McVicar Creek Protection & Rehabilitation Plan

A Lakehead Precedent

July 2014

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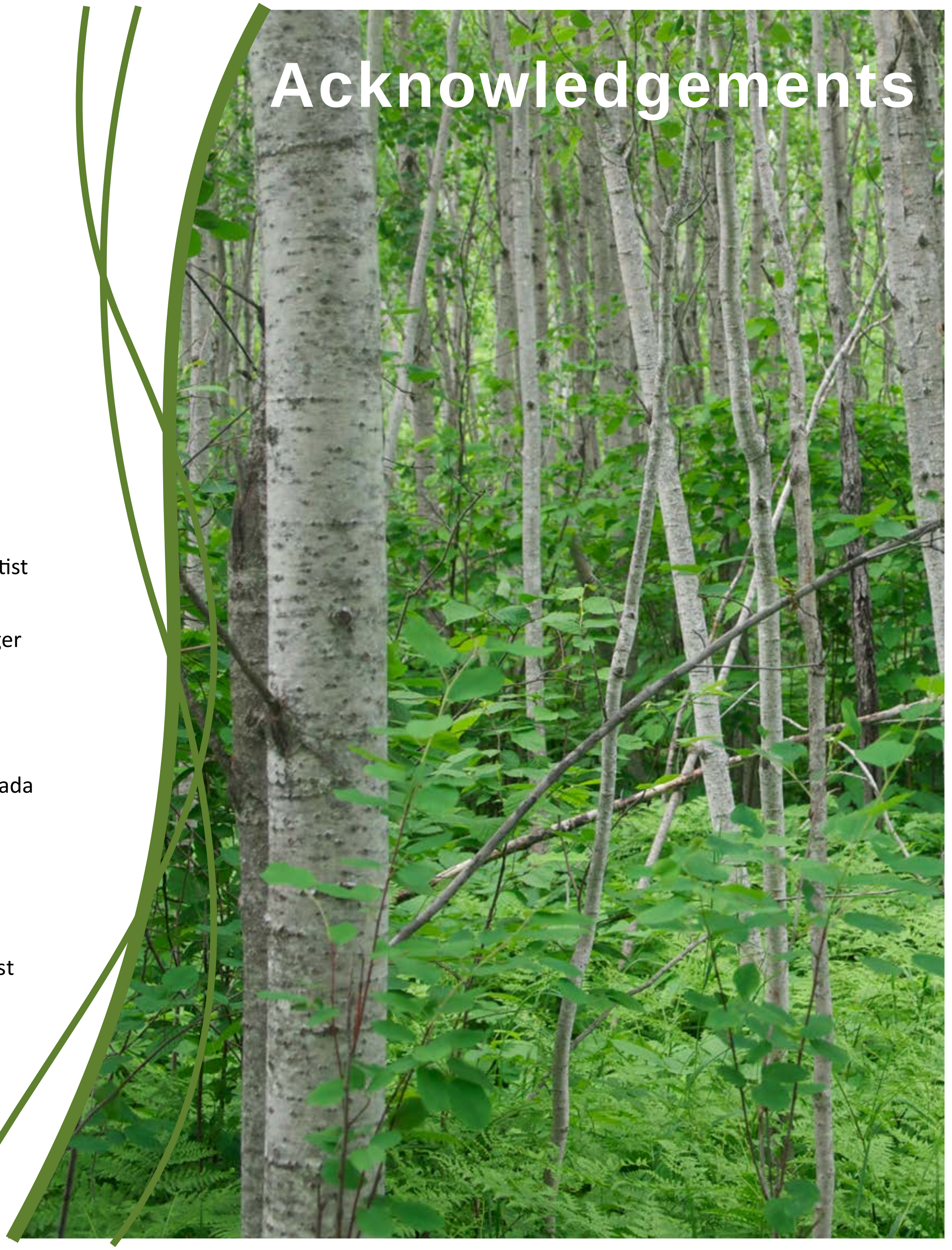
Acknowledgements



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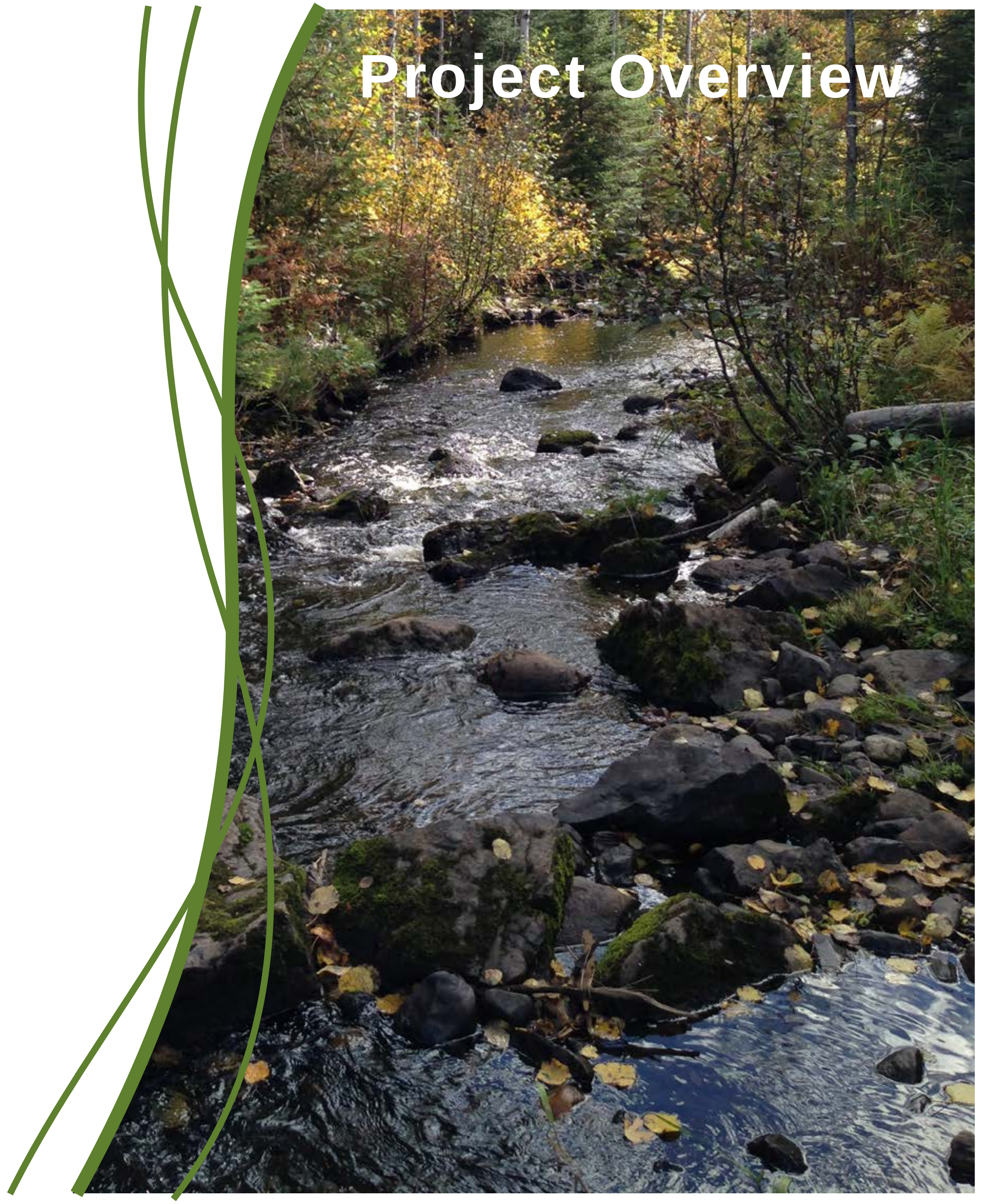


Project Overview

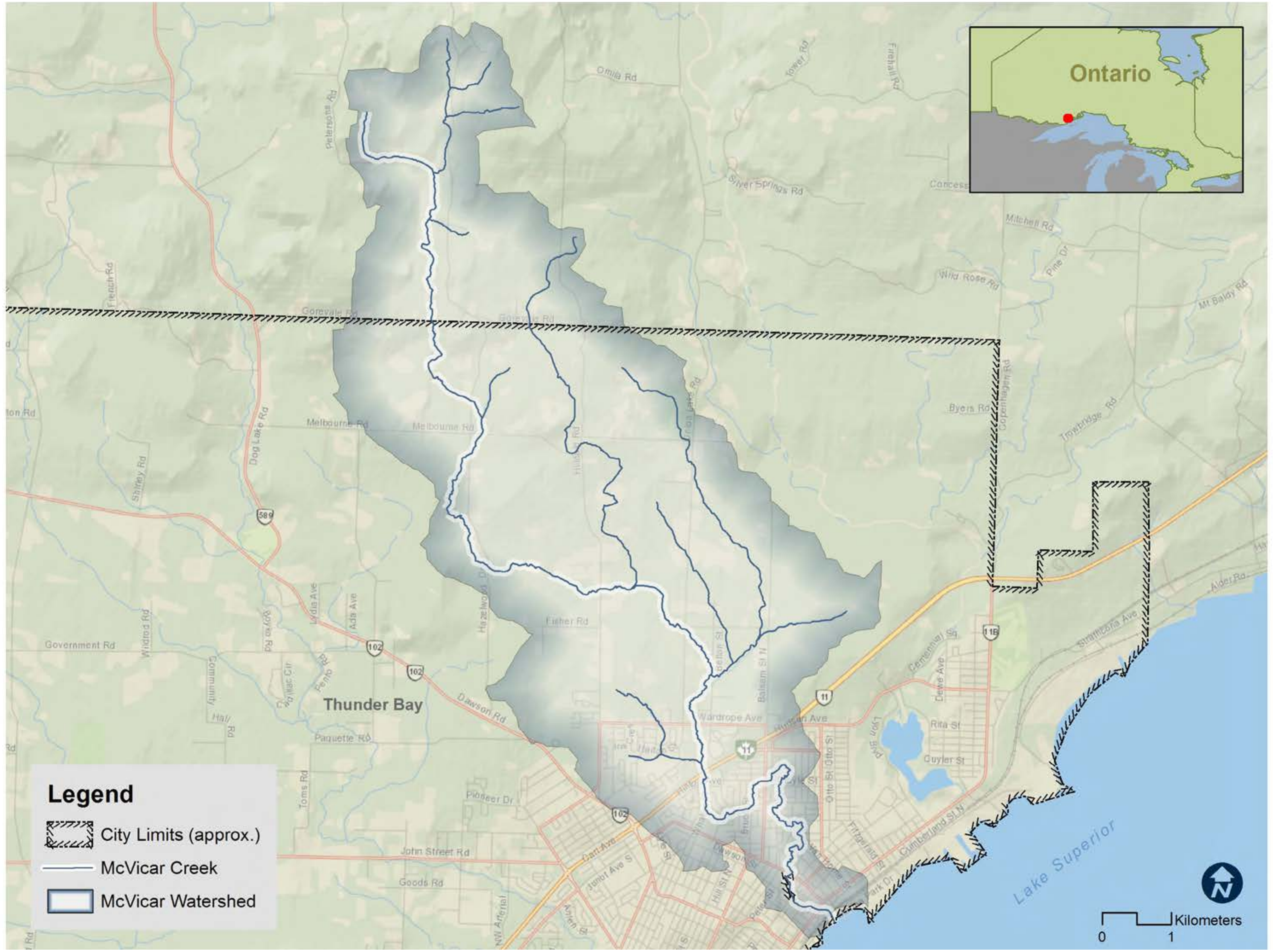
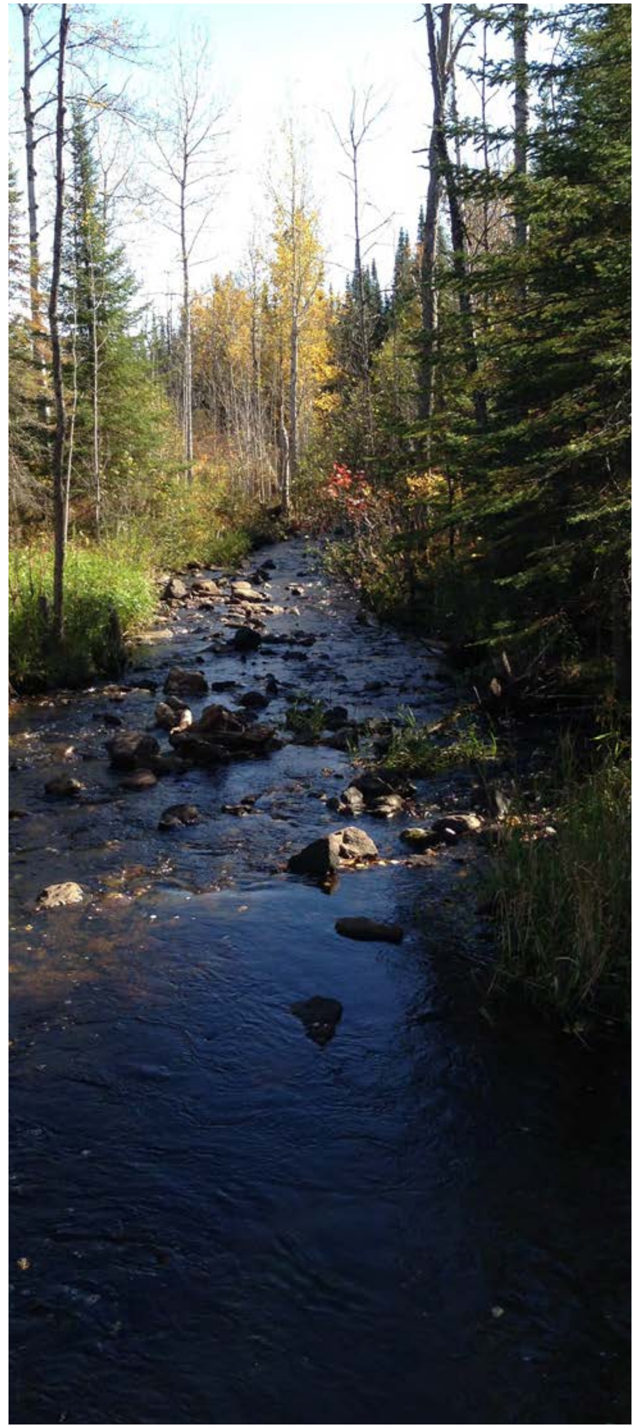


Figure 1 - Map of McVicar Creek Watershed



A. Background

Stormwater is considered a non-point source of pollution and can lead to aquatic habitat and ecosystem degradation. Currently, stormwater is relatively unmanaged in Thunder Bay and discharges directly into watercourses like McVicar Creek. These watercourses drain to the Thunder Bay harbour, which has been listed as an Area of Concern (AOC). An AOC is a location that has experienced environmental degradation. Major environmental issues for the Thunder Bay AOC include the following:

- Fish consumption restrictions
- Negative pressures on fish populations
- Dredging restrictions
- Loss of species abundance and diversity
- Reduced recreational opportunities
- Decline in aesthetic values

Research by Kok (2004) concluded that stormwater is a non-point source of pollution in the Thunder Bay AOC and contributes to many Beneficial Use Impairments (BUIs). The Thunder Bay Public Advisory Committee (PAC) and Remedial Action Plan (RAP) team came to the same conclusion and identified urban and stormwater runoff as a priority focus for remedial actions that can reduce the severity of BUIs. The BUIs most closely linked to stormwater include: beach advisories and impairments from the excessive nutrient levels that lead to eutrophication or undesirable algae, degradation of benthos, degradation of phytoplankton and zooplankton populations, and the loss of fish and wildlife habitat. Other stakeholders in the Lakehead Watershed, including the City of Thunder Bay, EcoSuperior, the Lakehead Region Conservation Authority, The Ministries of Environment and Natural Resources, and Environment Canada have also identified stormwater management as a priority action to maintain the health of Lakehead Region streams and rivers, and that of Lake Superior.

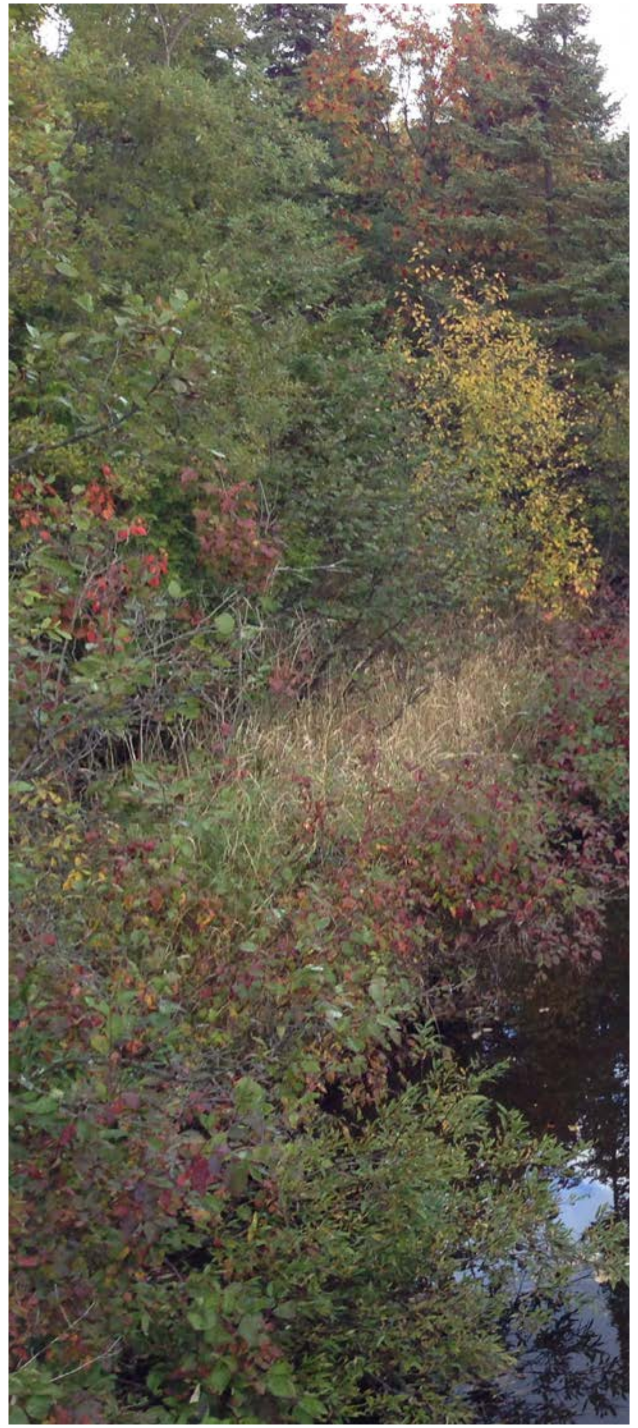
B. Resource

McVicar Creek is the smallest of five major watercourses that flow through the city of Thunder Bay. The creek is a coldwater stream system tributary to Lake Superior that drains a total area of 50.65km2 with its outlet located in the Thunder Bay Harbour. The creek is approximately 16km long and typically 2.5 to 3 metres in width with an average bank height of one metre immediately adjacent to the stream (Lakehead Region Conservation Authority, 1995). The upper reaches of McVicar Creek (84% of the drainage basin) are generally undeveloped and located mostly in forested open meadows, whereas the lower reaches (which represent 13% of the basin) are intensely urbanized (Lakehead Region Conservation Authority, 2002). Of the remaining 3% of the basin, mineral aggregate extraction occurs in 1% and the rest consists of wetland and open water areas (Lakehead Region Conservation Authority, 2002). For a comprehensive assessment of McVicar Creek, readers are directed to the Lakehead Region Conservation Authority's McVicar Creek Stewardship Program (2002).

McVicar Creek flows from its headwaters north of Melbourne Road to its outlet into Lake Superior, within the Thunder Bay Harbour. The headwaters of the creek are situated at an elevation of 490m and flow downstream for approximately 16km at a relatively constant gradient to the outlet at an elevation of 183m (Lakehead Region Conservation Authority, 1995). The creek slopes from 2.7° near the headwaters to 0.6° at the outlet (Lakehead Region Conservation Authority, 1995) and passes through three distinct areas of varying soil conditions. The upper reaches are characterized by undifferentiated soil which transitions into shallow sandy soils and finally stratified sands and gravel in the lower reaches (Lakehead Region Conservation Authority, 1995). The soil types reflect the underlying bedrock composition which consists of rolling Precambrian shield in the upper reaches and shaley Sibley Group sedimentary rock in the mid to lower reaches (Lakehead Region Conservation Authority, 1995). The bedrock is at close proximity to the ground surface in the urbanized lower reaches of the creek, which leads to high stormwater runoff values (Lakehead Region Conservation Authority, 1995).

Table 1 - Mc Vicar Creek Facts

Watershed Size	50.65 km^2
Length of Creek	16 km
Channel Slope	2.7% near headwaters 0.6% near outlet to Lake Superior
Avg. Channel Width	2.5 to 3.0 metres
Avg. Bank Height	1.0 metre
Thermal Regime	coldwater
Streamflow Gauge / Precipitation Gauge Location (1985 to present)	Briarwood Drive
Flow at Streamflow Gauge Location during Regional Storm	63.1 cms
Flow at Lake Superior during Regional Storm	148.4 cms
Highest Recorded Instantaneous Flow at Gauge Site	June 2008, approx. 20 cms



C. Objective

Addressing the aforementioned Thunder Bay AOC environmental issues is a driving a force behind the funding and formation of this project. Outcomes of this project are intended to ensure that the gains realized through Remedial Action Plan (RAP) implementation are maintained, and progress towards restoration and ultimate delisting of Thunder Bay as an AOC continues.

The overall goal of the Plan is a healthy and sustainable watershed that contributes to the economic, environmental, and social vitality of the city, while serving as a precedent for Thunder Bay and the greater Lakehead community.

The Plan is a new paradigm for the city – one that recognizes 1) that the Harbour and the tributaries that feed it are the lifeblood of the community and 2) that sound investment in preserving and rehabilitating these resources will provide returns twofold. The steering committee members offered two guiding principles in the development of this precedent:

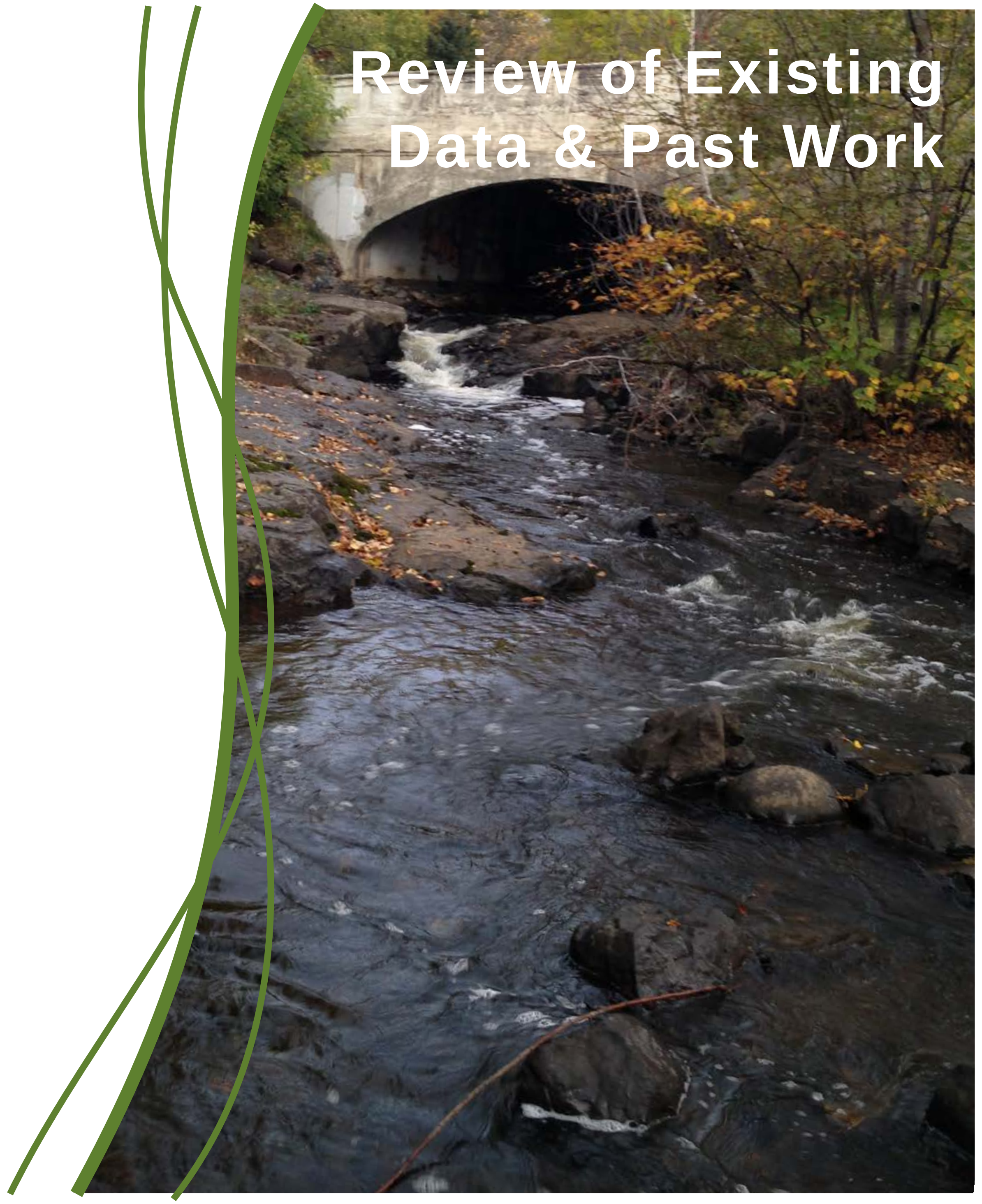
1. Restoration:

The most effective protection and reinstatement of stream health occurs with community support at the watershed scale.

2. Rehabilitation:

Awareness of and connection to Thunder Bay's natural resources is fundamental to the vitality of these resources and the community.

Review of Existing Data & Past Work



A. Watershed Gap Analysis

One of the first steps in the development of the McVicar Creek Preservation Plan was the review of existing hydrologic, hydraulic, water quality studies, and monitoring activities which have taken place in the McVicar Creek watershed. This step provides a foundation for the Preservation and Rehabilitation Plan and identifies gaps in the knowledge-base. Table 2 summarizes the findings of this gap analysis. The main findings of this analysis are as follows:

1. Hydrologic and Hydraulic Modeling is dated and limited in geographic extent. The primary goal of these modeling efforts was to delineate the floodplain of McVicar Creek.

2. A Stormwater Impacts Assessment was conducted for the resource in an effort to identify areas along McVicar Creek that were highly susceptible to stormwater impacts. This assessment, which was conducted in multiple phases, evaluated the resource, biotic health, in-stream water quality downstream of stormsewer outfalls, and land use of the contributing drainage area. The main findings included the identification of water quality parameters that exceeded Provincial Water Quality Objectives, the identification of three hot spot areas, and the development of stormwater remediation options for these hot spot areas.

3. Baseline monitoring data has been collected by Environment Canada and the Ontario Ministry of the Environment in partnership with the Lakehead Region Conservation Authority (LRCA). Environment Canada collects continuous flow data on McVicar Creek as well as precipitation data and the Ontario Ministry of the Environment (MOE) has been collecting water quality data on the creek. The LRCA collects the water samples and the MOE analyzes the samples and publishes the results.

The main gaps in the knowledge-base are as follows:

1. An evaluation of the existing water quantity and water quality data should be conducted to characterize flow regimes of the resource and to evaluate exceedances of Provincial Water Quality Objectives. This data should also be used to conduct a baseflow analysis and evaluate change in baseflow contribution with time.

