Off with the Rule of Thumbs: Rethinking Hydrologic Impacts on Stormwater Infrastructure

IAFSM
Illinois Association for Floodplain and Stormwater Management

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Storm & Flood Products Manager

22 year in Industry
6 with Autodesk

Improving the tools, workflows and technology engineers use to study and design civil infrastructure & water resources

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Abstract

Rainfall events do not obey our theoretical nested intensity distributions, despite decades of continual use and the codification of these methods. Extreme events continue to stress local and regional civil infrastructure; our techniques and tools must change. It is no longer a matter of if, but rather when will next extreme event occur. We must **challenge** the **general assumptions**, our rules of thumb when it comes to rainfall, and the surrounding infrastructure's response to these events. In this session, we will look at a typical stormwater workflow using the **XPSWMM** Model. We'll investigate the general trends toward rainfall distributions using Atlas 14 as well as the hydrologic response methods and trends globally and how they apply to you today, saving your thumbs, and making you smarter & more productive.

Learning Objectives:

- Understanding rainfall information
- Learn how temporal distributions effect stormwater infrastructure
- Leverage the latest tools to assist in quickly evaluate critical durations

InfoSWMM®

InfoWorks® ICM

xpswmm

SWMMLive™

ICMLive™

RETHINKING HYDROLOGIC IMPACTS

"Based on existing data, … the 100-year floodplain is a **poor predictor of property damage** … there is **no solid evidence** to justify a default 1% annual chance design level for flood reduction"

"The **reliability** of modeled flood risk can thus quickly **deteriorate as time** goes on, especially in rapidly developing regions."

Houston FEMA flood map missed 75 percent of flood damages, says new study

By Fernando Ramirez Updated 10:22 am, Wednesday, September 20, 2017

Photo: Brett Coomer, Houston Chronicle

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REMOVING ASSUMPTIONS

CLEAR

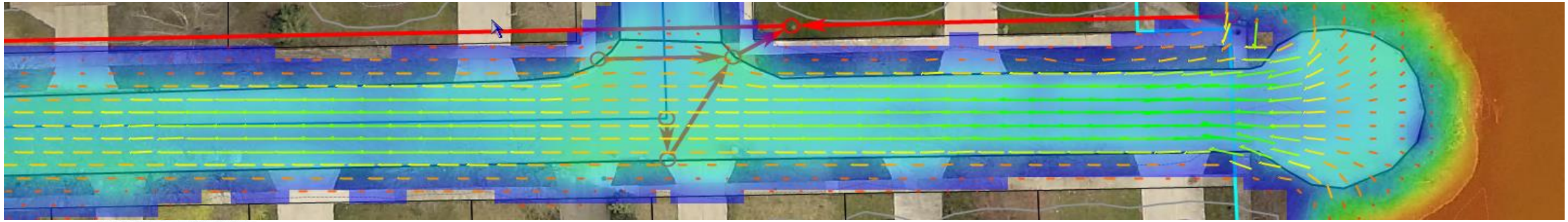
Understand assumptions in hydrology methods so the resulting flood depths, velocity and hazard are visual & easily understood.

ACTIONABLE

Make hydrologic response actionable by viewing the results spatially, or statistically. Plan evacuation responses in the model.

SHARE

Results can be shared by video, or export the spatial extents of the hazard, depth or time to inundation.



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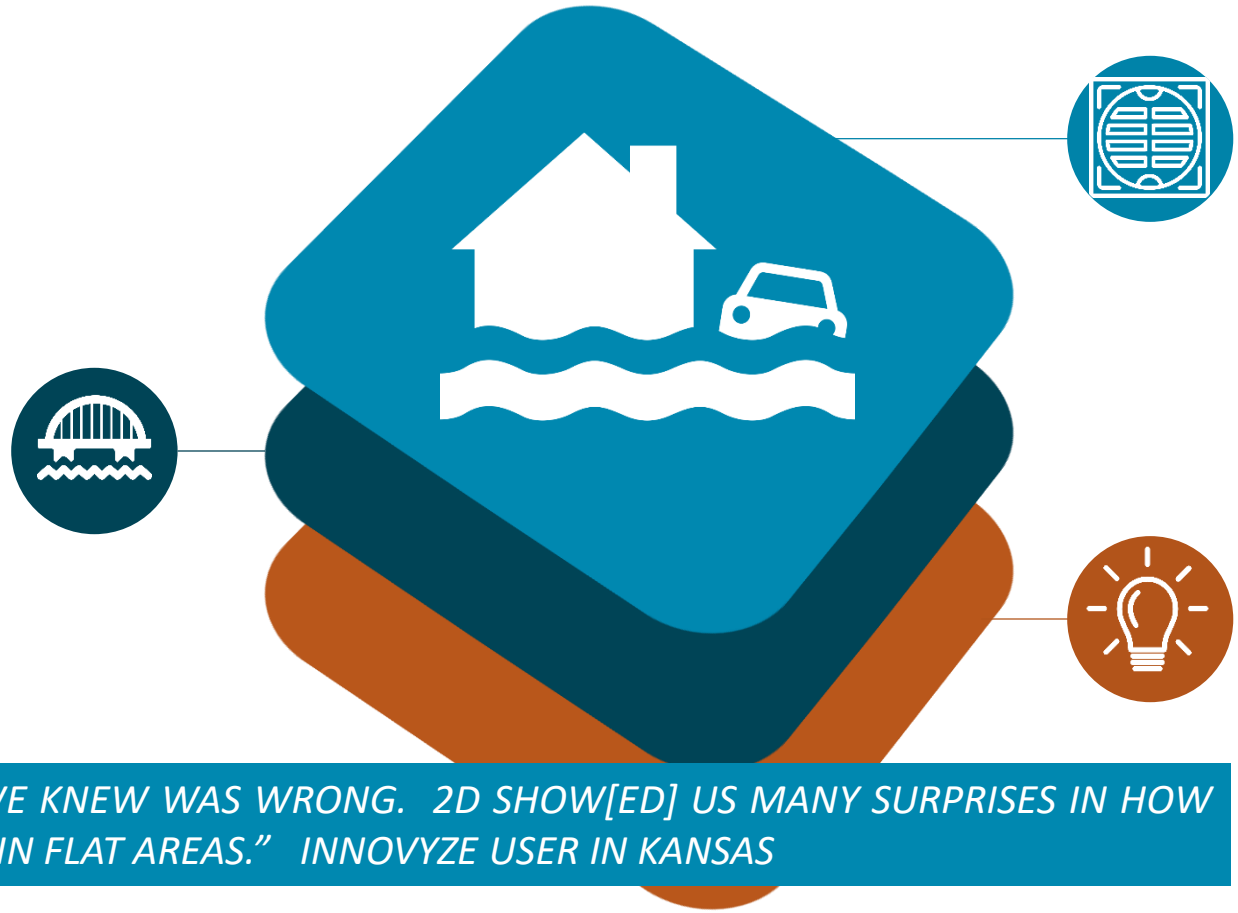
COUPLED 1D / 2D MODELS

STRUCTURES

INCLUDE ELEMENTS LIKE BRIDGES, INLETS, CULVERTS, BUILDINGS, MANHOLES, TIME-VARYING DAM/LEVEES BREACHES INTO THE MODEL



BUILD

SIMPLE TO CONSTRUCT A DISTRIBUTED RUNOFF MODEL WITH TERRAIN & LAND USE TOGETHER WITH GIS DATA

UNDERSTAND

PROVIDE A VISUAL STORY OF HOW THE FLOOD PROGRESSES & PRODUCING STATISTICAL ANALYSIS OF RESULTS

"WHAT WE THOUGHT WE KNEW WAS WRONG. 2D SHOW[ED] US MANY SURPRISES IN HOW FLOODING PROGRESSES IN FLAT AREAS." INNOVYZE USER IN KANSAS

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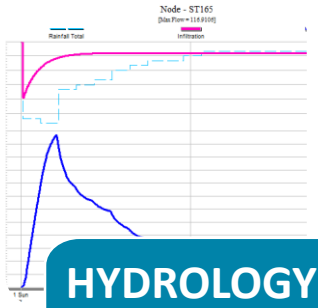
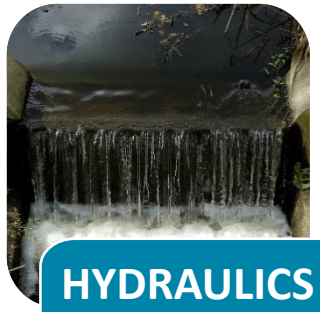
COMPLETE PACKAGE

