

# Upper West Side - Fluvial Geomorphological Assessment Twenty Road West, City of Hamilton



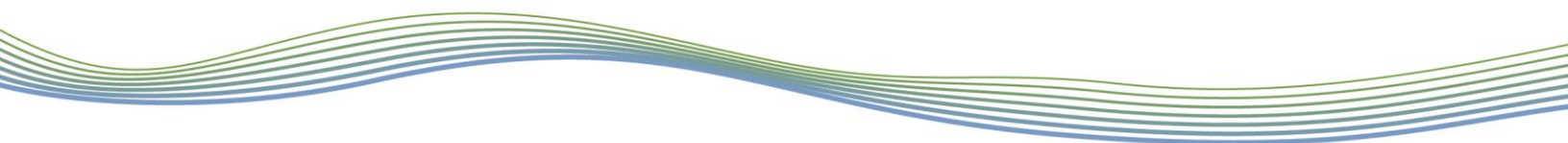
Prepared for:  
Upper West Side Landowners Group (UWSLG)  
c/o Corbett Land Strategies Inc.  
483 Dundas St. West, Suite 212  
Oakville, Ontario  
L6M 1L9

June 12, 2020  
PN18013

GEO

M O R P H I X

Geomorphology  
Earth Science  
Observations



Report Prepared by: GEO Morphix Ltd.  
2800 High Point Drive  
Suite 100A  
Milton, ON L9T 6P4

Report Title: Upper West Side Draft Plan of Industrial Subdivision  
Fluvial Geomorphological Assessment - Update

Project Number: PN18013

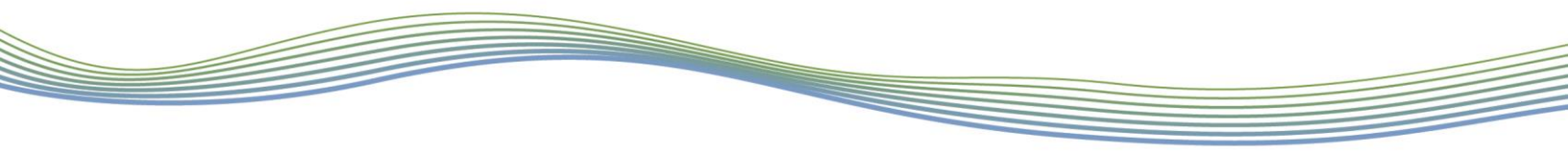
Status: Draft

Version: 2.0

Prepared by: André-Marcel Baril, M.Sc.; Carolina Villardo Mantega,  
M.Sc

Approved by: Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP

Approval Date: June 12, 2020



## Table of Contents

List of Appendices .....	2
1 Introduction.....	3
2 Background Review .....	3
3 Branch and Reach Delineation.....	3
4 Historical Assessment .....	5
5 Existing Conditions .....	7
6 Reach Observations .....	8
6.1 Branch TTMC-2 .....	8
6.2 Branch TTMC-3 .....	9
6.3 Branch TTMC-5 .....	11
6.4 Branch TTMC-6 .....	12
6.5 Branch TTMC-7 .....	13
6.6 Branch TTMC-8 .....	13
6.7 Branch TTMC-9 .....	14
7 Headwater Drainage Feature Classification .....	14
7.1 Management Recommendations .....	17
8 Erosion Mitigation.....	18
8.1 Preliminary Recommendations .....	18
9 Conceptual Channel Design.....	18
9.1 Channel Corridor .....	19
9.2 Habitat Restoration.....	20
9.3 Recommendations for Detailed and Conceptual Design.....	21
10 Monitoring Plan.....	21
10.1 Pre-Development Erosion Monitoring .....	21
10.2 Channel Design Monitoring .....	22
11 Conclusions and Next Steps .....	22

## List of Appendices

- Appendix A Reach Delineation
- Appendix B Historical Aerial Photographs
- Appendix C Photographic Record
- Appendix D Headwater Drainage Feature Classification



## 1 Introduction

This report provides a fluvial geomorphological assessment for the Upper West Side Study Area, bounded by Twenty Road West to the north, Upper James Street to the east, Dickenson Road West to the south, and the former Glancaster Golf and Country Club to the west. Characterization and management recommendations for the reaches within the property are included based on desktop and field assessments of several watercourses which are part of the Twenty Mile Creek Watershed. Notably, most watercourses within the subject site are classified as headwater features. This accomplish this, the report includes the following:

- Background review of existing documents related to the development lands, including topography, physiography, and geology maps of the study area
- Reach delineation for all watercourses in the study area
- A historical assessment of the channels within the study area using aerial imagery provided by the McMaster University Aerial Photo Collection and Google Earth Pro
- Detailed descriptions of channel characteristics based on field observations
- Headwater Drainage Features Assessments to provide management recommendations for the channels within the property
- High-level conceptual channel designs to provide recommendations for the restoration of the features to be retained on site
- Proposal for a monitoring protocol to mitigate impacts on channels within the study site

## 2 Background Review

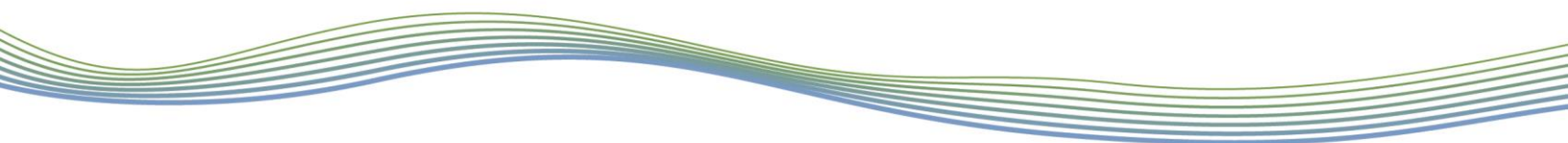
Channel planform and morphology are largely governed by the flow regime and by the type and availability of sediment (i.e. surficial geology) within the stream corridor. Physiography, riparian vegetation, and land use will also influence the channel. These factors provide insight to the existing conditions and perception to the future potential changes as they relate to a proposed activity.

Physiographically, the study area is in the northern portion of the Haldimand Clay Plain region, which is characterized as a stratified clay plain which has a heavy texture and low drainage (Chapman and Putnam, 1984). Interestingly, the subject site is specifically located in a trough between two low-relief till moraines, which direct surface water along the generally eastwardly sloping plain between the features (Chapman and Putnam, 1984). The surficial geology of the subject site is composed of fine-textured glaciolacustrine deposits consisting of massive to well laminated silt and clay, with minor sand and gravel (OGS, 2010). The quaternary geology is consistent with surficial conditions, and is described as silt and clay, with minor sand, basin and quiet water deposits (OGS, 2010).

The current land cover within the study area consists mainly of agricultural land, with three woodlots, three wetlands, and four ponds of varying sizes also present within the subject lands (NRSI, 2013). Surrounding the subject site, land use includes a golf course to the west, residential development to the north, agriculture to the east and the John C. Munro Hamilton International Airport to the south.

## 3 Branch and Reach Delineation

The study area extends north-south from Twenty Road West in the north to Dickenson Road West to the south. The east-west extent is roughly bounded by a hedgerow located 580 m west of Upper James



Street to the east and the former Glanaster Golf and Country Club to the west, in Hamilton, Ontario. Within this area, 6 headwater systems were delineated, and assessed.

To organize the watercourses within the study area into functional units, branches, which are loosely defined here as tributaries draining directly into Twenty Mile Creek, were delineated as independent sub-catchments. Reaches, which are homogeneous segments of channel used in geomorphological investigations, were then delineated within each branch.

Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity.

Reaches are delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Hydromodification, due to tributary inputs
- Soil type and surficial geology
- Certain types of anthropogenic channel modifications

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), Brierley and Fryirs (2005), and the Toronto and Region Conservation Authority (2004).

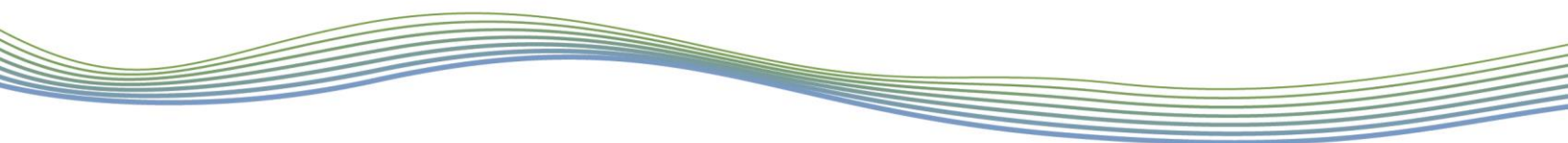
Reaches were initially identified through a desktop assessment completed by GEO Morphix based on changes to riparian conditions, channel morphology, and tributary confluences. During the three field assessments completed in 2019, reach delineation was field verified within the subject lands. A reach map is provided in **Appendix A**.

Branch **TTMC-2** originates approximately 250 m west of the study area within the adjacent agricultural field, before entering a woodlot at the southwest border of the property. The tributary conveys flows eastwards until meeting a large online pond beyond the eastern limit of the subject lands. The surrounding land use is primarily active agricultural fields, with a small woodlot also present towards the western extent of the property. Downstream of the study area, the main stem of the tributary conveys flows for approximately 1750 m before merging with Twenty Mile Creek.

Eight reaches were identified within the subject lands and field verified in 2019. Downstream of the property, eight additional reaches were identified on the main stem of the tributary, and three more were found on a secondary branch based on a desktop assessment.

Branch **TTMC-3** originates within the subject lands near the southwestern corner of the former orchard, and conveys flows eastwards through the central portion of the study area. Surrounding land use is predominantly agricultural, with the reach also passing along the southern limit of the aforementioned orchard and a provincially significant wetland (PSW) located nearby to Upper James Street. Within the PSW, a branch of the tributary forms a confluence with the mainstem of TTMC-3. Beyond the subject lands, on the east side of Upper James Street, the tributary meets Twenty Mile Creek.

Twelve reaches were defined within the subject lands, including two located in a secondary branch. No reaches were delineated downstream of the subject area as it was determined Reach TTMC3-1, which originates within the study area, ends at the mainstem of Twenty Mile Creek.



Branch **TTMC-5** originates near Glancaster Avenue and forms a series of ponds within the former Glancaster Golf and Country Club before entering the subject lands in the northern portion of the property's western border. The branch conveys flows on a generally north eastwardly path before leaving the subject lands near the corner of Twenty Road West and Twentyplace Boulevard. Within the subject lands, the branch transects four agricultural fields and passes along the northern limit of the central orchard area. Downstream of the property, the stream enters a series of storm water management (SWM) ponds constructed as part of the residential development north of Twenty Road, before forming a confluence with Twenty Mile Creek east of the development.

Seven reaches were delineated within the subject lands, and three additional reaches were defined downstream of the property.

Branch **TTMC-6** originates within the subject lands near the hedgerow associated with orchard property. The branch conveys flows northeastwards through 2 agricultural fields and the orchard itself before discharging into the ditch associated with Twenty Road. The total length of the branch is approximately 670 m before reaching the roadside ditch.

Four reaches were delineated within Branch **TTMC-6**. No reaches were identified further downstream as the ditch forms a confluence with Branch **TTMC-5** before conveying flows across Twenty Road and through the urban development to the north.

Branch **TTMC-7** conveys flows northeastward and consists of only two reaches, one of which is located within the subject lands. The branch originates within a small private property located at Twenty Road approximately 100 m west of Garth Street before being conveyed through a small culvert into an agricultural field within the subject lands. This reach then discharges into the roadside ditch at Twenty Road.

Branch **TTMC-8** originates within the former Glancaster Golf and Country Club and conveys flows north eastwards through the north west corner of the study area. Land use in the immediate vicinity of the branch is predominantly agricultural. The branch briefly exits the subject lands as it passes through the south east corner of a non-participating residential property, within which a small on-line pond is located. After re-entering the subject lands, the channel is clearly defined whereas upstream the channel lacked banks. The branch then crosses Twenty Road West through a culvert which discharges into a woodlot located 140 m west of Garth Street, north of Twenty Road West. Downstream of the woodlot, the channel is conveyed through storm water pipes and ponds within the residential development before forming a confluence with Twenty Mile Creek within the hydro corridor north of the residential development. An additional sub-branch was delineated immediately to the north within the subject lands, Reach 8-3-3. This sub-branch only contained one reach, which conveys flows northeastward through an agricultural field. It is unknown specifically where a confluence between these two sub-branches is located, as they both become piped within the developed land to the north.

Six reaches were delineated within Branch **TTMC-8**, with an additional 5 located downstream of the study area.

