



SELECTION OF ALLOWABLE RELEASE RATES FROM STORMWATER MANAGEMENT FACILITIES – A CASE STUDY, CITY OF RED DEER, ALBERTA, CANADA

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Abstract: Urbanization increases imperviousness of the developed areas resulting in increased peak flows and volumes of stormwater from the developed areas. The increased volume of water and peak flows may result in erosion and flooding of the receiving watercourses without any mitigation measures in place. As a result, stormwater management facilities are constructed to store stormwater during rainfall events and discharge at maximum allowable release rates to minimize effect on the environment. The allowable released rates are determined based on pre-development peak flow rates and physical conditions of the received watercourses and water bodies. The allowable release rates need to be equalled or less than the pre-development flow rates. Normally, a constant unit pre-development flow rate per unit area (e.g. L/s/ha) is determined based on statistical analysis of available streamflow data and is used to compute allowable release rates from the SWM facilities. In the present study, it is demonstrated that pre-development peak flows per unit area significantly decrease as drainage areas increase. As a result, a variable peak flow rate per unit area needs to be used in determining allowable release rates depending on the area of the developments. In addition, we have also established a cost effective release rate by optimizing the land requirements for SWM facilities and conveyance requirements without adversely affecting natural environment. Approaches used in this study result in allowable rates that are cost effective and environmentally defensible and should be considered for determining allowable release rates and for sizing SWM facilities.

1 Introduction

Urbanized areas present more complex challenges for managing stormwater than those for natural or rural areas, and the complexity increases with size. Urban areas have increased imperviousness, varying land uses, buildings, topography, underground and aboveground surface drainage routes, and surface water management facilities that affects drainage patterns and water quality. Peak flows in developed areas will typically increase compared to pre-development conditions, which could cause increased flooding frequency and severity and erosion. Thus, stormwater management (SWM) facilities are designed to store water and release it at the pre-development flow rate so that natural flow conditions can be maintained downstream of the development and mitigate potential effects.

Several key factors need to be considered in developing an environmentally friendly and cost effective SWM plan for an area. These factors include an understanding of the effect of urbanization, physical and hydraulic conditions of the receiving watercourses and water bodies, SWM philosophy stipulated by the

regulatory requirements, stormwater quality requirements, and enhancement and consideration of best management practices (BMPs) such as low impact developments.

The allowable released rates and the storage requirements for SWM facilities are determined based on pre-development peak flow rates and physical conditions of the received watercourses and water bodies. The allowable release rates need to be equaled or less than the pre-development flow rates and approved by the regulatory authorities. The paper presents the methodology used and rationale for selecting allowable release rates for developing the master storm drainage plan for the Greater East Hill area of the City of Red Deer, Alberta, Canada.

1.1 Overview of Study Area

The study area is located within the Red Deer River basin. Part of the study area is located in the Piper Creek watershed, which is a subwatershed of Waskasoo Creek (a tributary of the Red Deer River). The rest of the study area drains into the Red Deer River via overland flow or via several ravines. Figure 1 shows the study area boundary.

