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Ecological risk based assessment used to restore riparian physical functions to a fresh water Creek

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Abstract

The purpose of this study was to determine if an interdisciplinary team using a qualitative proper functioning condition (PFC) assessment protocol could identify and reverse significant detrimental ecological alterations which occurred within Gertie's Creek watershed, Ontario, Canada. At potential, Gertie's Creek supported a woody debris glacial outwash fine gravel substrate fish spawning habitat. The anthropogenic activities on Georgina Island caused a denuded anadromous fish population since the early-to mid-1990's in the Gertie's Creek watershed. The PFC assessment indicated that anthropogenic activities on Georgina Island negatively impacted stream flows in Gertie's Creek. Reduced stream flow resulted in the natural stream (lotic) riparian habitat not advancing out of an early seral silver maple and eastern hemlock vegetated swamp (forested wetland) habitat. The Gertie's Creek interdisciplinary team PFC assessment indicated that the entire watershed is not in balance with the water and sediment being supplied along with a lack of diverse riparian vegetation. Sediment was not being transported to the wetland and lake coastal areas because of chronic reduced flows. Further qualitative assessments by the authors of other smaller lentic and lotic ecosystems on Georgina Island indicate that reduced hydrologic flow is an issue for the entire island. Ecosystem function management planning works with the ecosystem to continually respond as the ecology changes in ways that enhance remarkable natural recovery.

Keywords

Ecosystem function; Water quality; Non-point source; Proper functioning condition

1. Introduction

Ecosystems are dynamically affected by bio-geoclimatic setting and anthropogenic modification of natural conditions (Tamario et al., 2018). Centering the focus on ecosystem physical processes prioritizes actions for maintaining and restoring the foundation needed

for resilience and restoration (Rollan et al., 2018, Hall et al., 2014, Kondolf, 2006, Kondolf et al., 2006, Kondolf, 2011). To determine impacts from environmental stressors, it is important to understand ecosystem functions and recognize their role in the capture, storage and safe release of water, sediment, nutrients, and organic materials (Swanson et al., 2017, Kozlowski et al., 2013, Kozlowski et al., 2016, Hall et al., 2009, Hall et al., 2014). The degree to which stream and wetland riparian areas function properly, regarding their potential/alter potential, makes the connection between form, function, management and monitoring to address the underlying causative factors behind the restoration of biological values and ecosystems (Aron et al., 2013, Pander et al., 2018, Swanson et al., 2015). This study determined the restoration potential of Gertie's Creek back to a functional lotic ecosystem. The determination of other Georgina Island upland areas to their potential natural condition (PNC) and restoring these areas to a white pine and sugar maple ecosystem is also included. Stream and wetland riparian proper functioning condition (PFC) assessments are an appropriate starting point for determining, prioritizing and inventorying riparian resources (Ward et al., 2003, Winward, 2000), and developing monitoring needs (Swanson et al., 2017). More important, PFC provides context for quantitative data. Therefore, monitoring focused on the drivers (vegetation, hydrology, soil and landform) of ecosystem functions is fundamental to maintaining water quality and the rich values of riparian ecosystems (Aron et al., 2013, Swanson et al., 2015, Swanson et al., 2017, Winward, 2000).

Restoring an ecosystem to its potential is dependent on the development of a riparian and upland management strategy, which considers and adapts to certain basic ecological and economic relationships (Kozlowski et al., 2013, Kozlowski et al., 2016, Swanson, 1996, Swanson et al., 2015, Wyman et al., 2006). Ecosystems are defined as an interconnected community of vegetation, soils, landforms, hydrology, and micro-organisms, linked by physical and chemical interactions (Dickard et al., 2015, Kondolf, 2006, Nakano and Murakami, 2001, Nakano et al., 1999, Prichard et al., 1998a, Prichard et al., 1998b). An appropriate management strategy incorporates ecosystem patterns, attributes (vegetation, soils, landforms) and processes (hydrology) to attain sustainable ecosystem functions that support biological diversity (Garcia et al., 2017, Barbour et al., 2000, Angermeier and Karr, 1994). Understanding the ecosystem function physical processes allows sustainable management of many ecological goods and services (Aron et al., 2013) including water quality through assimilation, water stability (aquifer recharge), fish and wildlife habitat, and enhancement of focal niches (Kozlowski et al., 2016, Swanson et al., 2015, Hall et al., 2014). Managing for restoration efforts requires focus on the drivers of ecosystem function. These drivers are the leading indicators used to augment and manage the physical process through adaptive management based on monitoring (Swanson et al., 2012, Swanson et al., 2017). Linking the leading indicators of ecological functions to time yields an ecosystem condition status and then ecological risk can be determined. For example, what would be the consequences of success/failure if an ecosystem is left unattended? How fast would the ecosystem improve/degrade? What is the importance to users in maintaining and/or increasing long-term sustainability?

