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Erosion Risk Evaluation Tool for Prioritizing Infrastructure Encroachment Sites for Protection along Meandering Streams

Robin McKillop
Brian Greck
Matt Johnston

Toronto and Region Conservation for The Living City
Greck and Associates Limited
Water Resources and Environmental Engineering
Palmer Environmental Consulting Group Inc.

Outline

- The Problem
  - Channel encroachment along sewer infrastructure
- The Assessment
  - Evaluation of risk due to lateral and vertical erosion
- The Mitigation
  - Conceptual strategies for mitigation at highest priority sites

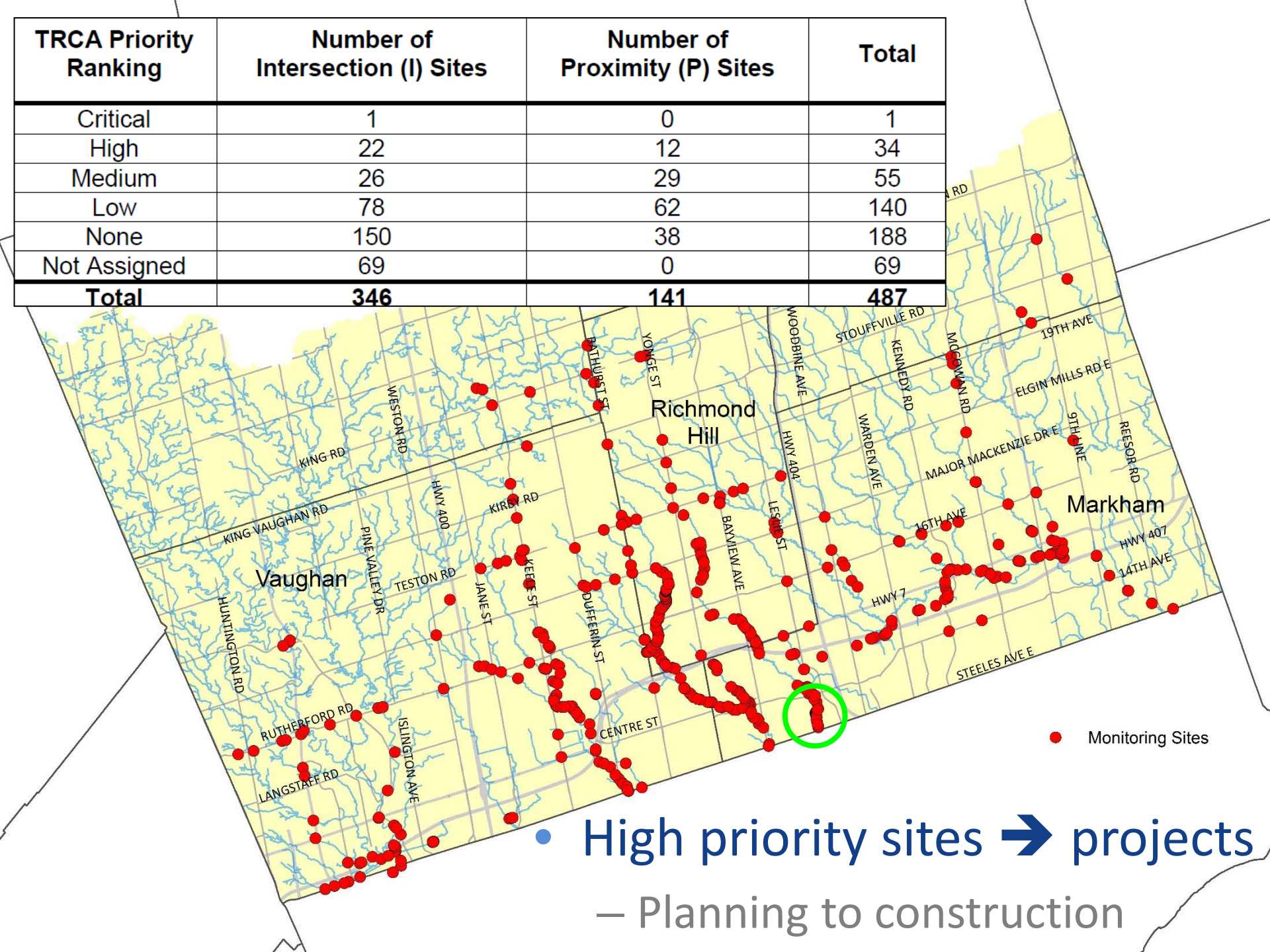
THE PROBLEM

Channel encroachment along sewer infrastructure

Infrastructure Hazard Monitoring Program (IHMP)

- Collaborative partnership since 2011
  - Long-term management of regional infrastructure assets subject to erosion hazards
- Monitoring 487+ sites
  - Priorities assigned based on risk to infrastructure

TRCA Priority Ranking	Number of Intersection (I) Sites	Number of Proximity (P) Sites	Total
Critical	1	0	1
High	22	12	34
Medium	26	29	55
Low	78	62	140
None	150	38	188
Not Assigned	69	0	69
Total	**346**	**141**	**487**



