APPENDIX A
Design Storm Review

Design Storm Review and Recommendation for Stormwater Master Plan

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Introduction

Storm drainage systems collect and convey surface runoff resulting from precipitation over a basin. To evaluate existing system deficiencies and to design new facilities, a defined event ("storm") is applied to the basin through established engineering procedures. This defined event is usually characterized by an estimate of the probability of it's re-currence in any year, and by its specific characteristics that describe how much rainfall or runoff occurs, over what time, and at what intensity. These characteristics define a "design storm".

This design storm provides a common basis for City staff, the development community, regulators, and the public to ensure that when a level of service for the drainage system is defined, the details of the evaluation are based on shared understanding. Design storms are generally described by a specific parameter, related to a selected recurrence interval (frequency). The most common parameters for precipitation are duration, depth, peak intensity, average intensity, and volume. Selection of the key parameter depends on the methods selected for computing stormwater runoff, since the design storm parameters are the primary input for these calculations. For example, if the Rational Method ($Q = CiA$) is being used for computing peak runoff rates, then rainfall intensity would be the key parameter in selecting a design storm.

Also important are the antecedent conditions within the basin, which vary seasonally and spatially throughout the watershed. Antecedent conditions have a significant effect on runoff quantity. For example, a 10-year rainfall event could fall on dry soil and only produce 5-year runoff, compared to a 10-year event falling on wet soils immediately after an annual rain event and produce peak runoff in excess of 10-year peak flows. This distinction between rainfall and runoff is important to consider in selecting the method for developing the design event because each runoff calculation method accounts for antecedent conditions differently, or may not account for it at all.

Design Storm Development

There are two general approaches for developing design storms: synthetic storm development (Alternative A and C below), and historical storm selection (Alternative B).

Alternative A: Synthetic Storm Development

Synthetic storms are developed by first selecting the storm duration, then selecting the total depth, typically from available sources such as local IDF (Intensity-Duration-Frequency) curves (or these can be created), or isopluvial maps. Then the rainfall is applied to a distribution which defines the shape, thus, timing of the storm. This is often represented by a hyetograph, showing rainfall intensities for a specific time interval over the length of the storm event. In practice, the sources for selecting each of these three variables are as follows:

- **Duration:** Common practice is to use a short duration event to synthesize a summer thunder storm (2-6 hours), if that is typically when the controlling runoff events occur, and a longer duration storm ranging from 12 hours to 72 hours depending on the application of the design storm, for areas where these types of storms tend to control runoff rates. Often, a short duration (usually with higher peak intensities) is used to design facilities for peak flow capacity, and a longer duration (with lower intensities and greater total rainfall volume) is used to size volume-based storage facilities.

- **Depth:** Total depth for the given duration is determined from either an IDF curve or isopluvial maps. Sources of available IDF curves are ODOT regional curves, locally developed curves for nearby cities or counties, or curves developed for a specific area if historic data is available. Depths can also be determined from isopluvial maps produced by NOAA and NRCS.

- **Distribution:** Rainfall can be distributed in time (varying intensities) using either published distributions or using a general macro pattern (i.e. ramping down or triangular). The most common published distribution used west of the Cascades is the SCS Type 1A. Rainfall studies have shown that the two most common macro patterns for the Willamette Valley are the Type I which is front loaded and ramps down exponentially, and the Type VI which ramps up linearly to the peak then ramps down exponentially[\]. The SCS Type 1A storm is much “flashier” with a higher peak intensity compared to the macro pattern Type I or Type VI distributions. The SCS type 1A will produce greater peak flows which then leads to conservative designs for conveyance facilities. Figure 1 shows a comparison between these distributions.

