Mosquito Control Study for Parkhill, Ontario, 2011

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EXECUTIVE SUMMARY

Parkhill is located northwest of London and south of Grand Bend in the Municipality of North Middlesex. The land use around the town is mainly agricultural with some small woodlots, wetlands, lagoons and a reservoir. The Lower Parkhill Watershed drains an area of 310 km^2 through the Parkhill Creek and outlets at Grand Bend.

In the summer of 2011, the Municipality of North Middlesex had mosquito related complaints from the residents of Parkhill. As a result of concerns expressed by the residents, the Municipality of North Middlesex asked the Middlesex-London Health Unit (MLHU) and the Ausable Bayfield Conservation Authority (ABCA) to report on the mosquito populations and potential mosquito habitat in Parkhill.

The Municipality of North Middlesex and residents would like to see strategies to reduce the standing water and mosquito breeding sites. North Middlesex has had a mosquito larvicide program in place since 2000. The Middlesex-London Health Unit has been monitoring adult mosquito populations using traps, as well as performing larval mosquito counts in standing water, since 2002. There have been high numbers of mosquitoes in past years but the increase in mosquitoes in 2011, following a wet spring, has prompted public concern.

On July 19th, 2011, the Municipality of North Middlesex held a public community meeting in Parkhill with representatives from the Middlesex-London Health Unit; Pestalto Environmental Health Services, an Integrated Pest Management Control Company (herein referred to as Pestalto); and the Ausable Bayfield Conservation Authority. More than 400 people from the community attended this public meeting to discuss the mosquito issue, identify areas of standing water that might be removed or maintained, and provided the agencies with possible solutions to decrease the mosquito habitat in Parkhill. The Parkhill community and agencies are working together towards a multi-pronged approach due to the complexity of the issue, the history of the issue, and the high mosquito population in the summer of 2011.

The intent of this report is to document the results of identified mosquito breeding habitat and provide short term and long term strategies to better manage the mosquitoes and their breeding habitats. The Middlesex-London Health Unit, the Municipality of North Middlesex, and Pestalto have identified a 25-hectare (62-acre) focus area that they believe provides much of the mosquito breeding habitat. The ABCA partnered with these agencies to assist with investigations of the mosquito habitat and collectively develop strategies for consideration by the Council of the Municipality of North Middlesex.

Data about local precipitation and water levels are collected by the ABCA. The data that has been collected includes hourly precipitation (mm) in Parkhill and hourly water levels (m) in Parkhill Creek from 2007 to 2011. The Middlesex-London Health Unit has collected baseline data on the number of adult mosquitoes trapped on a weekly basis throughout the summer from 2002 to 2011. Data collected to date is considered baseline information by the agencies. This data has not been intentionally collected to address potential relationships between precipitation, water levels and mosquito population abundances.

From a preliminary assessment there appear to be three factors that provide habitat and favourable conditions for mosquitoes in the Parkhill area. Firstly, the wooded wetland provides habitat for mosquitoes. Secondly, the precipitation events, particularly in 2011, provide water levels appropriate for mosquitoes to breed. Thirdly, in the area of focus there are currently locations that are continuously flooding. Locations within the wetland that are continuously flooded for prolonged periods or become re-flooded often after heavy precipitation events are potentially providing additional mosquito breeding habitat. The first two factors (*i.e.*, wetland habitat and precipitation amounts) are natural and difficult to manage. However, the third factor, locations that are continuously flooding is something that could be managed differently to control how frequently the wetlands flood and how long they hold water. One potential solution is to determine the location of these shallow areas that are becoming inundated with water numerous times in the season.

From this preliminary assessment it seems that there have been attempts to drain the water in the wetlands in Parkhill but it is not clear what activities have been undertaken and how effective these works have been. It is common to have mosquitoes; however, managing the wetlands to not be continuously inundated with water should reduce the mosquito populations.

BACKGROUND

Mosquito Biology

There are more than 50 mosquito species present in Ontario (Middlesex-London Health Unit, 2005). The mosquito has four stages of its life cycle: egg, larva, pupa, and adult (Figure 1). Depending on the species, eggs are laid singly or in rafts of hundreds of eggs on the water surface, or on damp soil or tree holes that will become flooded (Alameda County Mosquito Abatement District, retrieved July 14, 2011). Eggs can hatch within two days or remain dormant for several years until conditions are appropriate for hatching. The larvae live in water and breathe at the surface through siphon tubes. If the siphon tubes are long they hang vertically from the surface or if they are short they lie parallel to the surface of the water (Figure 2). Larvae need standing water, *i.e.* non-moving water, for breathing and feeding on organic matter. The larvae grow and shed its skin, on the fourth molt it becomes the pupa. The larval stage takes as little as five to seven days if conditions such as water temperature, food, crowding, persistence of water and predation by fish and invertebrates are favourable (Sarneckis, 2002). As a pupa, it does not feed. This resting stage allows the pupa to transform into the adult, which may take one to four days. Adults feed on nectar and only females require a blood meal for development of eggs (Ontario Ministry of Agriculture, Food and Rural Affairs, April, 2011). Eggs can lay dormant over the winter. Adults can live four to eight weeks. Some species of mosquitoes prefer to feed on reptiles or amphibians, others prefer mammals or birds.

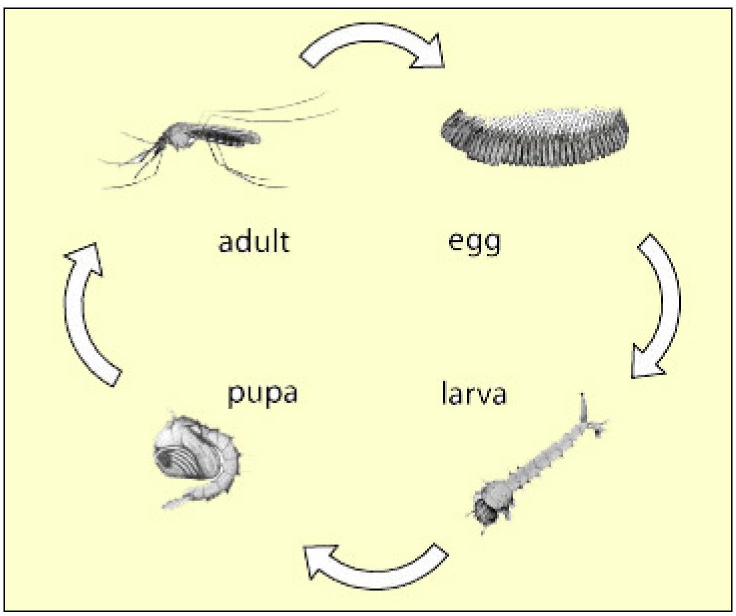

Figure 1: Mosquito life cycle. (Alameda County Mosquito Abatement District, retrieved July 14, 2011).

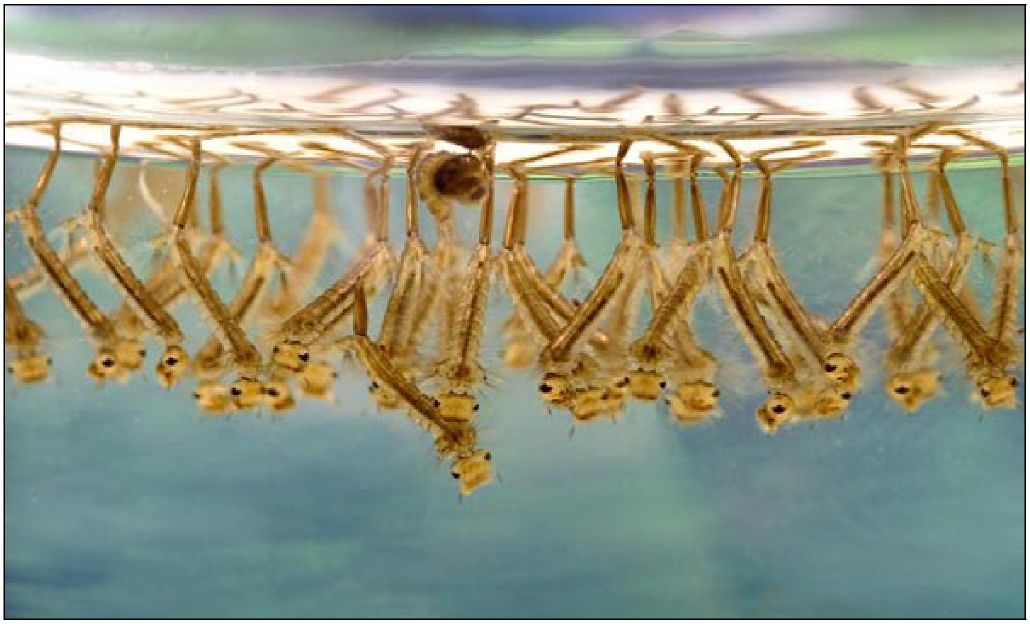

Figure 2: Mosquito larvae breathing at surface of water using breathing tubes.
(Image Author: James Gathany, CDC; Gross, 2006).

Mosquitoes can be found in many different habitats but all require standing water for the larval stage. Larval habitats may include catch basins, tires, eaves troughs, rain barrels, shallow ponds, woodland pools, and edges of swamps (Middlesex-London Health Unit, 2005). Adult mosquitoes prefer shade and variable amounts of vegetation. Mosquitoes require standing water to breed but that does not mean there should be large populations of mosquitoes when standing water is present. Areas with shallow, sheltered, isolated pools produce higher populations of mosquitoes (Sarneckis, 2002).

The constant fluctuating water levels due to flooding within the wetlands provide a greater chance of mosquito eggs laid in moist habitats during water levels receding to hatch once water levels come back up again during the next rain event. If the flooding occurred in early spring and eventually receded during the late spring and summer months, the mosquito eggs would not get a chance to continuously hatch and continue their life cycle. The wetland edges should not have wet, dry and wet cycles as it leads to micro-habitats for mosquitoes with no aquatic predators (Society of Wetland Scientists, 2009). In seasonal wetlands, the aquatic mosquito predators perish when the wetland dries out, but the mosquito eggs are viable in moist environments and hatch during the next water cycle (Society of Wetland Scientists, 2009).

Wetlands that have been drained and degraded often have large mosquito populations. You can expect mosquitoes after each rain in drained wetlands (Indiana Wetlands Conservation Plan, 1996). There may be small hydric depressions on land in a drained wetland, which fill with water during a precipitation event. This is enough water to allow mosquitoes to breed and lay eggs. The eggs can remain dormant if the water dries up too soon, but will hatch during the next rainfall. When a wetland is drained it may still have viable mosquito eggs and hold enough rain water to breed mosquitoes (Indiana Wetlands Conservation Plan, 1996).

It is a common fact that mosquitoes breed in wetlands (Sarneckis, 2002). Certainly, mosquitoes are a natural part of wetlands. Treed wetlands or swamps are more sheltered and typically have higher number of mosquitoes than open water marshes that have higher diversity of predators. In some wetlands, the protected water bodies, isolated pools, limited predator access, poor water quality produce higher mosquito numbers (Sarneckis, 2002). Healthy wetlands that have diverse wildlife, plants and habitat generally do not have large populations of mosquitoes. Natural mosquito control is often achieved when fish, insects, aquatic birds, and frogs are present (Sarneckis, 2002). Effective insect predators include water bugs, aquatic beetle larvae, dragonflies and damselflies (Sarneckis, 2002).

Wetlands

Wetlands are: "lands that are seasonally or permanently flooded by shallow water as well as lands where the water table is close to the surface; in either case the presence of abundant water has caused the formation of hydric soils and has favoured the dominance of either hydrophytic or water tolerant plants". (Ontario Ministry of Natural Resources, 1993). Wetlands are transition areas (*i.e.* riparian areas, floodplains) between aquatic systems (*i.e.* rivers, streams, and lakes) and uplands (*i.e.* woodlots). Wetlands can also include ground water discharges on slopes or isolated depressions.

Two common southern Ontario wetland ecosystems include marshes and swamps. Marshes are wet regions occasionally flooded with standing or slow moving water. Marsh wetlands are characterized by emergent plants, floating plants and submerged plants and seasonally fluctuating surface water levels. Swamps are wooded wetlands that have 25 per cent or more cover of tall shrubs and trees. Many swamps have seasonal standing water typically in the spring; others may have surface water that persists for long periods or most of the growing season. (Ontario Ministry of Natural Resources, 1993).

Swamps or wooded wetlands originally develop in low areas that have poor drainage or a high water table. Typically these wooded wetlands are along lakes, rivers, and floodplains (Hebert, 2002). Wooded wetlands act as reservoirs, important in times of drought. The main source of water in wooded wetlands is groundwater (Hebert, 2002). Wooded wetlands typically have nutrient-rich, lush and productive vegetation. Swamps that receive high inputs of nutrients from a pulsing hydro period have higher productivity than drained or continuously flooded swamps (Hebert, 2002). Silver maple, elm, black ash and yellow birch are common indicators of wooded wetlands. (Ontario Ministry of Natural Resources, 1993).

Benefits of Wetlands

Wetlands are extremely cost-effective and beneficial features of our landscape. They provide biological, ecological, hydrological functions and society values. The plants and animals in wetlands remove and filter many harmful impurities, as well as nitrogen and phosphorus that end up in our streams, creeks, rivers and lakes. Wetlands help to remove these excessive nutrients before entering our drinking water. Many communities and businesses use constructed treatment wetlands to treat and clean wastewater (Ducks Unlimited Canada, 1996-2011).

Snowmelt and heavy rain events provide too much water for the landscape to absorb. Wetlands act as a sponge, providing natural temporary water storage for excess water and the water is slowly released back into the soils. The groundwater and base flows in the creeks are recharged throughout dryer seasons. Water storage also reduces the flow and risk of flooding downstream. Wetlands capture sediment and allow it to settle out in depressions or the basin, reducing the sediment from going into the creeks and rivers. Vegetation in wetlands slows the water flow and stabilizes the soils, reducing erosion.

More than 600 species of plants, animals, birds, reptiles, amphibians, fish and invertebrates use wetlands and the surrounding upland areas for habitat (Ducks Unlimited Canada, 1996-2011). People use these natural places to relax, hunt, camp, canoe, as well as providing educational and research opportunities. Wetlands are complex ecosystems that provide many benefits.

Management of Wetlands

In many places across south-western Ontario wetlands have been drained or degraded and this has resulted in major changes in watershed hydrology that need to be assessed and managed. Wetlands fit into broader issues of resource management because the wetland area is connected to other water–related functions from the headwaters to downstream water bodies such as lakes. Management includes a multi-pronged approach from multiple decision makers and a community that considers protecting our water and watershed resources, management of water resources, and restoration objectives (Kusler, 2003).

