



# Taming the Flow, Then and Now: A Canadian Case of Floodplain Management

Rehana Rajabali<sup>1</sup> and Nirupama Agrawal<sup>2\*</sup>

<sup>1</sup> Engineering Services, Toronto Region Conservation Authority, Toronto, ON, Canada, <sup>2</sup> Disaster and Emergency Management, York University, Toronto, ON, Canada

**Keywords:** floodplain management and restoration, Canada, naturalization, Don River Toronto, Port Land

## INTRODUCTION

In this opinion note, we present a brief overview of the paradigm shift in the Toronto's Don River floodplain management by examining the alteration systems over time, in particular before and after the 1954 flood caused by Hurricane Hazel, the only such storm to impact Toronto area in recorded history. Don River has a long history of floods, ice jams, and sedimentation, influenced by a feedback loop between human attempts to control the river's flow, the ensuing natural responses of the river, and further attempts to tame the flow. The river valley was home to a variety of industrial uses, including sawmills, paper mills, and brick manufacturing, which were bolstered by the alteration and straightening of the Don River in 1888 (Bonnell, 2014) with the intention of reducing the risk of flooding by increasing the speed of the water flow and potentially allowing for steamship transport up the river. The project went significantly over budget and failed to perform as anticipated, resulting in a massive "boondoggle" at the time, as well as the loss of ecological function (Kuriqi et al., 2021).

Evidence of tools used by local indigenous peoples trace back the human settlement to 7,000 years ago in the Don Valley, a river system that has been vital in Toronto's development in the province of Ontario, Canada. Increasing urbanization put tremendous pressure on the Don Watershed (Toronto Region Conservation Authority, 2021a) (it is 85% urbanized today and home to 1.4 million people). The rapid urbanization combined with the loss of flood plain due to industrial development near the river mouth resulted in a tendency toward flooding and erosion. The Port Lands was constructed in the early 1900s through the infilling of one of the largest coastal wetlands on Lake Ontario, Ashbridges Bay Marshlands (The Port Lands, 2021). Once the wetland was infilled and the mouth of the Don River channelized and redirected into the Inner Harbor through the Keating Channel (Keating Channel, 2021), the heavy sediment load from the Don that previously made its way into the wetland now was deposited in both the Keating Channel and Inner Harbor, to the detriment of navigation. Flooding was compounded by the design of the Keating Channel, built in 1922, which makes a sharp right turn before going into the lake; an inefficient alignment resulting from a land dispute with an oil company located there.

Empowered by natural heritage-conscious planning policies, Toronto has taken a leap forward in correcting past practices that demonstrated shortcomings on several fronts by utilizing improved understandings of the lost biodiversity, impacts of human modifications, growing urban sprawl, and an ever-increasing demand for economic opportunities. By way of this article, we aim to provide encouragement for other regions in similar situations to take bold steps toward better floodplain management and reduce flood risk for their population.

## OPEN ACCESS

### Edited by:

Gemma Carr,  
Vienna University of  
Technology, Austria

### Reviewed by:

Alban Kuriqi,  
Universidade de Lisboa, Portugal

### \*Correspondence:

Nirupama Agrawal  
nirupama@yorku.ca

### Specialty section:

This article was submitted to  
Water and Human Systems,  
a section of the journal  
Frontiers in Water

**Received:** 28 April 2022

**Accepted:** 02 June 2022

**Published:** 08 July 2022

### Citation:

Rajabali R and Agrawal N (2022)  
Taming the Flow, Then and Now: A  
Canadian Case of Floodplain  
Management. *Front. Water* 4:931214.  
doi: 10.3389/frwa.2022.931214

## 20TH CENTURY PART I—WAKEUP CALL

The Don River mouth has had a long history of modification. Coastal wetlands of Lake Ontario became an outlet for the growing city's sewerage, while industrial pressures called for the filling of shorelines to accommodate deeper berths to support the shipping industry. The Port Lands were thus created with a mix of industrial uses, including storage facilities for coal and oil that contributed to extensive contamination of the land and water.