2. Limited fluvial geomorphology data is available on McVicar Creek and its tributaries. A "rapid visual assessment" of McVicar Creek was completed by Lakehead University in 2010 utilizing the Unified Stream Assessment (USA) and Unified Subwatershed and Site Reconnaissance (USSR) methods developed by the Center for Watershed Protection (CWP; Kitchell and Schueler 2004, Wright et al. 2004). This information provides an important qualitative perspective on stream health and its stressors, but lacks the quantitative morphology data necessary to assess stream channel stability and understand or predict the evolution of channel adjustment that must take place in response to anthropogenic or other external influences. This

Table 2 - Summary matrix of existing hydrologic, hydraulic, and water quality studies and monitoring activities in the McVicar Creek Watershed

Source <Electronic Filename>	Objective	Results	Physical	Chemical	Biological
Flood Line Mapping Study: McVicar Creek (1978) M. M. Dillon Limited *<1978 floodplain report.pdf>*	• To determine the land inundated as a result of the Regional Storm (7.37 inches over 12 hours) within the study area	• Description of flood prone areas during the Regional Design Storm			
McVicar's Creek Floodplain Study (1995) M. M. Dillon Limited *<Flood_plain_study_1995.pdf>*	• Estimate the Flood Plain limits • Locate the Fill and Construction limits	• There are very few locations where existing buildings could be affected by high floods	• **Flow**: Nine years of instantaneous flow at Briarwood Drive gage predicted with the OTTHYMO model • **Water levels**: Computed from the 1978 HEC-2 model updated to include recent structure and survey data		
Stormwater Impacts Assessment Phase I (2011) The North Shore Remedial Action Plan, Lakehead University, The Lakehead Region Conservation Authority, EcoSuperior Environmental Programs *<2011 stormwater impacts assessment.pdf>* *<2010 aquatic benthic macro communities eval.pdf>* **Sample collection**: 8 stormwater outfalls, 6 reach sites, and 1 reference site x 1 sample x 1 year (October 2010)	• Highlighted specific areas along McVicar Creek that were highly susceptible to urban and stormwater impacts • Stream physical attributes were described using the unified stream assessment • Water quality monitoring sites were chosen based on which outfalls were likely to contribute high levels of contaminants based on pipe length and diameter through a GIS analysis of the sewer system • Biotic health was assessed in stream reaches that exhibited poor water quality • Three hotspots were identified for further study in Phase II	• Ammonia, chlorides, and metals (Aluminum, cadmium, copper, iron, lead and zinc) exceeded Provincial Water Quality Objectives or EPA guidelines (Chloride)	• Total Alkalinity • pH • Conductivity • Total dissolved solids • Total suspended solids	• **Metals**: Total Aluminum, Arsenic, Barium, Berryllium, Cadmium, Cobalt, Chromium, Copper, Iron, Manganese, Nickel, Lead, Sulfur, Vanadium, Zinc • **Nutrients**: Dissolved Organic Carbon, Chloride, Ammonia/ Ammonium, Nitrate/ Nitrite, Phosphate, Sulfate	• **Macroinvertebrates**: 7 sites x 3 samples x 1 year (2010) • **Biotic Indices**: Simpson's index, H' diversity, Hilsenhoff's Biotic Index, % Dominants (by taxonomic group)
Stormwater Impacts Assessment Phase II (2012) Kestrel Wraggett, Dr. Robert Stewart, Aaron Nicholson *<2012 stormwater impacts assessment.pdf>* **Sample collection**: 18 samples x 3 sites x 1 year (2011) **Sample dates**: Spring (May 12 – June 14), Summer (July 12 – Aug. 11), and Fall (Sept. 20 – Oct. 18)	• Re-sampled the three hotspots identified in Phase I over a greater spatial and temporal scale • Investigated the land-use classification of the subwatersheds and street/site inventory of subwatershed features that could be a cause of poor water quality	• **Court Street**: Heavy traffic, auto vehicle operations, and road salts • **Castlegreen**: Private garden fertilizers, pet waste, and combined sewers • **County Fair**: high percent of impervious surface area, illegal dumping, and excessive sediment accumulation rates		• **Metals**: Total Aluminum, Cadmium, Copper, Iron, Lead, Zinc • **Nutrients**: Chloride, Ammonia	
Stormwater Impacts Assessment Phase III (2012) Kestrel Wraggert and Dr. Robert Stewart (Lakehead University) *<2012 stormwater remediation options.pdf>*	• Identify suitable stormwater remediation options for the County Fair, Castlegreen, and Court Street subwatersheds and outfalls based on local expertise of stormwater management	**Overall objectives**: • Maximize surface infiltration • Sediment (nutrients, excess…) • Bioretention • Biodiversity/habitat • Reducing peak flows • Build up science surrounding stormwater impacts • Groundwater • Clearly defined water quality targets			
Environment Canada Website (accessed October 2013) *<http://www.wateroffice.ec.gc.ca/ index_e.html>*	• McVicar Creek at Thunder Bay (02AB019) 48°26'57"/89°13'06"	*http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=02AB019&prm1=6&prm2=-1&mode=graph&smo=10&sday=29&syr=2013&emo=11&eday=6&eyr=2013&y1min=&y1max=&y2min=&y2max=*	• Continuous flow and level (2002-2013) • Continuous flow (1985-2001) • Precipitation (1986 – present collected at Briarwood gauge site with a tipping bucket at 15-minute intervals)		
Ontario Ministry of the Environment Data Downloads Website (accessed October 2013) *<http://www.ene.gov.on.ca/ environment/en/resources/collection/ data_downloads/index.htm#PWQMN>*	• McVicar Creek at Cumberland St N (01010500102) 48.439655/89.214110 • Monthly, Apr/May-Oct/Nov (2008-present)	*http://www.ene.gov.on.ca/environment/en/resources/collection/data_downloads/index.htm#PWQMN*	• Alkalinity • Conductivity • Dissolved oxygen • Hardness • pH • Temperature	• **Metals**: Aluminum, Barium, Berylium, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Magnesium, Manganese, Molybdenum, Nickel, Strontium, Titanium, Vanadium, Zinc • **Nutrients**: Calcium, Dissolved Inorganic Carbon, Dissolved Organic Carbon, Chloride, Ammonium, Nitrates, Nitrite, Total Kjeldahl Nitrogen, Total Phosphorus, Phosphate, Potassium, Silicate, Sodium, Sulfate	
Environment Canada Website (accessed February 2014)	• Thunder Bay Station 6048260 48°22'19"/89°19'18" • Thunder Bay A 6048262 48°22'19"/89°19'18" • Thunder Bay CS 6048268 48°22'10"/89°19'38"	*http://climate.weather.gc.ca/*	• Temp (Hourly and Daily) • Dew Point Temp (Hourly) • Relative Humidity (Hourly) • Wind Direction (Hourly) • Wind Speed (Hourly) • Precipitation (Daily)		
Lakehead Region Conservation Authority	• Snow surveys completed bi-weekly on McVicar Creek at Madeline Street • November – May • 1974-present		• Snow depth and water content		

resource assessment will provide the City of Thunder Bay with a better understanding of existing stream health, existing or potential threats, areas of concern, and specific resource protection needs.

3. No monitoring data for groundwater resources was identified. Given the groundwater-dependency of the resource it is important to have a basic understanding of surface water and groundwater contributions to the resource. This will facilitate long-term management of the resource. As landuse in the contributing drainage area shifts from a more natural state to a developed state, it will be important to know the relative contributions of surface water and groundwater so that these levels can be maintained in the future through the use of regulations (i.e. volume control standards), guidance on BMP design, and construction to minimize thermal loads and/or evaluating future well locations.

4. There is a lack of in-stream thermal monitoring data. This information could be used to gain a better understanding of surface water impacts (i.e. discharge to the resource from impervious surfaces and/or stormwater management facilities), effects of riparian buffer (or lack thereof), and response to climatic variability.

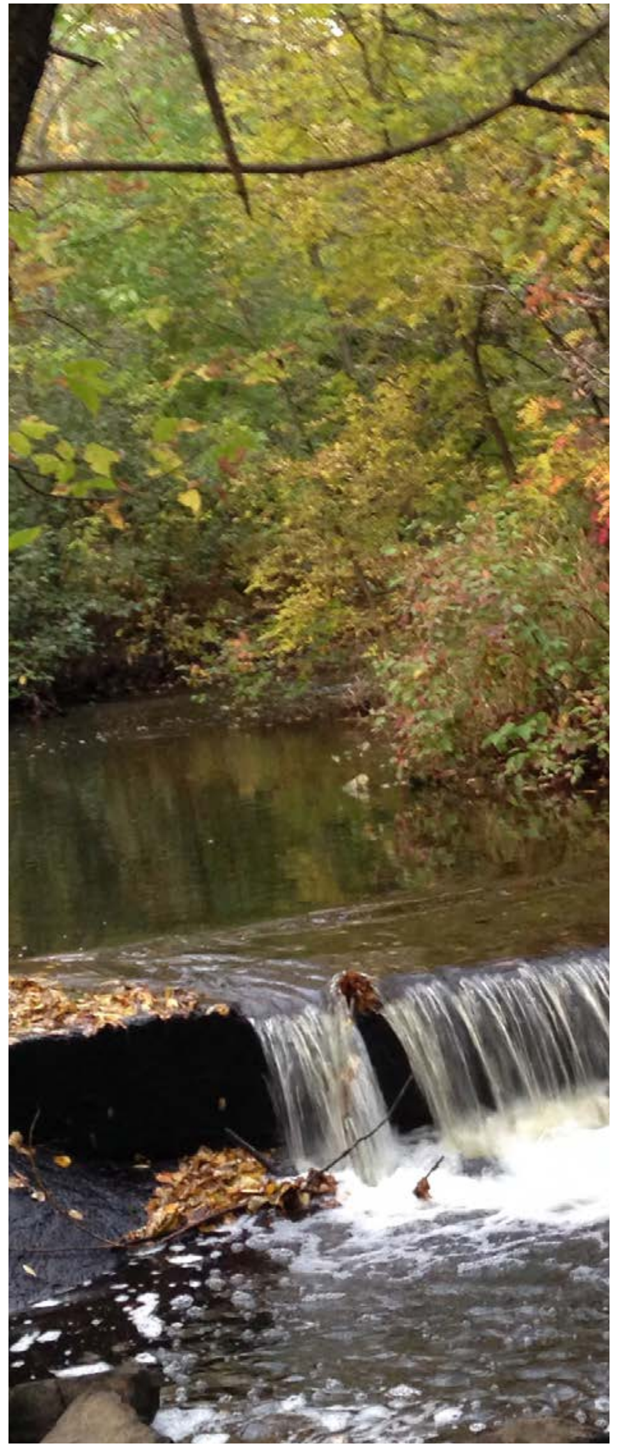
5. Development of a Hydrologic & Hydraulic Model which will allow for scenario planning to assess floodplain impacts as well as potential climate change impacts requires local climatological data. While many of the requisite climatological parameters are being monitored it would be useful if there was local evaporation and/or evapotranspiration measurements to calibrate what otherwise might have to be calculated.

6. Existing Hydrologic & Hydraulic (H/H) models are outdated and limited in coverage. Development of a watershed-wide H/H model will enable the City to evaluate existing storm sewer capacity, floodplain impacts, and major overland flow routes and will help evaluate impacts under more extreme events (e.g. larger events and/or back-to-back events) or for longer periods of time (i.e. continuous simulations). This model could also be used to evaluate the impact future development will have on the creek and facilitate future ordinance development.

In addition, a review of existing and/or proposed water quality standards was conducted to document regulatory resource management goals. The standards identified during this Watershed Gaps Analysis are briefly acknowledged below:

1. The Ministry of Environment (MOE) has surface water quality criteria that can be used to determine pollutant discharge limits based on the existing physical, chemical and biological conditions of the receiving water.

2. A new water quality standard in development by the Minnesota Pollution Control Agency proposes a TSS standard of 10 mg/L for streams supporting coldwater fish, such as Rainbow Trout (*Oncorhynchus mykiss*) and Brook Trout (*Osmerus mordax*) which are common to McVicar Creek. This standard must not be exceeded more than 10% of the time over a multiyear



B. Water Quality & Quantity Trend Analysis

Water quality data collected from McVicar Creek at Cumberland St. N. (01010500102) and flow data collected on McVicar Creek at Briarwood Drive between 2008 to 2011 was downloaded from Environment Canada and the Ontario Ministry of the Environment and summarized below. Seasonal patterns of pollutant concentration and stream flow are illustrated for phosphorus and the pollutants that exceeded Provincial Water Quality Objectives (ammonia, chlorides, aluminum, cadmium, copper, iron, lead, and zinc) are illustrated in Figure 2 through Figure 10. Higher concentrations of ammonium and phosphorus typically occur under conditions of higher stream flows, such as during spring snow melt, while higher concentrations of chlorides and metals typically occur under summer baseflow conditions. Very few water quality samples were collected during summer and fall rainfall events (precipitation ≥ 10 mm during a 24-36 hour period), so it is unclear whether the dominant source of pollutant loads originates during spring snowmelt, baseflow, or peak rainfall event flow conditions. Average concentrations of pollutants collected between 2008 and 2011 were summarized by season (spring, summer, and fall) in Table 2.

[1] Water Management, Policies, Guidelines, Provincial Water Quality Objectives. Ministry of Environment and Energy. July 1994.

[2] Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity). Minnesota Pollution Control Agency. Revised Draft, May 2011.

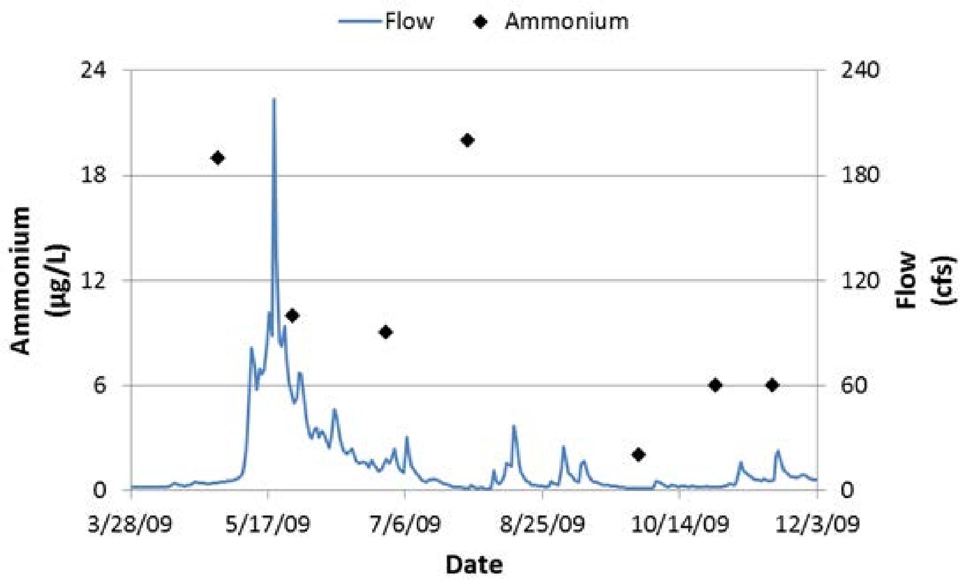


Figure 2 - Seasonal patterns of ammonium concentration and stream flow in McVicar Creek, 2009

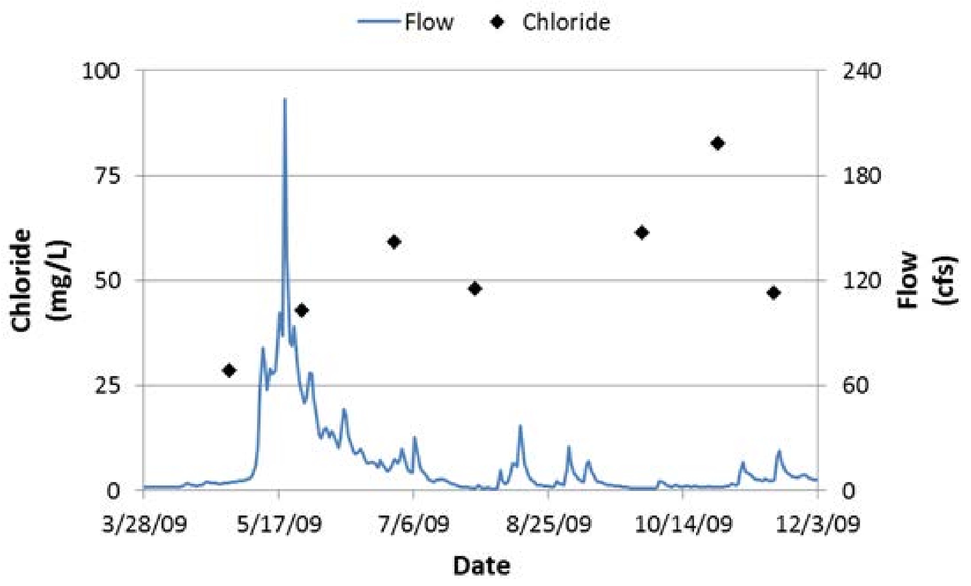


Figure 3 - Seasonal patterns of chloride concentration and stream flow in McVicar Creek, 2009

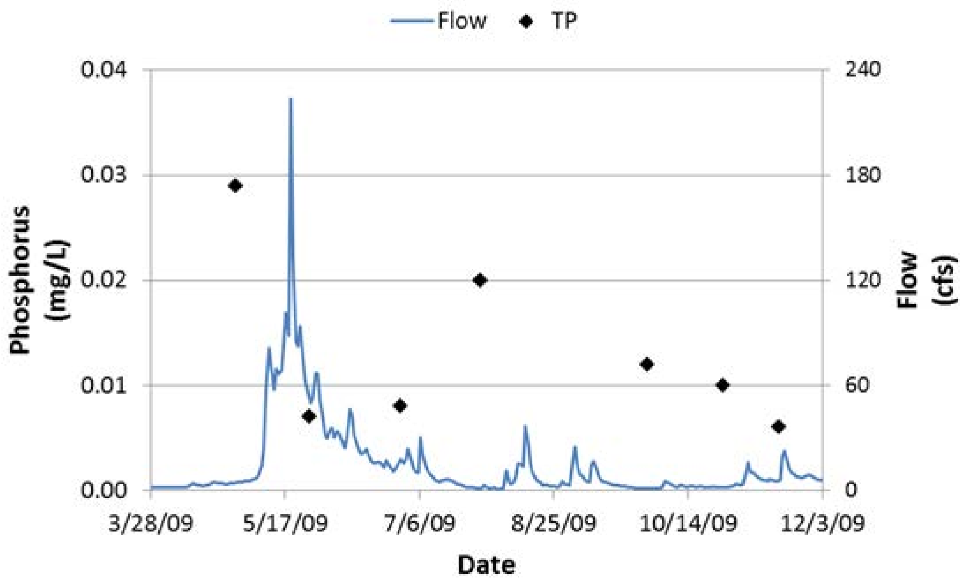


Figure 4 - Seasonal patterns of Total Phosphorous (TP) concentration and stream flow in McVicar Creek, 2009

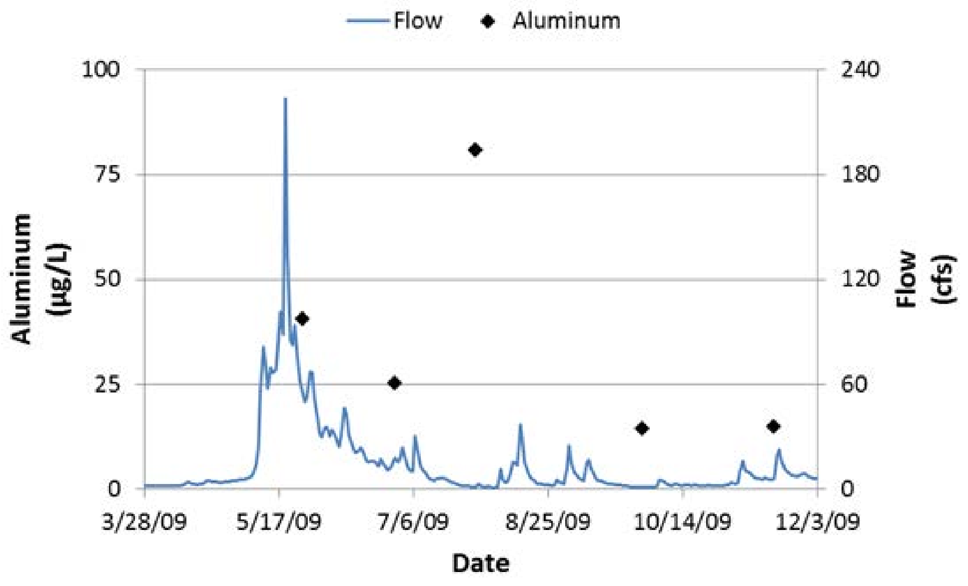


Figure 5 - Seasonal patterns of aluminum concentration and stream flow in McVicar Creek, 2009

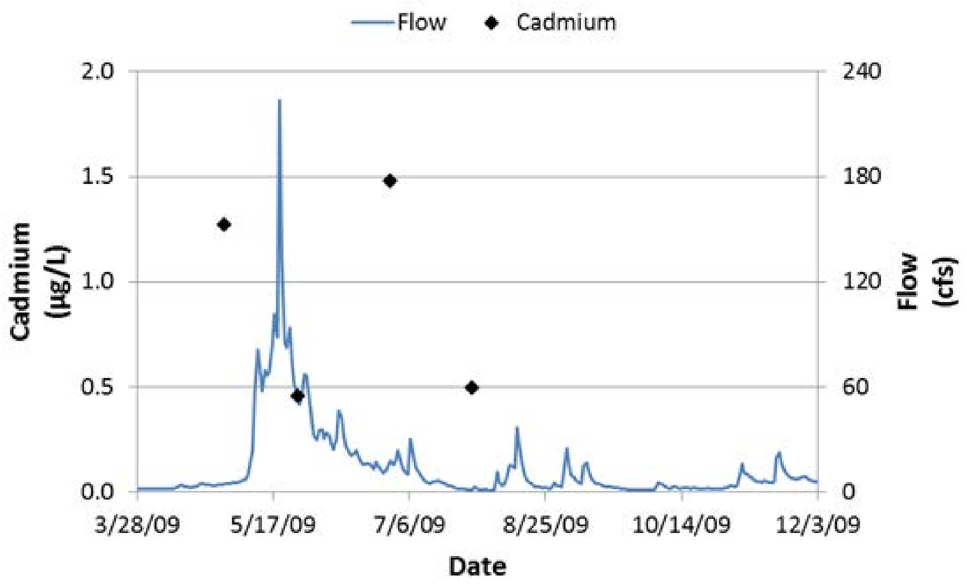


Figure 6 - Seasonal patterns of cadmium concentration and stream flow in McVicar Creek, 2009

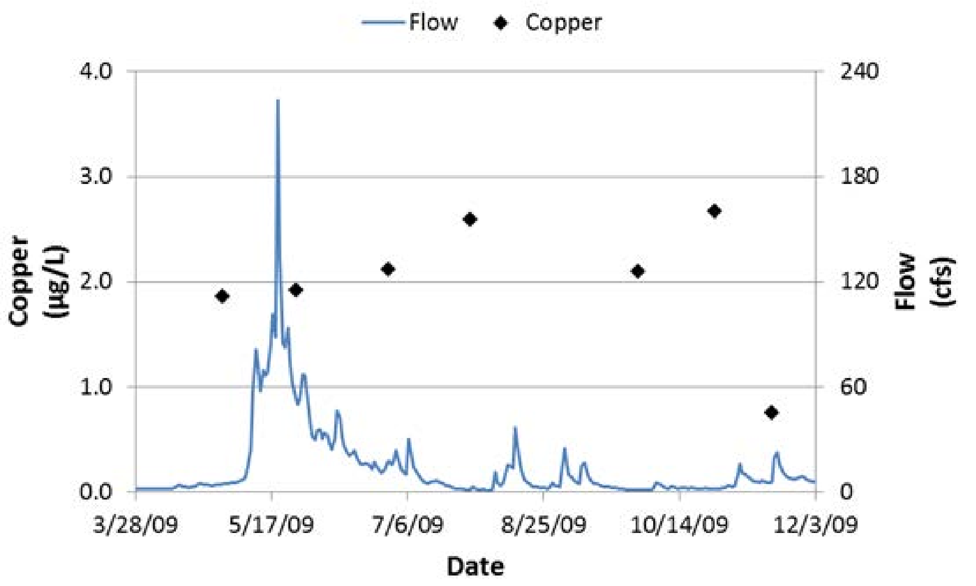


Figure 7 - Seasonal patterns of copper concentration and stream flow in McVicar Creek, 2009

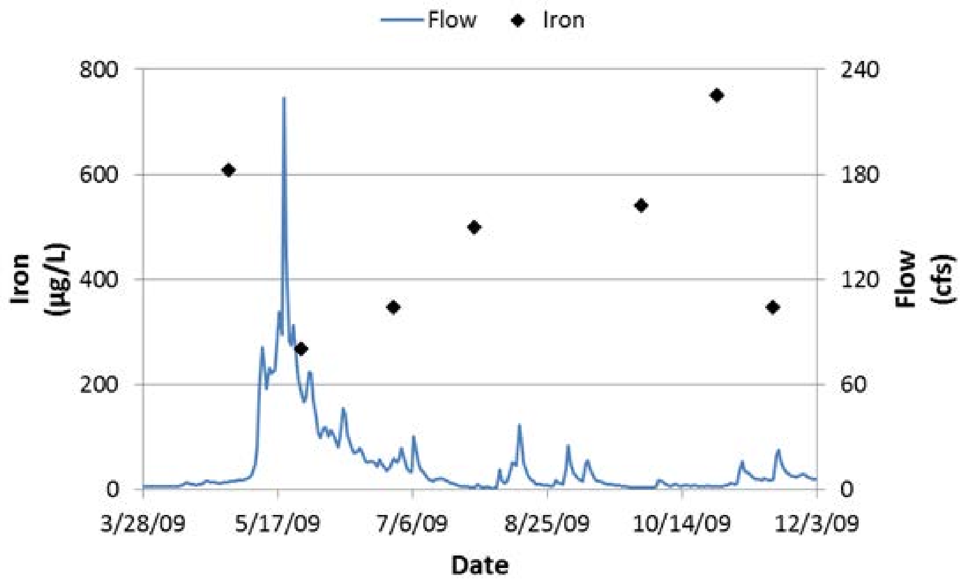


Figure 8 - Seasonal patterns of iron concentration and stream flow in McVicar Creek, 2009

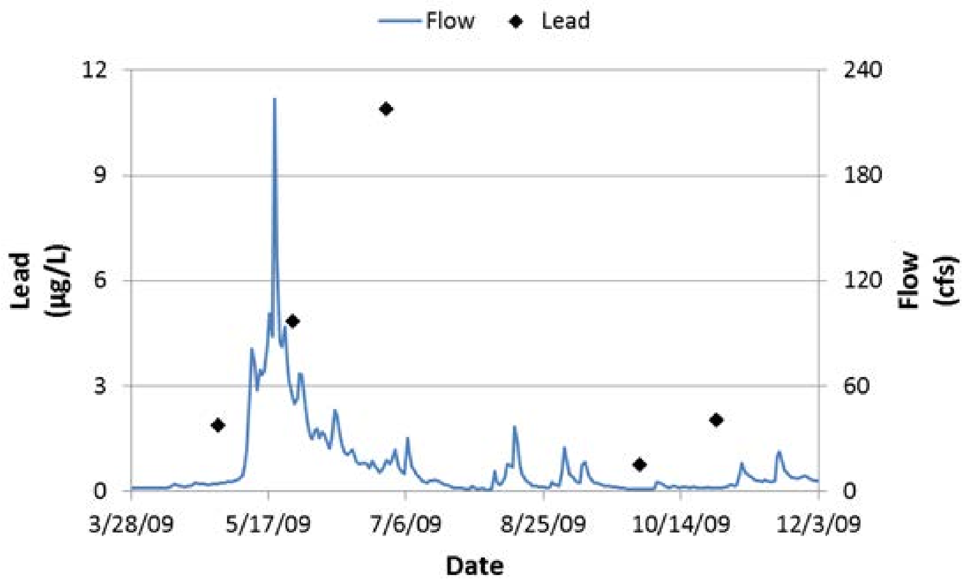


Figure 9 - Seasonal patterns of lead concentration and stream flow in McVicar Creek, 2009

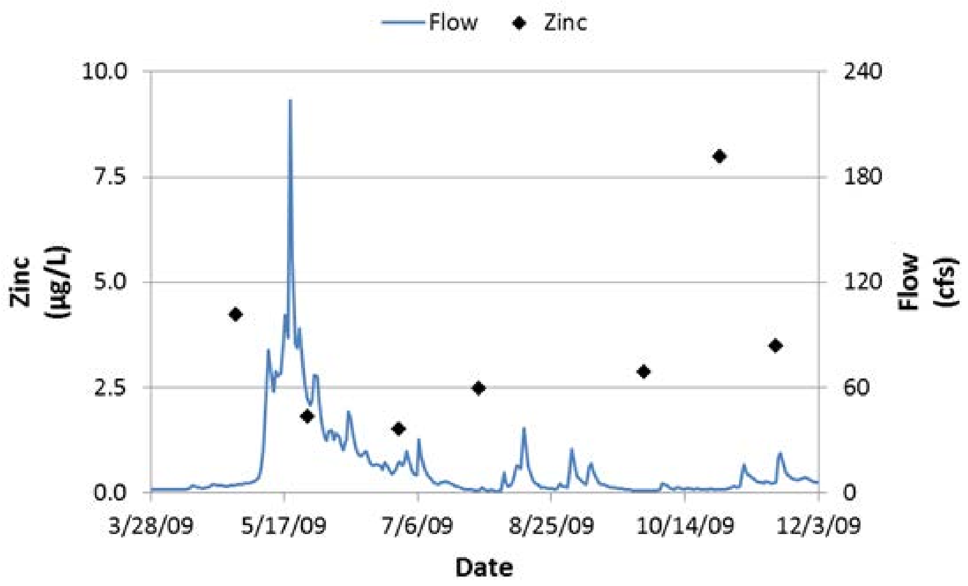


Figure 10 - Seasonal patterns of zinc concentration and stream flow in McVicar Creek, 2009