Development in the southern Ontario has made changes to the natural landscape. These changes include soil erosion, irrigation, deforestation, and urbanization which degrade wetland quality (Heimlich, R. et al, 1998). Middlesex County had lost approximately 89 per cent of its wetlands, mostly wooded wetlands, by 2002 (Ducks Unlimited Canada, 2010). It is estimated that the former McGillivray Township was 15.8 per cent wetland prior to settlement in the 1800s; currently, only one per cent of those wetlands are remaining (Ducks Unlimited Canada 2010). Wetland loss impacts our drinking water, intensifies flooding and erosion issues, and can contribute to prolonged periods of drought.

In some places, wetlands are being re-created. Construction of various structures is included in wetland restoration and watershed management. These can include excavation to create wetlands, construction of berms, and installing water control structures. Excavation is used to create wetlands in wet areas where the water table is close to the surface and may hold water for seasonal periods or permanently. The water levels are typically low, up to one and a half meters deep. Berms are created to constrict water flows in a basin or water storage area, slow surface water drainage and store water for longer periods of time. In addition, berms may be constructed in old channels that once drained wetlands to restore water levels in wetlands. Water control structures are often used to control water levels within created wetlands. This management can mimic natural seasons and allow flooding in the spring but slowly drain the wetland throughout the summer to allow for water storage in the fall again.

Channelization or drainage of wetlands or tiling of agricultural fields still occurs to manage areas with a surplus of water.

Management of lands around water often requires a plan to help to streamline a permitting process. Please refer to Regulatory Approvals for more information about permits required to undertake works near water (Appendix A). Furthermore, management efforts will require ongoing monitoring, assessment and adjustments as the wetland and its uses change over time (Kusler, 2003).

Wetland Evaluations

Wetlands are evaluated by the Province of Ontario using the Ontario Wetland Evaluation System (OWES), a science-based ranking system. This evaluation uses a standardized method to rank wetlands by assessing biological functions, societal values, hydrological component, and special features (Ontario Ministry of Natural Resources, Significant Wetlands Factsheet). The significance of an evaluated wetland is based on points and can either be Locally Significant Wetland (LSW) or Provincially Significant Wetland (PSW). A wetland complex occurs when more than one wetland is functionally linked to other nearby wetlands.

Regulatory Approvals

Depending on the nature of a work proposal, it may be necessary to obtain approvals to develop or to do works in wetlands. There are numerous agencies that have permitting responsibilities that provide protection for the aquatic environment. A partial listing of some of the Acts and legislation which is relevant with work proposals in or around water include: the Drainage Act, Federal Fisheries Act, Species at Risk Act (SARA), Conservation Authorities Act, Navigable Waters Protection Program, Endangered Species Act (ESA), Public Lands Act (PLA), and Lakes and Rivers Improvement Act (LRIA). There are also Municipal by-laws that include woodlot and forestry conservation and weed control. Refer to Appendix A for a summary of the *Federal Fisheries Act and Species at Risk Act (SARA)* and *Conservation Authorities Act.*

Area of Focus

One of the mosquito breeding focus areas identified by the Municipality of North Middlesex, Pestalto, and Middlesex-London Health Unit includes two wetlands adjacent to Parkhill Creek downstream of the dam (Concession 5WCR, Lot 7, part Lot 6, McGillivray and part of Concession 20, Lot 6 & 7, West Williams) (Figure 3). The area is about 25 hectares or 62 acres in size. Property ownership in the area includes the Ausable Bayfield Conservation Authority, Municipality of North Middlesex and 19 per cent is privately owned. The Parkhill Creek meanders through this low area and flows between the south and north wetland which is part of the focus area. The south and north wetlands are low flat water storage areas or floodplains adjacent to Parkhill Creek.

Figure 3: Parkhill Creek north of Parkhill, Ontario outlining the 25 hectare (62 acre) area of focus for mosquito habitat.

Parkhill Dam

The construction of Parkhill Dam was completed in 1969. The project involved the construction of two large earth fill dams (one with a concrete control structure), the acquisition of lands required for the area to be flooded behind the dam, the relocation of Highway 81 to the top of the dams, and the construction of a diversion channel connected to the Cameron-Gillies Drain.

Although the dams create a lake with a surface area of approximately 86 hectares at the normal summer level, the water depths in the reservoir are generally less than two meters.

The dam and reservoir control the runoff waters from approximately 90 square kilometers of the Parkhill Creek watershed and help to reduce the amount of flooding of agricultural lands in the Thedford / Klondyke area near Grand Bend. The diversion channel connected to the Cameron-Gillies Drain reduces the amount of flooding that would be experienced in Parkhill along the Cameron-Gillies Drain.

The dam is designed so that during normal flows and smaller floods, water flows through an opening in the concrete control structure which is sized to provide a reduction in downstream flooding without having to operate gates. This opening also controls the normal level of the reservoir so that constant gate operation is not required. During large floods, there are two, two meter by two meter gates that can be operated to allow more water to flow through the dam to protect the structure. The operation of these gates takes place infrequently – the last two operations during floods were in 1985 and 2009. There is also a large emergency spillway which will allow water to flow around the dam if needed.

Before the construction of the Dam, flooding of the lands which are now downstream of the Dam was more frequent and more severe.

Historical and Current Land Use

The town of Parkhill was settled during the 1860s after a railway was built. A few mills and several large brick yards were operating by 1875. By 1880s the area was well cultivated and productive with mixed farming (Ausable Valley Conservation Report, 1949).

Many treed areas were cleared for crops and pasture. According to the historical aerial photos, some of the unproductive agricultural land was left to slowly re-naturalize.

Currently, the land use in the Lower Parkhill Watershed is mostly agriculture (83%), with a small portion of woodlot (14%), urban area (1%), and other (2%) (OMAFRA, 1983).

The Lower Parkhill Watershed soils are made up of a mix of silty clay loam (27%), clay loam (24%), sandy loam (23%), loam (11%), silty loam (6%), clay (5%), bottomland (2%), and sand (1%) (County Soils Maps, 1951-1991).

Parkhill and surrounding areas have poor draining clay soils, large low basin areas next to the creek for storing water under high water conditions and a large natural Creek system that typically floods in the spring and a few times throughout the year.

Significant Natural Areas

The Provincial Government and the Provincial Policy Statement requires municipalities to protect natural heritage features.

The Middlesex Natural Heritage Study (MNHS) was initiated through the County of Middlesex to provide information on the significant woodland and wetland features. The County recognized these natural heritage areas to be critical to the health of the overall natural heritage system.

The Environmentally Significant Areas (ESA) includes natural features and performs significant ecological functions. An Environmentally Significant Area is identified if it includes one of the three criteria: significant earth science feature (*i.e.*, unique land form), significant hydrological function (*i.e.*, groundwater discharge), or significant ecological function (*i.e.*, habitat for rare species).

The Area of Natural and Scientific Interest (ANSI) represent significant geological and biological features of land and water. The Province of Ontario evaluates the sites with the highest value for conservation, scientific study and education.

The Species at Risk (SAR) and their habitat are protected by the federal government to prevent extinction of wildlife species and conserve their biological diversity. The Endangered Species Act provides protection for species at risk and their habitats, support for stewardship efforts, and commitment to recovery of species.

The natural areas in the Lower Parkhill Watershed include: Parkhill Creek Complex (Provincially Significant Wetland), O'Brien Swamp Complex, McGillivray 4 (Locally Significant Wetland), McGillivray Environmentally Significant Areas 5 to 10, West Williams Environmentally Significant Areas 1, 2 and 5, and the Stephen Wildlife Management area (Veliz et al, 2006).

The 25-hectare area of focus includes a treed low basin area with a mix of silty clay loam soils conducive for mosquito habitat. This provides a large storage area for water under flooding conditions. The soils help to store the water and slowly release it through the ground in drier conditions. The trees and vegetation potentially filter the excess nutrients improving water quality going back into the creek or replenishing the ground water supplies. The basin area allows sediment from surrounding land use activities to settle out in the wetland and reduces transportation of sediment via the Parkhill Creek to Lake Huron. The large storage area holds water back from flooding other areas downstream of Parkhill Creek, or reduces the existing flooding. This 25-hectare area is a wetland by definition, with a water table close to the surface, hydric soils, periodic flooding and the presence of water tolerant trees and plants. This wetland is closely connected to other Environmentally Significant Areas and other wetlands downstream of this area of focus. In early settlement, some of the trees in the area of focus were cleared for pasture. Between 1947 and 1955 the trees started growing back along the Parkhill Creek in the low wet unproductive pasture areas (Appendix B: Figure 1-2). The 1989 aerial photos show full recovery of the woodlots (Appendix B: Figure 3). Currently the treed wetland area of focus provides water storage during flooding events which is an important hydrologic function of wetlands.

Study Area

Although the 25-hectare wetland area is the main study area and in 2011, staff from the ABCA conducted site visits and an elevation survey in the area; the investigation and cleanup of mosquito habitat is not limited to this wetland area. The Municipality of North Middlesex has investigated and initiated cleanup of areas around the town of Parkhill where water accumulates and provides mosquitoes with standing water habitat. Examples of standing water habitat found around town include dumped garbage, tire ruts, and depressions in the soil. The Municipality of North Middlesex and Middlesex-London Health Unit have provided education on eliminating standing water in and around property owners' properties. The Middlesex-London Health Unit also provided treatments to control mosquito larvae along roadside and backyard catch basins.

INVESTIGATIONS

The wetland management area of focus was investigated by the ABCA staff on a number of occasions. More than 450 hours (or 64 days) of in-kind ABCA staff time have been spent on meetings, site visits, surveying, mapping, analyzing and putting together documents for The Parkhill Mosquito Management Project. The ABCA staff involved includes the General Manager, Water & Planning Department, Stewardship & Conservation Lands Supervisor, Communications Specialist, Forestry & Land Stewardship Specialist, Wetlands Specialist and GIS Specialist.

Site visits were conducted on June 22, July 12, July 27, August 3, and August 12 of 2011. During the site visits, general observations of the wetland, water levels, inflows, outflows, drainage corridors, function of the wetland, and inventory on plants and animals were taken. On October 25 and 27, 2011 ABCA staff set out control stakes for the elevation survey. The elevation land survey was performed on October 27, November 4, 7, and 8 of 2011 by the ABCA staff. Elevations of the Parkhill wetland, edge of wetland and the base of some of the hills were taken, as well as elevations of the water level in Parkhill Creek on different days, top of bank of Parkhill Creek, and elevations within and top of bank of the human-made channels.

The coordinates and elevation survey data were later downloaded to Geographic Information System (GIS) to be added as a point layer on the 2010 South Western Ontario Orthophotography Project (SWOOP 2010), a high resolution aerial imagery with 0.5 meter accuracy. A map was created with the locations of the survey points, watercourses and dug channels (Figure 4). The existing elevation models from SWOOP 2010 were compared with the accurate surveyed elevations. The survey control was adjusted to match the SWOOP 2010 digital elevation data and added to create an accurate (centimeter) digital elevation model. The digital elevation model map provides a colour gradient of the elevations from high elevations 209 meters above sea level (m.a.s.l.) shown in brown and red to lower elevations, 184 m.a.s.l. shown in blue and green (Figure 5). The creek and dug channels and low areas show up in blue and depending on the water level set on the model, it will be able to indicate how much of the area will flood during different conditions. The Digital Elevation Model (Figure 5) shows the water levels in Parkhill Creek and the wetland on November 8, 2011 when water levels were receding from the wetland and draining back into the Parkhill Creek. The water levels in Parkhill Creek were below the top of bank. Under flooding conditions when the creek water levels were to over top the banks then the whole low basin areas would flood. The created channels that were dug to connect the Parkhill Creek to the wetland allows water to backfill into the wetland sooner than if it had to go over top of the banks.

General observations of the wetland and water levels were taken during site visits. The wetland was flooded during the June 22 site visit. The water in the wetland started to recede by July 12 and by July 27 there were only a few small pools of water. During the July 27 and August 3 site visits, fifteen log and stick jams were encountered in the meandering Parkhill Creek within the area of focus (Lot 7, Con 20) (Appendix C: Figure 1-4). The water level in the Parkhill Creek was low and not flowing. There was an old channel dug (Channel 1, south east) up to the Parkhill Creek but not connecting to Parkhill Creek at this time (Figure 4). The channel was separated by the high top of bank. There were some broken flat pieces of concrete or patio stones along the side of the creek bank opposite of the dug channel. There was a second channel (Channel 2, south west) either an old meandering scar of Parkhill Creek or a dug channel (Figure 4). The channel was deeper where it intersects the Parkhill Creek and then declines in elevation and width as it follows the wetland around to the south marsh. It had old clay tile remnants in the channel. The wetlands were flooded again on Oct 25 and 27 and had started to recede by November 4, 2011. Ausable Bayfield Conservation Authority staff noticed new dug channels (Channel 3) in the northern part of the wetland near the outflow of the natural intermittent watercourse from Mollard Drainage works (Figure 4). These new channels would have been dug at the time of the log jam removal.

The following common plants and animal species were found during these visits (Table 1). For a complete list see Appendix C: Table 1.

Table 1: Common plants and animals found in the Parkhill Creek wetland.

Vegetation:	**Animals:**
Soft maple	Mosquitoes
Ash	Water striders
White Elm	Water boatman
Dogwood species	Red chironomids
Reed canary grass	Aquatic snails
Stinging nettle	Toads and frogs
Poison ivy	Carp

Mosquito predators (Table 2) were also noted in the wetland study area.

Table 2: Natural predators of mosquitoes found in Parkhill Creek wetland.

Predators of mosquito larvae:	**Predators of adult mosquito:**
Tadpoles,	Frogs,
Dragonfly and Damselfly nymphs,	Dragonflies and Damselflies,
Water striders,	Birds
Water boatman,	
Adult diving beetles	

*Mosquitoes may not be the only food source of these predators. Other mosquito predators not seen but may be present include salamander larvae, backswimmers, fish and ducks.

