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SCS STORM TYPE SELECTION FOR ESTIMATING DESIGN FLOWS IN BRITISH COLUMBIA

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Abstract: The US Soil Conservations Service (SCS) methodology for estimating design peak flows in small watersheds is widely used for design of water management infrastructure and has been incorporated in the HEC-HMS computer software. A key component of the methodology is selection of the appropriate design storm. Four synthetic 24-hour rainfall temporal distributions, or storm types (Type 1, 1A, 2 and 3), have been developed and are options within HEC-HMS. Within the USA, the geographical boundaries of the four storm types have been determined and the appropriate storm type can be readily selected. However, there is no established methodology for determining the appropriate storm type for projects located outside the USA, or whether these storm types are even applicable. A methodology is presented that allows for a rational approach to determining the appropriate SCS storm type for a project that is located outside of the USA. The approach requires depth-duration-frequency (DDF) table values. The storm-selection methodology is applied to three climate stations in British Columbia that have Environment Canada DDF values: Vancouver YVR, Williams Lake, and Stewart A stations. For the Stewart A station, none of the SCS storm types are appropriate, and a site-specific temporal distribution is developed using the alternating-block methodology to provide a user-defined hyetograph for input to HEC-HMS

1 Introduction

The US Soil Conservation Service[1] (SCS) methodology (USDA, 1986) for estimating design peak flows in small watersheds is widely used for design of water management infrastructure in the USA and globally. The SCS method has been incorporated in the HEC-HMS computer software (USACE, 2009). A key component of the methodology is selection of the appropriate design storm. Four synthetic 24-hour rainfall temporal distributions, or storm types (Type 1, 1A, 2 and 3) have been developed and are options within HEC-HMS. Peak flow estimates are sensitive to the choice of storm type. For a typical small watershed of a few km^2, peak flow estimates assuming a Type 2 storm may be three or more times greater than derived using a Type 1A storm.

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[1] Now the Natural Resources Conservation Service (NRCS)

determining the appropriate storm type for projects located outside the USA, or whether these storm types are even applicable.

This paper presents a methodology for determining selecting the appropriate SCS storm type outside of the USA and is applied to examples from British Columbia.

2 SCS Storm Types

Four synthetic storm types that provide 24-hour rainfall distributions have been developed for the lower 48 states of USA, and for Alaska and Hawaii (SCS, 1986). The cumulative 24-hour rainfall distributions for SCS Storm Types 1, 1A, and 2 are presented in Figure 1. Storm Type 3 is similar to the Type 2 distribution, and applies to eastern and south-eastern USA. The Type 3 storm is not considered further in this paper.

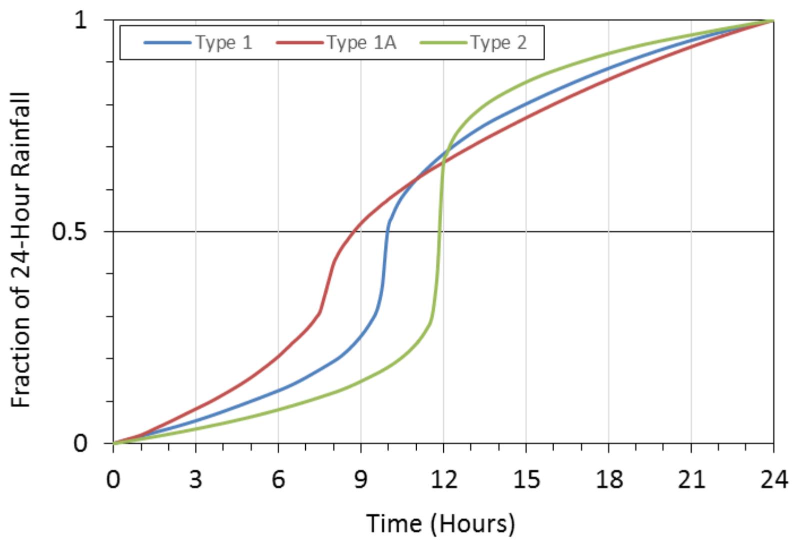

Figure 1: Cumulative 24-hour Rainfall Distributions for SCS Storm Types 1, 1A, and 2 (after SCS, 1986)