xpswmm/xpstorm

HOLISTIC MODELING



HYDROLOGY
- Local Methods
- Global Storms



HYDRAULICS
- FEMA Approved
- 1D & 2D Coupled
- Infiltration

WATER QUALITY
- Pollution
- Treatment

2D OVERLAND
- Layered Data
- Flexible & Layered

SANITARY
- Loading & RTK
- Treatment

xpstorm features

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Bulletin 70 vs. Atlas 14

<u>Depths</u>

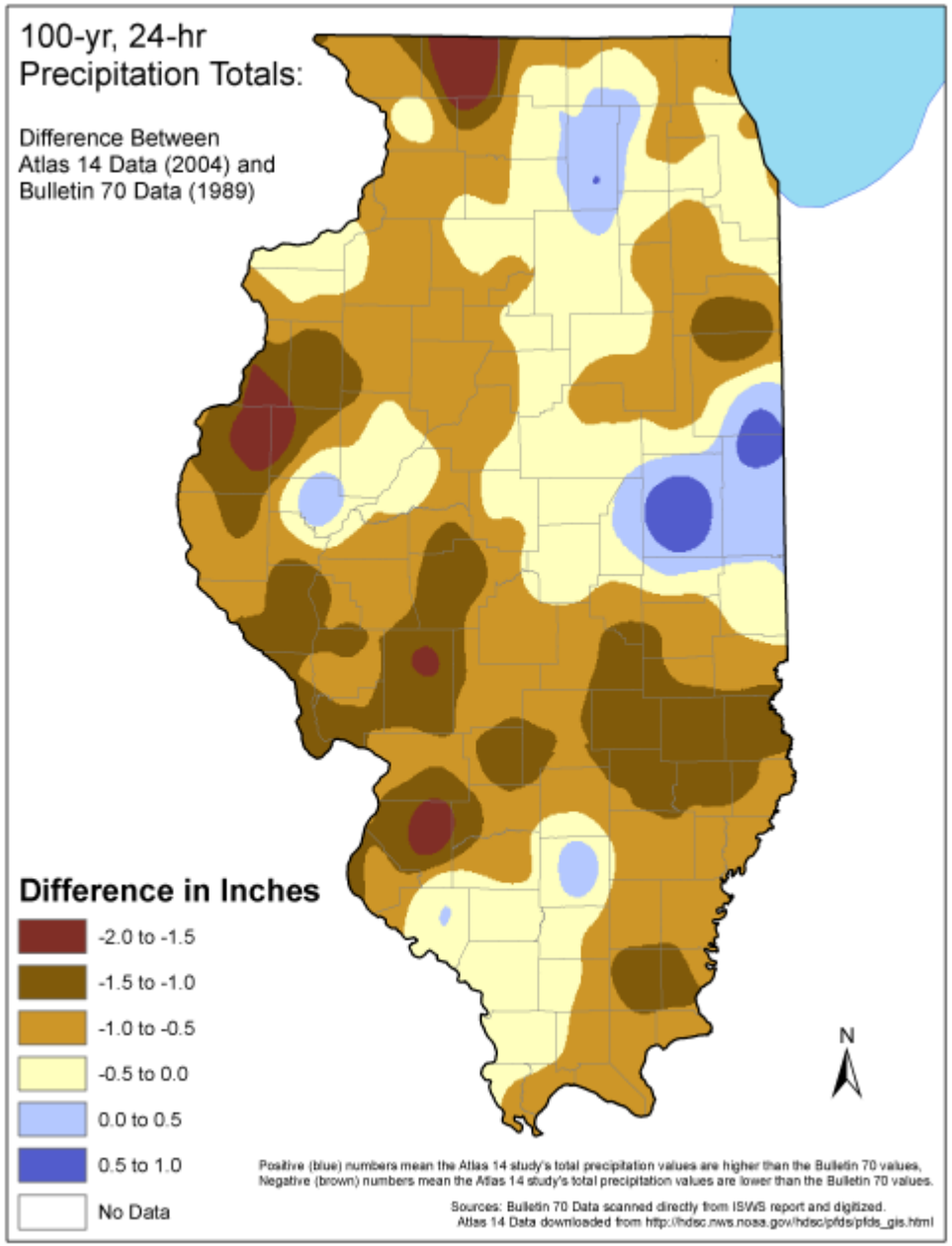
1989: Bulletin 70

2004: NOAA Atlas 14

<u>Huff Distributions</u>

Circular 173 (1990)

Atlas 14 Temporals (2004)



http://www.isws.illinois.edu/atmos/statecli/RF/rf-update.htm

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NOAA ATLAS 14 – VOL 2

ATLAS 14 Provides:

- Updated Rainfall Depths*
- **Temporal Distributions**

Percent of Occurrence

- 9 cumulative probabilities –
  - 10% to 90% per Quartile
- 4 Quartiles + Average
- 6, 12, 24, & 96-hour Duration Sets

PF tabular | PF graphical | Supplementary information

Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.353 (0.272-0.457)	0.418 (0.322-0.542)	0.525 (0.403-0.683)	0.615 (0.470-0.803)	0.741 (0.548-0.992)	0.839 (0.607-1.14)	0.938 (0.658-1.29)	1.04 (0.701-1.47)	1.18 (0.764-1.69)	1.28 (0.812-1.87)
10-min	0.516 (0.398-0.670)	0.611 (0.471-0.794)	0.769 (0.590-1.00)	0.901 (0.688-1.18)	1.08 (0.803-1.45)	1.23 (0.889-1.66)	1.37 (0.963-1.90)	1.52 (1.03-2.15)	1.72 (1.12-2.48)	1.87 (1.19-2.73)
15-min	0.630 (0.486-0.817)	0.746 (0.575-0.968)	0.937 (0.720-1.22)	1.10 (0.839-1.43)	1.32 (0.979-1.77)	1.50 (1.08-2.03)	1.68 (1.17-2.31)	1.86 (1.25-2.62)	2.10 (1.36-3.03)	2.29 (1.45-3.33)
30-min	0.864 (0.667-1.12)	1.03 (0.792-1.33)	1.30 (0.996-1.69)	1.52 (1.16-1.99)	1.84 (1.36-2.46)	2.08 (1.50-2.81)	2.32 (1.63-3.21)	2.58 (1.74-3.63)	2.91 (1.89-4.20)	3.17 (2.01-4.62)
60-min	1.09 (0.841-1.42)	1.32 (1.01-1.71)	1.69 (1.30-2.19)	2.00 (1.52-2.60)	2.43 (1.79-3.25)	2.76 (2.00-3.74)	3.10 (2.17-4.28)	3.45 (2.32-4.86)	3.91 (2.54-5.63)	4.26 (2.70-6.22)
2-hr	1.32 (1.03-1.69)	1.60 (1.25-2.05)	2.07 (1.61-2.66)	2.47 (1.91-3.18)	3.02 (2.26-3.99)	3.45 (2.52-4.60)	3.88 (2.75-5.28)	4.32 (2.94-6.01)	4.91 (3.23-6.98)	5.36 (3.44-7.71)
3-hr	1.45 (1.14-1.84)	1.78 (1.39-2.26)	2.31 (1.81-2.94)	2.76 (2.15-3.53)	3.39 (2.56-4.45)	3.89 (2.87-5.16)	4.39 (3.14-5.94)	4.91 (3.37-6.78)	5.60 (3.71-7.91)	6.14 (3.96-8.77)
6-hr	1.71 (1.36-2.15)	2.07 (1.64-2.59)	2.66 (2.11-3.34)	3.18 (2.51-4.00)	3.92 (3.00-5.10)	4.51 (3.38-5.92)	5.13 (3.71-6.86)	5.77 (4.02-7.89)	6.66 (4.47-9.29)	7.35 (4.80-10.4)
12-hr	2.02 (1.62-2.49)	2.35 (1.89-2.91)	2.95 (2.36-3.65)	3.48 (2.78-4.33)	4.28 (3.33-5.52)	4.94 (3.75-6.42)	5.64 (4.15-7.48)	6.40 (4.52-8.65)	7.47 (5.08-10.3)	8.32 (5.50-11.6)
24-hr	2.30 (1.88-2.80)	2.66 (2.17-3.24)	3.30 (2.68-4.02)	3.88 (3.13-4.75)	4.75 (3.75-6.04)	5.48 (4.21-7.02)	6.26 (4.66-8.18)	7.10 (5.08-9.47)	8.29 (5.71-11.3)	9.25 (6.19-12.7)
2-day	2.56 (2.12-3.08)	3.02 (2.49-3.63)	3.82 (3.14-4.59)	4.51 (3.69-5.45)	5.53 (4.40-6.90)	6.36 (4.94-8.01)	7.22 (5.43-9.27)	8.14 (5.88-10.7)	9.42 (6.55-12.6)	10.4 (7.06-14.1)
3-day	2.81 (2.34-3.35)	3.30 (2.74-3.93)	4.15 (3.44-4.95)	4.90 (4.03-5.86)	5.99 (4.80-7.42)	6.88 (5.39-8.60)	7.81 (5.92-9.95)	8.81 (6.41-11.5)	10.2 (7.14-13.5)	11.3 (7.70-15.1)
4-day	3.05 (2.55-3.60)	3.54 (2.96-4.19)	4.41 (3.67-5.22)	5.17 (4.28-6.15)	6.30 (5.08-7.76)	7.23 (5.69-8.98)	8.20 (6.25-10.4)	9.25 (6.77-12.0)	10.7 (7.55-14.2)	11.9 (8.14-15.8)
7-day	3.66 (3.09-4.28)	4.16 (3.51-4.86)	5.03 (4.23-5.89)	5.81 (4.86-6.83)	6.97 (5.69-8.48)	7.93 (6.31-9.74)	8.95 (6.89-11.2)	10.0 (7.43-12.8)	11.6 (8.25-15.1)	12.8 (8.87-16.9)
10-day	4.20 (3.58-4.87)	4.72 (4.01-5.48)	5.63 (4.76-6.54)	6.43 (5.42-7.50)	7.62 (6.25-9.19)	8.60 (6.89-10.5)	9.63 (7.46-11.9)	10.7 (7.99-13.6)	12.3 (8.80-15.9)	13.5 (9.41-17.6)
20-day	5.74 (4.95-6.56)	6.43 (5.53-7.34)	7.56 (6.49-8.65)	8.52 (7.27-9.79)	9.86 (8.15-11.6)	10.9 (8.82-13.0)	12.0 (9.37-14.6)	13.1 (9.83-16.3)	14.6 (10.5-18.5)	15.7 (11.1-20.2)
30-day	7.03 (6.10-7.96)	7.89 (6.84-8.93)	9.26 (8.00-10.5)	10.4 (8.92-11.8)	11.9 (9.87-13.8)	13.0 (10.6-15.3)	14.1 (11.1-17.0)	15.2 (11.5-18.7)	16.7 (12.1-20.9)	17.7 (12.6-22.6)
45-day	8.68 (7.60-9.73)	9.76 (8.52-10.9)	11.4 (9.96-12.9)	12.8 (11.1-14.4)	14.5 (12.1-16.6)	15.8 (12.9-18.3)	17.0 (13.4-20.1)	18.1 (13.7-21.9)	19.5 (14.3-24.2)	20.5 (14.7-25.9)
60-day	10.1 (8.89-11.3)	11.4 (9.98-12.7)	13.3 (11.7-14.9)	14.8 (12.9-16.6)	16.8 (14.0-19.0)	18.1 (14.9-20.9)	19.4 (15.4-22.8)	20.6 (15.7-24.7)	22.0 (16.2-27.0)	22.9 (16.5-28.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