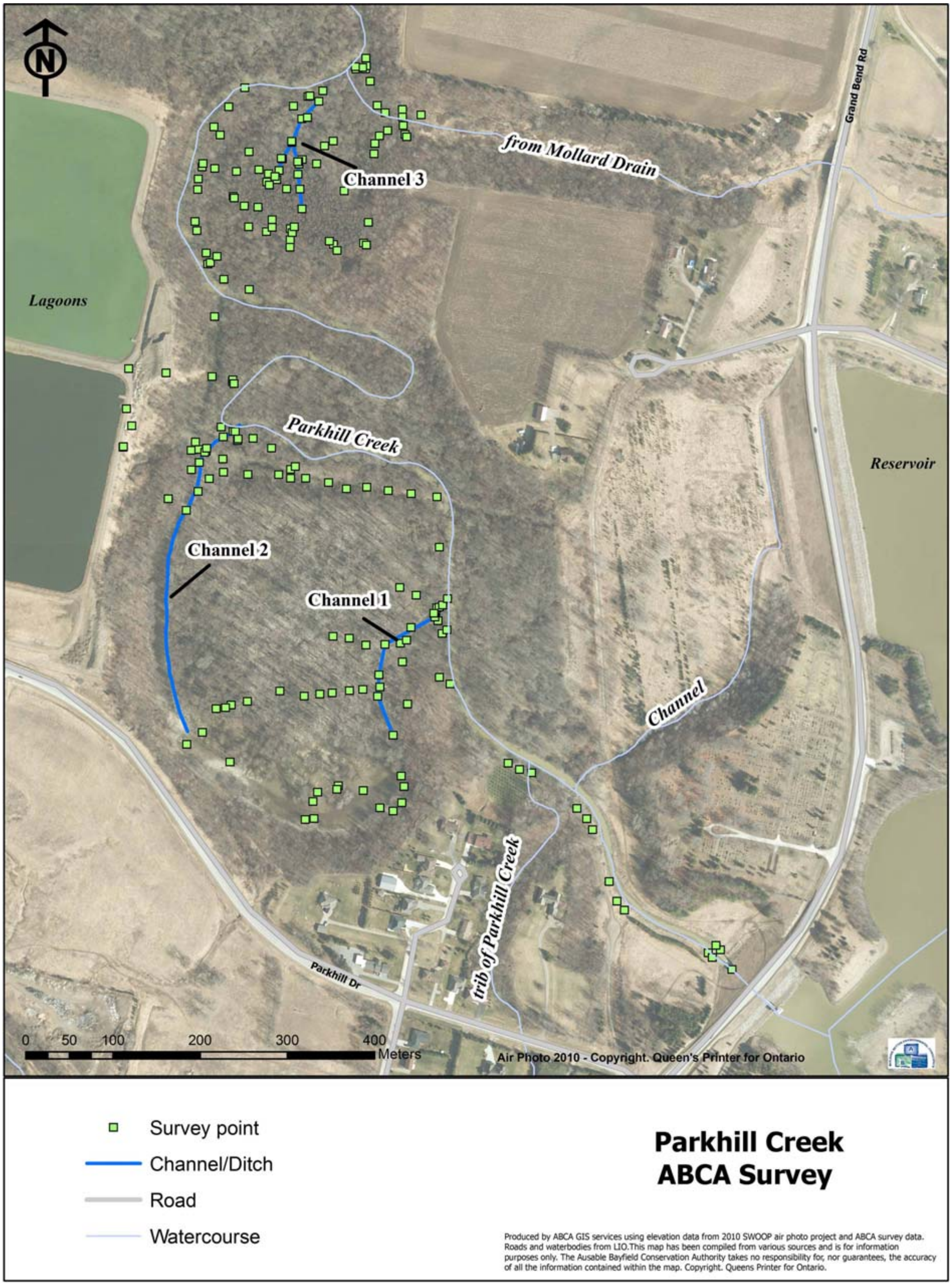

Figure 4: Parkhill Creek wetland survey indicating watercourses, dug channels and survey points within the area of focus.

The watershed boundary for Lower Parkhill Creek follows Parkhill Drive along the south border of the wetland area of focus. The area south of Parkhill Drive is in the Cameron-Gilles Drain watershed. However, there are two 24 inch culverts under Parkhill Drive that potentially transport water into the wetland area of focus.

Within this study area, drainage alterations have been made by adjacent landowners. The capacities of these drains are unknown. For example a tile was installed in the vicinity of Channel 2 (refer to Figure 4) in the 1970's. The function and capacity of this drain should be better understood.

Figure 5: Parkhill Creek wetland digital elevation model using water elevations surveyed on November 8, 2011.

Response to high water levels in Parkhill Creek and floodplain

The Parkhill Creek was observed by ABCA staff on several occasions during a period when flow levels within the creek were elevated.

In both the north and south wetland areas it was observed that the lower lying areas that were well separated from the main river channel were significantly flooded. The flooding of these areas which was observed coincided with a period of flood stage within the Parkhill Creek best described to be a time when flows with the Parkhill Creek were just marginally below bank full levels. The bank full condition is described as a period in time when the flow is confined to the main river channel however does not overtop the river banks into the broader flood plain. Ausable Bayfield Conservation Authority staff were able to observe the influence of the Side Channels Two and Three which have been constructed in both the north and south wetland areas. The side channels described are human-made channels which have been excavated in the past extending from the main river channel back up into the wetlands. It is understood these channels have been excavated for the purpose of allowing ponded water within the floodplain to drain more efficiently once river levels within the Parkhill Creek have receded. The channels are generally constructed to bottom elevations and grades such that the channels will positively drain back into the Parkhill Creek during periods of lower flood stage in the Creek. The constructed side channels generally run perpendicular to the main Parkhill Creek channel and provide a direct connection for the interaction of surface water between the Parkhill Creek and the wetlands.

From the elevation survey there is a conceptual model of the relationship between flow level within the Parkhill Creek main channel and the wetland areas (Figures 6 to 9). The figures provide two scenarios, a scenario described as “Unaltered” and a scenario described as “Altered”.

The “Unaltered” figures describe conceptually what would be occurring for a system which had not been artificially altered *(i.e.* if side channels as described had not been excavated). Under the “Unaltered” conditions, the flooding of the disconnected wetland areas would be expected to occur generally only during a condition when the Parkhill Creek flood level is on the rise and the level has exceeded the bank full condition and the Creek has spilled over the banks (Figure 6 and Figure 7).

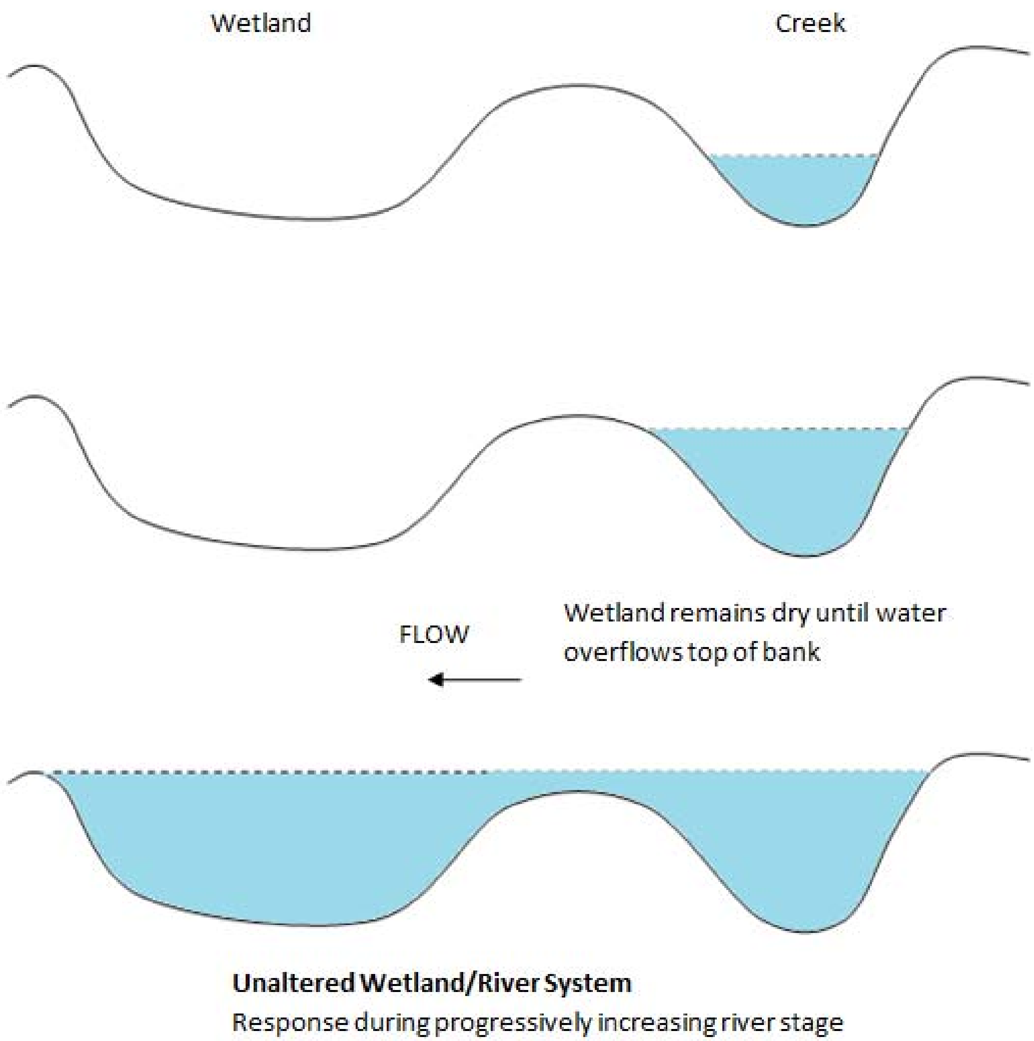

Figure 6: Unaltered wetland and creek system where the water in the creek levels increase over time overflowing the top of the banks and flooding the wetland.

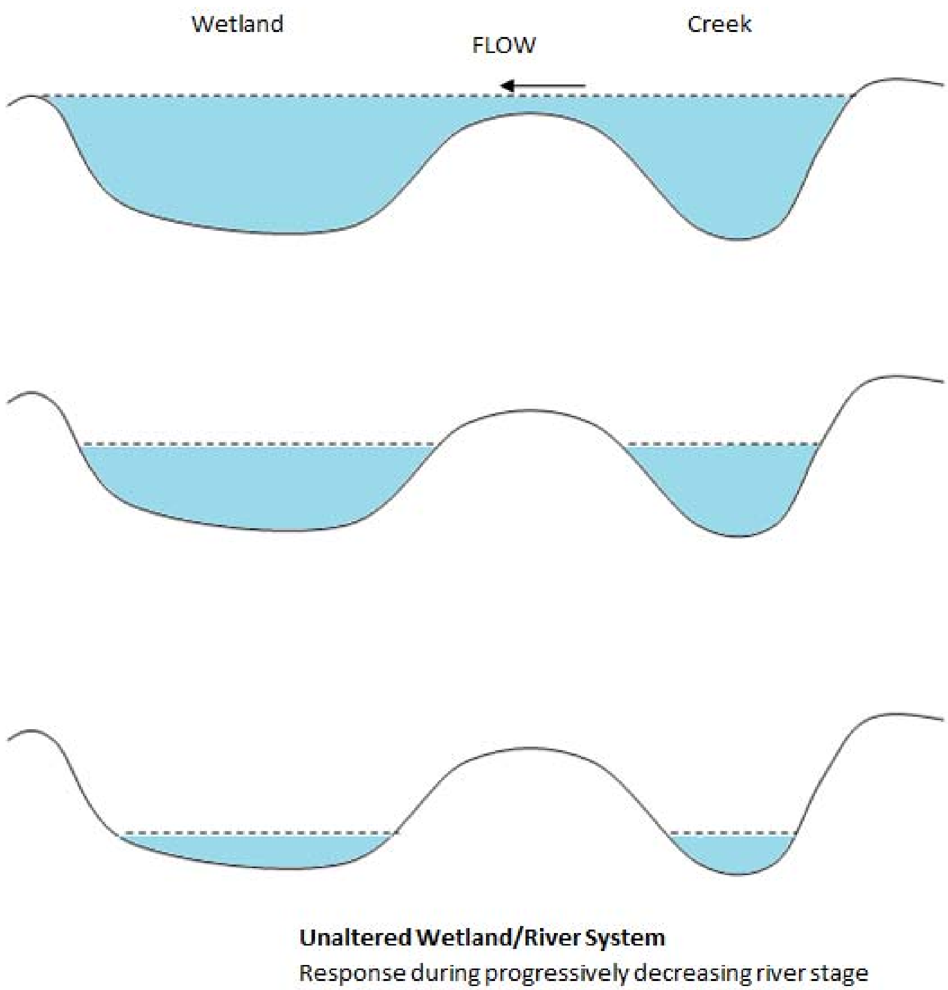

Figure 7: Unaltered wetland and creek system where the water in the creek levels decrease over time. The water levels in the wetland eventually decrease, slower than the creek water levels, after initially overflowing the top of the banks.

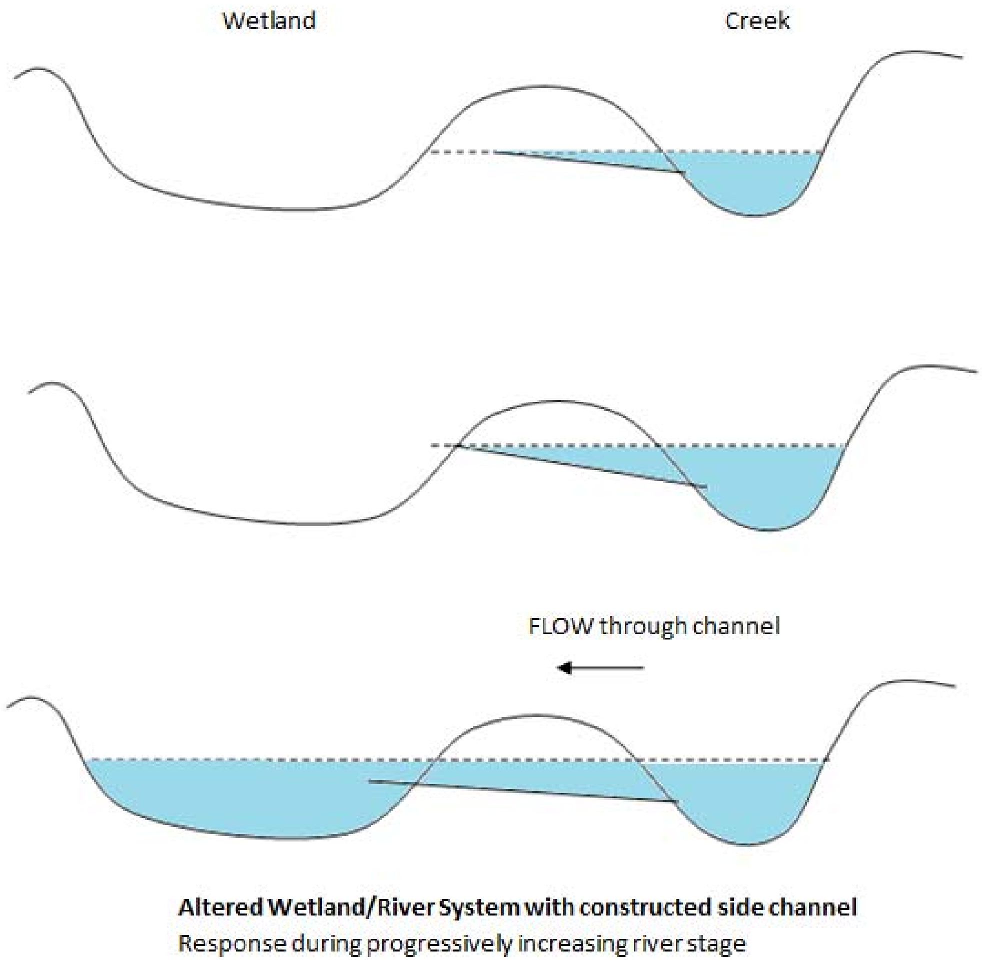

Figure 8: Altered wetland and creek system where the water in the creek levels increase over time overflowing into the channel and flooding the wetland before overtopping the creek banks.