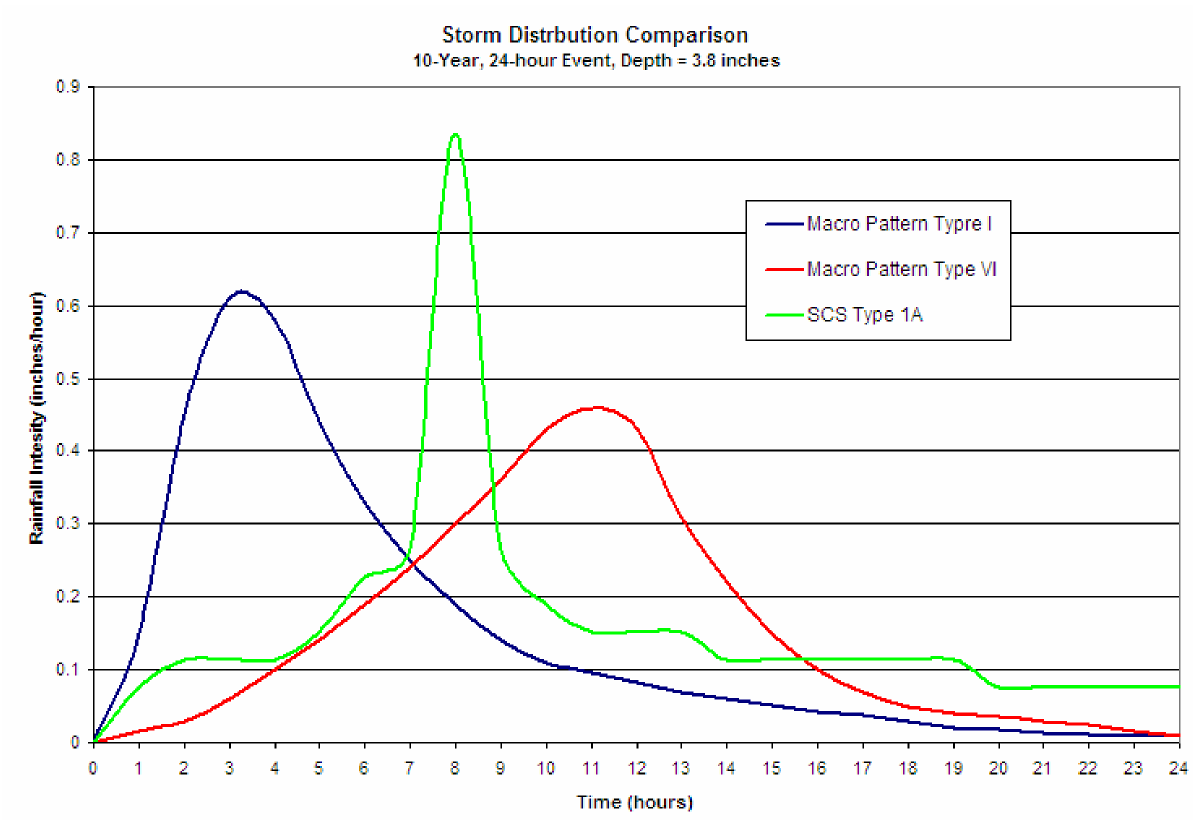

Figure 1 - Comparison of Alternative Design Storm Distributions

It is also important to define the objective for the intended application of the design storm. A design storm may be used to size conveyance infrastructure, storage/detention facilities, or water quality facilities. Different design events may be prudent, depending on whether peak intensity or greatest volume is likely to control the facility capacity requirements.

The disadvantage of using a synthetic storm approach is that the duration and shape are not site-specific and depth is based on probability analysis (usually of regional rainfall data); therefore, the true return period for the area of interest is unknown. Antecedent conditions are not accounted for in the rainfall, however, this can be addressed in the methods used to compute runoff.

Synthetic storms can be developed relatively quickly and easily, which is one reason this approach is so commonly used.

Alternative B: Historic Storm Selection

There are three primary approaches that apply frequency analysis to historical data. The availability of historical data is often the limiting factor for the type of analysis that can be performed. Each of the three approaches is described below.

Frequency Analysis of Historic Runoff: Analysis of runoff data is the best method since it incorporates antecedent conditions and accounts for the basin specific runoff response to rainfall. The analysis entails identification of a storm, or multiple storms, for each recurrence interval if interest. The design storm would be selected from the list of storms that correspond to the respective recurrence interval. However, long term stormwater runoff data is rarely available, which is the case with the City of McMinnville and therefore not a viable option.

Continuous Simulation and Frequency Analysis on Resulting Runoff: This approach realizes the fact that long-term rainfall data is more commonly available compared to long-term stormwater runoff data. A rainfall-runoff model is created and calibrated using measured runoff. A continuous simulation of runoff is performed using the calibrated model. Then a frequency analysis is applied to the resulting peak flow database. This approach requires a long-term rainfall record (greater than 25 years), which is available for McMinnville, and an overlapping short-term runoff record which is not available for McMinnville.

Frequency Analysis on Rainfall Events: This method involves separating the continuous rainfall record into separate storm events based on a separation interval (i.e. 6 consecutive hours without rain defines the separation). A statistical frequency analysis is performed by applying a common distribution, or calculating a unique distribution, to determine the recurrence interval for each storm. The design storm is then selected from the resulting frequency analysis. The disadvantage of this approach is that it bases the return period on rainfall characteristics rather than runoff similar to using a synthetic storm. However, unlike the synthetic storm, the duration, depth, and distribution are site specific, therefore the recurrence interval at the site for the selected storm is more accurately known. Using a historic design storm also gives a snapshot of the performance and status of the drainage system. The public and City staff are able to relate to a historic event and might even have performance data collected during that event or at least anecdotal information which provides a good basis for comparison.