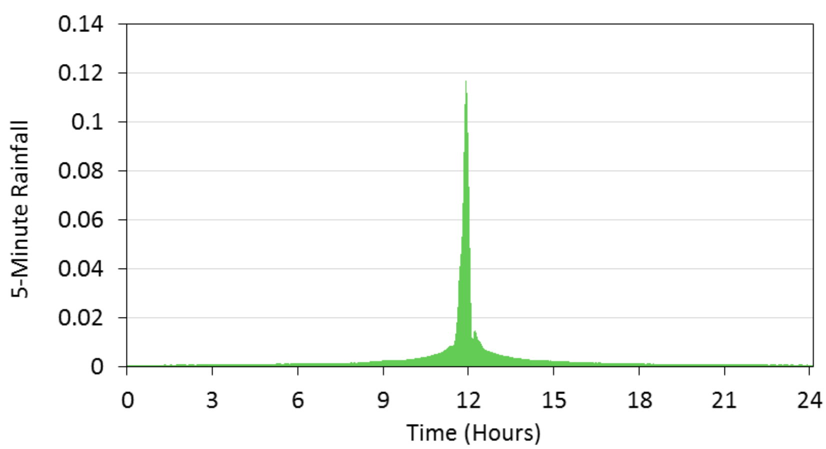

Figure 2: Temporal Rainfall Distribution for the Type 2 Storm in 5-minute increments as a proportion of the total 24-hour Rainfall. The peak 5-minute interval captures 11.7% of the total 24-hour rainfall.

The rainfall distributions represent synthetic design storms and do not reflect actual storm events. The storms begin with low intensity, increase to a maximum, with intensity decreasing later in the storm. Figure 2 shows the incremental distribution of the Type 2 storm in 5-minute increments. The peak intensity is near the mid-point of the storm, with the maximum 5-minute rainfall depth equal to 11.7% of the total 24-hour depth.

2.1 Geographic Distribution

The geographic distribution of the storm types is limited to the USA, and there is no guidance for selecting the appropriate storm type in British Columbia (BC). The geographic distribution of the storm types in western North America adjacent to BC is shown in Figure 3. Within BC, the distribution suggests that Type 1A storm would be appropriate for the south coastal and the adjacent south-west interior, Type 2 within the interior of BC, and Type 1 for north coast and areas adjacent to Alaskan pan handle.

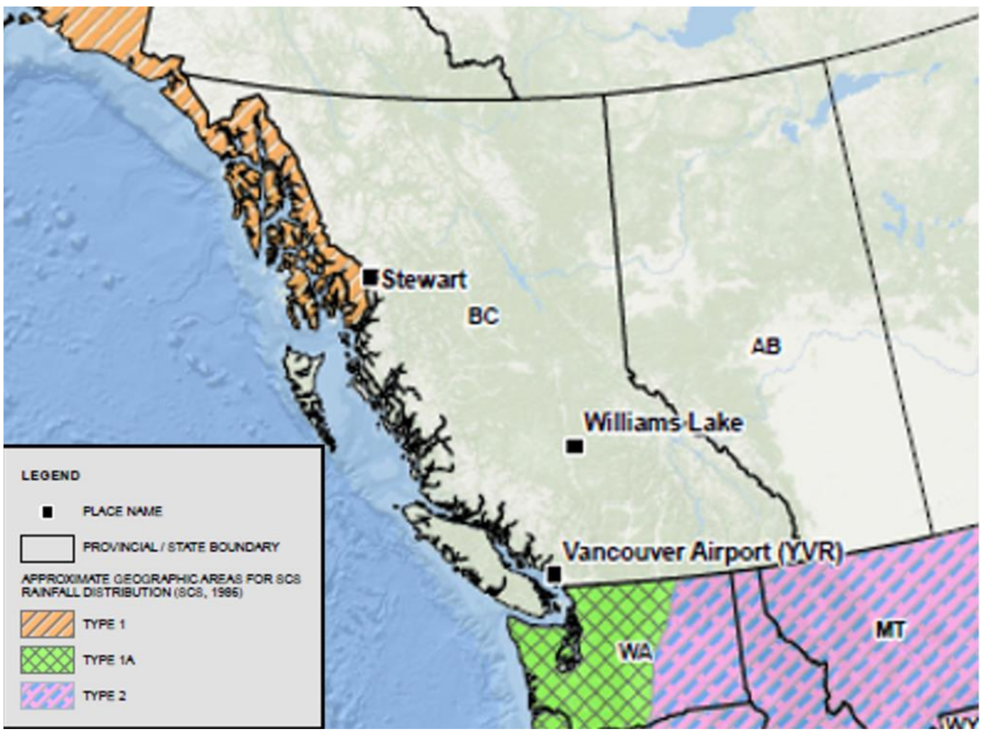

Figure 3: Approximate Geographic Boundaries for SCS Storm Types in Western US adjacent to British Columbia (after SCS, 1986)

2.2 Depth-Duration

An alternate way of characterising the SCS storm types developed here is to extract the depth-duration (DD) values. Maximum rainfall depths as a proportion of the 24-hour total have been determined for Type 1, Type 1A, Type 2 storms for selected durations from 5 minutes through 24-hours (Table 1). For example, the maximum 5-minute rainfall depth for the Type 2 storm is 11.7% of the total 24-hour depth (see also Figure 2). The values in Table 1 can be readily scaled to the total 24-hour depth.