Figure 8 describes the condition when flow levels within Parkhill Creek are on the rise for the condition where side channels have been constructed (existing conditions). The Figure is intended to describe the influence that the side channels have during periods when flow level within Parkhill Creek remains below the bank full condition. The figure shows that even though flow levels remain below bank full, the constructed side channels provide a direct route for flood flows to back into the floodplain areas and flood the low lying areas which would otherwise be disconnected from the main river channel.

Figure 9 describes the condition when flood levels within the Parkhill Creek are receding for the condition where side channels have been constructed (existing conditions). The figure shows that the rate that the flooded backwater areas (wetlands) will drain is directly influenced by the water level within the Parkhill Creek. The release of floodwaters from the wetlands and side channels will not occur until the recession of flow levels and flood stage within the Parkhill Creek. The level of ponded water within the side channels and more disconnected wetland areas will closely match the flood stage within the creek.

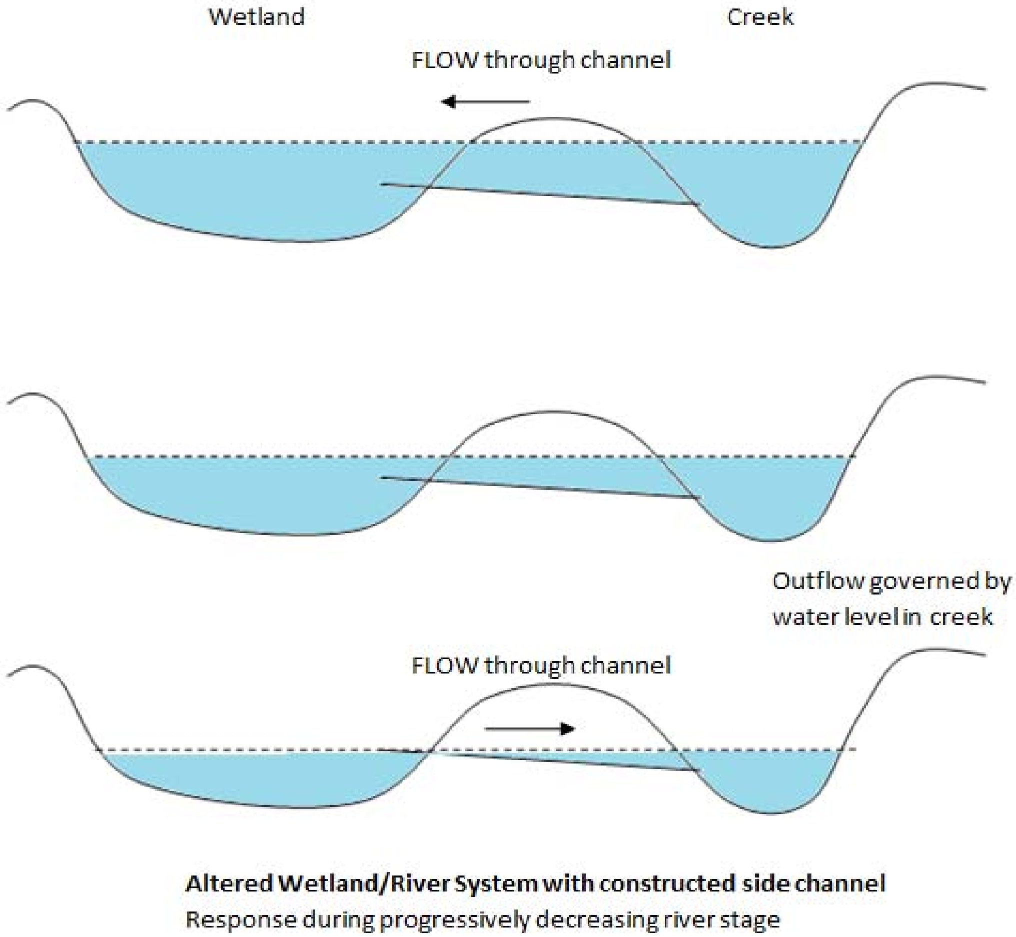

Figure 9: Altered wetland and creek system where the water in the creek levels decrease over time and allow some of the excess water in the wetland to flow out into the channel back to the creek.

Ausable Bayfield Conservation Authority staff had observed conditions within the Parkhill Creek over a course of two weeks during a period in October following significant precipitation events when flow levels and water level within the Creek had risen to a level just below the bank full condition. At this time, staff observed that the side channels which have been constructed in both the north and south wetland areas were significantly flooded. During this time staff observed that the flood level within the side channels and wetland areas closely matched the flood level within the Parkhill Creek.

It is interesting to note, based on observations made during the site reconnaissance, the artificially constructed side channels may in fact provide a direct route for the flow of water directly from the Parkhill Creek back into the wetland areas during periods when river levels within the Creek have risen however when flood levels remain below the bank full level. This influence on the wetland areas would occur during periods when the flow level within the Parkhill Creek exceeds the bottom elevation of the constructed side channels. It is expected that this condition does occur on a more frequent basis throughout the year when flow levels within the Creek are elevated however remain significantly below the bank full level.

To date, the ABCA has not undertaken a comprehensive review of historical meteorological data and flow records associated with the Parkhill Creek system in vicinity of the Parkhill Dam. If such a review were undertaken, it may be possible to describe or better characterize the relationship between periods when the flow levels within the Parkhill Creek are elevated and periods when the side channels and wetland areas are flooded and better describe the relationship which Figures 6 through 9 depict.

MOSQUITO SURVEILLANCE

The Middlesex-London Health Unit (MLHU) provides a Vector-Borne Disease (VBD) Program. This program includes monitoring significant vector-borne diseases in Ontario, including West Nile Virus (WNV), Lyme Disease (LD), and Eastern Equine Encephalitis (EEE). The Middlesex-London Health Unit conducts a dead bird surveillance, which provides an early indicator of local activity of the West Nile Virus. In addition, the MLHU conducts a surveillance, identification and treatment of mosquito larvae, and an adult mosquito surveillance program. The adult and larval surveillance programs provide information on density and species of mosquito populations (Middlesex-London Health Unit, 2010).

The dead bird surveillance is measured by public reports of dead birds, which are then tested for West Nile Virus. The Middlesex-London Health Unit monitors and identifies mosquito larvae vector species and provides treatment at sites with WNV or EEE vector species. Sites were chosen based on high risk locations around population centers as well as floodplains, marshes, creeks, and ponds (Middlesex-London Health Unit, 2004). A larval dipper was used to sample each site once a week. Mosquito larvae were identified in the lab with a Leica microscope to determine the species which would determine if larvicide is required (Middlesex-London Health Unit, 2004). Catch basins typically produce high numbers of *Culex* species and are regularly monitored and treated. The adult mosquito surveillance program uses CDC light traps to collect adult mosquitoes at three sites in Parkhill. The CDC light trap uses a black light, a 6 volt battery, an electric fan attached to a modified cooler baited with dry ice allowing carbon dioxide to escape through a small hole, and a collection basket and net (Middlesex-London Health Unit, 2004). The traps last for about 24 hours (Middlesex-London Health Unit, 2004). Traps are set once a week between the beginning of June to the beginning of October. Cosray laboratories assist the MLHU with counting, identification, and viral testing of the adult mosquitoes (Middlesex-London Health Unit, 2010).

The 2011 results for Parkhill include 3 WNV positive crows; 108,471 adult mosquitoes collected, 33 per cent of those being vector species; 1,213 larvae mosquitoes collected, 90 per cent of those being vector species; and 72 treatments performed in areas with vector-species. Vector species are certain mosquito species noted for their ability to transmit WNV or EEE (Middlesex-London Health Unit, 2004). The following table is from the MLHU and provides a summary of mosquito results from 2002 to 2011.

Table 3: Mosquito surveillance summary from the Middlesex-London Health Unit.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Birds	0	0	0	0	0	0	0	0	0	3
Mosquito Pools	0	1	0	1	0	0	0	0	0	0
Human Cases	0	0	0	0	0	0	0	0	0	0
Adults Collected	945	2,900	19,990	13,435	1,260	8,900	32,318	5,339	36,130	108,471
Vectors	31%	15%	29%	35%	95%	56%	89%	49%	66%	33%
Non-Vectors	69%	85%	71%	65%	5%	44%	11%	51%	34%	67%
Larvae Collected	141		18	276	251	306	485	319	1,036	1,213
Vectors	61%		55%	89%	94%	82%	96%	82%	93%	90%
Non-Vectors	39%		45%	11%	6%	18%	4%	18%	7%	10%
Treatments Performed									50	72

Control of larval mosquito populations is most effective when targeting vector species to prevent the virus multiplying through adult mosquitoes (Middlesex-London Health Unit, 2004). The mosquito surveillance indicates mosquito populations have been increasing since 2002, with the highest populations in 2011.

RESULTS

The ABCA has analyzed the last four years of historical data regarding rainfall in Parkhill and water levels just below the dam in Parkhill Creek. The baseline data that has been collected over the years provides simple monitoring data, not intended for making relationships with mosquitoes for this report. Appendix D (Figures 1 to 5) provides graphs with daily precipitation (mm) recorded in Parkhill and daily water levels (m) recorded below the dam in Parkhill Creek for June to October for each year 2007 through to 2011. The Middlesex-London Health Unit provided weekly adult mosquito numbers that were trapped from their mosquito surveillance program. A graph was created for the yearly total number of adult mosquitoes collected (Figure 10). The mosquito numbers peaked during the following years: 2004, 2008, 2010, and 2011.

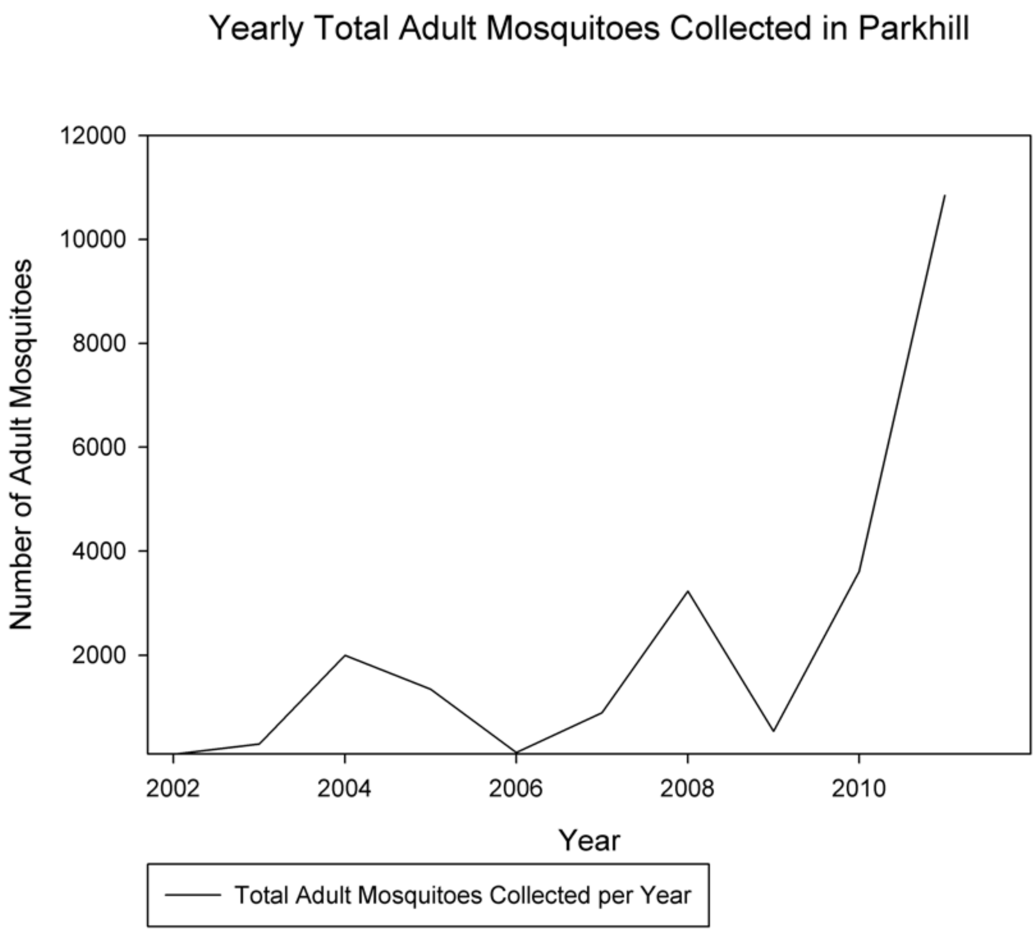

Figure 10: Yearly total adult mosquitoes collected in Parkhill from 2002 to 2011.

The precipitation and water levels were compared with the total adult mosquitoes collected from Middlesex-London Health Unit surveillance data to see if there were any obvious relationships. The yearly total adult mosquitoes collected from 2002 to 2011 were compared to the yearly average precipitation (mm) in Parkhill and yearly average water levels (m) in Parkhill Creek from 2007 to 2011. Not surprisingly, the precipitation and water levels peaked during 2008 and 2011 and this corresponds well with peak mosquito population years (Figure 11).

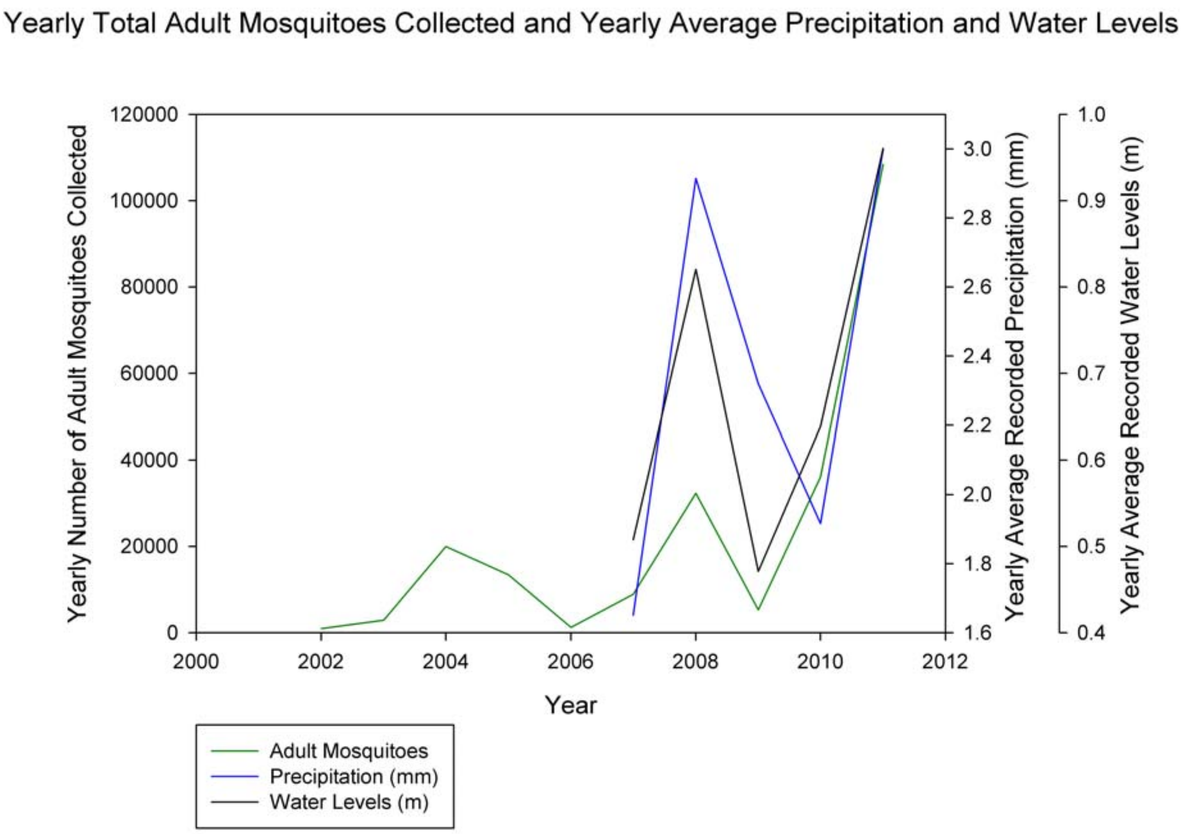

Figure 11: Yearly total adult mosquitoes trapped in Parkhill, and yearly average precipitation and yearly average water levels from 2007 to 2011.