Evaluating and managing ecosystems proactively provides the largest return for the investment in time and resources for the benefit of the users. This research outlines the

essential goods and services of an ecosystem by focusing on the drivers of stream and wetland riparian functions, which often determine if resource goals and objectives are being met. This study identifies and analyzes areas of ecological modification (hydrology, vegetation, erosion/deposition) to improve best management practices (BMP) implementation, and what parameters need to be monitored (Swanson et al., 2017).

2. Method – riparian proper functioning condition (PFC)

Stream and wetland riparian proper functioning condition (PFC) is an assessment protocol focusing on physical structure and functioning in relation to on-site potential (Dickard et al., 2015). Although qualitative, it is based upon quantitative science (Dickard et al., 2015, Prichard et al., 1998a; Leonard et al., 1992). PFC incorporates the important attributes numerically-based (CWMW, 2013) and other qualitative surveys commonly address (Ward et al., 2003). The PFC assessment method refers to a consistent quantitative science-based approach for considering stream and wetland hydrologic, vegetative, and geomorphic attributes and processes (Schumm, 1977, Schumm et al., 1984) at a point in time (Dickard et al., 2015). An interdisciplinary (ID) team conducting a PFC assessment in the field uses all relevant science and life experience to inform understanding of local potential to determine what is locally possible, and what is needed for the ecosystem to maintain functions during large flow events. Potential is defined by Dickard et al. (2015), as “the highest ecological status an ecosystem can attain given no social, political or economic constraint.” An altered potential is the highest ecological status an ecosystem can attain given these constraints are present (Dickard et al., 2015).

The ID team analyzes the “yes’s” and “no’s,” in relation to the reaches potential/altered potential and determines a functional rating and trend. To be properly functioning, a riparian system will: “Dissipate stream energy associated with high water flows, thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve floodwater retention and groundwater recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses, and; support greater biodiversity” (Prichard et al., 1998a).

The term proper functioning condition (PFC) also is used to describe both an assessment process, and a defined, on-the-ground, condition of a riparian-wetland area. Therefore, PFC refers to how well the physical processes within a stream and wetland riparian area can sustain a state of resiliency (Wyman et al., 2006, Prichard et al., 1998a, Prichard et al., 1998b; Prichard et al., 1996; Dickard et al., 2015). This resiliency allows an area to provide and produce desired and valued ecosystem services (e.g., fish habitat, livestock and/or wildlife forage, water purification, carbon storage and nutrient cycling) over time (Wyman et al., 2006). To determine how well a lotic riparian area functions to achieve these criteria, an interdisciplinary team of experienced professionals uses a checklist of seventeen attributes for lotic ecosystems (Dickard et al., 2015) and twenty for lentic (Prichard et al., 1998b) in three categories: hydrology, vegetation, and geomorphology. The functional attributes in the PFC assessment form provide important foci for this study’s research. The rationale for the

PFC assessment are summarized in technical references (Prichard et al., 1998a, Dickard et al., 2015).

Stream and wetland riparian PFC assessments connect to water quality and aquatic habitat by assessing the degree of functionality and the risk of losing those functions (Swanson et al., 2017). By focusing on physical functioning, the PFC protocol is designed to yield information about the biology of the plants and animals dependent on the riparian-wetland area (Prichard et al., 1998a, Prichard et al., 1998b; Prichard et al., 1996; Dickard et al., 2015). When the stream and riparian ecosystem functions properly, it is stable and resilient to major hydrologic events (Prichard et al., 1998a). Stream stability requires that a stream be self-sustaining, retain the same general geometry over time (decades), and balance the import and export of sediment (Ward and Trimble, 2004).

Functional at Risk, refers to riparian areas functioning, but with an existing soil, water, or vegetation attribute making them susceptible to degradation. Apparent trend is an assessment of direction of change (e.g., upward or downward) in conditions either toward or away from the potential or functionality (Prichard et al., 1998a, Prichard et al., 1998b; Prichard et al., 1996; Dickard et al., 2015). Trend is determined by comparing the present condition with previous photos, trend studies, inventories, other documentation, or personal knowledge. The lack of historical information on the condition of a site may lead to a “trend not apparent” assessment unless other clues are well understood such as the population growth of young woody species (e.g., willows). Nonfunctional indicates the stream and wetland riparian is in a degraded state.

3. Results - Gerties Creek PFC assessment

Georgina Island is located approximately 3km north of the southeast shoreline of Lake Simcoe, Ontario, Canada. Lake Simcoe is located approximately 80km north-northeast of Toronto, Ontario, Canada (Fig. 1). Stream and wetland riparian PFC assessments were completed for Gertie's Creek, which is located on the west side of Georgina Island (Fig. 2).

