# APPENDIX C
# Characterization and Development of Alternatives (Phase 2)

# APPENDIX C4
# LiDAR Topography Integration

# APPENDIX C4

# LIDAR SURVEY INTEGRATION

## 1 PREFACE

Matrix Solutions Inc. conducted topographic and bathymetric surveys in September 2021 at German Mills Creek from the confluence with Duncan Creek and the bridge crossing at Steeles Avenue East on the upstream end to the confluence at Don River East Branch and German Mills Creek at the downstream end. The survey was conducted in the following coordinate systems:

- Horizontal: NAD_1983_CSRS_MTM_10 | WKID: 2952 | Authority: EPSG
- Vertical: CGVD_1928 | WKID: 5713 | Authority: EPSG

These data were merged with LiDAR data from the Ontario GeoHub (MNRF 2021a) to generate two versions of the topographic surface:

- to support hydraulic modeling of alternate scenarios and the coordinate system of the modeling environment (HEC-RAS):
    - Horizontal: NAD_1983_UTM_Zone_17N | WKID: 26917 | Authority: EPSG
    - Vertical: CGVD_1928 | WKID: 5713 | Authority: EPSG
- to accommodate existing mapping extensive mapping already completed and to minimize transforming other datasets for erosion risk assessment:
    - Horizontal: NAD27_MTM_zone_10 | WKID: 7991 | Authority: EPSG
    - Vertical: CGVD_1928 | WKID: 5713 | Authority: EPSG

The final issued data products include two alternate versions of the surface:

- BareEarthLiDARWithSurvey.tif: issued October 30, 2021
- BareEarthLiDARWithSurveyHECRAS.tif: issued October 30, 2021; revised November 6, 2021

Transformations used to reproject the final surfaces were as follows:

- BareEarthLiDARWithSurvey.tif: ON83CSv1.gsb used for CSRS/NAD83 transformation
- BareEarthLiDARWithSurveyHECRAS.tif: ON27CSv1.gsb used for CSRS/NAD27 transformation

## 2 METHODS FOR CROSS-SECTION AND CHANNEL SURVEY INTEGRATION WITH LIDAR

### 2.1 Creating a Processing Mask

The purpose of this task was to establish a processing mask to ensure the area where survey data was superseding the existing LiDAR was restricted only to areas where we had suitable data. Two masks were generated: a channel mask and a cross-section mask.

The channel mask was generated using the River Bathymetry Toolkit (RBT; McKean et al. 2009) using the Detrend From Line functionality. This tool required two inputs: the LiDAR surface and the thalweg generated from the survey data. The resulting product was a detrended surface that could allow for determining the approximate bank lines of the creek by simple raster thresholding. Through a series of geoprocessing steps and some minor manual adjustments, this surface was converted to a polygon mask. With cross-section survey data, a cross-section mask was set up to confine the interpolation of the data point immediately 2 m around the cross-section. Two separate masks were produced because the interpolation of the two types of data points is conducted separately.

### 2.2 Interpolation

To effectively interpolate the field data up- and downstream, channel data points were projected perpendicular to an offset buffer of the thalweg (32 m from the thalweg) to the left and right side of the channel. Figure 1 displays the LiDAR merged with the channel surface.

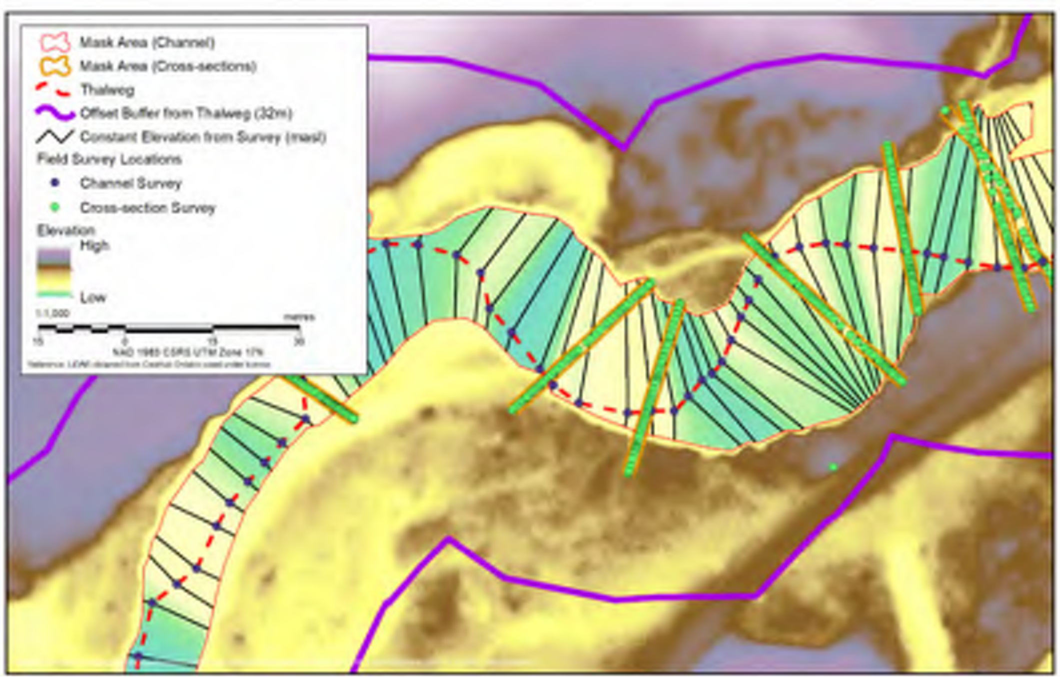



**FIGURE C4a Topographic Survey Data was Integrated with LiDAR**

The interpolation of elevations between the constant elevations was done using ArcGIS 3D Analyst by creating a triangular irregular network (TIN). The lines of constant elevation extend from the thalweg all the way to the offset buffer to avoid any boundary effects; however, the surface is only applied to the area within the mask area for the channel. In a separate interpolation, the cross-section elevation was interpolated and applied to areas under the cross-section mask areas. This was based on the same process as the channel mask interpolation.

