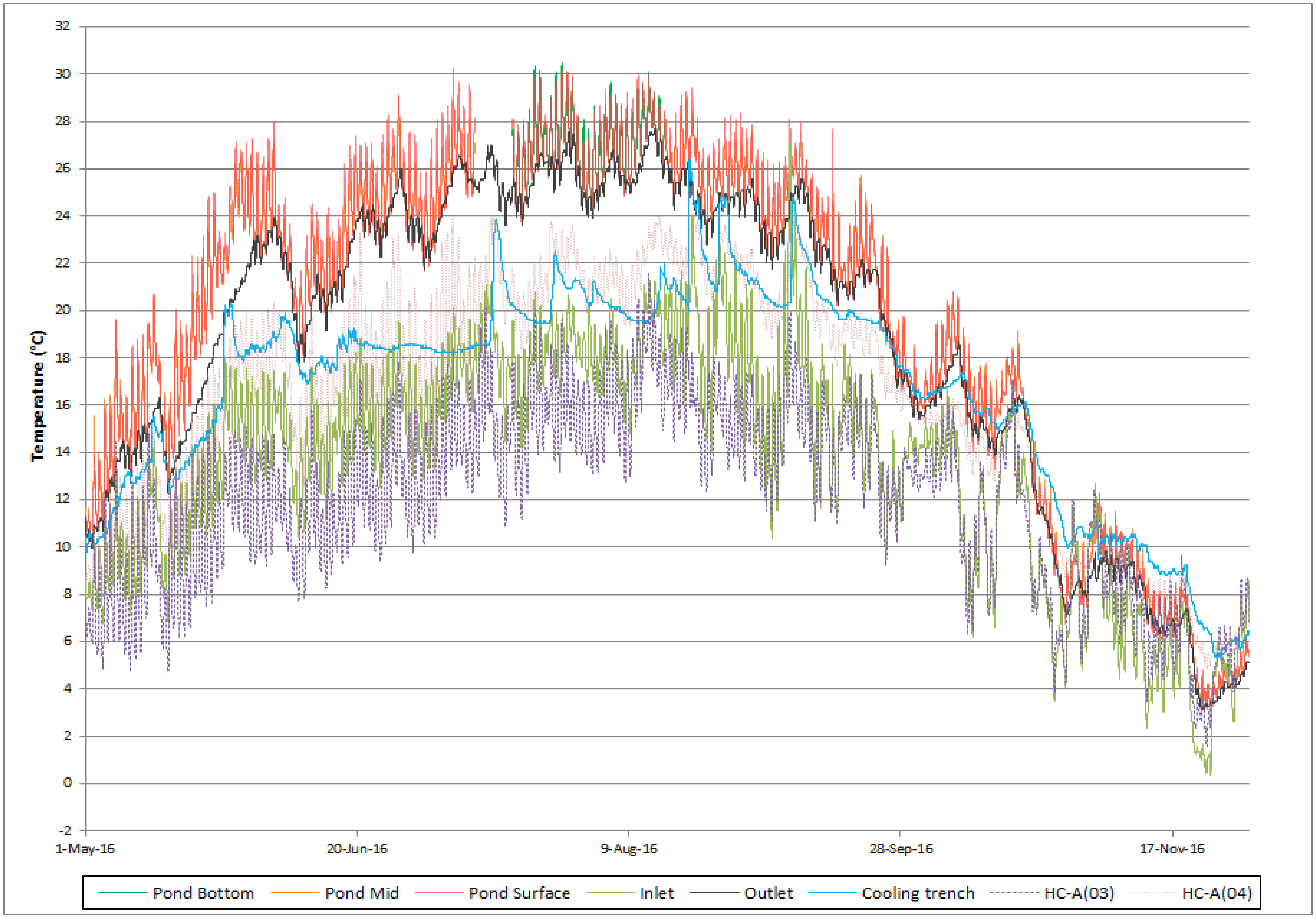


Figure 6-5: Measured temperatures through Pond 4 and directly upstream and downstream of the Pond 4 outlet

Figure 6-6: Flow and Temperature during a precipitation event for Pond 4 as well as directly upstream and downstream of the Pond 4 outlet

Figure 6-7: Vegetation along Pond 4's cooling trench looking towards Pond 4. (2016/8/9)

6.3 Effluent Water Quality

To establish the performance efficiency of the SWM facilities and to satisfy the MOECC Environmental Compliance Approval, the water quality sampling program consists of grab samples at the inlet, outlet and downstream of each pond. Parameters that were analyzed in 2016 included:

- CBOD5
- Total Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Metals (total and dissolved, lead, zinc and copper)
- Escherichia coli
- Nitrate as N
- Chloride

The Consolidated Monitoring Program included the following water quality sampling requirements:

- One sample per season (Winter and Fall) within one hour commencement of a storm event;
- Five wet weather samples collected during summer months (June-September);
- One sample collected during the snowmelt freshets (Spring); and
- Three dry samples taken at least 72 hours after a wet weather event

Eight wet weather samples were collected over the course of the 2016 monitoring season. Both the winter and spring freshet samples were collected. Five wet weather samples were collected between May and October 2016. The reaming wet weather sample was taken during the month of November. One dry sample was taken during the spring, summer and fall (three in total). From May to October, water levels at Pond 1 and 2 were too low prior to a rainfall event to result in stormwater being discharged from the outlet into Hanlon Creek Tributary A. Therefore, samples at Pond 1 and 2 were not taken during discharge events. As a result, the only interactions between these SWM facilities and Hanlon Creek Tributary A would have occurred though ground water. Samples collected during non-discharge periods in the summer months were taken directly from the SWM facilities. As such, the water samples did not necessary represent the water flowing into Hanlon Creek Tributary A. Pond 4 was discharging during the summer months and stormwater samples were collected from the pond outlet. The tabular results of the water quality sampling have been included in **Appendix E**.

Water quality sampling results are presented as the number of exceedances as compared to the Provincial Water Quality Objectives (PWQO) in **Table K.** A number of water quality parameters were typically higher in the SWM facilities with lower concentration in Hanlon Creek. E.Coli concentrations exceeded the recommended PWQO guidelines for recreational use for both wet weather and dry weather sampling events. Total phosphorus showed an overall reduction as the water moved though the pond. The in-stream phosphorus levels exceed the PWQO during both wet and dry weather sampling events. However; this is not uncommon for streams in the Grand River watershed (GRCA, 2012). Nitrate, total suspended solids, copper and lead all showed higher concentrations entering the SWM facilities with concentrations decreasing in the outlet samples. Aluminum, cadmium, copper, iron, lead, vanadium and zinc exceeded PWQO in the SWM facilities. However, in-stream levels did not exceed PWQO guidelines for aluminum or vanadium. Copper, iron, lead and zinc exceeded PWQO guidelines for both wet weather and dry weather sampling events. Zinc concentration in both the SWM facilities and in-stream exceeded PWQO.

Chloride concentrations were typically higher at pond outlets and in-stream locations, compared to samples taken at pond inlets. However, inlet chloride levels sharply increased during winter sampling. All samples were below the short term exposure target of 640 mg/L (CCME 2011) All ponds and stream locations recorded chloride level exceedances above the long term exposure target of 120 mg/L (CCME 2011) during the monitoring season.

Table K: Number of Guideline Exceedances per Water Quality Sampling Location

			PWQO		**CCME**			**Number of Exceedances for Wet Weather Sampling Events**											**Number of Exceedances for Dry Weather Sampling Events**			**Total**
Analyte	**Units**	**LOR**[1]	**Lower Limit**	**Upper Limit**	**Short Term**	**Long Term**	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4 (04)	HC-P4 (05)	HC-A (04)	HC-A (13)	HC-A (14)	HC-A(04)	HC-A(13)	HC-A(14)	
Dissolved Oxygen(DO)	mg/L	0.05	5	-	-	-	2	1	2	1	2	2	1	1	0	0	0	1	1	0	0	14
pH	pH units	0.1	6.5	8.5	-	-	1	1	2	0	1	1	2	0	1	0	1	1	0	0	0	11
Chloride	mg/L	2	-	-	120	640	4	3	7	2	2	3	2	3	6	5	7	7	3	3	3	60
Total Phosphorus	mg/L	0.003	-	0.03	-	-	6	6	4	7	7	7	6	5	1	3	5	5	0	1	2	65
E. Coli	CFU/100mL	10	-	100	-	-	5	5	5	7	5	3	4	5	2	4	5	5	1	1	1	58
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	7	7	7	7	7	7	7	7	5	7	6	6	3	3	3	89
Arsenic (As) - Total	Mg/L	0.001	-	0.005	-	-	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	-	0	3	0	0	3	0	1	0	0	2	1	1	0	1	0	12
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	1	4	0	0	1	0	1	0	0	0	1	0	0	0	0	8
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	-	6	6	1	7	7	3	6	6	1	1	2	2	0	0	0	48
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	2	7	2	7	5	4	5	4	1	4	1	1	0	1	1	45
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	-	0	4	2	7	6	3	5	4	1	1	1	1	0	1	1	37
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0	2	0	0	0	0	4	0	0	0	1	0	0	0	0	7
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	-	1	4	2	6	5	0	1	4	1	7	1	1	3	1	1	38
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015*	-	-	4	6	3	7	7	6	6	6	1	0	0	0	0	0	0	46
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001*	-	-	7	7	5	7	7	7	6	6	2	6	4	4	1	1	1	71
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001*	-	-	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02*	-	-	0	0	0	0	0	0	0	0	0	7	0	0	2	0	1	10

Notes: [1] Limit of reporting (LOR)

- 8 Wet weather grab samples and 2 dry weather grab samples were collected
- Exceedances based upon the PWQO limits, Chloride exceedances were based upon the CCME short term level.

* objectives for total metals.

7. Conclusions and Recommendations

7.1 Conclusions

In-stream flow conditions in 2016 were generally consistent with those observed in previous years when climatic conditions are considered. Low precipitation during the summer months made for overall dryer conditions throughout the system, with higher average air temperatures generally resulting in below average baseflow conditions.

The monitored temperature results show that the system overall experienced warmer temperatures than in previous years, largely due to the warmer summer months. Monitoring results show summer temperatures may still not have been suitable for brook trout habitat based on the ranges provided in the Hanlon Creek Business Park Stream Temperature Impact Report Continuous Modeling with HSP-F (AECOM, 2009). Thermal monitoring results consistently produce higher thermal conditions than those predicted by the HSP-F model for average summer temperatures and exceedances above 19°C in the summer as well as for all autumn predicted values for all in-stream monitoring stations.

Pond 4 was continuously discharging into Hanlon Creek Tributary A during the summer of 2016 and is likely a contributing factor to the observed increased temperatures at stations downstream of the pond outflow including HC-A(04), HC-A(06) and HC-A(09). The bottom-draw and cooling trench design of Pond 4 appears to be functioning well, and overall reducing outflow temperatures, resulting in discharges cooler than water in the pond, but still higher than the creek monitoring station upstream of the pond. Vegetation that was planted on the banks of the pond and along its cooling trench in 2012 had not matured and therefore did not provide additional cooling benefits to Pond 4. Slight improvements were observed in 2016, and it is expected that with the vegetation growth, water temperatures will decrease.

General trends observed in the in-stream thermal monitoring data indicates that continuous discharge from Pond 4 impacts thermal conditions in the stream from downstream of the pond outlet to station HC-A(09). Downstream of this station the cool groundwater-fed tributary and the elimination of online ponding downstream of Hanlon Creek Boulevard provide for slight improvements. Further downstream, the open nature of the creek, and its exposure to ambient air temperatures and solar radiation have resulted in little change to in-stream thermal conditions since monitoring has begun.

In August 27, 2015, AECOM provided a memo to the City outlining recommended improvements to Pond 4 in order to reduce overall thermal impacts to the Creek . Following discussion with stakeholders, AECOM recommended that the water level in Pond 4 be lowered to its original design elevation and that plantings be provided throughout the pond to provide shading as originally intended. As well, it was recommended that two additional thermal monitoring stations are installed between HC-A(04) and HC-A(06). These additional stations were implemented in 2016 to further evaluate causes of temperature exceedances of 24°C at station HC-A(06). Additionally, if in the future the implementation of a cut-off drain at Pond 4 is considered, it was recommended that a review is completed by all three disciplines (aquatic ecology, groundwater and surface water) to evaluate the net benefit to the system prior to moving forward with this option.

In 2016, through the RAAP meetings and the 2017 work plan meeting, a number of measures were discussed for further evaluation, including interception and re-routing of groundwater from the pond to the outlet of the cooling trench, lowering water level in the pond and re-establishing the vegetation (including exclusionary fencing to discourage waterfowl as the vegetation gets established), as well as various sharing structures (e.g. floating island, shade screening, etc.).

Collected data for Pond 1 show that no water exited through a surface pathway from Pond 1 during 2016. Site inspections confirmed low water levels in Pond 1 in the summer and fall months. Previous annual monitoring reports have assumed that infrequent flows at Pond 1 may have contributed to high temperatures observed at HC-A(13) and HC-A(14), however this was not indicated in the 2016 monitoring results. Further temperature monitoring of the Pond 1 cooling trench should be completed to evaluate the effectiveness of this system as it is unknown at this time. Similarly, it is not expected that the Pond 2 SWM facility was the cause of the single temperature exceedance of 24°C observed during 2016, as no flow exited the facility during the summer months.

Overall in-stream water quality conditions appeared to be consistent with conditions noted in previous years. Of the three parameters collected during baseflow measurements (DO, pH and specific conductivity), pH was the only parameter that produced a visible change in trend. Overall pH levels within the system appear to have been decreasing since 2012. However, average pH levels increased in 2016. Further years of data collection are required to confirm this observation.

Overall SWMF effluent water quality samples indicate conditions typically for SWMF located with the Grand River watershed for both dry and wet weather conditions. It was noted that exceedances generally decreased from each ponds inlet to outlet. Pond 4, the only pond to record discharge during the 2016 monitoring season, recorded fewer exceedance events at the ponds outlet compared to the ponds inlet for all measured parameters with the exception of Chloride exceedance events. The Pond 4 outlet experienced a large amount of exceedance events for both Chloride (6) and Total Aluminum (5). Several exceedance events for Chloride, Total Phosphorous, E.coli, Aluminum and copper were recorded throughout Tributary A. A high number of exceedance events for Zinc were also noted at station HC-A(04).

7.2 Recommendations

The following recommendations were formulated based on observations made during the 2016 monitoring program.

7.2.1 In-stream Monitoring Program

For the 2017 program, it is recommended that water depth/temperature loggers (U20) should continue at each telemetry station (HC-A(03), HC-A(06), HC-A(11) and HC-A(14). While each telemetry station is thoroughly checked each year before installation equipment malfunctions and theft have occurred in the past causing large data gaps. The U20 loggers will serve as a back-up to prevent unnecessary data loss.

High flow measurements are required for stations HC-(A)11 and HC-(A)12 to obtain greater confidence in the existing rating curves.

7.2.2 Stormwater Management Facility Monitoring Program

Pond inflow monitoring is not recommended to be carried through in future monitoring initiatives as due to the nature of flow into the SWMF it has been difficult to estimate pond inflows. Outflow conditions of Ponds should continue to be monitored to continue to provide an understanding of the impacts of the SWMFs on the creek system. However, the 2016 pond flow data identified no outflow from Ponds 1 and 2 and near consistent outflow from Pond 4. Therefore, it is recommended that a single depth logger is installed within each SWMF to provide a continuous record of referenced water levels within each SWMF throughout the monitoring period. Available design information may be used to establish a staging curve for each pond.

The overall SWMF temperature monitoring program has collected a robust data set over the past few monitoring seasons. The previous years of data collection have confirmed the thermal stratification within the SWMF. The in-pond temperature monitoring of Ponds 1 and 2 could be ceased as five years of thermal data have been collected in the ponds and overall a good understanding of the thermal regime of each facility has been established. Thermal monitoring of conditions within the Pond 1 cooling trench is required to verify the effectiveness of the Pond 1 cooling trench.

So far, five years SWMF water quality effluent sampling has been completed and it would be reasonable hold off this component until build-out of 75% of the site is complete, at which point, three consecutive years of water quality sampling results should be collected.

Prior to any rehabilitation works to Pond 4, a multidisciplinary review is required to establish the overall net benefit of any proposed works.

8. References

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Appendix A

Monitoring Reports

AECOM
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Kitchener, ON, Canada N2P 0A4 519.650.3424 fax
www.aecom.com

Field/Sampling Report

Client City of Guelph Page 1

Project Hanlon Creek Monitoring 2015, High flow measurements

Date February 03, 2016 Project Number 60265453

Weather: Overcast/partial cloudiness, low of 1.1°C, max of 14.5°C.

Tasks:

- Water Samples
- YSI measurements
- Photos

Field Crew: Sachet Siwakoti and Steve Scott

Notes: Surface ice (over 6" in some locations) was present at a number of sites. Snow depth was between 1' in most locations. Access was difficult and varied as a result.

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(04)	02/03/2016 10:44	4.51	1.07	6.06	7.57	
HC-A(13)	02/03/2016 11:43	2.53	0.960	5.09	7.88	
HC-A(14)	02/03/2016 11:59	2.62	0.964	4.94	8.13	

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	02/03/2016 11:07	1.15	1.91	7.54	7.43	
HC-P1(05)	02/03/2016 11:29	3.69	1.47	5.61	7.52	
HC-P1(06)	02/03/2016 11:22	3.56	1.72	9.91	7.62	
HC-P2(04)	02/03/2016 13:09	3.46	2.33	1.29	7.73	
HC-P2(05)	02/03/2016 12:18	5.90	7.47	0.99	7.34	
HC-P2(06)	02/03/2016 12:27	2.77	0.930	2.77	7.94	
HC-P2(07)	02/03/2016 11:54	2.03	1.02	6.57	7.97	
HC-P4(04)	02/03/2016 10:30	2.56	0.612	11.76	6.80	
HC-P4(05)	02/03/2016 10:36	4.95	1.30	6.00	6.74	

Weather, General Conditions
Site: HC-A(04)
Time: 02/03/2016 10:40
Comments: Snow found on stream banks, no surface ice.

Looking Upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 02/03/2016 11:45
Comments: Minimal surface ice present. Some snow on bank.

Looking Upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 02/03/2016 12:00
Comments: Samples and YSI measurements collected in the channel. No surface ice present.


Looking Upstream


Looking downstream


Looking across stream

Site: Pond 1
- Significant ice cover on pond
- Both inlets pipes (HC-P1(04) and HC-P1(05)) were frozen
- HC-P1(04) was flowing at inlet. Sample and YSI were taken at the inlet.
- HC-P1(05) had some flow. Sample and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was flowing. Samples and YSI were taken in the outlet catchbasin.

Site: Pond 2
- Significant ice cover at pond
- HC-P2(04) is backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) was flowing. Sample and YSI were taken at inlet.
- HC-P2(06) was not flowing. Sample and YSI were taken at pond.
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4
- Significant ice cover at pond
- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing higher than normal. Sample and YSI were taken at outlet.

Pond 1: Drainage Swale (HC-P1(04))

Pond 1: HC-P1(04) flowing under ice

Pond 1: Forebay looking toward HC-P1(04)

Pond 1: Forebay looking toward HC-P1(05)


Pond 2: Deep Cell looking from HC-P2(07)


Pond 2: (HC-P2(04)) flowing


Pond 2: HC-P2(04) looking toward forebay


Pond 2: HC-P2(05)) flowing


Pond 2: HC-P2(05) looking toward forebay


Pond 2: Drainage Swale (HC-P2(06))


Pond 4: HC-P4(04) looking upstream


Pond 4: HC-P4(04) looking downstream


Pond 4: HC-P4(04) looking across


Pond 4: Main cell


Pond 4: Main cell


Pond 4: Pond Outlet (HC-P4(05)) flowing

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Field/Sampling Report

Client City of Guelph

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Project Hanlon Creek Monitoring 2016, High flow measurements

Date March 10, 2016

Project Number 60265453

Weather: Overcast/partial cloudiness, low of 2.3 °C with a high of 13.0 °C. Spring melt/precipitation event triggering high flows on March 10th, with intermittent rain totaling 5.5 mm (Measurements taken from onsite rain gauge).

Tasks:

- Water Samples
- YSI measurements
- Photos

Field Crew: Steve Scott and Andrew Minielly

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(04)	03/10/2016 11:45	6.17	1057	13.23	7.47	-25.6
HC-A(13)	03/10/2016 12:38	5.47	905	13.00	7.82	-44.3
HC-A(14)	03/10/2016 12:53	5.47	902	12.27	7.84	-45.5

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	03/10/2016 13:08	8.89	3795	10.76	7.82	-44.8
HC-P1(05)	03/10/2016 13:30	7.23	1474	10.91	7.62	-33.6
HC-P1(06)	03/10/2016 13:20	5.89	2005	23.27	7.56	-30.4
HC-P2(04)	03/10/2016 12:27	8.40	2343	12.98	8.19	-64.6
HC-P2(05)	03/10/2016 12:07	7.68	3526	9.43	7.21	-12.0
HC-P2(06)	03/10/2016 12:17	6.57	603	11.17	7.63	-34.4
HC-P2(07)	03/10/2016 12:48	8.16	1562	18.59	8.89	-101.8
HC-P4(04)	03/10/2016 11:22	8.54	824	12.41	7.37	-20.5
HC-P4(05)	03/10/2016 11:31	6.72	1535	20.37	7.29	-16.2

Weather, General Conditions
Site: HC-A(04)
Time: 03/10/2016 11:45
Comments: Samples Collected


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 03/10/2016 12:38
Comments: Samples Collected


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 03/10/2016 12:53
Comments: Samples Collected

Looking upstream

Looking downstream

Looking across stream

Site: Pond 1

- HC-P1(04) was flowing. Samples and YSI were taken in channel.
- HC-P1(05) was flowing. Samples and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was flowing. Minimal surface ice in pond. Samples and YSI were taken at outlet.

Site: Pond 2

- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.
- HC-P2(06) experiencing minimal flow, pooling occurring in the drainage swale. Samples were taken in the inlet channel.
- HC-P2(05) had visible flow (normally backwatered/stagnant). Algae present at inlet pool. Sample and YSI were taken at inlet.
- HC-P2(04) had visible flow (normally backwatered/stagnant). Sample and YSI were taken at inlet.

Site: Pond 4

- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) had higher flow than normal. Sample and YSI were taken at outlet.


Pond 1: Drainage Swale (HC-P1(04))


Pond 1: HC-P1(04) flowing


Pond 1: Looking toward HC-P1(04)


Pond 1: Forebay looking toward HC-P1(05)

Pond 1: HC-P1(05) inlet

Pond 1: HC-P1(05) drainage swale

Pond 1: Pond Outlet (HC-P1(06)) flowing

Pond 1: Pond Outlet (HC-P1(06)) flowing

Pond 1: Main cell

Pond 1: Pond Outlet (HC-P1(06)) and main cell

Pond 2: (HC-P2(04)) flowing

Pond 2: HC-P2(04) looking toward forebay

Pond 2: HC-P2(04) looking toward forebay

Pond 2: HC-P2(05) flowing

Pond 2: HC-P2(05) flowing

Pond 2: Forebay


Pond 2: HC-P2(06) looking towards forebay


Pond 2: HC-P2(06) drainage swale looking across stream


Pond 2: HC-P2(06) drainage swale looking upstream


Pond 2: Main cell looking towards HC-P2(07)


Pond 4: HC-P2(07) main cell looking towards forebay


Pond 4: HC-P2(07) outlet not flowing


Pond 4: HC-P2(07) outlet not flowing


Pond 4: Inlet (HC-P4(04)) looking upstream


Pond 4: Inlet (HC-P4(04)) looking across stream


Pond 4: Inlet (HC-P4(04)) looking downstream towards main cell


Pond 4: Main cell


Pond 4: Outlet (HC-P4(05)) flowing

Pond 4: Outlet (HC-P4(05)) flowing

Pond 4: HC-P4(06) cooling trench outlet flowing

Pond 4: HC-P4(06) looking downstream of cooling trench outlet towards trib A

Pond 4: Cooling trench looking towards Pond 4

Pond 4: Cooling trench looking downstream towards Trib A

Pond 4: Cooling trench looking towards pond 4

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Field/Sampling Report

Client City of Guelph
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Project Hanlon Creek Monitoring 2016, Wet day Grab Samples
Date May 26, 2016
Project Number 60265453

Weather: Overcast, low of 12.5°C, high of 26.4°C. Precipitation event triggering high flows in the morning with total rainfall of 35.6 mm (recorded using the projects rain gauge).

Tasks:

- Water Samples
- YSI measurements
- Photos

Field Crew: Steven Scott and Andrew Minielly

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(04)	05/26/2016 13:20	16.09	747	12.22	7.63	-47.1
HC-A(13)	05/26/2016 14:09	16.91	761	8.26	7.78	-55.1
HC-A(14)	05/26/2016 14:27	17.14	762	8.41	7.80	-56.5

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	05/26/2016 14:58	20.98	215	13.92	8.75	-109.5
HC-P1(05)	05/26/2016 14:48	20.28	152	6.53	8.25	-81.5
HC-P1(06)	05/26/2016 14:39	21.72	1280	4.75	8.11	-74.2
HC-P2(04)	05/26/2016 13:59	19.45	76	8.25	8.51	-95.7
HC-P2(05)	05/26/2016 13:41	17.58	313	10.09	8.16	-75.9
HC-P2(06)	05/26/2016 13:47	21.81	1054	12.95	10.24	-191.2
HC-P2(07)	05/26/2016 14:15	21.19	857	8.70	9.54	-152.7
HC-P4(04)	05/26/2016 12:58	19.67	78	9.55	7.83	-58.4
HC-P4(05)	05/26/2016 13:09	19.86	1063	25.46	8.02	-69.1

Weather, General Conditions
Site: HC-A(04)
Time: 05/26/2016 13:34
Comments: None


Looking Upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 10/28/2015 14:25
Comments: Watercress growth observed around logger site.


Looking Upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 05/26/2016 14:34
Comments: Abundant watercress growth observed near cross section (flow) site

Looking Upstream

Looking downstream

Looking across stream

Site: Pond 1
- HC-P1(04) was flowing at inlet. Sample and YSI were taken at the inlet.
- HC-P1(05) was flowing. Sample and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was flowing. Samples and YSI were taken in outlet.

Site: Pond 2
- HC-P2(04) is backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) is backwatered. Sample and YSI were taken at inlet.
- HC-P2(06) was flowing. Sample and YSI were taken in channel.
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4
- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing. Sample and YSI were taken at outlet.


Pond 1: Drainage Swale (HC-P1(04))


Pond 1: HC-P1(04) flowing


Pond 1: Forebay looking toward HC-P1(04)


Pond 1: Main cell


Pond 1: Outlet flowing (HC-P1(06))


Pond 1: Outlet flowing (HC-P1(06))


Pond 1: Upstream drainage swale from HC-P1(05)


Pond 1: HC-P1(05) Pond inlet


Pond 2: Main cell


Pond 2: HC-P1(07) outlet not flowing


Pond 2: HC-P1(07) outlet not flowing


Pond 2: HC-P2(04) inlet, backwater conditions

Pond 2: HC-P2(04) forebay

Pond 4: Pond inlet HC-P2(05), backwater conditions

Pond 2: Pond inlet (HC-P2(06)) drainage swale, upstream

Pond 2: Pond inlet (HC-P2(06)) drainage swale, xstream

Pond 2: Pond inlet (HC-P2(06)) drainage swale, downstream

Pond 4 – HC-P4(04) Inlet - upstream

Pond 4 – HC-P4(04) Inlet – downstream

Pond 4 – HC-P4(04) Inlet – xstream

Pond 4: Pond Outlet (HC-P4(05)) flowing

Pond 4: Pond Outlet (HC-P4(05)) flowing

Pond 4: Cooling trench (HC-P4(06)) flowing

Pond 4: Cooling trench (HC-P4(06)) flowing

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Field/Sampling Report

Client City of Guelph

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Project Hanlon Creek Monitoring 2016, Base flow measurements

Date May 31, 2016

Project Number 60265453

Weather: Clear with a high of 24.5 °C (recorded in Guelph).

Tasks:

- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Sachet Siwakoti

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	5/31/2016 10:16	10.78	704	10.90	7.31	-26.2
HC-A(04)	5/31/2016 10:57	17.93	930	7.10	7.46	-34.5
HC-A(06)	5/31/2016 11:31	18.46	933	8.33	7.78	-51.7
HC-A(10)	5/31/2016 12:40	18.79	1086	9.51	8.03	-65.4
HC-A(11)	5/31/2016 13:12	19.44	921	9.26	8.16	-72.6
HC-A(12)	5/31/2016 14:00	18.05	1009	10.27	7.75	-50.1
HC-A(13)	5/31/2016 14:34	21.36	1080	9.29	8.20	-75.3
HC-A(14)	5/31/2016 14:52	21.71	1076	10.11	8.28	-80.0

Weather, General Conditions

Site: HC-A(03) Flow Tracker Filename: HC-A(03) 20160531.WAD

Time: 2016/05/31 09:47:43 Measured Flow: Q= 0.0023 m^3/s

Comments: Downed tree laying above the stream behind cross section site. Tree is not currently disturbing the creek flow.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.50	0.08
0.10	0.06	0.55	0.07
0.20	0.06	0.60	0.07
0.30	0.08	0.65	0.06
0.35	0.08	0.70	0.06
0.40	0.10	0.80	0
0.45	0.08		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04)
Time: 2016/05/31 10:39:35
Comments: None

Flow Tracker Filename: HC-A(04) 20160531.WAD
Measured Flow: Q= 0.0133 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.21
0.25	0.10	0.85	0.21
0.35	0.07	0.90	0.21
0.45	0.08	0.95	0.21
0.55	0.11	1.00	0.19
0.65	0.15	1.10	0
0.75	0.21		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/05/31 11:32:02
Comments: None

Flow Tracker Filename: HC-A(06) 20160531.WAD
Measured Flow: Q= 0.0157 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.09
0.20	0.05	0.90	0.12
0.40	0.08	1.00	0.10
0.50	0.10	1.10	0.10
0.60	0.10	1.20	0.11
0.70	0.09	1.30	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)
Time: 2016/05/31 12:31:33
Comments: None

Flow Tracker Filename: HC-A(10) 20160531.WAD
Measured Flow: Q= 0.0164 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.00	0.09
0.20	0.05	1.10	0.10
0.40	0.07	1.20	0.10
0.50	0.08	1.30	0.10
0.60	0.08	1.40	0.10
0.70	0.08	1.50	0.10
0.80	0.09	1.60	0
0.90	0.09		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/05/31 13:12:17
Comments: None

Flow Tracker Filename: HC-A(11) 20160531.WAD
Measured Flow: Q= 0.0246 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	3.20	0.09
0.80	0.06	3.40	0.10
1.60	0.14	3.60	0.90
2.00	0.15	3.80	0.10
2.40	0.12	4.00	0.12
2.60	0.11	4.20	0.10
2.80	0.09	4.90	0
3.00	0.10		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/05/31 13:49:57
Comments: Photos N/A

Flow Tracker Filename: HC-A(12) 20160531.WAD
Measured Flow: Q= 0.0358 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.55	0.28
0.20	0.26	0.65	0.22
0.30	0.27	0.75	0.22
0.35	0.28	0.85	0.22
0.40	0.28	0.95	0.21
0.45	0.28	1.20	0
0.50	0.28		

Weather, General Conditions
Site: HC-A(13)
Time: 2016/05/31 14:35:31
Comments: None

Flow Tracker Filename: HC-A(13) 20160531.WAD
Measured Flow: Q= 0.0147 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.21
0.20	0.18	0.65	0.21
0.30	0.18	0.70	0.21
0.40	0.20	0.75	0.20
0.45	0.20	0.80	0.18
0.50	0.20	1.00	0
0.55	0.21		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/05/31 14:59:47
Comments: None

Flow Tracker Filename: HC-A(14) 20160531.WAD
Measured Flow: Q= 0.0161 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.55	0.32
0.20	0.14	0.60	0.23
0.30	0.20	0.65	0.24
0.35	0.21	0.70	0.24
0.40	0.21	0.80	0.24
0.45	0.23	0.90	0.23
0.50	0.23	1.10	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1	• Pond outlet (HC-P1(06)) was not flowing.
Site: Pond 2	• Pond outlet (HC-P2(07)) was not flowing.
Site: Pond 4	• HC-P4(05) was flowing. • HC-P4(06) was flowing.

Pond 1: HC-P1(06) Main cell

Pond 4: Main cell from HC-P4(05)

Pond 4: HC-P4(06) Cooling trench outlet

Pond 4: HC-P4(06) Cooling trench outlet

Client	City of Guelph	Page	1
Project	Hanlon Creek Monitoring 2016, Baseflow measurements		
Date	June 24, 2016	Project Number	60265453

Weather: Clear with a high of 30.3 °C (recorded in Guelph).

Tasks:

- Downloaded stream loggers only
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Angus Keir

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	6/24/2016 9:54	10.21	388	10.55	7.87	-57.0
HC-A(04)	6/24/2016 10:29	17.83	832	6.78	7.82	-55.7
HC-A(06)	6/24/2016 11:26	18.43	831	8.34	7.97	-64.0
HC-A(10)	6/24/2016 12:57	18.16	990	8.64	8.07	-69.0
HC-A(11)	6/24/2016 13:31	18.94	989	7.57	8.14	-73.0
HC-A(12)	6/24/2016 13:56	19.18	986	8.45	8.16	-74.1
HC-A(13)	6/24/2016 14:44	20.51	961	8.24	7.79	-54.5
HC-A(14)	6/24/2016 15:18	22.52	993	6.86	8.05	-68.9

Weather, General Conditions
Site: HC-A(03)
Time: 2016/06/24 09:49:44
Comments: Photos N/A

Flow Tracker Filename: HC-A(03) 2016-06-24.WAD
Measured Flow: Q= 0.0031 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.50	0.08
0.20	0.06	0.55	0.08
0.25	0.06	0.60	0.07
0.30	0.08	0.65	0.06
0.35	0.08	0.70	0.50
0.40	0.08	0.80	0
0.45	0.08		

Weather, General Conditions
Site: HC-A(04)
Time: 2016/06/24 10:20:39
Comments: Photos N/A

Flow Tracker Filename: HC-A(04) 2016-06-24.WAD
Measured Flow: Q= 0.0101 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.18
0.20	0.03	0.75	0.18
0.30	0.04	0.80	0.18
0.40	0.07	0.85	0.17
0.50	0.10	0.90	0.17
0.55	0.15	0.95	0.14
0.60	0.16	1.00	0
0.65	0.17		

Weather, General Conditions
Site: HC-A(04A)
Time: 2015/06/24 11:00
Comments: None


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04A)
Time: 2015/06/04 11:15
Comments: None


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/06/24 11:28:28
Comments: None

Flow Tracker Filename: HC-A(06) 2016-06-24.WAD
Measured Flow: Q= 0.0085 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.06
0.20	0.05	0.80	0.06
0.30	0.05	0.90	0.04
0.40	0.06	1.00	0.06
0.50	0.05	1.10	0.05
0.60	0.04	1.20	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)
Time: 2016/06/24 12:56:56
Comments: None

Flow Tracker Filename: HC-A(10) 2016-06-24.WAD
Measured Flow: Q= 0.0070 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.07
0.20	0.05	1.00	0.08
0.30	0.06	1.10	0.08
0.40	0.04	1.20	0.08
0.50	0.06	1.30	0.09
0.60	0.06	1.40	0.10
0.70	0.06	1.60	0
0.80	0.07		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/06/24 13:27:56
Comments: Photos N/A

Flow Tracker Filename: HC-A(11) 2016-06-24.WAD
Measured Flow: Q= 0.0082 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.50	0.11
1.00	0.12	2.70	0.09
1.50	0.13	2.90	0.09
1.70	0.13	3.10	0.08
1.90	0.12	3.30	0.12
2.10	0.12	4.30	0
2.30	0.12		

Weather, General Conditions
Site: HC-A(12)
Time: 2016/06/24 14:02:49
Comments: None

Flow Tracker Filename: HC-A(12) 2016-06-24.WAD
Measured Flow: Q= 0.0068 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.14
0.20	0.18	0.65	0.12
0.30	0.18	0.70	0.13
0.40	0.18	0.75	0.13
0.45	0.15	0.80	0.12
0.50	0.14	0.85	0.11
0.55	0.13	1.05	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13) Flow Tracker Filename: HC-A(13) 2016-06-24.WAD
Time: 2016/06/24 14:42:41 Measured Flow: Q= 0.0046 m^3/s
Comments: Photos N/A. Watercress beginning to build up directly upstream from the flow monitoring cross section.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.50	0.18
0.20	0.17	0.55	0.18
0.30	0.17	0.60	0.18
0.35	0.17	0.65	0.18
0.40	0.17	0.70	0.18
0.45	0.18	0.90	0

Weather, General Conditions
Site: HC-A(14) Flow Tracker Filename: HC-A(14) 2016-06-24.WAD
Time: 2016/06/24 15:14:57 Measured Flow: Q= 0.0059 m^3/s
Comments: Flow is being deflected by the additional vegetation in the channel.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.55	0.22
0.20	0.20	0.60	0.22
0.30	0.21	0.65	0.22
0.40	0.21	0.70	0.21
0.45	0.22	0.75	0.20
0.50	0.22	0.95	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1	• HC-P1(04) was not flowing. • HC-P1(05) was not flowing. • Pond outlet (HC-P1(06)) was not flowing.
Site: Pond 2	• Pond outlet (HC-P2(07)) was not flowing.
Site: Pond 4	• HC-P4(05) was flowing.

Pond 1: Low water levels in main cell

Pond 1: Low water levels in main cell

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Field/Sampling Report

Client	City of Guelph	Page	1
Project	Hanlon Creek Monitoring 2016, Wet day Grab Samples		
Date	July 14, 2016	Project Number	60265453

Weather: Overcast, low of 17.5°C, high of 28.7°C. Precipitation event triggering high flows in the morning with total rainfall of 22.2 mm (recorded using the projects rain gauge).

Tasks:

- Water Samples
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Angus Keir

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(04)	07/14/2016 11:50	23.59	895	5.07	7.90	-59.3
HC-A(13)	07/14/2016 9:59	19.85	972	5.16	7.61	-43.1
HC-A(14)	07/14/2016 9:35	19.87	956	6.22	7.75	-41.0

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	07/14/2016 8:46	21.92	279	3.45	8.06	-67.5
HC-P1(05)	07/14/2016 9:20	21.67	215	3.70	7.79	-53.2
HC-P1(06)	07/14/2016 9:03	24.36	1096	1.38	9.20	-130.2
HC-P2(04)	07/14/2016 10:24	22.70	72	6.17	7.74	-50.2
HC-P2(05)	07/14/2016 10:41	21.83	115	4.34	7.76	-51.1
HC-P2(06)	07/14/2016 10:58	24.75	981	2.02	7.67	-46.9
HC-P2(07)	07/14/2016 9:50	22.84	226	4.34	7.78	-52.3
HC-P4(04)	07/14/2016 11:13	20.81	242	3.62	7.41	-32.5
HC-P4(05)	07/14/2016 11:34	26.56	944	8.96	8.68	-102.3

Weather, General Conditions
Site: HC-A(04)
Time: 07/14/2016 11:50
Comments: None

Looking Upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 07/14/2016 9:59
Comments: Lots of vegetation growth on both stream banks


Looking Upstream

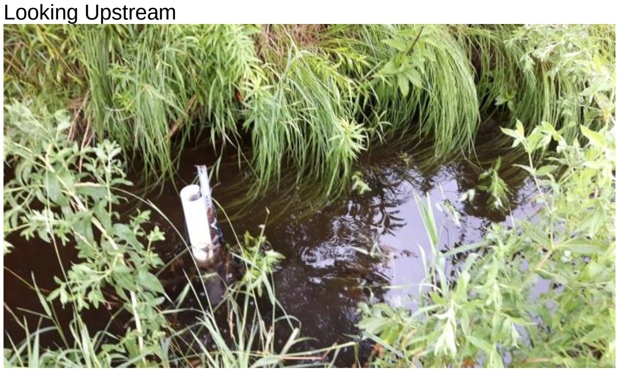

Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 07/14/2016 9:35
Comments: Lots of vegetation growth on both stream banks


Looking Upstream


Looking downstream


Looking across stream

Site: Pond 1
- HC-P1(04) was flowing at inlet. Sample and YSI were taken at the inlet.
- HC-P1(05) was flowing. Sample and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was not flowing. Samples and YSI were taken in pond.

Site: Pond 2
- HC-P2(04) is backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) was flowing. Sample and YSI were taken at inlet.
- HC-P2(06) was not flowing. Sample and YSI were taken in forebay
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4
- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing. Sample and YSI were taken at outlet.


Pond 1: Drainage Swale (HC-P1(04))


Pond 1: HC-P1(04) flowing


Pond 1: Forebay looking toward HC-P1(05)


Pond 1: Forebay looking toward HC-P1(04)


Pond 1: Drainage swale upstream of HC-P1(05)


Pond 1: Inlet flowing (HC-P1(05))

Pond 1: Water level still low in main cell

Pond 1: Main cell, bottom draw structure exposed

Pond 2: Main cell

Pond 2: Main cell

Pond 2: HC-P2(07) outlet not flowing

Pond 2: HC-P2(07) outlet not flowing

Pond 2: Main cell

Pond 4: Main cell looking towards HC-P2(05 and 06)

Pond 2: Temperature pedants still exposed

Pond 2: Inlet HC-P2(04), backwater conditions

Pond 2: Pond inlet (HC-P2(04)) forebay

Pond 2: HC-P2(05) inlet flowing

Pond 2: HC-P2(05) forebay

Pond 2: HC-P2(06) drainage swale, upstream

Pond 2: HC-P2(06) drainage swale, downstream

Pond 2: HC-P2(06) drainage swale, cross stream. Some pools in drainage swale but no consistent flow

Pond 4: Inlet HC-P4(04), upstream. Abundant vegetation in channel

Pond 4: Inlet HC-P4(04), cross stream

Pond 4: Inlet HC-P4(04), downstream

Pond 4: Main cell from HC-P4(05)

Pond 4: Outlet HC-P4(05), flowing

Pond 4: Outlet HC-P4(05), flowing

Pond 4: Cooling trench HC-P4(06), flowing

Pond 4: Cooling trench HC-P4(06), flowing

Client	City of Guelph	Page	1
Project	Hanlon Creek Monitoring 2016, Baseflow measurements		
Date	July 27, 2016	Project Number	60265453

Weather: Clear and humid with a high of 30.8 °C (recorded in Guelph).

Tasks:

- Downloaded Temperature Loggers Only
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Braden Fleming

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	7/27/2016 9:57	14.13	649	9.30	7.97	-61.5
HC-A(04)	7/27/2016 10:33	22.29	874	5.02	7.77	-51.7
HC-A(06)	7/27/2016 11:14	22.39	867	6.50	7.92	-60.1
HC-A(10)	7/27/2016 12:49	21.27	1082	7.26	8.00	-64.4
HC-A(11)	7/27/2016 13:24	19.67	1062	1.02	7.54	-39.3
HC-A(12)	7/27/2016 14:11	22.33	1043	7.04	8.08	-68.7
HC-A(13)	7/27/2016 14:46	24.06	1068	6.17	8.05	-67.3
HC-A(14)	7/27/2016 15:18	24.22	1059	5.94	7.99	-64.3

Weather, General Conditions
Site: HC-A(03)
Time: 2016/07/27 09:45:20
Comments: None

Flow Tracker Filename: HC-A(03) 2016-07-27.WAD
Measured Flow: Q= 0.0028 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.50	0.06
0.20	0.04	0.55	0.04
0.30	0.05	0.60	0.04
0.35	0.06	0.65	0.03
0.40	0.06	0.70	0.03
0.45	0.07	0.90	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04)
Time: 2016/07/27 10:21:50
Comments: None

Flow Tracker Filename: HC-A(04) 2016-07-27.WAD
Measured Flow: Q= 0.0071 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.15
0.20	0.03	0.65	0.16
0.30	0.06	0.70	0.16
0.40	0.06	0.75	0.13
0.45	0.07	0.80	0.12
0.50	0.09	1.05	0
0.55	0.13		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/07/27 11:10:41
Comments: None

Flow Tracker Filename: HC-A(06) 2016-07-27.WAD
Measured Flow: Q= 0.0114 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.65	0.04
0.30	0.04	0.75	0.06
0.40	0.04	0.85	0.05
0.45	0.04	0.95	0.06
0.50	0.04	1.05	0.06
0.55	0.04	1.15	0
0.60	0.04		

Weather, General Conditions
Site: HC-A(10)
Time: 2016/07/27 12:42:25
Comments: None

Flow Tracker Filename: HC-A(10) 2016-07-27.WAD
Measured Flow: Q= 0.0063 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.10
0.20	0.08	1.00	0.10
0.30	0.08	1.10	0.09
0.40	0.08	1.20	0.10
0.50	0.08	1.30	0.10
0.60	0.08	1.40	0.15
0.70	0.09	1.55	0
0.80	0.09		

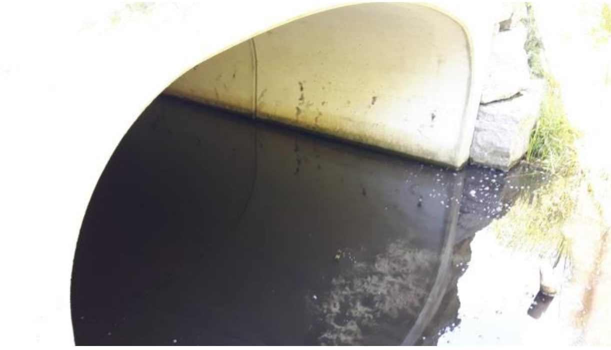

Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/07/27
Comments: Flow Tracker file became corrupted and the data is unobtainable.

Flow Tracker Filename: HC-A(11) 2016-08-09.WAD
Measured Flow: Q= N/A


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/07/27 14:04:01
Comments: None

Flow Tracker Filename: HC-A(12) 2016-07-27.WAD
Measured Flow: Q= 0.0126 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.65	0.20
0.20	0.18	0.70	0.20
0.30	0.15	0.75	0.20
0.40	0.17	0.80	0.20
0.50	0.16	0.85	0.21
0.55	0.20	1.00	0
0.60	0.20		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/07/27 14:44:36
Comments: None

Flow Tracker Filename: HC-A(13) 2016-07-27.WAD
Measured Flow: Q= 0.0053 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.40	0.19
0.10	0.19	0.45	0.19
0.20	0.18	0.50	0.19
0.25	0.18	0.55	0.19
0.30	0.18	0.60	0.18
0.35	0.19	1.05	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 2016/07/27 15:12:26
Comments: None

Flow Tracker Filename: HC-A(14) 2016-07-27.WAD
Measured Flow: Q= 0.0047 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.65	0.21
0.10	0.16	0.70	0.22
0.20	0.16	0.75	0.22
0.30	0.17	0.80	0.22
0.40	0.18	0.85	0.22
0.50	0.20	1.10	0
0.60	0.21		


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1
- HC-P1(04) was not flowing.
- HC-P1(05) was not flowing.
- Pond outlet (HC-P1(06)) was not flowing.

Site: Pond 2
- Pond outlet (HC-P2(07)) was not flowing.

Site: Pond 4
- HC-P4(05) was flowing.

Pond 4: Main cell from HC-P4(05)

Pond 1: Cooling trench looking towards HC-P4(05)

Pond 1: Cooling trench HC-P4(06), no flow

Pond 1: Cooling trench HC-P4(06), looking towards the creek, no flow

Client	City of Guelph	Page	1
Project	Hanlon Creek Monitoring 2016, Baseflow measurements		
Date	August 09, 2016	Project Number	60265453

Weather: Clear and humid with a high of 30.5 °C (recorded in Guelph).

Tasks:

- Downloaded Temperature Loggers Only
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Sachet Siwakoti

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	8/9/2016 10:21	14.23	676	9.88	7.85	-59.6
HC-A(04)	8/9/2016 10:42	20.83	892	5.30	7.69	-52.0
HC-A(06)	8/9/2016 11:15	20.58	889	7.80	7.85	-60.3
HC-A(10)	8/9/2016 11:28	16.24	1234	9.59	8.00	-67.9
HC-A(11)	8/9/2016 12:06	16.96	1207	9.07	8.07	-71.6
HC-A(12)	8/9/2016 12:54	19.15	1233	8.62	8.13	-75.5
HC-A(13)	8/9/2016 13:33	22.18	1168	7.02	7.62	-48.1
HC-A(14)	8/9/2016 13:53	22.02	1224	6.36	7.70	-52.2

Weather, General Conditions
Site: HC-A(03)
Time: 2016/08/09 10:26:09
Comments: None

Flow Tracker Filename: HC-A(03) 2016-08-09.WAD
Measured Flow: Q= 0.0012 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.35	0.06
0.10	0.04	0.40	0.05
0.15	0.06	0.45	0.04
0.20	0.06	0.50	0.02
0.25	0.06	0.75	0
0.30	0.07		


Looking upstream


Looking downstream


Looking across stream


Turbidity sensor out of water

Weather, General Conditions
Site: HC-A(04)
Time: 2016/08/09 10:53:36
Comments: None

Flow Tracker Filename: HC-A(04) 2016-08-09.WAD
Measured Flow: Q= 0.0048 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.50	0.09
0.10	0.05	0.55	0.11
0.20	0.06	0.60	0.10
0.30	0.06	0.65	0.08
0.35	0.06	0.70	0.08
0.40	0.06	0.75	0.08
0.45	0.90	1.00	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06) Flow Tracker Filename: HC-A(06) 2016-08-09.WAD
Time: 2016/08/09 Measured Flow: Q= N/A
Comments: Flow Tracker file became corrupted and the data is unobtainable.

Looking upstream

Looking downstream

Looking across stream

Flows too low to take proper measurments

Weather, General Conditions
Site: HC-A(10)
Time: 2016/08/09 11:44:37
Comments: None.

Flow Tracker Filename: HC-A(10) 2016-08-09.WAD
Measured Flow: Q= 0.0037 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.11
0.20	0.08	1.00	0.12
0.40	0.10	1.10	0.11
0.50	0.10	1.20	0.12
0.60	0.10	1.30	0.13
0.70	0.10	1.50	0
0.80	0.10		


Looking upstream

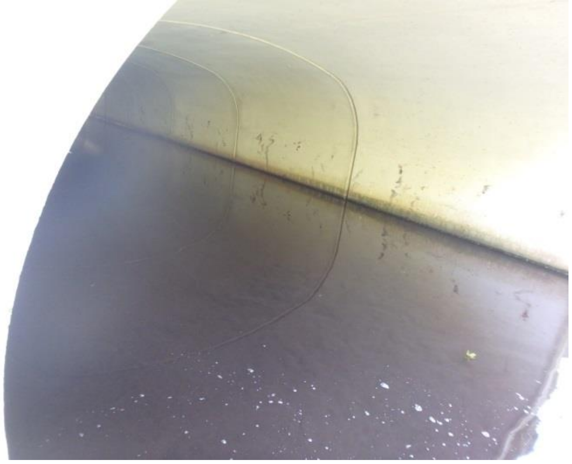

Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2015/06/04 14:15:17
Comments: None

Flow Tracker Filename: HC-A(11) 2015-06-04.WAD
Measured Flow: Q= 0.0189 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.90	0.15
1.50	0.21	3.10	0.15
1.70	0.21	3.30	0.14
1.90	0.20	3.50	0.16
2.10	0.18	3.70	0.20
2.30	0.16	3.90	0.14
2.50	0.17	4.90	0
2.70	0.16		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/08/09 13:07:57
Comments: None

Flow Tracker Filename: HC-A(12) 2016-08-09.WAD
Measured Flow: Q= 0.0028 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.10
0.20	0.07	0.65	0.11
0.30	0.04	0.70	0.13
0.40	0.06	0.75	0.13
0.50	0.06	0.80	0.19
0.55	0.09	1.00	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/08/09 13:44:25
Comments: None

Flow Tracker Filename: HC-A(13) 2016-08-09.WAD
Measured Flow: Q= 0.0016 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.45	0.14
0.20	0.14	0.50	0.14
0.25	0.14	0.55	0.14
0.30	0.14	0.60	0.14
0.35	0.14	0.85	0
0.40	0.14		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 2016/08/09 14:06:15
Comments: None

Flow Tracker Filename: HC-A(14) 2016-08-09.WAD
Measured Flow: Q= 0.0013 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.55	0.17
0.20	0.11	0.60	0.17
0.30	0.14	0.65	0.18
0.40	0.16	0.70	0.18
0.45	0.16	0.75	0.18
0.50	0.17	0.90	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1	• Pond outlet (HC-P1(06)) was not flowing.
Site: Pond 2	• Pond outlet (HC-P2(07)) was not flowing.
Site: Pond 4	• HC-P4(05) was flowing.


Pond 1: Main cell, low water level


Pond 1: Main cell, low water level looking from outlet structure. Vegetation starting to grow on exposed pond bottom.


Pond 1: Main cell, exposed outlet structure


Pond 1: Main cell, low water level looking from outlet structure. Vegetation starting to grow on exposed pond bottom.


Pond 2: Main cell, low water level


Pond 2: Main cell, low water level


Pond 4: Main cell from HC-P4(05)


Pond 4: Outlet


Pond 4: Cooling trench HC-P4(06), no flow


Pond 4: Cooling trench HC-P4(06), looking towards the creek, no flow

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Field/Sampling Report

Client City of Guelph

Page 1

Project Hanlon Creek Monitoring 2015, High flow measurements and samples

Date August 16, 2016

Project Number 60265453

Weather: Overcast/partial cloudiness, low of 14.9°C. Precipitation event triggering high flows with total precipitation of 14.2 mm (recorded in Guelph).

Tasks:

- Water Samples
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Casey O'Driscoll

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	8/16/2016 8:43	16.4	381.4	7.96	-	-
HC-A(04)	8/16/2016 8:43	22.3	686	4.16	-	-
HC-A(06)	8/16/2016 8:43	21.9	776	6.00	-	-
HC-A(10)	8/16/2016 8:43	19.2	909	6.86	-	-
HC-A(11)	8/16/2016 8:43	19.2	840	5.41	-	-
HC-A(12)	8/16/2016 8:43	19.7	913	6.67	-	-
HC-A(13)	8/16/2016 8:43	20.4	1014	6.37	-	-
HC-A(14)	8/16/2016 8:43	20.4	1014	6.12	-	-

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	8/16/2016 8:43	21.9	236.8	5.86	-	-
HC-P1(05)	8/16/2016 8:43	21.4	295.4	5.44	-	-
HC-P1(06)	8/16/2016 8:43	23.8	1009	5.67	-	-
HC-P2(04)	8/16/2016 8:43	23.7	82	7.86	-	-
HC-P2(05)	8/16/2016 8:43	22.3	90.9	7.20	-	-
HC-P2(06)	8/16/2016 8:43	25.5	569	15.27	-	-
HC-P2(07)	8/16/2016 8:43	24.1	175.4	9.44	-	-
HC-P4(04)	8/16/2016 8:43	21.1	83	6.59	-	-
HC-P4(05)	8/16/2016 8:43	25.7	891	6.86	-	-

Weather, General Conditions
Site: HC-A(03)
Time: 2016-08-16 08:37:18
Comments: Photos N/A

Flow Tracker Filename: HC-A(03) 2016-08-16.WAD
Measured Flow: Q= 0.0015 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.45	0.05
0.10	0.04	0.50	0.04
0.20	0.05	0.55	0.04
0.25	0.06	0.60	0.03
0.30	0.08	0.70	0.03
0.35	0.08	0.80	0
0.40	0.06		

Weather, General Conditions
Site: HC-A(04)
Time: 2016/08/16 09:08:40
Comments: None

Flow Tracker Filename: HC-A(04) 2016-08-16.WAD
Measured Flow: Q= 0.0082 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.14
0.20	0.04	0.90	0.12
0.30	0.06	1.00	0.12
0.40	0.08	1.10	0.10
0.50	0.09	1.20	0.09
0.60	0.10	1.30	0
0.70	0.15		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/08/16 10:02:20
Comments: None

Flow Tracker Filename: HC-A(06) 2016-08-16.WAD
Measured Flow: Q= 0.0187 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.06
0.20	0.05	0.80	0.07
0.30	0.05	0.90	0.06
0.40	0.05	1.00	0.06
0.50	0.05	1.10	0.06
0.60	0.06	1.25	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)
Time: 2016/08/16 10:45:15
Comments: Watercress present

Flow Tracker Filename: HC-A(10) 2016-08-16.WAD
Measured Flow: Q= 0.0195 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.18
0.20	0.13	1.00	0.18
0.30	0.16	1.10	0.16
0.40	0.16	1.20	0.19
0.50	0.18	1.30	0.19
0.60	0.17	1.40	0.20
0.70	0.17	1.50	0.22
0.80	0.18	1.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Flow Tracker Filename: HC-A(11) 2016-08-16.WAD
Time: 2016/08/16 11:16:23
Measured Flow: Q= 0.0203 m^3/s
Comments: Watercress growth occurring around cross section

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	3.20	0.22
1.50	0.27	3.40	0.23
2.00	0.29	3.60	0.24
2.20	0.27	3.80	0.24
2.40	0.25	4.00	0.27
2.60	0.25	4.20	0.23
2.80	0.26	4.40	0.19
3.00	0.22	5.40	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/08/16 12:18:52
Comments: None

Flow Tracker Filename: HC-A(12) 2016-08-16.WAD
Measured Flow: Q= 0.0158 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.85	0.28
0.30	0.18	0.90	0.26
0.50	0.16	0.95	0.26
0.60	0.22	1.00	0.29
0.70	0.22	1.05	0.29
0.75	0.22	1.15	0
0.80	0.26		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Flow Tracker Filename: HC-A(13) 2016-08-16.WAD
Time: 2016/08/16 13:28:11
Measured Flow: Q= 0.0123 m^3/s
Comments: Samples and YSI measurements collected in the channel.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.24
0.20	0.23	0.65	0.22
0.30	0.23	0.70	0.24
0.40	0.24	0.75	0.23
0.45	0.24	0.80	0.22
0.50	0.24	0.90	0.22
0.55	0.24	1.30	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Flow Tracker Filename: HC-A(14) 2016-08-16.WAD
Time: 2016/08/16 13:58:46
Measured Flow: Q= 0.0110 m^3/s
Comments: Samples and YSI measurements collected in the channel.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.24
0.20	0.17	0.65	0.24
0.30	0.19	0.70	0.25
0.40	0.21	0.75	0.25
0.45	0.22	0.80	0.24
0.50	0.23	1.00	0.23
0.55	0.24	1.15	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1
- HC-P1(04) was flowing. Samples and YSI were taken in channel.
- HC-P1(05) was flowing. Samples and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 2
- HC-P2(04) was backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) was flowing. Sample and YSI were taken at inlet.
- HC-P2(06) was not flowing. Sample and YSI were taken in forebay.
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4
- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing. Sample and YSI were taken at outlet.

Pond 1: Drainage Swale (HC-P1(04))

Pond 1: HC-P1(04) flowing

Pond 1: HC-P1(05) flowing

Pond 1: Drainage Swale (HC-P1(05))


Pond 1: Pond Outlet (HC-P1(06)) and Deep Cell


Pond 2: Deep Cell


Pond 2: Deep Cell


Pond 2: Pond inlet HC-P2(04)


Pond 2: Pond inlet HC-P2(04) forebay


Pond 2: Pond inlet HC-P2(05)


Pond 2: Pond inlet HC-P2(06) forebay


Pond 2: Pond inlet HC-P2(06) upstream drainage swale


Pond 4: Main cell from outlet HC-P4(05)


Pond 4: HC-P4(05) outlet


Pond 4: HC-P4(05) outlet


Pond 4: Cooling trench HC-P4(06) looking towards creek

Pond 4: Inlet HC-P4(04) drainage swale upstream

Pond 4: Inlet HC-P4(04) drainage swale downstream

Pond 4: Inlet HC-P4(04) drainage swale across stream

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Field/Sampling Report

Client City of Guelph Page 1

Project Hanlon Creek Monitoring 2016, Wet day Grab Samples

Date September 27, 2016 Project Number 60265453

Weather: Overcast, low of 8°C, high of 20.6°C. Precipitation event triggering high flows in the morning with total rainfall of 7.2 mm overnight and morning (recorded using the projects rain gauge).

Tasks:

- Water Samples
- YSI measurements
- Photos

Field Crew: Steven Scott and Andrew Minielly

YSI Results: YSI was malfunctioning so no measurements were recorded.

Weather, General Conditions
Site: HC-A(04)
Time: 05/26/2016 13:34
Comments: None


Looking Upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 10/28/2015 14:25
Comments: Watercress growth observed around logger site.


Looking Upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 05/26/2016 14:34
Comments: Abundant watercress growth observed near cross section (flow) site


Looking Upstream


Looking downstream


Looking across stream

Site: Pond 1

- HC-P1(04) was not flowing at inlet. Sample and YSI were taken at upstream drainage channel.
- HC-P1(05) was flowing. Sample and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 2

- HC-P2(04) is backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) is flowing. Sample and YSI were taken at inlet.
- HC-P2(06) was not flowing. Samples and YSI were taken at pond.
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4

- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing. Sample and YSI were taken at outlet.


Pond 1: Drainage swale (HC-P1(04))


Pond 1: HC-P1(04) not flowing


Pond 1: HC-P1(05) flowing


Pond 1: Drainage swale (HC-P1(05))

Pond 1: HC-P1(07) outlet and main cell

Pond 2: HC-P1(07) outlet not flowing

Pond 2: HC-P1(07) outlet not flowing

Pond 2: HC-P2(04) inlet, backwater conditions

Pond 2: HC-P2(04) forebay

Pond 4: Pond inlet HC-P2(05), backwater conditions

Pond 2: HC-P2(05) pipe

Pond 2: Pond inlet HC-P2(06) drainage channel

Pond 2: HC-P2(06) inlet and forebay

Pond 2: Main cell looking towards HC-P2(07)

Pond 2: HC-P2(07) outlet

Pond 2: HC-P2(07) outlet not flowing


Pond 4: (HC-P4(04)) inlet


Pond 4: (HC-P4(04)) inlet


Pond 4: (HC-P4(04)) inlet


Pond 4: Main cell looking towards HC-P4(05)


Pond 4: Pond Outlet (HC-P4(05)) flowing


Pond 4: Pond Outlet (HC-P4(05)) flowing

Pond 4: Cooling trench (HC-P4(06)) flowing

Pond 4: Cooling trench (HC-P4(06)) flowing

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Field/Sampling Report

Client City of Guelph Page 1

Project Hanlon Creek Monitoring 2015, High flow measurements and samples

Date October 20, 2016 Project Number 60265453

Weather: Overcast/partial cloudiness, high of 13°C and low of 9.7°C. Precipitation event triggering high flows with total precipitation of 10.6 mm (recorded in Guelph).

Tasks:

- Water Samples
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Steven Scott and Andrew Minielly

YSI Results: Temperature and DO were the only parameters collected in the field as the YSI device is currently being repaired. All Conductivity and pH measurements were recorded by ALS from the collected water samples.

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	8/20/2016 8:58	12.1	-	7.55	-	-
HC-A(04)	8/20/2016 10:22	15.3	771	6.10	7.72	-
HC-A(06)	8/20/2016 11:26	14.7	-	8.31	-	-
HC-A(10)	8/20/2016 12:50	12.7	-	7.71	-	-
HC-A(11)	8/20/2016 13:27	12.8	-	7.98	-	-
HC-A(12)	8/20/2016 14:04	12.7	-	9.06	-	-
HC-A(13)	8/20/2016 14:32	12.7	1070	8.47	7.97	-
HC-A(14)	8/20/2016 15:18	12.7	1070	8.55	7.94	-

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-P1(04)	8/20/2016 9:36	14.1	1400	3.65	7.69	-
HC-P1(05)	8/20/2016 9:28	13.9	747	7.02	7.74	-
HC-P1(06)	8/20/2016 9:19	14.7	939	4.18	7.90	-
HC-P2(04)	8/20/2016 15:09	15.4	431	7.11	7.18	-
HC-P2(05)	8/20/2016 15:03	13.7	96.3	6.13	7.60	-
HC-P2(06)	8/20/2016 14:55	15.7	308	11.24	8.53	-
HC-P2(07)	8/20/2016 14:42	15.1	172	18.70	9.29	-
HC-P4(04)	8/20/2016 8:22	21.9	89.8	5.86	7.68	-
HC-P4(05)	8/20/2016 8:36	16.3	771	12.11	8.17	-

Weather, General Conditions
Site: HC-A(03)
Flow Tracker Filename: HC-A(03) 2016-10-20.WAD
Time: 2016/10/20 09:56:47
Measured Flow: Q= 0.0005 m^3/s
Comments: Minimal flow with significant leaf debris built up in channel

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.06
0.20	0.04	0.70	0.04
0.30	0.06	0.80	0.04
0.40	0.06	0.90	0
0.50	0.08		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions

Site: HC-A(04)

Time: 2016/10/20 10:18:38

Comments: None

Flow Tracker Filename: HC-A(04) 2016-10-20.WAD

Measured Flow: Q= 0.0053 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.14
0.20	0.04	0.90	0.12
0.30	0.06	1.00	0.12
0.40	0.08	1.10	0.10
0.50	0.09	1.20	0.09
0.60	0.10	1.30	0
0.70	0.15		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/10/20 10:58:05
Comments: None

Flow Tracker Filename: HC-A(06) 2016-10-20.WAD
Measured Flow: Q= 0.0041 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.06
0.20	0.04	0.90	0.08
0.30	0.06	1.00	0.08
0.40	0.07	1.10	0.08
0.50	0.07	1.20	0.07
0.60	0.07	1.30	0
0.70	0.07		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)　　Flow Tracker Filename: HC-A(10) 2016-10-20.WAD
Time: 2016/10/20 12:30:16　　Measured Flow: Q= 0.0097 m^3/s
Comments: Minor watercross present within cross-section

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.20	0.17
0.50	0.20	1.30	0.17
0.60	0.16	1.40	0.16
0.70	0.18	1.50	0.16
0.80	0.18	1.60	0.14
0.90	0.17	1.70	0.12
1.00	0.18	1.80	0
1.10	0.17		


Looking upstream

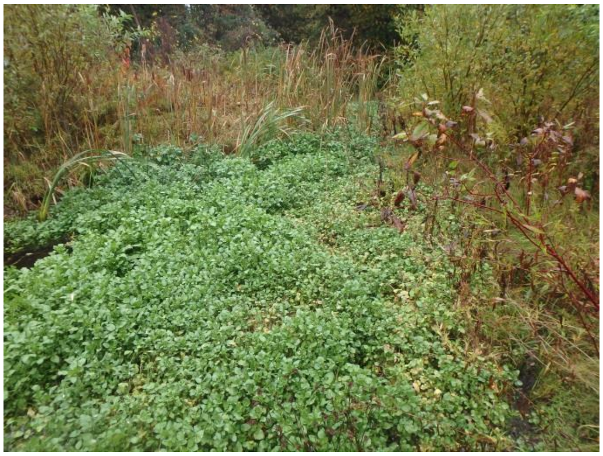

Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11) Flow Tracker Filename: HC-A(11) 2016-10-20.WAD
Time: 2016/10/20 13:01:44 Measured Flow: Q= 0.0062 m^3/s
Comments: Watercress is fully developed across cross-section. Measurements recorded at culvert mouth.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.10	0.16
0.30	0.12	2.40	0.18
0.60	0.16	2.70	0.18
0.90	0.14	3.00	0.18
1.20	0.12	3.30	0.16
1.50	0.12	3.60	0.16
1.80	0.14	3.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions

Site: HC-A(12)

Flow Tracker Filename: HC-A(12) 2016-10-20.WAD

Time: 2016/10/20 13:41:16

Measured Flow: Q= 0.0081 m^3/s

Comments: Flows contained within channel (not overflowing into adjacent wetland)

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.24
0.20	0.14	0.80	0.24
0.30	0.16	0.90	0.24
0.40	0.18	1.00	0.12
0.50	0.24	1.10	0
0.60	0.24		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions

Site: HC-A(13)

Flow Tracker Filename: HC-A(13) 2016-10-20.WAD

Time: 2016/10/20 14:17:59

Measured Flow: Q= 0.0055 m^3/s

Comments: Significant vegetation growth upstream and downstream of cross-section

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.20	0.14
0.60	0.08	1.30	0.16
0.70	0.10	1.40	0.18
0.80	0.16	1.50	0.18
0.90	0.16	1.60	0.18
1.00	0.12	1.71	0.18
1.10	0.14		0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions

Site: HC-A(14) Flow Tracker Filename: HC-A(14) 2016-10-20.WAD

Time: 2016/10/20 14:47:04 Measured Flow: Q= 0.0094 m^3/s

Comments: Flow measurements taken upstream of station due to vegetation accumulation at normal cross-section location.

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.20
0.20	0.20	0.80	0.20
0.30	0.20	0.90	0.18
0.40	0.18	1.00	0.16
0.50	0.18	1.10	0.13
0.60	0.18	1.30	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1
- HC-P1(04) was not flowing (almost completely dry at swale). Samples and YSI were taken at pond.
- HC-P1(05) was flowing. Samples and YSI were taken in channel.
- Pond outlet (HC-P1(06)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 2
- HC-P2(04) was backwatered. Sample and YSI were taken at inlet.
- HC-P2(05) had minor flow. Sample and YSI were taken at inlet splash pool.
- HC-P2(06) was not flowing. Sample and YSI were taken in forebay.
- Pond outlet (HC-P2(07)) was not flowing. Samples and YSI were taken at pond.

Site: Pond 4
- HC-P4(04) was flowing. Sample and YSI were taken in channel.
- HC-P4(05) was flowing. Sample and YSI were taken at outlet.

Pond 1: Drainage Swale (HC-P1(04))

Pond 1: HC-P1(04) with no water at swale culvert

Pond 1: HC-P1(04) not flowing at pond

Pond 1: Drainage Swale (HC-P1(05))


Pond 1: Drainage Swale (HC-P1(05))


Pond 1: Forebay looking towards HC-P1(05)


Pond 1: Forebay looking towards HC-P1(04)


Pond 2: Deep Cell


Pond 1: HC-P1(07) Outlet not flowing


Pond 1: HC-P1(07) Outlet not flowing

Pond 1: HC-P1(07) Outlet not flowing

Pond 2: HC-P2(04) Inlet flowing

Pond 2: HC-P2(04) Inlet Forebay

Pond 2: HC-P2(05) Inlet flowing

Pond 2: HC-P2(04) Inlet pool

Pond 2: HC-P2(04) Inlet looking towards forebay

Pond 2: Forebays for HC-P2(05) and HC-P2(06)

Pond 2: HC-P2(06) Inlet swale not flowing

Pond 2: HC-P2(06) Inlet looking toward Forebay

Pond 2: HC-P2(07) Outlet not flowing

Pond 2: Deep Cell

Pond 2: Deep Cell looking toward HC-P2(07) outlet


Pond 4: HC-P4(04) swale looking upstream


Pond 4: HC-P4(04) swale looking across


Pond 4: HC-P4(04) swale looking towards forebay


Pond 4: HC-P4(05) outlet looking toward deep cell


Pond 4: HC-P4(05) outlet flowing


Pond 4: HC-P4(05) outlet flowing

Pond 4: HC-P4(06) outlet channel flowing

Pond 4: HC-P4(06) outlet channel flowing

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Field/Sampling Report

Client City of Guelph Page 1

Project Hanlon Creek Monitoring 2016, Base flow measurements

Date October 26, 2016 Project Number 60265453

Weather: Clear with a high of 24.5 °C (recorded in Guelph).

Tasks:

- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Sachet Siwakoti

YSI Results: Temperature and DO were the only parameters collected in the field as the YSI device is currently being repaired. All Conductivity and pH measurements were recorded by ALS from the collected water samples.

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	10/26/2016 09:40	-	-	-	-	-
HC-A(04)	10/26/2016 10:10	9.9	826	7.25	7.55	-
HC-A(06)	10/26/2016 11:50	8.9	-	10.28	-	-
HC-A(10)	10/26/2016 13:15	5.7	-	11.01	-	-
HC-A(11)	10/26/2016 13:50	6.7	-	10.91	-	-
HC-A(12)	10/26/2016 14:20	5.8	-	12.04	-	-
HC-A(13)	10/26/2016 15:10	5.8	1180	11.94	7.95	-
HC-A(14)	10/26/2016 15:40	5.7	1170	12.06	8.01	-

Weather, General Conditions
Site: HC-A(03)
Time: 2016/10/26 09:41:59
Comments: None

Flow Tracker Filename: HC-A(03) 2016-10-26.WAD
Measured Flow: Q= 0.0006 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.06
0.20	0.03	0.70	0.04
0.30	0.04	0.80	0.03
0.40	0.06	0.90	0.02
0.50	0.06	1.00	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04)
Time: 2016/10/26 10:10:07
Comments: None

Flow Tracker Filename: HC-A(04) 2016-10-26.WAD
Measured Flow: Q= 0.0035 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.12
0.20	0.08	0.80	0.08
0.30	0.09	0.90	0.06
0.40	0.12	1.00	0.04
0.50	0.12	1.10	0.04
0.60	0.12	1.20	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/10/26 11:47:26
Comments: None

Flow Tracker Filename: HC-A(06) 2016-10-26.WAD
Measured Flow: Q= 0.0040 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.07
0.20	0.06	0.90	0.08
0.30	0.07	1.00	0.08
0.40	0.07	1.10	0.08
0.50	0.07	1.20	0.07
0.60	0.07	1.30	0
0.70	0.07		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)
Time: 2016/10/26 13:12:27
Comments: None

Flow Tracker Filename: HC-A(10) 2016-10-26.WAD
Measured Flow: Q= 0.0085 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.00	0.18
0.30	0.20	1.10	0.17
0.40	0.18	1.20	0.17
0.50	0.18	1.30	0.17
0.60	0.18	1.40	0.16
0.70	0.18	1.50	0.13
0.80	0.18	1.60	0.12
0.90	0.18	1.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/10/26 13:44:58
Comments: None

Flow Tracker Filename: HC-A(11) 2016-10-26.WAD
Measured Flow: Q= 0.0081 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.10	0.14
0.30	0.14	2.40	0.14
0.60	0.12	2.70	0.15
0.90	0.12	3.00	0.15
1.20	0.12	3.30	0.13
1.50	0.10	3.60	0.12
1.80	0.10	3.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/10/26 14:23:15
Comments: Photos N/A

Flow Tracker Filename: HC-A(12) 2016-10-26.WAD
Measured Flow: Q= 0.0085 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.26
0.30	0.10	0.80	0.26
0.40	0.11	0.90	0.26
0.50	0.22	1.00	0.16
0.60	0.24	1.20	0

Looking upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/10/26 15:04:09
Comments: None

Flow Tracker Filename: HC-A(13) 2016-10-26.WAD
Measured Flow: Q= 0.0058 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.00	0.11
0.50	0.05	1.10	0.12
0.60	0.10	1.20	0.16
0.70	0.10	1.30	0.16
0.80	0.12	1.40	0.16
0.90	0.11	1.50	0

Looking upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 2016/10/26 15:32:50
Comments: None

Flow Tracker Filename: HC-A(14) 2016-10-26.WAD
Measured Flow: Q= 0.0075 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.20
0.20	0.16	0.80	0.18
0.30	0.18	0.90	0.16
0.40	0.18	1.00	0.10
0.50	0.18	1.10	0.08
0.60	0.20	1.20	0


Looking upstream


Looking downstream


Looking across stream

Site: Pond 1
- Pond outlet (HC-P1(06)) was not flowing.

Site: Pond 2
- Pond outlet (HC-P2(07)) was not flowing.

Site: Pond 4
- HC-P4(05) was flowing.
- HC-P4(06) was flowing.


Pond 4: HC-P4(04) Inlet looking upstream


Pond 4: HC-P4(04) Inlet looking toward pond


Pond 4: HC-P4(04) Inlet looking across


Pond 4: Main cell from HC-P4(05)

Pond 4: HC-P4(05) outlet

Pond 4: HC-P4(05) outlet

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Field/Sampling Report

Client City of Guelph

Page 1

Project Hanlon Creek Monitoring 2016, Base flow measurements

Date October 26, 2016

Project Number 60265453

Weather: Clear with a high of 24.5 °C (recorded in Guelph).

Tasks:
- Flow Measurements
- YSI measurements
- Photos

Field Crew: Andrew Minielly and Sachet Siwakoti

YSI Results: The YSI has been repaired and is back in service.

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	11/15/16 10:46:35	4.50	579	10.16	7.27	-11.8
HC-A(04)	11/15/16 11:02:05	7.71	800	8.47	7.74	-38.1
HC-A(06)	11/15/16 11:30:48	7.23	777	11.08	7.94	-49.5
HC-A(10)	11/15/16 12:41:15	5.87	948	11.39	7.88	-45.7
HC-A(11)	11/15/16 13:06:43	6.52	890	9.53	7.85	-43.9
HC-A(12)	11/15/16 13:44:06	6.20	1154	12.43	8.11	-58.5
HC-A(13)	11/15/16 14:21:03	6.19	1073	11.89	8.18	-62.4
HC-A(14)	11/15/16 14:44:40	6.28	1156	11.75	8.20	-63.5

Weather, General Conditions
Site: HC-A(03)
Time: 2016/11/15 10:44:08
Comments: None

Flow Tracker Filename: HC-A(03) 2016-11-15.WAD
Measured Flow: Q= 0.0009 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.07
0.10	0.04	0.70	0.06
0.20	0.06	0.80	0.05
0.30	0.06	0.90	0.05
0.40	0.06	1.00	0
0.50	0.06		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04)
Time: 2016/11/15 11:11:39
Comments: None

Flow Tracker Filename: HC-A(04) 2016-11-15.WAD
Measured Flow: Q= 0.0036 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.06
0.20	0.06	0.80	0.06
0.30	0.80	0.90	0.06
0.40	0.10	1.00	0.06
0.50	0.08	1.10	0.06
0.60	0.08	1.20	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/11/15 11:45:37
Comments: None

Flow Tracker Filename: HC-A(06) 2016-11-15.WAD
Measured Flow: Q= 0.0034 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.08
0.20	0.06	0.90	0.08
0.30	0.08	1.00	0.09
0.40	0.08	1.10	0.09
0.50	0.08	1.20	0.08
0.60	0.08	1.30	0
0.70	0.08		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(10)
Time: 2016/11/15 12:51:00
Comments: None

Flow Tracker Filename: HC-A(10) 2016-11-15.WAD
Measured Flow: Q= 0.0074 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	1.00	0.18
0.40	0.20	1.10	0.18
0.50	0.19	1.20	0.17
0.60	0.19	1.30	0.16
0.70	0.19	1.40	0.15
0.80	0.18	1.50	0.12
0.90	0.18	1.60	0.12


Looking upstream

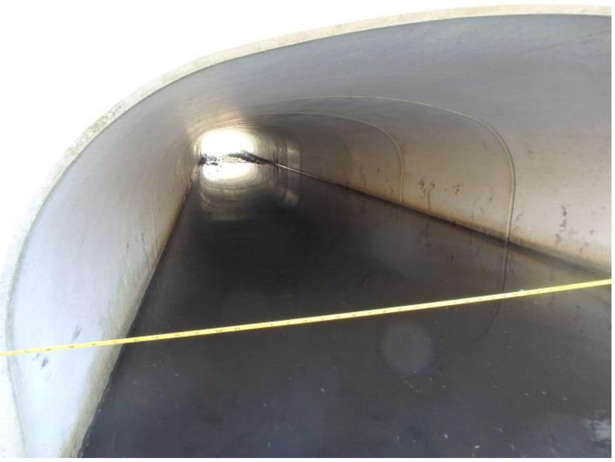

Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/11/15 13:20:01
Comments: None

Flow Tracker Filename: HC-A(11) 2016-11-15.WAD
Measured Flow: Q= 0.0076 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.10	0.13
0.30	0.14	2.40	0.14
0.60	0.12	2.70	0.15
0.90	0.12	3.00	0.14
1.20	0.12	3.30	0.12
1.50	0.11	3.60	0.12
1.80	0.12	3.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/11/15 14:00:17
Comments: Photos N/A

Flow Tracker Filename: HC-A(12) 2016-11-15.WAD
Measured Flow: Q= 0.0080 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.25
0.20	0.14	0.70	0.18
0.30	0.20	0.80	0.14
0.40	0.28	0.90	0.10
0.50	0.28	1.00	0

Looking upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/11/15 14:33:12
Comments: None

Flow Tracker Filename: HC-A(13) 2016-11-15.WAD
Measured Flow: Q= 0.0078 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.14
0.40	0.04	1.00	0.12
0.50	0.08	1.10	0.14
0.60	0.12	1.20	0.18
0.70	0.12	1.30	0.19
0.80	0.10	1.40	0

Looking upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 2016/11/15 14:57:34
Comments: None

Flow Tracker Filename: HC-A(14) 2016-11-15.WAD
Measured Flow: Q= 0.0072 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.18
0.20	0.14	0.80	0.18
0.30	0.17	0.90	0.12
0.40	0.18	1.00	0.10
0.50	0.18	1.10	0
0.60	0.20		


Looking upstream


Looking downstream


Looking across stream

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Field/Sampling Report

Client City of Guelph Page 1

Project Hanlon Creek Monitoring 2016, Base flow measurements

Date November 28, 2016 Project Number 60265453

Weather: Clear with a high of 24.5 °C (recorded in Guelph) with 1mm of rainfall measured in the past 24 hours.

Tasks:

- Flow Measurements
- YSI measurements
- Photos

Field Crew: Steven Scott and Sachet Siwakoti

YSI Results:

Site	DateTime (M/D/Y H:M)	Temp (°C)	SpCond (uS/cm)	DO Conc (mg/L)	pH	pH (mV)
HC-A(03)	11/28/16 12:00:02	5.86	812	10.77	7.60	-32.9
HC-A(04)	11/28/16 12:35:34	5.92	829	12.44	7.72	-39.4
HC-A(06)	11/28/16 13:07:03	5.04	1104	11.87	7.69	-37.8
HC-A(10)	11/28/16 13:37:39	5.67	1084	10.10	7.50	-26.9
HC-A(11)	11/28/16 14:58:36	5.07	1088	12.57	8.03	-56.1
HC-A(12)	11/28/16 15:39:56	4.72	1035	12.78	8.00	-54.4
HC-A(13)	11/28/16 16:13:48	4.70	1090	12.68	8.03	-55.9
HC-A(14)	11/28/16 12:00:02	5.86	812	10.77	7.60	-32.9

Weather, General Conditions
Site: HC-A(03)
Time: 2016/11/28 11:32:43
Comments: None

Flow Tracker Filename: HC-A(03) 2016-11-28.WAD
Measured Flow: Q= 0.0015 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.08
0.20	0.06	0.80	0.08
0.30	0.06	0.90	0.06
0.40	0.07	1.00	0.04
0.50	0.07	1.10	0
0.60	0.08		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(04)
Time: 2016/11/28 12:14:20
Comments: None

Flow Tracker Filename: HC-A(04) 2016-11-28.WAD
Measured Flow: Q= 0.0028 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.60	0.08
0.10	0.06	0.70	0.07
0.20	0.06	0.80	0.07
0.30	0.08	0.90	0.05
0.40	0.10	1.10	0.06
0.50	0.10	1.20	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(06)
Time: 2016/11/28 12:49:21
Comments: None

Flow Tracker Filename: HC-A(06) 2016-11-28.WAD
Measured Flow: Q= 0.0061 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.80	0.10
0.20	0.08	0.90	0.10
0.30	0.08	1.00	0.10
0.40	0.09	1.10	0.10
0.50	0.09	1.20	0.10
0.60	0.10	1.30	0
0.70	0.10		


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions

Site: HC-A(10)
Time: 2016/11/28 13:20:23
Comments: None

Flow Tracker Filename: HC-A(10) 2016-11-28.WAD
Measured Flow: Q= 0.0115 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.17
0.20	0.21	1.00	0.17
0.30	0.20	1.10	0.17
0.40	0.18	1.20	0.16
0.50	0.19	1.30	0.16
0.60	0.19	1.40	0.14
0.70	0.18	1.50	0.12
0.80	0.18	1.60	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(11)
Time: 2016/11/28 13:51:36
Comments: None

Flow Tracker Filename: HC-A(11) 2016-11-28.WAD
Measured Flow: Q= 0.0107 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	2.10	0.18
0.30	0.16	2.40	0.18
0.60	0.16	2.70	0.17
0.90	0.16	3.00	0.16
1.20	0.15	3.30	0.16
1.50	0.15	3.60	0.14
1.80	0.16	3.70	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(12)
Time: 2016/11/28 15:12:32
Comments: Photos N/A

Flow Tracker Filename: HC-A(12) 2016-11-28.WAD
Measured Flow: Q= 0.0112 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.26
0.20	0.08	0.80	0.22
0.30	0.08	0.90	0.18
0.40	0.14	1.00	0.15
0.50	0.24	1.20	0.08
0.60	0.26	1.30	0


Looking upstream


Looking downstream


Looking across stream

Weather, General Conditions
Site: HC-A(13)
Time: 2016/11/28 15:54:21
Comments: None

Flow Tracker Filename: HC-A(13) 2016-11-28.WAD
Measured Flow: Q= 0.0123 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.90	0.16
0.30	0.06	1.00	0.16
0.40	0.10	1.10	0.18
0.50	0.14	1.20	0.23
0.60	0.12	1.30	0.22
0.70	0.14	1.40	0.20
0.80	0.14	1.50	0

Looking upstream

Looking downstream

Looking across stream

Weather, General Conditions
Site: HC-A(14)
Time: 2016/11/28 16:25:31
Comments: None

Flow Tracker Filename: HC-A(14) 2016-11-28.WAD
Measured Flow: Q= 0.0135 m^3/s

Distance from Edge of Creek (m)	Water Depth (m)	Distance from Edge of Creek (m)	Water Depth (m)
0	0	0.70	0.22
0.20	0.06	0.80	0.22
0.30	0.14	0.90	0.20
0.40	0.14	1.00	0.17
0.50	0.20	1.10	0.08
0.60	0.20	1.20	0

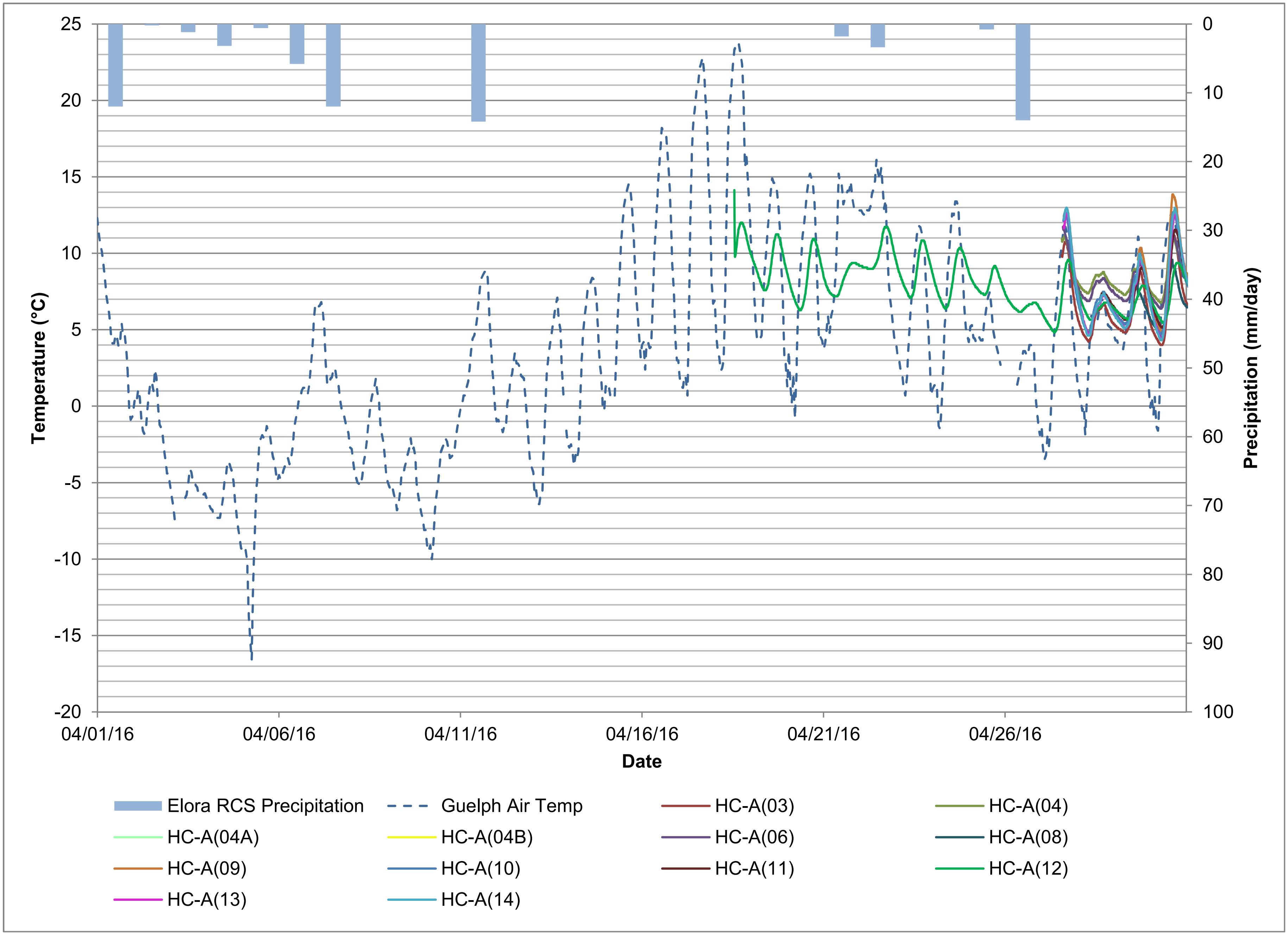

Looking upstream


Looking downstream


Looking across stream

Appendix B

Monthly Temperature Plots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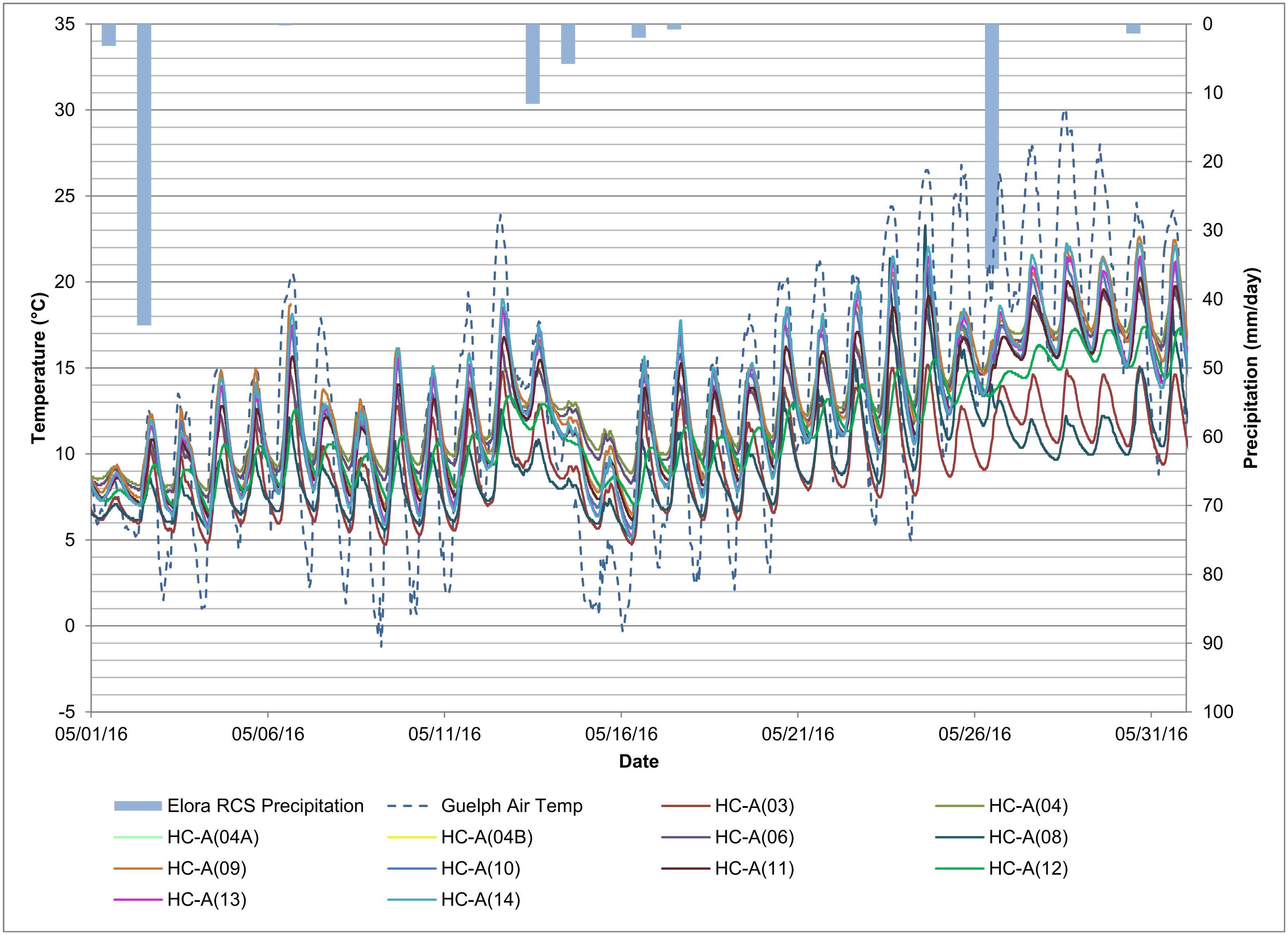
20
15
10
5
0
-5
-10
-15
-20
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
Precipitation (mm/day)
04/01/16
04/06/16
04/11/16
04/16/16
04/21/16
04/26/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)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25
20
15
10
5
0
-5
Temperature (°C)
0
10
20
30
40
50
60
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80
90
100
Precipitation (mm/day)
05/01/16
05/06/16
05/11/16
05/16/16
05/21/16
05/26/16
05/31/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
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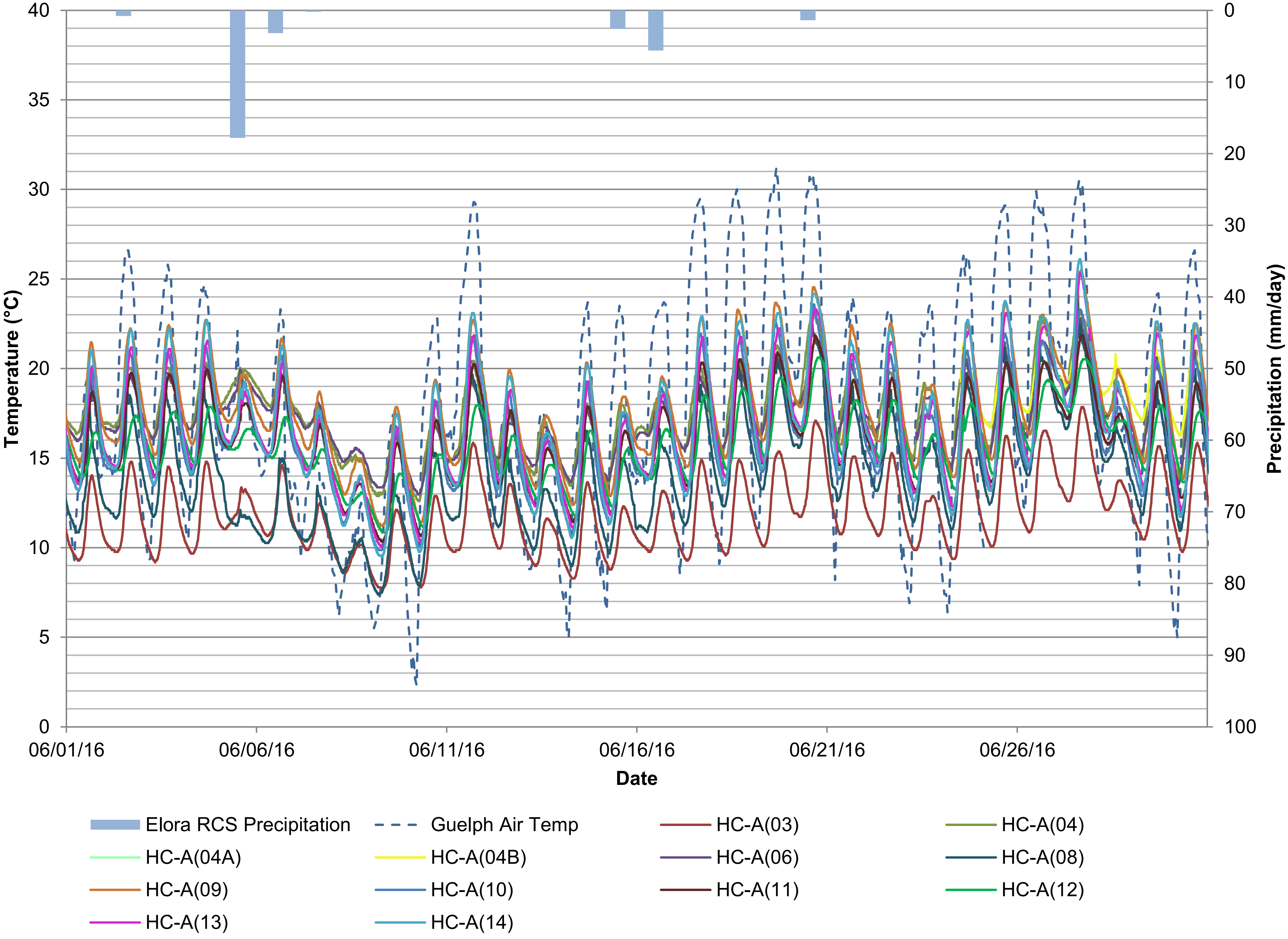
HC-A(12)
HC-A(13)
HC-A(14)



40
35
30
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20
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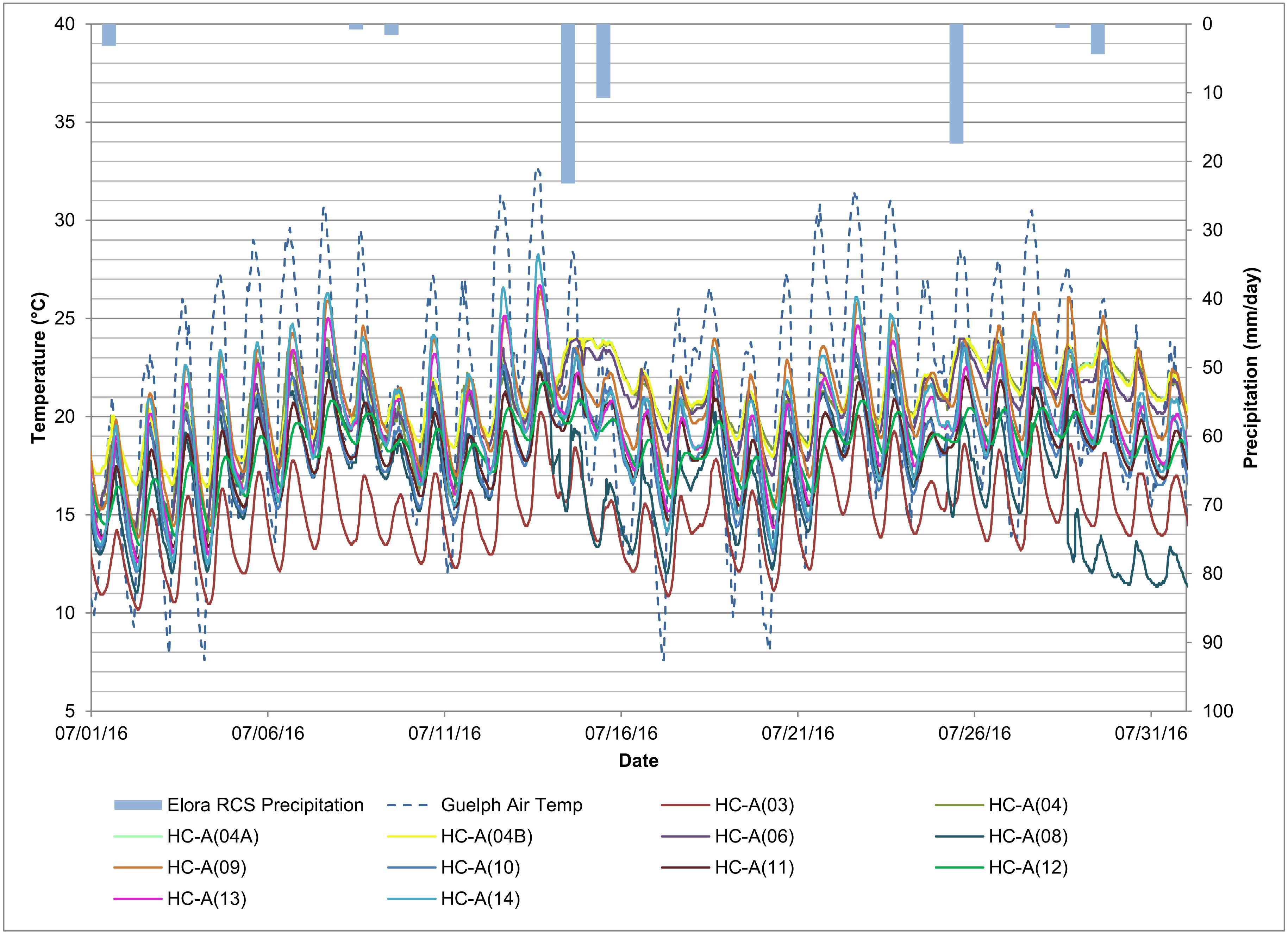
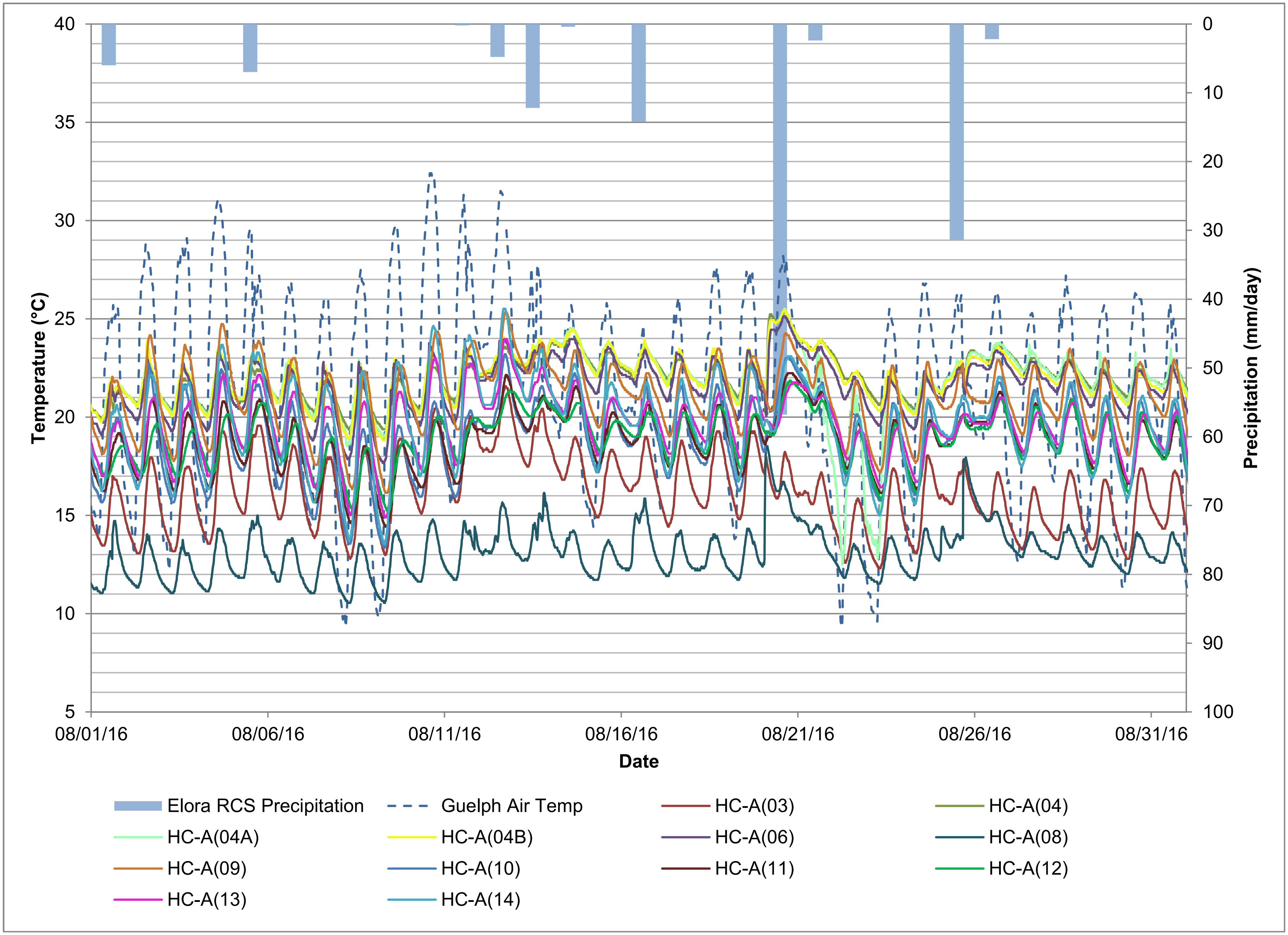
50
60
70
80
90
100
Temperature (°C)
Precipitation (mm/day)
06/01/16
06/06/16
06/11/16
06/16/16
06/21/16
06/26/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)


40
35
30
25
20
15
10
5
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
Precipitation (mm/day)
07/01/16
07/06/16
07/11/16
07/16/16
07/21/16
07/26/16
07/31/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)