A multidisciplinary team completed PFC assessments for 4 lotic reaches (Dickard et al., 2015) and 1 lentic reach (Prichard et al., 1996) starting at the Lake Simcoe shoreline to a point approximately 1 kilometer up into Gertie's Creek watershed. Tributary streams were not assessed. A narrative description of each reach is agreed upon by the interdisciplinary identification (ID) team. Reaches were defined to represent changes in resource management, to match an existing Ontario Ministry of Natural Resources and Forestry monitoring reach, and/or represent changes in ecology (lotic, lentic), flow regime and geomorphology. As per Hall et al., 2017, the ID team determined Gertie's Creek had an altered potential from the anthropogenic activity within the watershed. Assessed stream reaches were classified, based on each of the reach's altered potential, into proper functioning condition (PFC), functional at risk (FAR), or nonfunctional (NF) by analyzing the “yes's” and “no's” from each of the questions in the lotic (https://www.blm.gov/or/programs/nrst/files/lotic_checklist.pdf) and lentic (https://www.blm.gov/or/programs/nrst/files/lentic_checklist.pdf) checklists. In the summary section of the PFC lentic and lotic field sheets the ID team further classified the current level of condition by determining an

approximate location on the “thermometer” (Prichard et al., 1996, Dickard et al., 2015). This further classification assists the ID team in determining if the reach is improving (e.g., riparian area is expanding, diverse age and composition of vegetation), degrading (e.g., channel is incising), or there is no change.

Reach 1 (lotic) extends from the lake shoreline to Chief Joseph Snake Road (CJSR), approximately 200m. Extensive management changes from urbanization along the shoreline and straightening of the channel below CJSR for flood control can be found on this reach. The straightening of the channel occurred in the 1960s when the wooden bridge over Gertie’s Creek was removed. (Fig. 2). Reach 2 (lotic) extends from CJSR to 40m upstream (i.e., to the east). Ontario Ministry of Natural Resources and Forestry has been monitoring the plant communities in this reach since the early to mid-1990s. Reach 3 (lotic) extends ~150m further up Gertie’s Creek to a slight break in slope. Reach 4 (lotic) extends from the break in slope to a constructed dam approximately another 200m. This reach has distinct stream morphologic features (i.e., floodplain) and ends at what appears to be a rock dam, which has created a ponded area. Reach 5 (lentic – ponded area) extends from the rock dam approximately 200–300m to a rise at the north end of the lentic wetland. These five reaches represent approximately 50–60 percent of the linear extent of the mainstem of Gertie’s Creek’s.

3.1. PFC assessment of Gertie’s Creek

Reach 1 (red) is classified as nonfunctional (Fig. 2) and the trend is not apparent (Table 1). Reach 2 (orange) is at the low end of functional at risk (FAR), and the trend for this short reach is not apparent (i.e., static), not improving or degrading, because of the Chief Joseph Snake Road (CJSR) and the culverts running under the road (Fig. 3). Reach 3 (yellow) is FAR and affected by the road/culverts. Trend is downward from the continuous deposition of sediment at and near the CJSR. Reach 4 (yellow) is also FAR, but at the upper end (Fig. 2), and the trend is assessed as downward, but this reach has potential to improve if a BMP can be implemented to relieve the constriction of the culverts and improve forest management to increase conifer and sugar maple communities. Reach 5 (green) is assessed as being a proper functioning condition, but at the lower one-third (Fig. 2), with a trend of not apparent because of reduced stream flows.

3.1.1. Reach 1—Gertie’s Creek Reach 1 extends from Lake Simcoe shoreline to the CJSR, an approximate distance of 200m (Fig. 2). The potential of Gertie’s Creek is a sinuous, 2–3m wide by 0.5-m-deep stream Rosgen E channel type (Rosgen, 1994, Dickard et al., 2015). Vegetation should be a mix of herbaceous and trees (willow, maple) riparian area with woody debris providing fish refuge. This reach has an altered potential because of long-term impacts beginning in the 1920s from the construction of the Trent Severn Waterway, conversion of CJSR bridges to culverts and lake shore cottage construction. PFC “no’s” indicate the stream channel had been straightened to allow peak flows to quickly move through channel without causing flooding to shoreline cottages. However, upstream perched culverts (Fig. 3) and culverts near shoreline cottages impeded flow in such a manner to increase flooding. Current vegetation lacks the diversity (silver maple, hemlock), stability and quantity to maintain a sinuous stream channel (Table 2). Lack of sunlight is preventing

ground and mid-story plant communities from becoming established. Without the stabilizing plant community, the stream channel is not laterally stable. Geomorphologic (erosion/deposition) components, as seen in Table 2, are a lack of stream lateral stability and water sediment imbalance. Sediment core samples showed large pebble-cobble substrate is overlain by six inches of fine silt and clay and organic detritus, indicating stream flows are not moving the fine material out into the lake.