This results in two surfaces:

- interpolation for the channel
- interpolation for the cross-section

All surfaces created from the topographic survey during this step were in CGVD 1928.

## 3 HORIZONTAL AND VERTICAL TRANSFORMATIONS

Because there were multiple coordinate systems to accommodate for the two different use-cases (one for HEC-RAS; one for mapping), a transformation is required to ensure datums were consistent between survey and LiDAR data. Using a benchmark in the area (0011960UT121), the offset between CGVD 1928 (165.496 m above sea level [asl]) and CGVD 2013 (165.087 m asl) is -0.409 m (MNRF 2021b). To match the surveyed surfaces to the LiDAR, the LiDAR (originally in CGVD 2013) was raised uniformly by +0.409 m. The surveyed surfaces and LIDAR were then mosaicked in increasing priority:

- adjusted LiDAR (lowest priority)
- channel surface
- cross-section surface (highest priority)

Horizontal transformations were also applied based on whether the surface was for the hydraulic model or project mapping. Transformations used reproject the final surfaces was as follows:

- BareEarthLiDARWithSurvey.tif: ON83CSv1.gsb used for CSRS/NAD83 transformation
- BareEarthLiDARWithSurveyHECRAS.tif: ON27CSv1.gsb used for CSRS/NAD27 transformation

## 4 REFERENCE

McKean J. et al. 2009. “Remote sensing of channels and riparian zones with narrow-beam aquatic-terrestrial LIDAR.” *Remove Sensing 1*: 1065–1096. 2009.

Ontario Ministry of Natural Resources and Forestry (MNRF). 2021a. *Ontario Digital Terrain Model (Lidar-Derived)*. Provincial Mapping Unit. Published August 23, 2019. Updated September 10, 2021. https://geohub.lio.gov.on.ca/maps/mnrf::ontario-digital-terrain-model-lidar-derived/explore?location=45.737321%2C-80.756250%2C6.82

Ontario Ministry of Natural Resources and Forestry (MNRF). 2021b. *Control Survey Information Exchange - Station 0011960UT121*. Retrieval Date July 22, 2021. file://matrix-

solutions.com/public/Gis/CityofToronto/32227/ToGIS/FromField/20211027_VerticalDatumInformation/COSINE%20REPORT%200011960UT121%20(VERT%20ONLY).HTML

# APPENDIX C5
# Rapid Geomorphic Assessment and Rapid Stream Assessment Technique Methods

# APPENDIX C5-1
## Site Photographs

1. Reach GM-4 – German Mills Creek at Steeles Ave. bridge. Outfalls on left (risk site 27.2) and right (risk site 27.1) becoming undermined at toe of bank.

2. Reach GM-4 – Series of rocky ribs in German Mills Creek constructed concurrent to Duncan Creek realignment and restoration works.

3. Reach GM-4 – View downstream; large cobble/boulder point bar towards right (in image), while watercourse is confined towards left with an overhanging, steep bank.

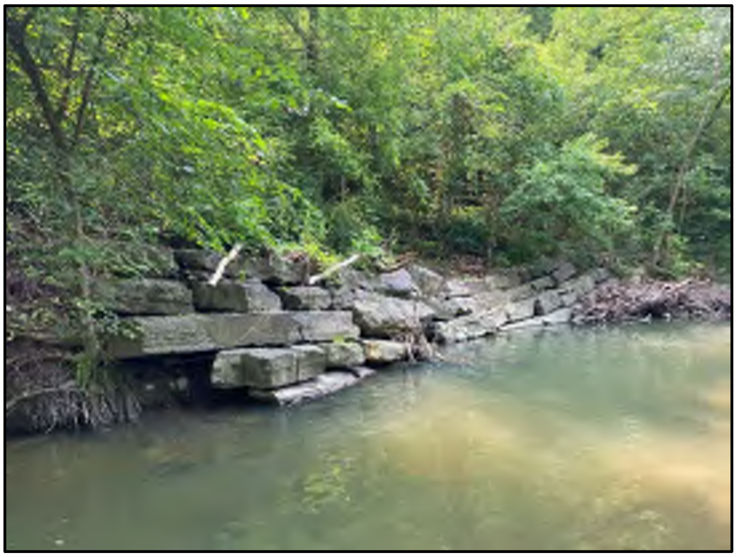
4. Reach GM-4 – Armourstone wall and outfall on left bank with large woody debris in channel. Sanitary sewer runs parallel to creek behind armourstone wall.

5. Reach GM-4 – Sheet pile wall with outfall along right bank upstream of Leslie St. bridge in good condition.

6. View upstream under Leslie St. bridge; well defined channel under bridge with large drop (~0.8 m) in profile.

7. Reach GM-3 – View of fully exposed maintenance hole on right bank (looking upstream); banks are vertical in this area and actively slumping.

8. Reach GM-3 – View downstream of typical channel planform; reach contains numerous cobble/gravel point and medial bars, some of which are partially vegetated.



9. Reach GM-3 – View of left bank with armourstone wall at a deep pool that has become undermined and is failing. Pedestrian pathway directly behind wall at risk.

10. Reach GM -3 – Second exposed maintenance hole mid-reach on right bank; channel widening is prevalent throughout all of reach resulting in vertical, undercut, and overhanging banks.

11. Reach GM-3 – View downstream of riprap placed along bank protecting property above; riprap in moderate condition, some minor toe erosion occurring.

12. Reach GM -3 – Third exposed maintenance hole towards downstream reach break along left bank. Lateral pipe connected to MH also exposed and bank continues to erode.

13. Reach GM-3 – Another view of third exposed maintenance hole looking downstream towards pedestrian bridge.

14. View downstream towards reach break between GM-3 and GM -2; active bank erosion occurring underneath pedestrian bridge requiring protection.

15. Reach GM – 2 – View of outfall channel on right bank; active erosion occurring around confluence with German Mills Creek.

16. Reach GM – 2 – View downstream under CN Railway bridge; riprap placed on both banks under railway and is in good condition.