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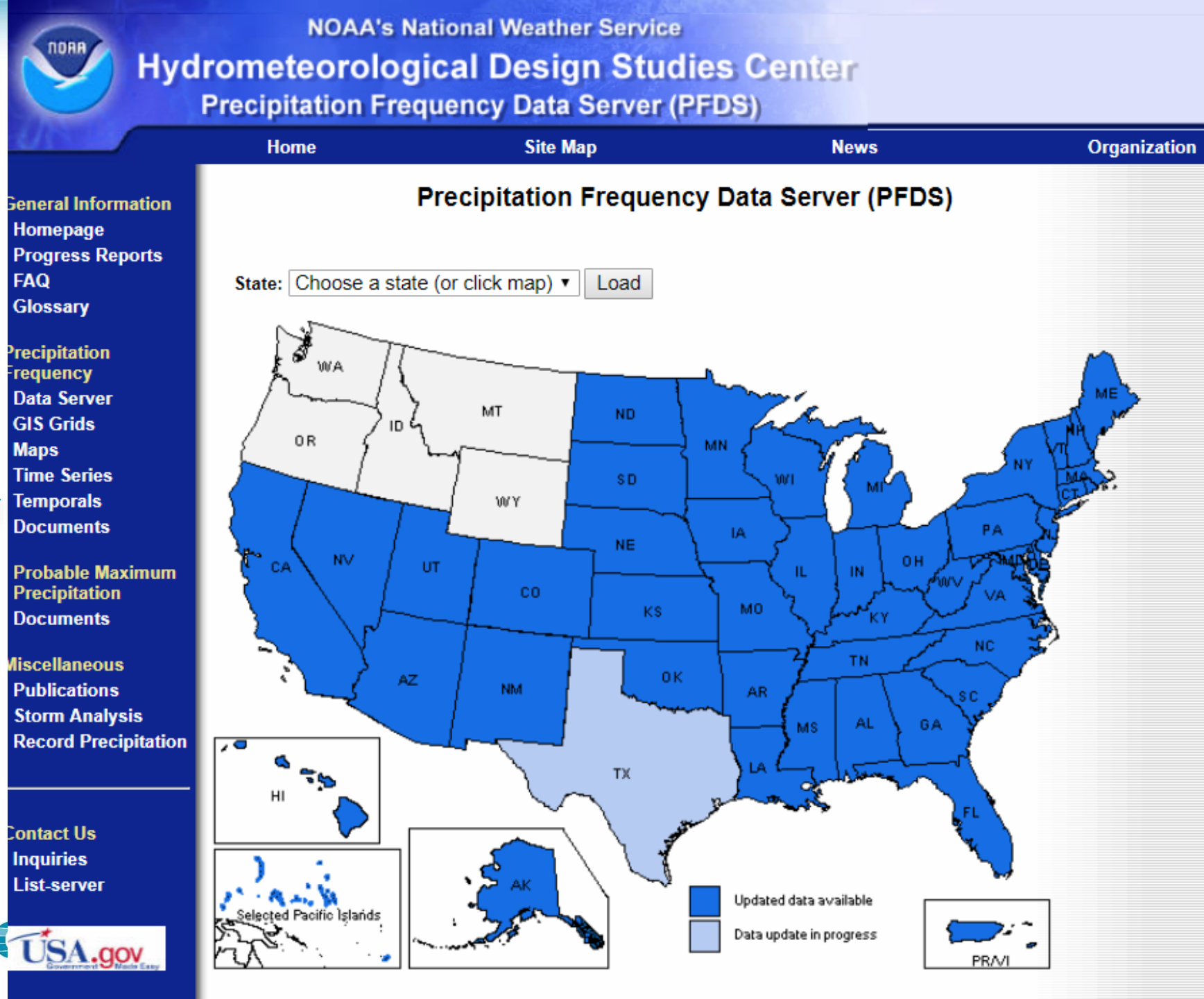
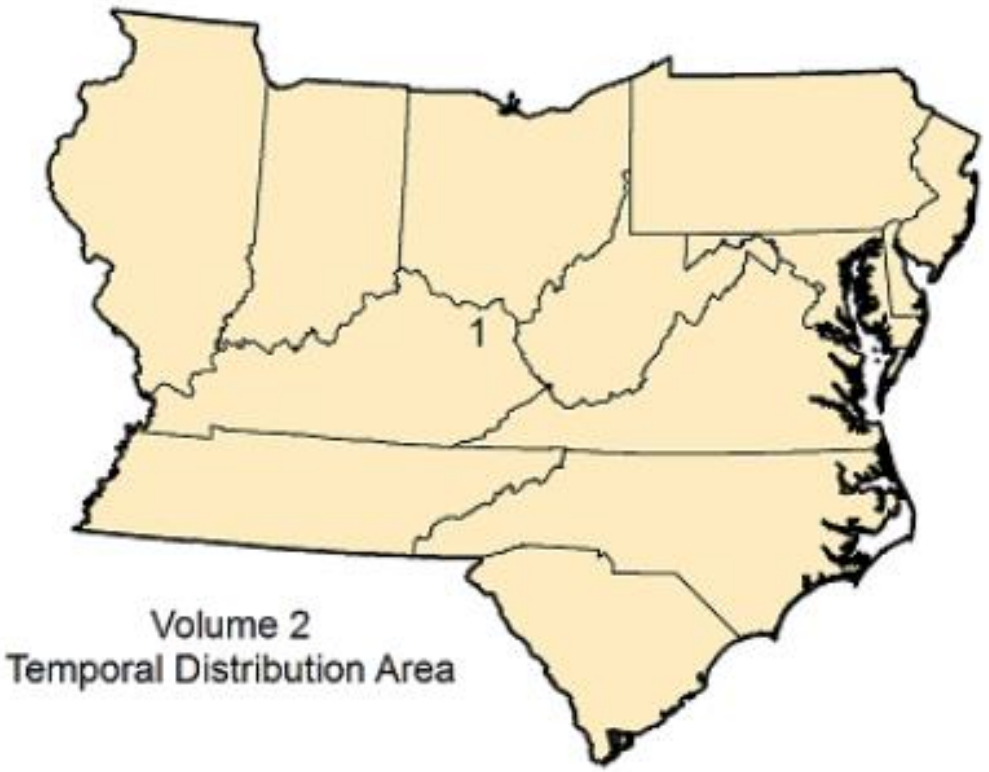
NOAA Atlas 14

TEMPORALS



Regionality of Temporal Distribution

Volume 8
Temporal Distribution Areas



Volume 2
Temporal Distribution Area

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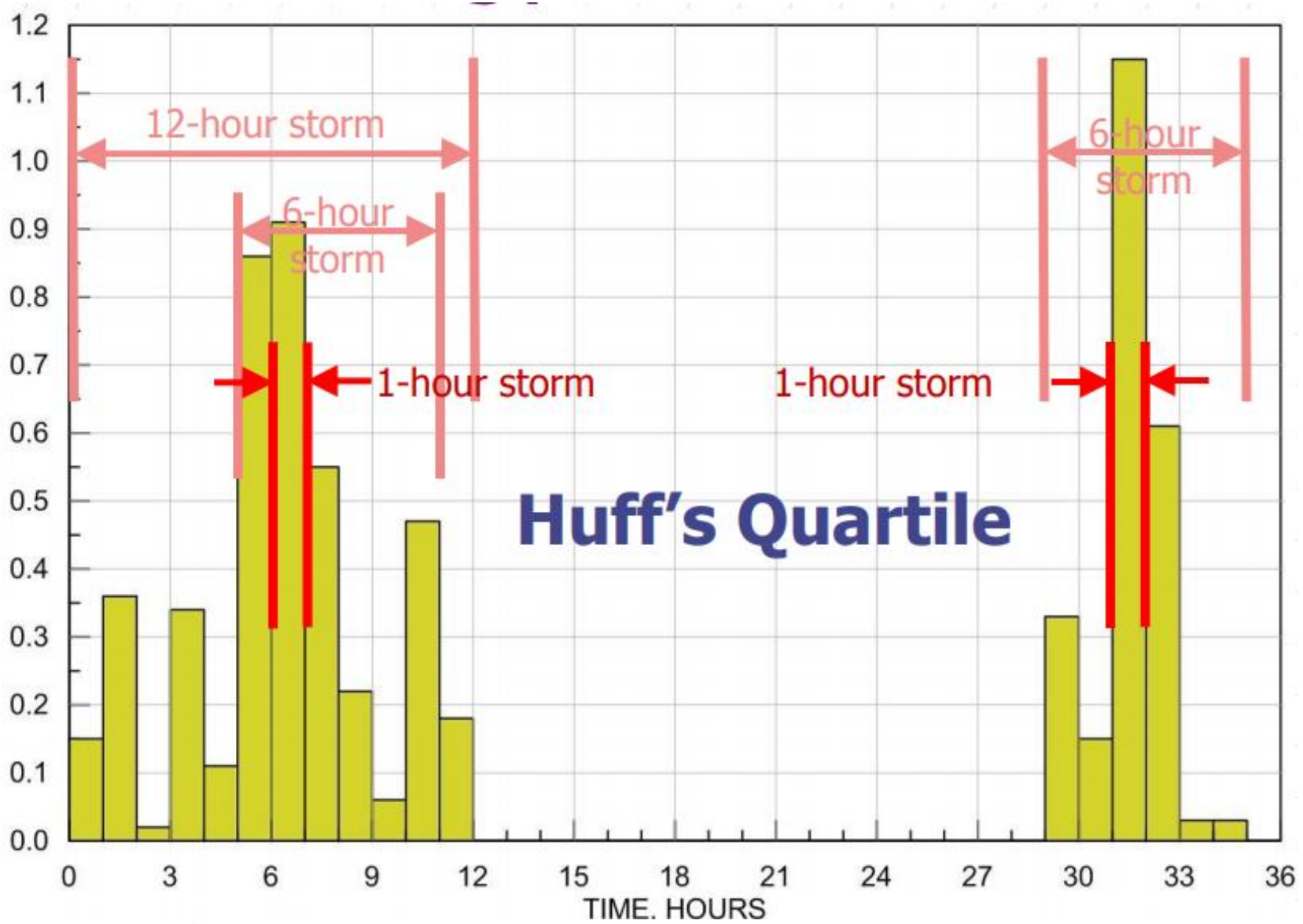
HUFF ANALYSIS