- High priority sites ➔ projects
  - Planning to construction

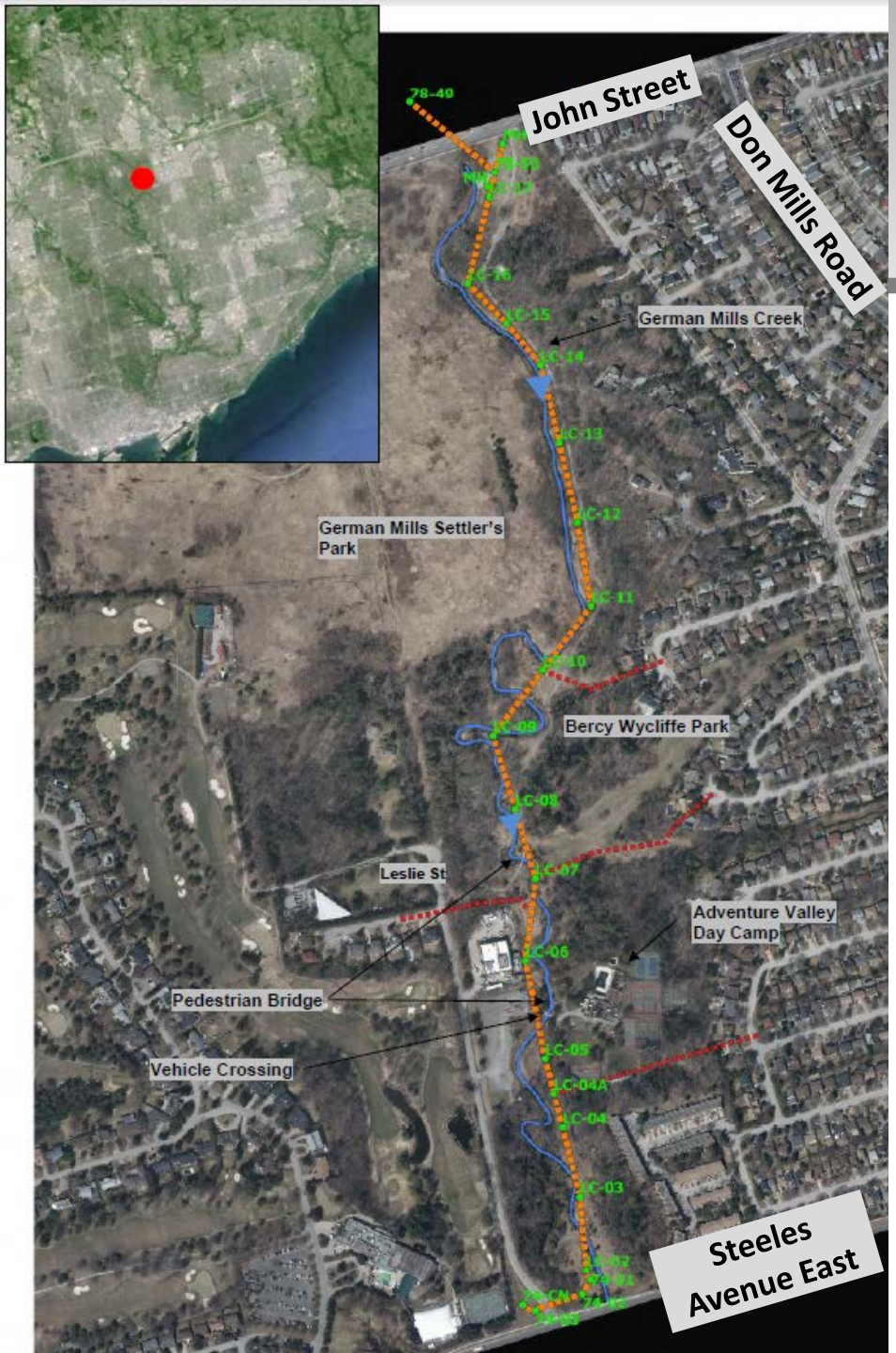
Integrated Infrastructure Protection Works Program (IIPWP)

- Extension of IHMP
  - Allows for the detailed planning, design and implementation of regional infrastructure protection works
- Projects prioritized based on information collected by monitoring staff