17. Reach GM – 2 – View towards right bridge pier under pedestrian bridge; pier is at risk of becoming exposed due to ongoing bank erosion and channel widening under bridge; no bank protection present.

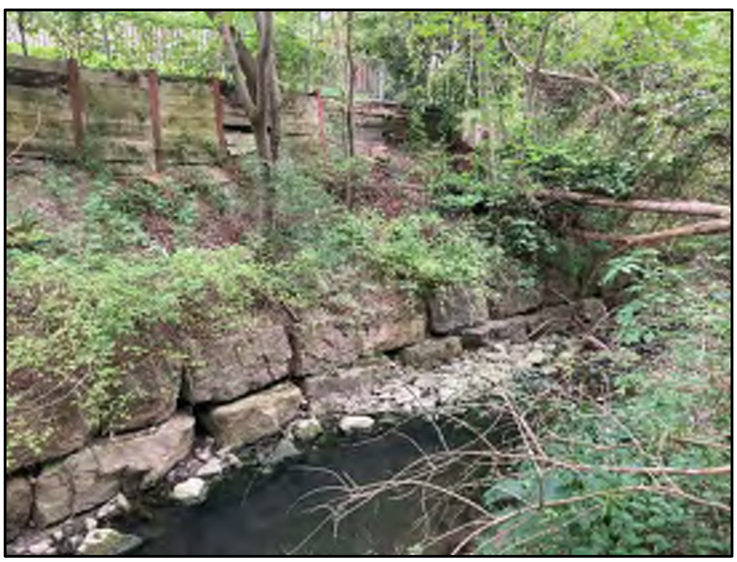
18. Reach GM – 2 – View downstream of typical channel planform; well vegetated riparian zone.

19. View upstream of confluence of Bestview Tributary (left) with German Mills Creek (right).

20. Reach GM – 2/GM – 1 reach break – View of right bank across from Bestview Tributary confluence; sewer is directly behind bank parallel to creek and bank has undergone extensive erosion placing sewer at risk.

21. Reach GM-BV-2 – View looking upstream of outfall outletting to Bestview tributary; channel is lined with armourstone blocks and appears stable.

22. Reach GM-BV-2 – View downstream of armourstone Bestview tributary channel; property (left) within close proximity to channel.



23. Reach GM-BV-2 – View of right bank in Bestview tributary of armourstone wall protecting adjacent property; armourstone in fair condition.

24. Reach GM-BV-1 – View of downstream reach of Bestview tributary; channel no longer contains/ bed/bank protection and is undergoing substantial erosion.

25. Reach GM – 1 – View downstream of large pool; channel is generally well connected to floodplain and contains a wide riparian zone.

26. Reach GM – 1 – View downstream of another large pool that is actively migrating towards sewer; vertical channel banks within vicinity of sewer.

27. Reach GM – 1 – View of left bank which is highly eroded and vertical; channel has occasional valley-wall contacts within reach.

28. Reach GM – 1 – View looking upstream of riprap weir mid-reach acting as grade control.

29. Reach GM – 1 – View of left bank; riprap has washed into middle of channel from previous bank protection/armouring of channel.

30. Reach GM – 1 – View looking downstream at pedestrian bridge near confluence with East Don River.

31. Reach GM – 1 – View looking upstream at German Mills Creek from pedestrian bridge near confluence; left bank and adjacent maintenance hole protected with armourstone blocks in good condition.

32. View downstream from pedestrian bridge looking at confluence with East Don River.

# APPENDIX C5-2
# RGA and RSAT Methods

# APPENDIX C5-2

# RAPID GEOMORPHIC ASSESSMENT AND RAPID STREAM ASSESSMENT TECHNIQUE METHODS

The Rapid Geomorphic Assessment (RGA) was designed by the Ontario Ministry of Environment (currently the Ontario Ministry of the Environment, Conservation and Parks; MOE 2003) to assess reaches in rural and urban channels. This qualitative technique documents indicators of channel instability. Observations are quantified using an index that identifies channel sensitivity based on the presence or absence of evidence of aggradation, degradation, channel widening, and planform adjustment. Overall, the index produces values that indicate whether the channel is Stable/In Regime (score ≤0.20), Stressed/Transitional (score 0.21 to 0.40), or Adjusting (score ≥0.40; Table C5a).

**TABLE C5a RGA Classification**

| Stability Index | Condition | Description |
|---|---|---|
| <0.20 | In Regime or Stable (Least Sensitive) | The channel morphology is within a range of variance for streams of similar hydrographic characteristics; evidence of instability is isolated or associated with normal river meander propagation processes. |
| 0.21-0.40 | Transitional or Stressed (Moderately Sensitive) | Channel morphology is within the range of variance for streams of similar hydrographic characteristics, but the evidence of instability is frequent. |
| >0.41 | In Adjustment (Most Sensitive) | Channel morphology is not within the range of variance and evidence of instability is widespread. |

The Rapid Stream Assessment Technique (RSAT) was developed by John Galli at the Metropolitan Washington Council of Governments (Galli 1996). The RSAT provides a more qualitative and broader assessment of the overall health and functions of a reach. This system integrates visual estimates of channel conditions and numerical scoring of stream parameters using six categories:

- channel stability
- erosion and deposition
- physical in-stream habitat
- water quality
- riparian conditions
- biological indicators

Once a condition has been assigned a score, the total of these scores produces an overall rating, which is based on a 50-point scoring system. The result of the assessment then categorizes the stream as:

- <20 low
- 20-35 moderate
- >35 high

While the RSAT scores streams from a more biological and water quality perspective than the RGA, this information is also of relevance within a geomorphic context. This is based on the fundamental notion that, in general, the types of physical features that generate good fish habitat tend to represent good geomorphology as well (i.e., fish prefer a variety of physical conditions, pools provide resting areas while riffle provide feeding areas and contribute oxygen to the water; good riparian conditions provide shade and food, woody debris and overhanging banks provide shade). Additionally, the RSAT approach includes semi-quantitative measures of bankfull dimensions, type of substrate, vegetative cover, and channel disturbance.