Hurricane Hazel, which struck the Toronto area on 15–16 October 1954, served as a wakeup call, and consideration of natural hazards in land use planning was re-evaluated. The storm, which remains Toronto's worst natural disaster, caused widespread flooding along the Don River and record flooding on the neighboring Humber River. This dreadful storm left 81 dead, nearly 1,900 families homeless and incurred damages worth up to \$100 million at the time (the modern-day cost is estimated at over \$1 billion) (Marsh, 2015). Although Conservation Authorities had existed in Ontario since 1946, their responsibilities were amended by the province in the aftermath of Hurricane Hazel. They were empowered to acquire lands for recreation and conservation purposes and to regulate land for the safety of the community. The Metropolitan Toronto Region Conservation Authority [now Toronto Region Conservation Authority, or TRCA (Toronto Region Conservation Authority, 2022)] was amalgamated in 1956. After Hurricane Hazel, development in river valleys became subject to greater regulation, and a scheme of drainage and flood control measures was adopted, including the construction of G. Ross Lord Dam (Toronto Region Conservation Authority, 2021b) on the West Don River, which provides some local attenuation. Typical flood protection measures at the time included constructing straight channels with localized drop structures for a faster water flow, with no consideration of ecological or geomorphological conservation, and collecting floodwaters in reservoirs.

## 20TH CENTURY PART II—DYNAMIC MOVES

Flooding along the straightened Don River continued to occur from ice jams and severe thunderstorms. Over time, updated sewer systems improved the air and water quality, the former industrial uses waned, and the value of the land—so close to Toronto's commercial core—increased. A tussle between various perceptions and visions for the Lower Don River followed. Competing ideas included developing the valley as a corridor for transportation vs. a place for recreation or restoration (Colton, 1980), ending in favor of the highway, Don Valley Parkway (DVP) construction in 1961 and altering the natural landscape. This north-south artery increased the

amount of winter road salt, intensifying salinity in the Lower Don River, further upsetting the aquatic habitat, and increasing sedimentation in the Keating Channel by 4-fold. Meanwhile, portions of the land adjacent to the river were acquired by the public sector, recognizing the possibility of remediating the land to develop social housing. Concerned stakeholders, including conservationists, geographers, urban planners, and hydrologists, all agreed that the highly altered landscape within the Lower Don's floodplain was a constraint on the river's ability to move the flood swell into Lake Ontario with minimum flooding. Significant floods in 1976, 2005, and 2013 (Nirupama et al., 2013; Armenakis and Nirupama, 2014) emphasized the continued urgency for innovative flood protection measures in the area. Plans to remediate the Don stemmed from extensive citizen engagement. In the ensuing years, special task forces to “Bring Back the Don” were developed, all of which centered around flood protection and river naturalization.