The values in Table 1 form the basis for selecting the appropriate storm type by comparing with station depth-duration-frequency (DDF) values. In BC, short duration intensity-duration-frequency (IDF) datasets including DDF data are available for 121 stations in British Columbia as part of the Environment Canada

Engineering Climate Datasets program[2]. Data from Vancouver YVR, Williams Lake, and the Stewart A climate stations are used to demonstrate the proposed methodology for storm type selection. The location of these climate stations in shown in Figure 3.

Table 1: Maximum Rainfall Depth-Duration Values as a Proportion of the Total 24-hour Rainfall

	Rainfall Depth-Proportion of 24-hour		
Duration (mins)	Type 1	Type 1A	Type 2
5	0.064	0.020	0.117
10	0.116	0.040	0.213
15	0.153	0.060	0.279
20	0.179	0.079	0.327
30	0.216	0.115	0.386
60	0.281	0.172	0.454
120	0.370	0.252	0.538
240	0.492	0.372	0.639
360	0.578	0.468	0.707
720	0.761	0.687	0.841
1440	1.0	1.0	1.0

3 Application to BC Climate Stations

The DDF values (mm) for Vancouver YVR, Williams Lake, and Stewart A stations are plotted with scaled values from Table 1 (Figures 4 to 6). The storm depth-duration curves are scaled with the 1:100-year 24-hour rainfall depth from Environment Canada. Comparing the depth-duration curves for the three storm types with the Environment Canada DDF data allows the most appropriate storm type to be selected.

- For Vancouver YVR (Figure 4), the Environment Canada DDF values correspond closely to the Type 1 storm distribution. However, the geographic distribution of storm types (Figure 3) would suggest that Type 1A, not Type 1, would be applicable to Vancouver YVR.
- For Williams Lake (Figure 5), the Environment Canada DDF values correspond closely to the Type 2 storm distribution, which is consistent with the geographic distribution of storm types (Figure 3).
- For Stewart A (Figure 6), the DDF values do not correspond to any of the SCS storm distributions, whereas the geographic distribution of storm types (Figure 3) would suggest that the Type 1 distribution would be appropriate.

For Stewart A station, additional analysis is provided below to develop a site-specific storm distribution.

[2] Can be downloaded from ftp://ftp.tor.ec.gc.ca/Pub/Engineering_Climate_Dataset/IDF/

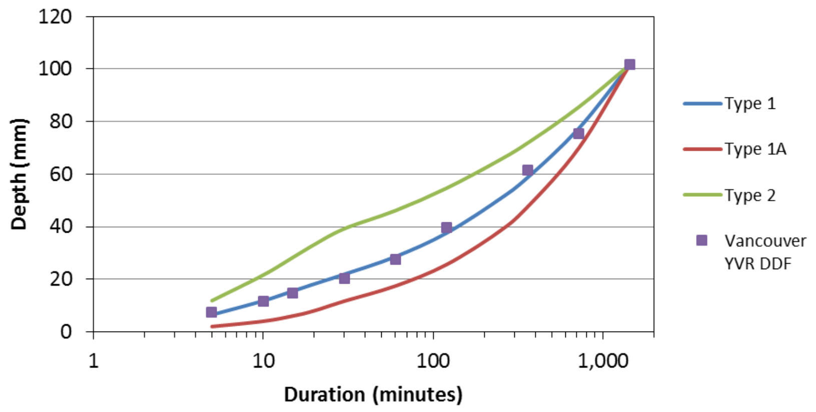

Figure 4: Vancouver YVR 1:100-year Depth-Duration plot. The 1:100-year 24-hour depth is 101.7 mm. The Vancouver YVR DDF values correspond closely to the Type 1 distribution.