Parameter	Units	Spring (April – May)				Summer (June – Sept.)				Fall (Oct. – Nov.)			
		Average	N	Min.	Max.	Average	N	Min.	Max.	Average	N	Min.	Max.
Ammonium	mg/L	0.019	5	0.004	0.053	0.018	11	0.002	0.058	0.010	4	0.006	0.018
Chloride	mg/L	46	5	28	67	80	13	37	158	67	4	43	96
Phosphorus	mg/L	0.016	5	0.007	0.031	0.012	12	0.005	0.020	0.007	4	0.006	0.010
SRP	mg/L	0.001	5	0.001	0.002	0.004	10	0.001	0.012	0.002	4	0.001	0.007
Dissolved Oxygen	mg/L	12.0	3	10.8	13.6	10.0	12	7.9	11.7	13.5	4	12.3	14.3
pH		8.1	5	7.8	8.2	8.3	13	8.2	8.7	8.2	4	8.1	8.3
Iron	µg/L	414	4	252	607	405	12	211	668	495	4	322	749
Aluminum	µg/L	72	4	21	172	35	13	3	127	39	4	5	120
Copper	µg/L	1.6	4	0.4	2.3	2.7	13	1.7	6.3	1.6	4	0.8	2.7
Nickel	µg/L	0.6	4	0.1	1.5	1.1	12	0.5	1.9	0.7	2	0.2	1.3
Lead	µg/L	2.8	3	1.7	4.8	5.2	5	0.8	10.9	2.0	2	2.0	2.1
Zinc	µg/L	2.9	4	1.8	4.2	3.3	12	0.6	10.2	3.7	4	1.1	8.0
Cadmium	µg/L	0.9	2	0.5	1.3	0.7	8	0.0	1.5	0.7	1	0.7	0.7
Chromium	µg/L	1.0	3	0.6	1.3	1.0	6	0.3	1.7	0.9	1	0.9	0.9

N = number of samples

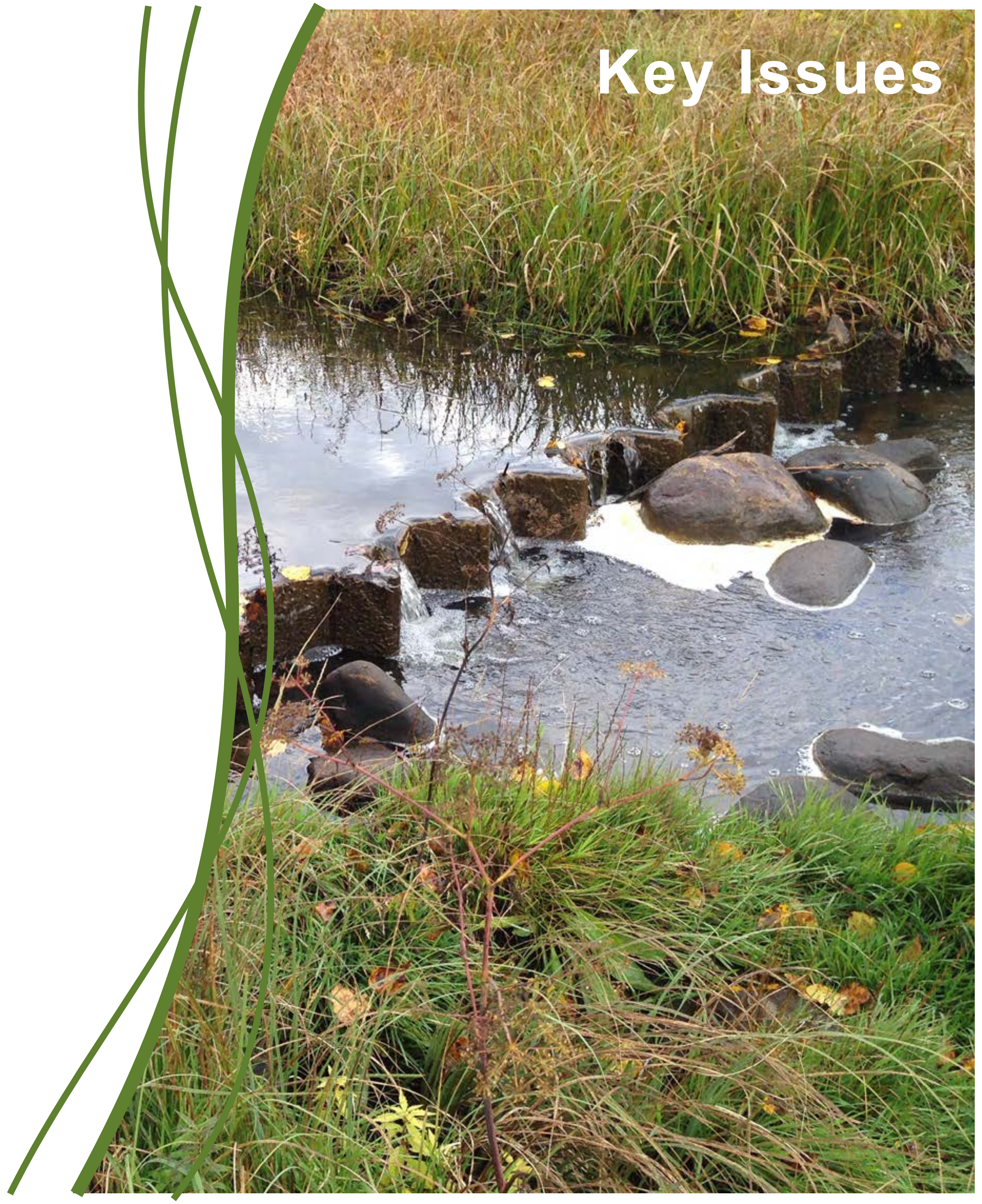
Table 3 - Average concentration of pollutants collected between 2008-2011 summarized by season.

C. Spatial Data

Existing spatial data was gathered to better understand and characterize the watershed tributary to McVicar Creek as well as ground the evaluation of stormwater and restoration practices. Spatial data utilized during development of this plan, provided primarily by the City and Lakehead University, is summarized in Table 4.

Table 4 - McVicar Creek Watershed Spatial Data Summary

		Format									
Group	Data	Line	Polygon	Point	Layer	TIF	CAD	Supplied by	Area Covered	Description of data	Comments
Image											
	Mcvr_nad83_z16_1m_buildings_dem					X		Lakehead University	McVicar area	DEM	broken at buildings
	Mcvr_nad83_z16_1m_dem					X		Lakehead University	McVicar area	DEM	
	Mcvr_nad83_z16_30m_dem					X		Lakehead University	most of the city	DEM	low resolution, but can be used for analysis
	mcvr_nad83_z16_1m_rgb					X		Lakehead University	city	aerial image	
	mcvr_nad83_z16_20cm_rgb					X		Lakehead University	city	aerial image high resolution	
	mcvr_basin_bare_1m					X		Lakehead University	part of McVicar area	TIF image	values don't seem to be elevations. TIF format is not useful.
	mcvr_basin_houses_1m					X		Lakehead University	part of McVicar area	TIF image	values don't seem to be elevations. TIF format is not useful.
	mcvr_basin_nts_30m					X		Lakehead University	part of the city	TIF image	poor resolution, doesn't cover entire city limits, not useful format
	mcvrUSSRMap					X		Lakehead University	part of the city	JPG McVicar watershed with points	
Transportation											
	streets	X						CTB	city	streets	includes street names
	rail_city	X						CTB	city	railroad	
	McVicarRoads		X					Lakehead University	McVicar area	streets	
Hydrography											
	Watercourse	X						CTB	city	Major waterways	
	Watershed CAD polyline	X						CTB	city	partial watershed boundaries	Not complete
	McVicar_Creek		X					Lakehead University	McVicar area	McVicar Creek and tributaries	No creek names, very generalized
	McVicarWatershed		X					Lakehead University	part of the city	McVicar watershed	basis for study area
	mcvr_cf_bare basin		X					Lakehead University	McVicar area	McVicar watershed	includes subwatersheds
	mcvr_cs_bare basin		X					Lakehead University	McVicar area	McVicar watershed	includes subwatersheds but accuracy is questionable
	onhydro		X					Canada GIS	Ontario	open water polygons	very generalized
Boundary											
	city lots OS res		X					CTB	city	City owned, open space, lot, reserve	
	parcels		X					CTB	city	parcels - has type (reg, city owned), LROpin	
Topography											
	contour_all	X						CTB	city	1 meter interval	broken at buildings, 1 meter resolution
	5m Contour Only						X	CTB	city	5 meter interval	CAD format, 5 meter resolution
	5mCnt						X	CTB	city	5 meter interval	CAD format, 5 meter resolution
	obm_OBMUSER_Contour_line	X						OBM	McVicar area	10m? contours	of little use
Utility											
	gravity_lines	X						CTB	city	sanitary details	
	San_combined			X				CTB	city	sanitary details	
	San_laterals	X						CTB	city	sanitary details	
	San_mains	X						CTB	city	sanitary details	
	San_structures			X				CTB	city	sanitary details	
	Storm_laterals	X						CTB	city	stormsewer details	no elevations
	Storm_mains	X						CTB	city	stormsewer details	some invert elevations (about 25% located in north 1/2 of city area)
	Storm_structures			X				CTB	city	stormsewer details	very few have elevation less than 10%
	Water_chambers			X				CTB	city	potable water details	
	Water_city	X						CTB	city	potable water details	
	water_hydrants			X				CTB	city	potable water details	
	water_laterals	X						CTB	city	potable water details	
	water_mains	X						CTB	city	potable water details	
	water_nodes			X				CTB	city	potable water details	
	water_pumping_stations			X				CTB	city	potable water details	
	water_reservoirs			X				CTB	city	potable water details	
	water_valves			X				CTB	city	potable water details	
	McVicar_outfalls		X					Lakehead University	McVicar area	stormsewer details	27 of 76 have elevation - may be a portion of the city database
	McVicarPipes	X						Lakehead University	McVicar area	stormsewer details	172 of 1055 have elevation - may be a portion of the city database
GIS - Geology											
	soils		X					CTB	part of city	very generalized (clay, silt, rock, organic)	covers downtown, very generalized
	McVicarSoils		X					Lakehead University	part of city	very small portion	even more generalized than city data
	soil_survey_area		X					Canada GIS	Ontario	generalized	only 3 soil types, no understandable coding
GIS - Land Status											
	Impervious	X						CTB	city	building, roadway, driveway, sidewalks	covers entire city, useful for impervious calculations
	McVicar_cf_imperv		X					Lakehead University	McVicar area	18 individual spatial layers covering different impervious types (buildings, roads, sidewalks, driveways, parking)	questionable accuracy and overlap in data sets; not used for analysis



Key Issues

Lacking Surface & Ground Water Protection

Scientific evidence clearly shows that healthy headwaters — tributary streams, intermittent streams, spring seeps, and wetlands — are essential to the health of stream and river ecosystems. Unfortunately, current city and provincial regulations and education initiatives fall short of protecting the McVicar Creek headwaters.

Headwater streams, beginning as spring seeps and first-order stream channels in a stream and river network, have an immediate and intimate connection with the terrestrial environment, forming an extensive terrestrial/aquatic mosaic. However, the very attributes that make headwaters critical to the health of stream networks also makes them exceedingly vulnerable to degradation when landscapes are altered.

Unregulated development and industry, which divert, consume, and pollute surface and groundwater are threats to the entirety of McVicar Creek and the greater Thunder Bay Community. Furthermore, the combined impact of hydrologic changes and water pollution associated with wetland loss and landcover alterations will degrade the entire system.

Figure 11 - Recent home construction in upper watershed of McVicar Creek. Note wetland filling and lack of erosion control

Stormwater Runoff

In urban areas such as Thunder Bay, impervious surfaces created by buildings and pavement cause rainwater and snowmelt to flow quickly over the landscape, rather than soaking naturally into the soil or being absorbed by plants. This can change stream flows, increase flooding, endanger private and public infrastructure, erode stream banks and channels, and destroy fish habitat. Runoff also carries pollutants such as oil, heavy metals, bacteria, sediment, pesticides, and fertilizers into streams or groundwater.

Currently, stormwater runoff is relatively unmanaged in Thunder Bay, meaning the combined impacts of hydrologic changes and water pollution can be disastrous for both water resources and public and private infrastructure. Research by Kok (2004) concluded that stormwater is a non-point source of pollution in the Thunder Bay Area of Concern (AOC) and contributes to many of the Beneficial Use Impairments (BUIs).

Related to stormwater runoff, Thunder Bay appears to have higher contributing sediment loads from the landscape. There is insufficient monitoring data to confirm this hypothesis, but visual observations and anecdotal input from the steering committee indicates an exorbitant potential source. This is of concern because excessive sediment can degrade instream habitat, increase risk of disease in the fishery, and sediment particles are vehicles for other pollutants (metals, nutrients, bacteria, etc.). The salt and sanding routine of a northern climate like Thunder Bay is an obvious sediment source, but the higher source potential appears to also be related to a number of other compounding landscape and landuse effects. The combination of vehicle traffic and on-street parking on unpaved thin soils (low organic matter), coupled with a short growing season and limited stormwater management controls, results in a higher volume of potential erodible sediment sources (see Figure 12 for example at Brent Street).

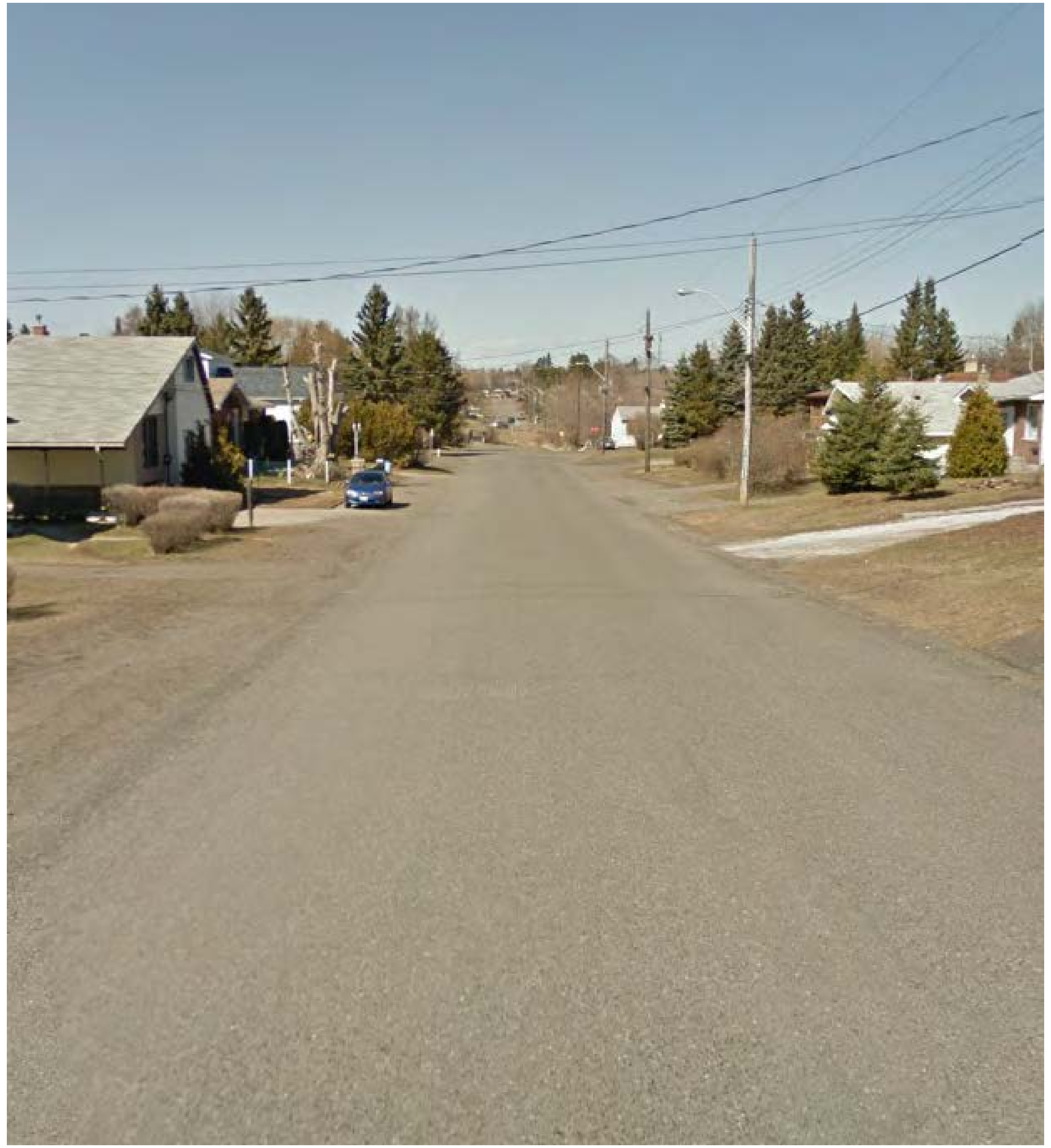


Figure 12 - 100 Block of Brent Street looking North towards McVicar Creek. Note curbless pavement edge and loose gravel shoulders and driveways. © Google Maps

Stream Crossings

The design and condition of stream crossings determine whether a stream can function naturally and whether biota can move unimpeded along the stream corridor. These are key elements in assuring the overall health of the system. Furthermore, placement and design decisions greatly impact the longevity of the crossing infrastructure. The following common stream crossing problems were observed within the McVicar Creek watershed:

• *Undersized Crossings* - can result in restrictions of natural flow, scouring and erosion, high flow velocities, clogging, and ponding.

• *Shallow Crossings* – are frequently caused by a single culvert sized for large flood event, whereby water depths are too low for many organisms to move through during low or baseflow, and the bottom may lack appropriate stream bed material.

• *Perched Crossings* – are elevated crossings which are frequently vertical and/or velocity barriers which also frequently result in erosion and ponding.

• *Insufficient culvert length* – is resulting in unstable road shoulders, which is increasing sediment loading and road maintenance.

The instream utility crossings, which are prevalent throughout McVicar Creek, were noted by the steering committee (see Figure 14 for example). Local fisheries experts with long-standing perspectives of McVicar Creek were consulted and have stated that these vertical obstructions are not significant barriers to the primary game fish, but may be serving as a barrier to invasive species such as Sea Lamprey (*Petromyzon marinus*).

Figure 13 - Sightly perched crossing in the upper watershed that may be a barrier during periods of low flow

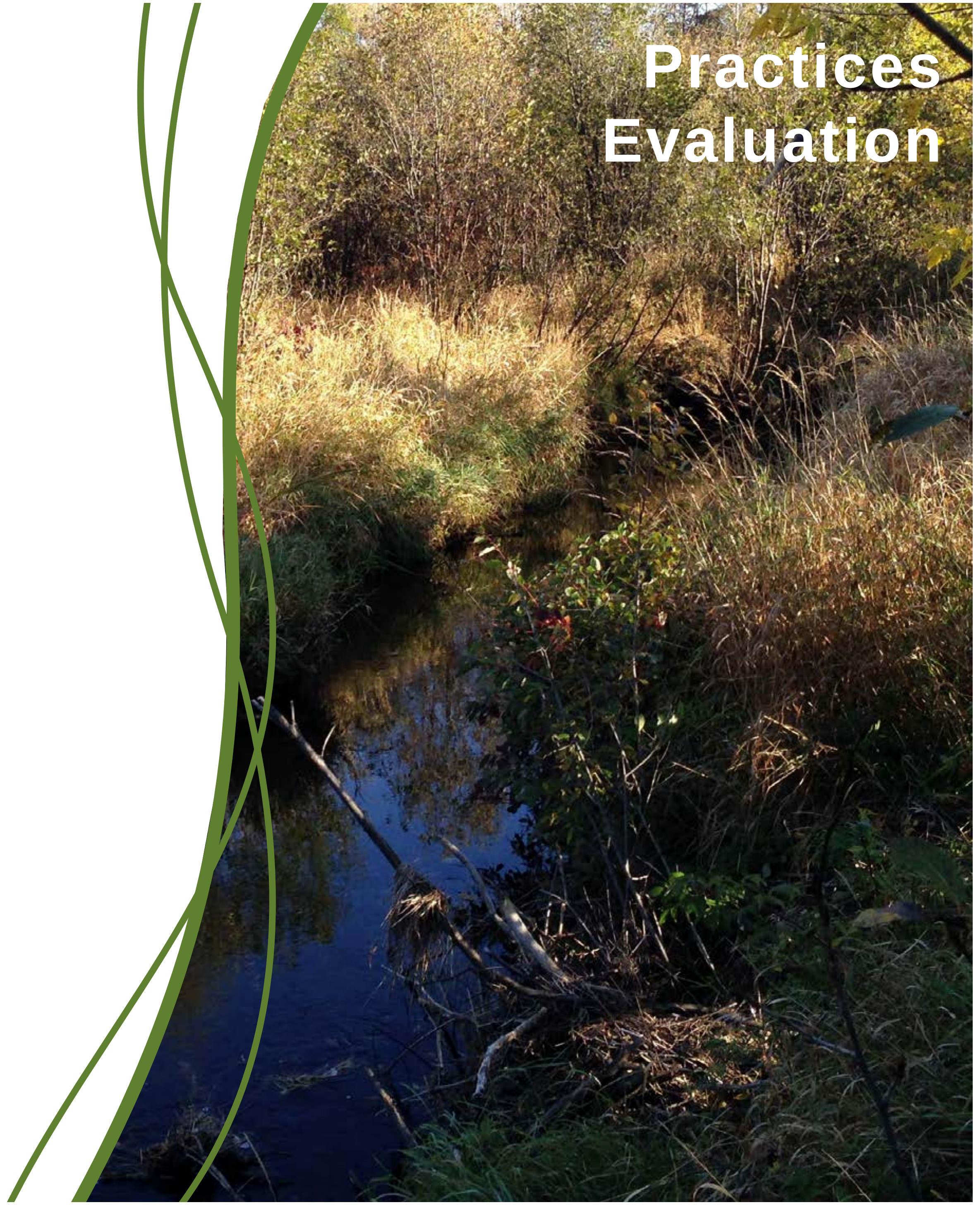
Figure 14 - Utility crossing downstream of Cumberland Street. These obstructions, which are common throughout McVicar Creek are not thought to be barriers to game fish, but may be to the invasive Sea Lamprey.

Channel Alteration and Manipulation

As mentioned previously, McVicar Creek and its tributaries have been indirectly impacted by urbanization as a result of changes in hydrologic and sediment regimes. These watercourses have also been directly impacted by the manipulation of stream beds and banks. The Unified Stream Assessment (USA), completed by Lakehead University in 2010, identified both channel revetment (rock, gabions, concrete, and other "hard armor") and native vegetation removal with some frequency. Removal of native vegetation and frequent conversion to turf grass has predictable complications for McVicar Creek. Loss of deep-rooted vegetation will frequently result in bank erosion (greater sediment contribution) and stream widening (shallower water depth). Revetment is an attempt to protect infrastructure and/or a response to unwanted stream channel migration. The use of this technique in urban areas is a necessary practice in some cases, but there can be related local stability consequences.

Sections of McVicar Creek and its tributaries have also been dredged and/or straightened in the name of drainage and flood control. A recent example includes a project within County Park, intended to "reinstate the original condition" of a tributary, but failed to provide appropriate morphology. As a result the tributary is actively evolving to reach equilibrium (Figure 15).

Figure 15 - Drainage alterations to McVicar Creek tributary within County Park.



Practices Evaluation

Practices Evaluation

It is generally understood that McVicar Creek and its watershed are not sufficiently studied to determine if the system is impaired, the degree of any impairment, and cause of impairment. Even without this certainty and specificity there are obvious signs (see preceding chapters) that stormwater runoff and stream/ floodplain encroachment are degrading the system and increasing flooding risk. McVicar Creek is further threatened by impending development without stormwater management controls.

If McVicar Creek is to be preserved and even rehabilitated, the City of Thunder Bay needs to begin to retrofit the city to provide stormwater management and adopt adequate policy to ensure that future development includes sufficient stormwater management to protect the headwaters of McVicar Creek.

Stormwater

Stormwater is water that originates during precipitation events. It may also be used to apply to water that originates with snowmelt that enters the stormwater system. Stormwater that does not soak into the ground becomes surface runoff, which either flows directly into surface waterways or is channeled into storm sewers, which eventually discharge to surface waters.

Stormwater is of concern for two main issues: one related to the volume and timing of runoff water (floodingk or quantity control) and the other related to potential contaminants that the water is carrying, i.e. water pollution (or quality control).

Stormwater is also a resource and is growing in importance as the world's human population demand exceeds the availability of readily available water. Techniques of stormwater harvesting with point source water management and purification can potentially make urban environments self-sustaining in terms of water.

Traditional stormwater management design has been focused on collecting stormwater in piped networks and transporting it off site as quickly as possible, either directly to a stream or river, or to a large stormwater management facility (basin or pond), but this approach has been woefully inadequate in addressing all the issues raised above.

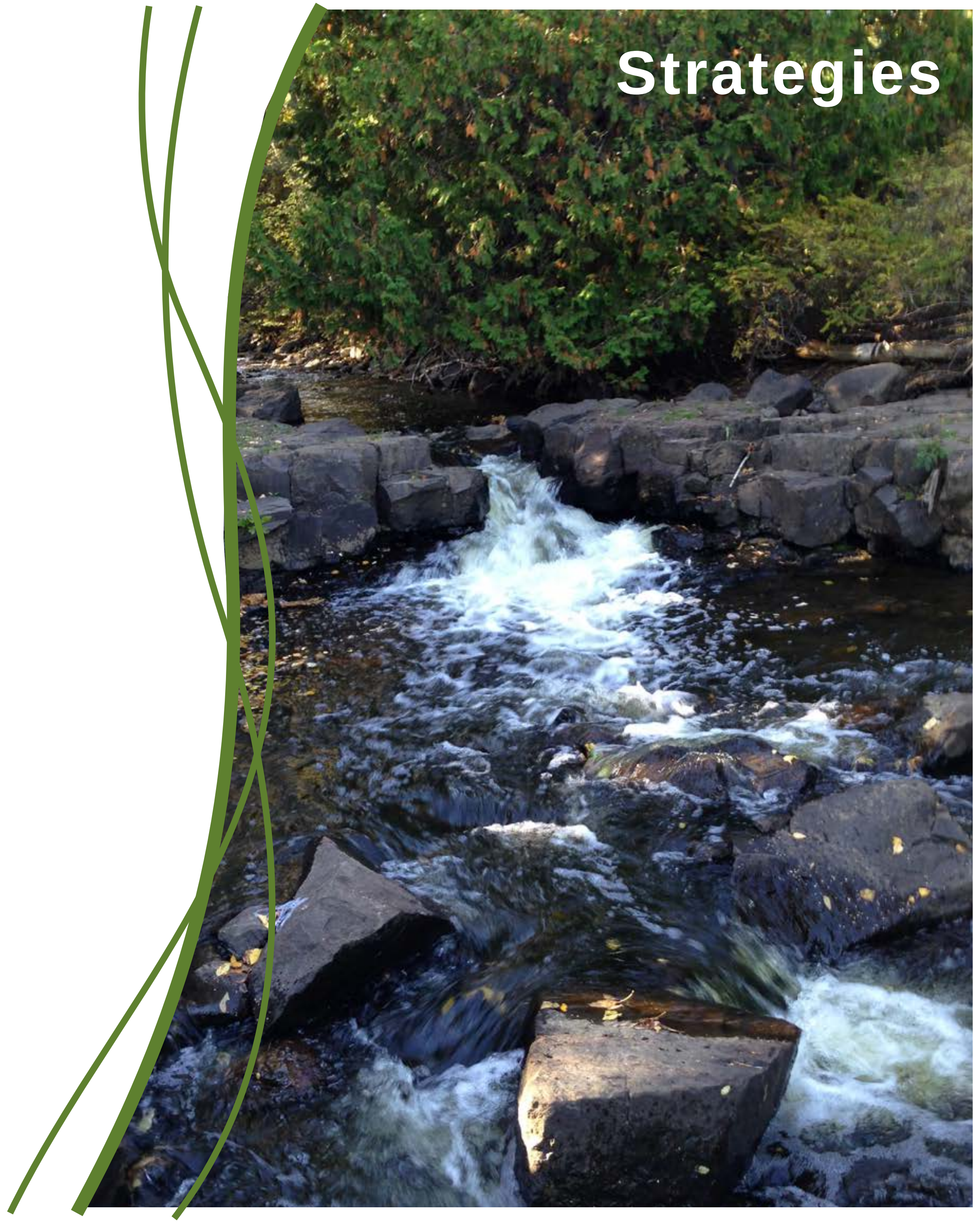
LID (Low Impact Development)

There is a more holistic approach to stormwater management that has been practiced in portions of the U.S. and Canada since the 1990's. A concept that began in Prince George's County, Maryland in 1990, LID began as an alternative to traditional stormwater best management practices (BMPs) installed at construction projects. Officials found that the traditional practices such as detention ponds and retention basins were not cost-effective and the results did not meet water quality goals.