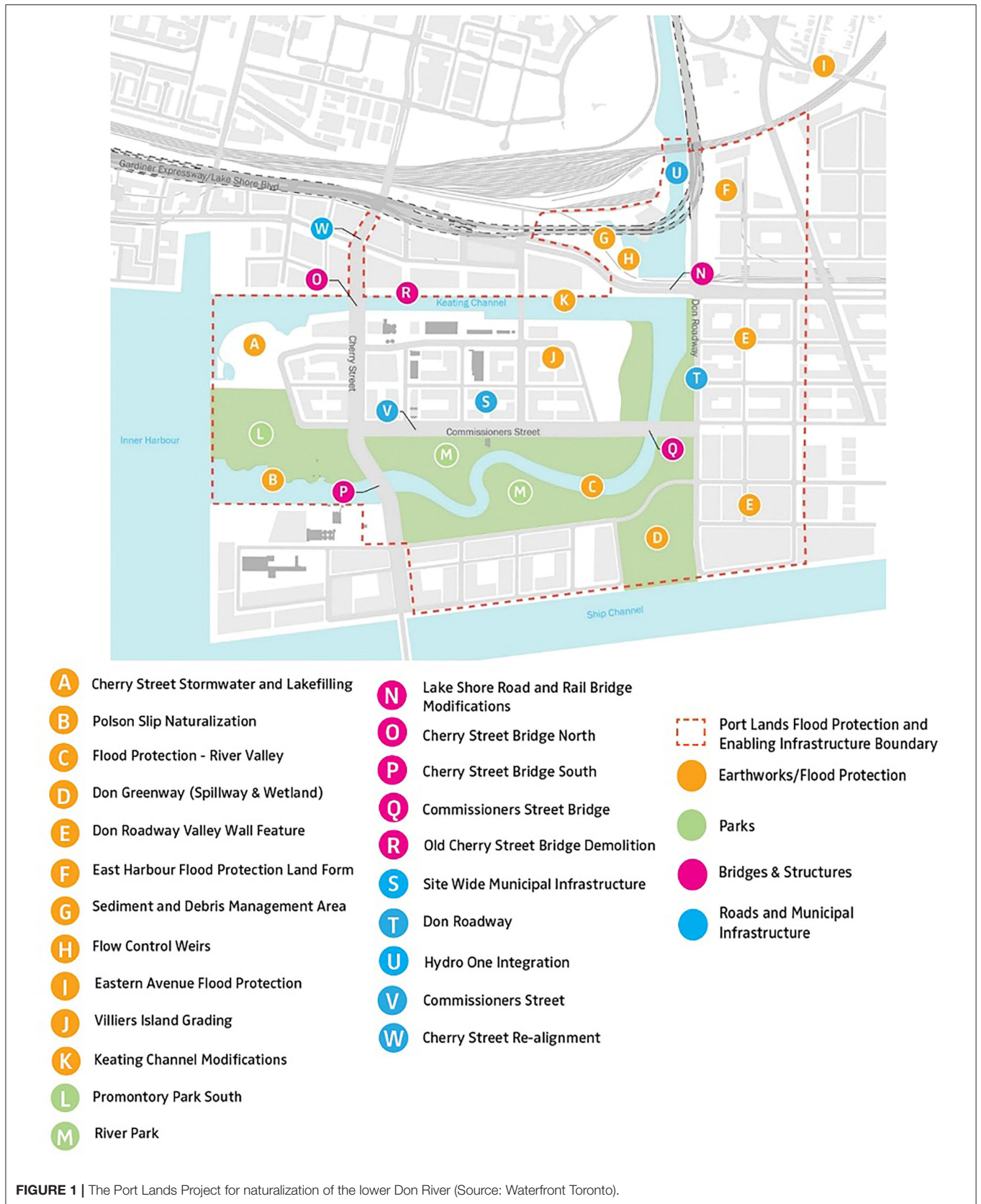
## EARLY 21ST CENTURY—RETURNING TO THE RIVER

Through the early 2000s, all three levels of government created Waterfront Toronto, which would lead the remediation and flood protection of the Port Lands. The project also helped the 2015 Pan American Games in Toronto. Actively underway, the Port Lands Flood Protection (The Port Lands, 2016) project consists of several components, all aimed at (i) River Naturalization, (ii) Flood Protection, and (iii) Working within the existing urban environment to—remediate the soil, create recreational and cultural opportunities, and work with other planning initiatives and sustainability frameworks. The cost of making all this happen was prohibitively high. However, as the vision proceeded through an Environmental Assessment process that informed the international design competition, the preferred design of a 3-outlet river mouth emerged, coincidentally aligning with the “Room for the River” (Room for the River Program, 2019) model. The new river mouth is expected to improve the river's capacity and ability to flow freely, people's access to the river and its ecological function, all while optimizing the mixed land uses—from port uses to film studios to homes and enabling placemaking with signature bridges.

As a brownfield site with a history of land uses that brought about wide-suite of contamination, a key component of the project included assessing and implementing remedial technologies for the soils. The award-winning Don Mouth Naturalization and Port Lands Flood Protection Treatment Technology Evaluation Program (PLFPTTEP) (Toronto Region Conservation Authority, 2021c) included the assessment and documentation of 11 innovative technologies, which had the potential to be included as part of the final remedial action plan for the Port Lands and whose assessment could be leveraged for other brownfield sites across North America. The criticality of this aspect of the project must not be overlooked; it provides sustainability and longevity to the naturalization process.

