MEMORANDUM

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SUBJECT: Atlas 14 Rainfall Depth Revisions and IDF Curves

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PROJECT: CPK16183 – Stormwater Master Plan

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Introduction

In September 2018, the National Oceanic and Atmospheric Administration (NOAA) published *Atlas 14: Precipitation-Frequency Atlas of the United States, Volume 11 Version 2.0: Texas*. This study provides precipitation frequency estimates for the entire state of Texas, including a set of digital rasters that cover the state at a resolution of approximately 100 feet. These estimates were computed based on hundreds of daily and hourly rain gage records throughout the state covering a period of record ranging from the mid-1800s through 2018. Atlas 14 serves as the United States government's official source of precipitation frequency estimates and associated information for Texas, and replaces previous federal studies, including National Weather Service TP-40 (1961) and NOAA HYDRO-35 (1977).

Before publication of Atlas 14, Volume 11, most Texas communities have relied on either TP-40 (1961) or USGS SIR-2004: *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas* (2004). The City of Cedar Park's development regulations currently refer to the City of Austin's Drainage Criteria Manual (DCM), which currently includes rainfall depths based on a 2001 study by Dr. William Asquith of the USGS, which is based on the same dataset published in USGS SIR-2004. The City of Austin is in the process of updating their DCM to include Atlas 14 rainfall depths averaged across Austin's city limits and ETJ. Neither the 2001 USGS depths nor the proposed Atlas 14 depths for Austin accurately reflect the latest Atlas 14 rainfall statistics within the limits of the City of Cedar Park.

In order to take advantage of the latest available data, more accurately document the risk of extreme rainfall in Cedar Park, and provide a consistent basis for drainage analysis and design, Freese and Nichols (FNI) has developed Atlas 14 rainfall depths and intensity-duration-frequency (IDF) curve parameters for the City of Cedar Park. This technical memorandum documents (1) the procedure used to spatially average the rainfall depths from NOAA geospatial data and (2) the procedure used to fit the IDF curve parameters to the rainfall intensities.

Rainfall Depths

NOAA has provided Atlas 14 precipitation frequency estimates for the state of Texas on their website (https://hdsc.nws.noaa.gov/hdsc/pfds/). This includes a series of rasters that document precipitation-frequency estimates in inches for a range of storm durations and average recurrence intervals. For this analysis, FNI used the partial-duration rasters covering storm durations between 5 minutes and 24 hours and for average recurrence intervals from 1 to 500 years. Figure 1 shows Cedar Park's city limits and ETJ along with contours representing the Atlas 14 100-year 24-hour depth. The 100-year 24-hour depth generally ranges from 11.6 inches at the north edge to 12.0 inches at the south.

FNI used ArcMap's Zonal Statistics tool to average the NWS partial-duration precipitation frequency rasters across the entirety of the City of Cedar Park's city limits and ETJ. The tool provides a minimum, maximum, range, mean, and standard deviation of each precipitation-frequency estimate raster across Cedar Park's city limits and ETJ. The tool only considers raster cells whose centers lie within the city limits and ETJ. In order to improve resolution around the perimeter, FNI first resampled each raster from a cell size of approximately 0.5 mi to a cell size of approximately 0.05 mi.

The mean value for each precipitation-frequency estimate (e.g., the 100-year 24-hour storm) represents the mean rainfall depth within Cedar Park's city limits and ETJ. The range and standard deviation values show the level of variation and indicates how closely the mean value represents the actual values within the city limits and ETJ.

The recommended rainfall depths are shown in Table 1 below. Table 2 provides the range and standard deviation of depths for select durations and recurrence intervals. The Table 2 results indicate that the mean values selected generally match the underlying Atlas 14 values across the city within ±2%. This holds true across a range of durations and recurrence intervals.

Table 1. Recommended Atlas 14 Rainfall Depths

Duration	Rainfall Depth (in.) by Average Recurrence Interval								
	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
5 min	0.42	0.51	0.65	0.77	0.95	1.10	1.26	1.43	1.66
10 min	0.68	0.82	1.04	1.23	1.52	1.76	2.02	2.28	2.63
15 min	0.85	1.03	1.30	1.54	1.89	2.19	2.51	2.84	3.29
30 min	1.21	1.45	1.82	2.15	2.64	3.04	3.48	3.95	4.61
60 min	1.56	1.90	2.39	2.84	3.50	4.05	4.65	5.32	6.28
2 hr	1.86	2.32	2.99	3.62	4.57	5.38	6.30	7.34	8.88
3 hr	2.01	2.57	3.35	4.11	5.26	6.27	7.42	8.74	10.71
6 hr	2.31	3.01	3.98	4.93	6.39	7.67	9.17	10.90	13.51
12 hr	2.67	3.47	4.58	5.68	7.36	8.83	10.55	12.55	15.59
24 hr	3.07	3.96	5.23	6.44	8.30	9.90	11.76	13.95	17.30

