MULTI-EVENT CALIBRATION VERSUS SINGLE EVENT CALIBRATION RESULTS IN BETTER INTERACTION WITH DESIGN STORMS

ICWMM February 28th, 2019

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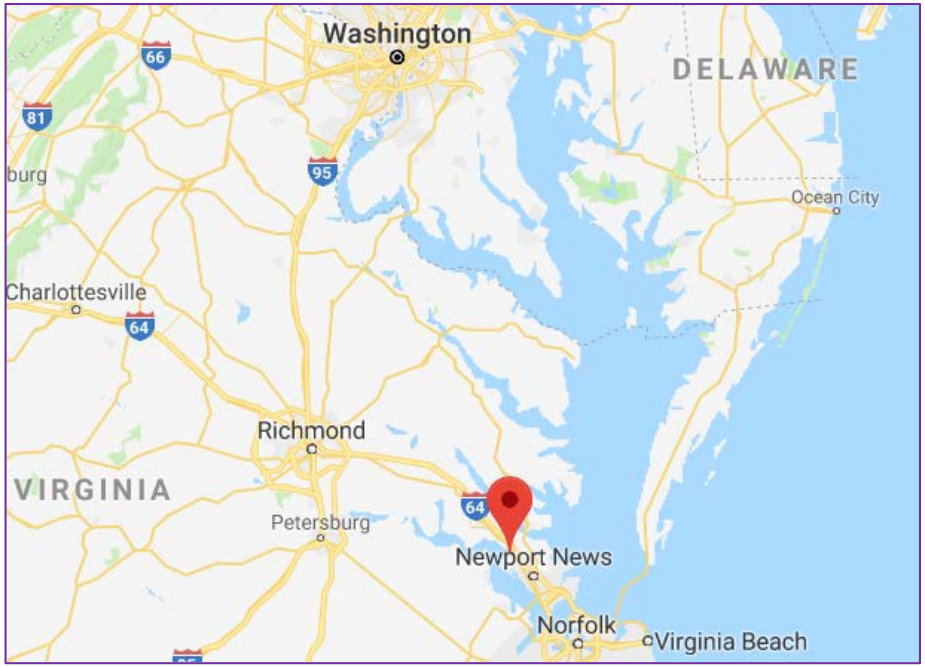
McKim & Creed

OLD DOMINION
UTILITY SERVICES

McKIM&CREED

OLD DOMINION UTILITY SERVICES, INC. (ODUS)

- ODUS was created to manage Ft. Lee, Ft. Story, and Ft. Eustis utilities
- Parent Company is American State Utility Services (ASUS)



PROJECT BACKGROUND– A BRIEF HISTORY

- Ft. Eustis ceased treating their own wastewater in 1999
- Flows then were conveyed to **Hampton Roads Sanitation District (HRSD)** for treatment
- In 2002, ~100,000 gallons (~400 cu. m) overflowed from the system into a tributary of the Warwick River
- Notice of Violation issued in 2003
- Subsequent flow monitoring by Ft. Eustis staff identified significant I/I issues

PROJECT BACKGROUND– CURRENTLY

- ODUS took over ownership of Ft. Eustis wastewater collection system in 2006
- HRSD entered into a Memorandum of Agreement (MOA) with tributary localities
- Goal to develop a **Regional Wet Weather Management Plan**

- ODUS required to follow HRSD's **Federal Facility Technical Standards (FFTS)** to develop a Hydrologic Performance Assessment