# APPENDIX C6
## Risk Assessment

**FIGURE C6a German Mills Risk Assessment Methodology**

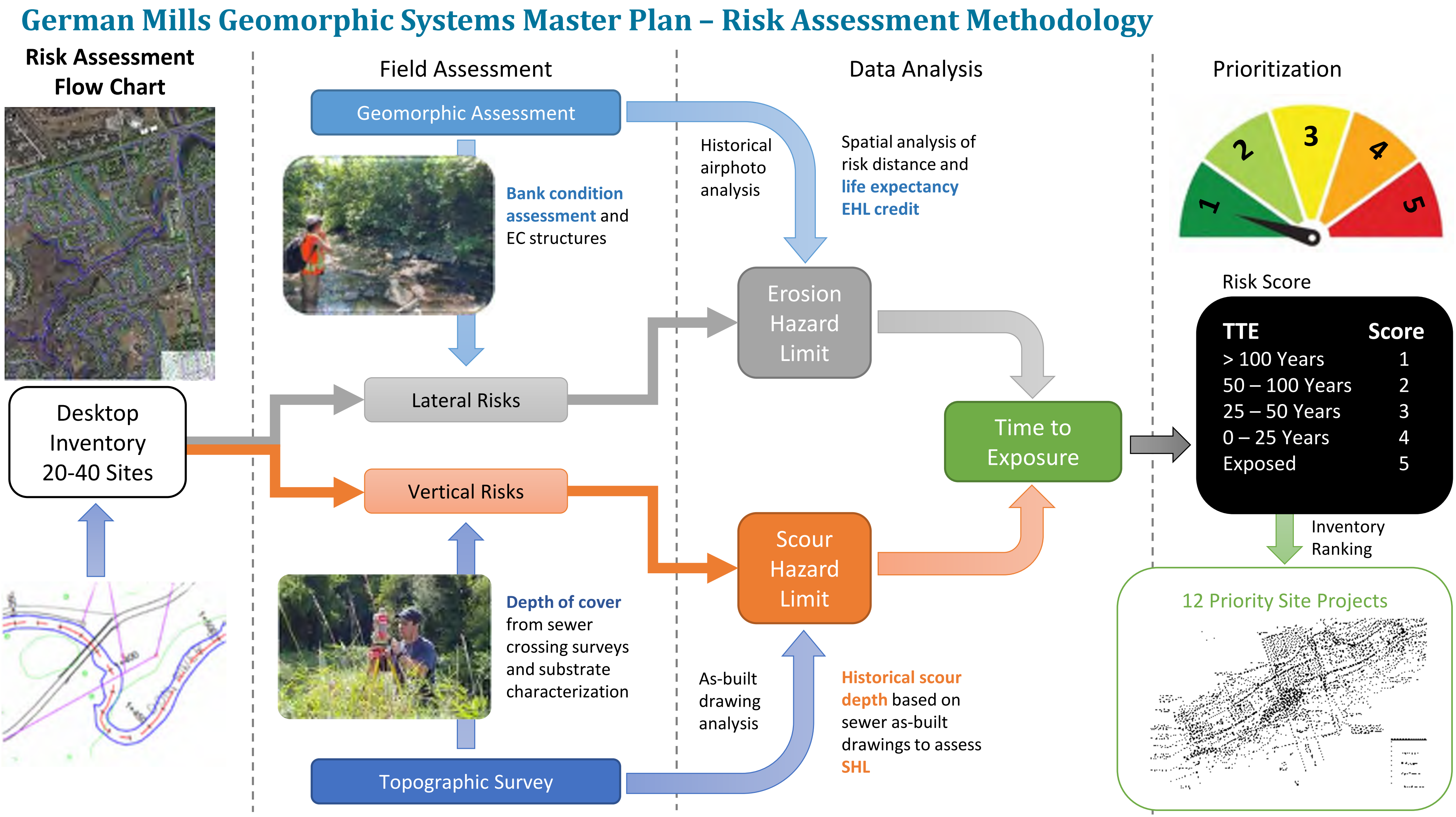


**FIGURE C6b Photograph Examples for Scoring of Bank Structures**

## Condition of Bank Structures

Gabion Baskets, Amourstone, Rip-Rap, Round Stone, Various Concrete Applications

Condition Scores


1 – Good (Amourstone)


2 – Fair (Armourstone)


3 – Poor (Armourstone Slump)


4 – Failure on Bank (Armourstone)


5 – Failure into Channel (Amourstone)