Bercy Park – Sanitary Sewer Protection Project

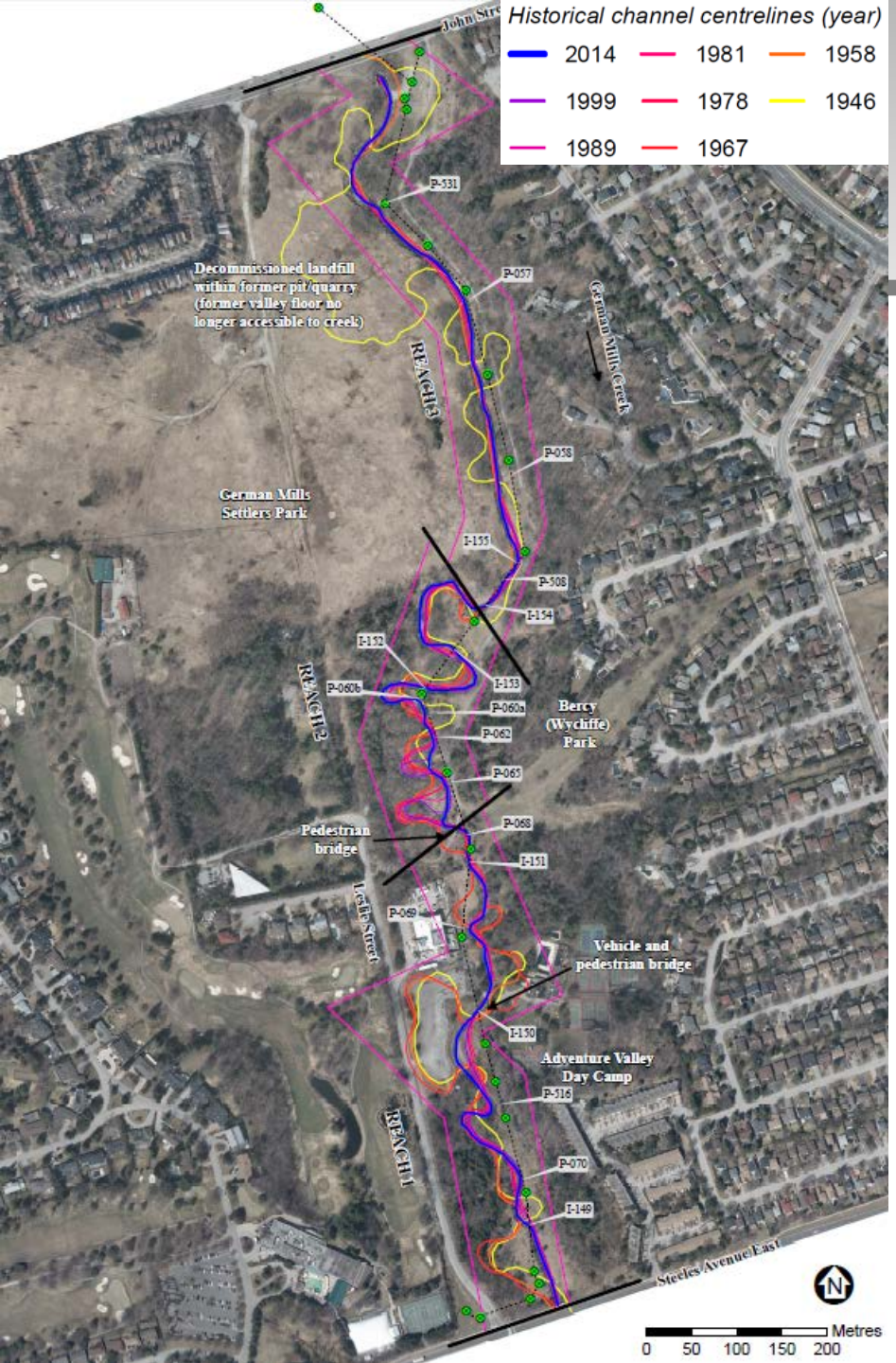
- 6 of the 10 highest priority sites within the IHMP located along German Mills Creek, in Markham
- TRCA and York Region agreed concentration of at-risk sites warranted reach-based assessment

Study area

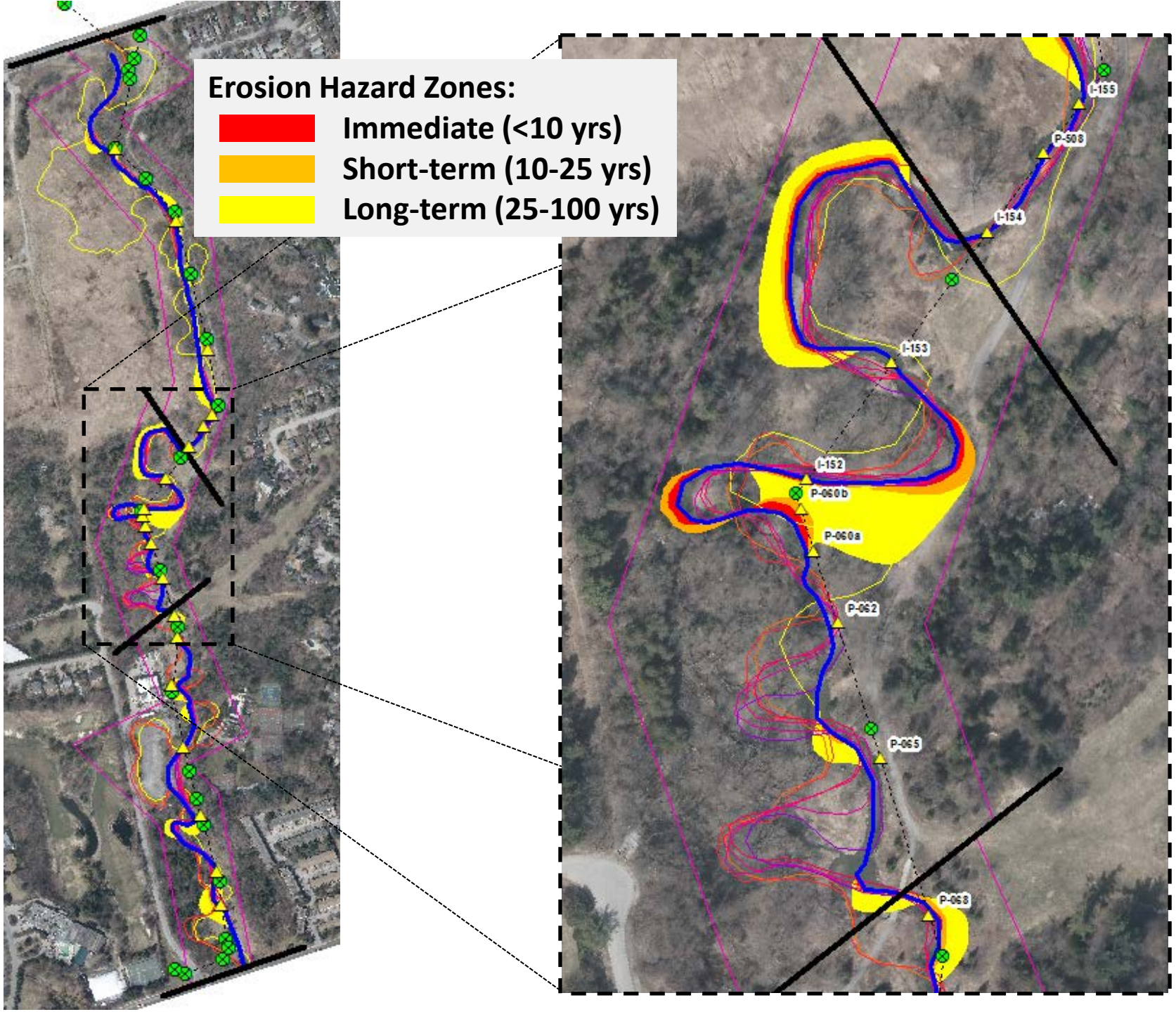


- Sanitary sewer infrastructure along German Mills Creek valley
  - Encroachments
  - Crossings
  - Manholes
- Recreational trail & pedestrian bridges