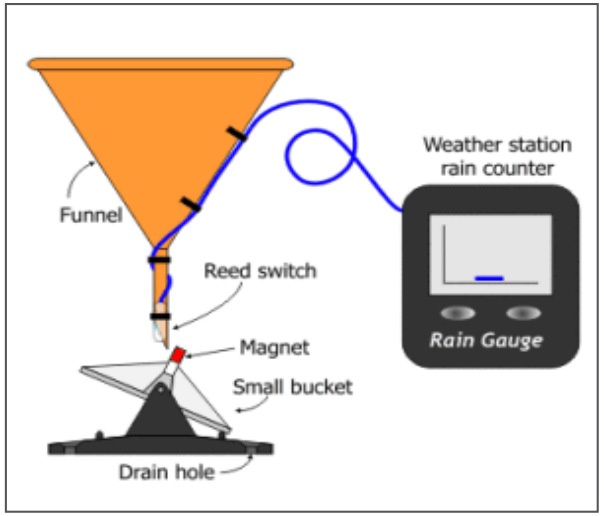
SYSTEM CHARACTERIZATION

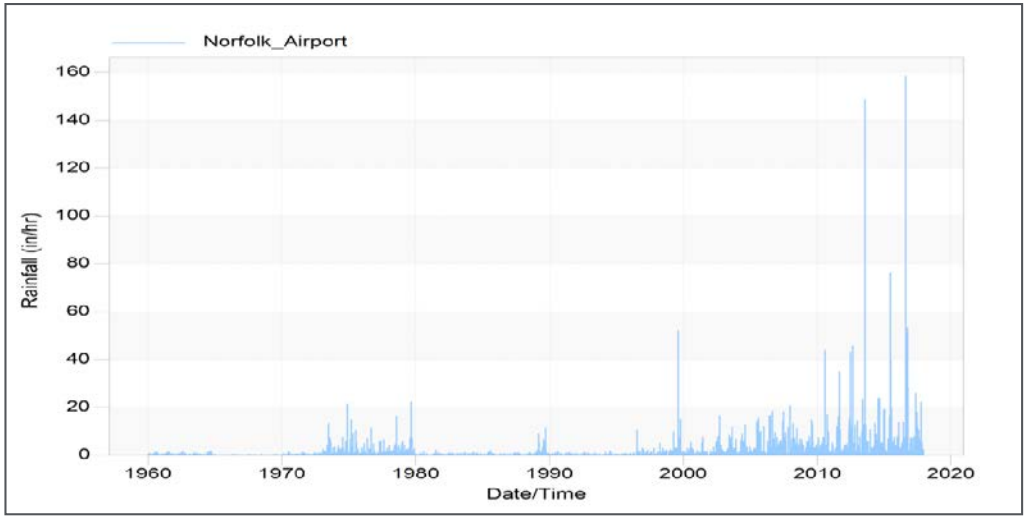
How to develop a Hydrologic Performance Assessment?

- Monitoring & collecting rainfall data
- Sanitary sewer flow monitoring
- Compiling & checking collection systems data
- Computer modeling to evaluate wet weather solution scenarios
- Evaluation of HRSD pump station operational capacities