# FIGURE C6c Photograph Examples for Scoring of Bank Erosion

## Degree of Erosion

Condition of Natural Banks


Degree of Erosion

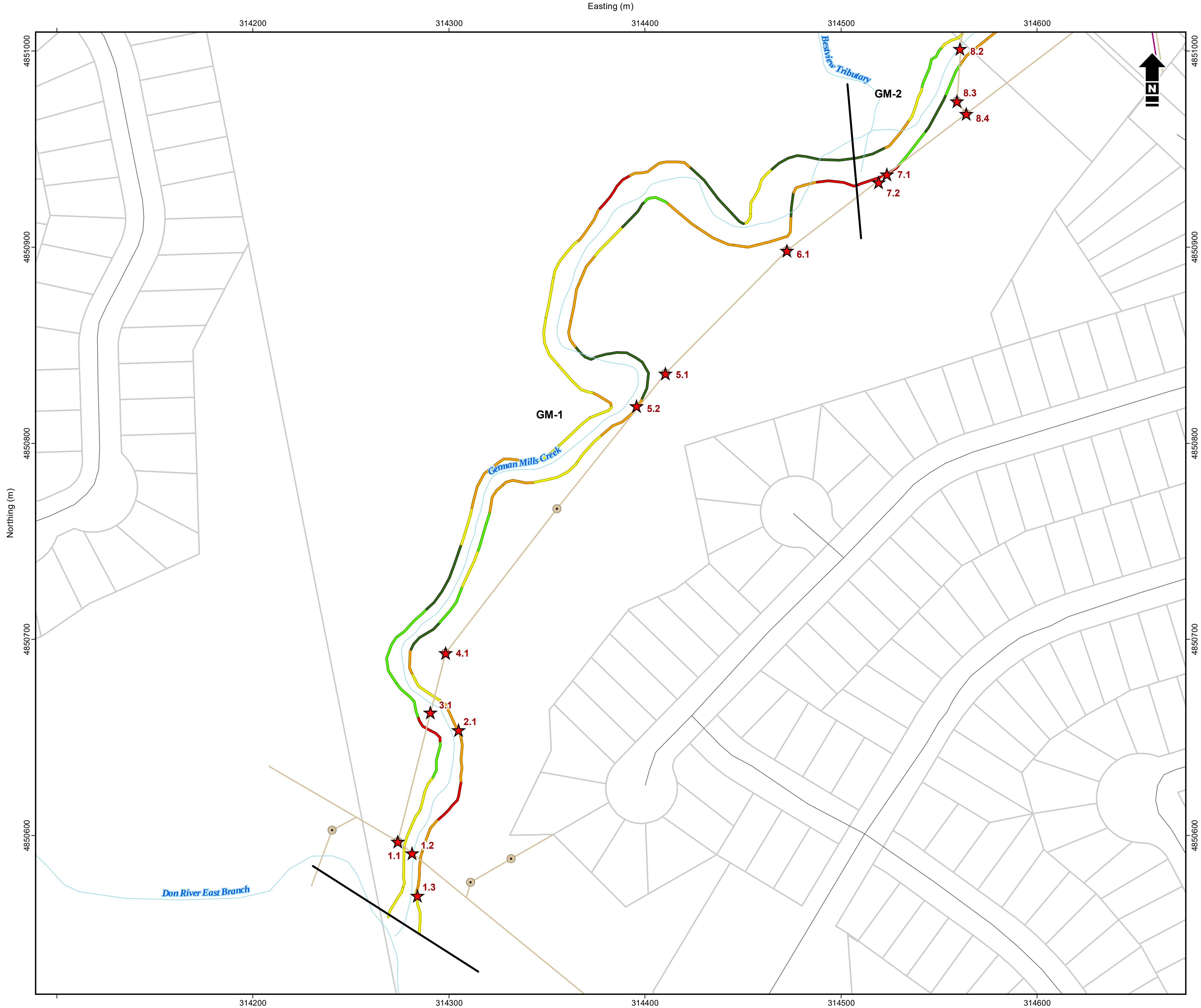
1 – Stable Bank

2 – Minor Bank Erosion

3 – Moderate Bank Erosion

4 – Major Bank Erosion

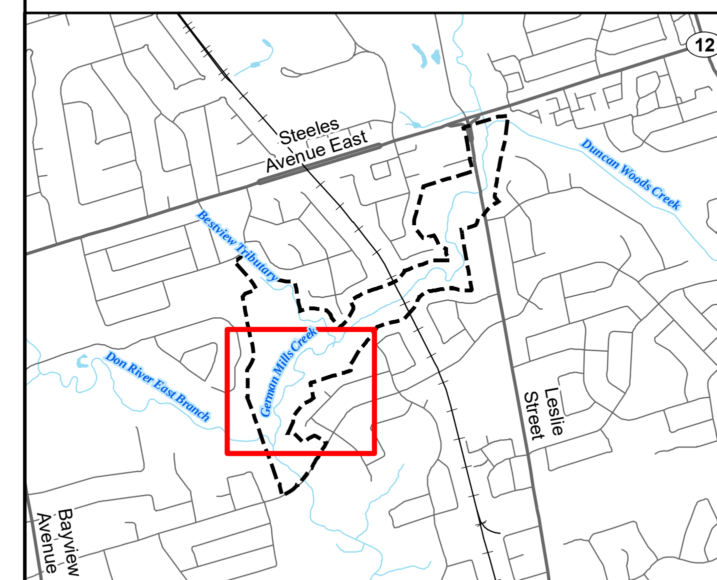
5 – High Rate/Risk Major Bank Erosion




Property Boundary
Reach Break
Watercourse
Sanitary Sewer
Storm Sewer
Sanitary Sewer Maintenance Hole
Erosion Risk Site

**Maximum Bank Condition Score**

1 - Stable
2 - Minor Erosion
3 - Starting to fail, still relativley stablel
4 - Continuing to fail, actively eroding
5 - Failure, features at risk or exposed




Disclaimer: Sewers have been clipped to the Focused Study Area.

1:2,000 metres
20 0 20 40
NAD27 MTM zone 10

Reference: Contains information licensed under the Open Government Licence – Ontario.

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# Maximum Bank Condition Scoring and Erosion Risk Sites - GM-1

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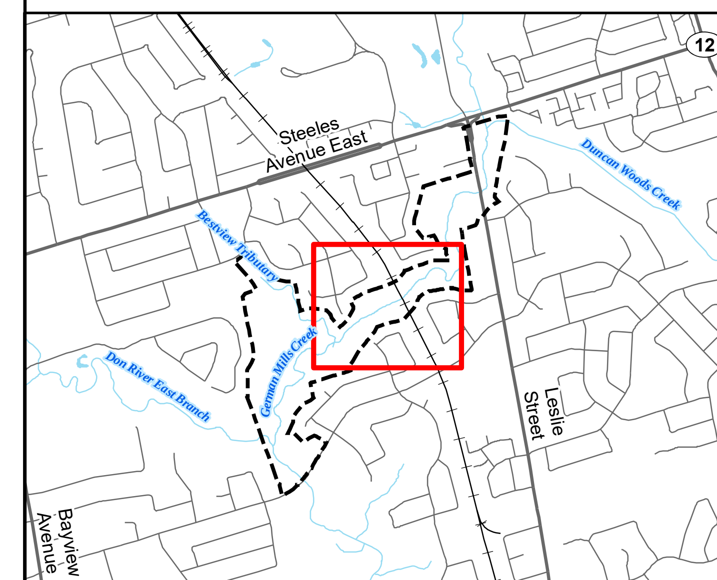
Figure C6d


