“THE PRAIRIE RUNOFF ROUTING & FLOOD MODELLING TOOL”:

Report of the 13th of October 2021 Workshop.

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Global Institute for Water Security
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1. INTRODUCTION

This report summarises the proceedings of Prairie Water's introductory workshop for the Prairie Runoff Routing and Flood Modelling Tool. The workshop was a continuance of Prairie Water's commitment to open dialogue among researchers and water managers to translate Prairie specific water science into useable and useful products. The best tools are those that are user-driven and developed.

The Prairie Runoff Routing and Flood Modelling Tool uses a characterisation of headwater catchment classes across the Canadian Prairie to simulate flow using a physically-based hydrological model. The model is run for long periods using historic climate data and future climate scenarios. The outputs of focus are rainfall, evaporation, and upland runoff for different catchment classes.

Having carried out a successful 'proof-of-concept' test in early 2020, Prairie Water decided it was time to share the prototype tool with water managers in the Prairies and held an introductory workshop on October 13th, 2021. At this workshop, short presentations were given to describe the tool, why it is needed, and to explore potential applications identified by our partners. After the presentations, participants had the opportunity to discuss other potential applications for the tool within their organisations, and obstacles to testing the tool in practice.

The Prairie Water team found the workshop extremely helpful to guide strategy for further development of the tool. We are very grateful for all the comments, questions and insights brought up by the participants, and hope that you found the workshop valuable too. We look forward to continued dialogue and collaboration as we develop the tool further.

The next section of this report provides a summary of the presentations given at the workshop. You can also view the slides and presentations on Prairie Water's website at - https://gwf.usask.ca/prairiewater/resources/presentations.php

2. SUMMARY OF PRESENTATIONS

Presentation 1

“Why a new tool is needed for Canadian Prairie Modelling” - Kevin Shook, University of Saskatchewan

Kevin has been at the University of Saskatchewan for 14 years, studying the complex hydrology of the Canadian Prairies. He has contributed significantly to the work of the University’s Centre for Hydrology, the Global Institute for Water Security, and Global Water Futures. Kevin is a member of the Prairie Water team and the key architect of the research on which the Prairie Runoff Routing and Flood Modelling tool is founded.

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Existing hydrological modelling tools can struggle to accurately simulate prairie processes. This is because these existing models have been developed in more temperate regions such as the United States and Europe, and/or cannot simulate the complex hydrography of the prairies. There is a need, therefore, for new models and tools to support detailed infrastructure design for the specific hydrological characteristics of prairie landscapes.

What is needed	Limitations of existing tools
Tools that simulate complex prairie hydrology *AND* hydraulics	Existing tools simulate either prairie hydrology *OR* hydraulics.
Hydrological models for small prairie basins (<100km^2)	Building detailed models for small basins is expensive.
Hydrological model outputs that can be used with existing hydraulic models to simulate local conditions	No models exist to link small basin hydrological function to for small-scale local hydraulics.

Dr. Shook has spent many years studying prairie hydrology. Prairie Water has been combining Kevin’s work with research that classified over 4000 basins across the Canadian Prairie Ecozone. This work is the foundation of new, prairie-specific tools and datasets that we are developing at Prairie Water. These tools require development and testing in real-life settings before they can be used operationally. The goal of the workshop for Prairie Water was to introduce this tool to potential users and find partners to conduct pilot tests in an operational setting.

Presentation 2

"Culvert Modelling Applications" – Katherine Finn, North Saskatchewan River Basin Council

Katherine is the manager of the North Saskatchewan River Basin Council. She has been instrumental in increasing community engagement in watershed stewardship projects and implementing projects to protect and improve the natural resources in the watershed. Katherine has been one of Prairie Water's key partners from the project's inception working with us on several projects, including an early proof-of concept test of the tool being introduced at this workshop.