FLOW, PRESSURE & RAINFALL MONITORING PROGRAM

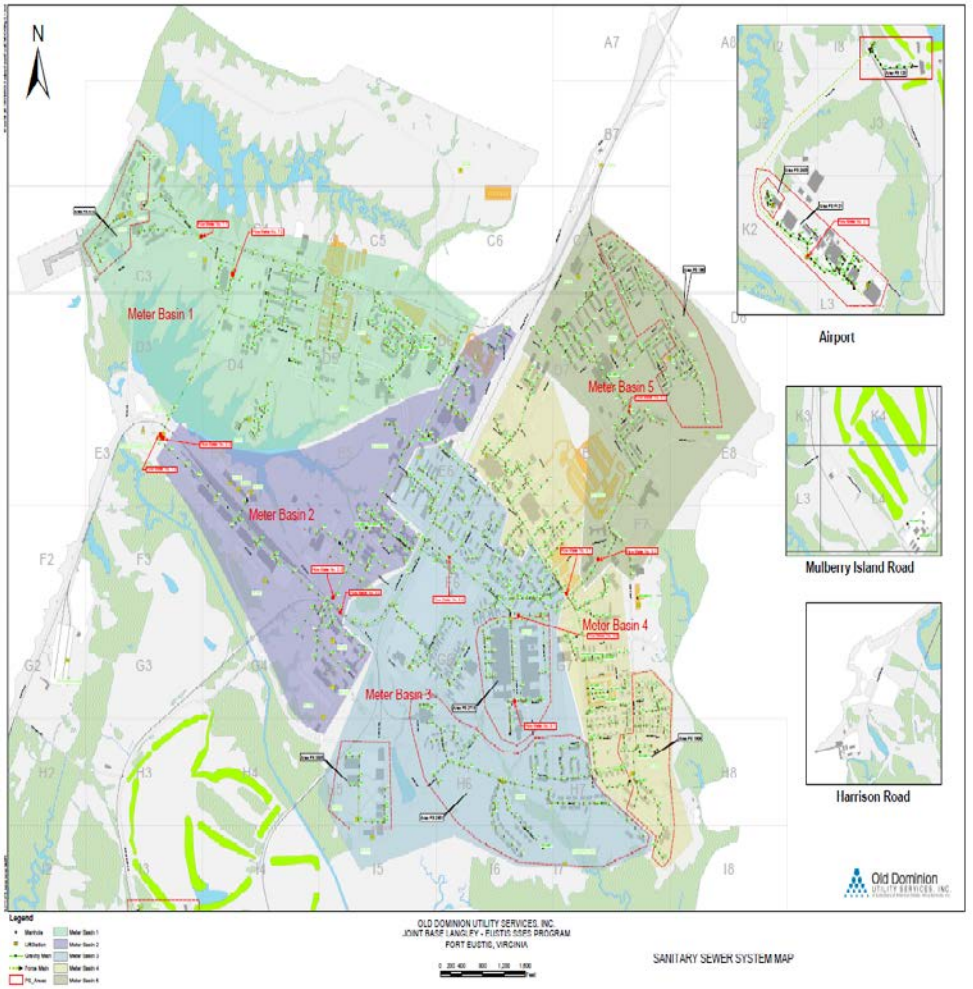
- One rainfall monitoring gauge
- National Weather Service (NWS) maintains long-term gauge at Norfolk Airport
- HRSD required that meters capture 3 events of over 1” including one event that was a 1-year 24-hour storm





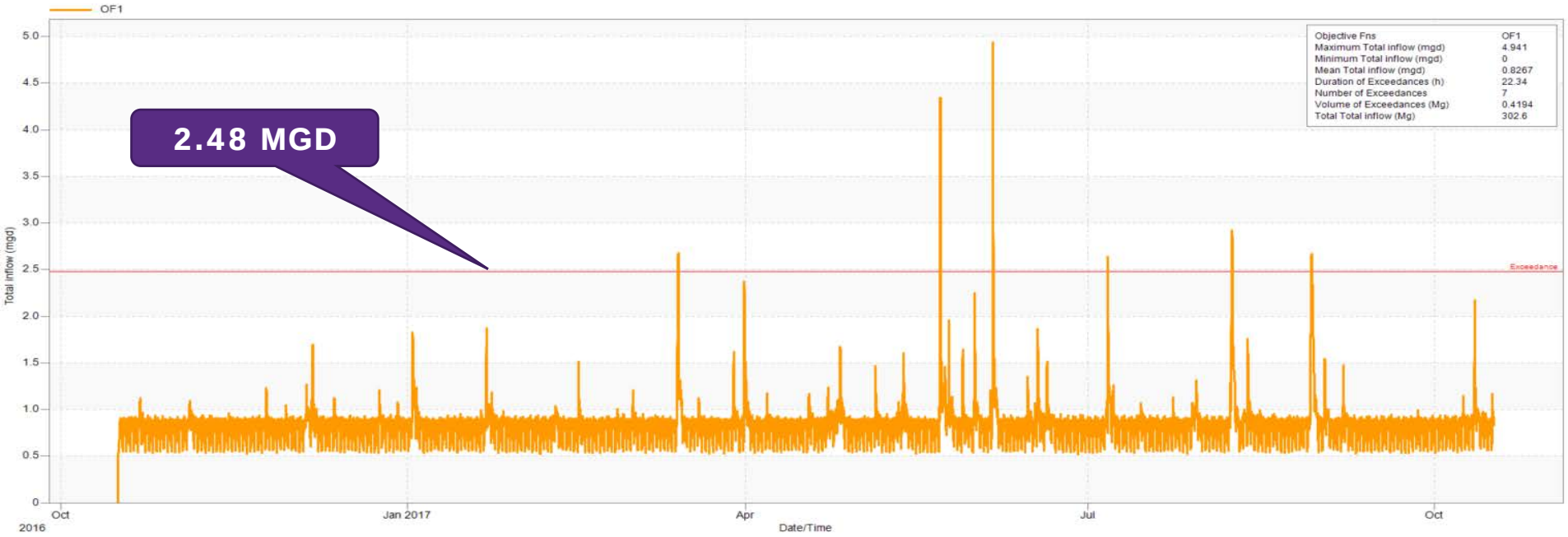
FLOW, PRESSURE & RAINFALL MONITORING PROGRAM