HUFF

- 12 year Record
- 261 Storms

NOAA Temporals

- 69 year record rainfall (Volume 8)
- 111,000 + precipitation cases



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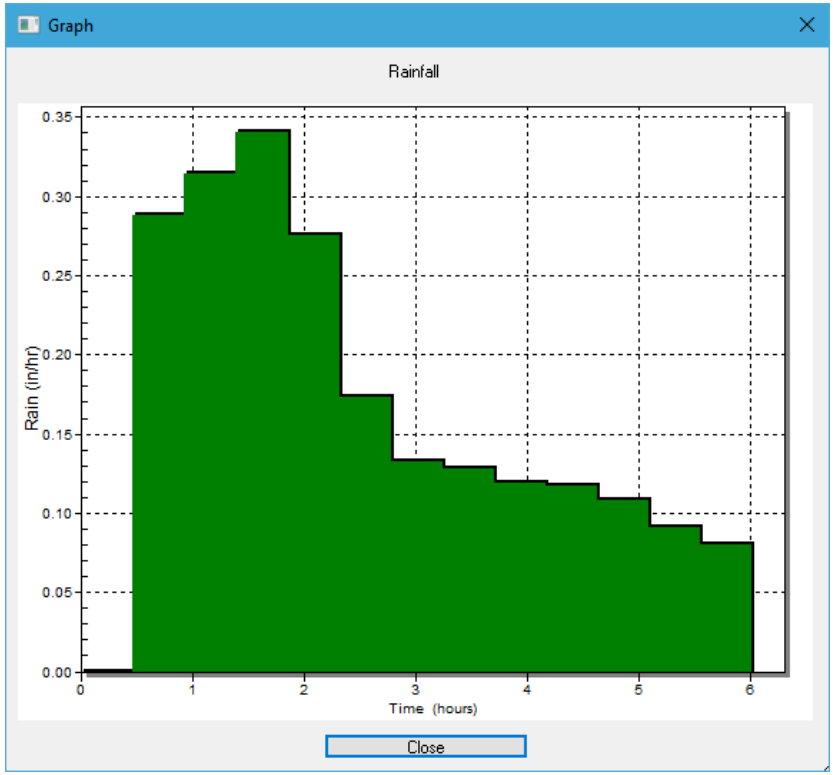
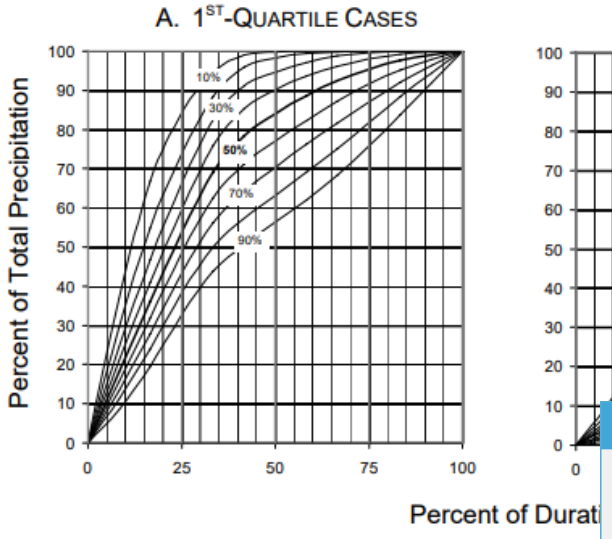
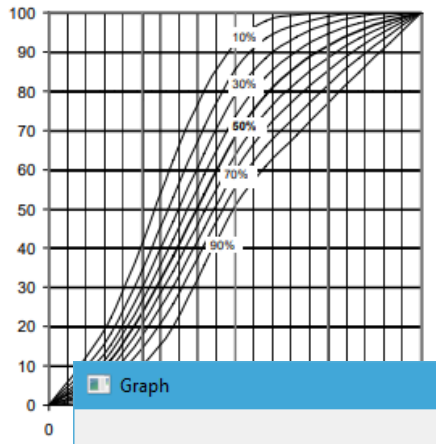
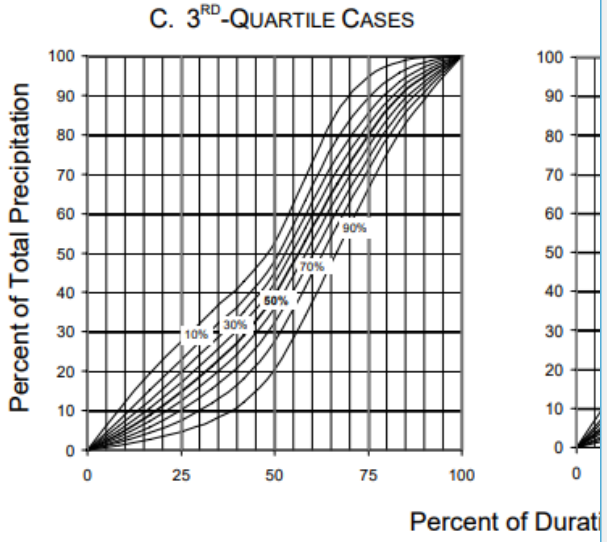
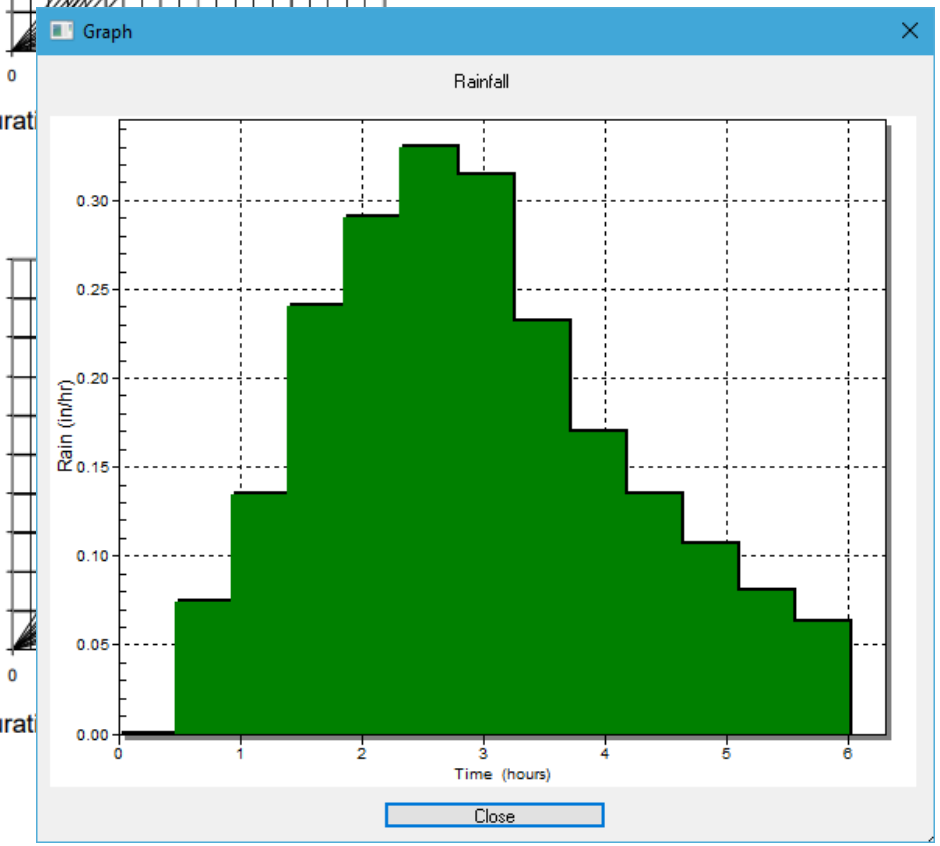
NOAA TEMPORALS











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WHY USE TEMPORALS ?

USE **RAINFALL DISTRIBUTIONS** FROM ATLAS 14

> "*If rout[ing] flow, especially if have significant amounts of storage, the unit hydrograph and rainfall distribution [MSE3/Type II] used have much less impact*" (MnDOT Atlas 14 Document)

THE SCS & NRCS NESTED INTENSITY CURVES ARE GREAT FOR "PEAK" FLOWS

RECOMMENDATION:

- ***If Flooding occurs*** [i.e. **Storage**]
  - Use ~~*NOAA Temporal Distributions* (Quartile 1-4, 10% - 90% Exceedance)~~ HUFF
  - Test All Events with xpswmm Global Storms to find Critical Duration – *Use Ensemble Statistics*
  - *Perform all 28 temporals against each 4 durations with Atlas 14 depth per AEP.*

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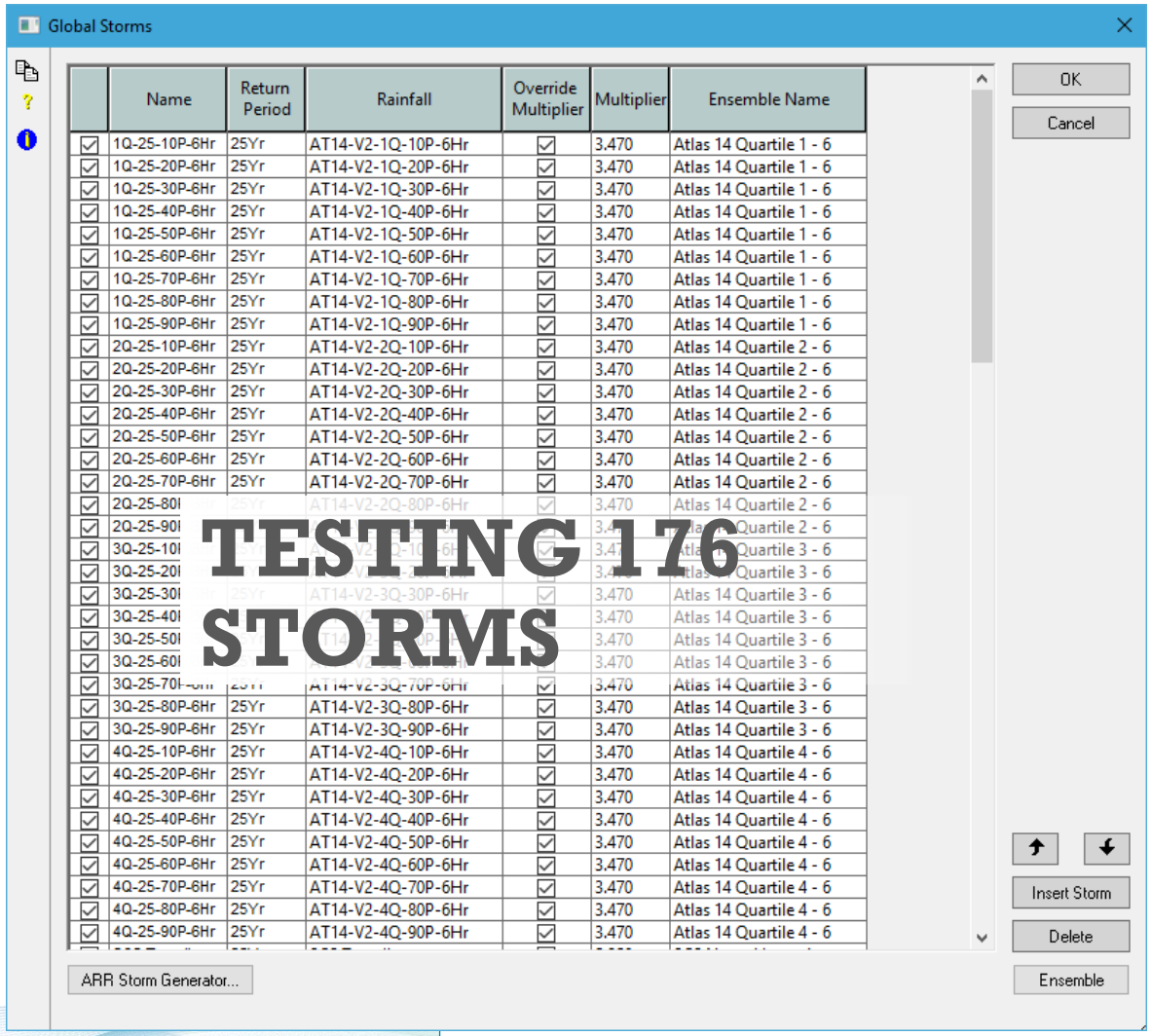
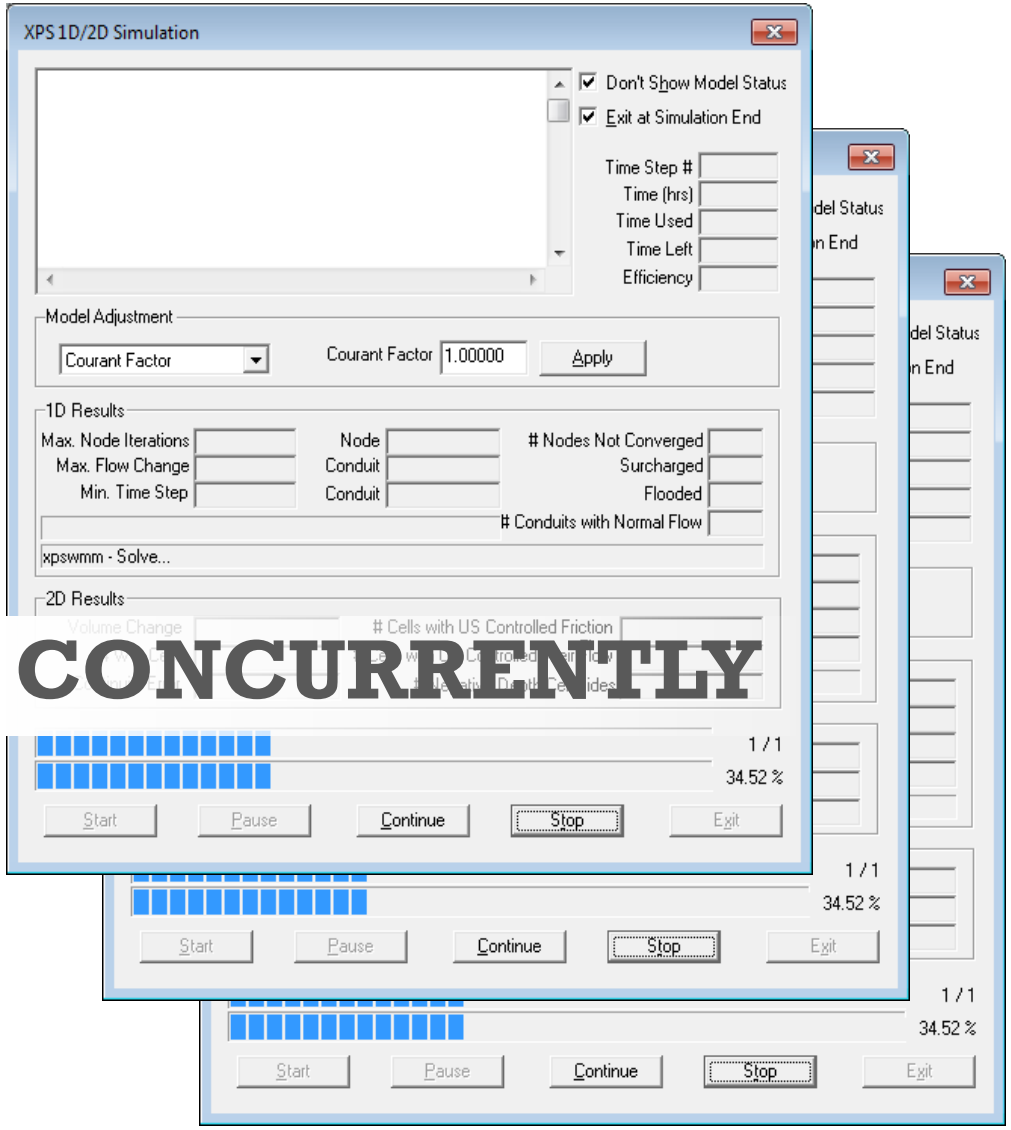
GLOBAL STORMS