As seen in the comments section of Table 2, the net result is this reach has an altered potential. The increase in lake level has decreased the shore zone slope preventing low energy flow from reaching the lake and backing up and creating a swamp area between the lake front homes and the CJSR. Cottage construction decreased potential stream flow access points. From past road construction, the stream was channelized to head straight to the lake (Fig. 4, red line). However, at potential, Gertie's Creek would have a more sinuous channel form (Fig. 4). From the CJSR, Gertie's Creek's path would have been towards the south before turning towards the north. Note the location of the starting point (blue dot) of the assessment reach.

As seen in Fig. 4, the natural stream channel would normally enter the lake approximately 100m further north. Because of channelization, the stream has lost sinuosity, gradient, and width to depth ratio.

Objective of channeling lower Gertie's Creek was to move water away from lake shore properties and to move the storm water through the lower reach and into the lake faster. However, higher lake levels have reduced the flow gradient for lower Gertie's Creek, increasing the stream power needed to break through the beach berm (Fig. 5).

3.2. PFC assessment of Gertie's Creek Reach 2

Gertie's Creek Reach 2 extends from Chief Joseph Snake Road (CJSR) to 40m upstream (to the east) from the road (Fig. 2). Reach 2 reestablishes an Ontario Ministry of Natural Resources and Forestry Wetland Conservation Programme (WCP) monitoring site. The potential of Gertie's Creek Reach 2 is a sinuous stream Rosgen E channel (Rosgen, 1996) meandering through a predominantly herbaceous riparian area with a broad flood plain. Forest management has reduced the upper story canopy near the road, but silver maple dominates the upper portion of the reach (Table 3, Fig. 6). Reach 2 has an altered potential of a silver maple-eastern hemlock swamp, because of impacts from CJSR, culverts and roadside maintenance of clearing of shrubs and trees (Fig. 3). Reach 2 is assessed at the lower end of functional at risk (FAR) (Dickard et al., 2015). PFC "no's" indicate the stream channel had been channelized to force the flows into the culverts. However, the culvert became perched (Fig. 3) creating an obstruction allowing for deposition of sediment on the upstream side of the road. The trend is not apparent (i.e., static), because of the road and perched culverts.

As seen in Fig. 3, presence of the road has created a low velocity zone restricting sediment transport. Sediment not moving through the aquatic ecosystem or even into the lake has created a sediment deprived (i.e., hungry water) situation below the CJSR (Fig. 6). Channel incision is not occurring on the downstream side of CJSR, because of the flow restrictions of

the perched culverts and at the lake shoreline (i.e., raised lake level, beach berm). Therefore, hydrologically, the stream is not in balance with the water and sediment being supplied by the watershed. Flow restrictions created a backwater swamp conducive to the silver maple and hemlock vegetative community. The swamp conditions provided the silver maple with a competitive advantage, preventing diversity of stabilizing riparian vegetation. As seen in the background of Fig. 6, the silver maple can create a thick canopy capable of reducing and/or blocking out sunshine, thus inhibiting ground level photosynthesis and herbaceous plant respiration potential.

3.3. PFC assessment of Gertie's Creek Reach 3

Gertie's Creek Reach 3 extends from the end of Reach 2—~150m upstream to a slight break in slope (Fig. 2). At potential, Gertie's Creek Reach 3 is a Rosgen E channel type (Rosgen, 1996), with herbaceous stabilizing (sedges, rushes) plant community (Dickard et al., 2015). Reach 3 has an altered potential of a palustrine wetland consisting of silver maple – eastern hemlock vegetation and a Rosgen D anastomosed channel type (Fig. 7), because of low flow from the watershed. Vegetation is predominantly silver maple with some hemlock in areas where the sun can peak through the canopy (Table 4). Sediment core samples are composed of, on average, a 10-cm layer of detritus overlying a small gravel–sand substrate. The thick organic mat seen in the core samples is predominantly leaf litter with some silt and clay.

Reach 3 is rated slightly above the center of FAR (Dickard et al., 2015). The trend for Reach 3 is assessed as being downward because of low flow conditions. Chippewas of Georgina Island environmental department indicates flows in Gertie's Creek decreased just prior to the year 2000. This would indicate that sedimentation within Gertie's Creek is approximately 10 centimeters (cm) per year. This portion of Gertie's Creek has an anastomosed channel with a bank full width of approximately 15m. Spring peak flows would be dissipated over a broad area, but a sediment accumulation rate of 10cm comprised of mostly organic debris seems excessive. Accumulation rate of around 3–5mm per year (mm/year), would place the transformation of Gertie's Creek to a swamp around 1990 (Hall et al., 2017).