Low-impact development (LID) is a term used in Canada and the United States to describe a land planning and engineering design approach to managing stormwater runoff. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source.

The case for LID is not made herein, but there are in fact numerous U.S. and Canadian studies and precedents which document the principles and validity of the practice. LID is rapidly being adopted around the world, including "cold-climate" portions of Canada and the U.S.

The project steering committee wholly supports LID for the City of Thunder Bay and thus many of the McVicar Creek protection and restoration strategies identified and vetted herein are based on LID.



Strategies

A. Understanding the Resource

Strategies to restore and rehabilitate McVicar Creek were identified and vetted by the steering committee. These strategies have since been divided into three unique categories: 1) Understanding the Resource; 2) Projects & Programs; and 3) Policy & Education.

Strategies under the *Understanding the Resource* category are primarily focused on further study of the creek and the watershed and/or the development of data and models to more accurately comprehend the resource and its drainage. This analysis is essential to better identify and understand impairments and to make more informed decisions regarding actions to study and protect McVicar Creek.

I. Monitoring Program

Effective watershed management entails the development and implementation of a comprehensive and effective monitoring program. While monitoring activities can be expensive and time intensive, the cost of collecting the data leads to more successful and more cost-effective resource management and can create long-term cost savings by eliminating additional time needed to analyze poor data or making incorrect management decisions. Watershed management stakeholders are also more informed. Monitoring data makes it possible to conduct cost-benefit analyses, it allows for performance measurement, and it gives the entity responsible for management the tools to better communicate resource protection needs and improvements to its constituents.

Development of an effective watershed monitoring program depends upon a number of factors including resource availability (funding), existing natural resource assessments and issues specific to McVicar Creek. Given the information presented in the Watershed Gap Analysis and understanding that financial resources are limited, this section of the report presents a Monitoring Program that will provide the City of Thunder Bay and its stakeholders the information needed to make informed decisions regarding the management of a cold water fishery in an urban environment. The proposed monitoring program for the McVicar Creek Watershed is summarized in Table 5.

Components of an effective monitoring program include:

- frequent monitoring
- dedicated & long-term staffing
- automatic sampling equipment and regular maintenance
- quality assured practices (follow standard operation procedures)
- certified laboratory

Annual monitoring of flow, in-stream water quality, temperature, and biota should continue while a thorough evaluation of the monitoring data should be conducted every five years. Annual variability in climatic conditions and potential lag time for BMPs and IDs to achieve full load reduction potential will need to be considered when assessing the data.

Table 5 - McVicar Creek Monitoring Program

Issue	Monitoring Activity	Parameters	Monitoring Equipment and Laboratory Needs	Frequency / Location	Estimated Cost*	Implementation Schedule					Higher Priority	Lower Priority
						2015	2016	2017	2018	2019		
Resource Assessment	Geomorphic Assessment	Rosgen Level II – Morphological Description	NA	Entire mainstream & primary tributaries – 15+/- surveyed reaches. Repeat survey every 15+/- years.	$30,000 +/-	√					√	
	Geomorphic Assessment	Rosgen Level III & IV – Stream State & Validation Level	NA	Entire mainstream & primary tributaries – 15+/- surveyed reaches	$50,000 +/-					√		√
	Macroinvertebrate Survey		NA	Conduct every five years	$5,000	√					√	
	Fish Survey		NA	Conduct every five years	$5,000	√	√	√	√	√	√	
Baseline Monitoring**	Stream Discharge and Rating Curve	Stream Flow	1. Continuous flow recorders and staff gauge measurements (10-15 per year). Rating curve development requires a minimum of three years of monitoring data. 2. Automated samplers to collect storm and baseflow composite samples. Sampler at the outlet of McVicar Creek to sample all year. Remainder of the samplers to collect samples from March through November. 3. Grab samples for snowmelt event, baseflow conditions, and storm composite	Recommend installing additional flow and WQ monitoring stations at the following locations: 1. **Wardrope Avenue** *Downstream of major tributary; break between developed and undeveloped portions of WD; accessible* 2. **Onion Lake Road** *Upstream of major tributary; accessible* 3. **Hazelwood Drive** *Quantify flows in upper portion of stream system; select most accessible crossing* Monitoring equipment needs will depend upon in-stream velocities, access, and safety.	$15,000 annually per site	√	√	√	√	√	Wardrope Avenue Monitoring Station Nutrients/Sediment: TSS, TP, Dissolved P, Nitrate, Ammonia, Chloride, Sulfate, pH, DO Metals: Iron, Aluminum, Copper, Nickel, Lead, Zinc, Cadmium, Chromium Bacteria: *E. coli*	Hazelwood Drive Monitoring Station TVS, TKN, COD, TBOD, CBOD, Turbidity, Hardness
	Water Quality	Nutrients, Sediment, Metals and Bacteria										
Thermal Impacts	Installation of Temperature Probes	Temperature	Hobo Temperature Sensors	In the urban portion of the watershed install temperature sensors upstream and downstream of stormwater outfalls, pond discharge locations, and stream reaches with little to no shading. In the rural portion of the watershed install a handful of temperature probes equally spaced to begin collecting stream temperature profile.	$150/sensor	√	√	√	√	√	Installation of temperature sensors in urban portion of the watershed	Installation of temperature sensors in rural portion of the watershed
Characterization of Surface Water / Groundwater Contributions	Soils Information											
	Surficial Geology											
	Groundwater Level Measurements *(for future groundwater contour mapping)*	Groundwater Elevation	Water Level Meter Hand-held GPS Unit	Conduct Annually Cost reflects water level readings on approximately 20 wells; to be taken in different aquifers in different locations in the watershed	$10,000		√					√
Local Climate Data	Weather Monitoring Station	Temperature, Relative Humidity, Wind Speed, Wind Direction, Precipitation	Onset® Brand Hobo U30-NRC Weather Station Starter Kit, an equipment tripod stand and a continuous "tipping bucket" precipitation logger.	Conduct annually for the monitoring season	$2,500	√	√	√	√	√	√	
Hydrologic & Hydraulic (H/H) Model	No new monitoring activities proposed. Recommended activities for other issues will provide requisite model input and the data needed for model calibration.	No new parameters proposed.	No new equipment proposed.	NA	NA							

*Estimated costs in CDN.

Specific comments regarding the recommendations made for the Baseline Monitoring activities are as follows:

• Recommend reevaluating the feasibility of locating a stream flow monitoring station at the mouth of McVicar Creek to align flow measurements with water quality monitoring data.

• Recommend a critical evaluation of the existing discharge rating curve for McVicar Creek. As the United States Geological Survey guidance on discharge rating curves explains, "Discharge ratings for gauging stations are usually determined empirically by means of periodic measurements of discharge and stage. The discharge measurements are usually made by current (flow) meter. Measured discharge is then plotted against concurrent stages to define the rating curve. At a new station many discharge measurements are needed to define the stage-discharge relation throughout the entire range of stage. Periodic measurements are needed thereafter to either confirm the permanence of the rating or to follow changes (shifts) in the rating. A minimum of 10 discharge measurements per year is recommended, unless it has been demonstrated that the stage-discharge relation is unvarying with time. In that event the frequency of measurements may be reduced. It is of prime importance that the stage-discharge relation be defined for flood conditions and for periods when the rating is subject to shifts as a result of ice formation or as a result of variable channel and control conditions." [3]

• Wardrope Avenue – This site was selected because it is located at the intersection of the urban and rural portions of the watershed. Given that industrial sources are potentially important, a station just upstream of the city's urban area would facilitate differentiation between natural sources from the headwaters and anthropogenic sources from the urban area. This site is located downstream from a major tributary. If this monitoring data is coupled with monitoring data collected at the Onion Lake Road crossing, it will be possible to tease out contributions from the tributary.

• Onion Lake Road – This site was selected because it is located in the central portion of the watershed and because it is located upstream of a major tributary to McVicar Creek. As the comments for Wardrope Avenue indicate, monitoring data at this station could be used with monitoring data collected at Wardrope Avenue to tease out contributions from the tributary.

• Installation of continuous flow recorders and a minimum of 10 to 15 staff/discharge measurements per year.

USGS, 1982: Measurement and Computation of Streamflow: Volume 2. Computation of Discharge
By S. E. RANTZ and others. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2175. UNITED STATES

II. Spatial Data

Comprehensive spatial data is the foundation of understanding and characterizing the McVicar Creek watershed and is critical for the development of a robust watershed model and further evaluation of stormwater and restoration practices. As the City moves forward with implementation of the strategies identified in this report it will be important to collect, validate and/or maintain the following primary spatial data sets listed in general order of priority.

Topography – existing City topography (1 meter) is a limiting factor on many implementation fronts, for instance, it was wholly insufficient for the feasibility-level Public Park Stormwater Retrofits (see - Strategies under Projects & Programs section). Sub-meter topography is critical to advance feasibility-level and comprehensive watershed management models for the McVicar watershed.

Subwatershed Boundaries – the understanding of subwatershed boundaries and routing is virtually nonexistent and or anecdotal at best. Delineation of subwatersheds based on outfalls to McVicar Creek would be a first step towards a comprehensive watershed management model for McVicar watershed.

Utilities (Stormsewer) – the City database for stormsewer pipes and outfalls is incomplete with less than 15% of stormsewer data having elevation information. Additional database information should be collected via as-built plans and surveys to validate all stormsewer pipe sizes, type and conditions; catch basin locations and grate types; manhole and junction locations; pipe alignments and pipe invert elevations.

Wetlands – As a first step, all wetland areas should be mapped within the McVicar watershed to better inform enforcement of provincial regulation 180/06. Beyond basic delineation of boundaries, wetland type determination and a functional assessment is also warranted to better inform decision making and potentially expanded environmental overlay districts such as shallow groundwater recharge zones for preservation of creek baseflows.

Aerial Imagery – while existing imagery is of high quality it is important to establish a schedule to maintain an up-to-date data set by obtaining aerial imagery on an annual or 2-year basis.

Impervious Surfaces – the existing impervious surface dataset must be maintained to remain relevant and useful for modeling and stormwater practice evaluation.

III. Watershed Model

The primary goal of developing a watershed (hydrologic and hydraulic) model is to have a detailed understanding of the system and its sensitivity to development pressure and climate change, while being able to evaluate the effectiveness of the existing and proposed stormwater infrastructure to reduce the risk of flooding and the impact of stormwater on the environment. In addition, a watershed model affords more meaningful recommendations for standards, upgrades/improvements and the ability for new stormwater measures to be identified. Well beyond the scope of this project, it is recommended that the City embark upon development of a base model for the McVicar Creek watershed early in the development of the City's SMMP. This may be accomplished by updating and enhancing the existing hydrologic and hydraulic model (OTTHYMO / HECRAS model (1987)). Update of this base model will allow for continued examination and quantitative analysis of the McVicar Creek system affording for better allocation of financial resources in the long-term.

Envisioned Modeling Framework

If pursued, the City could further refine the McVicar Creek base model incorporating additional feasibility-level detail in order to assess Capital Improvement Program projects and ultimately to develop a Comprehensive Watershed Management Model for the entire watershed. The framework for said Comprehensive Watershed Management Model would be fleshed out during development of the Base and Feasibility-Level Models with detailed direction provided in the SMMP, including the recommendations for monitoring and calibration. This suggested approach is illustrated in the following table:

Table 6 - Stormwater Management Model Planning

To be provided with the SMMP for each watershed	*3-5 models to be provided with the SMMP*	*Framework developed with the SMMP; Models to be developed in the future*
Base Models	**Feasibility-Level Models**	**Comprehensive Watershed Management Models**
Model Capabilities:	Model Capabilities:	Model Capabilities:
Resource evaluation and estimation of pre-development conditions Assessment of existing condition and potential future development impacts Assessment of potential impacts of climate change Critical area identification Scenario planning to improve stormwater quality	Site level BMP Design Facilitate optimization/ improvements in the system Allows for sizing, cost, location and timing of improvements	Resource evaluation – higher resolution Basis for future Feasibility-Level models
Information used for: Implementation Plan Development and General CIP	Information used for: Detailed Capital Improvement Program development	Information used for: Standards evaluation & testing Refined CIP budgeting

B. Projects & Programs

A number of unique project and program strategies to restore and rehabilitate the McVicar Creek Watershed were identified and vetted by the steering committee. While it is generally understood that stream impairment is not yet sufficiently understood to prioritize actions there were a number of "low-hanging fruit" options identified. These options are intended to serve as stream restoration and watershed management precedents for the Lakehead Region.

I. Public Park Stormwater Retrofits

One of the "low hanging fruit" options promoted by the steering committee was making use of underutilized publicly owned lands, more specifically public park lands, for stormwater management (Site Control). There are numerous parks (Grandview, Brent, Albany, Pringle, Regent, Shuniah, etc.) within the McVicar Creek Watershed that contain underutilized lands with the potential for managing stormwater and providing wildlife habitat within the public view.

Evaluation

All City and Conservation Authority owned properties within the McVicar Creek watershed were evaluated in person for suitability and further vetted via available spatial information and data. Twenty-seven stormwater retrofits were fully advanced and are detailed herein. Many other suitable projects were identified, but only projects that scored highly on all of the following criteria were advanced:

- Educational opportunity & visibility
- Cost-benefit (water quality & quantity returns)
- Ease of construction

For each of the 27 stormwater Best Management Practices (BMPs), the following assessments and evaluations were completed (as detailed in Table 7):

- Delineation of potential catchment (Note: curb cut and simple catch basin modifications were assumed to direct stormwater to the BMP and to size drainage area relative to treatment potential)
- Impervious area within catchment
- Treatment type
- BMP footprint
- Cost – design, construction, and maintenance for 5 years
- Pollutant loading, removal, and BMP efficiency
- Contributing volume, removal, and efficiency

A Windows-based Source Loading and Management Model (WinSLAMM – version 10.0.2) was constructed and used to estimate the pollutant and volume contributions and removals. WinSLAMM is a leading model for evaluating LID practices and green infrastructure. The model utilizes small storm hydrology - the concept that the majority of the runoff volume and pollutant loadings in urban areas is a result of the small and medium rainfall events.

Design Particulars

The practice type selected for the majority of the park stormwater retrofits was bioretention. Bioretention is an important technique that uses soil, plants, and microbes to treat stormwater before it is infiltrated or discharged. Bioretention "cells" are shallow depressions filled with sandy soil, topped with a layer of mulch, and planted with suitable vegetation. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow ponded water 15-20 cm deep, with an overflow outlet to prevent flooding during heavy storms. Where soils are tight or infiltration is otherwise limited (which is the case here) a perforated underdrain, connected to stormsewer or alternatively discharge should be utilized.

Infiltration potential and suitability is limited throughout most of the McVicar Creek Watershed due to the shallow depth to bedrock and shallow depth to the seasonally high water table throughout most of the watershed. High porosity soils and a minimum of 1 meter of vertical separation is required between the practice and bedrock and/or the seasonally high water table. Therefore filtration (versus infiltration) practices are assumed for most of the watershed. A typical filtration style bioretention practice can be seen in Figure 27.

To maintain efficiency, reduce maintenance cost, and extend the life of a bioretention facility, pretreatment is a necessary component of any bioretention practice. To prevent clogging of the infiltration or filtration system, use of a pretreatment device such as a vegetated filter strip, small sedimentation basin, or water quality inlet (e.g., sump) to settle particulates before the stormwater discharges into the infiltration or filtration system is required. A water quality inlet is recommended here and detailed in Figure 28.

Next Steps

The following primary next steps will help ensure successful implementation and function:

1. Identify Budgets and Responsibilities
   a. Site Assessment
   b. Design
   c. Construction
   d. Maintenance
      i. Identify & secure maintenance dollars
      ii. Identify activities and associated responsible parties
2. Design – hire a quailed consultant to design and oversee the construction of the facilities
   a. Identify survey & soil assessment requirements
   b. Compute runoff control volumes
   c. Determine bioretention type and size practice
   d. Size outlet structure and/or flow diversion structure if needed
   e. Determine pre-treatment volume and design pre-treatment measures
   f. Prepare vegetation and landscaping plan
   g. Prepare operations and maintenance (O&M) plan
   h. Prepare cost estimate

Table 7 - Cost Benefit Analysis for Proposed Public Park Stormwater Retrofits

BMP ATTRIBUTES						ESTIMATE OF PROBABLE BMP COST*				AVERAGE ANNUAL CATCHMENT POLLUTANT LOAD				AVERAGE ANNUAL BMP POLLUTANT REMOVA				AVERAGE ANNUAL BMP EFFICIENCY %			
ID	PARK	TREAMENT TYPE	ESTIMATED PRACTICE FOOTPRINT (M^2)	ESTIMATED CATCHMENT AREA (Hectares)	ESTIMATED CATCHMENT IMPERVOUS AREA (Hectares)	DESIGN (site assessment, design & const. admin.)	CONST.**	5-YR MAINT	TOTAL	TP Total Phosphorus (kg)	METALS Copper† (kg)	PS Particulate Solids (kg)	VOLUME (M^3)	TP Total Phosphorus (kg)	METALS Copper† (kg)	PS Particulate Solids (kg)	VOLUME (M^3)	TP Total Phosphorus (kg)	METALS Copper† (kg)	PS Particulate Solids (kg)	VOLUME (M^3)
BA-1	Brent Albany	Biofiltration w/ Pretreatment	218	1.41	0.34	$10,000	$30,812	$5,933	$46,745	1.24	0.09	361.7	2349	0.94	0.07	299.0	1862	76	82	83	79
BA-2			118	0.14	0.10	$10,000	$18,972	$4,588	$33,559	0.12	0.01	36.2	235	0.12	0.01	36.2	235	100	100	100	100
BA-3			236	0.26	0.15	$10,000	$32,943	$6,175	$49,118	0.23	0.02	67.2	436	0.23	0.02	67.2	436	100	100	100	100
BA-4			340	1.70	0.71	$10,000	$45,257	$7,575	$62,832	1.49	0.11	434.1	2818	1.24	0.09	383.2	2419	83	88	88	86
GV-1	Grand View	Stromwater Wetland w/ Pretreatment	625	2.63	0.71	$10,000	$38,637	$9,727	$58,365	2.31	0.17	672.8	4369	2.02	0.14	630.8	3277	88	84	94	75
GV-2		Biofiltration w/ Pretreatment	62	0.11	0.11	$10,000	$12,341	$3,834	$26,175	0.10	0.01	27.9	181	0.10	0.01	27.8	180	100	100	100	100
GV-3			340	0.43	0.28	$10,000	$45,257	$7,575	$62,832	0.38	0.03	110.6	718	0.38	0.03	110.6	718	100	100	100	100
GV-4			115	0.88	0.41	$10,000	$18,616	$4,547	$33,164	0.77	0.06	224.3	1456	0.54	0.04	176.2	1089	71	78	79	75
GV-5			62	1.05	0.46	$10,000	$12,376	$3,838	$26,215	0.91	0.07	266.6	1732	0.39	0.03	137.7	800	43	50	52	46
GV-7			167	2.83	0.99	$10,000	$24,733	$5,242	$39,975	2.48	0.18	723.5	4698	1.05	0.09	368.4	2134	42	50	51	45
GV-8			156	1.21	0.53	$10,000	$23,471	$5,099	$38,570	1.06	0.08	310.0	2014	0.75	0.06	241.8	1493	70	78	78	74
GV-9			37	0.82	0.27	$10,000	$9,375	$3,497	$22,873	0.72	0.05	209.8	1363	0.25	0.02	87.7	500	34	40	42	37
PR-1	Pringle	Biofiltration w/ Pretreatment	81	0.55	0.33	$10,000	$14,588	$4,090	$28,678	0.48	0.03	139.5	906	0.36	0.03	114.4	711	75	82	82	79
PR-2			20	0.05	0.04	$10,000	$7,368	$3,269	$20,637	0.04	0.00	12.4	81	0.04	0.00	11.3	72	87	91	91	89
PR-3			41	0.26	0.12	$10,000	$9,885	$3,555	$23,440	0.22	0.02	65.1	423	0.17	0.01	54.7	342	78	84	84	81
PR-4		Sediment capture only	N/A	0.23	0.08	$5,000	$10,000	$3,000	$18,000	0.21	0.01	59.9	389	0.04	0.00	15.4	4	20	10	26	1
PR-5			N/A	0.35	0.14					0.30	0.02	88.9	577	0.05	0.00	18.5	6	15	10	21	1
PR-6		Biofiltration w/ Pretreatment	107	0.57	0.24	$10,000	$17,701	$4,443	$32,144	0.50	0.04	144.7	939	0.41	0.03	126.4	796	82	87	87	85
PR-7			149	1.08	0.51	$10,000	$22,673	$5,008	$37,681	0.94	0.07	274.9	1785	0.69	0.05	220.3	1366	73	80	80	77
PR-8			112	0.87	0.35	$10,000	$18,269	$4,508	$32,777	0.76	0.05	223.2	1450	0.54	0.04	174.0	1074	70	77	78	74
PR-9			106	1.49	0.94	$10,000	$17,573	$4,429	$32,001	1.30	0.09	379.3	2463	0.64	0.05	219.5	1295	49	57	58	53
PR-10			79	1.50	0.84	$10,000	$14,372	$4,065	$28,437	1.32	0.10	384.5	2496	0.51	0.04	181.8	1042	39	46	47	42
RG-1	Regent	Biofiltration w/ Pretreatment	135	0.59	0.12	$10,000	$20,984	$4,816	$35,801	0.51	0.04	149.9	973	0.45	0.03	136.2	866	87	91	91	89
RG-2			164	1.24	0.52	$10,000	$24,418	$5,207	$39,625	1.08	0.08	316.3	2054	0.77	0.06	249.2	1542	71	79	79	75
SH-1	Shuniah	Bioretention w/ Pretreatment	270	0.79	0.36	$10,000	$36,969	$6,633	$53,602	0.69	0.05	202.8	1246	0.66	0.05	196.4	1196	95	97	97	96
SH-2			175	0.57	0.41	$10,000	$25,721	$5,355	$41,075	0.50	0.04	146.5	950	0.47	0.03	140.2	898	94	95	96	95
WE-1	Wellington	Biofiltration w/ Pretreatment	218	0.95	0.37	$10,000	$30,812	$5,933	$46,745	0.83	0.06	242.2	1579	0.72	0.05	220.0	1406	87	91	91	89

*Costs for each practice are estimated separately; all costs would be reduced by 5%-20% if multiple BMPs were advanced congruently
**Estimate includes construction of practice, pretreatment device and stormsewer manipulation (if applicable)
†Copper is used as a surrogate for all metals

Next Steps Cont.

3. Soil borings, pits or perimeter tests – sufficient collection and analysis to determine depth to seasonal high water table, depth to bedrock and soil infiltration capacity
   a. See MN Stormwater Manual for recommend number and recommend analysis
4. Complete a detailed survey of the site
   a. Identify property boundaries
   b. Identification of utilities
   c. Site topography
   d. All infrastructure, including existing inverts of the storm drain system
5. Neighborhood Engagement
6. Permitting
7. Tendering – hire a qualified contractor as proper construction techniques are critical to achieve long-term functionality
8. Construction & Construction Observation
   a. Adherence to construction documents
   b. Verification of physical site conditions
   c. Erosion control measures installed appropriately
9. Execute Operations & Maintenance Plan