Temperature (°C)
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35
30
25
20
15
10
5
Precipitation (mm/day)
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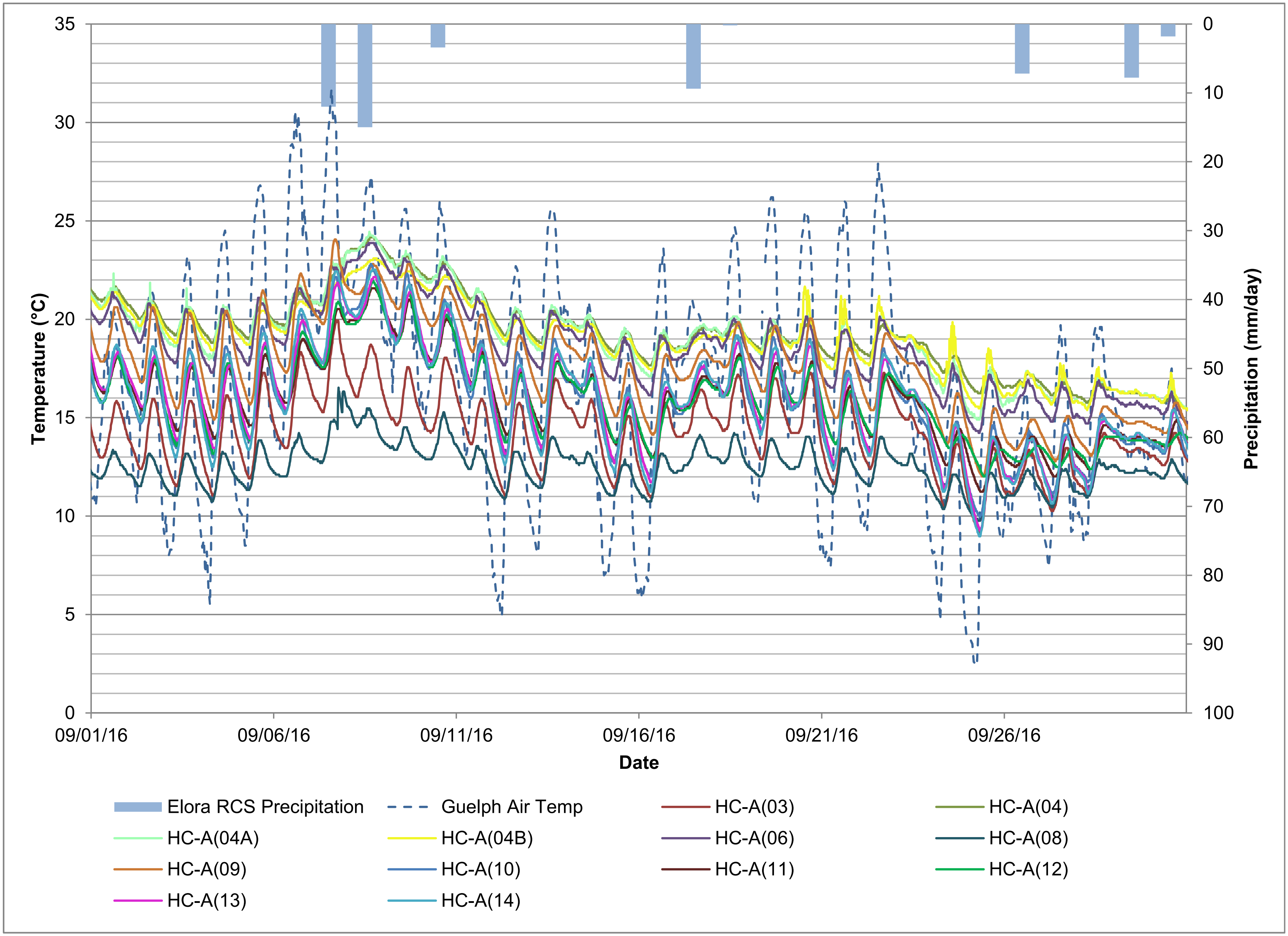
10
20
30
40
50
60
70
80
90
100
08/01/16
08/06/16
08/11/16
08/16/16
08/21/16
08/26/16
08/31/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)



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30
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20
15
10
5
0
Temperature (°C)
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10
20
30
40
50
60
70
80
90
100
Precipitation (mm/day)
09/01/16
09/06/16
09/11/16
09/16/16
09/21/16
09/26/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
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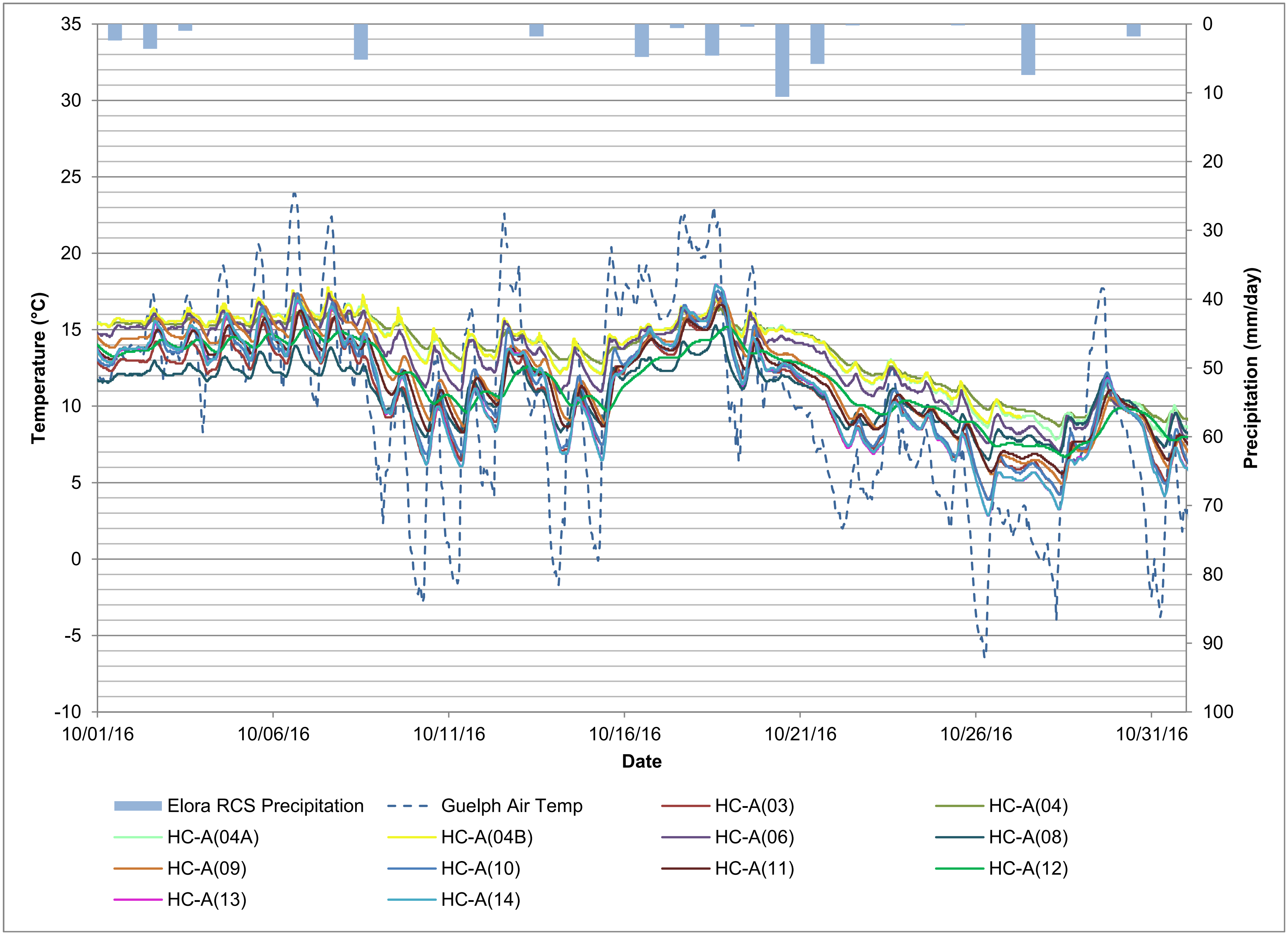
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)



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5
0
-5
-10
Temperature (°C)
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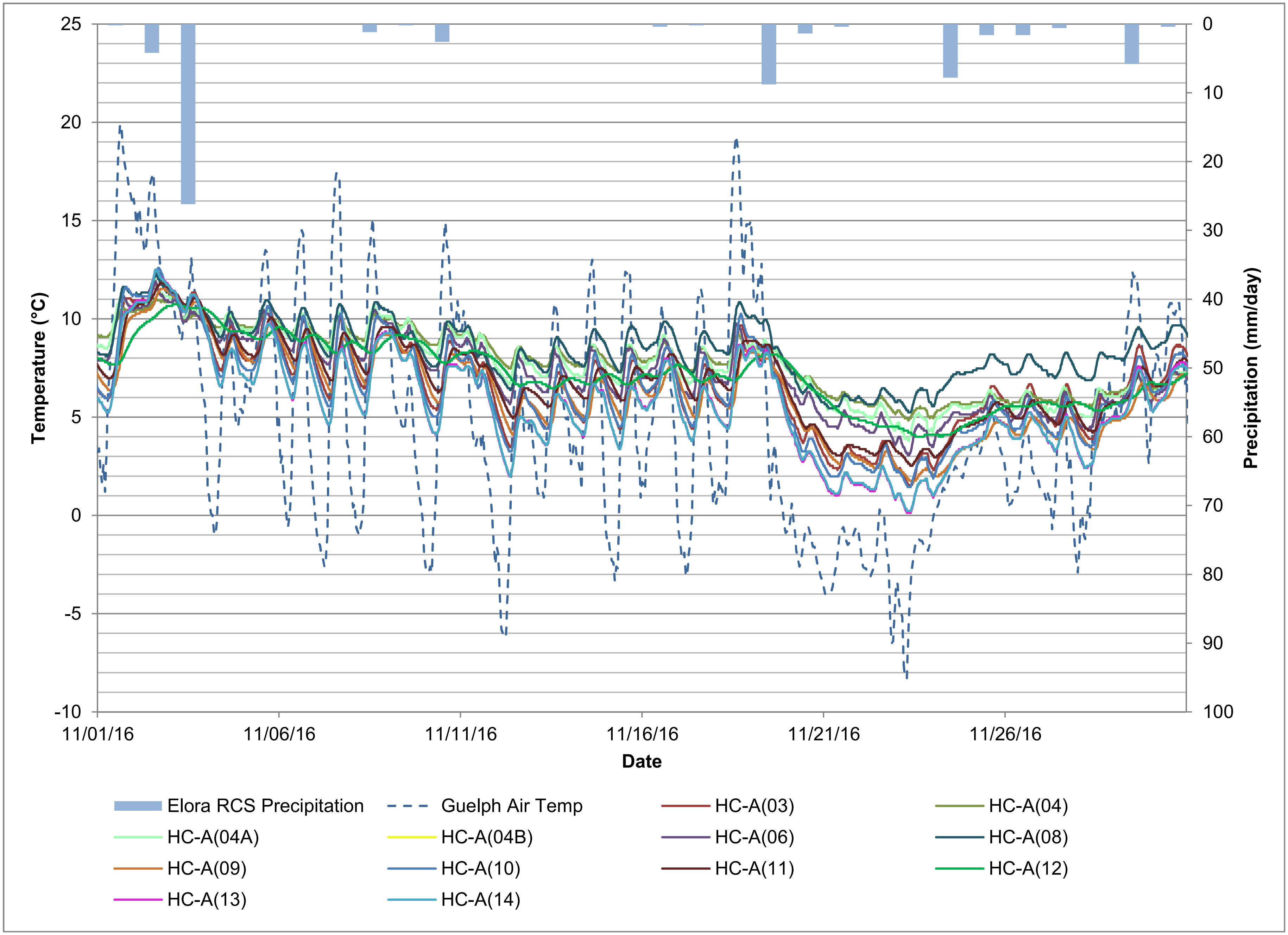
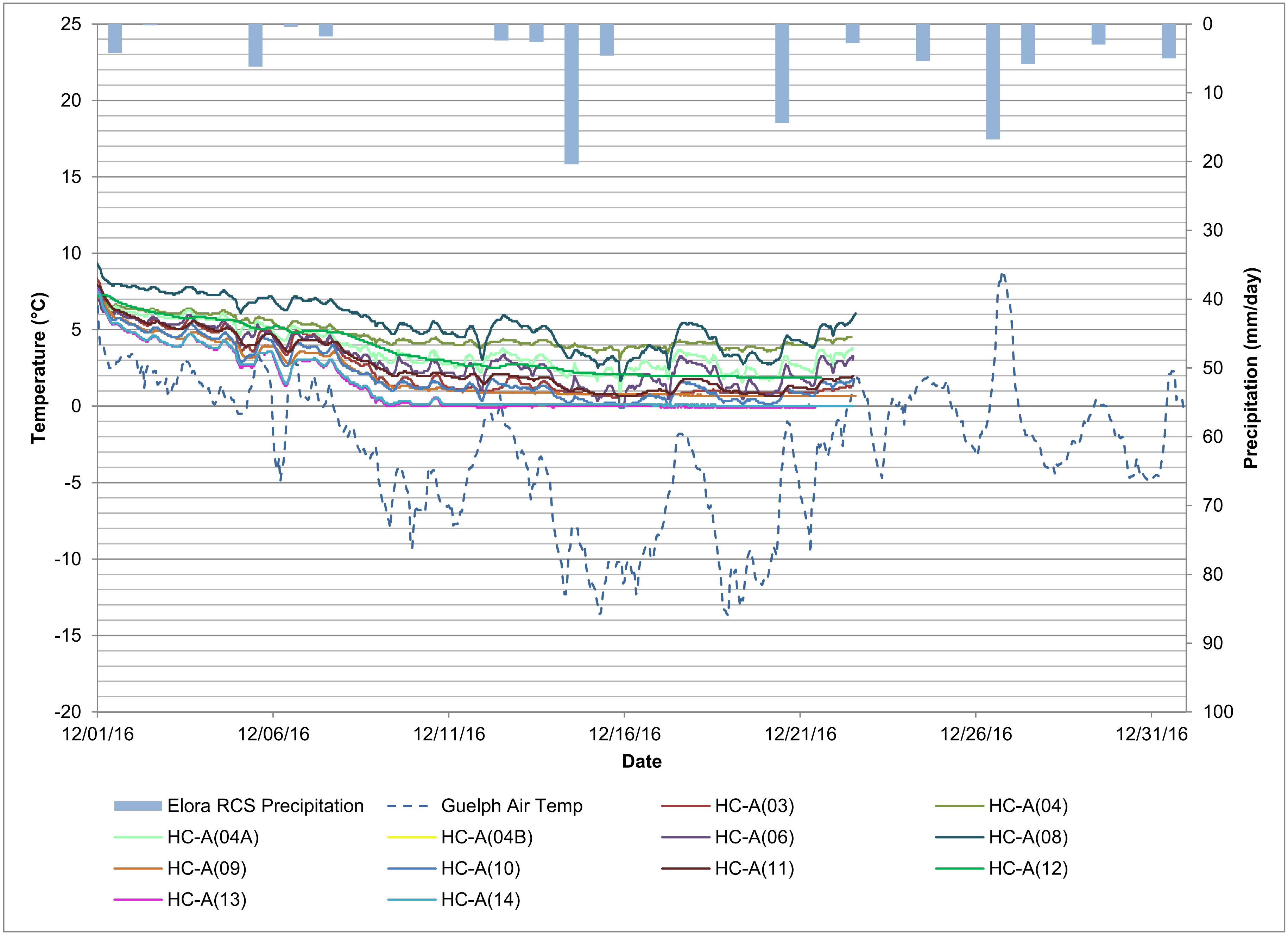
10
20
30
40
50
60
70
80
90
100
Precipitation (mm/day)
10/01/16
10/06/16
10/11/16
10/16/16
10/21/16
10/26/16
10/31/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)



Temperature (°C)
Precipitation (mm/day)
Date
25
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60
70
80
90
100
11/01/16
11/06/16
11/11/16
11/16/16
11/21/16
11/26/16
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)


25
20
15
10
5
0
-5
-10
-15
-20
Temperature (°C)
0
10
20
30
40
50
60
70
80
90
100
Precipitation (mm/day)
12/01/16
12/06/16
12/11/16
12/16/16
12/21/16
12/26/16
12/31/16
Date
Elora RCS Precipitation
Guelph Air Temp
HC-A(03)
HC-A(04)
HC-A(04A)
HC-A(04B)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)

Appendix C

Historical Comparison of Statistical Stream Temperatures

Station	**HC-A(03)**						
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011***
Summer (July-August) average maximum	14.5 - 19.9	17.87	18.03	15.68	15.60	19.34	19.01
Summer (July-August) average	12.5 - 14.5	15.59	14.56	13.13	13.59	18.00	18.28
Summer (July-August) average minimum	9.0 - 12.0	13.25	11.83	11.23	12.02	16.66	16.67
Maximum 3-day mean	14.0 - 19.0	18.75	17.27	14.72	16.03	20.39	21.50
Maximum 7-day mean	13.0 - 17.0	17.93	16.69	14.28	15.09	19.38	20.77
Maximum 7-day mean of daily maximums	15.0 - 23.5	19.84	21.05	16.88	18.05	20.81	21.94
Hours over 19°C	15.4	76.00	84.25	0.00	5.00	384.50	237.50
Percent of Time over 19°C	1%	0.05	0.06	0.00	0.00	0.26	0.41
Frequency of Exceedance over 19°C (Days/yr)	4.1	13.00	19.00	0.00	1.00	40.00	17.00
Average Duration of Event Over 19°C (h)	3.1	5.43	4.01	0.00	5.00	9.86	14.84
Hours over 22°C		0.00	0.25	0.00	0.00	4.25	32.00
Percent of Time over 22°C		0.00	0.00	0.00	0.00	0.00	0.06
Frequency of Exceedance over 22°C (Days/yr)		0.00	1.00	0.00	0.00	1.00	6.00
Average Duration of Event Over 22°C (h)		0.00	0.25	0.00	0.00	1.81	5.33
Hours over 24°C	0	0.00	0.00	0.00	0.00	0.00	4.25
Percent of Time over 24°C	0	0.00	0.00	0.00	0.00	0.00	0.01
Frequency of 24°C Exceedance (Days/yr)		0.00	0.00	0.00	0.00	0.00	1.00
Average Duration of Event Over 24°C (h)		0.00	0.00	0.00	0.00	0.00	4.25

Station	**HC-A(04)**								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	22.47	20.91	20.03	20.52	23.56	19.63	18.3	15.5
Summer July-August) average	12.5 - 14.5	21.28	19.54	19.02	19.55	22.41	17.74	15.5	13.8
Summer (July-August) average minimum	9.0 - 12.0	18.70	18.21	18.06	18.66	21.29	16.10	13.4	12.6
Maximum 3-day mean	14.0 - 19.0	23.40	21.73	20.27	23.23	24.18	21.45	15	13.2
Maximum 7-day mean	13.0 - 17.0	22.87	21.47	19.61	22.36	23.53	19.77	14.5	12.8
Maximum 7-day mean of daily maximums	15.0 - 23.5	23.54	22.83	21.05	23.35	25.65	21.57	16.8	14.8
Hours over 19°C	51.1	1329.50	920.00	771.00	924.00	1477.50	452.50	101.5	0
Percent of Time over 19°C	3%	0.90	0.62	0.52	0.62	0.99	0.30	0.09	0
Frequency of Exceedance over 19°C (Days/yr)	9.4	61.00	55.00	53.00	55.00	62.00	40.00	19	0
Average Duration of Event Over 19°C (h)	5	73.86	21.90	16.76	27.18	295.50	14.60	5.3	0
Hours over 22°C		564.25	96.75	3.75	101.00	901.00	35.75	0	0
Percent of Time over 22°C		0.38	0.07	0.00	0.07	0.61	0.02	0	0
Frequency of Exceedance over 22°C (Days/yr)		41.00	16.00	2.00	6.00	48.00	7.00	0	0
Average Duration of Event Over 22°C (h)		15.94	5.17	0.95	35.28	45.03	5.11	0	0
Hours over 24°C	0	21.00	0.00	0.00	20.50	182.25	4.50	0	0
Percent of Time over 24°C	0%	0.01	0.00	0.00	0.01	12%	0%	0%	0%
Frequency of 24°C Exceedance (Days/yr)		2.00	0.00	0.00	2.00	24.00	1.00	0	0
Average Duration of Event Over 24°C (h)		21.00	0.00	0.00	10.25	5.88	4.50	0	0

Station	**HC-A(04A)**	
Year	**Modeled**	**2016**
Summer (July-August) average maximum	14.5 - 19.9	22.77
Summer (July-August) average	12.5 - 14.5	21.33
Summer (July-August) average minimum	9.0 - 12.0	18.90
Maximum 3-day mean	14.0 - 19.0	23.40
Maximum 7-day mean	13.0 - 17.0	22.99
Maximum 7-day mean of daily maximums	15.0 - 23.5	23.91
Hours over 19°C		1312.75
Percent of Time over 19°C		0.89
Frequency of Exceedance over 19°C (Days/yr)		62.00
Average Duration of Event Over 19°C (h)		65.64
Hours over 22°C		604.00
Percent of Time over 22°C		0.41
Frequency of Exceedance over 22°C (Days/yr)		47.00
Average Duration of Event Over 22°C (h)		23.96
Hours over 24°C		29.25
Percent of Time over 24°C		0.02
Frequency of 24°C Exceedance (Days/yr)		3.00
Average Duration of Event Over 24°C (h)		14.63

Station	**HC-A(04B)**	
Year	**Modeled**	**2016**
Summer (July-August) average maximum	14.5 - 19.9	22.83
Summer July-August) average	12.5 - 14.5	21.44
Summer (July-August) average minimum	9.0 - 12.0	18.48
Maximum 3-day mean	14.0 - 19.0	23.36
Maximum 7-day mean	13.0 - 17.0	22.94
Maximum 7-day mean of daily maximums	15.0 - 23.5	24.02
Hours over 19°C		1338.00
Percent of Time over 19°C		0.91
Frequency of Exceedance over 19°C (Days/yr)		62.00
Average Duration of Event Over 19°C (h)		63.71
Hours over 22°C		600.75
Percent of Time over 22°C		0.41
Frequency of Exceedance over 22°C (Days/yr)		50.00
Average Duration of Event Over 22°C (h)		23.89
Hours over 24°C		30.25
Percent of Time over 24°C		0.02
Frequency of 24°C Exceedance (Days/yr)		4.00
Average Duration of Event Over 24°C (h)		10.08

Station	**HC-A(06)**								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	22.77	21.64	20.42	20.63	24.07	19.98	19.7	16.1
Summer July-August) average	12.5 - 14.5	20.97	18.86	18.95	19.48	21.88	18.02	16.7	13.9
Summer (July-August) average minimum	9.0 - 12.0	17.11	16.31	17.79	18.49	20.22	16.01	14.3	12.5
Maximum 3-day mean	14.0 - 19.0	22.90	21.39	20.10	23.12	24.18	21.65	16	13.3
Maximum 7-day mean	13.0 - 17.0	22.46	21.11	19.51	22.29	23.32	19.96	15.2	12.8
Maximum 7-day mean of daily maximums	15.0 - 23.5	23.76	25.43	21.58	23.60	26.17	21.90	17.7	15.1
Hours over 19°C	0.9	1263.00	753.25	728.75	902.25	1386.75	512.00	269.75	0
Percent of Time over 19°C	0	0.86	0.51	0.49	0.61	0.93	0.35	0.18	0
Frequency of Exceedance over 19°C (Days/yr)	0.3	61.00	57.00	56.00	57.00	62.00	46.00	38	0
Average Duration of Event Over 19°C (h)	3	52.63	10.46	12.35	24.39	99.05	12.80	7.1	0
Hours over 22°C		473.50	107.00	5.00	99.25	685.25	55.50	19.25	0
Percent of Time over 22°C		0.32	0.07	0.00	0.07	0.46	0.04	0.01	0
Frequency of Exceedance over 22°C (Days/yr)		49.00	24.00	2.00	7.00	55.00	8.00	7	0
Average Duration of Event Over 22°C (h)		9.60	3.39	1.01	23.21	14.35	6.94	2.75	0
Hours over 24°C	0	17.25	14.75	0.00	12.50	193.50	6.50	0	0
Percent of Time over 24°C	0	0.01	0.01	0.00	0.01	0.13	0.00	0	0
Frequency of 24°C Exceedance (Days/yr)		1.00	8.00	0.00	2.00	35.00	1.00	0	0
Average Duration of Event Over 24°C (h)		17.25	1.64	0.00	6.25	5.23	6.50	0	0

Station	**HC-A(08)**								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	8.24	14.45	8.55	18.16	15.00	14.40	14.1	13.9
Summer July-August) average	12.5 - 14.5	13.07	12.60	12.21	16.03	13.56	12.56	13	13
Summer (July-August) average minimum	9.0 - 12.0	6.53	11.28	6.17	14.37	12.40	11.21	12.1	12.2
Maximum 3-day mean	14.0 - 19.0	14.36	16.18	13.38	20.82	16.57	14.43	12.4	12.6
Maximum 7-day mean	13.0 - 17.0	13.97	15.48	12.95	20.23	15.46	13.42	12	12.3
Maximum 7-day mean of daily maximums	15.0 - 23.5	15.59	19.12	15.53	22.42	17.28	16.00	12.9	12.3
Hours over 19°C		0.00	3.75	0.00	393.25	8.50	0.00	19.25	0
Percent of Time over 19°C		0.00	0.00	0.00	0.26	0.01	0.00	0.02	0
Frequency of Exceedance over 19°C (Days/yr)		0.00	5.00	0.00	38.00	2.00	0.00	3	0
Average Duration of Event Over 19°C (h)		0.00	0.63	0.00	10.63	4.25	0.00	6.4	0
Hours over 22°C		0.00	0.00	0.00	41.75	0.00	0.00	0	0
Percent of Time over 22°C		0.00	0.00	0.00	0.03	0.00	0.00	0	0
Frequency of Exceedance over 22°C (Days/yr)		0.00	0.00	0.00	9.00	0.00	0.00	0	0
Average Duration of Event Over 22°C (h)		0.00	0.00	0.00	2.69	0.00	0.00	0	0
Hours over 24°C		0.00	0.00	0.00	0.00	0.00	0.00	0	0
Percent of Time over 24°C		0.00	0.00	0.00	0.00	0.00	0.00	0	0
Frequency of 24°C Exceedance (Days/yr)		0.00	0.00	0.00	0.00	0.00	0.00	0	0
Average Duration of Event Over 24°C (h)		0.00	0.00	0.00	0.00	0.00	0.00	0	0

Station	HC-A(09)								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	23.37	22.34	21.80	21.75	23.70	20.72	19.7	17.2
Summer July-August) average	12.5 - 14.5	20.79	19.18	18.62	19.24	20.33	18.85	17.9	15
Summer (July-August) average minimum	9.0 - 12.0	18.68	16.76	16.36	17.31	17.57	17.11	16.3	13.1
Maximum 3-day mean	14.0 - 19.0	22.81	21.97	20.43	23.46	23.92	22.26	17.1	n/a
Maximum 7-day mean	13.0 - 17.0	22.02	21.31	19.47	22.63	22.45	20.67	16.2	n/a
Maximum 7-day mean of daily maximums	15.0 - 23.5	24.69	25.49	23.03	25.67	26.75	23.00	18.9	n/a
Hours over 19°C	10	1200.00	742.25	621.50	784.00	1014.75	701.00	506.25	11.75
Percent of Time over 19°C	1%	0.81	0.50	0.42	0.53	0.68	0.47	0.34	2.15
Frequency of Exceedance over 19°C (Days/yr)	2.8	62.00	58.00	60.00	59.00	62.00	54.00	28	3
Average Duration of Event Over 19°C (h)	3.4	37.50	14.55	10.90	16.33	23.06	17.10	18.1	3.9
Hours over 22°C		448.50	223.75	106.25	171.25	417.50	115.50	52	0
Percent of Time over 22°C		0.30	0.15	0.07	0.12	0.28	0.08	0.03	0
Frequency of Exceedance over 22°C (Days/yr)		57.00	38.00	26.00	22.00	46.00	13.00	6	0
Average Duration of Event Over 22°C (h)		6.42	3.90	2.66	8.22	7.90	8.88	8.7	0
Hours over 24°C	0	80.50	47.50	13.50	41.75	169.00	10.75	5.5	0
Percent of Time over 24°C	0	0.05	0.03	0.01	0.03	0.11	0.01	0.00	0
Frequency of 24°C Exceedance (Days/yr)		17.00	10.00	6.00	6.00	26.00	1.00	2	0
Average Duration of Event Over 24°C (h)		4.74	4.75	2.25	6.96	6.50	10.75	2.75	0

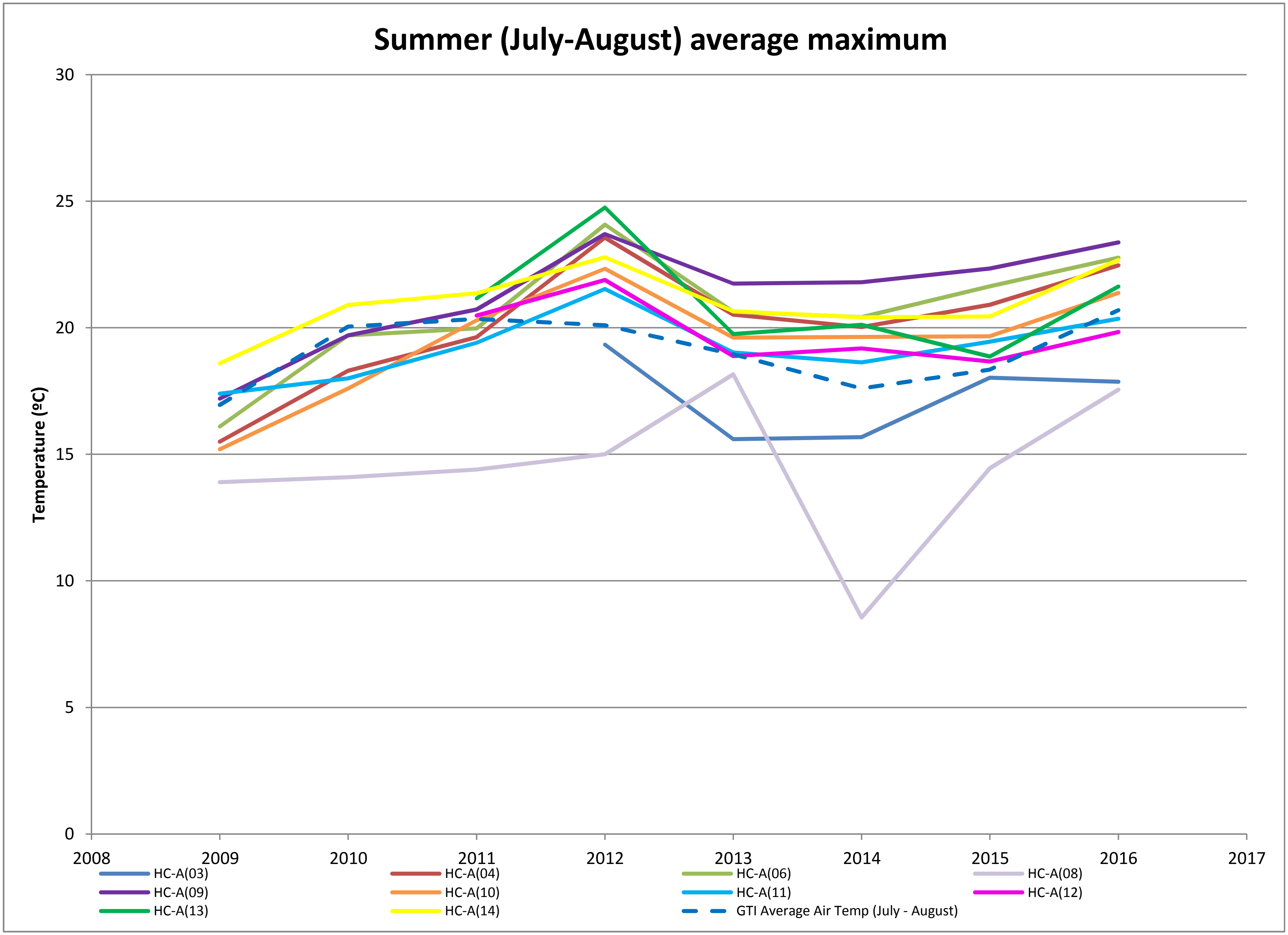
Station	HC-A(10)								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	21.37	19.66	19.63	19.62	22.33	20.30	17.6	15.2
Summer July-August) average	12.5 - 14.5	18.67	16.89	16.88	17.34	18.00	18.28	14.7	13.7
Summer (July-August) average minimum	9.0 - 12.0	16.50	14.81	14.82	15.59	14.99	16.47	12.5	12.7
Maximum 3-day mean	14.0 - 19.0	20.60	19.34	18.74	21.06	20.64	21.93	14	n/a
Maximum 7-day mean	13.0 - 17.0	19.79	18.85	17.76	20.31	19.48	20.26	13.4	n/a
Maximum 7-day mean of daily maximums	15.0 - 23.5	22.65	21.31	21.20	23.20	29.53	22.67	14.8	n/a
Hours over 19°C	58.4	692.75	260.25	221.75	295.00	513.50	573.75	18.75	0
Percent of Time over 19°C	4%	0.47	0.17	0.15	0.20	0.35	0.39	0.01	0
Frequency of Exceedance over 19°C (Days/yr)	10.3	61.00	44.00	40.00	33.00	53.00	50.00	7	0
Average Duration of Event Over 19°C (h)	5.2	12.60	5.66	5.28	9.52	9.01	13.99	2.7	0
Hours over 22°C		84.25	12.50	9.50	36.00	121.25	92.50	0	0
Percent of Time over 22°C		0.06	0.01	0.01	0.02	0.08	0.06	0	0
Frequency of Exceedance over 22°C (Days/yr)		20.00	6.00	4.00	6.00	25.00	14.00	0	0
Average Duration of Event Over 22°C (h)		3.28	1.40	1.97	3.27	3.28	6.61	0	0
Hours over 24°C	0.4	0.00	0.00	0.00	2.00	46.75	9.50	0	0
Percent of Time over 24°C	0%	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0%
Frequency of 24°C Exceedance (Days/yr)		0.00	0.00	0.00	2.00	12.00	1.00	0	0
Average Duration of Event Over 24°C (h)		0.00	0.00	0.00	1.00	3.60	9.50	0	0

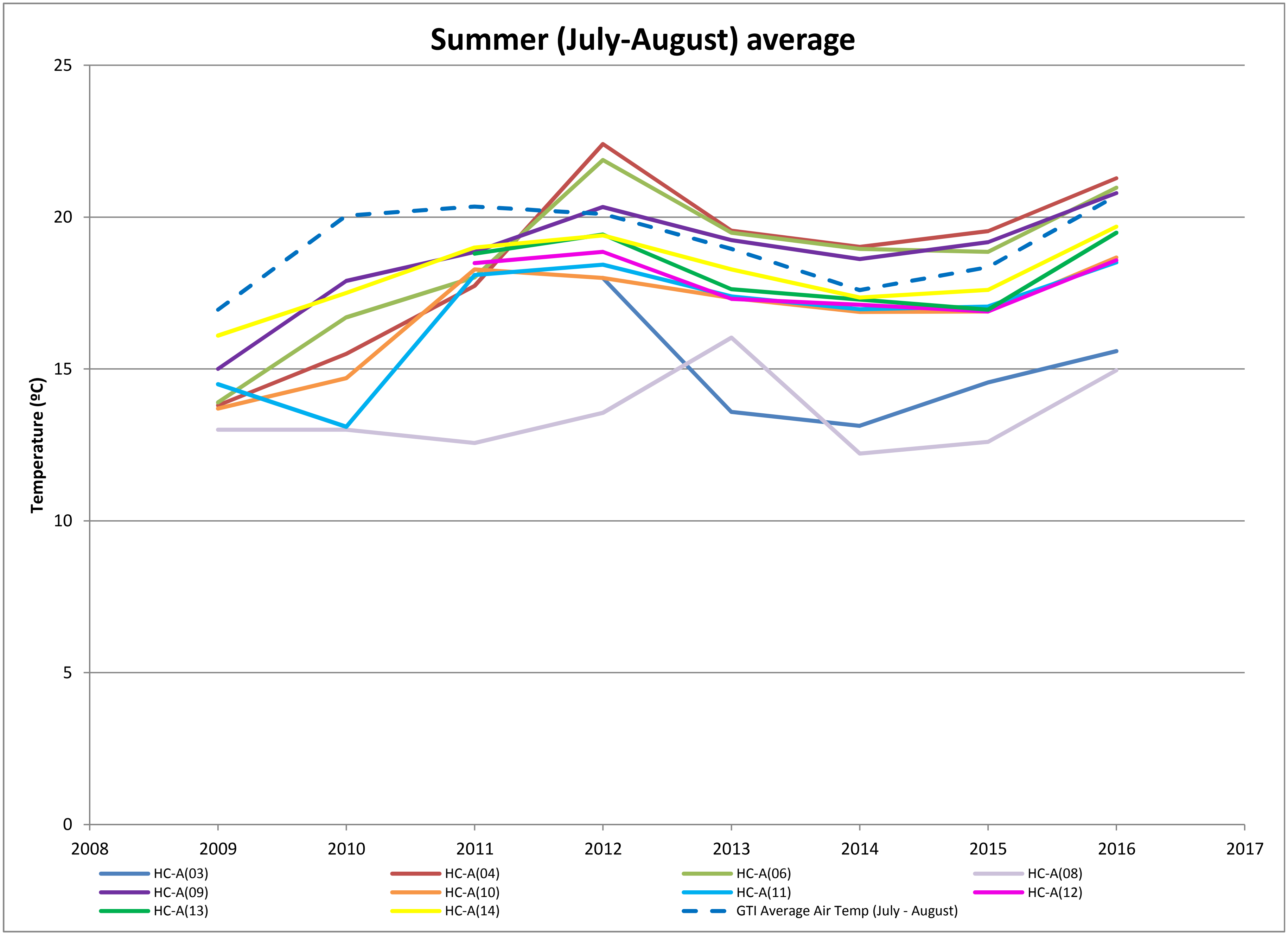
Station	HC-A(11)								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	20.36	19.45	18.63	19.03	21.53	19.41	18	17.4
Summer July-August) average	12.5 - 14.5	18.51	17.06	16.97	17.39	18.43	18.09	13.1	14.5
Summer (July-August) average minimum	9.0 - 12.0	16.95	15.19	15.60	16.10	16.04	16.84	15.1	12.3
Maximum 3-day mean	14.0 - 19.0	20.31	19.40	18.89	20.67	21.09	20.96	14.4	n/a
Maximum 7-day mean	13.0 - 17.0	19.61	18.94	17.87	20.00	19.90	19.97	13.8	n/a
Maximum 7-day mean of daily maximums	15.0 - 23.5	21.23	21.00	19.88	21.69	23.43	20.79	15.3	n/a
Hours over 19°C	57.8	611.50	259.00	135.50	264.25	587.75	457.25	61.5	11.75
Percent of Time over 19°C	4%	0.41	0.17	0.09	0.18	0.39	0.31	0.04	215%
Frequency of Exceedance over 19°C (Days/yr)	9.8	55.00	43.00	23.00	30.00	56.00	37.00	12	6
Average Duration of Event Over 19°C (h)	5.6	12.48	5.89	5.89	9.44	11.09	9.33	5.1	2
Hours over 22°C		15.25	3.25	0.00	11.00	117.50	13.50	11.25	0
Percent of Time over 22°C		0.01	0.00	0.00	0.01	0.08	0.01	0.01	0
Frequency of Exceedance over 22°C (Days/yr)		6.00	1.00	0.00	4.00	26.00	3.00	4	0
Average Duration of Event Over 22°C (h)		2.34	1.75	0.00	1.77	3.40	4.50	2.8	0
Hours over 24°C	0.8	0.00	0.00	0.00	0.00	23.75	0.00	1.00	0
Percent of Time over 24°C	0.06%	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0
Frequency of 24°C Exceedance (Days/yr)		0.00	0.00	0.00	0.00	6.00	0.00	1	0
Average Duration of Event Over 24°C (h)		0.00	0.00	0.00	0.00	3.96	0.00	1	0

Station	HC-A(12)						
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**
Summer (July-August) average maximum	14.5 - 19.9	19.83	18.67	19.18	18.88	21.88	20.48
Summer July-August) average	12.5 - 14.5	18.58	16.89	17.11	17.31	18.86	18.49
Summer (July-August) average minimum	9.0 - 12.0	17.43	15.33	15.41	15.97	16.21	16.71
Maximum 3-day mean	14.0 - 19.0	20.34	19.23	19.36	21.53	22.40	22.02
Maximum 7-day mean	13.0 - 17.0	19.70	18.62	18.38	20.68	20.90	20.32
Maximum 7-day mean of daily maximums	15.0 - 23.5	20.66	21.23	21.12	23.45	25.79	23.04
Hours over 19°C	57.8	615.75	184.00	218.00	226.75	636.50	597.25
Percent of Time over 19°C	4%	0.41	0.12	0.15	0.15	0.43	0.40
Frequency of Exceedance over 19°C (Days/yr)	9.8	48.00	25.00	28.00	26.00	51.00	49.00
Average Duration of Event Over 19°C (h)	5.6	16.64	7.36	7.52	9.86	12.48	15.31
Hours over 22°C		0.00	2.50	10.75	43.00	205.00	105.00
Percent of Time over 22°C		0.00	0.00	0.01	0.03	0.14	0.07
Frequency of Exceedance over 22°C (Days/yr)		0.00	1.00	3.00	6.00	30.00	15.00
Average Duration of Event Over 22°C (h)		0.00	1.38	2.06	4.05	4.66	7.00
Hours over 24°C	0.8	0.00	0.00	0.00	9.00	78.50	10.00
Percent of Time over 24°C	0.06%	0.00	0.00	0.00	0.01	0.05	0.01
Frequency of 24°C Exceedance (Days/yr)		0.00	0.00	0.00	3.00	18.00	1.00
Average Duration of Event Over 24°C (h)		0.00	0.00	0.00	3.00	3.74	10.00

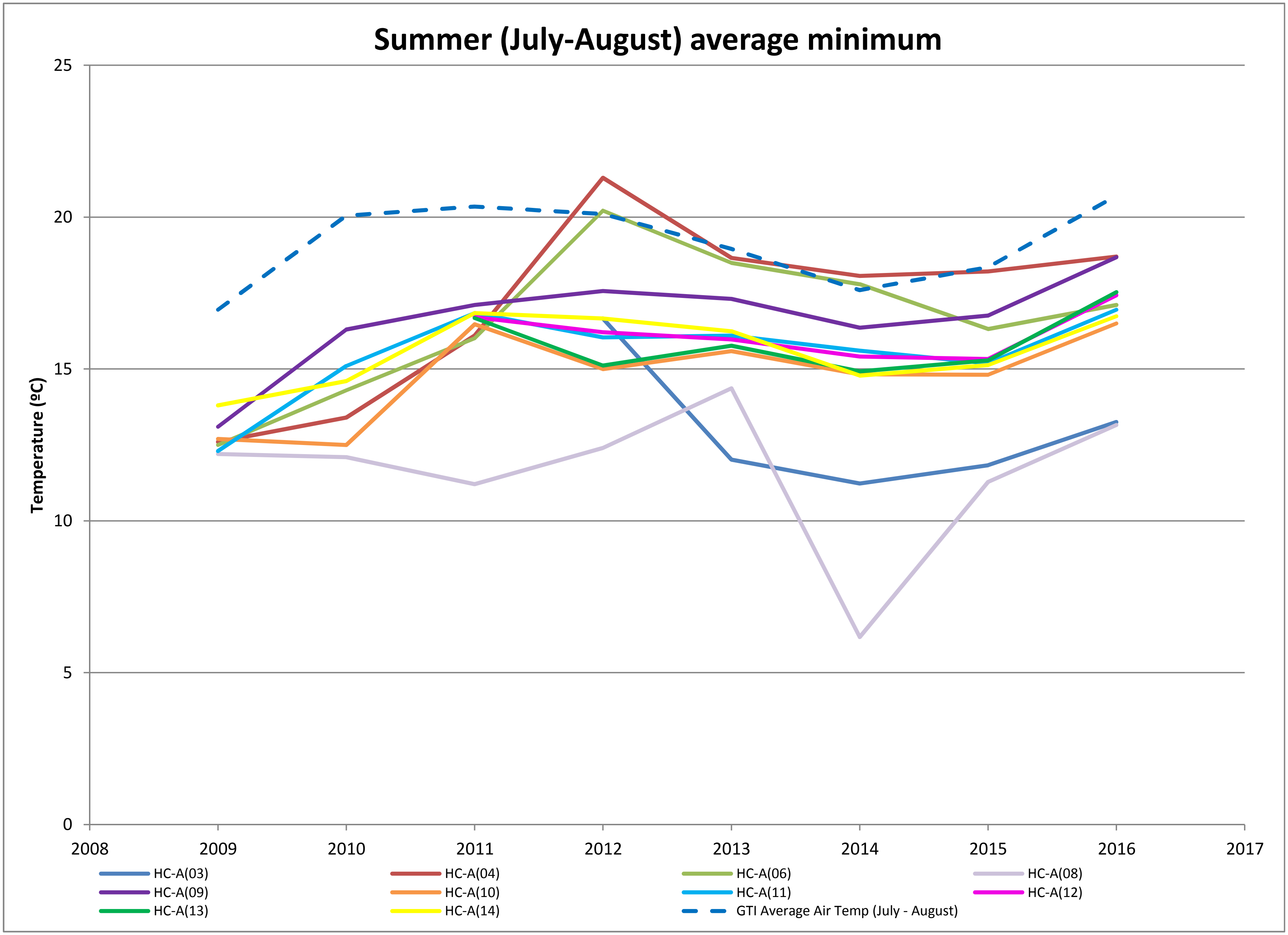
Station	**HC-A(13)**						
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**
Summer (July-August) average maximum	14.5 - 19.9	21.63	18.87	20.12	19.75	24.76	21.16
Summer July-August) average	12.5 - 14.5	19.49	16.95	17.29	17.63	19.43	18.80
Summer (July-August) average minimum	9.0 - 12.0	17.53	15.28	14.92	15.77	15.11	16.68
Maximum 3-day mean	14.0 - 19.0	21.54	19.23	19.52	21.93	23.42	22.30
Maximum 7-day mean	13.0 - 17.0	20.64	18.62	18.37	21.05	22.01	20.67
Maximum 7-day mean of daily maximums	15.0 - 23.5	23.66	21.23	21.76	24.11	29.89	23.56
Hours over 19°C	57.8	930.50	198.50	350.00	365.75	713.50	690.75
Percent of Time over 19°C	4%	0.63	0.13	0.24	0.25	0.48	0.46
Frequency of Exceedance over 19°C (Days/yr)	9.8	61.00	28.00	46.00	35.00	57.00	55.00
Average Duration of Event Over 19°C (h)	5.6	19.80	7.09	7.61	11.43	12.30	14.70
Hours over 22°C		142.75	2.50	28.00	62.25	352.00	138.50
Percent of Time over 22°C		0.10	0.00	0.02	0.04	0.24	0.09
Frequency of Exceedance over 22°C (Days/yr)		22.00	1.00	6.00	9.00	41.00	18.00
Average Duration of Event Over 22°C (h)		4.11	1.38	2.87	4.45	4.90	7.69
Hours over 24°C	0.8	24.25	0.00	0.00	18.00	207.00	16.25
Percent of Time over 24°C	0.06%	0.02	0.00	0.00	0.01	0.14	0.01
Frequency of 24°C Exceedance (Days/yr)		4.00	0.00	0.00	4.00	30.00	4.00
Average Duration of Event Over 24°C (h)		6.06	0.00	0.00	4.50	6.27	4.06

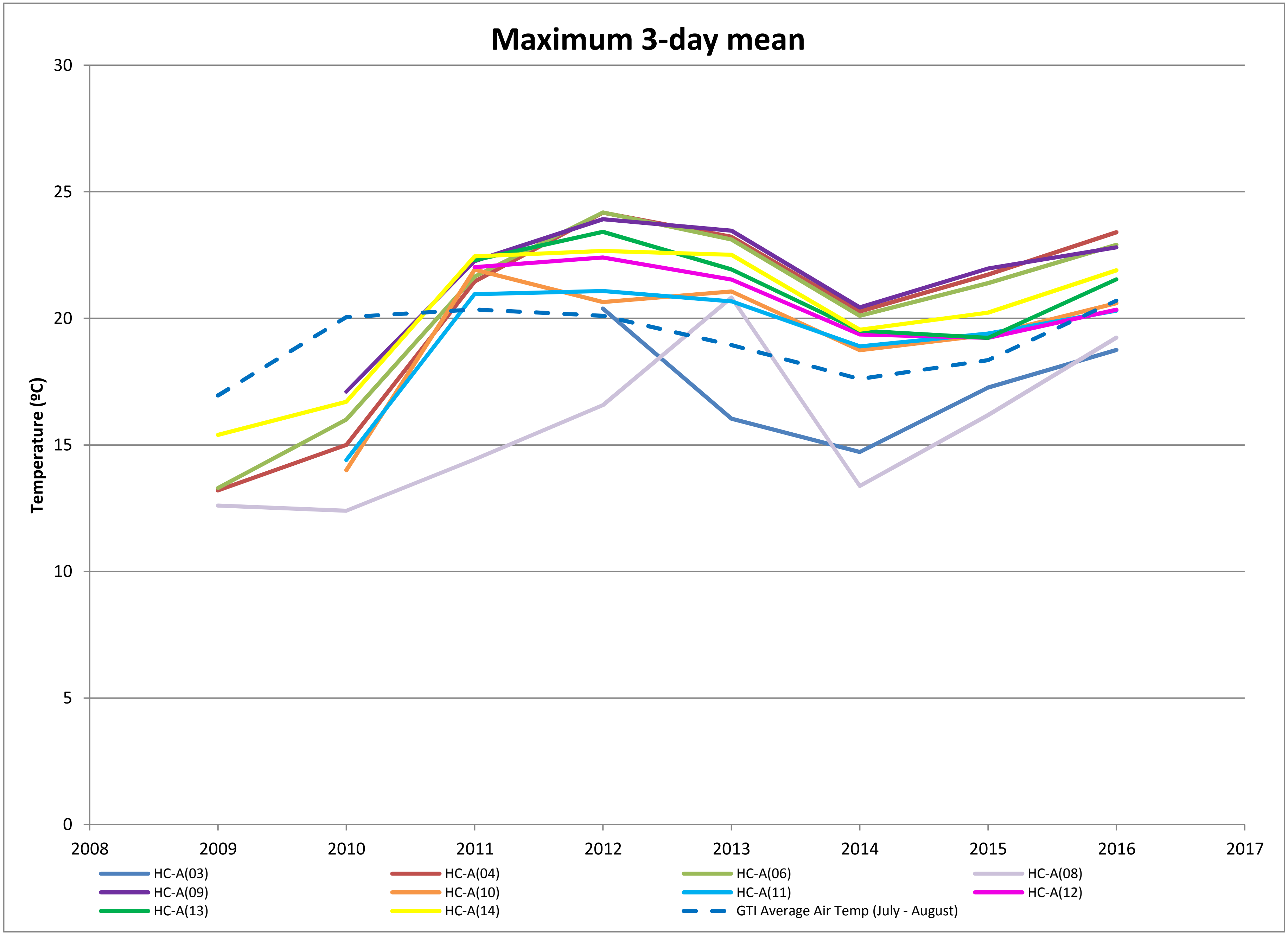
Station	**HC-A(14)**								
Year	**Modeled**	**2016**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2009**
Summer (July-August) average maximum	14.5 - 19.9	22.68	20.44	20.41	20.65	22.79	21.36	20.9	18.6
Summer July-August) average	12.5 - 14.5	19.69	17.60	17.35	18.28	19.40	19.00	17.5	16.1
Summer (July-August) average minimum	9.0 - 12.0	16.74	15.13	14.78	16.24	16.66	16.84	14.6	13.8
Maximum 3-day mean	14.0 - 19.0	21.90	20.23	19.55	22.51	22.67	22.45	16.7	15.4
Maximum 7-day mean	13.0 - 17.0	20.99	19.57	18.46	21.65	21.45	20.86	15.8	14.8
Maximum 7-day mean of daily maximums	15.0 - 23.5	24.70	23.31	22.43	24.66	26.40	23.78	18.3	17.8
Hours over 19°C	130.7	927.75	431.00	383.00	578.50	778.50	741.25	422.25	187
Percent of Time over 19°C	9%	0.62	0.29	0.26	0.39	0.52	0.50	0.28	12.57
Frequency of Exceedance over 19°C (Days/yr)	26.8	62.00	49.00	50.00	50.00	55.00	56.00	49	29
Average Duration of Event Over 19°C (h)	4.3	18.56	8.98	7.37	13.15	16.56	12.15	8.6	6.2
Hours over 22°C		260.00	59.00	41.00	86.50	287.25	157.75	95	0.5
Percent of Time over 22°C		0.17	0.04	0.03	0.06	0.19	0.11	0.06	0.00
Frequency of Exceedance over 22°C (Days/yr)		37.00	14.00	9.00	11.00	37.00	19.00	20	1
Average Duration of Event Over 22°C (h)		4.57	2.91	4.50	5.15	5.09	8.30	4.75	0.5
Hours over 24°C	3.2	59.00	3.25	3.00	26.75	113.50	28.00	25.75	0
Percent of Time over 24°C	0.21%	0.04	0.00	0.00	0.02	0.08	0.02	0.00	0
Frequency of 24°C Exceedance (Days/yr)		12.00	1.00	1.00	5.00	24.00	9.00	5	0
Average Duration of Event Over 24°C (h)		4.54	3.25	1.50	5.35	4.37	2.15	5.15	0

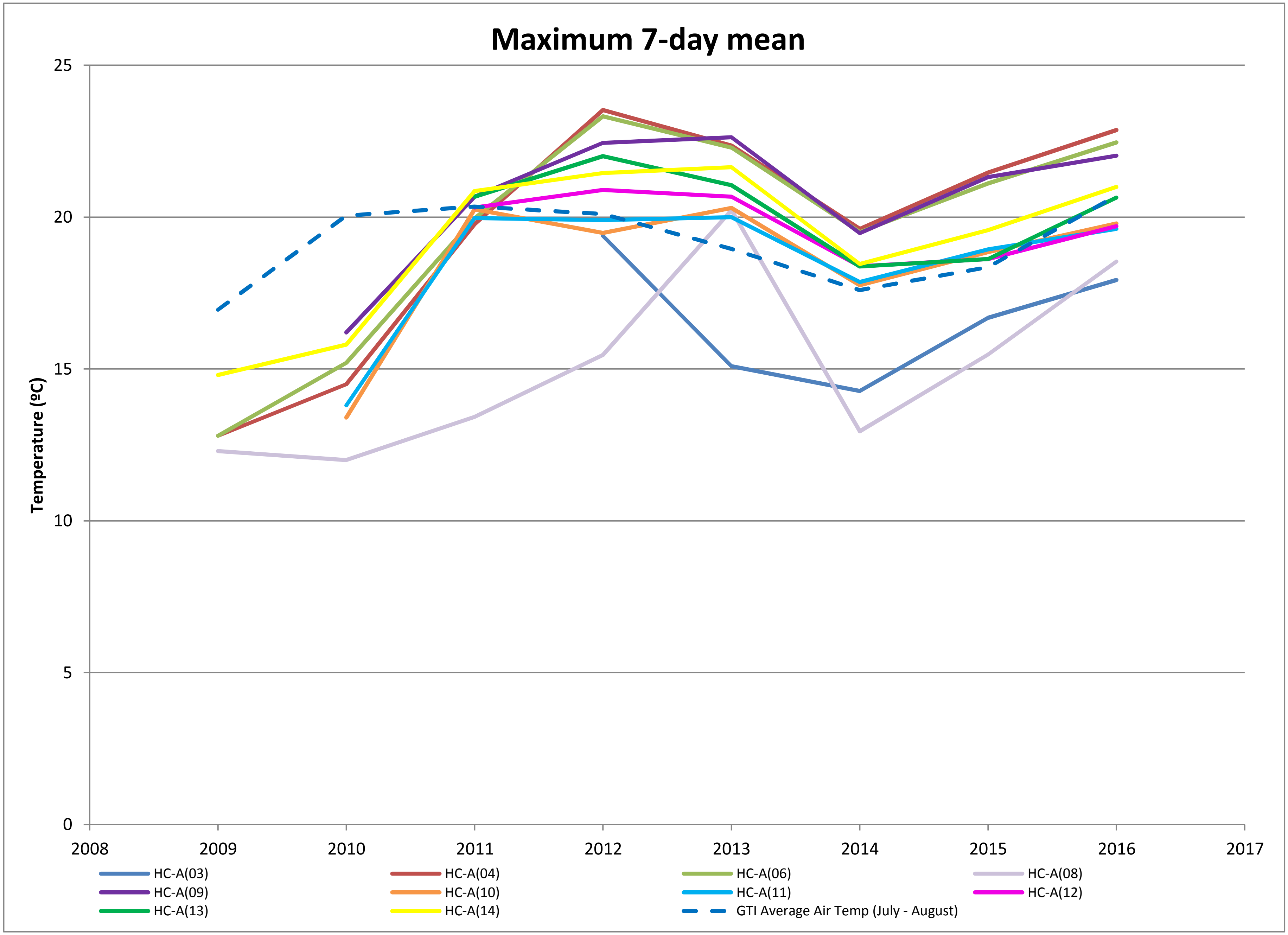

Summer (July-August) average maximum
Temperature (ºC)
30
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

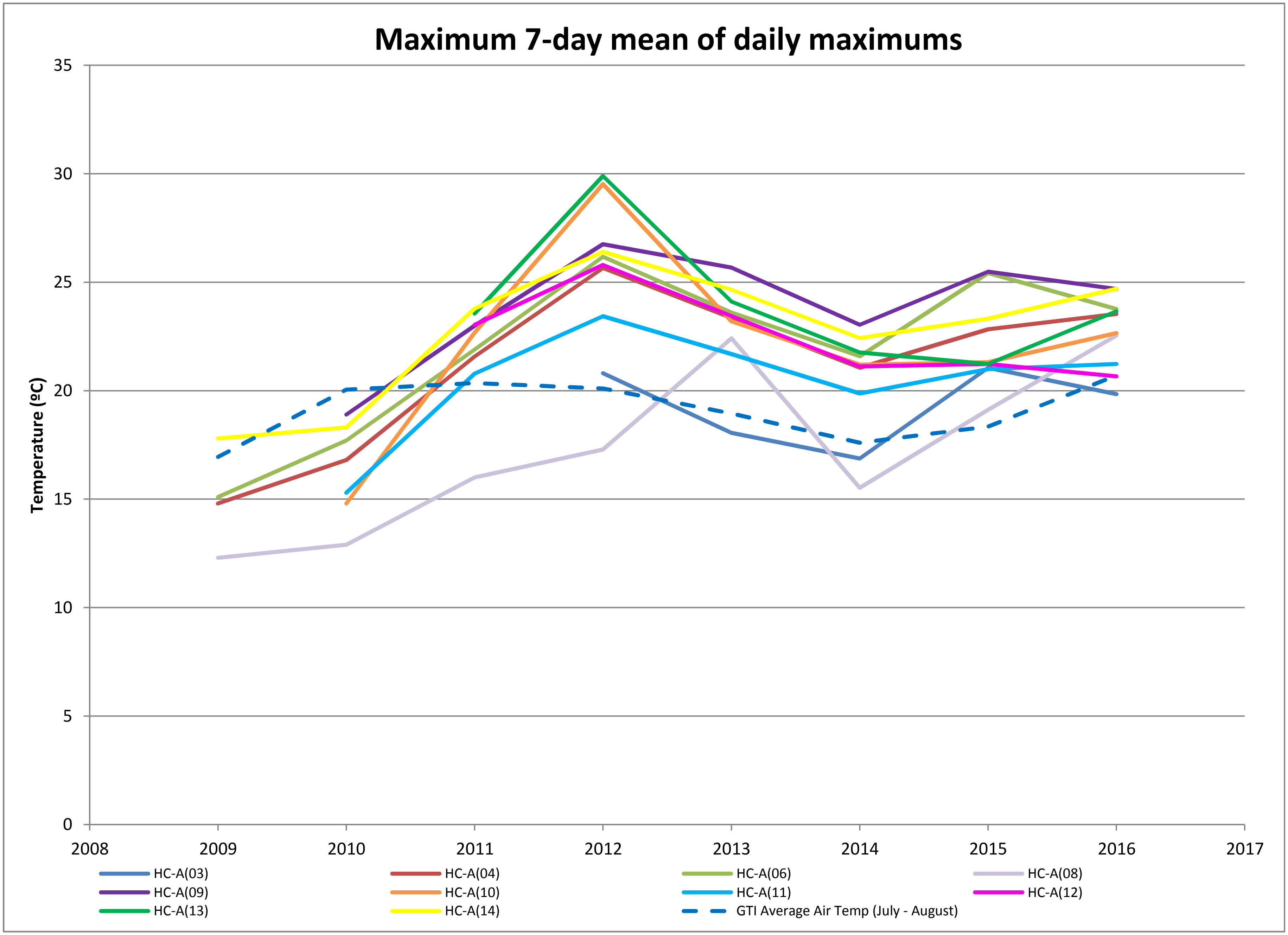


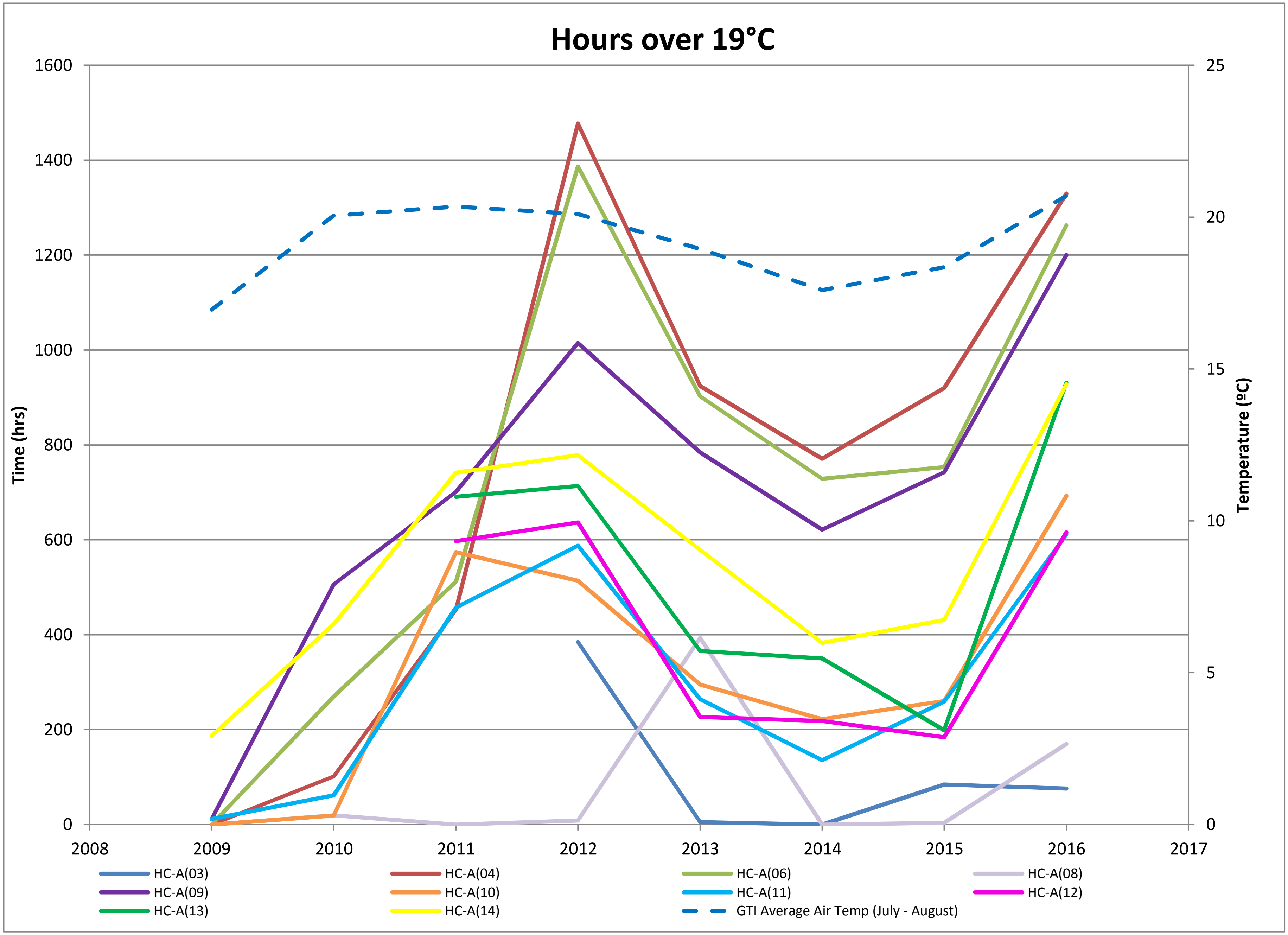
Summer (July-August) average
Temperature (ºC)
0
5
10
15
20
25
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

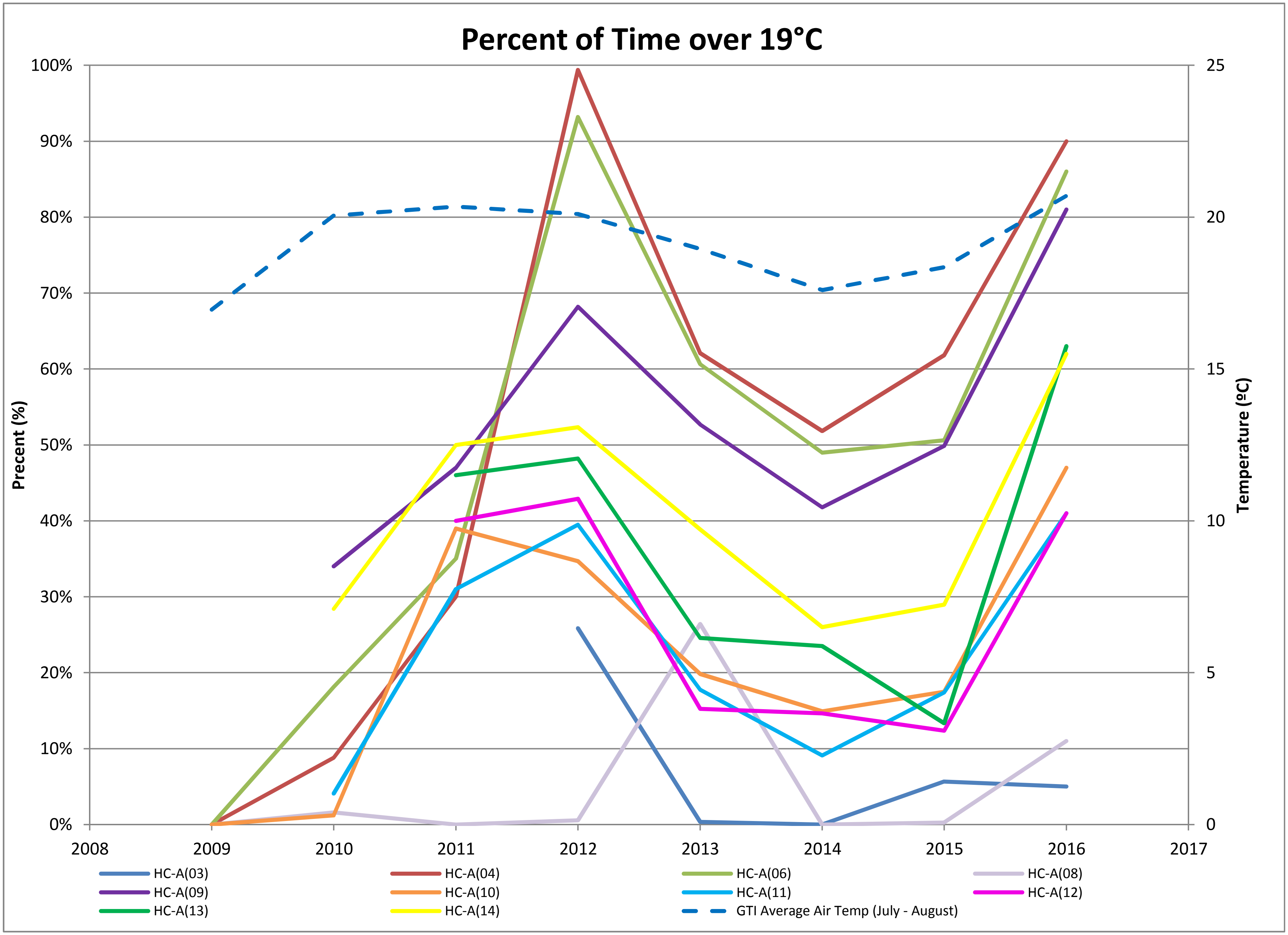

Summer (July-August) average minimum
Temperature (ºC)
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

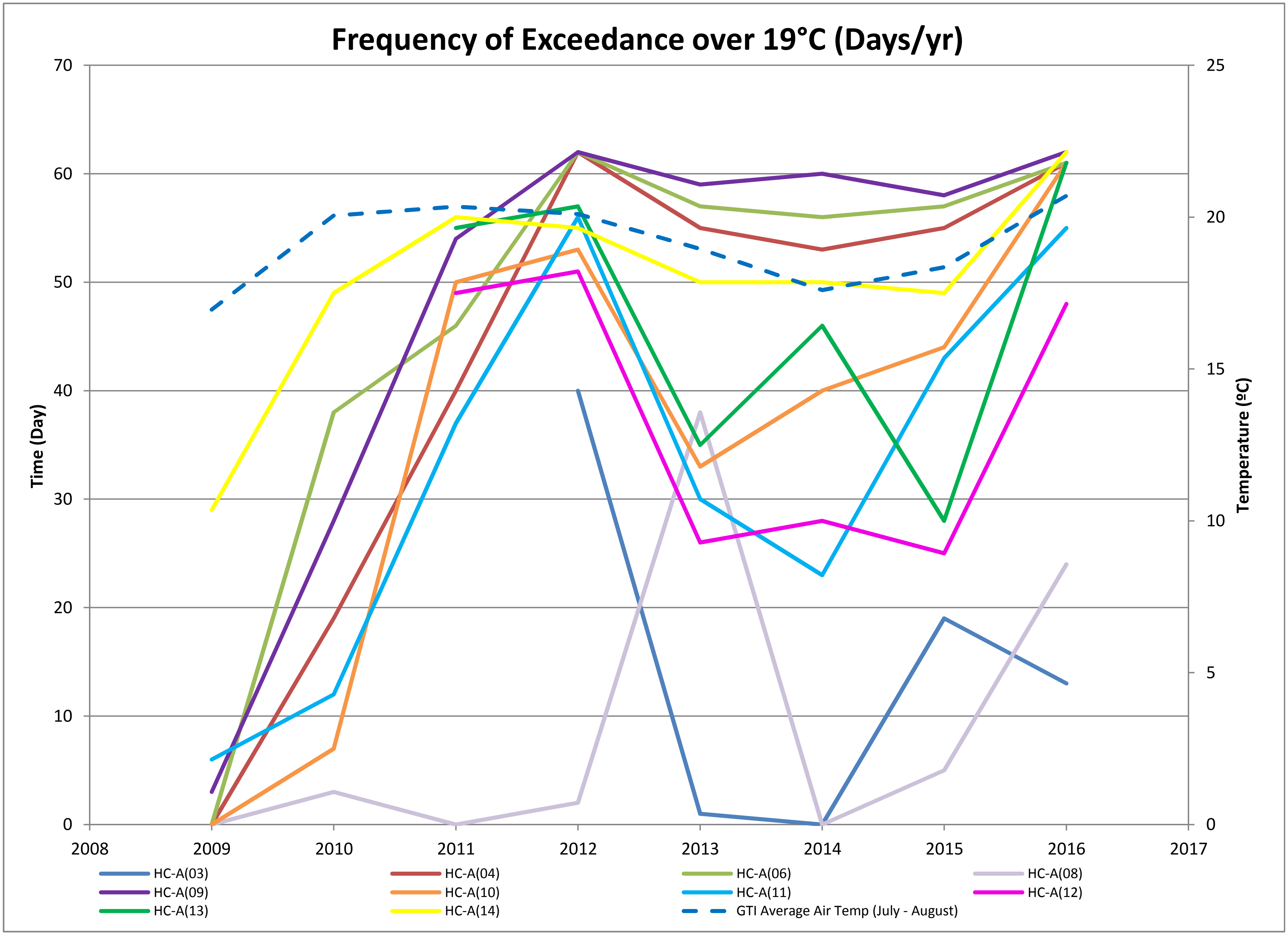

Maximum 3-day mean
Temperature (ºC)
30
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

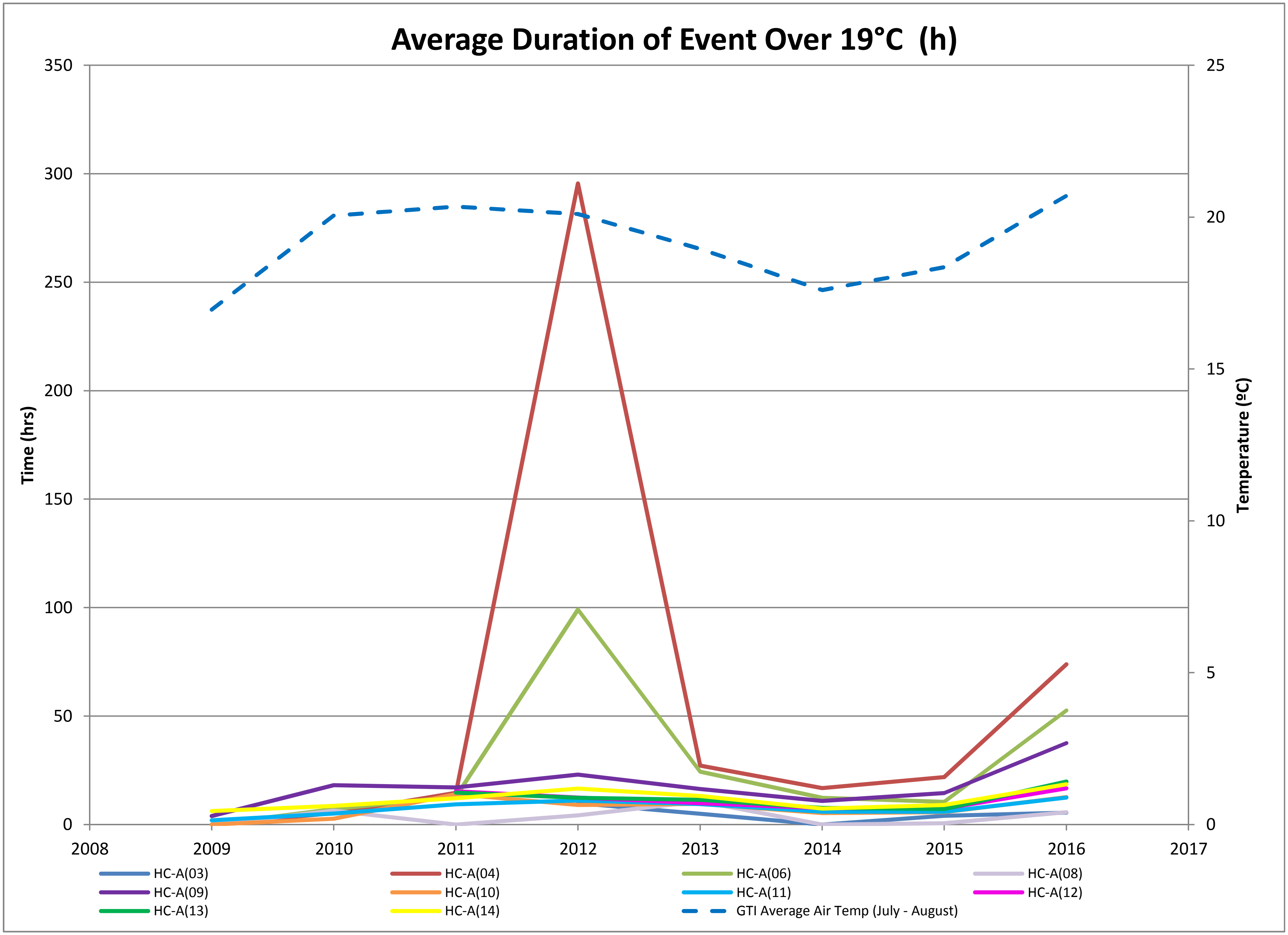

Maximum 7-day mean
Temperature (ºC)
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)


Maximum 7-day mean of daily maximums
Temperature (ºC)
35
30
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

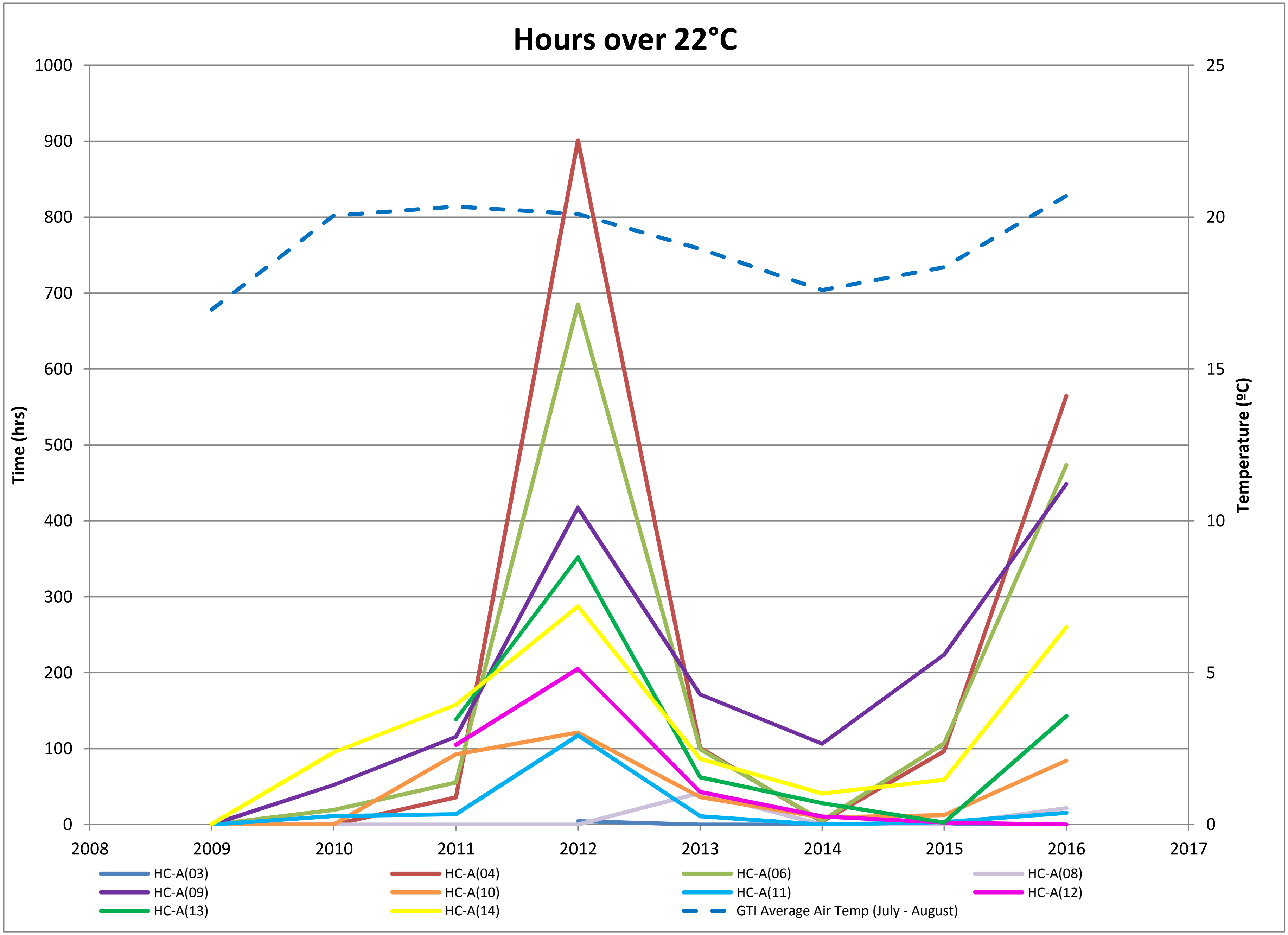

Hours over 19°C
Time (hrs)
1600
1400
1200
1000
800
600
400
200
0
Temperature (ºC)
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

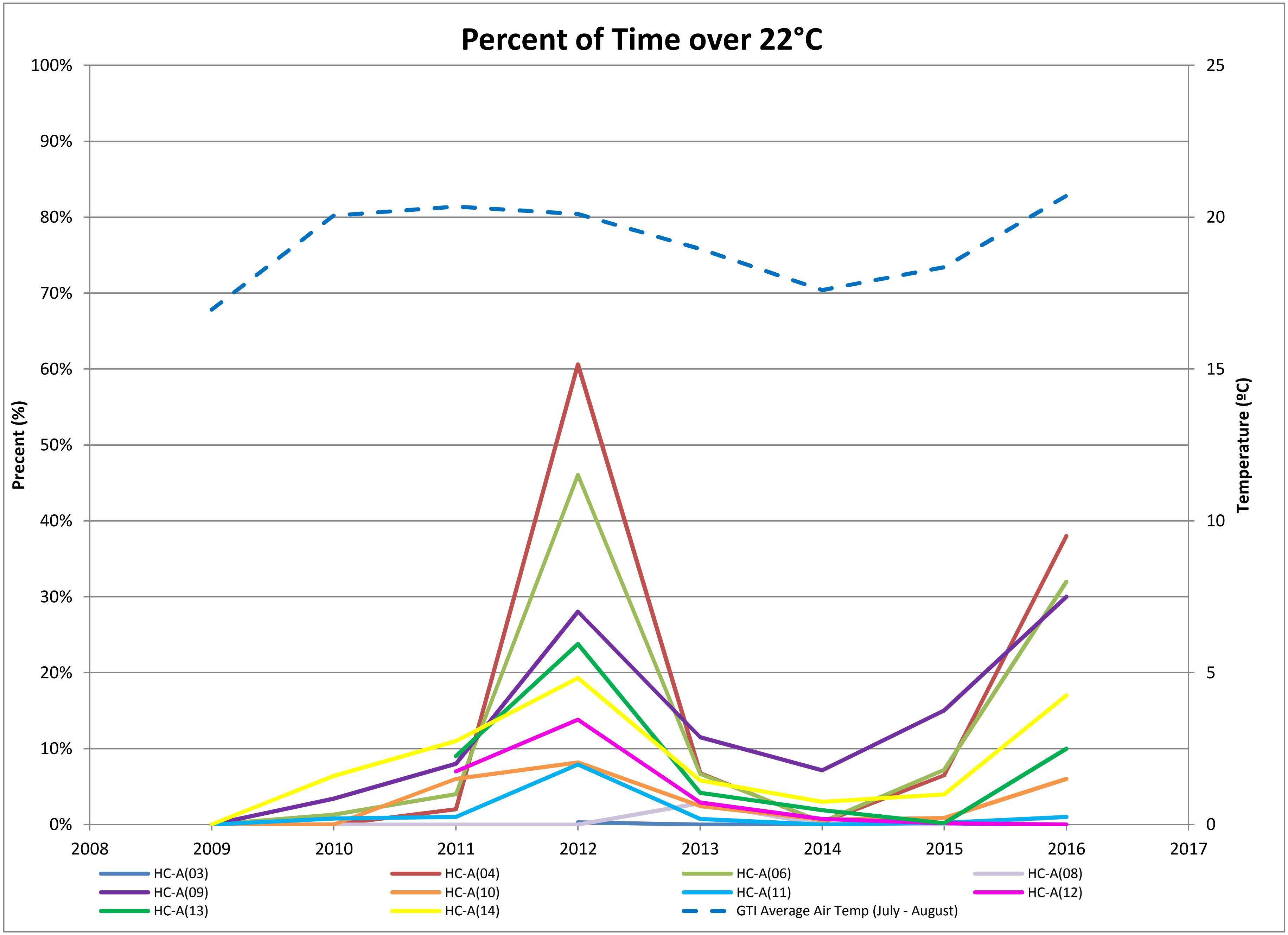

Percent of Time over 19°C
Precent (%)
Temperature (ºC)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

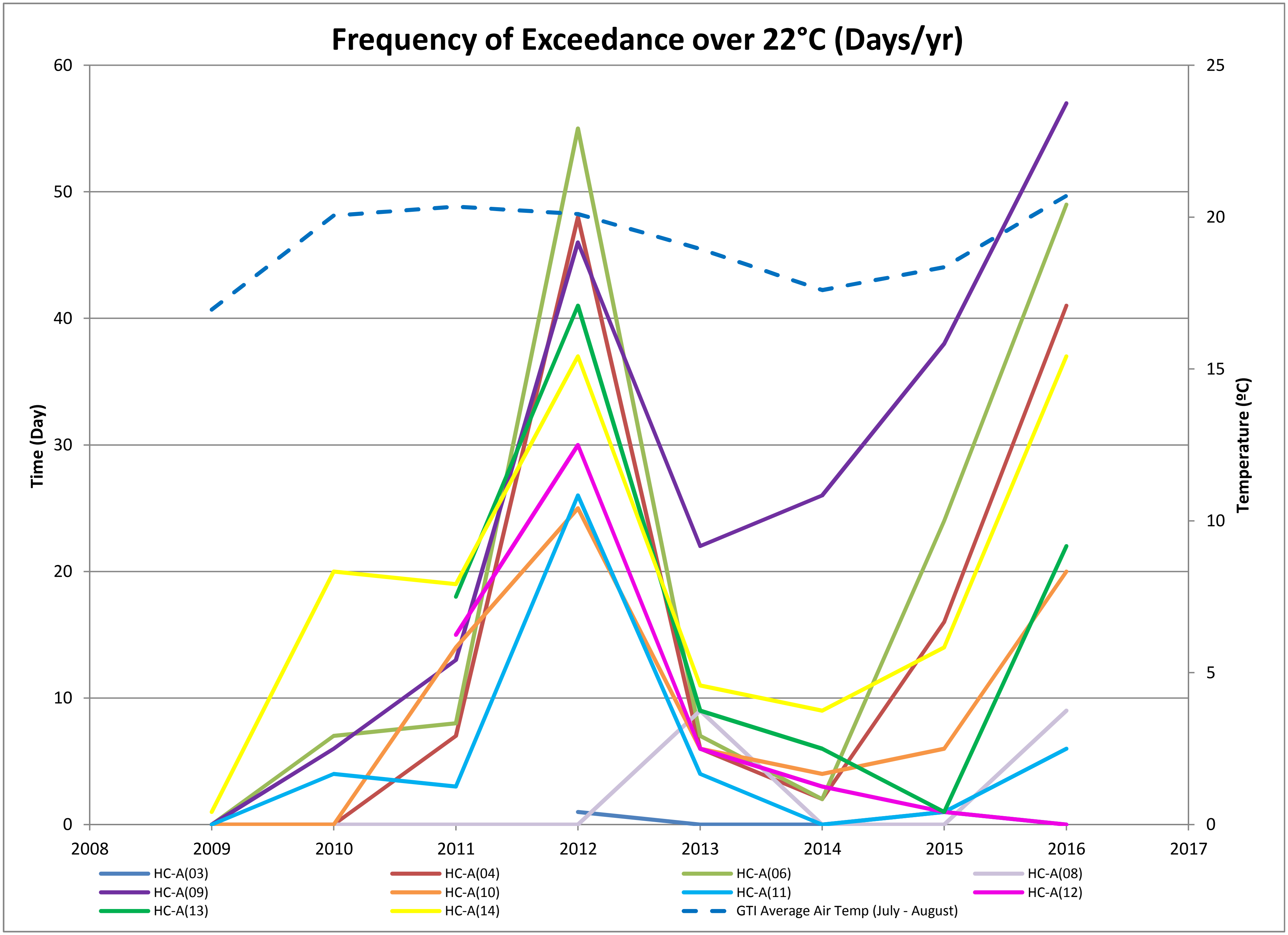

Frequency of Exceedance over 19°C (Days/yr)
Time (Day)
Temperature (ºC)
70
60
50
40
30
20
10
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

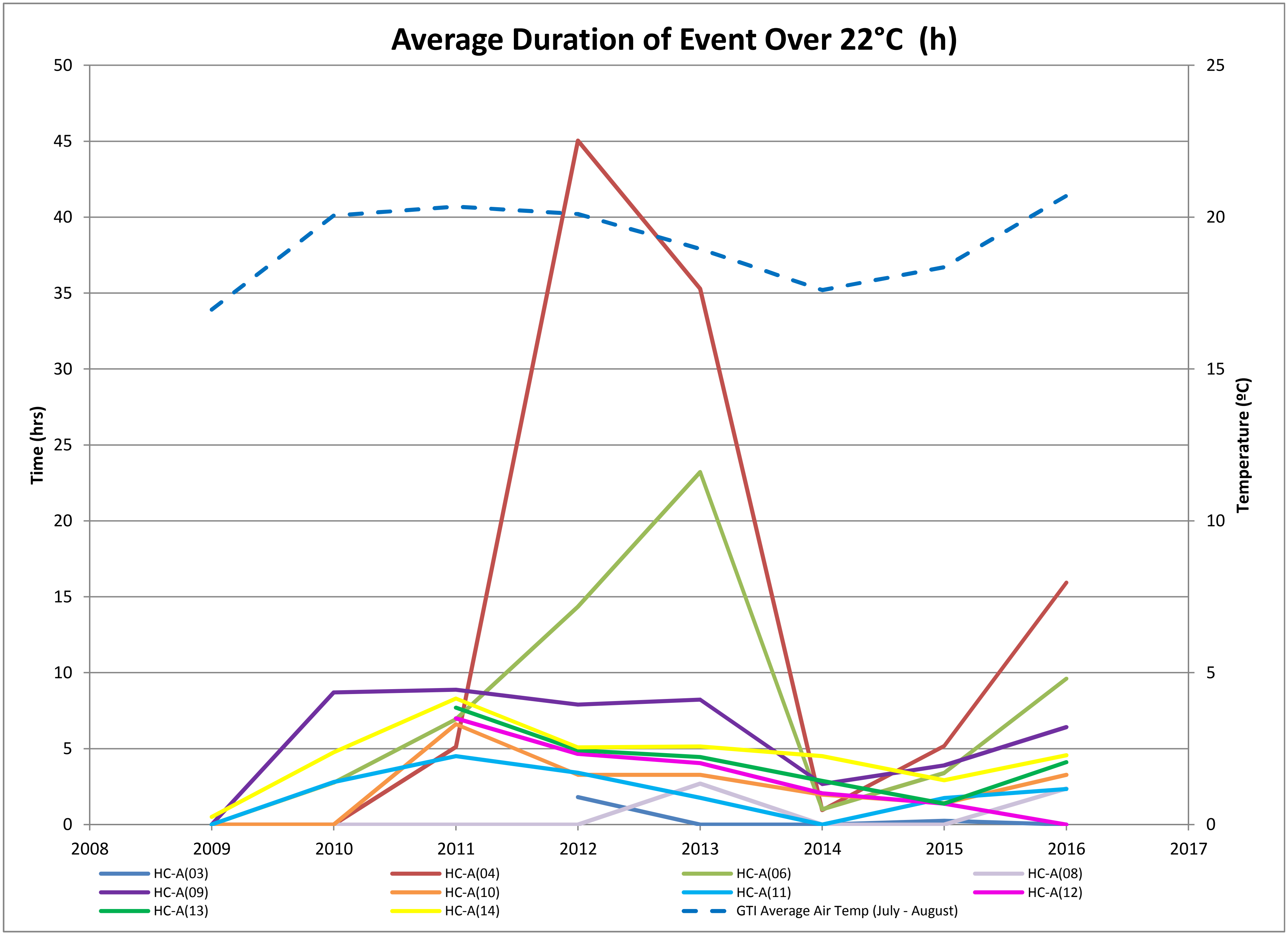


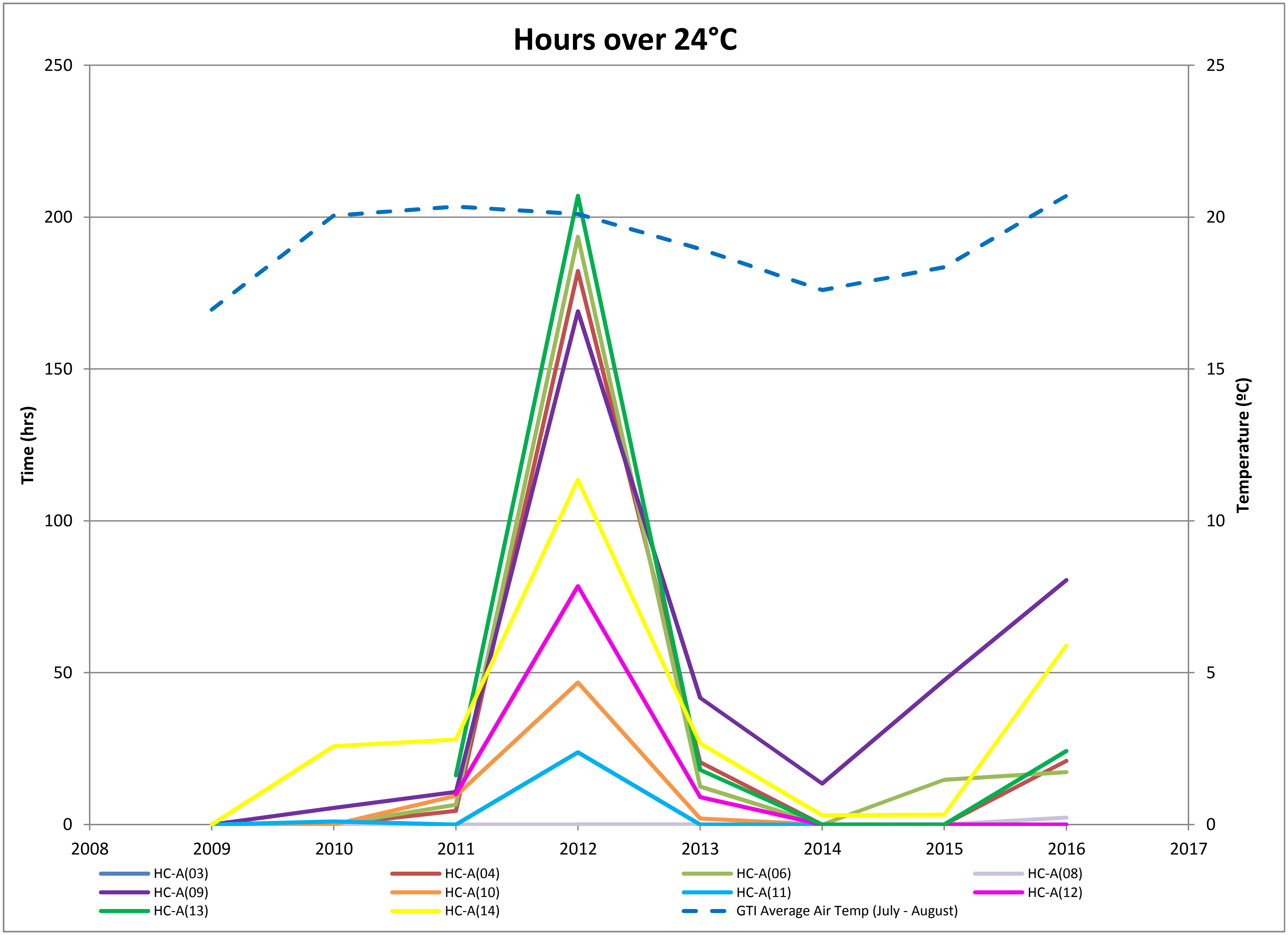
Average Duration of Event Over 19°C (h)
Time (hrs)
Temperature (ºC)
350
300
250
200
150
100
50
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

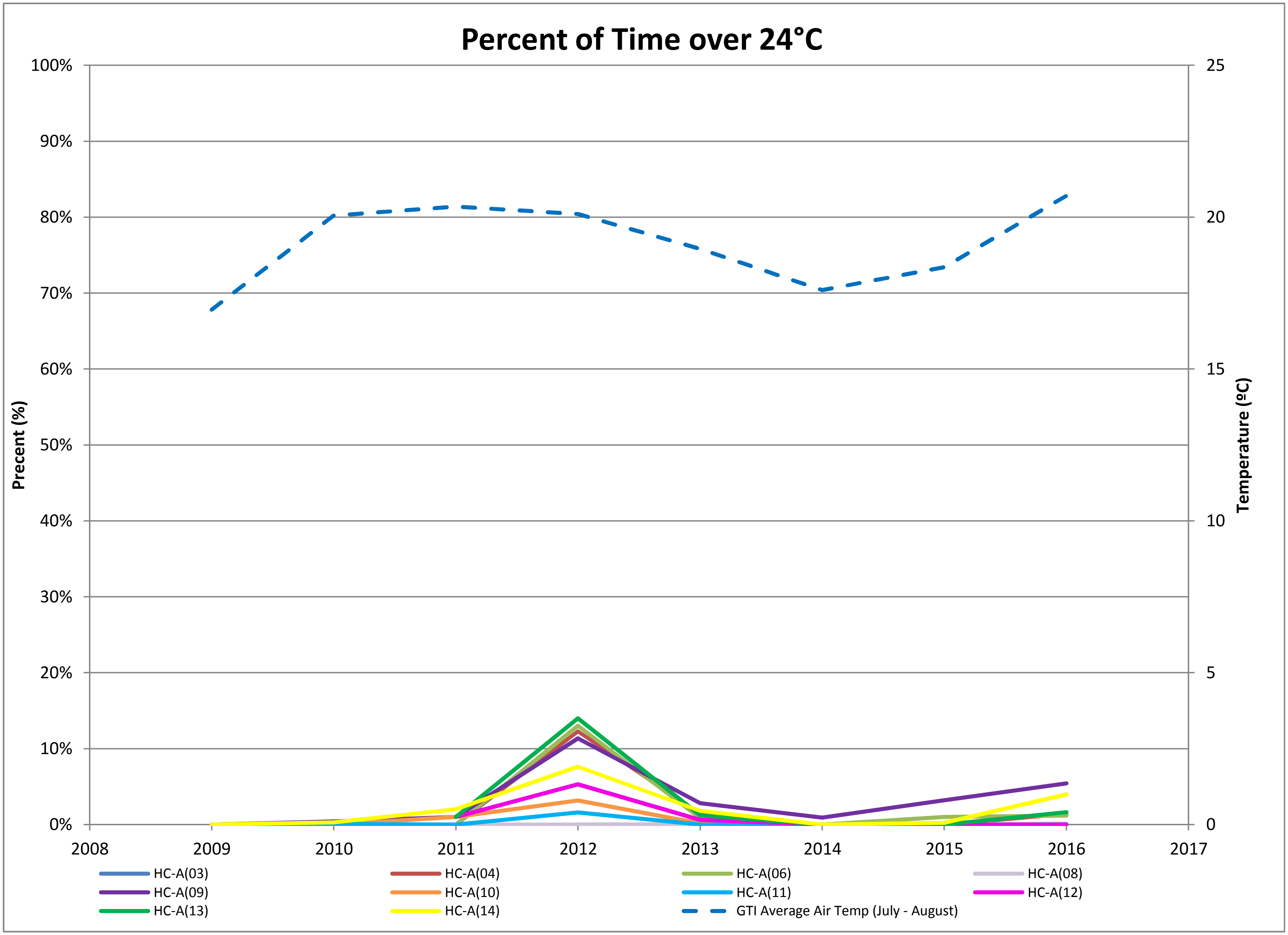

Hours over 22°C
Time (hrs)
Temperature (ºC)
1000
900
800
700
600
500
400
300
200
100
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

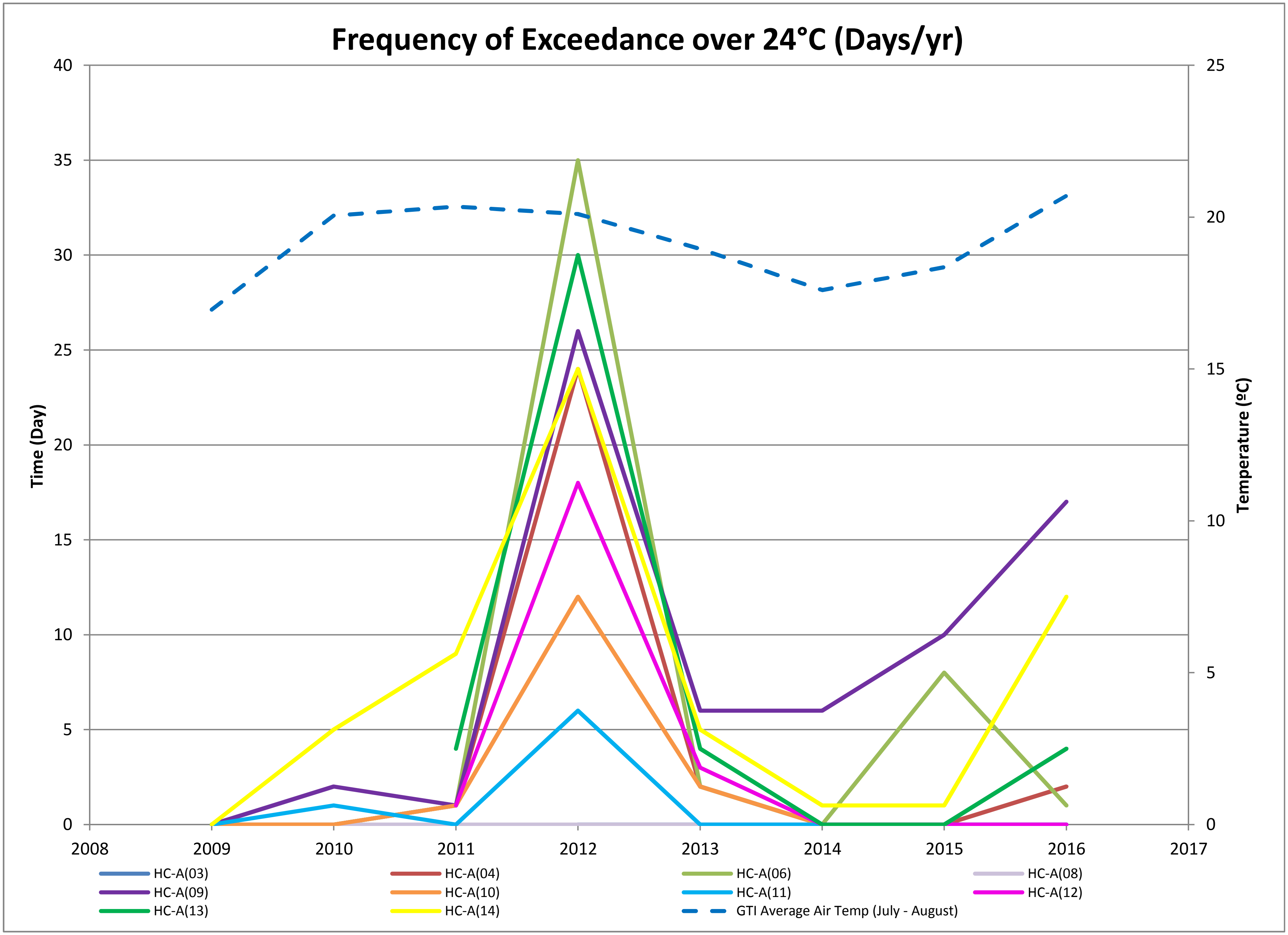

Percent of Time over 22°C
Precent (%)
Temperature (ºC)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

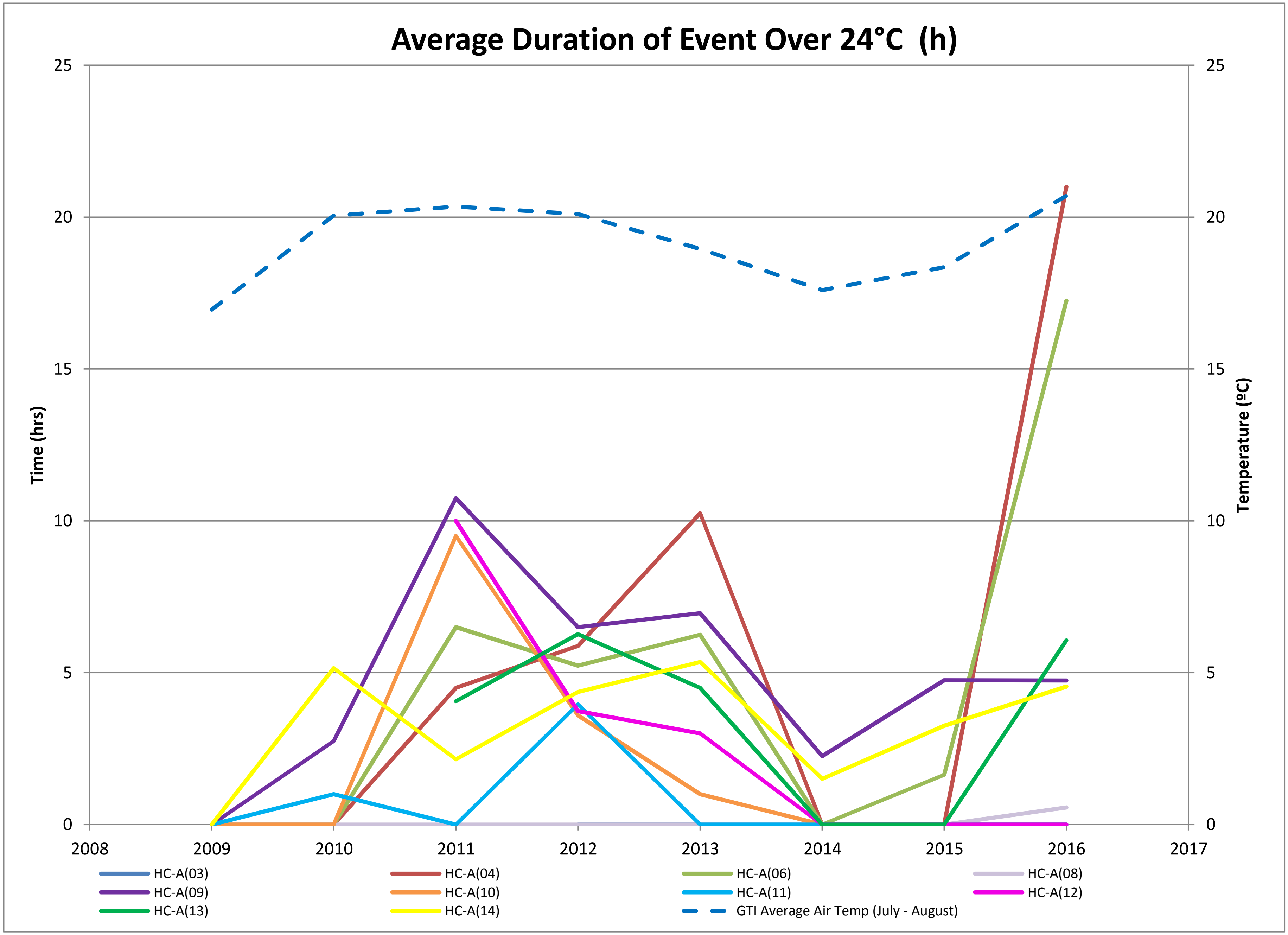

Frequency of Exceedance over 22°C (Days/yr)
Time (Day)
Temperature (ºC)
60
50
40
30
20
10
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)


Average Duration of Event Over 22°C (h)
Time (hrs)
Temperature (ºC)
50
45
40
35
30
25
20
15
10
5
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)


Hours over 24°C
Time (hrs)
Temperature (ºC)
250
200
150
100
50
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