The net result is Gertie's Creek Reach 3 is currently a Rosgen D (Rosgen, 1996) anastomosed multi-channel ecosystem meandering through a predominantly woody (silver maple) lentic riparian area (Fig. 7). An anastomosed channel system is characterized by multiple (i.e., 2 or more) highly stable channels (Rosgen, 1994) where flow shifts between the well-defined channels. As seen in Fig. 7, the anastomosed channels are sinuous to very sinuous, well vegetated, and are vertically accreting from the deposition of excess sediment and organic material.

According to GIFN, 2017, Gertie's Creek was an important cold-water fisheries and spawning area. It should be noted, one of the ponded/backwater areas is formed from groundwater upwelling into the creek. This upwelling area would have attracted trout and other cold-water fish (e.g., mud minnow, brook stickleback, emerald shiner) to spawn in this portion of Gertie's Creek (GIFN, 2017).

3.4. PFC assessment of Gertie's Creek Reach 4

Gertie's Creek Reach 4 extends from the end of Reach 3 to approximately 200m further upstream to a slight break in slope and a rock dam (Fig. 2). Reach 4 has an increased stream gradient and distinct stream morphologic features (i.e., channel, floodplain). At potential Gertie's Creek Reach 4 is a transportational reach (Dickard et al., 2015). However, due to the low gradient of the watershed, Reach 4 is assessed at potential of being a less sinuous Rosgen C channel type (Rosgen, 1996), with herbaceous stabilizing (sedges, rushes) and possible woody (e.g., willow) plant communities (Winward, 2000, Dickard et al., 2015). As seen in Fig. 4, there are multiple tributaries into this reach. At the time of assessment, these tributaries were dry and were not assessed. Georgina Island First Nation natural resources reports (GIFN, 2017, GIFN, 2000) indicate this portion of Gertie's Creek has the highest potential within the watershed for spawning Lake Whitefish and/or Northern Pike habitat. The PFC assessment indicates Reach 4 has an altered potential of a silver maple – eastern hemlock wetland (Fig. 8), because of low stream flow. PFC rating of Reach 4 is at the upper end of FAR (Table 5). The trend is assessed as downward, because of the long-term effects of reduced stream flow. However, this reach has potential to improve if a BMP can be implemented to increase flows and groundwater infiltration in the upper portions of Gertie's Creek watershed (e.g., change in forest management, closure of rock quarry).

Soil cores indicate a retreating glacial esker and/or moraine sequence overlain by a period of high flow conditions (i.e., erosional boundary) followed by a current sequence of reduced flows (i.e., increased organic material). The sequence is glacial outwash gley clay overlain by fine grained silty-sand and organic layers above. There is a distinct erosional contact between gley clay and the silty-sand. Stream channel substrate grain size is a result of the available sediment being supplied from the glacial outwash till. The fabric of the silt and sand till is fragmented with sharp edges indicating an initial deposition from glacial outwash (angular) and reworking through fluvial activity (rounding of the angular edges). Overlying the silty-sand is an organic mat, indicating a very low energy environment.

There are several (at least three) floodplains, and the upper two abandoned flood plains are now terraces (Fig. 8). Presence of the terraces indicates Gertie's Creek has gone through at least two, possible three, incision events. It's a possibility that the last event caused the rock dam at the top of Reach 4 to fail. However, current flow conditions indicate several years of low flows allowed the silver maple-eastern hemlock riparian plant community to proliferate.

3.5. PFC assessment of Gertie's Creek Reach 5 - lentic

Reach 5 (lentic – ponded area) extends from the rock dam (Fig. 9) approximately 200–300m to a rise at the north end of the lentic wetland (Fig. 10). The potential for Reach 5 is difficult to determine because of the condition of the rock dam at the beginning of this reach. If the rock dam was human made, then the potential for this reach is a lentic wetland open waterarea. At potential, Gertie's Creek Reach 5 would be considered a small lake with a mix of stabilizing herbaceous and woody plant communities. If the rock dam is natural then the potential of Reach 5 is a lentic forested glacial till wetland (Prichard et al., 1998b) with a thin layer of hydric soils and mid-to late-seral mixed forest (e.g., maple, ash, cedar, white pine) ecosystem. Because of the long-term effects of reduced stream flow and the

dilapidated condition of the dam, Reach 5, in its current condition, was assessed as having the potential of a forested glacial till wetland consisting of a mixed forest plant community. However, chronic low flow conditions have allowed the silver maple – eastern hemlock (Fig. 9, Fig. 10) to dominate this lentic wetland area (Table 6). Tributaries into this reach (Fig. 4) were dry at the time of the assessment.