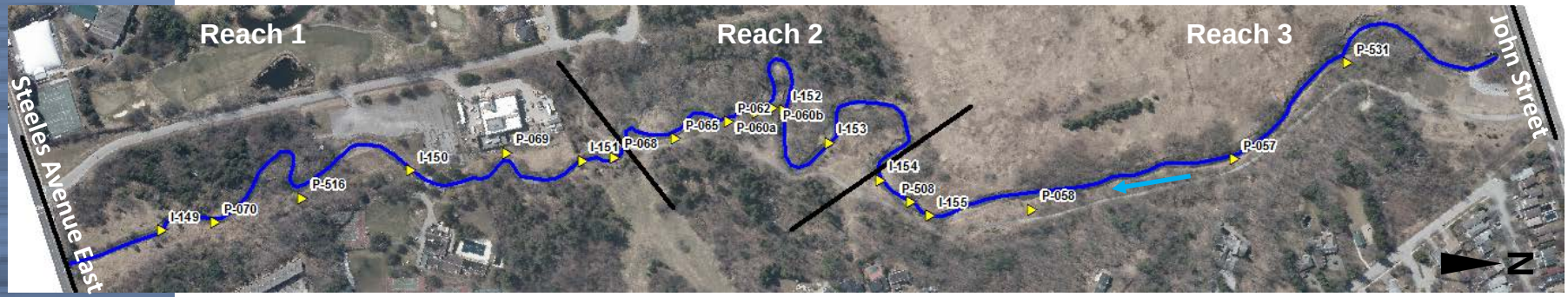
Understanding lateral erosion processes



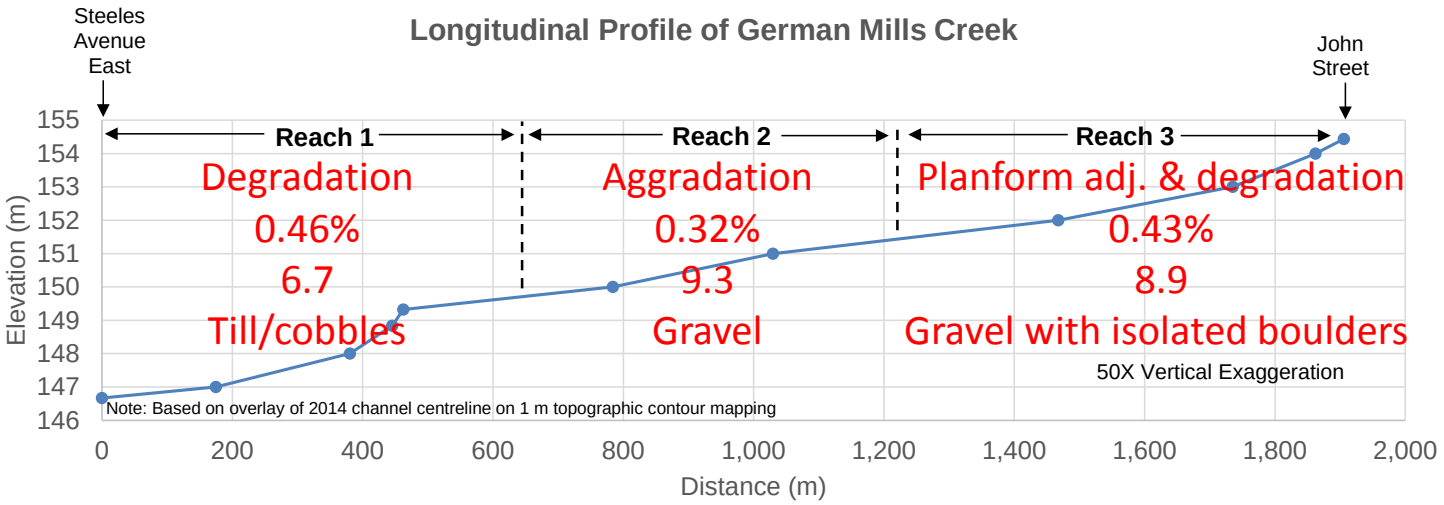
- Historical channel realignment (straightening)
- Watershed urbanization
- Meander adjustment
  - Progressive migration down-valley
  - Cut-off


Erosion Hazard Zones:
Immediate (<10 yrs)
Short-term (10-25 yrs)
Long-term (25-100 yrs)
I-155
P-508
I-154
I-153
I-152
P-060b
P-060a
P-062
P-065
P-068