Proactive land management is key to mitigating many water-related problems, including erosion, flooding, and water quality. Culvert and drainage infrastructure have a significant influence on how water flows through rural basins, therefore understanding how structures modify flows is important in land-management decisions. Although the North Saskatchewan River Basin Council and other watershed groups may have the resources to survey community culvert infrastructure, they do not have the resources to accurately model how these culverts perform under different climatic and land-use conditions. Historically, this has led to planning challenges and inadequate infrastructure with unexpected negative impacts.

Situation	Challenge
Culvert upscaling in the RM of Leask, SK.	Mistawasis Nehiyawak Community experiences severe flooding.
Mistawasis Nehiyawak Community retaining water on lands due to unknown risk to stakeholders downstream.	Lack of tools or data to help determine a safe drainage policy.
Agricultural water drainage network design	Appropriate design needs to balance erosion, deposition, water quality, and performance under extreme events.

The North Saskatchewan River Basin Council and Prairie Water partnered in 2020 to complete an initial proof-of-concept test, modelling a small basin and culvert near Radisson, SK. The results were promising and North Saskatchewan River Basin Council sees great potential for using Prairie Water's tool to overcome some of the challenges to making good land-use management decisions.

Presentation 3

"Potential Applications for Ministry of Highways" – Amir Khatibi, Ministry of Highways, SK.

Amir is a Senior Project Manager and Hydraulic Engineer with the Saskatchewan Ministry of Highways, working to maintain and improve the Province's hydraulic infrastructure. Amir is currently studying towards a Masters degree in Civil Engineering at the University of Saskatchewan. His research is exploring spatial extent of flooding at small scale in a Saskatchewan prairie watershed impacted by landscape depressions and culverts. The results of Amir's research will be a significant and much needed contribution to the practice of hydraulic engineering in the Prairies.

Existing methods used for hydrological assessments of highway infrastructure include the rational method and frequency analysis. There are known limitations to using these tools for engineering design in the Canadian Prairie region, and significant challenges to assessing the impact of future climate and land-use change on the performance of hydraulic infrastructure.

Disadvantage of Existing tools	Advantage of PW tool
Using the rational method in small prairie basins (<10 km^2) does not account for complex prairie hydrological processes.	Model is based specifically on prairie hydrology, accounting for snowmelt, depression storage, blowing snow, infiltration of frozen soils
Current flow rate estimation methods heavily rely on historical performance of structures and do not consider site specific risk criteria. This often leads to over design scenarios.	Compensates for lack of historical data and accounts for geometric and hydroclimatic features of a subject site. This leads to an optimum performance-based flow estimation.
Resiliency of existing Ministry's assets against extreme events are unknown which is due to lack of adapted vulnerability assessment tool for prairies.	Could simulate spatial extent of floods at crossings. Accounts for potential changes in climate and land-use. Could assess vulnerability index for existing Highway's infrastructure.

Ministry of Highways hydraulic engineers see potential for the tool to overcome some of these limitations. Advantages could be realised through improved and more efficient design, strategic maintenance and improvement planning, greater network resilience, and minimising impacts on other water users. Amir and Prairie Water are currently developing a pilot project to test the tool for one of these applications.

3. ADOPTING THE TOOL IN PRACTICE – DISCUSSION POINTS

Potential tool applications

Discussions at the workshop identified 14 potential applications. The tool can primarily be used to model current runoff and potential inundation, or model the impact of future water management scenarios (Tables 1a and 1b). Runoff and inundation modelling applications of current conditions primarily support engineering design or strategic planning and policy development. Modelling of future scenario modelling primarily are more appropriate for strategic planning and policy. Examples of engineering design applications include supporting infrastructure design for highways, wetland plug design for wetland conservation and protection, and designing drainage and wetland drainage infrastructure. Proposed strategic planning and policy development applications include watershed management planning, municipal development planning, future water resource studies and wetland conservation strategy. Other applications include supporting regulatory activities and public education.

Potential tool users

The proposed applications suggest that the tool has potential value for many stakeholder groups. Applications were identified that would be of use to Provincial and Municipal engineers and planners, conservation groups, watershed organisations and businesses and individuals.