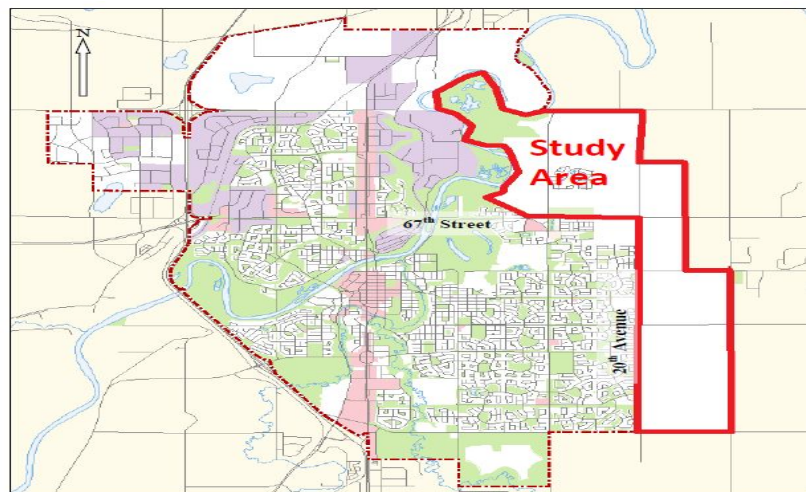


Figure 1: Study Area

2 Pre-development Flow Rates

Information on allowable release rates from each SWM facility is required to determine storage requirements and to size conveyance infrastructure. Flows recorded from a watershed during rainfall events, in combination with corresponding records of the watershed's condition at the time of a given event, typically represent the best dataset to be used for estimating pre-development flow rates. In the absence of such data, regional hydrologic analysis of recorded streamflow data and stormwater modelling software is often used to determine pre-development flow rates. Due to a lack of measured flows during rainfall events available for the study area, the following methods were used in this assessment to generate a range of pre-development peak flows for comparison and evaluation:

- reviewing literature to gather information on allowable release rates adopted by other municipalities located in the general vicinity of the study area
- evaluating previous study findings using regional hydrology analysis
- computer modelling of land areas with various sizes and topographies under the pre-development scenario using single and multiple non-linear regression analysis under a 1:100 year, 24 hour design rainfall event

- assessing hydraulic and morphologic characteristics of receiving watercourses

2.1 Regional Hydrology Analysis

MPE (2014) developed relationships between peak flows corresponding to various return periods and drainage areas by carrying out a regional hydrology analysis of the recorded flow data at the following hydrometric gauging stations.

- Waskasoo Creek at Red Deer (05CC011)
- Haynes Creek near Haynes (05CD006)
- Parlby Creek at Alix (05CD007)
- Pipestone Creek near Wetaskiwin (05FA102)
- Maskwa Creek No. 1 above Beaverhills Lake (05FA014)
- Weiller Creek near Wetaskiwin (05FA024)

The developed relationship between 1:100 year pre-development peak flow and drainage area is presented in the equation below.

$$[1] Q = 0.9869 \times A^{0.6315}$$

Where, A is the drainage area in kilometre squared (km²) and Q is the peak flow in m³/s.

2.2 Computer Modelling

Hydrologic modelling using EPA SWMM software was completed to establish pre-development flow rates that can be expected in the study area during a 100 year, 24 hour design rainfall event. The current land use characteristics and topography have been used in completing the hydrologic modelling exercise.

It has been well established that peak flows from a watershed during rainfall events primarily depend on land use, ground topography (slope), and soil characteristics. A combination of various drainage areas and ground slopes was used in computing peak flows through the developed hydrologic model. Representative ground slopes within the study area ranging from 0.5% to 1.8% and drainage areas ranging from 0.2 km² to 20 km² were assessed with the model.

The estimated peak flows for various ground slopes and drainage areas were used to develop a relationship between peak flows and these two variables. Using a non-linear multiple regression analysis, the following relationship was obtained:

$$[2] Q = 0.83 \times A^{0.604} \times S^{0.48}$$

Where, A is the drainage area in kilometre squared (km²), S is the ground slope and Q is the peak flow in m³/s.

It is a normal practice to express peak flows as a function of drainage areas only, the modelling results were used to establish the following relationship between peak flows and drainage areas for comparison with Equation [1]:

$$[3] Q = 0.82 \times A^{0.608}$$

Where, A is the drainage area in kilometre squared (km²) and Q is the peak flow in m³/s.