## 4 Historical Assessment

Historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Our assessment used historical imagery retrieved from the McMaster University Aerial Photo Library, and Google Earth Pro. A summary of the historical changes to the watercourses are provided in **Table 2**. Aerial photographs are provided in **Appendix B**.

**Table 2 – Historical Assessment**

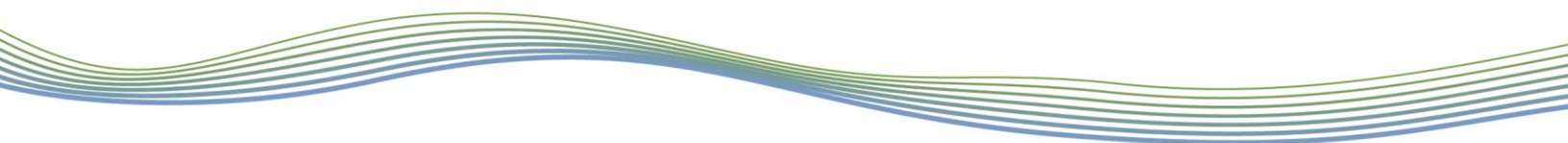
Watercourse	1952	1959	2005	2017
<b>TTMC2</b>	Land use near the channel is predominantly agricultural, with some woodland and grassland at the upstream extent of the property. A riparian buffer is predominantly absent within the subject lands, apart from the upstream and downstream extents of the property where trees are present. Downstream of the subject lands, the channel has a treed riparian buffer. The channel is generally straight.	No observable changes to land use, riparian conditions or channel planform since 1952	The only significant change to Reach TTMC-2 since 1959 is the establishment of a large online pond approximately 600 m west of Upper James Street, downstream of the subject site. Although land use nearby to the subject site has changed, including the construction of Glancaster Golf Course to the west of the property.	The only observable change to Branch TWH1, or the land use surrounding it, was the removal of a row of trees south west of the woodlot within which the online pond is located.
<b>TTMC3</b>	Land use near the channel is almost exclusively agricultural within the subject lands, including an orchard located roughly in the middle of the property. No riparian buffer is present on the branch.	Between 1952 and 1950 the only significant change was the expansion of the orchard, and the creation of a large online pond to its south which is a part of the branch.	Between 1959 a large wetland feature has formed at the downstream extent of the reach, nearby to Upper James Street. As well, Glancaster Golf Course was constructed to the west of the subject site.	No observable changes to land use, riparian conditions or channel planform since 2005.
<b>TTMC5</b>	Land use near the channel within the property is agricultural and includes a central orchard. The channel is generally straight within the subject site.	Between 1952 and 1959 the orchard property has expanded to the south of the channel. No changes to channel planform were observed as a consequence of this change.	Between 1959 and 1952 Glancaster Golf Course was constructed to the west of the subject site, which includes the presence of a pond impounding flows on Branch TTMC-5.	No observable changes to land use, riparian conditions or channel planform since 2005.

Watercourse	1952	1959	2005	2017
<b>TTMC6</b>	Branch TTMC6 is a sinuous channel which conveys flows through three agricultural fields within the subject site. Within the property, the channel lacks riparian vegetation whereas Downstream the channel is flanked by a woodlot to the west.	The only notable change to the channel is the expansion of the orchard to the north of the branch in the central part of the subject property. Here, the channel has retained a moderate riparian buffer.	No significant changes to the branch are observed between 1959 and 2005, within the subject property. Downstream, the channel has been piped to facilitate the development of a subdivision	No observable changes to land use, riparian conditions or channel planform since 2005.
<b>TTMC7</b>	Branch TTMC7 conveys flows through a single agricultural field within the subject site. Downstream, the branch appears to enter a woodlot. Land use for the branch is exclusively agricultural, and no discernible riparian buffer is present.	No observable changes to land use, riparian conditions or channel planform since 1952	Between 1959 and 2005 the agricultural field has been replaced by a residential property, and the channel has maintained its planform through the area. The feature still lacks a riparian buffer, and a small pond has been installed.	No observable changes to land use, riparian conditions or channel planform since 2005.
<b>TTMC8</b>	Branch TTMC-8 conveys flows through agricultural fields within and has no discernible riparian buffer. The planform of both features is generally straight or has low sinuosity.	No observable changes to land use, riparian conditions or channel planform since 1952	Between 1959 and 2005 the construction of Glanaster Golf Club upstream of the site has re-aligned the drainage on TTMC-8. As well, a short section of the branch has been interrupted by a residential development. The planform and lack of riparian buffer is maintained through the residential section.	No observable changes to land use, riparian conditions or channel planform since 2005.

## 5 Existing Conditions

Reach observations and channel measurements were collected on April 3, June 8 and August 15, 2019 by GEO Morphix Ltd. and Natural Resource Solutions Inc. (NRSI). Because all features on site were determined to function as headwater drainage features, the TRCA and CVC Headwater Drainage Feature





Assessment methodology (2014) was applied to evaluate these channels. This method requires three visits to understand the variability in flow and channel morphology throughout the year, which is required to determine the appropriate management classification to apply to each reach. This management classification is determined based on principles of hydrology, geomorphology and ecology. To provide context, a photographic record has been included in **Appendix C**.

## 6 Reach Observations

### 6.1 Branch TTMC-2

Reach **TTMC2-9** is characterized as a poorly-defined swale which conveyed flows through agricultural fields located in the south-central portion of the subject lands. The feature is 280 m long and has no riparian vegetation, with bed and banks occupied by crops. Channel substrate was indistinguishable from the surrounding fields, and consisted of clay and silt. Water with substantial flow was observed during the Spring visit, but the feature was dry in the second Spring and summer visits resulting in a flow regime classification of ephemeral. The low gradient feature had an average bankfull width of 1.4 m, and average bankfull depth was 0.22 m.

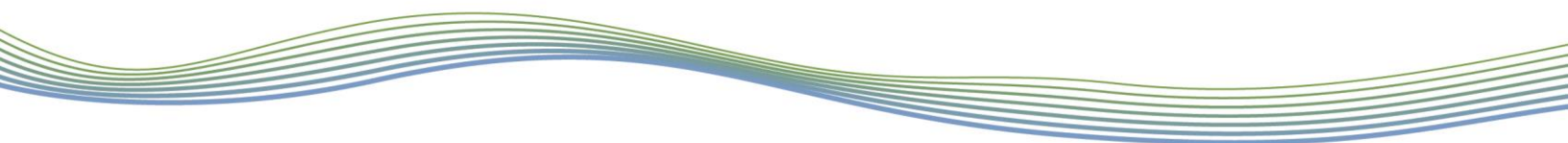
Reach **TTMC2-10** conveyed flows eastwards through a wet meadow located south of the agricultural fields in the south western quadrant of the subject lands. The approximately 500 m long reach had poor channel definition with riparian and instream vegetation consisting predominantly of herbaceous and grass species. Although flow was minimal, water was evident within the channel during both Spring visits, however the feature was dry in August. Average bankfull width in the spring was 2.3 m, and average bankfull depth was 0.37 m. Bed materials were not discernible from the floodplain and consisted of fine materials and organics.

Reach **TTMC2-10-1** is 93 m long and conveyed flows eastwards within a wet meadow in the south western quadrant of the subject lands. The reach was poorly defined, with infrequent channel definition within the wet meadow corridor which consisted predominantly of hydrophilic herbaceous vegetation and grass species. Where observed, the average bankfull width of the feature in the spring was 1.9 m, and average bankfull depth was 0.22 m. Bed materials consisted of silt and organic material.

Reach **TTMC2-10-2** is 270 m long and conveyed flows eastwards within a woodlot located in the south western quadrant of the subject lands. The reach is best described as an intermittent swale, as it had water during both Spring visits and showed poor channel definition. Average bankfull width in the spring was 1.9 m, and average bankfull depth was 0.3 m. Bed materials consisted of silt and clay, and were consistent with the material found in the floodplain.

Reach **TTMC2-11** conveyed flows eastwards within a forest located south of the agricultural fields in the south western quadrant of the subject lands. The reach is approximately 70 m long and had a riparian buffer which consisted of deciduous trees. The average bankfull width of the feature at the time of assessment was 3.3 m, and the average bankfull depth was 0.46 m. The bed materials observed were predominantly silt and clay, with some gravel was also present. Notably, these substrates were not well sorted.

Reach **TTMC2-12** is a 112 m channel which conveyed flows eastwards through a woodlot at the south west corner of the subject site. Riparian vegetation was continuous and primarily consisted of deciduous trees, with one small area dominated by grasses and herbaceous species. Bed materials consisted of



clay, silt and organic matter and were poorly sorted. Minimal flow was observed during the Spring visit (April 3, 2019), and was absent in subsequent assessments. Where observable, the average bankfull width of the feature was 1.3 m and the average bankfull depth was 0.2 m. The reach is best described as a poorly defined ephemeral swale, as made evident by the poor channel definition and the lack of consistent flows.

Reach **TTMC2-12-1** conveyed flows southeastwards within a significant woodlot in the south western quadrant of the subject lands. The reach was a low gradient ephemeral swale which is approximately 82 m long. The riparian vegetation consisted of deciduous trees with some herbaceous plants in the understory. Bed materials consisted of clay, silt and organic matter. Although the channel was poorly defined, where measurable the feature width of the flow path was 1.4 m and the average depth was 0.25 m.

Reach **TTMC2-12-1b** is an 83 m long poorly defined ephemeral swale which conveyed flows northeastwards within a significant woodlot located in the south western quadrant of the subject lands. The low gradient swale had a riparian buffer which consisted of deciduous trees. Similar to TTMC2-12-1, bed materials consisted of sand, silt and organic matter with no coarse substrate observed. Bankfull measurements of the feature were not determined due to a lack of channel definition. Instead, the feature width of the flow path was measured and is defined by the corridor extent occupied by flows. It is typically determined using the extent of hydrophilic vegetation. In this instance, the feature width was approximately 2.6 m.

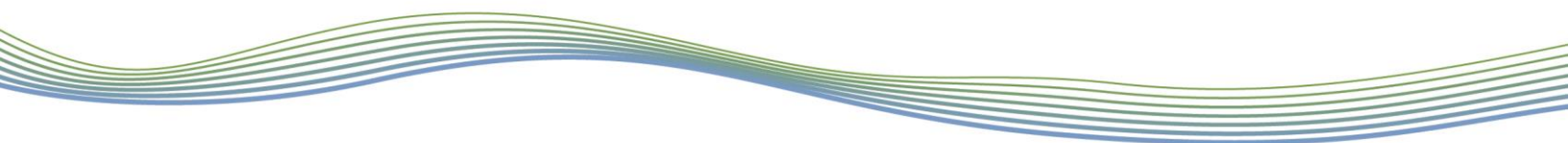
## 6.2 Branch TTMC-3

Reach **TTMC3-1** is a defined, straight channel which conveys flows eastwards for approximately 100 m before reaching a culvert under Upper James St. The reach was delimited on the east side of Upper James Street at its confluence with Twenty Mile Creek. Riparian vegetation consisted of scrubland and some hydrophilic vegetation. The reach had a bankfull channel width of 8.1 m, and an average bankfull channel depth of 0.6 m. During the Spring site visit, the wetted width of the feature was 5.45 m, and the average wetted depth was 0.17 m.

Reach **TTMC3-2** is a 610 m long feature which conveyed flows eastwards in the northeast corner of the subject lands. The feature occupies a wide grassy corridor characterized as a provincially significant wetland (PSW). The feature was wet during all site visits, and had substrate which consisted of clay, silt and organic materials. The reach had no discernible banks, and given its wide corridor measurements of the width of the wetland were completed using GIS which indicated the flow path to be approximately 35 m in width.

Reach **TTMC3-2-2** is 170 m long intermittent channel which conveyed flows eastwards from an agricultural field to a woodlot near the northeast quadrant of the subject site. The feature is surrounded by agricultural crops along its first portion and ends in a woodlot populated by deciduous trees. Substrate consisted predominately of clay, silt and gravel which were poorly sorted. Water was present in the channel during the first two visits. The average bankfull width of this feature within the woodlot was 1.3 m, with a corresponding bankfull depth of 0.27 m. During the first site visit, the wetted width of the feature was 0.57 m, with an average wetted depth of 0.05 m.

Reach **TTMC3-2-1** is a 383 m long intermittent channel which conveyed flows eastwards through a woodlot near the eastern limit of the subject property. Riparian vegetation included mature deciduous trees as well as some shrubs and herbaceous vegetation. Hydrophilic vegetation was commonly found



within the channel. No geomorphic units were observed, and the substrate composition was predominately clay, silt and organic material which were poorly sorted. Water was present in the channel during the first two visits. The average feature width was 1.1 m, and its average feature depth was 0.5 m, while its average wetted width and depth during the first visit were 0.5 m and 0.05 m, respectively.