Reach 5 is assessed as a lentic ecosystem at PFC (Dickard et al., 2015), but at the lower end (Table 6). Statement of the trend is not necessary when the reach is assessed at PFC, but for this reach, the trend is assessed as being static for its altered potential. However, this reach has potential to improve, if a BMP can be implemented to manage the forested ecosystem to increase mid-to late-seral tree species in the upper portions of Gertie's Creek watershed.

PFC assessment of Reach 5 is like Reach 4 in that the assessment resulted in more questions than answers. Soil cores indicate a lentic ecosystem has been present for several years, possibly decades, but deeper soil conditions indicate a lotic ecosystem was present during an earlier period (date unknown). The soil cores would suggest that the rock dam was constructed. Therefore, the primary questions for Gertie's Creek watershed are: where is the water, and where is it going?

4. Discussion

The hydrologic, physical and ecological alterations resulting from terrestrial anthropogenic activity can have a pronounced impact on the natural function of a stream, lake and wetland. The PFC assessment captures the stressors impacting the drivers of stream and wetland riparian physical functions (vegetation, hydrology, soil/landform) and presents the solutions for environmental restoration and resiliency based on the ecosystem's potential (Dickard et al., 2015). The potential for Gertie's Creek is a fish hatchery. However, because of economic constraints (limestone quarry, agriculture, logging, urbanization), Gertie's Creek has evolved into a swamp because of the loss of hydrologic flows.

Discharge of water and sediment can vary greatly due to geologic and bioclimatic conditions. When the water or bedload sediment from upstream is out of balance, a net degradation (erosion, incision) can occur, as seen in the multiple floodplains occurring in Reach 4 (Fig. 8). When there is an excess of sediment due to low stream flows, aggradation (Reach 2) occurs. Too much sediment is an obvious water quality problem, but so is too little. A lack of sediment (e.g., below impoundments – Reach 5) can degrade habitat for sediment or substrate size dependent organisms.

Hydrologic flows in Gertie's Creek have been reduced for some time (Hall et al., 2017, Prichard et al., 1996), such that the natural stream (lotic) riparian habitat has been replaced with an altered potential silver maple and eastern hemlock vegetated swamp (lentic) habitat. Historically, Gertie's Creek used to flow under the Chief Joseph Snake Road (CJSR) bridge, which was located approximately to the right of the culverts as seen in Fig. 6. With the replacement of the bridge, Gertie's Creek was channelized to go through the culverts (Fig. 6). Once the culverts became perched, sediment was not able to be transported through the culverts under CJSR.

PFC assessments indicate the entire watershed is not in balance with the water and sediment being supplied. Qualitative assessment of other smaller lentic and lotic ecosystems on Georgina Island indicates hydrologic flow is an issue for the entire island. For Georgina Island, the disconnect between surface water and groundwater appears to have occurred around 1986, or possibly earlier (Hall et al., 2017). The PFC assessments indicate there are potentially multiple stressors depleting surface water flow and groundwater interaction. A time series land cover analysis showed a loss in spatial area of wetlands/open water on Georgina Island after 1986 (Hall et al., 2017). This suggests the groundwater level had decreased or was being drawn down. Possible explanations for the reduced flows could result from increased urban development along the island's shoreline, decreased logging allowing the early seral silver maple tree populations to expand and take up more water, quarry activity reducing the water table (Collier et al., 2015) on the north end of the island, and/or a change in the limestone groundwater aquifers. Most likely all the above and/or combinations of other factors have affected surface water flows on Georgina Island. According to Hall et al. (2017), loss of open water occurred prior to, or during the period from 1986 to 1989, which has continued to date at this lower flow stage. This loss in wetland spatial coverage occurred over a forty-year period, which coincides with urban expansion, quarry activity and alteration in the forest cover.

Management of stream and wetland riparian ecosystems is essential for the protection and preservation of these productive environmental resources. Some riparian-wetland areas may be prevented from achieving their potential because of anthropogenic activities. If not managed correctly, multi-use activities can impact the quality of riparian areas. The goal of any natural resource management plan is to "achieve an advanced ecological status that provides the widest variety of vegetation and habitat diversity for wildlife, fish, and watershed protection" (Prichard et al., 1996). Therefore, the objective, if possible, is to focus management on the entire watershed. Therefore, any restoration effort needs to include removal of the perched culverts to allow Gertie's Creek to move freely under the road. This will allow Gertie's Creek to follow a more natural flow pattern (sinuosity), which will dissipate more stream energy, causing less damage to the shoreline cottages.