Understanding vertical erosion processes

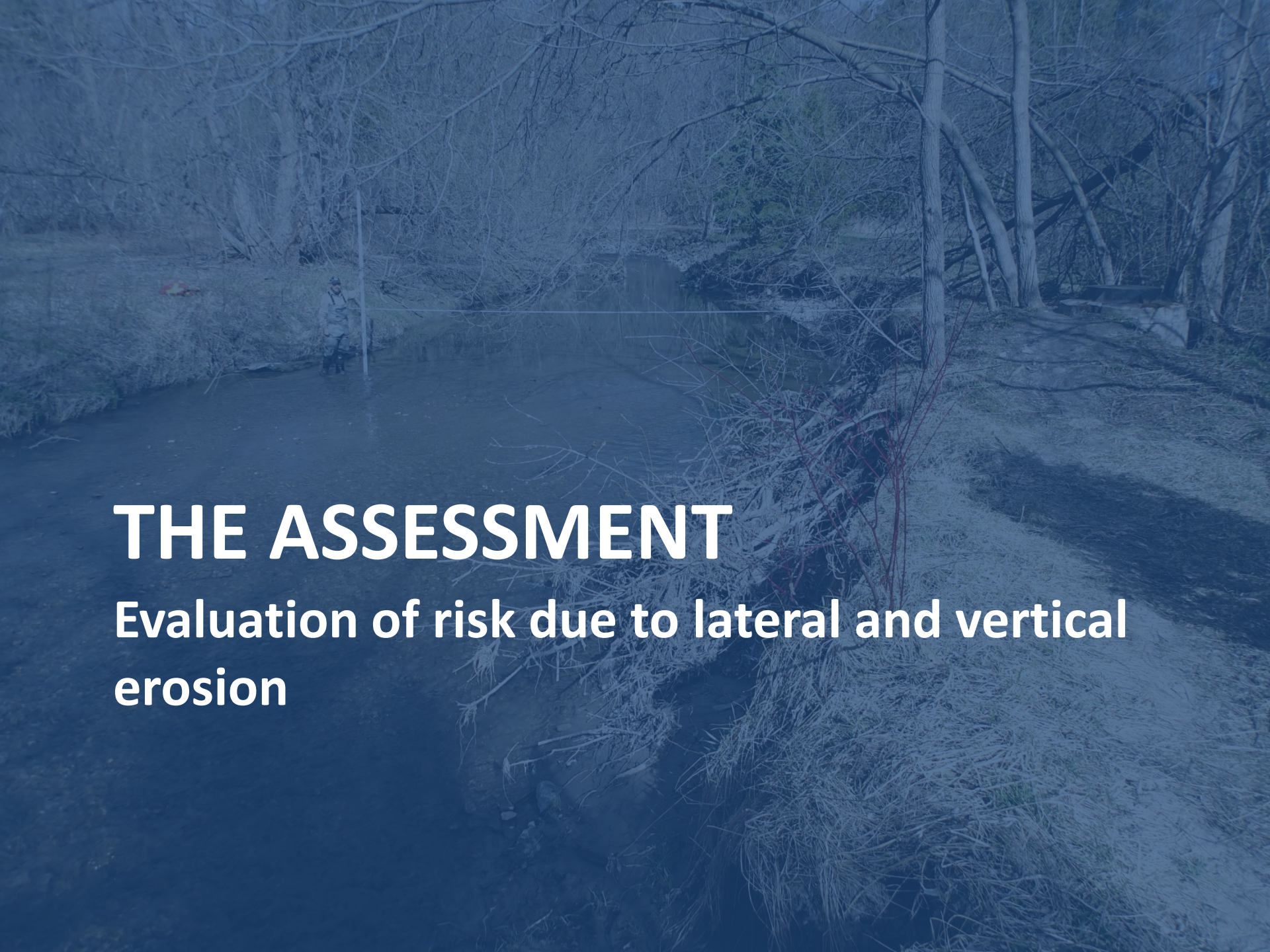


Mode of adjustment:
Gradient:
W/D ratio:
Bed material:



Scale of evaluation

- Site-specific evaluation approach needed
- **Lateral** – timeframe estimates based on air photo analysis unrepresentative of recent acceleration in bank failure
  - Used as independent check to corroborate site-specific evaluation results
- **Vertical** – reach-scale trends not necessarily representative of site-specific processes



THE ASSESSMENT

Evaluation of risk due to lateral and vertical erosion

Evaluation approach

- Objectives
  - Systematic
  - Comparable
  - Transparent
  - Flexible
- Insight from…
  - *Cooksville Creek Rehabilitation Study* and *Markham Erosion Restoration Implementation Plan* (Aquafor Beech Limited, 2011)

Lateral erosion risk (LER) parameters

Category	Parameter	Low (1)	Moderate (2)	High (3)	Weight
BANK DISTANCE	Distance from Top-of-Bank (DB)	>5 m	2 – 5 m	<2 m	0.150
BANK STRESS	Planform Position (PL)	Inner bank of meander	Straight	Outer bank of meander	0.150
	Thalweg Position (TH)	Inside	Centre/flat	Outside	0.100
	Radius of Curvature (RC)	>50 m	10 – 50 m	<10 m	0.100
BANK ERODIBILITY	Grain Size (GS)	Silt/sand dominated	Sand/gravel dominated	Cobble or till dominated	0.075
	Stratigraphy (ST)	No	-	Yes	0.050
	Bank Angle (BA)	<45°	45 – 55°	>55°	0.075
	Vegetative Cover (VC)	Low (<30% of area)	Medium (30-70% of area)	High (>70% of area)	0.200
	Bank Height-to-Bankfull Depth (HD)	<1.6	1.6 – 2.5	>2.5	0.100

Vertical erosion risk (VER) parameters

Category	Parameter	Low (1)	Moderate (2)	High (3)	Weight
BED ERODIBILITY	Reach-scale Process (RP)	Aggradation	Widening or Planform Adjustment	Degradation	0.200
	Site-scale Process (SP)	Erosion (e.g., scour pool)	Neutral (e.g., shallow pool, low riffle)	Deposition (e.g., bar)	0.500
	Bed Material (BM)	Till, large cobbles or riprap	Small to medium cobbles	Silt, sand and/or gravel	0.300