- Property Boundary
- Reach Break
- Watercourse
- Railway
- Sanitary Sewer
- Storm Sewer
- Stormwater Outfall
- Sanitary Sewer Maintenance Hole
- Storm Sewer Maintenance Hole
- Erosion Risk Site

**Maximum Bank Condition Score**

- 1 - Stable
- 2 - Minor Erosion
- 3 - Starting to fail, still relativley stablel
- 4 - Continuing to fail, actively eroding
- 5 - Failure, features at risk or exposed

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1:2,000 metres
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# Maximum Bank Condition Scoring and Erosion Risk Sites - GM-2

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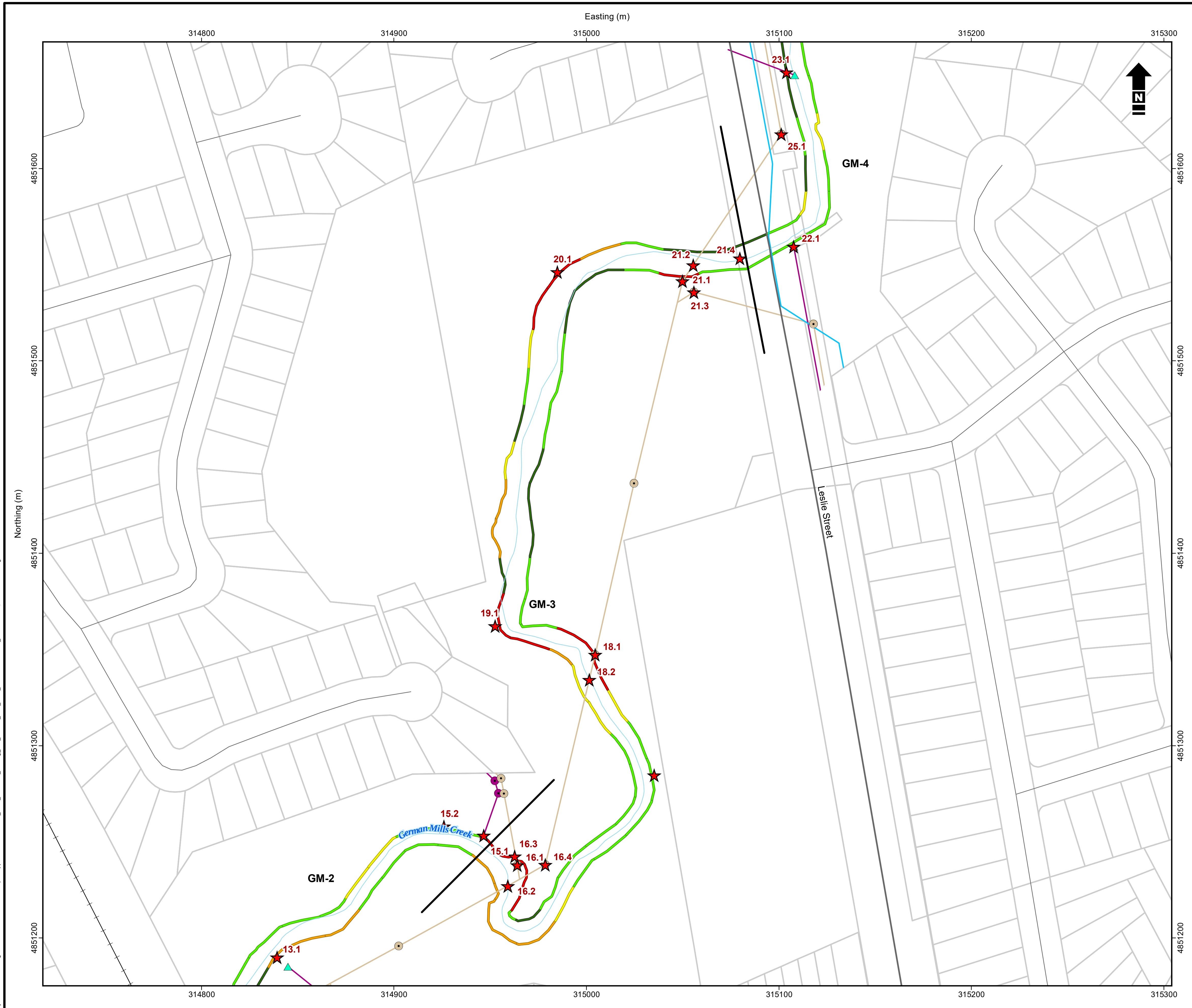
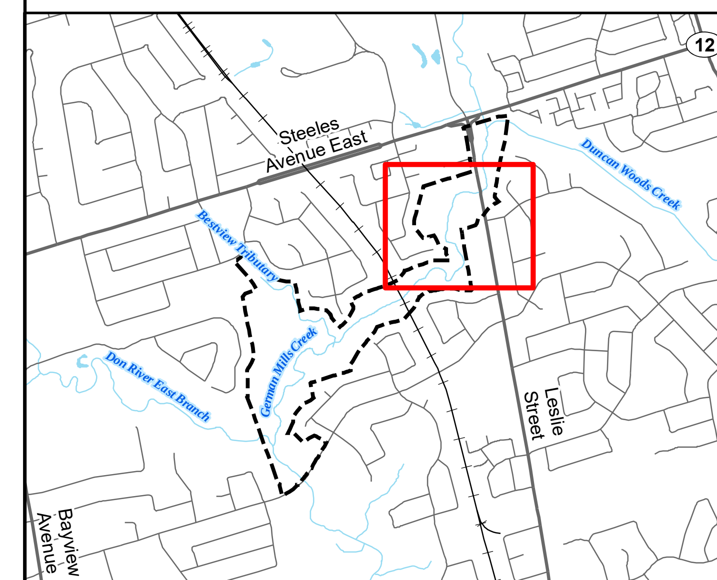
Figure
C6e