Alternative C: Synthetic Storm Bases on a Single Design Parameter

Not all methods for computing runoff require a design hyetograph. The Rational Method, the most commonly used method for designing urban stormwater facilities, only requires a peak intensity for a given recurrence interval. This method is commonly used because its simple, requires very little data, and produces conservative peak flows.

Design Storm Comparison

This section compares the City's current design storm and source of parameters to those used by near-by communities and overlapping agencies. Table 1 summarizes the findings.

TABLE 1
Summary of Design Storms for Agencies and Municipalities Near McMinnville, OR

Agency / Municipality	Synthetic or Historic	Adopted Methods and Parameters for Design Standards		
City of McMinnville	Synthetic	**Duration:**	**Depth:**	**Distribution:**
		24-hour	Recommended from Newton and Associates, values are similar to NOAA Isopluvial Maps	SCS Type 1A

TABLE 1
Summary of Design Storms for Agencies and Municipalities Near McMinnville, OR

Agency / Municipality	Synthetic or Historic	Adopted Methods and Parameters for Design Standards	
City of Portland (BES)	Both	Rational Method for Stormwater	**Peak Intensity**: City IDF Curve
		Both a Synthetic and Historic Storm for Combined system.	
ODOT	Synthetic	Rational Method	**Peak Intensity**: Regional IDF Curves
Clean Water Services	Synthetic	Rational Method	**Peak Intensity**: Agency Specific IDF Curve

To illustrate the impact of using different methods and data sources, peak flows were computed for a sample basin using 4 different approaches: (1) SCS Curve Number Method, Type 1A Distribution, NOAA isopluvial maps, (2) Rational Method, Clean Water Services IDF curve, (3) Rational Method, Bureau of Environmental Services IDF curve, and (4) Rational Method, Oregon Department of Transportation, Region 8 IDF curve. The sample basin is 10 acres, 60% impervious, zoned for medium residential land use, with an assumed time of concentration of 15 minutes. A 10-year, 24 hour storm was selected for comparison. The primary rainfall input parameters and resulting peak runoff rates are compared in Table 2.

TABLE 2
Comparison of Peak Runoff Using Different Methods

Method	Data Source / Resulting Rainfall Parameter	Peak Runoff Rate (cfs)
Rational	Clean Water Services IDF Curve / Peak Intensity = 1.8 in/hr	16.1
Rational	Bureau of Environmental Services IDF Curve / Peak Intensity = 1.63 in/hr	14.6
Rational	ODOT Region 8 IDF Curve / Peak Intensity = 1.5 in/hr	13.5
SCS Curve Number, Type 1A	NOAA Isopluvial Maps for 24-hr Rainfall Depth / Depth = 3.8 inches	7.4

As expected, the Rational Method produces much higher peak flows compared to the SCS Curve Number Method. There is a small difference between the two Rational Method peak flows due the different data sources (IDF curves) for the rainfall intensity, but the difference is small compared to the difference computational methods. This example illustrates the conservatism of the Rational Method, which can be advantageous for small drainage design projects because it builds in a factor of safety to account for uncertainty in the input parameters and the resulting design will perform better over the life of the facility. However, since the Rational Method significantly overestimates peak flows in larger basins and when the percentage of pervious area is high, it is not be the most appropriate method for evaluating flows at the basin scale or in rural areas.

Recommendation

For the Stormwater Master Plan and other sub-basin scale design or analysis, continue using the 24 hour, SCS Type 1A storm. The 24 hour, Type 1A storm distribution produces large peak runoff in the major drainage ways, compared to other common rainfall distributions (refer to Figure 1). The Type 1A is the most commonly used distribution for the region around McMinnville. The NOAA isopluvial maps are a reliable and readily available source for 24-hour precipitation depths. Table 1 shows the total rainfall depths for various recurrence intervals using the NOAA Isopluvial maps.

TABLE 3
Total 24-Hour Precipitation for Select Recurrence Intervals

Recurrence Interval	24-hr Precipitation (in), Source: NOAA Isopluvial Maps	24-hr Precipitation (in), Source: Newton & Associates
	(Recommended)	(From 1991 Master Plan)
2-YR	2.6	na
10-YR	3.8	3.6
25-YR	4.2	4.2
50-YR	4.7	4.7
100-YR	5.2	5.3

For analyzing and designing facilities for small project areas (less than 25 acres), use the Rational Method approach and peak rainfall intensities from the ODOT IDF curves.

Historic precipitation data is available if the City prefers to select a historic design storm or conduct rainfall analysis in order to determine site specific rainfall depths for various recurrence intervals which would be applied to a synthetic design storm distribution (e.g. SCS type 1A). Hourly precipitation data is available at the Haskins Dam (Co-op ID 353705) in Yamhill from 1948 to 2006, located approximately 13 miles away. Hourly data is not sufficient to develop and IDF curve, the City will have to utilize available curves such as the ODOT IDF curves for the Rational Method analysis recommended for small projects sites.