Figures 1 to 4 (Appendix E) provide the monthly average adult mosquitoes trapped compared to the average precipitation and water levels for each year, 2008 to 2011. Some of these graphs show a peak in mosquito numbers after a precipitation spike. It is likely that the rain events and large snow accumulations in the wetter years do increase mosquito populations. Daily precipitation was graphed with weekly mosquito totals to see if there were common spikes relating higher rainfall with higher mosquito population spikes a few weeks later after emerging as adults (Appendix F: Figures 1 to 4). It is hard to recognize specific relationships between the precipitation and mosquito populations from just the baseline data, but rainfall seem to be an important factor.

CONCLUSION AND RECOMMENDATIONS

There are many complex variables that determine mosquito population numbers. We have looked at physical data, such as precipitation in Parkhill and water levels in Parkhill Creek from 2008 to 2011. In addition, the biological (*i.e.*, mosquito population) data from the Middlesex-London Health Unit included the weekly trapped adult mosquito numbers from 2008 to 2011 and yearly totals from 2002 to 2011. There has also been a historical effort to change the natural features existing within the town of Parkhill to minimize mosquito habitat.

The main variables that appear to determine the mosquito populations include the wooded wetland habitat, the rain events, and the human efforts to manage the water levels. The natural habitat and precipitation are features that cannot be controlled and will likely always provide some habitat for mosquitoes. The problem is not the flooding of the wetland in the spring but the prolonged flooding and continuous re-flooding of the wetland that provides the mosquitoes with the right conditions to complete more life cycles. The management of the wetland can be changed to reduce the amount of times the wetland floods and the length of time that the wetlands flood. It is still unclear as to when and where tiles exist in the wetland and if they work, one channel was dug and then bermed, newer channels were dug, and additional surface water drainage is added to these wetlands from the fields, roads and existing culverts. Further evaluation of the drainage in this wetland area and a potential redirection of management features should help to reduce mosquito habitat. Management of the wetland will likely not eliminate mosquitoes but should prevent extra life cycles of mosquitoes and a reduction in overall annual numbers.

Actions undertaken to date include the Middlesex-London Health Unit providing application of mosquito larvicide to eleven additional catch basins within Parkhill. Great Lakes Lawn Care has applied garlic to an area of the Great Canadian Hideaway Campground near Parkhill to evaluate its effectiveness. The ABCA has cut grass in some areas around the Parkhill Dam to reduce possible mosquito habitat. Activities also include removing obstructions in the Cameron-Gillies Drain to improve flow and reduce standing water.

The municipality organized a volunteer clean-up event on August 13, 2011 to provide residents opportunities to take part in the clean-up effort along the former railway tracks. The Council of the Municipality of North Middlesex and the community have worked together to reduce potential mosquito habitat adjacent to the sewage lagoons, at catch basins on private properties, at the landfill site and along the old railway tracks. The Municipality of North Middlesex has also cleaned out log jams in Parkhill Creek downstream of the reservoir.

The ABCA has provided an in-depth investigation of the management area of focus and found many log jams in Parkhill Creek. The Municipality of North Middlesex has completed removal of those log jams in October, 2011 which has helped the Parkhill Creek to flow.

The ABCA has completed a detailed elevation survey and model of the wetland elevations to further investigate water levels in the focus area. This model can help to analyze elevations within the wetland area to see what happens during low and high water conditions in natural conditions and with regards to the channels that were created to manage water levels. It is the finding of this report that had the side channels not been excavated, flooding of the disconnected wetland areas would likely only have occurred during periods of significantly elevated flood stage within the Parkhill Creek to levels exceeding the bank full condition (Figures 6 and 7). This condition would generally occur infrequently throughout the year however would be expected to occur on a regular basis each spring during the period of thaw (spring freshet).

Furthermore, there may be additional surface water draining into the wetlands from areas such as fields, tiles, culverts. In summary, the ABCA finds that as a result of the constructed side channels, flooding within the wetland areas may in fact be occurring on a more frequent basis throughout the year when flow levels within the Parkhill Creek are elevated but remain below the bank full level.

The ABCA has also analyzed the four year historical data regarding rainfall, water flow levels and compared this with the mosquito surveillance data to see if there are any trends from 2008 to 2011. It seems that the mosquito populations increase with higher precipitation events; however, there may be many other variables also contributing to the mosquito habitat. Other variables include: additional surface water from the top of the banks, fields, and roads draining into the wetland area of focus providing more water; the constructed channels connecting the creek to the wetland allows wetlands to flood more often or longer; temperature; shade; and degraded water quality.

Too much drainage in the wetlands could result in trees dying and blocking existing waterways, not enough water to maintain mosquito predators and smaller isolated pockets of water. Interestingly, too much drainage can result in more mosquitoes. This type of wooded wetland is supposed to flood in the spring and gradually dry up in late spring or the early summer months. If continuous flooding throughout the year was prevented, the number of mosquito life cycles being completed should be reduced. The issue with the constant re-flooding of the wetlands should be the concern, not the amount of standing water.

To date, this draft report has been initiated by the ABCA and reviewed by the Middlesex-London Health Unit, Council of the Municipality of North Middlesex, and Committee appointed by the Council for comments. Collaboratively, all agencies will review and discuss any suggested recommendations and next steps and discuss with the community before further implementation.

Recommendations

Continued Monitoring

Existing water levels, watershed boundaries, log jams and mosquito populations should continue to be monitored to gain data to collaboratively make management decisions, such as removing log jams each year.

The ABCA would like to establish water level monitoring downstream of the Parkhill dam and possibly in the wetlands to understand existing water levels better.

The area south of Parkhill Drive or County Rd 18 should be investigated further to determine if there is a way to direct this surface water and the drainage along County Rd 18 in a different direction than through the two culverts and down the hillside into the south wetland area of focus. In addition, the drainage tile that was installed in the 1970's could be inspected to see if it is working properly and if it is contributing water to the wetland before draining the water when Parkhill Creek flooding recedes. Landowners are also concerned with large fish using channel two to get into the wetland and not having enough time to get out if the water recedes too fast or if channels are closed. Closing the channels or installing a control structure would address this concern.

The Middlesex-London Health Unit will continue to fund and implement educational strategies to help protect the residents of North Middlesex from mosquito-borne illnesses. The MLHU will continue to provide North Middlesex with personal information and mosquito population data, both print and on their website. This data will be updated weekly during the mosquito season. The Middlesex-London Health Unit will also continue to fund the monitoring of all standing water locations and apply a biological larvicide to the site when vector mosquito larvae are present. All roadside and backyard catch basins will receive three rounds of treatment to control mosquito larvae located in them. The Middlesex-London Health Unit believes that all landowners should continue to work together and make efforts to best manage the adult mosquito populations in North Middlesex.

The Council of the Municipality of North Middlesex should consider continued monitoring for log jams which restrict water flow in Parkhill Creek below the dam. If the water in Parkhill Creek is able to flow, there should be less frequent flooding in the wetlands.

North Middlesex should continue its monitoring and larvicide program. The ABCA should continue monitoring snow levels and rainfall events to compare with mosquito populations.

The following is a list of recommendations or actions to discuss collaboratively with all involved agencies and the Parkhill community.

The Council of the Municipality of North Middlesex may consider a selective thinning of the north wetland. The south wetland was selectively logged in August of 2008. Thinning the wetland may provide less shade and protection for the mosquitoes and allow for more diversity of plants to grow.

The Municipality may wish to consider undertaking further study for purposes of reviewing the relationship between the side channels and Parkhill Creek. Or further assessment in terms of whether there may be merit in considering some degree of modification to the side channels which have been constructed and described above in Figures 6 to 9. An example of modification which might be considered would be filling or re-grading the side channels to the height of the wetland basin and the top of the bank next to Parkhill Creek so as to reduce the potential that the wetland areas are flooded during the more frequent periods throughout the year when the flow levels within the Parkhill Creek are below the bank full level. If the side channels are filled and graded, monitoring should be continued to document the results relative to mosquito habitat and number of larvae and adults.

Another option to consider may be installing water control structures to prevent water from backfilling into the wetlands from significant flooding in Parkhill Creek but allowing water levels in the wetland to recede through the water control structures throughout the late spring and early summer. The details of such a system would need to be developed collaboratively with the ABCA having regard for the Authority's Regulatory responsibility (*i.e.* ABCA Regulations) and provisions of the Federal Fisheries Act. A possible water control structure would involve construction of a berm on the channels where it outlets to the creek. The berm height would be even with the top of the bank next to Parkhill Creek. A pipe would be installed with a backflow prevention gate on the downstream side. This would allow water in the wetland to drain out once the Parkhill Creek flooding recedes, but prevent water from continuously re-flooding the wetlands. This should also prevent fish from entering the channels and becoming caught in the wetlands. There would be costs associated with constructing the berms and installation of the pipes as well as for monitoring and regular maintenance. Also, it is likely necessary that the operational aspects of such a system would need to be monitored following installation to ensure performance as planned and no resulting detrimental impacts on the Fisheries Resources (*i.e.* no stranding of fish, etc.)

The ABCA and the Municipality of North Middlesex could host a bird and bat box building workshop this winter for residents of Parkhill and surrounding areas.

The ABCA could host a tour of the dam for the public to view and see how it operates. This could also include the diversion channel on the Cameron-Gillies Drain.

Together the Municipality of North Middlesex and the ABCA should develop a budget for continued monitoring and possible implementation of these action items (*i.e.* to remove log jams in Parkhill Creek, maintain the Cameron-Gilles Drain, monitor water levels in Parkhill Creek and provide education events). There may be a few funding opportunities that the Municipality of North Middlesex and ABCA could consider applying to that address health, environment and community action. The Royal Bank of Canada (RBC) Blue Water Grant may be a possible source of money if the Parkhill wetland management deliverables fit the RBC criteria. The funding deadline for this RBC grant is February 3, 2012.

Continued collaborative discussion of the Parkhill focus area is important and recommended. Agencies can collectively review the new collection of data and the best options to manage and minimize mosquito abundance.

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APPENDIX A - Regulatory Approvals

Federal Fisheries Act and Species at Risk Act (SARA)

The protection of fish and fish habitat is a federal responsibility and is administered by the Federal Department of Fisheries and Oceans, Canada (DFO).

Works which are undertaken in or around water need to be reviewed to determine whether it is likely that the planned works will result in impacts to fish and fish habitat which are prohibited by the habitat protection provisions of the *Fisheries Act* or those prohibitions of the *Species at Risk Act* that apply to aquatic species.

The ABCA has a Level II Agreement with the DFO which empowers Authority staff to undertake initial screening in regard to a project's compliance with the provisions of the Fisheries Act. For those projects deemed not to result in a HADD (harmful alteration, disruption or destruction of fish habitat), ABCA staff have the ability to issue what is referred to as a letter of advice (LOA) on behalf of the DFO, which sets out the conditions under which a project may be undertaken to be in compliance with the provisions of the Fisheries Act.

Where there are concerns or considerations in regard to Species at Risk, or where it has been determined that a significant HADD will result, ABCA staff do not have the authority to review such files and in such case files are referred directly to the DFO for review.

Conservation Authorities Act

Much of the area identified in Figure 3 is regulated by the ABCA under *Ontario Regulation 147/06*.

Through this regulation, the ABCA is required to regulate development and activities in or adjacent to areas including river or stream valleys, watercourses, and hazardous lands. These regulations also govern activities which change or interfere, in any way, with a wetland.

Through this regulation the ABCA must confirm that the control of flooding, erosion or the conservation of land is not affected.

This means that it should be expected that site alteration – including grading and drainage works in the subject area will require formal written permission of the ABCA under *Ontario Regulation 147/06*. When considering a proposal the ABCA must consider the potential impacts of the work. For example, the ABCA must consider the potential of a proposal to cause or introduce erosion and the impacts to the floodplain characteristics of a system.

When reviewing applications which impact a wetland area, policy requires that the potential impacts to that wetland be considered. Applications which do not enhance the form and function of a wetland are not supported by ABCA policy.

APPENDIX B - Historical aerial photography

Figure 1: 1947 aerial photo of Parkhill wetland. Black dotted line marks area of focus.

Figure 2: 1955 aerial photo of Parkhill wetland.

Figure 3: 1989 aerial photo of Parkhill wetland.

APPENDIX C - Observations

Table 1: Complete list of plants and animals observed in the Parkhill Creek wetland during site visits in 2011.

Vegetation:	Animals:
Soft maple	Bald eagle
Cottonwood	Red-tailed hawk
Ash	Great blue heron
White Elm	Kingfisher
Dogwood species	Wood ducks
Reed canary grass	Redwing blackbirds
Stinging nettle	Catbird
Poison ivy	Nuthatch
Wild grape	Robins
Meadow rue	Grackles
Jewelweed	Deer
Iris	Snapping turtles
Green Dragon *	Carp
Swamp milkweed	Green frogs
Cardinal flower	Wood frogs
Monkey flower	Toads
Green sedge	Tadpole sp.
Other Sedge sp.	Mosquitoes
Grass sp.	Water striders
	Water boatman
	Red chironomids
	Fly sp. at edge of pools
	Aquatic snails
	Adult diving beetles
	Giant water bug
	Ebony jewel wings
	Damselfly bluets
	Spreadwing damselfly
	Meadowhawk dragonflies
	Katydid
	Grasshoppers
	Monarchs
	Beetle sp. (terrestrial)

*special concern Provincially and Nationally

Parkhill wetlands (north area and south area) with locations of log jams and channels, July 2011.