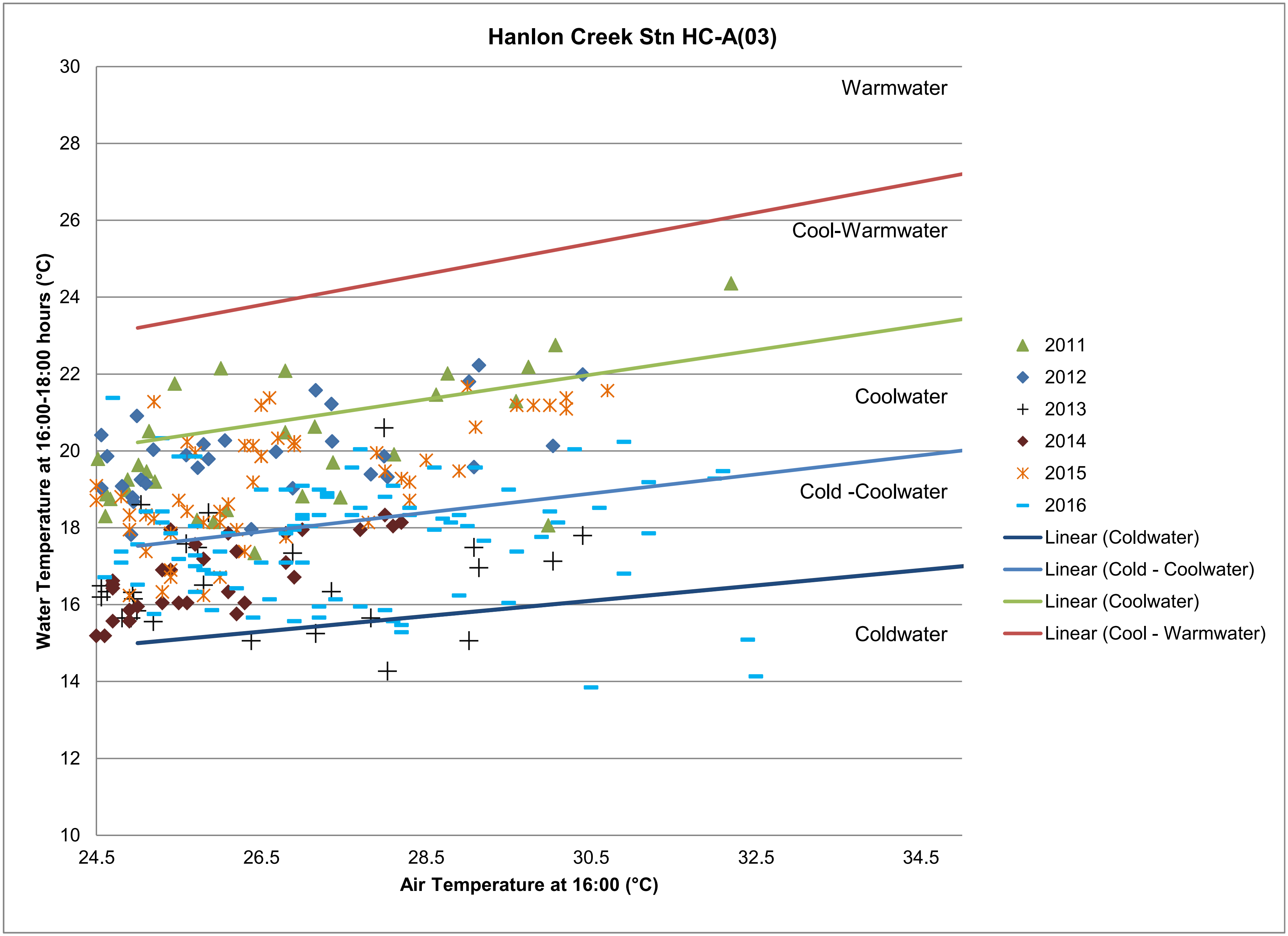

Percent of Time over 24°C
Precent (%)
Temperature (ºC)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

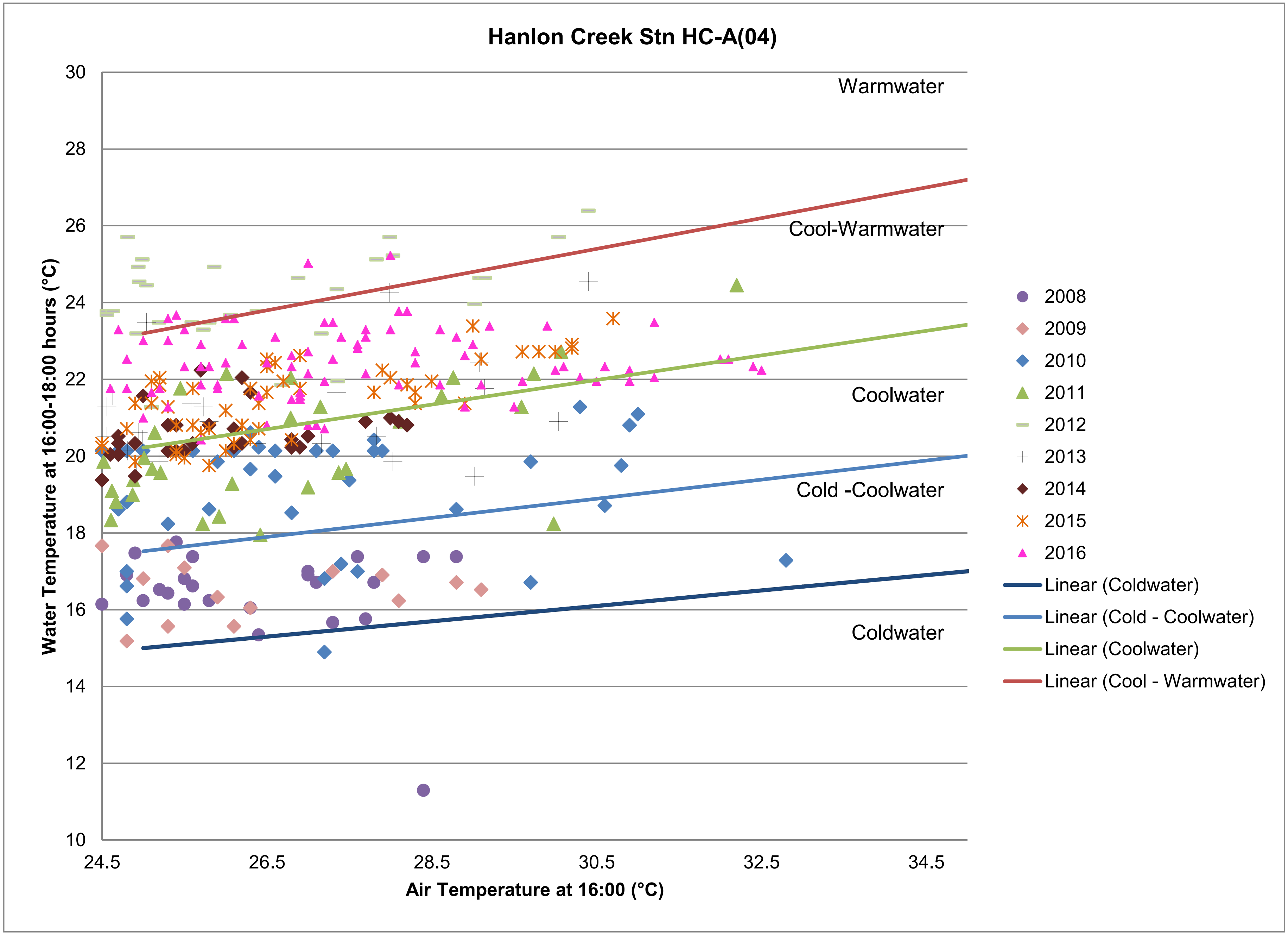

Frequency of Exceedance over 24°C (Days/yr)
Time (Day)
Temperature (ºC)
40
35
30
25
20
15
10
5
0
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)


Average Duration of Event Over 24°C (h)
Time (hrs)
Temperature (ºC)
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
HC-A(03)
HC-A(04)
HC-A(06)
HC-A(08)
HC-A(09)
HC-A(10)
HC-A(11)
HC-A(12)
HC-A(13)
HC-A(14)
GTI Average Air Temp (July - August)

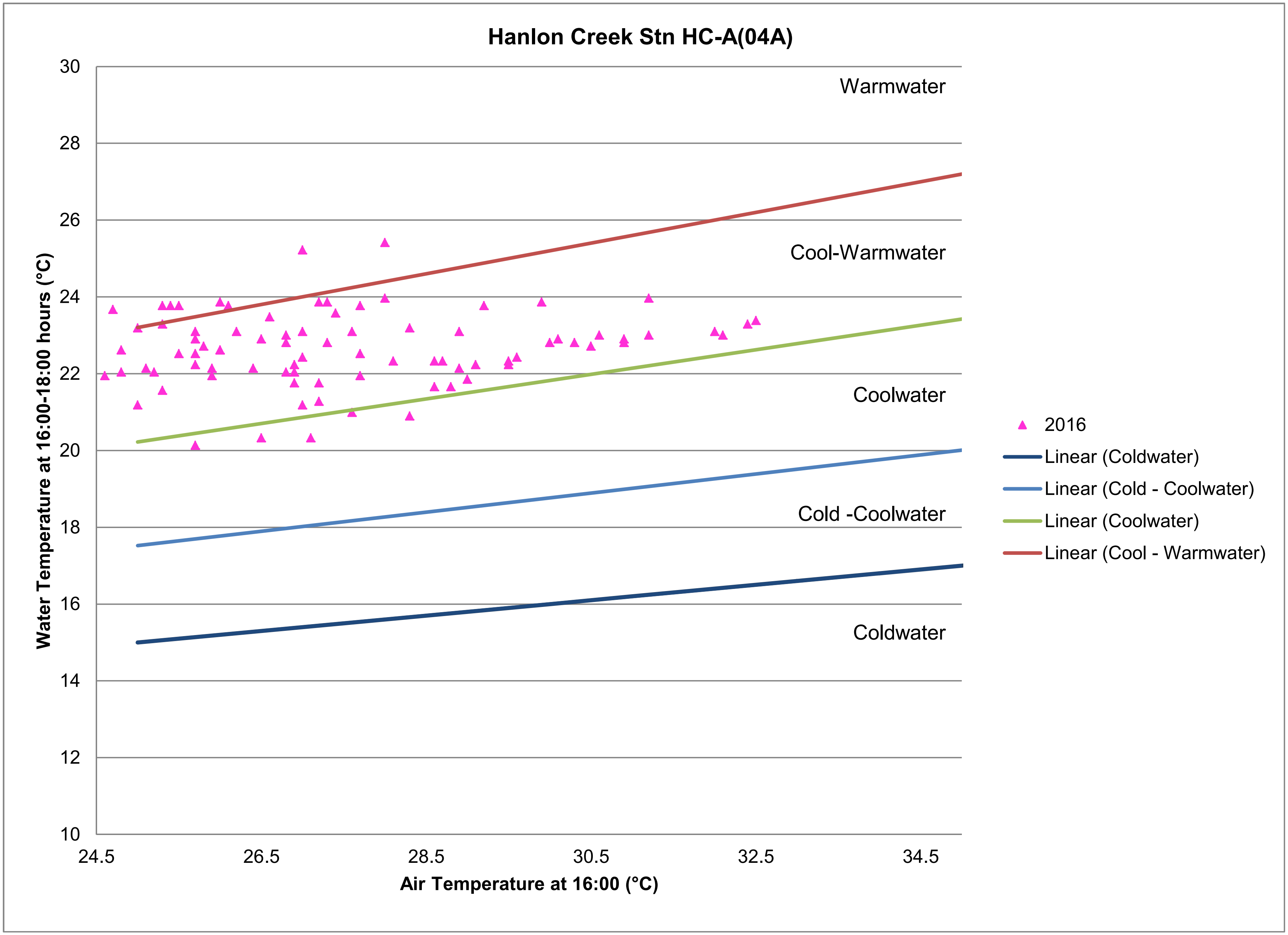
Appendix D

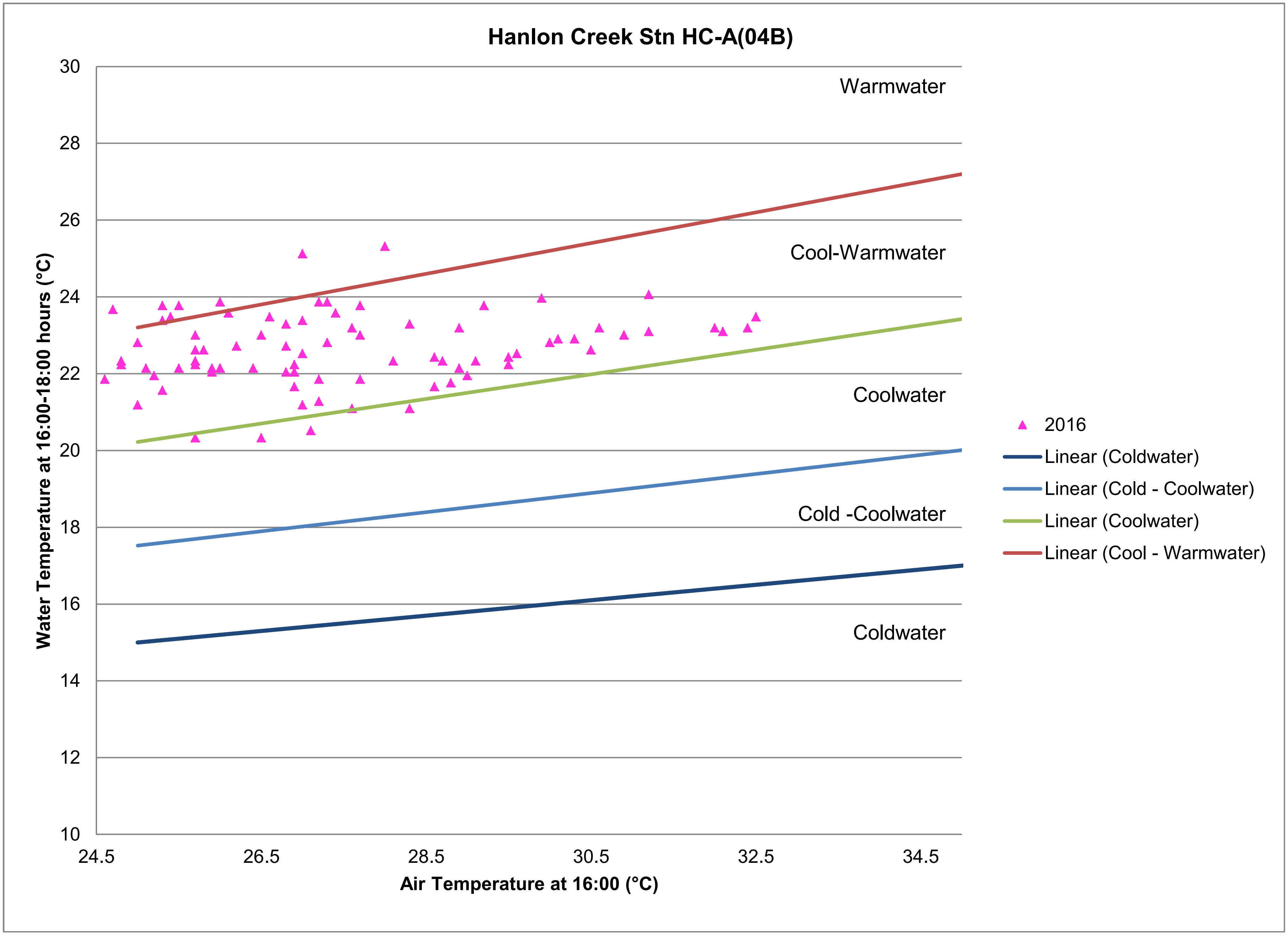
Thermal Regime Classification

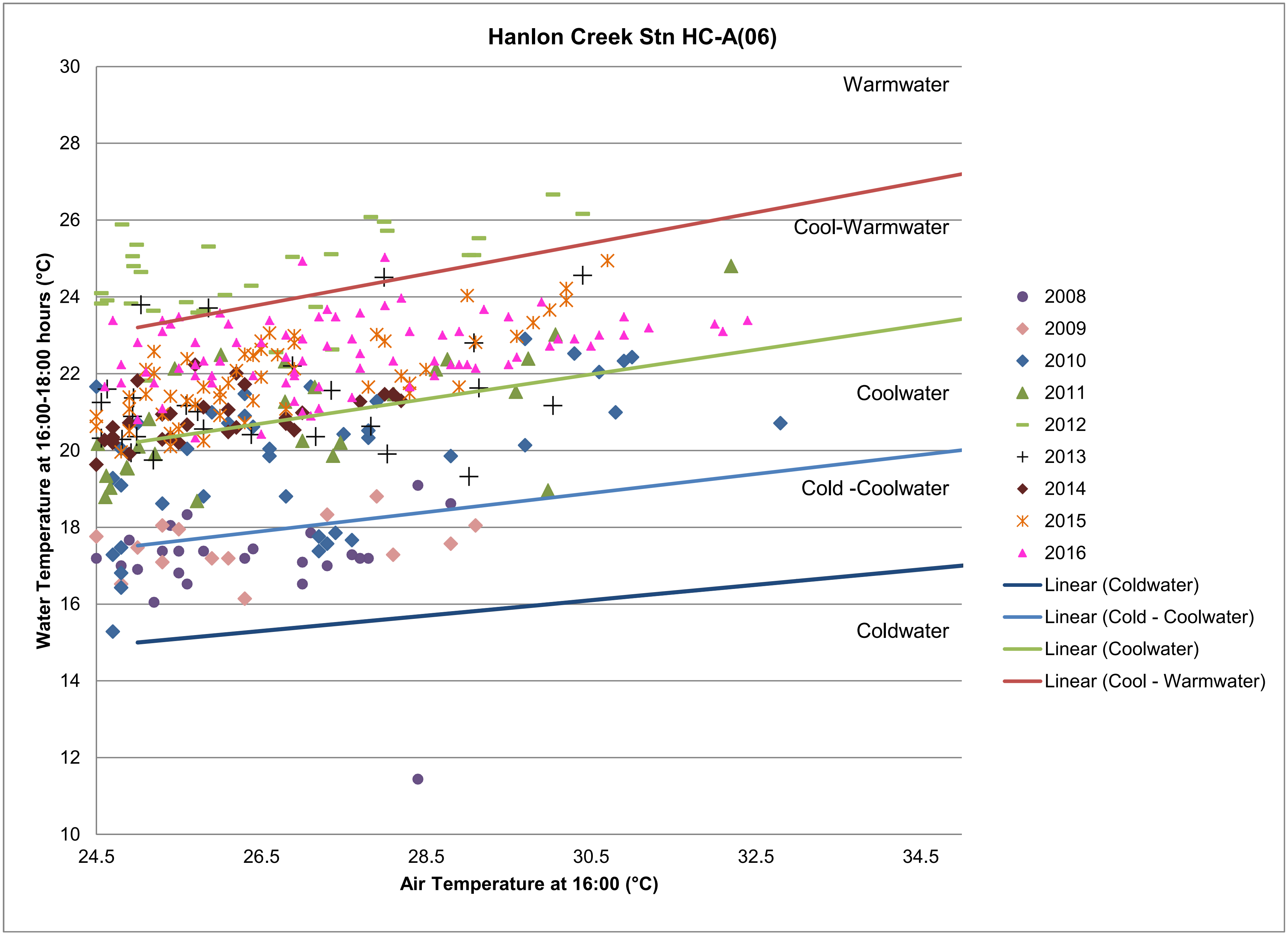

Hanlon Creek Stn HC-A(03)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

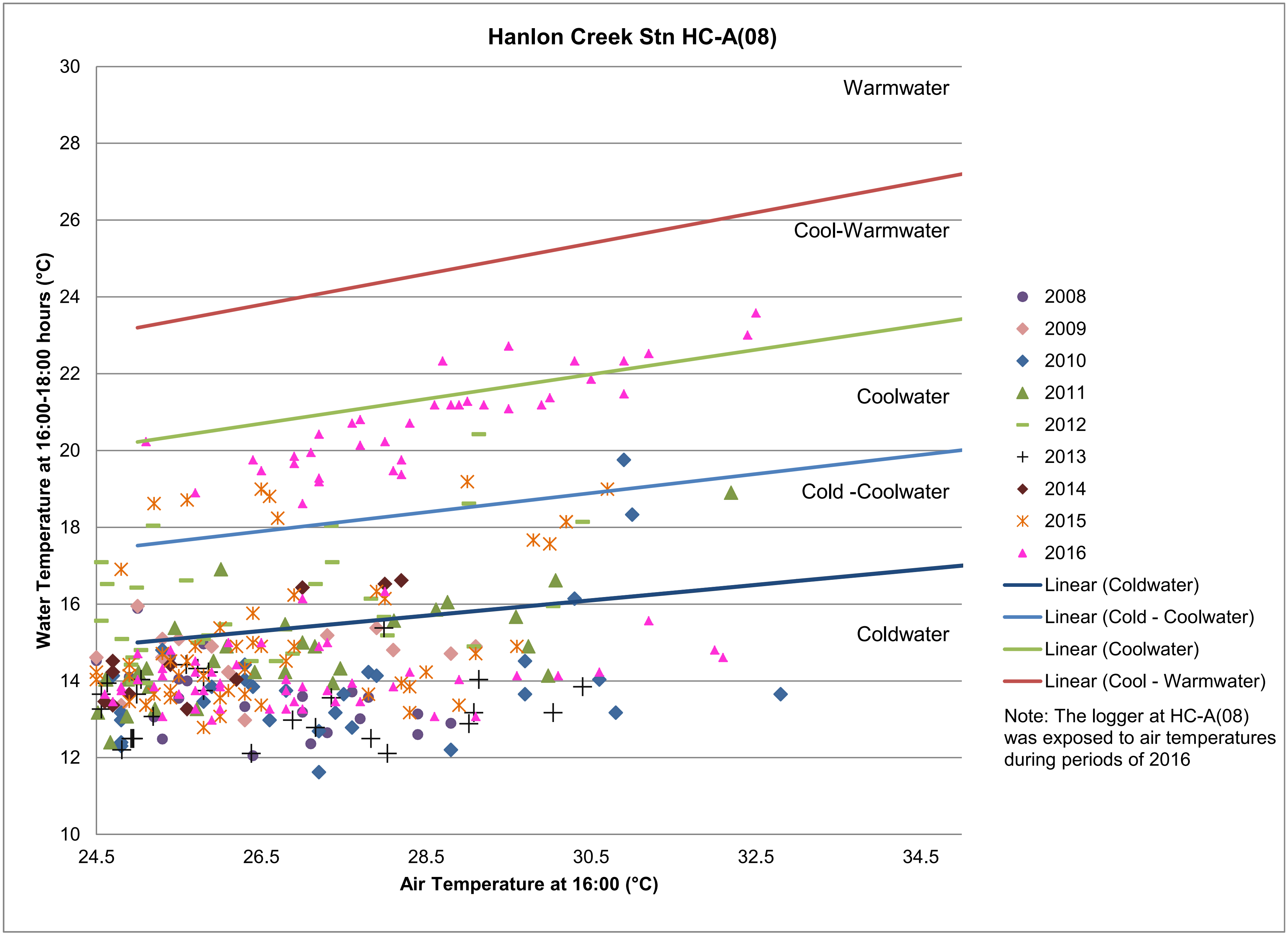


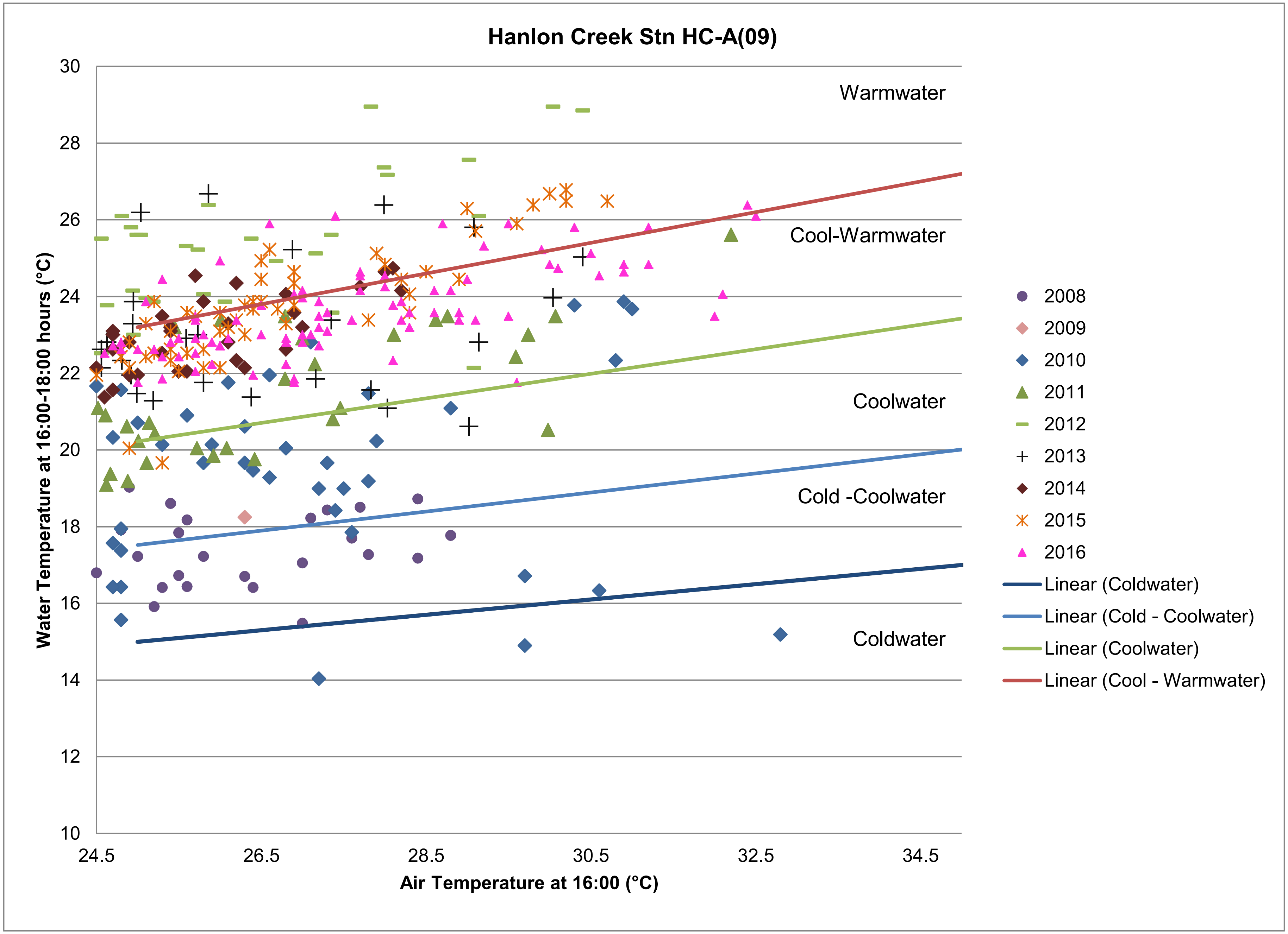
Hanlon Creek Stn HC-A(04)
Water Temperature at 16:00-18:00 hours (°C)
Air Temperature at 16:00 (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

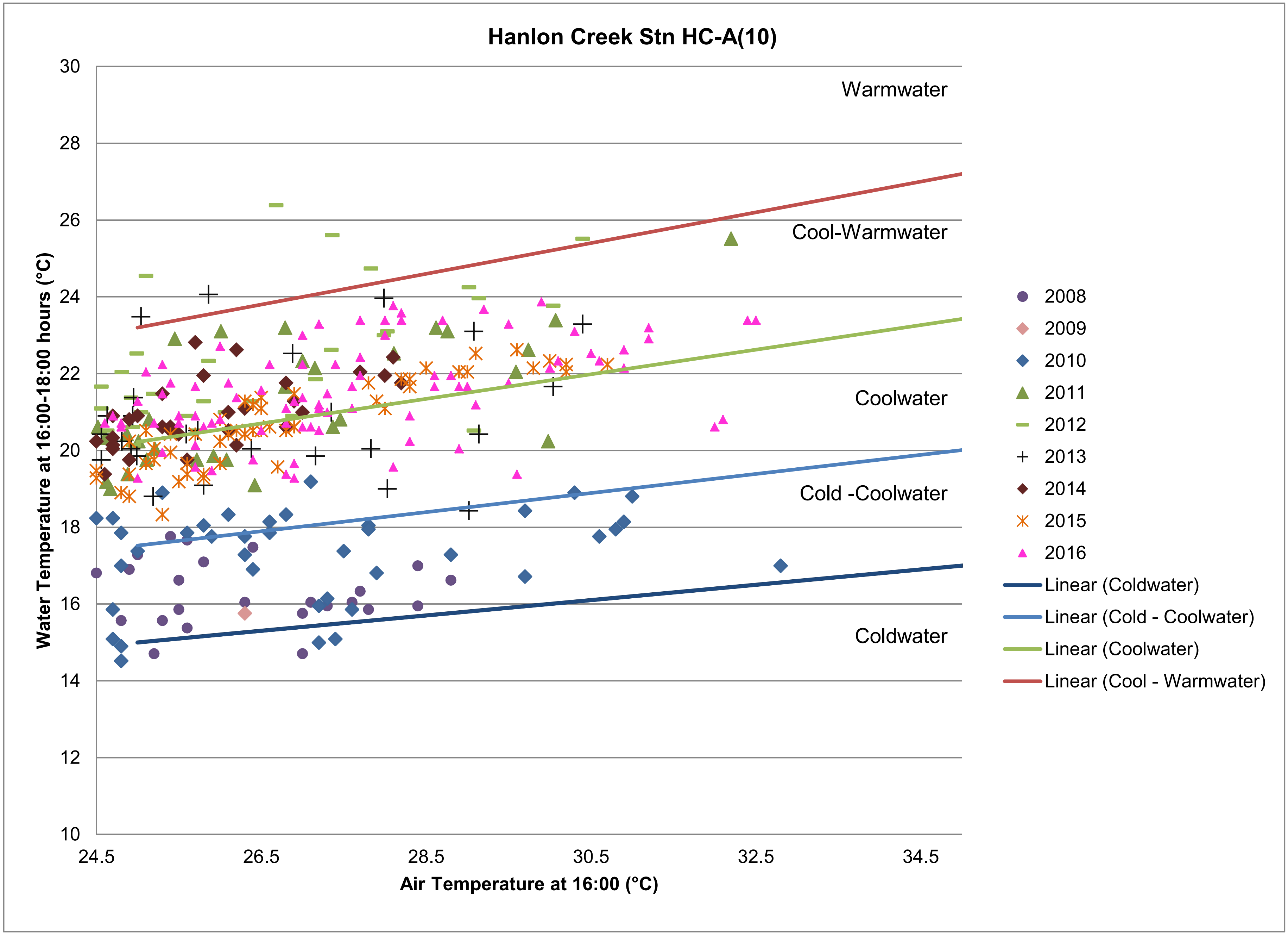

Hanlon Creek Stn HC-A(04A)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)


Hanlon Creek Stn HC-A(04B)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

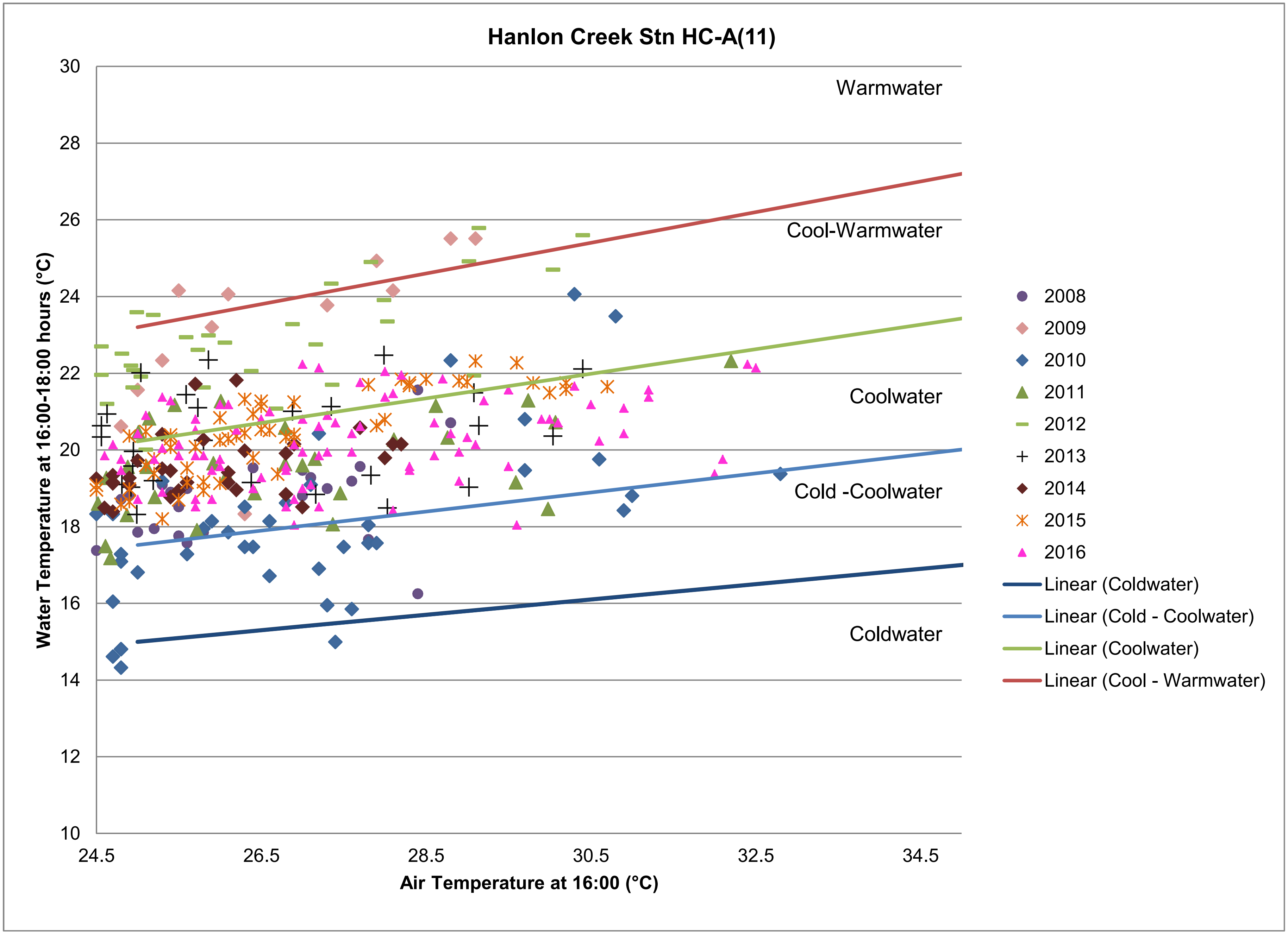

Hanlon Creek Stn HC-A(06)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

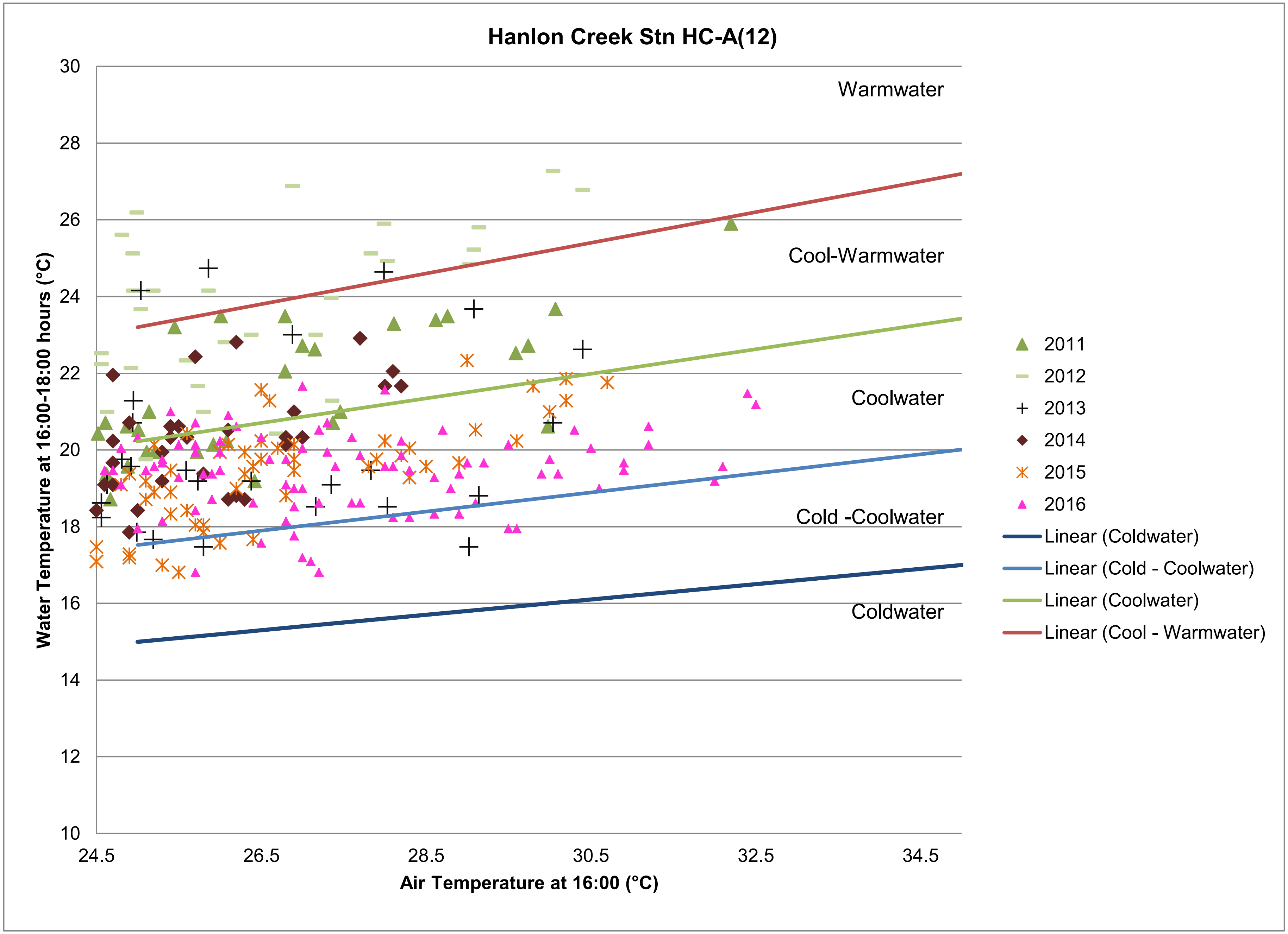

Hanlon Creek Stn HC-A(08)
Water Temperature at 16:00-18:00 hours (°C)
Air Temperature at 16:00 (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)
Note: The logger at HC-A(08) was exposed to air temperatures during periods of 2016

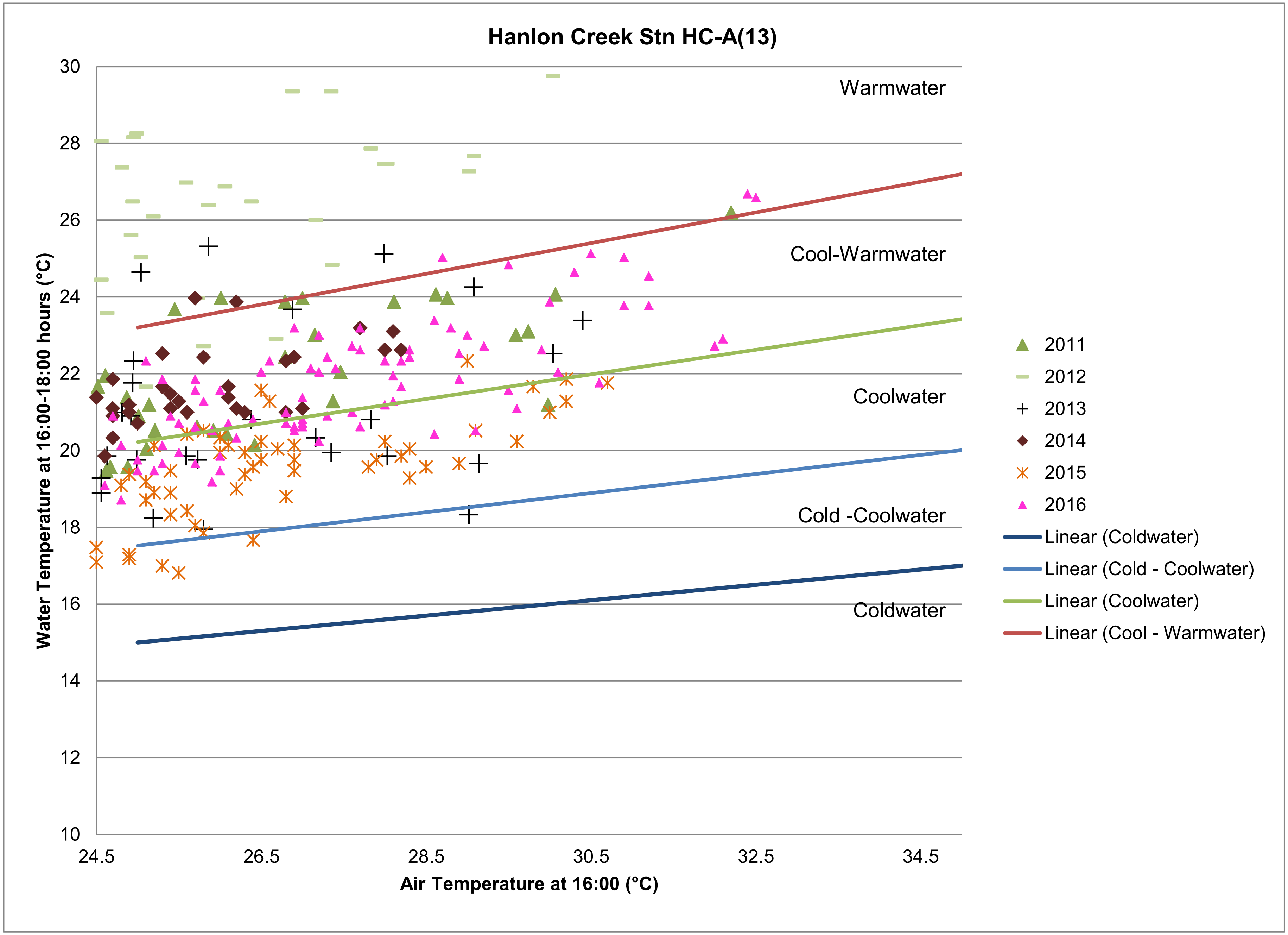

Hanlon Creek Stn HC-A(09)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

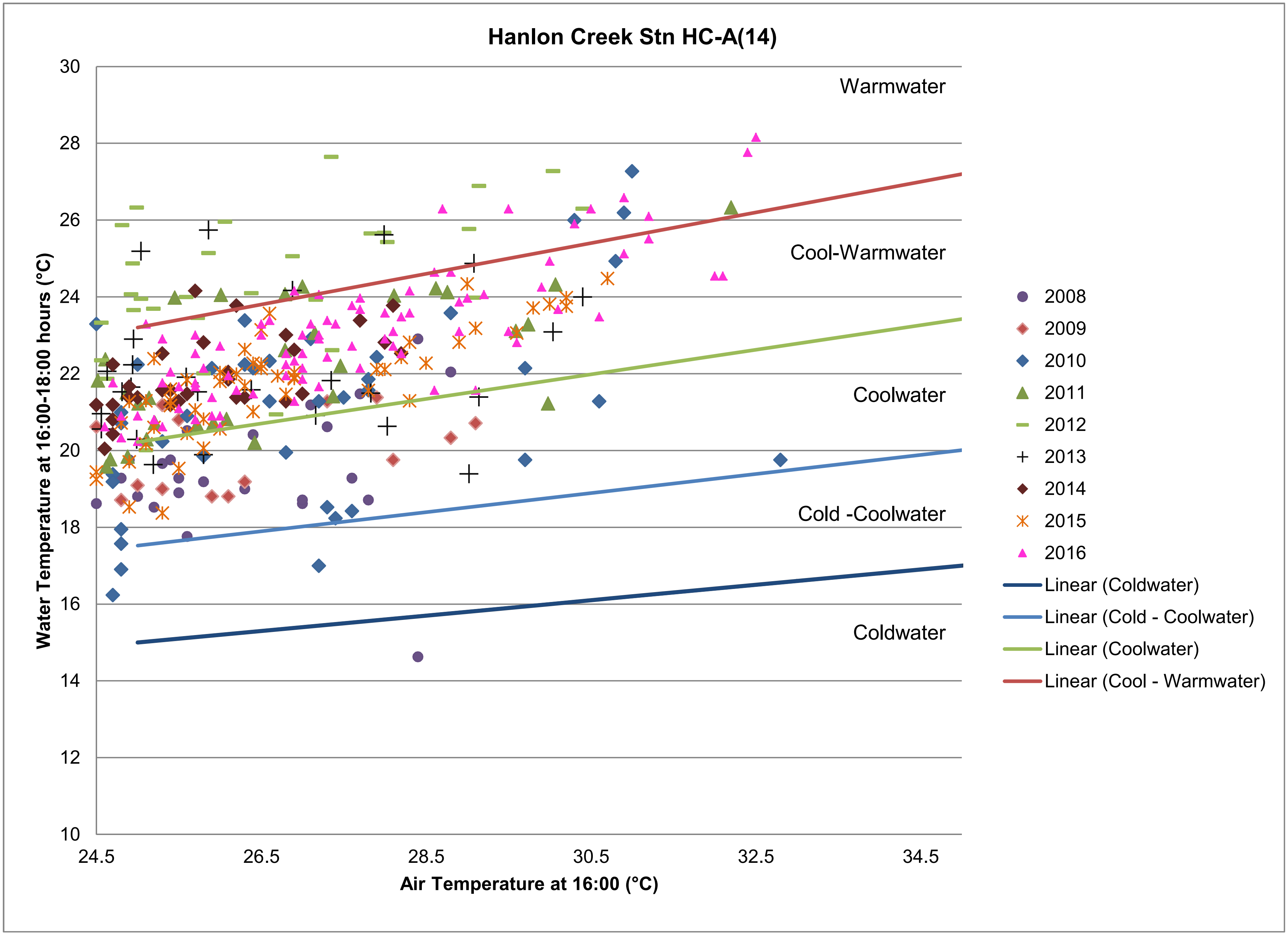


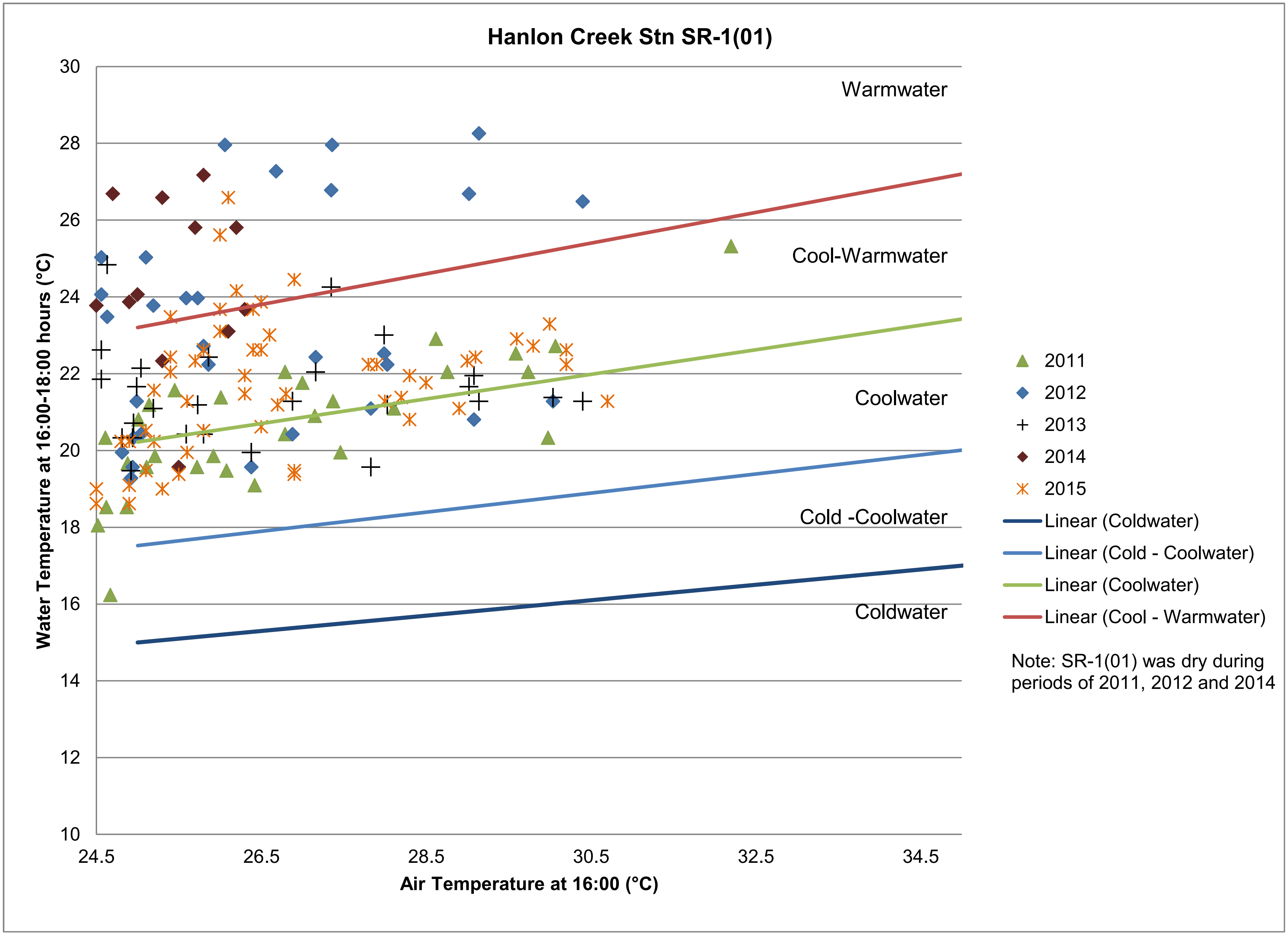
Hanlon Creek Stn HC-A(10)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)


Hanlon Creek Stn HC-A(11)
Water Temperature at 16:00-18:00 hours (°C)
Air Temperature at 16:00 (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)


Hanlon Creek Stn HC-A(12)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

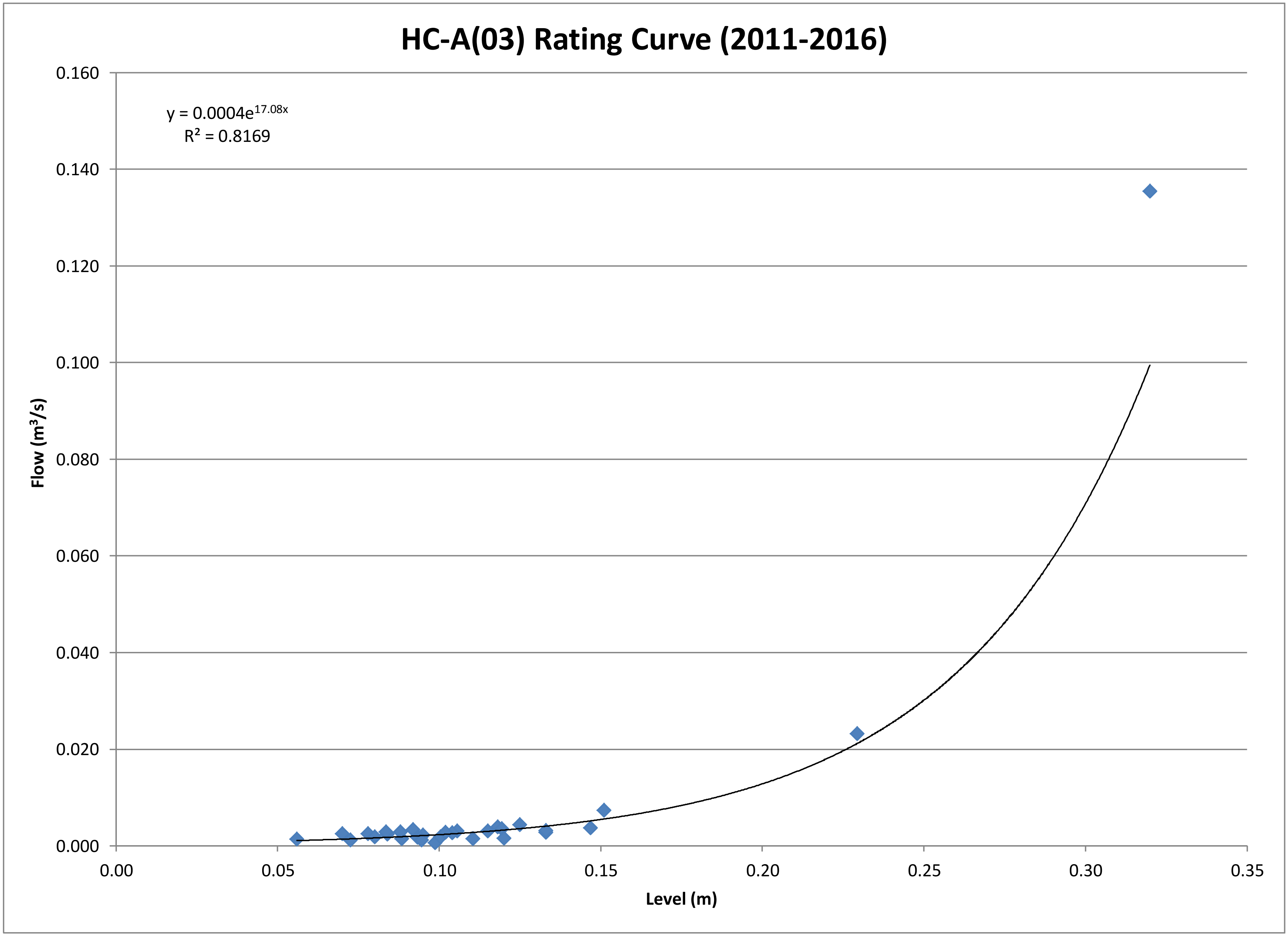

Hanlon Creek Stn HC-A(13)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
Air Temperature at 16:00 (°C)
24.5
26.5
28.5
30.5
32.5
34.5
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

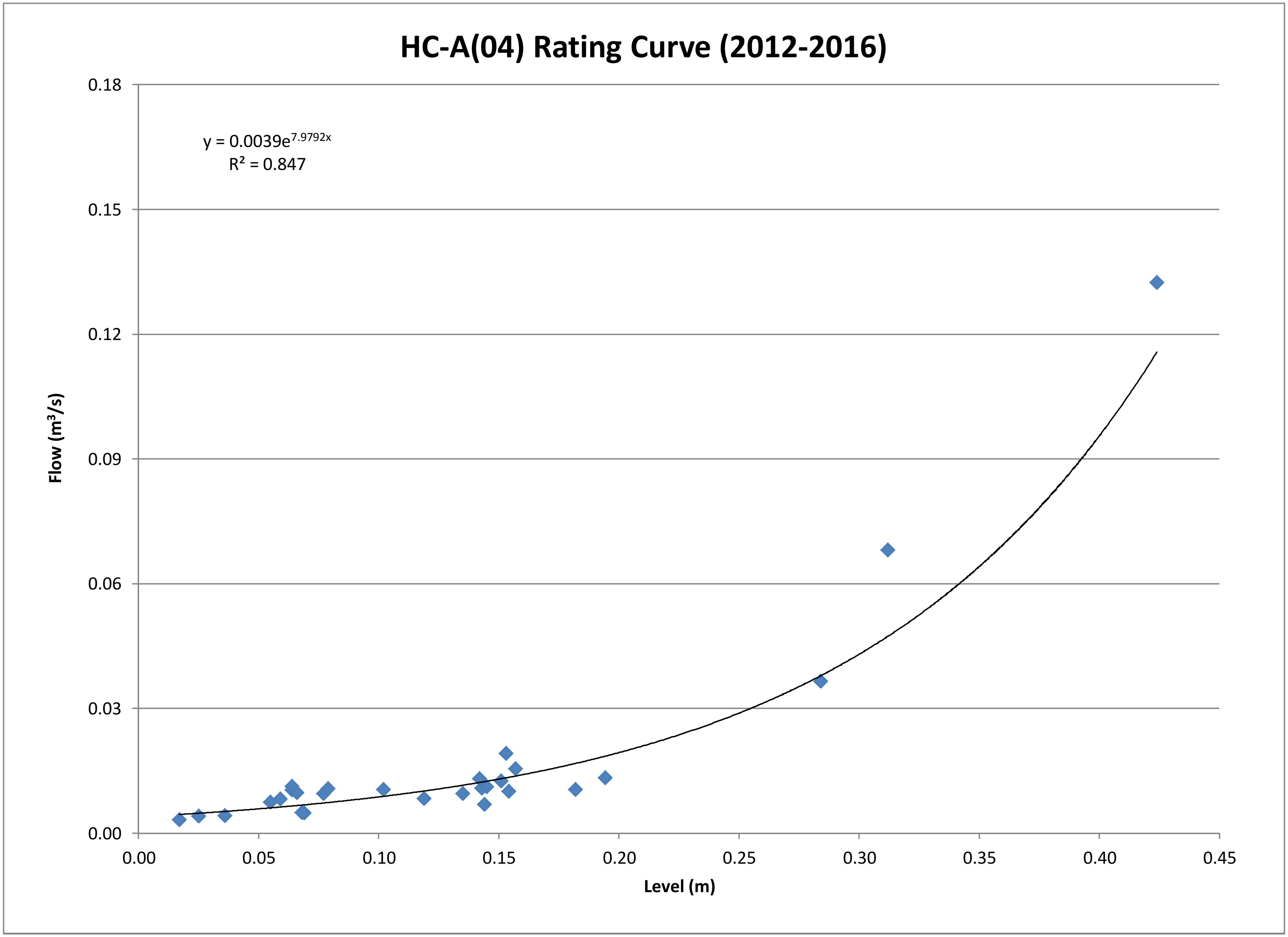

Hanlon Creek Stn HC-A(14)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2008
2009
2010
2011
2012
2013
2014
2015
2016
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)

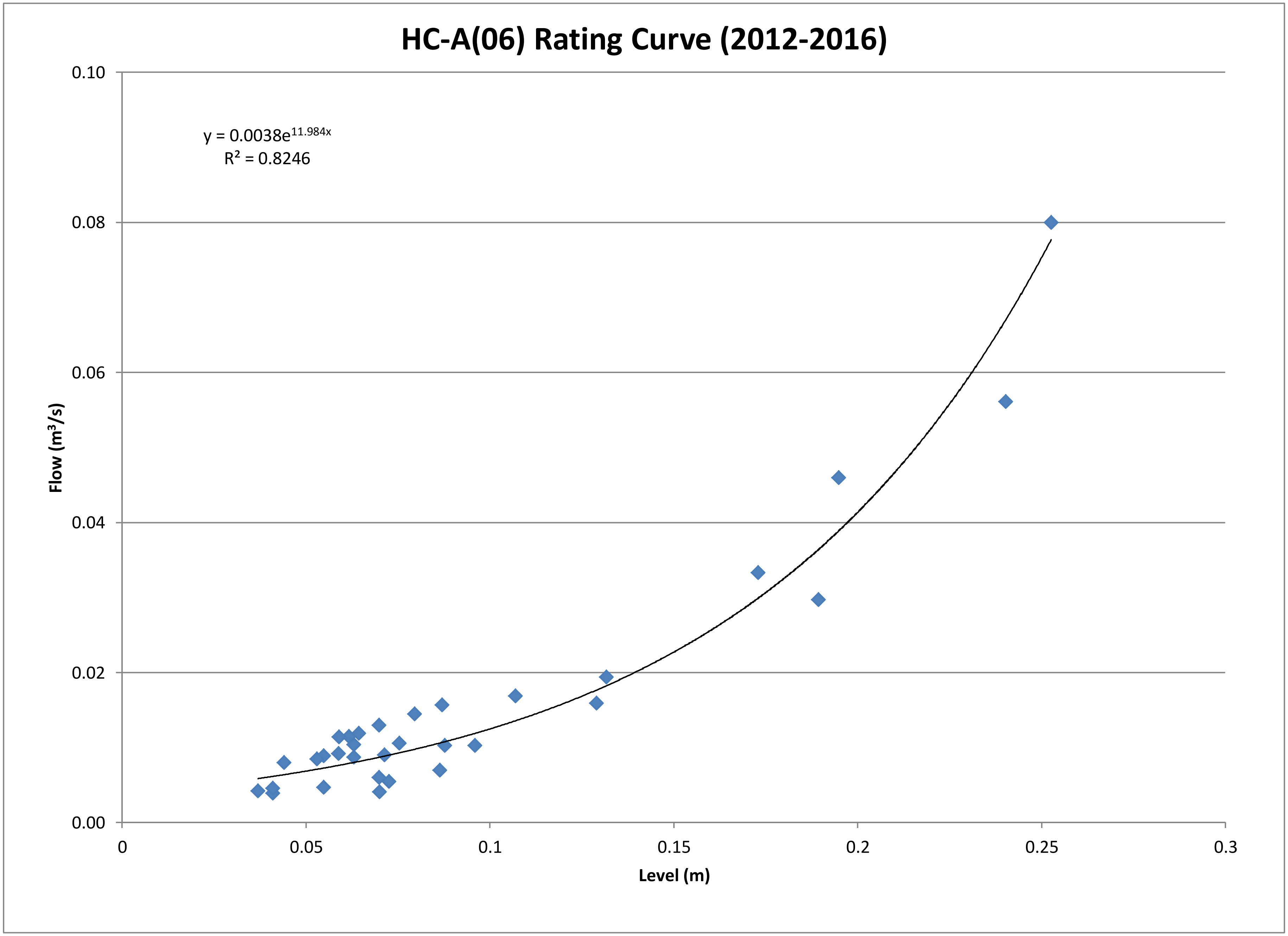

Hanlon Creek Stn SR-1(01)
Water Temperature at 16:00-18:00 hours (°C)
30
28
26
24
22
20
18
16
14
12
10
24.5
26.5
28.5
30.5
32.5
34.5
Air Temperature at 16:00 (°C)
Warmwater
Cool-Warmwater
Coolwater
Cold -Coolwater
Coldwater
2011
2012
2013
2014
2015
Linear (Coldwater)
Linear (Cold - Coolwater)
Linear (Coolwater)
Linear (Cool - Warmwater)
Note: SR-1(01) was dry during periods of 2011, 2012 and 2014

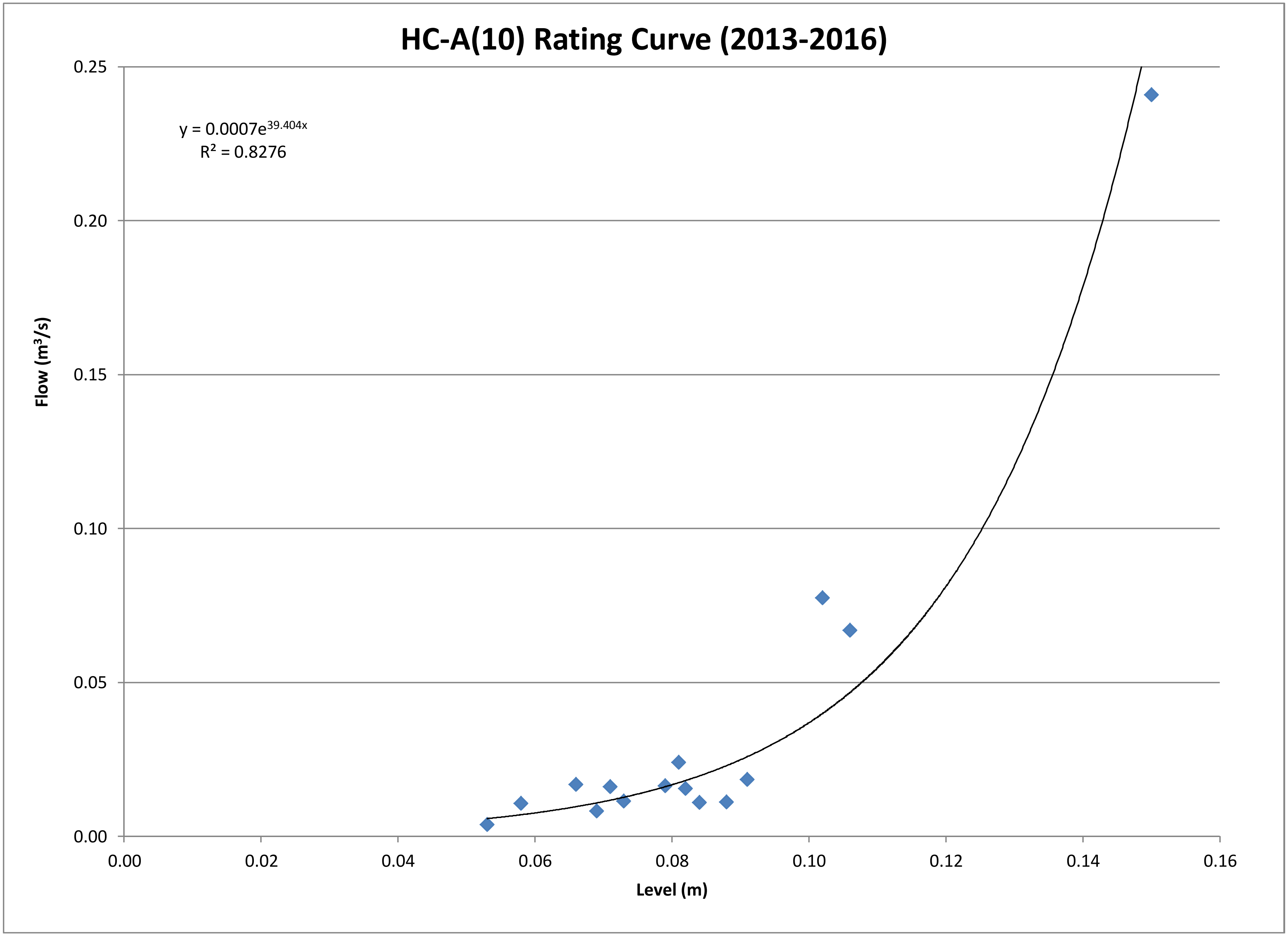
Appendix E

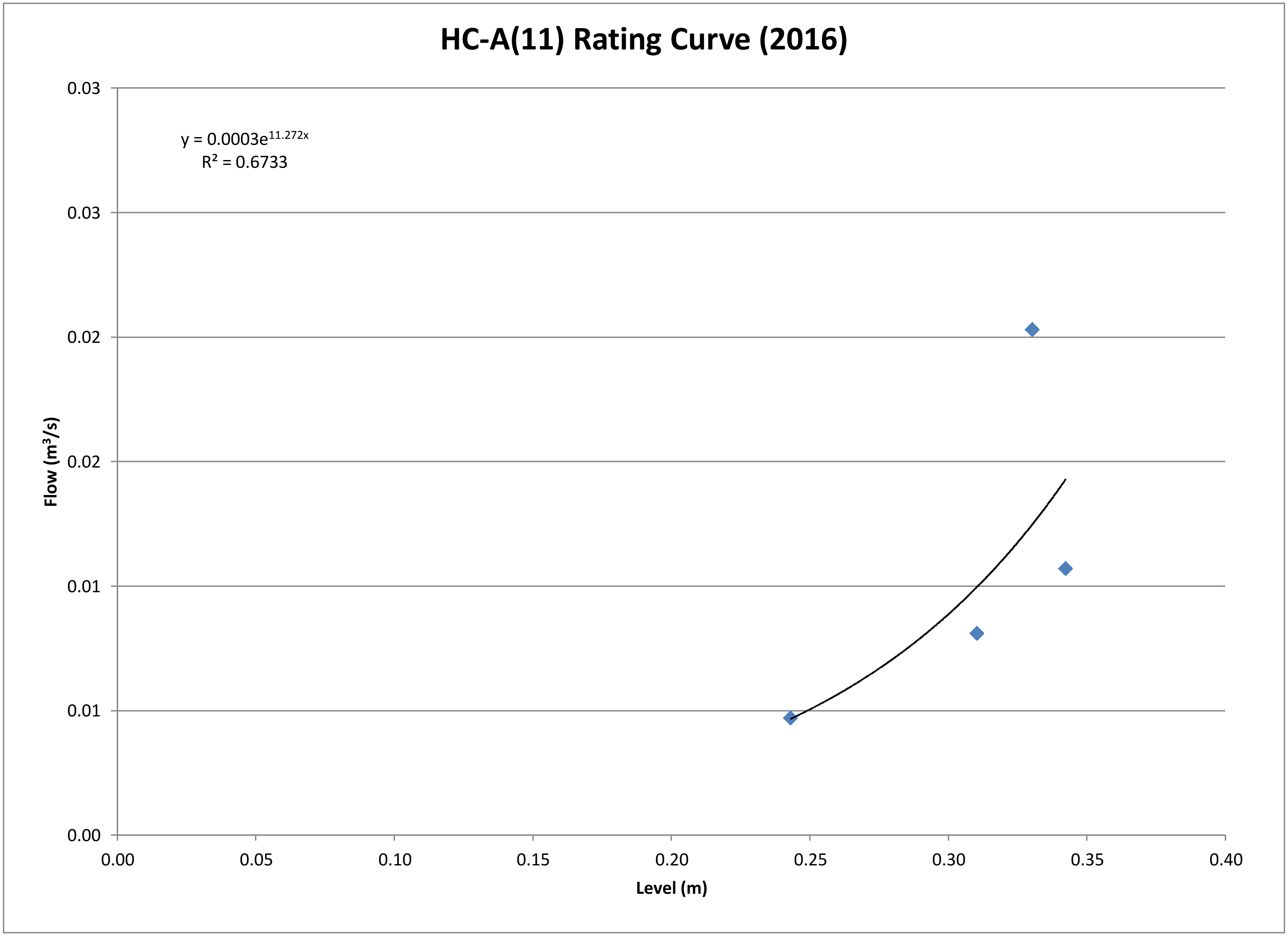
Stage (level) – Discharge Relationship Plots

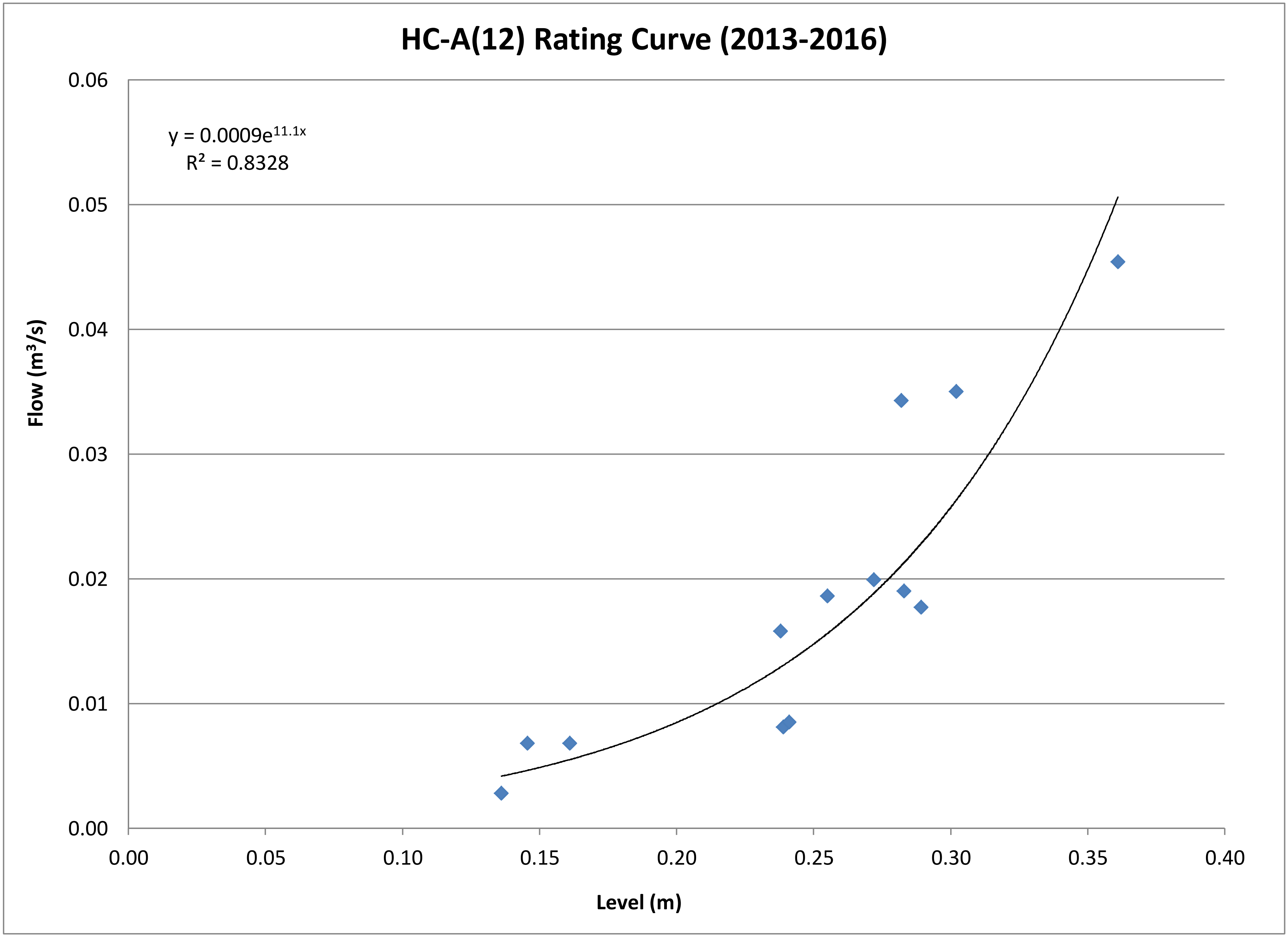

HC-A(03) Rating Curve (2011-2016)
y = 0.0004e^17.08x
R² = 0.8169
Flow (m³/s)
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Level (m)


HC-A(04) Rating Curve (2012-2016)
y = 0.0039e^7.9792x
R² = 0.847
Flow (m³/s)
0.18
0.15
0.12
0.09
0.06
0.03
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Level (m)

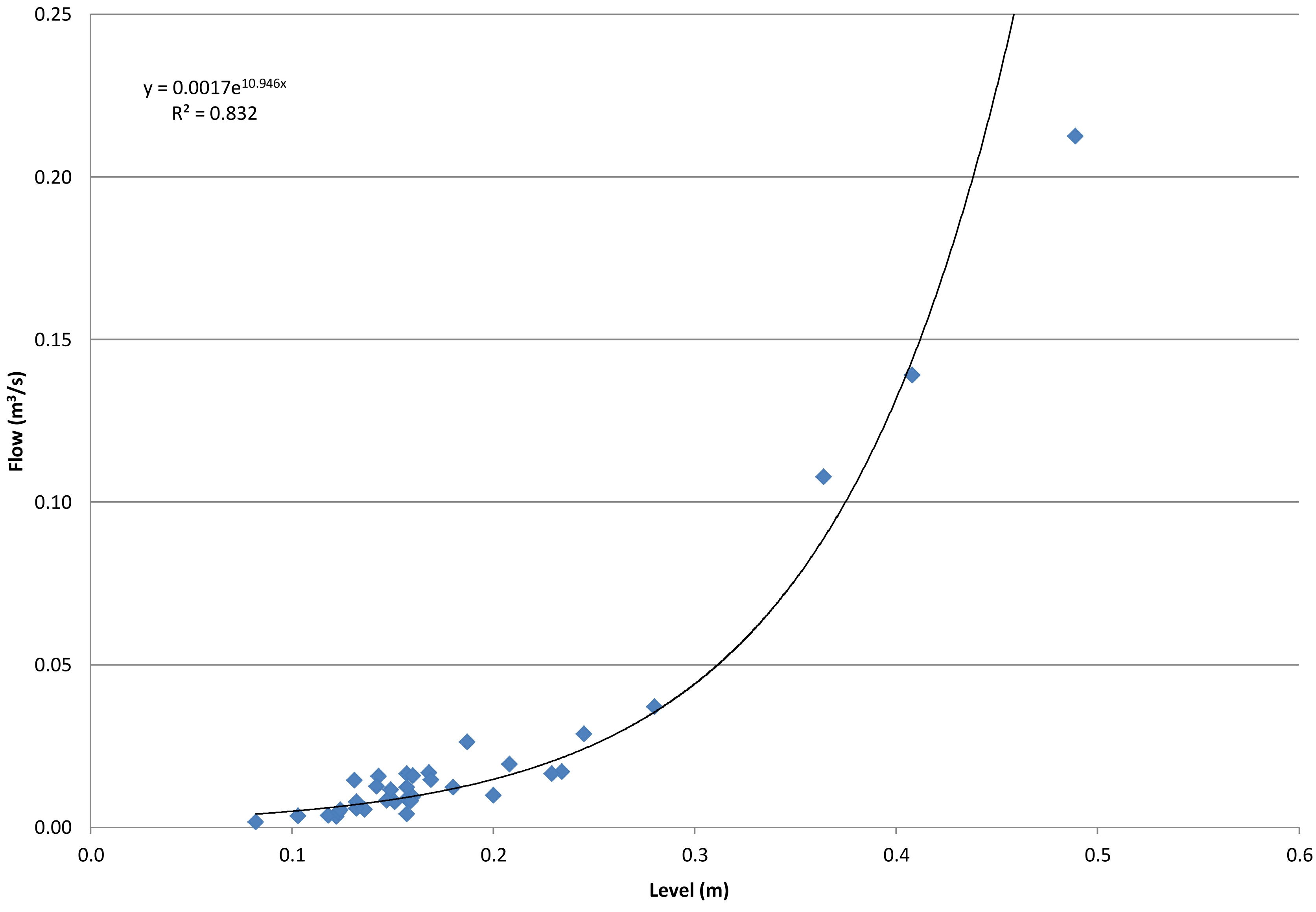

HC-A(06) Rating Curve (2012-2016)
y = 0.0038e^11.984x
R² = 0.8246
Flow (m³/s)
0.10
0.08
0.06
0.04
0.02
0.00
0
0.05
0.1
0.15
0.2
0.25
0.3
Level (m)

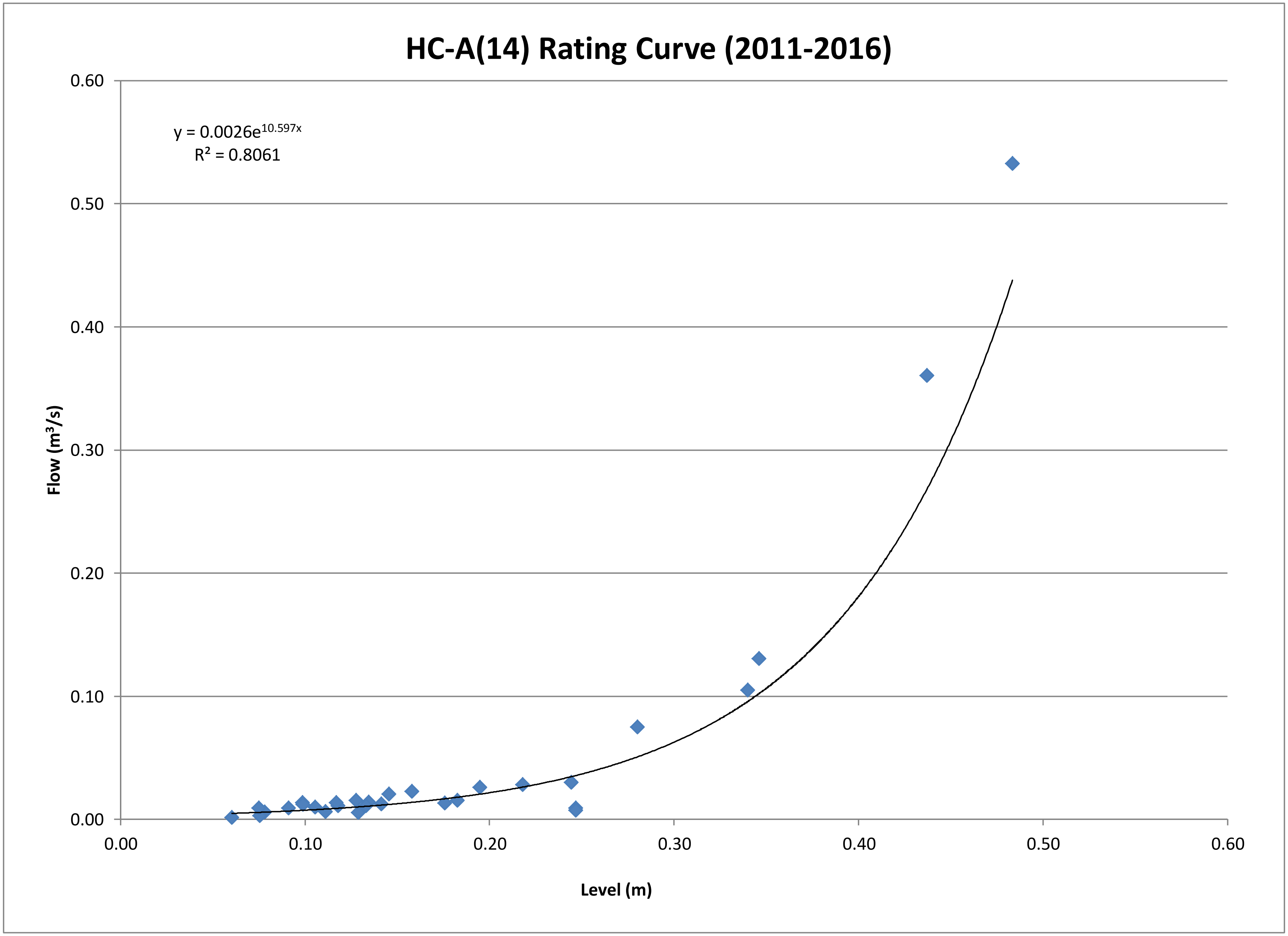

HC-A(10) Rating Curve (2013-2016)
y = 0.0007e$^{39.404x}$
R² = 0.8276
Flow (m³/s)
0.25
0.20
0.15
0.10
0.05
0.00
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Level (m)


HC-A(11) Rating Curve (2016)
y = 0.0003e^11.272x
R² = 0.6733
0.03
0.03
0.02
0.02
0.01
0.01
0.00
Flow (m³/s)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Level (m)


HC-A(12) Rating Curve (2013-2016)
y = 0.0009e^11.1x
R² = 0.8328
Flow (m³/s)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
Level (m)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

HC-A(13) Rating Curve (2012-2016)




HC-A(14) Rating Curve (2011-2016)
y = 0.0026e^10.597x
R² = 0.8061
Flow (m³/s)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
Level (m)

Appendix F

Tabular Water Quality Sampling Results

			PWQO		Guelph Storm		SITES SAMPLED ON 2/03/2015 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	<0.0050	<0.0050	<0.0050	0.0262	0.0258	0.0077	0.0612	0.0208	0.0144	0.0127	0.0445	<0.0050
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.102	0.016	0.023	0.179	3.14	0.141	0.395	0.228	0.263	0.093	0.692	0.038
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.052	0.026	0.034	0.021	0.041	<0.020	0.068	0.022	0.025	0.103	0.025	0.048
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00017	0.00011	<0.00010	0.00025	0.00011	0.00014	0.0001	<0.00010	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00018	0.00016	<0.00010	0.00036	0.00016	0.00018	0.00013	0.00012	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00044	0.00034	0.00035	0.00042	0.00032	0.00028	0.00147	0.00037	0.00032	0.00019	0.00025	0.00027
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00054	0.00035	0.00033	0.00048	0.00134	0.00034	0.0017	0.00044	0.00051	0.00022	0.00046	0.00028
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.064	0.052	0.0524	0.0372	0.0327	0.0737	0.017	0.0261	0.0236	0.00677	0.0123	0.0772
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0614	0.0488	0.048	0.036	0.0475	0.0742	0.0196	0.0278	0.0265	0.00566	0.0148	0.0733
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	<2.0	<2.0	<2.0	<2.0	4.9	2.5	3.5	3.6	<2.0	<2.0	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	<0.010	<0.010	<0.010	0.013	0.01	0.012	0.012	<0.010	0.011	<0.010	<0.010	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	<0.010	<0.010	<0.010	0.013	0.014	0.013	0.013	<0.010	0.012	<0.010	<0.010	<0.010
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.000016	<0.000010	<0.000010	0.000018	0.000028	<0.000010	0.00003	0.000057	0.000018	0.00001	<0.000010	0.000012
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000032	<0.000010	0.00001	0.000025	0.000103	0.000016	0.000046	0.00007	0.00004	0.000017	0.000039	0.000015
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	78.4	75.2	77.9	39.6	46.1	97.7	35	59.8	43.8	10.4	31.3	86.6
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	77	77.8	72.6	36.6	50.3	96.3	37.1	60.8	44.2	7.85	34.5	86.2
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.00001	<0.000010	<0.000010	0.000018	0.000245	0.000012	0.000035	0.000021	0.000026	0.000011	0.000062	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	180	146	147	479	345	344	336	139	168	79.1	122	245
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00102	<0.00050	<0.00050	<0.00050	0.00066	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	0.00104	0.00092	0.00084	0.00127	0.0043	0.00106	0.00213	0.00142	0.00124	0.00082	0.002	0.00078
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.00012	<0.00010	<0.00010	0.00015	0.00107	0.00012	0.00027	0.00014	0.00017	<0.00010	0.00035	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00076	0.00065	0.00062	0.00174	0.00178	0.00083	0.00507	0.00187	0.001	0.00077	0.00138	0.00086
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0011	<0.0010	<0.0010	0.0022	0.006	0.0011	0.0064	0.0022	0.0019	<0.0010	0.0027	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	10 *	50 *	52 *	<2 *	2 *	<2 *	460 *	60 *	10 *	4 *	36 *	6 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.02	0.019	0.019	0.031	0.039	0.012	0.054	0.022	0.019	<0.010	0.021	0.01
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.182	<0.050	0.05	0.172	2.78	0.159	0.436	0.222	0.344	0.103	0.69	0.094
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	<0.000050	<0.000050	<0.000050	0.000082	0.000108	<0.000050	0.000197	0.000055	<0.000050	<0.000050	0.000059	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00036	<0.00010	0.0001	0.00044	0.00734	0.00061	0.00163	0.00067	0.00085	0.00045	0.00171	0.00017
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	<0.0010	<0.0010	0.0011	0.001	<0.0010	0.0014	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.0011	<0.0010	<0.0010	<0.0010	0.0028	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	0.0013
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	24.5	24.9	25.1	8.32	12.6	30.1	6.08	17.2	11.7	1.78	5.35	27.6
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	24	24	23.4	7.9	13.4	28.6	6.43	16.9	11.7	1.48	5.79	26.1
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.026	0.00752	0.00721	0.0143	0.0159	0.0124	0.00963	0.00895	0.00506	0.0042	0.0143	0.0119
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.0421	0.0112	0.0124	0.0206	0.103	0.0615	0.0294	0.0274	0.0388	0.0104	0.0429	0.0297
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000354	0.000253	0.000258	0.000509	0.000507	0.000291	0.000679	0.000831	0.000403	0.000143	0.000659	0.000299
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000379	0.000288	0.00027	0.000555	0.000623	0.000309	0.000785	0.000947	0.000476	0.000136	0.00078	0.000334
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00053	<0.00050	<0.00050	0.0005	0.00273	<0.00050	0.00083	0.00066	0.00054	<0.00050	0.00081	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.726	0.333	0.338	0.568	0.416	0.524	0.549	0.369	0.058	0.081	0.164	0.776
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.129	0.127	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	0.063	0.13	<0.050	0.206	0.168	0.149	<0.050	0.072	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0031	0.0134	0.0141	0.0353	0.0416	0.0109	0.13	0.089	0.0132	0.0089	0.0216	0.003
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.53	1.53	1.54	2.85	1.72	2.25	3.58	4.1	2.41	0.824	1.76	1.8

Potassium (K)-Total	mg/L	1	-	-	-	-	1.54	1.5	1.46	2.73	2.48	2.18	3.65	3.96	2.4	0.65	1.89	1.7
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00103	0.00086	0.00082	0.0013	0.00059	0.00056	0.00094	0.00063	0.00057	0.00029	0.00111	0.00117
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00116	0.00089	0.00076	0.00142	0.00496	0.00071	0.00134	0.00091	0.00104	0.00034	0.00204	0.00111
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000176	0.000121	0.000108	0.0001	0.000121	0.00007	0.000116	0.00013	0.000065	0.000056	0.000075	0.000159
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000177	0.000114	0.000113	0.000095	0.000101	0.000078	0.000118	0.000147	0.000088	<0.000050	0.000094	0.000143
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	2.43	3.54	3.58	1.83	2.04	2.44	1.98	2.6	1.45	0.247	1.42	2.27
Silicon (Si)-Total	mg/L	1	-	-	-	-	2.56	3.57	3.51	2.08	7.95	2.66	2.66	3.01	1.9	0.317	2.43	2.39
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	110 *	89.9	88.2	334 *	247 *	226 *	238 *	132 *	112 *	51.4	82	146 *
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	106 *	86.5	86.5	343 *	242 *	222 *	229 *	126 *	120 *	44.1	78.3	150 *
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.107	0.101	0.101	0.17	0.107	0.152	0.172	0.21	0.329	0.0588	0.0755	0.122
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.107	0.107	0.102	0.164	0.116	0.162	0.156	0.207	0.341	0.0437	0.0824	0.122
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	6.36	5.36	5.34	8.16	6.3	8.67	5.96	4.98	5.4	1.59	1.7	6.17
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	6.76	5.5	5.51	8.82	6.28	8.9	5.5	5.11	6.28	1.29	1.82	6.86
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	0.000016	0.00004	<0.000010	<0.000010	0.000011	<0.000010	<0.000010	0.000011	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00049	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00015	<0.00010	0.00017	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	0.00105	0.00185	<0.00030	0.00181	0.00078	0.00046	<0.00030	0.00072	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.00335	0.00056	0.00065	0.00556	0.104	0.00458	0.0126	0.00918	0.00721	0.00355	0.0208	0.00107
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0136	0.0776	0.189	0.0407	0.111	0.0229	0.151	0.125	0.0837	0.018	0.0498	0.0083
Total Suspended Solids	mg/L	3	-	-	-	15	5	2	<2.0	<2.0	9.7	26.2	15	5.5	5.9	3	20.6	<2.0
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00015	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000557	0.000468	0.000478	0.000182	0.000293	0.000474	0.000183	0.000382	0.000261	0.000056	0.000116	0.000424
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000576	0.000485	0.000467	0.000196	0.000373	0.000466	0.000211	0.000413	0.000314	0.000055	0.000136	0.000438
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	0.00059	<0.00050	<0.00050	0.00075	<0.00050	<0.00050	<0.00050	0.00057	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	0.00092	0.00582	0.00056	0.0015	0.00082	0.00089	<0.00050	0.00169	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0407	0.0087	0.0084	0.002	0.0022	0.0019	0.0093	0.0069	0.0024	0.0019	0.0024	0.0043
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0469	0.0106	0.0098	0.0051	0.0495	0.0065	0.0224	0.0119	0.0096	0.0055	0.0208	0.0063
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030		0.00199	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00042	<0.00030	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key:	Within Guideline	Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key:	Within Guideline	**Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 3/10/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	<0.0050	<0.0050	<0.0050	<0.050 *	<0.050 *	0.0111	0.0824	0.0173	0.0209	0.0295	0.0919	<0.0050
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.09	0.011	0.01	<0.10 *	0.11 *	1.41	0.775	0.792	0.156	0.101	1.32	0.044
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	<0.020	0.027	0.032	<0.020	0.057	0.028	0.225	0.099	0.035	<0.020	0.117	<0.020
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00017	0.00053	0.00023	0.00013	0.00018	0.0003	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00025	0.00096	0.00052	0.00013	0.00027	0.00078	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.0005	0.00034	0.00033	<0.0010 *	<0.0010 *	0.00024	0.00076	0.00025	0.00084	0.00034	0.00026	0.00026
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00054	0.00035	0.00036	<0.0010 *	<0.0010 *	0.00076	0.00108	0.00052	0.00094	0.0005	0.00073	0.00027
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0575	0.053	0.0518	0.113 *	0.0668 *	0.047	0.011	0.0447	0.0109	0.0158	0.0105	0.0695
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0568	0.0506	0.0499	0.116 *	0.0662 *	0.0567	0.0144	0.0443	0.0147	0.021	0.0191	0.0676
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.00050 *	<0.00050 *	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.00050 *	<0.00050 *	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	2.3	<2.0	<2.0	<2.0	2.2	<2.0	3	<2.0	5.2	5.8	3.2	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	<0.010	<0.010	<0.010	<0.10 *	<0.10 *	0.013	0.015	0.013	<0.010	<0.010	<0.010	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	<0.010	<0.010	<0.010	<0.10 *	<0.10 *	0.015	0.017	0.015	0.011	<0.010	0.013	<0.010
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.000018	<0.000010	<0.000010	<0.00010 *	<0.00010 *	0.000026	0.000014	0.000112	0.000019	0.000013	<0.000010	0.000012
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000037	<0.000010	<0.000010	<0.00010 *	<0.00010 *	0.000061	0.000045	0.000139	0.000042	0.00002	0.000049	0.000017
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	75.8	73.4	72.8	116 *	89.5 *	56.1	21.8	89.9	16.9	21.7	18.7	83.4
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	82.3	76.2	74.7	120 *	85.5 *	58.7	23.4	85.2	21.6	27.8	23	79.2
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.00010 *	<0.00010 *	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000011	<0.000010	<0.000010	<0.00010 *	<0.00010 *	0.000112	0.000065	0.000069	0.000014	<0.000010	0.00012	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	185	138	139	971	457	331	163	398	13.9	290	197	326
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.0050 *	<0.0050 *	0.00124	0.00134	0.00067	<0.00050	<0.00050	0.00095	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	<0.00050	<0.00050	<0.0050 *	<0.0050 *	0.00304	0.00328	0.00238	0.00077	0.00053	0.00362	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	0.00014	<0.00010	<0.00010	<0.00010	0.00015	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.00012	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00052	0.00047	0.00043	0.00017	<0.00010	0.00081	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00076	0.0006	0.00059	<0.0020 *	<0.0020 *	0.00194	0.00669	0.00302	0.00215	0.00155	0.00411	0.00068
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0011	0.0015	<0.0010	<0.010 *	<0.010 *	0.0042	0.011	0.0062	0.0026	0.0022	0.009	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	<2 *	12 *	4 *	<2 *	<2 *	<2 *	450 *	2 *	<2 *	<2 *	290 *	<2 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.03	0.022	0.02	<0.10 *	<0.10 *	0.014	0.055	0.011	0.045	0.016	0.045	0.017
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.191	<0.050	<0.050	<0.50 *	<0.50 *	1.26	0.858	0.867	0.199	0.076	1.66	0.1
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	<0.000050	<0.000050	<0.000050	<0.00050 *	<0.00050 *	0.00005	0.000266	0.00006	0.00008	0.000079	0.000138	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00035	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00367	0.00343	0.00337	0.00048	0.00031	0.00443	0.00024
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	<0.0010	<0.0010	<0.0010	<0.010 *	<0.010 *	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	<0.0010	<0.0010	<0.0010	<0.010 *	<0.010 *	0.0017	<0.0010	0.0013	<0.0010	<0.0010	0.0014	<0.0010
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	22.4	22.3	23.3	27.8 *	25.3 *	15.5	3	20.8	3.66	4.34	2.82	24.2
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	22.9	21.9	22.2	27.8 *	26.5 *	16	4.1	19.8	4.83	5.75	4.37	24.3
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.0193	0.00782	0.00822	<0.0050 *	<0.0050 *	0.0178	0.0128	0.0527	0.00064	0.00113	0.0167	0.0046
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.0351	0.0148	0.0137	0.0065 *	0.0249 *	0.0659	0.0349	0.0765	0.0346	0.00926	0.0612	0.0239
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.00035	0.00026	0.000266	0.00083 *	<0.00050 *	0.000633	0.000569	0.000411	0.00115	0.00029	0.00071	0.000337
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000373	0.000302	0.000301	0.00090 *	<0.00050 *	0.000721	0.000717	0.000538	0.00135	0.000438	0.000981	0.000355
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.0050 *	<0.0050 *	<0.00050	0.00067	0.00085	<0.00050	<0.00050	0.00061	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00053	<0.00050	<0.00050	<0.0050 *	<0.0050 *	0.00159	0.00156	0.00183	0.00069	<0.00050	0.00232	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.692	0.301	0.294	1.4	0.368	0.481	0.488	0.892	<0.020	<0.020	0.318	0.678
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.50 *	<0.50 *	<0.050	<0.050	<0.050	0.098	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.50 *	<0.50 *	0.054	0.087	<0.050	0.19	0.051	0.069	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0058	0.0109	0.0112	0.0159	0.0073	0.0079	0.0355	0.0147	0.108	0.0144	0.0114	0.0033
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.4	1.44	1.42	4.33 *	2.07 *	1.55	1.39	2.14	5.74	1.55	1.34	1.68

Potassium (K)-Total	mg/L	1	-	-	-	-	1.41	1.38	1.37	4.37 *	2.05 *	1.82	1.51	2.21	5.93	2.02	1.57	1.62
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00098	0.00089	0.00093	<0.0020 *	<0.0020 *	0.00078	0.00084	0.00089	0.00052	0.00037	0.00157	0.00102
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00108	0.00084	0.00082	<0.0020 *	<0.0020 *	0.00274	0.0018	0.0021	0.0007	0.00058	0.00365	0.00112
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000207	0.000138	0.000132	<0.00050 *	<0.00050 *	0.00013	0.000146	0.000161	0.000076	<0.000050	0.000182	0.000193
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000193	0.000113	0.000101	<0.00050 *	<0.00050 *	0.000099	0.000125	0.00016	0.000072	0.000074	0.000152	0.000171
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.98	2.96	2.92	2.39 *	0.98 *	2.04	1.02	2.51	3.13	0.306	0.82	1.08
Silicon (Si)-Total	mg/L	1	-	-	-	-	2.16	3.06	2.93	2.57 *	1.16 *	4.5	2.36	3.7	3.02	0.466	3	1.14
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.00050 *	<0.00050 *	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.00050 *	<0.00050 *	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	106 *	79.2	78.5	574 *	282 *	210 *	125 *	254 *	11.7	147 *	139 *	193 *
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	109 *	76.5	75.5	566 *	282 *	221 *	116 *	242 *	19.3	208 *	143 *	191 *
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.104	0.102	0.106	0.336 *	0.175 *	0.154	0.174	0.233	0.0943	0.121	0.104	0.127
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.108	0.106	0.102	0.356 *	0.167 *	0.159	0.168	0.234	0.125	0.169	0.112	0.128
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	6.27	4.38	4.52	15.3 *	7.5 *	10.3	6.92	8.82	<0.50	2.98	6.39	6.56
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	7.01	4.95	4.8	14.8 *	7.3 *	11.1	7.23	9.17	<0.50	4.52	6.73	6.96
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.0020 *	<0.0020 *	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.0020 *	<0.0020 *	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.00010 *	<0.00010 *	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.00010 *	<0.00010 *	0.000018	0.000011	0.000014	<0.000010	<0.000010	0.000018	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00022	0.00011	0.00012	<0.00010	<0.00010	0.00019	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00012	0.00046	0.00028	<0.00010	<0.00010	0.00046	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.0030 *	<0.0030 *	0.00064	0.00189	0.00047	0.00089	<0.00030	0.00201	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	<0.0030 *	0.00032	0.00032	<0.0030 *	<0.0030 *	0.0415	0.0289	0.027	0.00402	0.0026	0.0537	0.00117
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0154	0.0188	0.0191	0.0258	0.0154	0.0569	0.0742	0.0484	0.169	0.0502	0.0633	0.0077
Total Suspended Solids	mg/L	3	-	-	-	15	8.4	<2.0	2.8	<2.0	3.2	28.7	19.6	14	16	6.4	58.2	2.4
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	<0.00010	0.00022	<0.00010	<0.00010	<0.00010	0.00018	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.0010 *	<0.0010 *	0.00011	0.00043	0.00024	<0.00010	<0.00010	0.00085	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000678	0.000466	0.000467	0.00035 *	0.00047 *	0.000308	0.000122	0.000459	0.000081	0.000139	0.000089	0.000386
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000713	0.00048	0.000482	0.00038 *	0.00045 *	0.00036	0.000148	0.000449	0.000184	0.000212	0.00013	0.000396
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	<0.0050 *	<0.0050 *	<0.00050	0.00128	0.00073	<0.00050	0.00053	0.00133	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	<0.0050 *	<0.0050 *	0.00292	0.00296	0.00257	0.00073	0.00086	0.00452	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0421	0.0093	0.0093	<0.010 *	<0.010 *	0.0032	0.0125	0.0144	0.0029	0.0011	0.0101	0.004
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0501	0.0107	0.0102	<0.030 *	<0.030 *	0.0292	0.0528	0.0451	0.0065	0.0048	0.075	0.0064
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.0030 *	<0.0030 *	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.0030 *	<0.0030 *	0.00091	0.00068	0.00062	<0.00030	<0.00030	0.00072	<0.00030

* = Result Qualified

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Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key:	Within Guideline	Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key:	Within Guideline	**Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 5/26/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	0.0123	0.0058	0.0058	0.0801	0.1	0.0211	0.0602	0.0533	0.027	0.0478	<0.0050	0.0796
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.496	0.092	0.093	0.308	5.4	1.65	0.377	0.8	0.132	0.726	0.029	1.24
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.066	0.299	0.063	0.238	0.28	0.031	0.722	0.762	0.072	0.061	0.028	0.58
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00019	0.00016	<0.00010	0.00026	0.00022	0.00022	0.00091	<0.00010	0.00012
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.0002	0.00023	0.00012	0.00035	0.00046	0.00022	0.0011	<0.00010	0.00024
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00056	0.00051	0.00057	0.00038	0.00042	0.00069	0.00155	0.00027	0.00079	0.00225	0.00048	0.00024
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00088	0.00064	0.00062	0.00046	0.00245	0.00121	0.00141	0.00067	0.00079	0.00263	0.00049	0.00074
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0367	0.0414	0.0423	0.00989	0.00657	0.0207	0.00446	0.00573	0.0033	0.00599	0.0343	0.0025
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0457	0.046	0.0456	0.0124	0.0442	0.0428	0.00747	0.0222	0.00591	0.0103	0.0379	0.0108
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00022	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	0.000053	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	3.1	3.1	2.7	3.5	4.2	3.7	6.4	4.8	11	19.5 *	2.9	3.7
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	<0.010	0.011	0.012	<0.010	<0.010	0.013	<0.010	<0.010	0.011	0.012	<0.010	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.011	0.012	0.012	<0.010	0.012	0.015	<0.010	<0.010	0.012	0.016	<0.010	<0.010
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.000028	<0.000010	<0.000010	0.000017	0.000021	<0.000010	0.000037	0.000022	<0.000010	<0.000010	<0.000010	<0.000010
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000186	0.000041	0.000036	0.000032	0.000271	0.000075	0.000057	0.00014	0.000025	0.000046	<0.000010	0.000077
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	49.4	48.9	51.3	13.3	13.4	34.6	7.67	13.2	13.2	17	41.7	6.83
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	51.3	52.1	50.4	13.8	32.1	42.4	8.19	19.5	13.1	22.1	42.9	10.3
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000057	0.000012	0.000011	0.000033	0.000513	0.00016	0.000036	0.000087	0.000013	0.000067	<0.000010	0.000128
Chloride (Cl)	mg/L	2	-	-	-	-	119	126	125	33.7	16.9	281	5.12	24.2	258	197	224	5.04
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	0.00058	0.0022	<0.00050	0.00208	0.00223	<0.00050	<0.00050	<0.00050	0.00099
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	0.00101	<0.00050	<0.00050	0.00092	0.00896	0.00252	0.00282	0.00441	<0.00050	0.00136	<0.00050	0.0026
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	0.00011	0.00021	0.00033	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.0004	0.00011	0.00011	0.00026	0.00294	0.0008	0.00041	0.00064	0.00028	0.00078	0.00011	0.00079
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00132	0.00109	0.00118	0.00228	0.00236	0.00089	0.00674	0.00138	0.00155	0.00192	0.00077	0.00119
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0035	0.0017	0.0018	0.003	0.0139	0.0038	0.0091	0.0059	0.0019	0.0036	<0.0010	0.0044
E. Coli	CFU/100mL	10	-	100	-	-	900 *	10000 *	12000 *	1500 *	400 *	1600 *	85000 *	1200 *	100 *	4400 *	50 *	170 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.054	0.058	0.058	0.068	0.077	0.067	0.063	0.063	0.069	0.057	0.027	0.055
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.889	0.237	0.218	0.338	6.81	1.87	0.494	1.29	0.221	0.941	0.152	1.66
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000077	0.000055	0.000052	0.000133	0.00022	0.000345	0.000277	0.000263	0.000364	0.00056	0.000053	0.000172
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00203	0.00057	0.0005	0.00071	0.0185	0.00536	0.00183	0.00457	0.00074	0.00356	0.00032	0.00502
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0011	<0.0010
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	<0.0010	<0.0010	<0.0010	<0.0010	0.0049	0.0018	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	21.3	18.3	19.1	2.57	2.57	25.8	0.953	2.18	17.7	6.65	27.9	0.789
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	21	18.3	18.1	2.58	7.8	25.2	1.3	4.41	16.5	7.29	27	2.47
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.0155	0.0203	0.0163	0.00345	0.0289	0.00398	0.00593	0.0737	0.0137	0.00472	0.0029	0.0156
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.101	0.0772	0.0686	0.0276	0.275	0.156	0.0369	0.14	0.0293	0.0437	0.0436	0.0955
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000375	0.000274	0.000305	0.000427	0.000548	0.000403	0.000292	0.000287	0.000467	0.000736	0.000272	0.000241
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000433	0.000336	0.000317	0.000482	0.000696	0.000476	0.000329	0.000365	0.000493	0.00103	0.000303	0.000307
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00051	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00116	0.00087	<0.00050	0.00063	0.00659	0.00198	0.00098	0.0027	0.00084	0.00124	0.00069	0.00193
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.381	0.416	0.4	0.219	0.256	<0.020	0.517	0.245	<0.020	<0.020	<0.020	0.203
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.078	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	0.089	0.058	0.054	0.072	0.239	0.159	0.178	0.134	0.056	0.187	<0.050	0.091
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0111	0.0115	0.0114	0.0214	0.0165	0.0088	0.0923	0.0202	0.017	0.0392	0.0061	0.0084
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.28	1.62	1.72	1.45	1.89	1.04	2.19	0.634	1.81	1.89	0.97	0.994

Potassium (K)-Total	mg/L	1	-	-	-	-	1.44	1.7	1.68	1.52	3.09	1.41	2.19	0.887	1.87	2.07	1.03	1.2
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00109	0.00118	0.00119	0.001	0.00105	0.00043	0.00102	0.00065	0.00049	0.00047	0.00085	0.00162
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00203	0.00136	0.00139	0.00131	0.00935	0.003	0.0014	0.00187	0.00063	0.00152	0.00097	0.00349
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000267	0.000198	0.000189	0.000114	0.000158	0.000084	0.000121	0.000167	0.000128	0.000162	0.000185	0.000133
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000366	0.000206	0.000217	0.000127	0.000193	0.000112	0.000141	0.000154	0.000122	0.000195	0.000157	0.000122
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.5	2.05	2.1	0.659	0.651	0.153	0.412	0.399	0.516	0.661	0.062	0.29
Silicon (Si)-Total	mg/L	1	-	-	-	-	2.28	2.21	2.16	0.977	9.49	2.84	0.833	1.6	0.66	1.71	0.121	2.02
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	61.1	65.8	69.4	23.2	13.4	165 *	3.94	16.5	160 *	125 *	121 *	4.48
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	59.5	65.2	64.6	21.6	13.3	156 *	3.81	17.4	163 *	134 *	133 *	2.97 *
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.0807	0.0776	0.0779	0.0386	0.0354	0.107	0.0556	0.0502	0.123	0.17	0.0934	0.029
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.082	0.0806	0.078	0.0402	0.0608	0.116	0.0564	0.0576	0.119	0.214	0.097	0.0315
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	4.53	3.69	3.79	2.02	2.13	5.82	1.1	1.25	4.59	4.83	6.3	0.91
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	5	3.76	3.62	1.93	2.15	5.91	0.96	1.18	4.59	5.04	6.59	0.58
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	0.000017	<0.000010	<0.000010	<0.000010	0.000084	0.000024	0.000011	0.000016	<0.000010	0.000012	<0.000010	0.000025
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00103	0.00019	<0.00010	0.00017	<0.00010	0.00015	<0.00010	0.00027
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	0.0248	<0.00010	<0.00010	<0.00010	0.00017	<0.00010	0.00019	0.00031	<0.00010	<0.00010	<0.00010	0.00026
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	0.00044	<0.00030	<0.00030	0.00286	0.0045	<0.00050 *	0.0019	0.00133	0.00115	0.00093	<0.00030	<0.0030 *
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.0106	0.00212	0.00225	0.00776	0.127	0.0428	0.0103	0.0238	0.00345	0.017	0.00086	0.0368
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0701	0.0504	0.0456	0.0691	0.246	0.178	0.165	0.132	0.0431	0.163	0.0187	0.0909
Total Suspended Solids	mg/L	3	-	-	-	15	60	21	21.7	8.4	159 *	34	16.2	59.3	26.7	30.4	12.1	76.3
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	0.00017	<0.00010	0.00012	<0.00010	0.00021
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000694	0.000282	0.00028	0.000022	0.000088	0.000417	0.00002	0.000075	0.000433	0.000327	0.000385	0.000022
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000822	0.000305	0.000296	0.00003	0.000233	0.000476	0.000042	0.000117	0.000437	0.000456	0.000384	0.000063
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	0.00102	0.00097	<0.00050	0.00114	0.00112	0.00154	0.00789	<0.00050	0.00129
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0.0017	<0.00050	<0.00050	0.0015	0.011	0.00376	0.00178	0.00292	0.00173	0.00977	<0.00050	0.0038
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0202	0.0057	0.006	0.0027	0.0019	<0.0010	0.0129	0.0048	<0.0010	<0.0010	<0.0010	0.0027
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0519	0.0142	0.0132	0.007	0.107	0.0279	0.0218	0.0415	0.0036	0.0118	<0.0030	0.0386
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	0.00134	0.0004	<0.00030	0.00037	<0.00030	0.00038	<0.00030	0.00047