Adoption challenges and feasibility

The most prevalent challenge discussed was the availability and accessibility of data (Table 2). The availability of high-resolution elevation data (typically obtained from LiDAR surveys) is key to supporting many of the suggested applications. LiDAR data are patchy across the Prairie Ecozone and concentrated on major river corridors. The prevailing view coming from discussions is that there is an urgent need to gather Province-wide LiDAR data. Provincial Governments in Manitoba and Alberta are engaged in expanding LiDAR databases. Currently there is no formalised plan in Saskatchewan to do the same. It was also clear that much of the data that exists is held by different groups. Although this data might be useful to its owners, others may not be aware that it exists, and there is no formal coordination of that data.

Governance 'fit' is another challenge evident from discussions. Municipal Development planning and infrastructure design in Saskatchewan, for example, must meet a 1:500 year design standard. It was not clear at the workshop if the tool would be appropriate for these activities. Another significant point raised was implementing the tool in a multi-jurisdictional setting. Non-universal uptake of the tool across jurisdictions within a watershed may limit the effectiveness of water management plans and limiting water resource planning to within jurisdictional boundaries is not ideal. Consideration needs to be given to where (which organisations) and what (which applications) might be most effective in terms of tool adoption.

Table 1a - Drainage/runoff tool applications identified

Application type	Specific application	Potential users	Use	Known challenges	Current feasibility
Drainage/Runoff modelling	Flow rate estimation of small catchment basins for highway infrastructure design.	Provincial ministries in charge of highways	Engineering design	high resolution elevation data	Good - assuming available LiDAR
	Risk-based return period flow rate estimation	Provincial ministries in charge of highways	Engineering design	high resolution elevation data	Good - assuming available LiDAR
	Hydrological modelling and water management for small basins	WSA Watershed Organisations	Strategic planning/policy	high resolution elevation data	Good - assuming available LiDAR
	Agricultural lot development planning - water infrastructure design on new Ag lots.	Farmers Provincial Agriculture Ministries and depts.	Engineering design	High resolution elevation data	Unknown - dependent on available LiDAR and willing partner
	Wetland plug design	Conservation groups Landowners	Engineering design	High resolution elevation data	Uknown - would need expert partner
	Municipal Infrastructure design and planning - design support for roads, bridges, buildings	Municipalities, Municipal Associations	Engineering design	High resolution elevation data Fit with required standards (e.g. 1:500)	Poor - 1:500 return period is statistically unrealistic with data availale for model
	Municipal development planning	Municipalities, Municipal Associations	Strategic planning/policy Regulatory	Fit with required standards (e.g. 1:500)	
	Interactive water planning/information tool. A user-friendly interface on which basin response to different water management decisions can be explored	Provincial planners, Muncipal planners, Individuals & businesses	Public education Regulatory suppport	High resolution elevation data Resources to develop interface	Moderate - Possible in the longer term. PW does not have the resources to develop.
	Supplementary tool to complement existing riverine modelling	Provincial hydrological engineers	Strategic planning/policy Emergency planning	High resolution elevation data	Moderate - Unclear if the application would be worth the effort required

Table 1b - Future change/scenario modelling tool applications identified

Application type	Specific application	Users	Use	Known challenges	Current feasibility
Future change/scenario modelling	Vulnerability assessment of key highway infrastructure	Provincial ministries in charge of highways	Strategic planning/network preservation	High resolution elevation data	Moderate - Assessing whole network would require data and resources from partners
	Future water supply studies w.r.t. climate change	WSA	Strategic planning	High resolution elevation data	Moderate - Requires data and resources from partners
	Interactive water planning/information tool. A user-friendly interface on which basin response to different water management decisions can be explored	Provincial planners, Muncipal planners, Individuals & businesses	Public education Regulatory suppport	High resolution elevation data Resources to develop interface	Moderate - Possible in the longer term. PW does not have the resources to develop.
	Siting of man-made wetlands, identifying priority wetlands for retention and protection	Conservation organisations, Watershed groups, Provincial ministries, Landowners, Farmers	Strategic planning/policy, Regulatory	High resolution elevation data	Moderate - would require significant data and resources from partners
	Impact assessment of water storage changes, landuse change, and climate changes on habitat, water quantity and quality	Conservation organisations, Watershed groups, Provincial ministries	Strategic planning/policy	Availability of data Need for local surveys over assessed area	

(Adoption challenges and feasibility – cont.)