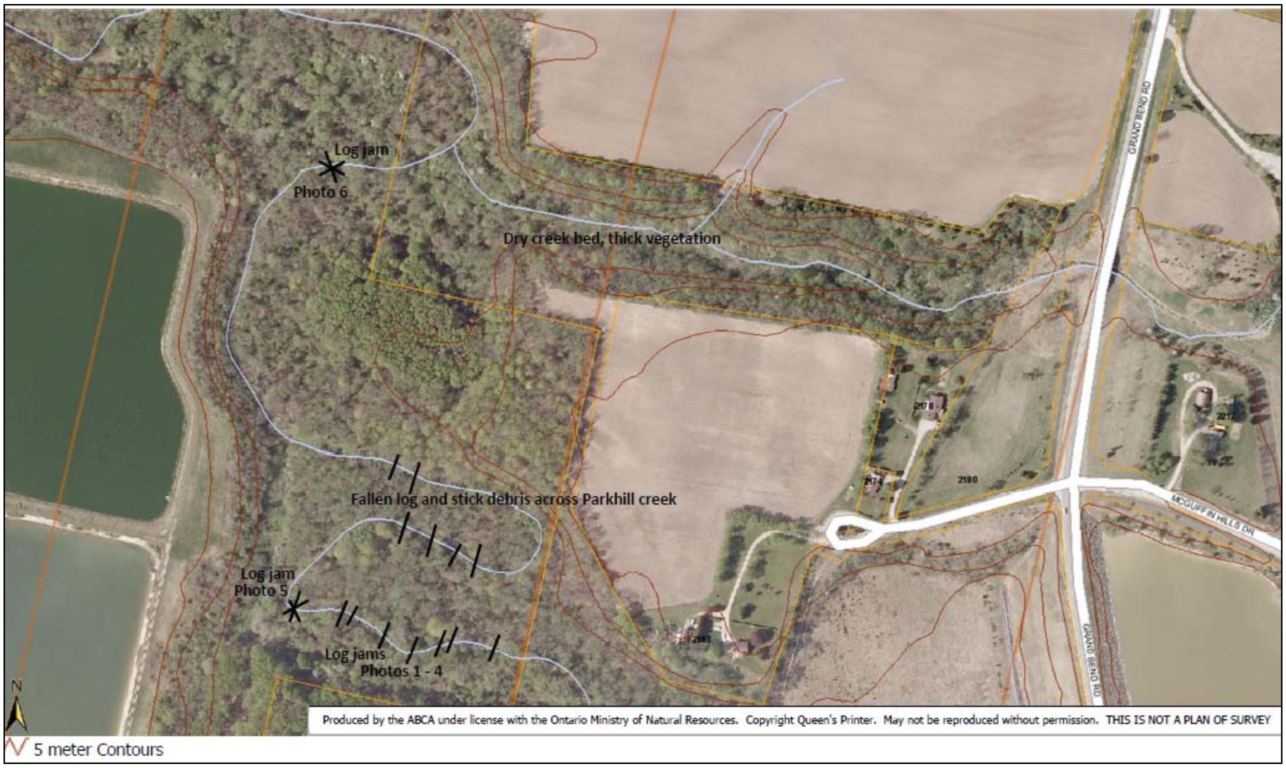


Figure 1: Location of fallen logs and log jams in the north area of Parkhill wetland.

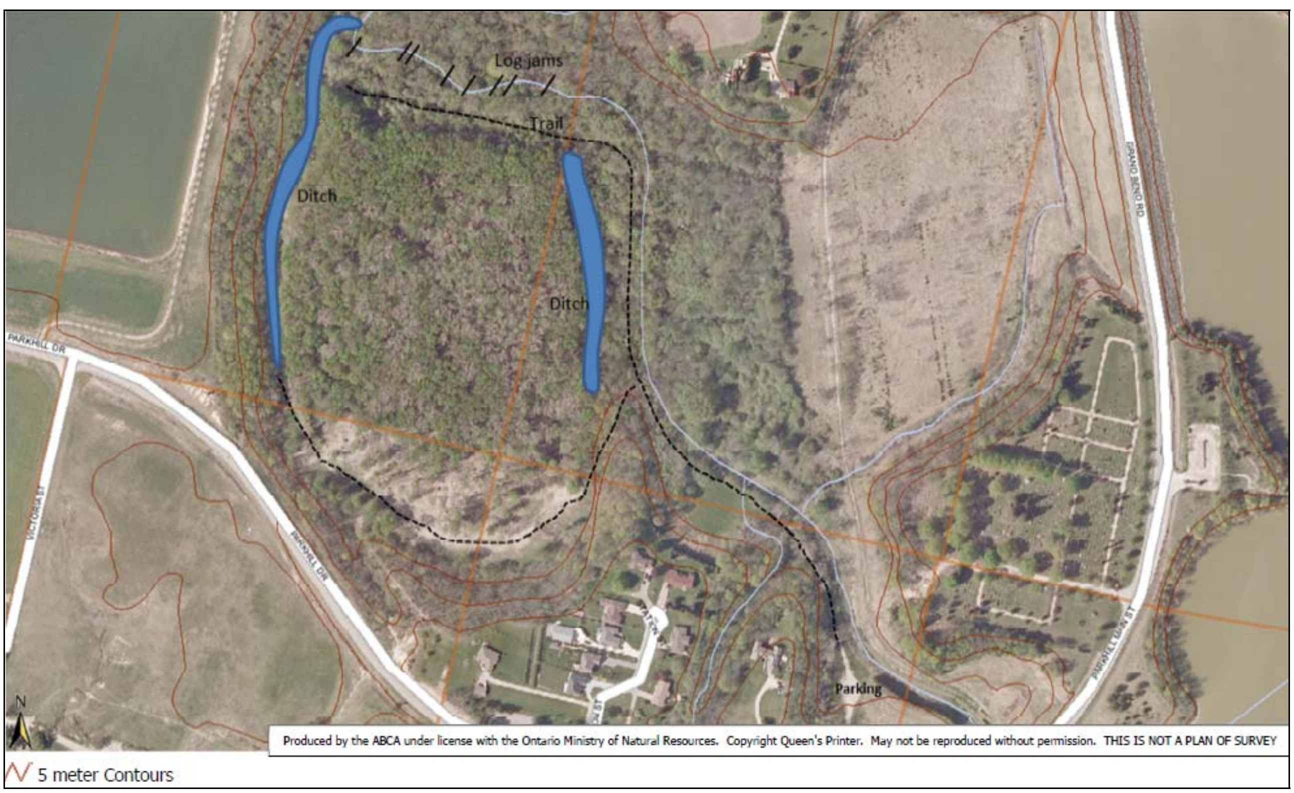


Figure 2: Location of fallen logs and log jams in the south area of Parkhill wetland and location of dug channels and trail.

Photos of log jams in Parkhill Creek, summer 2011.

Figure 3: Photo of log jam in Parkhill Creek.

Figure 4: Photo of log jam in Parkhill Creek, facing outlet of Channel 2.

APPENDIX D – Precipitation and Water Levels in Parkhill Creek

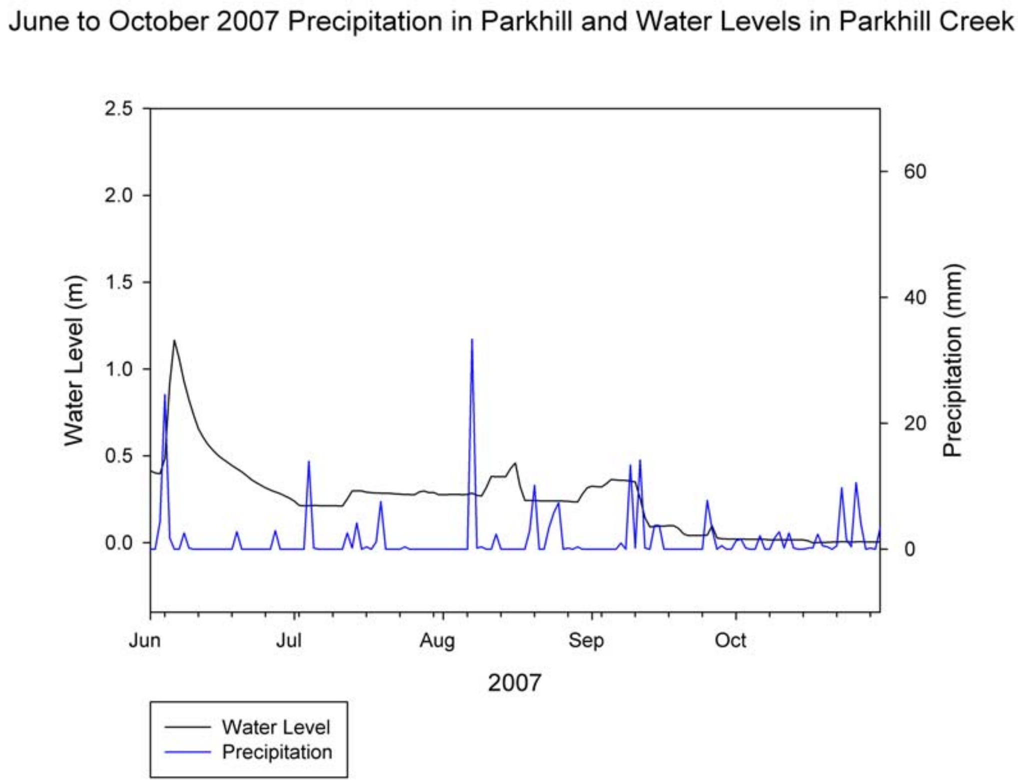


Figure 1: Precipitation (mm) recorded in Parkhill and Water Levels (m) recorded below dam in Parkhill Creek.

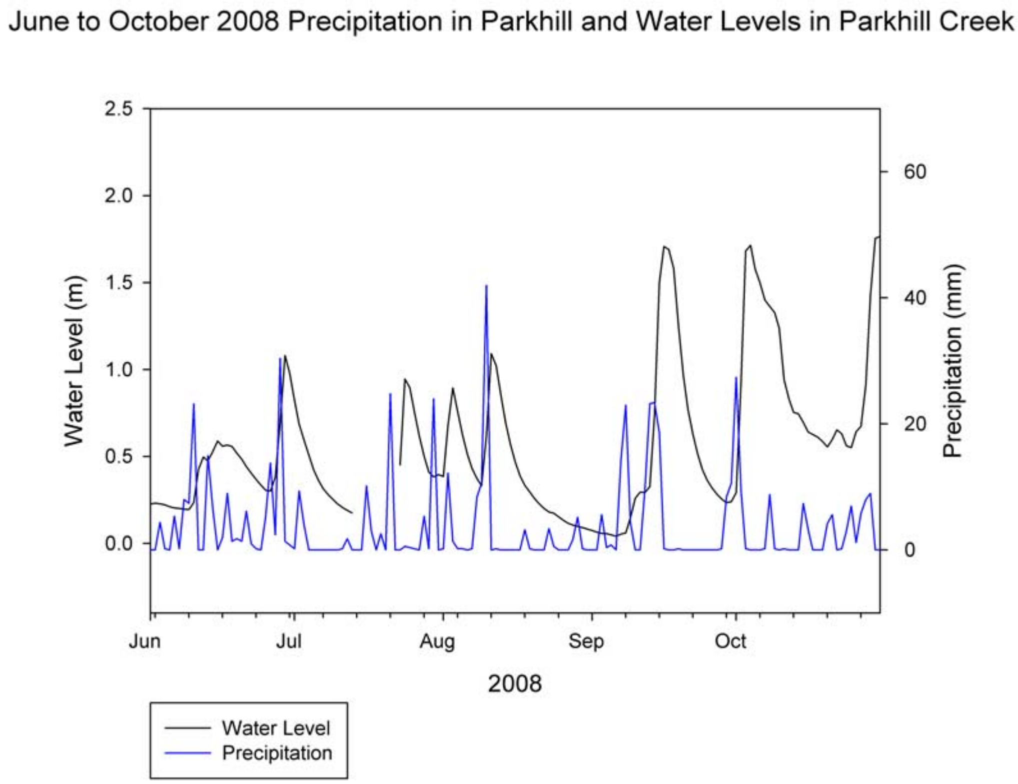
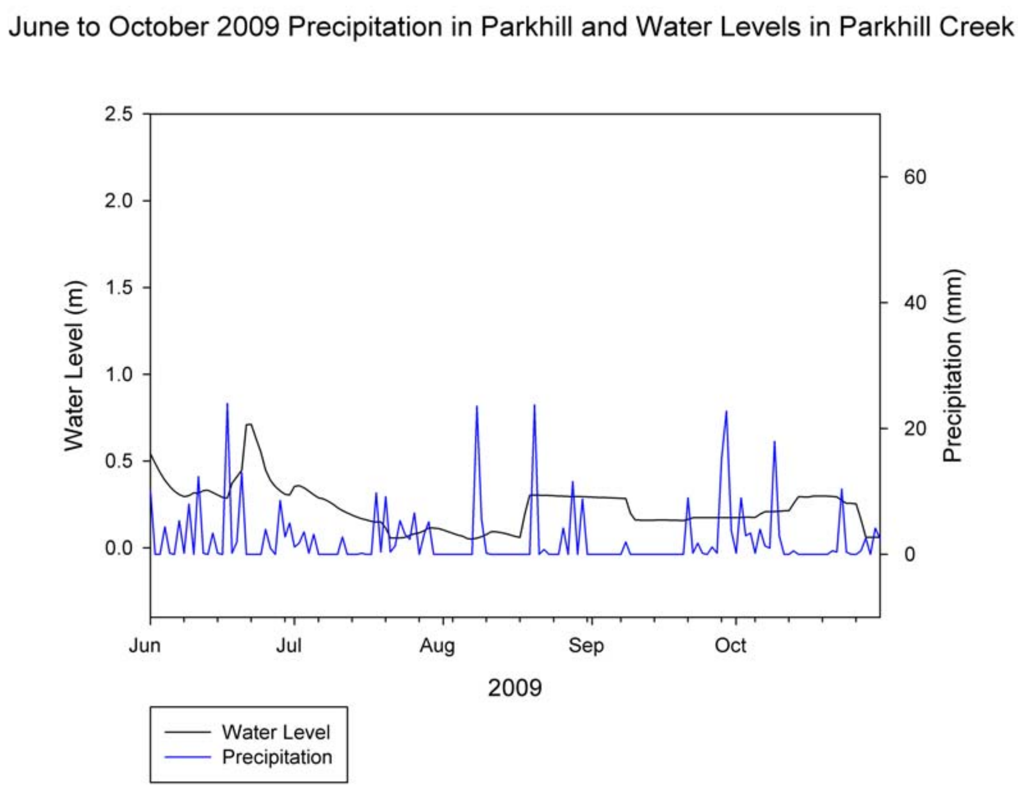


Figure 2: Precipitation (mm) recorded in Parkhill and Water Levels (m) recorded below dam in Parkhill Creek.