TESTING 176 STORMS



CONCURRENTLY

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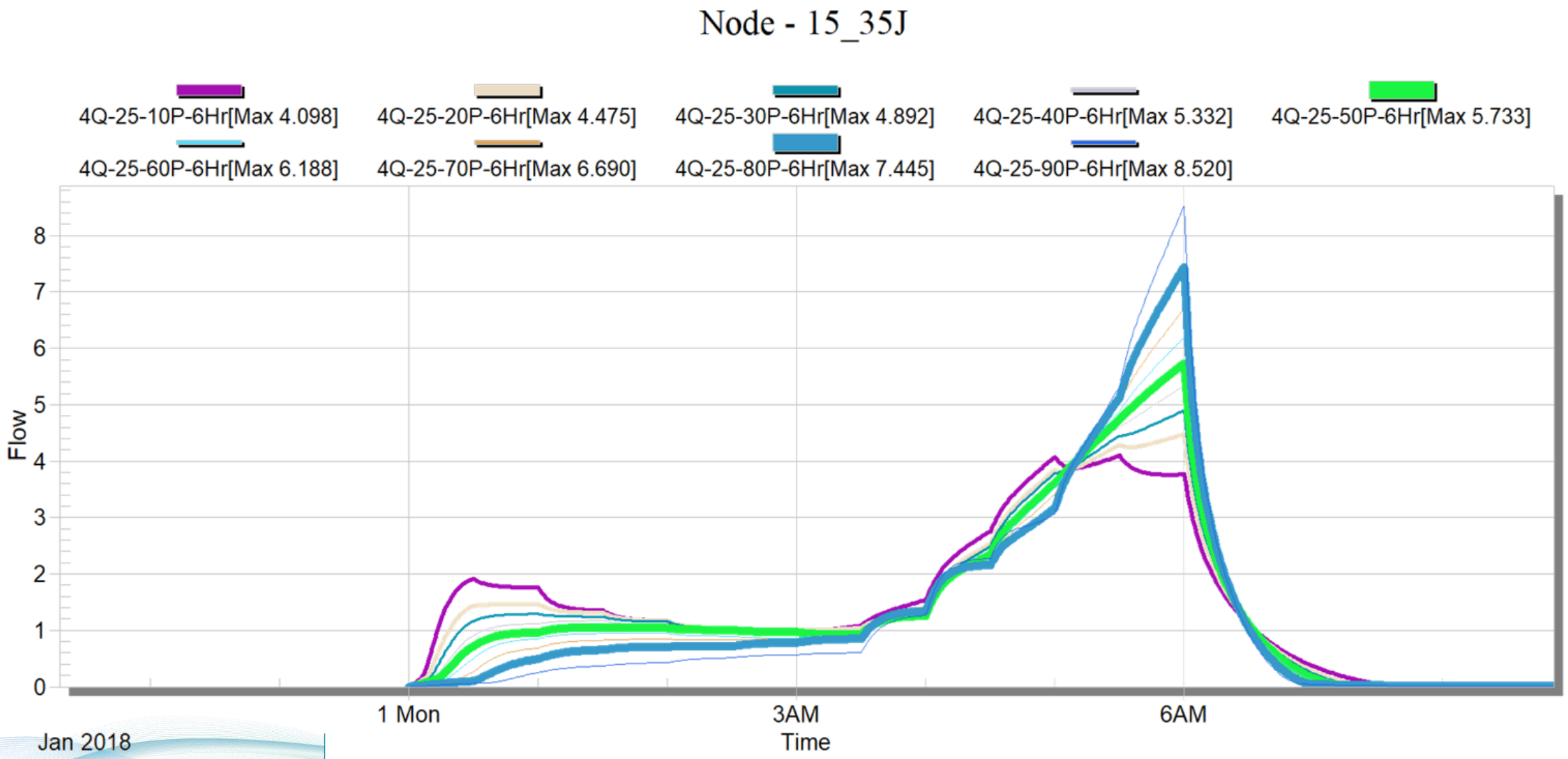
Flow at Top of Watershed