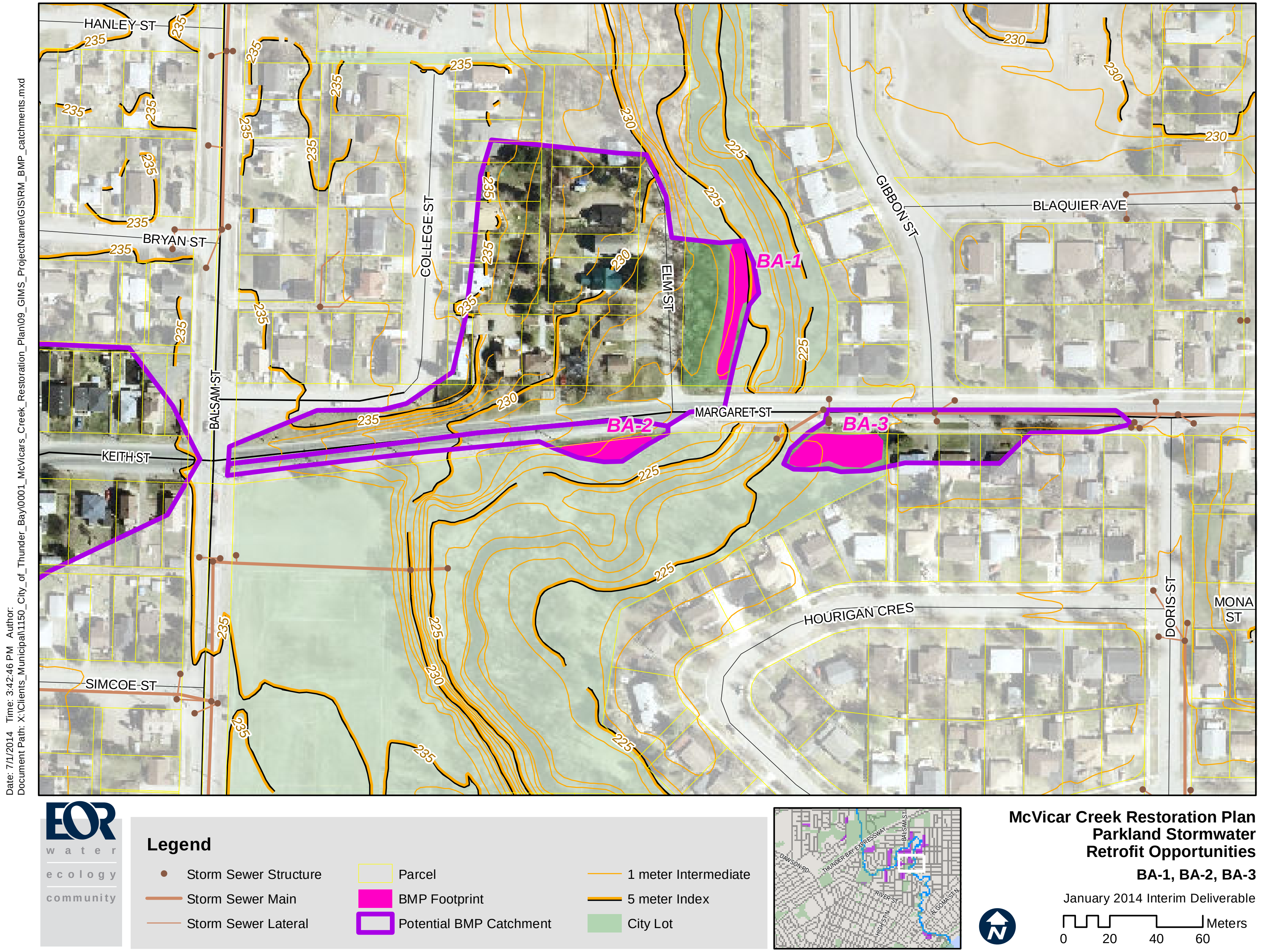


Figure 16 - Parkland Retrofits: BMPs and Catchments

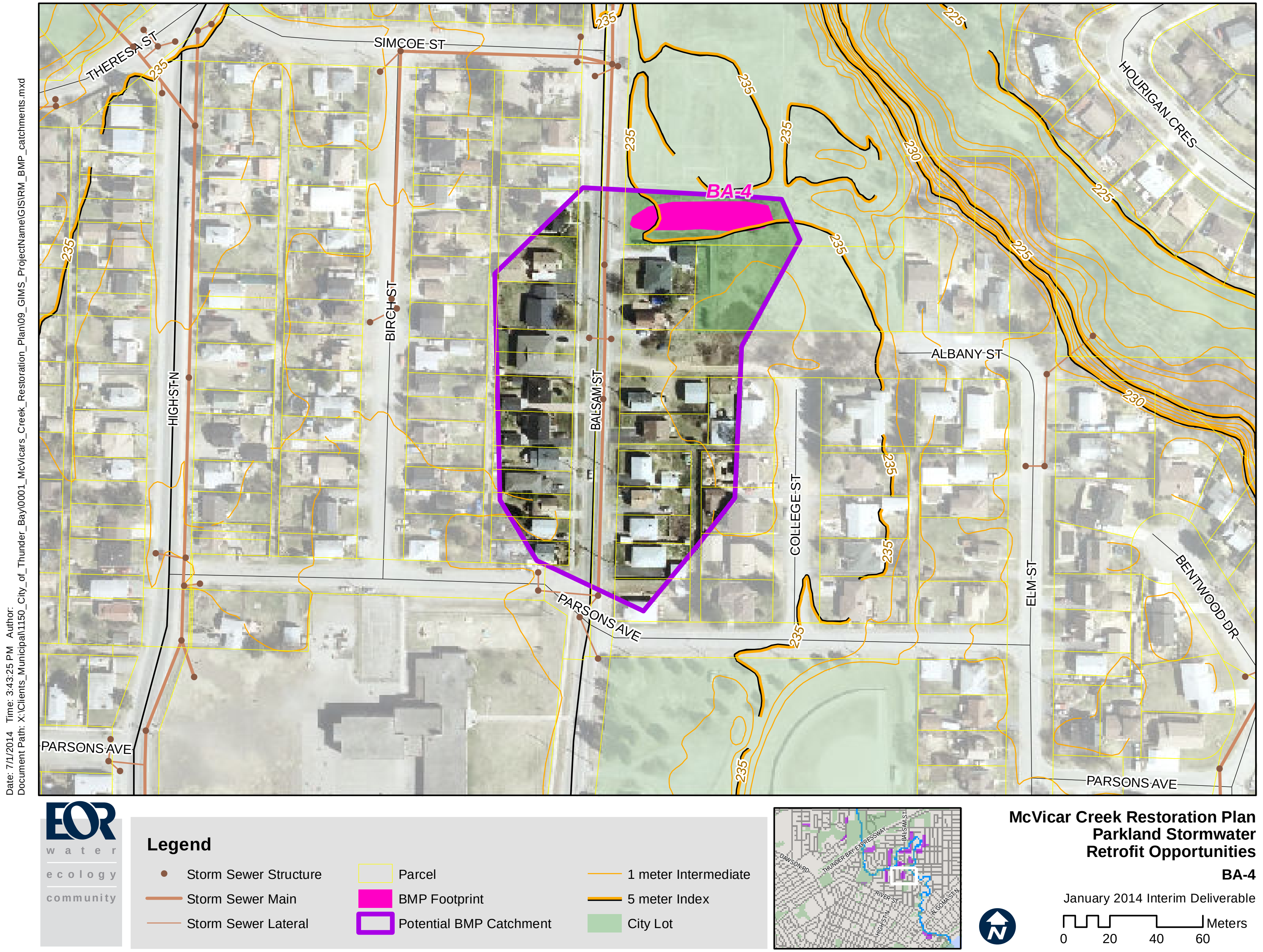


Figure 17 - Parkland Retrofits: BMPs and Catchments

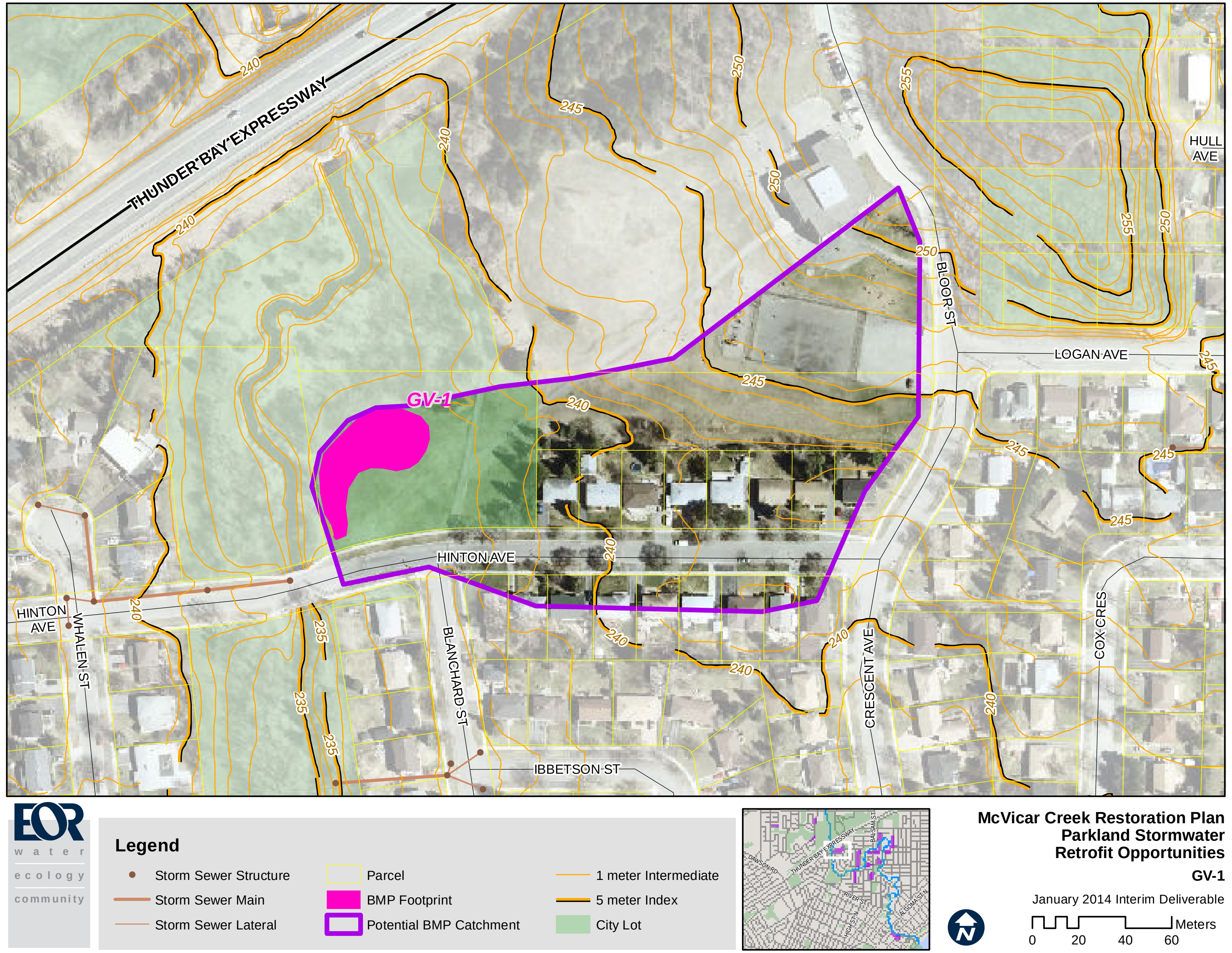


Figure 18 - Parkland Retrofits: BMPs and Catchments

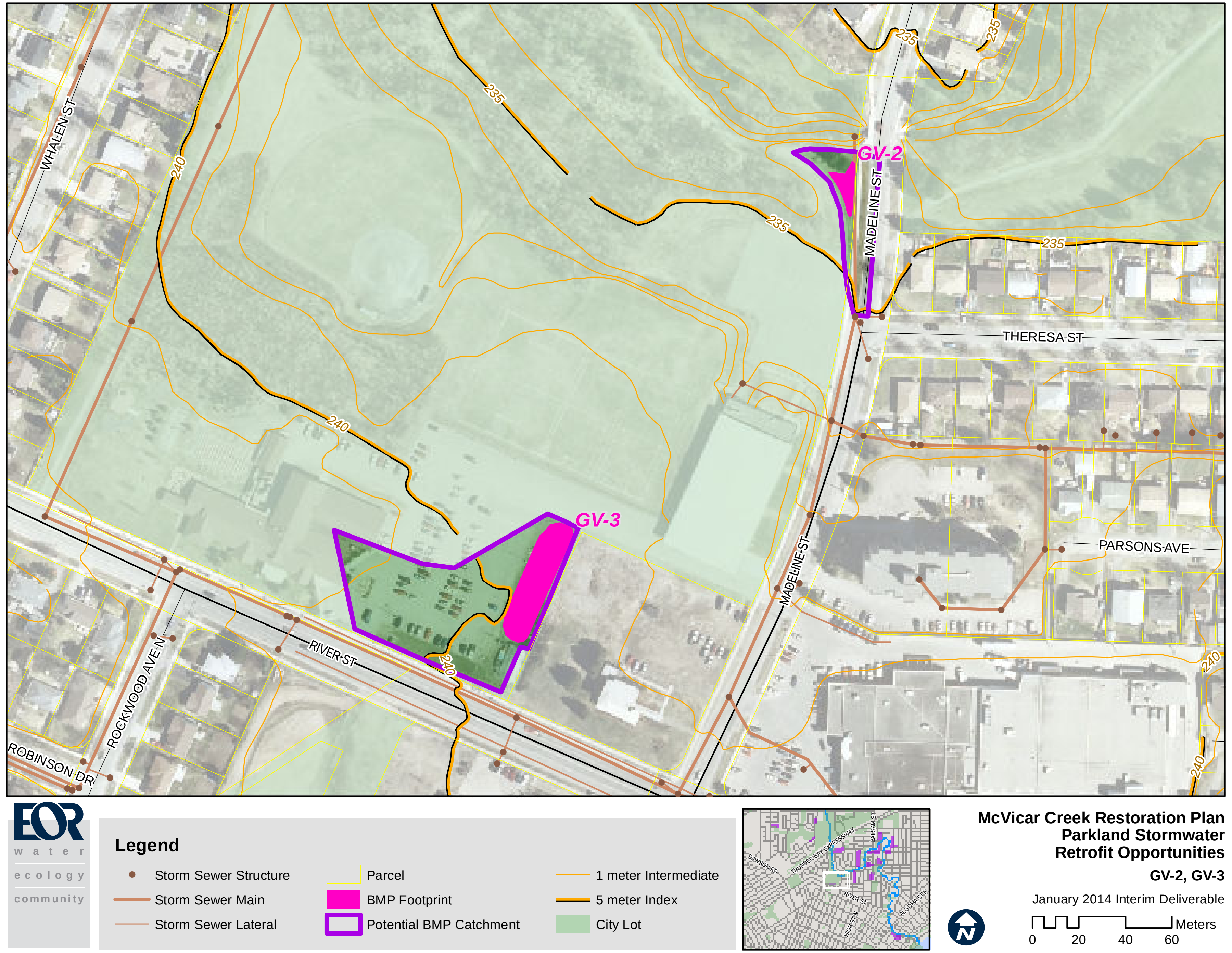


Figure 19 - Parkland Retrofits: BMPs and Catchments

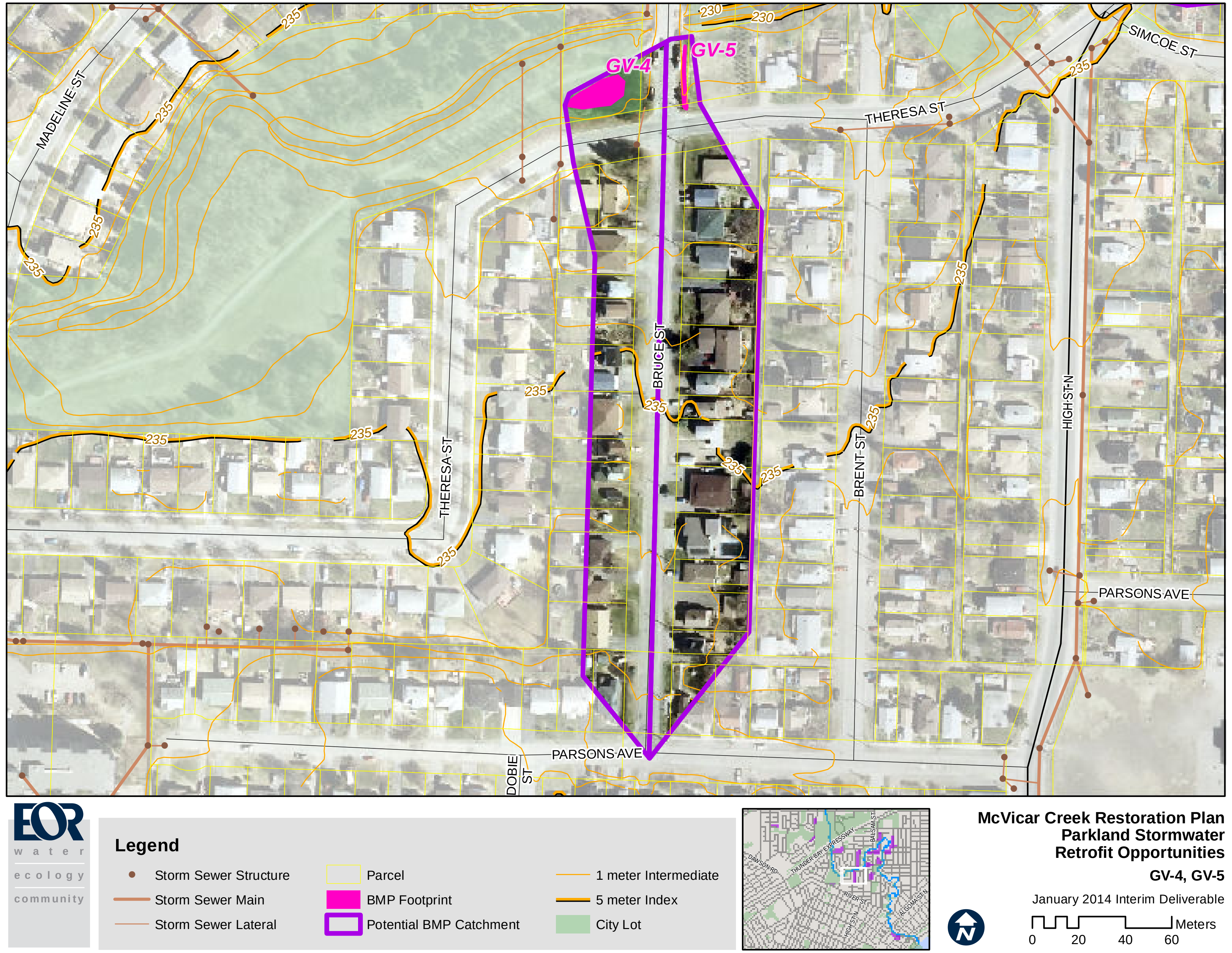


Figure 20 - Parkland Retrofits: BMPs and Catchments

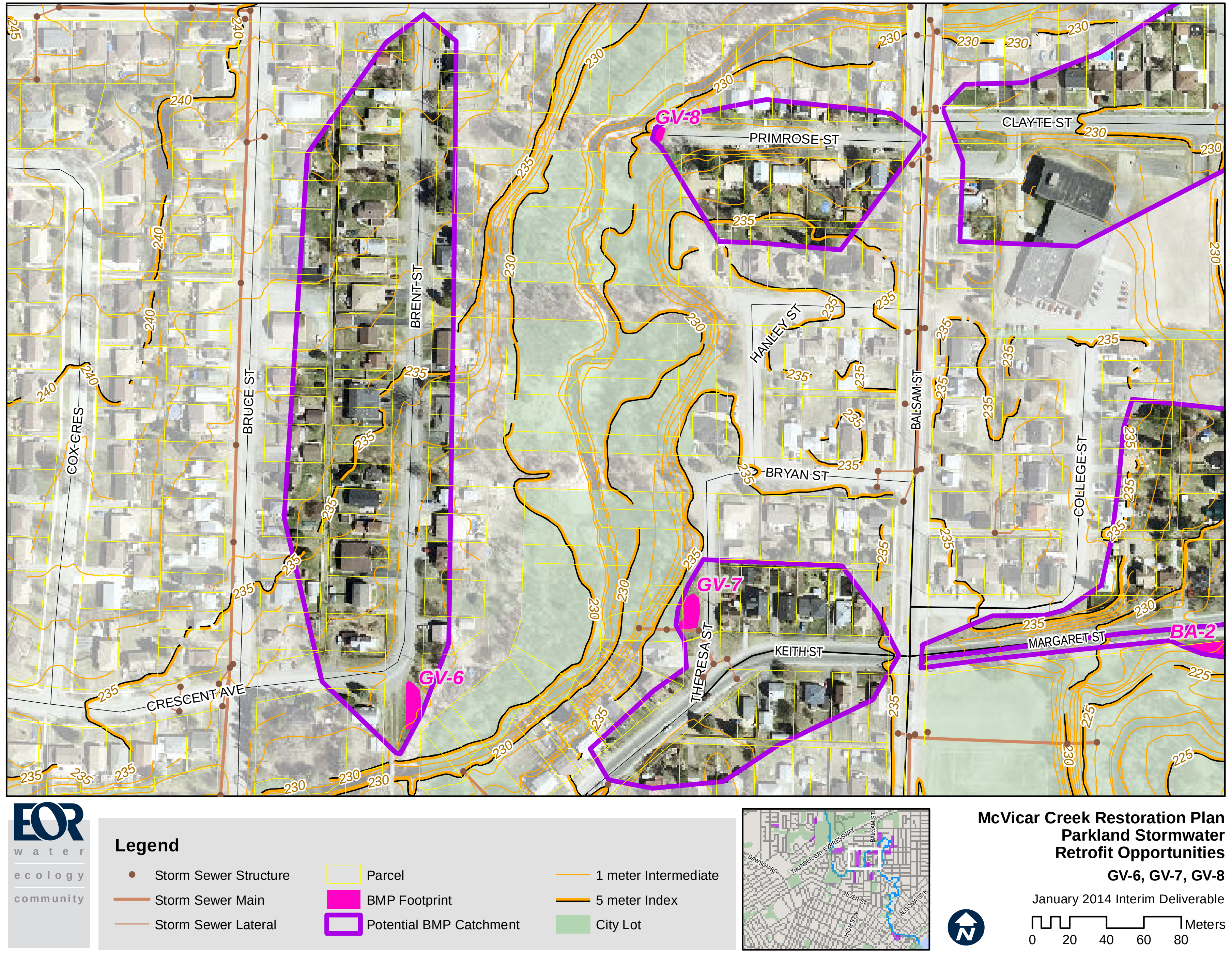


Figure 21 - Parkland Retrofits: BMPs and Catchments

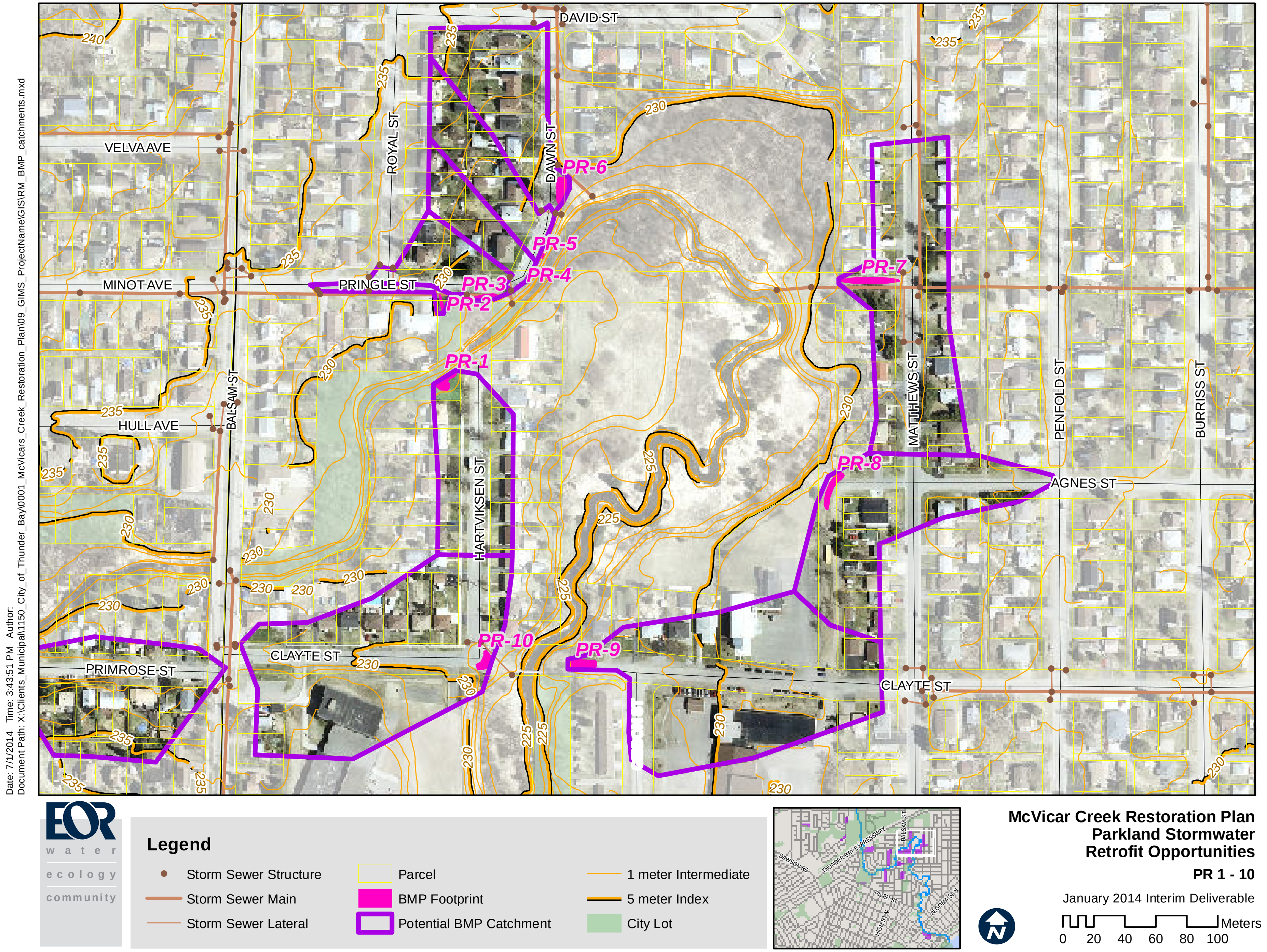


Figure 22 - Parkland Retrofits: BMPs and Catchments

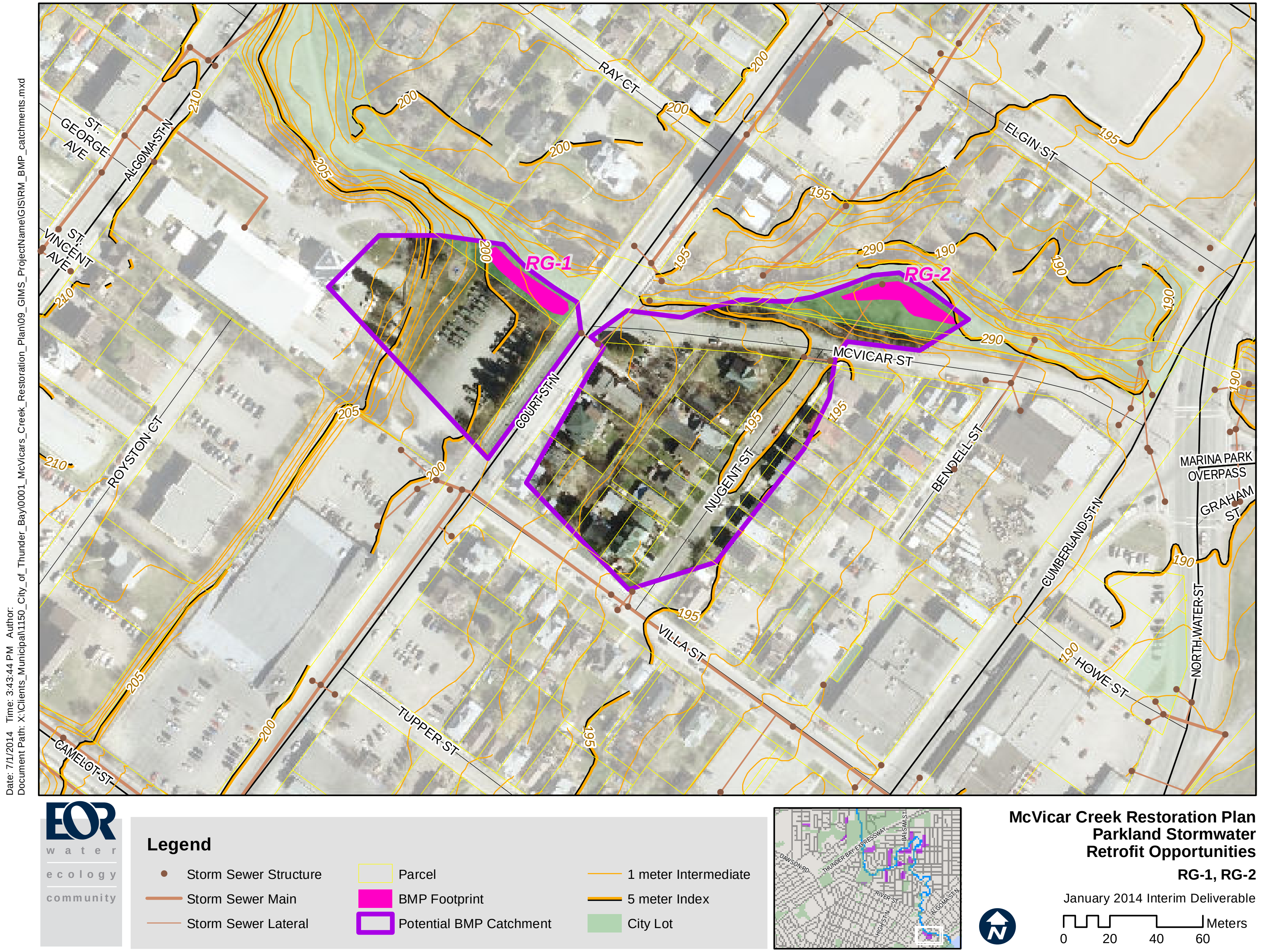


Figure 23 - Parkland Retrofits: BMPs and Catchments

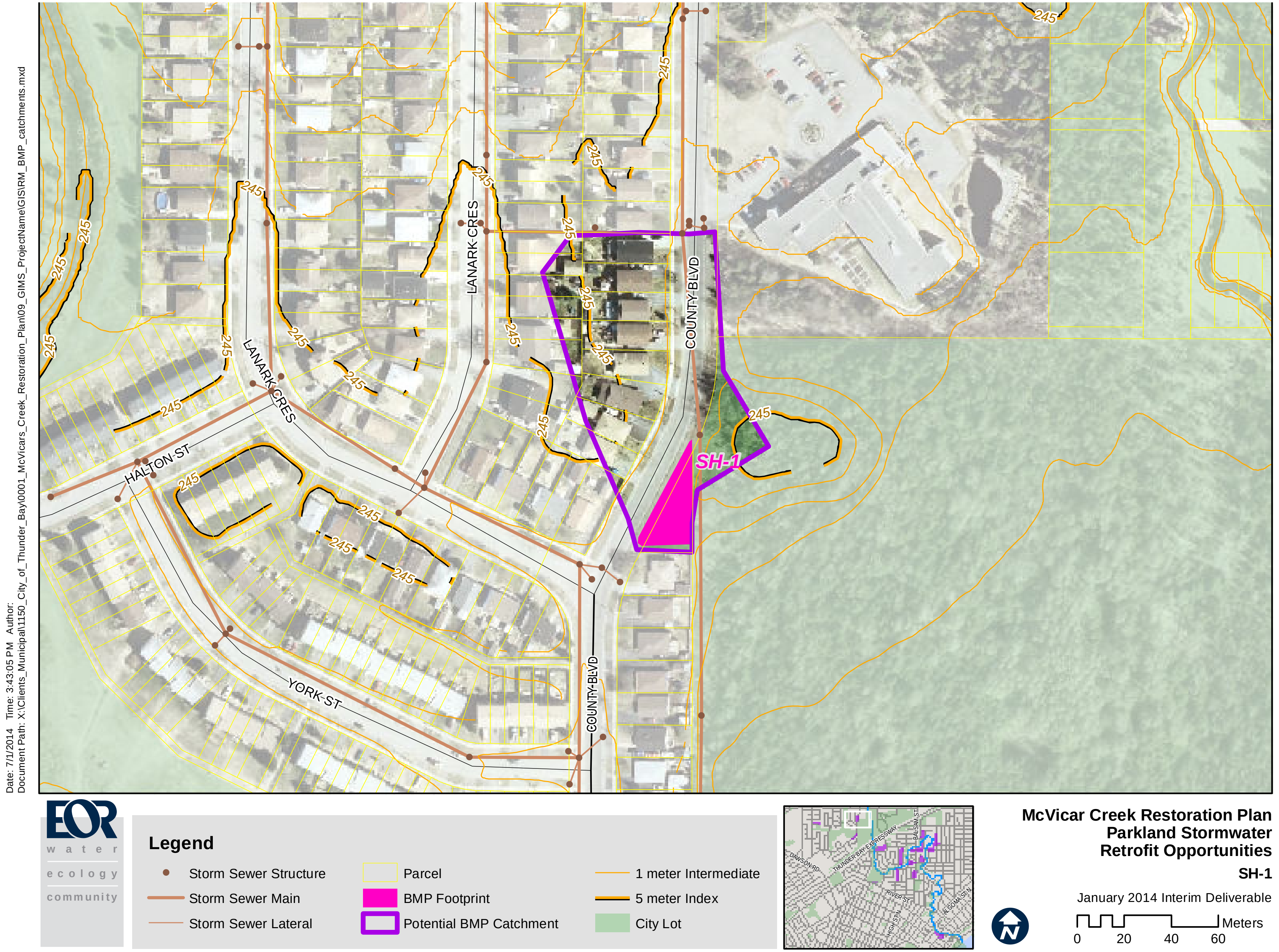


Figure 24 - Parkland Retrofits: BMPs and Catchments

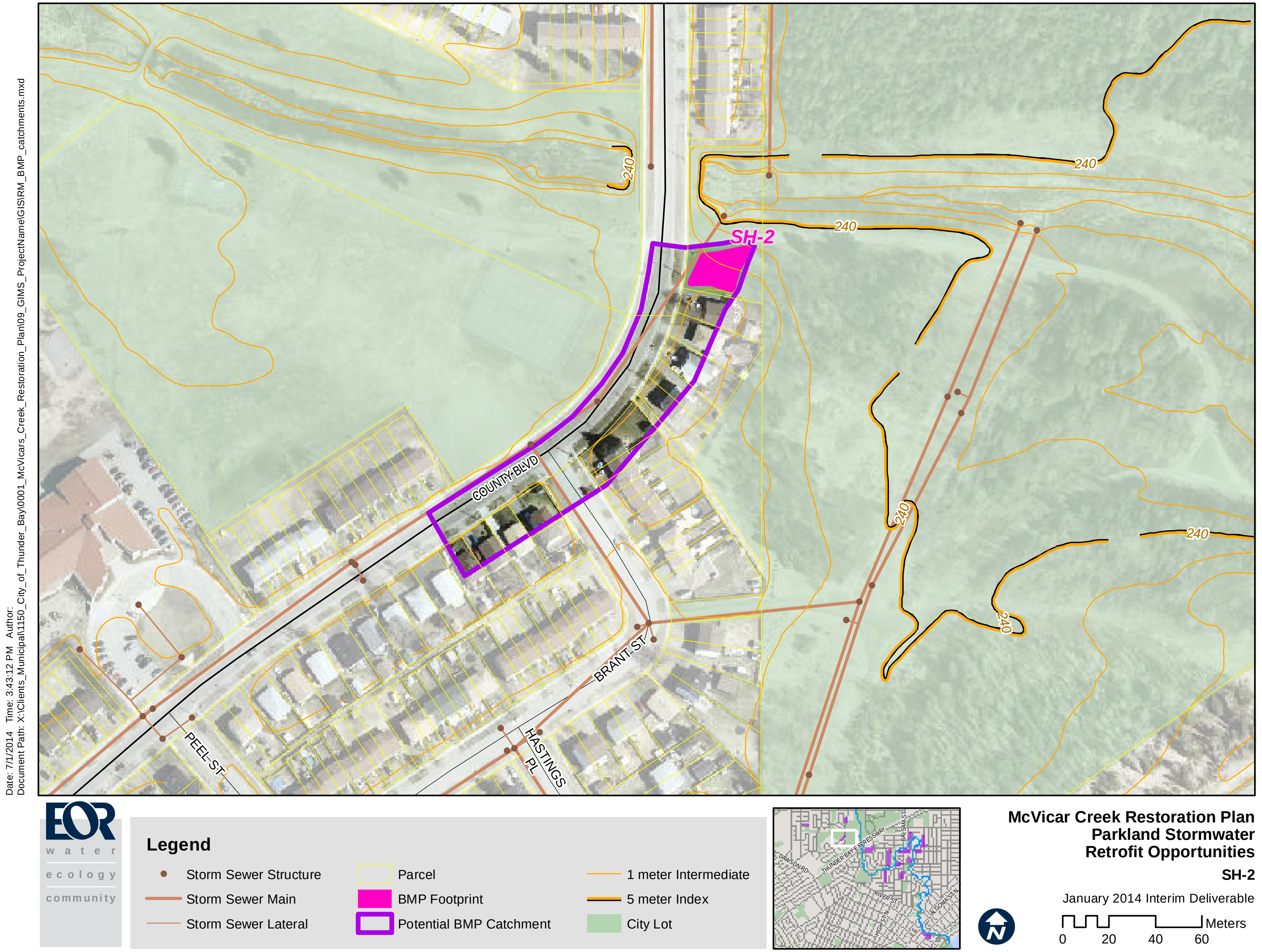


Figure 25 - Parkland Retrofits: BMPs and Catchments

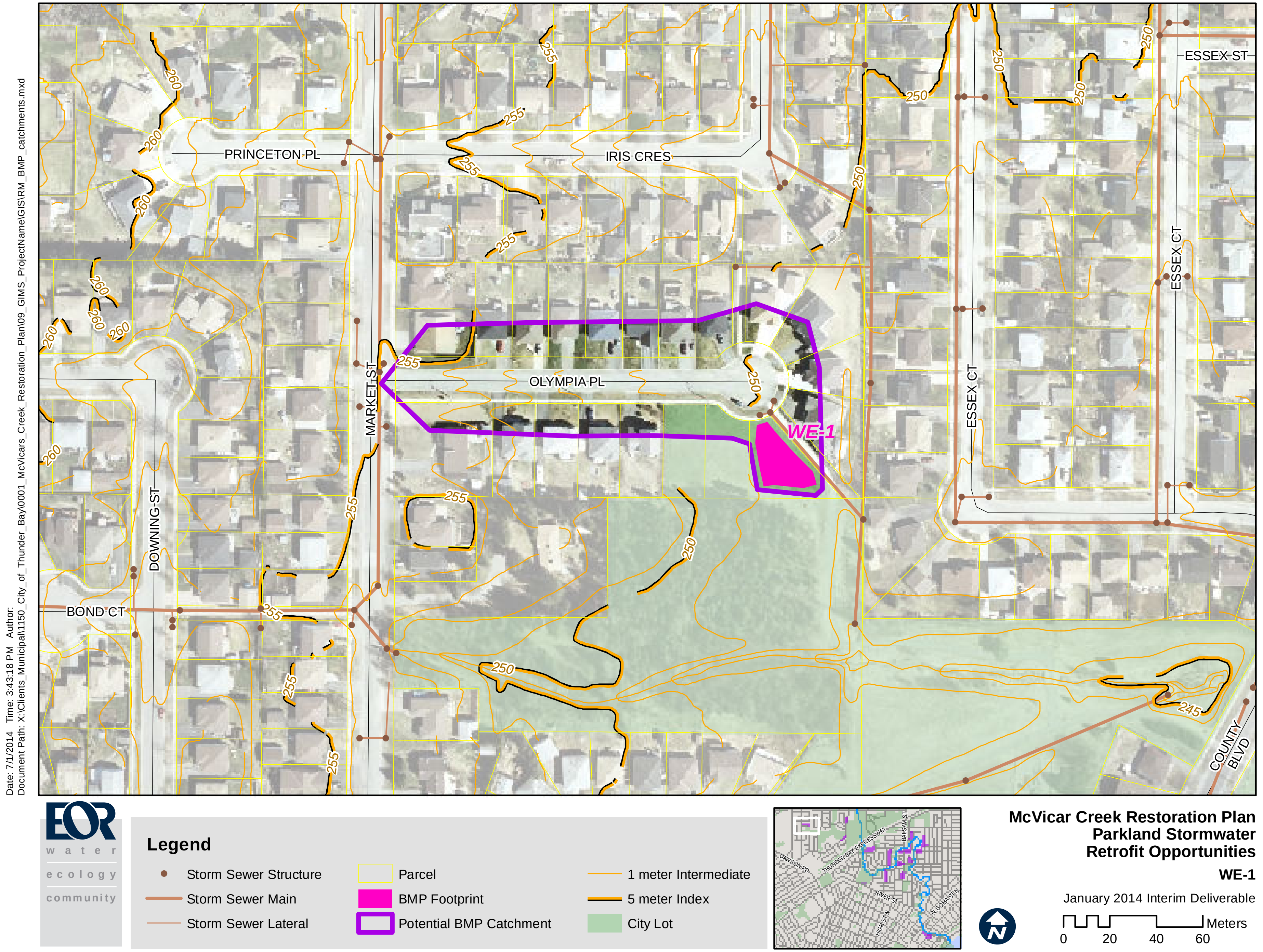


Figure 26 - Parkland Retrofits: BMPs and Catchments

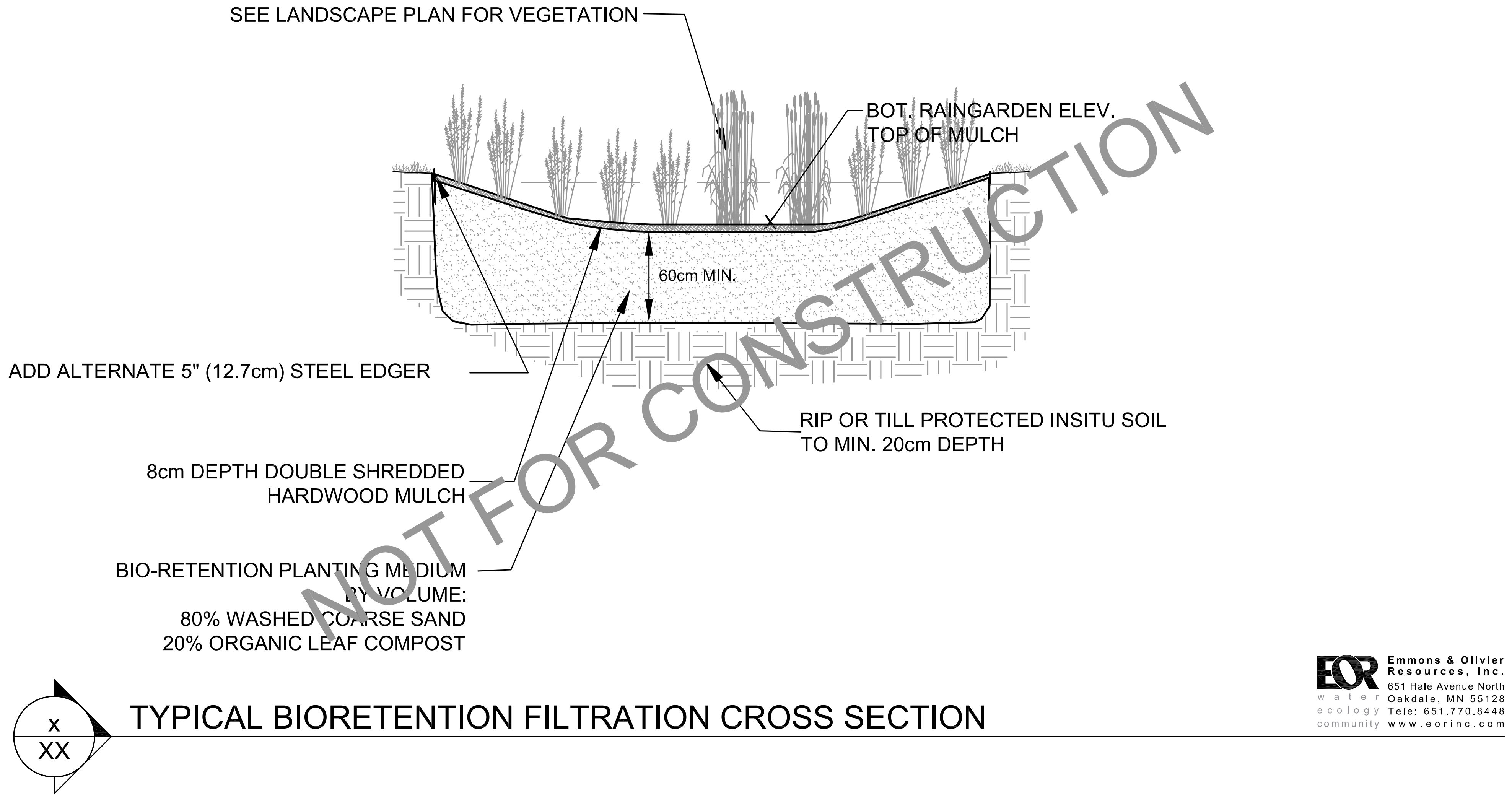


Figure 27 - Public park stormwater retrofit - typical bioretention (filtration style) detail

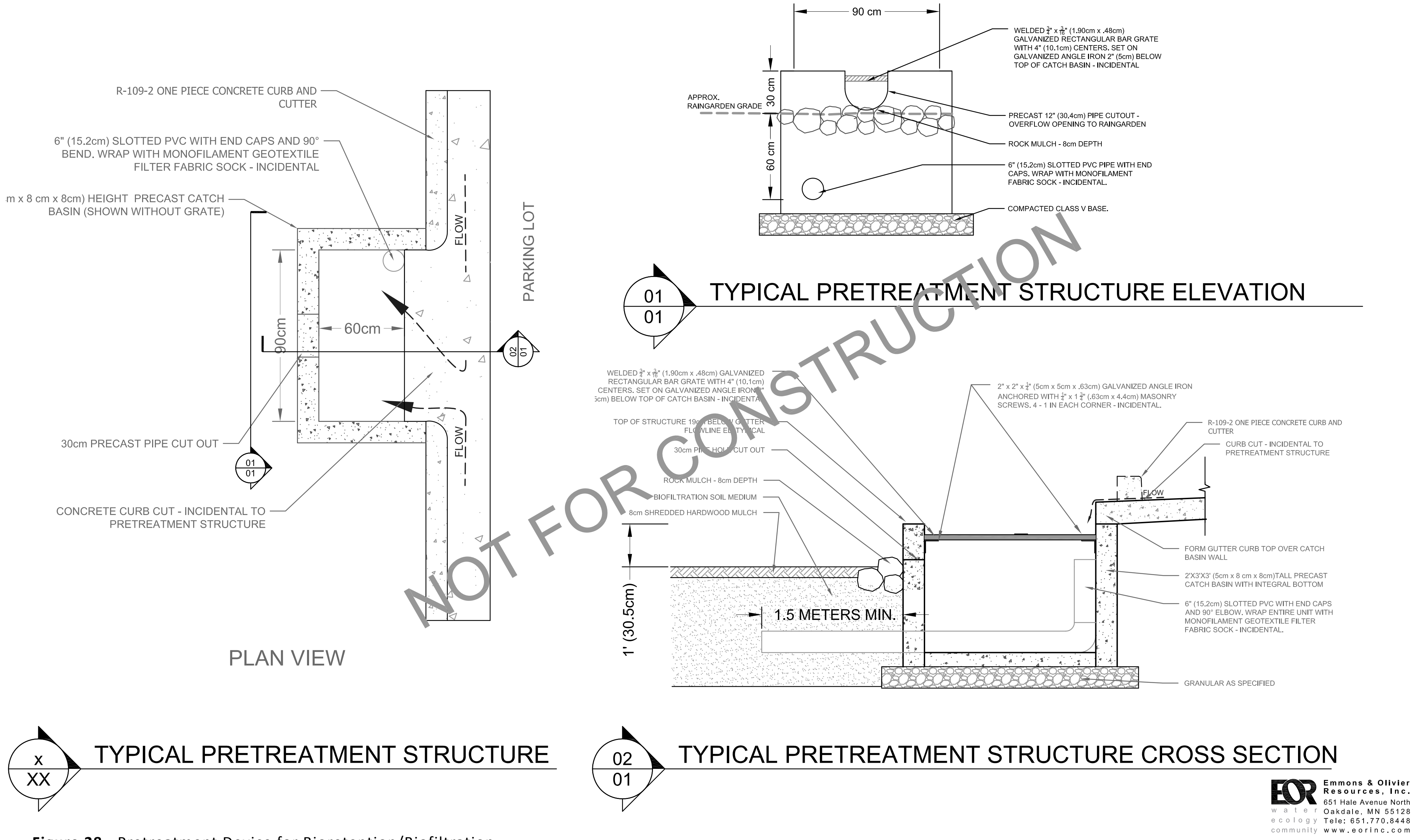


Figure 28 - Pretreatment Device for Bioretention/Biofiltration

II. Residential Green Streets and Alleys

A major impairment to a large urban section of McVicar Creek is the excessive Total Suspended Solids (TSS) that are contributed from adjacent neighbourhoods and streets. TSS sediments are a natural part of streams and other water bodies. However, excessive sedimentation in streams and rivers is considered to be the major cause of surface water pollution in North America. A large portion of the streets in this section of the City are unimproved and are directly contributing substantial TSS to the creek.

Streets considered unimproved, for the purposes of this report, are those that have no curb and gutter at the edges, often have no storm sewer or controlled conveyance method for storm water, and have large areas of gravel and bare earth at the sides of the road where cars park in what is considered the front or side yards of properties. These streets have many of the same traits and issues of construction sites; large areas of exposed and compacted soils are easily washed away by stormwater runoff. The following sections analyse the issues of a typical unimproved street and some of the potential sediment control and stormwater management improvements.

Figure 29 - Green alley precedents

Figure 30 - (above) green street examples; (lower) sediment capture device

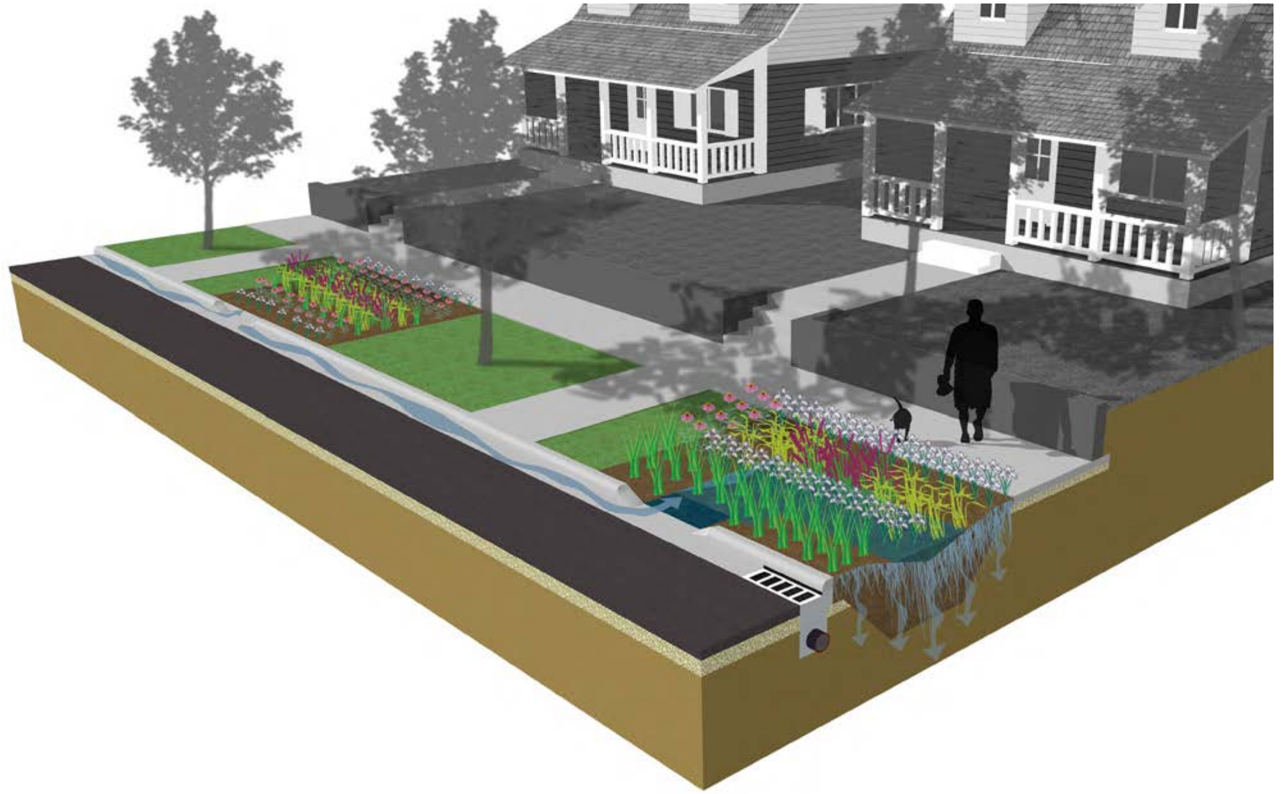


Figure 31 - Example of green street retrofit within public right-of-way

Existing Conditions

A

Poorly defined road edges encourage parking on the roadside and in front lawns. This creates an erosion and sediment control issue as the vehicular traffic prohibits vegetation that naturally stabilizes the soil. Severely compacted ground becomes an impervious surface itself, contributing large amounts of sediment during runoff events, potentially more sediment than a stable asphalt or concrete surface. Residents have placed compacted gravel in lieu of asphalt or concrete driveways. This likely contributes greater amounts of sediment than traditional impervious surfaces during runoff events, because of the mobile gravel fines, rutting that occurs in concentrated flow areas, and the ease of the materials disturbance. This sediment becomes increasingly difficult to control or capture as length, slope, and time of concentrated flow increase. Sediment deposits are visible in many locations.

The poorly defined road doubles the roadway's effective impervious surface by allowing parking anywhere between the paved road edge and a house or garage. This issue does not occur in other areas of the City with a traditional curb and gutter section. The urban section clearly defines the road edge, curb cuts are placed to define the driveway entries and approaches, and parking is limited to designated areas.