Table 2. Variation in Atlas 14 Rainfall

Duration	Value (in.)	Average Recurrence Interval			
		2-yr	10-yr	25-yr	100-yr
5 min	Mean	**0.51**	**0.77**	**0.95**	**1.26**
	Range	0.51–0.52	0.77–0.78	0.94–0.96	1.24–1.29
	Std. dev.	0.001	0.003	0.005	0.010
3 hr	Mean	**2.57**	**4.11**	**5.26**	**7.42**
	Range	2.54–2.59	4.08–4.16	5.21–5.34	7.31–7.57
	Std. dev.	0.010	0.018	0.030	0.060
6 hr	Mean	**3.01**	**4.93**	**6.39**	**9.17**
	Range	2.98–3.03	4.89–4.99	6.32–6.48	9.04–9.37
	Std. dev.	0.012	0.022	0.037	0.076
24 hr	Mean	**3.96**	**6.44**	**8.30**	**11.76**
	Range	3.92–3.99	6.40–6.51	8.22–8.41	11.60–12.01
	Std. dev.	0.014	0.024	0.043	0.095

The City of Austin and many surrounding communities currently distribute 24-hour storms using the NRCS' regional Type III rainfall distribution as documented in NRCS TR-55 (1975). Due to the ready availability of local rainfall frequency information, the Type III distribution is now obsolete. The NRCS now recommends distributing Atlas 14 rainfall using nested frequency storms. This method is built into the freely available HEC-HMS software: users can simply enter the depths from Table 1 below into a HEC-HMS model to have a nested frequency storm created automatically. FNI recommends that the City of Cedar Park discontinue use of the Type III NRCS distribution and instead require use of the nested frequency storm method in HEC-HMS or other time-varying models.

Intensity-Duration-Frequency Curves

The city currently references the City of Austin's Drainage Criteria Manual (DCM). This manual provides a depth-duration-frequency (DDF) table, an intensity-duration-frequency (IDF) table, and a set of parameters fitted to the IDF power-law equation $i = a/(b + t)^c$. The parameters a, b, and c are provided for each recurrence interval and used in conjunction with the time of concentration t (in minutes) to produce the rainfall intensity in inches per hour for use with the rational method. These parameters need to be updated to match the new Atlas 14 data described above.

The Atlas 14 data does not necessarily follow a smooth, idealized set of IDF curves. The objective of the IDF curve-fitting process is to produce a set of parameters that minimize the difference between the fitted curves and the mean values. Each set of parameters was fitted to the mean Atlas 14 depths in Table 1.

FNI used the evolutionary algorithm in Excel's Solver to fit the a, b, and c parameters to the Atlas 14 depths. The objective of the Solver procedure was to minimize the sum of squared differences between the original intensity value and the calculated value by adjusting the a, b, and c parameters. The use of IDF curves is only appropriate for use with rational method calculations for drainage areas under 100 acres; therefore, these curves are rarely needed for times of concentration exceeding 2 hours. FNI weighted the sums of squared differences more heavily for the lower durations to encourage a closer match to those values. The sums of squared differences were also weighted more heavily when the calculated value was below the original value. These adjustments encouraged the algorithm

to produce curves that fit the original rainfall values as closely as possible without significantly underestimating rainfall for any duration between 5 minutes and 2 hours.