Property Boundary
Reach Break
Watercourse
Highway
Road
Railway
Sanitary Sewer
Storm Sewer
Stormwater Outfall
Sanitary Sewer Maintenance Hole
Storm Sewer Maintenance Hole
Erosion Risk Site

**Maximum Bank Condition Score**

1 - Stable
2 - Minor Erosion
3 - Starting to fail, still relativley stablel
4 - Continuing to fail, actively eroding
5 - Failure, features at risk or exposed

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1:2,000 metres
20 0 20 40
NAD27 MTM zone 10

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# Maximum Bank Condition Scoring and Erosion Risk Sites - GM-3

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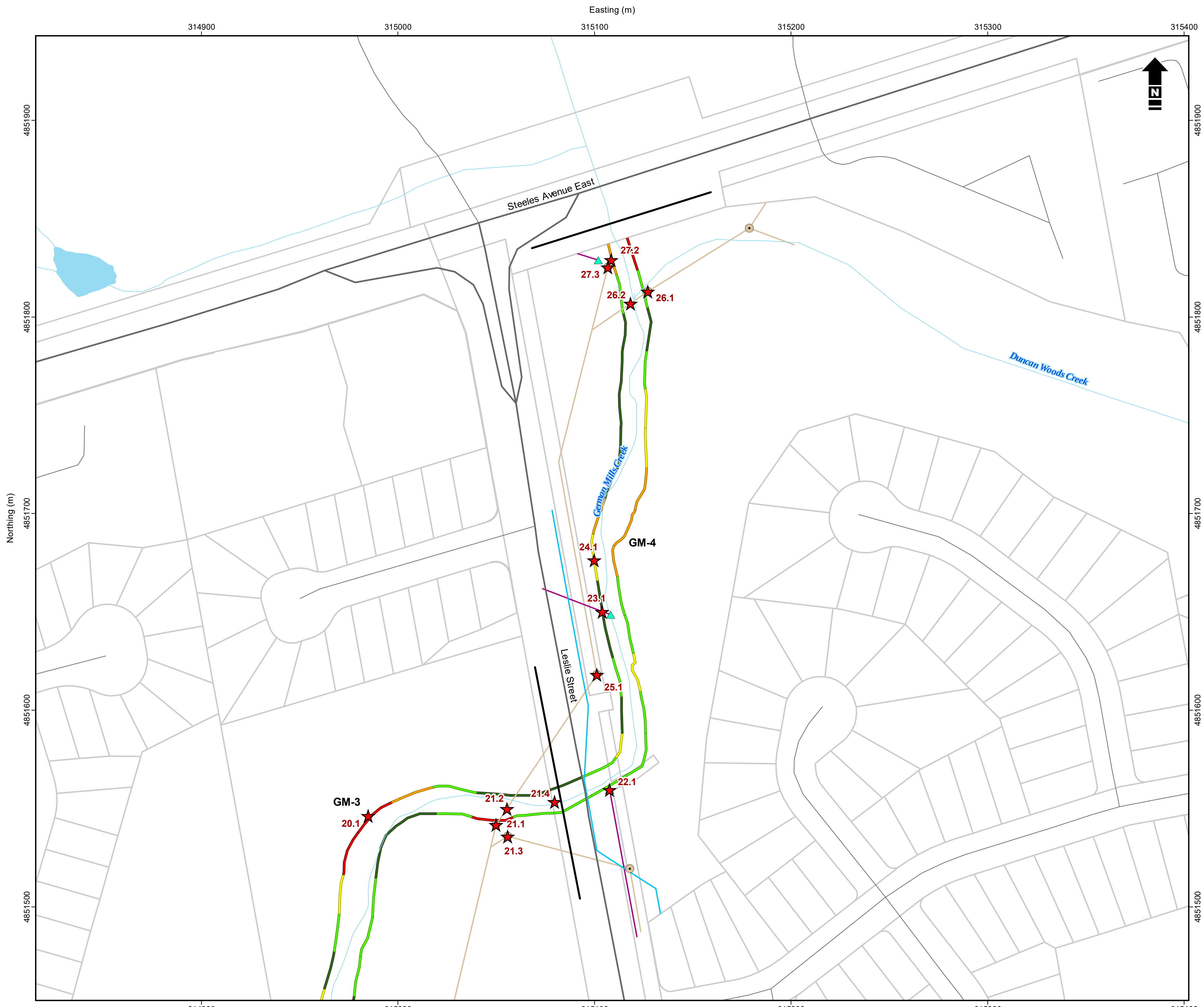
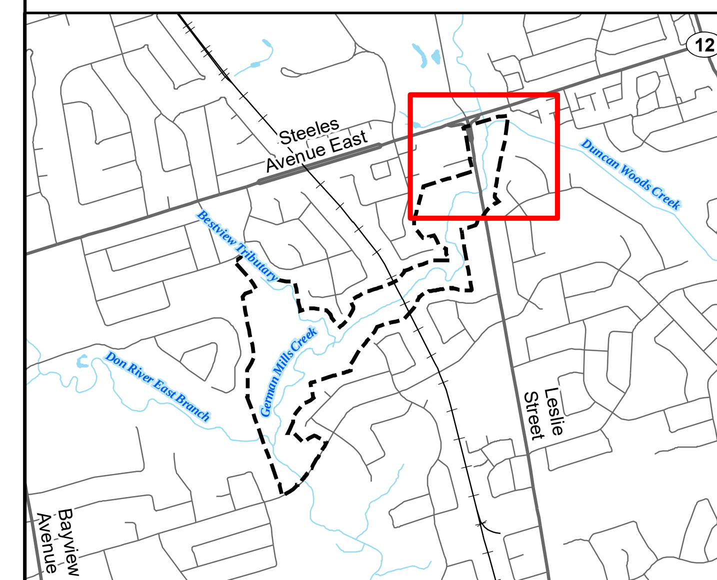
Figure C6f




Property Boundary
Reach Break
Watercourse
Highway
Road
Sanitary Sewer
Storm Sewer
Stormwater Outfall
Sanitary Sewer Maintenance Hole
Erosion Risk Site