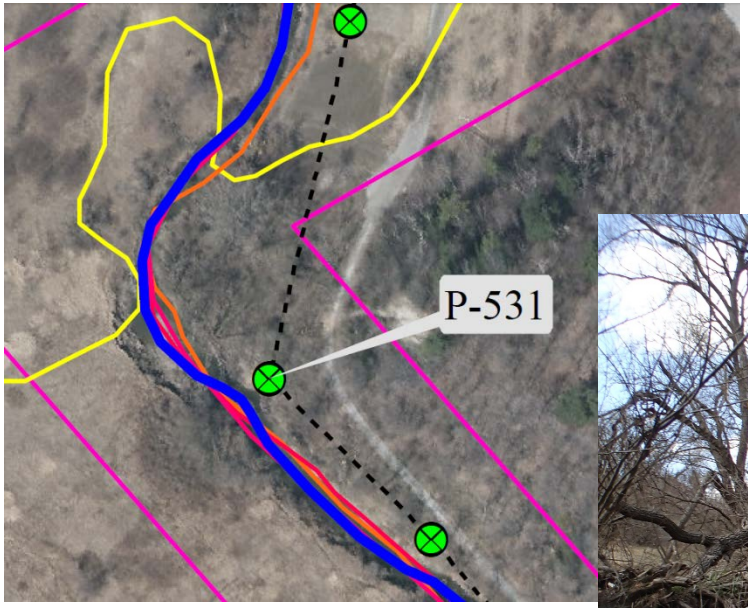
- Depth of cover
  - Should be included explicitly; was considered separately
  - Conflicting information stemming from channel realignments, old sewer as-built drawings and recent TRCA survey

Parametric equations

Lateral Erosion Risk (LER) Index = $DB*w_{DB} + PL*w_{PL} + TH*w_{TH} + RC*w_{RC} + GS*w_{GS} + ST*w_{ST} + BA*w_{BA} + VC*w_{VC} + HD*w_{HD}$

Vertical Erosion Risk (VER) Index = $RP*w_{RP} + SP*w_{SP} + BM*w_{BM}$

Example LER Index calculation: Site P-531



Manhole exposed in 5 m-high collapsed bank

Example LER Index calculation: Site P-531

Parameter	Value	Rank
Distance from Top-of-Bank (DB)	0.2 m	3
Planform Position (PL)	Outer bank of meander	3
Thalweg Position (TH)	Outer	3
Radius of Curvature (RC)	19 m	2
Grain Size (GS)	Silt/sand dominated	3
Stratigraphy (ST)	Yes (fill overlying alluvium)	3
Bank Angle (BA)	60°	3
Vegetative Cover (VC)	Low (<30% of area)	3
Bank Height-to-Bankfull Depth (HD)	3.9	3

LER Index = 3*0.15 + 3*0.15 + 3*0.10 + 2*0.10 + 3*0.075 + 3*0.050 + 3*0.075 + 3*0.20 + 3*0.10 = **2.90**

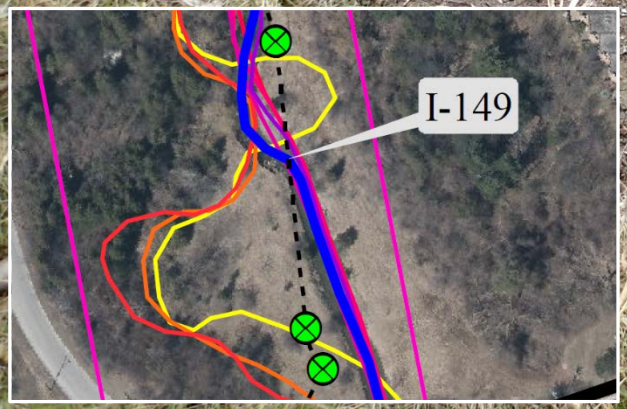
Example VER Index calculation: Site I-149

Till exposed along bed

Pinch-point at old rock vein/riprap

Buried sewer

Deep scour pool below knickpoint



Example VER Index calculation: Site I-149

Parameter	Value	Rank
Reach-scale Process (RP)	Degradation	3
Site-scale Process (SP)	Erosion (e.g., scour pool below knickpoint)	3
Bed Material (BM)	Till (clayey)	1