* = Result Qualified

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Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key:	Within Guideline	Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key:	Within Guideline	**Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 7/14/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	0.006	0.0056	0.0056	0.0131	0.0511	0.0179	0.026	0.033	0.0272	0.0298	0.0194	0.0055
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.132	0.066	0.069	0.066	0.64	0.227	0.38	0.216	0.185	0.476	0.094	0.012
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.025	0.351	0.094	0.48	0.399	0.948	0.974	1.17 *	0.792	0.542	0.479	0.079
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	0.0001	0.0001	0.00024	0.00013	0.00018	0.00021	0.00023	0.00053	0.00039	0.00021	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00022	0.00014	0.00016	0.00029	0.00033	0.00051	0.00043	0.00021	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00108	0.00082	0.00082	0.00089	0.00055	0.00181	0.00052	0.00025	0.00389	0.001	0.00067	0.00072
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00123	0.00082	0.00083	0.00085	0.00071	0.0018	0.00064	0.00036	0.00362	0.00123	0.00073	0.00072
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0366	0.0614	0.0608	0.012	0.012	0.025	0.00435	0.00798	0.00656	0.0146	0.0159	0.0319
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0394	0.0666	0.0622	0.0125	0.0169	0.0285	0.00742	0.0129	0.00672	0.0188	0.0177	0.0333
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	2.4	2.2	3.6	3.2	2.5	3.9	3.4	11.7 *	7.5	5.2	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	0.01	0.017	0.017	0.012	0.011	0.011	<0.010	<0.010	0.013	0.011	0.012	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.012	0.02	0.019	0.014	0.013	0.012	<0.010	<0.010	0.014	0.012	0.011	0.01
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.00001	<0.000010	<0.000010	0.000017	0.000015	<0.000010	<0.000010	0.000013	<0.000010	0.000013	0.00001	<0.000010
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000053	0.000023	0.000022	0.00003	0.00004	0.000011	0.000026	0.00004	0.000017	0.000041	0.000028	<0.000010
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	36.9	62.6	61.8	18.8	20.5	16.6	6.84	11.8	18.9	17.8	27.5	26.9
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	40.2	71.1	65.6	19	21.2	17.2	7.74	14.1	20.2	18.1	25.6	28.5
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000018	<0.000010	<0.000010	<0.000010	0.000057	0.000018	0.000034	0.000022	0.000015	0.00004	<0.000010	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	186	179	175	39.1	20.6	271	7.12	6.01	219	29.4	16.2	210
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.0007	0.00068	<0.00050	0.0005	<0.00050	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	<0.00050	<0.00050	0.00075	0.00138	0.00063	0.00165	0.00121	0.0005	0.00153	0.00056	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00014	<0.00010	<0.00010	0.00028	0.00016	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.00018	<0.00010	<0.00010	0.00015	0.00032	0.00021	0.00032	0.00024	0.00035	0.00049	0.00019	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00056	0.00105	0.00114	0.00441	0.00238	0.00084	0.00245	0.00209	0.00104	0.00313	0.00266	0.00033
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0011	0.0013	0.0013	0.0052	0.0036	0.0022	0.0048	0.0133	0.0013	0.0049	0.0033	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	900 *	13000 *	12000 *	4200 *	1800 *	400 *	12000 *	5000 *	4400 *	26000 *	2700 *	40 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.05	0.103	0.098	0.02	0.075	0.012	0.07	0.021	0.066	0.173	0.076	0.026
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.295	0.208	0.199	0.064	0.669	0.148	0.45	0.267	0.299	0.8	0.182	<0.050
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000084	0.000082	0.00009	<0.000050	0.00017	0.000197	0.00027	0.00008	0.000345	0.000581	0.000068	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00061	0.00035	0.00035	0.00022	0.00171	0.00082	0.00148	0.00157	0.00085	0.00205	0.0003	<0.00010
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	0.0013	0.0012	0.001	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.0016	0.0016	0.0016	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0015
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	27.9	24.7	24.2	3.11	4.04	22.1	0.676	1.05	12.5	1.99	5.73	29
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	29.1	25.1	24	3.1	4.3	24.3	1.06	1.49	12.2	2.24	6	29.6
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.0169	0.00642	0.0044	0.00159	0.00262	0.00235	0.00592	0.0195	0.0133	0.0177	0.0034	0.00435
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.046	0.0314	0.0271	0.0128	0.0447	0.0124	0.0367	0.0641	0.0261	0.0652	0.0492	0.0119
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000302	0.000357	0.000368	0.000667	0.000593	0.000638	0.000271	0.000365	0.000701	0.000539	0.000947	0.000203
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000349	0.00042	0.000421	0.000673	0.000667	0.000641	0.000326	0.000452	0.000733	0.000574	0.000971	0.000231
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	0.00052	<0.00050	0.00059	<0.00050	0.00057	0.00063	0.0006	0.00068	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00073	0.00053	0.00071	0.00063	0.00144	0.00092	0.00098	0.0015	0.00151	0.00113	0.00101	0.00052
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.16	0.214	0.23	0.165	0.065	<0.020	0.214	0.254	<0.020	0.279	0.095	<0.020
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	0.124	0.056	<0.050	<0.050	<0.050	<0.050	<0.050	0.082	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	0.069	0.077	0.169	0.127	0.057	0.11	0.065	0.083	0.154	0.124	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0089	0.0302	0.0326	0.0967	0.0529	0.0125	0.0375	0.0102	0.0298	0.0418	0.0705	0.0047
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.51	2.36	2.48	1.91	2.2	1.72	1.21	0.696	2.01	2.32	2.36	1.36

Potassium (K)-Total	mg/L	1	-	-	-	-	1.51	2.37	2.38	1.83	2.18	1.81	1.24	0.732	1.87	2.3	2.42	1.35
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00128	0.00172	0.00177	0.00066	0.00083	0.00063	0.00067	0.00077	0.0006	0.00101	0.00135	0.00111
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00153	0.00183	0.00201	0.00075	0.00182	0.00107	0.00126	0.00113	0.00084	0.00173	0.00163	0.00121
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000129	0.000225	0.000194	0.000142	0.000105	0.000098	0.000079	0.000094	0.000143	0.00014	0.000121	0.000092
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000126	0.000205	0.0002	0.00011	0.000083	0.000085	0.000096	0.00012	0.000129	0.000139	0.000124	0.00008
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.22	3.56	3.43	1.95	1.27	1.17	0.283	0.351	0.262	0.389	1.76	0.673
Silicon (Si)-Total	mg/L	1	-	-	-	-	1.45	3.72	3.57	2.02	2.29	1.44	0.816	0.635	0.477	1.03	1.82	0.704
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	101	93.2	91.4	29	16.1	173 *	5.41	6.21	150 *	20.1	11.2	114 *
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	110 *	94.3	90.1	28.7	14.8	168 *	5.04	6.05	149 *	19.6	11.1	128 *
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.0653	0.0921	0.0928	0.0464	0.0713	0.0658	0.0394	0.0433	0.135	0.0931	0.0565	0.0587
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.0695	0.0997	0.0942	0.0448	0.0736	0.0641	0.0405	0.0475	0.138	0.0939	0.0508	0.0605
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	6.18	11.5	11.2	4.84	2.63	5.08	1.12	5.42	5.95	7.53	2.98	5.83
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	6.55	11.8	11.2	4.9	2.69	5.48	1.11	5.66	5.55	6.87	3.1	6.26
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	0.000011	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	0.000014	<0.000010	<0.000010	<0.000010	0.000011	<0.000010	<0.000010	0.00001	<0.000010	0.00001	<0.000010	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	0.00012	0.00012	<0.00010	0.00015	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	0.00057	0.00242	0.00065	0.0006	0.00033	0.00104	0.00102	0.00052	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.00308	0.00145	<0.0020 *	0.00153	0.0163	0.00498	0.00984	0.00461	0.00458	0.0119	<0.0030 *	<0.00030
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0253	0.0549	0.172	0.122	0.0955	0.0372	0.0972	0.0516	0.0528	0.124	0.0972	0.0093
Total Suspended Solids	mg/L	3	-	-	-	15	11.1	7	3	<2.0	9.5	6.4	14.2	8.8	9.5	18.7	2.6	<2.0
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00012	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	0.00013	<0.00010	<0.00010	<0.00010	0.00014	<0.00010	<0.00010	0.00014	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000301	0.000274	0.000278	0.000026	0.000086	0.000343	0.000011	0.000023	0.000358	0.000029	0.000046	0.000218
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000321	0.000285	0.000285	0.000029	0.000103	0.000395	0.000027	0.000039	0.000361	0.00005	0.000049	0.000242
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	0.00052	0.00051	0.00177	0.00117	0.00321	0.0014	0.0015	0.00494	0.00167	0.00103	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0.00058	0.00064	0.00064	0.00192	0.00219	0.0037	0.00219	0.0019	0.00528	0.00279	0.00128	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0289	0.0045	0.0044	0.0021	0.0017	<0.0010	0.007	0.005	<0.0010	0.0051	0.0078	<0.0010
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0472	0.0081	0.0082	0.0048	0.0118	0.0081	0.0194	0.0191	0.0034	0.0163	0.0124	<0.0030
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	0.00036	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key: Within Guideline | Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key: Within Guideline | **Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 8/16/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	0.0061	0.0086	0.011	0.0397	0.0328	0.0153	0.093	0.162	0.0528	0.149	0.0338	0.0065
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.183	0.06	0.097	0.147	0.271	0.177	0.786	1.48	0.222	0.749	0.148	0.012
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.345	<0.020	0.056	0.055	0.069	0.079	0.201	0.103	<0.020	0.28	0.048	0.048
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00023	0.00015	0.00016	0.00038	0.00034	0.0006	0.00083	0.00016	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00024	0.00016	0.00017	0.00078	0.00063	0.00061	0.00087	0.00023	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00101	0.00071	0.00059	0.00078	0.00051	0.00158	0.00032	0.00029	0.00374	0.00349	0.00019	0.00058
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00128	0.00072	0.00076	0.00083	0.00068	0.00161	0.0008	0.0011	0.00426	0.00426	0.00028	0.00063
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0418	0.0647	0.057	0.0128	0.0216	0.0146	0.00572	0.00699	0.00438	0.00554	0.00564	0.0384
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0441	0.0653	0.0669	0.0136	0.0242	0.0164	0.0125	0.017	0.00599	0.00952	0.00704	0.0412
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	<2.0	<2.0	2.2	2.3	3.1	4.3	2.5	10	10.2	2.4	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	0.012	0.015	0.015	0.013	0.014	0.014	<0.010	<0.010	0.015	0.016	<0.010	0.01
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.012	0.016	0.016	0.013	0.014	0.014	<0.010	<0.010	0.015	0.017	<0.010	0.011
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.00001	<0.000010	<0.000010	0.000023	<0.000010	<0.000010	0.000012	0.000024	<0.000010	<0.000010	<0.000010	<0.000010
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000094	0.000016	0.000028	0.000036	0.000022	0.000013	0.00008	0.000134	0.000018	0.000045	0.000015	<0.000010
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	45.5	64.3	63.1	24.2	29.3	18	9.92	13.9	18.9	21.1	11.9	34.2
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	46.9	67.1	66.8	23.7	30.4	19.3	13.1	16.2	19.4	23.4	12.3	35.8
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000023	<0.000010	<0.000010	0.000012	0.000024	0.000018	0.00009	0.000163	0.000018	0.000064	0.000016	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	151	185	185	20.1	28.2	241	4.81	4.85	117	17.7	3.95	180
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	0.00062	<0.00050	0.00136	0.00348	<0.00050	<0.00050	0.00126	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	<0.00050	<0.00050	0.00067	0.00115	<0.00050	0.00301	0.00568	0.00053	0.00135	0.00177	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0001	<0.00010	<0.00010	0.00016	0.00021	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.0002	<0.00010	<0.00010	0.00014	0.00017	0.00019	0.00061	0.00092	0.00029	0.00061	0.00011	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00055	0.00056	0.00047	0.00399	0.0014	0.00076	0.00447	0.00331	0.0009	0.00151	0.00116	0.00024
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0017	<0.0010	<0.0010	0.0045	0.0024	0.0013	0.0108	0.0097	0.0015	0.0035	0.0021	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	1000 *	1600 *	1800 *	600 *	1300 *	300 *	2800 *	1700 *	900 *	39000 *	900 *	30 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.044	0.044	0.041	0.038	0.075	<0.010	0.072	0.098	0.09	0.243	0.028	0.019
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.465	0.128	0.175	0.142	0.418	0.197	1.2	1.99	0.395	1.26	0.212	0.054
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000068	0.00007	0.000072	0.00009	0.000146	0.000119	0.000678	0.000977	0.000553	0.00139	0.000073	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00093	0.00032	0.00051	0.00031	0.00088	0.0008	0.00897	0.018	0.0012	0.00461	0.00064	<0.00010
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	0.0015	0.0017	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0016
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.0015	0.0016	0.0016	<0.0010	<0.0010	<0.0010	0.001	0.0017	<0.0010	<0.0010	<0.0010	0.0014
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	24.4	25.5	23	3.2	6.35	21	0.806	1.04	5.89	1.75	1.19	25
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	24.9	26.2	26	3.23	6.66	20.5	2.57	2.95	6.57	2.26	1.34	27.3
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.024	0.00419	0.00339	0.00122	0.00646	0.0022	0.00286	0.014	0.00809	0.00675	0.00445	0.00155
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.0535	0.0113	0.0166	0.0058	0.044	0.0112	0.0744	0.104	0.0205	0.0708	0.0242	0.0139
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000355	0.000291	0.000308	0.000447	0.000474	0.000533	0.000623	0.0006	0.000747	0.00119	0.000346	0.000184
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000375	0.000317	0.000309	0.000463	0.0005	0.000505	0.000709	0.000669	0.000753	0.00121	0.000364	0.000199
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00053	0.00056	<0.00050	0.00081	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00072	<0.00050	<0.00050	0.00071	0.00074	0.00074	0.00176	0.00248	0.00096	0.00173	0.00062	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.197	0.241	0.238	<0.020	0.03	<0.020	0.242	0.295	<0.020	<0.020	0.147	<0.020
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	0.077	<0.050	<0.050	<0.050	<0.050	<0.050	0.068	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	0.103	0.069	<0.050	0.108	0.091	0.055	0.219	<0.050	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0096	0.0192	0.0207	0.0726	0.0295	0.0113	0.0177	0.0187	0.0244	0.0681	0.0096	0.0064
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.82	1.99	1.78	1.64	1.84	2.03	0.611	0.631	1.82	1.11	0.58	1.56

Potassium (K)-Total	mg/L	1	-	-	-	-	1.83	1.99	1.99	1.64	1.87	1.93	0.784	0.927	1.96	1.27	0.604	1.7
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.0015	0.00149	0.0013	0.00056	0.00099	0.00054	0.00056	0.00072	0.00052	0.00047	0.00081	0.00108
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00187	0.00163	0.00157	0.00073	0.00134	0.00078	0.00177	0.00307	0.00082	0.00135	0.00114	0.00122
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.00011	0.000157	0.000148	0.000137	0.000099	0.000072	0.000142	0.000129	0.000119	0.000154	0.000116	0.000086
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000187	0.000139	0.000159	0.000138	0.000107	0.000086	0.00017	0.000155	0.000132	0.000198	0.000139	0.000078
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.77	3.39	3.37	4.34	2.07	1.13	0.477	0.708	0.223	1.93	0.519	0.801
Silicon (Si)-Total	mg/L	1	-	-	-	-	2.06	3.51	3.6	4.61	2.51	1.36	1.62	2.76	0.446	2.79	0.68	0.842
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	81	101 *	104 *	19.2	19.7	148 *	4.64	5.1	71.1	13	3.3	90.8
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	81.1	105 *	107 *	19.4	20.6	145 *	4.58	4.79	78.3	13.4	3.39	99.3
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.0732	0.0949	0.0917	0.0533	0.0962	0.0762	0.0476	0.0515	0.114	0.066	0.0457	0.065
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.0763	0.0986	0.0993	0.053	0.1	0.0768	0.0505	0.0523	0.12	0.072	0.0462	0.0698
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	5.89	6.25	6.24	2.17	2.21	10.2	1.33	1.6	3.26	2.39	1.17	5.44
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	5.99	6.43	6.48	2.29	2.22	10.4	1.27	1.46	3.71	2.56	1.14	5.6
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	0.000011	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	0.000017	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000019	0.000037	<0.000010	0.000011	<0.000010	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00016	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00045	0.00046	<0.00010	0.00014	0.00015	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00060 *	0.00164	0.00122	0.00048	0.00176	0.00301	0.00169	0.004	0.00077	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.00381	0.00144	0.00222	0.00405	0.00895	<0.0050 *	0.0267	0.0381	0.00571	0.018	0.00443	<0.00030
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0355	0.0315	0.0363	0.0974	0.0608	0.0405	0.0931	0.0912	0.0522	0.245	0.027	0.0112
Total Suspended Solids	mg/L	3	-	-	-	15	23.8	10	9.3	<2.0	7.4	9.5	47.1	14.4	12	145	10.8	<2.0
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00014	0.00014	<0.00010	<0.00010	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000287	0.000332	0.000336	0.000035	0.000109	0.00033	0.000017	0.000039	0.000257	0.000167	0.000018	0.000202
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000311	0.000355	0.000353	0.000037	0.000119	0.000333	0.00005	0.000095	0.000278	0.000189	0.000023	0.000214
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	0.0005	0.0005	0.00176	0.00094	0.00289	0.0019	0.00162	0.0037	0.00425	0.00164	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0.00075	0.0007	0.00075	0.00199	0.00146	0.00312	0.00382	0.00461	0.00454	0.00652	0.00207	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0381	0.0021	0.0018	0.002	0.0012	<0.0010	0.0077	0.0085	<0.0010	0.0018	0.0052	<0.0010
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0673	0.0066	0.0091	0.0053	0.0087	0.0092	0.0634	0.0926	0.0053	0.0154	0.0143	<0.0030
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00034	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00038	0.00054	<0.00030	<0.00030	<0.00030	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key:	Within Guideline	Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key:	Within Guideline	**Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 9/27/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	<0.0050	0.0056	0.0058	0.0092	0.0221	0.0098	0.029	0.0488	0.0406	0.391	0.0728	<0.0050
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.194	7.4	0.863	0.103	0.317	0.032	0.201	0.323	0.228	0.586	1.07	0.018
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.037	0.056	0.053	0.048	0.444	0.097	0.318	0.243	<0.020	<0.020	0.211	0.042
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00018	0.00018	<0.00010	0.00041	0.00039	0.00028	0.00119 *	0.00015	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	0.00021	<0.00010	0.00022	0.00022	<0.00010	0.00062	0.00062	0.00029	0.00094	0.0003	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00102	0.00053	0.00052	0.00091	0.00038	0.00054	0.00045	0.00039	0.00199	0.00317	0.0002	0.00044
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.0014	0.00544	0.00107	0.00098	0.00057	0.00058	0.00065	0.00056	0.00222	0.00329	0.00072	0.00046
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0456	0.0679	0.0675	0.0489	0.0287	0.0266	0.00859	0.00629	0.0229	0.00613	0.00346	0.0462
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.05	0.227	0.0865	0.0546	0.0325	0.0269	0.012	0.00898	0.0254	0.02	0.0114	0.0452
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	0.00035	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	0.000132	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	<2.0	<2.0	8.1	4.4	<2.0	6.2	4.6	5	10.3	4.1	2.1
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	0.011	0.013	0.013	0.015	<0.010	0.014	0.026	<0.010	0.014	0.011	<0.010	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.012	0.169	0.014	0.015	0.011	0.014	0.029	<0.010	0.012	0.012	<0.010	<0.010
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	0.000013	<0.000010	<0.000010	0.000031	<0.000010	<0.000010	0.000013	0.000014	<0.000010	0.000018	<0.000010	<0.000010
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000101	0.00257	0.000279	0.000043	0.000028	<0.000010	0.000043	0.00004	0.00002	0.000032	0.000055	0.000017
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	50.7	72.2	72.4	62.8	31.4	28.1	11.9	10.6	28	19.2	8.41	41
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	51.2	104	71	65.7	31.5	27.4	12.5	11.1	25.3	23.8	10.6	39.8
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.00002	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000021	0.000482	0.000078	<0.000010	0.000026	<0.000010	0.000019	0.000031	0.000018	0.000038	0.000102	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	120	200	202	276	60.3	160	39.5	7.99	27.5	10.9	2.67	143
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	0.00114	<0.00050	0.00077	0.00339	<0.00050	0.00053	0.00077	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	0.0111	0.0014	0.00075	0.00198	<0.00050	0.00136	0.00424	<0.00050	0.00108	0.00251	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010	0.00017	0.00034	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.0002	0.00447	0.00051	0.00016	0.0002	<0.00010	0.00027	0.00021	0.00031	0.00057	0.0006	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00058	0.00052	0.00052	0.00301	0.00158	0.00056	0.0037	0.00384	0.00057	0.00256	0.00137	0.00034
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0017	0.0305	0.0041	0.0041	0.0031	<0.0010	0.0066	0.0056	0.0013	0.0031	0.0045	0.0012
E. Coli	CFU/100mL	10	-	100	-	-	3700 *	2100 *	1800 *	5300 *	1000 *	11900 *	9400 *	2000 *	90 *	310 *	380 *	160 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.055	0.023	0.022	0.026	0.055	<0.010	0.113	0.055	0.12	0.498	0.044	0.016
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.528	10.3	1.19	0.178	0.46	<0.050	0.466	0.474	0.524	1.19	1.37	0.073
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000085	<0.000050	0.000051	0.000051	0.000105	0.000062	0.00039	0.000229	0.000619	0.0027	0.000131	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00099	0.0393	0.00418	0.00039	0.001	0.00018	0.00147	0.0019	0.00174	0.00393	0.00373	0.00012
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	<0.0010	0.0011	0.0011	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.001	0.0086	0.0019	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	21.8	25.1	24.7	15.9	8.07	18.8	1.88	1.14	4.19	1.1	0.91	22
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	22.6	35.2	26.6	17	8.75	18.5	2.44	1.73	4.16	2.03	2.2	21.6
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.0137	0.00348	0.00217	0.00232	0.0339	0.00068	0.0125	0.00557	0.00369	0.0148	0.0179	0.0006
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.0456	1.73	0.184	0.0116	0.0654	0.00434	0.0425	0.0206	0.0752	0.0874	0.0678	0.0104
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000387	0.000313	0.000307	0.000845	0.000574	0.000536	0.000523	0.000711	0.000823	0.000969	0.000289	0.000295
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000412	0.000662	0.000362	0.000988	0.000668	0.00056	0.00057	0.000721	0.000782	0.000883	0.000389	0.000332
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	0.00068	<0.00050	<0.00050	0.00054	0.00059	0.00059	0.00099	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00073	0.00997	0.0013	0.00095	0.00096	<0.00050	0.00099	0.00106	0.00095	0.00144	0.00186	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.213	0.46	0.454	1.18	0.246	<0.020	0.277	0.526	<0.020	<0.020	0.166	<0.020
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	0.132	<0.050	<0.050	0.111	0.052	<0.050	0.094	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	0.054	1.31	0.162	0.23	0.086	<0.050	0.237	0.086	0.131	0.287	0.072	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0064	0.014	0.0124	0.123 *	0.0239	0.0068	0.0675	0.0431	0.0266	0.0904	0.0143	0.0046
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.95	2.36	2.4	7.8	2.78	1.66	2.1	0.922	2.96	1.27	0.738	1.66

Potassium (K)-Total	mg/L	1	-	-	-	-	2.07	3.47	2.54	8.15	2.97	1.64	2.32	0.941	2.92	2.66	1.06	1.63
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00152	0.00149	0.00151	0.00217	0.00159	0.00056	0.00087	0.00083	0.00052	0.00066	0.00119	0.00116
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00178	0.00989	0.00284	0.00235	0.00195	0.00056	0.00108	0.00125	0.00079	0.00156	0.00283	0.00117
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000108	0.000119	0.000117	0.000194	0.000152	<0.000050	0.000154	0.000174	0.000077	0.000194	0.000119	0.000058
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000173	0.00241	0.000322	0.00023	0.000142	0.000054	0.000201	0.000207	0.00008	0.000227	0.000131	0.000082
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.64	2.84	2.89	3.69	1.61	<0.050	0.426	0.555	0.074	1.77	0.378	0.401
Silicon (Si)-Total	mg/L	1	-	-	-	-	1.96	13.4	4.06	4.13	2.05	0.068	0.697	0.955	0.411	2.12	2.15	0.401
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	0.000115	<0.000050	<0.000050	<0.000050	<0.000050	0.000055	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	64.1	113 *	112 *	161 *	34.4	95.2	23.7	6.54	18.4	7.21	1.87	78.5
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	66.7	115 *	113 *	174 *	35.5	93.5	25.8	6.07	18.6	8.04	2.02	76.7
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.0819	0.105	0.102	0.241	0.0753	0.0933	0.15	0.0427	0.124	0.0826	0.0356	0.0846
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.0893	0.144	0.11	0.267	0.0807	0.0982	0.162	0.0452	0.122	0.109	0.0411	0.0851
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	4.94	6.48	6.69	16.5	3.23	5.04	2.83	2.21	2.2	2.36	0.74	4.64
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	5.2	11.1	6.98	18.5	3.33	5.11	3.14	1.93	2.19	2.19	0.77	4.57
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	0.000012	0.000157	0.000022	<0.000010	<0.000010	<0.000010	<0.000010	0.000013	<0.000010	<0.000010	0.000018	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00013	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	0.00027	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00015	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	0.00047	<0.00010	<0.00010	0.0001	<0.00010	0.00027	0.00029	<0.00010	<0.00010	0.00027	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.00050 *	0.0009	<0.00030	0.00071	0.00129	<0.00060 *	0.0124	0.00229	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.00433	0.124	0.0186	<0.0040 *	0.0101	0.00071	0.00653	0.0105	<0.0060 *	0.014	0.0367	0.00043
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0321	0.869 *	0.097	0.196	0.0577	0.0143	0.183	0.0789	0.113	0.238	0.0738	0.0106
Total Suspended Solids	mg/L	3	-	-	-	15	13.1	48.7	68.7	<2.0	10.4	3.5	10.5	14	19.7	12.5	25	2.6
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00013	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	0.00012	<0.00010	<0.00010	<0.00010	0.00011	<0.00010	<0.00010	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000359	0.000411	0.00042	0.000237	0.000129	0.000296	0.000043	0.000039	0.000276	0.000223	0.000027	0.000274
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000376	0.000925	0.000464	0.000255	0.000139	0.000283	0.000068	0.000047	0.000277	0.000213	0.000052	0.000267
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	0.00098	0.00124	<0.00050	0.00126	0.00148	0.00081	0.00798 *	0.00204	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	0.00073	0.0125	0.00191	0.00133	0.002	<0.00050	0.00201	0.00228	0.00167	0.00611	0.0045	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0415	0.0016	0.0017	0.0032	0.0016	<0.0010	0.0087	0.0057	<0.0010	0.0036	0.0035	<0.0010
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.071	0.52	0.0594	0.0082	0.0107	<0.0030	0.0259	0.0235	0.0062	0.011	0.0396	<0.0030
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00077	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	0.00152	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.00061	<0.00030	0.00031	0.00052	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key: Within Guideline | Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key: Within Guideline | **Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 10/20/2016 WET DAY											
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-P1 (04)	HC-P1 (05)	HC-P1 (06)	HC-P2 (04)	HC-P2 (05)	HC-P2 (06)	HC-P2 (07)	HC-P4(04)	HC-P4(05)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	<0.0050	<0.0050	0.0055	<0.0050	0.0139	0.0077	0.0262	0.0614	0.0366	1.06	0.0746	0.012
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.089	0.107	0.102	0.031	4.98	0.088	0.298	0.363	0.271	15.8 *	0.75	0.02
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	<0.020	<0.020	0.095	0.05	0.081	0.035	0.369	0.093	<0.020	0.151	0.203	0.045
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.0005	0.00052	0.00032	0.00136	0.0002	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	0.00013	<0.00010	<0.00010	<0.00010	0.00019	<0.00010	0.00068	0.0007	0.00039	0.00118	0.00039	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00118	0.00047	0.00047	0.00055	0.00039	0.00051	0.00041	0.00028	0.00136	0.00458	0.00019	0.00044
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00147	0.00058	0.0006	0.00053	0.00233	0.00058	0.00063	0.00047	0.00165	0.00939	0.00054	0.00045
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0473	0.0709	0.0694	0.0727	0.0539	0.0358	0.0159	0.00674	0.0196	0.00681	0.00642	0.0447
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0509	0.074	0.0741	0.0711	0.103	0.0417	0.0176	0.00988	0.0237	0.22	0.012	0.0464
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00023	<0.00010	<0.00010	<0.00010	<0.00010	0.0007	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	0.000062	<0.000050	<0.000050	<0.000050	<0.000050	0.000229	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	<2.0	<2.0	3	3.6	3	7.6	4.1	4.9	18.5	3.5	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	0.011	0.013	0.012	0.017	0.011	0.017	0.087	<0.010	0.032	0.018	<0.010	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.011	0.013	0.013	0.017	0.015	0.018	0.083	<0.010	0.033	0.026	<0.010	<0.010
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	<0.000010	<0.000010	<0.000010	0.00002	<0.000010	<0.000010	0.000012	0.000028	<0.000010	0.000024	0.000012	<0.000010
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000039	0.000035	0.000035	0.000025	0.000312	0.00001	0.000034	0.000075	0.000022	0.00088	0.000043	<0.000010
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	51.2	73.3	71.6	88.5	54.4	38	18.1	15	28.3	22.4	12.7	37.7
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	55.5	76.3	76.2	93.9	75.3	41.7	17.9	15.7	30.6	71	14.4	40.5
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000055	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000014	0.000011	0.000012	<0.000010	0.000381	<0.000010	0.00003	0.000038	0.000022	0.000924	0.00007	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	134	204	202	289	132	203	112	5.21	42.7	19.5	3.52	153
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00344	<0.00050	0.00123	0.00053	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	<0.00050	<0.00050	<0.00050	0.00716	<0.00050	0.00122	0.00423	0.00052	0.0251	0.00163	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00014	0.0005	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.00012	0.00011	0.00011	0.0001	0.00278	<0.00010	0.00032	0.00024	0.00031	0.0102	0.00041	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00048	0.0005	0.00048	0.00085	0.00087	0.00052	0.00406	0.00395	0.00063	0.00279	0.00199	0.00053
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	<0.0010	<0.0010	0.0011	0.0013	0.0108	<0.0010	0.0067	0.007	0.0014	0.0406	0.0041	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	100 *	500 *	400 *	600 *	800 *	900 *	400 *	600 *	500 *	100 *	2700 *	40 *
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.063	0.032	0.032	0.031	0.043	<0.010	0.082	0.063	0.033	1.27	0.053	<0.010
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.314	0.164	0.166	0.105	6.05	0.106	0.501	0.506	0.494	20.9	0.927	<0.050
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000072	0.000055	0.000064	0.000188	0.000096	<0.000050	0.000254	0.000239	0.000197	0.00715	0.000133	<0.000050
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00045	0.00058	0.00058	0.00067	0.0159	0.00044	0.0016	0.00196	0.00161	0.0583	0.00269	0.00011
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	0.0015	0.0017	0.0015	0.0016	0.0013	<0.0010	0.0017	<0.0010	<0.0010	<0.0010	<0.0010	0.0014
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.0013	0.0016	0.0017	0.0016	0.0055	<0.0010	0.0016	<0.0010	<0.0010	0.0148	0.0011	0.0012
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	23.2	26.3	26.2	31.7	16.2	24.8	3.9	1.39	4.54	1.41	1.39	23.3
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	24.4	27	27.3	31.4	21.8	24.8	3.61	1.93	4.74	16.9	2.11	23.6
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.0233	0.00536	0.0044	0.00444	0.0433	<0.00050	0.00496	0.00393	0.0013	0.0362	0.00938	0.00066
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.038	0.0229	0.0237	0.0155	0.621	0.0132	0.0576	0.0195	0.0617	0.673	0.0498	0.00823
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000438	0.000284	0.000293	0.000376	0.000464	0.000517	0.000602	0.000613	0.000906	0.00144	0.000367	0.000347
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000486	0.000309	0.000333	0.000355	0.000603	0.000531	0.000607	0.00062	0.000981	0.000999 *	0.000435	0.000359
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00062	<0.00050	0.00055	0.00173	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.00058	<0.00050	<0.00050	<0.00050	0.00586	0.00058	0.00118	0.00127	0.00108	0.0207	0.0015	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.121	0.235	0.222	0.147	0.286	<0.020	0.251	0.483	<0.020	<0.020	0.205	0.051
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	0.069	<0.050	0.16	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	0.284	<0.050	0.212	0.12	0.077	1.35	0.087	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0048	0.0085	0.0075	0.0065	0.0126	0.0068	0.0297	0.0591	0.0176	0.0938	0.0283	0.0077
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.79	2.44	2.54	2.68	2.76	2.09	2.9	0.954	3.06	1.32	1.34	1.59

Potassium (K)-Total	mg/L	1	-	-	-	-	1.79	2.38	2.57	2.43	3.39	1.97	2.55	0.947	3.06	5.7	1.45	1.49
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00134	0.00145	0.00156	0.00075	0.00124	0.00048	0.00126	0.00066	0.00063	0.00144	0.00181	0.00125
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.0016	0.00173	0.00174	0.0007	0.00724	0.00058	0.00148	0.00115	0.00103	0.0163	0.00296	0.00127
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000088	0.000098	0.000088	0.000076	0.000059	<0.000050	0.00008	<0.000050	0.000084	0.000252	<0.000050	0.000066
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000094	0.00013	0.000111	0.000084	0.000215	<0.000050	0.000099	<0.000050	0.000089	0.000492	0.000069	0.000064
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.66	3.41	3.45	1.14	2.69	0.07	0.367	0.759	0.113	2.68	0.596	0.566
Silicon (Si)-Total	mg/L	1	-	-	-	-	1.8	3.63	3.64	1.11	9.85	0.201	0.777	1.19	0.453	22.6	1.59	0.578
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000052	<0.000050	<0.000050	0.000164	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	69.3	110 *	106 *	161 *	68.6	116 *	71.1	4.88	26.4	11.4	2.78	80.9
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	74.7	116 *	119 *	168 *	73.9	121 *	64.9	4.86	27.7	12.7	2.86	82.6
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.087	0.107	0.103	0.141	0.0915	0.129	0.289	0.0573	0.139	0.0997	0.0518	0.0823
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.0939	0.113	0.113	0.149	0.118	0.134	0.263	0.0555	0.155	0.19	0.0542	0.0862
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	5.82	6.52	6.65	9.62	4.62	7.15	5.48	1.28	4.28	3.74	1	5.58
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	5.86	6.75	6.93	9.49	5.07	7.26	5.21	1.25	4.57	4.66	0.98	5.6
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	0.000014	0.000063	<0.000010	<0.000010	0.000012	<0.000010	0.000214	0.000015	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00033	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00022	<0.00010	<0.00010	<0.00010	<0.00010	0.00084	<0.00010	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	0.00031	<0.00010	0.00024	0.00027	<0.00010	0.00088	0.00016	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00070 *	<0.00030	0.00079	0.00204	<0.00030	0.0337	0.00294	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	<0.0030 *	0.00242	0.00245	<0.0010 *	0.123	0.0023	0.00933	0.0108	0.00642	0.294	0.0223	<0.00030
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0158	0.0196	0.0209	0.0307	0.246	0.0281	0.153	0.0955	0.0667	1.84 *	0.0585	0.0102
Total Suspended Solids	mg/L	3	-	-	-	15	4	12.7	9.1	4.6	102	3.5	18.5	10.1	14.9	770 *	23	<2.0
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00018	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00016	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000429	0.000426	0.000413	0.000545	0.00026	0.00038	0.00003	0.000052	0.000346	0.000344	0.00004	0.000345
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000445	0.000431	0.000426	0.000518	0.000385	0.000381	0.000053	0.000066	0.000367	0.000728	0.000063	0.000345
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	<0.00050	0.0007	<0.00050	0.00098	0.00146	0.00068	0.0123	0.00189	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	<0.00050	0.00059	0.00062	<0.00050	0.00998	0.00061	0.00192	0.00217	0.00152	0.0362	0.00347	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0515	0.0017	0.0016	0.0023	<0.0010	0.0019	0.0102	0.0075	<0.0010	0.0086	0.006	0.0017
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.0698	0.0097	0.0096	0.0048	0.096	0.0055	0.024	0.0277	0.0067	0.282	0.034	0.0033
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	0.0017	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	0.00052	<0.00030	<0.00030	<0.00030	<0.00030	0.00129	0.00031	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key: Within Guideline | Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key: Within Guideline | **Exceeds Guideline**

			PWQO		Guelph Storm		SITES SAMPLED ON 06/24/2016 DRY DAY			SITES SAMPLED ON 10/26/2016 DRY DAY			SITES SAMPLED ON 11/15/2016 DRY DAY		
Analyte	Units	LOR	Lower Limit	Upper Limit	Lower Limit	Upper Limit	HC-A (04)	HC-A (13)	HC-A (14)	HC-A (04)	HC-A (13)	HC-A (14)	HC-A (04)	HC-A (13)	HC-A (14)
Aluminum (Al)-Dissolved	mg/L	0.01	-	0.015	-	-	<0.0050	0.0053	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Aluminum (Al)-Total	mg/L	0.01	-	0.015	-	-	0.101	0.074	0.094	0.032	0.403	0.367	0.084	0.047	0.023
Ammonia, Total (as N)	mg/L	0.05	-	-	-	-	0.09	0.038	0.183	0.045	0.073	0.115	0.114	0.677	0.215
Antimony (Sb)-Dissolved	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Antimony (Sb)-Total	mg/L	0.005	-	0.02	-	-	<0.00010	<0.00010	<0.00010	0.00011	0.00013	0.00012	<0.00010	<0.00010	<0.00010
Arsenic (As)-Dissolved	mg/L	0.001	-	0.005	-	-	0.00078	0.00062	0.00065	0.00116	0.00044	0.00044	0.00043	0.00044	0.00121
Arsenic (As)-Total	mg/L	0.001	-	0.005	-	-	0.00088	0.00062	0.0007	0.0013	0.00067	0.00065	0.00133	0.00043	0.00040 *
Barium (Ba)-Dissolved	mg/L	0.01	-	-	-	-	0.0426	0.0587	0.0594	0.0441	0.0678	0.0692	0.0688	0.0715	0.0486
Barium (Ba)-Total	mg/L	0.01	-	-	-	-	0.0429	0.0591	0.0613	0.047	0.0735	0.0724	0.0498 *	0.0702	0.0698
Beryllium (Be)-Dissolved	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Beryllium (Be)-Total	mg/L	0.001	-	0.011	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Bismuth (Bi)-Dissolved	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Bismuth (Bi)-Total	mg/L	0.001	-	-	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
BOD Carbonaceous	mg/L	2	-	-	-	15	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Boron (B)-Dissolved	mg/L	0.05	-	0.2	-	-	<0.010	<0.010	<0.010	0.01	0.011	0.01	0.01	0.01	<0.010
Boron (B)-Total	mg/L	0.05	-	0.2	-	-	0.012	0.012	0.011	0.01	0.011	0.011	<0.010	0.011	0.011
Cadmium (Cd)-Dissolved	mg/L	0.00009	-	0.0001	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000013
Cadmium (Cd)-Total	mg/L	0.00009	-	0.0001	-	0.001	0.000052	0.000022	0.000032	0.000019	0.000126	0.000095	0.000031	0.000017	<0.000010
Calcium (Ca)-Dissolved	mg/L	0.5	-	-	-	-	49.6	61.6	61.7	57.8	80.9	77.3	77.6	81.5	61.3
Calcium (Ca)-Total	mg/L	0.5	-	-	-	-	52.1	65.6	66.6	59.1	85.5	82.4	65.6	82.1	83.9
Cesium (Cs)-Dissolved	mg/L	0.00001	-	-	-	-	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Cesium (Cs)-Total	mg/L	0.00001	-	-	-	-	0.000012	<0.000010	0.000013	<0.000010	0.000039	0.000033	0.00001	<0.000010	<0.000010
Chloride (Cl)	mg/L	2	-	-	-	-	148	180	180	133	215 *	232 *	122	211 *	213 *
Chromium (Cr)-Dissolved	mg/L	0.0005	-	-	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Chromium (Cr)-Total	mg/L	0.0005	-	-	-	0.2	<0.00050	<0.00050	<0.00050	<0.00050	0.00064	0.00055	<0.00050	<0.00050	<0.00050
Cobalt (Co)-Dissolved	mg/L	0.0005	-	0.0009	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Cobalt (Co)-Total	mg/L	0.0005	-	0.0009	-	-	0.00013	<0.00010	<0.00010	<0.00010	0.00025	0.00022	0.00011	<0.00010	<0.00010
Copper (Cu)-Dissolved	mg/L	0.001	-	0.001	-	-	0.00061	0.00054	0.00056	0.0004	0.0004	0.00039	0.00039	0.00044	0.0007
Copper (Cu)-Total	mg/L	0.001	-	0.001	-	0.01	0.0012	<0.0010	<0.0010	<0.0010	0.002	0.0016	0.001	<0.0010	<0.0010
E. Coli	CFU/100mL	10	-	100	-	-	800 *	2100	1700 *	10 *	100 *	24 *	10	30	20
Iron (Fe)-Dissolved	mg/L	0.05	-	0.3	-	-	0.026	0.016	0.015	0.041	0.014	0.013	0.019	0.018	0.057
Iron (Fe)-Total	mg/L	0.05	-	0.3	-	-	0.255	0.119	0.152	0.155	0.514	0.43	0.267	0.088	0.053
Lead (Pb)-Dissolved	mg/L	0.001	-	0.001	-	-	0.000058	<0.000050	<0.000050	0.000061	<0.000050	<0.000050	<0.000050	<0.000050	0.000081
Lead (Pb)-Total	mg/L	0.001	-	0.001	-	0.05	0.00059	0.00038	0.00049	0.00026	0.00197	0.0016	0.00071	0.00028	0.00013
Lithium (Li) - Dissolved	mg/l	0.1	-	-	-	-	0.0011	0.0011	0.0011	0.0018	0.0021	0.002	0.0013	0.0015	0.0012
Lithium (Li) - Total	mg/L	0.1	-	-	-	-	0.0013	0.0015	0.0013	0.0012	0.0019	0.0019	0.0012	0.0015	0.0015
Magnesium (Mg)-Dissolved	mg/L	0.5	-	-	-	-	24.5	25.2	25.3	24.6	28.2	27.5	28.5	28.5	24.7
Magnesium (Mg)-Total	mg/L	0.5	-	-	-	-	25.1	25.9	25.9	24.8	29.2	29	24.9	28.7	28.6
Manganese (Mn)-Dissolved	mg/L	0.001	-	-	-	-	0.00052	0.00051	0.00053	0.0193	0.00651	0.0047	0.0127	0.00428	0.0257
Manganese (Mn)-Total	mg/L	0.001	-	-	-	-	0.037	0.0216	0.0339	0.0268	0.067	0.0608	0.0394	0.0229	0.00804 *
Molybdenum (Mo)-Dissolved	mg/L	0.001	-	0.04	-	-	0.000294	0.000289	0.000291	0.000463	0.000303	0.000316	0.0003	0.000303	0.000467
Molybdenum (Mo)-Total	mg/L	0.001	-	0.04	-	-	0.000305	0.00034	0.000358	0.00047	0.000336	0.000335	0.000491	0.000333	0.000308 *
Nickel (Ni)-Dissolved	mg/L	0.002	-	0.025	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Nickel (Ni)-Total	mg/L	0.002	-	0.025	-	0.05	0.0005	<0.00050	<0.00050	0.00056	0.00077	0.00067	0.00069	<0.00050	<0.00050
Nitrate-N (NO3-N)	mg/L	0.1	-	-	-	-	0.553	0.495	0.483	0.175	0.36 *	0.39 *	0.294	0.37 *	0.38 *
Phosphorus (P)-Dissolved	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	0.05	-	-	-	-	<0.050	<0.050	<0.050	<0.050	0.086	0.068	<0.050	<0.050	<0.050
Phosphorus, Total, Dissolved	mg/L	0.003	-	-	-	-	0.0087	0.0152	0.0183	0.0047	0.0095	0.0088	0.0055	0.0045	<0.0030
Potassium (K)-Dissolved	mg/L	1	-	-	-	-	1.01	1.06	1.07	1.52	1.77	1.77	1.54	1.57	1.57

Potassium (K)-Total	mg/L	1	-	-	-	-	1.02	1.09	1.14	1.51	1.76	1.75	1.49	1.53	1.51
Rubidium (Rb)-Dissolved	mg/L	0.0002	-	-	-	-	0.00099	0.00087	0.00086	0.00107	0.00103	0.00101	0.00097	0.00096	0.00109
Rubidium (Rb)-Total	mg/L	0.0002	-	-	-	-	0.00125	0.00098	0.00107	0.00124	0.00162	0.00151	0.00116	0.00098	0.00093
Selenium (Se)-Dissolved	mg/L	0.0004	-	0.1	-	-	0.000195	0.000172	0.000163	0.000076	0.000078	0.000081	0.000081	0.000088	0.000085
Selenium (Se)-Total	mg/L	0.0004	-	0.1	-	-	0.000162	0.000158	0.000149	0.000092	0.000192	0.00014	0.000095	0.000077	0.000078
Silicon (Si)-Dissolved	mg/L	1	-	-	-	-	1.62	2.32	2.32	1.83	3.35	3.34	3.24	3.29	1.84
Silicon (Si)-Total	mg/L	1	-	-	-	-	1.86	2.58	2.56	1.87	3.86	3.77	1.99 *	3.24	3.1
Silver (Ag)-Dissolved	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Silver (Ag)-Total	mg/L	0.0001	-	0.0001	-	-	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
Sodium (Na)-Dissolved	mg/L	0.5	-	-	-	-	75.8	95.5	96.1	66.4	112 *	111 *	114 *	116 *	65.1
Sodium (Na)-Total	mg/L	0.5	-	-	-	-	76.2	96.6	98.3	71.3	120 *	118 *	63.5 *	111 *	111 *
Strontium (Sr)-Dissolved	mg/L	0.001	-	-	-	-	0.0827	0.0957	0.0958	0.0951	0.114	0.111	0.115	0.114	0.0935
Strontium (Sr)-Total	mg/L	0.001	-	-	-	-	0.0827	0.0966	0.1	0.0952	0.122	0.12	0.101	0.123	0.124
Sulfur (S)-Dissolved	mg/L	0.5	-	-	-	-	5.3	6.15	6.29	5.79	7.44	7.54	7.53	7.38	6.17
Sulfur (S)-Total	mg/L	0.5	-	-	-	-	5.73	6.45	6.48	5.79	7.45	7.5	6.10 *	7.46	7.13
Tellurium (Te)-Dissolved	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Tellurium (Te)-Total	mg/L	0.0002	-	-	-	-	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Thallium (Tl)-Dissolved	mg/L	0.0003	-	0.0003	-	-	0.00001	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
Thallium (Tl)-Total	mg/L	0.0003	-	0.0003	-	-	<0.000010	<0.000010	<0.000010	<0.000010	0.000012	0.00001	<0.000010	<0.000010	<0.000010
Thorium (Th)-Dissolved	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Thorium (Th)-Total	mg/L	0.0001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Dissolved	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tin (Sn)-Total	mg/L	0.001	-	-	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Titanium (Ti)-Dissolved	mg/L	0.002	-	-	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Titanium (Ti)-Total	mg/L	0.002	-	-	-	-	0.00205	0.00175	0.00202	0.0008	0.00884	0.00711	0.00226	0.00169	0.00093
Total Phosphorus	mg/L	0.003	-	0.02	-	-	0.0181	0.0247	0.0333	0.0106	0.0766	0.0449	0.0138	0.0078	0.0192
Total Suspended Solids	mg/L	3	-	-	-	15	11.3	6.3	10.8	3.5	22	27.4	5.1	3.6	9.9
Tungsten (W)-Dissolved	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Tungsten (W)-Total	mg/L	0.01	-	0.03	-	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
Uranium (U)-Dissolved	mg/L	0.005	-	0.005	-	-	0.000382	0.000438	0.000449	0.000488	0.000484	0.000501	0.000502	0.000493	0.000566
Uranium (U)-Total	mg/L	0.005	-	0.005	-	-	0.000411	0.000484	0.000485	0.000521	0.000513	0.0005	0.000551	0.000496	0.00052
Vanadium (V)-Dissolved	mg/L	0.001	-	0.006	-	-	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
Vanadium (V)-Total	mg/L	0.001	-	0.006	-	-	<0.00050	0.00054	0.00062	<0.00050	0.00124	0.00091	<0.00050	<0.00050	<0.00050
Zinc (Zn)-Dissolved	mg/L	0.003	-	0.02	-	-	0.0251	0.0018	0.0014	0.0526	0.0013	0.0013	0.0015	0.0021	0.0544
Zinc (Zn)-Total	mg/L	0.003	-	0.02	-	0.05	0.042	0.0063	0.0079	0.0623	0.0297	0.024	0.0692	0.0052	0.0036 *
Zirconium (Zr)-Dissolved	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030
Zirconium (Zr)-Total	mg/L	0.004	-	0.004	-	-	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030	<0.00030

* = Result Qualified <

Applied Guideline: **Ontario Provincial Water Quality Objectives (JULY, 1994) - Surface Water PWQO**

Color Key:	Within Guideline	Exceeds Guideline

Applied Guideline: **Ontario City of Guelph Storm Sewer Guidelines 15202 (1996)**

Color Key:	Within Guideline	**Exceeds Guideline**

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APPENDIX IV

AQUATIC MONITORING REPORT

HANLON CREEK BUSINESS PARK

CONSTRUCTION-PHASE AQUATIC MONITORING 2016

Prepared for:

City of Guelph
Economic Development Services
65 Delhi Street
Guelph, ON

Project No. 1034G l April 2017

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Hanlon Creek Business Park
Construction-Phase Aquatic Monitoring 2016

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Report submitted on April 5, 2017

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1.0 Introduction

The need for aquatic monitoring for the Hanlon Creek Business Park development was identified in the *Hanlon Creek Business Park Consolidated Environmental Impact Study* (NRSI 2004), which recommended benthic invertebrate sampling and more frequent fish sampling at the state-of-the-watershed fish sampling site. Monitoring of aquatic habitat was also recommended in the conditions for the Draft Plan approval of the Hanlon Creek Business Park as set by the Ontario Municipal Board (2006). Specifically, Draft Plan Condition #12 requires that thermal impact of stormwater management ponds be monitored.

A multi-disciplinary monitoring program was developed for the Hanlon Creek Business Park development to achieve a variety of objectives, including the aquatic habitat. The overall monitoring program also includes terrestrial features, hydrogeology, surface water flows, surface water temperatures, benthic invertebrates and fish.

This monitoring report addresses the benthic invertebrate and fish communities. The aquatic monitoring components were implemented prior to construction to establish an adequate baseline data set against which development conditions can be compared. The pre-construction data includes the years 2006 - 2009. Data has been collected at 5 stations (3 stations prior to 2009). One of the stations coincides with the aforementioned state-of-the-watershed fish sampling station. Monitoring will continue until 75% of the development is built by area in Phases I, II and III of the HCBP, plus an additional 2 years.

In 2016, construction activities continued within the Hanlon Creek Business Park. Construction activities began in 2010 with grading, servicing, and building construction initiated. As a result, aquatic monitoring conducted since 2010 is considered construction-phase monitoring.

In addition to the monitoring for the Hanlon Creek Business Park, state-of-the-watershed monitoring in the Hanlon Creek watershed is to occur on a 5-year schedule based on the recommendation for long-term monitoring in the Hanlon Creek Watershed Plan (1993).

The aquatic component of the state-of-the-watershed monitoring includes one fish sampling site within the Hanlon Creek Business Park development lands (PEIL 2004).

2.0 Study Area

The Hanlon Creek Business Park (HCBP) is located in the south end of the City of Guelph. As shown on Map 1, the project area is bounded to the east by Hanlon Expressway, to the north by the Kortright IV subdivision, to the west by Downey Road and to the south by Forestell Road. Laird Road runs parallel to Forestell Road, dividing the project area into north and south sections. The project area comprises forested areas and swamp/marsh pockets, as well as lands to be developed. The project area also includes a system of tributary streams that is part of the Hanlon Creek watershed. These streams are the subject of the aquatic monitoring. The watercourses are shown on Map 1.

The aquatic monitoring program is being conducted primarily in the northern portion (Phase I) of the business park development, north of Laird Road. The interest in this location is based on the historic presence of Brook Trout (*Salvelinus fontinalis*) in the coldwater habitat provided by Tributary A1, and Tributary A north of Laird Road. One of the stations, added in 2009, is south of Laird Road, situated downstream of the outlet of Stormwater Management (SWM) Pond 4.

2.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2016. Construction activity in 2016 within Phases 1 and 2 is outlined below and highlighted on Map 2. No construction activity occurred within Phase 3 in 2016.

Phase 1, Stage 2

- Operation of commercial building – 500 Hanlon Creek Boulevard (Fusion Homes)
- Operation of commercial building – 501 Hanlon Creek Boulevard (Compass)

Phase 1, Stage 3

- Operation of commercial buildings – 197-345 Hanlon Creek Boulevard (Wurth Canada, Graniteworx, etc.)
- Operation of commercial building – 28 Bett Court (MF Property Management Inc.)

Phase 2

- Operation of commercial building – 104 Cooper Drive (Ontario One Call)
- Preliminary grading of Blocks 8, 9 and 26 was completed in 2014 with a structure being built in fall 2016
- Laird Road overpass has been in-use since 2014

3.0 Methods

A total of 3 sampling sites in the northern portion of the subject property were selected during the 2006 field season. The same sites were sampled again every year from 2007 to 2016. Two sites were added in 2009 to expand the monitoring program and have been sampled continuously, including 2016. At each site, there is a benthic invertebrate sampling station (BTH) and a quantitative fish sampling station (EMS).

- Site 1 (BTH-001 and EMS-001) is located on Tributary A approximately 150m downstream (north) of Laird Road.
- Site 2 (BTH-002 and EMS-002) is located on Tributary A immediately downstream of the confluence with Tributary A1 and upstream (south) of Hanlon Creek Boulevard.
- Site 3 (BTH-003 and EMS-003) is located on Tributary A1.
- Site 4 (BTH-004 and EMS-004) is located on Tributary A downstream (north) of the Hanlon Creek Boulevard crossing.
- Site 5 (BTH-005 and EMS-005) is located on Tributary A upstream (south) of Laird Road

Fish sampling and benthic invertebrate collections were conducted at each site, but they occurred in separate areas of the stream to facilitate collection of both parameters on the same day (Map 1).

The original selection of stations was based in part on historic knowledge of Brook Trout inhabitance. The stations were also positioned to help locate sources of future impacts, should any occur. To the extent possible, station selection followed the recommendation in the Ontario Stream Assessment Protocol (Stanfield 2005) to establish the upstream and downstream extents of a site at a crossover point of the thalweg (concentration of flow). The specific sections of stream were selected to represent the habitat types in the vicinity of each station.

3.1 Benthic Invertebrate Community

There are a number of advantages in sampling benthic invertebrates for water quality monitoring:

- They reflect local aquatic conditions as a result of their limited mobility;
- They integrate all the surrounding parameters of their environment into one easily assessable sampling unit;
- They integrate the physical and chemical aspects of water quality over annual time periods due to their short life spans (approximately 1 year); and
- They may indicate the probable cause of impairment because many benthic invertebrate species have known environmental sensitivities and/or tolerances.

3.1.1 Benthic Invertebrate Sampling

Sampling for the benthic invertebrate monitoring took place on September 1 and 2, 2016. It employed the sampling methodology from the Ontario Benthos Biomonitoring Network (OBBN) protocols (Jones et al 2005). Most of the following procedures have been taken from these protocols. Some of the specimen processing procedures are not covered by the OBBN protocols.

According to the OBBN methods for streams, a total of 3 subsamples are collected at each station in stream habitats: 2 from riffles, and 1 from a pool. Where riffle and pool habitats are not clearly defined (as is the case at some of the subject stations) pools and riffles can be functionally defined as slow/deep and fast/shallow sections, respectively. For wadable streams, the OBBN protocol employs a Travelling Transect Kick and Sweep method. For each subsample, a total of at least 10 linear metres of transect must be sampled in approximately 3 minutes. For small streams such as those in this study, this requires that several transects be positioned in the same riffle or pool in order to sample 10 metres of transect. Beginning at one bank and moving across each transect, the substrate is disturbed to a depth of approximately 5cm by vigorously kicking the substrate. A 500-µm-mesh D-net is held downstream of and close to the disturbed area by the person sampling. The net is held on or close to the bottom, and is swept back and forth so that dislodged invertebrates will be carried into the net. In areas of slow current, the sweeping motion is important for collecting the invertebrates into the net. A stopwatch is used to time the sampling.

When sampling is complete, the net is rinsed and the sample is placed in plastic jars. The sample is then preserved with a 75% concentration of ethyl alcohol and sent to a professional taxonomist for identification. Benthic samples collected in 2016 were processed and identified in the NRSI laboratory. Samples are identified to the lowest practical taxonomic level. Between 2006 and 2012 as well as in 2015 and 2016 all samples were identified to genus. In 2013 and 2014, samples were identified to genus with the exception of chironomids, which were identified to sub-family. Subsampling is conducted by randomly dipping a small portion of the sample from a container until at least 200 organisms are obtained. After reaching the 200th organism, the portion being sampled is completed in order to facilitate measurement of the proportion of the total sample that is subsampled and identified. This also helps to ensure that samples are not biased towards larger individuals. The subsample proportion is determined by measuring the total sample weight/volume before identification and the remaining sample weight/volume after identification. The difference between those 2 measurements represents the portion sampled, which is recorded as a percentage of the total sample. While the OBBN protocol requires that a minimum of 100 organisms be collected, 200 organisms per subsample are collected to provide a robust sample for this program’s use of the Percent Model Affinity analysis.

The OBBN data form was used to record habitat information at the benthic invertebrate sampling stations. The form includes both measured and visually estimated parameters, and facilitates comparison with other years provided the estimated parameters are treated as approximations.

3.1.2 Benthic Invertebrate Data Analysis

Analysis was performed using the Percent Model Affinity (PMA) method developed in New York State by Novak and Bode (1992). This method was adapted for southern Ontario by Dr. David Barton (1996) of the University of Waterloo.

In his 1996 paper, Dr. Barton sampled over 200 streams in southern Ontario, 69 of which were used as the reference streams for the model community. Instead of using the 7 groupings originally used by Novak and Bode (1992), Dr. Barton compared the use of model communities at the order, family, genus, and ‘lowest practical’ taxonomic levels. He found that there was an improvement with increasing taxonomic resolution, particularly between the family and genus levels. He also analyzed seasonal differences (Barton 1996).

The model communities used for analysis in this study are based on values from Dr. Barton for streams with mud and cobble/gravel substrates sampled in August (Barton 2007). The model community for mud substrates was used for BTH-001, BTH-003, BTH-004 and BTH-005, and the model community for cobble/gravel substrates was used for BTH-002. The family level of taxonomic resolution was used because many of the invertebrates are very small in August and September, making it difficult or impossible to identify some of the specimens beyond their family.

The equation used to determine the percent similarity of community (PSC) is as follows:

$$\text{PSC} = 100 - 0.5\,\Sigma\,\left|a - b\right|$$

Where: a is the model community value for a taxonomic group expressed as a percentage of the organisms in the model community; and

b is the percentage of the same taxonomic group in a sample from the stream being studied.

The sample PSC value is calculated by summing the absolute differences between the family model values and the families in the sample, multiplying the sum by 0.5 and subtracting this number from 100 (Novak and Bode 1992). The sample PSC value is then compared to the critical PSC value for the chosen model community.

Each critical PSC value is effectively a lower confidence limit of the mean for the expected community. It is essentially a statistical one-tailed t-test comparing a single observation with the mean of the sample, where the P-Value = 0.05 (Zar 1999). The critical PSC values were provided by Dr. Barton along with the model community data (Barton 2007).

This index does not assign a degree of impairment or non-impairment. Rather, significant impact at a sample site is determined when the calculated sample PSC value is less than the critical PSC value. Significant impact implies that the sample community is statistically significantly different from the model community. A determination of no significant impact occurs when the calculated sample PSC value is greater than the critical PSC value (Barton 1996).

The PMA analysis was conducted for each station with the 3 subsamples (riffles and pool) combined into one sample, which is the intention of the OBBN protocol.

In addition to PMA analysis, three other indices were calculated to provide additional insight into the water quality conditions at the sampling sites. They were:

- The number of taxa present in each sample (taxonomic richness);
- The percentage of individuals in each sample belonging to the taxonomic groups Ephemeroptera, Plecoptera, and Tricoptera (EPT richness); and
- The percentage of individuals in each sample that were the dominant taxon (% dominant taxon).

Taxonomic richness is a measure used to determine the number of different species that are present in a sampled area and provide an indication of the diversity of a given site. Generally, a higher number of taxa present in a sample reflect a more diverse habitat and/or better water quality.

The percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT richness) is based on the premise that EPT taxa are less tolerant of pollution. Therefore, a higher EPT richness value suggests better water quality and/or habitat conditions.

The dominant taxon and its percentage of the sample are very helpful in characterizing the benthic community at a site. It describes an aspect of the diversity of the community, and can provide some indication of habitat and/or water quality at the site.

3.2 Fish Community

NRSI biologists conducted quantitative fish sampling at the 5 stations to provide population estimates that can be compared over the years of monitoring.

3.2.1 Fish Community Sampling

Fish sampling was conducted on August 30, 31, and September 1, 2016 using a depletion sampling method that is outlined in the Ontario Stream Assessment Protocol (Stanfield 2010). At each quantitative station, the chosen stream length was isolated from the rest of the stream using block nets. The block nets were small seine nets with a mesh size similar to the size of mesh on the dip net used with the electrofisher. The rope across the bottom of the net was weighted to keep it against the bottom of the channel, and the top of the net was a floating line. The nets were secured to trees or woody material on each shore.

A 2-person electrofishing crew conducted multiple passes of the enclosed area using a Smith-Root LR-20B backpack electrofisher set to a pulsating frequency of 40 to 50Hz, and an electric potential of 100, 150 or 200 volts with current (amperes) ranging from approximately 2.0 to 3.0A. Once collected, the fish were identified, measured on site, and released outside of the sampling area downstream of the block nets. This process was repeated until the number of individuals caught exhibited a downward trend, or a minimum of three times. The number of individual fish, and minimum and maximum lengths were recorded for each species. The water quality conditions, electrofisher settings, and number of shocking seconds for each pass were recorded. An effort was made to keep the sampling effort the same for each pass with respect to shocking seconds and netting technique.

Habitat information for the stations included classifications of adjacent lands, and basic visual estimates of macrohabitats (riffles, pools, etc.), instream vegetation, instream cover and overhead canopy shading. General flow conditions were also determined by measuring the wetted width, bankfull width, and five equally spaced depths, at five transects along the station. These habitat parameters provide a basic description of the conditions and help to understand the fish data. This information is intended to help interpret the fish community data for the quantitative stations. Because the focus of the monitoring is on the fish community, they are approximate and not intended for detailed comparison among years of monitoring.

Brook trout spawning surveys were carried out during the spawning season in the fall of 2016. Three site visits were conducted, occurring on October 31, November 11, and November 25, 2016 to document redds and observe any Brook Trout that might be exhibiting spawning behaviour within the Hanlon Creek tributaries. The survey was conducted at several locations along Tributary A and Tributary A1 within the HCBP and covered approximately 650 m of creek.

3.2.2 Fish Community Data Analysis

The analysis of the data for the sampling stations provides estimates of the population of the fish at each station. A simple method for these calculations uses a regression of the data, which is plotted on a 2-dimensional graph with the catch from an individual fishing (1 pass) on the y-axis and the previous total catch (sum of previous passes) on the x-axis. This method is described by Zippen (1958) in the context of trapping small mammals. This calculation assumes a constant probability (P) of capture with each fishing pass. However, this method is generally considered inferior because it does not give valid estimates of the standard error of the estimated population size. Two of the five stations (EMS-001 and EMS-002) utilized the least squares regression method for calculating population estimates in 2016.

A better method employs maximum likelihood estimates, as described by Schnute (1983). This method calculates the probability of capture, and this probability can be either constant or variable. For 2016, the data collected at 4 of the 5 sampling sites were limited to 3 passes since they exhibited a consistent downward trend. Station EMS-005 required a fourth pass to achieve a consistent downward trend. These data are well suited to the maximum likelihood constant P method. Three of the five stations (EMS-003, EMS-004, and EMS-005) met the necessary criteria required for estimating population size under the constant P method, and the population estimates are considered reliable.

A computer software package called *Removal Sampling 2* by Pisces Conservation Ltd. was used to perform the calculations using the maximum likelihood – constant probability method. The estimated population calculations were carried out separately for each station, and estimates were made for all species combined. Capture of Brook Trout warrants a separate estimate, but none were captured in 2016.

4.0 Results and Discussion

4.1 Benthic Invertebrate Sampling

4.1.1 Habitat and Sampling Conditions

Station BTH-001 is situated within a white cedar – hardwood mixed swamp as defined in the Ecological Land Classification for Southern Ontario Guide (ELC, Lee et al. 1998). This swamp extends up to 100 m to the west, but a fallow agricultural field occupies land within 50 m to the southeast of the station. The riparian vegetative community is predominantly coniferous forest which was estimated to provide 75 - 100% shade. The channel is comprised of shallow runs, riffles, and pools. At the time of sampling no aquatic macrophytes or algae were observed within the channel. Woody debris and detritus was present throughout the entire site with woody debris abundant in some locations. The sampling conditions are summarized in Table 1.

Table 1. Benthic Invertebrate Sampling Conditions for Station BTH-001

Date	September 2, 2016		
Time	09:14		
Air Temperature (°C)	25.0		
Water Temperature (°C)	21.6		
Dissolved Oxygen (mg/L, %)	6.72, 72.8		
Conductivity (µS/cm)	680		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	1.45	1.12	1.74
Maximum Depth (m)	0.17	0.14	0.11
Maximum Hydraulic Head (mm)	5	0	5
Dominant Substrate	Clay	Clay	Sand
Second Dominant Substrate	Gravel	Gravel	Cobble
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	4	6	4

Station BTH-002 is situated within a white cedar – hardwood mixed swamp (Lee et al. 1998). The vegetative community adjacent to the stream is mainly deciduous forest from 1.5 to 30 m on the west side and 1.5 to 10 m on the east side. Beyond 30 m to the west a 100 m meadow buffer separates forest from a newly developed block of land with a recently built Fusion Homes corporate office building. Beyond 10 m of forest to the east exists a strip of meadow approximately 10 m wide and a recently constructed gravel walking trail, which runs parallel to Tributary A and A1 and is fenced along both sides. The overhead canopy at this station provides an estimated 75 to 100% shade. The channel includes shallow riffle, pool, and run features. Within the channel aquatic macrophytes and algae are generally absent with some crusted algae covering the substrate. Detritus was noted to be abundant and woody debris is present throughout the sample location. In 2016, a large branch was noted to have fallen across the channel approximately halfway up the site creating a small backwater effect. The ponding upstream resulted in some accumulation of some silt and detritus. Sampling conditions are summarized in Table 2.

Table 2. Benthic Invertebrate Sampling Conditions for Station BTH-002

Date	September 1, 2016		
Time	12:30		
Air Temperature (°C)	25.0		
Water Temperature (°C)	17.0		
Dissolved Oxygen (ppm, %)	6.32, 71.6		
Conductivity (µS/cm)	980		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	3.7	2.9	3.0
Maximum Depth (m)	0.11	0.11	0.14
Maximum Hydraulic Head (mm)	3	2	3
Dominant Substrate	Cobble	Cobble	Cobble
Second Dominant Substrate	Gravel	Gravel	Gravel
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	2:50
Number of Jars to Retain Sample	1	2	2

Station BTH-003 is situated within a white cedar – hardwood mixed swamp (Lee et al. 1998). The riparian community is dominated by deciduous forest along both banks of the creek, providing up to 100% canopy cover. To the west this vegetative community extends beyond 100m while to the east it extends to approximately 30 m. Beyond the trees a 30 m strip of meadow habitat separates the forest from the gravel walking path described under station BTH-002, which occurs within the Phase 1 construction area. The channel includes flats, runs and shallow pools. There is limited to no aquatic vegetation or algae in the channel, however woody debris and detritus are both found to be abundant throughout the site. This abundance of woody debris, provided by fallen logs and branches, adds complexity to the instream habitat. Sampling conditions for this site are provided in Table 3.

Table 3. Benthic Invertebrate Sampling Conditions for Station BTH-003

Date	September 1, 2016		
Time	11:20		
Air Temperature (°C)	19.0		
Water Temperature (°C)	12.4		
Dissolved Oxygen (ppm / %)	7.12, 68.8		
Conductivity (µS/cm)	1,720		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	1.5	1.7	1.24
Maximum Depth (m)	0.1	0.13	0.09
Maximum Hydraulic Head (mm)	1	1	1
Dominant Substrate	Silt	Silt	Silt
Second Dominant Substrate	Sand	Sand	Sand
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	2	2	2

<u>Station BTH-004</u> is situated in a white cedar – hardwood mixed swamp (Lee et al. 1998). The vegetative community adjacent to the stream is a white cedar – hardwood mixed swamp along both banks and extending approximately 30 m. Beyond this to the west exists a section of mineral meadow marsh and fallow agricultural land. To the east this transitions to a predominantly deciduous forest and then to meadow. Beyond this lies the Phase 1 construction area which includes a gravel walking trail. The forest adjacent to the creek is estimated to provide approximately 75 to 100% shade over the station. The channel at this station includes a variety of shallow flats, runs and pool features. No aquatic vegetation was present in the channel at the time of sampling, however detritus and woody material were found to be present throughout the station. Sampling conditions for BTH-004 are summarized in Table 4.

Table 4. Benthic Invertebrate Sampling Conditions for Station BTH-004

Date	September 1, 2016		
Time	14:40		
Air Temperature (°C)	19.0		
Water Temperature (°C)	18.0		
Dissolved Oxygen (ppm / %)	7.60, 83.1		
Conductivity (µS/cm)	1010		
	Riffle 1	**Pool**	**Riffle 2**
Wetted Width (m)	1.8	1.8	2.25
Maximum Depth (m)	0.12	0.2	0.15
Maximum Hydraulic Head (mm)	1	0	1
Dominant Substrate	Sand	Sand	Sand
Second Dominant Substrate	Silt	Silt	Silt
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	3	3	3

Station BTH-005 is situated in a fresh – moist poplar deciduous forest which provides from 25 to 100% canopy cover, depending on the sample location. Smaller areas of reed canary grass mineral meadow marsh and willow mineral thicket swamp communities occur from 1.5 to 10 m on both sides of the channel (Lee et al. 1998). Fallow agricultural land occurs beyond 30 m to the southwest, and Laird Road is approximately 30 m to the north. Instream habitat is characterized by flat and run features with a limited amount of emergent and rooted floating vegetation within the channel. An abundance of detritus and variable amounts of woody debris were also observed. Sampling conditions are summarized in Table 5.

Table 5. Benthic Invertebrate Sampling Conditions for Station BTH-005

Date	September 2, 2016		
Time	11:00		
Air Temperature (°C)	28.0		
Water Temperature (°C)	22.5		
Dissolved Oxygen (ppm / %)	4.98, 59.1		
Conductivity (µS/cm)	680		
	Riffle 1	**Pool 2**	**Riffle 3**
Wetted Width (m)	1.16	1.89	1.45
Maximum Depth (m)	0.12	0.25	0.13
Maximum Hydraulic Head (mm)	6	0	5
Dominant Substrate	Silt	Sand	Clay
Second Dominant Substrate	Sand	Clay	Sand
Total Transect Length (m)	10	10	10
Kick & Sweep Sampling Time (min:sec)	3:00	3:00	3:00
Number of Jars to Retain Sample	5	5	5

4.1.2 Benthic Invertebrate Community Data

The identification and enumeration of benthic invertebrates are summarized in tabular format in Appendix I.

The Percent Model Affinity (PMA) index calculation generates Percent Similar Community (PSC) values, which are summarized in Table 6. Values that are higher than the critical PSC value indicate no impact, while values that are lower than the critical PSC value indicate impact. The impact determinations for the years 2006 through 2015 are provided along with the 2016 results for comparison.

Table 6. Percent Similar Community Values and Impact Determination

Station	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016 Critical PSC	2016 Sample PSC	2016 Result
BTH – 001	NI	NI	NI	NI	NI	NI	NI	NI	NI	I	42.12	47.60	NI
BTH – 002	I	NI	I	I	NI	I	I	I	I	I	50.7	29.6	I
BTH – 003	NI	NI	NI	NI	NI	NI	I	I	NI	NI	42.12	59.42	NI
BTH – 004	-	-	-	NI	NI	NI	I	I	I	NI	42.12	57.36	NI
BTH – 005	-	-	-	NI	NI	NI	NI	NI	I	I	42.12	56.17	NI

NI – No Impact
I – Impact

The additional indices that were calculated include taxonomic richness, EPT richness, and % dominant taxon. These results are summarized in Tables 7 through 11 and are shown on Figures 3, 4, and 5. The results are discussed by station in the text that follows.

Table 7. Benthic Invertebrate Metrics for Station BTH-001 for the Years 2006 to 2016

	BTH-001										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Taxonomic Richness	40	42	38	38	47	46	48	25	25	26	27
% EPTs	21.3	25.0	41.8	37.2	23.6	27.0	11.9	9.1	3.9	6.7	9.2
% Dominant Taxon	27.8	19.4	25.5	20.5	23.8	17.2	16.6	16.4	27.5	11.8	9.9

Table 8. Benthic Invertebrate Metrics for Station BTH-002 for the Years 2006 to 2016

	BTH-002										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Taxonomic Richness	47	42	39	32	49	42	43	23	19	27	30
% EPTs	42.9	16.4	44.4	48.8	29.6	47.6	25.1	31.6	21.3	31.4	25.0
% Dominant Taxon	18.5	32.0	20.2	19.1	14.4	16.3	31.2	16.8	30.0	14.3	11.3

Table 9. Benthic Invertebrate Metrics for Station BTH-003 for the Years 2006 to 2016

	BTH-003										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Taxonomic Richness	21	28	30	35	42	19	22	16	13	15	28
% EPTs	6.9	16.3	25.4	22.2	15.3	2.8	2.0	6.7	0.8	3.5	7.3
% Dominant Taxon	66.3	37.2	42.4	30.7	34.9	68.4	54.9	57.9	41.2	37.8	18.3

Table 10. Benthic Invertebrate Metrics for Station BTH-004 for the Years 2009 to 2016

	BTH-004										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Taxonomic Richness	-	-	-	39	43	41	27	18	15	19	21
% EPTs	-	-	-	12.5	10.0	8.2	0.8	3.9	1.3	7.5	3.5
% Dominant Taxon	-	-	-	29.0	19.0	29.3	49.7	56.8	34.3	20.6	11.5

Table 11. Benthic Invertebrate Metrics for Station BTH-005 for the Years 2009 to 2016

	BTH-005										
Year	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Taxonomic Richness	-	-	-	42	26	34	31	14	18	14	20
% EPTs	-	-	-	14.8	2.8	5.1	16.9	9.3	1.4	35.3	6.7
% Dominant Taxon	-	-	-	22.5	31.6	24.9	26.9	22.2	31.6	29.1	23.7

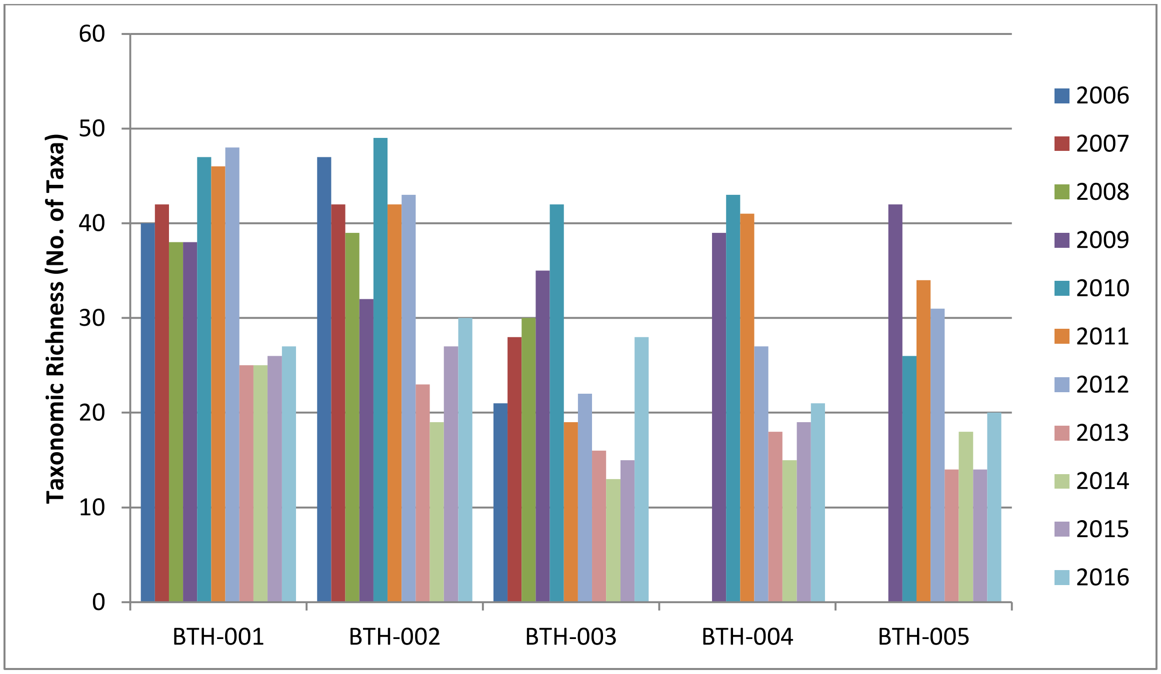

Figure 1. Benthic Invertebrate Taxonomic Richness for the Years 2006 to 2016

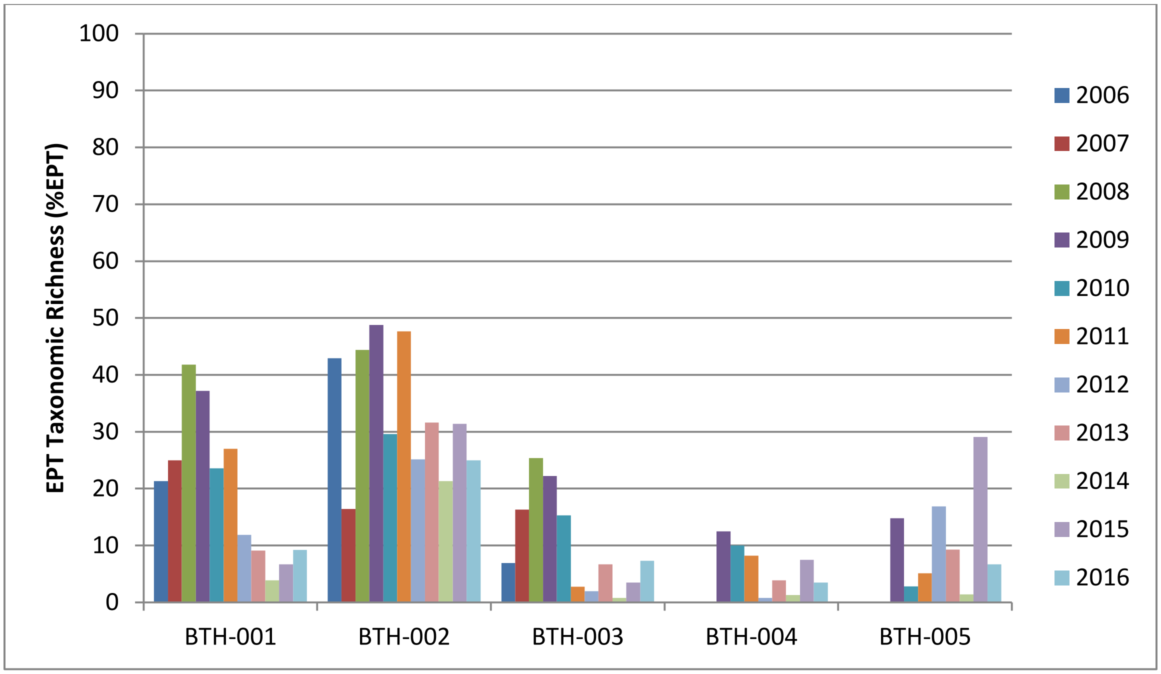

Figure 2. Benthic Invertebrate EPT Taxa Richness for the Years 2006 to 2016

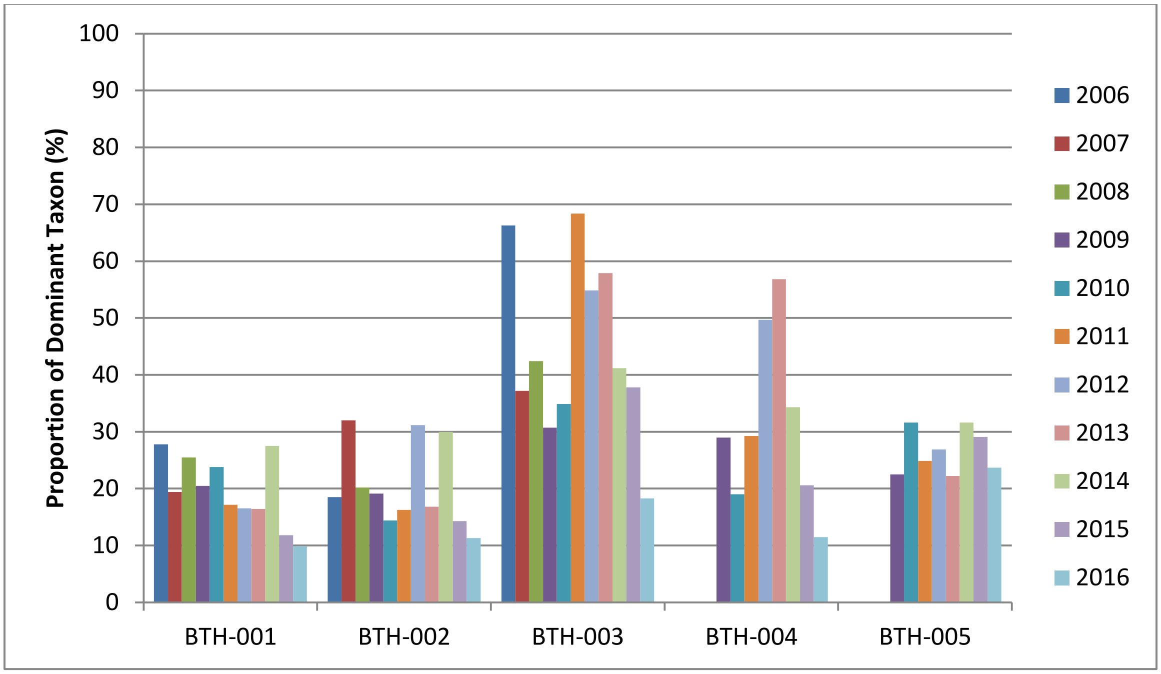

Figure 3. Benthic Invertebrate Proportion of Dominant Taxa for the Years 2006 to 2016

Station BTH-001

Taxonomic richness at station BTH-001 has varied from 25 to 48 over the 11 years of monitoring. Between 2006 and 2012 the taxa richness at this station remained fairly consistent with an increase observed in 2010. The highest taxa richness occurred in 2012 with a high of 48 (Figure 1). In 2013 and 2014, taxonomic richness was 25 for each of those years. These values were lower due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. In 2015 and 2016, taxa richness remained relatively low for station BTH-001, with only a slight increasing trend in spite of the genus-level identification of all specimens. The years 2015 and 2016 have notably lower taxa richness compared to other years of monitoring, although not low enough to trigger a threshold exceedance at any point in time. The variation in numbers has been further discussed in Section 4.1.3.

The EPT richness at BTH-001 has varied greatly between 2006 and 2016. Pre-construction values ranged from a low of 21.3% in 2006 to a high of 48.1% in 2008, which appeared to be uncharacteristically high for this station (Figure 2). Following 2008 the EPT richness has declined to below 10% with the lowest EPT richness (3.9%) occurring in 2014. The EPT richness increased slightly in 2015 and then again to 9.2% in 2016, but overall remains lower than what had been observed during pre-construction monitoring.

The dominant taxon in 2016 was *Chironomus*, belonging to the family Chironomidae (midges) and sub-family Chironominae of the order Diptera (true flies). Species belonging to this sub-family may be associated with a variety of habitats but can generally be found in the littoral and profundal areas of lentic systems as well as the depositional areas of lotic systems (Merritt et al. 2008), typically associated with finer substrates including silt and sand. The conditions at station BTH-001 are consistent with this generalized habitat description providing silt, sand and gravel substrates, as well as moderately abundant detritus and woody debris. *Chironomus* can occur in systems with poor water quality and severe organic pollution (Mandaville 2002). This species represented 9.9% of the total number of individuals within the sample in 2016 (Figure 3). Species of Dipterans (true flies) have also previously comprised large proportions of the samples at BTH-001, and did again in 2016 with approximately 68% of the sample contributed to Dipteran species. Dipteran species previously dominated the samples in

2006, 2007, 2013, and 2014. Previously observed dominant taxa have also included a species of caddisfly (Trichopteran) of the family Hydropsychidae in 2008 and 2009. Families that have also historically been found at BTH-001 include Amphipods (*Gammarus pseudolimnaeus*), Isopods (*Caecidotea intermedius*), and Coleopterans (*Optioservus fastiditus*). These species have all historically comprised a large proportion of the samples at this station and have dominated the samples during different years from 2010 to 2012. A species of Megalopteran of the family Sialidae dominated the sample in 2015.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 47.6 was higher than the critical PSC value of 42.12 (Table 6). The PMA index has consistently shown ‘no impact at BTH-001 with the exception of 2015, which was the first year the results have shown an ‘impact’ determination. A decrease in EPT species at this site between 2012 and 2014 indicated a potential change in conditions, and continued low EPT richness combined with the PMA impact determination in 2015 suggests that conditions may be changing.

Station BTH-002

Taxonomic richness at station BTH-002 was 30 in 2016 (Figure 1). Results show an increase trend following two consecutive years of decreasing taxa richness in 2013 and 2014. In 2013 and 2014, taxonomic richness was 23 and 19, respectively for each of those years. These values were lower than previous years due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. An increasing trend is noted for 2015 and 2016 with the taxa richness in 2016 approaching a similar number to what was observed during pre-construction monitoring in 2009. Generally, it appears that taxonomic richness has continued to be fairly consistent at BTH-002. The variation in numbers has been further discussed in Section 4.1.3.

The EPT richness was 25% in 2016, a decrease from 31.4% in 2015 but generally similar to what has been observed since 2012 (Figure 2). This metric has shown no obvious increasing or declining trends. EPT richness has frequently been high (above 40%) with large declines noted in 2007 (16.4%), 2010 (29.6%), and most recently in 2012. Further to this, it has never experienced declining richness values over consecutive years. The lowest levels in EPT richness at BTH-002 were seen during a pre-construction year in 2007 indicating that the observed declines in EPT taxa are within the natural variations of the station. Station BTH-002 has consistently shown the highest EPT richness values of the five monitoring stations.

The dominant taxa at station BTH-002 in 2016 belonged to the family Sialidae of the order Megaloptera (Alderfly). Species belonging to this family may be associated with a variety of substrates and current types and are exclusively predatory (Merritt *et al*. 2008). The conditions at station BTH-001 are consistent with this generalized habitat description providing substrates that include gravel and cobble, as well as moderately abundant detritus and woody debris. Sialidae are considered to be indicative of very good water quality with only slight organic pollution (Mandaville 2002). This species represented 11.3% of the total number of individuals within the sample (Figure 3) and has also dominated the sample in 2006. Species belonging to the family Elmidae (riffle beetle) from the order Coleoptera dominated the sample in 2015 and represented a large proportion of the sample again in 2016. The result for % dominant taxon has generally been lower at this station over the years of monitoring with 2007, 2012 and 2014 being relatively high (32.0%, 31.2% and 30.0%, respectively). The dominant taxonomic group has changed several times at BTH-002 including *Micropsectra sp.* (Diptera) in 2007 and 2008, *Cheumatopsyche spp.* (Trichoptera) in 2009, and *Leuctra spp.* (Plecoptera) in 2010 and 2011. In 2013 two species dominated the sample including *G. pseudolimnaeus* and *Diplectrona modesta*, a species of Trichoptera. Prior to 2015 *Gammarus pseudolimnaeus* had been the dominant taxa at this station between 2012 and 2014. EPT species, and specifically Trichopteran species, have typically been well represented within the sample at BTH-002 over the years and were again in 2016 including species of Hydropsychidae and Philopotamidae. The site characteristics associated with BTH-002 are well suited for EPT including gravel and cobble riffles. As noted in Section 4.1.1a large branch was noted to have fallen across the channel which created a slight backwater effect. This may affect the proportion of EPT species over time.

The PMA index in 2016 showed ‘impact’ for the sixth consecutive year. Results since pre-construction monitoring began in 2006 have been inconsistent up until 2011 with results showing no reliable trend of ‘impact’ or ‘no impact’. Since 2011 results have consistently indicated ‘impact’, which has been the most common result, with ‘no impact’ observed only two out of ten years of monitoring (2007 and 2010) (Table 6). Continuation of the ‘impact’ determinations suggests that some change has occurred, although it may not be a major change. Taxonomic richness and % EPT are somewhat lower in recent years, corroborating the PMA results. Monitoring using the PMA analysis should continue with the intention of determining whether or not a ‘no impact’ determination is observed again. The other metrics should also be considered along with the results of the PMA analysis.

Lastly, the predominance of the ‘impact’ result should not be construed to mean that station BTH-002 is in poorer condition than the other stations. This station is the only station that uses the cobble/gravel model community for PMA index, and it was chosen based on the habitat characteristics of the station. Because of this difference, comparisons among the other four stations using the PMA index are not valid. The monitoring program is intended to provide temporal comparison within stations.

Station BTH-003

Taxonomic richness at station BTH-003 was 28 in 2016. This is a substantial increase from 15 in 2015 (Figure 1) and higher than has been observed annually since 2011. Taxa richness has experienced a general decrease that began in 2011, which followed an exceptionally high year in 2010 where the richness was 42. The lowest result occurred in 2014 with a value of 13. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae in 2013 and 2014, compared to genus-level identification for all other years. Over the 5 years of monitoring prior to 2011 species richness had increased steadily by 50%, beginning in 2006 with a measure of 21 and increasing to 42 in 2010. The results observed in 2011 and 2012 appeared to be a return to the degree of taxonomic richness that was observed during pre-construction monitoring. In 2016 taxa richness was noted to increase substantially with numbers similar to pre-development values.

The EPT richness was 7.3% in 2016, an increase from 3.5% in 2015 and 0.8% in 2014 (Figure 2). Results have varied throughout the years with an increasing trend observed during the first three years of monitoring and a decreasing trend between 2008 and

2014. The EPT richness values seen between 2011 and 2015 generally show levels that were lower than results from pre-construction monitoring, with the exception of 2013 which saw an increase to pre-construction levels. The result from 2016 marks the second consecutive increase in EPT at BTH-003 and a value that is the highest that has been observed since 2010 and slightly higher than the preconstruction value of 6.9%, observed in 2006.

The dominant taxon in 2016 was *Gammarus pseudolimnaeus*, which comprised 18.3% of the total sample (Figure 3). This marks the fifth consecutive year that *G. pseudolimnaeus* has been the dominant species at BTH-003 comprising between 37.8% and 68.4% of the samples since 2012. *G. pseudolimnaeus* prefers soft substrates and the shallow areas of both lotic and lentic environments. The preference of this species for depositional areas explains its abundance at station BTH-003 as this station occurs in a slow-flowing, groundwater-fed headwater tributary with abundant detritus and underlying substrates dominated by silt and clay. *G. pseudolimnaeus* are indicative of very good water quality (Mandaville 2002). Prior to 2012, the dominant taxon was *Micropsectra* spp., a Dipteran species that had previously been the dominant taxon throughout all six years of pre-construction monitoring. In 2015 a variety of Chironomid species comprised the majority of the subdominant groups including several species belonging to the *Prodiamesinae* and *Orthocladiinae* subfamilies. The 2016 dominant taxa value marks the lowest that has been observed since sampling began. The dominant taxa values at BTH-003 has typically been the highest observed across the site with *G. pseudolimnaeus* comprising the majority of samples. The low value in 2016 indicates a potential shift in the dominant taxa as the subdominant taxa comprised larger proportions of the sample.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 59.4 was higher than the critical PSC value of 42.12 (Table 6). The result of ‘no impact’ is consistent with the results from 2014 and 2015. This is a change from 2012 and 2013, both of which showed ‘impact’. Prior to 2011 the results suggested that habitat and/or water quality conditions at station BTH-003 were generally improving as evidenced by a consistent increase in species diversity (taxonomic richness) and a similarly consistent result of ‘no impact’. Results in 2011 and 2012, however, suggested a change in the habitat conditions at this site leading to results that are similar to those observed in

2006. This was demonstrated through a decrease in taxonomic richness and EPT taxa richness, and a large increase in the proportion of the dominant taxon, *Micropsectra* spp in 2011, and *G. pseudolimnaeus* in 2012 and 2013. However, since this change was consistent with pre-construction monitoring results in 2006, it was attributed to natural variation. Results in 2015 and 2016 show increases in taxa richness and EPT richness, which suggest an improvement in water quality.

Station BTH-004

This was the eighth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-004 was 21 in 2016, a slight increase from 19, which was observed in 2015 and 15 in 2014, was the lowest taxa richness observed to date (Figure 1). The highest taxa richness at BTH-004 was 43 in 2010 and results in 2009 and 2011 were similarly high. A decrease in taxa richness at BTH-004 began in 2010 and continued to 2014. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae, compared to genus-level identification for all other years. In 2015 and 2016 taxa richness was noted to remain relatively low overall with a slight increase between years. The variation in numbers has been further discussed in Section 4.1.3.

The EPT richness was 3.5% in 2016, a decrease from 7.5% in 2015 (Figure 2). Since 2012 the EPT richness values have been up and down but have overall been relatively low in relation to the other four monitoring stations. The highest proportion of EPT taxa (12.5%) occurred in 2009 while the lowest occurred in 2012 with a value of 0.78%. A trend of decreasing EPT richness was observed between 2009 and 2012, however since then no consistent trends have been observed.

The dominant taxon at BTH-004 in 2016 was *Prodiamesa sp.*, a species of Diptera belonging to the sub-family *Prodiamesinae*. Species belonging to this sub-family are generally associated with the erosional and depositional areas of lotic systems (Merritt et al. 2008). The conditions at station BTH-004 are consistent with this generalized habitat preference providing silt and sand substrates, as well as moderately abundant detritus and woody debris. *Chironomus* can occur in systems with poor water quality and severe organic pollution (Mandaville 2002). This species represented 11.5% of the total number of individuals within the sample in 2016 (Figure 3). *Gammarus pseudolimnaeus* was the dominant taxa at this site for the four consecutive year (between 2012 and 2015), although its proportion within the sample had decreased by over 35.0% since 2013. In 2016 *G. pseudolimnaeus* maintained a relatively high abundance and was the subdominant family, representing 11.2% of the sample. Prior to 2012, the dominant taxa was identified as *Caecidotea intermedius*, a species of aquatic sowbug, which dominated the sample in 2010 and 2011. Both *C. intermedius* and *G. pseudolimnaeus* inhabit shallow waters where detritus is present and are likely to coexist in such habitat. Several other species of Chironomid also comprised large proportions of the sample at BTH-004 in 2016 including *Chironomus sp.* and *Polypedilum sp.*, both taxa belonging to the subfamily Chironominae.

The PMA index showed 'no impact' in 2016 as the calculated PSC value of 57.36 was higher than the critical PSC value of 42.12 (Table 6). This is the second consecutive year of a 'no impact' determination following three consecutive years of 'impact' (2012, 2013, and 2014) which resulted in two years of threshold exceedances at this station. Prior to 2012 the PMA analysis had shown 'no impact', which is the most consistent determination for BTH-004.

Station BTH-005

This was the eighth consecutive year of sampling conducted at this station, which began in 2009. Taxonomic richness at Station BTH-005 was 20 in 2016, an increase from 14 in 2015. This is the highest value that has been seen since the substantial decline from 31 in 2012 to 14 in 2013. These results continue to be considerably lower than what was generally observed at this station prior to 2013. A threshold exceedance was observed in 2013 following a decrease from 42, the highest value that has been noted at this site, to 14, the lowest that has been observed. In 2013 and 2014, taxonomic richness values were lower than previous years due to sub-family level of identification of the family Chironomidae, compared to genus-level identification for all other years. In 2015 and 2016 taxa richness remained relatively low overall with an increase observed in 2016. The variation in numbers has been further discussed in Section 4.1.3.

In 2016 the EPT taxonomic richness experienced a decrease at BTH-005 following a substantial increase between 2014 and 2015 (1.4% to 29.1%). In 2016 the richness decreased from 29.1% in 2015, the highest observed at this station, to 6.7%. The EPT richness values at BTH-005 have fluctuated since 2006 with no obvious trends observed. The highest results have been observed in 2009, 2012 and 2015 while low results were observed in 2010, 2011, and 2014. The 2016 value is roughly average for the station.

The dominant taxon at BTH-005 was *Gammarus pseudolimnaeus* in 2016, similar to what was observed at BTH-003 and BTH-004. *G. pseudolimnaeus* represented 23.7% of the total sample in 2016 (Figure 3). The habitat preferences of this species are consistent with the habitat characteristics of BTH-005, which is largely comprised of silt and sand along with detritus and some woody debris. This was the dominant species in 2014 and 2015 at this station as well. Prior to 2014 the dominant taxa had been *Caecidotea* sp., which includes a variety of sowbug species (Asellidae spp.). In 2014 and 2015 this species continued to comprise a large proportion of the sample. In 2015 the subdominant species was a species of Trichoptera (caddisfly) belonging to the family *Hydropsychidae*. Both the dominant and subdominant species observed at BTH-005 in 2015 are indicative of very good water quality (Mandaville 2002). Several species of Chironomid comprised a large proportion of the sample at BTH-005 in 2016 as well, including species of the subfamilies Chironominae and Prodiamesinae.

The PMA index showed ‘no impact’ in 2016 as the calculated PSC value of 56.17 was higher than the critical PSC value of 42.12 (Table 6). Results from 2014 and 2015 showed ‘impact’ for two consecutive years, which resulted in a threshold exceedance in 2015. Between 2009 and 2013 results had consistently shown ‘no impact’, which was again seen in 2016. Overall the results suggest an improvement in the conditions at BTH-005.

4.1.3 Benthic Invertebrate Threshold Analysis

The HCBP Consolidated Monitoring Program includes thresholds for various monitoring parameters. For benthic invertebrate monitoring, thresholds were developed for three benthic invertebrate metrics based on the degree of variation observed in the pre-construction monitoring data. The thresholds are as follows:

1. For the Percent Model Affinity (PMA) analysis, the threshold is an ‘impact’ determination at a station for 2 consecutive years following 2 consecutive years where the determination was ‘no impact’ at that station.
2. For Total Taxonomic Richness, the threshold is a 50% decline in the total number of taxa at a station, as compared to the results from the previous year.
3. For EPT Taxonomic Richness, the threshold is a 50% decline in the number of EPT taxa at a station, as compared to the average results from the previous 2 years.

Benthic Invertebrate Threshold 1

Based on the criteria for the exceedance of threshold number one, none of the stations experienced an exceedance in 2016 as no stations experienced two consecutive years of ‘impact’ following two years of ‘no impact’.

The only station to experience an ‘impact’ determination in 2016 was BTH-002. This station routinely shows ‘impact’, and it has never experienced two consecutive years of ‘no impact’. The ‘impact’ determination has been seen at BTH-002 for five consecutive years beginning in 2011 and, although no threshold exceedances have been identified, these results suggest a potential problem with the quality of the benthic community at this station. However, the EPT richness and dominant taxa indicate that the water quality and habitat are still very good at this station. Further, the model community used is for streams with rock/cobble substrate, and it sets a higher standard for BTH-002.

Station BTH-002 has experienced changing habitat conditions resulting from a branch falling across the channel and creating a small backwater effect, which has resulted in the accumulation of some finer materials. EPT species have typically comprised a large proportion of the samples at this station and are associated with gravel and cobble riffles. As such, this station should continue to be monitored carefully to identify any natural effects on the EPT species at BTH-002.

Benthic Invertebrate Threshold 2

For the second benthic invertebrate threshold, no stations had an exceedance as none of them exhibited a 50% reduction in the total number of benthic taxa in 2016 as compared to 2015. All five stations exhibited increases in benthic taxa when compared to 2015 with taxonomic richness increasing by between 3.8% (BTH-001) and 86.7% (BTH-003).

The taxonomic richness was noted to decrease across the HCBP in 2013. These relatively low numbers persisted through 2014, 2015 and 2016 at most of the stations with minor increasing and decreasing values. The results for 2013 and 2014 are explained by the different level of identification for chironomids that occurred in those years. Prior to 2013 and following 2014, chironomids were identified to genus, while in 2013 and 2014 chironomids were identified to sub-family. It is interesting to note that the taxa richness has remained low at several stations in 2015 and 2016, including at BTH-001, BTH-004 and BTH-005. It has been demonstrated that SWM Pond 4 has been continuously discharging water to Tributary A since 2012 upstream from BTH-005. This continuous discharge has resulted in increased flows and warmer overall stream temperatures within Tributary A, which are most notable in the vicinity of BTH-005 and BTH-001 (to a lesser extent). Although taxa richness has remained relatively low throughout 2015 and 2016 it is difficult to determine if these low numbers are attributable to the continuous outflow from Pond 4 due to the potential inherent variability resulting from natural changes in conditions and sampling variance (date of sampling, sampler bias etc.). It will be important to continue to monitor taxonomic richness across the HCBP site with particular attention to BTH-001 and BTH-005.

Benthic Invertebrate Threshold 3

Benthic invertebrate threshold number three was reached at one station in 2016. Station BTH-005 exhibited a 63% decline in the number of EPT taxa as compared to the averaged results from 2014 and 2015. This exceedance is due to a very low proportion of EPT observed in 2015 (1.4%) and an uncharacteristically high proportion of EPT in 2015 (35.3%). The 2014 result is the lowest that has been observed to date at BTH-005 while the result in 2015 is the highest. The low proportion in 2014 is more typical to what has been in previous years at this monitoring station while the high in 2015 appears uncharacteristic. Although the threshold was exceeded in 2016 it is mainly a function of the very high proportion in 2015, which acted to increase the averaged result for 2014 and 2015. The EPT richness in 2016, which was 6.7%, appears to be more ‘typical’ for this station when compared to the results between 2009 and 2013.

Prior to 2015 there appeared to be a trend of decreasing EPT richness across the five benthic monitoring stations starting in 2008 and 2009 when the EPT richness values were generally at their highest. This decrease followed a trend of increasing EPT richness that was observed during pre-construction monitoring from 2006 to 2008. Known potential stressors include the drought conditions in 2012, and the continuous discharge from SWM Pond 4 beginning in late 2011. However, EPT values were noted to increase at all stations in 2015 and at two of three stations in 2016 even though there was continued discharge from SWM Pond 4 into Tributary A. It is important to note that the change in level of identification that affected the overall taxonomic richness in 2013 did not apply to the EPT richness, because Ephemeroptera, Plecoptera and Trichoptera groups were identified to the same taxonomic resolution throughout all years of monitoring.

4.2 Fish Sampling

4.2.1 Habitat Conditions

Station EMS-001 starts and ends within a riffle feature, and pools and runs are present throughout the station. Channel substrates are dominated by gravel, along with some silt, clay, sand and cobble. Instream habitat and cover is provided by woody debris, shallow pools and riffles, undercut banks, with some cover offered by cobble, overhanging terrestrial vegetation and backwater areas. At this monitoring station the creek exhibits a low gradient, meandering channel. At the time of sampling, the wetted width ranged from 1.5 to 2.6 m. Riffles were measured no deeper than 6 cm while a maximum depth of 16.4 cm was measured within one of the pools at this station. Watercress was also observed at this station in low abundance.

Fish sampling was conducted on August 31, 2016. Water quality measurements were made at 0900hrs and are provided in Table 12.

Station EMS-002 was noted to have variable channel substrates consisting of mainly of gravel with some cobble, sand, silt and clay. Riffles mark the upstream and downstream extents of the station throughout which pools, cobble, backwater areas and aquatic vegetation provides instream habitat and cover. The creek at this location exhibits a meandering channel with a moderate gradient. Wetted widths ranged from 1.4 to 3.6 m. A maximum water depth of 25 cm was measured within a pool at this station while the average water depth was approximately 15 cm. Dense mats of watercress were observed growing throughout nearly the entire length of the station, which made electrofishing and netting difficult in some areas.

Fish sampling was conducted at this location on August 30, 2016. Water quality measurements were made at 1620hrs and are provided in Table 12.

Station EMS-003 was noted to have channel substrates comprised of silt and detritus with some sand. Riffles mark the upstream and downstream extents of the station throughout which instream habitat and cover are provided by woody debris, undercut banks, backwater areas, and pools. At this monitoring station the creek exhibits a low gradient through a meandering channel. At the time of sampling, it had a wetted width ranging from 1.3 to 1.7 m and a maximum depth of 11 cm. The average water depth was approximately 5 cm.

Fish sampling was conducted at this location on September 1, 2016. Water quality measurements were made at 1040hrs and are provided in Table 12.

Station EMS-004 was noted to have a variety of channel substrates, dominated by sand and gravel with some cobble and silt. Detritus and muck are also present throughout the site. Riffles mark the upstream and downstream extents of the station. Woody debris provides the majority of instream habitat and cover but additional cover is present in the form of shallow riffles, small backwater areas, undercut banks, and cobble. At this monitoring station the creek exhibits a moderate gradient, meandering channel. At the time of sampling, it had a wetted width ranging from 2.1 to 3.7 m. A maximum water depth of 13.4 cm was measured within a pool at this station while the average depth was approximately 7 cm.