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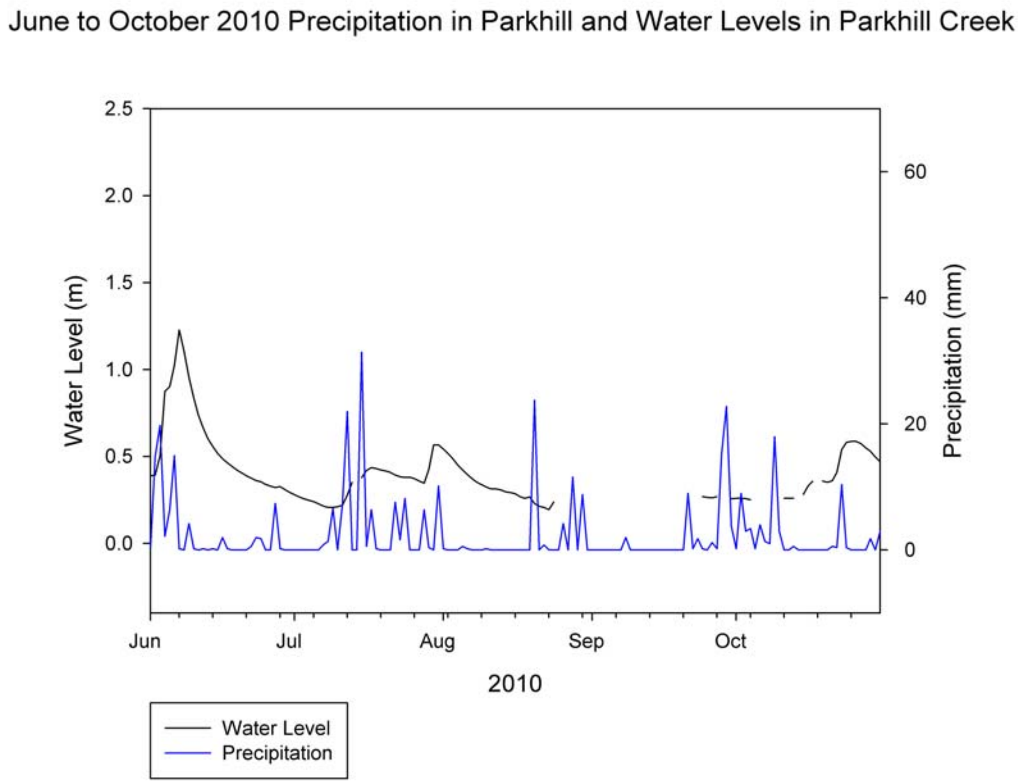

Figure 4: Precipitation (mm) recorded in Parkhill and Water Levels (m) recorded below dam in Parkhill Creek.

June to October 2011 Precipitation in Parkhill and Water Levels in Parkhill Creek

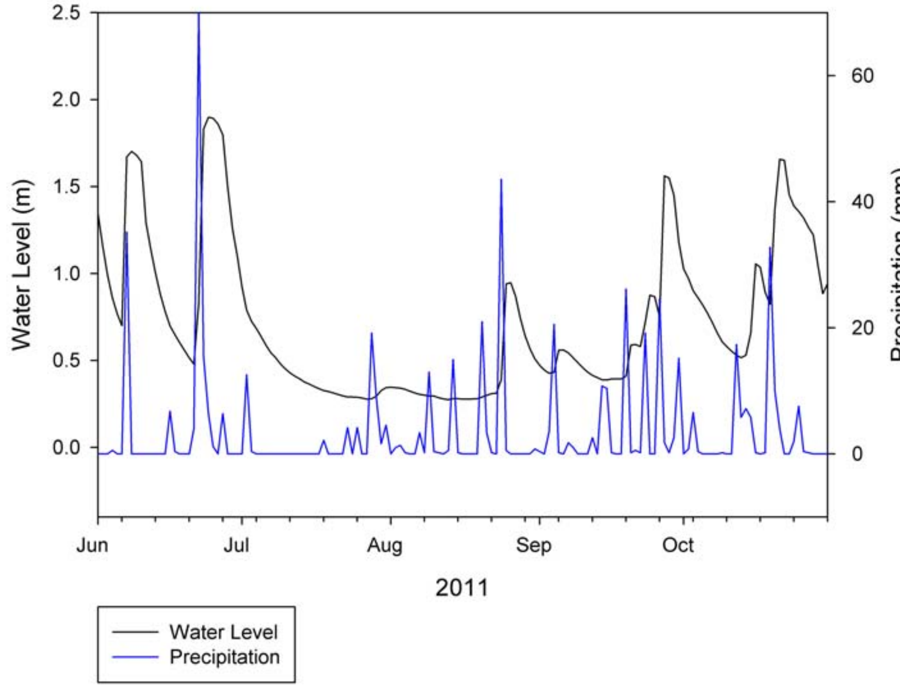

Figure 5: Precipitation (mm) recorded in Parkhill and Water Levels (m) recorded below dam in Parkhill Creek.

APPENDIX E – Mosquitoes, Precipitation and Water Levels in Parkhill Creek

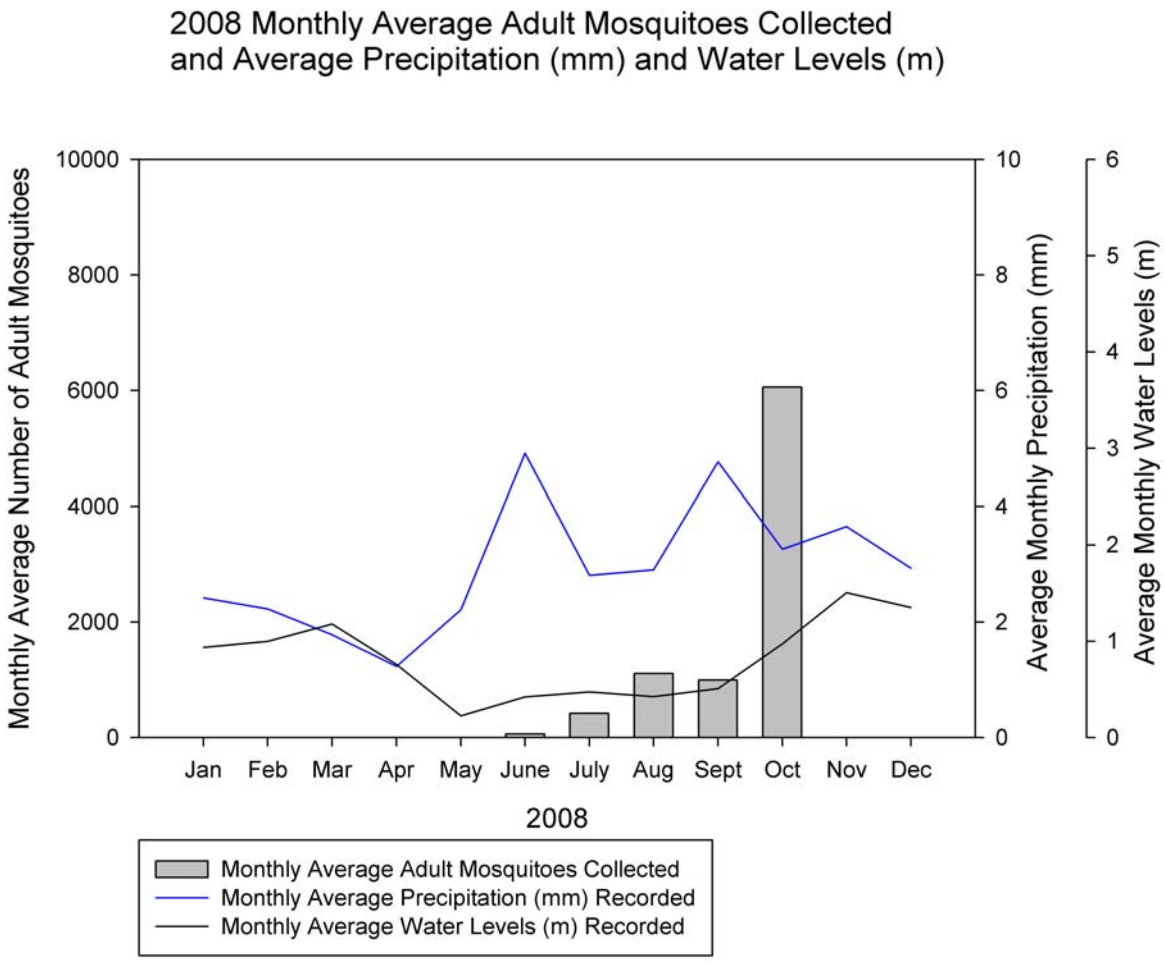

Figure 1: 2008 monthly average of adult mosquitoes collected over the summer months and the average precipitation in Parkhill (mm) and average water levels (m) recorded in Parkhill Creek below the dam.

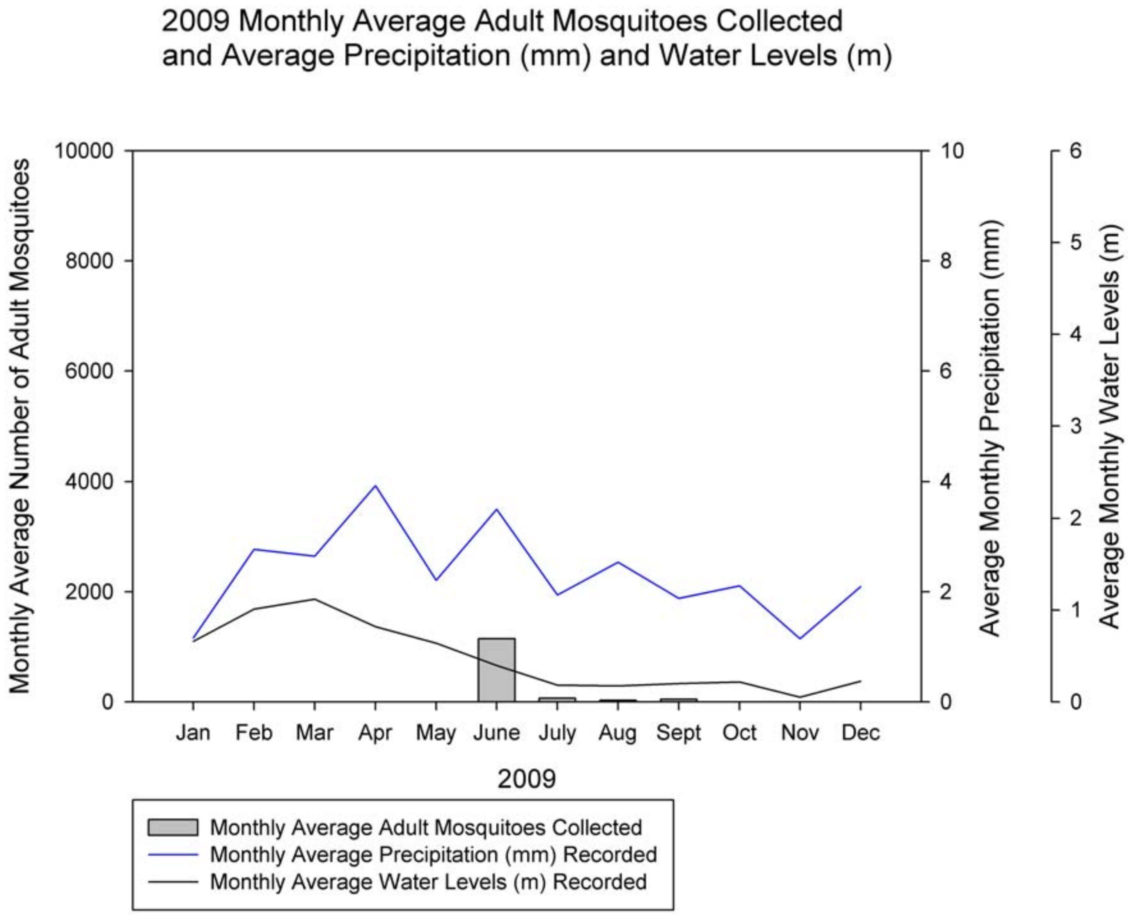

Figure 2: 2009 monthly average of adult mosquitoes collected over the summer months and the average precipitation in Parkhill (mm) and average water levels (m) recorded in Parkhill Creek below the dam.

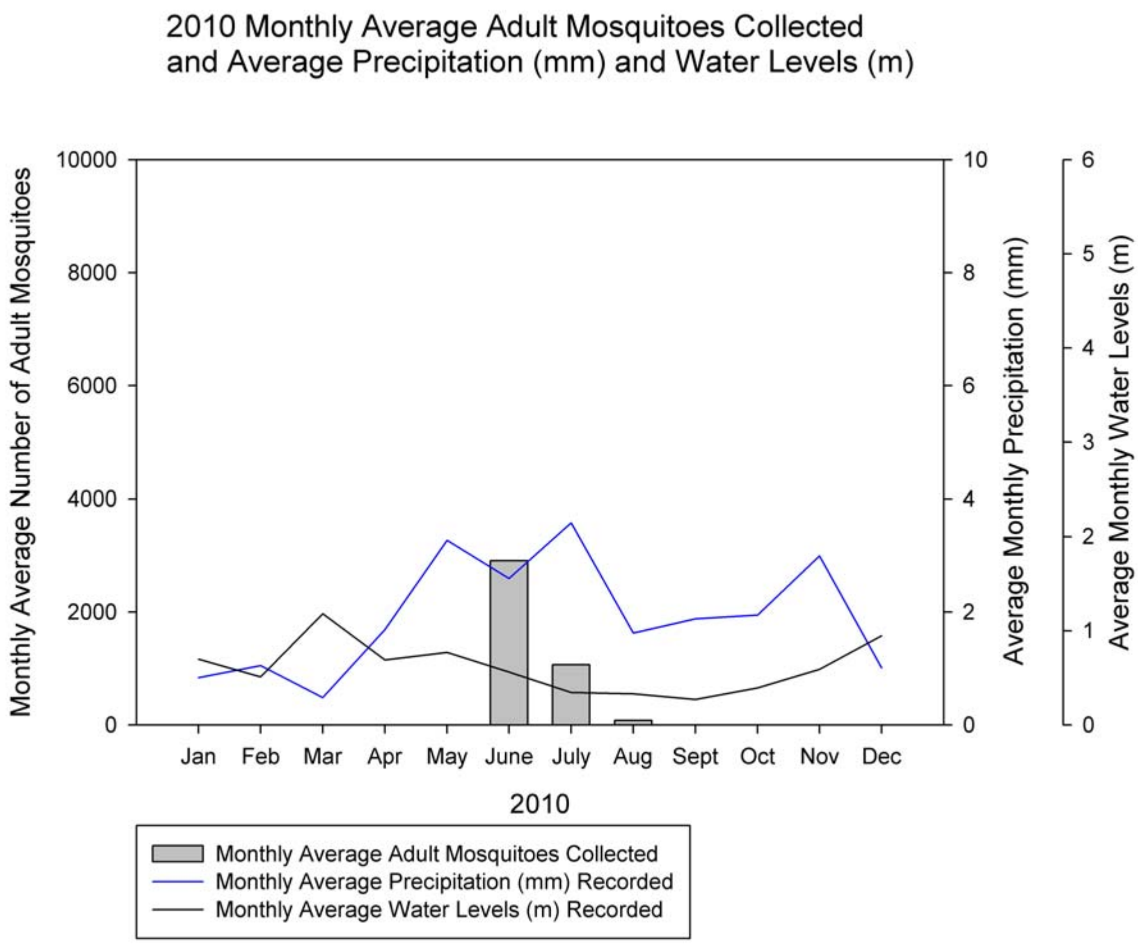

Figure 3: 2010 monthly average of adult mosquitoes collected over the summer months and the average precipitation in Parkhill (mm) and average water levels (m) recorded in Parkhill Creek below the dam.