It was evident from discussions that user acceptance of the tool and underlying modelling approach may be a challenge for Prairie Water translating this work into practical applications. Several questions were asked relating to the robustness and reliability of the tool and model, and how much confidence can be placed in its outputs. Some brief responses to these questions are given in table 3. However, going forward, we are aware that we need to be prepared for these kinds of questions to build user confidence in our products.

Other challenges relate to human resource availability. For example, a popular application would be a publicly available, user-friendly interface to explore the impact of land-use decisions and climate scenarios on areas of interest. However, this would require human and financial resources that are not available at this time.

Opportunities

Through discussions of the challenges to adopting the tool for use in operational settings, several opportunities also emerged. A significant opportunity, that Prairie Water strongly recommends exploring further, is the potential for several of the different organisations and groups represented at the workshop to pool resources. In particular, cost-sharing province-wide LiDAR acquisition was identified as a potential path forward to address endemic difficulties for design and planning activities. Creating an economy of scale would benefit all parties involved and initial costs will very likely be repaid many times over in coming decades. Prairie Water continues to recommend that the Province of Saskatchewan invest in a Province-wide LiDAR survey. One way that this might be done is by setting up a working group with representation from government departments, municipal government associations, utilities, conservation groups, watershed groups, First Nations administrations and other public sector bodies that would benefit from LiDAR data. Participants at the workshop agreed tha the benefit to cost ratio of gathering these data is likely to be significant. It is therefore likely that a strong business-case could be made for gathering province-wide LiDAR, and may be an effective way to achieve buy-in from seniour decision makers.

It was also evident that useful data for water resource planning is fragmented between different organisations. Another opportunity that exists is to establish an inventory of that data, either across the Prairie Provinces or within each province. Sharing of data on culvert locations, drainage infrastructure location, cadastral and existing LiDAR would likely be beneficial to several users. This could make design and planning activities more efficient, and reduce unecessary duplication of effort. Taking advantage of this opportunity would require a formal process to coordinate the inventorying efforts of each organisation and collate the results.

Some promising opportuinities for pilot testing of the tool were identified. The Saskatchewan Water Security Agency suggested there was potential to test the tool in upcoming projects, including future water resource studies, and water management in small basins. Several watershed organisations in Manitoba have LiDAR data and could provide valuable sites to explore how the tool can support planning activities. We are currently discussing these opportunities further, as well as developing a test project with Amir Khatibi at the Saskatchewan Ministry of Highways.