Fish sampling was conducted at this location on August 30, 2016. Water quality measurements were made at 1200hrs and are provided in Table 12.

Station EMS-005 exhibited channel substrates comprised mainly of gravel with some cobble, clay and silt and small amounts of sand. Riffles mark the upstream and downstream extents of the station throughout which the riffles provide the majority of instream habitat and cover in the channel. Instream habitat and cover at EMS-005 is provided by a combination of pools, riffles, undercut banks, woody debris, aquatic vegetation, and cobble. At this monitoring station the creek exhibits a moderate gradient, meandering channel. At the time of sampling, it had a wetted width ranging from 0.8 to 1.2 m. A maximum water depth of 28.9 cm was measured within a pool at this station while the average depth was approximately 10 cm.

Fish sampling was conducted at this location on August 30, 2016. Water quality measurements are provided in Table 12.

4.2.2 Fish Community Data

The water conditions during electrofishing, the settings on the electrofisher, and sampling duration are all important to document for comparing fish sampling results from year to year. This information is summarized in Table 12.

Table 12. Water Quality Measurements, Electrofishing Settings, and Shocking Times.

	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Date	August 31, 2016	August 30, 2016	September 1, 2016	August 30, 2016	August 30, 2016
Sampling Start Time	0900	1330	0900	0930	1300
Sampling End Time	1115	1600	1030	1200	1525
Air Temperature (°C)	25.0	28.0	19.0	22.0	28.0
Water Temperature (°C)	21.6	21.1	12.4	18.0	22.5
Time Water Temp. Taken	1115	1600	1040	1200	1530
Conductivity (µs/cm)	680	980	680	1010	680
Dissolved Oxygen (ppm, %)	6.72, 72.8	6.32, 71.6	7.12, 68.8	7.60, 83.1	4.98, 59.1
Electrofisher Type	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B	Smith-Root LR-20B
Number of Netters	1	1	1	1	1
Voltage (V)	150	150	100 – 200	150	150
Pulsating Frequency (Hz)	50	50	40 – 50	50	50
Shocking Time (sec.) – Pass 1	776	843	521	859	783
Shocking Time (sec.) – Pass 2	575	812	695	951	717
Shocking Time (sec.) – Pass 3	689	790	604	690	721
Shocking Time (sec.) – Pass 4	N/A	N/A	N/A	N/A	581

DNC – Did not collect
N/A – Not applicable

During 2016 construction-phase aquatic monitoring a total of 448 individual fish were captured representing nine different species: Blacknose Dace (*Rhinichthys obtusus*), Brook Stickleback (*Culaea inconstans*), Central Mudminnow (*Umbra limi*), Creek Chub (*Semotilus atromaculatus*), White Sucker (*Catostomus commersonii*), Fathead Minnow (*Pimephales promelas*), Northern Redbelly Dace (*Chrosomus eos*), Pumpkinseed (*Lepomis gibbosus*), and Mottled Sculpin (*Cottus bairdii*). The total catch in 2016 was slightly lower than the 481 fish captured in 2015 but was almost identical to 2014 sampling when 451 fish were captured. It appears that the numbers of fish across the Hanlon site have stabilized over the past three years following an uncharacteristically high catch of 735 fish in 2013. Prior to 2013 the total catches ranged from 92 in 2006 (3 stations) to 260 in 2012 (5 stations). In spite of the 2 stations added in 2009, it generally appears that fish numbers have increased since sampling began. A description of electrofishing results for each station in 2016 can be found below.

The data collected during 2016 monitoring produced reliable statistical models for three of five electrofishing monitoring stations (EMS-003, EMS-004, and EMS-005) using the maximum likelihood constant P model. The least squares regression model was used to produce population estimates for EMS-001 and EMS-002. The results for 2016 are provided in Table 18 along with the results from all past years of monitoring and have been described below. Results from the model output are provided in Appendix II. Some of the results in the past years could not be reported as estimates because a statistical model could not produce a reliable estimate. In these cases the actual catch data is provided in Table 18, denoted by a single asterisk. Population estimates that were calculated using the least squares regression method are denoted in Table 18 by a double asterisk.

Station EMS-001

Electrofishing in 2016 resulted in the capture of five species; Blacknose Dace, White Sucker, Brook Stickleback, Northern Redbelly Dace, and Creek Chub. A combined total of 118 individual fish were captured through a total of three passes, slightly higher than 116 from 2015. All species have been captured previously at EMS-001 with Blacknose Dace being the only species captured every year since sampling began in 2006. Fathead Minnow has also been previously captured at this station but was absent in 2016. The detailed results are provided in Table 13. This site has typically seen between three and five species with only two species being captured in 2015.

Fish population estimates at this station have varied greatly between 2006 and 2016, and have generally been higher during construction-phase monitoring beginning in 2010 than they were during pre-construction monitoring prior to 2010. The lowest population estimate was observed in 2010, which was estimated at 5. This result was similar to the low population estimate observed in 2006. In 2013 the population was estimated at 184, the highest that has been observed at the site. This was attributed to increased baseflows following a year of above-average precipitation. Following 2013 the population estimates have remained between 100 and 125 and appear to be relatively stable. Detailed results are provided in Table 18.

Station EMS-002

Electrofishing in 2016 resulted in the capture of seven fish species and combined for a total of 101 individual fish over three passes. The species captured were Blacknose Dace, Brook Stickleback, Mottled Sculpin, Fathead Minnow, White Sucker, Central Mudminnow and Creek Chub. Blacknose Dace and Brook Stickleback have been captured at this station every year while Creek Chub have been captured sporadically. Central Mudminnow and White Sucker have also been previously captured throughout the years at this station. Mottled Sculpin (*Cottus bairdii*), a coldwater species was also captured at this site in 2011. This is the first year that Fathead Minnow, a warmwater species, has been captured at this monitoring station. However, Pumpkinseed, also a warmwater species, was captured here in in 2014. Fathead Minnow have also been captured on site in the past at EMS-001 and EMS-005 in 2011 and 2013, respectively. The detailed results are provided in Table 14. This station has typically seen between three or four species with five species being captured in 2013 and six species captured in 2014.

The estimated fish population at EMS-002 has exhibited no obvious trend since sampling began in 2006. The estimated numbers have experienced a great deal of variation with the lowest estimate occurring in 2009 (approximately 40) and the highest estimate of approximately 241 occurring in 2013. The estimate observed in 2016 is similar to what was seen in 2015, which followed a decrease from 2013 and 2014 numbers but continue to remain above most of the previous years. Detailed results are provided in Table 18.

Station EMS-003

Electrofishing in 2016 resulted in the capture of three fish species and a combined total of 9 fish over three passes. The species captured were Blacknose Dace, Creek Chub and Brook

Stickleback. Electrofishing results at this station continue to indicate a low diversity of species relative to the other stations as only the three species captured in 2016 have been captured here since 2006. Blacknose Dace and Brook Stickleback have been captured consistently while Creek Chub has only been captured at this station previously in 2006. The detailed results are provided in Table 15.

Population estimates at EMS-003 have been consistently low relative to the other stations within the HCBP study area. The estimate calculated in 2016 shows a slight increase from 2015 but a similarly low estimate to what has been observed at this station since 2010, with the exception of a high year in 2013. Overall, the pre-construction population estimates have been generally higher than during-construction. Detailed results are provided in Table 18.

Station EMS-004

Electrofishing took place at this site for the first time in 2009 and it has been sampled every year since. Electrofishing in 2016 resulted in the capture of three fish species and a combined total of 93 fish over three passes. The species captured included Backnose Dace, White Sucker, and Creek Chub. Blacknose Dace and Creek Chub have been consistently captured over the previous years of monitoring. White Sucker has also been previously captured at this station in 2013. The detailed results are provided in Table 16. This site has typically seen three or four species with five species being captured in 2013.

Fish population estimates remained relatively consistent at EMS-004 between 2009 and 2012 ranging from approximately 29 to 58. In 2013 the population estimate increased substantially to 266, the highest estimate recorded at any of the five stations since sampling began in 2006. In 2014 the numbers decreased to more typical levels before increasing again to 114 in 2015. The 2016 population estimate of 108 is similar to what was observed in 2015 and is generally higher than previous results. Detailed results are provided in Table 18.

Station EMS-005

Electrofishing took place at this site for the first time in 2009 and has been sampled every year since. Electrofishing in 2016 resulted in the capture of six fish species and a combined total of 127 individual fish over four passes. The species captured included Blacknose Dace, Central Mudminnow, Creek Chub, Northern Redbelly Dace, Pumpkinseed, and White Sucker. Prior to

2013, this station typically contained between two and three species. In 2013, seven species were captured here including Fathead Minnow, Northern Redbelly Dace and White Sucker. White Sucker has been captured at this site every year since 2013 while Fathead Minnow and Northern Redbelly Dace have been absent previously. Blacknose Dace has been captured during every year of sampling at this station. Brook Stickleback, Central Mudminnow and Creek Chub have also been captured regularly throughout previous years of monitoring. The detailed results are provided in Table 17.

The population estimate at station EMS-005 in 2016 was 151, a slight decrease from 2015 and a second consecutive year of decrease following 2014, which has the highest estimate that has been observed at EMS-005 (204). This marks a continued decline following four consecutive years of increasing estimates that started in 2010 with a low of approximately 2. The population estimate at EMS-005 in 2016 was the highest observed across any of the five monitoring stations within the HCBP. Detailed results are provided in Table 18.

Table 13. Fish Sampling Results for EMS-001

Fish Name		Number Captured				Fork Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	42	10	7	59	30	74
White Sucker	*Catostomus commersonii*	8	3	0	11	53	95
Brook Stickleback	*Culaea inconstans*	0	1	0	1	0	30
Northern Redbelly Dace	*Chrosomus eos*	0	0	2	2	42	52
Creek Chub	*Semotilus atromaculatus*	26	11	8	45	33	138
COMBINED TOTAL		76	25	17	**118**		

Table 14. Fish Sampling Results for EMS-002

Fish Name		Number Captured				Fork Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	23	22	5	50	32	84
Brook Stickleback	*Culaea inconstans*	1	4	0	5	0	32
Mottled Sculpin	*Cuttus bairdii*	1	0	1	2	86	89
Fathead Minnow	*Pimephales promelas*	1	0	0	1	0	60
White Sucker	*Catostomus commersonii*	4	1	1	6	56	139
Central Mudminnow	*Umbra limi*	9	4	0	13	65	103
Creek Chub	*Semotilus atromaculatus*	15	7	2	24	26	127
COMBINED TOTAL		54	38	9	**101**		

Table 15. Fish Sampling Results for EMS-003

Fish Name		Number Captured				Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	3	0	0	3	68	69
Creek Chub	*Semotilus atromaculatus*	2	1	0	3	73	109
Brook Stickleback	*Culaea inconstans*	1	2	0	3	45	49
COMBINED TOTAL		6	3	0	**9**		

Table 16. Fish Sampling Results for EMS-004

Fish Name		Number Captured				Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	22	14	8	44	21	80
White Sucker	*Catostomus commersonii*	2	0	1	3	74	100
Creek Chub	*Semotilus atromaculatus*	27	15	4	46	21	130
COMBINED TOTAL		51	29	13	**93**		

Table 17. Fish Sampling Results for EMS-005

Fish Name		Number Captured					Length (mm)	
Common	**Scientific**	**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Total**	**Smallest**	**Largest**
Blacknose Dace	*Rhinichthys obtusus*	21	20	10	10	61	30	73
Central Mudminnow	*Umbra limi*	11	2	0	0	13	64	79
Creek Chub	*Semotilus atromaculatus*	16	14	10	4	44	30	136
Northern Redbelly Dace	*Chrosomus eos*	0	0	0	1	1	0	52
Pumpkinseed	*Lepomis gibbosus*	1	0	0	0	1	0	98
White Sucker	*Catostomus commersonii*	6	1	0	0	7	77	166
COMBINED TOTAL		55	37	20	15	**127**		

Species Biology

Nine fish species were captured during the 2016 monitoring program: Blacknose Dace, Brook Stickleback, Central Mudminnow, Creek Chub, Fathead Minnow, Northern Redbelly Dace, White Sucker, Pumpkinseed, and Mottled Sculpin. Descriptions of each species' habitat preferences have been provided below.

Blacknose Dace are known to inhabit small to medium-sized, clear, swiftly flowing streams with gravelly substrate. These typically exhibit a moderate to steep gradient and provide a variety riffle habitat. This species is considered to be benthic and an invertivore, feeding primarily on aquatic insect larvae (Scott and Crossman 1998; Eakins 2016).

Brook Stickleback are a native species to Ontario that inhabit the "clear, cold, densely vegetated waters of small streams and spring-fed ponds and may also be found along the swampy margins of beach ponds of larger lakes" (Scott and Crossman 1998). This species is considered to be benthopelagic and a planktivore/invertivore, feeding on a variety of aquatic insects and crustaceans. This species is tolerant of low dissolved oxygen, acidity and alkalinity but is generally intolerant of turbidity (Scott and Crossman 1998; Eakins 2016).

The central Mudminnow is a native species common to Ontario that inhabits"heavily vegetated ponds, wetlands or pools of small creeks and quiet, shallow (0.5 m) areas of lakes with mud and organic substrates" (Eakins 2016). It is considered to be a benthic species and an invertivore, which feeds primarily on benthic invertebrates. This species is tolerant of low dissolved oxygen, low pH and high water temperatures (29°C) and is moderately tolerant of turbidity (Scott and Crossman 1998; Eakins 2016).

The Creek Chub is a species known to inhabit the pools of small, clear streams and rivers with preferred water temperatures around 21°C (Eakins 2016). It is considered to be benthopelagic and an invertivore/carnivore, feeding on a variety of aquatic and terrestrial invertebrates. This species is tolerant of pollution and low dissolved oxygen but is moderately intolerant of turbidity (Scott and Crossman 1998; Eakins 2016).

The Fathead Minnow is a species that generally inhabits the still waters of ponds and flowing waters of streams with soft substrates. It is considered to be benthopelagic and a detritivore/invertivore and prefers warm water with temperatures between 23 and 29°C in the warm period of the year (Scott and Crossman 1998; Eakins 2016).

The Northern Redbelly Dace is a species known to inhabit lakes, bogs, ponds and pools of creeks with organic substrates and aquatic vegetation. This species is often found in tea-stained waters and has a preferred water temperature of 25.3°C (Eakins 2016). It is considered to be benthopelagic and an invertivore/planktivore, feeding on a combination of algae, zooplankton and aquatic insects (Scott and Crossman 1998; Eakins 2016).

The White Sucker is a species known to inhabit the pools and riffles of creeks and rivers, warm shallow lakes and embayments of larger lakes with preferred water temperature range from 17 to 23°C (Eakins 2016). White suckers are considered to be benthic fish and are invertivore/detritivores, feeding on a variety of benthic invertebrates. This species is tolerant of pollution and is moderately tolerant of turbidity (Scott and Crossman 1998; Eakins 2016).

Pumpkinseed typically inhabit the warm, shallow areas of lakes and ponds as well as the quiet pools of creeks and small rivers where aquatic vegetation and organic debris is present. This is a warm water species with a preferred temperature range of 22 to 30°C. Pumpkinseed are moderately tolerant of turbidity (Eakins 2016).

The Mottled Sculpin is a native species to Ontario that is known to inhabit the cobble and gravel riffles of cool creeks, small rivers and rocky shorelines of lakes. It is a benthic species that feeds primarily on aquatic insect larvae and some crustaceans. Mottled Sculpin generally prefer cold water with temperatures ranging from 13 to 18°C in the warm period of the year (Scott and Crossman 1998; Eakins 2016).

The nine fish species captured in 2016 are previously known from the monitoring program and exhibit a variety of thermal preferences. However, the majority of species prefer a cool-water thermal regime (Eakins 2016). Warmwater species captured in 2016 include Fathead Minnow and Pumpkinseed. These species have previously been captured at the site including Pumpkinseed at EMS-002 in 2014 and Fathead Minnow at

EMS-001 in 2011 and at EMS-005 in 2013. One coldwater species, Mottled Sculpin, was also captured in 2016. This species has also been previously captured at EMS-002 in 2011. The thermal preferences of the fish captured in 2016 are generally consistent with the cool to cold water temperatures known from these watercourses, in spite of the incidental occurrences of warmwater species.

No trout species were captured during monitoring in 2016, which is consistent with sampling in the quantitative stations in previous years.

Population Estimates

Population estimates have fluctuated over the years with no obvious increasing or decreasing trends for Tributary A as a whole. The populations estimates calculated for 2016 appear similar to what was observed in 2015 with small increases at two stations (EMS-001 and EMS-003) and small decreases at three stations (EMS-002, EMS-004, and EMS-005). None of the declines observed in 2016 resulted in threshold exceedances (Table 18 and Figure 6).

Table 18. Fish Population Estimates by Station for the Years 2006 to 2016

Station	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
EMS-001	9.07	> 87*	80	48.5	5.22	59.37	129.32	184.20**	101.57	122.78	124.07**
EMS-002	55.56	173.07	>53*	40.2	76.95	100.31	73.78**	241.1	210.1	123.02	119.37**
EMS-003	>31*	13.89	31	32.7	>5*	8.35	1	33.03	16.05	5.04	9.22
EMS-004				29.4**	58.33	54.47	53.46	266.39	62.84	114.08	108.11
EMS-005				82.3	2.18	10.16	42.95	167.53	203.77**	168.35	151.39

* These results are approximate because the population estimate was not statistically valid.
** Estimate obtained using the least squares regression method.

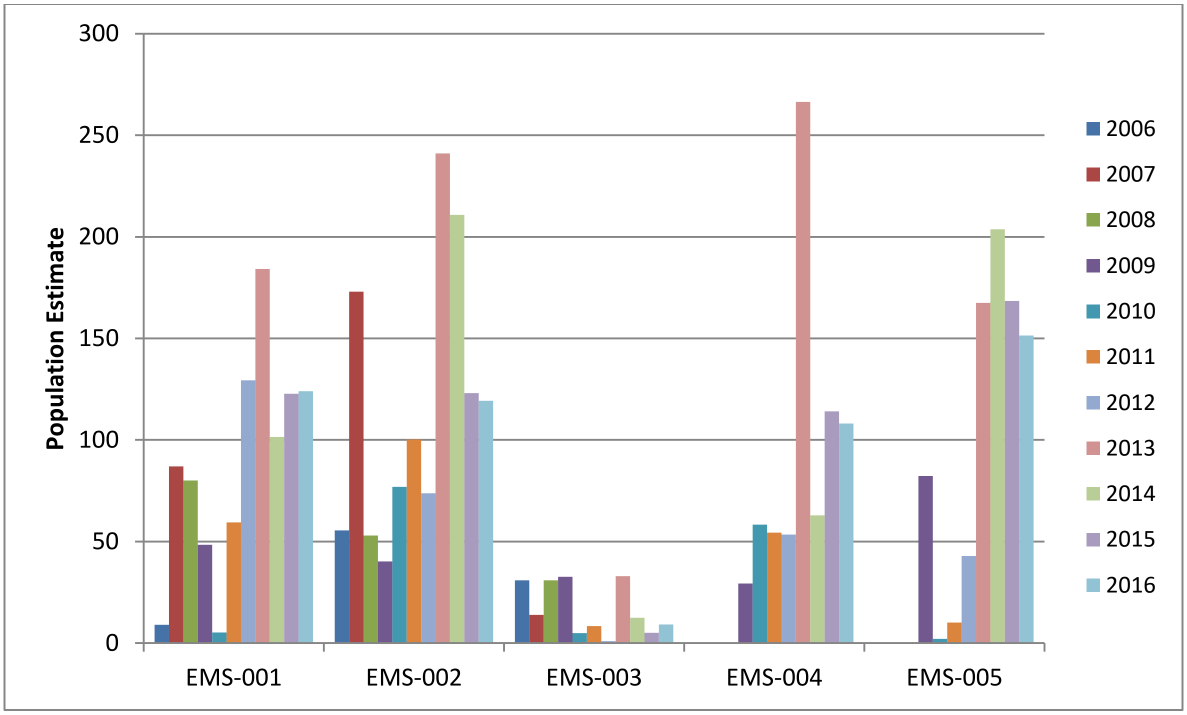

Figure 4. Population Estimates at Electrofishing Stations for the Years 2006 to 2016

Brook Trout Spawning Survey

Brook Trout spawning surveys were conducted on three separate occasions during the fall of 2016. These were conducted on October 31, November 11, and November 25, 2016. No Brook Trout, Brook Trout redds, or evidence of Brook Trout spawning were observed during any of the surveys. The survey area shown on Figure 1 includes the sections of Tributary A and Tributary A1 from the swamp north of the newly constructed Road A – Tributary A crossing to the tile drain outlet located approximately 400m north of Laird Road. A summary of the survey conditions are provided in Table 19.

Table 19. 2016 Brook Trout Spawning Survey Summary

Date (2016)	Location	Start Time	End Time	Water Temperature (°C)	Air Temperature (°C)	Spawning /Evidence Observed
October 31	Tributary A	1250	1330	6.0 – 6.8	4.0	No
	Tributary A1	1200	1230	7.5 – 8.5	4.0	No
November 11	Tributary A	0930	1030	6.0 – 7.0	5.0	No
	Tributary A1	1040	1105	7.0 – 8.0	5.0	No
November 25	Tributary A	0930	1015	4.2 – 5.2	3.0	No
	Tributary A1	1015	1035	7.0 – 8.5	3.0	No

Spawning survey and habitat conditions were found to vary within the survey area based on differences in flow rates, water temperatures, substrate composition, and habitat availability.

In 2016 water temperatures were lowest on Tributary A ranging from 4.2 to 7.0°C while along Tributary A1 water temperatures ranged from 7.0 to 8.5°C (Table 19). At the upstream extent of the surveyed reach, along Tributary A1, the dominant substrates consisted of silt, muck, and detritus (primarily leaf litter). Woody debris was also found throughout the channel and a small amount of watercress was present along the margins of the creek in several locations. This section is believed to offer little to no suitable spawning habitat for Brook Trout.

Throughout the centre of the site, near the new road crossing (Tributary A) water velocities were noted to be higher than upstream and substrates were dominated by cobble and gravel with small amounts of silt and sand. The water temperature here was generally the lowest observed throughout the entire reach and watercress was observed in very high abundance at this location. The water temperature at this location is typically similar to or slightly lower than what is seen in Tributary A1. This section of creek offered the most suitable spawning habitat for Brook Trout. A large pool, aquatic vegetation, and woody debris provided a relatively high amount of instream cover at the Hanlon Creek Boulevard crossing. Schools of small cyprinids were regularly observed throughout this section of Tributary A within the woody debris and aquatic vegetation.

Near the downstream extent of the survey area (Tributary A) substrates were similar to the upstream extent, comprised of silt and detritus. Flow at this location is evident and velocity is greater than the upstream extent, but less than what was observed throughout the middle section, which also has a higher gradient. At this location there was a high density of fallen trees and woody debris throughout the channel. It appeared that there was more woody debris throughout this section than what has been observed in past years. This added woody debris created a slight backwater effect on the upstream side of some of the log jams.

Within the surveyed reaches of the creek the most suitable Brook Trout habitat was observed immediately upstream and downstream of the Hanlon Creek Boulevard culvert crossing of Tributary A. This area provided appropriate spawning conditions which included predominantly gravel substrates, groundwater upwelling, and oxygenation of the water as a result of the variety of shallow riffle sections (Scott and Crossman 1998). Tributary A1 offers little to no suitable spawning habitat as result of the sand and silt substrates and detritus. Although conditions throughout Tributary A appeared suitable for Brook Trout spawning, no Brook Trout or Brook Trout spawning activities (ie. redds, visible eggs, etc.) were observed during any of the three spawning surveys.

4.2.3 Fish Threshold Analysis

The HCBP Consolidated Monitoring Program (NRSI 2010) includes thresholds for various monitoring parameters. For fish monitoring, pre-construction and initial construction-phase fish monitoring did not result in capture of any Brook Trout at the quantitative monitoring stations. A specific quantitative threshold for Brook Trout is not appropriate unless sufficient numbers of Brook Trout become established such that they can be monitored in a quantitative manner.

Although a threshold is not provided for Brook Trout, the overall fish community is being monitored as a surrogate indicator of the suitability of the aquatic habitat for Brook Trout. The results will be evaluated and compared to previous year’s data from the same stations. If any anomalies are seen, these will be addressed. Two thresholds have been developed as follows:

1. A 50% change in the number of taxa represents a potential decline in the suitability of the habitat for Brook Trout. Because coldwater fish communities typically have a lower species diversity, an increase in species diversity may represent a negative change in relation to the Brook Trout management objective. Specifically, the warm-water fish community may increase in species richness as a result of warmer water temperatures, which indicates that the habitat is becoming less suitable for Brook Trout. A decrease in species diversity may also represent a negative change in the suitability of the habitat for Brook Trout, likely attributable to some cause other than water temperature.
2. A 50% reduction in the number of fish captured represents a potential decline in the fish community resulting from habitat impacts. However, it may also represent an improvement in habitat suitability for Brook Trout based on temperature changes, as discussed above.

Fish Threshold 1

For the first fish threshold, no stations exhibited a 50% reduction in the number of taxa captured in 2016.

Fish Threshold 2

For the second fish threshold, no stations exhibited a 50% reduction in the number of fish captured in 2016.

5.0 Conclusions and Recommendations

The 2016 construction-phase monitoring program was successful in providing informative aquatic monitoring data on conditions during the seventh year of construction.

A great deal of variation has been observed between 2006 and 2016 in both benthic invertebrate and fish communities within the Hanlon Creek watershed. This has largely been attributed to natural variation caused by inconsistencies in abiotic factors (ie. temperature, precipitation etc.) and stream dynamics across years in which monitoring occurred. The 2014 monitoring results indicated that a dry winter and lower than average precipitation between March and October likely impacted benthic and fish habitat suitability at many of the stations, which resulted in both benthic and fish threshold exceedances. In 2015 precipitation levels were once again lower than average throughout the summer months and were lower than what had been observed in 2014. Average air temperatures were also higher during the summer months. Although benthic and fish threshold exceedances were observed in 2015, generally the 2015 monitoring results indicate improvements in both the benthic and fish communities.

Benthic invertebrate threshold number three as identified in the HCBP Consolidated Monitoring Program (NRSI 2010) was reached at one station; BTH-005 in 2016. This station exhibited more than a 50% decline in the proportion of EPT taxa compared to the averaged results from 2014 and 2015. Even though a threshold exceedance was observed at BTH-005, the proportion of EPT taxa in 2016 is more typical for the site than what was observed in 2014 and 2015. The EPT taxa result from 2014 is the lowest that has been observed at the site while the result from 2015 is the highest that has been observed, and is substantially higher than what has previously been observed. This result is likely to have substantially increased the overall average, resulting in the threshold exceedance. This exceedance is not believed to be of concern as the EPT taxa richness at BTH-005 have been quite variable since 2009 and the 2016 result appears to be typical for this station.

Neither of the fish community thresholds identified in the HCBP Consolidated Monitoring Program (NRSI 2010) were reached in 2016.

We recommend the following regarding future monitoring:

1. Aquatic biological monitoring should continue during the construction and build-out of the HCBP until 75% of the development is built (by area) in Phases 1, 2 and 3 of the HCBP, plus an additional 2 years. The aquatic biological monitoring will continue to be one component of the complete monitoring program, which is outlined in the HCBP Consolidated Monitoring Program.

2. Fish and benthic invertebrate monitoring should continue to occur at the 5 sites sampled in 2016.

3. A Brook Trout spawning survey should continue to be conducted in autumn throughout the months of October and November. Even if Brook Trout are not captured during fish sampling at the 5 biomass stations, the spawning survey will provide an additional opportunity to observe the presence/absence of Brook Trout on the subject property during a different part of the Brook Trout life cycle.

References

5.1 General References

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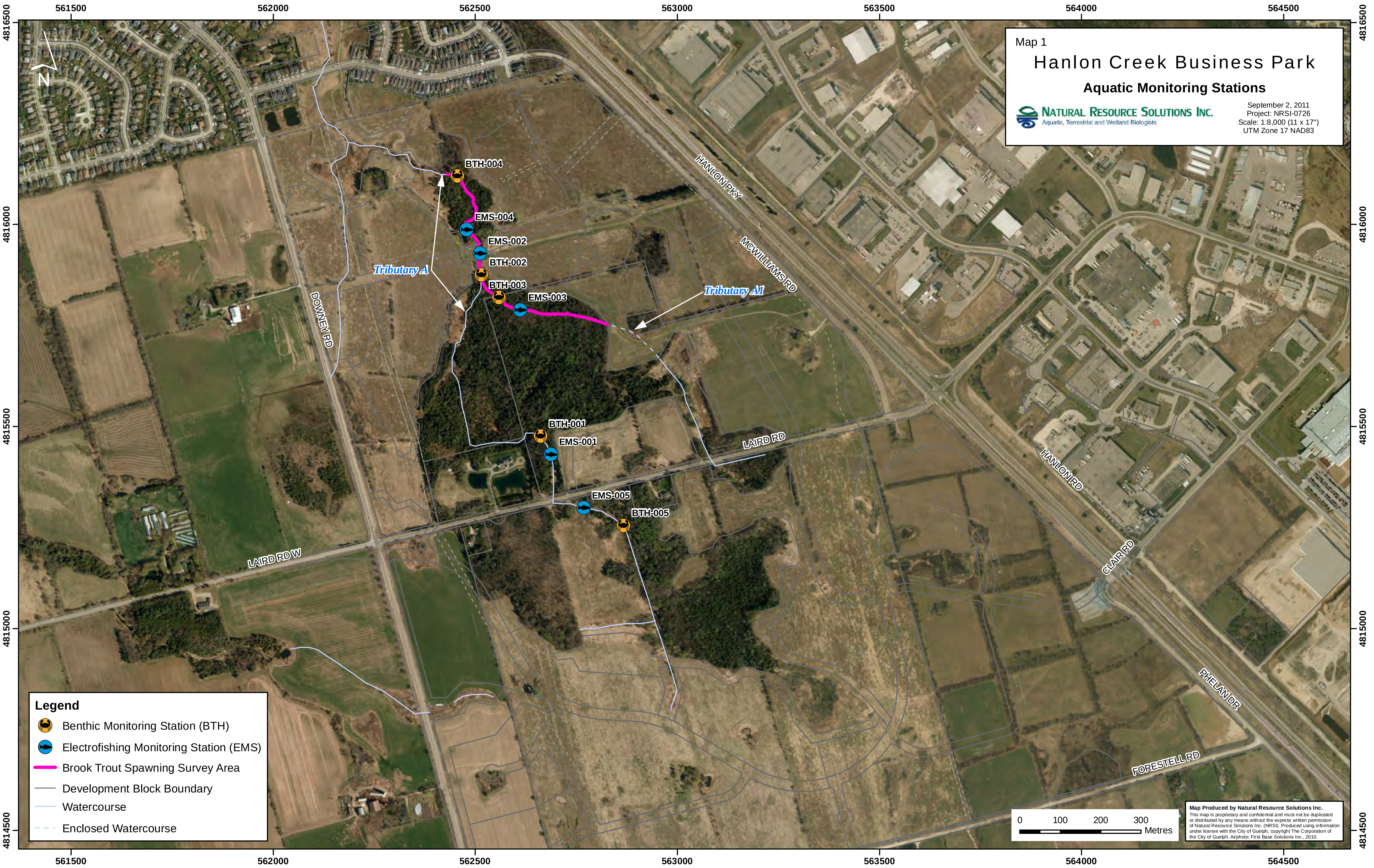
MAPS



Map 1

Hanlon Creek Business Park

Aquatic Monitoring Stations

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

September 2, 2011
Project: NRSI-0726
Scale: 1:8,000 (11 x 17")
UTM Zone 17 NAD83

Map Produced by Natural Resource Solutions Inc.
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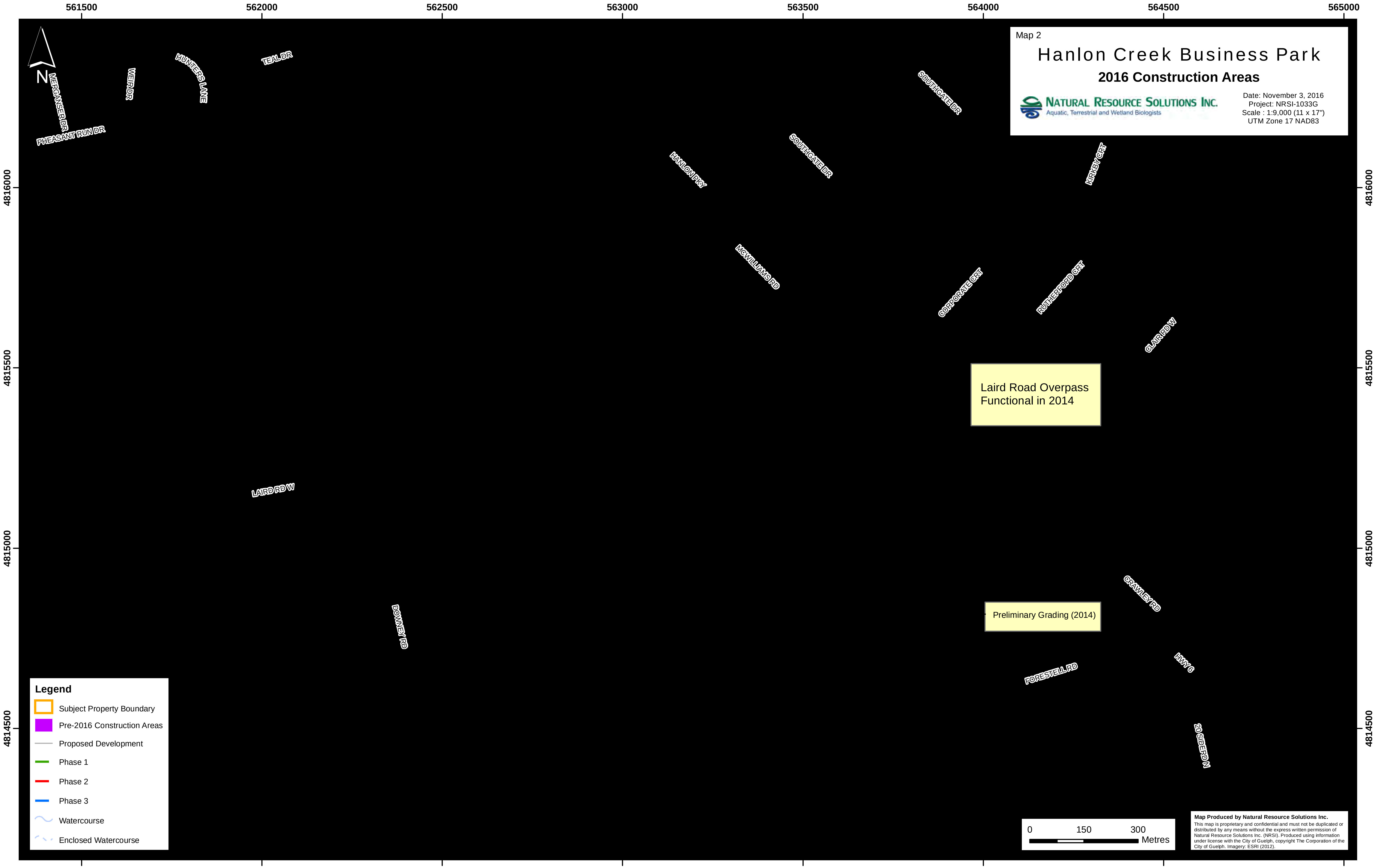
NRSI_0682H_AquaticMonitoring_8K_2011_09_02_GCS



Map 2

Hanlon Creek Business Park

2016 Construction Areas

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Date: November 3, 2016
Project: NRSI-1033G
Scale : 1:9,000 (11 x 17")
UTM Zone 17 NAD83

Laird Road Overpass Functional in 2014

Preliminary Grading (2014)

Legend

- ☐ Subject Property Boundary
- 🟪 Pre-2016 Construction Areas
- — Proposed Development
- — Phase 1
- — Phase 2
- — Phase 3
- ∼ Watercourse
- ╌ Enclosed Watercourse

Map Produced by Natural Resource Solutions Inc.
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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1033G_Map2_2016ConstructionAreas_9K_2016_11_03_LEH.mxd

APPENDIX I

Benthic Invertebrate Raw Data

Appendix I - 2016 HCBP Aquatic Monitoring
Raw Benthic Invertebrate Data

GROUP	FAMILY	TAXON	BTH001	BTH001	BTH001	BTH001	Proportion	BTH002	BTH002	BTH002	BTH002	Proportion	BTH003	BTH003	BTH003	BTH003	Proportion	BTH004	BTH004	BTH004	BTH004	Proportion	BTH005	BTH005	BTH005	BTH005	Proportion
			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2			riffle 1	pool	riffle 2		
			2-Sep	2-Sep	2-Sep	Pooled		1-Sep	1-Sep	1-Sep	Pooled		1-Sep	1-Sep	1-Sep	Pooled		1-Sep	1-Sep	1-Sep	Pooled		2-Sep	2-Sep	2-Sep	Pooled	
AMPHIPODA	Gammaridae	Gammarus pseudolimnaeus	6	8		14	**3.381642512**	11	19	21	51	**9.732824427**	18	9	43	70	**18.32460733**	22	14	3	39	**11.23919308**	38	29	14	81	**23.68421053**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
ISOPODA	Asellidae	Caecidotea intermedius		15		15	**3.623188406**	2	3	6	11	**2.099236641**		9	8	17	**4.45026178**			6	6	**1.729106628**	10	9	8	27	**7.894736842**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
COLEOPTERA	Elmidae	Dubiraphia quadrinotata	3		10	13	**3.140096618**	30	10	17	57	**10.8778626**				0	**0**	1			1	**0.288184438**	3			3	**0.877192982**
		Optioservus fastiditus			9	9	**2.173913043**	45	2	8	55	**10.49618321**		2		2	**0.523560209**				0	**0**				0	**0**
		Stenelmis crenata				0	**0**		6	5	11	**2.099236641**	1	1		2	**0.523560209**				0	**0**				0	**0**
											0	**0**				0	**0**				0	**0**				0	**0**
HEMIPTERA	Veliidae	Rhagovelia							1		1	**0.190839695**				0	**0**				0	**0**				0	**0**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
DIPTERA	Ceratopogonidae	Ceratopogonidae type I	1	2		3	**0.724637681**				0	**0**		1	1	2	**0.523560209**	7		2	9	**2.593659942**				0	**0**
	Chironomidae					0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
	Chironominae	Chironomus	19	5	17	41	**9.903381643**	7	15	3	25	**4.770992366**	15		7	22	**5.759162304**	15	11	12	38	**10.95100865**	7	4	15	26	**7.602339181**
		Microtendipes	5	20	5	30	**7.246376812**	5	7	4	16	**3.053435115**	7		5	12	**3.141361257**	5	7	7	19	**5.475504323**		7	4	11	**3.216374269**
		Paratendipes	12	19	4	35	**8.45410628**	7	6	5	18	**3.435114504**				0	**0**	11	6		17	**4.899135447**	15	15	14	44	**12.86549708**
		Polypedilum	9	8	8	25	**6.038647343**	5			5	**0.954198473**	5	5		10	**2.617801047**	13	13	10	36	**10.37463977**		14	9	23	**6.725146199**
		Tribelos		7	4	11	**2.657004831**				0	**0**				0	**0**	14	5	7	26	**7.492795389**	10	5	5	20	**5.847953216**
	Prodiamesinae	Prodiamesa sp	15	9	5	29	**7.004830918**	7	4	4	15	**2.86259542**	17	14	12	43	**11.2565445**	16	12	12	40	**11.52737752**	9	9	12	30	**8.771929825**
	Orthocladiinae	Thienemanniella		7	4	11	**2.657004831**	12	7		19	**3.625954198**	21	15	15	51	**13.35078534**		6	5	11	**3.170028818**			7	7	**2.046783626**
		Parametrocnemus		5		5	**1.207729469**				0	**0**	5	7		12	**3.141361257**			10	10	**2.88184438**			8	8	**2.339181287**
	Tanypodinae	Apsectrotanypus		24	15	39	**9.420289855**	9	8	3	20	**3.816793893**	19	15	7	41	**10.73298429**	11	11	6	28	**8.069164265**		4		4	**1.169590643**
		Natarsia		3		3	**0.724637681**				0	**0**	3			3	**0.785340314**				0	**0**				0	**0**
		Macropelopia	7	15	7	29	**7.004830918**	5	2		7	**1.335877863**	7	10	6	23	**6.020942408**		9	5	14	**4.034582133**				0	**0**
	Empididae	Hemerodromia sp	10		7	17	**4.106280193**	1	2		3	**0.572519084**			7	7	**1.832460733**				0	**0**	4			4	**1.169590643**
	Simulidae	Simulium sp juv				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
	Tabanidae	Chrysops sp	3		2	5	**1.207729469**	2			2	**0.381679389**		5		5	**1.308900524**	3			3	**0.864553314**	2			2	**0.584795322**
	Stratiomyidae	Odontomyia				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
	Tipulidae	Tipula				0	**0**		4		4	**0.763358779**	1			1	**0.261780105**			2	2	**0.576368876**				0	**0**
		Dicranota				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
MEGALOPTERA	Sialidae	Sialis sp		11	4	15	**3.623188406**	3	40	16	59	**11.25954198**	7	1	2	10	**2.617801047**	4	6	5	15	**4.322766571**	9	1		10	**2.923976608**
	Corydalidae	Nigronia				0	**0**			3	3	**0.572519084**		2		2	**0.523560209**				0	**0**				0	**0**
											0	**0**				0	**0**				0	**0**				0	**0**
ODONATA	Aeshnidae	Boyeria	2		4	6	**1.449275362**		2		2	**0.381679389**		1		1	**0.261780105**				0	**0**				0	**0**
	Aeshnidae	Aeshna				0	**0**				0	**0**		3		3	**0.785340314**				0	**0**				0	**0**
	Calopterygidae	Calopteryx		3		3	**0.724637681**		2	1	3	**0.572519084**		1		1	**0.261780105**				0	**0**	5		1	6	**1.754385965**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
PLECOPTERA	Leuctridae	Leuctra sp				0	**0**				0	**0**	1			1	**0.261780105**				0	**0**				0	**0**
	Nemouridae	Malenka				0	**0**			2	2	**0.381679389**	2			2	**0.523560209**				0	**0**				0	**0**
											0	**0**				0	**0**				0	**0**				0	**0**
TRICHOPTERA	Glossosomatidae	Glossosoma		12		12	**2.898550725**	1	2	4	7	**1.335877863**				0	**0**				0	**0**				0	**0**
	Hydropsychidae	Cheumatopsyche	15		4	19	**4.589371981**	10	18	15	43	**8.20610687**		14	7	21	**5.497382199**				0	**0**	13	1	6	20	**5.847953216**
		Hydropsyche				0	**0**	12	13	9	34	**6.488549618**	1			1	**0.261780105**				0	**0**	3			3	**0.877192982**
		Diplectrona					**0**		4	3	7	**1.335877863**				0	**0**				0	**0**				0	**0**
	Lepidostomatidae	Lepidostoma sp	1			1	**0.241545894**	3		3	6	**1.145038168**				0	**0**		3	4	7	**2.017291066**				0	**0**
	Limnephilidae	Frenesia sp				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
	Philopotamidae	Chimarra sp				0	**0**	27	1	4	32	**6.106870229**	2	1		3	**0.785340314**		3		3	**0.864553314**				0	**0**
	Phryganeidae	Phryganea	2			2	**0.483091787**				0	**0**				0	**0**			2	2	**0.576368876**				0	**0**
	Polycentropodidae	Polycentropus			4	4	**0.966183575**				0	**0**				0	**0**				0	**0**				0	**0**
	Rhyacophilidae	Rhyacophila				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
GASTROPODA	Physidae	Physella gyrina				0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
BIVALVIA	Sphaeriidae	Pisidium sp		6	12	18	**4.347826087**		4		4	**0.763358779**	1	1	12	14	**3.664921466**	3	4	14	21	**6.051873199**		8	4	12	**3.50877193**
						0	**0**				0	**0**				0	**0**				0	**0**				0	**0**
PLATYHELMINTHES	Tricladida	Planariidae				0	0	2			2	**0.381679389**				0	**0**				0	**0**	1			1	**0.292397661**
		TOTALS	110	179	125	414	100	206	182	136	524	100	133	117	132	382	100	125	110	112	347	100	129	106	107	342	100
		Number of Taxa	15	18	18	27		21	24	20	30		18	20	13	28		13	14	17	21		14	12	13	20	
		Percentage picked	11.11%	100.00%	11.11%			5.88%	3.70%	5.88%			6.45%	23.53%	27.27%			27.27%	19.51%	20.00%			16.67%	25.71%	7.41%		

APPENDIX II

Fish Population and Biomass Estimate Data

Fish Population Estimates Using Maximum Likelihood Constant P – 2006

Results	EMS-001	EMS-002	EMS-003
Estimated Population	9.07	55.56	34.81
Chi-squared	0.52	1.44	2.57
Standard error	0.3	3.05	3.82
Degrees of freedom	1	1	1
Number observed	9	52	31
Lower 95% conf. interval	9.00	52.00	31.00
Upper 95% conf. interval	9.66	61.53	42.30
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4724 (accept)	0.2305 (accept)	0.1089 (reject)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2006

Results	EMS-001	EMS-002	EMS-003
Estimated Biomass (g)	5.03	66.10	67.21
Chi-squared	0.23	0.03	14.37
Standard error	0.19	1.30	2.05
Degrees of freedom	1	1	1
Number observed	5	65	65
Lower 95% conf. interval	5.00	65.00	65.00
Upper 95% conf. interval	5.40	68.65	71.22
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.6319 (accept)	0.8638 (accept)	0.0002 (reject)

Fish Population Estimates Using Maximum Likelihood Constant P – 2007

Results	EMS-001	EMS-002	EMS-003
Estimated Population	88.76	173.07	13.89
Chi-squared	3.42	0.44	0.23
Standard error	1.68	3.84	1.53
Degrees of freedom	1	1	1
Number observed	87	166	13
Lower 95% conf. interval	87.00	166.00	13.00
Upper 95% conf. interval	92.05	180.59	16.88
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0646 (reject)	0.5073 (accept)	0.6315 (accept)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2007

Results	EMS-001	EMS-002	EMS-003
Estimated Biomass (g)	52.51	158.46	18.45
Chi-squared	3.97	1.06	0.02
Standard error	1.65	5.28	0.88
Degrees of freedom	1	1	1
Number observed	51	148	18
Lower 95% conf. interval	51.00	148.11	18.00
Upper 95% conf. interval	55.75	168.81	20.17
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0463 (reject)	0.3040 (accept)	0.8853 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2008

Results	**EMS-001**	**EMS-002**	**EMS-003**
Estimated Population	80.02	91.84	30.93
Chi-squared	1.08	3.39	0.58
Standard error	4.17	35.62	5.22
Degrees of freedom	1	1	1
Number observed	74	53	26
Lower 95% conf. interval	74.00	53.00	26.00
Upper 95% conf. interval	88.20	161.65	41.15
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.2922 (accept)	0.0655 (reject)	0.4444 (accept)

Fish Biomass Estimates Using Maximum Likelihood Constant P – 2008

Results	**EMS-001**	**EMS-002**	**EMS-003**
Estimated Biomass (g)	55.82	105.00	36.08
Chi-squared	1.13	9.30	5.39
Standard error	4.63	1.17	9.68
Degrees of freedom	1	1	1
Number observed	50	104	27
Lower 95% conf. interval	50.00	104.00	27.00
Upper 95% conf. interval	64.89	107.29	55.05
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.2870 (accept)	0.0023 (reject)	0.0202 (reject)

Fish Population Estimates Using Maximum Likelihood Variable P – 2009

Results	EMS-001	EMS-002	EMS-003	EMS-005
Estimated Population	48.51	40.19	32.73	82.31
Chi-squared	0.56	0.35	0.24	0.17
Standard error	0.90	7.84	5.71	23.13
Degrees of freedom	1	1	1	2
Number observed	48	33	28	61
Lower 95% conf. interval	48.00	33.00	28.00	61.00
Upper 95% conf. interval	50.28	55.56	43.93	127.64
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4550 (accept)	0.5516 (accept)	0.6234 (accept)	0.9179 (accept)

** Constant P method used for Population Estimate due to only 3 passes.

Fish Population Estimates Using Least Squares Regression – 2009

Results	EMS-004
Estimated Population	29.42
Slope	- 0.596
Y – Intercept	17.55
r^2 (Coefficient of Determination)	0.969
Residual Sum of Squares	3.916
Regression Sum of Squares	124.084
Degrees of Freedom	1
F	31.687

Fish Population Estimates Using Maximum Likelihood Constant P – 2010

Results	EMS-001	EMS-002	EMS-003	EMS-005
Estimated Population	5.22	76.95	-	2.18
Chi-squared	1.03	0.44	-	0.68
Standard error	0.67	1.17	-	0.74
Degrees of freedom	1	1	-	1
Number observed	5	76	-	2
Lower 95% conf. interval	5.00	76.00	-	2.00
Upper 95% conf. interval	6.54	79.24	-	3.63
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.3111 (accept)	0.5073 (accept)	-	0.4096 (accept)

Fish Population Estimates Using Maximum Likelihood Variable P – 2010

Results	EMS-004
Estimated Population	58.33
Chi-squared	0.47
Standard error	6.45
Degrees of freedom	1
Number observed	52
Lower 95% conf. interval	52.00
Upper 95% conf. interval	70.97
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.4929 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2011

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	59.37	100.31	8.35	54.47	10.16
Chi-squared	0.29	0.55	0.14	0.05	0.14
Standard error	7.99	7.22	9.69	5.16	2.15
Degrees of freedom	1	1	1	1	1
Number observed	49	88	5	48	9
Lower 95% conf. interval	49	88	5	48	9
Upper 95% conf. interval	75.03	114.46	27.33	64.58	14.37
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.59 (accept)	0.4565 (accept)	0.7095 (accept)	0.8316 (accept)	0.7105 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2012

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	129.32	70.08	1.00	53.46	42.95
Chi-squared	0.09	3.54	0.00	4.11	0.37
Standard error	5.57	11.05	0.00	5.78	3.55
Degrees of freedom	1	1	1	3	2
Number observed	119	55	1	46	39
Lower 95% conf. interval	119.00	55.00	1.00	46.00	39.00
Upper 95% conf. interval	140.24	91.74	1.00	64.80	49.90
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.7649 (accept)	0.0597 (**reject**)	0.9748 (accept)	0.2496 (accept)	0.8294 (accept)

Fish Population Estimates Using Least Squares Regression – 2012

Results	EMS-002
Estimated Population	73.78
Intercept (a)	27.35
Probable uncertainty of Intercept (a)	5.54
Gradient (b)	-0.37
Probable uncertainty of Gradient (b)	0.18
Chi-squared	36.24
Number observed	55.00

Fish Population Estimates Using Maximum Likelihood Constant P – 2013

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	190.10	241.10	33.03	266.39	159.89
Chi-squared	3.48	0.34	0.29	1.07	0.46
Standard error	5.62	18.73	5.14	27.56	9.46
Degrees of freedom	1	1	1	1	2
Number observed	178	193	28	197	139
Lower 95% conf. interval	179.09	204.40	28.00	212.37	141.34
Upper 95% conf. interval	201.11	277.81	43.11	320.40	178.44
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.0619 (**reject**)	0.5593 (accept)	0.5903 (accept)	0.3001 (accept)	0.7933 (accept)

Fish Population Estimates Using Least Squares Regression – 2013

Results	EMS-001
Estimated Population	184.20
Intercept (a)	117.69
Probable uncertainty of Intercept (a)	7.13
Gradient (b)	-0.64
Probable uncertainty of Gradient (b)	0.06
Chi-squared	52.59
Number observed	178.00

Fish Population Estimates Using Maximum Likelihood Constant P – 2014

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	101.57	210.10	16.05	62.84	198.34
Chi-squared	0.01	1.73	0.72	1.35	3.64
Standard error	4.16	6.72	11.68	8.95	67.17
Degrees of freedom	1	2	2	1	1
Number observed	95	194	10	51	104
Lower 95% conf. interval	95.00	196.93	10.00	51.00	104.00
Upper 95% conf. interval	109.72	223.27	38.93	80.38	329.99
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.9142 (accept)	0.4221 (accept)	0.6993 (accept)	0.2450 (accept)	0.0564 **(reject)**

Fish Population Estimates Using Least Squares Regression – 2014

Results	EMS-005
Estimated Population	203.77
Intercept (a)	43.22
Probable uncertainty of Intercept (a)	8.91
Gradient (b)	-0.21
Probable uncertainty of Gradient (b)	0.17
Chi-squared	97.29
Number observed	104.00

Fish Population Estimates Using Maximum Likelihood Constant P – 2015

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	122.78	123.02	5.04	114.08	168.35
Chi-squared	0.00	0.05	2.66	0.27	0.26
Standard error	4.04	5.07	0.23	12.43	6.73
Degrees of freedom	1	1	2	1	1
Number observed	116	114	5	92	154
Lower 95% conf. interval	116.00	114.00	5.00	92.00	155.17
Upper 95% conf. interval	130.70	132.95	5.50	138.45	181.53
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.9903 (accept)	0.8229 (accept)	0.2650 (accept)	0.6034 (accept)	0.6129 (accept)

Fish Population Estimates Using Maximum Likelihood Constant P – 2016

Results	EMS-001	EMS-002	EMS-003	EMS-004	EMS-005
Estimated Population	128.53	113.92	9.22	108.11	151.39
Chi-squared	2.31	5.25	1.24	0.24	0.39
Standard error	5.68	7.14	0.62	8.52	11.40
Degrees of freedom	1	1	1	1	2
Number observed	118	101	9	93	127
Lower 95% conf. interval	118.00	101.00	9.00	93.00	129.04
Upper 95% conf. interval	139.65	127.92	10.44	124.81	173.73
Probability, or P-Value (if > 0.2, accept the model; if < 0.2, reject)	0.1288 **(reject)**	0.0220 **(reject)**	0.2664 (accept)	0.6231 (accept)	0.8232 (accept)

Fish Population Estimates Using Least Squares Regression – 2016

Results	EMS-001	EMS-002
Estimated Population	124.07	119.37
Intercept (a)	75.00	56.84
Probable uncertainty of Intercept (a)	5.08	7.97
Gradient (b)	-0.60	-0.48
Probable uncertainty of Gradient (b)	0.07	0.13
Chi-squared	26.80	71.57
Number observed	118.00	101.00

APPENDIX V

TERRESTRIAL AND WETLAND MONITORING REPORT

Hanlon Creek Business Park 2016 During-Construction

Terrestrial and Wetland Monitoring

Prepared for:
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Economic Development & Tourism Services
City of Guelph
1 Carden Street, City Hall
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Project No. 1033G I February 2017

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Hanlon Creek Business Park
2016 During-Construction

Terrestrial and Wetland Monitoring

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1.0 Introduction

Terrestrial and wetland monitoring in the Hanlon Creek Business Park (HCBP) has been ongoing annually since 2006. The objective of terrestrial and wetland monitoring is to identify and track any changes that may occur to the terrestrial and wetland ecology resulting from the planned industrial development of the HCBP. The terrestrial and wetland monitoring program focuses on assessing features within the entire subject property; however, it is noted that development of the Business Park is occurring in phases (Phases 1 (Stages 2 & 3), 2, and 3) (Map 1). Baseline (pre-construction) monitoring was conducted from 2006 to 2009. During construction monitoring commenced in 2010, making 2016 the seventh during construction monitoring year. The monitoring program also includes components related to the Mast-Snyder Gravel Pit, located west of the HCBP. These components of the monitoring are tied to the timing of the pit's operation and restoration.

Over time, the terrestrial and wetland monitoring program has expanded to address concerns and recommendations made by reviewing groups and agencies. The following taxonomic groups were monitored in 2016 and are documented in this report:

- Vascular flora
- Breeding birds
- Calling anurans (frogs and toads)

This report provides a summary of findings from the 2016 monitoring year, as well as a comparison of the data to previous baseline and during construction years. Recommendations related to the terrestrial and wetland monitoring program are summarized.

1.1 Construction Activity

Construction commenced in late 2009 and has continued each year through to 2016. Construction activity in 2016 within Phases 1 and 2 is outlined below and highlighted on Map 2. No construction activity occurred within Phase 3 in 2016.

Phase 1, Stage 2

- Operation of commercial building – 500 Hanlon Creek Boulevard (Fusion Homes)
- Operation of commercial building – 501 Hanlon Creek Boulevard (Compass)

Phase 1, Stage 3

- Operation of commercial buildings – 197-345 Hanlon Creek Boulevard (Wurth Canada, Graniteworx, etc.)
- Operation of commercial building – 28 Bett Court (MF Property Management Inc.)

Phase 2

- Operation of commercial building – 104 Cooper Drive (Ontario One Call)
- Preliminary grading of Blocks 8, 9 and 26 was completed in 2014 with a structure being built in fall 2016
- Laird Road overpass has been in-use since 2014

2.0 Methodology

Since 2006, the terrestrial and wetland monitoring program has focused on plot-based surveys to document breeding anuran, breeding birds and vascular flora (herbaceous, shrubs and trees) as well as incidental wildlife throughout the property. Baseline soils information was collected from each of the monitoring plots between 2006 and 2014.

For plot set-up and annual monitoring survey methodologies, the reader is referred to Section 3.0 in the HCBP Terrestrial and Wetland Monitoring Reports submitted to the City for the 2011-2013 monitoring years (NRSI 2011 – 2015).

Table 1 provides a summary of the plots that have been monitored in each year and the monitoring focus. Map 3 identifies the vegetation communities throughout the Business Park and monitoring locations.

2.1 Incidental Observations

Incidental observations of all wildlife (i.e. birds, mammals, butterflies, dragonflies, reptiles, etc.) were documented during all field visits conducted in 2016. This included observations of individuals, as well as signs of animal presence, such as tracks, scat, trails, dens, etc.

Table 1. Summary of Plot Monitoring

Plot	2006				2007-2008				2009-2010				2011-2016			
	A	V	S	B	A	V	S	B	A	V	S	B	A	V	S	B
1	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
2	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
3		🟢	🟦	🟪		🟢	🟦	🟪		🟢	🟦	🟪		🟢	🟦	🟪
4	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
5		🟢	🟦	🟪		🟢	🟦	🟪		🟢	🟦	🟪		🟢	🟦	🟪
6	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
7	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
8	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
9					🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪	🟩	🟢	🟦	🟪
10									🟩		🟦		🟩		🟦	
11									🟩		🟦	🟪	🟩		🟦	🟪
12									🟩		🟦		🟩		🟦	
13									🟩		🟦		🟩		🟦	
14									🟩		🟦		🟩		🟦	
15									🟩		🟦		🟩		🟦	
16									🟩		🟦		🟩	🟢	🟦	🟪
17									🟩		🟦		🟩		🟦	
18													🟩	🟢	🟦	
19																🟪
20																🟪

🟩 Calling anuran monitoring
🟢 Vegetation monitoring
🟦 Soil monitoring (discontinued after 2014)
🟪 Breeding bird monitoring

3.0 Monitoring Results

3.1 Vascular Flora Surveys

The Ecological Land Classification (ELC) vegetation community codes and descriptions for each monitoring plot are shown on Map 3.

Refer to Appendix I for a comprehensive list of vascular flora species observed within the monitoring plots between 2006 and 2016. Table 2 lists the number of species that were observed each year. In 2016, 127 species of vascular flora were observed within the 11 vegetation monitoring plots. A total of 4 species of vascular flora were documented during the 2016 vegetation surveys which had not been previously recorded;

Plot 1

- Cleavers (*Galium aparine*)

Plot 2

- Woodland Horsetail (*Equisetum sylvaticum*)

Plot 4

- Bearded Shorthusk (*Brachyelytrum erectum*)
- Bristle-stalked Sedge (*Carex leptalea*) (also considered regionally rare)

Specimens cannot always be identified to species level due to a lack of diagnostic features (i.e. sedge or grass species lacking an inflorescence due to the time of year) and as such some plants were only identified to genus.

Table 2. Number of Vegetation Species Observed by Year

Year	Number of Species
2006	97
2007	110
2008	109
2009	118
2010	124
2011	140
2012	147
2013	146
2014	136
2015	140
2016	127

3.1.1 Significant Vascular Flora Species

In 2016, Woodland Horsetail, Meadow Horsetail (*Equisetum pratense*), Rough Avens (*Geum laciniatum*) and Clearweed (*Pilea pumila*) were observed and are considered rare within Wellington County (Dougan 2009). 2016 was the first year Woodland Horsetail has been observed within any plot. Previously documented regionally rare species are listed in Table 3. No federally or provincially significant species of vascular flora were observed during 2016 monitoring.

3.1.2 Floristic Indices

A common method for evaluating and assessing natural areas is using floristic composition. This method is based on the character of a region's flora. Plant species display varying degrees of fidelity to specific habitats, which is expressed by species conservatism. Species conservatism is the degree of faithfulness a plant displays to a set of environmental conditions. The quality of a natural area is reflected in the number of conservative species found within a certain habitat (Wilhem and Ladd 1988 *In* Oldham et al. 1995). There are several floristic indices which can be used to describe the character of the vegetation in the plot. These include the Coefficient of Wetness (CW), the Coefficient of Conservatism (CC), and the Natural Area Index (NAI). All species (herbaceous, shrubs, and trees) from each plot are considered in these equations.

Coefficient of Wetness

The CW is based on wetland values given to each individual plant species. Values range from -5 to +5, where -5 indicates an obligate wetland species, and +5 indicates an obligate upland species. "0" is assigned to facultative species, those that are just as likely to be found in wetland or upland habitats. The CW values used are based on Oldham et al. (1995). Figure 1 shows the average wetness per plot, based on the wetness coefficients of all species found within a plot. All of the monitoring plots, with the exception of 2 are located within wetland areas. Both Plot 1 and Plot 4 consistently show the lowest average CW values; -2.40 and -2.53 in 2016 respectively. Plot 1 is situated within a thicket swamp which generally contains some degree of shallow standing water within the plot during July vegetation monitoring each year. Plot 1 average CW data from recent years may suggest a drying trend (-3.67 in 2014 and -3.00

in 2015, -2.40 in 2016); however it is noted that the 2016 value reflects the pre-construction 2006 and 2007 values. Within the plot, 9 of the 22 identified species have a CW value of -5 and 18 of 22 species have CW values between -1 and -5. The presence of upland species in the western edge of the plot (which transitions to meadow) such as Canada Goldenrod (*Solidago canadensis*), Canada Thistle (*Cirsium arvense*), Cleavers (*Galium aparine*) and Common Dandelion (*Taraxacum officinale*), all have a CW value of 3 which impacts the average CW value considerably.

In 2016, Plot 5 exhibited the lowest average CW value which has been recorded in the plot since monitoring began at -0.60. As noted in previous annual monitoring reports, this plot contains low diversity and minimal groundcover (none of the 5 sub-plots contained any herbaceous vegetation in 2016). As the average CW value does not account for abundance and only provides an analysis of the overall species list, outlier species can inflate the average for low diversity plots.

Plot 6 is situated within an area which transitions from meadow marsh conditions (to the north and west of the plot) to upland fresh-moist meadow conditions. In previous monitoring years the average CW value has varied between -0.04 and -1.54. In 2016 the average jumped to +0.75. The 3 most abundant species within the plot were Coltsfoot (*Tussilago farfara*), Panicled Aster (*Symphyotrichum lanceolatum*) and Canada Goldenrod (*Solidago canadensis*); all with a CW value of +3. Species with low CW values (-5) which had been documented in previous years such as Marsh Bedstraw (*Galium palustre*), Canada Bluejoint (*Calamagrostis canadensis*) and Fox Sedge (*Carex vulpinoidea*) were not recorded in the plot in 2016. As a transition between wetland and upland conditions some degree of data fluctuation can be expected within the data set. It is also noted that the plot contains a dense thatch of grasses, coupled with trampling of vegetation during plot monitoring, which may cause plants which are low growing or uncommon in the plot to be overlooked.

Table 3. Significant Vascular Flora Species Recorded

Common Name	Scientific Name	SRANK[1]	Wellington[2]	Year of Observation											Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Clinton's Wood Fern	*Dryopteris clintoniana*	S4	R		x			x	x						
Hay-scented Fern	*Dennstaedtia punctilobula*	S5	R										x		
Marsh Horsetail	*Equisetum palustre*	S5	R	x	x				x						
Meadow Horsetail	*Equisetum pratense*	S5	R	x		x	x	x	x	x		x	x	x	5,7,18
Woodland Horsetail	*Equisetum sylvaticum*	S5	R											x	2
Rough Avens	*Geum laciniatum*	S4	R		x				x	x				x	16
Witch Hazel	*Hamamelis virginiana*	S5	R			x		x							
Pale Jewelweed	*Impatiens pallida*	S5	R		x	x			x						
Clearweed	*Pilea pumila*	S5	R			x					x		x	x	2
Yellow Water-crowfoot	*Ranunculus flabellaris*	S4?	R			x			x						
Bristly Buttercup	*Ranunculus hispidus* var. *hispidus*	S3				x									
Smooth Gooseberry	*Ribes hirtellum*	S5	R				x								
Rough-leaved Goldenrod	*Solidago patula*	S5	R		x	x			x	x		x	x		
Mountain Ash	*Sorbus americana*	S5	R					x					x		

[1]MNRF 2016a; [2]Dougan & Associates 2009

LEGEND	
SRANK	**Wellington Status**
S3 Vulnerable	R Rare
S4 Apparently Secure	
S5 Secure	
#? Uncertainty about rank	

Plots 16 and 18 were added in 2011 to monitor any changes within the wetland community due to the potential dewatering required as part of the City of Guelph SW Quadrant Class EA. At Plot 16 and Plot 18, CW values had shown a steady drying trend between 2011 and 2015, with the most pronounced decrease in CW values occurring between 2011 and 2013. Both plots are within swamp features which are physically separate from the core PSW but considered part of the Hanlon Swamp Wetland Complex. These plots are located in close proximity to recent commercial building development and the Hanlon Creek Boulevard (Map 3). In 2016, both plots showed a marked drop in average CW values (i.e. indicative of wetter conditions), Plot 16 dropping to -2.00 from -1.13 in 2015 and Plot 18 dropping to -2.42 from -1.55 in 2015. As both plots are located within Silver Maple (*Acer saccharinum*) swamp, this return to wetter conditions (as indicated through average CW values) is considered to be a positive change which reverses the drying trend previously being observed.

Vegetation coverage within Plot 16 appears to be somewhat influenced by the amount of seasonal standing water within the plot which results in a large proportion of un-vegetated substrates and can influence the various floristic indices which are analyzed. The average percentage cover of detritus within each of the 5 sub-plots in 2016 was 96%. Both Sensitive Fern (*Onoclea sensibilis*) CW-3 and Marsh Fern (*Thelypteris palustris*) CW -4 were the most abundant herbaceous species within the plot in 2016. Given that soils within the plot remained saturated into the July vegetation monitoring period, and the presence of these (and other) facultative wetland species, it appears that the plot is maintaining a hydrological balance which supports herbaceous wetland flora.

Previous monitoring reports had inferred that, to some extent, the seasonal standing water may inundate the plot to a degree which excludes some wetland species periodically thus giving the impression of a drying trend from the data set. Analysis of groundwater levels in recent years indicates that the water table is generally below the elevation of the plot and larger wetland feature. Observations of standing water noted during calling anuran surveys indicate that in some years Plot 16 may contain standing water into June, while other years the plot may only contain saturated detritus. Based upon discussions with the monitoring team, it is now suspected that altered surface water inputs may be contributing to the changes in herbaceous vegetation within this plot and perhaps others such as Plot 18 and Plot 6. Site drainage is designed in a manner which directs all surface water flows from the adjacent developable land into conveyance swales that then flow into the SWM ponds. Therefore the wetland features only receive surface water flows from their own blocks (Map 2). Regardless of whether vegetation fluctuates as a result of inundation or as a result of drier conditions brought about by reduced surface flow contributions, at least several years would be required for those species to recolonize the plot once soil moisture returns to favourable conditions.

The swamp within which Plot 18 is located does not contain the same well-defined topographical depression that Plot 16 does. During calling anuran surveys (April through June) and July vegetation monitoring, standing water is rarely observed within this plot. The continued presence of species with low CW values including Purple-stemmed Aster (*Sympyotrichum puniceum*), Winterberry (*Ilex verticillata*) and Spotted Water Hemlock (*Cicuta maculata*) indicate that wetland conditions are being maintained within this feature. It is also noted that the presence of hummocks within the plot allows for the persistence of upland species such as Hairy Solomon's Seal (*Polygonatum pubescens*) which has a CW value of +5).

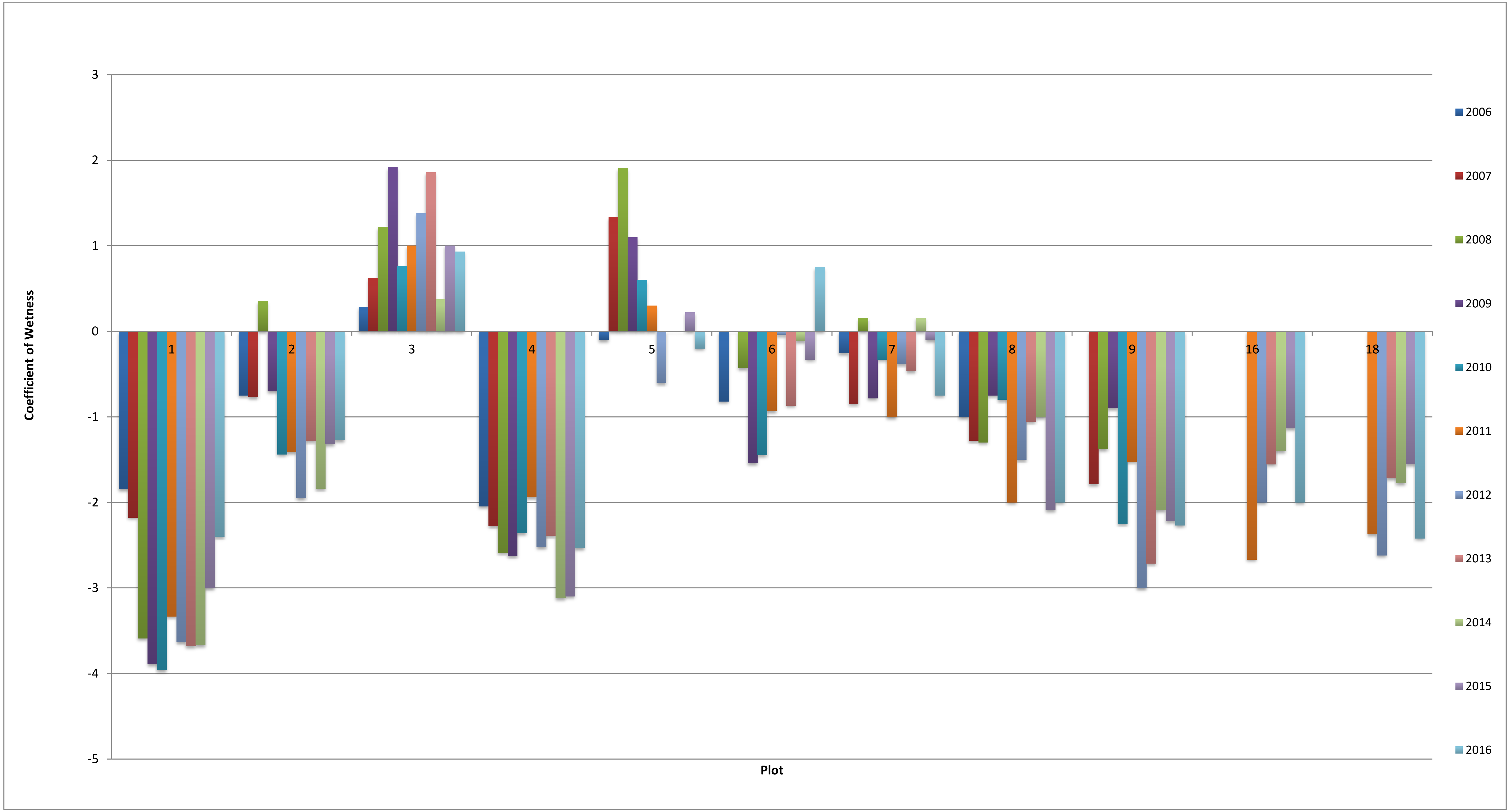

Figure 1. Coefficient of Wetness by Plot 2006 - 2016

Coefficient of Conservatism

The CC is also based on Oldham et al. (1995). Each species is given a rank between 0 and 10, based on its degree of fidelity to a range of synecological parameters (Oldham et al. 1995). Synecology is the study of the structure, development, and distribution of ecological communities. Species ranked between 0 and 3 are found in a variety of plant communities, including disturbed sites. Species ranked between 4 and 6 are those associated with a specific plant community, but which can tolerate moderate disturbance. Species ranked from 7 to 8 are found in plant communities in an advanced stage of succession with minor disturbance. Plants with a ranking of 9 or 10 have high degrees of fidelity to a narrow range of synecological factors.

The average CC per plot is shown on Figure 2. The highest average CC value in 2016 was found in Plot 7 (5.27), a slight increase from 4.93 in 2015. This plot is located at the transition between Fresh-Moist Sugar Maple Deciduous Forest and White Cedar-Hardwood Mineral Mixed Swamp habitats and is bisected by a watercourse (Map 3). With invasive species such as Common Buckthorn (*Rhamnus cathartica*) and Glossy Buckthorn (*R. frangula*) limited to a small number of seedlings, this plot has retained a high diversity of native species. A closed canopy (97%) may be partially responsible for limiting the growth of these invasive shrub species.

The lowest average CC value occurred in Plot 6 (1.58 in 2016) which is consistently among the lowest CC values due to the old field conditions and the dominance of non-native cool season grasses. In 2016, 8 of the 20 species recorded in the plot were non-native (no CC value is assigned for these species). This plot is likely to exhibit low CC values for many years as natural succession occurs and the balance of native to non-native species shifts as tree and shrub species become established and the presence of cool season grass species decreases.

As discussed in previous years, Plot 5 has a consistently low average CC value due to the low diversity of species which can grow among the conifer-dominated canopy. In 2016 the CC value increased slightly with the addition of White Trillium (*Trillium* *grandiflorum*) (CC 5) to the plot; the remaining 4 species in the plot are trees which have been present throughout the monitoring period.

The 2016 average CC value for Plot 1 was notably lower than in previous years (3.19). This plot had recorded a high value of 5.13 in 2009. Several factors are likely to influence data for this plot. The western edge of the plot contains a portion of old field meadow which contains non-native species, seasonal standing water levels can influence the presence of certain species, and the hummocks at the base of many Slender Willow (*Salix petiolaris*) shrubs act as microhabitats for high CC value species which tend to be limited in numbers and not present in every year.

Both Plot 16 and Plot 18 showed an increase in average CW values with 2014 and 2015 data being markedly lower than 2016 data. This trend is likely due to recolonization of the plot by higher CC species which were not recorded in the last couple of years due to unsuitable soil moisture conditions. Coupled with decreases in average CW values for these plots (i.e. wetter conditions), the CC data supports that 2016 marked a positive rebound for each of these plots.

The overall trend between 2006 to 2016 is that average CC values have remained relatively steady. The spring of 2012 was notable quite dry and may have reduced or eliminated some of the higher CC value species which may now be permanently absent from certain features or drastically reduced in numbers. In 2016, 2 species with a CC value of 8 were documented; Bristle-leaved Sedge (*Carex leptalea*) in Plot 4, and Meadow Horsetail (*Equisetum arvense*) in Plot 7 and Plot 18. Additionally 14 species with a CC value of 7 were documented in various plots (Appendix II).

There is potential that species which have seemingly disappeared from a plot may re-appear in later years through the germination of the seedbank or recolonization from areas adjacent to the plot. While most species observed are perennials, the groundcover composition within the subject property is dynamic and resilient to changes in soil moisture conditions. An individual species may die-off or re-establish within a plot from one year to the next; however analysis of impacts should focus on holistic shifts to wetter or drier conditions based on the complete range of flora present.

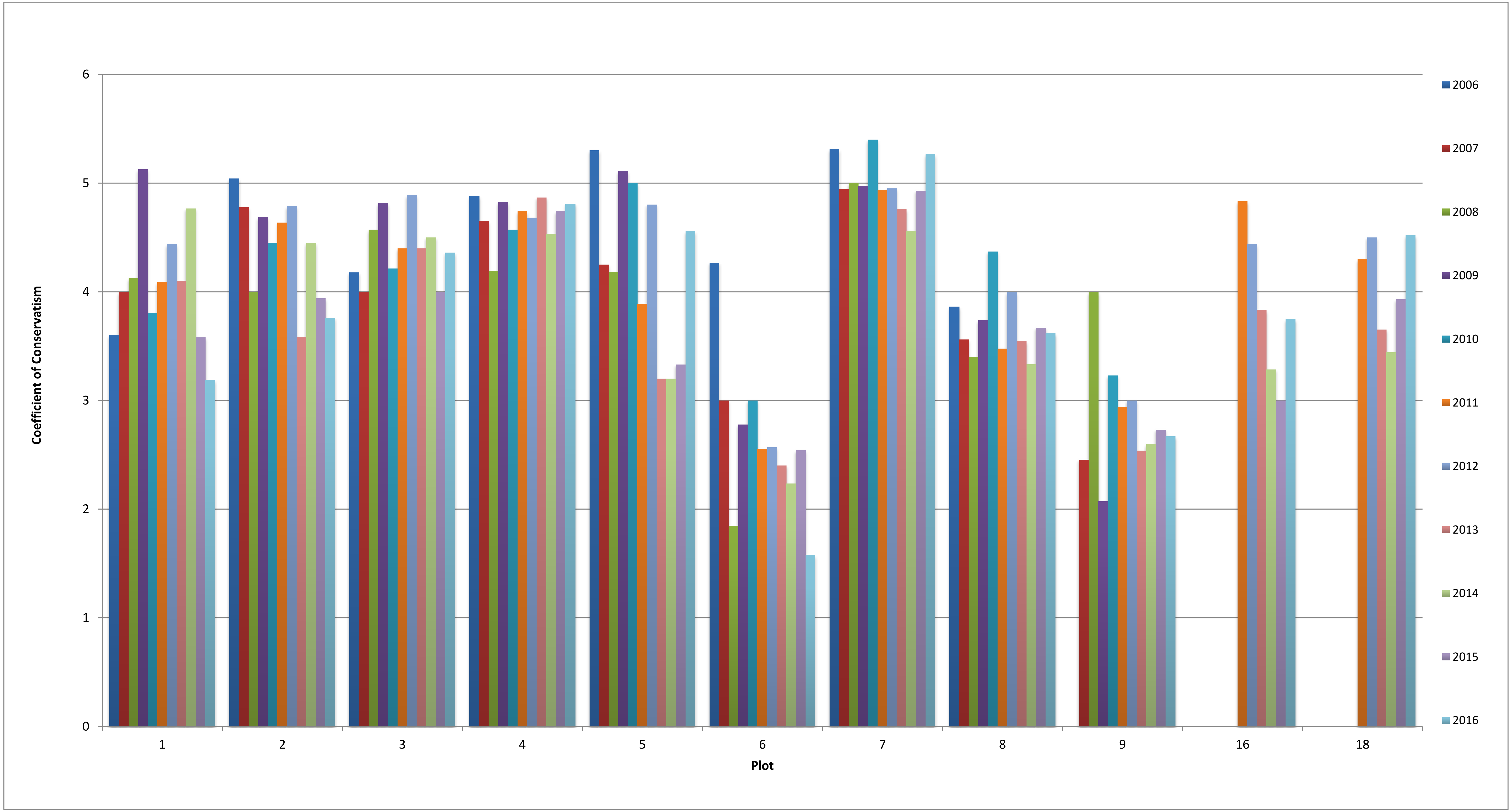

Figure 2. Coefficient of Conservatism by Plot 2006 - 2016

Natural Area Index

The NAI, or floristic quality index, allows the objective comparison of 2 or more natural areas or vegetation types (Oldham et al. 1995). The NAI is calculated by multiplying the average CC value by the square root of the total number of *native* species. Whereas the abundance and frequency of species can fluctuate greatly by season and year, the NAI is more stable and offers a more accurate picture. The NAI for each plot is shown on Figure 3.

The Ministry of Natural Resources and Forestry (MNRF) reports that natural areas with NAI values of over 35 are considered significant at the provincial level (Wilhelm and Ladd 1988 *in* Oldham et. al 1995). For comparison, an old successional field may score as low as <5 (Andreas et al. 2002). None of the plots within the HCBP score a value of 35 or higher. In 2016, Plot 6 showed a marked decrease in NAI values from the previous 10 year average. As an old field, NAI values here are always among the lowest for all monitoring plots and this drop (from 9.50 to 5.47) is not a concern at this time.

Plot 7, which exhibited the highest average CC value in 2016, had an NAI value of 27.38 in 2016. While the value for this plot has been as high as 32.70 in 2015, the rich habitat continues to support a diversity of native species. Other plots including Plot 2, Plot 4 and Plot 18 all showed an NAI value greater than 20 in 2016 and are unique high quality swamp features within the subject property. Those plots which tend to exhibit high NAI values are typically within the core of the natural feature, contain a somewhat complex micro-topography and are often situated on organic soils.

A number of factors will influence the parameters of the NAI equation (average CC and number of native species). Other factors include plant senescence or mortality due to drought (i.e. 2012). Given that most of the vegetation monitoring plots are located within wetlands, it is likely that the dry conditions in recent years, 2012 in particular, had a lingering effect on vegetation composition. Long term data indicates that between 1997 and 2006, 14 of the 20 years were below the 46-year average precipitation (Banks 2017). This drying trend is also evident in that 19 of the 24 months leading up to the end of 2016 recorded a less-than-normal amount of precipitation (Banks Groundwater

Engineering 2017). Some species may re-appear in time through the seed bank or colonization from areas adjacent to the plot.

3.1.3 Non-Native Vegetation Species

A total of 20 non-native species were recorded within vegetation plots in 2016. The number of non-native species found in each plot is compared on Figure 4. In general, non-native species have been present in all plots over the course of monitoring with the exception of Plot 5 which periodically contains a low number of invasive species but in very low numbers and not present every year.

Plot 6 consistently has the greatest number of non-native species with 8 documented in 2016. The dominant non-native species in 2016, and in recent years, have been Coltsfoot, Smooth Brome (*Bromus inermis* ssp. *inermis*), Orchard Grass (*Dactylis glomerata*) and Bird's-foot trefoil (*Lotus corniculatus*). The data shown on Figure 4 may suggest that once agricultural land use ceased prior to 2006, a flush of early successional weed species established, peaked in 2010 at 15 species, and has since shifted to a smaller group of dominant non-native species. Those species which are present will likely continue to exclude early successional weeds and to some extent desirable native vegetation. All species which were documented in Plot 6 in 2016 are unlikely to spread into the treed natural features as they require full sunlight and prefer disturbance.

In 2016 none of the plots contained newly introduced non-native species. The most widespread and abundant species continue to be Glossy Buckthorn, Common Buckthorn, Bittersweet Nightshade (*Solanum dulcamara*) and Common Dandelion. Mature (fruit-bearing) Buckthorn is quite common at the edges of all of the swamp and forest features throughout the site as well as within the features where canopy openings permit. Due to the ability of these species to establish beneath a dense canopy, a groundcover of herbaceous vegetation is often interspersed with many young Common Buckthorn seedlings which germinate from the seedbank (few of which reach maturity under closed canopy conditions). Common Buckthorn is widespread throughout Southern Ontario; it is often found on calcium-rich soils and occurs in a range of soil moisture and sunlight conditions (Anderson 2012). Other invasive shrubs including

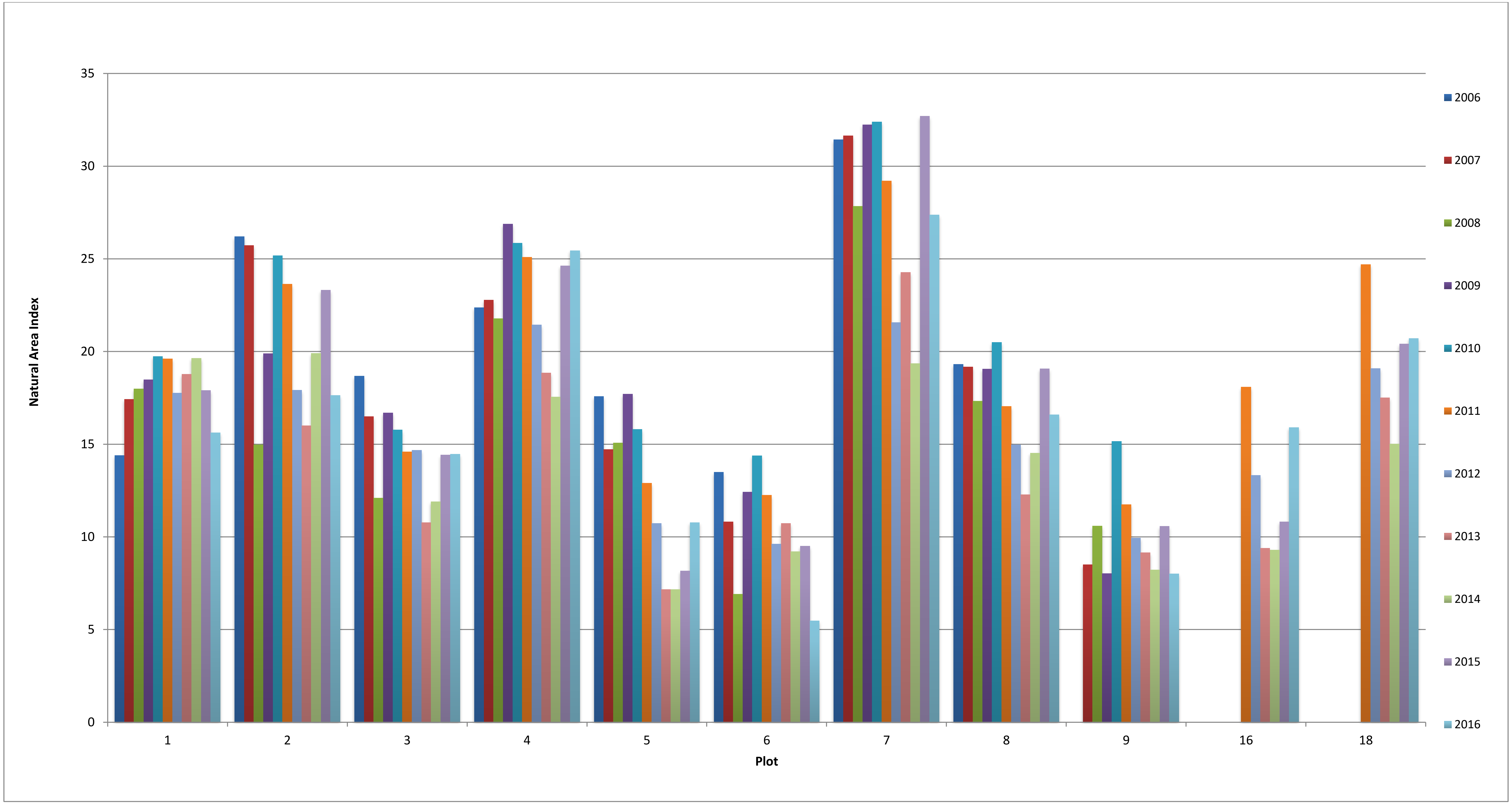

Figure 3. Natural Area Index by Plot 2006 - 2016

Tartarian Honeysuckle (*Lonicera tatarica*) and Guelder Rose (*Viburnum opulus*) are present in much smaller numbers within the subject property and have not had notable impacts on native species diversity or vegetation community structure. The control of Buckthorn or any other woody invasive species is not recommended for the site due to the current extent of plants, feasibility and long-term cost and commitment to properly manage these species. Glossy and Common Buckthorn were present within the subject property prior to the development and are not the result of any disturbance related to the construction.

To the east of Plot 6, a small stand of Common Reed (*Phragmites australis* ssp. *australis*) was noted in 2016. Additionally, several small stands were noted at the fringe of SWM Pond 4. This aggressive non-native species has the potential to spread into adjacent wetlands and meadows and create monocultures which compromise native species diversity. The stand near Plot 6 is approximately 10m x 10m in size and is located in the ditch on the north side of an access gate leading toward the plot. The stands within SWM Pond 4 are at several locations along the perimeter of the pond. To date, the Business Park, including the SWM features and roadside ditches, has remained free of this species. It is imperative that these populations of Common Reed be managed and removed. Given that the species occurs in a recently engineered ditch feature and SWM pond associated with the development, the introduction of this species is likely a result of recent grading activities during the construction of Phase 1 and Phase 2. Control of this species will require repeated herbicide application by a licensed professional. It is recommended that a full site inspection be conducted to document all stands of Common Reed, focusing on SWM ponds. Monitoring of the effectiveness of management efforts should also be continued annually until the species is no longer present. The full removal of all live rootstock is required or the species will re-establish and continue to spread.

Garlic Mustard (*Alliaria petiolata*) was only recorded in Plot 18 during the 2011 monitoring year. This invasive species is very common in Southern Ontario and it is rare to find upland wooded areas that do not contain this plant. It is noted that this species has been observed within the subject property, but for the most part has not established in high numbers within the natural features, many of which are swamp or marsh which would not support the species. Most of the non-native species present within the monitoring plots are common agricultural weeds or shrub species which produce prolific amounts of berries that are distributed by deer, birds and other wildlife.

Certain non-native species are considered particularly invasive, and are given a score of ‘-3’ on a weediness scale ranging from ‘-1’ to ‘-3’. The invasive species found within the HCBP vegetation monitoring plots include 5 shrub species (3 species with a weediness value of -3) and 15 herbaceous species. Non-native species observed in each monitoring year is provided in Table 4. In general, those species with weediness values of -2 or -3 tend to be present year after year, while less invasive species with a value of -1 are present intermittently and often in low numbers.

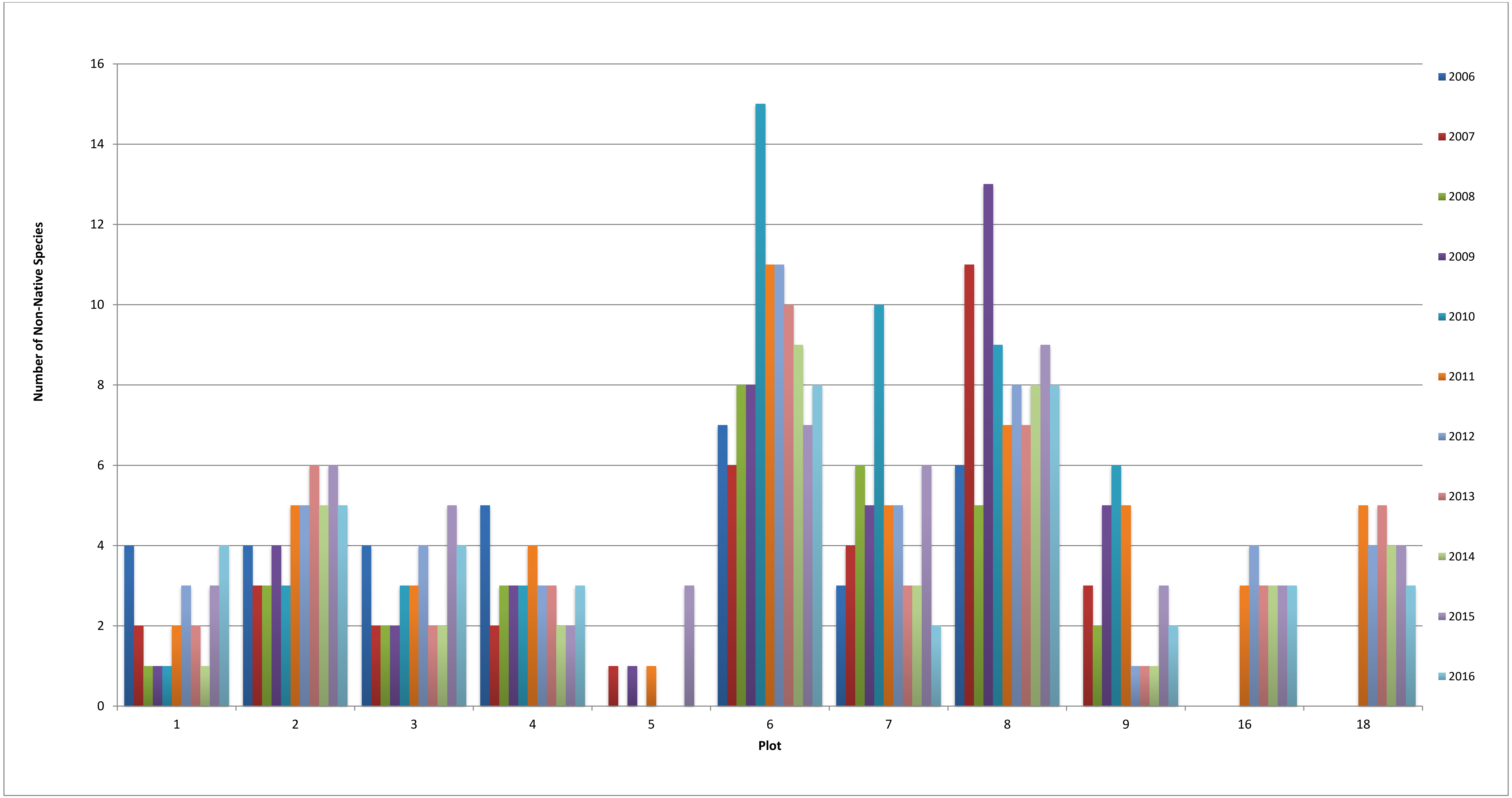

Figure 4. Non-Native Species by Plot 2006 - 2016

Table 4. Non-Native/Invasive Vascular Flora Observed

Common Name	Scientific Name	SRANK[1]	Weed	Year of Observation											Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Garlic Mustard	*Alliaria petiolata*	SE5	-3						x						
Common Burdock	*Arctium minus*	SE5	-2		x										
Smooth Brome	*Bromus inermis ssp. inermis*	SE5	-3		x				x				x	x	6
Mouse-ear Chickweed	*Cerastium fontanum*	SE5	-1								x				
Canada Thistle	*Cirsium arvense*	SE5	-1	x	x	x	x	x	x	x	x	x	x	x	1
Orchard Grass	*Dactylis glomerata*	SE5	-1							x	x	x	x	x	6
Queen Anne's Lace	*Daucus carota*	SE5	-2		x		x	x	x	x	x			x	9
Barnyard Grass	*Echinochloa crusgalli*	SE5	-1				x	x				x			
Quack Grass	*Elymus repens*	SE5	-3			x						x			
Hairy Willow-Herb	*Epilobium hirsutum*	SE5	-2				x	x	x	x	x			x	
Helleborine	*Epipactis helleborine*	SE5	-2			x	x	x		x			x	x	2
Tall Fescue	*Festuca arundinacea*	SE5	-1								x	x		x	6
Glossy Buckthorn	*Frangula alnus*	SE5	-3	x	x	x	x	x	x	x	x	x	x	x	2,3,4,7,8,16,18
Herb Robert	*Geranium robertianum*	SE5	-2	x	x	x	x	x	x				x		
Prickly Lettuce	*Lactuca serriola*	SE5		x			x								
Butter-and-eggs	*Linaria vulgaris*	SE5	-1			x									
Tartarian Honeysuckle	*Lonicera tatarica*	SE5	-3	x	x	x	x	x	x	x	x	x	x	x	8
Bird's-foot Trefoil	*Lotus corniculatus*	SE5	-2	x	x	x	x	x	x	x	x	x		x	
Moneywort	*Lysimachia nummularia*	SE5	-3		x										
Purple loosestrife	*Lythrum salicaria*	SE5	-3							x			x		
Common Mallow	*Malva neglecta*	SE5	-1						x						

Common Name	Scientific Name	SRANK^1	Weed	Year of Observation											Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Black Medick	*Medicago lupulina*	SE5	-1					x	x	x	x				
Pepper Mint	*Mentha X piperita*	SE4	-1							x					
Watercress	*Nasturtium officinale*	SE?	-1				x	x	x	x	x	x	x	x	8
Timothy	*Phleum pratense*	SE5	-1			x		x	x	x		x	x	x	
English Plantain	*Plantago lanceolata*	SE5	-1					x							
Common Plantain	*Plantago major*	SE5	-1					x	x						
Sulphur Cinquefoil	*Potentilla recta*	SE5	-2							x					
Tall Buttercup	*Ranunculus acris*	SE5	-2	x	x		x	x	x	x		x	x		
Creeping Buttercup	*Ranunculus repens*	SE5	-1										x	x	8
Common Buckthorn	*Rhamnus cathartica*	SE5	-3	x	x	x	x	x	x	x	x	x	x	x	2,3,4,8,16,18
Red Currant	*Ribes rubrum*	SE5	-2			x			x						
Curled Dock	*Rumex crispus*	SE5	-2			x		x	x						
Bladder Campion	*Silene cucubalus*		-1	x											
Bittersweet Nightshade	*Solanum dulcamara*	SE5	-2	x	x	x	x	x	x	x	x	x	x	x	1,2,4,9,16,18
Field Sow Thistle	*Sonchus arvensis*		-1			x		x							
Common Dandelion	*Taraxacum officinale*	SE5	-2	x	x	x	x	x	x	x	x	x	x	x	1,2,3,7,8
Alsike Clover	*Trifolium hybridum*		-1	x				x	x						
Red Clover	*Trifolium pratense*	SE5	-2			x									
White Clover	*Trifolium repens*	SE5	-1					x							
Coltsfoot	*Tussilago farfara*	SE5	-2	x	x	x	x	x	x	x	x	x	x	x	6,8
Water Speedwell	*Veronica anagallis-aquatica*	SE5	-1	x					x	x				x	8
Common Speedwell	*Veronica officinalis*	SE5	-2			x	x		x	x				x	3

Common Name	Scientific Name	SRANK[1]	Weed	Year of Observation											Plot
				2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Bird's-eye Speedwell	*Veronica persica*	SE4	-1							x					
Guelder-rose	*Viburnum opulus*	SE4	-1							x	x	x	x	x	8

[1]MNRF 2016a

LEGEND	
SRANK	
SE4 Uncommon but not rare	SE Exotic Species
SE5 Common, widespread, and abundant	? Rank Uncertainty

3.1.4 Herbaceous Inventory

Appendix I summarizes all species observed during the plot-based monitoring in the subject property from 2006 – 2016, while Appendix II summarizes the herbaceous species observed within each monitoring plot in 2016. A total of 89 species of herbaceous plants were observed during the plot-based vegetation monitoring that was conducted in 2016. During vegetation surveys some species were only identified to genus as the identifying traits of the plant may not have been apparent at the time of the survey. These include an Avens species (*Geum* spp.), Sedge species (*Carex* spp.), Willow Herb species (*Epilobium* spp.) and unidentifiable grass species. These species were included in the overall species count for the plot but were not included in the non-native species totals as a positive identification of the species was not possible.

Appendix III compares the herbaceous species recorded in each subplot between 2006 and 2016. Although the same subplot is monitored each year, the results vary as it is very difficult to monitor the exact same location from year to year, despite using the same compass bearing and location.

3.1.5 Shrub Inventory

The number of shrub species found within each monitoring plot and their approximate percent cover was recorded. In 2016, 22 shrub species were recorded. This number has varied over the monitoring years with low values of 15 species recorded in 2007, 2008, and 2009. Refer to Appendix IV for shrub species recorded within each monitoring plot in 2016 and Appendix V for a comparison between all years. All shrub species documented within vegetation monitoring plots had been noted in previous years with no new species additions in 2016.

3.1.6 Tree Inventory

Following the 2014 monitoring the scope of tree inventory work was reduced to collect only canopy cover data. Data pertaining to tree health is not conducive to quantitative analysis and DBH measurements were determined to be of little value for comparison from one year to the next and this activity was thus discontinued.

In 2016 the canopy cover at Plot 8 was 70%. This value has increased slightly since the removal of vegetation to the south of the plot for the construction of the watercourse crossing. At this point the restoration plantings have yet to contribute to enhancing the canopy within the plot and minor increases are likely the result of existing tree canopies filling in. It is noted that tree and shrub plantings to the south of the plot were observed to be in good health in 2016. These plantings will ultimately help to regulate water temperatures within Hanlon Creek through restoring shade to this section of the watercourse. No tree species are present within Plots 1, 6 and 9. An assessment of tree canopy change is outlined in further detail in Section 3.2.3.

Signs of Emerald Ash Borer (*Agrilus planipennis*) (EAB) were observed within Plot 2 and Plot 18 in 2015 and the Ash in these plots continues to decline. EAB was likely present within the larger natural feature at least several years prior but had not yet affected any of the trees within the plots. A loss of canopy cover due to Ash decline is likely to make for a temporary increase in herbaceous species both in numbers and in vigour. In time the canopies of existing trees including White Cedar, Red Maple (*Acer rubrum*) and Yellow Birch (*Betula alleghaniensis*) will fill in those areas where Ash was once present. Additionally, Ash saplings and young trees will continue to establish but are likely to succumb to EAB as they reach maturity. Canopy openings will also spur the growth of shrub and tree saplings which may include Glossy Buckthorn and Common Buckthorn.

3.2 Vegetation Threshold Assessment

The thresholds for vegetation and soils established in the *HCBP Consolidated Monitoring Program* (NRSI 2010) are as follows:

- A change in herbaceous cover by more than 25%.
- A change in species diversity by more than 25%.
- A change in canopy cover by more than 25%.

3.2.1 Herbaceous Cover

The average herbaceous cover per year and plot is shown on Figure 5. The herbaceous cover fluctuates annually, with large fluctuations observed even in the pre-construction monitoring years (2006 - 2009). Herbaceous cover by plot in 2016 was generally consistent with the overall average among monitoring years.

In 2016, Plot 1 showed a decrease to 53.1%, down from 87.6% on 2015. As shown on Figure 5, the percentage cover within this plot varies greatly from one year to the next. Discussion of CW and CC values earlier in Section 3.1.2 noted that seasonal standing water may influence the herbaceous vegetation within the plot. Years of prolonged inundation may lead to a reduction in cover whereas years with less extensive flooding would allow for a greater amount of herbaceous growth within the plot. Additionally, the location of the plot adjacent to mixed meadow habitat may allow for some colonization of meadow species into the edge of the plot. The fluctuations observed within this plot are considered to be a result of varying amounts of snowmelt and seasonal precipitation which dictate to what degree the plot is inundated each year. As indicated on Figure 6, the 2016 data falls within the threshold and the annual fluctuations in data are not a concern at this time.

Herbaceous cover spiked in Plot 2 in 2014 at 77.8% and has decreased gradually over the past to 2 years to 33% in 2016. Between 2006 and 2013, herbaceous cover remained low and had varied from 11.4% to 23.6%. This plot is situated within an organic swamp which contains a number of White Cedar (*Thuja occidentalis*) and Black Ash (*Fraxinus nigra*). It would appear that the White Cedar trees are prone to periodic blowdown events which result in the creation of canopy openings. Over the past several years, 2 tagged White cedar trees have blown over, becoming uprooted and dying. Similarly, EAB has resulted in the decline of 3 Ash within Plot 2 (and others adjacent) leading to a reduction in canopy. In time the canopies of adjacent standing trees fill in and available sunlight decreases. During periods where sunlight is increased, herbaceous vegetation shows a positive response and will grow vigorously for a period dependent upon the extent of canopy opening. It is inferred that the changes in canopy within Plot 2, which are discussed in Section 3.2.3, are responsible for the changes in herbaceous cover. Within Plot 2, Spotted Jewelweed (*Impatiens capensis*) and Marsh Marigold (*Caltha palustris*) comprise much of the herbaceous cover within the plot, potentially due to favourable soil moisture and sunlight levels for these species. The plot remains well above the pre-construction average which is interpreted as a positive trend.

In 2016, Plot 3 remained consistent with 2015 herbaceous cover values increasing only slightly to 28.6% from 28.2%. There had been a drastic reduction in the presence of Ostrich Fern (*Matteuccia struthiopteris*) between 2011 to 2014, potentially the result of browse by White-tailed Deer (*Odocoileus virginianus*) or varying climatic conditions, in particular seasonal precipitation and soil moisture. Data collected in the last 2 years has shown a rebound in herbaceous cover, which although still below the pre-construction average threshold, appears to be improving. In 2016 Ostrich Fern was present in all 5 sub-plots ranging from 10% coverage to as high as 50% within the 1m x 1m plot. The increase in native herbaceous cover within the plot is a positive trend which will continue to be analyzed in coming monitoring years.

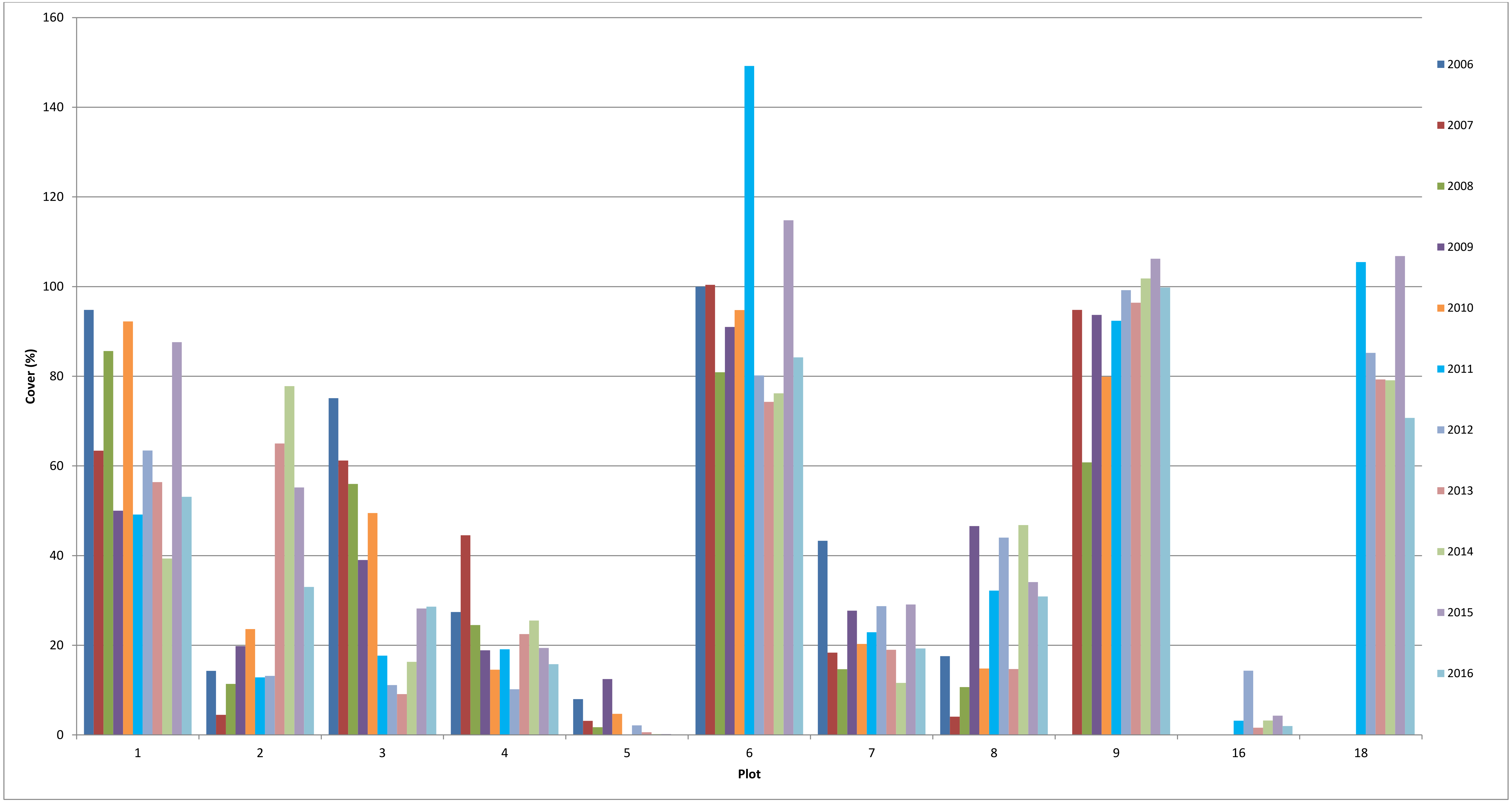

Figure 5. Change in Herbaceous Cover from 2006 to 2016

Figure 6 represents the change in herbaceous cover from 2010 to 2016 in comparison to the preconstruction year average (2006 - 2009). A range bar on the preconstruction average column on Figure 6 shows an increase and decrease of 25% herbaceous cover. An increase in herbaceous cover is generally ecologically positive, as it means greater plant matter for foraging and refuge for wildlife, as well as a generally well-being of the plant species. An increase can be negative if the increase is due to an introduction or expansion of a non-native and/or invasive species. A decrease in herbaceous cover is generally negative as it means removal of soil protection, forage and refuge material, as well as a potential decrease in biodiversity. A decrease in herbaceous cover can be due to direct vegetation removal, annual fluctuation in climatic conditions, trampling, erosion, flooding, or the effects of sun (sun scald) or salt, among other reasons.