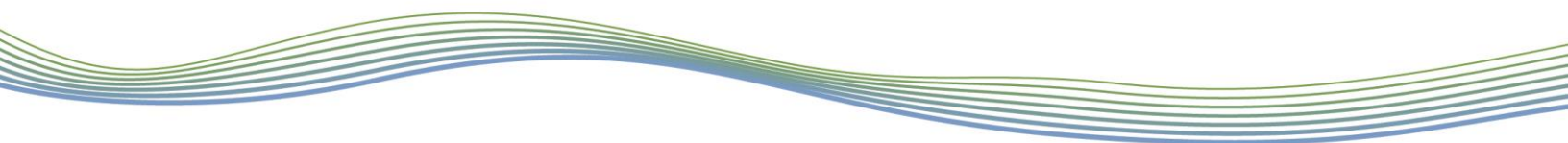
Reach **TTMC3-3** is a 223 m long feature which conveyed flows eastwards through an agricultural field in the northeast portion of subject area. Water was only observed within the feature during the first assessment. The channel's riparian buffer consisted of an agricultural field, while the feature itself was populated by herbaceous vegetation and grasses. Some evidence of sediment transport and deposition was observed within the feature, including sheet erosion and rilling within the floodplain. The poorly defined channel had an average width of 3 m, and an average depth of 0.15 m. In the spring, its average wetted depth was 4.5 m and its averaged wetted depth was 0.08 m.

Reach **TTMC3-4** is a short, 114 m long reach which conveyed flows eastwards between two agricultural fields along the southern border of a residential property. The riparian buffer consisted predominantly of herbaceous species to the north and agricultural crops to the south. The channel bed was composed of clay and gravel, which was overlaid by a thin layer of silt and sand which was deposited during freshet. The reach appears to have been channelized as made evident by its high entrenchment relative to adjacent reaches and its straight planform. The feature has an average bankfull width of 2.5 m, and an average bankfull depth of 0.2m. During the first visit, the average wetted width of the feature was 1.3 m and the average wetted depth was 0.09 m.

Reach **TTMC3-5** is a 316 m long intermittent channel which conveyed flows eastwards through an agricultural field in the northeast portion of the subject lands. The upstream portion of the riparian corridor consisted of herbaceous vegetation, but a larger section of it was dominated by agricultural crops. The dominant substrates were clay and silt, but some poorly sorted sand, gravel and, cobbles were also observed. During the first visit substantial flow was present because of the spring freshet. However, similar to Reach TTMC3-6 upstream, during the summer visit water was only found in isolated pools. A bluegill was observed in one of these pools which was located at the hedgerow near the upstream extent of the reach, where a tile drain discharged into the feature. The feature had an average bankfull depth of 2.15 m, and an average bankfull depth of 0.2 m. During the first visit, its average wetted width was 0.9 m and its average wetted depth was 0.04 m.

Reach **TTMC3-6** is 280 m long intermittent channel, which conveyed flows eastward through an agricultural field in the central portion of subject area. Riparian vegetation, when present, consisted of grasses however the channel was primarily flanked by agricultural crops. Bed and banks were mostly composed of the same material as the agricultural fields, a clay, silt, sand mixture, although some cobbles were present. Although water was observed within the feature during all three visits, during visits two and three water was only found in isolated stagnant pools with no connectivity between these features. The average feature width of the reach was 2.8m, and during the spring its average wetted width was 1.53 m and its average wetted depth was 0.1 m.

Reach **TTMC3-7** is a short 79 m long feature which conveyed flows eastwards from the central woodlot through a meadow to the agricultural field to the east. The bed composition observed was clay, silt, sand and sparse gravels which were poorly sorted. Water was present only during the first visit in the Spring. The average width of this feature, which had poorly defined banks, was 4.37 m. During the spring its average wetted width was 2 m and its average wetted depth was 0.09 m.



Reach **TTMC3-8** is an ephemeral feature which conveyed flows eastward from the online pond to the meadow flanking the agricultural field to the east. The low gradient feature is 48 m long, has a poorly defined channel and its bed consisted of clay, silt, sand and organic material. This material was equivalent to that found within the riparian buffer, which was populated by deciduous trees. The feature had an average width of 5.77 m, and during the spring visit had an average wetted width of 3.7 m and an average wetted depth of 0.03 m.

Reach **TTMC3-9** is an approximately 3000 m<sup>2</sup> online pond located approximately in the middle of the subject lands within a woodlot. The feature's riparian vegetation predominantly consists of mature deciduous trees which provides shading to the pond.

Reach **TTMC3-10** is 194 m long headwater feature conveying flows eastwards through a meadow area immediately south of the former orchard in the center of the subject lands. The reach is best described as a swale which is populated by dense hydrophilic vegetation in the feature itself and in its riparian zone. No clearly defined channel was observed, and the substrate was clay, silt and sand. Although water was present in the feature during all three visits, it was limited to fragmented, stagnant pools during the summer visit with no observable flow. Given the poor channel definition, a feature width was measured which was an average of 6.3 m. The average wetted width of the feature in the spring was 3.32, and the average wetted depth was 0.12 m.

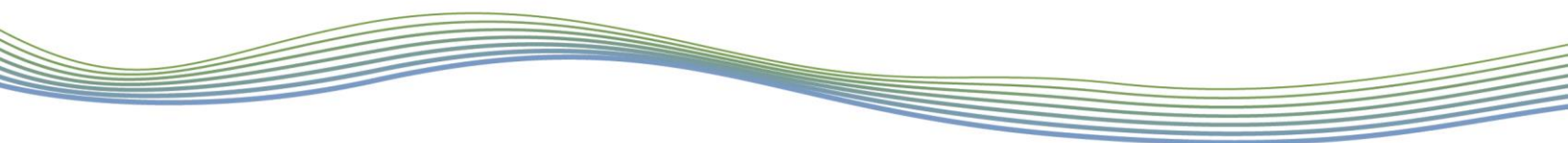
### 6.3 Branch TTMC-5

Reach **TTMC5-4** is 336 m long intermittent swale which conveyed flows eastwards in the central-north portion of the subject area. The swale occupies a relatively wide corridor composed of hydrophilic herbaceous vegetation and grasses. Given the poor bank definition within the reach, the feature width was instead measured and determined to be an average of 21.7 m wide. Substrate within the feature was consistent with the agricultural fields which occupied the riparian buffer, and was clay, silt and sand. Water was present during visit 1 and 2, but it was dry during visit 3. The feature discharges to a 750 mm culvert flowing under Twenty Road W. During the spring visit, the channel had an average wetted width of 18 m and an average wetted depth of 0.09 m.

Reach **TTMC5-5** is 327 m long intermittent swale which conveyed flows eastwards through an agricultural field. The headwater feature lacked a natural riparian corridor and was instead flanked by crops. It appeared that the feature was occasionally ploughed, and consequently substrate was generally consistent with the adjacent fields with the exception of occasional cobbles. Water was present during the first 2 visits, and an unknown minnow species was observed within the upstream portion of the reach during visit 2. The feature width of the poorly defined channel was measured as 3.22 m, and during the Spring the average wetted width was 1.93 m and the average wetted depth was 0.13 m.

Reach **TTMC5-6** is a 452 m long headwater feature which conveyed flows eastwards in the central-west portion of the subject lands. The reach is best described as a wide grassy corridor composed of hydrophilic vegetation with deciduous trees occupying the riparian buffer. Water was present during all visits except the summer and is therefore considered to be intermittent. The substrate was predominantly clay, silt and sand, and the feature was full of rooted emergent aquatic vegetation. At the upstream extent of the reach, an offline agricultural pond was present which contained water during the first two site visits, but not the third. The feature lacked defined banks and was approximately 29.3 m wide, and during the Spring had an average wetted width and depth of 20 m and 0.11 m, respectively.

Reach **TTMC5-7** is a 188 m long feature which conveyed flows eastwards in the northwest portion of the subject lands. The reach is differentiated from Reach TTMC5-6 by its riparian buffer which consisted



of an agricultural field as opposed to an orchard, and is otherwise a similar grassy corridor which acts as a flow path. Like the adjacent reach, the feature was intermittent, had substrate which consisted of clay, silt and sand and was occupied by sparse rooted emergent aquatic vegetation. The feature had poorly defined banks, an average width of 24 m and had an equivalent wetted width during the first assessment.

Reach **TTMC5-8** is 313 m long intermittent swale which conveyed flows eastwards through an agricultural field in the western portion of the subject area. The feature had a narrow riparian corridor composed of herbaceous vegetation which was particularly evident towards the downstream extent of the reach. Water was observed during visit 1 and 2 and, and the reach was dry during visit 3 resulting in its classification as an intermittent channel. Substrate composition was predominantly clay, silt and sand with some scattered gravel. The average feature width was 3.0 m, and during the Spring it had an average wetted width of 2.7 m and an average wetted depth of 0.08 m.

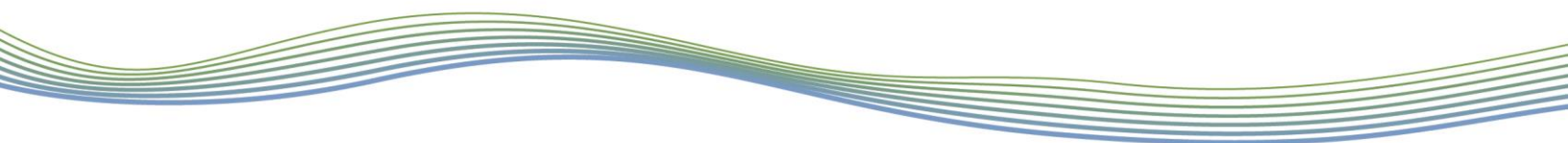
Reach **TTMC5-8-1** is a short flow path with a moderate gradient which conveyed flows from a damaged 300 mm CSP at its upstream extent discharging flows from the abandoned golf course. The channel was wet during the first site visit, but dry during both subsequent visit and was therefore classified as ephemeral. Although the feature had poorly defined banks, a discernible channel was observed at its upstream extent which had an average bankfull width of 0.51 m and an average bankfull depth of 0.18 m. During the spring, the average wetted width was 0.06 m and had an average wetted depth of 0.02 m

Reach **TTMC5-9** is a short 120 m long feature which originates at the outlet of a small pond within the former Glancaster Golf and Country Club and conveys flows eastwards in the western extent of the subject area. The feature is occupied by dense rooted emergent aquatic vegetation, particularly cattails, and is flanked by a deciduous forest to the north and an agricultural field to the south. The low gradient, intermittent feature's substrate was predominantly organic deposits, silt and sand which were poorly sorted. The feature had an average width of approximately 20 m, and during the Spring an average wetted width of 14.6 m, and an average wetted depth of 0.06 m.

## 6.4 Branch TTMC-6

Reach **TTMC6-1** is 315 m long poorly defined feature which conveyed flows eastwards towards a roadside ditch on the south side of Twenty Road West. The feature is surrounded by agricultural crops and showed evidence of being ploughed. Vegetation within the feature was predominantly composed of the same crops which occupied the adjacent fields, with sparse aquatic vegetation infrequently observed. Minimal flow was observed within the feature during spring freshet, and for the subsequent two visits the feature was dry resulting in it being classified as ephemeral. Substrate within the feature was consisted with that of the adjacent fields, and was clay, silt and sand. The average feature width was 2.8 m, with the average wetted width during the first visit being 0.15 m, and the average wetted depth being 0.02 m.

Reach **TTMC6-2** is 177 m long feature with poor channel definition which conveyed flows eastwards within the former orchard property. The feature was filled with dense, rooted emergent aquatic vegetation, particularly grasses, and was flanked by both meadow and scrubland within the riparian buffer. The substrate within the feature was predominantly clay, silt and sand which were poorly sorted. The reach had an intermittent flow regime, although the water observed during the second visit appeared to be standing and no water was observed during the third visit. The average feature width



was 22.8 m, and the wetted width and depth observed during the Spring visit was 5.5 m, and 0.23 m, respectively.

Reach **TTMC6-3** is a 190 m long swale which conveyed flows eastwards through an agricultural field north of a centrally located residential property. The channel was located adjacent to an un-planted agricultural field and had a narrow herbaceous riparian buffer. Substrate within the feature was clay, silt and sand which were poorly sorted. Particularly at the upstream extent of the reach, no discernible channel could be located, and it appears that its connection with the upstream reach is somewhat limited. Where discernible, the ephemeral feature had an average width of 5.7 m, and during the first visit the average wetted width was also 5.7 m and the average wetted depth was 0.04 m.

