Delimiting Freedom Space for Rivers Using GIS and Remote Sensing: Updating existing tools to manage functional and resilient river systems

Joanna Eyquem and Fabien Hugue (AECOM)
Pascale Biron (University of Concordia)

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Early Experiences in Ontario

Protocols are just a guide

Don’t just turn the handle…

If you have a better idea, let’s hear it!
a) How is the “Freedom Space” approach different from current Ontario protocols?

b) How can we make better use of GIS and Remote Sensing data?
climate change will bring more frequent floods and more severe low water levels, which will pose a threat to public safety and alter the condition of river ecosystems. the freedom space concept relies on using the hydro-geomorphology of rivers to manage the entire river corridor. the goal is to identify areas where the river is prone to flooding or to shift paths, and let these processes occur instead of forcing the river into a path shaped by human interventions. this approach seems promising for sustainable development under the current climate and also in a changing climate, because it maintains the natural physical functions of the rivers (transporting water and sediment) while at the same time it improves the functions of ecosystems and provides ecological services. ultimately, this helps increase the resilience of the entire river ecosystem.
Flood Risk Mapping… not Erosion Risk Mapping
River Management Around the World

Netherlands

UK

Flooding risk based room...

France

Spain

And more recently erosion...

Vermont
Approach and Protocols in Ontario

3.1 NATURAL HAZARDS

3.1.1 Development shall generally be directed to areas outside of:

a) hazardous lands adjacent to the shorelines of the Great Lakes - St. Lawrence River System and large inland lakes which are impacted by flooding hazards, erosion hazards and/or dynamic beach hazards;

b) hazardous lands adjacent to river, stream and small inland lake systems which are impacted by flooding hazards and/or erosion hazards; and

c) hazardous sites.
Freedom Space (Espace de liberté) in Quebec

- Flood Risk +
- Erosion Risk +
- Wetlands

Freedom Space cf. Natural Hazards in Ontario

- Identifies different levels of flood and erosion risk within the overall « Freedom Space »

- Involves hydrogeomorphological assessment of flood and erosion mechanisms using LiDAR data

- Specifically incorporates wetlands as part of the minimal corridor

- Requires field reconnaissance to predict different levels of flood and erosion risk
Different Degrees of Freedom!

- Identification of short term erosion hazards or cut-offs: historic migration rate projected on 50 years
  - \( M_{50} \)

- Identification of long term lateral migration: corridor with the actual and past meander amplitude
  - \( M_{\text{floodplain}} \)

- Floodplain segmentation: geomorphological indicators of the flood extents
  - \( F_{\text{high}} \)
  - \( F_{\text{med}} \)
  - \( F_{\text{low}} \)

**Mobility space (M)**

**Freedom space (L)**

- \( L_{\text{min}} = M_{50} + F_{\text{high}} + \text{wetlands} \)
  - Minimal area where natural processes can operate, highly hazardous area

- \( L_{\text{func}} = M_{\text{floodplain}} + F_{\text{med}} \)
  - Functional area where all hydrogeomorphological processes can operate on a long term scale

- \( L_{\text{rare}} = F_{\text{low}} \)
  - Area reached by extreme events
### Different Degrees of Freedom!

<table>
<thead>
<tr>
<th>L(_{\text{min}}) (Minimal Level):</th>
<th>L(_{\text{func}}) (Functional Level):</th>
<th>L(_{\text{rare}}) (Rare Level):</th>
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<tr>
<td>• Frequent flooding AND/OR short-term erosion AND/OR Riparian wetlands</td>
<td>• Moderately frequent flooding AND/OR long-term erosion risk (similar to meander belt width)</td>
<td>• Rare floods with minor erosion risk</td>
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**Diagram:***

- **L\(_{\text{min}}\):**
  - Frequent flooding AND/OR short-term erosion AND/OR Riparian wetlands

- **L\(_{\text{func}}\):**
  - Moderately frequent flooding AND/OR long-term erosion risk (similar to meander belt width)

- **L\(_{\text{rare}}\):**
  - Rare floods with minor erosion risk
Flooding space + Mobility space = Freedom space

Matane River, Gaspesie peninsula, Qc, Canada
Need for Field Reconnaissance

- Different levels of flood and erosion risk are delineated by combining hydrogeomorphology and hydraulic modeling.

- Typically field work is required:
  - indicators of flooding (alluvial deposits on floodplain, scouring from extreme floods, bank erosion, ice scars)
  - indicators of non-flooding (non-alluvial deposits, extensive pedogenesis indicating long term stability)
a) How is the “Freedom Space” approach different from current Ontario tools?

b) How can we make better use of GIS and Remote Sensing data?
Remote Sensing - all about “Resolutions”

- **Spatial**
  (what extent and how detailed / pixel size)

- **Spectral**
  (what colors / how many bands / band widths)

- **Temporal**
  (time of day; season; year / time-lapse between two images / change detection)

- **Radiometric**
  (color (bit) depth)
LiDAR Coverage in Quebec
Research and Development

Dr Pascale Biron

“Remote sensing of fluvial environments: Automating the freedom space delineation to support sustainable river management at large scale”

Dr Fabien Hugue

Joanna Eyquem

AECOM  Imagine it. Delivered.

Concordia University
Use of LiDAR for Hydromorphological Analysis

– Flooding mechanisms

– Fluvial geomorphological processes / channel evolution

Identification of erosional (Er) and depositional (Sed) zones of the Matane River using LiDAR (from Demers et al. 2014).
Case Study: River Mastigouche, Quebec

- Additional complexity due to presence of abandoned channels and fluvial terraces
- Terraces formed due to the lowering of base level
- Use of LiDAR to identify terrace features and understand flooding mechanisms
- Combined with hydraulic modeling to identify areas of disconnected floodplain
Case Study: River Mastigouche, Quebec

Cross-section of the Mastigouche River, Qc, using LiDAR data, showing abandoned channel and formation of fluvial terraces.
Automating the Freedom Space Approach

Remote sensing techniques can help to:

- Detect the river course at different dates (avoid hand digitizing of channel evolution)
- Objectively identify homogenous reaches (avoid hand digitizing / subjectivity)
- Provide estimations of water depth for flood modelling (to determine flood damages)
- Standardize mapping techniques to export the methodology in other rivers and watershed contexts
- Avoid cost / time required for field work (particularly in remote locations)
Automating the Freedom Space Approach

Computing mobility space from historical air photo digitization
Automating the Freedom Space Approach

Compute mobility spaces from historical air photo digitization

Erosion and accretion rates calculation

Erosion and accretion rates

Cumulative erosion and accretion
Automating the Freedom Space Approach

Compute mobility spaces from historical air photo digitization

Mobility space delineation
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