The first pass of the algorithm was run using broad minimum and maximum values for the a, b, and c parameters. This first pass explored a large decision space with many possibilities. The resulting set of parameters fit the curves well but exhibited some inconsistencies between recurrence intervals. For example, the a and b values are generally expected to increase with recurrence interval while the c value is generally expected to decrease. FNI ran a second pass of the algorithm for each recurrence interval using the neighboring storm event parameters as minimum and maximum values. This allowed the algorithm to explore a smaller decision space for each recurrence interval and find alternate solutions that preserved consistency between recurrence intervals.
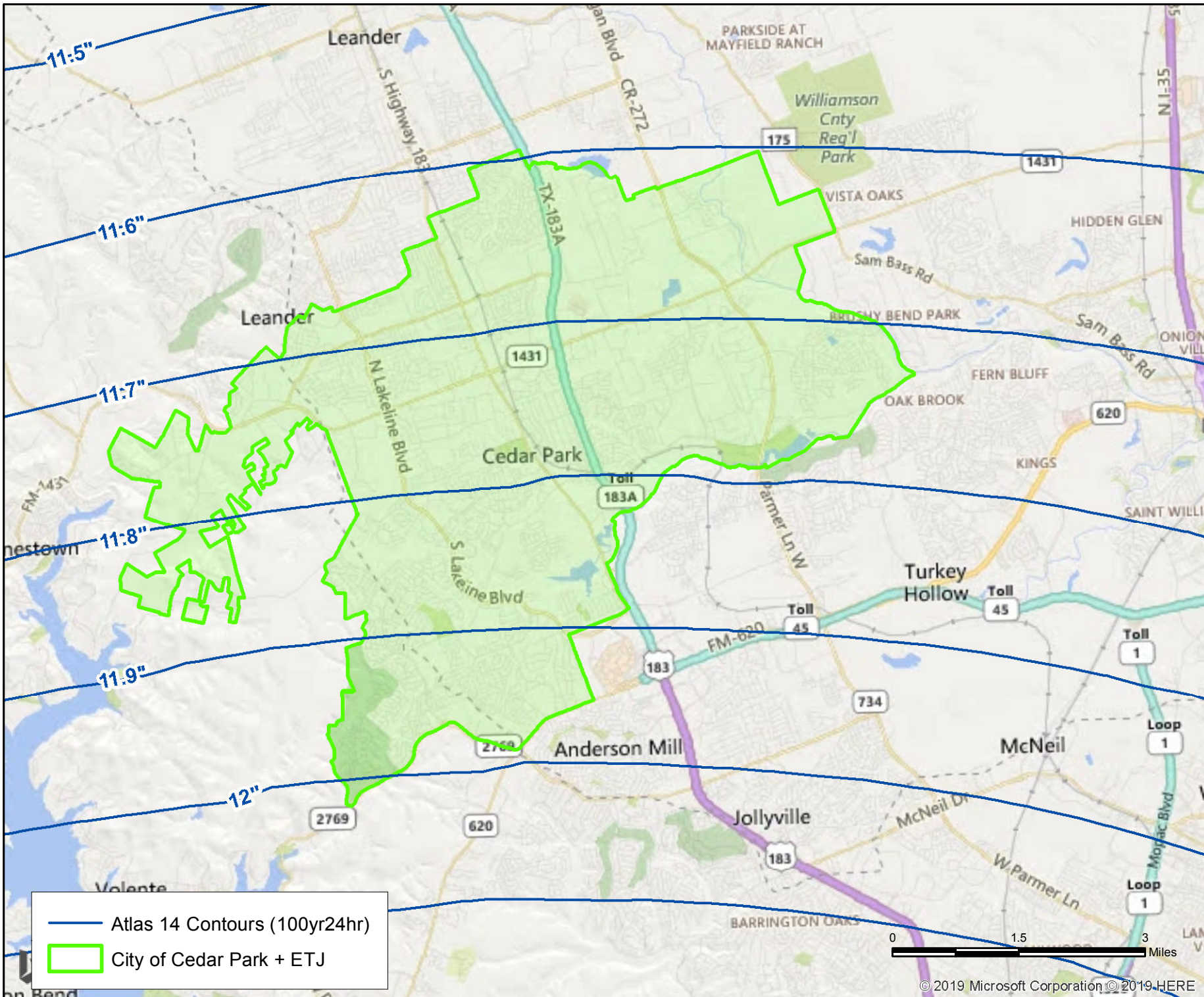
The recommended IDF parameters are shown in Table 3 below. A plot of the IDF curves is shown in Figure 2. For durations between 5 minutes and 2 hours, the maximum error is +5.5% and the average error is +1.2%.

Table 3. IDF Curve Parameters – Fit to Atlas 14 Data

Average Recurrence Interval	a	b	c
1-yr	40.43	10.07	0.7635
2-yr	46.14	9.47	0.7523
5-yr	53.62	8.83	0.7341
10-yr	61.08	8.41	0.7253
25-yr	70.71	8.12	0.7071
50-yr	78.96	7.90	0.6964
100-yr	84.57	7.47	0.6790
200-yr	85.96	6.79	0.6511
500-yr	89.20	6.12	0.6214

Conclusion and Implementation Recommendations

We recommend that the City of Cedar Park publish these new rainfall depths for local use, overriding the corresponding depths and IDF parameters listed in the City of Austin's DCM. This will allow for Cedar Park's local developments and capital projects to be designed in a consistent manner based on the best available rainfall data. After the data is published, we recommend that the City of Cedar Park formally adopt these design standards through an ordinance update and/or adoption of a local DCM.

Atlas 14 100y24hr Contours

City of Cedar Park

Legend:
- Atlas 14 Contours (100yr24hr)
- City of Cedar Park + ETJ
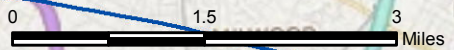
FIGURE

1

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Figure 2: City of Cedar Park Atlas 14
Intensity-Duration-Frequency (IDF) Curves