VER Index = 3*0.20 + 3*0.50 + 1*0.30 = **2.40**

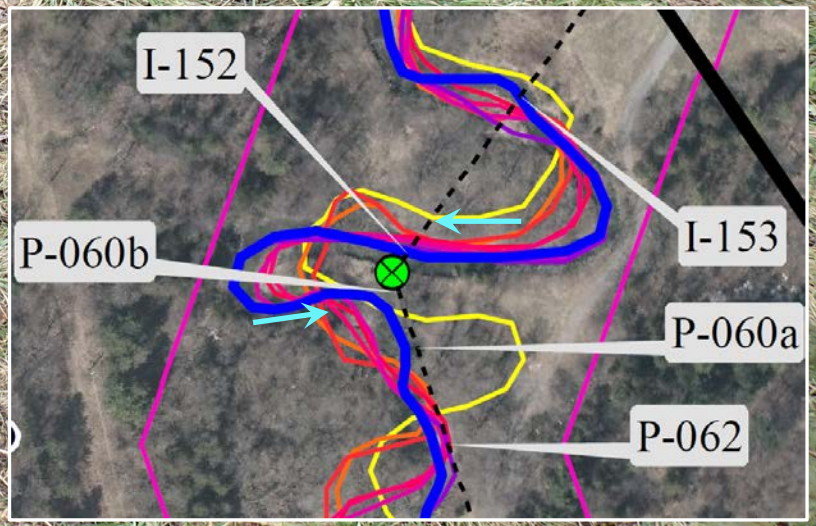
Overall Erosion Risk

Site ID	Lateral Erosion Risk (LER) Index	Lateral Erosion Risk (LER) Rank	Vertical Erosion Risk (VER) Index	Vertical Erosion Risk (VER) Rank	Overall Erosion Risk (OER) Rank
P-531	2.9	1	N/A	N/A	**1**
P-060b	2.5	3	N/A	N/A	**2**
I-152	2.175	5	1.6	12	**3**
P-057	2.6	2	N/A	N/A	**4**
P-068	2	9	3	1	**5**
I-149	N/A	N/A	2.4	2	**6**
P-058	2.45	4	N/A	N/A	**7**
P-070	2.175	6	2.2	6	**8**
I-155	N/A	N/A	2.3	4	**9**
I-150	N/A	N/A	2.4	3	**10**
P-060a	N/A	N/A	1.6	10	**11**
P-069	1.95	10	N/A	N/A	**12**
I-154	N/A	N/A	2.3	5	**13**
P-065	2.15	8	1.8	8	**14**
P-516	2.15	7	N/A	N/A	**15**
I-151	N/A	N/A	2.0	7	**16**
P-062	N/A	N/A	1.6	11	**17**
P-508	N/A	N/A	1.5	13	**18**
I-153	N/A	N/A	1.8	9	**19**