An appropriate restoration adaptive management strategy should start with an objective based on improving Gertie's Creek ecological response to support riparian function potential (Swanson et al., 2015, Kondolf, 2006, Kondolf et al., 2006). Based on the PFC assessments, a Gertie's Creek restoration management plan was developed, and the recommendations are to:

1. Replace road culverts to bottomless culverts to re-establish Gertie's Creek stream channel under Chief Joseph Snake Road to Lake Simcoe, i.e., bring back channel sinuosity.
2. Closing, or reclamation of the north island limestone quarry.
3. Initiating the GIFN forest management plan to achieve Gertie's Creek successional potential.

The Gertie's Creek Management Plan is to convert the perched culverts into bottomless culverts spanning $1.2 \times$ bank full width, allowing more freedom for the stream to flow under

the road (Kondolf, 2011). Bank full width at CJSR was measured to be 7m (Fig. 3). Therefore, the bottomless culvert needs to span at least 8.4m. Of the culvert replacement scenarios, the most practical option was to place three 5-foot (1.52m) bottomless culverts side by side. This option was put in place in the summer of 2016. Placement of the bottomless culverts were impacted by the location of utility lines (Fig. 11).

5. Conclusion

Purpose of any restoration effort is to improve the ecosystem function physical processes. The objective is to determine the ecological risks to that ecosystem and where these stresses occur within the watershed. Risk assessment based on ecosystem function yields management strategies aimed at increasing ecological physical processes. By narrowing the difference between potential/alterd potential and actual/current function, the risk is lowered and the stream and wetland riparian ecosystem is guided toward a desired/potential natural condition. For example, where a risk is present (i.e., loss of stream flow, nick point), ecological functions fall short of potential. An ecosystem function assessment in these situations can reveal loss/gain in key physical (i.e., loss of Georgina Island fisheries) and sometimes chemical processes (i.e., nutrients not being transported into wild rice habitat). Interdisciplinary field methods (e.g., PFC) result in a comprehensive assessment and identification of management goals.

Ecosystems are a key factor in human well-being. Nature is not static, it adjusts and adapts to climatic and anthropogenic stresses, which are themselves dynamic. For Georgina Island, humans are a key factor impacting their environment. Managing for PFC physical processes alters behaviors producing alterations to the ecosystem and/or contaminants, which triggers risks. Risk uncertainty from management actions is far more likely contained when key ecosystem function factors (i.e., leading indicators - drivers of ecosystem function), of how anthropogenic impacts alter stream and wetland functions, are employed in risk assessment and management.

The point of ecosystem function management is to work with the ecosystem, continually responding as the ecology changes in ways that enhance natural remediation or quicken its pace to a level of functionality. For example, the potential of Gertie's Creek is a low-to a moderately-low gradient sinuous stream channel meandering through a herbaceous riparian area draining the evergreen and hardwood forested watershed. At potential, Gertie's Creek supported a woody debris glacial outwash fine gravel substrate spawning habitat for Lake Simcoe fish. However, if an assessment identifies a fish population as non-existent, and a riparian plant community at risk due to lack of nursery areas within a stream, the risk may be managed by regulating stream flow. For Gertie's Creek, the management strategy is to repair impacts from anthropogenic activity to increase stream flow and recover the spawning habitat and connectivity from Lake Simcoe to Gertie's Creek. Gertie's creek is now flowing into Lake Simcoe due to the culvert update. Time and the adaptation of the two remaining recommendations will tell the story of fish hatchery restoration.

Within the ecological approach, the functional condition is monitored, and indicators change in response to the ecosystem changes. As the ecosystem changes and evolves, vegetation

density can be incorporated into the key PFC indicators. Steps can be taken to encourage vegetative growth prior to the loss of stream flow, nursery pools, or a significant proportion of the fish population.

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Fig. 1. Location map of Georgina Island on the south end of Lake Simcoe, southern Ontario, Canada. Lake Simcoe is located approximately 80km north of Toronto, Canada. Satellite image taken from Google Earth.

Fig. 2.

Assessed condition of Gertie's Creek reaches. Reach 1 – nonfunctional; Reach 2 – low end of functional at risk; Reaches 3 and 4 – functional at risk; Reach 5 – proper functioning condition for its altered potential as a retention pond.

Fig. 3. Gertie's Creek culverts under Chief Joseph Snake Road (CJSR). Bank full width is approximately 7 Meters. Photograph taken June 2016.

Fig. 4. Hydrologic stream model of Georgina Island. Red line indicates current channelized path of Gertie's Creek. Inset photograph of Gertie's Creek below CJSR. Note the straight channel, which was done for flood control and the modeled path of Gertie's Creek near the shoreline.

Fig. 5.
Photograph of the altered/current mouth of Gertie's Creek. Note, the beach berm built from wave action, which has decreased the stream gradient.