Reach **TTMC6-4** is a short feature which occupies the relatively wide hedgerow between two agricultural fields. No channel could be clearly defined through the hedgerow, although a vernal pool was noted during the first two visits which received drainage from the field to the west. The feature was surrounded by scrubland and deciduous trees, and substrate within the pool was predominantly decomposing organics. The feature is considered intermittent since water was present during the first and second visits and no water was observed in the summer. The feature lacked definition, and had an approximate maximum average width of 21.7 m, and in the Spring the average wetted width was 16.67 m with an average wetted depth of 0.16 m.

## 6.5 Branch TTMC-7

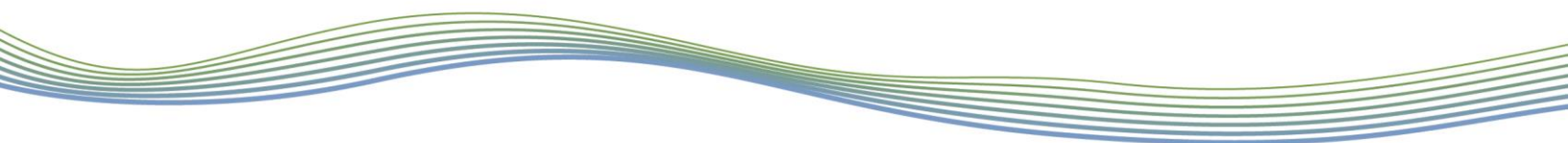
Reach **TTMC7-1** is a short 76 m long feature which lacked bank definition. The feature originated from a culvert which conveyed flows eastwards across a driveway in the northwest portion of subject area before discharging into the roadside ditch at Twenty Road West. The feature was surrounded by grasses, and had no discernible bankfull channel. The feature width occupied by hydrophilic vegetation was 32.5 m, and during the Spring visit the average wetted width and depth were 24.3 m and 0.03 m, respectively. Substrate within the feature was predominantly clay, silt and sand which were poorly sorted. The flow regime of the feature was determined to be ephemeral given that water was only flowing during the first site visit, water observed during the second visit was stagnant and no water was observed during the third visit.

## 6.6 Branch TTMC-8

Reach **TTMC8-6** is 146 m long ephemeral swale conveying flows eastwards towards Twenty Road West at the northwest portion of subject area. The riparian buffer of the feature, where visible, consisted of a lawn which also occupied the feature itself. Measurements of the feature and characterization of the substrate of the channel were not achievable due to the reach being located within non-participating lands.

Reach **TTMC8-7** is a 120 m long intermittent swale which conveyed flows eastwards through an agricultural field between two non-participating lands near the northwest corner of the subject site. The feature lacked a natural riparian buffer, and was predominantly cropped. Substrate composition was predominantly clay, silt, sand and sparse gravel which was poorly sorted. The feature lacked definition and had an average width of 2.55 m, and during the Spring visit the average wetted width and depth were 2.4 m and 0.05 m, respectively.

Reach **TTMC8-8** could not be observed due to it being contained within unparticipating lands, and trees blocking the view of the feature from the adjacent agricultural fields.



Reach **TTMC8-9** is a 300m long intermittent swale which conveyed flows eastwards through an agricultural field at the northwest portion of subject land. Riparian vegetation consisted exclusively of agricultural crops, which were generally absent from the channel. Substrate composition was consistent with the adjacent fields, and was predominantly clay, silt, and sand. The reach was considered intermittent since water was present during the first and second visits and dry during the summer. The average bankfull width of the feature was 2.6 m, and its average bankfull depth was 0.1 m. During the spring, the average wetted width of the feature was 2.39 m, with a corresponding averaged wetted depth of 0.03 m.

Reach **TTMC8-9-1** is a 250 m long intermittent swale which conveyed flows north-eastwards towards reach **TTMC8-9** from the former golf course lands at the northwest portion of subject land. The feature was surrounded by agricultural crops and itself was predominantly cropped. The reach was considered intermittent since water was present during the first and second visits and dry during the summer. The poorly defined feature had an average width of 1.1 m, and an average depth of 0.2 m. During the Spring visit, the average wetted width and depth of the feature were 0.3 m, and 0.03 m, respectively.

Reach **TTMC8-3-3** is a 280 m long intermittent swale which conveys flows eastwards through an agricultural field at the northwest corner of subject land. The feature lacked natural riparian vegetation and was flanked by crops, which encroached the channel. Substrate within the intermittent feature was poorly sorted and consisted of clay, silt, and sand. The low gradient feature lacked clearly defined banks, and had an average feature width of 2.65 m. During the Spring, the average wetted width of the feature was 2.65 m and had a corresponding average wetted depth of 0.04 m.

## 6.7 Branch TTMC-9

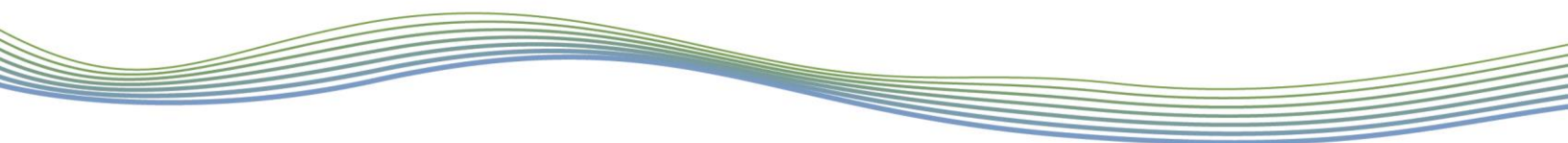
Reach **TTMC9-1** is a 114 m long ephemeral swale which conveyed flows south-eastwards towards a ditch on the north side of Dickenson Road West at the southern extent of the subject site. Riparian vegetation adjacent to the feature was deciduous trees, as it conveyed flows within a woodlot. The low gradient feature's substrate was predominantly composed of decomposing organic matter and silt. Water was only observed within the feature during the Spring site visit, resulting in an ephemeral flow regime classification. The average channel width was 2.7 m, and had an average depth of 0.23 m. The average wetted width of the feature during the Spring was 0.23 m, and its average wetted depth was 0.03 m.

## 7 Headwater Drainage Feature Classification

The classification results are summarized in Table 3, and the management recommendations for each reach are shown graphically in **Appendix C**. The management recommendations are defined as follows:

- Protection – The feature serves an important function to all criteria
- Conservation – The feature serves a valued function to all criteria
- Mitigation – The feature serves a contributing function to all criteria
- Maintain or replicate terrestrial linkage – for features with terrestrial function only
- No management required – for features with limited or no function

How each reach is classified is dependent on 4 categories: Hydrology, Riparian Conditions, Fish and Fish Habitat and Terrestrial Function. These classifications are given a score based on function of either limited, contributing, valued or important depending on observations from the three site visits. For



instance, the hydrological significance of a feature is established based on the presence and conveyance of water through the reach. Perennial systems where water is present during all three visits is considered important, whereas if only standing water or no water is observed during the three visits its function is considered limited. For other descriptions, please consult the TRCA/CVC Headwater guide (2014).

The 'Modifiers' in **Table 3** reflect local details that alter the form, function, or importance of the feature, such as downstream conditions or local anthropogenic influences. Consequently, the management recommendations identified via strict application of the Headwater Guideline decision are adjusted to account for the modifiers. For instance, for those features that are located immediately upstream of pipes and/or storm water management facilities professional judgement was used to alter the classification recommendations to reflect the lack of downstream connectivity. The Headwater Guideline allows for these modifications through the following statement: "Classification should consider the influence of modifiers and professional judgement to determine the appropriate classification, where applicable. The results of the process need to be clearly articulated within the table" (TRCA and CVC 2014).

Each of the classifications come with specific management requirements for the post-development scenario, which are:

- *Protection* – Important functions: protect and/or enhance the existing feature and its riparian zone and groundwater discharge or wetland in-situ
- *Conservation* – Valued functions: maintain, relocate, and/or enhance drainage feature and its riparian zone corridor
- *Mitigation* – Contributing functions: replicate or enhance functions through enhanced lot level conveyance measures for downstream connection
- *No Management Required* – Limited functions: no feature and/or functions associated with the feature are present on the ground and/or there is no downstream connection



**Table 3 – Headwater Drainage Feature Classification**

Reach	Hydrology	Modifier	Riparian Conditions	Fish and Fish Habitat	Terrestrial Function	Original Classification	Modified Classification
TTMC2-9	Valued	None	Limited	Contributing	Limited	Protection	
TTMC2-9-1	Valued	None	Important	Contributing	Valued	Protection	
TTMC2-10	Valued	None	Important	Contributing	Important	Protection	
TTMC2-10-1	Valued	None	Valued	Contributing	Important	Conservation	
TTMC2-10-2	Valued	None	Important	Contributing	Contributing	Conservation	
TTMC2-11	Valued	None	Important	Contributing	Contributing	Conservation	
TTMC2-12	Valued	None	Important	Contributing	Contributing	Conservation	
TTMC2-12-1	Value	None	Important	Contributing	Contributing	Conservation	
TTMC2-12-1b	Contributing	None	Important	Contributing	Contributing	Conservation	
TTMC3-1	Important	None	Important	Important	Important	Protection	
TTMC3-2	Important	None	Important	Important	Important	Protection	
TTMC3-2-1	Valued	None	Important	Contributing	Valued	Conservation	
TTMC3-2-2	Valued	None	Limited	Contributing	Limited	No Management	
TTMC3-3	Contributing	Poor quality habitat	Limited	Contributing	Limited	Protection	Conservation
TTMC3-4	Contributing	Poor quality habitat	Valued	Contributing	Limited	Protection	Conservation
TTMC3-5	Valued	Poor quality habitat	Limited	Important	Limited	Protection	Conservation
TTMC3-6	Valued	Poor quality habitat	Limited	Important	Limited	Protection	Conservation
TTMC3-7	Contributing	Poor quality habitat	Valued	Valued	Contributing	Protection	Conservation
TTMC3-8	Contributing	Poor quality habitat	Important	Contributing	Valued	Protection	Conservation
TTMC3-9	Important	Anthropogenic Feature	Important	Important	Valued	Protection	Conservation
TTMC3-10	Valued	Poor quality habitat	Important	Contributing	Important	Protection	Conservation
TTMC5-4	Contributing	No DS watercourse	Important	Important	Important	Protection	Conservation
TTMC5-5	Valued	No DS watercourse	Limited	Contributing	Important	Protection	Conservation

<b>TTMC5-6</b>	Valued	No DS watercourse	Important	Contributing	Important	Protection	Conservation
<b>TTMC5-7</b>	Value	No DS watercourse	Important	Contributing	Important	Protection	Conservation
<b>TTMC5-8</b>	Valued	No DS watercourse	Limited	Contributing	Important	Protection	Conservation
<b>TTMC5-9</b>	Important	No DS watercourse	Important	Contributing	Important	Protection	Conservation
<b>TTMC5-9-1</b>	Valued	None	Limited	Contributing	Limited	No Management	
<b>TTMC6-1</b>	Limited	No DS watercourse	Limited	Contributing	Limited	Conservation	Mitigation
<b>TTMC6-2</b>	Contributing	No DS watercourse	Important	Contributing	Contributing	Conservation	Mitigation
<b>TTMC6-3</b>	Contributing	No DS watercourse	Limited	Contributing	Limited	Conservation	Mitigation
<b>TTMC6-4</b>	Contributing	No DS watercourse	Important	Contributing	Contributing	Conservation	Mitigation
<b>TTMC7-1</b>	Limited	None	Valued	Contributing	Contributing	Mitigation	
<b>TTMC8-7</b>	Limited	None	Limited	Contributing	Limited	Mitigation	
<b>TTMC8-9</b>	Valued	None	Limited	Contributing	Limited	Mitigation	
<b>TTMC8-9-1</b>	Limited	None	Limited	Contributing	Limited	No Management	
<b>TTMC8-3-3</b>	Valued	None	Limited	Contributing	Limited	Mitigation	
<b>TTMC9-1</b>	Valued	None	Important	Contributing	Contributing	Conservation	

## 7.1 Management Recommendations

Based on observations from the three site visits, the reaches within **Branch TTMC2** have been classified as either conservation or protection, requiring retention on site for those reaches classified as protection or re-alignment for those classified as conservation. For **Branch TTMC3**, all reaches have been designated as conservation, which can entail re-alignment. Similarly, for **Branch TTMC5** all reaches with the exception of the most upstream reach have been designated as conservation, with the most upstream reach **TTMC5-9-1** requiring no management. For both **Branch TTMC6** and **TTMC7**, reaches have been designated as mitigation, requiring no retention of the channels on site but lot level controls to ensure flow conveyance to downstream channels to maintain the function of those features. **Branch TTMC8** is predominantly classified as mitigation as well, however, **Reach TTMC8-3-3** will require lot level conveyance measures as it is classified as mitigation. For the single reach present within the site from **Branch TTMC9**, conservation is recommended to maintain its contributions to the downstream reaches.