Flood protection components include a Flood Protection Landform (FPL) and a Valley Wall Feature (VWF)

**Abbreviations:** MTRCA, Metropolitan Toronto Region Conservation Authority; TRCA, Toronto Region Conservation Authority; DVP, Don Valley Parkway; PLFP, Port Land Flood Protection; PLFPTTEP, Port Lands Flood Protection Treatment Technology Evaluation Program; FPL, Flood Protection Landform; VWF, Valley Wall Feature; EHFPL, East Harbor Flood Protection Landform; EAFF, Eastern Avenue Flood Protection; DDR, Due Diligence Report.



(Toronto Region Conservation Authority, 2014)—with specified materials, sizes, and slopes, designed to be resilient against the modes of failure that more traditional berms and dikes are prone to. They form a large landform by extending the confining river valley southward and removing the risk of flooding to nearly 300 hectares, including the East Harbor Flood Protection Landform (EHFPL) (“F” in **Figure 1**) and Eastern Avenue Flood Protection (EAFP) (“I” in **Figure 1**).

The project, at the cost of over 1.2 billion Canadian dollars and targeted to complete in 2024, will overcome both the technical complexity and iterative process necessary for natural physical processes and dynamics of the remediation of flood risk. Although originally driven by citizen environmental activism, the significant public ownership of the lands and their proximity to Canada’s primary urban economic center played a key role in seeing the project come to fruition. A 2016 Due Diligence Report (DDR) (The Port Lands, 2016) identified that the project would result in significant value-added to the Canadian economy and revenue (**Figure 1**). For future residents and visitors, though, the most striking features are likely to be the cycle of interaction between humans and the water systems people have sought to live symbiotically with.

## DISCUSSION

Flooding is among the most common and costly natural hazards in Canada (Government of Canada, 2016). Historical settlements near rivers, streams, lakes and coasts have resulted in high exposure to floods (The Geneva Association, 2020) that became worse over the course of history where humans interacted with floodplains in differing ways. Upon reflections on the past practices, it is now being realized that the best way forward would be to navigate the reshaping of tools and measures to co-exist with the rivers instead of never-ending attempts to control them. In Toronto, Canada, although the post-Hurricane Hazel

landuse framework played a key role in carefully assessing new development, the remediation of existing flood risk has remained a challenge. Nature-based solutions for flood protection that are rooted in the very basics of geomorphology and physical processes make the most sense, as evident in the literature (The New York Times, 2021). The Don River naturalization project appeared daring at first thought, almost impossible at times, but is ready to deliver on the literal meaning of the word “naturalization”. The remediation work represents a modern approach to flood risk reduction that brings alignment of growth, public concern, and agency investment. The renewed mouth of the Don River will provide sufficient space in the valley to pass massive floods and improve the quality of life while incorporating an ecologically “rough” natural landscape. Actual examples of large and expensive projects intended to reverse past actions are necessary for broader engagement and encouragement in societies around the world. The gaps between new knowledge and past/current practices have to be bridged in order to reduce hazard risk in general. With this brief note, we continue to expect that the naturalization of the Don will withstand the test of time and inspire and reassure other regions to take assertive steps toward lowering flood risk for their people, eventually leading to cordial and trusting dynamics between society and authorities.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

## ACKNOWLEDGMENTS

We are grateful to Ken Dion, Project Director, Port Lands Integration and Mira Shenker, Senior Manager, Communications and Public Engagement, Toronto Waterfront Revitalization Corporation, for their extensive review and valuable feedback.