2.3 Comparison of Results

A comparison of Equation [1] based on regional analysis of stream flows and Equation [3] based on hydrologic modelling of 100 year, 24 hour design storm event indicates that these two relationships are very similar. Figure 2 shows the variation of peak flows with drainage areas using Equation [1] derived by MPE (2014) and Equations [2] and [3] derived in this study. An additional curve showing peak flow versus drainage area for a particular slope of 1.8% using Equation [2] is also shown on Figure 1, which is in

excellent agreement with the results obtained by MPE (2014). The relationship provided in Equation [3] between peak flows and drainage areas (for all slopes considered) derived in this study provides a relatively lower peak flow for a given drainage area in comparison to the MPE (2014) report. A comparison of these curves demonstrates that the hydrologic modelling results from the current study are in agreement with the regional analysis results as provided in MPE (2014).

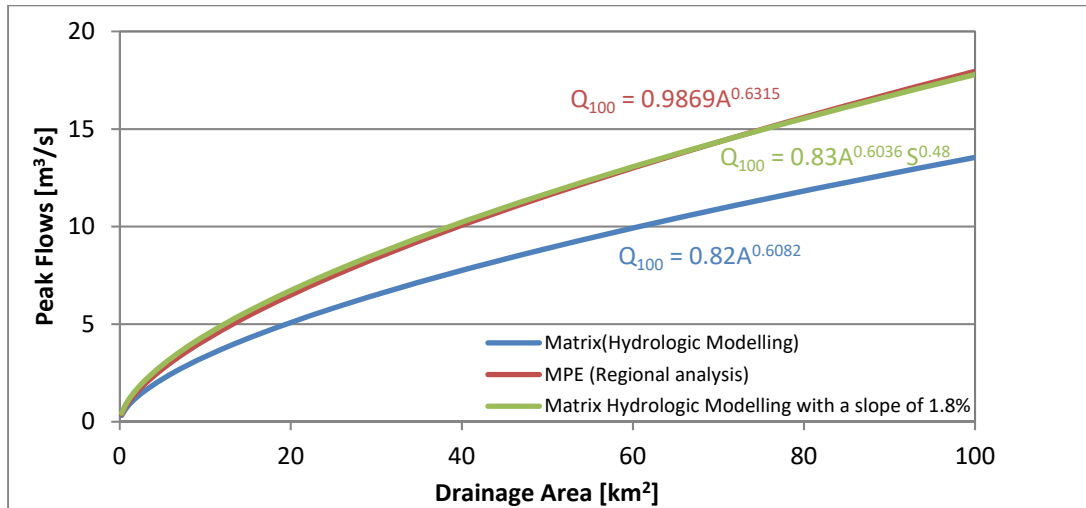


Figure 2: Peak Flow Variation with Drainage Area

Figure 3 shows the relationship between peak flows per unit area and drainage areas based on Equation [1] as derived in MPE (2014) and Equation [3] derived in this study. It is evident that peak flows per unit area significantly decrease as drainage areas increase. This reduction in flow rate per unit area is due to routing and storage effects as water flows through the natural watercourses and water bodies. Peak flow per unit area varies between 3.0 L/s/ha to 5.0 L/s/ha for drainage areas ranging from 5 to 10 km² for both relationships. Peak flows per unit area could exceed 10 L/s/ha for small drainage areas, although the magnitude of peak flows would be relatively small due to the small total area. For reference, for a quarter section (e.g., the scale at which development typically occurs), a peak flow per unit area of 9.8 L/s/ha can be expected.