## 8 Erosion Mitigation

### 8.1 Preliminary Recommendations

To determine preliminary recommendations regarding watercourse erosion mitigation both within and immediately downstream of the subject lands, documentation outlining existing conditions from NRSI (2013, 2014) and the City of Hamilton (2017) were reviewed and related to the preliminary stormwater plans from Urbantech (2018).

The AEGD Subwatershed Stormwater Master Plan (City of Hamilton, 2017) defers addressing watercourse specific erosion concerns to the development proponents in conference with the relevant Conservation Authority. The proponent will confer with the Niagara Peninsula Conservation Authority (NPCA) to review the necessity to complete an erosion analysis.

Most of the features which are planned to be maintained within the development lands are to be realigned and restored. As such, they will be designed to be resilient to erosion. The receiving watercourses downstream of the storm water ponds are either low gradient wetland features or are buffered by online ponds. As such, the systems capacity to assimilate changes in hydrology are relatively high. At this stage we suggest that the retention of the 25 mm storm event for 24 or 48 hours will be sufficient to mitigate potential downstream erosion concerns. In addition, stone-core wetlands should be installed at SWM pond outfalls, which will serve to accept discharge from the associated outlets. The short-term water retention function of these wetlands will help moderate the discharge of water into the channel and dissipate energy, thereby reducing the likelihood of erosion downstream.

To verify this approach a more detailed geomorphological assessment will be completed. Erosion sensitivity will be evaluated through the identification of reaches that demonstrate potential erosion concern. This will be followed by detailed geomorphological assessments of sensitive reaches and calculation of erosion thresholds. Erosion thresholds provide a tool with which to evaluate potential erosion within a channel under various conceptual flow management plans.

Several SWM facilities have been proposed to accommodate hydrological changes resulting from development. Detailed geomorphological assessments will be conducted for those receiving watercourses that appear sensitive to erosion in 2020.

## 9 Conceptual Channel Design

To accommodate the proposed development, **TTMC2** and **TTMC3** are proposed to be realigned into a common corridor, restored and maintained on the site. This provides an opportunity to replace the existing morphologically-limited channels with a naturalized riffle and pool typology, with cross sectional dimensions closer to that of a naturalized watercourse conveying similar flows. One goal of natural channel design is to replace existing degraded channels, particularly those impacted by past agricultural activities. As such, a naturalized watercourse will offer significant improvements to channel form and function.

The realignment and naturalization of these two branches provide opportunities for improved riparian conditions and well-developed bankfull channels with morphological variability. Improvement in morphology and function would provide additional benefits to sediment balance, floodplain storage, vegetation communities and terrestrial habitat features, edge impacts and restoration requirements, water balance, fish passage and water quality. The proposed future channel designs will provide an overall improvement over existing conditions.



Therefore, the primary objectives of the designs are to:

- Restore the physical form of the channels including planform and in-channel characteristics
- Improve the function of the channels as well as its interactions with the floodplain
- Improve retention and detention of flows upstream of the stormwater management ponds
- Enhance aquatic habitat through the provision of a morphologically diverse channels with spatially varied flows
- Improve riparian habitat by installing woody plantings and floodplain features
- Mitigate potential hazards to the development as well as lands downstream of the development

The recommended restoration designs will focus on a riffle-pool channel typology. The riffle-pool typology will provide significant improvements to not only the channel, as it essentially mimics a natural system, but also to aquatic habitat. When it is assessed to be an appropriate channel type, a riffle-pool system offers numerous benefits, namely:

- Channel bed relief for flow variability
- Water aeration in riffle sections
- Relatively quiescent flows in pool sections to provide refuge for fish during high flows
- Increased depths in pools to provide relatively cool water
- In-channel energy dissipation

Channel dimensions will be determined by bankfull discharge in the post-development condition, as this represents what is generally considered the channel-forming discharge or the dominant discharge. Several methods can be applied to select an appropriate bankfull discharge. Back calculation of discharge from a reference reach along with support from hydrological modelling is usually the most appropriate.

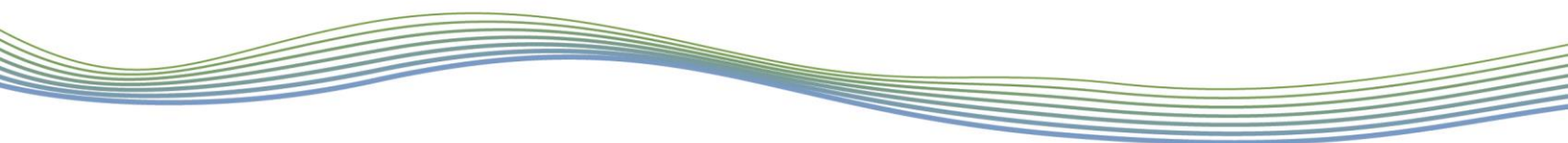
The sizing of proposed substrate materials will be guided by a review of hydraulic conditions (i.e., tractive force, flow competency) in the typical cross sections. These materials will always have a core of sediment that is not entrained under bankfull flow conditions. This is particularly important as the supply of natural sediment from upstream will be limited due to development. This material maintains the character of the native material, while providing slightly higher stability and opportunity for sediment sorting.

A stable geometry will be developed based on an effective or bankfull discharge estimated from post-development channel hydrology. Stable radius or curvature, meander amplitudes, and riffle pool spacing will be defined. This will also allow the meander belt width of the restored channel to be defined.

## 9.1 Channel Corridor

Offline and online wetland features will be constructed in addition to the channel. These features enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form. They also provide functional benefits such as short-term water retention and sediment banking. They will be irregularly shaped to maximize the perimeter for a given area, which increases potential for edge effects. Submerged and dry mounds are proposed within the wetland to provide topographically complex bottom that will increase habitat heterogeneity.

Stone-core wetlands will be installed at SWMP outfalls and serve to accept discharge from the associated outlets. The stone core refers to hydraulically-sized rounded stone, which is the subsurface material used to ensure wetland stability. The stone will be hydraulically sized during detailed design. The short-



term water retention function of these wetlands also helps to polish the water and moderate the discharge of water into the channel (in addition to the functions provided by the SWMPs).

The full channel corridor will be restored using native plant species. This includes appropriate species for the various seed mixed as well as woody vegetation. The plantings are intended to enhance the terrestrial habitat through the provision of species and habitat diversity, increase floodplain soil stability, and increase floodplain roughness and sedimentation. The landscaping plan will be prepared by others during detailed design.

## 9.2 Habitat Restoration

The design will incorporate habitat elements within the channel corridor, to improve riparian habitat and promote wildlife biodiversity. To maximize potential for wildlife passage, forage and residency, the habitat design incorporates varying topographies and woody debris. The habitat elements include potential overwinter pools, basking logs, brush piles, raptor poles, turtle nesting sites, snake hibernacula, rock piles and terrestrial mounds. The accompanying drawings provide design details and direction for the implementation of the proposed habitat features.

Potential overwintering pools are proposed to be implemented to provide critical habitat for resident fish. This habitat feature will provide fish with potential refuge from freezing conditions in the winter, but also provide ideal habitat during low flow periods, and increase habitat heterogeneity within the channel. Due to the size of the channel, the pools could freeze completely during the winter.

Basking logs consist of a mixture of hardwood and softwood species, place in shallow areas of wetlands and anchored with a mix of stone or limestone blocks. These logs are angled in a way to promote turtle basking.

Brush piles consist of logs, snags, and other wood debris, placed in a way that forms a stable interconnected mound, in the shape of a pallet. Additionally, the brush piles are planted with native fruit bearing vines, which provide forage opportunities for wildlife. Brush piles are placed at various location along the length of the floodplain.

Raptor poles are constructed from large conifer tree trunks, embedded into the ground, and serve to provide perches for larger raptors.

Turtle nesting sites are installed on south or west facing slopes away from the watercourse. These are constructed by excavating a small depression in the ground and filled with granular 'b' material.

Snake hibernacula are constructed similar to turtle nesting sites, on south or west facing slopes, away from the watercourse. The excavated depressions are filled with a mix of angular stones or various sizes and woody debris.

Rock piles consist of a mix of stone of varying sizes, piled up to create small mounds. These features provide hibernation habitat for various terrestrial species. The base of the piles is partially buried, the prevent rock falls. Rock piles are installed at various locations along the length of the floodplain.

Terrestrial mounds consist of native material, piled up to create small mounds with a small dimple on the top. The bottom of the mound is seeded with the specified seed mix, while the top has limited soil and seed on it to provide foraging opportunities.



### 9.3 Recommendations for Detailed and Conceptual Design

A detailed assessment would be completed on the reach(es) determined to be the most representative of the channels in their natural state. The detailed information gathered would inform the design of new channels. Specifically, the detailed assessments would include the following:

- Longitudinal profile survey of the channel
- Detailed cross sections surveyed at eight-ten locations
- Detailed instream measurements at each cross-section location including bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density
- Bed material sampling at each cross section following a modified Wolman (1954) pebble count

Using the field assessment data, a watercourse alignment would be developed. The design will be clearly shown in plan, profile and cross sections, and will include all necessary details for successful implementation. We will utilize design elements, such as bioengineering and spatially variable bed morphology, that would offer these benefits. The design will include:

- Section and profile detail of proposed habitat features (i.e. riffle, pools, etc.), including transition into and out of feature. Bank and low flow channel locations must be clearly identified
- Details regarding staging, phasing, sediment and erosion control measures, site dewatering, equipment, materials, access to and from work area, monitoring, site supervision, timing restrictions, etc.
- Confirm valley and channel gradients
- Confirm the location of Stormwater Management facilities, and requirements for outlet treatments
- Develop a native planting plan for the proposed corridor
- Develop a post-construction monitoring plan

A technical brief will be prepared to accompany the drawings. This report will include a summary of the field investigations, an overview of the designs and intent, rationale for the proposed designs, design calculations and site photographs.

## 10 Monitoring Plan

The fluvial geomorphology component of the monitoring program should address potential adjustment in channel geometry, rates of change with regards to channel adjustment, and instream sediment characteristics. Monitoring sites should be selected to cover areas of potential impact, address areas of concern, include sites from receiving watercourses, and include a location outside the expected zone of impact to act as a reference. The monitoring plan should include pre-construction monitoring and post-construction monitoring.

### 10.1 Pre-Development Erosion Monitoring

Prior to construction initiation, we recommend additional baseline monitoring be completed for Tributaries **TTMC-2**, **TTMC-3**, **TTMC-5**, **TTMC-8** to identify potential impacts from development. This monitoring will allow for identification of potential downstream channel erosion associated with the proposed stormwater management facilities. The following monitoring activities are suggested:

- Monumented cross sections at a pool and riffle to measure change in bankfull geometry and bank conditions;

- Monumented photographs at each site location;
- Erosion pins to specify the rate and extent of erosion at monumented cross-sections;
- Grain size analysis using the modified Wolman pebble count or a bed sample to observe changes in bed composition over time;
- Establishment of a longitudinal profile for observing change in pool-riffle sequence at the location over time; and
- Measurements of discharge and potential sediment transport to help refine erosion thresholds.

Monitoring sites should be installed immediately and reviewed annually and seasonally before and during construction, to identify natural variability of the system. This will allow for identification and mitigation of any potential instream erosion during construction.