Table 2 - Tool adoption challenges

Theme	Specific	Examples from discussion
Data accesibility & limitations	Many data owners, no formal coordination	It was clear that numerous organisation are likely to have LiDAR data, but the extent of this data is unknown. This is particularly the case in Saskatchewan where there is currently no provincial program to build a LiDAR database.
	Data gathered to different standards	Where different organisations have collected the same types data, it can be gathered to different standards. Saskatchewan Water Security Agency gave the example of the time and effort required to stitch together LiDAR data from several different sources around Lakes in Saskatchewan.
	Lack of LiDAR and high resolution elevation data	Lack of LiDAR coverage was a runing theme in the discussion. The issue appears to be universal across Alberta, Saskatchewan and Manitoba, although especially so in Saskatchewan. Alberta and Manitoba Provincial Governments are engaged in LiDAR acquisition.
	Cost of LiDAR acquisition	The cost of LiDAR for small, individual projects can be too high to justify in project budgets.
	Lack of field and observation data	Hydrometric station coverage is patchy. Historical data is not necessarily trustworthy and may require significant time and effort to process. Water survey Canada data has limited coverage, especially wrt small basins.
Goverance fit	Fit with existing governance processes and standards	Meeting design or planning standards for return periods e.g. 1:500 in SK, 1:200 in Manitoba. Accounting for additional cost of using new tools in RFPs. Using a new tool may require revising existing standards & guidelines.
	Ensuring consistent approach across jurisdictional boundaries	This is something to be aware of - universal adoption of any tools would be the ideal situation.
	Addressing differing priorities across jurisdictional boundaries	This is something to be aware of - how do you go beyond providing tools and information and encourage cohesive planning/design where jurisdictional priorities differ?
User acceptance	Concerns over robustness and confidence in outputs	The nature of the workshop did not allow for significant technical discussion of how the tool functions. Participants raised questions about how the tool copes with varying antecendent conditions, major climatic and land-use change in the future, and how the model accounts for error margins in input variables. The challenge for adoption would be to pre-empt or respond to these concerns that users might have. Responses to some of the concerns expressed in the workshop are given in Table 3.
Useability	Having a user-friendly interface for non-technical users	An ideal format for the tool would be an easy to use interface through which to explore different scenarios. Prairie Water may have an interface to visualize and access the data, but this still needs to be coupled to hydraulic data.
Ethics	There may be ethical considerations when using tool outputs.	Property values are negatively affected and can be harder to insure when shown to be at risk.

Table 3 - Participant questions on the model

Questions	Prairie Water response
The model inputs include multiple variables with associated error margins. How does the model deal with compounding error margins?	This is true of all models. Errors in inputs will translate to model results.The model structure/approach has been developed and tested using the most robust precipitation and runoff estimates available for the region.
Can the model account for the differing antecendent conditions that exist year to year on the Prairies?	The model will be run over long time series (>40 years), meaning that varying antecedent conditions are built-in to the outputs.
Is the model robust and how much confidence can be put in it?	CRHM is the best available hydrological model for the prairie ecozone. As a result it is the most robust and the model that should have the highest confidence.
How does the model account for major future changes in climate and land-use?	The model can be run for any number of scenarios. All that is needed is the inputs for those scenarios. However, each scenario run entails a significant amount of work. Prairie Water will run a few initial scenarios based on current climate trends and realistic future land-use changes. The value of running other scenarios could be assessed on a case by case basis.

4. FUTURE STEPS AND COMMUNICATING PROGRESS

Our next step is to follow up with participants who expressed interest in developing pilot applications for the tool. We are currently engaging in conversations with workshop attendees who have identified potential testing applications. Over the next year, we will participate in the development and implementation of two or three pilot projects under the direction of our partners.

What we learn from these pilot projects will be important for the technical development of the tool, facilitating its integration into existing processes, the scope for its use, and understanding and overcoming some of the institutional obstacles to its adoption. We expect that this information will be of interest beyond the organisations engaged in the pilot projects, so we will look for ways to share what we learn.

Our current forums for sharing progress are primarily our Annual Partners Meeting (APM), the Prairie Water Website and our Twitter account. We are exploring other ways we might share our progress on the pilot projects and other work, including attending or participating in meetings and conferences of partners. Our next APM will be in February 2022 and we will send invites to all who signed up for the workshop. This meeting will likely be too early to report any progress on pilot projects; however it is an opportunity to find out what else we have been working on at Prairie Water, and let us know how that might fit with your organisations' activities.

The Prairie Runoff Routing and Flood Modelling tool is the furthest developed of several that we plan to bring to potential users to guide development. Over the next year or two, we plan on delivering introductory workshops on other tools. We hope you will join us again to share your invaluable experience and guidance. Thanks once again for your participation, we cannot stress enough how much we appreciate having you engaged as we develop these tools and products to support resilience in the Prairies.