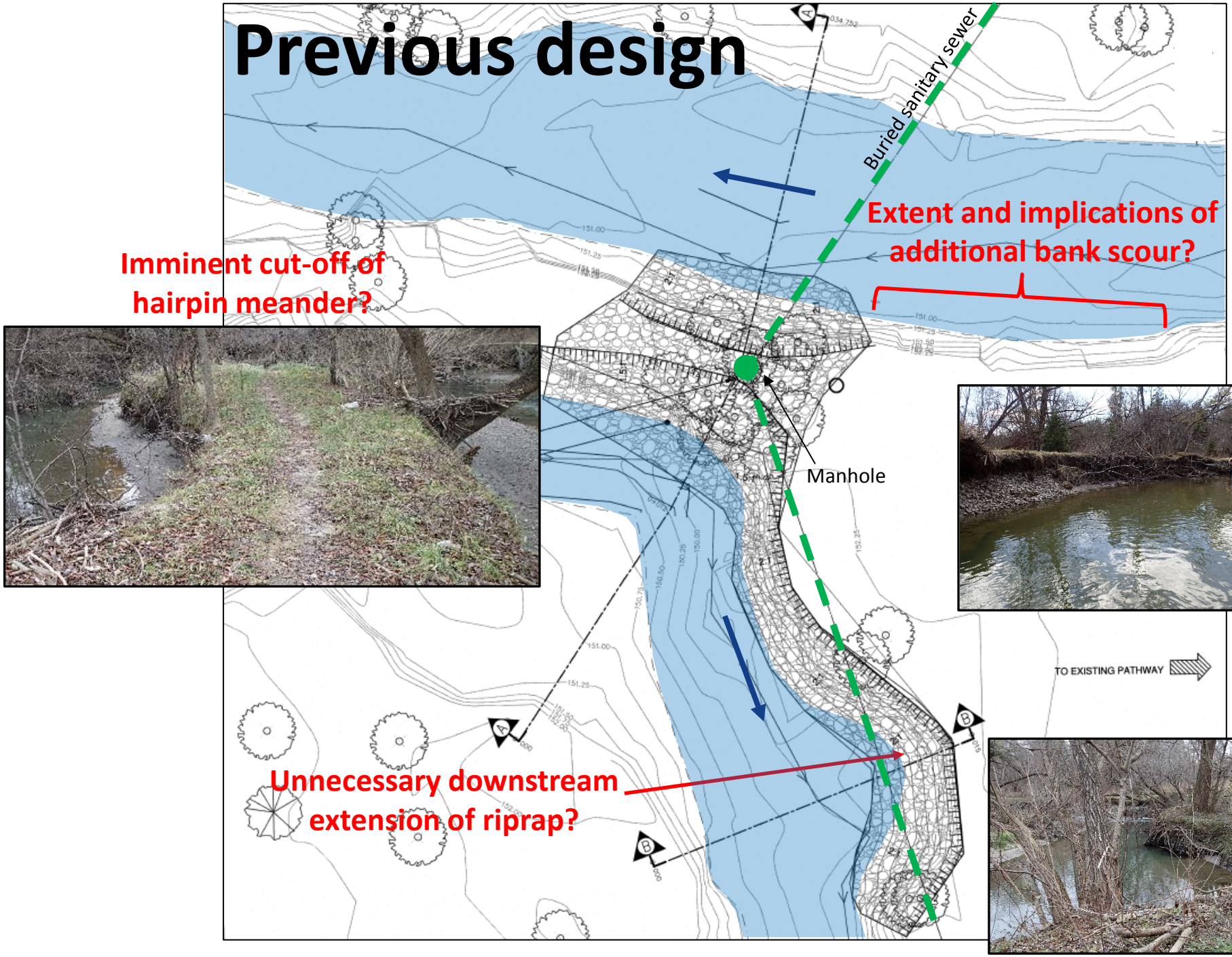
THE MITIGATION

Conceptual strategies for mitigation at highest priority sites

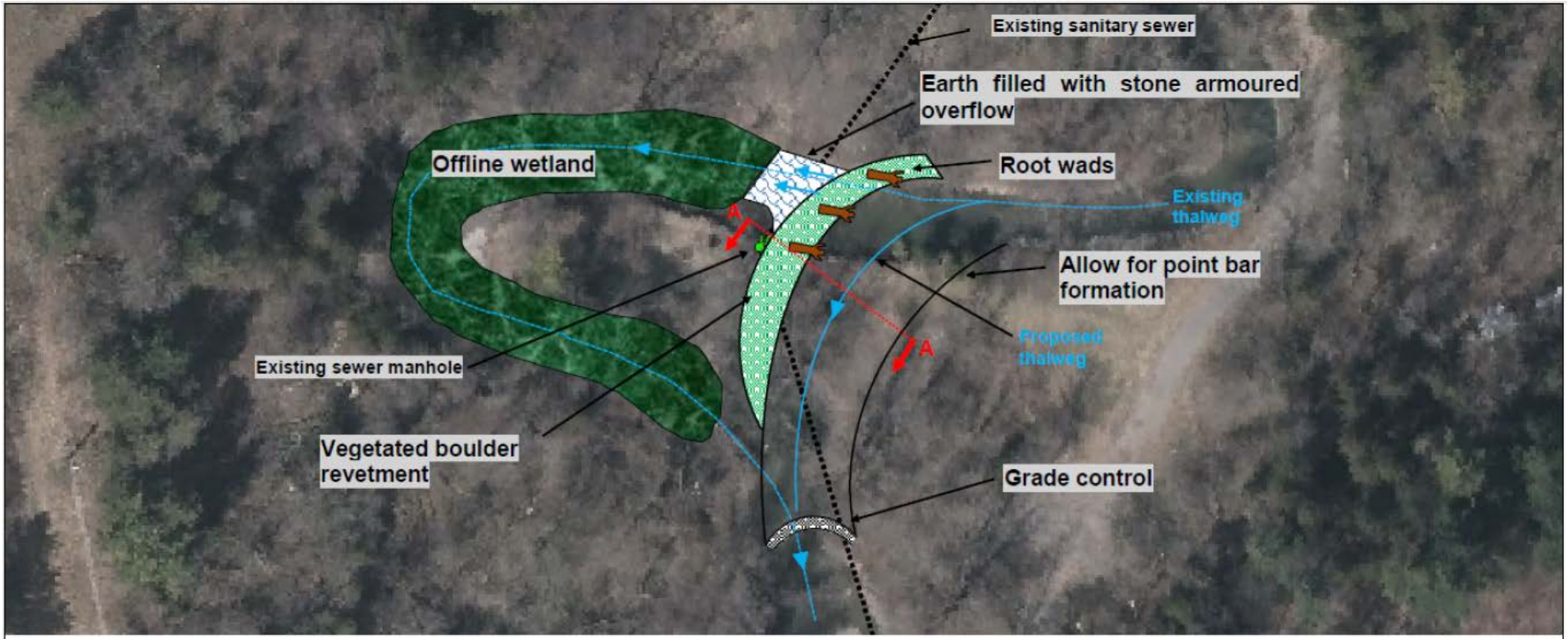
Manhole protection at Site I-152 / P-060b

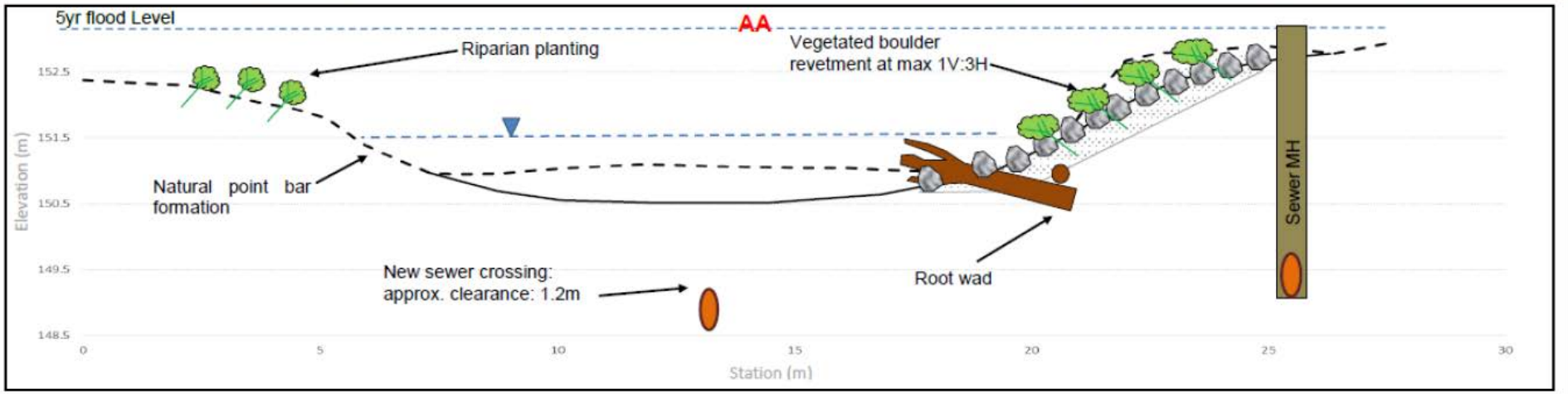


Previous design



Proactive mitigation alternative





Conclusions

- Concentration of erosion sites with at-risk infrastructure warrants reach-based assessment
- Risk of both lateral erosion and vertical erosion must be considered at a site scale
- Erosion risk evaluation tool – through the LER and VER indices – facilitates systematic and transparent prioritization of mitigative measures

Questions?

robin@pecg.ca

bgreck@greckassociates.ca

mjohnston@trca.on.ca

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