- 13 Flow meters
  - 2 by the HRSD pump station
  - 11 on the contributing drainage areas
- Monitoring period of **October 2016 to October 2017**



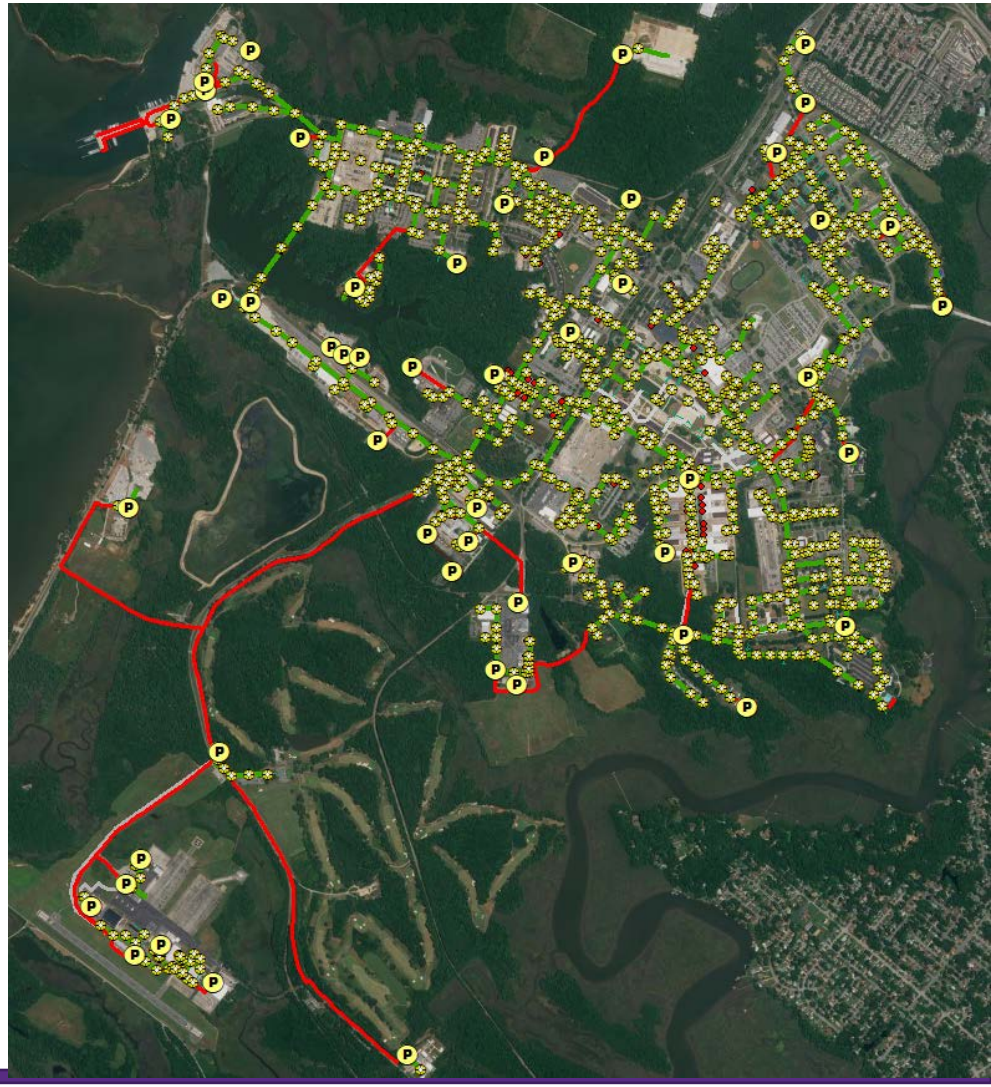
HRSD PERFORMANCE STANDARD

- HRSD requires that **peak flows** not be above 3 times the average annual flow (AAF) for the 10-year 24-hour storm event
- AAF = 0.83 MGD (3130 m^3/d)
- 3 X 0.83 MGD = 2.48 MGD (9400 m^3/d)