Variation in the percentage cover of any given species may also vary from year-to-year as a result of observer bias. By employing standard plot sampling methodology a relatively accurate value can be obtained for the percentage cover of a species; however variability in the perception of coverage is inevitable. By having vegetation surveys completed by the same NRSI biologists from year to year (where possible), bias in the perception of cover has been minimized.

In 2016, the 25% threshold was exceeded in Plot 3. Although herbaceous cover in Plot 3 was observed to be slightly below the 25% threshold, as discussed above the herbaceous cover within the plot is showing a rebounding trend whereby cover has doubled since 2014 and tripled since 2013 (when the cover was at its lowest to date). Data for this plot suggests that herbaceous cover is returning to pre-construction conditions. The fluctuations in this plot have been attributed to periodic browse and the availability of soil moisture and the bearing that this factor can have on plant vigour and representation during plot monitoring.

Given the proportion of vegetation monitoring plots located within wetland habitats on site (9 of 11 plots); any fluctuation in seasonal water levels will influence changes in vegetation composition within the plots.

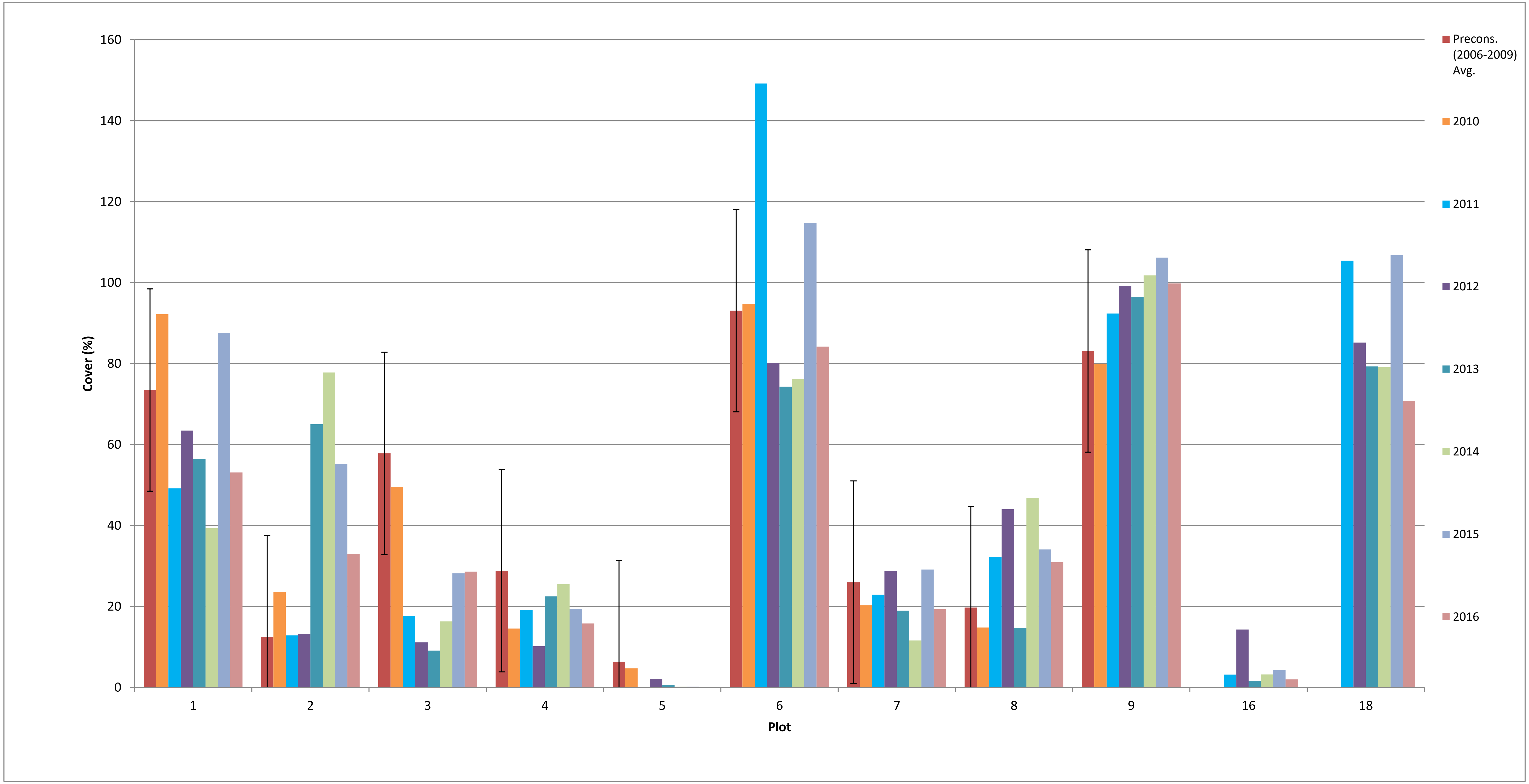

Figure 6. Change in Herbaceous Cover from 2010 to 2016 Compared to Preconstruction Average

(The range bar shows a 25% increase and decrease in herbaceous cover)

3.2.2 Vegetation Species Diversity

Species diversity is the number of species observed within each monitoring plot. Figure 7 compares vegetation species diversity per plot for each year since 2006. All species recorded in each plot are included in this data, which includes herbaceous species recorded within the overall 10m x 10m plot. In 2016, Plot 4 had the highest diversity at 32 species. This plot contains hummocky White Cedar swamp with both areas of saturated organic muck which provide habitat for a high diversity of wetland species.

In Plot 16, species diversity increased from 16 species in 2015 to 21 in 2016. Diversity in Plot 18 dropped slightly from 31 species in 2015 to 24 in 2016. Both of these plots have been monitored with particular attention following several years of decreases in diversity, average CW values and average CC values. At this time both plots exhibit values which do not deviate substantially from figures collected in the previous monitoring years (since 2011).

Plot 6 has shown a clear decrease in vegetation diversity with 21 species present in both 2015 and 2016 yet 43 species were present in 2013 and 31 in 2014. It is noted that the 2014 and 2015 values reflect pre-construction monitoring values. Given the presence of old field habitat, the eventual dominance of a select few species (Coltsfoot, Canada Goldenrod and Panicled Aster), is to be expected. Data collected from previous monitoring years indicates that many of the documented species within the plot have been present in very small numbers. Given the agricultural past within the plot, and considering the proportion of non-native species and successional changes occurring, the decrease in diversity within this plot is not concerning at this time.

Overall, species diversity in 2016 is representative of the 11 year average with some minor increases and decreases within various plots. Variation in species diversity can likely be attributed to a number of factors including changes in canopy cover or soil moisture which may encourage or discourage sensitive species. Additionally, the current approach of taking a compass bearing of 0°, 45° and 90° to determine corner locations based on the permanent t-bar stake may lead to the inclusion and exclusion of certain species located at the fringe of each plot.

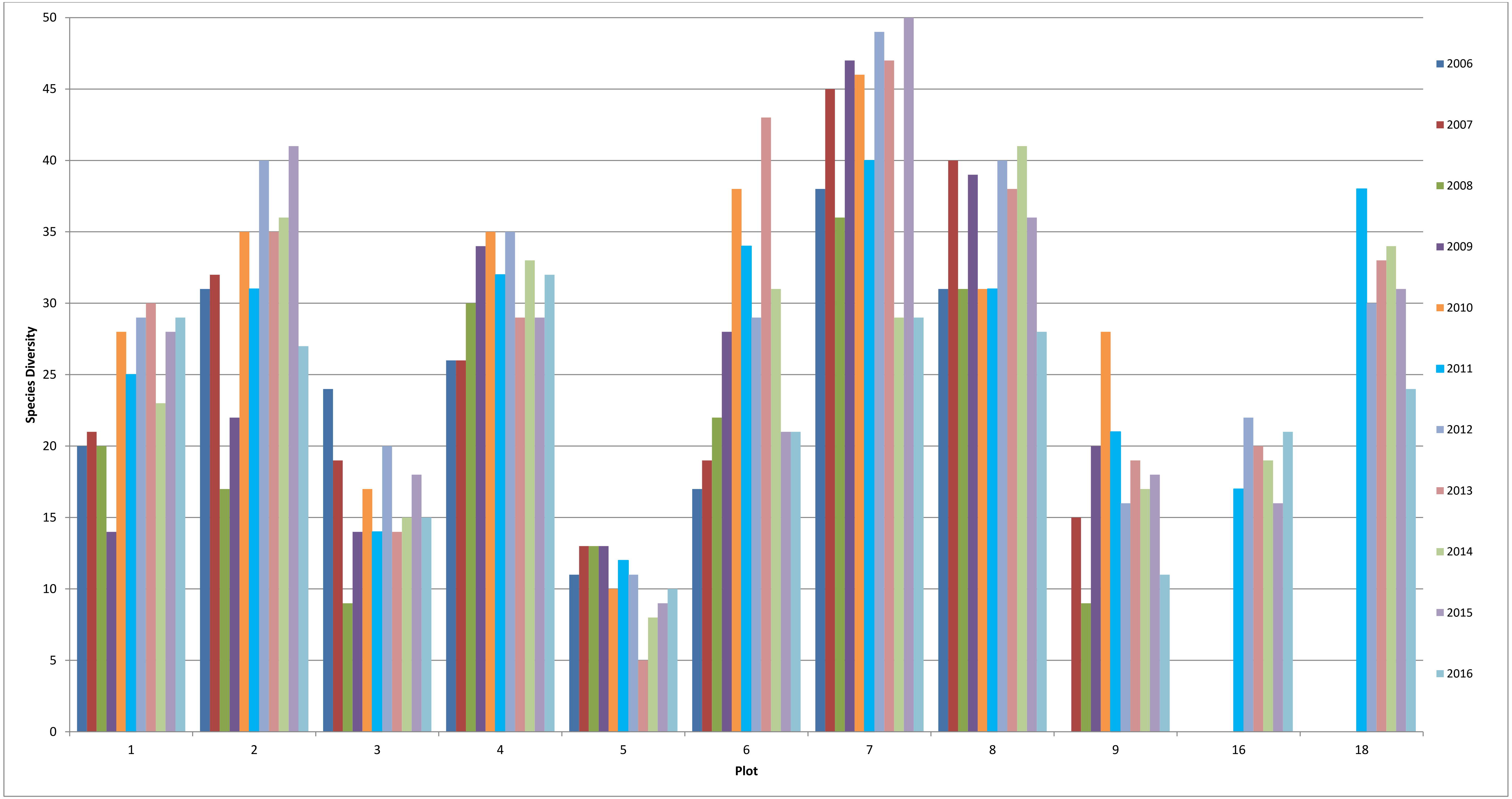

Figure 7. Change in Vegetation Diversity from 2006 to 2016

Figure 8 shows the vegetation diversity during the construction period (2010 to 2016) compared to the pre-construction average (2006 – 2009). Plot 1 exceeded the pre-construction average positively with 29 species in 2016 (18.8 pre-construction average). Plots 7 was the only plot below the pre-construction average with 29 species in 2016 (42 pre-construction average).

Overall, the 2016 monitoring data supports that species diversity is being maintained with some degree of annual fluctuation. with no notable concerns relating to decreases in species diversity. An increase in species diversity is generally associated with a benefit to the natural environment, unless the increase is due to an introduction of a non-native, invasive species. Abundance data for non-native, invasive species does not indicate any notable increases in any one species over the course of the 11 year monitoring period. As indicated on Figure 4, the number of non-native species has generally remained steady from 2006 to 2016, often with the addition or removal of a single species from 1 year to the next. Monitoring will continue to document the presence of non-native, invasive species and will specifically assess their abundance within the plots.

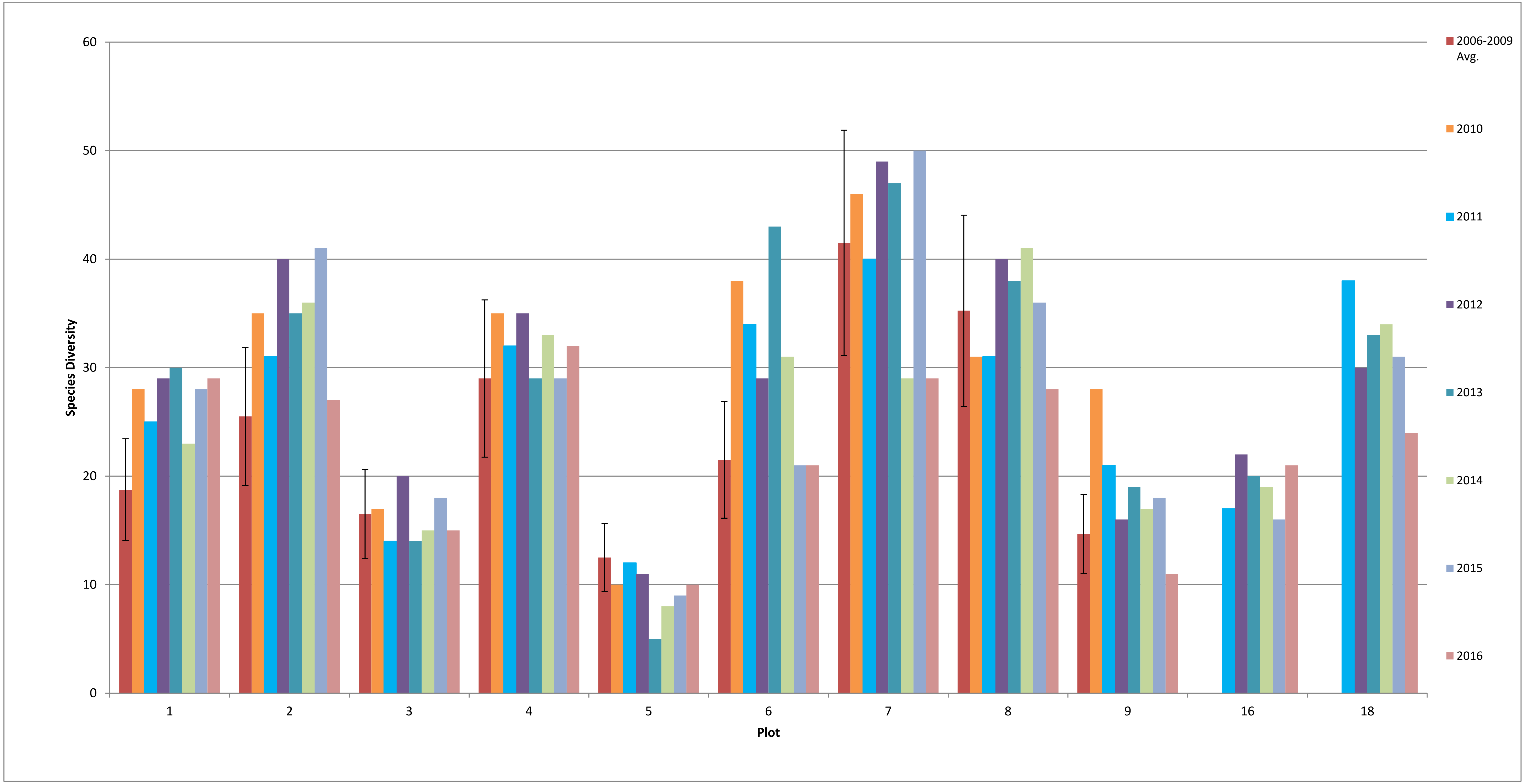

Figure 8. Change in Vegetation Diversity During 2010 to 2016 Compared to Preconstruction Average

(The preconstruction average column shows a 25% range bar)

3.2.3 Canopy Cover

The canopy cover per plot is shown on Figure 9. Plots 1, 6, and 9 have no trees and therefore canopy cover is 0%. The canopy cover in most plots has remained relatively similar over the 11 years of monitoring, with Plot 8 recovering from tree removal to the south of the plot in 2010 in preparation for the installation of the Hanlon Creek Boulevard (Road A) culvert. Plot 8 is bisected by Tributary A, with tree cover limited to the western, eastern and northern extent of the plot. Trees and shrubs were installed in the riparian area to the south of the plot in fall 2010, as detailed in the HCBP EIR Restoration Plans. It is anticipated that in time these plantings, coupled with natural succession, will begin to increase canopy cover of the plot and facilitate a return to pre-2010 conditions. The presence of EAB is also likely responsible for some of the slight changes observed in canopy cover for plots which contain Ash trees.

Figure 10 compares the canopy cover during the construction period (2010 to 2016) to the pre-construction average (2006 – 2009). A range bar shows a 25% increase and decrease from the average in canopy cover for each plot on the pre-construction column. All plots are within the threshold range including Plot 8 which showed a rebound in canopy cover to within the threshold range. Given the presence of a watercourse which bisects the plot, a percentage of open tree canopy is to be expected. The increase in canopy appears to be the result of the canopies of existing trees filling in; restoration plantings have not yet established to the point of providing canopy to the plot.

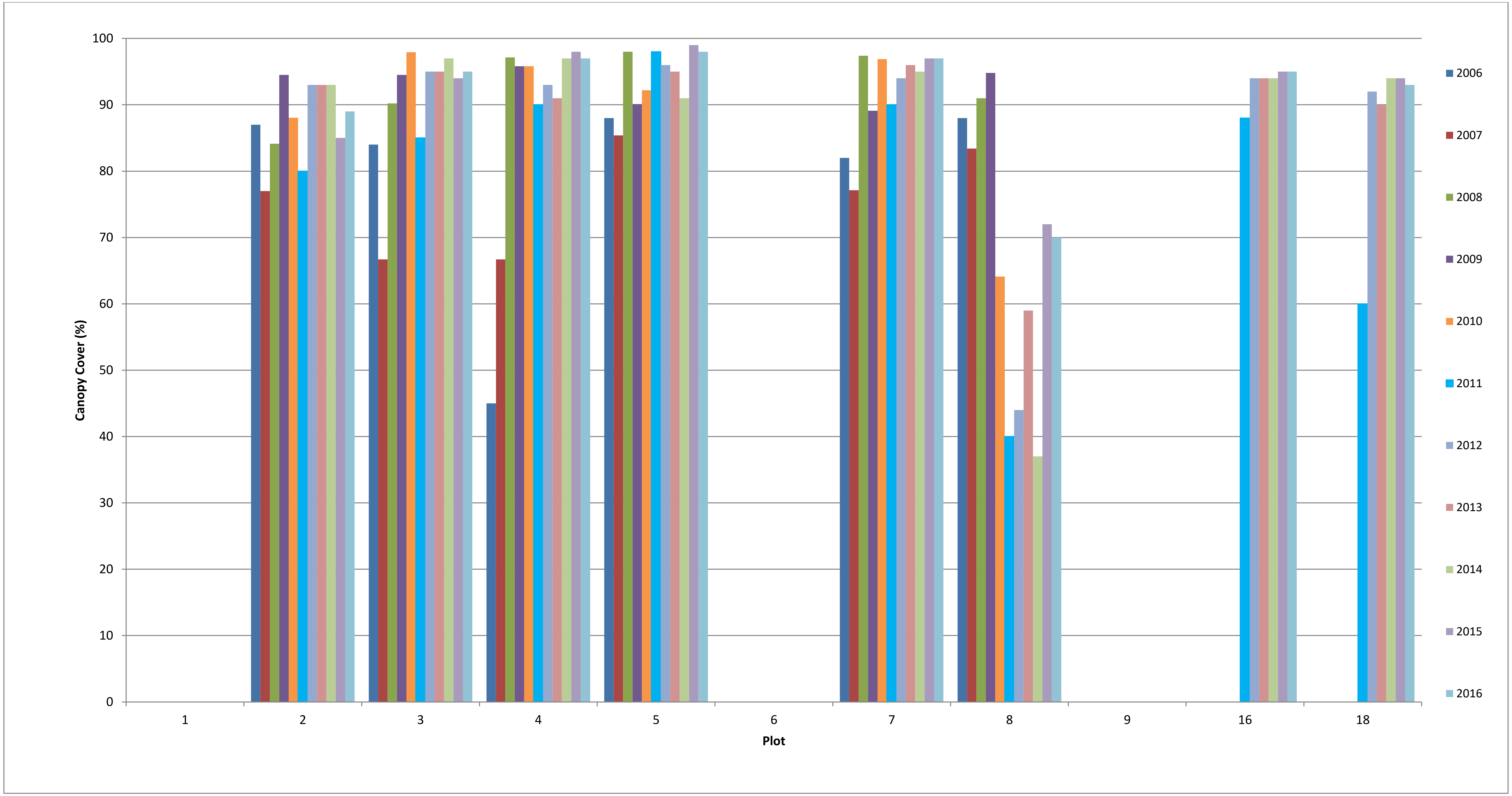

Figure 9. Change in Canopy Cover from 2006 to 2016

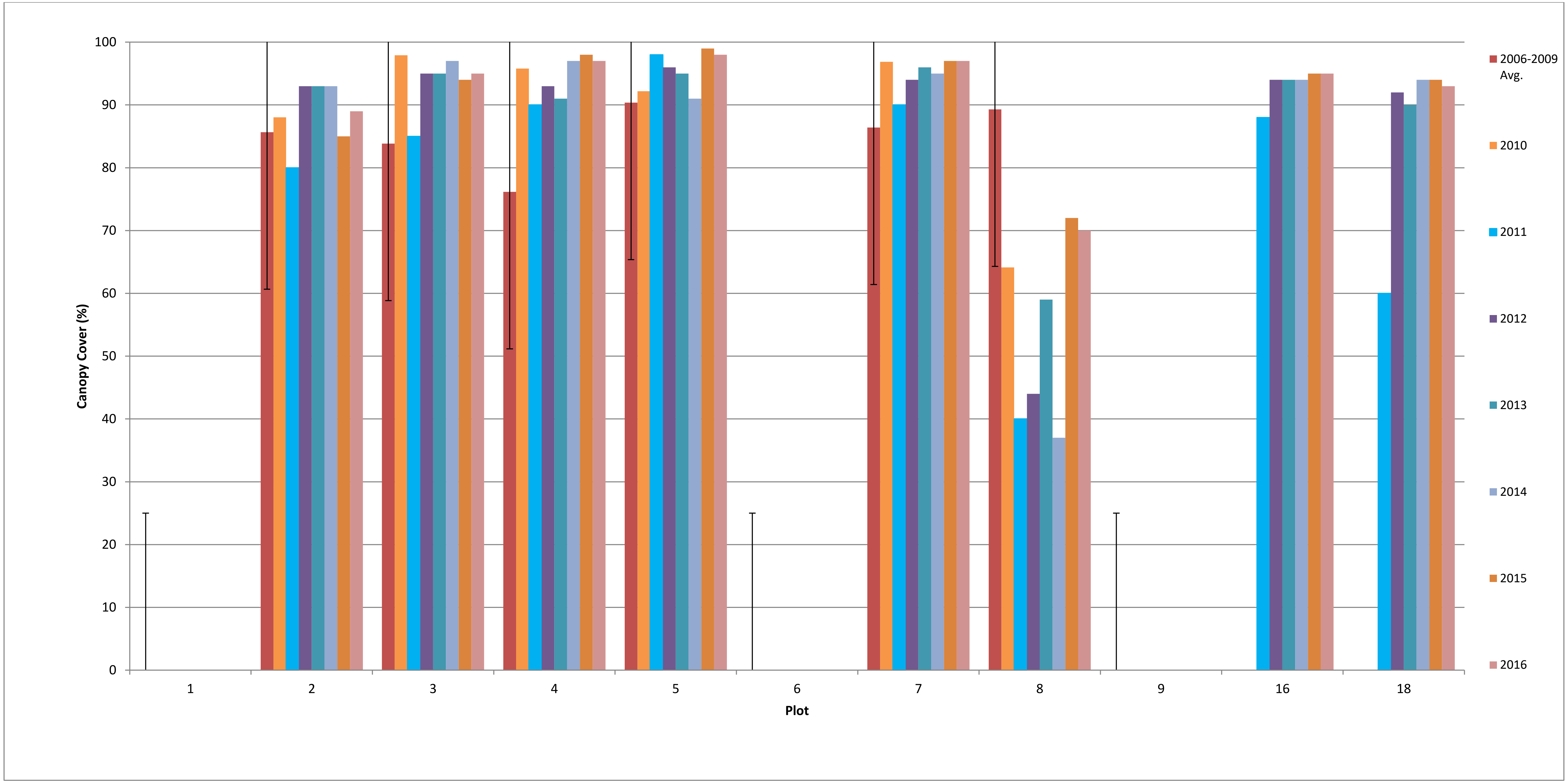

Figure 10. Change in Canopy Cover During 2010 to 2016 Compared to Preconstruction Average

(The range bar shows a 25% increase and decrease in canopy cover)

3.2.4 Vegetation Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 37) suggests the following measures when there is a change in vegetation or a shift in species composition beyond the established threshold:

- *"Initiate restoration efforts to enhance number of native wetland/woodland species.*
- *Provide educational material to neighbouring properties outlining importance of natural features and their protection.*
- *Provide additional signage regarding trail closures, etc.*
- *Refer to Section 6.1 Groundwater for the contingency measures associated with groundwater thresholds."*

Overall, the 2016 data set presents only 2 negative threshold exceedances; herbaceous cover in Plot 3 and species diversity in Plot 7. Both are minor exceedances which are at least in part due to natural fluctuation in the presence of plants within these plots. It is not recommended that any of the above-mentioned contingency measures be carried out at this time. As explained in further detail below, a variety of causes are likely responsible for these threshold exceedances; however potentially major or irreversible changes are not being observed. Continued monitoring is recommended to ensure that vegetation communities remain intact and diverse.

Between 2011-2015 Plot 16 and 18 showed a trend of increasing average CW values (i.e. an indication of drier conditions), coupled with reductions in wetland vegetation cover. These plots are located in close proximity to recent development (Block 9 and Block 10) and Hanlon Creek Boulevard. Review of groundwater monitoring data indicates that climate has been the driving factor behind groundwater elevations, both in the short-term and long-term across the HCBP (Banks Groundwater Engineering 2017). Generally, groundwater elevation data indicates that the wetland plots are situated at elevations above the groundwater table and thus the wetlands are largely dependent upon surface water flows to maintain their hydrology. To some extent the capillary action of the soils may also contribute groundwater to the wetlands.

Discussions among the project team have identified that altered surface water contributions to the wetlands may be responsible, in part, for some of the observed trends in lowered CW values and shorter hydro-periods. The stormwater management plan that was developed by AECOM for the Business Park was based on the premise that the wetland features were primarily fed by groundwater up-welling (previous hydrogeological investigations). Thus, the approved SWM approach included reducing the drainage areas to these wetlands to prevent untreated stormwater runoff from entering them from adjacent lands. Untreated stormwater runoff is directed to the stormwater swales, which then ultimately drain into the stormwater management ponds.

It is recommended that monitoring of vegetation and groundwater continue at these plots in order to better understand the influence that groundwater may have on the wetlands. During anuran survey visits a description of standing water (area and approximate depth) will be provided for each station to help characterize the spring hydro-period at these locations.

The aggressive invasive species Common Reed was identified east of Plot 6 and at the fringe of SWM Pond 4 in 2016. It is recommended that these stands be eradicated and periodic monitoring for reoccurrence considered. Having been detected early in their establishment, it is most practical and cost effective to manage these stands at this time.

Herbaceous Cover

In 2016, herbaceous cover negatively exceeded the threshold in Plot 3. Although Plot 3 exceeded the lower reach of the threshold in 2015 for the sixth consecutive year, herbaceous cover values have shown a steady increase over the last several years with cover doubling since 2014. Fluctuations in this plot have been attributed to deer browse and soil moisture, with values driven largely by the percentage cover of a single species; Ostrich Fern. The herbaceous cover within the plot increased from 9.1% in 2013 to 28.6% in 2016. This increase of 19.5% shows improvement within the plot but is still well below the pre-construction average of 57.83%.

As noted in previous monitoring reports, plots which contain a proportion of Ash trees declining due to EAB have experienced increases in herbaceous cover. An example of this is found within Plot 2 where the decline of Black Ash and Green Ash trees within the plot has resulted in additional sunlight reaching the groundcover within the plot. Forbs, including Spotted Jewelweed and Marsh Marigold have responded positively with increases in overall cover. It is noted that the decrease in canopy may also lead to increased growth of non-native Glossy Buckthorn within the plot. Where a closed canopy will normally limit a proportion of Buckthorn plants to small saplings, the opening of a canopy can result in a flush of growth which could have negative impacts for herbaceous cover and diversity. Continued monitoring will identify this species should it establish within the plot.

Species Diversity

Species diversity negatively exceeded the pre-construction threshold in Plot 7 in 2016. This plot contained 29 species, 2 of which were non-native, whereas the pre-construction average for the plot was 42 species. Review of monitoring data from previous years indicates that many species observed consisted of one or several individual plants. As the plot is relatively intact (few non-native species and with a complex, natural microtopography) this decrease in species is not considered reason for concern. It is also likely that many of those species present in low numbers in past years remain present in the larger ELC community surrounding the plot. On-going monitoring will continue to document species diversity at this plot and provide further analysis of this trend.

Similar to previous monitoring years, non-native species were recorded in all plots in 2016, except Plot 5. Recommendations regarding management of the recently established stands of Common Reed are outlined in Section 4.0.

Canopy Cover

Plot 8 remains the only plot which has ever exceeded the canopy cover threshold. As reported in the 2011 HCBP Consolidated Monitoring Report (NRSI 2012a), canopy cover has been reduced in Plot 8, but the area of impact, adjacent to the plot has been restored through native plantings according to the HCBP EIR Restoration Plans. Since 2015 the canopy cover has returned to within the pre-construction threshold. As the plantings continue to mature and edge trees fill out, the canopy cover will increase and contribute to shading Tributary A that bisects the plot.

Although most of the canopy Ash trees within monitoring plots have already shown decline due to EAB, there is still potential for further reductions in Ash canopy and conversely, increases in the canopy of other species which will fill in as Ash trees die off. Plot 2 contains numerous Ash trees, most of which are declining; however as this is not related to the development no inter-planting is recommended. Additionally, it is not recommended that nursery grown stock be introduced into the core of the natural feature, rather a passive approach of natural regeneration is favourable.

3.3 Breeding Bird Surveys

A total of 55 species of birds were observed during the breeding bird monitoring that was conducted in 2016 (Appendix VI). Including those species which were noted outside of point counts or incidentally during other surveys, a total of 58 bird species were documented within the subject property in 2016 (Appendix VII). Table 5 summarizes the number of birds observed during breeding bird point count surveys under each breeding evidence code.

Table 5. Breeding Bird Evidence

Breeding Evidence	Number of Species										
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Possible	30	12	20	21	20	21	25	21	15	19	23
Probable	11	15	14	20	18	22	21	24	23	25	19
Confirmed	0	11	2	4	2	2	4	3	2	3	6
None*	0	8	4	0	5	2	1	2	2	3	4
TOTAL	**41**	**46**	**40**	**45**	**46**	**47**	**51**	**50**	**42**	**49**	**55**

*Species observed with no breeding evidence (i.e. flying overhead)

The most abundant species observed during 2016 surveys were American Goldfinch (*Spinus tristis*), and Red-winged Blackbird (*Agelaius phoeniceus*), comprising 13% and 11% of the observations during breeding bird point counts respectively. These were followed by Song Sparrow (*Melospiza melodia*) at 8%. These species are consistently the most abundant within the point counts largely due to the presence of suitable habitat and the large populations of these species within Southern Ontario. Figure 11 represents the 12 most abundant species observed in 2016, with all other birds observed less frequently compiled as ‘Other Bird Species’.

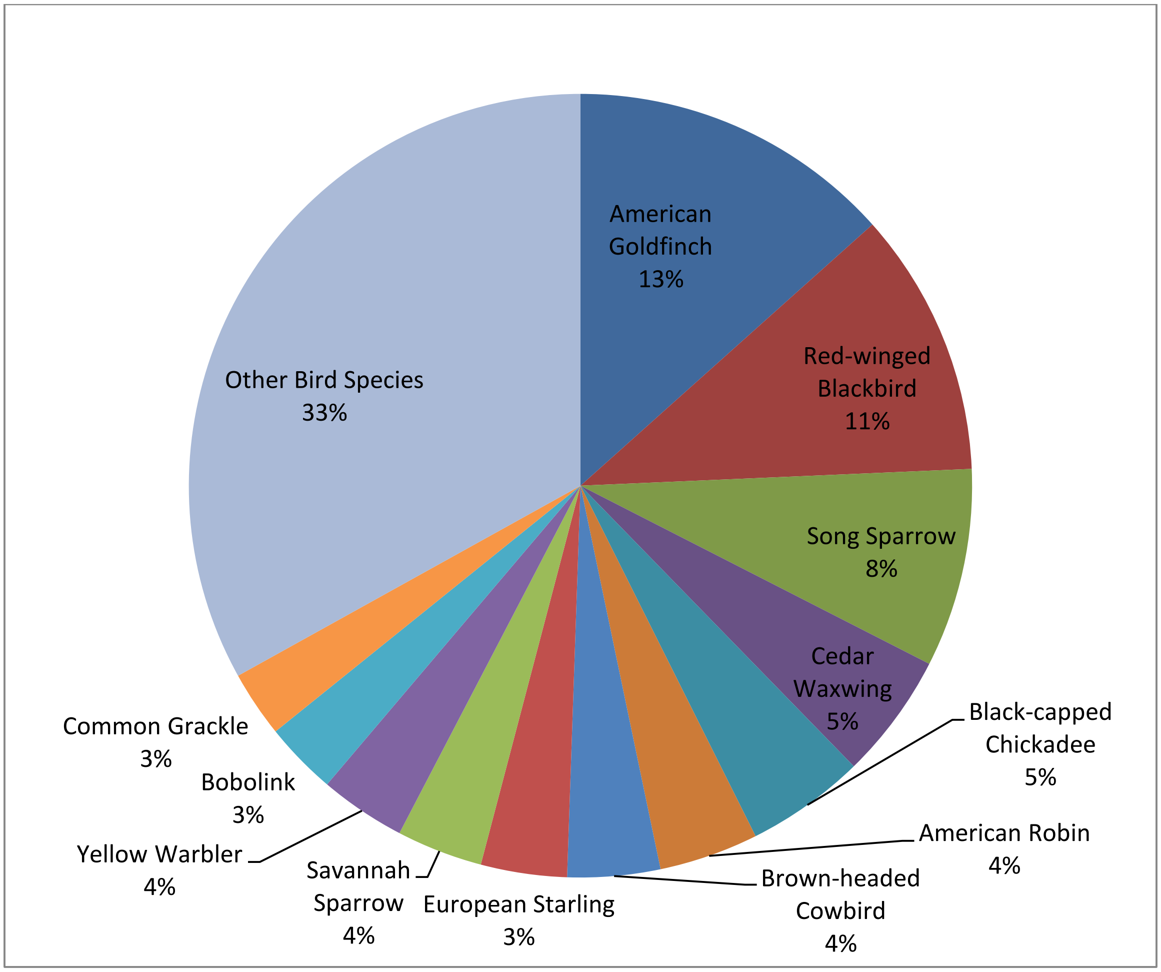

Figure 11. Most Abundant Bird Species Observed in 2016

3.3.1 Breeding Bird Species Diversity

Figure 12 graphs the species diversity of breeding birds at each plot since monitoring began in 2006.

The highest bird species diversity in 2016 was recorded at Plot 6 with 19 species while the lowest diversity was recorded at Plot 2 with 10 species. To date, the highest diversity was recorded at Plot 1 in 2013 with 23 species. In general, 2016 species diversity figures reflect the average for each respective plot. Certain plots show minor deviation, with Plot 1 diversity notably lower than the past several years and Plot 5 recording 15 species which is the highest value recorded in that plot to date and higher than most previous years by a sizable margin.

As in years prior to 2015, grassland species including Eastern Meadowlark (*Sturnella magna*), Bobolink (*Dolichonyx oryzivorus*) and Savannah Sparrow (*Passerculus sandwichensis*) all utilize the fallow field habitat present within Phase 3 (Plot 19 and Plot 20) for foraging and nesting. No construction has occurred in this area to date. Bird species diversity has decreased within these plots over the last several years which may simply be a result of point-in-time observations of species during the breeding bird surveys. Previous years had recorded species including Black-capped Chickadee (*Poecile atricapillus*), American Crow (*Corvus brachyrhynchos*), Blue Jay (*Cyanocitta cristata*), Ring-billed Gull (*Larus delawarensis*) and Downy Woodpecker (*Picoides pubescens*), none of which would typically utilize the open country habitat for breeding. Despite the reduction in diversity recorded within these plots, the maintained presence of grassland birds from one year to the next supports that the plot continues to provide functional habitat for those species which would require grassland for foraging and breeding.

In 2016, Great Horned Owl (*Bubo virginianus*) was recorded within the subject property for the first time at Plot 19. This species utilizes a wide variety of habitats including deciduous, mixed, or conifer forests, but prefers open and secondary-growth temperate woodlands, swamps, orchards, and agricultural areas (Artuso et al. 2013). The conifer-dominated swamps and open meadow habitats (including SWM areas) within the Hanlon Creek Business Park provide suitable foraging and breeding habitat for this species.

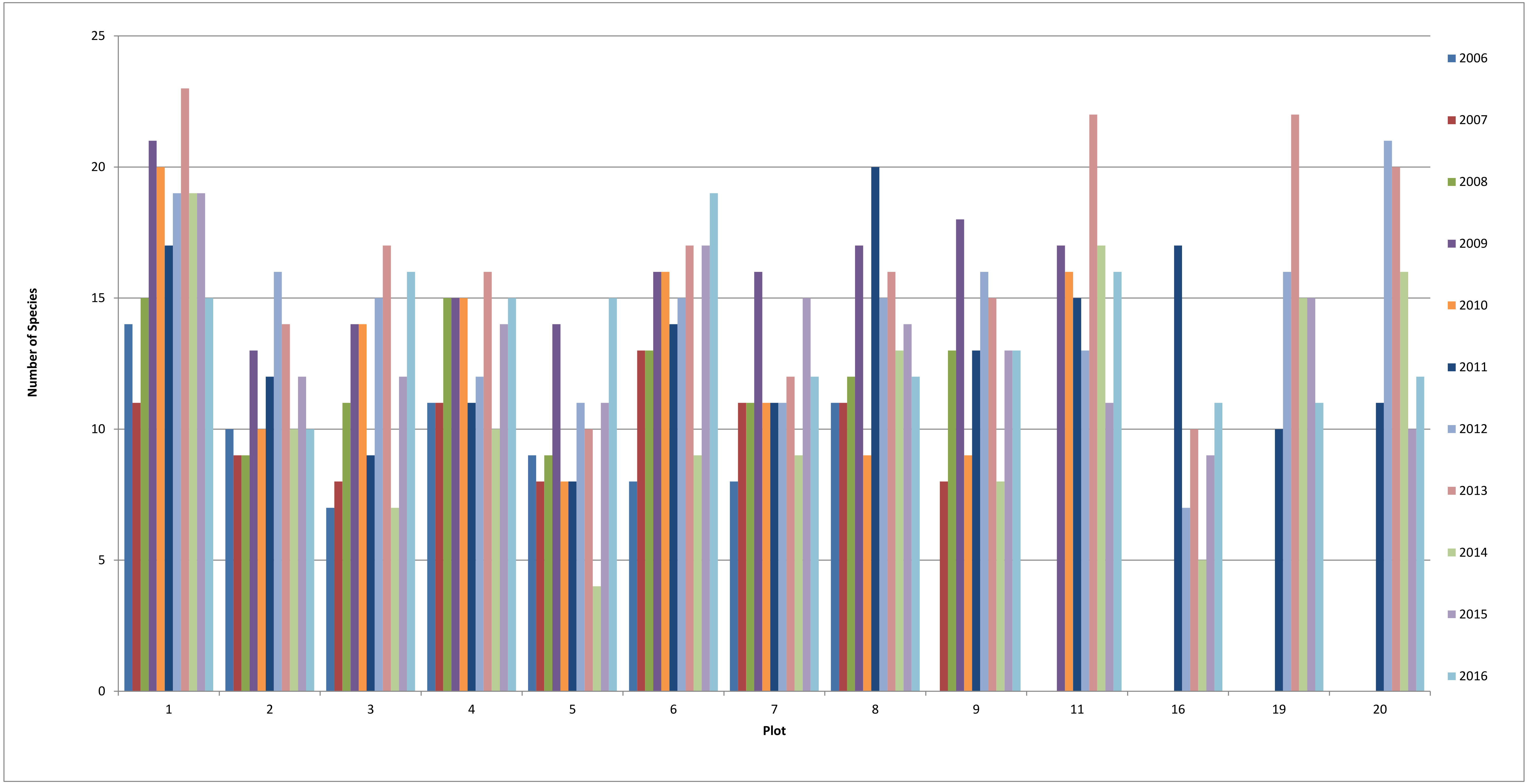

Figure 12. Breeding Bird Species Diversity 2006 – 2016

3.3.2 Breeding Bird Abundance

The breeding bird abundance (the number of individual birds) since 2006 is shown on Figure 13. In general the 2016 abundance reflects the overall average since monitoring began in 2006. Abundance data recorded during 2016 breeding bird surveys indicates that Plot 1, 6 and 9 all continue to have the highest bird abundance annually. All 3 plots are situated within or adjacent to open country which allows for good sight lines of nearby features. Bird abundance for a given breeding bird survey in 2016 ranged from 7 individuals (Plot 6, 7 and 8 on June 3) to as many as 32 individuals (Plot 6 on June 21).

Those species which have tended to comprise much of the abundance value for each plot, including American Goldfinch, Red-winged Blackbird, Song Sparrow, Cedar Waxwing (*Bombycilla cedrorum*), Black-capped Chickadee and American Robin (*Turdus migratorius*), continue to be most abundant across the site. Spikes in bird abundance have been observed in past monitoring years due to large flocks of a single species which have included Red-winged Blackbirds in Plot 6 in 2006 and Canada Goose (*Branta canadensis*) in Plot 9 in 2007.

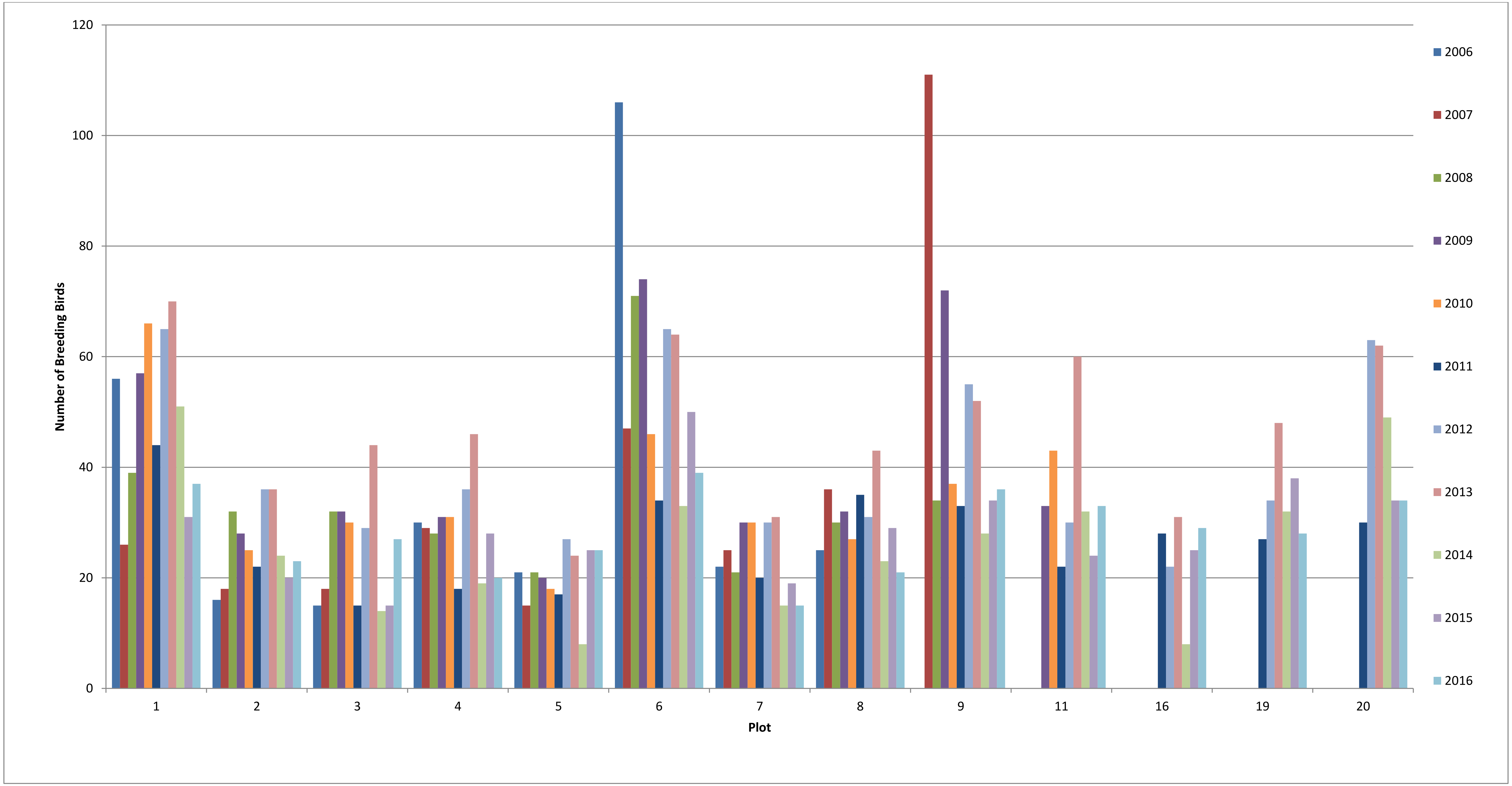

Figure 13. Breeding Bird Abundance 2006 - 2016

3.3.3 Significant Bird Species

In 2016, NRSI observed 4 species that are considered Threatened federally and provincially (COSEWIC 2016, MNRF 2016b): Bobolink, Eastern Meadowlark, Barn Swallow (*Hirundo rustica*), and Bank Swallow (*Riparia riparia*). Additionally, Eastern Wood-pewee (*Contopus virens*), a species listed as Special Concern federally and provincially (COSEWIC 2016, MNRF 2016b) was documented during 2016 breeding bird surveys.

Bobolink and Eastern Meadowlark share a similar habitat requirement and both were recorded at (or adjacent to) Plot 9, 11 and 20. Additionally a single Eastern Meadowlark was observed at Plot 1 in 2016. Bobolink showed probable breeding evidence at Plot 20 with as many as 6 individuals observed on the June 3 survey. Eastern Meadowlark showed possible breeding evidence with as many as 2 individuals observed on the June 21 survey. Bobolink requires large, open expansive grasslands (>50ha) with dense ground cover; hayfields, meadows or fallow fields; marshes (OMNR 2000). This species has been observed each monitoring year with probable breeding evidence documented in 2010 and 2012 through 2016. Eastern Meadowlark requires grassy meadows, farmland, pastures or hayfields at least 10ha in size (OMNR 2000). Suitable habitat is found within the southwest portion of the subject property (Phase 3) as well as within the retained open meadow habitat associated with Plot 19 (Map 3).

Barn Swallow was observed only as an incidental species during the 2016 breeding bird surveys. Individuals were observed adjacent to Plot 3 and 11 showing possible breeding evidence. Barn Swallows are found in farmlands and rural areas, and generally use buildings (such as barns) or other man-made structures for nesting. They are often found foraging in open country near water (Brown and Bomberger-Brown 1999, OMNR 2000). Suitable nesting habitat for this species is present at the Crawley farmhouse within Phase 3 and birds may also now be utilizing business park structures to nest. Birds may also be nesting outside of the subject property in barns along Forestell Road or Downey Road and utilizing the subject property as nearby foraging habitat.

A single Bank Swallow was observed at Plot 6 during the June 21 survey. This species nests within eroding banks of streams and rivers and forages within open and water-associated habitats (Garrison 1999). Although topsoil piles associated had been present in 2015, this potentially suitable habitat was no longer present in 2016. The SWM ponds may present may provide suitable foraging habitat for this species.

A single Eastern Wood-pewee was documented showing possible breeding evidence at each Plot 2 and 3 during the 2016 surveys. Incidental observations of this species were also documented at Plot 6 and 20, beyond the point count radius and within adjacent woodlots. Eastern Wood-pewee prefers open forest (deciduous, coniferous or mixed) often predominated by oak with little understory or forest clearings, edges, farm woodlots or parks (OMNR 2000). The open understory habitat present at Plot 3 provides ideal habitat for this species which may also utilize other treed and edge habitats throughout the subject property.

A total of 19 bird species were observed which are considered significant within the City of Guelph (Dougan & Associates 2009). Of these 19 species, 2 showed confirmed breeding evidence; Red-bellied Woodpecker (*Melanerpes carolinus*) (Plot 3) and Eastern Kingbird (*Tyrannus tyrannus*) (Plot 20). A total of 4 species showed probable breeding evidence, including American Redstart (*Setophaga ruticilla*) (Plot 11), Savannah Sparrow (Plot 19), and Willow Flycatcher (*Empidonax traillii*) (Plot 9). Additionally, 12 species showed possible breeding evidence and 4 did not show any breeding evidence (i.e. flying over habitat). Turkey Vulture (*Cathartes aura*), Bobolink, and Eastern Meadowlark are considered significant in Wellington County.

Table 6 lists the nationally, provincially, and locally significant bird species that were observed by NRSI in 2016.

Table 6. Significant Bird Species Observed in 2016

Common Name	Scientific Name	SRANK[1]	SARO[2]	COSEWIC[3]	Wellington County[4]	City of Guelph[4]	NRSI Observed
Cooper's Hawk	*Accipiter cooperii*	S4	NAR	NAR	√*	X	PO
Grasshopper Sparrow	*Ammodramus savannarum*	S4B	SC	SC	√	X	PO
Great Blue Heron	*Ardea herodias*	S4B			**	X	(X)
Turkey Vulture	*Cathartes aura*	S5B			√		X
Northern Flicker	*Colaptes auratus*	S4B			√*	X	PO
Eastern Wood-Pewee	*Contopus virens*	S4B	SC	SC	√	X	PO
Bobolink	*Dolichonyx oryzivorus*	S4B	THR	T	√*		PR
Willow Flycatcher	*Empidonax traillii*	S5B			√	X	PR
Barn Swallow	*Hirundo rustica*	S4B	THR	T			X
Orchard Oriole	*Icterus spurius*	S4B			√	X	PO
Ring-billed Gull	*Larus delawarensis*	S5B, S4N			**	X	X
Belted Kingfisher	*Megaceryle alcyon*	S4B			√	X	X
Red-bellied Woodpecker	*Melanerpes carolinus*	S4			√	X	CO
Savannah Sparrow	*Passerculus sandwichensis*	S4B			√*	X	PR
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S4B			√*	X	PO
Hairy Woodpecker	*Picoides villosus*	S5			√*	X	(X)
Bank Swallow	*Riparia riparia*	S4B	THR	T	√*	X	PO
American Redstart	*Setophaga ruticilla*	S5B			√*	X	PR
Pine Warbler	*Setophaga pinus*	S5B			√*	X	PO
Red-breasted Nuthatch	*Sitta canadensis*	S5			√*	X	PO
Field Sparrow	*Spizella pusilla*	S4B			√*	X	PO
Eastern Meadowlark	*Sturnella magna*	S4B	THR	T	√*		PO

Common Name	Scientific Name	SRANK[1]	SARO[2]	COSEWIC[3]	Wellington County[4]	City of Guelph[4]	NRSI Observed
Winter Wren	*Troglodytes hiemalis*	S5B			√*	X	PO
Eastern Kingbird	*Tyrannus tyrannus*	S4B			√*	X	CO

[1]MNRF 2016a; [2]MNRF 2016b; [3]COSEWIC 2016; [4]Dougan and Associates 2009

Legend
SRANK
S4 Apparently Secure
S5 Secure
B Breeding Population
N Non-breeding Population
COSEWIC/SARO
T/THR Threatened
SC Special Concern
NAR Not at Risk
Local Status (Wellington)
√ Significant and rare
√* Significant but not rare
Breeding Evidence Codes
CO Confirmed
PO Possible
PR Probable
X No breeding evidence
() Incidental observation

3.4 Bird Threshold Assessment

3.4.1 Breeding Bird Species Diversity

The threshold for breeding birds established in the HCBP Consolidated Monitoring Program (NRSI 2010) is a change of 25% in species diversity (number of different species). A decrease in species diversity beyond the threshold is considered to represent a potential concern. An increase beyond the threshold is considered to be positive and does not warrant that any remedial action be taken. Figure 12 graphs the species diversity for breeding birds since monitoring began in 2006. Figure 14 compares the 2010 to 2016 breeding bird species diversity to the preconstruction (2006-2009) average species diversity.

3.4.2 Breeding Bird Abundance

The threshold for breeding birds established in the HCBP 2010 Consolidated Monitoring Report (NRSI 2010) is a change of 25% in breeding bird abundance (the number of individual birds). Figure 13 provided above graphs breeding bird abundance since 2006. Bird abundance in 2015 reflected average to low numbers in comparison with the pre-construction average as well as the 2010-2014 monitoring period. Figure 15 compares 2010 to 2016 during construction data with breeding bird abundance from the preconstruction years (2006 – 2009). The preconstruction average column shows the 25% range bar, indicating the threshold.

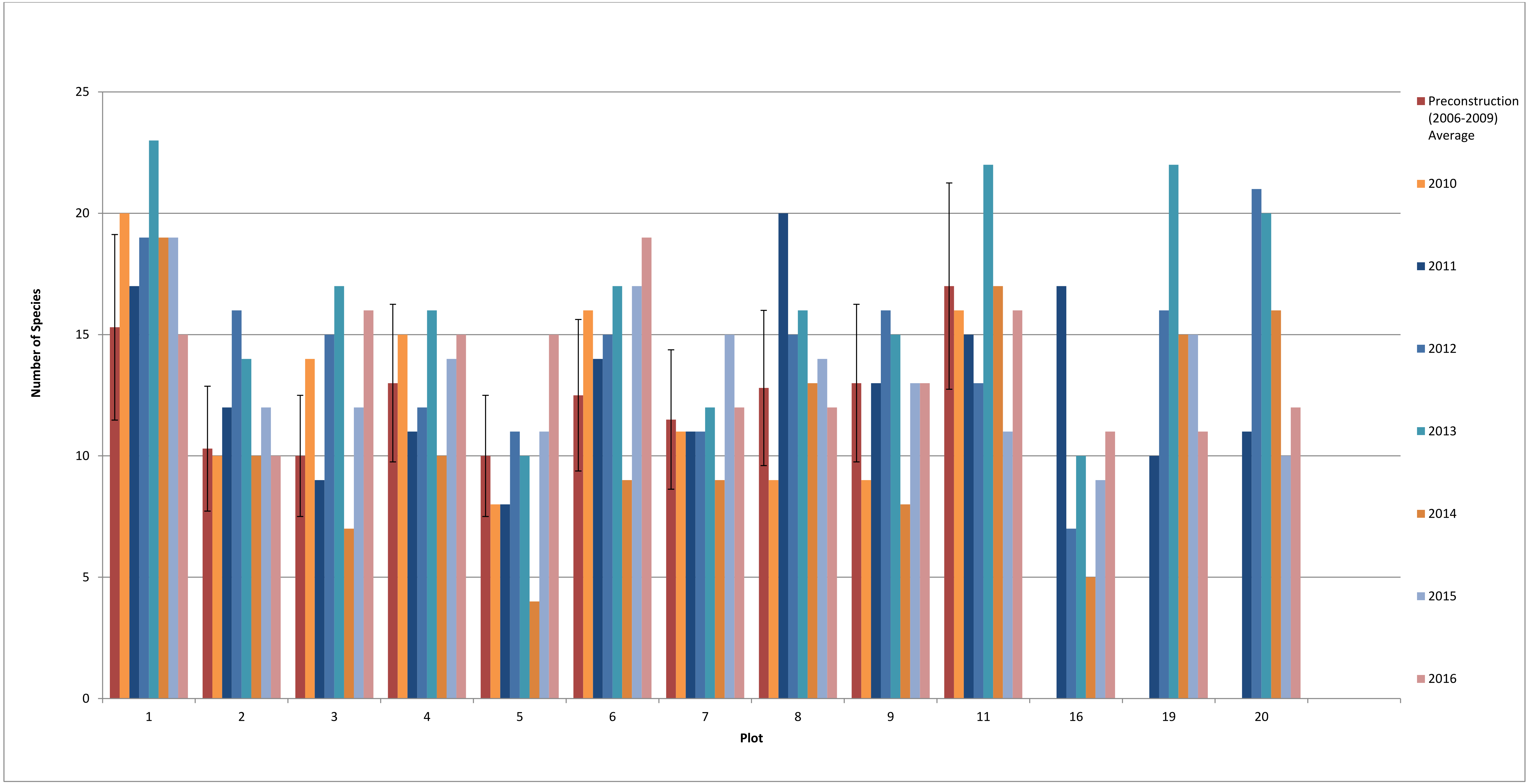

Figure 14. Breeding Bird Species Diversity During 2010 to 2016 Compared to Preconstruction Average

(The range bar shows a 25% change in the number of breeding bird species)

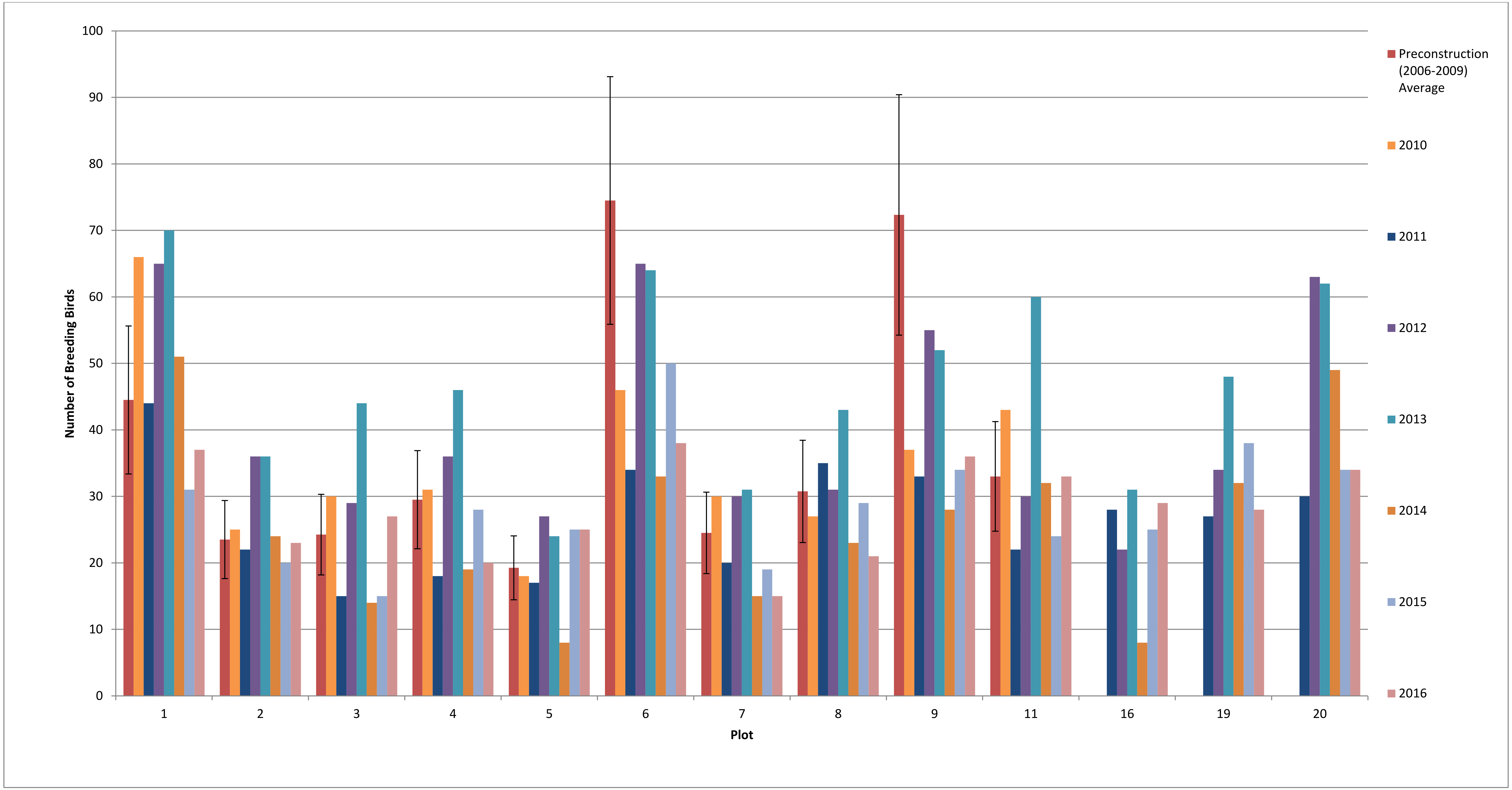

Figure 15. Breeding Bird Abundance 2006 - 2016

(The range bar shows a 25% change in the number of breeding birds)

3.4.3 Bird Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 39) suggests the following measures when bird species decline beyond the established threshold:

- *"Assess success of naturalization/restoration plantings. If plantings are not establishing, increase buffer/natural area plantings.*
- *Assess status of restoration plantings (e.g. if shrub and tree species are beginning to proliferate in open meadow areas, return naturalized area to intended habitat type).*
- *Increase buffer plantings or alter if necessary.*
- *Provide educational material to neighbouring properties outlining importance of natural features, wildlife and their protection.*
- *Provide additional signage regarding trail closures, etc."*

<u>Breeding Bird Species Diversity</u>

In 2016, bird species diversity was slightly above average in comparison with the preceding monitoring years. None of the plots exceeded the negative threshold for bird species diversity.

Plot 3, 5 and 6 positively exceeded the threshold by approximately 3 species during 2016 breeding bird surveys. This is a positive trend which may simply be the result of the incidental presence of a higher number of species. To some extent, the presence of fallow fields at the periphery of the main natural feature may contribute to slight increases in bird species diversity.

It is noted that Plots 19 and 20 continue to support significant species, including Bobolink and Eastern Meadowlark. Although no action is required at this time, trends within these plots should continue to be monitored. Both of these species are listed as Threatened provincially and federally (MNRF 2016a, Government of Canada 2017). Bobolink and Eastern Meadowlark and their habitat are protected under the Endangered Species Act, 2007. Future development within these habitats will need to consider provincial legislation and permitting requirements.

Breeding Bird Abundance

In 2016, breeding bird abundance was average to below average across most of the monitoring plots. The threshold for bird abundance was negatively exceeded in Plots 4, 6, 7, 8 and 9. In 2016, small flocks of certain species such as Red-winged Blackbird and European Starling were noted occasionally, but no exceptionally large flocks were observed and these figures are small in comparison to bird numbers documented in previous years. As discussed in previous monitoring reports, the threshold set within Plots 6 and 9 for pre-construction (2006-2009) both include very large numbers of Red-winged Blackbird or Canada Geese which inflated the threshold substantially. The negative exceedance observed at Plots 4, 7 and 8 was not major, for example, had an additional 3 birds been documented at Plot 4, the 2016 plot data would have fallen within the lower threshold limit.

Plot 16, a plot which has been subject to notable changes over the past few years had an average of 23 individuals between 2011 to 2015 with 2016 above average with 29 individuals recorded. In 2016 there was no active construction occurring adjacent to this plot which may be partially responsible for the increase in breeding birds.

Monitoring should continue to assess breeding bird abundance to determine if bird abundance is being maintained across the site and within the different vegetation communities.

3.5 Amphibian Surveys

3.5.1 Call Count Surveys

Five amphibian species were recorded during evening call count surveys in 2016; Spring Peeper (*Pseudacris crucifer crucifer*), Wood Frog (*Lithobates sylvatica*), Green Frog (*Rana clamitans melanota*), Gray Treefrog (*Hyla versicolor*) and American Toad (*Anaxyrus americanus*). Since 2006, the number of species recorded during the calling anuran surveys has fluctuated. The 5 anuran species recorded calling in 2016 is slightly above average (4.0) among species numbers recorded in previous years.

Amphibian species abundance recorded each year is shown in Table 7. These fluctuations may be correlated with changing weather conditions from year to year, such as spring precipitation and night-time air temperatures, which strongly influence amphibian breeding activity.

It should be noted that although 2006 surveys studied 6 amphibian monitoring stations, additional stations were added in subsequent years bringing the total number of stations monitored since 2011 to 16. Appendix VIII provides a list of amphibian species and their associated call count information observed by NRSI biologists during surveys from 2006 to 2016.

Table 7. Number of Calling Anuran Species Recorded During Call Count Surveys

Year	# of Species
2006	0
2007	5
2008	4
2009	6
2010	3
2011	4
2012	3
2013	4
2014	5
2015	5
2016	5

In order to compare species abundance over time and between stations, the maximum call code is used. The maximum call code is used to provide an estimate of abundance, as estimating numbers of individuals is not accurate. The three call codes as per the Marsh Monitoring Protocol (BSC 2008) are:

Call Level 1. Calls can be counted; not simultaneous
Call Level 2. Some simultaneous calls; yet distinguishable
Call Level 3. Calls not distinguishable; overlapping (i.e. “full chorus”)

By comparing the number of stations at which a species was observed, and the maximum call code over time, increases or decreases in species abundance can be determined (Tables 8 and 9). The following is a brief discussion of trends observed by species:

Spring Peeper

- consistently one of the most abundant calling anurans within the subject property, the species remained widely distributed and somewhat abundant in 2016,
- a full chorus (many individuals; too many to count accurately) recorded at Plots 15, 16, and 18,
- no individuals recorded at Plot 6, 9, 11 or 12 which have had Spring Peeper documented most years since monitoring began at the respective plots. In 2016 these plots did not contain standing water.
- a full chorus documented at Plot 18; this species was last recorded here (in full chorus) in 2011.

Green Frog

- an estimated 2 individuals noted calling at Plot 13 in 2016 (the first time this species has been recorded at this plot),
- this species has been documented sporadically between 2007 and 2016, always in low numbers and limited to 1 or 2 plots each year,
- since 2007, Green Frog has been documented within 9 of the 16 calling anuran plots.

Gray Treefrog

- was the most widely distributed species in 2016 at 8 of 16 stations,
- was one of the most abundant calling species in 2016 with an estimate of at least 24 individuals calling as well as 2 full chorus plots,
- in recent monitoring years, Plot 1 and Plot 16 have shown high numbers of Treefrogs calling. Plot 1 exists within Willow thicket swamp and is regularly subject to seasonal flooding. Plot 16 is located within an area of seasonal standing water surrounded by mature Silver Maples.

Wood Frog

- since 2006 this species has shown a pattern of higher numbers in one season followed by lower numbers (or none calling) in the next,
- with an estimated 3 individuals calling (and 1 full chorus), 2016 data reflects a year of lower Wood frog abundance,

- Over the course of calling anuran monitoring, Wood Frog have frequently been documented at Plot 1, 15 and 16. In 2016, the species was recorded at both Plot 1 and 15, but not at Plot 16.

American Toad

- a pair of American Toads were documented during calling anuran surveys at Plot 12 during 2016 surveys,
- a versatile species which will utilize SWM ponds and ditches containing water as breeding habitat, this species is likely to use many different areas of the business park.

Other Species

- no Leopard Frog (*Lithobates pipiens*), Pickerel Frog (Lithobates *palustris*) or Western Chorus Frog (*Pseudacris triseriata*) were documented in 2016, either during call counts or incidentally.
- each of these species have been recorded intermittently within the subject property in previous years, with a call code of 1 or 2 and in low numbers,
- Pickerel Frog and Western Chorus Frog have not been documented since 2012.

With regard to the plots:

- 11 of the 16 plots recorded calling anuran species in 2016,
- in 2016, Plots 1 and 15 recorded 3 species of anurans,
- no calling anurans were recorded in 2016 at Plots 4, 6, 7, 9 and 14. These plots often lack standing water and do not always provide ideal anuran breeding habitat.

Table 8. Maximum Call Code Recorded

Plot	American Toad											Gray Treefrog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1						1				2					1		1		2	3	2	3
2																				1	2	2
4			1				2															
6		1				1				1				3	1					1	2	
7																			2		2	
8																		1				2
9			3			1								1	1						2	
10										2											2	
11										3											2	1
12										2	2								1	1	2	1
13																			1			
14				1																		
15																2						2
16							2	1		2								2	2		2	3
17																				1		2
18							3												2	1		

Plot	Green Frog											Spring Peeper										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1													3	3	1	2	3		3	3	2	1
2														1		1						
4									1					3	1							
6			1	1									3	1	3	3	3		2		2	
7														1								
8							1											1				
9		1											2	1	1	1	1		2	3	3	
10																1						
11															1	2	1		1	1		
12				1											3	3	3		3	2		
13											2											
14										1										21		
15									1							1	3		1	2	2	3
16							2			1					3	1	3	2	3	1		3
17																				1		
18																	3					3

Plot	Leopard Frog											Pickerel Frog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1																						
2																						
4									1													
6																						
7																						
8							1											1				
9				1																		
10																						
11				1												1						
12				1																		
13																						
14																						
15																						
16							2											2				
17																						
18																						

Plot	Western Chorus Frog											Wood Frog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1													1		1		2		2	1		1
2																						
4																	1					
6		1															1		3		1	
7																						
8							1											1				
9													1		1		1				2	
10															1		1					1
11															1							
12															1		1		1			
13																						
14																						
15																			1	1	2	3
16							2										2	2	3		2	
17															1		1					1
18																	1					

Table 9. Number of Individual Anurans Recorded During Call Count Surveys

Plot	American Toad											Gray Treefrog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1						1				2					1		1		10	+	9	+
2																				3	3	6
4			1				2															
6		4				6				1				+	1					2	4	
7																			6		3	
8																		1				2
9			+			1								1	2						5	
10										5											8	
11										+											7	1
12										2	2								1	3	8	4
13																			1			
14				1																		
15																3						6
16							5	1		2								6	7		9	+
17																				2		5
18							+												2	1		
	0	4	1+	1	0	8	7+	1	0	12+	2	0	0	1+	4	3	1	7	27	11+	56	24+

Plot	Green Frog											Spring Peeper										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1													+	+	4	14	+		+	+	2	8
2														2		4						
4									2					+	2							
6			2	1									+	5	+	+	+		4		4	
7														1								
8							1											1				
9		1											12	3	11	1	6		5	+	+	
10																2						
11															1	6	8		1	1		
12				2											+	+	+		+	6		
13											2											
14										2										6		
15									5							3	+		1	4	4	+
16							6			2					+	3	+	6	+	1		+
17																				2		
18																	+					+
	0	1	2	3	0	0	7	0	7	2	2	0	12+	11+	18+	33+	14+	7	11+	20+	10+	8+

Plot	Leopard Frog											Pickerel Frog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1																						
2																						
4									1													
6																						
7																						
8							1											1				
9				1																		
10																						
11				1												1						
12				2																		
13																						
14																						
15																						
16							6											6				
17																						
18																						
	0	0	0	4	0	0	7	0	1	0	0	0	0	0	0	1	0	7	0	0	0	0

Plot	Western Chorus Frog											Wood Frog										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1													7		1		10		3	1		1
2																						
4																	1					
6		1															2		+		1	
7																						
8							1											1				
9													2		4		2				3	
10															2		1					
11															1							1
12															2		2		1			
13																						
14																						
15																			1	1	5	+
16							6										8	6	+		5	
17															2		5					1
18																	1					
	0	1	0	0	0	0	7	0	0	0	0	0	9	0	12	0	31	7	5+	2	14	3+

'+' =Many individuals; too many to be able to count accurately (cannot distinguish calls - Calling Code 3)

3.5.2 Amphibian Call Survey Site Conditions

Amphibians breed in several types of wetland habitat. All require the presence of water for some duration of the spring. Some species, such as Spring Peeper, Western Chorus Frog, and Wood Frog, take advantage of temporary, seasonal pools created by spring rains and melting snow. The temporary pools dry up by mid to late summer, at which time the tadpoles have metamorphosed into adults and moved to upland habitats. Some species of anurans, such as Leopard Frog, Green Frog, and Bullfrog (Lithobates *catesbeianus*), require semi-permanent to permanent water bodies in order for the tadpoles to develop into adults, which can take up to 2 years.

Since monitoring of calling anurans began in 2006, the hydro-period, depth and spatial extent of pooled water has varied greatly from one year to the next. These factors are subject to seasonal weather patterns including snow melt and spring precipitation. Research shows that prolonged periods of dry weather may reduce adult breeding populations either directly or through reduced juvenile recruitment and a shortened larval period (Berven 1990). Permanent standing water is present within the constructed SWM pond in Phase 2 (SWM Pond 4) and SWM Ponds 1 and 2 in Phase 1 (Map 2), as well as the 2 manicured ponds within the residential property north of Laird Road. Incidental observations of amphibians continue to be recorded within the SWM ponds (in particular SWM Pond 4). The maturation of buffer plantings surrounding these features will help to improve these habitats and increase the presence of frog and toad species, in particular American Toad and Spring Peeper.

Banks Groundwater Engineering notes that a significant rise in precipitation occurred between July 2013 to January 2015. Since January 2015 precipitation has shown a downward trend due to the less-than-normal amount of precipitation in 19 of 24 months (Banks Groundwater Engineering 2017). These significant fluctuations will have immediate impacts on the suitability of vernal pools for anuran breeding whereby a decreased hydro-period (or completely dry site) will not support breeding in a given year, but may return to suitable conditions in a subsequent year. Conditions in the spring of 2016 began with a lower-than-normal amount of meltwater available and low precipitation did not maintain water in most of the plots through to June. Anurans will respond to the changing suitability of sites by relocating within the subject property to better sites (at times SWM ponds), or the failure to breed may occur which will have a lag effect on species populations over a several year period. Repeated years of unsuitable breeding conditions will result in significant decreases in individuals. Presumably several years of ideal breeding conditions would be required to see increases in species diversity and abundance. The reoccurrence of winter and spring seasons with low precipitation over the past several years has not created ideal conditions for anuran breeding.

Weather on the first visit in 2016 (April 20), was 11°C, which was maintained by the end of the evening. Skies were partly cloudy with very a gentle breeze. The second visits occurred on May 23 (plots south of Laird Road) and May 30 (plots north of Laird Road). On May 23, skies were partly cloudy to overcast, with an air temperature of 18°C dropping to 17°C, with very little breeze. On May 30, the temperature dropped from 23°C to 19°C, with a partly cloudy sky, and a gentle breeze. During the final visit on June 21, the air temperature was 20°C dropping to 18°C, with partly cloudy skies changing to clear, and no wind. There was no precipitation on any of the 2016 calling anuran survey dates.

Water temperatures ranged from 5.8°C to13°C on the first visit with a number of plots not containing water during the April survey. During the second visit, water temperatures ranged from 15°C to 17°C. No standing water could be located in the vicinity of any of the plots on the last visit and thus temperature and pH data was not collected.

Anurans are known to prefer habitats that are pH neutral (pH 7) (Audubon International, 2000). When pH values decrease, becoming acidic, or increase, becoming alkaline, it can impact their survival. Seburn and Seburn (1998) stated that the Northern Leopard Frog breeds successfully at a pH range of 8.5-9.5 and that fertilization of eggs is reduced at a pH of less than 6.5.

Chemical processes such as photosynthesis and drying out that occur daily and throughout the breeding season result in fluctuations of water pH and other water chemistry values (Wetzel 1983). A study of 180 ponds across southwestern Ontario found that pH averaged 8.3 +/-0.05 with a range of 7.2-10.2 (Hecnar and M'Closkey 1996). According to this study, ponds in southwestern Ontario, are generally alkaline, hard, and well buffered with high pH values. Hecnar and M'Closkey (1996) did not find any correlation between amphibian species richness and water chemistry. Several studies have found that amphibian species richness is not related to water chemistry (pH, conductivity, and hardness) (Hecnar and M'Closkey 1996). The presence or absence of anuran species is more commonly related to hydroperiod and the presence of predatory fish.

pH values recorded during the April and May surveys ranged from 7.1 to 9.5 with most in the range of 7.1 - 8.3. This range aligns with average pH values recorded in previous monitoring years. Similar to previous years, pH values in 2016 were based upon all plots which contained water and it should be noted that a number of plots were dry on one or more of the calling amphibian survey dates. The pH values found during the monitoring period are within the normal range for southern Ontario. The recorded pH levels have not been recognized as having harmful effects on the presence of amphibian species.

3.6 Amphibian Threshold Assessment

The thresholds for amphibians established in the HCBP Consolidated Monitoring Program (NRSI 2010) and the HCBP 2011 Consolidated Monitoring Report (NRSI 2012a) are a decrease in species diversity (number of species) by more than 2 species and a significant change in species abundance, measured by a decrease in 2 call codes. Such changes may constitute a concern.

3.6.1 Amphibian Species Diversity

Figure 16 graphs the species diversity for anurans since 2006. In 2016, Plots 6 and 9 showed a reduction in species by more than 2 species between 2015 and 2016. Plot 6 decreased from 4 calling anuran species in 2015 to none heard in 2016. Plot 9 decreased from 3 calling anuran species in 2015 to none heard in 2016. Each of these plots had a minimal amount of standing water between April and June with much of the plot area comprised of damp matted grasses on saturated soils.

It is notable that species diversity in Plot 6 shows a regular pattern of fluctuating; between 2009 and 2014 diversity alternated annually between 3 species and 1 species with 2015 (4 species) and 2016 (0 species) complementing this trend. To some degree the data for Plot 9 reflects this pattern as well with years of higher diversity alternating with years of lower diversity. To a large extent it is likely that these fluctuations are a reflection of climatic conditions (temperature and precipitation); however further monitoring of these plots will provide additional insight as to whether the development has had any impact on species diversity.

Surveys in 2016 documented 2 calling anuran species at Plot 17 which had no species recorded in 2015. All other plots had an increase or decrease by a single species from one year to the next or maintained the same number of species between 2015 and 2016.

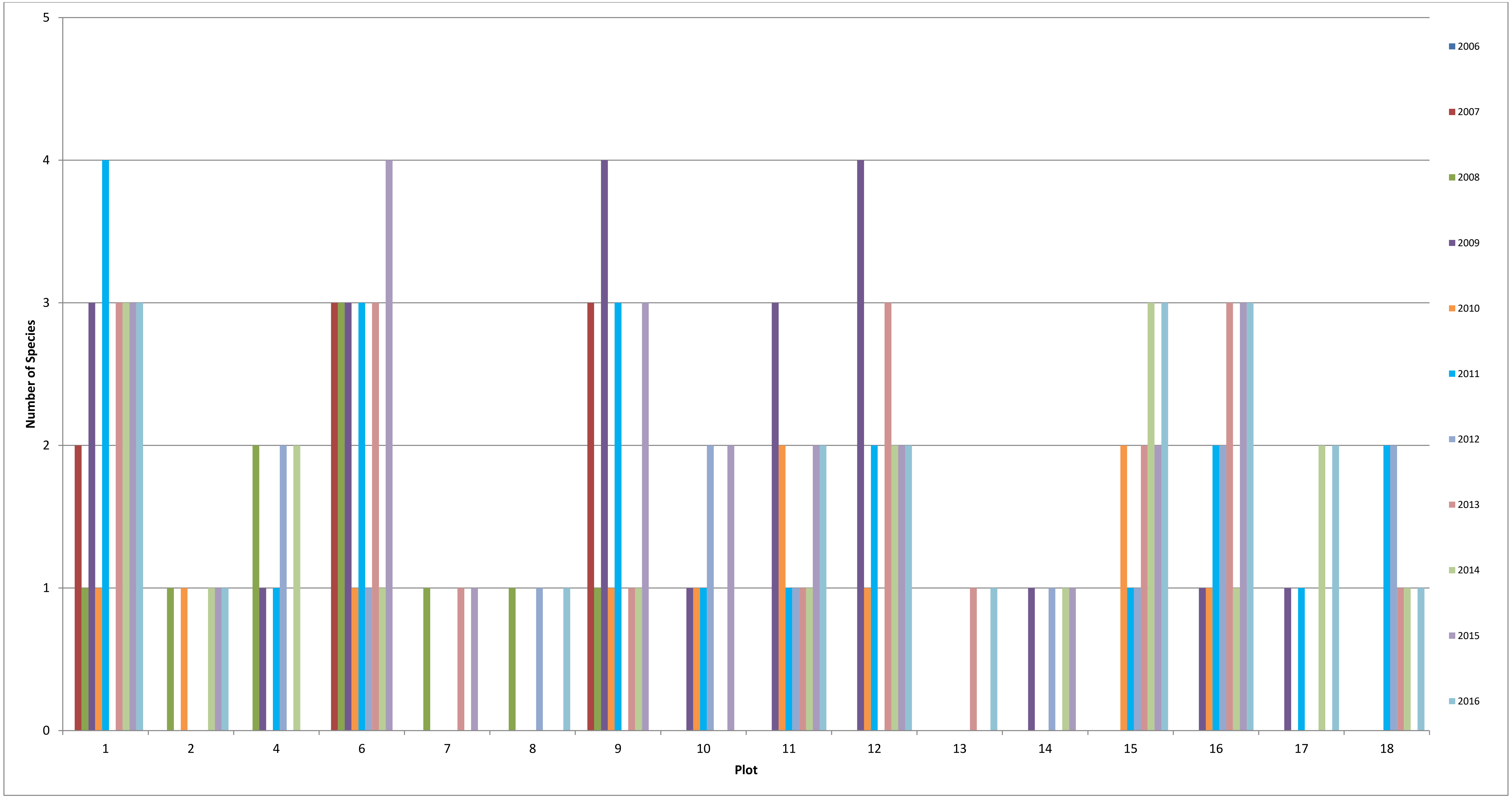

Figure 16. Amphibian Species Diversity 2006 - 2016

3.6.2 Amphibian Species Abundance

A drop in 2 calling codes was established as the threshold in the HCBP Consolidated Monitoring Program (NRSI 2010). 10 of these threshold exceedances were observed in 2016 as follows:

- American Toad in Plots 1, 10, 11 and 16 – no individuals recorded in 2016, down from a call code of 3 at Plot 11 in 2015 and 2 at the other plots. American Toad was only recorded at Plot 12 during the 2016 surveys,
- Gray Treefrog in Plots 6, 7, 9, and 10 – no individuals recorded in 2016 after call codes of 2 were recorded at all of these plots in 2015,
- Spring Peeper in Plots 6 and 9 – no individuals recorded in 2016, down from a call code 2 recorded at Plot 6, and a call code of 3 recorded at Plot 9 in 2015.

It should be noted that both Gray Treefrog and Spring Peeper remain widespread and abundant within the subject property. In 2016, increases in Gray Treefrog call codes from 0 to 2 were documented at Plots 8, 15, and 17. Increases in Spring Peeper call codes from 0 to 3 were observed in Plots 16 and 18 between 2015 and 2016. Green Frog was recorded for the first time at Plot 13 in 2016; this species occurs intermittently (not every year) and at various locations within the subject property.

As previous monitoring reports have noted, the creation and naturalization of the SWM ponds on site has led to increased use of these features for anuran breeding and foraging, in particular by Spring Peepers and American Toads.

The remaining identified species, Northern Leopard Frog, Pickerel Frog and Western Chorus Frog have all been observed intermittently within the subject property dating back to the 2007 monitoring year. Generally these species have been observed in low numbers at a call code of 1 or 2. It is likely that these species have always existed in low numbers within the property and are subject to natural population fluctuations.

During 2016 calling anuran surveys, a full chorus of both Gray Treefrog and Spring Peeper was recorded at Plot 16. This plot was flagged in previous monitoring reports for decreases in herbaceous vegetation and bird species diversity. The presence of a full chorus of Spring Peeper provides good indication that conditions within the plot were suitable for early-season breeding anurans. During the April survey it was noted that water within the plot was up to 15cm deep with shallow standing water still present during the May survey. By the June survey, water within Plot 16 was limited to small, fragmented puddles and saturated detritus.

3.6.3 Amphibian Threshold Summary and Contingency Measures

The HCBP Consolidated Monitoring Program (NRSI 2010, p. 41) suggests the following measures when amphibian species decline beyond the established threshold:

- *“Wetland creation where feasible.*
- *Enhancement plantings to improve wetland condition.*
- *Additional monitoring – broaden range of parameters (i.e. water quality).*
- *Increase buffer plantings or alter if necessary.*
- *Provide educational material to neighbouring properties outlining importance of natural features, wildlife and their protection.*
- *Provide additional signage regarding trail closures, etc.”*

The drop in American Toad abundance at Plots 1, 10, 11, and 16; Gray Treefrog abundance at Plots 6, 7, 9, and 10; and Spring Peeper abundance at Plots 6 and 9 is likely a reflection of the reduced amounts of seasonal standing water across the site. As all three of these species utilize a variety of natural and anthropogenic habitats across the site, it is not recommended that any contingency measures be implemented. It is noted that increases in abundance were documented for both Gray Treefrog and Spring Peeper at other monitoring plots, and all of these species are regularly documented outside of plots, with American Toads tending to utilize the SWM ponds during their breeding period. The thresholds that were exceeded are summarized as follows along with recommendations for continued monitoring.

Amphibian Species Diversity

A reduction in species number by more than 2 (between the preconstruction average and 2015 as well as between 2015 and 2016) was observed during 2016 monitoring. Plots 6 and 9 both showed decreases greater than 2 species with a drop from 4 to 0 species recorded at Plot 6 and from 3 to 0 species recorded at Plot 9; therefore this decrease exceeds the threshold limit. Plots 7 and 14 experienced a decrease in diversity by 1, while Plot 10 showed a reduction by 2; however these decreases are considered to be below threshold. On the other hand, Plots 8, 13, and 18 showed increases in species observed from 0 to 1 species and from 2 to 3 species at Plot 15. Species number increased in 2016 by a factor of 2 at Plot 17 from 0 species documented in 2015.

Amphibian Species Abundance

A decrease in species abundance beyond the established threshold was recorded for: American Toad at Plots 1, 10, 16, and 11; Gray Treefrog at Plots 6, 7, 9, and 10; and for Spring Peeper at Plots 6 and 9. It should be taken into account that although decreases in Gray Treefrog and Spring Peeper abundances were observed during the 2016 study period, these 2 species are still the most widespread among survey locations. Increases in call codes were still observed for both of these species between the 2015 and 2016 surveys. Furthermore, observations of Green Frog were made for the first time at Plot 13 during the 2016 study.

Monitoring of all anuran plots should continue with a particular focus on noting the spatial extent and depth of vernal pools at all plots. As it is noted previously, the design of the business park does not direct surface water from the development into the wetlands and a trend of lower-than-normal precipitation is contributing to less suitable anuran breeding habitat. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends.

3.7 Incidental Wildlife Observations

Surveys conducted throughout 2016 resulted in the documentation of a variety of incidental wildlife observations. These observations included birds, herpetofauna, butterflies and mammals that were recorded during the monitoring surveys.

3.7.1 Birds

The birds that were observed incidentally in 2016 are listed in Appendix VII. These species were observed on site incidentally during calling anuran surveys, vegetation surveys or during breeding bird point count surveys but beyond the 100m limit of the survey station.

3.7.2 Amphibians

A consolidated list of all herpetofaunal species observed by NRSI within the subject property since 1998 is included in Appendix IX. Similar to previous monitoring years, numerous calling individuals of both American Toad and Spring Peeper were noted from within the SWM ponds present on site. SWM ponds with regular mention of calling anuran activity include those directly east of Downey Road (SWM Pond 2), the SWM swale directly north of Plot 7, and south of Laird Road near Plot 13 (SWM Pond 4). Over the last several years the establishment of a fringe of aquatic and wetland vegetation within these features has begun to improve their function as habitat for anuran breeding. SWM pond locations are shown on Map 2.

3.7.3 Snakes

An Eastern Gartersnake (*Thamnophis sirtalis sirtalis*) was observed at Plot 1 during July vegetation surveys. Several species of snake have been observed in previous monitoring years (Appendix IX). The network of chip stone recreational trails throughout the business park is likely to provide ideal basking habitat for some snake species.

3.7.4 Butterflies

During the 2016 surveys an Eastern Tiger Swallowtail (*Papilio glaucus*) was observed at Plot 3 during July vegetation surveys. A number of butterfly species have been recorded from the site over the course of terrestrial and wetland monitoring. The ditches, successional meadows and vegetated periphery of SWM ponds all provide an abundance of nectar-producing plants throughout the late spring into fall.

3.7.5 Odonates

No odonates (dragonflies or damselflies) were documented within the site during 2016 surveys. The variety of wetlands, open water features and meadows are likely to provide suitable habitat for a number of odonate species.

3.7.6 Mammals

During 2016 surveys, tracks and scat of White-tailed Deer were noted throughout the site. No other mammal species were documented during 2016 surveys.

4.0 Conclusions and Recommendations

The 2016 monitoring year was successful in providing the seventh year of during construction data, contributing to a useful data set that can be compared to pre-construction data and data from future during construction years.

Vegetation

Vegetation plot surveys in 2016 identified 4 species which had not been previously recorded on site. These species, all native to Ontario, included Bearded Shorthusk, Cleavers, Bristle-stalked Sedge and Woodland Horsetail which is considered regionally rare.

The average Coefficient of Conservatism values for plots have remained relatively stable across the subject property. Plot 16 and Plot 18 both showed a notable rebound in CC values following 2 consecutive years of reductions in vegetation cover (and in turn CC values) in 2014 and 2015. The increases observed in these plots are attributed to recolonization of wetland plants from adjacent areas or the germination of the seedbank once suitable soil moisture conditions had returned. The highest Natural Areas Index value was recorded in Plot 7 (27.38), with Plot 2, 4 and 18 also above 20 in 2016. These plots continue to exhibit a rich herbaceous groundcover largely comprised of native species.

Average Coefficient of Wetness values indicate that Plot 1 and Plot 4 remain the wettest plots. It is noted that outlier species such as a dry upland plant at the edge of a predominantly wetland plot can have a sizable influence on average CW which only accounts for species presence and not relative abundance within a plot. A notable increase in values was observed at Plot 6, typically having an average CW value between -0.04 and -1.54 but with a value of +0.75 in 2016. Dominant species within the plot include Panicled Aster, Coltsfoot and Canada Goldenrod (all CW +3). Wetter species may be displaced by these dominant species, or it is also possible that these wetter species are still present, but are obscured from view by the dense grass thatch present within the plot. This plot is situated in a transitional area between meadow marsh and fresh-moist meadow. Both Plot 16 and Plot 18 showed wetter average CW values between 2015 to 2016, changing from -1.13 to -2.00 and -1.55 to -2.42 respectively. Plot 16 contained seasonal standing water during the April and May 2016 calling anuran surveys. Throughout much of the spring of 2014 and 2015 this plot contained only saturated detritus. Where previous analysis had suspected fluctuation in the groundwater table (resulting from the 2012 drought) to be a driver of change in these plots, discussion is now looking into what role altered surface water contributions may be playing in the hydrology of these features. These plots will remain a focus of discussion in future monitoring reports in order to understand if site grading to accommodate the approved stormwater management plans has created impacts to the hydrology of these plots.

Plot monitoring in 2016 did not document any new non-native species with those species present in previous years maintaining their presence overall. Populations of the aggressive non-native Common Reed were observed in a ditch to the east of Plot 6 as well in sparse stands along the edge of SWM pond 4. It is very likely that these stands are a result of the disturbance associated with the development and it is recommended that these stands be managed while still early in their establishment. Effective management will require that stands across the subject property be documented and mapped followed by herbicide application. Follow-up assessment of the herbicide application (and prescription of re-application, as needed) should be conducted annually.

Vegetation monitoring in 2016 recorded 2 negative threshold exceedances. At this time no contingency measures have been recommended. Although Plot 3 herbaceous cover was slightly below the 25% threshold limit, cover in this plot has doubled since 2014. The changes in this plot, focused largely around Ostrich Fern, are likely the result of natural changes in available soil moisture as well as impacts due to deer browse. There were no positive threshold exceedances in herbaceous cover in 2016.

The species diversity threshold was positively exceeded in Plot 1 for the sixth time since 2009. Plot 4 contained the highest diversity in 2016 with 32 species present, largely as a result of the saturated hummocky organic soils which support a diversity of wetland forbs. Plot 7 negatively exceeded the threshold in 2016. The 29 species documented in 2016 is notably lower than the pre-construction average of 42. There have been no widespread introductions of invasive species within the plot and it is suspected that this difference is attributed to the periodic inclusion or exclusion of certain species in low numbers. Species which are not present in one monitoring year tend to remain present adjacent to the plot and may be included within the plot in a following year. This change in diversity is not reason for concern at this time.

Canopy cover within Plot 8 had returned to within the threshold limit in 2015 and remained within the limit in 2016. While naturalization plantings have yet to mature to the point that they contribute to the canopy of the plot, existing tree canopies have filled in to some extent.

Birds

In 2016 bird species diversity figures were reflective of the overall average throughout the monitoring period. Plot 1 diversity was lower than the previous 6 years but at 15 species reflects the pre-construction average (15.25). The highest diversity in 2016 was recorded at Plot 6 with 19 species; the highest diversity to date was at Plot 1 with 23 species in 2013. The low diversity of 10 species at Plot 2 is somewhat expected given the reduce sight lines and homogenous habitat associated with cedar swamp habitat.

Bird abundance was also on average with previous monitoring years. Plot 1, 6 and 9 all exhibited the highest bird abundance which is typical at these plots from one year to the next. No large flocks of any one species were observed in 2016.

Provincially significant bird species observed in 2016 included Eastern Meadowlark, Bobolink, Eastern Wood-pewee, Barn Swallow and Bank Swallow. Most observations of these species occurred within Phase 3, in particular Plot 20 and Plot 9. Bobolink showed probable breeding evidence at Plot 20 in 2016.

The threshold for species diversity was positively exceeded at Plots 3, 5 and 6 in 2016 with no negative exceedances. The threshold set for bird abundance was negatively exceeded at Plots 4, 6, 7, 8 and 9. The pre-construction average for Plots 6 and 9 is greatly influenced by large flock observations thus setting a high threshold skewed by chance events. Had 3 to 4 additional birds been recorded at Plots 4, 7 and 8, all of these plots would have been within the threshold.

A total of 19 species considered significant within the City of Guelph were documented in 2016. At this time no contingency measures relating to breeding birds have been recommended.

Amphibians

Anuran surveys in 2016 identified a negative threshold exceedance for species diversity at Plot 6 and 9. In 2015 Plot 6 had 4 species documented and Plot 9 had 3, while 2016 resulted in no observations in either of these plots. Review of the data set shows a consistent fluctuation at these plots whereby a year of 3 to 4 species present is followed by a year of 1 or no species present. The absence of anurans in 2016 may be attributed to the lack of standing water as Plot 6 is essentially wet meadow and Plot 9 is a very dense stand of Reed Canary Grass. In past years these plots had contained a shallow depth of water among the vegetation; this depth of water has not been present at these plots for several years. Calling anurans were noted beyond the 100m survey plot radius.

A negative threshold exceedance for calling anuran abundance was noted for 3 species across 7 plots in 2016. Gray Treefrog, American Toad and Spring Peeper abundance exceeded the threshold in 10 instances. Although American toad was only documented within Plot 12 in 2016, the species is widespread among the SWM ponds and swales within the subject property. A full chorus of both Gray Treefrog and Spring Peeper was heard at Plot 16 which supports that this plot has rebounded somewhat over the past several years.

Monitoring of all anuran plots should continue with a particular focus on hydro-period and the extent and depth of vernal pooling at all plots. In the case that anuran diversity and abundance is found to be impacted by development activities, management recommendations may be made in order to mitigate or reverse negative trends. In addition, the swamp and surrounding lands should be investigated in the spring to determine whether there are substantial changes in hydrology.

In 2017, it is anticipated that further building construction will occur within Phase 2. No works are anticipated to occur within Phase 1, Stage 2/Stage 3 or Phase 3.

Given the observed monitoring trends and in consideration of the impacts relating to annual vegetation monitoring (trampling of plots), it is recommended that during-construction terrestrial and wetland monitoring not occur in 2017. It is recommended that the monitoring program resume in 2018 and be conducted on a biennial basis (every other year) until approximately 75% build-out, plus 2 years as identified in the Consolidated Monitoring Program and Environmental Implementation Report.

Recommendations

Based upon the results of the 2016 terrestrial and wetland monitoring, the following actions should be considered:

- Eradication of Common Reed stands near Plot 6 and at the fringe of SWM Pond 4. Should action be taken, periodic assessment of the managed areas should also be enacted to prevent re-establishment,
- Spatial characterization of vernal pools (approximated area and depth) at each anuran survey plot during each of the 3 monitoring visits. This assessment may be incorporated into a revised data form. The data collected will inform which plots are or are not providing suitable conditions at various times throughout the spring.