Fig. 6. Photograph of Gertie's Creek Reach 2 Looking up Stream. Lower Section of the Reach (~20 Meters) is Cleared of Over Story, which dominated by hemlock. Upper 20 Meters of the Reach is predominantly silver maple and hemlock. Note, the stream has been channelized to go through the culverts.

Fig. 7. Photograph of Gertie's Creek Reach 3 showing the locations of the anastomosed channel and pond morphology. Upper story is silver maple with hemlock and some grasses. Note the lack of mid-story vegetation.

Fig. 8. Photograph of Gertie's Creek Reach 4 showing the current floodplain and terraces. Silver maple with some grasses with a few young silver maple trees.

Fig. 9.
Photograph of the bottom section (Top of the Image) of Gertie's Creek Reach 5. Mostly older silver maple with middle aged trees.

Fig. 10. Photograph of the end of Reach 5. Note the rise or levy where the group (ID Team) is standing. Hemlock ground cover with older silver maple upper story. Very little to no mid-story or younger trees.

Fig. 11.

Photograph of the three 5ft. (1.52m) culverts placed side by side under CJSR. Nearby utility infrastructure and location of the downstream channel prevented placing the culverts within the predominate flow path of the stream (i.e., to the right in the photograph; Photograph was taken October 2016).

Table 1.

PFC assessment of Gerties Creek reaches.

Stream	Reach	PFC Rating	PFC Trend	Assessment Year
Gerties Creek	1	Nonfunctional	Not Apparent	2016
Gerties Creek	2	FAR-low	Not Apparent	2016
Gerties Creek	3	FAR	Downward	2016
Gerties Creek	4	FAR	Downward	2016
Gerties Creek (Lentic Assessment)	5	Proper Functioning	Not Apparent	2016

Table 2.

Reach 1 is assessed as nonfunctional. The key components in the PFC lotic assessment.

Hydrology	Vegetation	Geomorphology	Comments
Sinuosity, gradient, width to depth ratio; impacts from upstream road construction and channelization of the downstream reach below CJSR.	Lack of adequate diversity of stabilizing riparian vegetation, age classes, the amount of stabilizing plant communities, which are capable of withstanding high streamflow event.	Stream banks are not laterally stable, nor is the stream in balance with the water and sediment being supplied by the watershed.	Altered potential is a silver maple-eastern hemlock swamp resulting from reduced upstream flows (i.e., constriction from the culverts at CJSR, urbanization along the lake shoreline, and increased lake level from construction of the Trent Severn Waterway).

Table 3.

Reach 2 is assessed as functional at risk. The key components in the PFC lotic assessment.

Hydrology	Vegetation	Geomorphology	Comments
Channel has been altered to go through road culverts. Excessive sediment deposition is a result of the low flow regime existing behind the road. Width to depth ratio;	Herbaceous vegetation in the lower part of the reach is a result of clearing for road maintenance. Mostly older trees (silver maple).	Stream banks are not laterally stable, nor is the stream in balance with the water and sediment being supplied by the watershed.	Old abandon channel along the south side of riparian area. Could be original channel prior to conversion from bridge to culverts.

Table 4.

Reach 3 is assessed as functional at risk. The key components in the PFC lotic assessment.

Hydrology	Vegetation	Geomorphology	Comments
Some ATV activity, logging/fire wood. Low flows. Spring located within the channel near the end of reach.	Silver maple with hemlock. Canopy cover blocking sunshine to ground vegetation. Older maple trees in the upland areas.	Stream is not in balance with the sediment and water being supplied.	Core composed of gravel glacial outwash overlain by ~10cm organic detritus.

Table 5.

Reach 4 is assessed as functional at risk. The key components in the PFC lotic assessment.

Hydrology	Vegetation	Geomorphology	Comments
Several small tributaries to this reach. This reach has been incised possible during placement of culverts	Silver maple with hemlock. Canopy cover blocking sunshine to ground vegetation. No apparent plant succession to a stabilized community	Stream is not in balance with the sediment and water being supplied.	Sediment cores are composed of gravel glacial outwash overlain by organic detritus.

Table 6.

Reach 5 is assessed as being in proper functioning condition (PFC). The key components in the PFC lentic assessment.

Hydrology	Vegetation	Geomorphology	Comments
Several small tributaries to this reach. Very little flow and sediment input from the uplands. Difficult to determine in rock dam is natural or man-made. If man-made is placed to provide a catchment or water source for Georgina Island inhabitants possible decades/century ago.	Silver maple with hemlock dominate. However, poplar, white cedar, American elm are present with sedges and.	Stream is not in balance with the sediment and water being supplied.	Sediment cores are composed of gravel glacial outwash overlain by organic detritus.