ODUS – FT. EUSTIS COLLECTION SYSTEM MAP

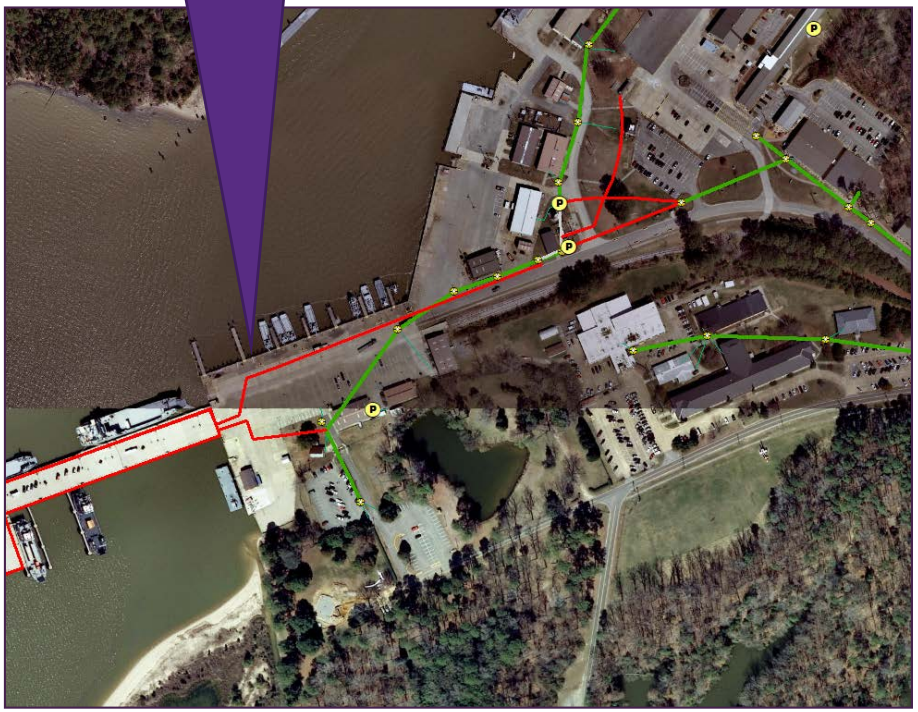
- ~172,000 linear ft. (lf) of gravity pipe (~52 km)
- ~54,000 lf of force main (~16.5 km)
- 992 Manholes
- 52 Pump Stations
- 1,200 Clean Outs
- 2,000 Laterals/Service Lines



FT. EUSTIS COLLECTION SYSTEM

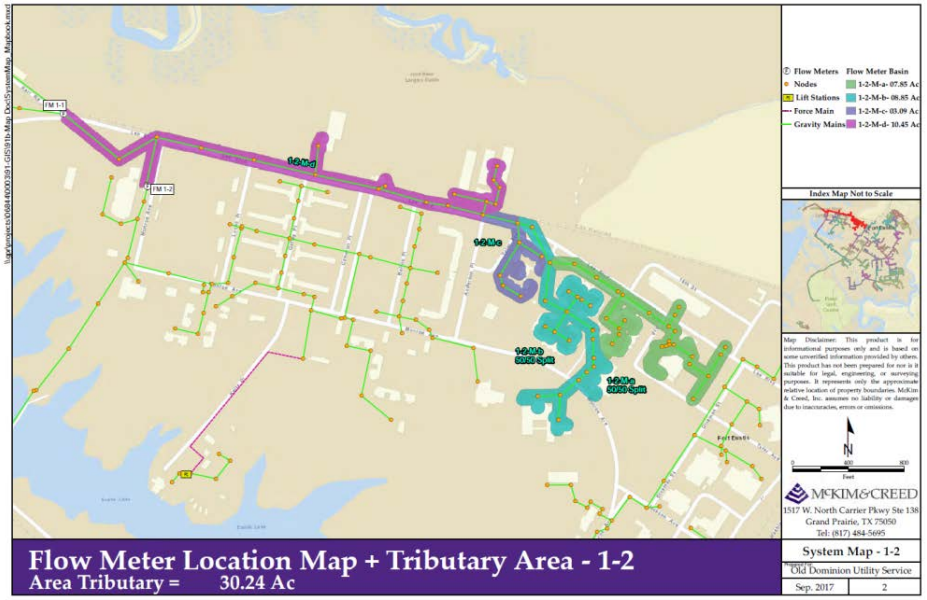
Laterals for a helicopter pad??