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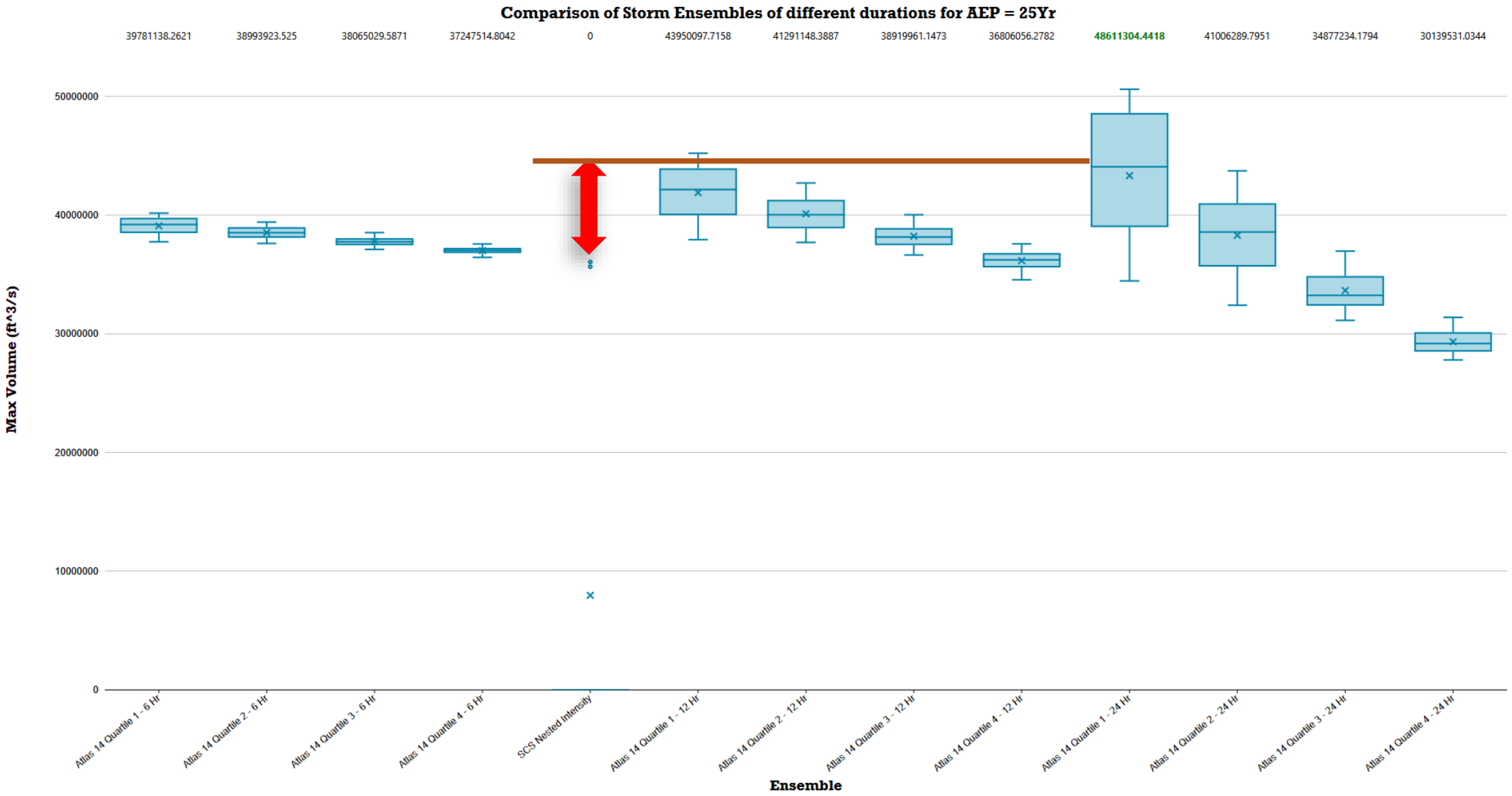
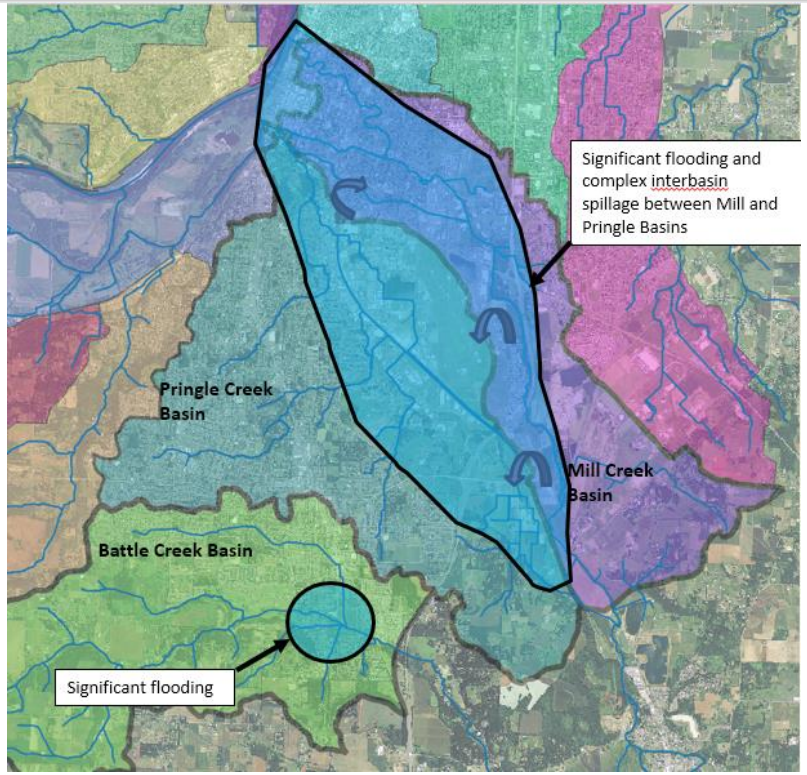
Storage Volume - Downstream



CUSTOMER SUCCESS

WEST Consultants, Inc.

CITY OF Salem AT YOUR SERVICE



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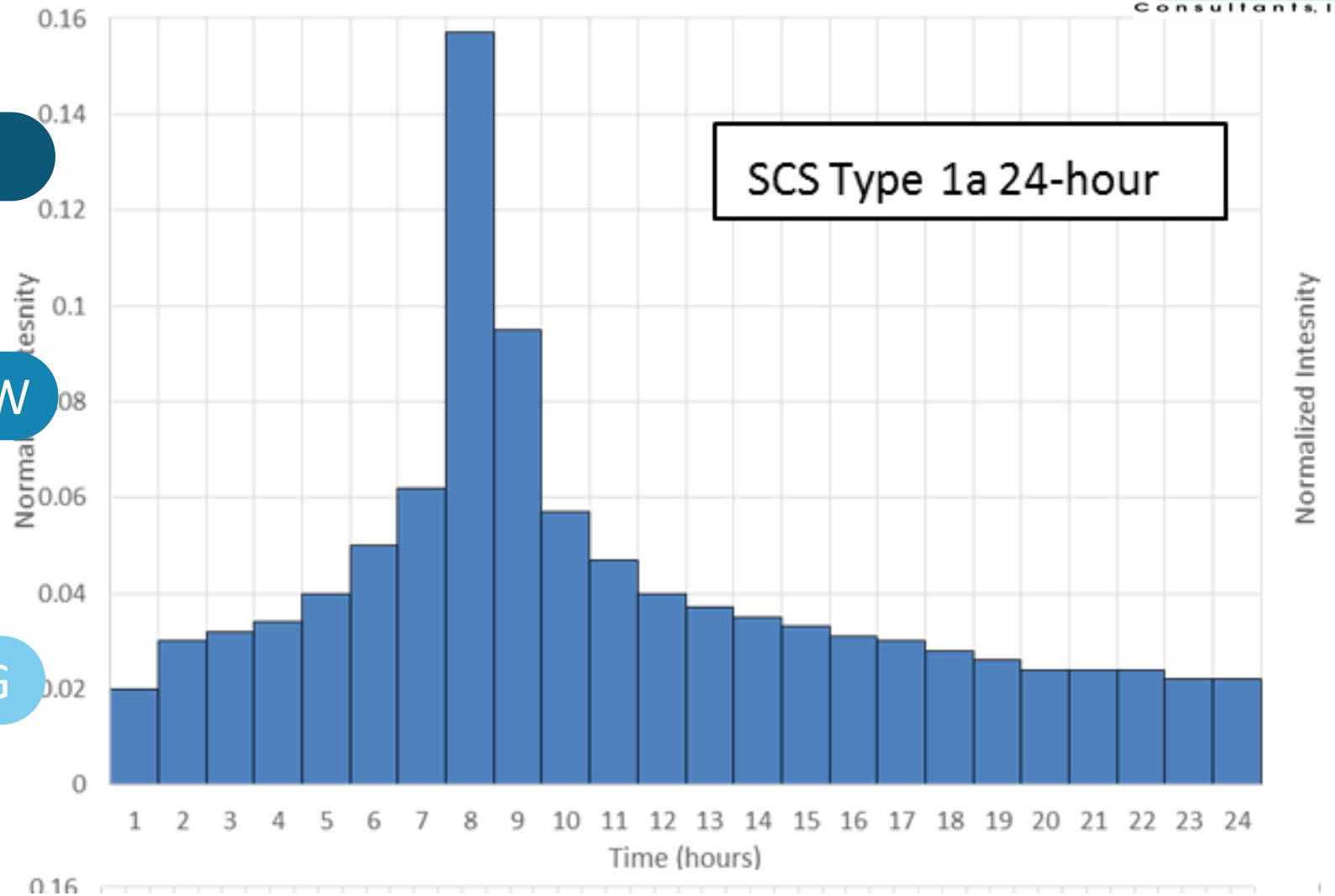
MASTER PLAN

- 2012 FLOOD EVENT
- FLAT – INTERBASIN FLOW
- MITIGATION PLANNING



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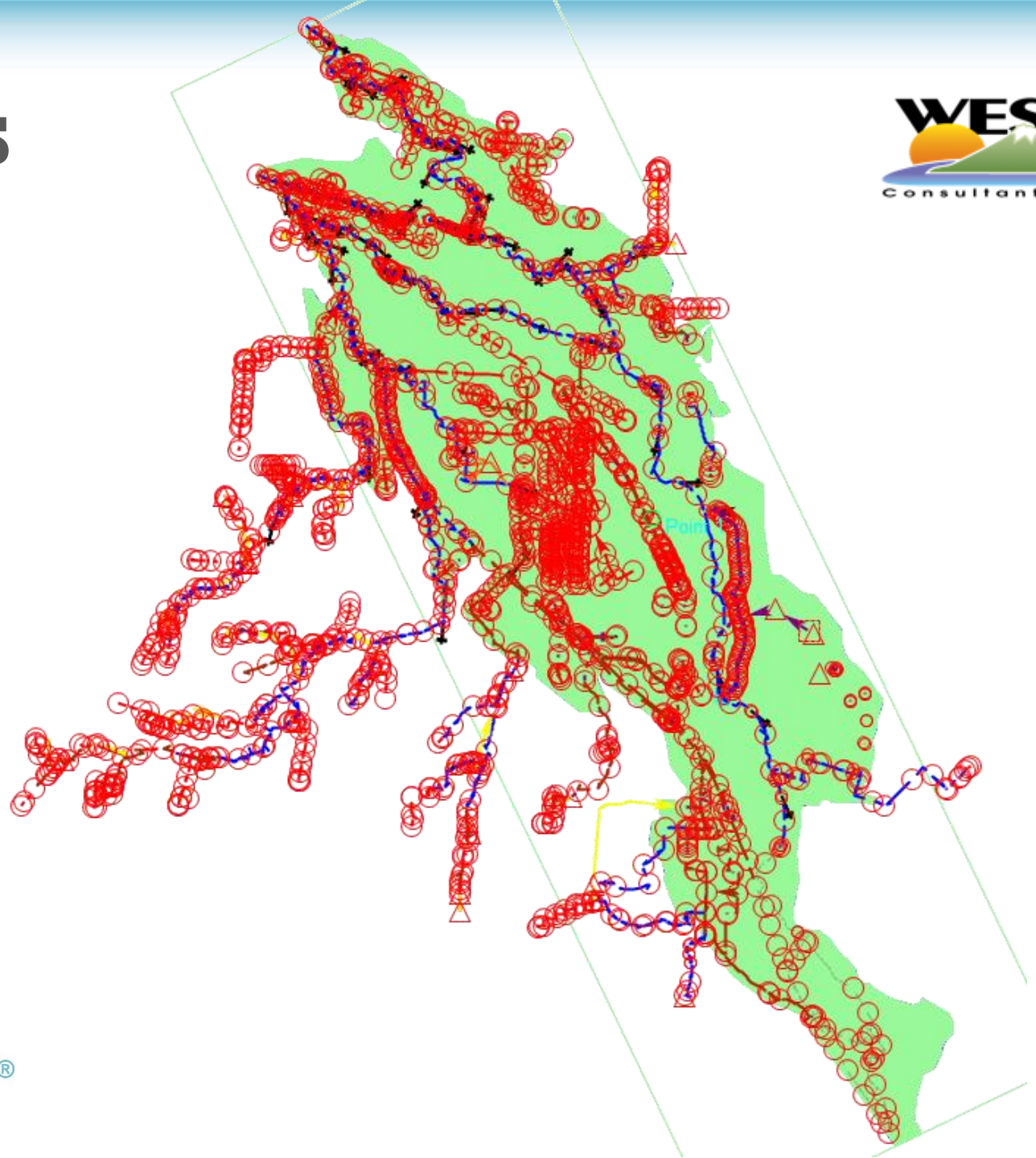
MODEL BOTH BASINS

MODEL INFORMATION

- 239 SUB-BASINS
- 1914 NODES
- 651,000 2D GRID CELLS

MIXED HYDROLOGY

- SWMM RUNOFF w/HORTON
- HMS MODEL & CITY GAGES



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2D INTERBASIN SPILLAGE

WEST Consultants, Inc.

