Value of Information (VOI) Analysis of a Stream Power-Based Toolbox for Erosion Risk Assessment and Management

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MOTIVATION

- Riverine erosion is dynamic and uncertain.

- To support management decisions, practitioners rely on:
- Monitoring data
- Predictive models
- Field assessments
- Historical records
- Expert judgment

- Yet significant uncertainty often remains.

VALUE OF INFORMATION (VOI)

- If uncertainty remains, what is the value of investing in better information?
- VOI: a framework that quantifies the benefit of reducing uncertainty before making a decision.

Incorporates uncertainty into decision-making

Evaluates whether additional information improves decisions

Compares the benefits of improved information against the costs of obtaining it

Supports cost-effective monitoring and management strategies

- This study evaluates the value of the information from a stream power-based toolbox for erosion risk assessment and management.
- Quantifies whether the toolbox improves decision accuracy and expected outcomes (cost/risk reduction) compared to decisions without the toolbox's information.
- VOI can also be applied to other environmental models.

TOOLBOX AND STUDY AREA

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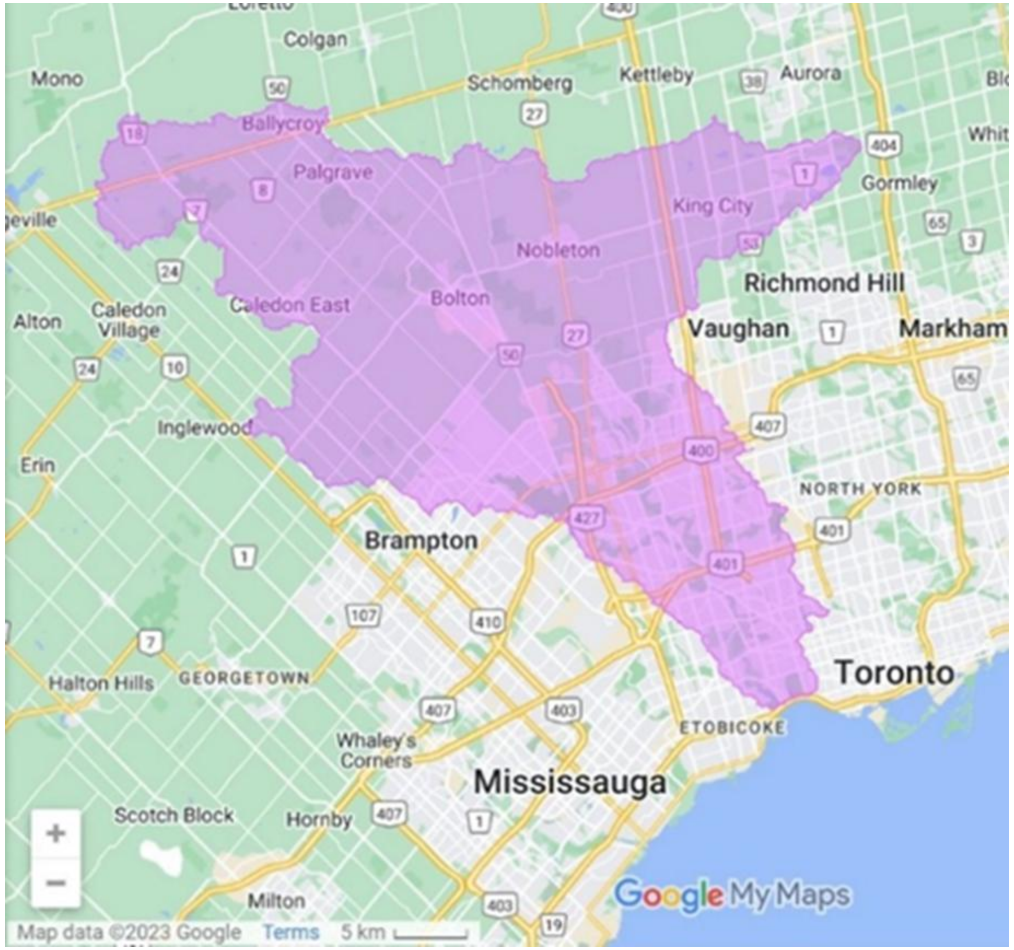
- The toolbox used in this study is called Stream Power Index for Networks (SPIN).
- SPIN was developed in 2021 to support watershed-scale erosion risk analysis.
- The initial version was developed as an ArcMap toolbox (Ghunowa et al., 2021) and was later converted into a Python-based toolbox (Thirimanne, 2024).
- The Humber River watershed encompasses 911 square kilometers and drains to Lake Ontario.
- It is the largest watershed in Toronto and Region Conservation Authority's (TRCA) jurisdiction and the only Canadian Heritage River in the Greater Toronto Area (GTA).
- It is a highly dynamic and urbanizing watershed, making it relevant for erosion risk assessment and management studies.