**Maximum Bank Condition Score**

1 - Stable
2 - Minor Erosion
3 - Starting to fail, still relativley stablel
4 - Continuing to fail, actively eroding
5 - Failure, features at risk or exposed

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1:2,000 metres
20 0 20 40
NAD27 MTM zone 10

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# Maximum Bank Condition Scoring and Erosion Risk Sites - GM-4

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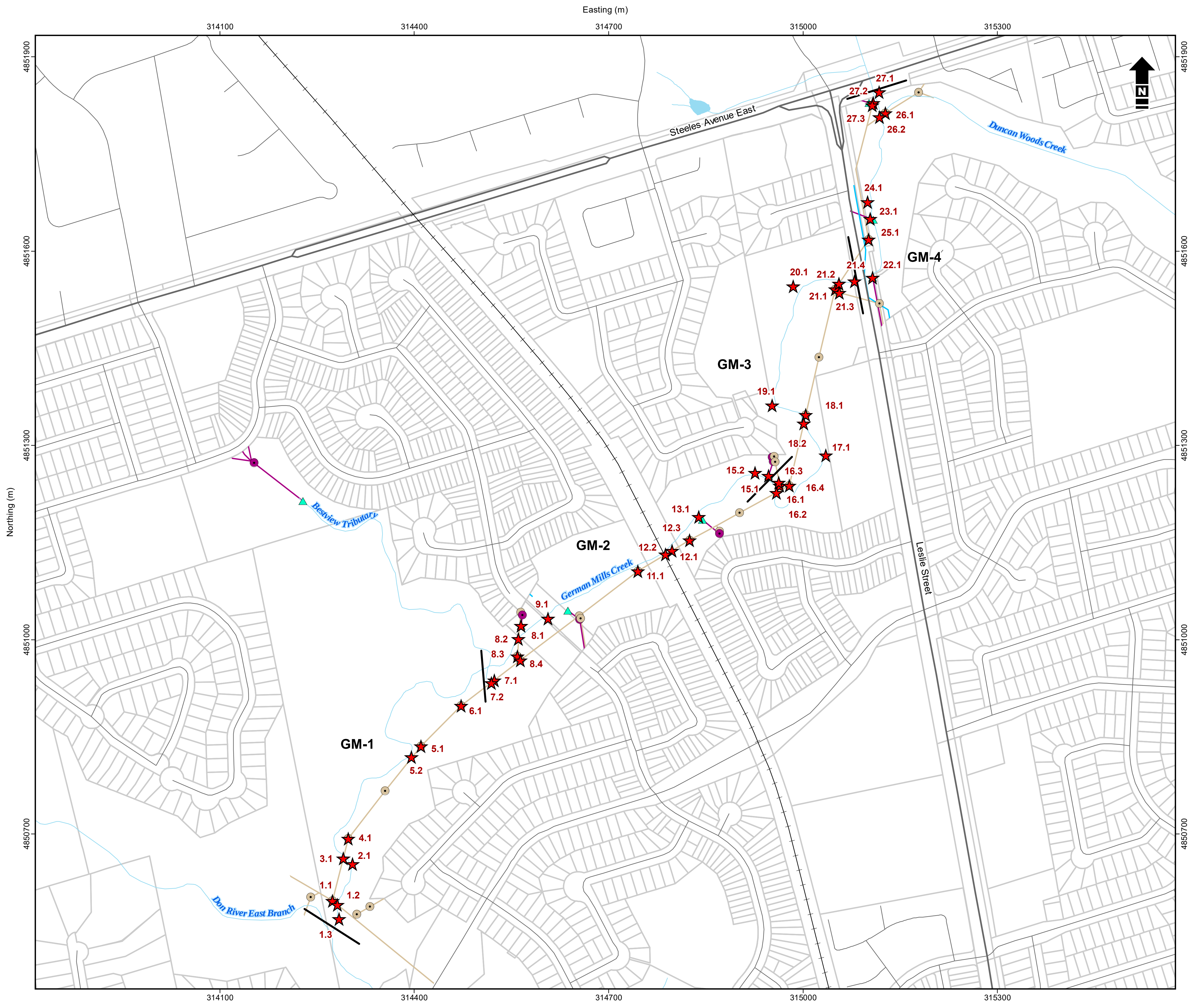
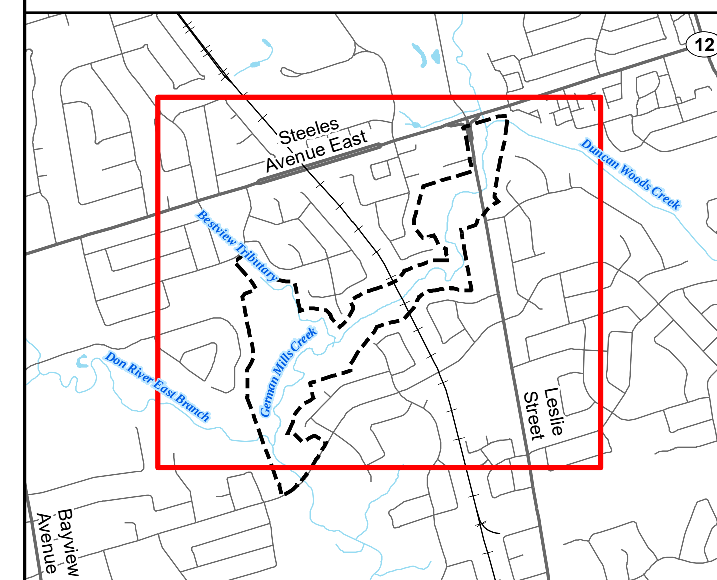
Figure C6g




Property Boundary
Reach Break
Watercourse
Highway
Road
Railway
Sanitary Sewer Constructed in 1969
Storm Sewer
Stormwater Outfall
Sanitary Sewer Maintenance Hole
Storm Sewer Maintenance Hole
Erosion Risk Site

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1:6,000 metres
60 0 60 120
NAD27 MTM zone 10

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# Overview of Erosion Risk Sites

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Figure C6h