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POTENTIAL

10-acres Site

Hydrology Method:

- SCS Method

- 30% Impervious
- Composite CN 82?

- Will you result in the same runoff volume with 30% @98 and 70% @75?

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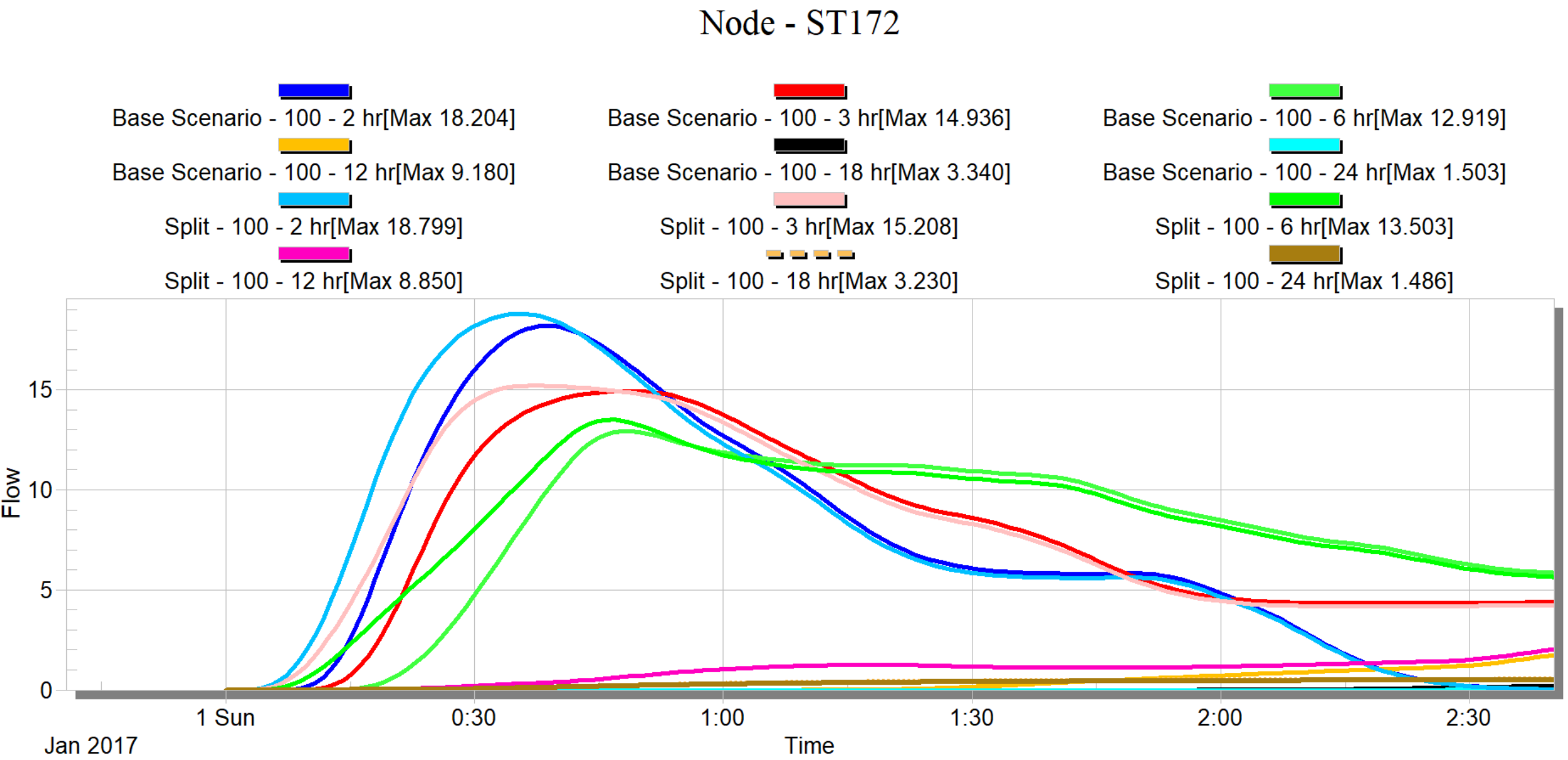
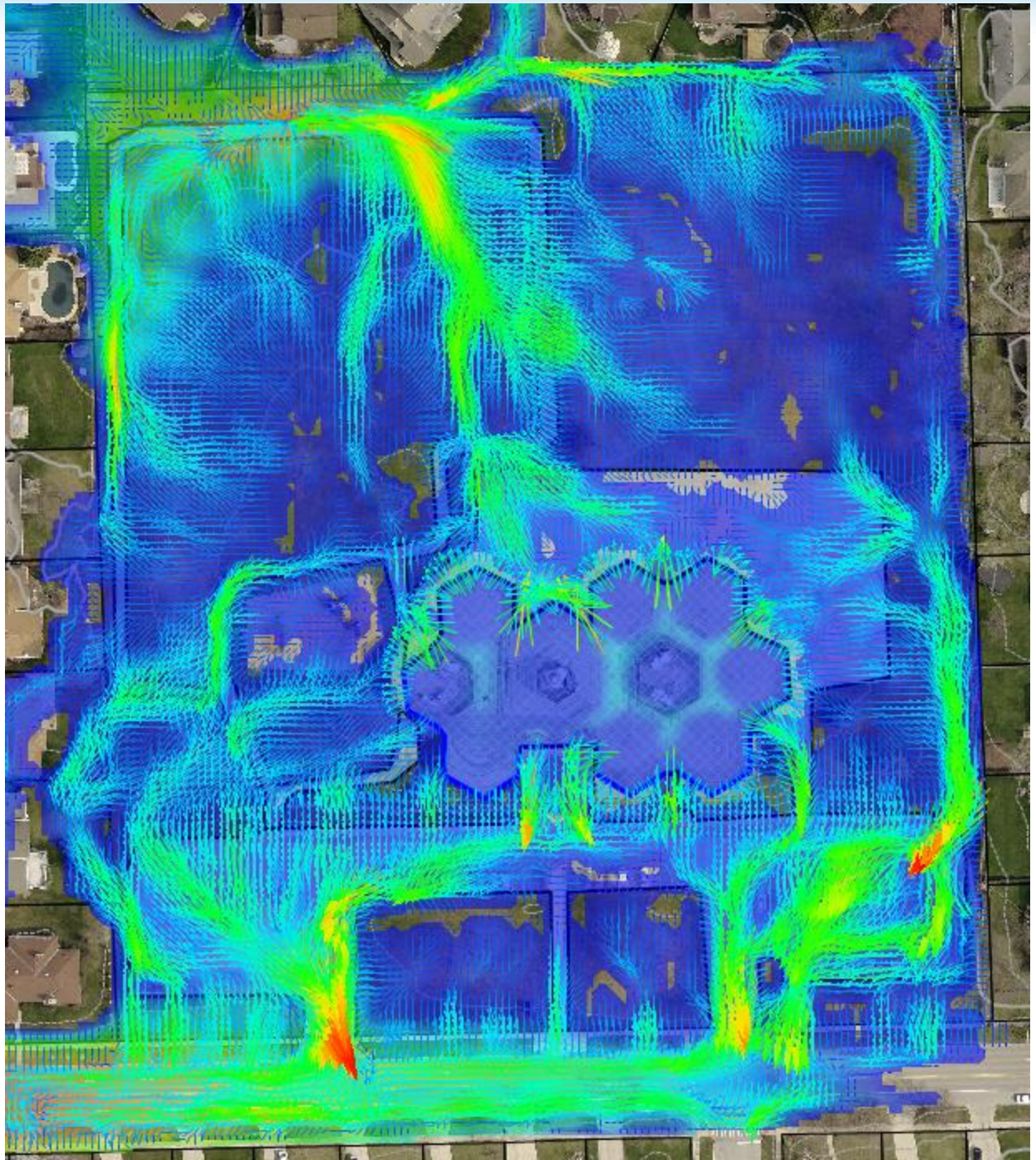
Does it make a difference?



HOW ABOUT 2D?



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PERFORMANCE COMPARISON

xpswmm

BENCHMARKED COMPLEX 2D ONLY

49,265 cells

Dell 7510 Precision Laptop (i7)