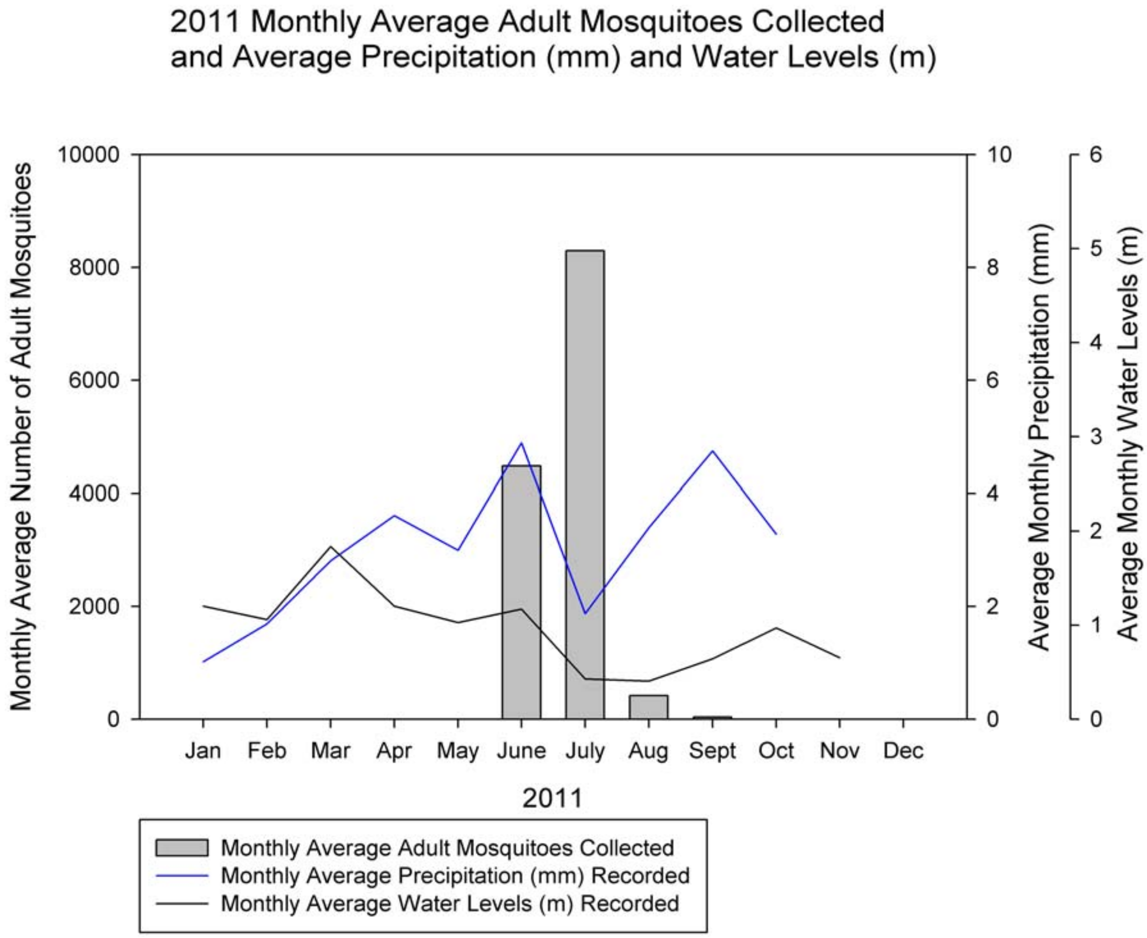

Figure 4: 2011 monthly average of adult mosquitoes collected over the summer months and the average precipitation in Parkhill (mm) and average water levels (m) recorded in Parkhill Creek below the dam.

APPENDIX F – Daily Precipitation and Weekly Mosquito Numbers

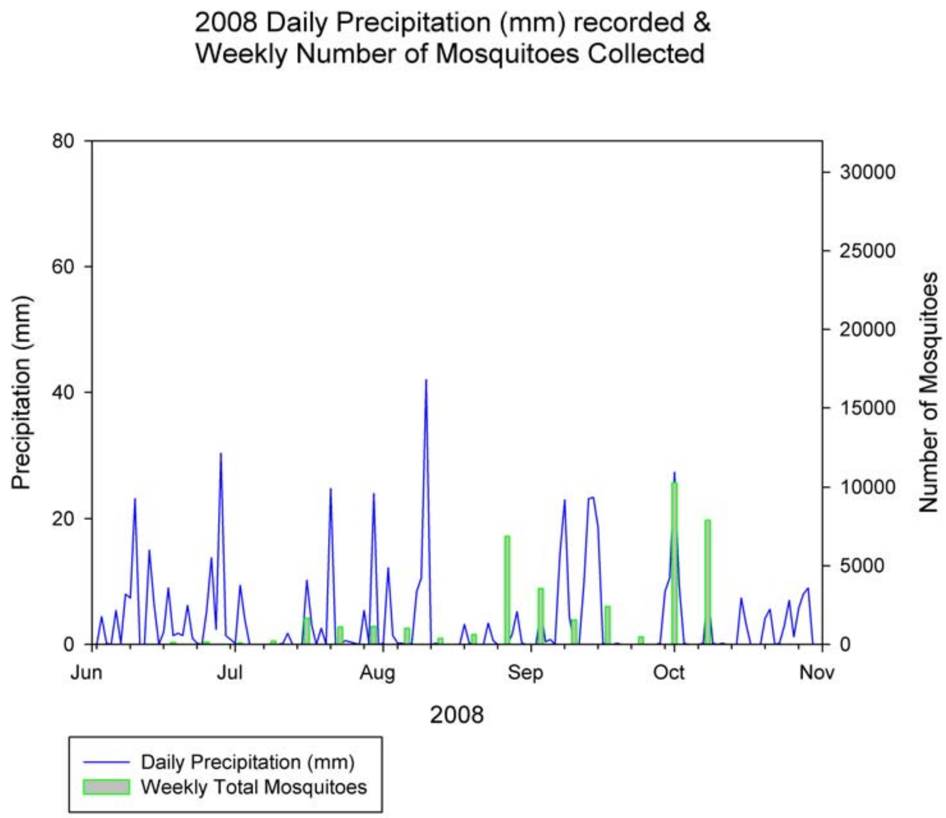

Figure 1: Daily precipitation (mm) recorded in Parkhill and total weekly mosquitoes collected in traps throughout June to October in Parkhill for 2008.

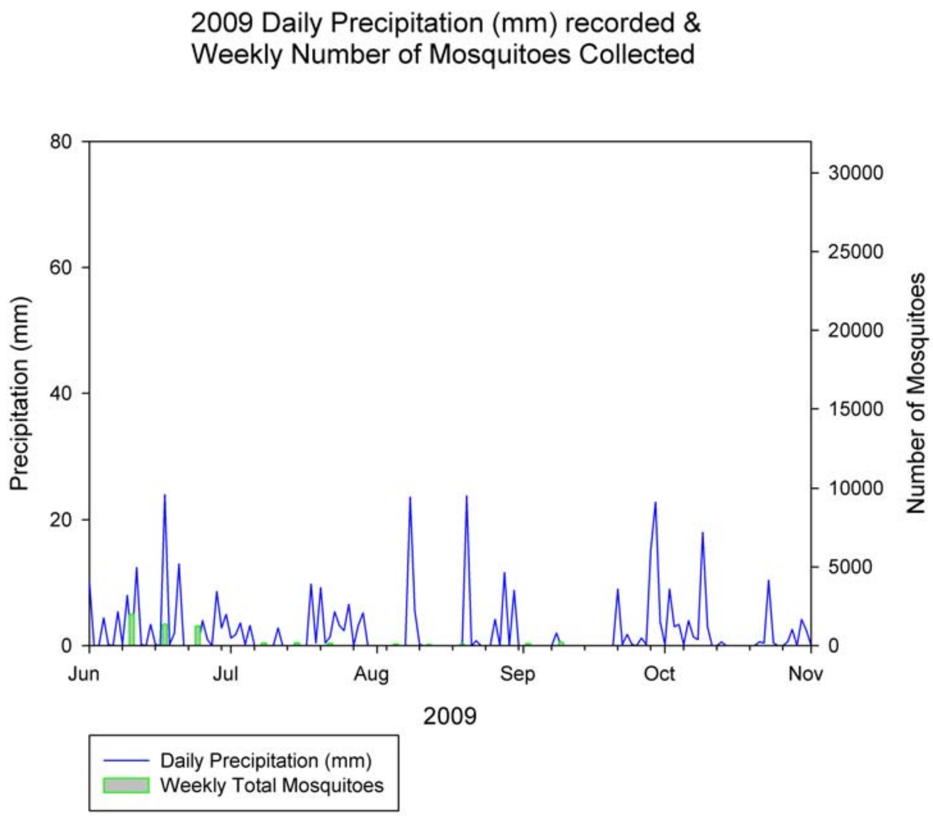

Figure 2: Daily precipitation (mm) recorded in Parkhill and total weekly mosquitoes collected in traps throughout June to October in Parkhill for 2009.

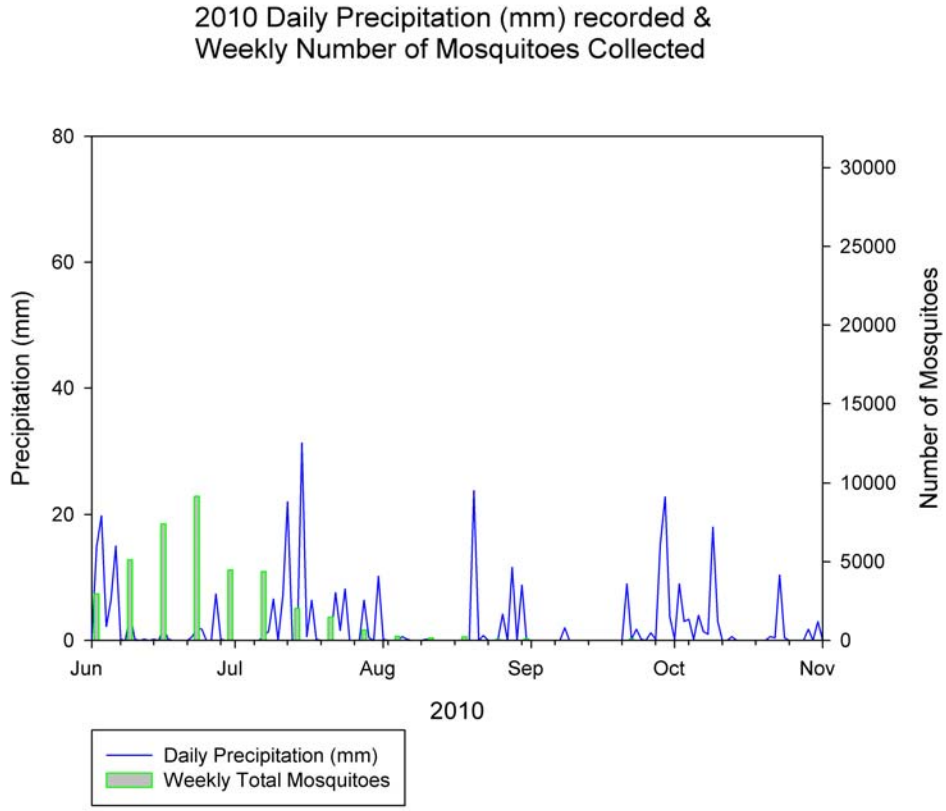

Figure 3: Daily precipitation (mm) recorded in Parkhill and total weekly mosquitoes collected in traps throughout June to October in Parkhill for 2010.

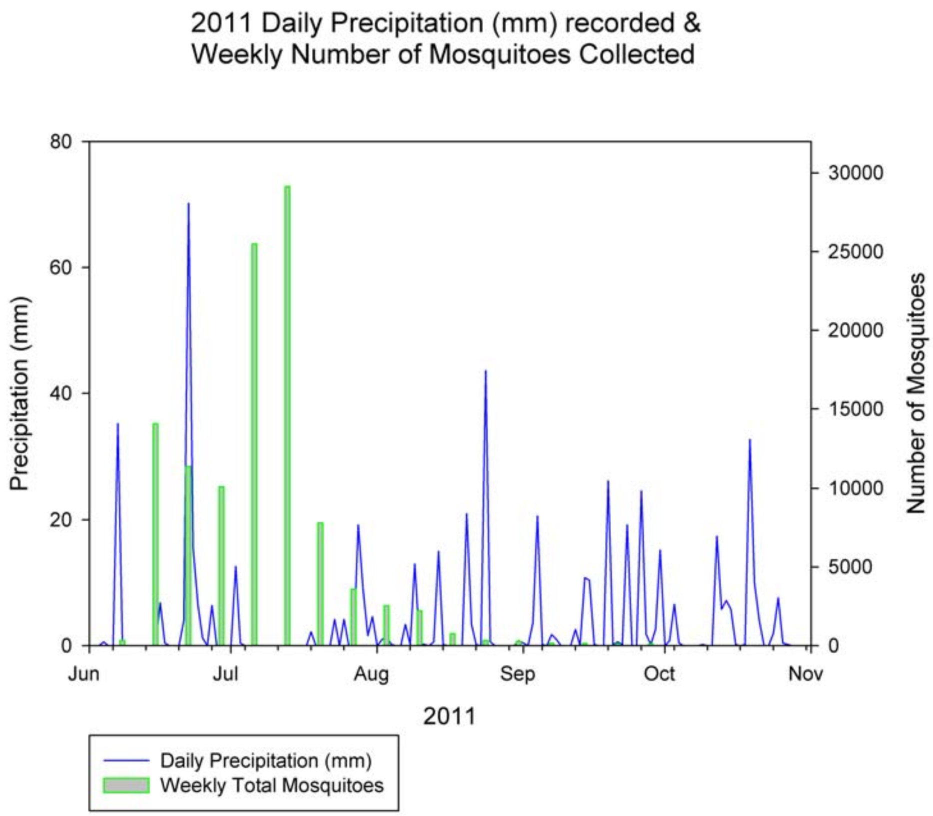

Figure 4: Daily precipitation (mm) recorded in Parkhill and total weekly mosquitoes collected in traps throughout June to October in Parkhill for 2011.