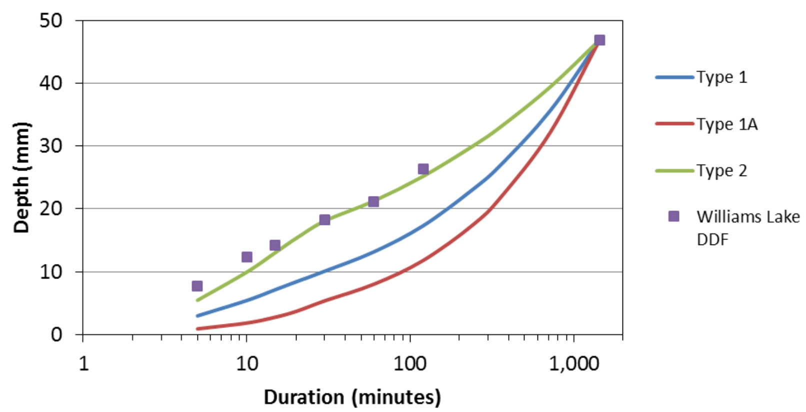

Figure 5: Williams Lake 1:100-year Depth-Duration plot. The 1:100-year 24-hour depth is 46.9 mm. The Williams Lake DDF values correspond closely to the Type 2 distribution.

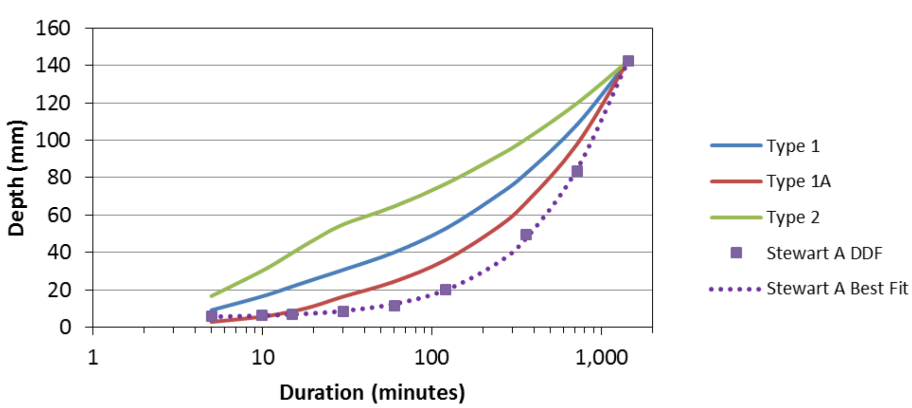

Figure 6: Stewart A 1:100-year Depth-Duration plot. The 1:100-year 24-hour depth is 142.5 mm. The William Lake DDF values do not correspond to an SCS distribution, and a polynomial has been fit to the data (Equation 1).

3.1 Development of a Site-Specific Rainfall Distribution

The DDF values for Stewart A station (Figure 6) do not correspond to any of the standard SCS Storm Types. An assumption that the Type 1 storm is applicable based on geographic distribution (Figure 3) would potentially have significant implications for hydrologic design. For example, the Environment Canada 30-minute 1:100-year depth is 8.5 mm, whereas the corresponding value from the Type 1 storm is 30.7mm, or 3.6 times greater. Using the Type 1 storm distribution for hydrologic design could therefore significantly overestimate the design flow. An alternate approach is presented below to derive a site-specific storm rainfall distribution (hyetograph) using the Environment Canada DDF values.

The process for deriving a site-specific storm requires two steps:

1. Fit a curve (polynomial) to the Environment Canada DDF values;
2. Develop a 5-minute hyetograph using the “alternating-block” methodology (Chow et al., 1988).

A second order polynomial was fit to the Steward A DDF values (Figure 6, $r^2 = 0.9997$):

[1] $D(T) = AT^2 + BT + C$

Where D = depth (mm) for duration T (mins), and A, B, and C are empirical coefficients. Other equation types can be used as appropriate.

The alternating block methodology is used to develop a design hyetograph from DDF values. Here, the cumulative rainfall depth *D(T)* is calculated for every 5 minute interval up to 24-hours using Equation [1]. The design storm is centered on the peak 5-minute rainfall depth at 12 hours, which corresponds to the 5 minute DDF value (5.7 mm). For each additional 5-minute time interval, or block, the incremental rainfall depth is added successively on alternating sides of the centre so that for any duration, the total depth is given by Equation [1]. The resultant design storm consists of a central peak, with remaining blocks arranged in descending order alternately either side of the central block. Close inspection of the peak of the Type 2 Storm incremental rainfall hyetograph (Figure 2) indicates that an alternating-block methodology has been used.

For Stewart A (Figure 7), the resultant cumulative rainfall distribution exhibits a generally constant accumulation over the 24-hour period, with a central “jump”, which represents the maximum 5-minute rainfall accumulation (5.7 mm). The corresponding incremental hyetograph (Figure 8) consists of a prominent 5-minute central peak (5.7 mm), and decreasing incremental rainfall depths from 0.63 mm to 0.32 mm for the remaining 5-minute intervals. The distribution is substantially different from the SCS storms types. While the derived Stewart distribution and hyetograph might appear unusual, they are consistent with the Environment Canada DDF values (Figure 6).