## REFERENCES

- Armenakis, C., and Nirupama, N. (2014). Flood risk mapping for the city of Toronto. *Proc. Econ. Finan.* 18, 320–326. doi: 10.1016/S2212-5671(14)00946-0
- Bonnell, J. (2014). *Reclaiming the Don: An Environmental History of Toronto’s Don River Valley*. Toronto, ON: University of Toronto Press 316. doi: 10.3138/9781442696808
- Colton, T. J. (1980). *Big Daddy: Frederick G. Gardiner and the Building of Metropolitan Toronto*. Toronto, ON: University of Toronto Press, 216.
- Government of Canada (2016). *Estimate of the Average Annual Cost for Disaster Financial Assistance Arrangements Due to Weather Events*. Available online at: [https://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/2016/DFAA/DFAA\\_EN.pdf](https://www.pbo-dpb.gc.ca/web/default/files/Documents/Reports/2016/DFAA/DFAA_EN.pdf) (accessed April 13, 2022).
- Keating Channel (2021). *Don Valley Historical Mapping Project Background*. Available online at: <https://maps.library.utoronto.ca/dvhmp/keating.html> (accessed November 15, 2021).
- Kuriqi, A., Pinheiro, A. N., Sordo-Ward, A., Bejarano, M. D., and Garrote, L. (2021). Ecological impacts of run-of-river hydropower plants-current status and future prospects on the brink of energy transition. *Renew. Sustain. Energy Rev.* 142, 110833. doi: 10.1016/j.rser.2021.110833
- Marsh, J. (2015). “Hurricane hazel” in *The Canadian Encyclopedia. Historic Canada*. Available online at: <https://www.thecanadianencyclopedia.ca/en/article/hurricane-hazel> (accessed November 15, 2021).
- Nirupama, N., Armenakis, C., and Montpetit, M. (2013). Is flooding in Toronto a concern? *Nat. Hazards* 72, 1259–1264. doi: 10.1007/s11069-014-1054-2
- Room for the River Program (2019). *Dutch Water Sector*. Available online at: <https://www.dutchwatersector.com/news/room-for-the-river-programme> (accessed April 9, 2022).
- The Geneva Association (2020). *Flood Risk Management in Canada – Building Flood Resilience in a Changing Climate*. Available online at: [https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf\\_public/frm\\_canada\\_web.pdf](https://www.genevaassociation.org/sites/default/files/research-topics-document-type/pdf_public/frm_canada_web.pdf) (accessed April 13, 2022).
- The New York Times (2021). *Big Step Forward for \$50 Billion Plan to Save Louisiana Coast by John Schwartz*. New York Times.
- The Port Lands (2016). *Port Lands Flood Protection and Enabling Infrastructure Due Diligence Report*. Available online at: <https://portlandsto.ca/project-details/> (accessed April 9, 2022).
- The Port Lands (2021). *Project Details*. Available online at: <https://portlandsto.ca/project-details/> (accessed April 9, 2022).
- Toronto Region Conservation Authority (2014). *Don Mouth Naturalization and Port Lands Flood Protection Environmental Assessment*. Available online at: <https://trca.ca/conservation/green-infrastructure/don-mouth-naturalization-port-lands-flood-protection-project/don-mouth-environmental-assessment/> (accessed April 13, 2022).

- Toronto Region Conservation Authority (2021a). *Don River*. Available online at: <https://trca.ca/conservation/watershed-management/don-river/> (accessed November 15, 2021).
- Toronto Region Conservation Authority (2021b). *Dams and Flood Control in Toronto*. Available online at: <https://trca.ca/conservation/flood-risk-management/flood-control-structures/> (accessed April 9, 2022).
- Toronto Region Conservation Authority (2021c). *Don Mouth Naturalization and Port Lands Flood Protection Project Treatment Technology Evaluation Program*. Available online at: [https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2021/10/15121423/20210126\\_Treatment-Technology-Evaluation-Program-Final-Report.pdf](https://trcaca.s3.ca-central-1.amazonaws.com/app/uploads/2021/10/15121423/20210126_Treatment-Technology-Evaluation-Program-Final-Report.pdf) (accessed April 13, 2022).
- Toronto Region Conservation Authority (2022). *Registered Charity under the Conservation Authorities Act*. Available online at: <https://trca.ca/> (accessed April 9, 2022).

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher's Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

*Copyright © 2022 Rajabali and Agrawal. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.*