Location of Humber River watershed

Would you spend $50,000 to stabilize this riverbank?

- ❑ Yes
- ❑ No
- ❑ Depends

Photo by Paul Anderson, geograph

DATA AND METHODOLOGY

Riverine Erosion Monitoring and Management Survey (responses from 30 riverine erosion practitioners across Canada)

- Erosion frequency and impacts
- Financial losses from erosion
- Costs and effectiveness of erosion control measures
- Maintenance and lifespan of erosion control measures

VOI Inputs Derived from Survey

- Baseline probability of erosion
- Baseline probability of no erosion
- Intervention cost
- Cost of erosion (no intervention)
- Residual cost (erosion despite intervention)

DATA AND METHODOLOGY

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Reality

- Field data from 22 TRCA monitoring sites
- <u>Erosion threshold:</u> % change in cross-section area ≥ 40% or % change in bankfull width ≥ 20%
- <u>Below threshold:</u> No erosion

SPIN

- Site-specific SSPR values
- <u>Erosion threshold:</u> SSPR ≥ 1.5
- <u>Below threshold:</u> No erosion

SSPR: Specific Stream Power Ratio, calculated by SPIN for each segment of river in the watershed

SPIN (Predicted Erosion) \ Reality (Observed Erosion)	Y	N
Y	Erosion observed in field and SPIN predicts erosion	No erosion observed in field, but SPIN predicts erosion
N	Erosion observed in field, but SPIN predicts no erosion	No erosion observed in field and SPIN predicts no erosion

PRELIMINARY RESULTS

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- Results are based on an illustrative scenario.
- Additional data processing and scenario development are ongoing.
- Costs are assumed per 100 metres of river per year.
- A VOI of $350 means using SPIN would save $350 per 100 metres of river per year in the Humber River Watershed.

Metric	Value	Notes
SPIN accuracy		
Sensitivity (True Positive Rate)	0.75	P(Signal=1 | Erosion=1) Correct signal for erosion. This is based on SPIN's performance
Specificity (True Negative Rate)	0.75	P(Signal=0 | Erosion=0) Correct signal for no erosion. This is based on SPIN's performance
Parameters and costs		
Baseline Prob. of Erosion P(E=1)	0.2	Prior probability of erosion (the long term historical probability of erosion per unit time, e.g., a year)
Baseline Prob. of No Erosion P(E=0)	0.8	Prior probability of no erosion (the long term historical probability of erosion per unit time, e.g., a year)
Cost of Forecast (Tool Cost)	0	Cost of SPIN (can be any value, even 0 or negative)
Cost of Intervention	4000	What it costs for erosion intervention
Cost of Erosion (No Interv.)	50000	Loss if erosion occurs and intervention
Residual Cost (Erosion despite Interv.)	5000	Loss if erosion occurs despite intervention
Total Cost of Interv. if Erosion	9000	Intervention cost + Residual Cost
Baseline decisions without information		
Expected Cost (Intervene)	5000	EV(Intervene) without forecast
Expected Cost (Do Not Intervene)	10000	EV(Do not intervene) without forecast
Optimal Expected Cost (Baseline)	5000	**Intervene**
Baseline decisions with information		
Prob P(Tool Predicts Erosion S=1)	0.35	Ideally, it should equal the baseline probability of erosion, but that would only happen if the tool was perfect
Prob P(Tool Predicts No Erosion S=0)	0.65	Ideally, it should equal 1-the baseline probability, but that would only happen if the tool was perfect
Posterior P(Erosion | S=1)	0.428571429	Probability of erosion if signal detected
Posterior P(No Erosion | S=1)	0.571428571	Probability of no erosion if signal detected
Posterior P(Erosion | S=0)	0.076923077	Probability of erosion if tool says clear
Posterior P(No Erosion | S=0)	0.923076923	Probability of no erosion if the signal says clear
Expected costs		
EV(Intervene | S=1)	6142.857143	Expected value if you intervene given a forecast of erosion
EV(Do Not Intervene | S=1)	21428.57143	Expected value if yo do not intervene given a forecast of erosion
Optimal Action Cost given S=1	6142.857143	**Best is to Intervene**
EV(Intervene | S=0)	4384.615385	Expected value if you intervene given a forecast of no erosion
EV(Do Not Intervene | S=0)	3846.153846	Expected value if yo do not intervene given a forecast of no erosion
Optimal Action Cost given S=0	3846.153846	**Best is to Do Not Intervene**
Value of information		
Expected Cost with Information System	4650	Weighted avg of optimal decisions
Value of Information (VOI)	350	Baseline Cost - Cost with Info System
Net Value of Information (Net VOI)	**350**	**VOI - Cost of Information (SPIN)**

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THANK YOU