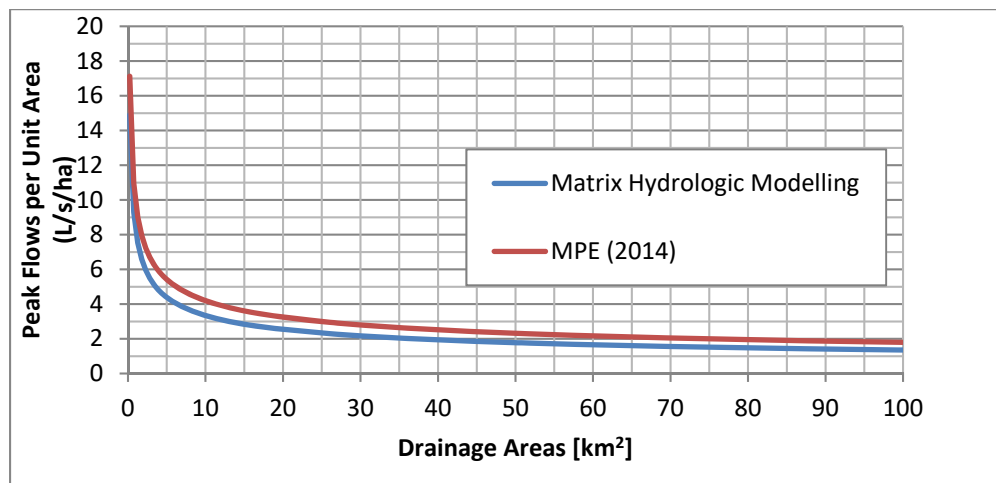


Figure 3: Peak Flow Variation with Drainage Area

3 Allowable Release Rates

A review of the findings of the pre-development flow rates obtained from computer modelling of the existing conditions and regional flow analysis, clearly indicate that release rates up to 10 L/s/ha from a typical quarter section can be justified for sizing the stormwater infrastructure. Based on a review of the physical features of the receiving watercourses and downstream flooding situations, different release rates were proposed depending on the discharge locations. The following factors were considered in determining release rates from the SWM facilities:

- hydraulic and morphologic conditions of receiving watercourses/water bodies
- flooding potential of downstream areas
- cost effectiveness of stormwater infrastructure (without affecting natural environment)
- effective drawdown capability of SWM facilities to accommodate runoff from consecutive rainfall events
- considering hydraulic capacity restrictions of the downstream drainage structure and natural watercourses, including Waskasoo Creek
- considering appropriate mitigation measures around outfall structure
- currently adopted release rates by the City and nearby municipalities for similar watercourses

The proposed allowable release rates for stormwater outfalls located on various watercourses and water bodies are provided in Table 1 below.

Table 1: Allowable Release Rates

Outfall location	1:100 Year Allowable Release Rates (L/s/ha)
Piper Creek	3.6
Ravines	3.6
Red Deer River	9.0

All stormwater flows from the future developed areas will be routed through SWM ponds before being discharged into Red Deer River, Piper Creek, or any of the tributary ravines to achieve the allowable release rates (and treat the stormwater to meet Alberta Environment and Parks (AEP) water quality requirements). Appropriate mitigation measures at each outfall location will be incorporated to minimize any adverse effect to receiving water bodies. The allowable release rates will be used to determine the opening sizes of outflow control devices (such as orifices) and also the storage requirements for the 100 year storm for each SWM facility.

4 Conclusions

The study demonstrated that pre-development peak flows per unit area significantly decrease as drainage areas increase. An allowable constant unit release rate (L/s/ha) based on a regional hydrology analysis may underestimate the peak outflow rates from SWM facilities servicing relatively small areas of developments. As a result, a variable peak flow rate per unit area needs to be used in determining allowable release rates as a function of the development area. Using this approach, optimal land requirements for SWM facilities can be obtained to reduce land dedication without affecting the natural environment.

The computed pre-development flow rates and the physical conditions of the receiving watercourses and downstream flooding situations were considered in selecting allowable release rates for the SWM facilities draining into different receiving watercourses and water bodies located within the study area. Approaches used in this study result in allowable rates that are cost effective and environmentally defensible and should be considered for determining allowable release rates and for sizing SWM facilities.

Acknowledgements

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References

Matrix Solutions Inc. (Matrix). 2017. Greater East Hill Area Master Drainage Plan, Red Deer, Alberta. Report prepared for the City of Red Deer. Edmonton, Alberta. April 2017.

MPE Engineering Ltd. (MPE). 2014. Master Drainage Plan for the Wolf Creek and Whelp Brook Watersheds. Report prepared for Lacombe County, Ponoka County, City of Lacombe, and Town of Blackfalds. Lacombe, Alberta. August 31, 2014.