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APPENDIX I

Vegetation Species Observed in the Subject Property 2006 - 2016

Appendix I. Vegetation Species Observed in the Study Area (2006 - 2016)

									Wellington	NRSI										
SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK^1	COSEWIC^2	COSSARO^3	County^4	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Abies balsamea	Balsam Fir	5	-3			S5				√	√	√	√	√	√	√	√	√	√	√
Acer rubrum	Red Maple	4	0			S5				√	√	√	√	√	√	√	√	√	√	√
Acer saccharinum	Silver Maple	5	-3			S5				√	√	√	√	√	√	√	√	√	√	√
Acer saccharum ssp. saccharum	Sugar Maple	4	3			S5				√	√	√	√	√	√	√	√	√	√	√
Actaea spp.	Baneberry species										√		√					√		
Agrostis stolonifera	Redtop		-3			S5												√		√
Alisma spp.	Water Plantain species											√								
Alliaria petiolata	Garlic Mustard	*	0	-3	+	SE5									√					
Allium tricoccum	Wild Leek	7	2			S5					√									
Amelanchier arborea	Downy Serviceberry	5	3			S5											√			
Arabis glabra	Tower-mustard	0	0			S5						√								
Aralia nudicaulis	Wild Sarsaparilla	4	3			S5				√	√	√	√	√	√	√	√	√	√	√
Aralia racemosa ssp. racemosa	Spikenard	7	5			S5													√	
Arctium minus	Common Burdock	*	5	-2	+	SE5					√						√			
Arctium species	Burdock species															√				
Arisaema triphyllum	Jack-in-the-pulpit	5	-2			S5				√	√	√	√	√	√	√	√	√	√	√
Aronia melanocarpa	Black Chokeberry	7	-3			S5										√				
Asclepias incarnata ssp. Incarnata	Swamp Milkweed	6	-5			S5				√	√						√	√	√	√
Asclepias syriaca	Common Milkweed	0	5			S5				√								√	√	√
Aster species	Aster species												√		√		√			
Athyrium filix-femina var. angustum	Northeastern Lady Fern	4	0			S5							√	√					√	√
Betula alleghaniensis	Yellow Birch	6	0			S5				√	√	√	√	√	√	√	√	√	√	√
Bidens cernua	Nodding Beggarticks	2	-5			S5								√				√		
Bidens frondosa	Devil's beggarticks	3	-3			S5										√	√	√	√	√
Bidens tripartita	Beggarticks	4	-3			S5					√	√								
Boehmeria cylindrica	False Nettle	4	-5			S5										√		√	√	√
Brachyelytrum erectum	Bearded Shorthusk	7	5			S4S5														√
Bromus inermis ssp. inermis	Smooth Brome	*	5	-3	+	SE5					√				√			√	√	√
Calamagrostis canadensis	Canada Blue-joint	4	-5			S5				√	√	√	√	√	√	√	√	√	√	
Caltha palustris	Marsh Marigold	5	-5			S5				√	√	√	√	√	√	√	√	√	√	√
Cardamine pensylvanica	Pennsylvania Bitter Cress	6	-3			S5							√							
Carex albursina	White bear Sedge	7	5			S5										√				
Carex aquatilis	Water Sedge	7	-5			S5							√	√	√	√	√	√	√	
Carex arctata	Compressed Sedge	5	5			S5							√							
Carex bebbii	Bebb's Sedge	3	-5			S5											√			
Carex blanda	Smooth Sedge	3	0			S5										√	√	√		
Carex eburnea	Bristle-leaved Sedge	6	4			S5													√	
Carex flava	Yellow Sedge	5	-5			S5										√	√			
Carex gracillima	Graceful Sedge	4	3			S5							√	√		√	√	√	√	√
Carex hystercina	Porcupine Sedge	5	-5			S5										√				
Carex intumescens	Bladder Sedge	6	-4			S5							√		√	√				
Carex lacustris	Lake Sedge	5	-5			S5				√		√	√	√	√	√	√	√	√	√
Carex laxiflora	Loose-flowered Sedge	5	0			S5							√				√	√	√	√
Carex leptalea	Bristle-stalked Sedge	8	-5			S5														√
Carex lupulina	Hop Sedge	6	-5			S5										√	√	√		√
Carex pedunculata	Long-stalked Sedge	5	5			S5													√	
Carex pensylvanica	Pennsylvania Sedge	5	5			S5										√			√	
Carex radiata	Radiate Sedge	4	5			S5													√	
Carex species	Sedge species									√	√	√	√	√	√		√		√	√
Carex stipata	Awl-fruited Sedge	3	-5			S5				√	√	√	√	√	√	√		√	√	√
Carex stricta	Stiff Sedge	4	-5			S5						√	√	√			√		√	
Carex utriculata	Beaked Sedge	7	-5			S5					√		√		√					
Carex vulpinoidea	Fox Sedge	3	-5			S5						√	√	√	√	√	√	√		
Carpinus caroliniana	Blue Beech	6	0			S5										√				
Cerastium fontanum	Mouse-eared Chickweed	*	3	-1	+	SE5											√			

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI										
										2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chelone glabra	Turtlehead	7	-5			S5										√	√	√	√	
Cicuta bulbifera	Bulbous Water-hemlock	5	-5			S5						√	√	√	√	√		√	√	√
Cicuta maculata	Spotted Water Hemlock	6	-5			S5				√	√	√	√	√	√	√	√	√	√	√
Circaea alpina	Dwarf Enchanter's Nightshade	6	-3			S5				√			√			√	√	√	√	
Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade																√	√	√	
Circaea quadrisulcata	Enchanter's Nightshade	3	3			S5				√	√	√	√	√	√	√				√
Cirsium arvense	Canada Thistle	*	3	-1	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Cirsium muticum	Swamp Thistle	8	-5			S5											√	√		
Cirsium species	Thistle species															√				
Cirsium vulgare	Bull Thistle	4	5			S5											√			
Clintonia borealis	Bluebead Lily	7	-1			S5					√	√	√	√	√	√	√	√	√	√
Coptis trifolia	Goldthread	7	-3			S5					√									
Cornus alternifolia	Alternate-leaved Dogwood	6	5			S5				√	√	√	√	√	√	√	√	√	√	√
Cornus amomum	Silky Dogwood	5	-4			S5										√	√	√	√	√
Cornus foemina	Gray Dogwood	2	-2			S5											√		√	
Cornus stolonifera	Red-Osier Dogwood	2	-3			S5				√	√	√	√	√	√	√	√	√	√	√
Corylus americana	American Hazel	5	4			S5								√						
Crataegus species	Hawthorn species									√	√				√					
Cypripedium calceolus var. parviflorum	Small Yellow Lady's Slipper	7	-1			S5							√							
Cysptopteris tenuis	Mackay's Fragile Fern	6	5									√						√		
Cystopteris bulbifera	Bulblet Fern	5	-2			S5				√	√		√	√	√	√	√	√	√	√
Dactylis glomerata	Orchard Grass	*	3	-1	+	SE5										√	√	√	√	√
Daucus carota	Queen Anne's Lace	*	5	-2	+	SE5					√		√	√	√	√	√	√		
Dennstaedtia punctilobula	Hay-scented fern					S5			R										√	
Doellingeria umbellata	Flat-top White Aster	6	-3			S5										√				
Dryopteris carthusiana	Spinulose Wood Fern	5	-2			S5				√	√	√	√	√	√	√	√	√	√	√
Dryopteris clintoniana	Clinton's Wood Fern	7	-4			S4			R		√			√	√					
Dryopteris cristata	Crested Wood Fern	7	-5			S5				√	√	√	√	√	√		√	√	√	√
Dryopteris intermedia	Evergreen Wood Fern	5	0			S5													√	
Dryopteris marginalis	Marginal Wood Fern	5	3			S5							√	√	√	√	√	√	√	
Dryopteris sp.	Wood Fern Species																	√		
Echinochloa crusgalli	Barnyard Grass	*	3	-1	+	SE5							√	√				√		
Echinocystis lobata	Wild Cucumber	3	-2			S5					√	√	√		√	√	√	√	√	
Eleocharis smallii	Small's Spike-rush	6	-5			S5								√						
Elymus repens	Quack Grass	*	3	-3	+	SE5						√					√			
Epilobium ciliatum ssp. glandulosum	Willow-herb	6	3			SU										√		√		
Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	+	SE5							√	√	√	√	√		√	√
Epilobium sp.	Willow-Herb species																√		√	√
Epipactis helleborine	Helleborine	*	5	-2	+	SE5						√	√	√		√		√	√	√
Equisetum arvense	Field Horsetail	0	0			S5					√	√	√	√	√	√	√	√	√	√
Equisetum palustre	Marsh Horsetail	10	-3			S5			R	√	√				√					
Equisetum pratense	Meadow Horsetail	8	-3			S5			R	√		√	√	√	√	√		√	√	√
Equisetum scirpoides	Dwarf Scouring-rush	7	-1			S5								√			√	√	√	
Equisetum sylvaticum	Woodland Horsetail	7	-3			S5			R											√
Erigeron annuus	Daisy Fleabane																	√		
Erigeron philadelphicus	Philadelphia Fleabane	1	-3			S5													√	
Erigeron species	Fleabane species										√					√				
Eupatorium maculatum	Spotted Joe-Pye Weed	3	-5							√	√	√	√	√	√	√	√	√	√	√
Eupatorium perfoliatum	Boneset	2	-4			S5					√	√				√	√	√	√	√
Eurybia macrophylla	Large-leaved Aster	5	5			S5				√			√							
Euthamia graminifolia	Grass-leaved Goldenrod	2	-2			S5						√	√	√	√	√	√	√	√	√
Fagus grandifolia	American Beech	6	3			S5					√									
Festuca arundinacea	Tall Fescue	*	2	-1	+	SE5											√	√		√
Festuca pratensis	Meadow Fescue	*	4	-1	+	SE5													√	
Fragaria vesca	Woodland Strawberry	4	4							√	√	√	√		√	√	√	√		
Fragaria virginiana	Wild Strawberry	2	1			S5					√	√	√	√	√	√	√	√		
Fraxinus americana	White Ash	4	3			S5				√	√	√	√	√	√	√	√	√	√	√
Fraxinus nigra	Black Ash	7	-4			S5				√	√	√	√	√	√	√	√	√	√	√

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI										
										2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fraxinus pennsylvanica var. subintegerrina	Green Ash	3	-3												√	√	√	√	√	√
Galium aparine	Cleavers	4	3			S5														√
Galium asprellum	Rough Bedstraw	6	-5			S5				√		√	√							
Galium palustre	Marsh Bedstraw	5	-5			S5				√	√	√	√	√	√	√	√	√	√	√
Galium triflorum	Sweet-scented Bedstraw	4	2			S5				√		√	√	√						√
Geranium robertianum	Herb Robert	*	5	-2	+	SE5				√	√	√	√	√	√		√	√	√	
Geum aleppicum	Yellow Avens	2	-1			S5						√	√	√	√	√	√	√	√	√
Geum canadense	White Avens	3	0			S5					√						√	√		
Geum laciniatum	Rough Avens	4	-3			S4			R		√				√	√				√
Geum species	Avens species									√							√	√	√	√
Glyceria species	Manna Grass species														√					
Glyceria striata	Fowl Manna Grass	3	-5			S5					√		√		√	√	√	√	√	√
Gymnocarpium dryopteris	Oak Fern	7	0			S5					√	√	√	√		√	√		√	√
Hamamelis virginiana	Witch Hazel	6	3			S5			R						√					
Heracleum lanatum	Cow Parsnip	3	-3			S5										√				
Hieracium species	Hawkweed species											√								
Hydrocotyle americana	Marsh-Water Pennywort	7	-5			S5				√			√						√	
Hydrophyllum virginianum	Virginia Waterleaf	6	-2			S5						√		√						
Ilex verticillata	Winterberry	5	-4			S5									√	√	√	√	√	√
Impatiens capensis	Spotted Jewelweed	4	-3			S5				√	√		√	√	√	√	√	√	√	√
Impatiens pallida	Pale Jewelweed	7	-3			S5			R		√	√			√					
Iris species	Iris species	0	0								√									
Juncus effusus	Soft Rush	4	-5										√	√			√			√
Juncus dudleyi	Dudley's Rush	1	0			S5													√	
Juncus species	Rush species									√	√									
Juncus tenuis	Path Rush	0	0			S5				√		√	√	√	√	√	√	√		√
Lactuca serriola	Prickly Lettuce	*	0			SE5				√			√							
Leersia oryzoides	Rice Cutgrass	3	-5			S5				√			√		√	√	√	√	√	√
Linaria vulgaris	Butter-and-eggs	*	5	-1	+	SE5						√								
Liparis loeselii	Fen Twayblade	5	-4			S4S5											√			
Lobelia siphilitica	Great Lobelia	6	-4			S5								√		√				
Lonicera canadensis	Fly Honeysuckle	6	3			S5										√				
Lonicera tatarica	Tartarian Honeysuckle	*	3	-3	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Lotus corniculatus	Bird's-foot Trefoil	*	1	-2	+	SE5				√	√	√	√	√	√	√	√	√		√
Lycopus americanus	American Water-horehound	4	-5			S5											√	√		√
Lycopus uniflorus	Northern Bugleweed	5	-5			S5				√	√	√	√	√	√	√	√	√	√	√
Lysimachia ciliata	Fringed Loosestrife	4	-3			S5					√	√	√	√	√	√	√	√	√	
Lysimachia nummularia	Moneywort	*	-4	-3	+	SE5					√									
Lysimachia terrestris	Swamp Candles	6	-5			S5					√		√		√	√	√			
Lysimachia thyrsiflora	Tufted Loosestrife	7	-5								√	√	√	√	√	√		√	√	√
Lythraceae spp.	Loosestrife species											√								
Lythrum salicaria	Purple loosestrife	*	-5	-3	+	SE5										√			√	
Maianthemum canadense	Canada Mayflower	5	0			S5				√	√	√	√	√	√	√	√	√	√	√
Maianthemum racemosum	False Solomon's Seal	4	3							√	√	√			√	√		√		
Maianthemum stellatum	Star Flowered False Solomon's-seal	6	1			S5						√	√	√					√	
Malva neglecta	Common Mallow	*	5	-1	+	SE5									√					
Marchantia polymorpha	Common Liverwort					S5										√				
Matteuccia struthiopteris	American Ostrich Fern	5	-3							√	√	√	√	√	√	√	√	√	√	√
Medicago lupulina	Black Medick	*	1	-1	+	SE5								√	√	√	√			
Mentha arvensis	Common Mint	3	-3							√	√		√	√	√	√	√	√	√	√
Mentha X piperita	Pepper Mint	*	-5	-1		SE4										√				
Mitella nuda	Naked Miterwort	6	-3			S5										√	√	√		
Myosotis sp.	Forget-me-not species																	√		
Nasturtium officinale	Watercress	*	-5	-1	+	SE?							√	√	√	√	√	√	√	√
Onoclea sensibilis	Sensitive Fern	4	-3			S5				√	√	√	√	√	√	√	√	√	√	√
Osmunda cinnamomea	Cinnamon Fern	7	-3			S5					√		√	√	√	√	√	√	√	√
Ostrya virginiana	Ironwood	4	4			S5				√		√								
Oxalis stricta	Upright Yellow Wood Sorrel	0	3			S5										√				

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI										
										2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Parthenocissus vitacea	Woodbine	3	3			S5											√	√	√	√
Parthenocissus quinquefolia	Virginia Creeper	6	1			S4?				√	√	√	√	√	√	√			√	√
Phalaris arundinacea	Reed Canary Grass	0	-4			S5					√	√	√	√	√	√	√	√	√	√
Phleum pratense	Timothy	*	3	-1	+	SE5						√		√	√	√	√	√	√	√
Physocarpus opulifolius	Ninebark	5	-2			S5													√	
Picea glauca	White Spruce	6	3			S5				√	√	√	√	√	√					
Pilea pumila	Clearweed	5	-3			S5			R			√					√		√	√
Pinus strobus	Eastern White Pine	4	3			S5				√	√	√	√	√	√	√	√			√
Plantago lanceolata	English Plantain	*	0	-1	+	SE5								√						
Plantago major	Common Plantain	*	-1	-1	+	SE5								√	√					
Poa nemoralis	Woodland Spear Grass	0	0	-1		SE3							√							
Poa palustris	Fowl Meadow Grass	5	-4			S5									√	√	√	√	√	√
Poa pratensis	Kentucky Blue Grass	0	1								√	√	√	√	√	√	√	√	√	√
Poa sp.	Grass species									√	√	√	√	√	√	√	√	√	√	√
Polygonatum pubescens	Hairy Solomon's Seal	5	5			S5					√	√			√	√	√		√	√
Polygonum amphibium	Water Smartweed	5	-5												√					
Polygonum species	Smartweed species																√			
Polygonum virginianum	Jumpseed	6	0			S4										√				
Polystichum acrostichoides	Christmas Fern	5	5			S5				√		√	√	√	√					
Populus balsamifera	Balsam Poplar	4	-3			S5													√	√
Populus tremuloides	Trembling Aspen	2	0			S5										√		√		
Potentilla recta	Sulphur Cinquefoil	*	5	-2	+	SE5										√	√			
Prenanthes alba	White Rattlesnake-root	6	3			S5				√										
Prunella vulgaris ssp. lanceolata	Selfheal	5	5			S5								√	√	√	√	√	√	√
Prunus pensylvanica	Pin Cherry	3	4			S5								√						
Prunus serotina	Black Cherry	3	3			S5				√	√	√	√	√	√	√	√	√		
Prunus virginiana	Chokecherry	2	1									√	√		√		√	√	√	√
Quercus macrocarpa	Bur Oak	5	1			S5												√	√	√
Quercus rubra	Red Oak	6	3			S5								√						
Quercus sp.	Oak species																√	√		
Ranunculus abortivus	Small-flowered Buttercup	2	-2			S5				√	√						√			√
Ranunculus acris	Tall Buttercup	*	-2	-2	+	SE5				√	√		√	√	√	√	√	√	√	
Ranunculus flabellaris	Yellow Water-crowfoot	7	-5			S4?			R			√			√					
Ranunculus hispidus var caricetorum	Swamp Buttercup	5	-5							√			√			√	√	√		
Ranunculus pensylvanicus	Bristly Buttercup	3	-5			S5						√								
Ranunculus recurvatus	Hooked Buttercup	4	-3								√	√				√			√	
Ranunculus repens	Creeping Buttercup	0	-1	-1		SE5					√			√		√	√		√	√
Ranunculus sceleratus	Cursed Crowfoot	2	-5								√		√	√						
Ranunculus species	Buttercup species														√					
Rhamnus cathartica	Common Buckthorn	*	3	-3	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Rhamnus frangula	Glossy Buckthorn	*	-1	-3	+					√	√	√	√	√	√	√	√	√	√	√
Rhynchospora alba	White Beaked-rush	10	-5			S5										√				
Ribes americanum	Wild Black Currant	4	-3			S5				√	√	√		√	√	√		√	√	√
Ribes hirtellum	Smooth Gooseberry	6	-3			S5			R				√							
Ribes lacustre	Bristly Black Currant	7	-3			S5					√									
Ribes rubrum	Red Currant	*	5	-2	+	SE5						√			√					
Ribes species	Currant species									√	√			√	√					
Ribes triste	Swamp Red Currant	6	-5			S5									√	√				√
Rubus allegheniensis	Common Blackberry	2	2			S5					√				√					
Rubus idaeus	Red Raspberry	0	-2							√	√	√	√	√	√		√	√	√	√
Rubus occidentalis	Black Raspberry	2	5			S5							√			√				√
Rubus parviflorus	Sparse-flowered Thimbleberry	7	2			S4									√					
Rubus pubescens	Dwarf Raspberry	4	-4			S5				√	√	√	√	√	√	√	√	√	√	√
Rumex crispus	Curled Dock	*	-1	-2	+	SE5						√		√	√					
Sagittaria latifolia	Common Arrowhead	4	-5			S5										√	√	√	√	
Salix bebbiana	Bebb's Willow	4	-4			S5						√			√					
Salix eriocephala	Heart-leaved Willow	4	-3			S5								√	√	√	√	√		√

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI										
										2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Salix exigua	Sandbar Willow	3	-5			S5				√										
Salix lucida	Shining Willow	5	-4			S5									√					
Salix petiolaris	Slender Willow	3	-4			S5				√		√	√	√	√	√	√	√	√	√
Salix species	Willow species										√			√	√					
Sambucus canadensis	Common Elderberry	5	-2			S5				√				√	√		√	√	√	√
Sanguinaria canadensis	Bloodroot	5	4			S5									√					
Scirpus americanus	Common Three Square	6	-5							√										
Scirpus atrovirens	Dark Green Bulrush	3	-5			S5						√	√	√	√	√	√	√	√	√
Scirpus cyperinus var. cyperinus	Wool-grass	4	-5			S5												√		
Scutellaria galericulata	Common Skullcap	6	-5			S5				√		√	√		√	√	√	√	√	√
Scutellaria lateriflora	Mad-dog Skullcap	5	-5			S5				√	√			√		√			√	√
Scutellaria species	Skullcap species									√										
Silene cucubalus	Bladder Campion	*	5	-1	+					√										
Sium suave	Water Parsnip	4	-5			S5				√	√	√		√	√		√	√	√	√
Solanum dulcamara	Bittersweet Nightshade	*	0	-2	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Solidago altissima	Tall Goldenrod	1	3							√				√	√	√	√	√	√	√
Solidago caesia	Blue-stem Goldenrod	5	3			S5										√				
Solidago canadensis	Canada Goldenrod	1	3			S5				√	√	√	√	√	√	√	√	√	√	√
Solidago flexicaulis	Zig-zag Goldenrod	6	3			S5				√				√	√	√	√	√	√	√
Solidago gigantea	Late Goldenrod	4	-3			S5									√		√	√	√	√
Solidago nemoralis	Gray Goldenrod	2	5									√								
Solidago patula	Rough-leaved Goldenrod	8	-5			S5			R		√	√			√	√		√	√	
Solidago rugosa	Rough-stemmed Goldenrod	4	-1			S5										√	√	√	√	√
Solidago species	Goldenrod species									√	√	√	√	√						
Solidago uliginosa	Bog Goldenrod	9	-5			S5											√			
Sonchus arvensis	Field Sow Thistle	*	1	-1	+							√		√			√			
Sorbus americana	Mountain Ash	8	-1			S5			R					√					√	
Spirodela polyrhiza	Duckweed	4	-5			S5					√		√	√						
Stachys species	Hedge Nettle species															√				
Symphyotrichum lanceolatum	Panicled Aster	3	-3											√	√	√	√	√	√	√
Symphyotrichum lateriflorum	Calico Aster	3	-2												√	√	√	√	√	√
Symphyotrichum novae-angliae	New England Aster	2	-3			S5					√	√		√	√	√	√	√	√	√
Symphyotrichum puniceum	Purple Stemmed Aster	6	-5			S5				√	√		√	√	√	√	√	√	√	√
Taraxacum officinale	Common Dandelion	*	3	-2	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Thelypteris palustris	Marsh Fern	5	-4							√	√	√	√		√	√	√	√	√	√
Thuja occidentalis	Eastern White Cedar	4	-3			S5				√	√	√	√	√	√	√	√	√	√	√
Tiarella cordifolia	Foam Flower	6	1			S5					√			√	√				√	√
Tilia americana	Basswood	4	3			S5													√	√
Toxicodendron radicans ssp. negundo	Poison Ivy	5	-1							√	√		√		√	√		√		√
Toxicodendron rydbergii	Western Poison-ivy	0	0			S5											√		√	
Trientalis borealis	Starflower	6	-1							√	√		√		√	√	√		√	√
Trifolium hybridum	Alsike Clover	*	1	-1	+					√				√	√		√			
Trifolium pratense	Red Clover	*	2	-2	+	SE5						√								
Trifolium repens	White Clover	*	2	-1	+	SE5								√						
Trillium sp.	Trillium species																√	√		
Tsuga canadensis	Eastern Hemlock	7	3			S5				√	√	√	√	√	√	√	√	√	√	√
Tussilago farfara	Coltsfoot	*	3	-2	+	SE5				√	√	√	√	√	√	√	√	√	√	√
Typha angustifolia	Narrow-leaved Cattail	3	-5			S5								√	√		√	√	√	
Typha latifolia	Common Cattail	3	-5			S5				√	√	√	√	√			√			√
Ulmus americana	White Elm	3	-2			S5				√	√	√	√	√	√	√	√	√	√	√
Urtica dioica ssp. gracilis	American Stinging Nettle	2	-1			S5											√			
Verbascum thapsus	Common Mullein	*	5	-2	+	SE5											√			
Veronica americana	American Brooklime	6	-5			S5										√				
Veronica anagallis-aquatica	Water Speedwell	*	-5	-1	+	SE5				√					√	√				√
Veronica officinalis	Common Speedwell	*	5	-2	+	SE5						√	√		√	√	√		√	
Veronica persica	Bird's-eye Speedwell	*	5	-1	+	SE4										√				
Veronica scutellata	Marsh Speedwell	7	-5			S5				√		√							√	

SCIENTIFIC NAME	COMMON NAME	CC	CW	Weed	+	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	NRSI										
										2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Veronica species	Speedwell species										√	√	√	√						
Viburnum trilobum	High-bush Cranberry	5	-3			S5				√			√	√	√		√	√		√
Viburnum opulus	Guelder-rose	*	0	-1	+	SE4										√	√		√	√
Viola species	Violet Species														√					
Vitis riparia	Riverbank Grape	0	-2			S5				√	√	√	√	√	√	√	√	√	√	√
Waldsteinia fragarioides	Barren Strawberry	5	5			S5					√			√	√					
Total					**44**				**13**	**96**	**109**	**108**	**117**	**123**	**138**	**147**	**146**	**135**	**141**	**127**

[1]MNRF 2016a; [2]COSEWIC 2016; [3]MNRF 2016b, [4]Dougan & Associates 2009

LEGEND	
Floristic Information	
CC	Coefficient of Conservatism
CW	Coefficient of Wetness
Weed	Weediness Index
+	non-native species
SRANK	
S3	Vulnerable
S4	Apparently Secure
S5	Secure
?	Uncertainty about rank
SE	Exotic species
Wellington Status	
R	Rare

APPENDIX II

Herbaceous Species Observed by Plot 2016

Appendix II. Vegetation Species Observed by Plot (2016)

* Frequency is the percent chance the species is found in the 5 subplots. E.g. If the species was found in only one subplot, its frequency is 20%. If it was found in 4 subplots, its frequency is 80%.

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)*
Vegetation Plot 001		**MAMM1-3**	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					
1	*Carex lacustris*	Lake Sedge	5	-5	0		20	100
	Equisetum arvense	Field Horsetail	0	0	0	3	1	60
	Impatiens capensis	Spotted Jewelweed	4	-3	0	63	15	100
	Ranunculus abortivus	Kidney-leaf Buttercup	2	-2	0	1	1	20
	Epilobium hirsutum	Hairy Willow-Herb	*	-4	-2	1	1	20
	Scutellaria galericulata	Common Skullcap	6	-5	0	12	5	20
	Galium palustre	Marsh Bedstraw	5	-5	0	8	0.5	60
	Poa spp.	Grass species					2	20
	Carex spp.	Sedge species					1	60
	Cicuta bulbifera	Bulbous Water-hemlock	5	-5	0	6	2	60
	Solidago canadensis	Canada Goldenrod	1	3	0	1	1	20
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	2	2	40
	Taraxacum officinale	Common Dandelion	*	3	-2	1	1	20
	Lycopus americanus	American Water-horehound	4	-5	0	3	0.5	80
	Poa pratensis	Kentucky Blue Grass	0	1	0		0.1	20
2	*Carex lacustris*	Lake Sedge	5	-5	0		80	100
	Impatiens capensis	Spotted Jewelweed	4	-3	0	6	1	100
	Lycopus americanus	American Water-horehound	4	-5	0	16	3	80
	Galium palustre	Marsh Bedstraw	5	-5	0	9	1	60
	Carex spp.	Sedge species					5	60
	Cicuta bulbifera	Bulbous Water-hemlock	5	-5	0	2	0.5	60
3	*Carex lacustris*	Lake Sedge	5	-5	0		80	100
	Impatiens capensis	Spotted Jewelweed	4	-3	0	6	1	100
	Lycopus americanus	American Water-horehound	4	-5	0	6	1	80
	Galium palustre	Marsh Bedstraw	5	-5	0	5	1	60
4	*Carex lacustris*	Lake Sedge	5	-5	0		95	100
	Impatiens capensis	Spotted Jewelweed	4	-3	0	12	3	100
	Equisetum arvense	Field Horsetail	0	0	0	2	2	60
	Galium aparine	Cleavers	4	3	0	1	0.1	20
5	*Carex lacustris*	Lake Sedge	5	-5	0		20	100
	Carex spp.	Sedge species					60	60
	Impatiens capensis	Spotted Jewelweed	4	-3	0	65	20	100
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	3	3	40
	Cicuta bulbifera	Bulbous Water-hemlock	5	-5	0	5	3	60
	Equisetum arvense	Field Horsetail	0	0	0	2	2	60
	Lycopus americanus	American Water-horehound	4	-5	0	1	0.1	80

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 002		**SWCO1-2**	**White Cedar - Conifer Organic Coniferous Swamp**					
1	*Caltha palustris*	Marsh Marigold	5	-5	0	10	30	60
	Circaea quadrisulcata	Enchanter's Nightshade	3	3	0	4	1	40
	Lycopus americanus	American Water-horehound	4	-5	0	4	0.5	20
	Solidago altissima	Tall Goldenrod	1	3	0	1	1	60
	Geum var	Avens species				1	2	60
2	*Caltha palustris*	Marsh Marigold	5	-5	0	5	20	60
	Impatiens capensis	Spotted Jewelweed	4	-3	0	21	4	80
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	4	20	20
	Geum var	Avens species				1	0.5	60
3	*Impatiens capensis*	Spotted Jewelweed	4	-3	0	42	20	80
	Taraxacum officinale	Common Dandelion	*	3	-2	1	1	40
	Eupatorium maculatum	Spotted Joe-Pye Weed	3	-5		1	1	20
	Glyceria striata	Fowl Manna grass	3	-5	0	4	1	20
4	*Impatiens capensis*	Spotted Jewelweed	4	-3	0	48	20	80
	Solidago altissima	Tall Goldenrod	1	3	0	4	5	60
	Taraxacum officinale	Common Dandelion	*	3	-2	1	1	40
5	*Caltha palustris*	Marsh Marigold	5	-5	0	8	15	60
	Circaea quadrisulcata	Enchanter's Nightshade	3	3	0	4	0.5	40
	Impatiens capensis	Spotted Jewelweed	4	-3	0	47	20	80
	Solidago altissima	Tall Goldenrod	1	3	0	1	1	60
	Geum var	Avens species				1	0.5	60

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 003		**FODM6**	**Fresh-Moist Sugar Maple Deciduous Forest**					
1	*Matteuccia struthiopteris*	Ostrich Fern	5	-3	0	6	10	100
	Solidago flexicaulis	Zig-zag Goldenrod	6	3	0	15	25	20
	Glyceria striata	Fowl Manna grass	3	-5	0		1	20
2	*Matteuccia struthiopteris*	Ostrich Fern	5	-3	0	5	50	100
	Arisaema triphyllum	Jack-in-the-pulpit	5	-2	0	3	2	20
3	*Matteuccia struthiopteris*	Ostrich Fern	5	-3	0	6	20	100
4	*Matteuccia struthiopteris*	Ostrich Fern	5	-3	0	6	25	100
5	*Matteuccia struthiopteris*	Ostrich Fern	5	-3	0	2	10	100

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 004		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1		No vegetation						
2	*Dryopteris carthusiana*	Spinulose Wood Fern	5	-2	0	2	0.5	60
3	*Onoclea sensibilis*	Sensitive Fern	4	-3	0	10	10	40
	Thelypteris palustris	Marsh Fern	5	-4	0	4	3	40
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	2	1	60
	Dryopteris cristata	Crested Wood Fern	7	-5	0	3	1	20
4	*Onoclea sensibilis*	Sensitive Fern	4	-3	0	2	3	40
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	2	1	60
	Thelypteris palustris	Marsh Fern	5	-4	0	3	2	40
	Carex stipata	Awl-fruited Sedge	3	-5	0		30	20
	Leersia oryzoides	Rice Cutgrass	3	-5	0		10	20
	Cicuta maculata	Spotted Water Hemlock	6	-5	0	22	10	20
	Galium palustre	Marsh Bedstraw	5	-5	0	10	0.5	20
	Carex leptalea	Bristle-stalked Sedge	8	-5	0		1	20
	Poa palustris	Fowl Meadow Grass	5	-4	0		2	20
	Brachyelytrum erectum	Bearded Shorthusk	7	5			0.5	20
	Lycopus uniflorus	Northern Bugleweed	5	-5	0	6	2	20
	Sium suave	Water Parsnip	4	-5	0	1	1	20
	Equisetum pratense	Meadow Horsetail	8	-3	0		0.5	20
5		No vegetation						

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 005		**FOMM6**	**Fresh-Moist White Cedar Coniferous Forest**					
1		No vegetation						
2		No vegetation						
3		No vegetation						
4	*Equisetum pratense*	Meadow Horsetail	8	-3	0	1	0.5	20
5		No vegetation						

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 006		**MAMM1-3**	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					
1	*Asclepias syriaca*	Common Milkweed	0	5	0	2	5	20
	Tussilago farfara	Coltsfoot	*	3	-2	25	90	100
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	3	5	100
	Festuca arundinacea	Tall Fescue	*	2	-1		1	100
	Solidago canadensis	Canada Goldenrod	1	3	0	16	15	100
	Geum aleppicum	Yellow Avens	2	-1	0	2	3	60
	Bromus inermis ssp. inermis	Smooth Brome	*	5	-3		3	40
2	*Dactylis glomerata*	Orchard Grass	*	3	-1		2	60
	Symphyotrichum novae-angliae	New England Aster	2	-3	0	1	3	60
	Solidago canadensis	Canada Goldenrod	1	3	0	20	30	100
	Solidago altissima	Tall Goldenrod	1	3	0	1	1	60
	Euthamia graminifolia	Grass-leaved Goldenrod	2	-2	0	3	5	20
	Tussilago farfara	Coltsfoot	*	3	-2	21	40	100
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	7	4	100
	Festuca arundinacea	Tall Fescue	*	2	-1		4	100
	Juncus tenuis	Path Rush	0	0	0		1	60

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 006		**MAMM1-3**	**Reed-canary Grass Graminoid Mineral Meadow Marsh**					
3	*Symphyotrichum lanceolatum*	Panicled Aster	3	-3	0	5	3	100
	Juncus tenuis	Path Rush	0	0	0		2	60
	Solidago altissima	Tall Goldenrod	1	3	0	1	1	60
	Solidago canadensis	Canada Goldenrod	1	3	0	13	12	100
	Euthamia graminifolia	Flat-topped bushy Goldenrod	2	-2	0	8	8	20
	Agrostis stolonifera	Redtop	0	-3	0		1	40
	Tussilago farfara	Coltsfoot	*	3	-2	23	20	100
	Dactylis glomerata	Orchard Grass	*	3	-1		6	60
	Symphyotrichum novae-angliae	New England Aster	2	-3	0	1	2	60
	Festuca arundinacea	Tall Fescue	*	2	-1		4	100
4	*Symphyotrichum lanceolatum*	Panicled Aster	3	-3	0	8	10	100
	Lotus corniculatus	Bird's-foot Trefoil	*	1	-2	4	15	20
	Tussilago farfara	Coltsfoot	*	3	-2	19	50	100
	Solidago canadensis	Canada Goldenrod	1	3	0	7	9	100
	Geum aleppicum	Yellow Avens	2	-1	0	3	3	60
	Festuca arundinacea	Tall Fescue	*	2	-1		4	100
	Dactylis glomerata	Orchard Grass	*	3	-1		2	60
5	*Symphyotrichum novae-angliae*	New England Aster	2	-3	0	4	6	60
	Solidago rugosa	Rough-stemmed Goldenrod	4	-1	0	1	1	20
	Agrostis stolonifera	Redtop	0	-3	0		3	40
	Tussilago farfara	Coltsfoot	*	3	-2	15	20	100
	Juncus tenuis	Path Rush	0	0	0		3	60
	Festuca arundinacea	Tall Fescue	*	2	-1		3	100
	Solidago canadensis	Canada Goldenrod	1	3	0	9	7	100
	Geum aleppicum	Yellow Avens	2	-1	0	3	2	60
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	1	1	100
	Bromus inermis ssp. inermis	Smooth Brome	*	5	-3		10	40
	Solidago altissima	Tall Goldenrod	1	3	0	1	1	60

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 007		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1	*Cicuta maculata*	Spotted Water Hemlock	6	-5	0	1	2	40
	Scutellaria lateriflora	Mad-dog Skullcap	5	-5	0	2	1	40
2	*Cicuta maculata*	Spotted Water Hemlock	6	-5	0		10	40
	Scutellaria lateriflora	Mad-dog Skullcap	5	-5	0	3	0.5	40
3	*Aralia nudicaulis*	Wild Sarsaparilla	4	3	0	5	7	60
	Matteuccia struthiopteris	Ostrich Fern	5	-3	0	1	1	20
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	3	1	40
	Maianthemum canadense	Canada Mayflower	5	0	0	9	1	60
	Impatiens capensis	Spotted Jewelweed	4	-3	0	1	<0.5	20
	Trientalis borealis	Starflower	6	-1	0	2	<0.5	40
4	*Aralia nudicaulis*	Wild Sarsaparilla	4	3	0	3	4	60
	Carex laxiflora	Loose-flowered Sedge	5	0	0	3	2	40
	Trientalis borealis	Starflower	6	-1	0	15	0.5	40
	Maianthemum canadense	Canada Mayflower	5	0	0	3	0.5	60
	Dryopteris carthusiana	Spinulose Wood Fern	5	-2	0	3	2	40
5	*Aralia nudicaulis*	Wild Sarsaparilla	4	3	0	8	50	60
	Maianthemum canadense	Canada Mayflower	5	0	0	10	1	60
	Carex laxiflora	Loose-flowered Sedge	5	0	0	18	10	40
	Prunella vulgaris ssp. lanceolata	Common Heal-all	5	5	0	6	1	20
	Equisetum pratense	Meadow Horsetail	8	-3	0	1	0.5	20
	Cystopteris bulbifera	Bublet fern	5	-2	0	1	0.5	20
	Polygonatum pubescens	Hairy Solomon's Seal	5	5	0	2	1	20

Sub plot #	**Scientific Name**	**Common Name**	**CC**	**CW**	**Weed**	**Number/m^2**	**Cover (%)/m^2**	**Frequency (%)**
Vegetation Plot 008		**SWMM1-1**	**White Cedar - Hardwood Mineral Mixed Swamp**					
1	*Tussilago farfara*	Coltsfoot	*	3	-2	23	40	60
	Mentha arvensis	Common Mint	3	-3	0	9	0.5	40
	Solidago canadensis	Canada Goldenrod	1	3	0	8	5	40
	Leersia oryzoides	Rice Cutgrass	3	-5	0		1	20
2	*Taraxacum officinale*	Common Dandelion	*	3	-2	1	0.5	20
3	*Tussilago farfara*	Coltsfoot	*	3	-2	6	7	60
	Solidago canadensis	Canada Goldenrod	1	3	0	1	0.5	40
4		No vegetation						
5	*Tussilago farfara*	Coltsfoot	*	3	-2	9	12.5	60
	Ranunculus repens	Creeping Buttercup	0	-1	-1	95	85	20
	Nasturtium officinale	Watercress	*	-5	-1	5	1	20
	Veronica anagallis-aquatica	Water Speedwell	*	-5	-1	1	0.5	20
	Mentha arvensis	Common Mint	3	-3	0	4	1	40

Sub plot #	**Scientific Name**	**Common Name**	**CC**	**CW**	**Weed**	**Number/m^2**	**Cover (%)/m^2**	**Frequency (%)**
Vegetation Plot 009		**MASM1-1**	**Cattail Mineral Shallow Marsh**					
1	*Phalaris arundinacea*	Reed Canary Grass	0	-4	0		99	100
	Typha latifolia	Broad-leaved Cattail	3	-5	0	1	1	40
2	*Phalaris arundinacea*	Reed Canary Grass	0	-4	0		98	100
	Typha latifolia	Broad-leaved Cattail	3	-5	0	2	2	40
3	*Phalaris arundinacea*	Reed Canary Grass	0	-4	0		99	100
	Solanum dulcamara	Bittersweet Nightshade	*	0	-2	1	1	20
4	*Phalaris arundinacea*	Reed Canary Grass	0	-4	0		99	100
5	*Equisetum arvense*	Field Horsetail	0	0	0	1	1	20
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		99	100

Sub plot #	**Scientific Name**	**Common Name**	**CC**	**CW**	**Weed**	**Number/m^2**	**Cover (%)/m^2**	**Frequency (%)**
Vegetation Plot 016		**SWDM3-2**	**Silver Maple Mineral Deciduous Swamp**					
1	Onoclea sensibilis	Sensitive Fern	4	-3	0	1	1	20
	Thelypteris palustris	Marsh Fern	5	-4	0	4	1	40
2	*Thelypteris palustris*	Marsh Fern	5	-4	0	3	2	40
	Geum laciniatum	Rough Avens	4	-3	0	1	1	20
3		No vegetation						
4	Carex lupulina	Hop Sedge	6	-5	0		1	20
	Phalaris arundinacea	Reed Canary Grass	0	-4	0		4	20
	Mentha arvensis	Common Mint	3	-3	0	1	<0.5	20
5		No vegetation						

Sub plot #	**Scientific Name**	**Common Name**	**CC**	**CW**	**Weed**	**Number/m^2**	**Cover (%)/m^2**	**Frequency (%)**
Vegetation Plot 018		**SWDO2-2**	**Silver Maple Organic Deciduous Swamp**					
1	*Glyceria striata*	Fowl Manna grass	3	-5	0		30	60
	Caltha palustris	Marsh Marigold	5	-5	0	12	25	60
	Solidago gigantea	Late Goldenrod	4	-3	0	9	7	40
	Symphyotrichum puniceum	Purple-stemmed Aster	6	-5	0	1	1	40
	Onoclea sensibilis	Sensitive Fern	4	-3	0	1	1	80
2	*Onoclea sensibilis*	Sensitive Fern	4	-3	0	8	15	80
	Equisetum pratense	Meadow Horsetail	8	-3	0	3	2	80
	Caltha palustris	Marsh Marigold	5	-5	0	25	25	60
	Symphyotrichum puniceum	Purple-stemmed Aster	6	-5	0	12	5	40
3	*Caltha palustris*	Marsh Marigold	5	-5	0	20	25	60
	Equisetum pratense	Meadow Horsetail	8	-3	0	1	1	80
	Mentha arvensis	Common Mint	3	-3	0	1	1	40
4	*Onoclea sensibilis*	Sensitive Fern	4	-3	0	19	55	80
	Solidago gigantea	Late Goldenrod	4	-3	0	10	15	40
	Glyceria striata	Fowl Manna grass	3	-5	0		50	60
	Mentha arvensis	Common Mint	3	-3	0	5	3	40
	Equisetum pratense	Meadow Horsetail	8	-3	0	6	4	80
	Polygonatum pubescens	Hairy Solomon's Seal	5	5	0	2	1	40
	Dryopteris cristata	Crested Shield Fern	7	-5	0	1	0.5	20

Sub plot #	Scientific Name	Common Name	CC	CW	Weed	Number/m^2	Cover (%)/m^2	Frequency (%)
Vegetation Plot 018		**SWDO2-2**	**Silver Maple Organic Deciduous Swamp**					
5	*Polygonatum pubescens*	Hairy Solomon's Seal	5	5	0	3	3	40
	Onoclea sensibilis	Sensitive Fern	4	-3	0	10	40	80
	Glyceria striata	Fowl Manna grass	3	-5	0		15	60
	Symphyotrichum lanceolatum	Panicled Aster	3	-3	0	12	5	20
	Equisetum pratense	Meadow Horsetail	8	-3	0	4	2	80
	Solidago rugosa	Rough-stemmed Goldenrod	4	-1	0	3	2	20
	Cicuta maculata	Spotted Water Hemlock	6	-5	0	2	15	20
	Lycopus uniflorus	Northern Bugleweed	5	-5	0	13	5	20

APPENDIX III

Herbaceous Species Observed by Subplot 2006 - 2016

Appendix III. Herbaceous Species Observed by Sub-Plot (2006 - 2016)

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
VEG-001	1	*Asclepias incarnata*	Swamp Milkweed								√	√		
		Calamagrostis canadensis	Canada Blue-joint		√	√	√	√	√		√	√		
		Carex aquatilis	Water Sedge				√		√	√	√	√		
		Carex lacustris	Lake Sedge	√									√	√
		Carex stipata	Awl-fruited Sedge			√		√						
		Carex stricta	Tussock Sedge										√	
		Carex sp.	Sedge species											√
		Cicuta bulbifera	Bulbous Water-hemlock						√					√
		Cirsium arvense	Canada Thistle	√										
		Epilobium hirsutum	Hairy Willow-Herb											√
		Epilobium species	Willow-Herb species								√	√		
		Equisetum arvense	Field Horsetail		√	√					√	√	√	√
		Equisetum pratense	Meadow Horsetail	√						√				
		Galium palustre	Marsh Bedstraw								√	√		√
		Impatiens capensis	Spotted Jewelweed		√	√	√	√	√	√	√	√	√	√
		Lycopus americanus	American Water-horehound											√
		Lycopus uniflorus	Northern Bugleweed					√	√				√	
		Lysimachia thrysiflora	Tufted Loosestrife					√	√				√	
		Phalaris arundinacea	Reed Canary Grass							√				
		Poa palustris	Fowl Meadow Grass								√	√		
		Poa pratensis	Kentucky Blue Grass											√
			Grass species	√										√
		Ranunculus abortivus	Kidney-leaf Buttercup											√
		Scutellaria galericulata	Common Skullcap							√				√
		Solidago canadensis	Canada Goldenrod	√										√
		Solidago sp.	Goldenrod species			√								
		Symphyotrichum lanceolatum	Panicled Aster							√			√	√
		Symphyotrichum novae-angliae	New England Aster							√				
		Symphyotrichum sp.	Aster species		√	√	√							
		Taraxacum officinale	Common Dandelion											√
		Veronica sp.	Speedwell species				√							
	2	*Asclepias incarnata*	Swamp Milkweed								√	√		
		Calamagrostis canadensis	Canada Blue-joint	√	√									
		Carex aquatilis	Water Sedge				√		√	√	√	√		
		Carex lacustris	Lake Sedge			√	√							√
		Carex stipata	Awl-fruited Sedge	√	√									
		Carex utriculata	Beaked Sedge		√									
		Carex sp.	Sedge species											√
		Cicuta bulbifera	Bulbous Water-hemlock					√	√	√			√	√
		Dryopteris cristata	Crested Wood Fern										√	
		Epilobium hirsutum	Hairy Willow-Herb							√	√	√		
		Epilobium leptophyllum	Narrow-leaved Willow-herb					√						
		Equisetum arvense	Field Horsetail		√						√	√		
		Equisetum pratense	Meadow Horsetail	√						√				
		Galium palustre	Marsh Bedstraw			√		√			√	√		√
		Impatiens capensis	Spotted Jewelweed	√	√	√		√		√	√	√	√	√
		Juncus sp.	Rush species	√										
		Lemna sp.	Duckweed species				√							
		Lycopus americanus	American Water-horehound											√
		Lycopus uniflorus	Northern Bugleweed			√		√	√					
		Lysimachia thrysiflora	Tufted Loosestrife					√		√				
		Lythrum salicaria	Purple Loosestrife							√			√	
		Phalaris arundinacea	Reed Canary Grass						√	√				
			Grass species	√				√						
		Sium suave	Water Parsnip								√	√		
		Solanum dulcamara	Bittersweet Nightshade	√										
		Solidago canadensis	Canada Goldenrod	√									√	
		Symphyotrichum lanceolatum	Panicled Aster										√	
	3	*Bidens frondosa*	Devil's Beggarticks							√				
		Calamagrostis canadensis	Canada Blue-joint	√	√									
		Carex aquatilis	Water Sedge						√		√	√		
		Carex lacustris	Lake Sedge	√		√	√				√	√	√	√
		Carex stipata	Awl-fruited Sedge	√										
		Carex utriculata	Beaked Sedge		√									
		Carex vulpinoidea	Fox Sedge								√	√		
		Cicuta bulbifera	Bulbous Water-hemlock							√				
		Cirsium sp.	Thistle species							√				
		Epilobium hirsutum	Hairy Willow-Herb							√				
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail	√										
		Galium palustre	Marsh Bedstraw							√	√	√		√
		Impatiens capensis	Spotted Jewelweed	√	√	√				√	√	√		√
		Lycopus americanus	American Water-horehound								√	√		√
		Lycopus uniflorus	Northern Bugleweed		√			√		√			√	
		Lysimachia terrestris	Swamp Candles							√				
		Lysimachia thrysiflora	Tufted Loosestrife		√									
		Phalaris arundinacea	Reed Canary Grass					√	√	√				
			Grass species	√										
		Scutellaria galericulata	Common Skullcap							√				
		Sium suave	Water Parsnip		√						√	√		
		Solidago canadensis	Canada Goldenrod	√							√	√	√	
		Solidago sp.	Goldenrod species				√							
		Spirodela polyrhiza	Duckweed					√						
		Symphyotrichum lanceolatum	Panicled Aster							√				
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√		
		Symphyotrichum sp.	Aster species				√							
	4	*Asclepias incarnata*	Swamp Milkweed		√									
		Bidens frondosa	Devil's Beggarticks							√				
		Calamagrostis canadensis	Canada Blue-joint	√	√									
		Carex aquatilis	Water Sedge							√	√	√		
		Carex lacustris	Lake Sedge			√	√	√	√		√	√	√	√
		Carex stipata	Awl-fruited Sedge	√	√									
		Cicuta bulbifera	Bulbous Water-hemlock							√				
		Dryopteris cristata	Crested Wood Fern								√	√		
		Epilobium hirsutum	Hairy Willow-Herb							√				
		Equisetum arvense	Field Horsetail						√					√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Galium aparine	Cleavers											√
		Galium palustre	Marsh Bedstraw					√		√	√	√		
		Impatiens capensis	Spotted Jewelweed	√	√			√		√	√	√	√	√
		Leersia oryzoides	Rice Cutgrass	√										
		Lycopus uniflorus	Northern Bugleweed		√			√	√	√				
		Lysimachia terrestris	Swamp Candles								√	√		
		Lysimachia thrysiflora	Tufted Loosestrife						√					
		Lythraceae	Loosestrife species											
		Scutellaria galericulata	Common Skullcap	√						√				
		Sium suave	Water Parsnip			√		√						
		Spirodela polyrhiza	Duckweed					√						
		Symphyotrichum lanceolatum	Panicled Aster								√	√		
		Symphyotrichum novae-angliae	New England Aster							√				
	5	*Asclepias incarnata*	Swamp Milkweed								√	√		
		Calamagrostis canadensis	Canada Blue-joint	√	√	√	√	√	√					
		Carex aquatilis	Water Sedge				√			√	√	√		
		Carex lacustris	Lake Sedge		√				√				√	√
		Carex stipata	Awl-fruited Sedge	√	√	√	√	√	√					
		Carex stricta	Stiff Sedge		√								√	
		carex sp.	Sedge species											√
		Cicuta bulbifera	Bulbous Water-hemlock										√	√
		Cirsium arvense	Canada Thistle	√										
		Epilobium hirsutum	Hairy Willow-Herb										√	
		Equisetum arvense	Field Horsetail		√	√					√	√	√	√
		Equisetum palustre	Marsh Horsetail						√					
		Impatiens capensis	Spotted Jewelweed		√	√	√	√	√	√	√	√	√	√
		Lycopus americanus	American Water-horehound								√	√	√	√
		Lysimachia terrestris	Swamp Candles							√				
		Lysimachia thrysiflora	Tufted Loosestrife					√	√					
		Phalaris arundinacea	Reed Canary Grass							√	√	√		
		Sium suave	Water Parsnip								√	√		
		Solidago altissima	Tall Goldenrod							√				
		Solidago canadensis	Canada Goldenrod	√									√	
		Solidago sp.	Goldenrod species		√									
		Symphyotrichum lanceolatum	Panicled Aster							√				√
		Symphyotrichum sp.	Aster species		√									
		Taraxacum officinale	Common Dandelion										√	
VEG-002	1	*Caltha palustris*	Marsh Marigold	√		√	√	√	√	√	√	√	√	√
		Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade								√	√	√	
		Circaea quadrisulcata	Enchanter's Nightshade							√				√
		Cirsium sp.	Thistle species							√	√	√		
		Epilobium hirsutum	Hairy Willow-Herb							√	√	√		
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum palustre	Marsh Horsetail		√			√						
		Geum sp.	Avens species											√
		Impatiens capensis	Spotted Jewelweed										√	
		Lycopus americanus	American Water-horehound											√
		Lycopus uniflorus	Northern Bugleweed					√	√	√				
		Scutellaria galericulata	Common Skullcap							√				
		Solidago altissima	Tall Goldenrod											√
		Solidago canadensis	Canada Goldenrod								√	√		
		Symphyotrichum novae-angliae	New England Aster								√	√		
		Symphyotrichum sp.	Aster species		√									
	2	*Caltha palustris*	Marsh Marigold	√				√	√				√	√
		Cirsium sp.	Thistle species							√	√	√		
		Cysptopteris tenuis	Mackay's Fragile Fern		√									
		Dryopteris carthusiana	Spinulose Wood Fern								√	√		√
		Epipactis helleborine	Helleborine				√							
		Equisetum pratense	Meadow Horsetail	√				√		√				
		Fragaria vesca	Woodland Strawberry	√										
		Geum sp.	Avens species											√
		Impatiens capensis	Spotted Jewelweed								√	√	√	√
		Lycopus uniflorus	Northern Bugleweed	√										
		Maianthemum canadense	Wild Lily-of-the-Valley	√	√	√	√			√				
		Onoclea sensibilis	Sensitive Fern					√	√					
			Grass species		√									
		Solidago sp.	Goldenrod species		√			√						
		Taraxacum officinale	Common Dandelion		√	√				√				
		Thelypteris palustris	Marsh Fern					√						
	3	*Caltha palustris*	Marsh Marigold	√	√		√	√		√				
		Cirsium muticum	Swamp Thistle								√	√		
		Cirsium sp.	Thistle species							√				
		Epilobium hirsutum	Hairy Willow-Herb							√				
		Equisetum pratense	Meadow Horsetail	√										
		Eupatorium maculatum	Spotted Joe-Pye Weed											√
		Eupatorium perfoliatum	Boneset								√	√		
		Glyceria striata	Fowl Manna Grass										√	√
		Impatiens capensis	Spotted Jewelweed							√	√	√	√	√
		Lycopus uniflorus	Northern Bugleweed	√										
		Mitella nuda	Naked Miterwort							√				
		Pilea pumila	Clearweed								√	√		
		Scutellaria lateriflora	Mad-dog Skullcap							√			√	
		Taraxacum officinale	Common Dandelion										√	√
	4	*Caltha palustris*	Marsh Marigold		√	√		√						
		Epilobium hirsutum	Hairy Willow-Herb							√				
		Erigeron sp.	Fleabane species							√				
		Eupatorium maculatum	Spotted Joe-Pye Weed										√	
		Impatiens capensis	Spotted Jewelweed							√	√	√	√	√
		Maianthemum canadense	Canada Mayflower						√					
			Grass species						√					
		Scutellaria lateriflora	Mad-dog Skullcap							√				
		Solidago altissima	Tall Goldenrod											√
		Solidago canadensis	Canada Goldenrod										√	
		Taraxacum officinale	Common Dandelion							√				√
	5	*Arctium sp.*	Burdock species							√				
		Bidens frondosa	Devil's Beggarticks							√				
		Caltha palustris	Marsh Marigold	√	√	√	√	√	√		√	√	√	√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade										√	
		Circaea quadrisulcata	Enchanter's Nightshade											√
		Cirsium sp.	Thistle species							√		√		
		Dryopteris carthusiana	Spinulose Wood Fern		√									
		Eupatorium perfoliatum	Boneset								√	√		
		Geum sp.	Avens species											√
		Impatiens capensis	Spotted Jewelweed							√	√	√	√	√
		Lycopus americanus	American Water-horehound								√	√		
		Lycopus uniflorus	Northern Bugleweed		√									
		Maianthemum canadense	Canada Mayflower	√		√		√	√					
		Scutellaria lateriflora	Mad-dog Skullcap										√	
		Solidago altissima	Tall Goldenrod											√
		Solidago sp.	Goldenrod species								√	√		
		Taraxacum officinale	Common Dandelion		√				√					
VEG-003	1	*Arisaema triphyllum*	Jack-in-the-pulpit				√	√	√				√	
		Circaea lutetiana ssp. canadensis	Yellowish Enchanter's Nightshade								√	√		
		Circaea quadrisulcata	Enchanter's Nightshade						√					
		Glyceria striata	Fowl Manna Grass											√
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√	√	√
		Solanum dulcamara	Bittersweet Nightshade	√										
		Solidago canadensis	Canada Goldenrod						√					
		Solidago flexicaulis	Zig-zag goldenrod						√					√
		Taraxacum officinale	Common Dandelion						√	√				
		Thelypteris palustris	Marsh Fern			√								
		Trillium sp.	Trillium species								√	√		
	2	*Arisaema triphyllum*	Jack-in-the-pulpit						√					√
		Dryopteris marginalis	Marginal Wood Fern							√				
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√	√	√
		Taraxacum officinale	Common Dandelion							√				
	3	*Arisaema triphyllum*	Jack-in-the-pulpit				√	√		√				
		Circaea quadrisulcata	Enchanter's Nightshade							√				
		Dryopteris cristata	Crested Wood Fern						√					
		Dryopteris marginalis	Marginal Wood Fern				√							
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√		√	√	√	√	√	√
		Taraxacum officinale	Common Dandelion							√				
	4	*Arisaema triphyllum*	Jack-in-the-pulpit				√			√				
		Dryopteris clintoniana	Clinton's Wood Fern		√									
		Dryopteris marginalis	Marginal Wood Fern				√			√				
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√		√
		Onoclea sensibilis	Sensitive Fern										√	
		Taraxacum officinale	Common Dandelion							√				
	5	*Arisaema triphyllum*	Jack-in-the-pulpit				√		√					
		Dryopteris clintoniana	Clinton's Wood Fern		√									
		Matteuccia struthiopteris	American Ostrich Fern	√	√	√	√	√	√	√	√	√	√	√
		Trillium sp.	Trillium species								√	√		
VEG-004	1	*Asclepias incarnata*	Swamp Milkweed										√	
		Dryopteris clintoniana	Clinton's Wood Fern		√									
		Dryopteris cristata	Crested Wood Fern					√					√	
		Galium palustre	Marsh Bedstraw										√	
		Onoclea sensibilis	Sensitive Fern								√	√	√	
		Parthenocissus quinquefolia	Virginia Creeper	√										
	2	*Cicuta maculata*	Spotted Water hemlock		√									
		Circaea quadrisulcata	Enchanter's Nightshade		√			√						
		Cystopteris bulbifera	Bulblet Fern		√									
		Dryopteris carthusiana	Spinulose Wood Fern			√				√	√	√		√
		Dryopteris marginalis	Marginal Wood Fern								√	√		
		Equisetum arvense	Field Horsetail		√									
		Equisetum pratense	Meadow Horsetail	√										
		Galium palustre	Marsh Bedstraw		√									
		Maianthemum canadense	Wild Lily-of-the-Valley			√				√				
		Onoclea sensibilis	Sensitive Fern	√	√	√		√	√	√	√	√		
		Pilea pumila	Clearweed			√								
		Scirpus americanus	Common Three Square		√									
		Scutellaria lateriflora	Mad-dog Skullcap	√									√	
		Thelypteris palustris	Marsh Fern								√	√		
	3	*Asclepias incarnata*	Swamp Milkweed										√	
		Carex aquatilis	Water Sedge								√	√		
		Carex lacustris	Lake Sedge								√	√	√	
		Cystopteris bulbifera	Bulblet Fern		√									
		Dryopteris carthusiana	Spinulose Wood Fern	√				√	√	√				√
		Dryopteris cristata	Crested Wood Fern			√	√	√	√					√
		Dryopteris marginalis	Marginal Wood Fern							√				
		Equisetum arvense	Field Horsetail		√									
		Equisetum pratense	Meadow Horsetail	√			√							
		Galium palustre	Marsh Bedstraw		√									
		Impatiens capensis	Spotted Jewelweed		√									
		Leersia oryzoides	Rice Cutgrass								√	√	√	
		Lysimachia terrestris	Swamp Candles						√					
		Maianthemum canadense	Canada Mayflower				√							
		Onoclea sensibilis	Sensitive Fern	√	√	√	√	√	√	√	√	√	√	√
		Osmunda cinnamomea	Cinnamon Fern										√	
			Grass species	√		√	√	√						
		Scirpus americanus	Common Three Square	√	√									
		Taraxacum officinale	Common Dandelion				√							
		Thelypteris palustris	Marsh Fern	√		√	√			√				√
		Tiarella cordifolia	Foam Flower		√									
	4	*Bidens frondosa*	Devil's Beggarticks										√	
		Brachyelytrum erectum	Bearded Shorthusk											√
		Carex aquatilis	Water Sedge				√			√	√	√	√	
		Carex lacustris	Lake Sedge			√	√	√	√	√	√	√	√	
		Carex leptalea	Bristle-stalked Sedge											√
		Carex stipata	Awl-fruited Sedge											√
		Cicuta maculata	Spotted Water hemlock		√				√					√
		Dryopteris carthusiana	Spinulose Wood Fern	√					√	√				√
		Dryopteris clintoniana	Clinton's Wood Fern		√									
		Dryopteris cristata	Crested Wood Fern			√		√						

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Equisetum arvense	Field Horsetail		√	√								
		Equisetum pratense	Meadow Horsetail	√			√							√
		Eupatorium maculatum	Spotted Joe-Pye Weed	√										
		Galium palustre	Marsh Bedstraw	√	√	√	√	√	√	√				√
		Impatiens capensis	Spotted Jewelweed		√		√	√		√			√	
		Leersia oryzoides	Rice Cutgrass							√				√
		Lycopus uniflorus	Northern Bugleweed	√		√	√	√		√				√
		Lysimachia terrestris	Swamp Candles		√									
		Onoclea sensibilis	Sensitive Fern	√	√	√	√	√		√				
		Parthenocissus quinquefolia	Virginia Creeper	√		√								
		Poa palustris	Fowl Meadow Grass								√	√		√
			Grass species		√	√		√		√				
		Ranunculus sp.	Buttercup species						√					
		Rubus pubescens	Dwarf Raspberry					√						
		Scirpus americanus	Common Three Square	√	√	√								
		Scutellaria galericulata	Common Skullcap			√	√			√	√	√	√	
		Scutellaria lateriflora	Mad-dog Skullcap							√				
		Sium suave	Water Parsnip										√	√
		Solidago rugosa	Rough-stemmed Goldenrod							√				
		Solanum dulcamara	Bittersweet Nightshade			√								
		Symphyotrichum racemosum	Small White Aster					√						
		Taraxacum officinale	Common Dandelion	√										
		Thelypteris noveboracensis	New York Fern		√									
		Thelypteris palustris	Marsh Fern	√		√	√			√				√
		Veronica scutellata	Marsh Speedwell	√				√						
	5	*Dryopteris carthusiana*	Spinulose Wood Fern						√		√	√		
		Onoclea sensibilis	Sensitive Fern						√					√
		Thelypteris palustris	Marsh Fern							√				
VEG-005	1	*Arisaema triphyllum*	Jack-in-the-pulpit		√									
		Athyrium filix-femina	Northeastern Lady Fern		√									
		Equisetum pratense	Meadow Horsetail	√	√		√	√		√				
	2	*Equisetum arvense*	Field Horsetail		√	√		√						
		Equisetum pratense	Meadow Horsetail							√				
		Maianthemum canadense	Wild Lily-of-the-Valley		√	√								
	3	*Equisetum arvense*	Field Horsetail		√						√	√		
		Equisetum pratense	Meadow Horsetail	√				√		√				
		Equisetum pratense	Meadow Horsetail											
	4	*Equisetum arvense*	Field Horsetail		√	√							√	
		Equisetum pratense	Meadow Horsetail	√			√			√				
		Maianthemum canadense	Canada Mayflower				√							
		Carex sp.	Sedge species										√	
			Grass species				√							
		Equisetum pratense	Meadow Horsetail											
VEG-006	1	*Asclepias syriaca*	Common Milkweed											√
		Bromus inermis ssp. inermis	Smooth Brome						√					√
		Calamagrostis canadensis	Canada Blue-joint								√	√		
		Carex blanda	Smooth Sedge								√	√		
		Carex stipata	Awl-fruited Sedge					√						
		Carex vulpinoidea	Fox Sedge		√		√		√	√	√	√		
		Cirsium arvense	Canada Thistle	√	√				√	√				
		Dactylis glomerata	Orchard Grass							√	√	√		
		Daucus carota	Queen Anne's Lace						√					
		Echinochloa crusgalli	Barnyard Grass				√	√						
		Epilobium hirsutum	Hairy Willow-Herb					√			√	√		
		Equisetum arvense	Field Horsetail		√	√	√		√		√	√		
		Equisetum pratense	Meadow Horsetail							√				
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√				
		Festuca arundinacea	Tall Fescue								√	√		√
		Geum aleppicum	Yellow Avens											√
		Juncus effusus	Soft Rush								√	√		
		Juncus tenuis	Path Rush	√					√	√	√	√		
		Lotus corniculatus	Bird's-foot Trefoil		√		√	√						
		Mentha arvensis	Common Mint					√					√	
		Phalaris arundinacea	Reed Canary Grass								√	√		
		Phleum pratense	Timothy							√				
		Poa pratensis	Kentucky Blue Grass			√		√		√	√	√		
			Grass species	√	√									
		Scirpus atrovirens	Dark Green Bulrush						√					
		Solidago altissima	Tall Goldenrod	√					√	√			√	
		Solidago canadensis	Canada Goldenrod	√	√	√	√	√	√		√	√		√
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√	√	√
		Symphyotrichum novae-angliae	New England Aster		√									
		Symphyotrichum puniceum	Purple Stemmed Aster		√								√	
		Taraxacum officinale	Common Dandelion						√		√			
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√	√	√	√	√	√
	2	*Asclepias syriaca*	Common Milkweed										√	
		Bromus inermis ssp. inermis	Smooth Brome						√					
		Calamagrostis canadensis	Canada Blue-joint								√	√	√	
		Carex stipata	Awl-fruited Sedge	√										
		Carex trisperma var. trisperma	Three-seeded Sedge		√									
		Carex vulpinoidea	Fox Sedge				√	√	√	√				
		Cirsium arvense	Canada Thistle	√	√	√	√				√	√		
		Dactylis glomerata	Orchard Grass											√
		Daucus carota	Queen Anne's Lace					√		√				
		Echinochloa crusgalli	Barnyard Grass				√	√						
		Epilobium hirsutum	Hairy Willow-Herb					√	√	√	√	√		
		Equisetum arvense	Field Horsetail		√	√			√		√	√		
		Equisetum pratense	Meadow Horsetail							√				
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√				√
		Festuca arundinacea	Tall Fescue								√	√	√	√
		Galium palustre	Marsh Bedstraw				√							
		Hieracium pratense	King Devil Hawkweed			√								
		Juncus dudleyii	Dudley's Rush										√	
		Juncus tenuis	Path Rush				√	√	√	√	√	√		√
		Lactuca serriola	Prickly Lettuce	√										
		Lotus corniculatus	Bird's-foot Trefoil			√		√		√	√	√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Lycopus americanus	American Water-horehound								√	√		
		Medicago lupulina	Black Medick					√	√		√	√		
		Mentha arvensis	Common Mint			√		√	√	√	√	√		
		Phalaris arundinacea	Reed Canary Grass				√							
		Plantago major	Common Plantain						√					
		Poa pratensis	Kentucky Blue Grass		√	√					√	√		
			Grass species	√										
		Potentilla recta	Sulphur Cinquefoil							√				
		Scirpus atrovirens	Dark Green Bulrush						√	√				
		Solidago altissima	Tall Goldenrod	√						√			√	√
		Solidago canadensis	Canada Goldenrod			√			√		√	√		√
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√	√	√
		Symphyotrichum novae-angliae	New England Aster			√				√				√
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√					
		Taraxacum officinale	Common Dandelion	√	√		√		√	√	√	√		
		Trifolium hybridum	Alsike Clover					√						
		Trifolium repens	White Clover					√						
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√		√	√	√	√
		Waldsteinia fragarioides	Barren Strawberry		√									
	3	*Agrostis stolonifera*	Redtop											√
		Asclepias syriaca	Common Milkweed										√	
		Bromus inermis ssp. inermis	Smooth Brome						√				√	
		Calamagrostis canadensis	Canada Blue-joint								√	√		
		Carex stipata	Awl-fruited Sedge	√										
		Carex stricta	Stiff Sedge			√								
		Carex vulpinoidea	Fox Sedge			√		√			√	√		
		Cirsium arvense	Canada Thistle	√	√					√				
		Dactylis glomerata	Orchard Grass								√	√		√
		Daucus carota	Queen Anne's Lace								√	√		
		Echinochloa crusgalli	Barnyard Grass				√	√						
		Eleocharis smallii	Small's Spike-Rush					√						
		Epilobium hirsutum	Hairy Willow-Herb				√	√			√	√		
		Equisetum arvense	Field Horsetail		√	√	√		√		√	√		
		Equisetum pratense	Meadow Horsetail	√										
		Euthamia graminifolia	Grass-leaved Goldenrod			√	√	√	√					√
		Festuca arundinacea	Tall Fescue								√	√	√	√
		Galium palustre	Marsh Bedstraw						√					
		Geum aleppicum	Yellow Avens						√	√				
		Juncus effusus	Soft Rush								√	√		
		Juncus tenuis	Path Rush				√	√	√	√	√	√		√
		Lotus corniculatus	Bird's-foot Trefoil	√	√	√		√						
		Phalaris arundinacea	Reed Canary Grass				√				√	√		
		Phleum pratense	Timothy					√		√				
		Plantago major	Common Plantain					√						
		Poa palustris	Fowl Meadow Grass					√						
		Poa pratensis	Kentucky Blue Grass							√	√	√		
			Grass species	√	√									
		Scirpus atrovirens	Dark Green Bulrush			√								
		Solidago altissima	Tall Goldenrod	√						√			√	√
		Solidago canadensis	Canada Goldenrod						√		√	√		√
		Symphyotrichum lanceolatum	Panicled Aster			√				√			√	√
		Symphyotrichum novae-angliae	New England Aster							√				√
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√					
		Taraxacum officinale	Common Dandelion		√		√	√		√	√	√		
		Tussilago farfara	Coltsfoot	√	√	√	√		√	√	√	√	√	√
		Typha angustifolia	Narrow-leaved Cattail					√						
		Waldsteinia fragarioides	Barren Strawberry		√									
	4	*Asclepias syriaca*	Common Milkweed										√	
		Bromus inermis ssp. inermis	Smooth Brome						√				√	
		Calamagrostis canadensis	Canada Blue-joint								√	√		
		Carex stipata	Awl-fruited Sedge						√					
		Carex vulpinoidea	Fox Sedge						√	√				
		Cirsium arvense	Canada Thistle	√	√						√	√		
		Dactylis glomerata	Orchard Grass								√	√		√
		Echinochloa crusgalli	Barnyard Grass					√						
		Eleocharis smallii	Small's Spike-Rush		√									
		Epilobium hirsutum	Hairy Willow-Herb				√	√	√	√	√	√		
		Equisetum arvense	Field Horsetail		√			√	√		√	√		
		Equisetum pratense	Meadow Horsetail	√						√				
		Euthamia graminifolia	Grass-leaved Goldenrod			√	√	√	√	√				
		Festuca arundinacea	Tall Fescue								√	√		√
		Galium palustre	Marsh Bedstraw						√					
		Geum aleppicum	Yellow Avens								√	√		√
		Juncus tenuis	Path Rush				√		√		√	√		
		Lactuca serriola	Prickly Lettuce	√										
		Lotus corniculatus	Bird's-foot Trefoil	√	√	√				√	√	√		√
		Medicago lupulina	Black Medick					√			√	√		
		Mentha arvensis	Common Mint							√				
		Phalaris arundinacea	Reed Canary Grass				√							
		Plantago major	Common Plantain					√						
		Poa pratensis	Kentucky Blue Grass					√			√	√		
			Grass species	√	√	√			√					
		Scirpus atrovirens	Dark Green Bulrush						√					
		Solidago altissima	Tall Goldenrod	√									√	
		Solidago canadensis	Canada Goldenrod	√	√						√	√		√
		Symphyotrichum lanceolatum	Panicled Aster							√			√	√
		Symphyotrichum novae-angliae	New England Aster							√				
		Symphyotrichum puniceum	Purple Stemmed Aster		√				√				√	
		Taraxacum officinale	Common Dandelion					√	√	√	√	√	√	
		Trifolium hybridum	Alsike Clover	√				√						
		Tussilago farfara	Coltsfoot	√	√	√	√				√	√	√	√
		Typha angustifolia	Narrow-leaved Cattail					√						
		Typha latifolia	Common Cattail				√							
	5	*Agrostis stolonifera*	Redtop											√
		Bromus inermis ssp. inermis	Smooth Brome						√				√	√
		Calamagrostis canadensis	Canada Blue-joint								√	√		
		Carex blanda	Smooth Sedge								√	√		
		Carex flava	Yellow Sedge								√	√		

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Carex sp.	Sedge species						√					
		Carex stricta	Stiff Sedge				√				√	√		
		Carex trisperma var. trisperma	Three-seeded Sedge		√									
		Carex vulpinoidea	Fox Sedge				√		√		√	√		
		Cerastium fontanum	Mouse-eared Chickweed								√	√		
		Cirsium arvense	Canada Thistle	√		√								
		Dactylis glomerata	Orchard Grass							√	√	√		
		Daucus carota	Queen Anne's Lace							√	√	√		
		Echinochloa crusgalli	Barnyard Grass				√	√						
		Eleocharis smallii	Small's Spike-Rush					√						
		Epilobium hirsutum	Hairy Willow-Herb					√			√	√		
		Epipactis helleborine	Helleborine							√				
		Equisetum arvense	Field Horsetail		√	√	√	√	√		√	√		
		Equisetum pratense	Meadow Horsetail							√				
		Erigeron philadelphicus	Philadelphia Fleabane		√									
		Euthamia graminifolia	Grass-leaved Goldenrod				√	√	√	√	√	√		
		Festuca arundinacea	Tall Fescue								√	√	√	√
		Geum aleppicum	Yellow Avens											√
		Juncus tenuis	Path Rush			√		√	√	√	√	√		√
		Lotus corniculatus	Bird's-foot Trefoil		√		√	√						
		Medicago lupulina	Black Medick						√		√	√		
		Phalaris arundinacea	Reed Canary Grass				√							
		Phleum pratense	Timothy			√								
		Poa pratensis	Kentucky Blue Grass			√		√	√	√	√	√		
			Grass species	√	√				√					
		Scirpus atrovirens	Dark Green Bulrush					√	√					
		Solidago altissima	Tall Goldenrod	√					√	√	√	√	√	√
		Solidago canadensis	Canada Goldenrod	√	√	√			√		√	√		√
		Solidago rugosa	Rough-stemmed Goldenrod											√
		Sonchus arvensis	Field Sow thistle					√						
		Symphyotrichum lanceolatum	Panicled Aster			√				√	√	√		√
		Symphyotrichum novae-angliae	New England Aster		√									√
		Symphyotrichum puniceum	Purple Stemmed Aster		√								√	
		Taraxacum officinale	Common Dandelion					√	√		√	√		
		Tussilago farfara	Coltsfoot	√	√	√	√	√	√	√	√	√	√	√
VEG-007	1	*Aralia nudicaulis*	Wild Sarsaparilla			√	√	√			√	√		
		Arisaema triphyllum	Jack-in-the-pulpit				√							
		Carex laxiflora	Loose-flowered Sedge								√	√		
		Carex sp.	Sedge species						√					
		Cicuta maculata	Spotted Water hemlock	√	√					√			√	√
		Circaea quadrisulcata	Enchanter's Nightshade		√		√							
		Cystopteris bulbifera	Bulblet Fern				√		√					
		Dryopteris carthusiana	Spinulose Wood Fern		√								√	
		Geum sp.	Avens species								√	√		
		Impatiens capensis	Spotted Jewelweed		√					√				
		Impatiens pallida	Pale Jewelweed						√					
		Lycopus americanus	American Water-horehound	√										
		Ranunculus hispidus var caricetorum	Swamp Buttercup	√										
		Scutellaria lateriflora	Mad-dog Skullcap	√										√
		Taraxacum officinale	Common Dandelion		√									
		Thelypteris palustris	Marsh Fern	√										
		Veronica americana	American Brooklime							√				
	2	*Alisma plantago*	Water Plantain			√								
		Aralia nudicaulis	Wild Sarsaparilla				√							
		Arisaema triphyllum	Jack-in-the-pulpit								√	√	√	
		Bidens frondosa	Devil's Beggarticks										√	
		Carex laxiflora	Loose-flowered Sedge								√	√		
		Caltha palustris	Marsh Marigold	√										
		Cicuta maculata	Spotted Water hemlock	√	√		√	√		√	√	√	√	√
		Circaea alpina	Dwarf Enchanter's Nightshade				√							
		Circaea quadrisulcata	Enchanter's Nightshade	√	√				√					
		Cystopteris bulbifera	Bulblet Fern				√		√		√	√	√	
		Dryopteris carthusiana	Spinulose Wood Fern	√				√					√	
		Fragaria vesca	Woodland Strawberry								√	√		
		Hydrocotyle americana	Marsh-Water Pennywort	√			√	√					√	
		Hydrophyllum virginianum	Virginia Waterleaf			√								
		Impatiens capensis	Spotted Jewelweed	√	√	√	√	√		√	√	√	√	
		Lycopus uniflorus	Northern Bugleweed			√	√							
		Lythraceae sp.	Loosestrife species			√								
		Maianthemum canadense	Canada Mayflower	√					√					
		Mitella nuda	Naked Miterwort								√	√		
		Parthenocissus quinquefolia	Virginia Creeper	√										
			Grass species		√									
		Polystichum acrostichoides	Christmas Fern	√										
		Prunella vulgaris ssp. lanceolata	Selfheal								√	√	√	
		Ranunculus hispidus var caricetorum	Swamp Buttercup							√				
		Scutellaria galericulata	Common Skullcap						√					
		Scutellaria lateriflora	Mad-dog Skullcap					√						√
		Stachys sp.	Hedge Nettle species							√				
		Taraxacum officinale	Common Dandelion						√					
		Thelypteris palustris	Marsh Fern	√										
		Trientalis borealis	Starflower	√					√					
		Veronica americana	American Brooklime							√				
		Veronica officinalis	Common Speedwell			√		√						
		Viola sp.	Violet Species						√					
			Fern species						√					
	3	*Aralia nudicaulis*	Wild Sarsaparilla		√	√	√	√	√	√	√	√	√	√
		Arisaema triphyllum	Jack-in-the-pulpit			√	√	√						
		Carex blanda	Smooth Sedge							√				
		Carex gracillima	Graceful Sedge					√						
		Carex laxiflora	Loose-flowered Sedge				√						√	
		Clintonia borealis	Bluebead lily		√			√						
		Cystopteris bulbifera	Bulblet Fern		√					√	√	√		
		Dryopteris carthusiana	Spinulose Wood Fern					√			√	√	√	√
		Dryopteris intermedia	Intermediate Wood Fern										√	
		Dryopteris marginalis	Marginal Wood Fern				√							

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Impatiens capensis	Spotted Jewelweed	√							√	√	√	√
		Impatiens pallida	Pale Jewelweed						√					
		Maianthemum canadense	Canada Mayflower		√			√	√				√	√
		Matteuccia struthiopteris	American Ostrich Fern											√
		Mitella nuda	Naked Miterwort								√	√		
		Osmunda cinnamomea	Cinnamon Fern								√	√		
			Grass species		√									
		Scutellaria galericulata	Common Skullcap								√	√		
		Scutellaria lateriflora	Mad-dog Skullcap										√	
		Taraxacum officinale	Common Dandelion						√					
		Trientalis borealis	Starflower						√		√	√		√
	4	*Aralia nudicaulis*	Wild Sarsaparilla	√	√	√	√	√	√		√	√	√	√
		Arisaema triphyllum	Jack-in-the-pulpit	√		√								
		Carex laxiflora	Loose-flowered Sedge								√	√		√
		Carex pensylvanica	Pennsylvania Sedge										√	
		Carex sp.	Sedge species							√	√	√		
		Cystopteris bulbifera	Bulblet Fern						√		√	√		
		Dryopteris carthusiana	Spinulose Wood Fern	√	√								√	√
		Epipactis helleborine	Helleborine				√	√		√				
		Fragaria virginiana	Wild Strawberry						√					
		Gymnocarpium dryopteris	Oak Fern				√			√				
		Impatiens capensis	Spotted Jewelweed								√	√		
		Impatiens pallida	Pale Jewelweed						√					
		Maianthemum canadense	Wild Lily-of-the-Valley		√		√	√		√			√	√
		Maianthemum stellatum	Star Flowered False Solomon's-seal			√								
			Grass species		√		√		√					
		Prunella vulgaris ssp. lanceolata	Selfheal						√					
		Taraxacum officinale	Common Dandelion					√						
		Thelypteris palustris	Marsh Fern	√										
		Trientalis borealis	Starflower						√		√	√		√
	5	*Aralia nudicaulis*	Wild Sarsaparilla	√	√	√	√	√	√	√	√	√	√	√
		Arisaema triphyllum	Jack-in-the-pulpit		√									
		Carex sp.	Sedge species		√	√		√						
		Carex laxiflora	Loose-flowered Sedge								√	√		√
		Carex gracillima	Graceful Sedge										√	
		Circaea quadrisulcata	Enchanter's Nightshade	√	√									
		Cystopteris bulbifera	Bulblet Fern				√		√		√	√		√
		Dryopteris carthusiana	Spinulose Wood Fern		√			√		√	√	√	√	
		Dryopteris clintoniana	Clinton's Wood Fern		√									
		Dryopteris intermedia	Intermediate Wood Fern										√	
		Epipactis helleborine	Helleborine				√	√						
		Equisetum pratense	Meadow Horsetail											
		Fragaria virginiana	Wild Strawberry						√					
		Glyceria striata	Fowl Manna Grass							√			√	
		Impatiens pallida	Pale Jewelweed						√					
		Maianthemum canadense	Canada Mayflower	√	√	√	√	√	√	√	√	√	√	√
		Maianthemum racemosum	False Solomon's seal		√	√			√					
		Maianthemum stellatum	Star Flowered False Solomon's-seal			√	√	√						
		Polygonatum pubescens	Hairy Solomon's Seal											√
		Prunella vulgaris ssp. lanceolata	Selfheal										√	√
		Taraxacum officinale	Common Dandelion	√						√			√	
		Thelypteris palustris	Marsh Fern	√										
		Tiarella cordifolia	Foam Flower					√					√	
		Trientalis borealis	Starflower		√						√	√		
VEG-008	1	*Bidens frondosa*	Devil's beggarticks								√	√		
		Caltha palustris	Marsh Marigold							√				
		Carex lacustris	Lake Sedge								√	√		
		Carex stipata	Awl-fruited Sedge				√							
		Echinochloa crusgalli	Barnyard Grass				√							
		Eupatorium maculatum	Spotted Joe-Pye Weed				√							
		Galium palustre	Marsh Bedstraw				√	√						
		Geranium robertianum	Herb Robert	√										
		Glyceria striata	Fowl Manna Grass							√	√	√		
		Impatiens capensis	Spotted Jewelweed	√			√	√		√			√	
		Leersia oryzoides	Rice Cutgrass										√	√
		Lobelia siphilitica	Great Lobelia							√				
		Lysimachia nummularia	Moneywort		√									
		Lysimachia thrysiflora	Tufted Loosestrife		√									
		Mentha arvensis	Common Mint				√	√			√	√	√	√
		Mentha X piperita	Pepper Mint							√				
		Nasturtium officinale	Watercress							√	√	√		
		Poa nemoralis	Wood Bluegrass				√							
		Poa palustris	Fowl Meadow Grass					√		√				
			Grass species		√			√						
		Polygonum sp.									√	√		
		Ranunculus acris	Tall Buttercup				√							
		Ranunculus repens	Creeping Buttercup					√		√			√	
		Solidago canadensis	Canada Goldenrod										√	√
		Symphyotrichum puniceum	Purple Stemmed Aster				√	√		√				
		Tussilago farfara	Coltsfoot							√	√	√	√	√
	2	*Dryopteris carthusiana*	Spinulose Wood Fern			√								
		Geranium robertianum	Herb Robert		√	√								
		Solidago canadensis	Canada Goldenrod						√					
		Taraxacum officinale	Common Dandelion				√	√					√	√
	3	*Caltha palustris*	Marsh Marigold						√					
		Cystopteris bulbifera	Bulblet Fern				√				√	√		
		Fragaria vesca	Woodland Strawberry			√								
		Lactuca serriola	Prickly Lettuce				√							
		Leersia oryzoides	Rice Cutgrass						√					
		Mentha X piperita	Pepper Mint							√				
		Nasturtium officinale	Watercress						√					
			Grass species						√					
		Polygonum amphibium	Water Smartweed						√					
		Ranunculus flabellaris	Yellow Water-crowfoot						√					
		Scutellaria galericulata	Common Skullcap						√					
		Solidago canadensis	Canada Goldenrod										√	√
		Taraxacum officinale	Common Dandelion				√		√					

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Tussilago farfara	Coltsfoot				√			√	√	√	√	√
		Veronica anagallis-aquatica	Water Speedwell						√					
	4	*Galium palustre*	Marsh Bedstraw						√					
		Geum laciniatum	Rough Avens						√					
			Grass species		√				√					
		Ranunculus flabellaris	Yellow Water-crowfoot						√					
		Scirpus americanus	Common Three Square	√										
		Solidago canadensis	Canada Goldenrod						√					
		Taraxacum officinale	Common Dandelion	√	√									
		Tussilago farfara	Coltsfoot						√		√	√		
	5	*Caltha palustris*	Marsh Marigold	√		√			√					
		Carex aquatilis	Water Sedge				√							
		Carex lacustris	Lake Sedge			√								
		Galium palustre	Marsh Bedstraw				√							
		Impatiens capensis	Spotted Jewelweed	√	√					√			√	
		Leersia oryzoides	Rice Cutgrass				√							
		Lycopus uniflorus	Northern Bugleweed			√								
		Mentha arvensis	Common Mint	√	√		√	√						√
		Mentha X piperita	Pepper Mint							√				
		Nasturtium officinale	Watercress					√	√	√	√	√	√	√
		Phalaris arundinacea	Reed Canary Grass										√	
		Poa nemoralis	Wood Bluegrass				√							
			Grass species		√			√						
		Ranunculus acris	Tall Buttercup				√							
		Ranunculus flabellaris	Yellow Water-crowfoot			√								
		Ranunculus repens	Creeping Buttercup					√		√	√	√	√	√
		Symphyotrichum lanceolatum var. lanc	Tall White Aster	√										
		Symphyotrichum puniceum	Purple Stemmed Aster				√							
		Taraxacum officinale	Common Dandelion	√				√						
		Tussilago farfara	Coltsfoot		√									√
		Veronica anagallis-aquatica	Water Speedwell						√				√	√
		Veronica officinalis	Common Speedwell			√								
		Waldsteinia fragarioides	Barren Strawberry		√									
VEG-009	1	*Carex stipata*	Awl-fruited Sedge							√				
		Circaea quadrisulcata	Enchanter's Nightshade		√									
		Cirsium arvense	Canada Thistle							√				
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum palustre	Marsh Horsetail		√									
		Equisetum pratense	Meadow Horsetail							√				
		Eupatorium maculatum	Spotted Joe-Pye Weed								√	√	√	
		Galium palustre	Marsh Bedstraw						√					
		Lysimachia ciliata	Fringed Loosestrife			√		√	√					
		Mentha arvensis	Common Mint		√				√	√				
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√	√	√
		Scirpus atrovirens	Dark Green Bulrush							√				
		Symphyotrichum novae-angliae	New England Aster		√			√	√					
		Typha angustifolia	Narrow-leaved Cattail					√	√	√	√	√	√	
		Typha latifolia	Cattail											√
	2	*Carex sp.*	Sedge species			√								
		Carex stipata	Awl-fruited Sedge				√							
		Circaea quadrisulcata	Enchanter's Nightshade		√									
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail							√				
		Mentha arvensis	Common Mint					√	√					
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√	√	√
		Poa palustris	Fowl Meadow Grass										√	
		Symphyotrichum lanceolatum	Panicled Aster										√	
		Typha angustifolia	Narrow-leaved Cattail					√	√	√	√	√		
		Typha latifolia	Common Cattail		√		√						√	√
	3	*Carex stipata*	Awl-fruited Sedge				√							
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum palustre	Marsh Horsetail		√									
		Eupatorium maculatum	Spotted Joe-Pye Weed										√	
		Euthamia graminifolia	Grass-leaved Goldenrod					√						
		Lysimachia ciliata	Fringed Loosestrife			√			√					
		Mentha arvensis	Common Mint				√							
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√	√	√
		Ranunculus acris	Tall Buttercup					√	√					
		Solanum dulcamara	Bittersweet Nightshade											√
		Solidago canadensis	Canada Goldenrod				√	√						
		Sonchus arvensis	Field Sow thistle			√								
		Symphyotrichum lanceolatum	Panicled Aster										√	
		Symphyotrichum novae-angliae	New England Aster						√					
		Symphyotrichum puniceum	Purple Stemmed Aster										√	
		Taraxacum officinale	Common Dandelion				√							
		Tussilago farfara	Coltsfoot				√							
		Typha angustifolia	Narrow-leaved Cattail						√	√	√	√		
		Typha latifolia	Common Cattail		√									
	4	*Arabis glabra*	Tower-mustard			√								
		Carex sp.	Sedge species			√								
		Carex stipata	Awl-fruited Sedge		√		√	√						
		Circaea quadrisulcata	Enchanter's Nightshade		√									
		Eupatorium maculatum	Spotted Joe-Pye Weed								√	√		
		Euthamia graminifolia	Grass-leaved Goldenrod			√		√	√	√				
		Lysimachia ciliata	Fringed Loosestrife			√	√	√		√	√	√	√	
		Mentha arvensis	Common Mint				√	√	√					
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√	√	√
		Poa palustris	Fowl Meadow Grass					√						
		Scutellaria lateriflora	Mad-dog Skullcap					√						
		Solidago canadensis	Canada Goldenrod						√					
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√	√	
		Symphyotrichum novae-angliae	New England Aster						√	√				
		Symphyotrichum puniceum	Purple Stemmed Aster		√									
		Tussilago farfara	Coltsfoot						√					
		Typha angustifolia	Narrow-leaved Cattail							√				
		Typha latifolia	Common Cattail		√		√	√			√	√		
	5	*Equisetum arvense*	Field Horsetail			√							√	√

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Equisetum sp.	Horsetail species						√					
		Galium palustre	Marsh Bedstraw					√						
		Lycopus uniflorus	Northern Bugleweed					√						
		Lysimachia ciliata	Fringed Loosestrife					√						
		Mentha arvensis	Common Mint					√	√		√	√	√	
		Phalaris arundinacea	Reed Canary Grass		√	√	√	√	√	√	√	√	√	√
		Solidago canadensis	Canada Goldenrod								√	√		
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√	√	
		Typha angustifolia	Narrow-leaved Cattail					√	√	√				
		Typha latifolia	Common Cattail				√				√	√	√	
VEG-016	1	*Boehmeria cylindrica*	False Nettle							√				
		Carex lupulina	Hop Sedge							√	√	√		
		Carex sp.	Sedge species						√					
		Cicuta maculata	Spotted Water Hemlock							√				
		Heracleum lanatum	Cow Parsnip							√				
		Onoclea sensibilis	Sensitive Fern						√	√	√	√		√
		Phalaris arundinacea	Reed Canary Grass							√				
		Thelypteris palustris	Marsh Fern						√	√				√
	2	*Boehmeria cylindrica*	False Nettle							√				
		Cicuta maculata	Spotted Water Hemlock							√				
		Impatiens capensis	Spotted Jewelweed										√	
		Geum laciniatum	Rough Avens											√
		Onoclea sensibilis	Sensitive Fern										√	
		Phalaris arundinacea	Reed Canary Grass						√	√				
		Taraxacum officinale	Common Dandelion							√				
		Thelypteris palustris	Marsh Fern						√	√				√
	3	*Cicuta maculata*	Spotted Water Hemlock							√				
		Onoclea sensibilis	Sensitive Fern						√					
		Scutellaria galericulata	Common Skullcap						√					
		Thelypteris palustris	Marsh Fern							√				
	4	*Boehmeria cylindrica*	False Nettle							√				
		Carex lupulina	Hop Sedge											√
		Cicuta maculata	Spotted Water Hemlock							√				
		Impatiens capensis	Spotted Jewelweed							√				
		Mentha arvensis	Common Mint											√
		Onoclea sensibilis	Sensitive Fern						√	√	√			
		Phalaris arundinacea	Reed Canary Grass						√	√	√	√	√	√
		Sium suave	Water Parsnip						√					
	5	*Boehmeria cylindrica*	False Nettle							√				
		Carex lupulina	Hop sedge							√	√	√		
		Carex sp.	Sedge species						√					
		Cicuta maculata	Spotted Water Hemlock							√				
		Onoclea sensibilis	Sensitive Fern							√				
		Phalaris arundinacea	Reed Canary Grass						√					
		Scutellaria galericulata	Common Skullcap						√					
		Thelypteris palustris	Marsh Fern						√	√	√	√		
VEG-018	1	*Aster sp.*	Aster species						√					
		Caltha palustris	Marsh Marigold						√	√	√	√	√	√
		Equisetum pratense	Meadow Horsetail						√	√			√	
		Glyceria striata	Fowl Manna Grass								√	√	√	√
		Lycopus uniflorus	Northern Bugleweed						√					
		Mentha arvensis	Common Mint										√	
		Onoclea sensibilis	Sensitive Fern						√	√			√	√
		Rhus radicans ssp. negundo	Poison Ivy						√					
		Solidago gigantea	Late Goldenrod											√
		Symphyotrichum puniceum	Purple Stemmed Aster										√	√
		Taraxacum officinale	Common Dandelion								√	√		
	2	*Aster sp.*	Aster species						√					
		Caltha palustris	Marsh Marigold						√	√	√	√	√	√
		Daucus carota	Queen Anne's Lace								√	√		
		Echinocystis lobata	Wild Cucumber								√	√		
		Epilobium hirsutum	Hairy Willow-Herb						√					
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail						√				√	√
		Impatiens capensis	Spotted Jewelweed						√	√				
		Lycopus uniflorus	Northern Bugleweed						√					
		Mentha arvensis	Common Mint								√	√		
		Onoclea sensibilis	Sensitive Fern						√	√		√	√	√
		Phalaris arundinacea	Reed Canary Grass						√					
		Solidago canadensis	Canada Goldenrod						√					
		Solidago gigantea	Late Goldenrod						√		√	√		
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√	√	
		Symphyotrichum puniceum	Purple Stemmed Aster											√
		Rhus radicans ssp. negundo	Poison Ivy						√					
	3	*Caltha palustris*	Marsh Marigold						√	√	√	√	√	√
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail						√	√			√	√
		Galium palustre	Marsh Bedstraw						√	√	√	√		
		Glyceria striata	Fowl Manna Grass							√	√	√	√	
		Impatiens capensis	Spotted Jewelweed						√	√				
		Mentha arvensis	Common Mint						√		√	√		√
		Onoclea sensibilis	Sensitive Fern						√	√	√	√	√	
			Grass species						√					
		Symphyotrichum lanceolatum	Panicled Aster								√	√		
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√		
	4	*Caltha palustris*	Marsh Marigold						√	√	√	√	√	
		Dryopteris cristata	Crested Wood Fern											√
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail						√	√			√	√
		Impatiens capensis	Spotted Jewelweed						√	√				
		Galium palustre	Marsh Bedstraw								√	√		
		Glyceria striata	Fowl Manna Grass							√	√	√	√	√
		Maianthemum stellatum	Star Flowered False Solomon's-seal										√	
		Mentha arvensis	Common Mint						√				√	√
		Onoclea sensibilis	Sensitive Fern						√	√	√	√	√	√
			Grass species						√					

Plot #	Sub plot #	Scientific Name	Common Name	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
		Polygonatum pubescens	Hairy Solomon's Seal							√				√
		Solidago gigantea	Late Goldenrod										√	√
	5	*Aralia nudicaulis*	Wild Sarsaparilla			√	√	√			√	√		
		Cicuta maculata	Spotted Water Hemlock							√				√
		Dryopteris carthusiana	Spinulose Wood Fern						√		√	√		
		Dryopteris marginalis	Marginal Wood Fern						√					
		Epilobium hirsutum	Hairy Willow-Herb						√	√				
		Equisetum arvense	Field Horsetail								√	√		
		Equisetum pratense	Meadow Horsetail						√					√
		Glyceria striata	Fowl Manna Grass							√			√	√
		Impatiens capensis	Spotted Jewelweed								√	√		
		Lycopus uniflorus	Northern Bugleweed						√	√	√	√		√
		Maianthemum stellatum	Star Flowered False Solomon's-seal										√	
		Onoclea sensibilis	Sensitive Fern						√	√	√	√	√	√
		Polygonatum pubescens	Hairy Solomon's Seal						√	√	√	√		√
		Rhus radicans ssp. negundo	Poison Ivy						√					
		Solidago altissima	Tall Goldenrod							√				
		Solidago gigantea	Late Goldenrod								√	√		
		Solidago patula	Rough-Leaved Goldenrod						√					
		Solidago rugosa	Rough-stemmed Goldenrod							√	√	√		√
		Symphyotrichum lanceolatum	Panicled Aster							√	√	√	√	√
		Symphyotrichum lateriflorum	Calico Aster						√					
		Symphyotrichum puniceum	Purple Stemmed Aster								√	√		
		Taraxacum officinale	Common Dandelion								√	√		

APPENDIX IV

Shrub Species Observed by Plot 2016

Appendix IV. Shrub Species By Plot (2016)

						Data	
Plot #	**Scientific Name**	**Common Name**	**CC**	**CW**	**Weed**	**Number**	**Cover (%)**
1	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	100	10
	Salix petiolaris	Slender Willow	3	-4	0	20	90
	Salix eriocephala	Heart-leaved Willow	4	-3	0	2	5
	Ribes americanum	Wild Black Currant	4	-3	0	1	0.1
	Rubus idaeus	Red Raspberry	0	-2	0	2	0.1
2	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	29	1
	Rhamnus cathartica	Common Buckthorn	*	3	-3	7	10
	Rubus pubescens	Dwarf Raspberry	4	-4	0	2	0.1
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	96	35
	Vitis riparia	Riverbank Grape	0	-2	0	10	0.2
3	*Cornus alternifolia*	Alternate-leaved Dogwood	6	5	0	8	1
	Rhamnus cathartica	Common Buckthorn	*	3	-3	5	2
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	18	3
4	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	4	0.5
	Rhamnus cathartica	Common Buckthorn	*	3	-3	3	1
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	35	2
	Ribes triste	Swamp Red Currant	6	-5	0	1	0.5
	Vitis riparia	Riverbank Grape	0	-2	0	1	0.5
	Viburnum trilobum	Highbush-cranberry	5	-3	0	1	0.5
5		No shrubs present in plot					
6	*Salix petiolaris*	Slender Willow	3	-4	0	1	2
	Cornus stolonifera	Red-osier Dogwood	2	-3	0	12	5
	Salix eriocephala	Heart-leaved Willow	4	-3	0	1	5
7	*Cornus alternifolia*	Alternate-leaved Dogwood	6	5	0	6	0.5
	Rubus pubescens	Dwarf Raspberry	4	-4	0	25	1
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	10	0.5
8	*Lonicera tatarica*	Tartarian Honeysuckle	*	3	-3	2	3
	Rhamnus cathartica	Common Buckthorn	*	3	-3	25	5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	40	15
	Vitis riparia	Riverbank Grape	0	-2	0	1	1
	Prunus virginiana	Chokecherry	2	1	0	1	1
	Rubus occidentalis	Black Raspberry	2	5	0	1	1
	Cornus amomum	Silky Dogwood	5	-4	0	1	1
	Viburnum opulus	Guelder-rose	*	0	-1	1	1
9	*Rubus idaeus*	Red Raspberry	0	-2	0	6	0.5
	Rhamnus cathartica	Common Buckthorn	*	3	-3	1	0.1
	Solanum dulcamara	Bittersweet Nightshade	*	0	-2	4	1
	Cornus amomum	Silky Dogwood	5	-4	0	15	1
	Rubus occidentalis	Black Raspberry	2	5	0	1	0.1
16	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	5	0.5
	Rhamnus cathartica	Common Buckthorn	*	3	-3	7	0.5
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	6	0.5
	Vitis riparia	Riverbank Grape	0	-2	0	1	0.5
	Parthenocissus vitacea	Woodbine	3	3	0	4	0.5
18	*Solanum dulcamara*	Bittersweet Nightshade	*	0	-2	40	25
	Rhamnus cathartica	Common Buckthorn	*	3	-3	10	2
	Rubus pubescens	Dwarf Raspberry	4	-4	0	30	3
	Rhamnus frangula	Glossy Buckthorn	*	-1	-3	5	1
	Viburnum opulus	Guelder-rose	*	0	-1	1	0.5
	Vitis riparia	Riverbank Grape	0	-2	0	3	5
	Ilex verticillata	Winterberry	5	-4	0	10	5
	Toxicodendron radicans ssp. negundo	Poison Ivy	5	-1	0	100	10
	Parthenocissus vitacea	Woodbine	3	3	0	5	1

APPENDIX V

Shrub Species Observed by Plot 2006 - 2016

Appendix V. Shrub Species by Plot 2006-2016

			Year										
Plot #	**Scientific Name**	**Common Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
1	*Ribes americanum*	Wild Black Currant									√		√
	Ribes triste	Swamp Red Currant						√	√				
	Rubus idaeus	Red Raspberry	√	√			√	√					√
	Salix eriocephala	Heart-leaved Willow					√						√
	Salix petiolaris	Slender Willow	√		√	√	√		√	√	√	√	√
	Sambucus canadensis	Common Elderberry	√										
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√	√	√
	Salix lucida	Shining Willow						√					
	Parthenocissus quinquefolia	Virginia Creeper	√	√									
	Cornus amomum	Silky Dogwood								√	√	√	
2	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√									
	Cornus stolonifera	Red-osier Dogwood					√					√	
	Lonicera tatarica	Tartarian Honeysuckle								√	√		
	Prunus virginiana	Chokecherry										√	
	Rhamnus cathartica	Common Buckthorn	√	√	√	√		√	√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√	√	√
	Ribes americanum	Wild Black Currant	√	√			√	√				√	
	Rubus allegheniensis	Common Blackberry		√									
	Rubus idaeus	Red Raspberry	√										
	Rubus pubescens	Dwarf Raspberry	√	√		√	√	√		√	√	√	√
	Sambucus canadensis	Common Elderberry								√	√		
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√	√	√
	Viburnum trilobum	High-bush cranberry									√	√	
	Vitis riparia	Riverbank Grape						√	√	√	√	√	√
	Parthenocissus quinquefolia	Virginia Creeper	√	√			√						
	Parthenocissus vitacea	Woodbine								√			
3	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√	√	√	√	√	√	√		√	√
	Cornus stolonifera	Red-osier Dogwood					√						
	Rhamnus cathartica	Common Buckthorn	√	√	√	√	√	√	√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√	√	√
	Ribes triste	Swamp Red Currant					√						
	Solanum dulcamara	Bittersweet Nightshade							√			√	
	Viburnum trilobum	High-bush cranberry	√										
	Vitis riparia	Riverbank Grape	√	√									
	Parthenocissus quinquefolia	Virginia Creeper	√	√	√	√	√		√				
	Carpinus caroliniana	Blue Beech							√				
4	*Cornus stolonifera*	Red-osier Dogwood	√	√	√	√	√	√					
	Rhamnus cathartica	Common Buckthorn	√		√		√	√	√	√			√
	Rhamnus frangula	Glossy Buckthorn	√			√	√	√	√	√	√	√	√
	Ribes americanum	Wild Black Currant							√				
	Rubus pubescens	Dwarf Raspberry	√	√		√			√	√	√	√	
	Sambucus canadensis	Common Elderberry					√						
	Ribes triste	Swamp Red Currant											√
	Virbunum trilobum	High-bush cranberry											√
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√	√	√
	Vitis riparia	Riverbank Grape					√				√		√
	Ribes var	Currant species		√									
	Parthenocissus quinquefolia	Virginia Creeper	√	√		√	√	√	√				
	Cornus amomum	Silky Dogwood							√	√	√		
	Parthenocissus vitacea	Woodbine								√	√		
5	*Cornus alternifolia*	Alternate-leaved Dogwood		√									
	Rhamnus cathartica	Common Buckthorn		√		√		√				√	
	Rhamnus frangula	Glossy Buckthorn										√	
6	*Cornus stolonifera*	Red-osier Dogwood	√	√	√	√		√	√	√	√	√	√
	Lonicera tatarica	Tartarian Honeysuckle										√	
	Rhamnus cathartica	Common Buckthorn							√				
	Rhamnus frangula	Glossy Buckthorn										√	
	Salix bebbiana	Bebb's Willow			√			√					
	Salix eriocephala	Heart-leaved Willow							√	√	√		√
	Salix petiolaris	Slender Willow							√	√	√	√	√
	Salix var	Willow species		√				√					
7	*Cornus alternifolia*	Alternate-leaved Dogwood	√	√	√		√		√	√	√	√	√
	Prunus virginiana	Chokecherry								√			
	Rhamnus cathartica	Common Buckthorn				√	√		√	√	√	√	
	Rhamnus frangula	Glossy Buckthorn	√				√	√	√	√	√	√	√
	Ribes americanum	Wild Black Currant			√								
	Rubus pubescens	Dwarf Raspberry	√	√					√	√	√	√	√
	Solanum dulcamara	Bittersweet Nightshade	√	√		√	√	√	√	√		√	
	Viburnum trilobum	High-bush cranberry				√				√			

7	*Hamamelis virginiana*	Witch Hazel			√		√						
	Parthenocissus quinquefolia	Virginia Creeper	√	√	√		√	√	√				
	Parthenocissus vitacea	Woodbine									√	√	
	Amelanchier arborea	Downy Serviceberry								√			
8	*Cornus alternifolia*	Alternate-leaved Dogwood	√			√		√	√	√	√	√	
	Cornus amomum	Silky Dogwood										√	√
	Cornus stolonifera	Red-osier Dogwood	√	√	√		√	√					
	Crataegus spp.	Hawthorn species	√										
	Echinocystis lobata	Wild Cucumber		√	√								
	Lonicera tatarica	Tartarian Honeysuckle	√	√	√	√	√	√	√	√			√
	Physocarpus opulifolius	Ninebark										√	
	Prunus virginiana	Chokecherry			√	√				√	√		√
	Rhamnus cathartica	Common Buckthorn	√	√		√			√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn	√	√		√	√		√	√	√	√	√
	Ribes americanum	Wild Black Currant		√									
	Ribes triste	Swamp Red Currant	√										
	Rubus idaeus	Red Raspberry	√	√	√		√	√					
	Rubus parviflorus	Sparse-flowered Thimbleberry				√	√						
	Rubus pubescens	Dwarf Raspberry	√										
	Solanum dulcamara	Bittersweet Nightshade	√	√	√	√	√	√	√	√	√	√	
	Viburnum trilobum	High-bush cranberry				√	√					√	
	Vitis riparia	Riverbank Grape	√	√	√	√	√	√	√		√		√
	Rubus occidentalis	Black Raspberry							√				√
	Viburnum opulus	Guelder-rose							√	√	√		√
	Aronia melanocarpa	Black Chokeberry							√				
	Parthenocissus vitacea	Woodbine									√		
9	*Cornus stolonifera*	Red-osier Dogwood		√	√	√	√	√	√			√	
	Rhamnus cathartica	Common Buckthorn					√	√			√	√	√
	Rhamnus frangula	Glossy Buckthorn			√								
	Rubus idaeus	Red Raspberry				√	√	√		√	√		√
	Solanum dulcamara	Bittersweet Nightshade				√		√		√			√
	Cornus amomum	Silky Dogwood								√	√		√
	Rubus occidentalis	Black Raspberry									√		√
	Cornus foemina	Gray Dogwood								√		√	
16	*Echinocystis lobata*	Wild Cucumber						√					
	Rhamnus cathartica	Common Buckthorn						√	√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn						√	√	√	√	√	√
	Solanum dulcamara	Bittersweet Nightshade						√	√	√	√	√	√
	Vitis riparia	Riverbank Grape									√	√	√
	Parthenocissus quinquefolia	Virginia Creeper						√	√				
	Parthenocissus vitacea	Woodbine								√	√	√	√
18	*Rhamnus cathartica*	Common Buckthorn						√	√	√	√	√	√
	Rhamnus frangula	Glossy Buckthorn						√	√	√	√	√	√
	Rubus pubescens	Dwarf Raspberry						√	√	√	√	√	√
	Solanum dulcamara	Bittersweet Nightshade						√	√	√	√	√	√
	Vitis riparia	Riverbank Grape						√		√	√	√	√
	Ilex verticillata	Winterberry						√	√	√	√	√	√
	Viburnum opulus	Guelder-rose											√
	Parthenocissus quinquefolia	Virginia Creeper						√	√				
	Toxicodendron radicans ssp. negundo	Poison Ivy							√		√		√
	Parthenocissus vitacea	Woodbine								√	√	√	√
	Toxicodendron rydbergii	Western Poison-ivy								√		√	
Total			**42**	**37**	**25**	**30**	**40**	**47**	**51**	**53**	**53**	**54**	**52**

APPENDIX VI

Bird Species Observed by Plot 2016

Appendix VI. Bird Species Observed by Plot in 2006 - 2016

Breeding Bird Plot 001	**MAMM1-3**														
		Breeding Evidence													
												2016		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
Alder Flycatcher	*Empidonax alnorum*						PR	PO							Ring-billed Gull (X)
American Goldfinch	*Spinus tristis*	PR	X	PO	PO		PO	PR	PO	PO	PR	PR	2	4	Turkey Vulture (X)
American Robin	*Turdus migratorius*			PR	PR	PR	PR	PO	PR	PO	PO				Savannah Sparrow (S)
Baltimore Oriole	*Icterus galbula*		PR			PO	PO	PR		PR					Killdeer (S)
Bank Swallow	*Riparia riparia*						PO								
Barn Swallow	*Hirundo rustica*	PO	PR				PR	PO	PO		PO				
Black-billed Cuckoo	*Coccyzus erythropthalmus*									PR					
Black-capped Chickadee	*Poecile atricapillus*	PO			PO	PO				PR	PO	PO		2	
Blue Jay	*Cyanocitta cristata*											PO		1	
Bobolink	*Dolichonyx oryzivorus*		PO		PO	PO									
Brown-headed Cowbird	*Molothrus ater*			PR			PO	PR		PO	PO	PO		3	
Cedar Waxwing	*Bombycilla cedrorum*	PO	PO		PR	PR		PO	PR	PR	PO	PO	2		
Chipping Sparrow	*Spizella passerina*			PR					PO						
Common Grackle	*Quiscalus quiscula*					PO	PO								
Common Yellowthroat	*Geothylpis trichas*		PO	PR	PR	PR	PO	PR	CO	PR	PO	PR	1	1	
Downy Woodpecker	*Picoides pubescens*				PO				PO	PO	PR				
Eastern Kingbird	*Tyrannus tyrannus*	PO			PR	PO	PO	PO							
Eastern Meadowlark	*Sturnella magna*		PO	PO		PO		PO	PO		PO	PO		1	
Eastern Wood-pewee	*Contopus virens*			PO			PO	PO							
European Starling	*Sturnus vulgaris*				X	X					PO	PO	1		
Flycatcher species		PO		X											
Grasshopper Sparrow	*Ammodramus savannarum*								PO			PO	2		
Gray Catbird	*Dumetella carolinensis*				PO		PO		PO	PO					
Hairy Woodpecker	*Picoides villosus*								PR						
House Wren	*Troglodytes aedon*					PO			PO		PO	PR	1	1	
House Finch	*Carpodacus mexicanus*			CO											
Killdeer	*Charadrius vociferus*								PO						
Least Flycatcher	*Empidonax minimus*			PO											
Mallard	*Anas platyrhynchos*					X			PR	PO					
Mourning Dove	*Zenaida macroura*			PO				PO	PO	PO	PO				
Northern Cardinal	*Cardinalis cardinalis*				PO				PO	PO	PO	PO		1	
Northern Flicker	*Colaptes auratus*	PR						PO	PO						
Northern Waterthrush	*Parkesia noveboracensis*									PO					
Passerine species		PO													
Red-eyed Vireo	*Vireo olivaceus*				X										
Red-winged Blackbird	*Agelaius phoeniceus*	PR	CO	PR	PR	PR	CO	PR	PR	PO	PR	PO		1	
Ring-billed Gull	*Larus delawarensis*						X								
Rock Pigeon	*Columba livia*					X				PO					
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO										
Savannah Sparrow	*Passerculus sandwichensis*		PR		PO	PR		PR	PR		PO				
Scarlet Tanager	*Piranga olivacea*	PO													
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	3	4	
Swamp Sparrow	*Melospiza georgiana*	PO	PO		PO			PR			PO				
Tennessee Warbler	*Oreothlypis peregrina*	PO													
Tree Swallow	*Tachycineta bicolor*			PO	PO	PO									
Warbling Vireo	*Vireo gilvis*				PO	PR	PR	PR	PR						
Willow Flycatcher	*Empidonax traillii*				PR	PR			PR	PR	PO	PR	1	1	
Yellow Warbler	*Setophaga petechia*		X	PO	PR	PR	PO	PR	PR	PR	PR	PR	3	1	
Yellow-billed Cuckoo	*Coccyzus americanus*	PO													
Total	**43**	14	12	15	21	20	17	19	23	19	19	15	**16**	**21**	

Breeding Bird Plot 002	**SWCO1-2**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*		PO	PO		PO			PO			PO	2		
American Goldfinch	*Spinus tristis*						PR				PO	PO		4	
American Robin	*Turdus migratorius*		PR	PR	PR	PO		PO	PO	PO	PO	PO	1		
Baltimore Oriole	*Icterus galbula*		PR		PO										
Bank Swallow	*Riparia riparia*						X								
Black-capped Chickadee	*Poecile atricapillus*		PO	PR	PO	PO	PO	PR	PR	PR	PR	PR	1	3	
Blue Jay	*Cyanocitta cristata*	PO			PR	PO		PR	PO	PO	PO	PR	1	1	
Brown-headed Cowbird	*Molothrus ater*						PO								
Cedar Waxwing	*Bombycilla cedrorum*	PO					PR	PO				PR	1	2	
Chestnut-sided Warbler	*Setophaga pensylvanica*	PO													
Chipping Sparrow	*Spizella passerina*										PO				
Common Grackle	*Quiscalus quiscula*			PO				PO		PO					
Common Yellowthroat	*Geothylpis trichas*			PR	PO		PO		PR	PR	PO				
Downy Woodpecker	*Picoides pubescens*	PO		PO					PO						
Eastern Kingbird	*Tyrannus tyrannus*								PO						
Eastern Meadowlark	*Sturnella magna*						PO								
Eastern Wood-pewee	*Contopus virens*	PO	PO		PO	PR		PO	PR	PR		PO	1		
European Starling	*Sturnus vulgaris*								PO						
Great Crested Flycatcher	*Myiarchus crinitus*		PO		PO			PO		PR	PO				
Hairy Woodpecker	*Picoides villosus*							PO							
House Wren	*Troglodytes aedon*		PO	PO	PO	PO		PR	PO	PR					
Indigo Bunting	*Passerina cyanea*	PO		PO											
Killdeer	*Charadrius vociferus*				PR			PO							
Mourning Dove	*Zenaida macroura*					PO		PR							
Northern Cardinal	*Cardinalis cardinalis*		PO		PO			PO	PR		PO				
Northern Flicker	*Colaptes auratus*				PO							PO	1		
Northern Waterthrush	*Parkesia noveboracensis*					PR		PR	PR	PR	PO				
Passerine species		PO													
Red-bellied Woodpecker	*Melanerpes carolinus*								PO						
Red-breasted Nuthatch	*Sitta canadensis*							PO			PO				
Red-winged Blackbird	*Agelaius phoeniceus*	PO			PO		PO	PO			PO	PR	3	1	
Rose-breasted Grosbeak	*Pheucticus ludovicianus*					PR				PR					
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR		PR				
Turkey Vulture	*Cathartes aura*						X								
Wabler species		PO													
Warbling Vireo	*Vireo gilvis*						PO								
White-breasted Nuthatch	*Sitta carolinensis*											PO			
Yellow Warbler	*Setophaga petechia*						PO								
Total	**35**	10	9	9	13	10	12	16	14	10	12	10	**11**	**11**	