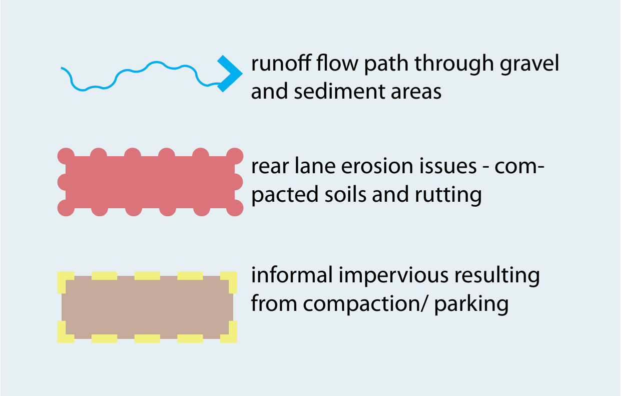
R1

High traffic rear lanes – consistent traffic has compacted the soil, killed vegetation, and created pervasive erosion issues. Rear lanes typically drain to the street with sediment laden runoff. This compounds the street's runoff issues.

High traffic rear lanes would be most effective if paved in a stable material such as asphalt or concrete. This would minimize the sediment contribution of rear lanes to McVicar Creek. Pervious pavements would also be desirable if traffic patterns and volumes would support this approach.

R2

Low traffic rear lanes – these lanes are rarely used by automobiles, but show signs of compaction. Soil reinforcement measures that stabilize the rear lane and help support vegetation growth would be effective in preventing erosion. Cellular confinement products or concrete mats would prevent compaction and allow rainfall to still soak into the ground.



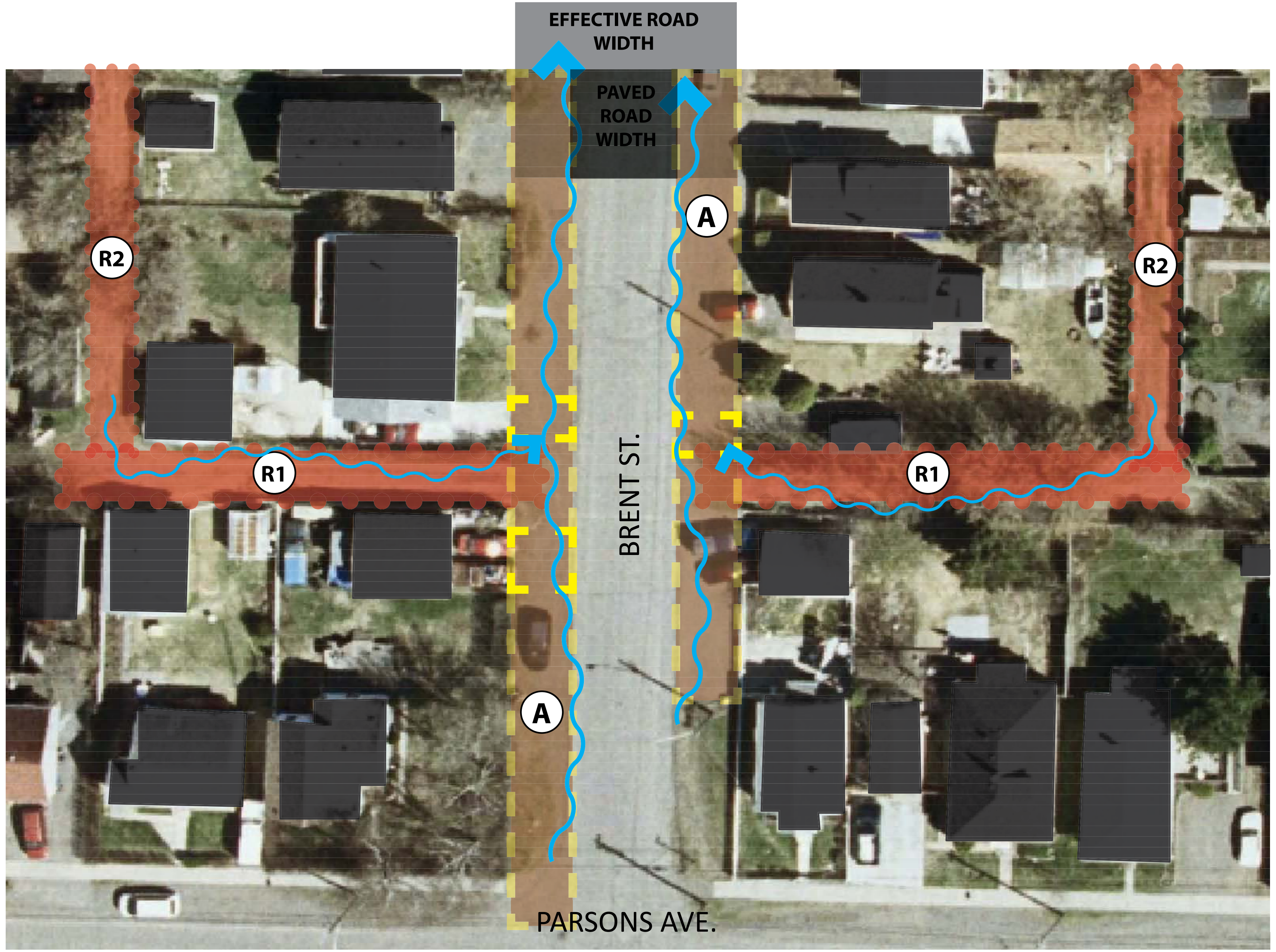


Figure 32 - Existing conditions at the intersection of Brent Street and Parsons Avenue

Controlling erosion and sediment should be the priority in the areas where unimproved streets are directly contributing to the creek. BMPs such as raingardens, tree trenches, and swales will have positive effects, but their efficacy will be offset by existing erosion issues if they are not rectified first. Many of the solutions to the erosion issues of unimproved streets are already mentioned in the Thunder Bay Urban Design and Landscape Guidelines and include improving the streets with barrier curb and gutter, better defined parking areas and driveway curb cuts, and street trees will all provide significant stormwater benefits in addition to the urban design and neighbourhood benefits. Following street improvements, additional BMPs can be inserted into the fabric of the street network much more effectively as runoff is now controlled and the contributing watershed is more stable.

A

Following and building on the guidelines of the Local Roads and Green Streets performance standards in "City of Thunder Bay - Urban Design and Landscape Guidelines" (CTB-UDLG) including aspects such as:

- Providing barrier curbs to control vehicular traffic and parking
- Street width should accommodate two travel lanes and one on-street parking lane
- Sidewalks should be provided on at least one side of the street, both sides if possible.
- Street trees should be planted in the boulevards on both sides of the road wherever possible. Mature trees provide significant stormwater benefits.
- Street curb cuts should define driveways for parking.
- Driveways should be consolidated or shared where possible to reduce impervious surfaces, maximize on-street parking, and allow street tree planting.
- Residential driveway widths should be no wider than the width of the garage door. The hardscaped area can be extended by 1 metre on either side in accent material or paver.
- Permeable surfaces are encouraged for driveways.
- 50% of the front yard should be landscaped.

Where possible, BMPs should be integrated into the streetscape including:

- Raingardens
- Tree trenches
- Sediment capture devices – sumped manholes, grit chambers, etc.
- Vegetated swales or other filtration facilities

R1

High traffic rear lanes should be paved either with traditional asphalt or concrete, permeable pavement, or a combination of wheel track paving with reinforced center tracks.

The CTB-UDLG recommends routing driveway traffic to rear lanes whenever possible to limit drive access of main streets – this will require significant upgrades in rear lane surfacing.

R2

Abandon rear lanes in areas where they are used rarely and there is adequate block-wide, on-street, and driveway parking oriented toward the street. These areas could be included into the fabric of the residential yard as porous turf areas or be landscaped.