Within HEC-HMS there is an option for a “Specified Hyetograph” to allow the derived hyetograph to be used as input.

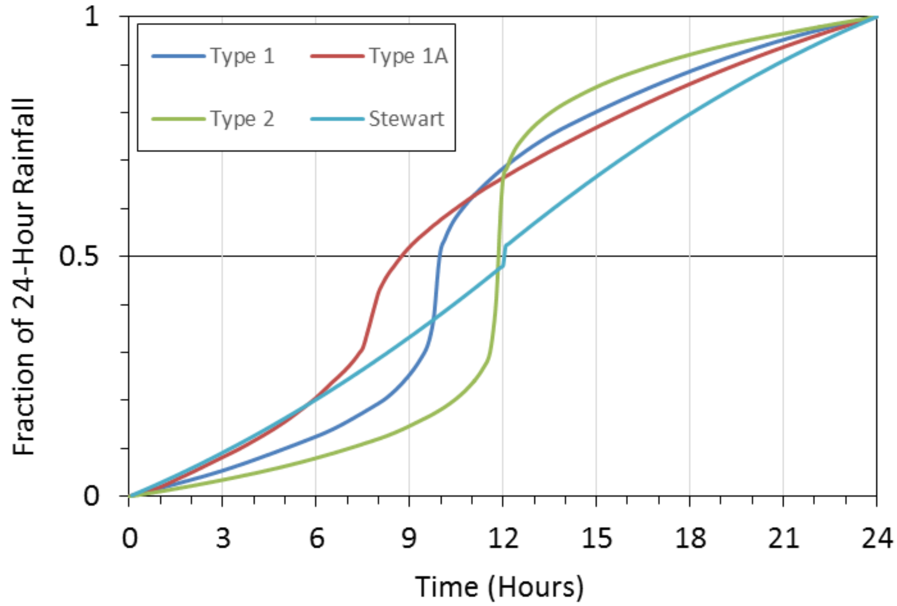

Figure 7: Derived Cumulative 24-hour Rainfall Distribution for Stewart, BC.

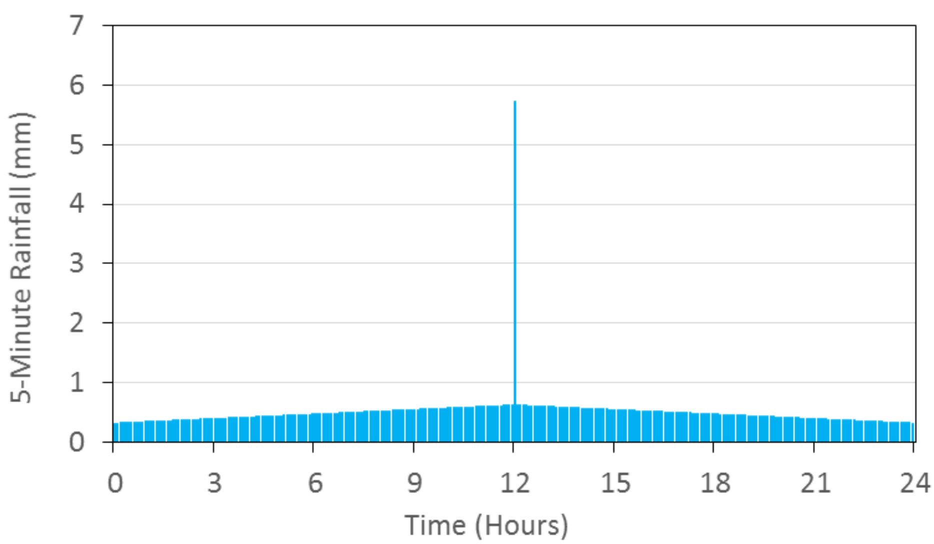

Figure 8: Derived Incremental 24-hour Hyetograph for Stewart, BC.

4 Summary and Conclusions

The analysis of Environment Canada DDF data from 3 climate stations in BC indicate that in general the appropriate SCS storm type (SCS, 1986) in BC cannot reliably be inferred from the geographic distribution of storm types within the USA. Furthermore, DDF data from a specific station in BC may not conform to any of the standard storm types.

A methodology is proposed using the “alternating-block” method to derive site-specific design storm hyetographs, which can be input to HEC-HMS as a “Specified Hyetograph”.

References

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