Breeding Bird Plot 003	**FODM6**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*	PR	PO		PR	PO	PO		PO			PO	1		Song Sparrow
American Goldfinch	*Spinus tristis*									PO					Eastern Meadowlark
American Robin	*Turdus migratorius*		PR	PR	PO	PO	PO	PO	PO	PR		PR	1	1	Barn Swallow
Baltimore Oriole	*Icterus galbula*		PO						PO						
Black-billed Cuckoo	*Coccyzus erythropthalmus*				PO										
Black-capped Chickadee	*Poecile atricapillus*	PR		PO		PO	PO	PO	PR	PO	PO	PO		1	
Blue Jay	*Cyanocitta cristata*			PR	PO	X		PO	PO	PO	PO	PO		3	
Brown-headed Cowbird	*Molothrus ater*					PO	PO					PO	1		
Cedar Waxwing	*Bombycilla cedrorum*						PO	PO	PO			PO	2		
Common Grackle	*Quiscalus quiscula*			PO				PO				CO	2		
Common Yellowthroat	*Geothylpis trichas*				PO	PR	PR	PO	PO						
Downy Woodpecker	*Picoides pubescens*					CO		PO	PO		PO	PO	1		
Eastern Wood-pewee	*Contopus virens*	PO	PO	PR	PR	PR		PR		PO	PO	PO	1		
European Starling	*Sturnus vulgaris*			PO				PO							
Gray Catbird	*Dumetella carolinensis*			PO											
Great Crested Flycatcher	*Myiarchus crinitus*	PO			PO	PR	PO	PO	PO		PO				
Great Horned Owl	*Bubo virgianus*											CO		2	
House Wren	*Troglodytes aedon*			PR	PR	PO		PO	PR		PR				
Indigo Bunting	*Passerina cyanea*					PO		PR				PO		1	
Northern Cardinal	*Cardinalis cardinalis*	PO			PR				PR		PO	PR	1	1	
Northern Flicker	*Colaptes auratus*										PO				
Red-bellied Woodpecker	*Melanerpes carolinus*								PO			CO		2	
Red-breasted Nuthatch	*Sitta canadensis*								PO						
Red-eyed Vireo	*Vireo olivaceus*	PR	PO		PO	PR		PO	PR	PR	PO	PR	2	1	
Red-tailed Hawk	*Buteo jamaicensis*		PR		PO						PO				
Red-winged Blackbird	*Agelaius phoeniceus*			PO	PR	PO						PO	2		
Ring-billed Gull	*Larus delawarensis*								PO						
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO										
Song Sparrow	*Melospiza melodia*	PR	PO	PR	PO	PR	PR	PO	PR	PO	PR				
Warbling Vireo	*Vireo gilvis*							PO							
White-breasted Nuthatch	*Sitta carolinensis*						PO								
Winter Wren	*Troglodytes hiemalis*											PO		1	
Wood Thrush	*Hylocichla mustelina*		PR												
Yellow-bellied Sapsucker	*Sphyrapicus varius*										PO				
Yellow Warbler	*Setophaga petechia*			PO					PO						
Total	**35**	7	8	11	14	14	9	15	17	7	12	16	**14**	**13**	

Breeding Bird Plot 004	**SWMM1-1**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*	PO	PR	PO	PO	X	PO		PO						Savannah Sparrow
American Goldfinch	*Spinus tristis*		PO	X	PO	PO		PO	PO	PO	PO	PO	1	1	Eastern Meadowlark
American Robin	*Turdus migratorius*	PO	PO	PO	PO	PO	PR	PR	PR	PR	PR	PR			Yellow Warbler
Belted Kingfisher	*Megaceryle alcyon*											X		1	Swamp Sparrow
Black-capped Chickadee	*Poecile atricapillus*	PO	PO	PR	CO	PO		CO		PR	PR	PO	1		Alder Flycatcher
Blue-gray Gnatcatcher	*Polioptila caerulea*				PO										Common Grackle
Blue Jay	*Cyanocitta cristata*	PR	PR		PO	PO	PO	PO	PO	PR		PR	1	1	Mallard
Brown-headed Cowbird	*Molothrus ater*				PO	X			PO	PO	PO				Black-capped Chickadee
Cedar Waxwing	*Bombycilla cedrorum*			PO		PO				PO		PO	1		
Chipping Sparrow	*Spizella passerina*		PO	PO					PR		PO				
Common Grackle	*Quiscalus quiscula*	PO		X	CO		PO		PO		PR	PO	1		
Common Yellowthroat	*Geothylpis trichas*	CO	PO	PR	PR	PR		PR	PO	PO	PO				
Downy Woodpecker	*Picoides pubescens*			PO											
European Starling	*Sturnus vulgaris*						PR		CO						
Gray Catbird	*Dumetella carolinensis*				PO			PO							
Great Crested Flycatcher	*Myiarchus crinitus*										PO	PO		1	
Hairy Woodpecker	*Picoides villosus*	PO													
House Wren	*Troglodytes aedon*								PO						
Mallard	*Anas platyrhynchos*		X									X		1	
Mourning Dove	*Zenaida macroura*								PO						
Northern Cardinal	*Cardinalis cardinalis*	PO		PO	PR	PO		PO	PO	PO					
Northern Flicker	*Colaptes auratus*					PO		PO							
Northern Waterthrush	*Parkesia noveboracensis*				PO	PO	PO				PR				
Orchard Oriole	*Icterus spurius*											PO	1		
Pine Warbler	*Setophaga pinus*					PO									
Red-eyed Vireo	*Vireo olivaceus*						PO								
Red-tailed Hawk	*Buteo jamaicensis*		PO												
Red-winged Blackbird	*Agelaius phoeniceus*	PR	PR	PO	PO	PO	PO		PO	PO	PR	PR	1	2	
Savannah Sparrow	*Passerculus sandwichensis*			PO				PO	PO		PO	PO		1	
Scarlet Tanager	*Piranga olivacea*							PO							
Song Sparrow	*Melospiza melodia*	PO	PO	PR	PO	PR	PO	PR	PR		PR	PR	1	1	
Swamp Sparrow	*Melospiza georgiana*	PO			PO			PR			PO				
White-breasted Nuthatch	*Sitta carolinensis*						PO					PO	1		
Wood Thrush	*Hylocichla mustelina*			PO											
Yellow-bellied Sapsucker	*Sphyrapicus varius*						PO								
Yellow Warbler	*Setophaga petechia*			PO		PO			PO	PR	PO	X		1	
Total	**36**	11	11	15	15	15	11	12	16	10	14	15	**9**	**10**	

Breeding Bird Plot 005	**FOMM6**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*	PO		PO	PO	PO									Northern Cardinal (S)
American Goldfinch	*Spinus tristis*	PO	PO					PR	PO			X	1		Red-eyed Vireo (S)
American Robin	*Turdus migratorius*	PO		PR	PO	PR	PR	PR	PR	PR	PR	PR	2	3	
Black-capped Chickadee	*Poecile atricapillus*	PR	PR	PO	PO	PR	PO	PR	PR	PO	PR	PR	2		
Blue Jay	*Cyanocitta cristata*	PR	PO	PO	PO	X	PO	PR	PR		PR	PO	1		
Brown Creeper	*Certhia americana*								PO						
Brown-headed Cowbird	*Molothrus ater*											PO	1		
Cedar Waxwing	*Bombycilla cedrorum*			PO							PO	PO		5	
Chipping Sparrow	*Spizella passerina*				PR										
Common Grackle	*Quiscalus quiscula*				CO							PO		2	
Common Yellowthroat	*Geothylpis trichas*		PO		PO			PO			PO				
Cooper's Hawk	*Accipiter cooperii*											PO		1	
Downy Woodpecker	*Picoides pubescens*			PO											
Gray Catbird	*Dumetella carolinensis*							PO							
Great Crested Flycatcher	*Myiarchus crinitus*	PO	PR	PO	PO	PO	PR	PO		PO	PR	PO	1		
Hairy Woodpecker	*Picoides villosus*								PO						
House Wren	*Troglodytes aedon*	PO													
Killdeer	*Charadrius vociferus*	PO					X		PO						
Mourning Dove	*Zenaida macroura*		PO						PO	PO		PO		1	
Northern Cardinal	*Cardinalis cardinalis*	PO	PO		PO		PR	PR			PO				
Northern Flicker	*Colaptes auratus*					PO			PO		PO				
Northern Waterthrush	*Parkesia noveboracensis*											PO	1		
Pine Warbler	*Setophaga pinus*			PR				PO				PO		1	
Red-breasted Nuthatch	*Sitta canadensis*				PO	X		PO			PO	PO	1		
Red-eyed Vireo	*Vireo olivaceus*				PR		PO	PO				PO		1	
Red-winged Blackbird	*Agelaius phoeniceus*				PO						PO				
Rose-breasted Grosbeak	*Pheucticus ludovicianus*						PR					PO	1		
Song Sparrow	*Melospiza melodia*			PO		PO			PO						
Swamp Sparrow	*Melospiza georgiana*				PO										
Tree Swallow	*Tachycineta bicolor*										PO				
White-breasted Nuthatch	*Sitta carolinensis*		PO		PO										
Total	**31**	9	8	9	14	8	8	11	10	4	11	15	**11**	**14**	

Breeding Bird Plot 006	**MAMM1-3**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
Alder Flycatcher	*Empidonax alnorum*											PO		1	Warbling Vireo
American Crow	*Corvus brachyrhynchos*					PO			PO						Great Crested Flycatcher
American Goldfinch	*Spinus tristis*	PR	PR	PR	PO	PO	PO	PR	PR	PR	PR	PR	1	3	Cedar Waxwing
American Redstart	*Setophaga ruticilla*					PO									Alder Flycatcher
American Robin	*Turdus migratorius*	PR	PO	PO	PR	CO	PO	PR	PR	PR	PO	PR	1	1	Red-breasted Nuthatch
Baltimore Oriole	*Icterus galbula*			PO			PR					PO		1	Eastern Kingbird
Bank Swallow	*Riparia riparia*										PO				Eastern Wood-pewee
Barn Swallow	*Hirundo rustica*	PO	PR	PR											Northern Flicker
Black-capped Chickadee	*Poecile atricapillus*			PO	PO	PO				PO	PO				Black-capped Chickadee
Blue Jay	*Cyanocitta cristata*	PO	PO					PO							Killdeer
Brown-headed Cowbird	*Molothrus ater*				X	PO	PO		PR		PO	PO		4	European Starling
Cedar Waxwing	*Bombycilla cedrorum*				X	X		PO			PR	PO		2	Great Blue Heron
Common Grackle	*Quiscalus quiscula*			PO	X		PO				PO	X		1	American Crow
Common Yellowthroat	*Geothylpis trichas*		PO	PR	PO	PO	PO	PR	PR	PR	PO	PO	1		
Downy Woodpecker	*Picoides pubescens*										PO				
Eastern Meadowlark	*Sturnella magna*								PO						
Eastern Wood-pewee	*Contopus virens*			PO				PO							
European Starling	*Sturnus vulgaris*			X	PO			PO			X	X		1	
Field Sparrow	*Spizella pusilla*		PO				PO					PO		1	
Gray Catbird	*Dumetella carolinensis*			PO			PO		PO			PO	1		
Great Crested Flycatcher	*Myiarchus crinitus*		PO						PO						
Hairy Woodpecker	*Picoides villosus*							PO							
House Wren	*Troglodytes aedon*						PO								
Indigo Bunting	*Passerina cyanea*				PO					PO		PO		1	
Killdeer	*Charadrius vociferus*								PO	PO					
Mallard	*Anas platyrhynchos*	PO	PR												
Mourning Dove	*Zenaida macroura*								PO						
Northern Cardinal	*Cardinalis cardinalis*	PO	PR		PO						PO	PO		1	
Northern Flicker	*Colaptes auratus*		CO			PO									
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*				PR			PO				PO		2	
Northern Waterthrush	*Parkesia noveboracensis*					PO									
Red-tailed Hawk	*Buteo jamaicensis*						PR		PO						
Red-winged Blackbird	*Agelaius phoeniceus*	PR	CO	CO	CO	PR	PR	CO	PR	PR	PR	PR	1	6	
Ring-billed Gull	*Larus delawarensis*		X												
Rock Pigeon	*Columba livia*					X						X		1	
Savannah Sparrow	*Passerculus sandwichensis*				PO			PO	PO						
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	1	3	
Spotted Sandpiper	*Actitis macularia*							PO							
Tree Swallow	*Tachycineta bicolor*			PO		PO		PO			PO				
Warbling Vireo	*Vireo gilvis*					PR	PR	PR	PO		PO	PO		1	
Willow Flycatcher	*Empidonax traillii*								PO		PR				
Vesper Sparrow	*Pooecetes gramineus*				PO										
Yellow Warbler	*Setophaga petechia*				PR	PO	PR		PR	PO	PO	PR	1	2	
Total	**42**	8	13	13	16	16	14	15	17	9	17	19	**7**	**32**	

Breeding Bird Plot 007	**SWMM1-1**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*	PR	PO												Hairy Woodpecker
American Goldfinch	*Spinus tristis*	PO	PO	PR	PO	PO		PR			PO	PO	2	2	Song Sparrow
American Robin	*Turdus migratorius*	PR		PO	PO	PR	PR	PR	PR	PR	PR	PO			Indigo Bunting
Baltimore Oriole	*Icterus galbula*				CO					PO					American Goldfinch
Bank Swallow	*Riparia riparia*									PO					Savannah Sparrow
Black-capped Chickadee	*Poecile atricapillus*		PR	PO	PR	PO	PO	PO	PR		PO	PO	1		Blue Jay
Blue Jay	*Cyanocitta cristata*	PR	PO		PR	PO	PO	PO	PO	PO	PR				Northern Flicker
Brown Creeper	*Certhia americana*					PO	PO	PO	PO						Red-eyed Vireo
Brown-headed Cowbird	*Molothrus ater*											PO		1	
Canada Goose	*Branta canadensis*		X												
Cedar Waxwing	*Bombycilla cedrorum*			PO		PO		PO	PO		PO				
Chipping Sparrow	*Spizella passerina*			PO	PO						PO				
Common Grackle	*Quiscalus quiscula*				X		PO				PO				
Downy Woodpecker	*Picoides pubescens*		X	PO							PO				
Eastern Kingbird	*Tyrannus tyrannus*		PO												
Eastern Meadowlark	*Sturnella magna*			PO											
Eastern Wood-pewee	*Contopus virens*				PO	PO									
Field Sparrow	*Spizella pusilla*			PO	PO										
Gray Catbird	*Dumetella carolinensis*				PO										
Great Crested Flycatcher	*Myiarchus crinitus*		PR		PO	PO	PO	PO		PO		PO		1	
Hairy Woodpecker	*Picoides villosus*	PO							PO						
Indigo Bunting	*Passerina cyanea*	PO			PO						PO	PO		1	
Killdeer	*Charadrius vociferus*						PO	PO	PO		PO				
Northern Cardinal	*Cardinalis cardinalis*		PO	PO	PO		PO		PO	PR					
Northern Flicker	*Colaptes auratus*								PO						
Mourning Dove	*Zenaida macroura*								PO	PO		PO		1	
Passerine Species		PO		PO		PO									
Red-breasted Nuthatch	*Sitta canadensis*					PR			PO		PO				
Red-eyed Vireo	*Vireo olivaceus*				PO		PO			PR	PO	PO	2		
Ring-billed Gull	*Larus delawarensis*										OB				
Red-winged Blackbird	*Agelaius phoeniceus*										PO	PO	1		
Savannah Sparrow	*Passerculus sandwichensis*							PO							
Song Sparrow	*Melospiza melodia*	PR	PO	PR	PR	PR	PR	PR	PR	PO	PO	PO		1	
Spotted Sandpiper	*Actitis macularia*							PO							
Warbling Vireo	*Vireo gilvis*											PO		1	
Winter Wren	*Troglodytes hiemalis*											PO	1		
White-breasted Nuthatch	*Sitta carolinensis*		PO		PR		PR					PO			
Total	**33**	8	11	11	16	11	11	11	12	9	15	13	**7**	**8**	

Breeding Bird Plot 008	SWMM1-1														
		Breeding Evidence											2016		2016 Incidental Observations
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*		PR		PO		PO			PO					Great Crested Flycatcher (S)
American Goldfinch	*Spinus tristis*	PR	PO	PR	PR	PO	PO	PR	PR	PO	PO	CO	2	4	American Crow (X)
American Robin	*Turdus migratorius*	PO	PO	PR	PO	PO	PO	PR	PR	PR	PR	PR	1	1	Brown-headed Cowbird (H)
American Woodcock	*Scolopax minor*							PO							Savannah Sparrow (S)
Bank Swallow	*Riparia riparia*											PO		1	American Robin (S)
Barn Swallow	*Hirundo rustica*								X						Canada Goose (X)
Belted Kingfisher	*Megaceryle alcyon*					PO			PO	CO					Song Sparrow (X)
Black-billed Cuckoo	*Coccyzus erythropthalmus*				PO										Gray Catbird (S)
Black-capped Chickadee	*Poecile atricapillus*		PR	PR	PR	PO	PO		PR	PO	PO	PO		2	Northern Cardinal (S)
Blue Jay	*Cyanocitta cristata*	PO	PO		PR	PO	PO	PO		PO	PR				Savannah Sparrow (S)
Brown-headed Cowbird	*Molothrus ater*		PO		PO	PO	PO		PO	PR	PO	PO	1		Killdeer (S)
Cedar Waxwing	*Bombycilla cedrorum*	PO			PO			PO							
Chipping Sparrow	*Spizella passerina*	PO													
Common Grackle	*Quiscalus quiscula*		PR	X	X		PO			PO	CO				
Common Yellowthroat	*Geothylpis trichas*	PO		PO	PO	PO	PO	PO	PO	PO	PR	PO	1		
Eastern Kingbird	*Tyrannus tyrannus*									PO					
Eastern Meadowlark	*Sturnella magna*			PR	PO										
Eastern Wood-pewee	*Contopus virens*						PO								
Gray Catbird	*Dumetella carolinensis*	CO	PR		PR		CO	PO			PO				
Great Crested Flycatcher	*Myiarchus crinitus*							PO							
Hairy Woodpecker	*Picoides villosus*	PO		PO											
House Wren	*Troglodytes aedon*						PO	PO			PO				
Killdeer	*Charadrius vociferus*						PO		PO						
Mallard	*Anas platyrhynchos*		X			X	X		X						
Mourning Dove	*Zenaida macroura*						PO		PO	PO	PR	PR		2	
Northern Cardinal	*Cardinalis cardinalis*	PO		PO	PR		PO	PR	PO	PO	PR	PO		1	
Northern Flicker	*Colaptes auratus*						PO		PO						
Northern Waterthrush	*Parkesia noveboracensis*							PO							
Red-eyed Vireo	*Vireo olivaceus*						PO	PO				PO	1		
Red-winged Blackbird	*Agelaius phoeniceus*	PO	PR	PR	PO		PO	PO	PR			PO		2	
Ring-billed Gull	*Larus delawarensis*								X		X				
Savannah Sparrow	*Passerculus sandwichensis*			PO	PO			PR			PO				
Song Sparrow	*Melospiza melodia*	PR	PR	PR	PR	PR	PR	PR	PR	PR	PR	PO		1	
White-breasted Nuthatch	*Sitta carolinensis*											PO	1		
Yellow Warbler	*Setophaga petechia*			PR	PO		PO		PR						
Total	**35**	11	11	12	17	9	20	15	16	13	14	12	**7**	**14**	

Breeding Bird Plot 009	**MASM1-1**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*			PO	PO	CO			PO						Eastern Meadowlark (S)
American Goldfinch	*Spinus tristis*				PR	PO	PO		PR		PO	PR	3	3	Savannah Sparrow (S)
American Robin	*Turdus migratorius*			PO	PR	PO	PR	PO	PO	PR					Bobolink (S)
Baltimore Oriole	*Icterus galbula*				PR		PO								American Robin (S)
Barn Swallow	*Hirundo rustica*			PR	PO	PO		PO		X	X				
Black-capped Chickadee	*Poecile atricapillus*			PO											
Blue Jay	*Cyanocitta cristata*								X		PO				
Bobolink	*Dolichonyx oryzivorus*				PO				PR			X		3	
Canada Goose	*Branta canadensis*		CO												
Cedar Waxwing	*Bombycilla cedrorum*									PO	PR				
Chipping Sparrow	*Spizella passerina*						PO								
Common Grackle	*Quiscalus quiscula*				X		PO	PO			PR	X		2	
Common Yellowthroat	*Geothylpis trichas*		PR	PO	PO	PR	PR	PO	PO	PR	PR	PR	1	1	
Eastern Kingbird	*Tyrannus tyrannus*				PR			PO							
Eastern Meadowlark	*Sturnella magna*				PR		PO	PR	PO						
Eastern Wood-pewee	*Contopus virens*				PO										
European Starling	*Sturnus vulgaris*				PO		PO	PO			PO	PO		4	
House Wren	*Troglodytes aedon*						PO								
Killdeer	*Charadrius vociferus*		PR		PR			PO	PO			PO		1	
Mallard	*Anas platyrhynchos*		X			X	PO					X		1	
Northern Cardinal	*Cardinalis cardinalis*			PO											
Northern Flicker	*Colaptes auratus*						PO								
Red-tailed Hawk	*Buteo jamaicensis*			PO	PO										
Red-winged Blackbird	*Agelaius phoeniceus*		CO	CO	CO	PR	PR	PR	PR	PR	PR	PR	4	4	
Ring-billed Gull	*Larus delawarensis*		X	X											
Rock Pigeon	*Columba livia*							PO				X		1	
Savannah Sparrow	*Passerculus sandwichensis*		PR	PO	PO	PR	PO	PR	PR	PO	PO	PO		1	
Song Sparrow	*Melospiza melodia*			PO	PR	PR		PO	PR	PO	PR	PR	1	2	
Tree Swallow	*Tachycineta bicolor*		CO	PO				PO	PO		PO				
Turkey Vulture	*Cathartes aura*							PO							
Warbling Vireo	*Vireo gilvis*								PO						
Wild Turkey	*Meleagris gallopavo*								PO						
Willow Flycatcher	*Empidonax traillii*				PO			PR	PO	PR	PO	PR	2		
Yellow Warbler	*Setophaga petechia*			PO	PO			PO			PR	PR	2		
Total	**34**		8	13	19	9	13	16	15	8	13	13	**13**	**23**	

Breeding Bird Plot 011	**FODR1-1**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*				PO	PO						PO		1	Eastern Meadowlark
American Goldfinch	*Spinus tristis*				X	PO	PO	PR	PR	PR	PO	PR	3	4	Bobolink
American Redstart	*Setophaga ruticilla*				PO			PO		PR	PR	PR	1	2	Grasshopper Sparrow
American Robin	*Turdus migratorius*				PO	PR	PR	PR	PR	PO	PO	PO		1	Barn Swallow
Baltimore Oriole	*Icterus galbula*					PO	PO		PR			PO		1	Blue Jay
Barn Swallow	*Hirundo rustica*					PO			X						Indigo Bunting
Black-capped Chickadee	*Poecile atricapillus*					PO	PO	PO	PR	PO	PO	PO	1		Killdeer
Blue Jay	*Cyanocitta cristata*				PO				PO						Turkey Vulture
Brown-headed Cowbird	*Molothrus ater*									PO		PO	1		Horned Lark
Cedar Waxwing	*Bombycilla cedrorum*					PO			PO	PO					American Crow
Chestnut-sided Warbler	*Setophaga pensylvanica*						PO								
Chipping Sparrow	*Spizella passerina*						PO			PO					
Cliff Swallow	*Petrochelidon pyrrhonota*								X						
Common Grackle	*Quiscalus quiscula*				X			PO	PO						
Common Yellowthoat	*Geothlypis trichas*										PO				
Downy Woodpecker	*Picoides pubescens*						PO				PO				
Eastern Kingbird	*Tyrannus tyrannus*					PR									
Eastern Meadowlark	*Sturnella magna*				PO				PO						
Eastern Wood-pewee	*Contopus virens*				PO	PO			PO						
European Starling	*Sturnus vulgaris*							PO	CO	PO		PO		2	
Gray Catbird	*Dumetella carolinensis*				PO	PO	PO	CO	PO	PO	PR	PO		1	
Great Crested Flycatcher	*Myiarchus crinitus*											PR	2		
Horned Lark	*Eremophila alpestris*								PO						
House Wren	*Troglodytes aedon*				PR	PO									
Killdeer	*Charadrius vociferus*				PO					PO					
Mourning Dove	*Zenaida macroura*					PO	PR		PO			PO		2	
Northern Cardinal	*Cardinalis cardinalis*				PO			PO		PO					
Northern Flicker	*Colaptes auratus*				PO				PO	PO		PO	1		
Red-eyed Vireo	*Vireo olivaceus*						PO	PO	PO	PO					
Red-winged Blackbird	*Agelaius phoeniceus*				PO	PO	PO	PO	PR		PR	PO		3	
Rose-breasted Grosbeak	*Pheucticus ludovicianus*				PO					PO	PO				
Savannah Sparrow	*Passerculus sandwichensis*					PR			PO						
Song Sparrow	*Melospiza melodia*				PR	PO	PO		PR	PR	PO	PR	1	3	
Tree Swallow	*Tachycineta bicolor*						PR				PO				
Turkey Vulture	*Cathartes aura*								X						
Warbling Vireo	*Vireo gilvis*				PO	PO	PO	PO		PO		PO	1		
White-breasted Nuthatch	*Sitta carolinensis*							PO							
Yellow Warbler	*Setophaga petechia*						PO	PR	PR	PO		PR	1	1	
Total	**38**				17	16	15	13	22	17	11	16	**12**	**21**	

Breeding Bird Plot 016	**SWDM3-2**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*						PO		PO						Yellow Warbler
American Goldfinch	*Spinus tristis*						PO	PO		PR	PR	PO		4	Warbling Vireo
American Redstart	*Setophaga ruticilla*						PO								Killdeer
American Robin	*Turdus migratorius*						PR	CO	PR	PO	PR	PO	2		Brown-headed Cowbird
Baltimore Oriole	*Icterus galbula*						PO		PO			PO		1	Northern Rough-winged Swallow
Black-capped Chickadee	*Poecile atricapillus*						PO	PR				PO		4	Savannah Sparrow
Blue Jay	*Cyanocitta cristata*						PR				PO				Great Crested Flycatcher
Brown-headed Cowbird	*Molothrus ater*						PO		PO						
Cedar Waxwing	*Bombycilla cedrorum*						PO					PO		2	
Common Grackle	*Quiscalus quiscula*											PO		1	
Downy Woodpecker	*Picoides pubescens*							PO							
Eastern Wood-pewee	*Contopus virens*							PO							
European Starling	*Sturnus vulgaris*											CO	4		
Hairy Woodpecker	*Picoides villosus*						PO								
Horned Lark	*Eremophila alpestris*								PO						
Indigo Bunting	*Passerina cyanea*										PO	PO	1		
Killdeer	*Charadrius vociferus*						PO	PR	PO		PO				
Red-eyed Vireo	*Vireo olivaceus*						PO		PO	PO	PO				
Red-winged Blackbird	*Agelaius phoeniceus*										PR	PO	1	3	
Rose-breasted Grosbeak	*Pheucticus ludovicianus*									PO					
Savannah Sparrow	*Passerculus sandwichensis*						PO		PO		PO				
Song Sparrow	*Melospiza melodia*						PR	PR	PR	PO	PR	PR	1	3	
Tree Swallow	*Tachycineta bicolor*						PO								
Warbling Vireo	*Vireo gilvis*						PR		PR			PR	1	1	
Yellow-bellied Sapsucker	*Sphyrapicus varius*						PO								
Yellow Warbler	*Setophaga petechia*								PR						
Total	**26**						17	7	10	5	9	11	**10**	**19**	

Breeding Bird Plot 019	**MEM**														
		Breeding Evidence											**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*							PR	PO			X	1		House Wren
American Goldfinch	*Spinus tristis*						PO	PO	PR	PO		PO		1	Black-capped Chickadee
American Robin	*Turdus migratorius*						PO	PO	PR	PO					Blue Jay
American Woodcock	*Scolopax minor*								PO						American Crow
Baltimore Oriole	*Icterus galbula*								PR		CO				Great Horned Owl
Bank Swallow	*Riparia riparia*						PO								Common Yellowthroat
Barn Swallow	*Hirundo rustica*						PO	PO	PO	X	CO				
Blue Jay	*Cyanocitta cristata*							PO	PO	PO	PR				
Bobolink	*Dolichonyx oryzivorus*							PR							
Brown-headed Cowbird	*Molothrus ater*						PO				PO	PO		2	
Cedar Waxwing	*Bombycilla cedrorum*							PO		PO	PR				
Common Grackle	*Quiscalus quiscula*						PO	X	PO	PO		PO		1	
Common Yellowthroat	*Geothylpis trichas*						PR	PO	PR	PO	PO	PR	2	1	
Eastern Kingbird	*Tyrannus tyrannus*									PO					
Eastern Meadowlark	*Sturnella magna*							PR							
Eastern Wood-pewee	*Contopus virens*						PO		PR	PO					
European Starling	*Sturnus vulgaris*								PO						
Gray Catbird	*Dumetella carolinensis*									PO	PO				
Great Blue Heron	*Ardea herodias*										X				
Great Crested Flycatcher	*Myiarchus crinitus*								PO	PO					
House Wren	*Troglodytes aedon*								PO						
Indigo Bunting	*Passerina cyanea*							PO		PR		PR	1	1	
Northern Cardinal	*Cardinalis cardinalis*								PR			PR	2	1	
Northern Flicker	*Colaptes auratus*								PO		PO				
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*								PO						
Red-bellied Woodpecker	*Melanerpes carolinus*								PO		PO				
Red-eyed Vireo	*Vireo olivaceus*										PR				
Red-winged Blackbird	*Agelaius phoeniceus*						PO	PR	PR	PO	PR	PR	4	1	
Rock Pigeon	*Columba livia*											X	4		
Savannah Sparrow	*Passerculus sandwichensis*							PO				PR	2	2	
Song Sparrow	*Melospiza melodia*						PR	PR	CO	PR	PR	PR	1	1	
Tree Swallow	*Tachycineta bicolor*							PO	PO		PO				
Warbling Vireo	*Vireo gilvis*								PO						
Willow Flycatcher	*Empidonax traillii*									PO					
Wood Thrush	*Hylocichla mustelina*								PO						
Yellow-bellied Sapsucker	*Sphyrapicus varius*										PO				
Yellow Warbler	*Setophaga petechia*							PO							
Total	**37**						10	16	22	15	15	11	**17**	**11**	

Breeding Bird Plot 020	**Agricultural Field**													
		Breeding Evidence										**2016**		**2016 Incidental Observations**
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	3-Jun	21-Jun	
American Crow	*Corvus brachyrhynchos*								PO	PO					Great Crested Flycatcher
American Goldfinch	*Spinus tristis*						PR	PR	PR		PR	PR	2	2	Northern Cardinal
American Robin	*Turdus migratorius*						PO	PO	PR	PO	PO				Gray Catbird
Baltimore Oriole	*Icterus galbula*							PR							Eastern Wood-pewee
Barn Swallow	*Hirundo rustica*							X	X	X					
Black-capped Chickadee	*Poecile atricapillus*							PO	PO						
Blue Jay	*Cyanocitta cristata*							PO	PR						
Bobolink	*Dolichonyx oryzivorus*						PO	PO	PR	PR	PR	PR	6	2	
Brown-headed Cowbird	*Molothrus ater*							PO							
Chipping Sparrow	*Spizella passerina*						PR								
Cedar Waxwing	*Bombycilla cedrorum*							PO				PO		2	
Common Grackle	*Quiscalus quiscula*						PO	PO	PO	PO					
Common Yellowthroat	*Geothylpis trichas*							PR	PO	PR	PO				
Downy Woodpecker	*Picoides pubescens*							PO							
Eastern Kingbird	*Tyrannus tyrannus*								PR	PO	PO	CO	2		
Eastern Meadowlark	*Sturnella magna*						PO	PO	PR	PO	PR	PO		2	
European Starling	*Sturnus vulgaris*								PO			PO		1	
Great Crested Flycatcher	*Myiarchus crinitus*							PO							
House Wren	*Troglodytes aedon*						PR	PO		PO					
Indigo Bunting	*Passerina cyanea*							PO				PO		3	
Killdeer	*Charadrius vociferus*								PO	PO					
Mallard	*Anas platyrhynchos*									X					
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*								X			PO	1		
Red-tailed Hawk	*Buteo jamaicensis*								PR						
Red-winged Blackbird	*Agelaius phoeniceus*						PR	CO	PR	CO	PO				
Ring-billed Gull	*Larus delawarensis*								PO						
Rock Pigeon	*Columba livia*									X					
Savannah Sparrow	*Passerculus sandwichensis*						PR	CO	PR	PR	PR	PR	2	5	
Song Sparrow	*Melospiza melodia*						PO	PR	CO	PO	PR	PO	2		
Tree Swallow	*Tachycineta bicolor*							X	X	X	X	PO		1	
Warbling Vireo	*Vireo gilvis*							PO	PO			PO	1		
Yellow Warbler	*Setophaga petechia*						PO								
Total	**32**						11	21	20	16	10	12	**16**	**18**	

Incidentals

Common Name	Scientific Name	Breeding Evidence										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Alder Flycatcher	*Empidonax alnorum*							PO				
American Crow	*Corvus brachyrhynchos*	PO		PO	PO	PO	PO	PO				
American Goldfinch	*Spinus tristis*	PR	X	PO	PO	PO	PO	PR			PO	
American Robin	*Turdus migratorius*	PO		PO	PO	PR	PO	PR			PO	PO
American Woodcock	*Scolopax minor*											CO
Baltimore Oriole	*Icterus galbula*	PR	PR		PO		PO	PO				
Barn Swallow	*Hirundo rustica*			X			PO				X	
Black-capped Chickadee	*Poecile atricapillus*			PO	PO		PO					PO
Black-billed Cuckoo	*Coccyzus erythropthalmus*											
Blue Jay	*Cyanocitta cristata*	PO			PO	PO	PO	PO			PO	PO
Bobolink	*Dolichonyx oryzivorus*	PO		PO		PR	PR	PR			PR	PR
Brown-headed Cowbird	*Molothrus ater*	PO	PO	PO	PO	PR	PO	PR				PO
Canada Goose	*Branta canadensis*		PR			X		PO				X
Cedar Waxwing	*Bombycilla cedrorum*		PR	PO		PO	PO					
Chimney Swift	*Chaetura pelagica*										PR	
Chipping Sparrow	*Spizella passerina*				PO		PO					
Common Grackle	*Quiscalus quiscula*		X	PO			PO	PO				
Common Yellowthroat	*Geothylpis trichas*		PO	PO		PR	PO	PO				
Cuckoo sp.											PO	
Downy Woodpecker	*Picoides pubescens*			PO								
Eastern Bluebird	*Sialia sialis*										PR	
Eastern Kingbird	*Tyrannus tyrannus*	PO	PO			PR					PO	
Eastern Meadowlark	*Sturnella magna*		PO	PO	PO	PR	PO	PO			PO	PO
Eastern Wood-pewee	*Contopus virens*		PO		PO	PO		PO				PO
European Starling	*Sturnus vulgaris*	PO		PO	PO		PO	PO				
Field Sparrow	*Spizella pusilla*		PO	PO			PO					
Grasshopper Sparrow	*Ammodramus savannarum*										PO	
Gray Catbird	*Dumetella carolinensis*		PO	PO	PO		PO	PO				PO
Great Blue Heron	*Ardea herodias*			X			X				X	
Great Crested Flycatcher	*Myiarchus crinitus*			PO			PO				PO	PO
Great Horned Owl	*Bubo virginianus*											X
Gull sp.								X				
Hairy Woodpecker	*Picoides villosus*						PO	PO				
Horned Lark	*Eremophila alpestris*											
House Sparrow	*Passer domesticus*											
House Wren	*Troglodytes aedon*				PO		PO	PO				PO
Indigo Bunting	*Passerina cyanea*	PO	PR	PR			PO				PO	
Killdeer	*Charadrius vociferus*						PR	PR			PO	PO
Mallard	*Anas platyrhynchos*		X		PR	X	X					
Mourning Dove	*Zenaida macroura*			PO	PO	PO		PR				
Nashville Warbler	*Leiothlypis ruficapilla*										PR	
Northern Cardinal	*Cardinalis cardinalis*	PO		PO	PO		PO				PR	PO
Northern Flicker	*Colaptes auratus*				PO	PR	PO	PO				
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*											
Northern Waterthrush	*Parkesia noveboracensis*					PO						
Pine Warbler	*Setophaga pinus*			PO								
Red-breasted Nuthatch	*Sitta canadensis*											
Red-eyed Vireo	*Vireo olivaceus*											PO
Red-tailed Hawk	*Buteo jamaicensis*	PR		PO	PO		PR	PO			PO	
Red-winged Blackbird	*Agelaius phoeniceus*	PO		PO	CO	PR	PO	CO			PR	
Ring-billed Gull	*Larus delawarensis*						X	X				X
Rock Pigeon	*Columba livia*					X						
Ruffed Grouse	*Bonasa umbellus*						PO					
Savannah Sparrow	*Passerculus sandwichensis*		PO	PO	PO	PR	PO	PO			PO	PR
Song Sparrow	*Melospiza melodia*	PO	PO	PO	PO	PR	PO	PO				PO
Spotted Sandpiper	*Actitis macularia*						PO	PO				
Swamp Sparrow	*Melospiza georgiana*											
Tree Swallow	*Tachycineta bicolor*	PR			CO	PO	PO	PO				
Turkey Vulture	*Cathartes aura*			X		X		X			X	X
Vesper Sparrow	*Pooecetes gramineus*				PO							

		Breeding Evidence										
Common Name	**Scientific Name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Warbling Vireo	*Vireo gilvis*					PO	PO					
Wild Turkey	*Meleagris gallopavo*							PO				
Willow Flycatcher	*Empidonax traillii*					PO						
Winter Wren	*Troglodytes hiemalis*					PO	PO					
White-breasted Nuthatch	*Sitta carolinensis*	PO					PO					
Wood Thrush	*Hylocichla mustelina*			PO								
Yellow Warbler	*Setophaga petechia*			PO	PO	PR	PO					
Total	**66**	**18**	**17**	**29**	**25**	**28**	**39**	**31**	**1**	**1**	**22**	**21**

APPENDIX VII

Bird Species Observed in the Study Area 2006 - 2016

Appendix VII. Bird Species Observed in the Study Area

Common Name	Scientific Name	SRANK[1]	COSEWIC[2]	COSSARO[3]	Wellington County[4]	2016
HERONS & BITTERNS						
Great Blue Heron	*Ardea herodias*	S4B			**	(X)
GEESE						
Canada Goose	*Branta canadensis*	S5				X
DUCKS						
Mallard	*Anas platyrhynchos*	S5				X
VULTURES						
Turkey Vulture	*Cathartes aura*	S5B			√	X
HAWKS, KITES & EAGLES						
Cooper's Hawk	*Accipiter cooperii*	S4	NAR	NAR	√*	PO
PLOVERS						
Killdeer	*Charadrius vociferus*	S5B, S5N				PO
SANDPIPERS & PHALAROPES						
American Woodcock	*Scolopax minor*	S4B				CO
GULLS						
Ring-billed Gull	*Larus delawarensis*	S5B, S4N				X
DOVES						
Rock Pigeon	*Columba livia*	SNA				X
Mourning Dove	*Zenaida macroura*	S5				PR
KINGFISHERS						
Belted Kingfisher	*Megaceryle alcyon*	S4B			√	X
WOODPECKERS						
Red-bellied Woodpecker	*Melanerpes carolinus*	S4			√	CO
Downy Woodpecker	*Picoides pubescens*	S5				PO
Hairy Woodpecker	*Picoides villosus*	S5			√*	(X)
Northern Flicker	*Colaptes auratus*	S4B			√*	PO
FLYCATCHERS						
Eastern Wood-pewee	*Contopus virens*	S4B	SC	SC		PO
Alder Flycatcher	*Empidonax alnorum*	S5B				PO
Willow Flycatcher	*Empidonax traillii*	S5B			√	PR
Great Crested Flycatcher	*Myiarchus crinitus*	S4B				PR
Eastern Kingbird	*Tyrannus tyrannus*	S4B			√*	CO
SWALLOWS						
Tree Swallow	*Tachycineta bicolor*	S4B				PO
Bank Swallow	*Riparia riparia*	S4B			√*[1]	PO
Barn Swallow	*Hirundo rustica*	S4B	T	THR		X
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	S4B				PO
CROWS & JAYS						
Blue Jay	*Cyanocitta cristata*	S5				PR
American Crow	*Corvus brachyrhynchos*	S5B				PO
CHICKADEES						
Black-capped Chickadee	*Poecile atricapillus*	S5				PR
NUTHATCHES						
Red-breasted Nuthatch	*Sitta canadensis*	S5			√*	PO
White-breasted Nuthatch	*Sitta carolinensis*	S5				PO
WRENS						
House Wren	*Troglodytes aedon*	S5B				PR
Winter Wren	*Troglodytes hiemalis*	S5B			√*	PO
THRUSHES						
American Robin	*Turdus migratorius*	S5B				PR
MIMIDS						
Gray Catbird	*Dumetella carolinensis*	S4B				PO

Common Name	**Scientific Name**	**SRANK[1]**	**COSEWIC[2]**	**COSSARO[3]**	**Wellington County[4]**	**2016**
WAXWINGS						
Cedar Waxwing	*Bombycilla cedrorum*	S5B				PR
STARLINGS						
European Starling	*Sturnus vulgaris*	SNA				CO
VIREOS						
Warbling Vireo	*Vireo gilvis*	S5B				PR
Red-eyed Vireo	*Vireo olivaceus*	S5B				PR
WOOD WARBLERS						
Yellow Warbler	*Setophaga petechia*	S5B				PR
Pine Warbler	*Setophaga pinus*	S5B			√*	PO
American Redstart	*Setophaga ruticilla*	S5B			√*	PR
Northern Waterthrush	*Parkesia noveboracensis*	S5B				PO
Common Yellowthroat	*Geothlypis trichas*	S5B				PR
CARDINALS & ALLIES						
Northern Cardinal	*Cardinalis cardinalis*	S5				PR
SUMMER FINCHES						
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S4B			√*	PO
Indigo Bunting	*Passerina cyanea*	S4B				PR
SPARROWS						
Grasshopper Sparrow	*Ammodramus savannarum*	S4B			√	PO
Field Sparrow	*Spizella pusilla*	S4B			√*	PO
Savannah Sparrow	*Passerculus sandwichensis*	S4B			√*	PR
Song Sparrow	*Melospiza melodia*	S5B				PR
Swamp Sparrow	*Melospiza georgiana*	S5B				(X)
BLACKBIRDS						
Bobolink	*Dolichonyx oryzivorus*	S4B	T	THR	√*	PR
Red-winged Blackbird	*Agelaius phoeniceus*	S4				PR
Eastern Meadowlark	*Sturnella magna*	S4B	T	THR	√*	PO
Common Grackle	*Quiscalus quiscula*	S5B				CO
Brown-headed Cowbird	*Molothrus ater*	S4B				PO
ORIOLES						
Baltimore Oriole	*Icterus galbula*	S4B			√*	PO
Orchard Oriole	*Icterus spurius*	S4B			√	PO
WINTER FINCHES						
American Goldfinch	*Spinus tristis*	S5B				CO
					Total	**58**

[1] MNRF 2016a; [2] COSEWIC 2016; [3] MNRF 2016b, [4] Dougan & Associates 2009

APPENDIX VIII

Amphibian Species Observed by Plot 2006 - 2016

Appendix VIII. Amphibian Species Observed by Plot 2006 - 2016

Station #1

	2006	2007			2008			2009			2010			2011			2012			2013			2014			2015			2016		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 5	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 17	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 16
American Toad	Nothing Heard			Nothing Heard			Nothing Heard		Nothing Heard				Nothing Heard	1 (1)			Nothing Heard	Nothing Heard	Nothing Heard							2(2)	Nothing Heard				Nothing Heard
Northern Spring Peeper		3	1 (4)		3	1 (5)		1 (4)			1 (7)	2 (7)		3	1 (10)					3	2 (6)		3	1 (4)		2(2)			1(8)		
Tetraploid Gray Treefrog										1 (1)						1 (1)					2 (3)				3			2(9)		3	
Western Chorus Frog																															
Northern Leopard Frog																															
Pickerel Frog																															
Green Frog																															
Mink Frog																															
Bullfrog																															
Wood Frog		1 (7)						1 (1)						2 (10)						2 (3)			1 (1)						1(1)		
Beaufort Wind Scale	0	5	0	1	0	0	3	1	0	2	1	2	2	3	3	1	1	3	2	1	0		4	1	1	1	1	1	1	1	0
%Cloud Cover	98	98	100	25	65	100	100	10	5	15	5	100	100	20	100	5	100	35	100	70	10		20	100	0	0	15	0	30	60	5
Air temp. (^{o}C)	21	13	10	10	7	9	16	2	3	12	10	10	18	15	13	12	12	16	12	6	15		5	15	17.5	12	-	18	11	18	18
Water temp. (^{o}C)	19.9	8.0	10.1	10.3	N/A	N/A	11.8	3.4	6.2	10.5		7.7		13	12	11.6	N/A	N/A	N/A	5.6	11.2		5	10.3	12.8	9.1	N/A	N/A	5.8	17	N/A
Water pH	7.2	7.4	7.1	7.2	N/A	N/A	8.2	9.1	8.6	9.4		6.5		N/A	7.6	7.5	N/A	N/A	N/A	7.4	7.3		7.4	7.4	8	7.8	N/A	N/A	9.5	7.3	N/A
Precipitation?	None	Light rain	Very light rain	None	None	None	None	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #2	2006			2007			2008			2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME			June 22	April 29	May 16	June 5	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 16
American Toad			Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		Nothing Heard
Northern Spring Peeper							1 (2)							1 (4)																			
Tetraploid Gray Treefrog																										1 (3)				2(3)		2(6)	
Western Chorus Frog																																	
Northern Leopard Frog																																	
Pickerel Frog																																	
Green Frog																																	
Mink Frog																																	
Bullfrog																																	
Wood Frog																																	
Beaufort Wind Scale			2	4	2	1	1	0	4	1	0	2	0	2	0	3	3	0	1	0	2	1	0		3	1	1	0	1	1	0	1	0
%Cloud Cover			98	98	100	25	65	100	100	20	10	25	10	100		20	100	5	100	35	100	0	10		20	100	0	0	15	0	10	60	5
Air temp. (^{o}C)			23	12	10	10	7	11	17	2	4	12	13	10	18	15	12.5	12	13	16	12	5.5	13		8	22	20	14	12	18	11.5	18	18
Water temp. (^{o}C)				10.0	12.1	11.7	7	7.8	13.2	5.2	6.3	8.5	8.6	6.9	11.3	9	8.7	8.1	N/A	N/A	N/A	3.6	N/A		5	9.2	13	N/A	9.1	N/A	8.8	N/A	N/A
Water pH				7.6	7.5	7.3	N/A	7.9	8.3	8.4	8.5	9.8	7.6	6.7	8.5	N/A	7.9	7.6	N/A	N/A	N/A	7.9	N/A		7.7	7.7	8.3	N/A	7.48	N/A	9.5	N/A	N/A
Precipitation?			None	None	None	None	None	None	None	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	Light rain	None	None		None	None	None	None	None	None	None	None	None

Station #4

	2006	2007			2008			2009		
	Calling	Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		1 (1)	Nothing Heard	Nothing Heard		Nothing Heard
Northern Spring Peeper					3				1 (2)	
Tetraploid Gray Treefrog										
Western Chorus Frog										
Northern Leopard Frog										
Pickerel Frog										
Green Frog										
Mink Frog										
Bullfrog										
Wood Frog										
Beaufort Wind Scale	1	3	2	1	1	1	1	1	0	1
%Cloud Cover	80	20	100	20	65	5	100	40	40	50
Air temp. (^{o}C)	20	14	10	9	12	17	16	5	8	16
Water temp. (^{o}C)		11.4	11.5	11.2	9	10.5	14.5	7.1	9.1	11.8
Water pH		7.6	7.7	7.6	N/A	7.8	8.3	8.2	9.3	9
Precipitation?	None	None	None	None	None	None	None	None	None	None

	2010			2011			2012			2013		
	Calling			Calling			Calling			Calling		
COMMON NAME	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10
American Toad	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	2 (2)	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	
Northern Spring Peeper							1 (1)					
Tetraploid Gray Treefrog												
Western Chorus Frog												
Northern Leopard Frog												
Pickerel Frog												
Green Frog												
Mink Frog												
Bullfrog												
Wood Frog				1 (1)								
Beaufort Wind Scale	0	2	0	3	2	0	1	0	1	0	0	
%Cloud Cover	5	100	100	40	100	5	100	0	100	60	15	
Air temp. (^{o}C)	5	8	24	15	14	12	12	22	15	7	15	
Water temp. (^{o}C)	6.2	6		10	N/A	8.1	N/A	N/A	N/A	4.8	N/A	
Water pH	7.8	7.6		N/A	N/A	7.6	N/A	N/A	N/A	8.1	N/A	
Precipitation?	None	Rain	None	None	Rain	None	Light rain	None	None	None	None	

	2014			2015			2016		
	Calling			Calling			Calling		
COMMON NAME	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard			Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper									
Tetraploid Gray Treefrog									
Western Chorus Frog									
Northern Leopard Frog		1 (1)							
Pickerel Frog									
Green Frog			1 (2)						
Mink Frog									
Bullfrog									
Wood Frog									
Beaufort Wind Scale	3	1	0	3	1	2	0	0	0
%Cloud Cover	5	0	90	90	5	10	35	5	20
Air temp. (^{o}C)	7.5	20	19	12	13	18	11	23	20
Water temp. (^{o}C)	5.5	18.8	10.4	7.8	N/A	N/A	N/A	17	N/A
Water pH	7.2	8	8.2	7.3	N/A	N/A	N/A	7.2	N/A
Precipitation?	None	None	None	None	None	None	None	None	None

Station #6	**2006**	**2007**			**2008**			**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling	**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard	1(4)		Nothing Heard					Nothing Heard				Nothing Heard	1 (6)		Nothing Heard	Nothing Heard	Nothing Heard					Nothing Heard	Nothing Heard			Nothing Heard	1(1)	Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper		3	2(3)		1 (2)	1(1)	1(2)	3			3	2 (5)		3	3				1 (1)	2 (4)	1 (2)					2(4)					
Tetraploid Gray Treefrog							3			1 (1)															1 (2)			2(4)			
Western Chorus Frog		1(1)																													
Northern Leopard Frog																															
Pickerel Frog																															
Green Frog							1(2)			1 (1)																					
Mink Frog																															
Bullfrog																															
Wood Frog														1 (2)						3						1(1)					
Beaufort Wind Scale	1	3	2	1	1	0	3	0	0	0	1	1	0	1	3	1	2	0	2	1	1		3	1	0	2	3	2	0	0	0
%Cloud Cover	2	40	100	20	65	100	100	30	10	50	10	100	100	40	100	0	100	0	100	70	5		5	0	90	0	5	10	35	0	20
Air temp. (^{o}C)	18	12	9	9	11	13	16	2	5	15	8	8	24	14	13.5	12	11	19	15	6	13		7.5	20	17	11	14	20	11	19	20
Water temp. (^{o}C)	23.6	14.4	14.1	15.3	N/A	13.8	16.3	8.9	7.7	16.7	13.3	9	19.1	13.5	N/A	10	N/A	N/A	N/A	10.5	N/A		6.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water pH	7.8	7.8	7.8	7.6	N/A	8.0	8.5	8.1	8.7	9.8	7.9	8.5	7.2	N/A	N/A	8.3	N/A	N/A	N/A	7.4	N/A		8.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #7	**2006**	**2007**			**2008**			**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling	**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper						1(1)																									
Tetraploid Gray Treefrog																												2(3)			
Western Chorus Frog																															
Northern Leopard Frog																															
Pickerel Frog																															
Green Frog																															
Mink Frog																															
Bullfrog																															
Wood Frog																															
Beaufort Wind Scale	1	3	2	1	1	0	2	0	0	0	1	1	0	1	1	2	1	0	2	1	0		3	1	0	2	1	3	0	0	0
%Cloud Cover	75	15	100	20	65	50	100	30	10	50	0	100	100	10	100	0	100	0	100	80	15		5	0	90	100	5	10	35	0	20
Air temp. (^oC)	18	13	10	7	11	13	16	4	7	15	8	8	24	13	14	13	12	20	15	7	14		7.5	20	18	12	13	18	11	19	20
Water temp. (^oC)	11.4	9.3	10.5	10.4	N/A	10.9	10.8	5.9	n/a	12	8.6	6		8	9.5	11.6	7.6	N/A	N/A	5.3	7.7		5.4	8.5	11.9	6	12.3	N/A	6.9	15	N/A
Water pH	8.2	7.7	7.7	7.6	N/A	8.2	8.4	8	n/a	9.7	7.6	7.9		N/A	8	8.4	7.8	N/A	N/A	8.1	8.6		7.3	7.8	7.8	7.8	8.9	N/A	8.3	7.1	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #8	2006	2007			2008			2009			2010			2011			2012			2013			2014			2015			2016		
	Calling	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	June 22	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	Apr 20	May 21	June 16	Apr 20	May 30	June 21
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard
Northern Spring Peeper																															
Tetraploid Gray Treefrog																		1 (1)												2(2)	
Western Chorus Frog																															
Northern Leopard Frog																															
Pickerel Frog																															
Green Frog																															
Mink Frog																															
Bullfrog																															
Wood Frog																															
Beaufort Wind Scale	1	2	2	1	1	0	1	0	0	1	1	2	0	2	2	1	1	1	2	0	0					3	1	2	1	0	0
%Cloud Cover	80	15	100	20	65	50	100	30	30	50	0	100	100	40	100	0	100	5	100	80	15					100	5	10	30	5	20
Air temp. (^oC)	18.5	13	10	9	11	14	16	3	7	16	8	8	24	14	13	13	12	22	15	7	14					12	13	18	11	19	20
Water temp. (^oC)	14.5	11.5	11.4	11	10	12.1	13	7.6	8.9	12.4	9.4	7	13.6	12	12	13	12.9	N/A	N/A	7	14.6					8.3	12.3	N/A	10.4	16	N/A
Water pH	8	7.7	7.8	7.8	N/A	8.2	8.5	8.1	9.4	9.4	7.6		7.1	N/A	8.4	8.4	8.4	N/A	N/A	8.4	8.4					7.4	8.9	N/A	8.1	7.3	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None	Rain	None	Light rain	None	None	None	None					None	None	None	None	None	None

Station #9	2007			2008			2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 29	May 16	June 6	April 24	May 15	June 4	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 21
American Toad				Nothing Heard		3					Nothing Heard	Nothing Heard	1 (1)			Nothing Heard	Nothing Heard	Nothing Heard						Nothing Heard		Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper	2(10)	1(2)			1(3)		1 (7)	1 (4)		1 (1)			1 (2)	1 (4)					1 (2)	2 (5)		3	1 (5)		3					
Tetraploid Gray Treefrog						1 (1)			1 (2)																		2(5)			
Western Chorus Frog																														
Northern Leopard Frog							1 (1)																							
Pickerel Frog																														
Green Frog			1(1)																											
Mink Frog																														
Bullfrog																														
Wood Frog	1(2)						1 (4)						1 (2)												2(3)					
Beaufort Wind Scale	5	2	1	1	0	1	0	0	2	0	2	0	3	3	2	1	3	2	1	0		4	1	1	3	1	1	1	1	0
%Cloud Cover	70	100	20	65	50	100	10	20	25	5	100	100	20	100	5	100	40	100	80	10		35	100	0	0	15	0	35	50	5
Air temp. (^{o}C)	13	10	9	11	14	16	2	6	14	1	10	18	15	9.4	11	12	16	12	5	16		5	22	18	11	12.6	18	11	18	18
Water temp. (^{o}C)	12.5	12.2	13.7	10	12.1	13	5.4	7.7	14.3	8.5			N/A	N/A	12.9	N/A	N/A	N/A	6.3	14.5		5.2	17.6	N/A	13	N/A	N/A	N/A	18	N/A
Water pH	7.7	7.5	7.3	N/A	8.2	8.5	8.2	8.7	9.6	8			N/A	N/A	6.6	N/A	N/A	N/A	7.5	7.6		7.4	7.6	N/A	7.1	N/A	N/A	N/A	7.2	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	Rain	None	None	Heavy Rain	None	Light rain	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #10	**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 21
American Toad		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard		Nothing Heard	Nothing Heard			Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	2(3)	Nothing Heard	2(2)	Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper					1 (2)					1 (1)	1 (1)													
Tetraploid Gray Treefrog																					2(8)			
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																								
Mink Frog																								
Bullfrog																								
Wood Frog	1 (2)						1 (2)																	
Beaufort Wind Scale	0	0	2	0	2	0	3	4	3	1	3	2	1	0		3	1	0	1	1	1	2	1	0
%Cloud Cover	20	10	15	5	100	100	90	100	5	100	40	100	60	10		35	100	90	10	15	0	20	60	5
Air temp. (^{o}C)		3	12	4	10	24	14.5	13.8	12	13	16	12	5	13		5	15	17	12	12.5	18	11	17	19
Water temp. (^{o}C)	8.5	10.7	14.1	12.1	9.3	19	12	13.1	16.5	14.3	17	N/A	9.3	18.9		8.4	17.9	15	13.2	N/A	N/A	13	N/A	N/A
Water pH	8.8	8.6	9.5	7.8	7	7.4	N/A	8	8.1	7.6	8.2	N/A	7.9	7.9		N/A	8	7.7	7.8	N/A	N/A	9	N/A	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #11

	2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 21
American Toad		Nothing Heard	Nothing Heard			Nothing Heard			Nothing Heard		Nothing Heard	Nothing Heard					Nothing Heard	Nothing Heard	3	Nothing Heard	2(2)			Nothing Heard
Northern Spring Peeper	1 (1)			1 (1)	2 (5)		1 (4)	1 (4)		2 (5)			1 (1)	1 (1)	1 (1)	1 (1)								
Tetraploid Gray Treefrog																					2(7)		1(1)	
Western Chorus Frog																								
Northern Leopard Frog	1 (1)																							
Pickerel Frog				1 (1)																				
Green Frog																								
Mink Frog																								
Bullfrog																								
Wood Frog	1 (1)																					1(1)		
Beaufort Wind Scale	0	0	2	0	2	0	3	4	1	1	3	2	1	0		3	1	0	0	1	1	2	1	0
%Cloud Cover	20	10	25	5	100	100	40	100	5	100	40	100	60	10		40	100	90	0	15	0	0	60	5
Air temp. (^{o}C)	3	3	12	4	10	24	14.5	13	12	13	16	12	5	13		6	16	17	11	12.9	18	11	17	19
Water temp. (^{o}C)	6.6	n/a	n/a	6	9.5		12	12	14.3	14.5	16.7	N/A	8.2	18.6		6.5	18.1	16	12	12.5	N/A	6.9	N/A	N/A
Water pH	7.8	n/a	n/a	8.1	7.8		N/A	7.1	8.0	7.8	8	N/A	7.9	7.8		7.9	7.7	7.6	7.4	7.81	N/A	9.4	N/A	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	None	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #12	**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 21
American Toad						Nothing Heard			Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard							2(2)	Nothing Heard		Nothing Heard	2(2)	
Northern Spring Peeper	3	1 (3)		1 (6)	3		3	3					3	3		2 (6)	1 (1)							
Tetraploid Gray Treefrog																	1 (3)	1 (2)			2(8)			1(4)
Western Chorus Frog																								
Northern Leopard Frog	1 (2)																							
Pickerel Frog																								
Green Frog			1 (2)																					
Mink Frog																								
Bullfrog																								
Wood Frog	1 (2)						1 (2)						1 (1)											
Beaufort Wind Scale	0	0	2	2	2	0	4	4	2	1	3	2	2	0		3	1	1	2	1	1	2	1	0
%Cloud Cover	20	10	15	30	100		50	100	0	100	15	100	70	10		10	100	0	0	15	0	20	60	5
Air temp. (^{o}C)	2	3	10	5	10		14.5	13.5	10	10.5	16	12	7	12		5	15	17.5	12	12	18	11	17	18
Water temp. (^{o}C)	6.9	11.5	14.6	11.1	10.4	19.8	N/A	N/A	10	N/A	N/A	N/A	9.7	12.3		N/A	13.4	N/A	N/A	N/A	N/A	N/A	18	N/A
Water pH	8	9.2	9.9	7.8	6.8	8	N/A	N/A	8.4	N/A	N/A	N/A	7.4	7.5		N/A	7.5	N/A	N/A	N/A	N/A	N/A	7.2	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Moderate Rain	None	Light rain	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #13	**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard
Northern Spring Peeper																								
Tetraploid Gray Treefrog																								
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																							2(2)	
Mink Frog																								
Bullfrog																								
Wood Frog																								
Beaufort Wind Scale	0	0	0	1	1	0	1	2	1	2	0	1	0	1		3	1	0	2	3	1	0	0	0
%Cloud Cover	30	10	50	10	100	100	30	100	0	90	0	100	60	5		5	0	90	90	5	10	35	0	5
Air temp. (^{o}C)	3	5	14	5	8	24	14	13	12	10	17	15	6	13		7	21	17	10	14	18	11	19	20
Water temp. (^{o}C)	6.2	8	11.3	6.6	8	14.5	11	N/A	12	N/A	N/A	N/A	N/A	N/A		5.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water pH	8	8.8	9.9	7.8	7.9	7.2	N/A	N/A	8.2	N/A	N/A	N/A	N/A	N/A		7.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	None	None	None		None	None	None	None	None	None	None	None	None

Station #14

	2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard	Nothing Heard	1 (1)	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard			Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard
Northern Spring Peeper										2 (2)							2 (6)							
Tetraploid Gray Treefrog																					1(2)			
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																								
Mink Frog																								
Bullfrog																								
Wood Frog																								
Beaufort Wind Scale	0	0	0	0		0	1	N/A	1	1	0	2	0			3	1	0	2	2	1	0	0	0
%Cloud Cover	20	10	50	5	100	100	30	100	0	90	0	100	50			5	0	90	90	5	10	35	0	5
Air temp. (^oC)	2	5	14	5		24	15	13	12	11	17	12	7			7	18	17	10	13	18	11	19	20
Water temp. (^oC)	6.6	8.8	n/a	7.1	7	13.7	N/A	N/A	12	N/A	N/A	N/A	N/A			6.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water pH	8	8.5	n/a	8.1	8	7.4	N/A	N/A	8.5	N/A	N/A	N/A	N/A			7.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Precipitation?	None	None	None	None	None	None	None	None	None	None	None	Light rain	None			None	None	None	None	None	None	None	None	None

Station #15	2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard					Nothing Heard		Nothing Heard	Nothing Heard					Nothing Heard			Nothing Heard	Nothing Heard			Nothing Heard
Northern Spring Peeper					1(3)		3	2 (4)		3			1 (1)			2 (4)			2(4)			3		
Tetraploid Gray Treefrog						2 (3)																	2(6)	
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																		1 (5)						
Mink Frog																								
Bullfrog																								
Wood Frog													1 (1)			1 (1)			2(5)			3		
Beaufort Wind Scale	0	0	0	0	2	0	3	2	0	1	0	1	0			3	0	0	2	1	1	0	0	0
%Cloud Cover	20	10	50	5	100	100	40	100	0	100	0	100	50			5	0	90	90	5	10	30	0	5
Air temp. (^{o}C)	2	5	14	5	10	24	15	13	14	12	16	12	7			7	18	17	10	-	18	11	19	20
Water temp. (^{o}C)	5.7	8.3	10.4		8.9	17.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A			6.2	17.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Water pH	8	9	9.8		7.2	6.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A			7.9	7.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Precipitation?	None	None	None	None	Light rain	None	None	Hard Rain	None	Light rain	None	None	None			None	None	None	None	None	None	None	None	None

Station #16	**2009**			**2010**			**2011**			**2012**			**2013**			**2014**			**2015**			**2016**		
	Calling			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**			**Calling**		
COMMON NAME	April 23	May 11	June 2	April 22	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad		Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard			Nothing Heard	*2 (2)*	Nothing Heard	2 (3)						Nothing Heard		Nothing Heard	2(2)			Nothing Heard
Northern Spring Peeper	3			1 (3)			2 (4)	3					2 (3)			1 (1)	1 (1)					3		
Tetraploid Gray Treefrog												2 (6)									2(11)		3	
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																							1(2)	
Mink Frog																								
Bullfrog																								
Wood Frog							2 (8)						3						2(5)					
Beaufort Wind Scale	0	0	0	1	1	0	2	2	1	2	0	1	0						3	3	2	1	0	0
%Cloud Cover	30	10	50		100	100	10	100	0	100	0	100	80						100	5	10	40	0	5
Air temp. (^{o}C)	4	7	16	8	8	24	14	13.5	13	11	20	16	6						12	14	20	11	19	20
Water temp. (^{o}C)	7.5	8.8	13.7	11.2	7.5		14	13.7	11.2	N/A	N/A	N/A	9.4						11.6	N/A	N/A	12.3	17	N/A
Water pH	8.1	9.1	9.5	7.5	7.9		N/A	8.1	8.4	N/A	N/A	N/A	7.9						7.5	N/A	N/A	8.2	7.2	N/A
Precipitation?	None	None	None	None	None	None	None	Hard Rain	None	Light rain	None	None	None						None	None	None	None	None	None

Station #17	2009			2010			2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 23	May 11	June 2	April 24	May 13	June 3	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 29	May 21	June 16	April 20	May 23	June 21
American Toad		No Datasheet	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard			Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard	Nothing Heard			Nothing Heard
Northern Spring Peeper																	1 (2)							
Tetraploid Gray Treefrog																	1 (2)						2(5)	
Western Chorus Frog																								
Northern Leopard Frog																								
Pickerel Frog																								
Green Frog																								
Mink Frog																								
Bullfrog																								
Wood Frog	1 (2)						1 (5)															1(1)		
Beaufort Wind Scale	0		2	0	2	0	3	3	1	1	3	2	0			4	1	1	2	1	1	2	1	0
%Cloud Cover	10		25	10	100	100	20	100	10	100	40	100	0			30	100	0	0	15	0	20	50	5
Air temp. (^{o}C)			12	12	10	18	15	13.2	12	11	16	12	6			6	22	20	11	13.5	18	11	18	18
Water temp. (^{o}C)	6.3		n/a	15	8		12	12.5	N/A	N/A	N/A	N/A	8.5			6.2	18.6	N/A	N/A	N/A	N/A	9.8	N/A	N/A
Water pH	8.2		n/a	7.9	6.9		N/A	8.1	N/A	N/A	N/A	N/A	7.8			7.4	8	N/A	N/A	N/A	N/A	9.1	N/A	N/A
Precipitation?	None		None	None	Rain	None	None	Heavy Rain	None	None	None	Light rain	None			None	None	None	None	None	None	None	None	None

Station #18	2011			2012			2013			2014			2015			2016		
	Calling			Calling			Calling			Calling			Calling			Calling		
COMMON NAME	April 27	May 18	June 2	April 19	May 15	June 4	April 16	May 9	June 10	April 29	May 21	June 9	April 20	May 21	June 16	April 20	May 30	June 21
American Toad			Nothing Heard	3	Nothing Heard		Nothing Heard			Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard	Nothing Heard		Nothing Heard	Nothing Heard
Northern Spring Peeper		3				1 (1)										3		
Tetraploid Gray Treefrog												1 (1)						
Western Chorus Frog																		
Northern Leopard Frog																		
Pickerel Frog																		
Green Frog																		
Mink Frog																		
Bullfrog																		
Wood Frog	1 (1)																	
Beaufort Wind Scale	1	2	2	1	0	1	1			3	1	0	2	1	3	1	0	0
%Cloud Cover	10	100	0	100	0	100	80			5	0	90	90	5	10	40	0	5
Air temp. (^{o}C)	14	14	13	11	20	15	6			7.5	20	18	12	14	20	11	19	20
Water temp. (^{o}C)	12	N/A	10	N/A	N/A	N/A	N/A			5.5	N/A	N/A	8.9	N/A	N/A	N/A	N/A	N/A
Water pH	N/A	N/A	8	N/A	N/A	N/A	N/A			7.6	N/A	N/A	7.9	N/A	N/A	N/A	N/A	N/A
Precipitation?	None	Hard Rain	None	None	None	None	None			None	None	None	None	None	None	None	None	None

LEGEND	
X	individual seen, but not calling
# (_)	call intensity and estimated number of individuals

Call Level Codes	
1	Calls can be counted; not simultaneous
2	Some simultaneous calls; yet distinguishable
3	Calls not distinguishable individually; overlapping

NA: (Not Applicable) denotes lack of water or not recorded

Beaufort Wind Scale #	**KPH**	**Description**
0	0-2	Calm; smoke rises vertically
1	3 to 5	Light air movement; smoke drifts
2	6 to 11	Slight Breeze; felt on face, leaves rustle
3	12 to 19	Gentle breeze; leaves and small twigs in constant
4*	20-30	Moderate breeze; small branches are moving, raises
5*	31-39	Fresh breeze; small trees in leaf begin to sway, crested
6*	40-50	Strong breeze, large branches in motion
	*	Unacceptable wind strengths for amphibian surveys

APPENDIX IX

Herpetofaunal Species Observed in the Subject Property

Appendix IX. Herptofaunal Species Observed in the Subject Property

					NRSI											
Common Name	**Scientific Name**	**SRANK[1]**	**COSEWIC[2]**	**COSSARO[3]**	**1998-2004**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Turtles																
Common Snapping Turtle	*Chelydra serpentina serpentina*	S5	SC		√											
Midland Painted Turtle	*Chrysemys picta marginata*	S5								√	√					
Snakes																
Eastern Milksnake	*Lampropeltis t. triangulum*	S3	SC	SC												
Eastern Gartersnake	*Thamnophis sirtalis sirtalis*	S5			√					√	√		√			√
Northern Brownsnake	*Storeria dekayi dekayi*	S5	NAR	NAR						√						
Northern Red-belied Snake	*Storeria occipitomaculata occipitomaculata*	S5								√						
Salamanders																
Jefferson/Blue-spotted Salamdander Polyploids	*Ambystoma jeffersonianum-laterale polyploids*	S2									√					
Eastern Red-backed Salamander	*Plethodon cinereus*	S5			√				√							
Toads and Frogs																
American Toad	*Anaxyrus americanus*	S5								√	√	√	√	√	√	√
Tetraploid Gray Treefrog	*Hyla versicolor*	S5			√	√	√	√	√	√	√	√	√	√	√	√
Western Chorus Frog*	*Pseudacris triseriata* pop.2	S3	T	NAR	√	√										
Northern Spring Peeper	*Pseudarcris crucifer crucifer*	S5					√	√	√	√	√	√	√	√	√	√
Bullfrog	*Lithobates catesbeianus*	S4			√	√	√	√	√	√						
Green Frog	*Rana clamitans melanota*	S5								√		√	√	√	√	√
Pickerel Frog	*Lithobates palustris*	S4	NAR	NAR	√	√	√	√	√	√						
Northern Leopard Frog	*Lithobates pipiens*	S5	NAR	NAR						√	√		√	√		
Mink Frog	*Lithobates septentrionalis*	S5			√	√			√	√						
Wood Frog	*Lithobates sylvatica*	S5			√		√	√	√	√	√	√	√	√	√	√

[1]MNRF 2016a; [2]COSEWIC 2016; [3]MNRF 2016b

*Great Lakes/ St. Lawrence - Canadian Shield Pop.

Legend	
SRANK	
S2 Imperiled	S4 Apparently Secure
S3 Vulnerable	S5 Secure
COSEWIC, SARO	
NAR Not at Risk	SC Special Concern
T/THR Threatened	
NRSI	
√ Observed	

MAPS

Map 1

Hanlon Creek Business Park

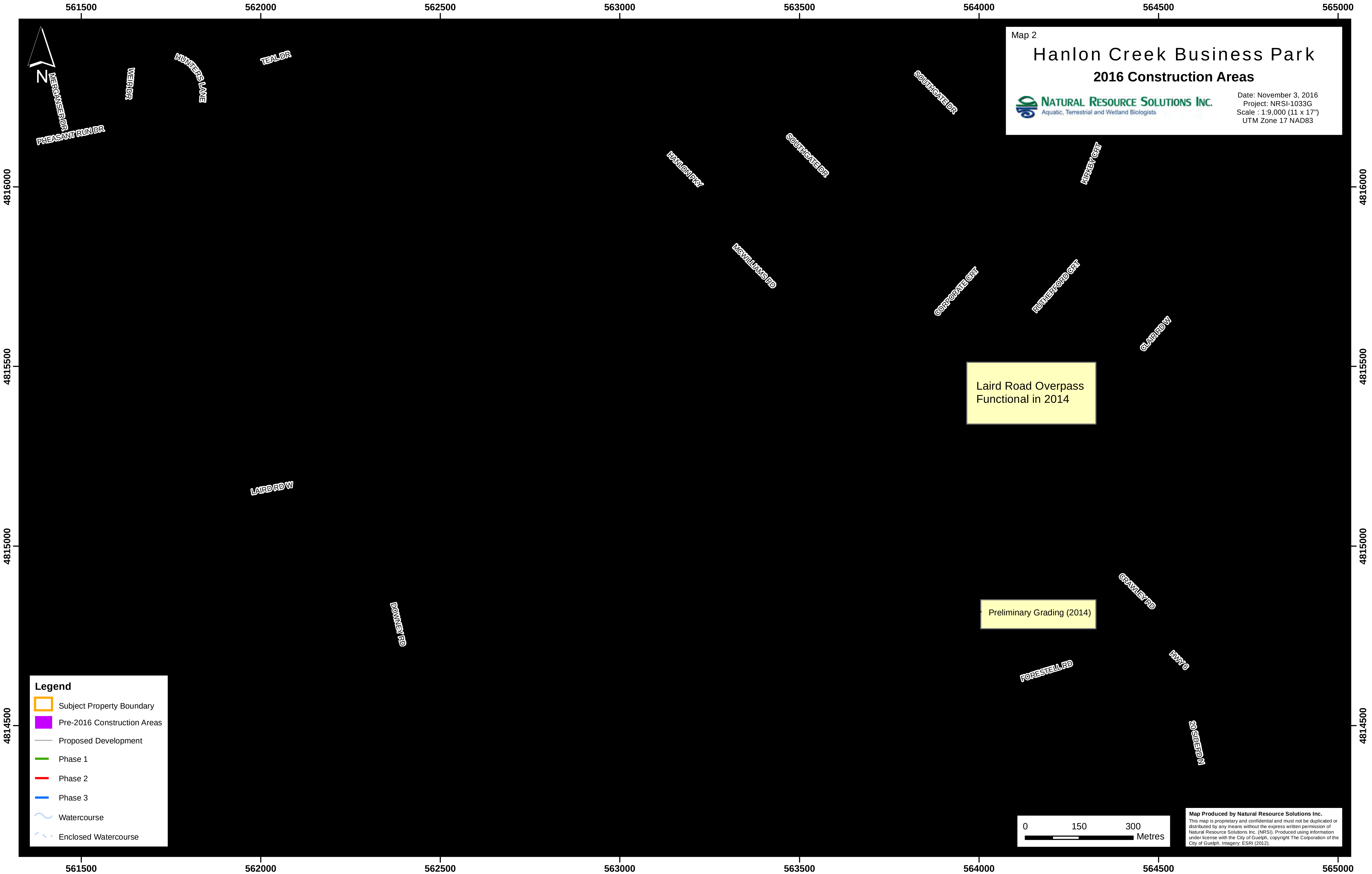
Study Area and Natural Features

Natural Resource Solutions Inc.
Aquatic, Terrestrial and Wetland Biologists

Date: February 15, 2017
Project: NRSI-1033G
Scale: 1:9,000 (11 x 17")
UTM Zone 17 NAD83

Map Produced by Natural Resource Solutions Inc.

Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1033G_Map1_StudyArea_9K_2017_02_15_LEH.mxd



Map 2

Hanlon Creek Business Park

2016 Construction Areas

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

Date: November 3, 2016
Project: NRSI-1033G
Scale : 1:9,000 (11 x 17")
UTM Zone 17 NAD83

Laird Road Overpass Functional in 2014

Preliminary Grading (2014)

Legend

🟧 Subject Property Boundary
🟪 Pre-2016 Construction Areas
— Proposed Development
— Phase 1
— Phase 2
— Phase 3
〜 Watercourse
╌ Enclosed Watercourse

Map Produced by Natural Resource Solutions Inc.
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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1033G_Map2_2016ConstructionAreas_9K_2016_11_03_LEH.mxd

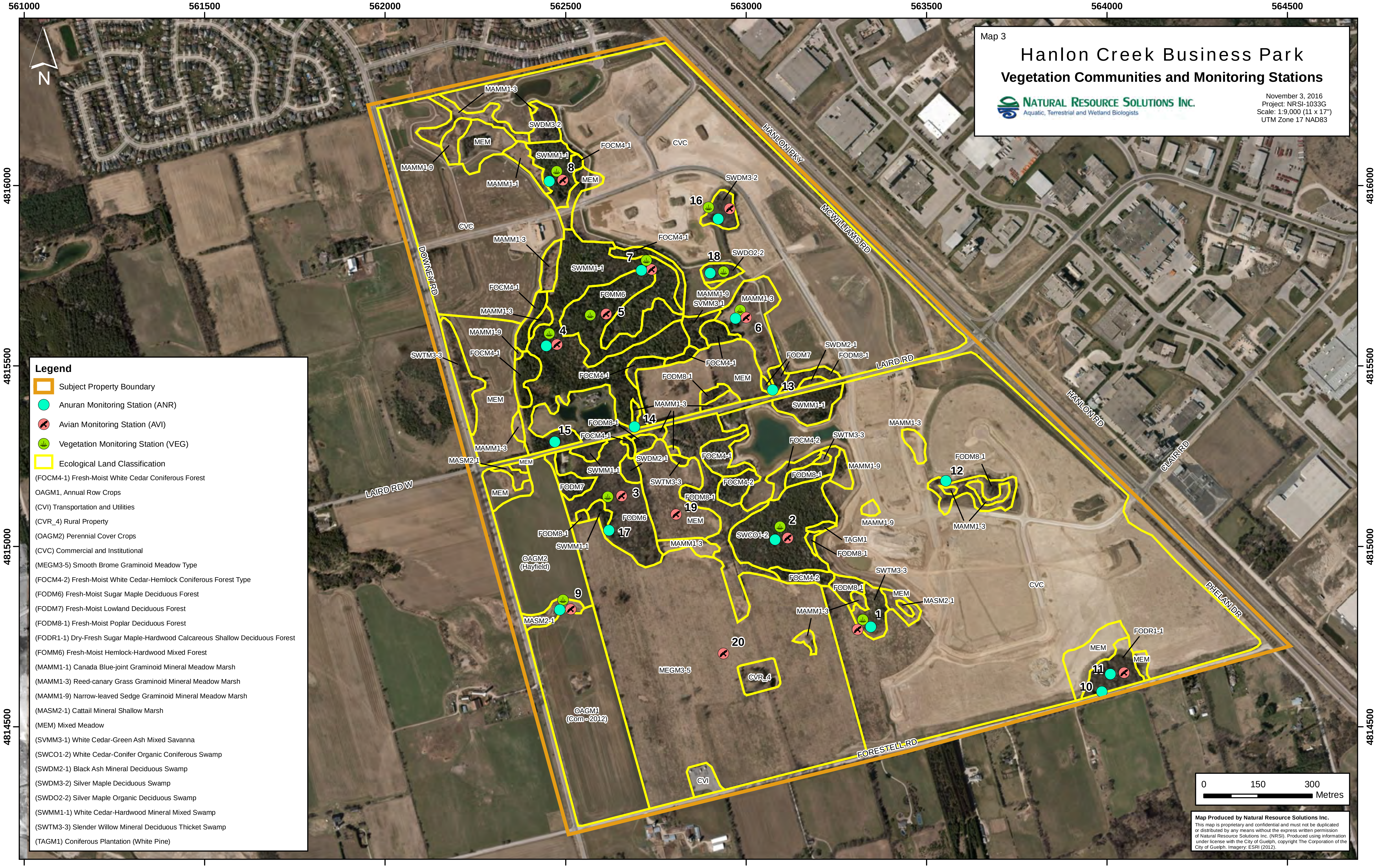
Map 3

Hanlon Creek Business Park

Vegetation Communities and Monitoring Stations

NATURAL RESOURCE SOLUTIONS INC.
Aquatic, Terrestrial and Wetland Biologists

November 3, 2016
Project: NRSI-1033G
Scale: 1:9,000 (11 x 17")
UTM Zone 17 NAD83



Legend

- Subject Property Boundary
- Anuran Monitoring Station (ANR)
- Avian Monitoring Station (AVI)
- Vegetation Monitoring Station (VEG)
- Ecological Land Classification

(FOCM4-1) Fresh-Moist White Cedar Coniferous Forest
OAGM1, Annual Row Crops
(CVI) Transportation and Utilities
(CVR_4) Rural Property
(OAGM2) Perennial Cover Crops
(CVC) Commercial and Institutional
(MEGM3-5) Smooth Brome Graminoid Meadow Type
(FOCM4-2) Fresh-Moist White Cedar-Hemlock Coniferous Forest Type
(FODM6) Fresh-Moist Sugar Maple Deciduous Forest
(FODM7) Fresh-Moist Lowland Deciduous Forest
(FODM8-1) Fresh-Moist Poplar Deciduous Forest
(FODR1-1) Dry-Fresh Sugar Maple-Hardwood Calcareous Shallow Deciduous Forest
(FOMM6) Fresh-Moist Hemlock-Hardwood Mixed Forest
(MAMM1-1) Canada Blue-joint Graminoid Mineral Meadow Marsh
(MAMM1-3) Reed-canary Grass Graminoid Mineral Meadow Marsh
(MAMM1-9) Narrow-leaved Sedge Graminoid Mineral Meadow Marsh
(MASM2-1) Cattail Mineral Shallow Marsh
(MEM) Mixed Meadow
(SVMM3-1) White Cedar-Green Ash Mixed Savanna
(SWCO1-2) White Cedar-Conifer Organic Coniferous Swamp
(SWDM2-1) Black Ash Mineral Deciduous Swamp
(SWDM3-2) Silver Maple Deciduous Swamp
(SWDO2-2) Silver Maple Organic Deciduous Swamp
(SWMM1-1) White Cedar-Hardwood Mineral Mixed Swamp
(SWTM3-3) Slender Willow Mineral Deciduous Thicket Swamp
(TAGM1) Coniferous Plantation (White Pine)

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Path: X:\0682_HanlonTerrestrialandAquaticMonitoring\NRSI_1033G_Map3_ELC_MonitoringStations_9K_2016_11_03_LEH.mxd

APPENDIX VI

RAPID ASSESSMENT AND ACTION PROTOCOL DOCUMENTATION

Subject: HCBP RAAP call - August 15th, follow up
From: "Sones, Adrienne" <Adrienne.Sones@aecom.com>
Date: 8/19/2016 1:26 PM
To: "Adele.Labbe@guelph.ca" <Adele.Labbe@guelph.ca>, "Prasoon.Adhikari@guelph.ca" <Prasoon.Adhikari@guelph.ca>, "John Palmer (jpalmer@grandriver.ca) (jpalmer@grandriver.ca)" <jpalmer@grandriver.ca>, "aschiedel@nrsi.on.ca" <aschiedel@nrsi.on.ca>, "tbrenton@nrsi.on.ca" <tbrenton@nrsi.on.ca>, "tzammit@grandriver.ca" <tzammit@grandriver.ca>, "Bill.Banks@banksgroundwater.ca" <Bill.Banks@banksgroundwater.ca>, "Tufgar, Ray" <Ray.Tufgar@aecom.com>, "Minielly, Andrew" <Andrew.Minielly@aecom.com>
CC: "Parhizgari, Zahra" <Zahra.Parhizgari@aecom.com>

Hello RAAP Team,

This e-mail is intended to follow-up on Monday's call regarding the exceedances observed on August 12 at HCBP stations HC-A(03) and HC-A(11).

The call was attended by Adele Labbe, John Palmer, Tony Zammit and myself.

It was noted exceedances occurred at two sites that do not typically see exceedances. AECOM had brief discussions Bill Banks prior to the call. Bill indicated that recent site visits showed there was likely no groundwater input to HC-A(11) at the time of exceedance due to low groundwater levels recorded near the site. He also noted that groundwater levels did not yet appear to be as low as noted in 2012.

To confirm whether the low water levels had caused temperature gauges to record temperatures reflective of the water surface, AECOM staff visited the site on Monday to download secondary loggers. AECOM noted the following:

- HC-A(03) - The telemetry station sensor was closer to the surface than the heavier backup logger. The backup logger recorded a maximum temperature of 21.6°C on the creek bottom. Telemetry station was 24.39 °C
- HC-A(11) - The telemetry station sensor was also closer to the surface than the heavier backup logger. The backup logger recorded a maximum temperature of 22.4° on the creek bottom. Telemetry station was 24.41°C. It was also noted that quite a bit of water pooled at HC-A(11).

AECOM also download the backup loggers for stations HC-A(04) and HC-A(06). These loggers indicated a slight exceedance at both stations that was not recorded by the telemetry stations. Following a further look at the data, AECOM internally discussed the secondary loggers provide a better dataset for comparison as the backup loggers are heavy and sit on the creek bottom. Telemetry temperature loggers are lighter and vary in location within the water column.

Adele will be meeting with Peter Cartwright next week to discuss potential remediation of Pond 4 next week. AECOM will provide Adele with a summary of all exceedances noted on site this year to aid in this discussion.

Please let me know if you have any comments to add to the discussion or concerns.

Regards,

Adrienne Sones, P.Eng.
Water Resources Engineer, Water
D +1-519-963-5922
adrienne.sones@aecom.com

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Subject: HCBP - RAAP call - Sites HC-A(06) - August 20th thermal exceedance
From: "Sones, Adrienne" <Adrienne.Sones@aecom.com>
Date: 8/29/2016 8:59 AM
To: "'Adele.Labbe@guelph.ca'" <Adele.Labbe@guelph.ca>, "'Prasoon.Adhikari@guelph.ca'" <Prasoon.Adhikari@guelph.ca>, "John Palmer (jpalmer@grandriver.ca) (jpalmer@grandriver.ca)" <jpalmer@grandriver.ca>, "'aschiedel@nrsi.on.ca'" <aschiedel@nrsi.on.ca>, "'tbrenton@nrsi.on.ca'" <tbrenton@nrsi.on.ca>, "'tzammit@grandriver.ca'" <tzammit@grandriver.ca>, "'Bill.Banks@banksgroundwater.ca'" <Bill.Banks@banksgroundwater.ca>, "Tufgar, Ray" <Ray.Tufgar@aecom.com>, "Minielly, Andrew" <Andrew.Minielly@aecom.com>
CC: "Parhizgari, Zahra" <Zahra.Parhizgari@aecom.com>

Hello RAAP Team,

This e-mail is intended to follow-up on the August 22nd call regarding the exceedances observed on August 20 at HCBP station HC-A(06).

The call was attended by Adele Labbe, Prasoon Adhikari, Tara Brenton, Ray Tufgar and myself.

On Saturday August 20, 2016 there was an exceedances of 24°C at HCBP stations HC-A(06). The table below summarizes the exceedance noted by the telemetry station.

Date	Time of Exceedance	Maximum Temperature (°C)	Station	Potential Justification
August 20, 2016	11:00 am – 10:00 pm	24.73	HC-A(06)	Rainfall event of approximately 50 mm occurred at the site 5:20 am to 6:25 am. Higher than typical daily minimum air temperature, overnight low was above average and could have not provided cooling trench with an opportunity to cool down.

The following highlights key discussion points of the meeting:

- AECOM staff were asked to download other relevant temperature loggers onsite to help verify the cause of the exceedance. This was completed and is further discussed below.
- The City of Guelph will consider returning the water level in the Pond to the design level and introduce more plantings as per the original design in attempt to provide more shading to the Pond. It was noted that the pond is currently owned by Cooper Construction.

AECOM staff visited the site August 23rd to downloaded all loggers located within Pond 4 and also between the Pond 4 outlet to Hanlon Creek and HC-A(06), located downstream of Laird Road. A graph summary of this data is included below. The data indicates after the rainfall event, the cooling trench was no longer able to provide the cooling effect noted prior the rainfall. This is likely due to the large rainfall runoff volume of water reaching the cooling trench, causing the rocks within the cooling trench to warm, thereby reducing the cooling trench's effectiveness to reduce outlet temperatures. It should also be noted that prior to the rainfall event the cooling trench is effectively reducing water temperatures by approximately 5°C.

Please let me know if you have any further questions, comments or concerns.

Regards,
Adrienne

Adrienne Sones, P.Eng.
Water Resources Engineer, Water
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adrienne.sones@aecom.com

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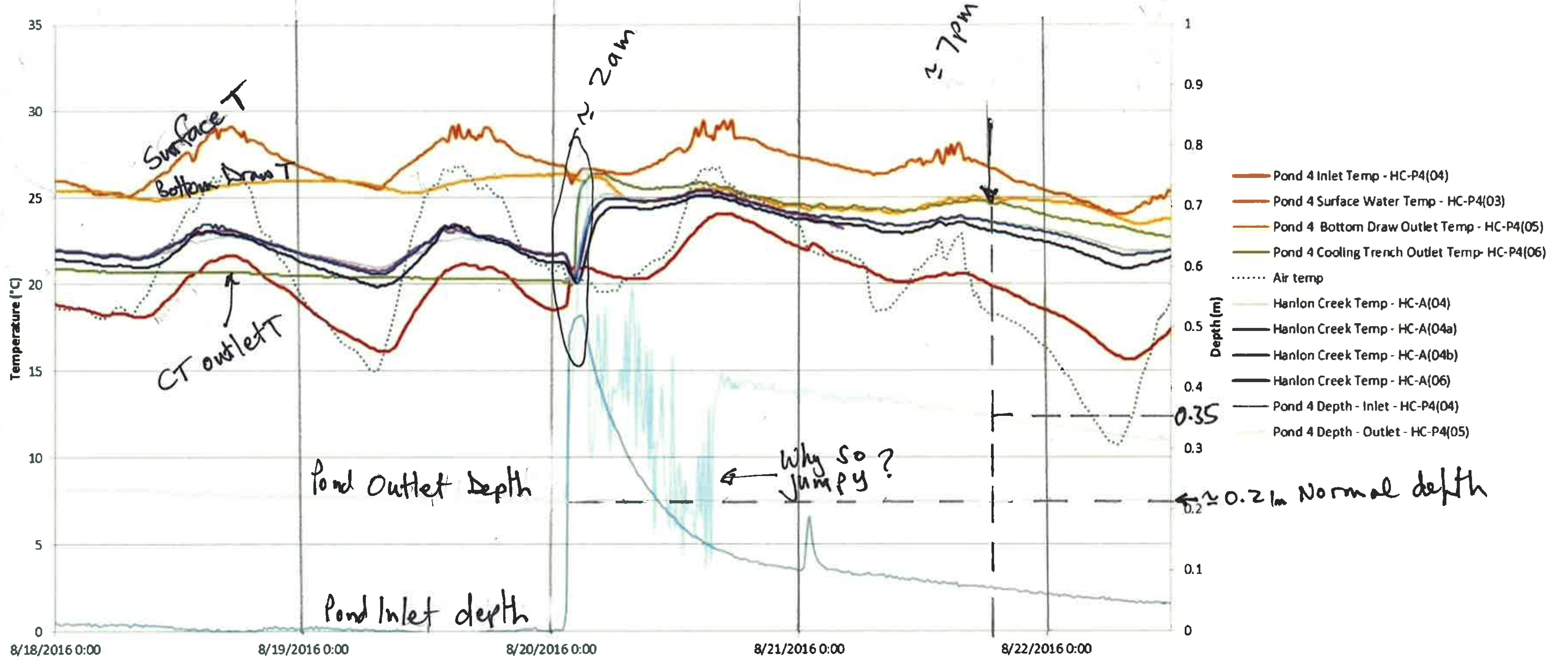
Stream Conditions - August 20, 2016, Temperature Exceedance Downstream of Pond 4



Subject: RE: HCBP - RAAP call - Sites HC-A(06) - August 20th thermal exceedance
From: John Palmer <jpalmer@grandriver.ca>
Date: 2016-08-29 2:30 PM
To: "'Sones, Adrienne'" <Adrienne.Sones@aecom.com>, "'Adele.Labbe@guelph.ca'" <Adele.Labbe@guelph.ca>, "'Prasoon.Adhikari@guelph.ca'" <Prasoon.Adhikari@guelph.ca>, "'aschiedel@nrsi.on.ca'" <aschiedel@nrsi.on.ca>, "'tbrenton@nrsi.on.ca'" <tbrenton@nrsi.on.ca>, "Tony Zammit" <tzammit@grandriver.ca>, "'Bill.Banks@banksgroundwater.ca'" <Bill.Banks@banksgroundwater.ca>, "Tufgar, Ray" <Ray.Tufgar@aecom.com>, "Minielly, Andrew" <Andrew.Minielly@aecom.com>
CC: "Parhizgari, Zahra" <Zahra.Parhizgari@aecom.com>, Nathan Garland <ngarland@grandriver.ca>, Fred Natolochny <fnatolochny@grandriver.ca>

Hello Team,

My analysis of the August 20th temperature exceedance chart is a little different.

Yes, prior to the rainfall event there was a 5°C lower but given that this was during a dry period between rainfall events, any discharge from the cooling trench is a reflection of ground water intercepted by the trench, mixing with the continuous low rate of discharge from Pond 4. As we know, the continuous discharge is caused by groundwater interception.
Very shortly after heavy rainfall in the early hours of August 20th, cooling trench outlet and pond discharge temperatures equalized at about 25°C, not because the rocks warmed but because pond discharge flow rate and temperature overwhelmed any benefit to be gained by mixing with groundwater in the cooling trench.
Cooling trench outlet temperature remained elevated until the evening of August 21st when it began a steady decline. From the chart it is unclear what the main causes of the decline were but my assumption is that it relates to a large drop in ambient air temperature. But why would this drop the cooling trench temperature and not the bottom draw temperature? Perhaps the pond discharge rate dropped off sufficiently to allow groundwater mixing in the trench to become effective again. However, this is not clearly discernable in the pond outlet depth log which appeared to be about 0.14m deeper than normal at that point and thus possibly still releasing considerable flow.

Turning now to some fundamentals of thermodynamics; University of Guelph research provided to TRCA's Temperature Mitigation Working Group indicates that cooling trenches receive little to no benefit from cold rock in a trench. This may appear illogical but rock has a very sluggish response to changing its heat content compared to water that under goes rapid change, i.e. rock is good a storing heat but transfer in or out is very slow. The implication is that rock can only change water temperature during long contact times (large rock surface areas with low flowrates). This research has also shown that contact with cold ground under a deeply buried trench provides cooling, with wide shallow trenches being much more effective than narrow deep trenches.

Unfortunately this knowledge doesn't help with improving temperature mitigation of discharge from Pond. In my opinion, now that Pond 4 and its cooling trench have been built in a location with high perpetually ground water, we are pretty well stuck with implementing mitigation measures that include groundwater management. As previously discussed, but not yet adopted, preventing or greatly reducing the flow of ground water into the pond is needed along with diverting that ground water to the cooling trench, either to the trench inlet or its outlet (yet to be determined). The volumetric flow rate of ground water ultimately discharging to the creek needs to be much greater than controlled release of warm water from the stormwater pond.

In light of the above, I'm wondering what the rationale is for proposing a return to the designed permanent pool level before solving the problem of groundwater entering the pond. Lowering the normal pond level may be feasible in spring or fall but seems unwise during our hot weather season.

Sincerely and with best regards,
John

John Palmer, P.Eng., Water Resources Engineer
Grand River Conservation Authority
400 Clyde Road, PO Box 729, Cambridge, Ontario N1R 5W6
Tel: 519-621-2763 x2289 | Fax: 519-621-4945 | www.grandriver.ca

---

From: Sones, Adrienne [mailto:Adrienne.Sones@aecom.com]
Sent: Monday, August 29, 2016 8:59 AM
To: 'Adele.Labbe@guelph.ca'; 'Prasoon.Adhikari@guelph.ca'; John Palmer; 'aschiedel@nrsi.on.ca'; 'tbrenton@nrsi.on.ca'; Tony Zammit; 'Bill.Banks@banksgroundwater.ca'; Tufgar, Ray; Minielly, Andrew
Cc: Parhizgari, Zahra
Subject: HCBP - RAAP call - Sites HC-A(06) - August 20th thermal exceedance

Hello RAAP Team,

This e-mail is intended to follow-up on the August 22nd call regarding the exceedances observed on August 20 at HCBP station HC-A(06).

The call was attended by Adele Labbe, Prasoon Adhikari, Tara Brenton, Ray Tufgar and myself.

On Saturday August 20, 2016 there was an exceedances of 24°C at HCBP stations HC-A(06). The table below summarizes the exceedance noted by the telemetry station.

Date	Time of Exceedance	Maximum Temperature (°C)	Station	Potential Justification
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The following highlights key discussion points of the meeting:

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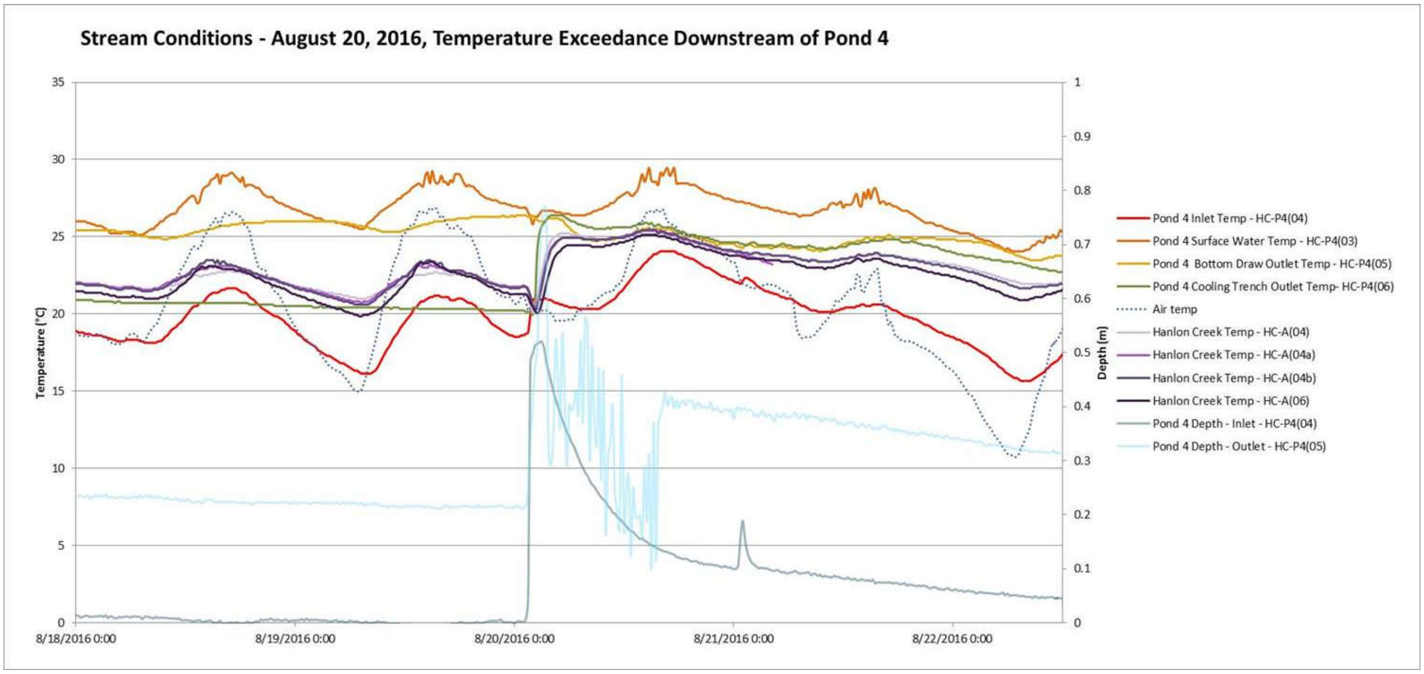

Please let me know if you have any further questions, comments or concerns.

Regards,
Adrienne

Adrienne Sones, P.Eng.
Water Resources Engineer, Water
D +1-519-963-5922
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London, Ontario N6A 6K2, Canada
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Attachments:

August 20, 2016 Pond 4 workup.pdf	27 bytes

Subject: Re: HCBP - RAAP call - Sites HC-A(06) - August 20th thermal exceedance
From: Andrew Schiedel <aschiedel@nrsi.on.ca>
Date: 8/30/2016 3:48 PM
To: John Palmer <jpalmer@grandriver.ca>, "'Sones, Adrienne'" <Adrienne.Sones@aecom.com>, "'Adele.Labbe@guelph.ca'" <Adele.Labbe@guelph.ca>, "'Prasoon.Adhikari@guelph.ca'" <Prasoon.Adhikari@guelph.ca>, "'tbrenton@nrsi.on.ca'" <tbrenton@nrsi.on.ca>, Tony Zammit <tzammit@grandriver.ca>, "'Bill.Banks@banksgroundwater.ca'" <Bill.Banks@banksgroundwater.ca>, "Tufgar, Ray" <Ray.Tufgar@aecom.com>, "Minielly, Andrew" <Andrew.Minielly@aecom.com>
CC: "Parhizgari, Zahra" <Zahra.Parhizgari@aecom.com>, Nathan Garland <ngarland@grandriver.ca>, Fred Natolochny <fnatolochny@grandriver.ca>, Steve Burgin <sburgin@nrsi.on.ca>

Hi Everyone,

I generally agree with John's assessment that the groundwater mixing seems to be the primary function of the cooling trench. I did some analysis in the draft 2014 consolidated report of a similar storm event (see sections 2.4.2.2 and 5.1.1), and made the same observations of the cooling trench outlet temperature responding to the pond outflows. Essentially, the resulting temperature at the cooling trench outlet reflects the proportion of pond outflow versus groundwater intercepted by the cooling trench.

I think the diversion of the cooling trench temperature from the bottom draw temperature at 7pm is in fact a result of a reduction in pond outflow after the storm event. There is still lots of pond outflow, but it's only the beginning of the divergence in temperatures. As another thought, how quickly would the local groundwater respond to the rain event? Would there be an extra push of groundwater into the trench about 17 hours after the storm, at least on a very small/local scale?

Andrew

Andrew Schiedel B.A.
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Waterloo, ON N2K 4M8
(p) 519-725-2227 (f) 519-725-2575
(m) 519-580-3987
(w) www.nrsi.on.ca (e) aschiedel@nrsi.on.ca

On 2016-08-29 2:30 PM, John Palmer wrote:

> Hello Team,
>
> My analysis of the August 20th temperature exceedance chart is a little different.
>
> Yes, prior to the rainfall event there was a 5°C lower but given that this was during a dry period between rainfall events, any discharge from the cooling trench is a reflection of ground water intercepted by the trench, mixing with the continuous low rate of discharge from Pond 4. As we know, the continuous discharge is caused by groundwater interception.
> Very shortly after heavy rainfall in the early hours of August 20th, cooling trench outlet and pond discharge temperatures equalized at about 25°C, not because the rocks warmed but because pond discharge flow rate and temperature overwhelmed any benefit to be gained by mixing with groundwater in the cooling trench.
> Cooling trench outlet temperature remained elevated until the evening of August 21st when it began a steady decline. From the chart it is unclear what the main causes of the decline were but my assumption is that it relates to a large drop in ambient air temperature. But why would this drop the cooling trench temperature and not the bottom draw temperature? Perhaps the pond discharge rate dropped off sufficiently to allow groundwater mixing in the trench to become effective again. However, this is not clearly discernable in the pond outlet depth log which appeared to be about 0.14m deeper than normal at that point and thus possibly still releasing considerable flow.
>
> Turning now to some fundamentals of thermodynamics; University of Guelph research provided to TRCA's Temperature Mitigation Working Group indicates that cooling trenches receive little to no benefit from cold rock in a trench. This may appear illogical but rock has a very sluggish response to changing its heat content compared to water that under goes rapid change, i.e. rock is good a storing heat but transfer in or out is very slow. The implication is that rock can only change water temperature during long contact times (large rock surface areas with low flowrates). This research has also shown that contact with cold ground under a deeply buried trench provides cooling, with wide shallow trenches being much more effective than narrow deep trenches.
>
> Unfortunately this knowledge doesn't help with improving temperature mitigation of discharge from Pond. In my opinion, now that Pond 4 and its cooling trench have been built in a location with high perpetually ground water, we are pretty well stuck with implementing mitigation measures that include groundwater management. As previously discussed, but not yet adopted, preventing or greatly reducing the flow of ground water into the pond is needed along with diverting that ground water to the cooling trench, either to the trench inlet or its outlet (yet to be determined). The volumetric flow rate of ground water ultimately discharging to the creek needs to be much greater than controlled release of warm water from the stormwater pond.
>
> In light of the above, I'm wondering what the rationale is for proposing a return to the designed permanent pool level before solving the problem of groundwater entering the pond. Lowering the normal pond level may be feasible in spring or fall but seems unwise during our hot weather season.
>
> Sincerely and with best regards,
> John
>
> cid:ima
>
> **John Palmer**, P.Eng., Water Resources Engineer
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>
> ---
>
> **From:** Sones, Adrienne [mailto:Adrienne.Sones@aecom.com]
> **Sent:** Monday, August 29, 2016 8:59 AM
> **To:** 'Adele.Labbe@guelph.ca'; 'Prasoon.Adhikari@guelph.ca'; John Palmer; 'aschiedel@nrsi.on.ca'; 'tbrenton@nrsi.on.ca'; Tony Zammit; 'Bill.Banks@banksgroundwater.ca'; Tufgar, Ray; Minielly, Andrew
> **Cc:** Parhizgari, Zahra
> **Subject:** HCBP - RAAP call - Sites HC-A(06) - August 20th thermal exceedance
>
> Hello RAAP Team,
>
> This e-mail is intended to follow-up on the August 22nd call regarding the exceedances observed on August 20 at HCBP station HC-A(06).
>
> The call was attended by Adele Labbe, Prasoon Adhikari, Tara Brenton, Ray Tufgar and myself.
>
> On Saturday August 20, 2016 there was an exceedances of 24°C at HCBP stations HC-A(06). The table below summarizes the exceedance noted by the telemetry station.

Date	Time of Exceedance	Maximum Temperature (°C)	Station	Potential Justification
August 20, 2016	11:00 am – 10:00 pm	24.73	HC-A(06)	Rainfall event of approximately 50 mm occurred at the site 5:20 am to 6:25 am. Higher than typical daily minimum air temperature, overnight low was above average and could have not provided cooling trench with an opportunity to cool down.

> The following highlights key discussion points of the meeting:
>
> - AECOM staff were asked to download other relevant temperature loggers onsite to help verify the cause of the exceedance. This was completed and is further discussed below.
> - The City of Guelph will consider returning the water level in the Pond to the design level and introduce more plantings as per the original design in attempt to provide more shading to the Pond. It was noted that the pond is currently owned by Cooper Construction.
>
> AECOM staff visited the site August 23rd to downloaded all loggers located within Pond 4 and also between the Pond 4 outlet to Hanlon Creek and HC-A(06), located downstream of Laird Road. A graph summary of this data is included below. The data indicates after the rainfall event, the cooling trench was no longer able to provide the cooling effect noted prior the rainfall. This is likely due to the large rainfall runoff volume of water reaching the cooling trench, causing the rocks within the cooling trench to warm, thereby reducing the cooling trench's effectiveness to reduce outlet temperatures. It should also be noted that prior to the rainfall event the cooling trench is effectively reducing water temperatures by approximately 5°C.

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Please let me know if you have any further questions, comments or concerns.

Regards,
Adrienne

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