## 10.2 Channel Design Monitoring

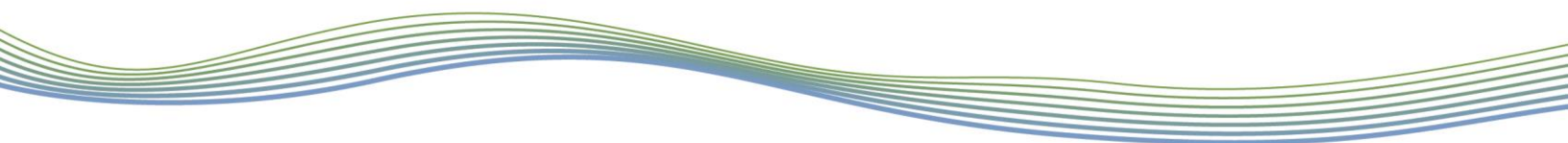
A post-construction monitoring program is recommended to assess the performance of the implemented channel design. Monitoring observations can also be used to determine the need for remedial works. The plan will be developed as part of developing the conceptual design. In general, it would include:

- General observations of the channel works should be documented after construction and after the first large flooding event to identify any potential areas of erosion concern
- Collection of a photographic record of site conditions
- Total station survey of the longitudinal profile and monumented cross sections following construction. This would serve as the as-built reference condition for use in comparing surveys completed in subsequent years
- Re-survey of the longitudinal profile and cross sections in subsequent years after construction.
- Installation of erosion pins at monumented cross sections after construction and monitoring of the erosion pins for the subsequent years
- Bed material characterization using pebble counts
- General vegetation surveys completed annually after construction, for the duration of the monitoring period
- Year-end report summarizing construction activities (i.e., design implementation), and subsequent year-end reports for the duration of the monitoring period

## 11 Conclusions and Next Steps

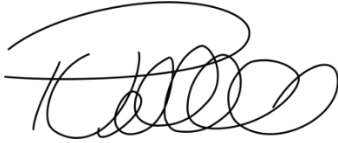
The fluvial geomorphological assessment summarized here is in support of the Twenty Road Development. The study will inform future development plans for the property. The fluvial geomorphological component included a background review of site conditions and field reconnaissance based on existing literature from NRSI (2013, 2013) and the City of Hamilton (2017), as well as three site visits during 2019. The study provided reach delineation and characterization, classification and management recommendations using the Headwater Drainage Feature Assessment framework from the TRCA/CVC (2014), preliminary recommendations regarding erosion threshold determination, a high-level conceptual natural channel design framework and monitoring recommendations.

For the 2020 field season, a Headwater Drainage Feature Assessment for the channels occupying the golf course lands is underway. As well, a re-assessment of the previously completed HDFA work on the main subject lands (east of the Glancaster Golf Course) is also being completed to verify results from the previous field season. Upon completion of these assessments, more detailed studies will be completed to inform potential channel designs and establish erosion thresholds within the receiving watercourses to ensure a dynamic equilibrium of erosional and depositional processes in line with existing conditions is maintained within these channels.



We trust this report meets your requirements. Should you have any questions please contact the undersigned.

Respectfully submitted,



Paul Villard Ph.D., P.Geo, EP, CERP, CAN-CISEC  
Director, Principal Geomorphologist



André-Marcel Baril, M.Sc.  
River Scientist





## References

Chapman, L.J., and Putnam, D.F. 1984: Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Toronto, ON.

Limerinos, J.T. 1970. Determination of the Manning coefficient from measured bed roughness in natural channels. United States Geological Survey Water-Supply Paper 1898B.

Ministry of Environment (MOE). 2003. Ontario Ministry of Environment. Stormwater Management Guidelines.

Montgomery, D.R. and Buffington, J.M. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

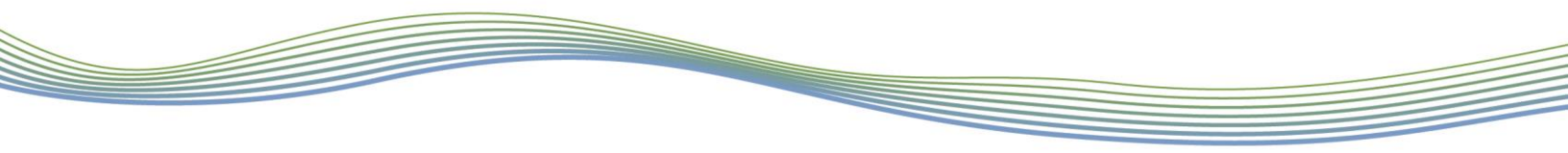
Natural Resource Solutions Inc. (NRSI). 2013. DRAFT – Twenty Road Natural Features and Headwater Characterization Report. Prepared for: Twenty Road Landowners Group.

Natural Resource Solutions Inc. (NRSI). 2014. Twenty Road Natural Feature and Headwater Characterization Report, Addendum. Prepared for: Twenty Road Landowners Group.

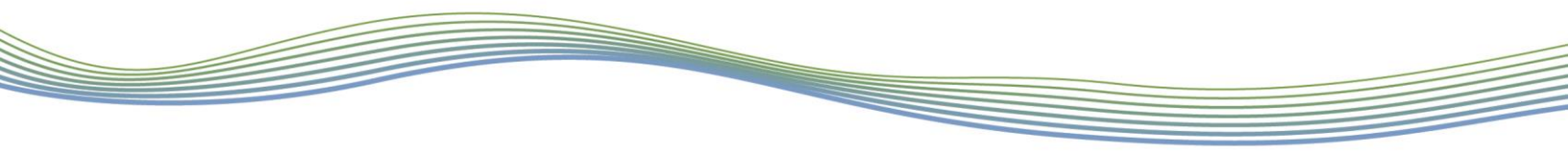
Ontario Geological Survey (OGS). 2010. Surficial Geology of Southern Ontario.

Richards, C., Haro, R.J., Johnson, L.B. and Host, G.E. 1997. Catchment and reach-scale properties as indicators of macroinvertebrate species traits. *Freshwater Biology*, 37: 219-230.

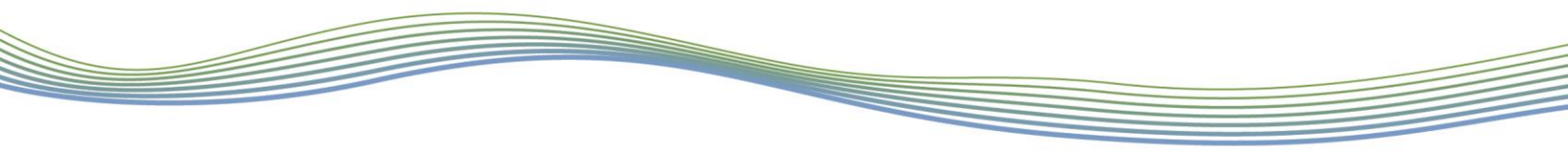
Toronto and Region Conservation Authority and Credit Valley Conservation Authority. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline.



## Appendix A Reach Map

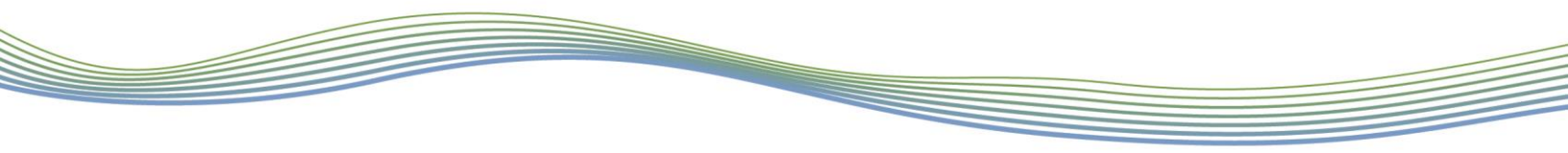


## **Appendix B** **Historical Aerial Photographs**

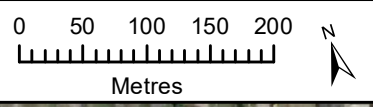


## **Appendix C**

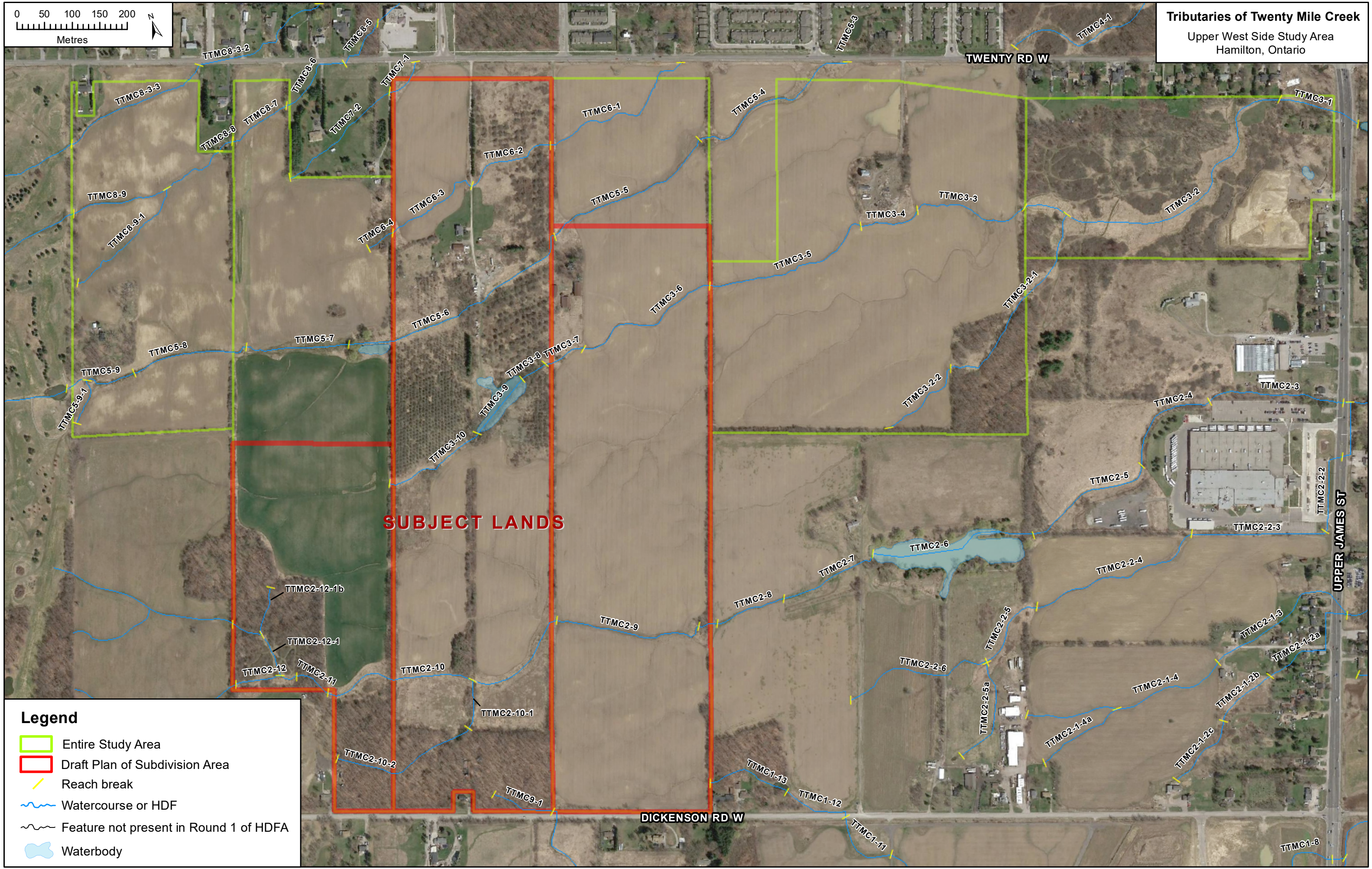
### **Photographic Record**



## **Appendix D** **Headwater Drainage Feature Management Classifications**

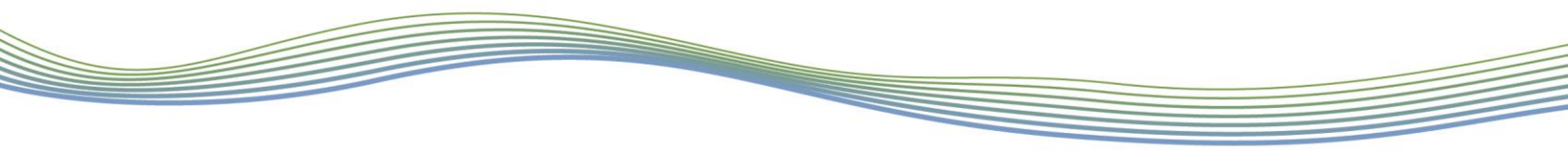


**Tributaries of Twenty Mile Creek**  
Upper West Side Study Area  
Hamilton, Ontario



**Legend**

- Entire Study Area
- Draft Plan of Subdivision Area
- | Reach break
- ~ Watercourse or HDF
- ~ Feature not present in Round 1 of HDFA
- ~ Waterbody