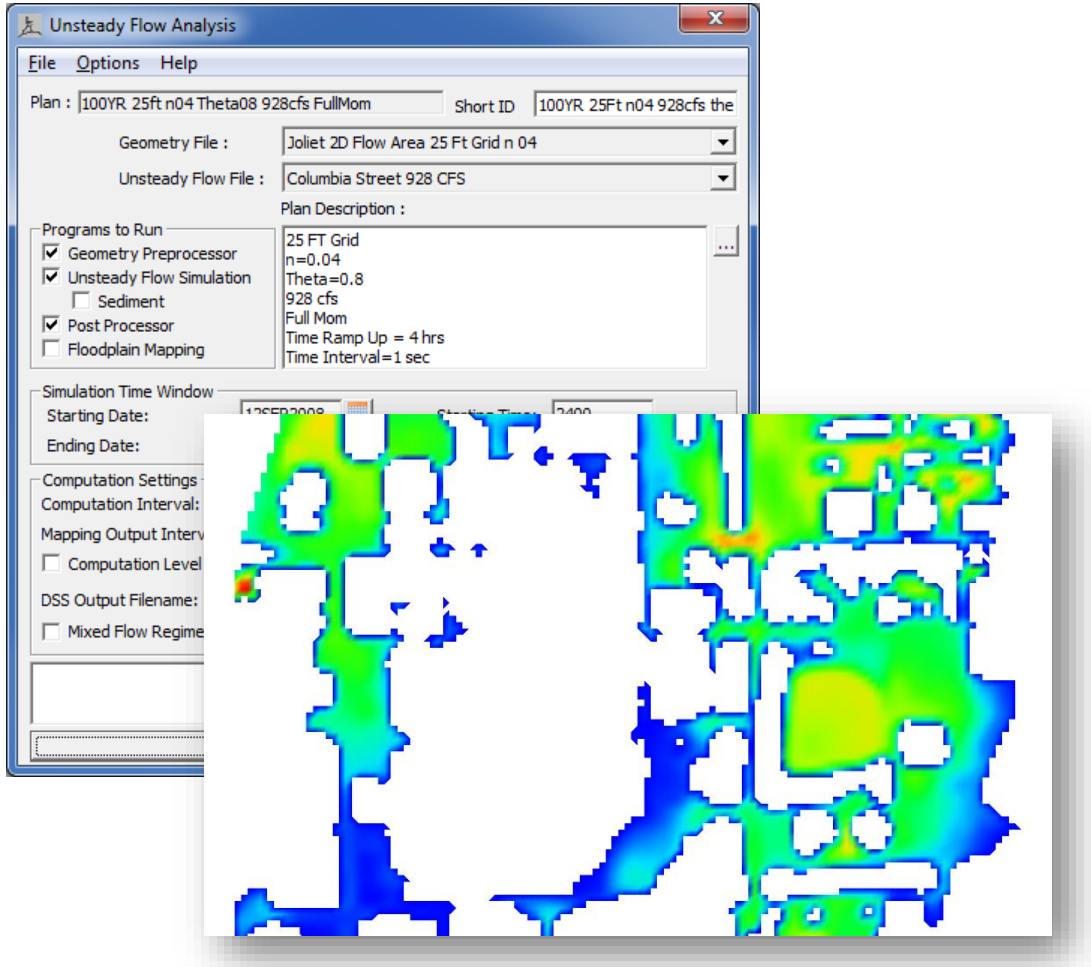
HEC-RAS 5.0.3

13 hrs 41 min 28 sec

xpswmm

6 hrs 35 min 38 sec
(1 core)
9 min 38 sec
GPU

GPU
Quadro
K1000M



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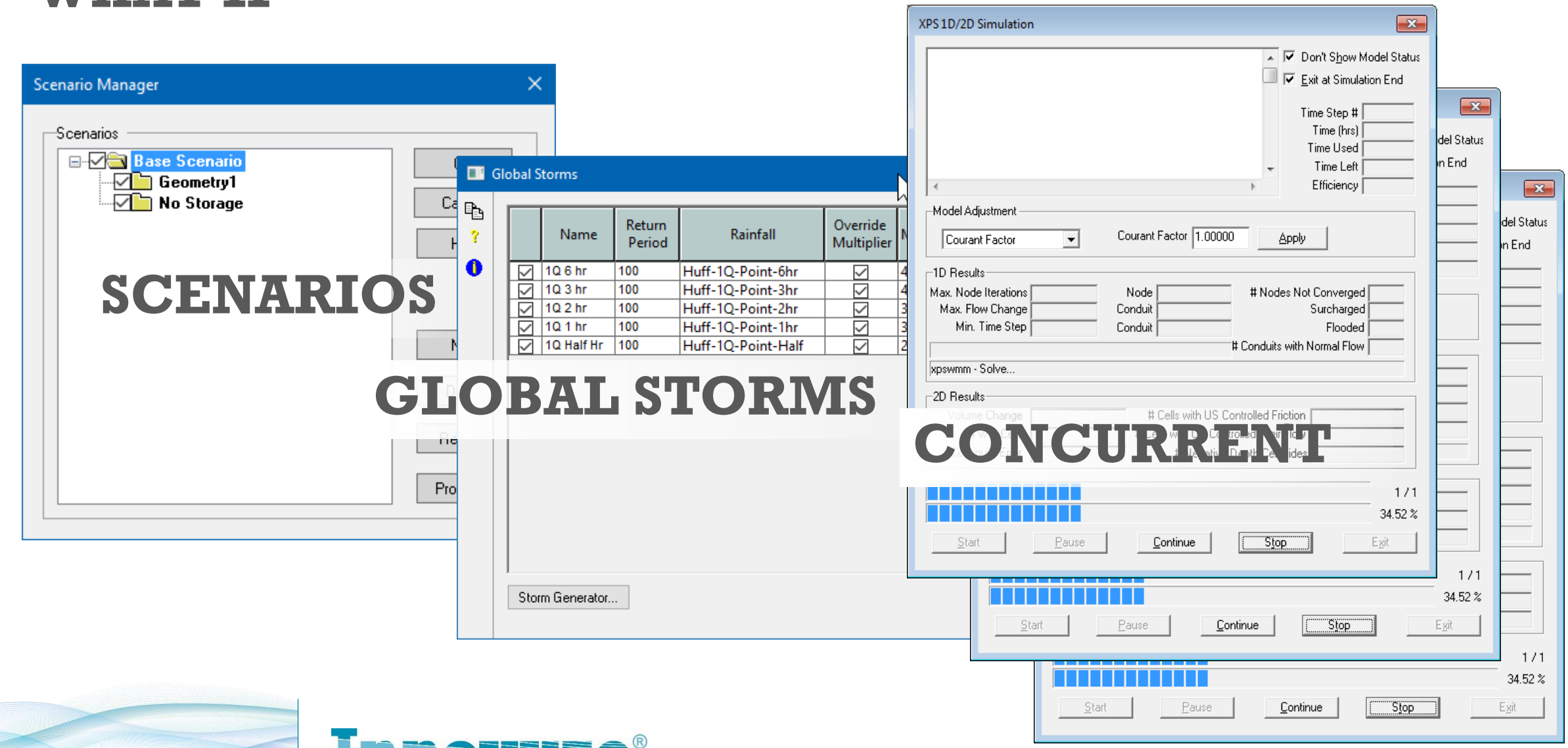
WHAT IF



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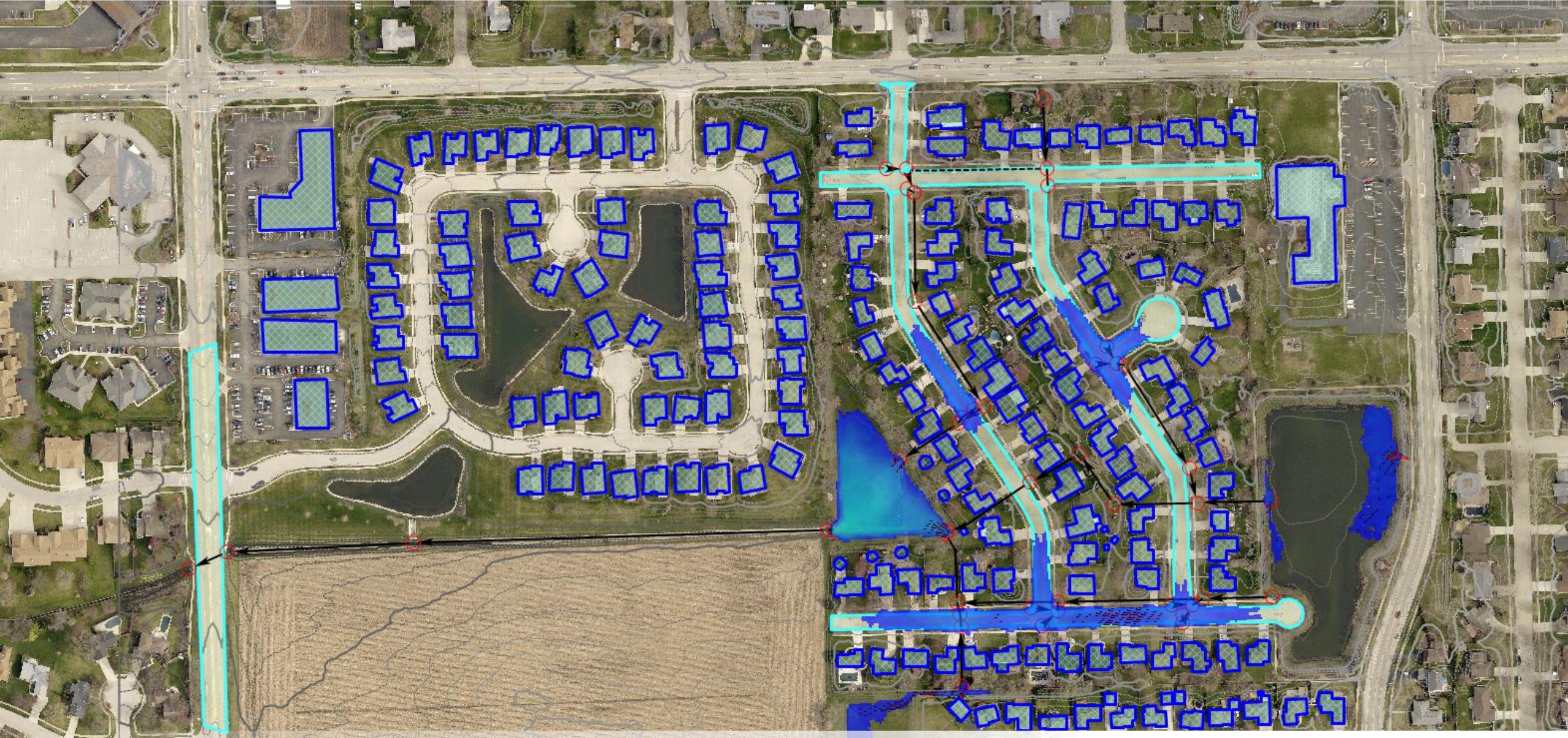

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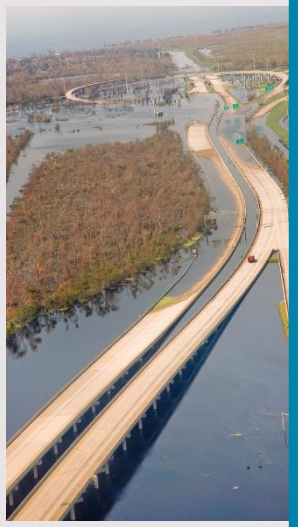
Thanks for attending



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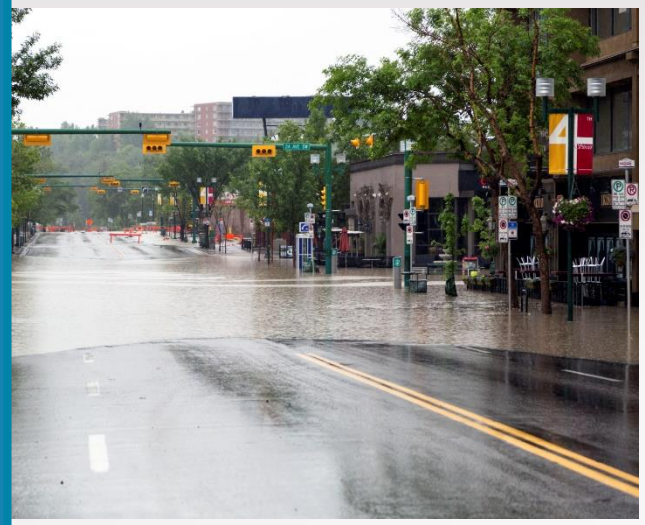

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