Low traffic rear lanes – these lanes are rarely used by automobiles, but show signs of compaction. Soil reinforcement measures that stabilize the rear lane and help support vegetation growth would be effective in preventing erosion. Cellular confinement products or concrete mats would prevent compaction and allow rainfall to still soak into the ground.

Figure 33 - Proposed improvements at the intersection of Brent Street and Parsons Avenue

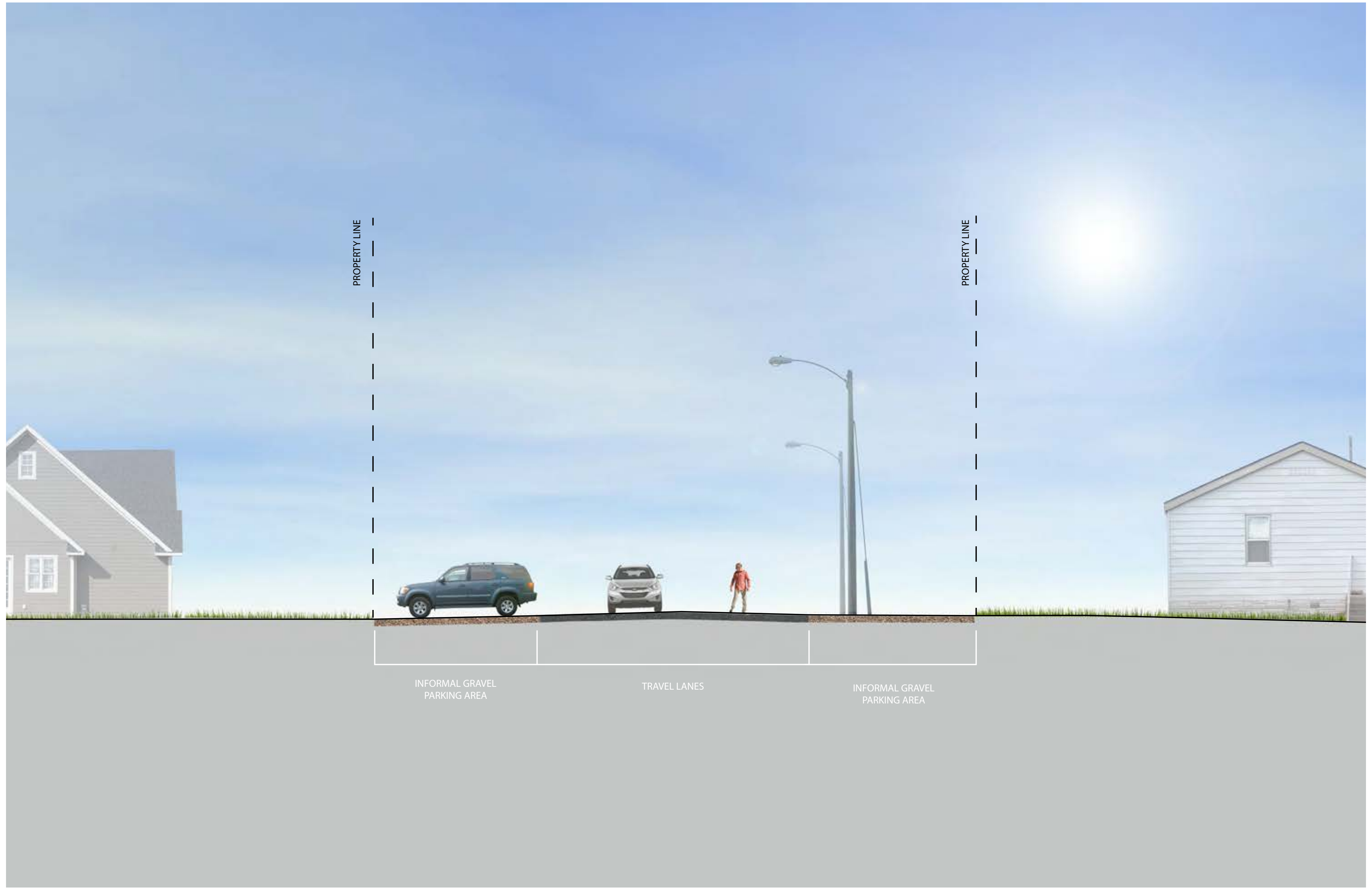


Figure 34 - Existing conditions on typical study area street (100 block of Brent Street)

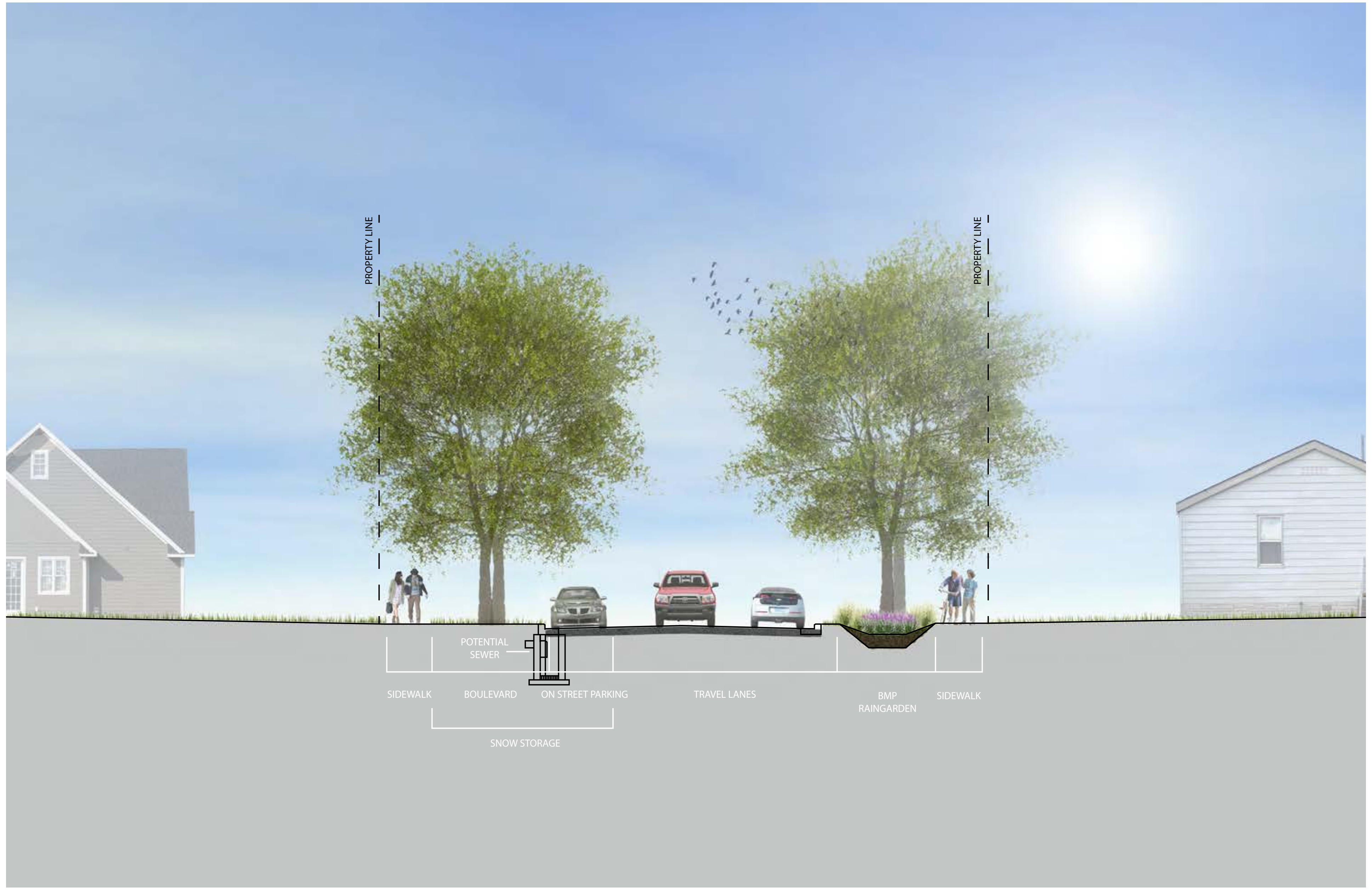


Figure 35 - Proposed improvements to typical study area street (100 block of Brent Street)

Benefits of Enhanced Street Sweeping

Most cities do some amount of street sweeping each year to improve road safety and appearance, but when considering BMPs for water quality, street sweeping is often overlooked. This may be due to a focus on infrastructure or because early reports on sweeping for water quality from the 1970s and 80s (USEPA NURP) were not always promising. But from a common sense perspective, street sweeping for water quality makes sense. Pollutants removed from the street are not available for transport to the storm sewer network. In agreement with this, several recent studies, which make use of newer sweeping technologies and advances in stormwater management, have reported that street sweeping offers a very cost-effective and efficient means to reduce pollutant loads to storm sewer infrastructure and to downstream waters (Beretta et. al (2011), SPU (2009), Kalinosky et. al (2013), others). Additional benefits of street sweeping include reduced clogging and flooding of storm drains, reduced maintenance to downstream stormwater infrastructure, improved safety for pedestrians, and even reduced presence of pests.

Street Particulate Matter Composition

Sediments that accumulate on roadways, sometime referred to as 'street particulate matter', (street PM) are made up largely of sand and silt with varying amount of gravel, trash, vegetative matter and other debris. Characterization studies have shown that this material does not typically qualify as hazardous waste, but does typically contain significant amounts nutrients, metals, and organic pollutants. The character of street PM varies with geography, land use type, traffic and climate patterns, and other factors, however, there are similarities across locations. Some "average" characteristics of street PM are listed in Table 8.

Street Sweeping Technologies

An important part of building a street sweeping program is choosing the appropriate sweeping technology. The main sweeper types available are listed in Table 9. Sweeper performance varies not only by make and model, but across different particle size fractions of street sediments. Simple mechanical broom sweepers are generally efficient at removing larger particles and trash, but are much less efficient than new technologies at removing fine particles. Generally, if sweeping is performed mainly for aesthetic and safety purposes, older mechanical technologies will suffice, but, if sweeping objective include improved water quality, newer technologies such as regenerative air, vacuum filtration or hybrid technologies are preferred.

Street Sweeping as a Source Control BMP

Although the composition of street PM varies somewhat from one geographic location to another, recoverable solids loads can be reasonably estimated for planning street sweeping operations for a given set of conditions. Recoverable loads can vary significantly from one sweeping to the next, but over time appear to be log-normally distributed with the median value representing a "typical" recoverable load (Beretta, et al., 2011, Kalinosky et al., 2013). Conditions which increase sediment accumulation rates and should be factored into estimates of recoverable loads include:

Table 8 - Typical Composition of the Mineral Portion of Street Particulate Matter.

<table>
<tr><th rowspan="2">Particle Size Fraction</th><th rowspan="2">Particle Size (mm)</th><th rowspan="2">Noted Characteristics</th><th colspan="5">Observed Pollutant Concentration Range (mg/kg)</th></tr>
<tr><th>Cadmium</th><th>Chromium</th><th>Copper</th><th>Lead</th><th>Zinc</th></tr>
<tr><td>Clay</td><td><0.0002</td><td rowspan="2">Highest pollutant concentrations</td><td rowspan="5">Range[1] 0.13 - 4.56
Median[2] 0.7</td><td rowspan="5">Range 19.4 – 371
Median 38.3</td><td rowspan="5">Range 0.3 – 6,240
Median 49.2</td><td rowspan="5">Range 0 – 3,940
Median 59.8</td><td rowspan="5">Range 10 – 1,100
Median 226.0</td></tr>
<tr><td>Silt</td><td>0.002-0.020</td></tr>
<tr><td>Very fine to fine sand</td><td>0.05-0.250</td><td rowspan="2">Largest mass fraction</td></tr>
<tr><td>Medium to coarse sand</td><td>0.25-2.0</td></tr>
<tr><td>Gravel</td><td>>2.0</td><td>Lowest pollutant concentrations</td></tr>
</table>

[1]Range reported across the following studies: Deletic et al. (2005) (Scotland), Breault et al. (2005) (Massachusetts), Townsend et al. (2002) (Florida), and SPU (2009) (Seattle).
[2]Median Value for street dirt concentrations from SPU (2009).

- Increased traffic
- Poor roadway conditions
- Application of winter non-skid materials
- Industrial land use
- Construction Activity
- Dense overhead tree canopy

Estimated recoverable solids and selected pollutant loads for residential land use in Minneapolis-St. Paul metropolitan area are shown in Table 10 and Table 11. It is expected that Thunder Bay area would have similar street PM loading with differences attributed largely to a longer winter maintenance season /shorter growing season. The per sweep recoverable loads listed in the Tables 10 and 11 are estimates of long-term averages. Individual sweeping events may vary significantly from the estimates. In addition to metal pollutants, nutrient pollution is associated with both the mineral fraction and the vegetative fraction of street sediments. Nutrient concentrations in street PM tend to follow a seasonal pattern, in particular in highly vegetated areas. For this reason estimated recoverable nutrients were linked to vegetation cycles (Table 11).

Cost-Effectiveness of Street Sweeping

Because street sweeping is a source control BMP, the cost of pollutant recovery is generally much cheaper than downstream treatment or end-of-pipe recovery. In Prior Lake, MN the average cost of solids recovery for 394 sweeping operations was US$0.18/lb (C$0.40/kg) (Kalinosky, et al, 2013). A similar study in Florida from 2008, the estimated the cost of solids recovery through street sweeping was US$0.10/lb (C$0.24/kg) compared to US$0.70/lb (C$1.70/kg) for catch basin cleaning, US$3/lb (C$7.28/kg) for baffled hydrodynamic separator, and US$26-47/lb (C$57 -104/kg) for other BMPs.

Of course the cost of sweeping, on a pollutant mass basis, depends on the pollutant of interest. Another important consideration is the cost operating and maintaining a sweeping program. These costs will vary depending on required investments in equipment and the local cost of labor and fuel. In the Prior Lake study, the average cost of operation was US$23/curb-mile, (st. dev US$7/curb-mile), or approximately C$/15.7/km. Based on a vehicle operational speed of 4.5 mph, the cost of operation was approximately C$70.75/hr. This cost did not include the purchase of a new vehicle, but did include vehicle depreciation and maintenance; fuel; vehicle operator wages and benefits; and scaled labor costs for other staff.

Sweeping Recommendations

The appropriate street sweeping schedule for any municipality depends on the objectives of the sweeping program. From a safety perspective, at a minimum, all street should be swept at least once in the spring to remove winter residuals and again in the fall wherever leaf collection practices are not sufficient to remove vegetative debris. To recognize other benefits of street sweeping such as reduced street flooding and improved water quality, streets should be swept more often with priority given to areas where storm sewers drain directly to surface waters or to critical stormwater infrastructure; and areas with higher pollutant accumulation on roadways (example heavy industrial land use). The Minnesota Department of Transportation (MNDOT) recommends 9-16 cleanings per year for arterials, heavy industrial, and commercial streets; 6-9 cleanings per year for light industrial; 4-9 cleanings per year for residential areas; and bi-weekly sweepings in central business districts (MNDOT, 2008). A reasonable target for initial efforts might be monthly sweepings during the snow free season with addition sweepings in commercial zones.

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Townsend T., Y. Jang, P. Thurdekoos, M. Booth, P. Jain, and T. Tolaymat. 2002. Characterization of Street Sweepings, Stormwater Sediments, and Catch Basin Sediments in Florida for Disposal and Reuse. University of Florida: Florida Center for Solid and Hazardous Waste Management.

Table 9 - Comparison of Street Sweepers by Type

Sweeper Type	Description	Observed Removal Efficiencies (%)	Benefits/Considerations	Cost Range[3]
Mechanical Broom	Gutter brooms move debris from the curb into the path of a main broom and conveyor belt.	55 -79[1] 9 - 40[2]	Efficiency with larger particle size fractions and larger objects (trash) typically comparable/better than other sweeper types. Low pick-up efficiency for fine particles.	$60,000-$140,000
Regenerative Air	Compressed air is directed onto the road surface loosening fine particle which are then vacuumed	89.4 – 99.4[1]	Typically use water spray to control fugitive dust losses. Water spray may reduce pick-up efficiency of fines.	$125,000-$250,000
Vacuum Filter	Gutter brooms move debris into the path of a vacuum nozzle and filtration system	86.5 -99.3[1] 31 - 94[2]	May capture particles as small as 0.2 µm. Higher power requirement and maintenance.	
High-Efficiency Mechanical	Mechanical sweeper combined with other technology.	81 – 91.5[1]	(Varies with technology).	

[1]Sweeper efficiency test results from Sutherland (2008).

[2]Observed field performance. Breault (2005).

[3]Based of MNDOT (2008). Price ranges are intended for relative comparison of technologies and vary significantly by make, model, and manufacturer.

Table 10 - Estimated recoverable solids sweeping once per month in residential land use. Solids recovery based on Kalinosky et. al (2013) (Minneapolis metropolitan area). Metals based on median concentrations reported in Table 1. Ranges represent variation in overhead tree canopy cover from low/none to dense.

Sweeper & Street Type	Spring Street Cleanings§ Estimated Solids Recovery per Sweep (kg/km)			Additional Street Cleanings, Estimated Solids Recovery per Sweep (kg/km)		
	Total Solids	Chromium	Zinc	Total Solids	Chromium	Zinc
Mechanical Broom*						
Curbed	60 - 75	<0.001	<0.01	28 - 32	<0.01	<0.005
Non-Curbed **	90 -150	<0.003	<0.03	42 - 64	<0.02	<0.009
Regenerative Air, Vacuum, or High-Efficiency Mechanical						
Curbed	100 - 125	0.003	0.02	45 - 50	0.02	0.009
Non-Curbed**	150 -250	0.005	0.05	68 -100	0.03	0.014

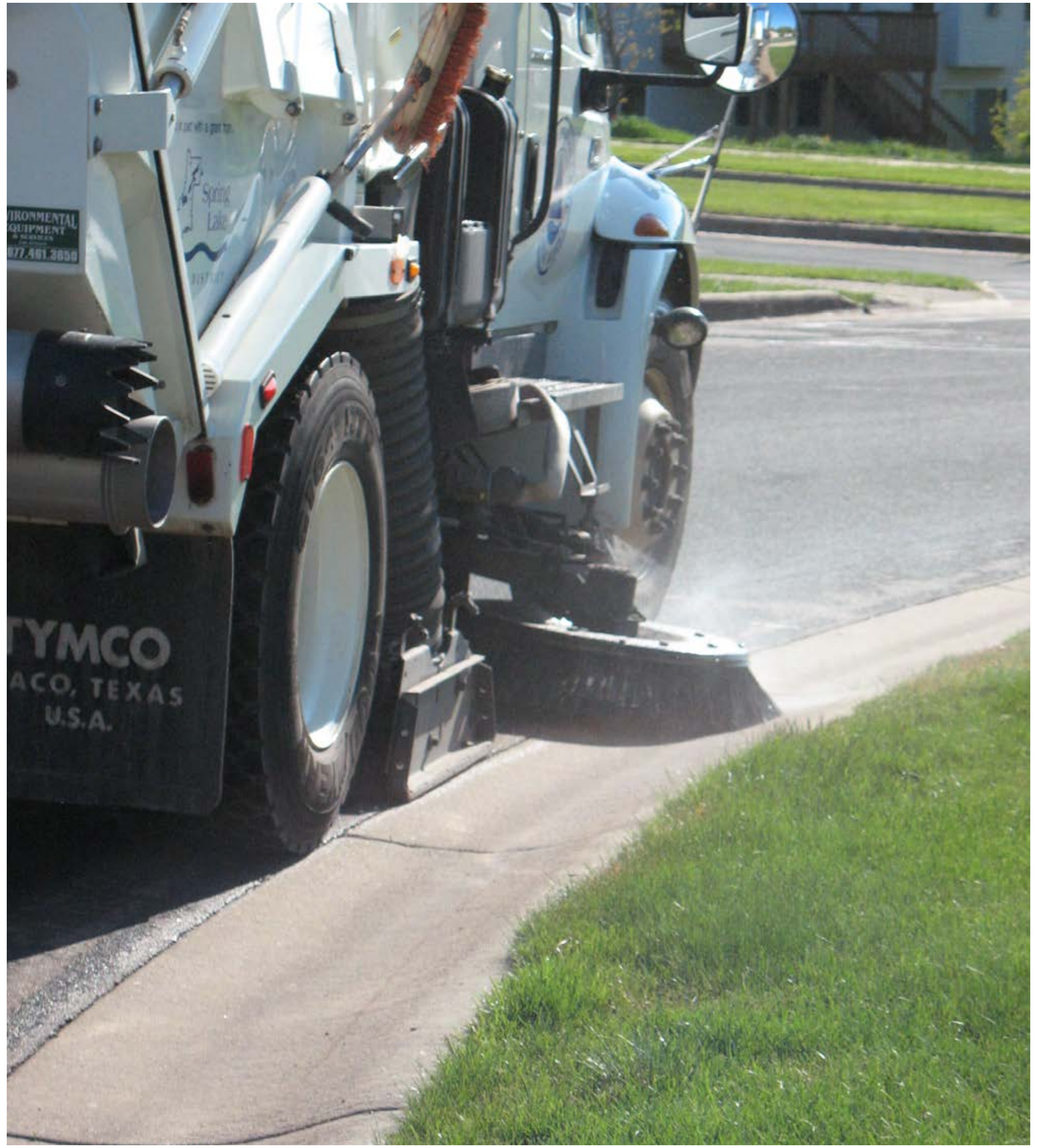
§Spring street cleaning includes sweeping operations conducted within the first two months of the start of operations after snow melt.

*Upper estimate for metals, pollutants tend to concentrate in the fine particle fraction that is not well removed by mechanical sweepers.

**Estimates assume that shoulders are at least partially void of vegetation and that the condition has the same effect of sediment loading as would a road condition rating of "fair to poor."

Table 11 - Estimated recoverable nutrient loads (regenerative air or vacuum type sweeper). Ranges represent variation in overhead tree canopy cover from low/none to dense.

Nutrient	Spring Street Cleanings (kg/km)	Mid-Growing Season (kg/km)	Fall Litter Drop (kg/km)
TP	0.05 – 0.06	0.03 – 0.04	0.04 – 0.07
TN	0.15 – 0.19	0.14 – 0.18	0.23 – 0.31



IV. Neighbourhood Pilot Raingarden Program

Targeting specific neighbourhoods or special areas for a volunteer based raingarden program is an excellent way to improve water quality, engage the community, and provide education to residents. The City should prioritize the locations of these programs, in coordination with its capital infrastructure replacement program, to address critical issues, take advantage of an interested and motivated citizen group, or a combination of these. Raingarden or BMP programs should be targeted only in areas where street improvements have been made. Pretreatment should be made a part of every BMP and maintenance responsibilities should be clearly defined for all BMPs prior to installation.

Once a neighbourhood or area has been identified, the following steps and procedures can help ensure a positive raingarden neighbourhood integration program:

1. Present informational seminar to interested residents. Topics to include:

- Raingarden overview
- What a raingarden will look like – examples of previous projects
- What the program is paying for – design, construction, materials, plants (determined by program authors)
- Maintenance responsibilities for each party – property owner expectations including activities, schedule, time, and money commitment
- Construction procedures and schedule

- Clarify what the particular program will not be providing
- Collect information (addresses) of property owners interested in having a raingarden

2. Desktop Analysis – Identifying potential properties and BMP locations by analyzing data, aerial photography, and additional information available in a particular area. This analysis is not a means to finalize BMP types and locations, but to narrow the potential sites, BMP types, and reduce field visit data collection and analysis. Aspects that can be analysed if data is available include:

- Topography – 3% slope is a maximum, less than this in narrow boulevard situations
- Utilities – water, sanitary, storm, gas, electric, communication, private utilities
- Available open space such as:
  - Boulevard widths – minimum of 2.5 meters wide
  - Lawns
  - Public space adjacent to streets, parking lots, or other large scale impervious
- Large trees
- Soil survey and preliminary infiltration rates
- Contamination potential – site history
- Neighbourhood watersheds

3. Field Investigation - the field visit allows design team to confirm or refute elements of the desktop analysis and identify additional elements that could impact raingarden siting such as:

- Downspout location and direction
- Signs of private utilities such as cable boxes, etc.
- Verify topography and watersheds
- Condition of contributing watershed – is the area stabilized or contributing sediment, is there a need for erosion control, etc.
- Soil borings if possible – hand augered sample for hand roll test a minimum (locate utilities prior to digging)
- Unique features

4. Combine Field analysis and desktop analysis and compare against list of interested residents.

- Rank potential sites for BMP based on:
  - Contributing watershed vs. BMP size
  - Location in landscape
  - Minimal impact on utilities or adjacent infrastructure
  - Visibility/ educational potential
- Check with specific residents of potential sites identified to verify or inquire about their interest

5. Create designs:

- Typical cross sections and planting plans for replicable BMP's (e.g. boulevard raingardens).
  - Create a sunny and shady planting palette for possible scenarios
  - Create a wet and dry planting palette for underdrain and no underdrain scenarios
  - Create grading, infrastructure, and planting plans for unique BMP's and sites
  - Prepare bidding documents

6. Verify designs with residents and property owners

- Create legal agreement with signatures
- Outline maintenance expectations
- Procedures for what happens if maintenance is not being performed
- Outline construction procedure

7. Construction

- Organize any volunteer efforts
- Identify and rectify construction issues – e.g. raingardens not draining, erosion issues

V. Public Cost Share Program

Another "low hanging fruit" option that could be explored is the development of a public cost share program to assist landowners with the implementation of stormwater management practices on private residential properties. In addition to water quality and quantity benefits, cost-share programs are excellent instruments for engaging the public and fostering stewardship which is likely to extend beyond the recipients backyard. Installation of a raingarden, stabilizing an erosion problem, establishing stream buffers and native vegetation, installing rain barrels or cisterns, directing gutter to green space, restoring degraded wetlands, and, in some cases, installing pervious pavers or green roofs are some of the practices that may be eligible for this type of program.