## **Appendix B** **Historical Aerial Photographs**

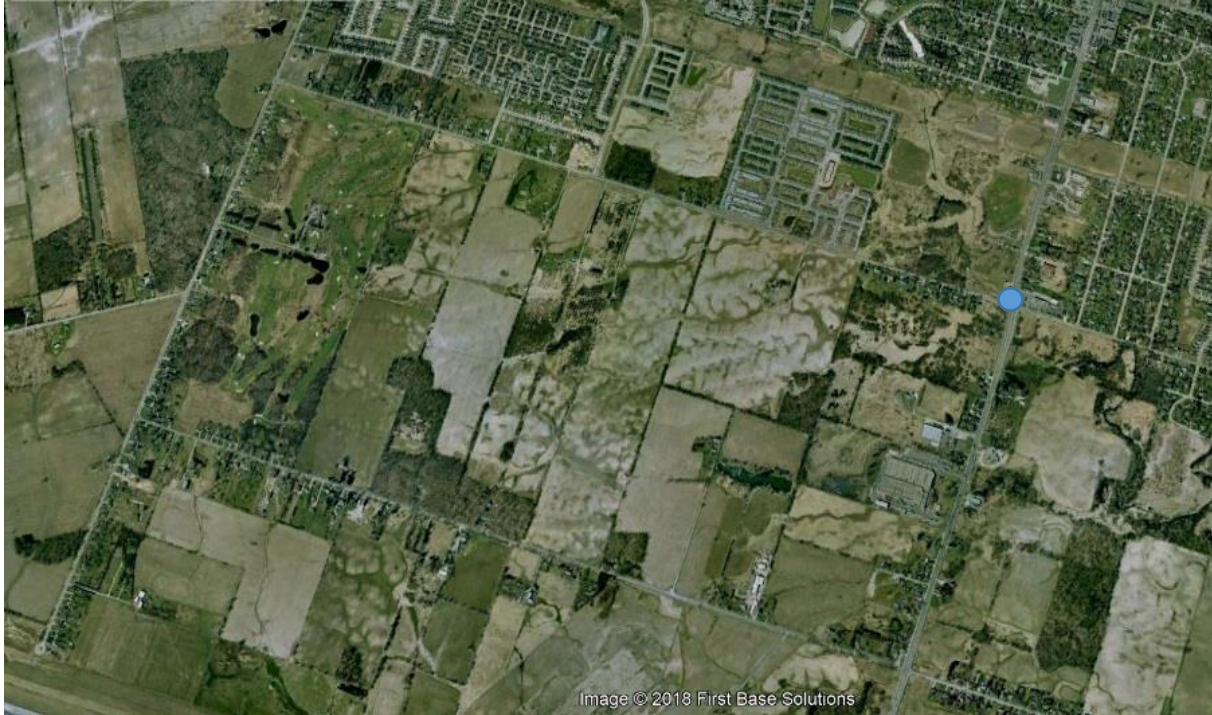


**Year:** 1952  
**Location** (blue dot): Upper James Street and Twenty Road West  
**Source:** McMaster University Aerial Photo Library





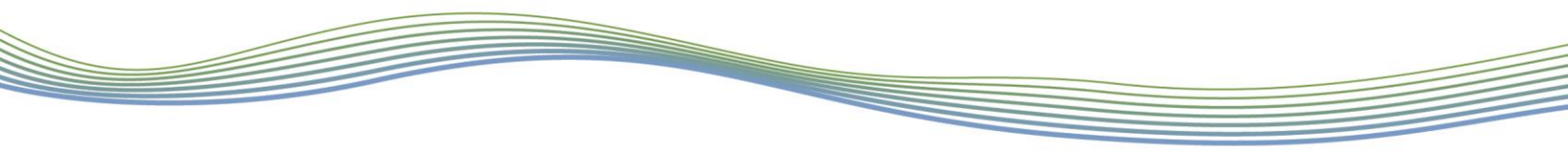
**Year:** 1959  
**Location** (blue dot): Upper James Street and Twenty Road West  
**Source:** McMaster University Aerial Photo Library



**Year:** 2005  
**Location** (blue dot): Upper James Street and Twenty Road West  
**Source:** Google Earth Pro



**Year:** 2017  
**Location** (blue dot): Upper James Street and Twenty Road West  
**Source:** Google Earth Pro



## **Appendix C**

### **Photographic Record**

Photo 1  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTCM2-9



The feature lacked defined bed and banks and conveyed substantial flow through an agricultural field during the spring visit. The Yellow arrow denotes the flow direction.

Photo 2  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTCM2-9



No riparian or aquatic vegetation was observed within or adjacent to the feature. Notably, the feature's substrate was equivalent to that of the surrounding fields.

Photo 3  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTCM2-9**



The feature was indistinguishable from the surrounding landscape during the summer, with no channel formation or hydrophilic vegetation observed.

Photo 4  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC2-10**



The feature was a poorly-defined channel with substantial water flowing through an agricultural field and a hedgerow during the spring visit.

Photo 5  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTM2-10**



Herbaceous and grass vegetation were observed within and adjacent to the channel. Bed materials were equivalent to the surrounding fields.

Photo 6  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTM2-10**



The feature was dry and indistinguishable from the surrounding fields during the summer, with no channel formation or hydrophilic vegetation observed.

Photo 7  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC2-10-1**



The feature lacked defined bed and banks and conveyed minimal flow through an agricultural field and a hedgerow during the spring visit.

Photo 8  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC2-10-1**



The wet meadow corridor consisted mostly of hydrophilic herbaceous and grass species. Bed materials were silt and organic material.



Photo 9  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC2-10-1**



The feature was dry and indistinguishable from the surrounding landscape during the summer, with no channel formation.

Photo 10  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC2-10-2**



The feature lacked defined bed and banks and conveyed substantial flow through a woodlot during the spring visit.

Photo 11  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC2-10-2**



Deciduous tree species were observed adjacent to the channel and minimal flow was present during the second visit.

Photo 12  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC2-10-2**



Feature was dry but distinguishable from the surrounding landscape during the third visit. Bed materials consisted predominantly of silt and clay.

Photo 13  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM2-11



The feature had defined bed and banks, with substantial water flowing during the spring visit.

Photo 14  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM2-11



Minimal flow was conveyed through the deciduous forest during the second visit.

Photo 15  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC2-11**



Feature was dry but distinguishable from the surrounding landscape in the summer visit. Bed materials consisted predominantly of silt, clay and some gravel which were poorly sorted.

Photo 16  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC2-12**



The feature lacked defined bed and banks and conveyed minimal flow nearby to the woodlot during the spring visit.

Photo 17  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC2-12**



The poorly defined channel had some standing water during the second visit, and lacked banks to distinguish it from the adjacent grassland.

Photo 18  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC2-12**



The feature was dry and indistinguishable from the surrounding landscape during the summer, with no channel formation. Bed materials consisted of clay, silt and organic matter.

Photo 19  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC2-12-1**



The feature lacked defined bed and banks and conveyed minimal flow through the woodlot during the spring visit.

Photo 20  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC2-12-1**



Riparian vegetation for the reach consisted predominantly of deciduous trees. Standing water was present during the second visit.

Photo 21  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM2-12-1



The feature was dry during the summer visit but was distinguishable from the surrounding woodlot. Bed materials consisted of clay, silt and organic matter.

Photo 22  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM2-12-1b



The feature was a low gradient swale conveying minimal flow through a woodlot. No bed or bank definition were observed.

Photo 23  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM2-12-1b



Riparian vegetation consisted of herbaceous vegetation and deciduous tree species. Standing water was observed during the second visit.

Photo 24  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM2-12-1b



The feature was dry during the summer visit but distinguishable from the surrounding woodlot. Bed materials consisted of sand, silt and organic matter



Photo 25  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC3-1**



The feature was a defined straight channel conveying flows towards its confluence with Twenty Mile Creek on the east side of Upper James Street.

Photo 26  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC3-1**



Riparian vegetation consisted of scrubland and some hydrophilic vegetation. Bed materials consisted of clay and silt.

Photo 27  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC3-1**



A culvert discharged flows into the feature near its downstream extent. No water was observed within the pipe during the second visit.

Photo 28  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC3-2**



The feature had no discernible banks, and occupied a wide grassy corridor characterized as a provincially significant wetland (PSW).

Photo 29  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC3-2**



Riparian vegetation consisted of grasses with sparse herbaceous vegetation, and water was present during all 3 visits.

Photo 30  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC3-2**



Tadpoles were observed within an isolated pool. Substrate consisted of clay, silt and organic materials.

Photo 31  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-2-1**



The feature was a defined channel which conveyed flows through a woodlot.

Photo 32  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC3-2-1**



Riparian vegetation included mature deciduous trees as well as some shrubs and hydrophilic herbaceous vegetation

Photo 33  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-2-1**



The feature was dry during the summer visit but distinguishable from the surrounding landscape. Bed materials consisted predominantly of clay, silt and organic material

Photo 34  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-2-2**



The feature had defined bed and banks within the agricultural lands during freshet.

Photo 35  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC3-2-2**



The feature was surrounded by agricultural crops along its upstream section and ends in a woodlot populated by deciduous trees. Some water was flowing during the second visit.

Photo 36  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-2-2**



The feature was dry during the last visit and the substrate consisted predominantly of clay, silt and gravel.

Photo 37  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM3-3



The feature lacked defined bed and banks and conveyed flows through an agricultural field during the spring visit.

Photo 38  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM3-3



Riparian vegetation consisted predominantly of crops, with some grasses. Bed materials were indistinguishable from the surrounding fields.

Photo 39  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-3**



The feature was dry and almost indistinguishable from the surrounding landscape during the summer.

Photo 40  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-4**



The feature had well defined bed and banks within the agricultural fields during the spring visit and was conveying flow.

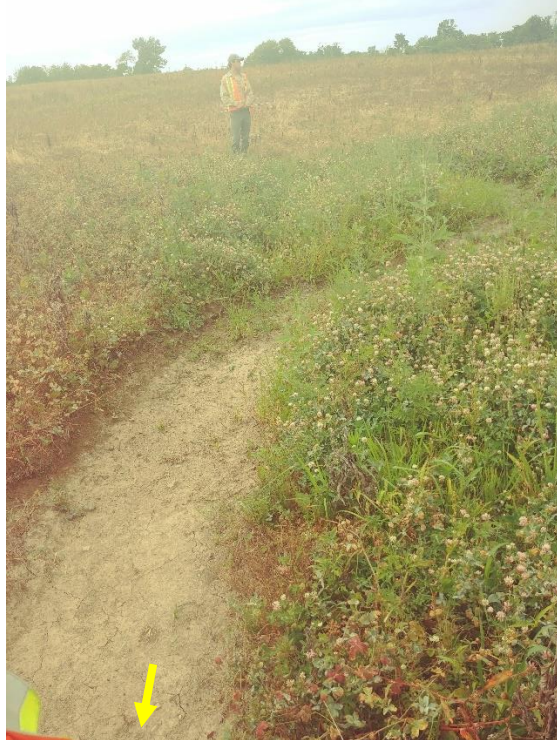


Photo 41  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTM3-4**



The riparian buffer consisted predominantly of herbaceous species, with some agricultural crops noted on the south side of the channel further downstream.

Photo 42  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTM3-4**



The channel bed was predominantly composed of clay and gravel and was dry during the summer visit.

Photo 43  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM3-5



The feature had some bed and bank definition within the agricultural lands during the spring and was conveying flow.

Photo 44  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM3-5



The majority of the riparian buffer consisted of agricultural crops.

Photo 45  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-5**



The dominant substrate was clay and silt, but some sand, gravel and, cobbles were also observed. The channel was mainly dry with some isolated stagnant pools.

Photo 46  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-6**



The feature conveyed flows through an agricultural field, with water present during the spring visit.

Photo 47  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM3-6



Riparian vegetation was predominantly agricultural crops, with some herbaceous and grass species also observed.

Photo 48  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM3-6



Bed and banks were mostly composed of the same material as the agricultural fields, a clay, silt, sand mixture, although some cobbles were present.

Photo 49  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-7**



The feature lacked bed and bank definition and conveyed flows from the central woodlot through a meadow to the agricultural field.

Photo 50  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC3-7**



The feature was dry and indistinguishable from the surrounding landscape during the summer, with no discernible channel.

Photo 51  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-7**



The bed was composed of poorly sorted clay, silt, sand and sparse gravel. The feature was dry during the summer visit.

Photo 52  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC3-8**



The feature was poorly defined and conveyed flows from the online pond to the meadow flanking the agricultural field to the east.

Photo 53  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM3-8



Riparian vegetation consisted of deciduous trees and herbaceous vegetation.

Photo 54  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM3-8



Bed materials consisted of clay, silt, sand and organic material. The feature was dry during the summer visit.

Photo 55  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC3-9**



The feature was an online pond located roughly in the middle of the subject lands within a woodlot.

Photo 56  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC3-9**



Riparian vegetation consisted predominantly of mature deciduous trees which provided shading to the pond



Photo 57  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM3-10



The feature lacked bed and bank definition and conveyed flows through a meadow.

Photo 58  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM3-10



The swale was populated by dense hydrophilic vegetation in the feature itself and its riparian zone.

Photo 59  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTM3-10**



The substrate within the reach was clay, silt and sand. No flows were observed during the summer visit.

Photo 60  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTM5-4**



The feature had poor channel definition and conveyed flows through an agriculture field.

Photo 61  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC5-4**



The feature occupied a relatively wide corridor composed of hydrophilic herbaceous vegetation and grasses.

Photo 62  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTMC5-4



The substrate material was equivalent to the surrounding fields and consisted of clay, silt and sand.

Photo 63  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC5-5**



The feature lacked bed and bank definition and conveyed flows through an agricultural field.

Photo 64  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC5-5**



The swale lacked a natural riparian corridor and was instead flanked by agricultural fields.

Photo 65  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC5-5**



The feature was dry during the summer visit and substrate was generally consistent with the adjacent fields.

Photo 66  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC5-6**



The feature lacked bed and bank definition and conveyed flows within a wooded area.

Photo 67  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTMCS-6



The feature was a wide grassy corridor composed of hydrophilic vegetation with deciduous trees occupying the riparian buffer.

Photo 68  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTMCS-6



The substrate within the channel was predominantly clay, silt and sand. No water was observed during the summer visit.

Photo 69  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMCS-7**



The feature had some bed and bank definition during the spring as it conveyed flows through an agricultural field.

Photo 70  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMCS-7**



Riparian vegetation consisted of grasses, with some areas lacking a buffer and instead being flanked by crops.

Photo 71  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC5-7**



Substrate within the feature consisted of clay, silt, and sand and the channel was occupied by sparse rooted emergent aquatic vegetation and grasses.

Photo 72  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC5-8**



The feature was a swale which conveyed flows through an agricultural field.



Photo 73  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC5-8**



The feature had a narrow riparian corridor composed of herbaceous vegetation and grasses.

Photo 74  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC5-8**



Substrate composition was predominantly clay, silt and sand with some scattered gravels.  
The feature was dry during the summer visit.

Photo 75  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC5-8-1**



The feature had poorly defined banks, but a discernible channel was observed. Water was flowing during the spring visit.

Photo 76  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC5-8-1**



Riparian vegetation consisted of herbaceous vegetation and grasses. The channel was dry during the second visit.

Photo 77  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC5-8-1**



Bed substrate consisted of clay, silt and sand. The feature was again dry during the summer visit.

Photo 78  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC5-9**



The feature originated at the outlet of a small pond within the former Glancaster Golf and Country Club and conveyed flows through an agricultural field.

Photo 79  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC5-9**



The feature's substrate consisted predominantly of organic material, silt and sand.

Photo 80  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC6-1**



The feature lacked defined bed and banks, and minimal flow was observed during the spring site visit.

Photo 81  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM6-1



The channel was dry during the 2<sup>nd</sup> visit and the substrate was predominantly clay, silt, and sand. Some gravel and cobbles were also observed.

Photo 82  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM6-1



Vegetation within the feature was predominantly composed of the crops which occupied the adjacent fields, with sparse aquatic vegetation was infrequently observed.

Photo 83  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC6-2**



The feature had poor channel definition and originated at a culvert. The reach conveyed flows within the fallow orchard.

Photo 84  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC6-2**



The feature was filled with dense, rooted emergent aquatic vegetation, particularly grasses, and was flanked by both meadow and scrubland within the riparian buffer.

Photo 85  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM6-2



Bed substrate within the feature was predominantly clay, silt and sand. No water was present during the summer visit.

Photo 86  
Tributary of Twenty Mile Creek: Visit 1  
Reach TTM6-3



he feature lacked bed and bank definition and conveyed flows through an agricultural field north of a central residential property.

Photo 87  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC6-3**



The channel was located adjacent to an un-planted agricultural field and had a narrow herbaceous riparian buffer.

Photo 88  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC6-3**



Substrate within the feature was clay, silt and sand. No discernable channel could be located at the upstream extent of the reach. The feature was dry during the summer visit.



Photo 89  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC6-4**



The feature lacked definition and is best described as a vernal pool within a wide hedgerow between two agricultural fields.

Photo 90  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC6-4**



The feature was surrounded by scrubland and deciduous trees.

Photo 91  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC6-4**



The feature was dry during the summer visit and its substrate consisted predominantly of decomposing organics.

Photo 92  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC7-1**



The feature originated at a culvert and was poorly defined.

Photo 93  
Tributary of Twenty Mile Creek: Visit 2  
Reach TTM7-1



The feature was surrounded by meadow and grass species and some standing water was observed during the second visit.

Photo 94  
Tributary of Twenty Mile Creek: Visit 3  
Reach TTM7-1



Bed material for the reach was predominantly clay, silt and sand. No water was present within the reach during the third visit.

Photo 95  
Tributary of Twenty Mile Creek: Visit 1  
**Reach TTMC8-6**



The feature lacked bed and bank definition and conveyed flows towards a roadside ditch at Twenty Road West.

Photo 96  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC8-6**



The feature's vegetation was equivalent to the surrounding area, and consisted of a manicured lawn.

Photo 97  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC8-6**



The feature was dry during the 2<sup>nd</sup> visit.

Photo 98  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC8-7**



The feature lacked a natural riparian buffer, and was predominantly cropped with some areas lacking any vegetation.

Photo 99  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC8-7**



Substrate composition was predominantly clay, silt, sand and sparse gravel. The feature was dry during the summer visit.

Photo 100  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC8-9**



The feature was a swale which conveyed flows through an agricultural field.

Photo 101  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTMC8-9**



Riparian vegetation consisted predominantly of agricultural crops, which were generally absent from the channel during the spring.

Photo 102  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTMC8-9**



Substrate composition was consistent with the adjacent fields, and was predominantly clay, silt, and sand. The feature was dry during the summer visit.

Photo 103  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC8-9-1**



The feature lacked definition and conveyed flows through an agricultural field. Standing water was observed during the 2<sup>nd</sup> visit.

Photo 104  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC8-9-1**



Bed composition was predominantly clay, silt and sand. The feature was dry during the summer visit.



Photo 105  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC8-3-3**



The feature lacked channel definition and conveyed flows through an agricultural field.

Photo 106  
Tributary of Twenty Mile Creek: Visit 2  
Reach **TTMC8-3-3**



The feature lacked natural riparian vegetation and was flanked by crops, which encroached the channel.

Photo 107  
Tributary of Twenty Mile Creek: Visit 3  
Reach **TTMC8-3-3**



Substrate within the intermittent feature was predominantly clay, silt, and sand. No water was observed during the 3<sup>rd</sup> visit.

Photo 108  
Tributary of Twenty Mile Creek: Visit 1  
Reach **TTMC9-1**



The feature lacked channel definition and conveyed flows through a woodlot.

Photo 109  
Tributary of Twenty Mile Creek: Visit 2  
**Reach TTM9-1**

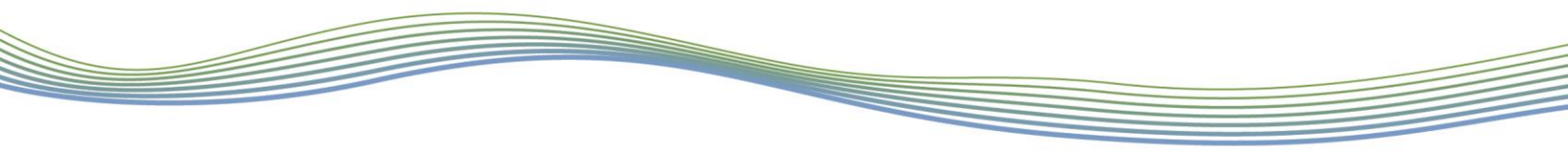


Riparian vegetation adjacent to the feature consisted of deciduous trees. No water was present during the 2<sup>nd</sup> visit.

Photo 110  
Tributary of Twenty Mile Creek: Visit 3  
**Reach TTM9-1**

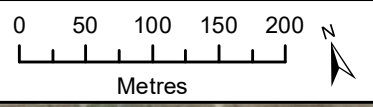


The low gradient feature's substrate was predominantly composed of decomposing organic matter and silt. Water was not observed during the 3<sup>rd</sup> visit.

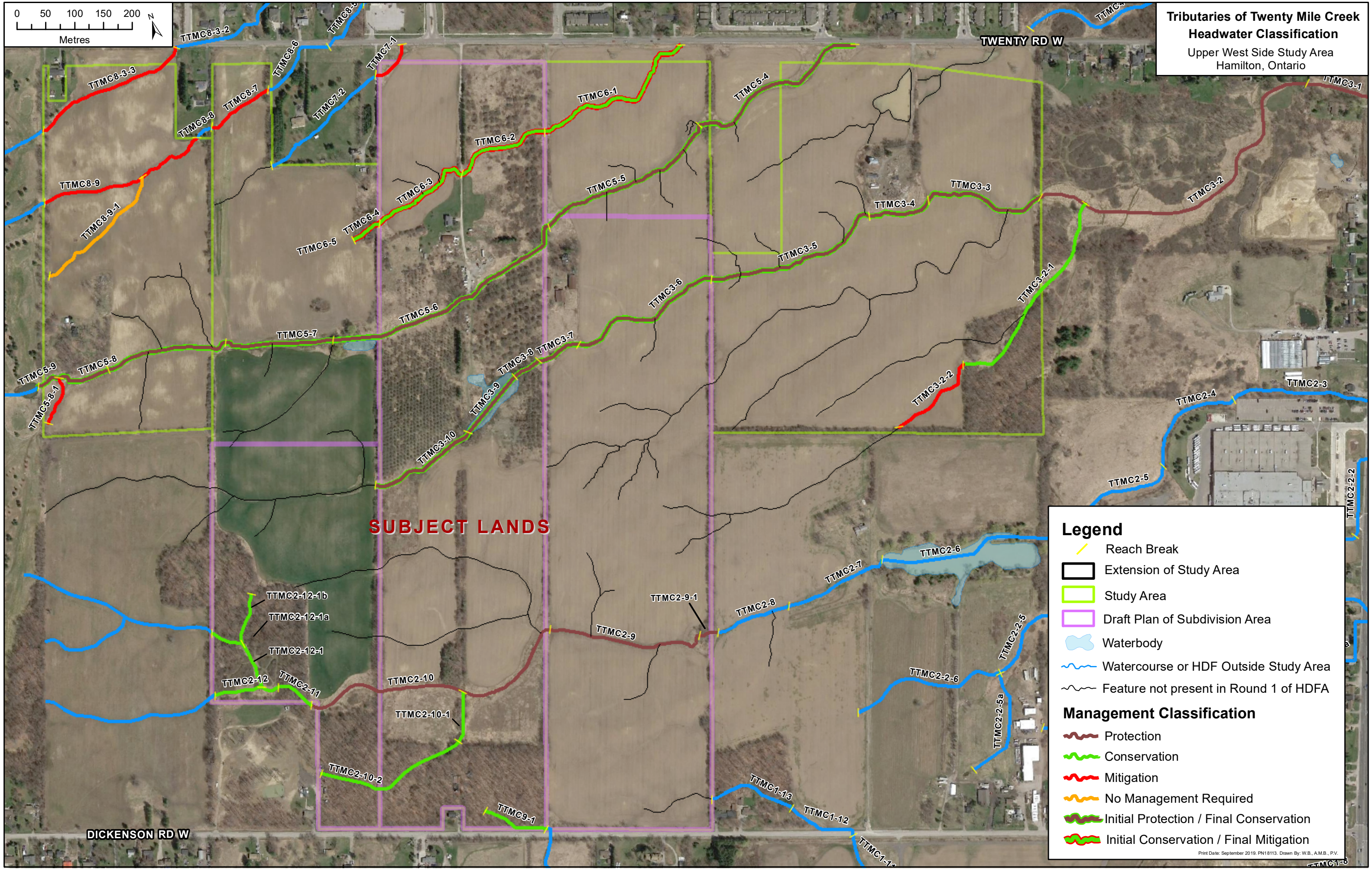


## **Appendix D**

# **Headwater Drainage Feature Management Classifications**



**Tributaries of Twenty Mile Creek  
Headwater Classification**  
Upper West Side Study Area  
Hamilton, Ontario



**Legend**

- Reach Break
- Extension of Study Area
- Study Area
- Draft Plan of Subdivision Area
- Waterbody
- Watercourse or HDF Outside Study Area
- Feature not present in Round 1 of HDFA

**Management Classification**

- Protection
- Conservation
- Mitigation
- No Management Required
- Initial Protection / Final Conservation
- Initial Conservation / Final Mitigation

Print Date: September 2019, PN18113, Drawn By: W.B. A.M.B., P.V.