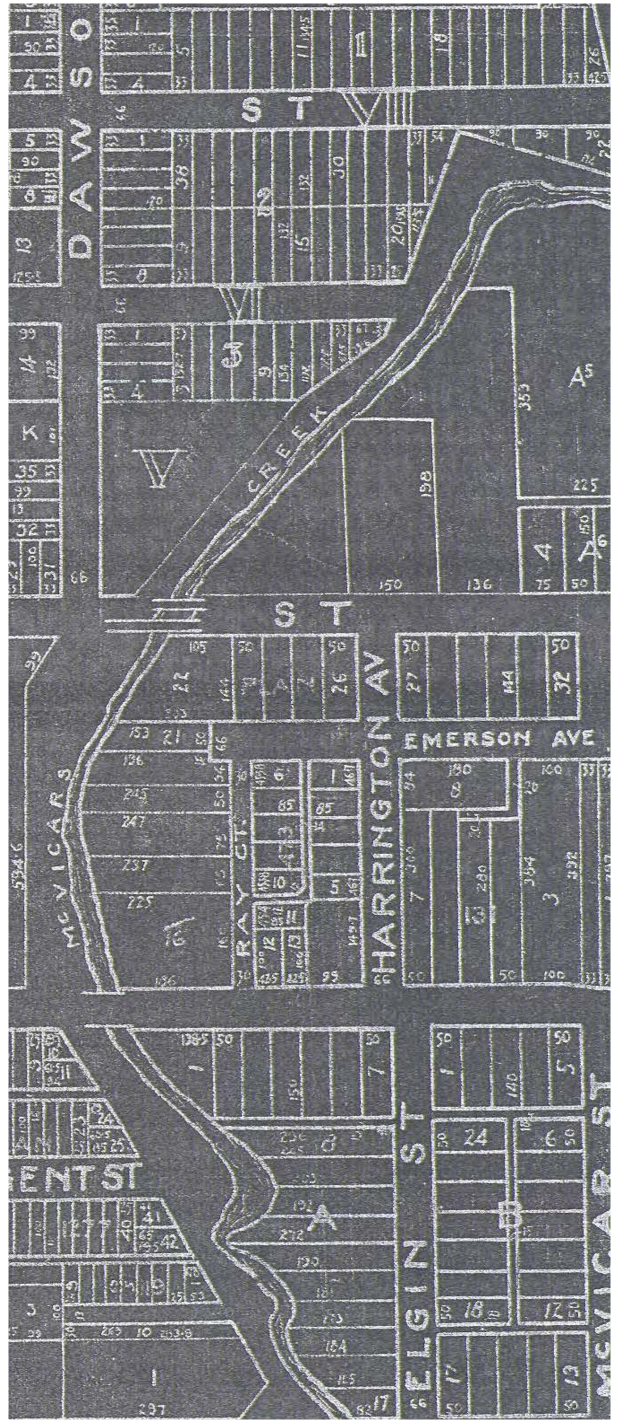
Elements of a Successful Cost-Share Program include:

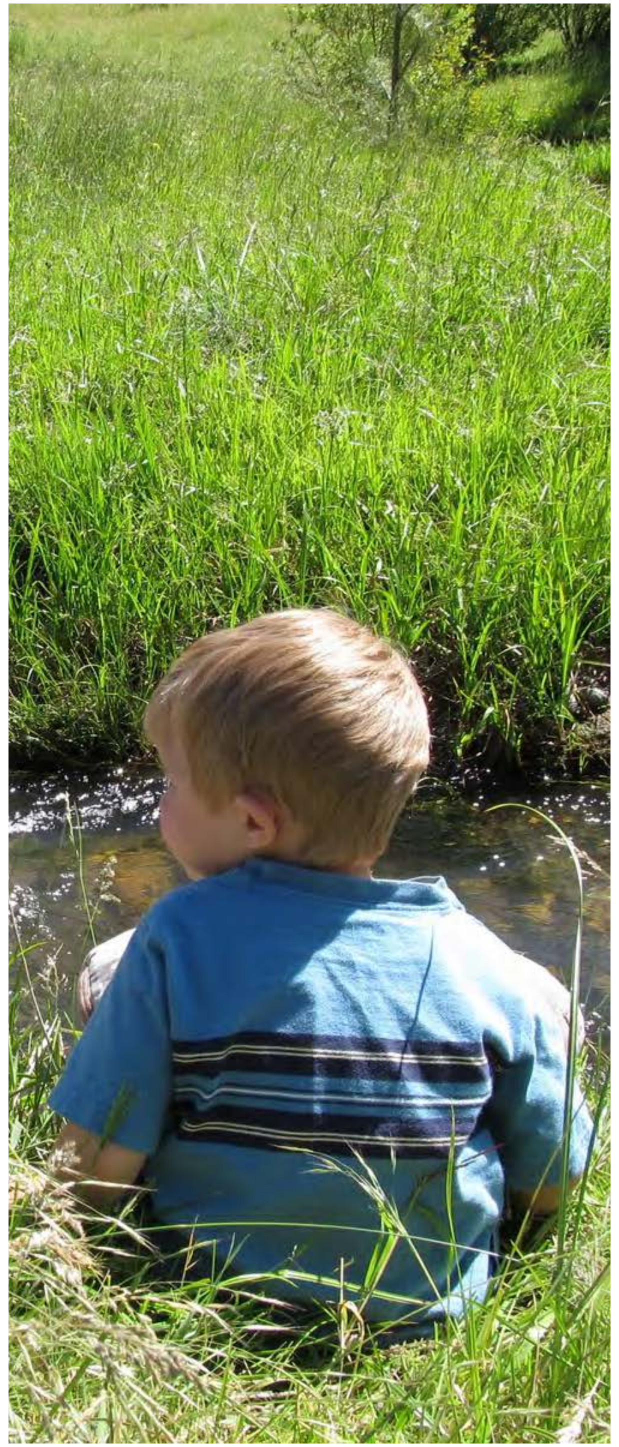
- Stakeholder-sponsored, free technical assistance including project location guidance and practice selection, site design, plant selection, construction guidance and/or tendering assistance to Cost-Share Program recipients

- Stakeholder-matched funding (for instance, 50% of total project costs up to a maximum of $5,000 with in-kind homeowner labor eligible for matching dollars). Percent of stakeholder-match or maximum contribution could increase if the landowner agrees to maintain the project for a longer duration.

- Landowner Maintenance Agreements – establishing stakeholder expectations and landowner obligations for land management of the practice for an expected term (minimum of 5-years, ideally 10 or more years)

- Recognition and award programs to strengthen environmental stewardship, public awareness and further interest in the Cost-Share Program





VI. Preserving & Utilizing Natural Drainage & Stormsewer Daylighting

In urbanized areas such as Thunder Bay, headwater streams are often buried, hidden, and forgotten. This tendency to disregard natural drainages and pipe our precious rainwater away still exists in many urbanizing communities. Preserving and protecting the small streams and ephemeral drainages is the best approach to ensure environmental and community benefits such as clean water and flood reduction.

Daylighting

In developed communities stream daylighting is a relatively new approach that brings these buried waterways back to life by physically uncovering and restoring them. Daylighting is an applicable technique to assist communities in reducing polluted runoff, addressing flash flooding concerns, and improving the livability of the built environment.

Preserving and Utilizing Natural Drainage

In developing communities existing natural drainages should be preserved and utilized. An open drainage system can work with natural landform and land uses to become a major design element of the community. Natural drainage systems help to integrate urban forms, giving the development an integral, more aesthetically pleasing relationship to the natural features of the site. Not only does the integrated site plan complement the land, but it can also save on development cost by minimizing earthwork and construction of expensive drainage structures.

A modest example of both daylighting and utilizing natural drainage ways can be seen in Figure 36. Currently within County Park an ephemeral drainage is unnecessarily piped to a McVicar Creek Tributary. In this instance the piping of this drainage not only limits the environmental and place-making opportunities of this site, but it is causing areas of standing water. Daylighting this pipe and utilizing/creating a natural drainage can reduce the risk of flooding and create character in this underutilized park. Furthermore, this approach provides economic benefits to communities through cost effective alternatives to ongoing culvert maintenance. The City would also gain ecological and water quality benefits, such as improved habitat and nutrient retention, by revitalizing a previously buried drainage stream.

Figure 36 - Daylighting and natural drainage proposal for County Park

It was apparent to the project steering committee that watershed policy and education is absolutely essential to the health and vitality of McVicar Creek and the community of Thunder Bay. Along those lines a number of strategies were identified and vetted via this study.

I. LID Training

Design and construction of Low Impact Development (LID) practices involves techniques and specifications that differ from both traditional development and traditional stormwater management. Failing to follow proper LID design and construction methods will likely result in poor performance, unsightly aesthetics, costly repairs, and ultimately deficient stormwater management.

To help avoid many of the common and costly LID mistakes made - ongoing training is highly recommend for the Thunder Bay community of designers, contractors, and related agency staff. LID has advanced significantly in the last two decades and current training can help communities like Thunder Bay avoid common mistakes made by earlier adopters.

LID training can occur across many different formats and on multiple LID subtopics, but for the purposes of introducing the topic to the community the following general approach is recommended. While the first may be more applicable to the engineering community and the later the contractor community, it is critical that all parties involved understand design decisions and necessary construction particulars.

Typical LID Training Outline

- Objective:
  - provide participants with practical LID construction knowledge to avoid failures, reduce risks, and avoid costly post-construction repairs
- Program - Phase 1: LID Theory and Design (1 full day of training)
  - *Introduction*
  - *Limitations of conventional stormwater management*
  - *Overview of LID philosophy, principles, and practices.*
  - *LID hydrologic analysis*
  - *LID site planning*
  - *LID site design and management practices*
  - *LID public participation and pollution prevention*
  - *Economic/environmental benefits of LID*
- Case Studies
  - *New technology and roadblocks to implementation*
  - *Current research directions*
  - *BMP selection, siting, and sizing*
  - *Detailed hydrologic analysis*
  - *Maintenance realities*
- Program - Phase 2: Construction (1 full day of training)
  - *LID construction: Why is it different?*
  - *Roles and responsibilities of LID construction Construction Team Members*
  - *Verification of LID practice design assumptions in the field*
  - *Integrating LID into mass grading and utility installation phases*
  - *LID consideration during the construction of buildings and pavement*
  - *Specifying and verifying LID materials*
  - *LID practice construction methods and finish grading*
  - *Stabilization and overwintering*
  - *Vegetation establishment*
  - *Certification and assumption*
- Plausible audiences/tracks
  - *Contractors and designers (engineering consultants, construction project managers, architects, landscape architects, and contractors)*
  - *Agency Staff (site inspectors plan reviewers, municipal stormwater management staff)*
- Instructor(s) - hire instructors that are both experienced with LID and can keep an audience energized

Cost

For facilitators who have already developed the content, the estimated cost for facilitating both Phase 1 and Phase 2 concurrently for a group of 100± in Thunder Bay is $5000±.

Example Course

An existing course to consider, which is currently being offered throughout Ontario is “Making it Work: How to Properly Construct Low Impact Development (LID) Stormwater Management.” This course is being facilitated by Education Program Innovations Center (EPIC) and is based on Credit Valley Conservation’s LID manuals and initiatives. The unsubsidized cost for this accredited (0.7 CEUs / 7 PDHs), day-long training session is $400 per individual.

The network organization of conservation authorities, Conservation Ontario, is also in the process of developing LID training.

II. Engineering & Development Standards

Historically, the goal of stormwater management was to move water off the landscape as quickly as possible and to reduce flooding concerns. Most of the urban areas within the McVicar Creek watershed, with few exceptions, were developed under this paradigm. Stormwater management is ever evolving, and in the last 10-years, there has been a significant shift to lot-level controls on new development and retrofitting of existing development in order to mitigate the impacts of urbanization on the natural environment. Those at the forefront of stormwater management now focus on keeping the raindrop where it falls and mimicking natural hydrology in order to minimize the amount of pollution reaching lakes, rivers, streams and wetlands, and to recharge groundwater.

The City's Engineering & Development Standards (2014 Edition) defers to the Ontario Ministry of the Environment (MOE) Stormwater Management Planning and Design Manual (March 2003) for stormwater quality control. While this design manual was considered state-of-the-art at the time of its publication, many of the agencies represented on the steering committee would agree that the environmental design criteria contained therein, too heavily focuses on end-of-pipe water quality storage requirements, provides little incentive for low impact development techniques, and may well be insufficient to preserve, protect, and enhance Ontario's water resources.

The following are recommended revisions and/or additions to the City Stormwater Management Design Standards that will better enable the City to preserve and enhance the quality of McVicar Creek.

Stormwater Quantity Control (Section 2.3.1.1)

- Revise the minimum control for post-development peak runoff rates to pre-settlement instead of pre-development (existing) runoff rates and specify the return frequency and duration of storm events for which this criteria will be assess. Pre-settlement land use assumptions should be set by the City via establishment of Curve Numbers based on pre-European settlement land cover and soil types.

- Incorporate a stormwater volume control criteria for new development and redevelopment. For new development it is recommended that the post-development runoff volume may not exceed the pre-settlement runoff volume for the 2-year, 24-hour event. For redevelopment and public linear (roadway) projects it is recommended that post-development runoff volume may not exceed existing conditions.

- Incorporate modeling requirements to account for the impacts of grading on soil structure, unless project specifications incorporate soil amendments to preserve infiltration and retention capacity of insitu soils.

- Expand the standards to specify modeling methodologies and/or credits for and to ensure consistency in design and performance of low impact development techniques.

- Consider incorporating requirements for discharge from new development through a subsurface system, flow spreader or other device that discharges water through or across the ground to lower discharge temperature to that of the ambient soil before discharge to McVicar Creek.

Stormwater Quality Control

- Enhance the stormwater quality control performance measures (beyond MOE's enhanced level of protection) setting a higher performance goal TSS, say 90% and consider incorporating a provision for nutrient reduction, say 60% Total Phosphorus (TP) reduction.

- Require sequencing of preferred stormwater management methods with emphasis on LID, infiltration and filtration over sedimentation practices, where feasible. A suitable sequencing of stormwater practices for the City is as follows:
  1. Low Impact Development techniques to limit runoff
  2. On-site infiltration
  3. Biofiltration
  4. Filtration
  5. Wetland treatment system
  6. Extended detention
  7. Wet detention
  8. Other methods

- Incorporate specifications of pretreatment measures for infiltration or filtration facilities (e.g. long-term removal of at least 50 percent of sediment loads).

- Consider explicit stormwater quality control standards for redevelopment and public linear (roadway) projects.

Erosion Protection & Sediment Control

- Significantly expand standards to require submittal of a formal erosion control plan showing proposed methods of retaining waterborne sediments on site during the period of construction and showing how the site will be restored, covered, or revegetated after construction, including a timetable for completion.

- Specify minimum control and compliance measures for topics such as:
  1. Implementation schedule and construction sequencing
  2. Critical erosion areas
  3. Limits of disturbed areas
  4. Stabilizing exposed and soil stockpile areas
  5. Stabilizing waterways and outlets
  6. Protecting adjacent properties from erosion
  7. Storm sewer inlet protection
  8. Riprap at culvert outfalls
  9. Rock construction entrances
  10. BMP construction details
  11. Horizontal slope grading
  12. Erosion control at construction entrances and exits (i.e. mud-mats)
  13. Permanent erosion control
  14. Specify minimum maintenance and inspection frequencies and reporting requirements

Stream Buffers & Streambank Alterations

Natural vegetation bordering the bed and banks of lakes, streams and wetlands serves a critical role in maintaining the ecological function of and societal benefits deriving from those water resources. Purposes served by vegetative buffers include bank and shoreline stabilization; erosion prevention; filtration of nutrients, sediments, and other pollutants from storm flows; protection of stream beds and banks and mitigation of downstream flooding through moderation of peak flows both into and within the resource; regulation of in-stream temperatures; preservation of aquatic and terrestrial habitat; protection of scenic resources; and maintenance of property values.

It is recommended that stream buffers be established for McVicar Creek and enforced on all new development activity. Recommended draft stream buffer criteria and standards include:

- Stream buffer minimum width of 15 meters as measured from the top of bank

- Expansion of the stream buffer minimum width to encompass:

1. Steep slopes (12% over a distance of greater than 15 meters)
2. Floodplain Area
3. Wetland (Provincially Significant or otherwise)

- Easement and monumentation requirements including:

1. Before any disturbance of ground vegetation or contour, or placement of any structure on the ground, a declaration, easement, or other instrument acceptable to the City memorializing the requirements of said stream buffer.
2. The buffer shall be indicated by either permanent, flush to the ground markers or permanent, post markers at the buffer's upland edge, with a design and text approved by the City.

- Prohibiting the following activities with the stream buffer:

1. Creating impervious cover
2. Excavating fill or placing fill or debris
3. Altering vegetation, except for (i) vegetative enhancements, as approved in writing by the City; and (ii) the removal of invasive exotic species or of trees for disease control or revegetation.
4. Locating of roads or utilities, except as authorized by the City after due minimization of impact including, but is not limited to, approach roads and rights-of-way that are perpendicular to the crossing and of a minimum width consistent with use and maintenance access needs.

- Where streambanks are altered, specify that soil-bioengineering techniques shall be used for streambank restoration unless it is demonstrated that it is infeasible to repair the erosion problem using such techniques. The following criteria should apply to soil-bioengineering projects:

1. The resultant project shall be structurally stable. Special emphasis shall be given to the stability of the toe of slope where traditional engineering techniques may be more appropriate.
2. Native vegetation shall be used in all cases. Preferable species include those that form dense root systems or can be planted from cuttings.
3. Soil-bioengineering projects shall include a long-term maintenance plan which will ensure that small erosion spots are corrected and native plant materials are successful.

III. Water Resource By-Laws

In addition to updating the Engineering & Development Standards, and in the absence of "Universal Site Plan Control", the City should create a stormwater management by-law requiring all new development and redevelopment to adhere to the City's Engineering & Development Standards, specifically with respect to stormwater management, Erosion Protection & Sediment Control and Stream Buffers & Streambank Alterations. This will ensure consistency across all developments, and will also aide in expanding the local expertise in stormwater management, LID's, and BMP's.

While the LRCA administers Ontario Regulation 180/06 under the Conservation Authorities Act, which regulates development in floodplains and wetlands it is understood that in the case of wetlands only Provincially Significant Wetlands are regulated due to a lack of data related to assessed wetlands. This appears to be a significant, if not alarming, gap in regulation that could prove to be problematic for the continued health of McVicar Creek considering that "there is relatively significant potential for mineral aggregate supply within the City" (Thunder Bay Official Plan 2002 Section 2, Chapter 9 – Mineral Aggregate Resources, Mineral Resources, and Mines). More specifically, Figure 1 of the Official Plan identifies much of the McVicar Creek watershed north of the Thunder Bay Expressway as areas of moderate or high aggregate potential. Given that the Official Plan permits pits and quarries, as well as mineral or aggregate exploration, within the "Rural," "Rural Residential," "Major Open Space," and "Utilities" land use designations, beyond the "Urban Area Limit," further examination by the City of its existing By-Laws, guidelines established by the Ministry of the Environment, and coordination with LRCA with respect to its implementation of wetland and floodplain regulation under the Conservation Authorities Act is warranted to ensure that there is sufficient protection of the headwaters of McVicar Creek in light of the potential for aggregate extraction.

IV. Stream Crossing Guidance

Although public awareness of environmental issues is rapidly expanding in Thunder Bay, few people consider the effects of road crossings and other infrastructure on the quality of stream habitat. The design and condition of a stream crossings determine whether a stream behaves naturally and whether biota can migrate along the stream corridor.

Stream continuity has not often been considered in the design and construction of stream crossings (culverts and bridges). Many crossings are barriers to fish and wildlife. Even crossings that were not barriers when originally constructed may now be barriers because of stream erosion, mechanical breakdown of the crossings, or changes in the upstream or downstream channel shape. Fortunately, we have learned how to design stream crossings that allow wildlife unrestricted access to a watershed, maintain natural stream conditions, and help protect roads and property from some of the damaging effects of floods.

There are three primary types of stream crossing problems—undersized crossings, shallow crossings, and crossings that are perched—can be barriers to fish and wildlife and lead to several common consequences. Recognizing poor stream crossings and their consequences is an important step in evaluating whether crossings should be fixed or replaced.

1. Undersized crossings restrict natural stream flow, particularly during high flows, causing several problems, including scouring and erosion, high flow velocity, clogging, ponding, and in some cases, washouts. Crossings should be large enough to pass fish, wildlife, and high flows.

2. Shallow crossings have water depths too low for many organisms to move through them and may lack appropriate bed material. Crossings should have an open bottom or should be buried into the streambed to allow for substrate and water depths that are similar to the surrounding stream.

3. Perched crossings are above the level of the stream bottom at the downstream end. Perching can result from either improper installation or from years of downstream bed erosion. Crossings should be open-bottomed or sunk in the bed to prevent perching.

The development and adoption of stream crossing guidance would help protect the headwaters of McVicar Creek, which is under development pressure and mitigate the ill-effects of existing crossing problems within Thunder Bay. The following general guidance can accommodate wildlife and protect stream health while reducing expensive erosion and structural damage.

1. Type of Crossing

- General: Spans (bridges, 3-sided box culverts, open-bottom culverts or arches) are strongly preferred.
- Optimum: Use a bridge.

2. Embedment

- All culverts should be embedded (sunk into stream) a minimum of 2 feet (.6 meters), and round pipe culverts at least 25%.
- If pipe culverts cannot be embedded this deep, then they should not be used.
- When embedment material includes elements >38 cm in diameter, embedment depths should be at least twice the D84 (particle width larger than 84% of particles) of the embedment material.

3. Crossing Span

- General: Spans channel width (a minimum of 1.2 times the bankfull width of the stream).
- Optimum: Spans the streambed and banks (at least 1.2 times bankfull width) with sufficient headroom to provide dry passage for wildlife.

4. Openness

- General: Openness ratio (cross-sectional area/crossing length) of at least 0.82 feet (0.25 meters). The crossing should be wide and high relative to its length.
- Optimum: Openness ratio of at least 1.64 feet (0.5 meters) and minimum height of 6 feet. If conditions significantly reduce wildlife passage near a crossing (e.g., steep embankments, high traffic volumes, and physical barriers), maintain a minimum height of 8 feet (2.4 meters), and an openness ratio of 2.46 feet (0.75 meters).

5. Substrate

- Natural bottom substrate should be used within the crossing and it should match the upstream and downstream substrates. The substrate and design should resist displacement during floods and maintain an appropriate bottom during normal flows.

6. Water Depth and Velocity

- Water depths and velocities are comparable to those found in the natural channel at a variety of flows.

This section modified from the Massachusetts Stream Crossing Handbook 2nd Edition June 2012

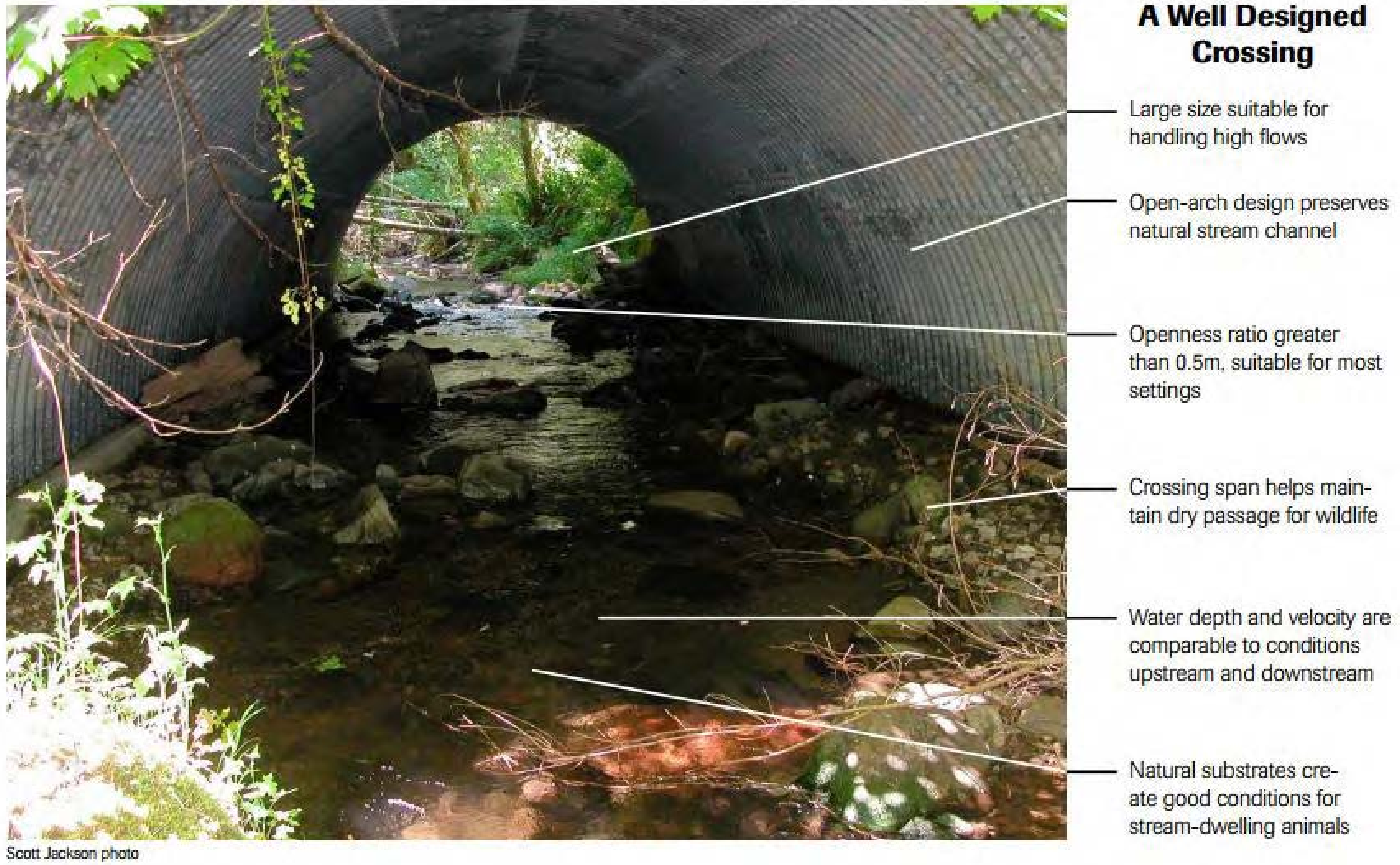


Figure 37 - Example of a well-executed crossing design. (Image courtesy of the State of Massachusetts Division of Ecological Restoration.)


Implementation Plan

A. Prioritization of Strategies

Prioritization of McVicar Creek protection and rehabilitation strategies was necessary as all strategies cannot be implemented concurrently. Resource limitations and data deficiencies dictate that this aggressive initiative be broken into phases. Project stakeholders therefore prioritized vetted strategies based on a number of qualitative evaluations:

- Dependency on the initialization and/or completion of other strategies
- Emanate threat/opportunity
- Cost-Benefit Analysis
- Education opportunity and potential to build momentum

The following table is an outcome of this prioritization. Specific dates and timing for completion was intentionally unspecified, but the initiative was delineated into three phases.

Table 12 - Prioritization of Strategies

CATEGORY	STRATEGY	PHASE/ PRIORITIZATION	CRITICAL DEPENDENCY
A. UNDERSTANDING THE RESOURCE	1. MONITORING PROGRAM	1ST	
	2. SPATIAL DATA	1ST	
	3. WATERSHED MODEL	2ND	A1 & A2
B. PROJECTS & PROGRAMS	1. PUBLIC PARK STORMWATER RETROFITS	1ST	
	2. GREEN STREETS & ALLEYS (REAR LANES)	3RD	
	3. SEDIMENT - STREET SWEEPING & SOURCE CONTROL	1ST	
	4. NEIGHBORHOOD PILOT RAINGARDEN PROGRAM	2ND	
	5. PUBLIC COST SHARE PROGRAM	3RD	
	6. PERSERVING & UTILIZING NATURAL DRAINAGE & STORMSEWER DAYLIGHTING	2ND	
C. POLICY & EDUCATION	1. LID TRAINING	1ST	
	2. ENGINEERING & DEVELOPMENT STANDARDS	3RD	A1, A2 & A3
	3. WATER RESOURCE BYLAWS	3RD	A1, A2 & A3
	4. STREAM CROSSING GUIDANCE	3RD	A1

Note - Estimated costs identified for 1st Phase/Prioritization strategies in Chapter V

B. Potential Project Partners & Associated Roles

Participation

All stakeholders involved in the development of this plan expressed a strong interest in fostering the initiatives identified. Furthermore, stakeholders expect that their past contributions be recognized, utilized, and archived and that they have an opportunity to further refine and advance the McVicar Creek Preservation and Rehabilitation Plan.

The following table is a characterization of probable key participants for each strategy. The designations do not mandate involvement nor are they necessarily a reflection of funding.

City of Thunder Bay Departments
Infrastructure & Operations (INOPS)
Engineering (ENG)
Environment (ENV)
Roads (RDS)
Parks (PKS)
Central Support (CNS)

Table 13 - Phase 1 Participation

PHASE	CATEGORY	STRATEGY	SUBTASKS/ COMPONENTS	(INOPS Division) Thunder Bay	Lakehead Region Conservation Authority	Lakehead University	Ontario	ecosuperior	Steelhead	Thunder Bay District Stewardship Council	Environment Canada	Other
1	Understanding the Resource	Monitoring Program	Geomorphic		√	√	√					
			Fish		√	√	√					
			Macroinvertebrates		√	√	√					
			Local Climate		√							
			Quantity	ENV	√		√					
			Quality	ENV	√		√					
			Thermal	ENV	√	√						
			Surface-Ground Water Interaction	ENV	√	√						
		Spatial Data	Landform			√					√	
			Soils				√				√	
			Surficial Geology				√				√	
			Landcover		√	√					√	
			Stormsewer	ENG, ENV								
			Wetlands		√	√					√	
			Watershed & Sewershed	ENG, ENV	√	√						
	Projects & Programs	Public Park Stormwater Retrofit	Design & Const.	PKS, ENG								
			Maintenance	PKS								
		Street Sweeping		RDS								
	Policy & Education	LID Training		ENG		√		√				

Table 14 - Phase 2 Participation

PHASE	CATEGORY	STRATEGY	SUBTASKS/ COMPONENTS	(INOPS Division) Thunder Bay	Lakehead Region Conservation Authority	Lakehead University	Ontario	ecosuperior	Steelhead	Thunder Bay District Stewardship Council	Environment Canada	Other
2	Understanding the Resource	Watershed Model		ENG	√							
	Projects & Programs	Neighborhood Pilot Raingarden Program	Design & Construction	ENV, ENG								
			Public involvement	ENG				√				
			Post occupancy evaluation	ENG				√				
		Preserving & Utilizing Natural Drainage & Stormsewer Daylighting		PKS, ENG								
	Policy & Education	*No new program this phase*										

Table 15 - Phase 3 Participation

PHASE	CATEGORY	STRATEGY	SUBTASKS/ COMPONENTS	(INOPS Division) Thunder Bay	Lakehead Region Conservation Authority	Lakehead University	Ontario	ecosuperior	Steelhead	Thunder Bay District Stewardship Council	Environment Canada	Other
3	Under-standing the Resource	*No new program this phase*										
	Projects & Programs	Green Streets & Alleys		RDS, ENG								
		Public Cost Share Program	Project evaluation & design assistance	ENG				√				
			Administration	ENG				√				
	Policy & Education	Engineering & Development Standards		ENG, ENV, RDS	√						√	
		Water Resource Bylaws		ENG, ENV	√						√	
		Stream Crossing Guidance		ENG, ENV	√						√	

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