Gravity lines along docks

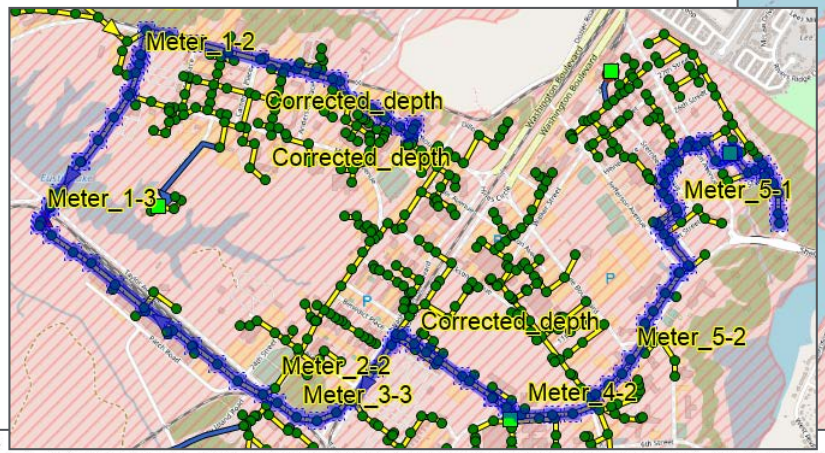


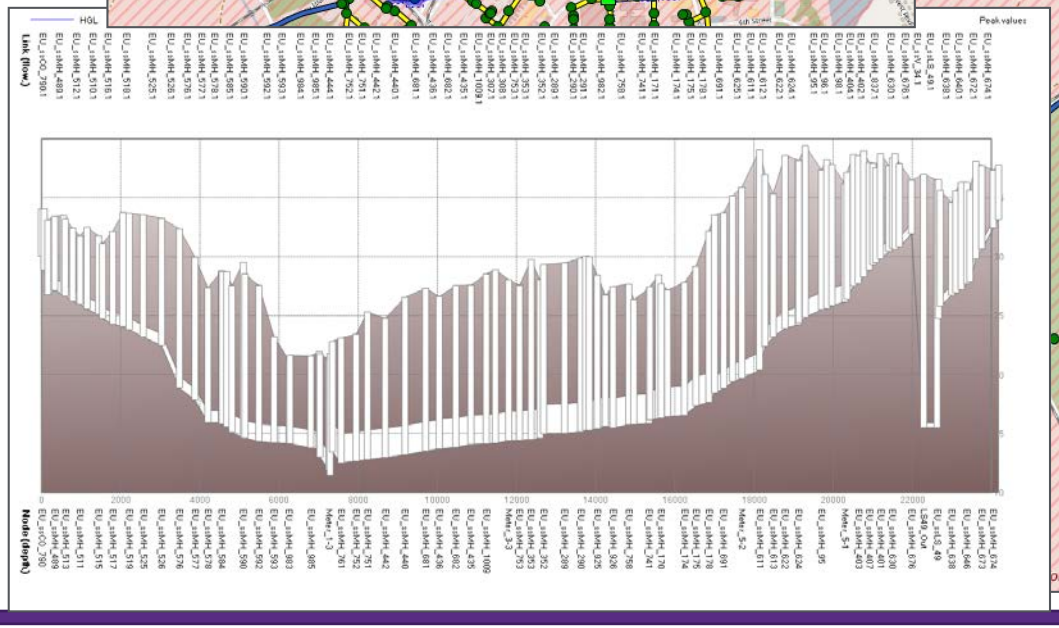
COLLECTION SYSTEM– SEWERED AREA

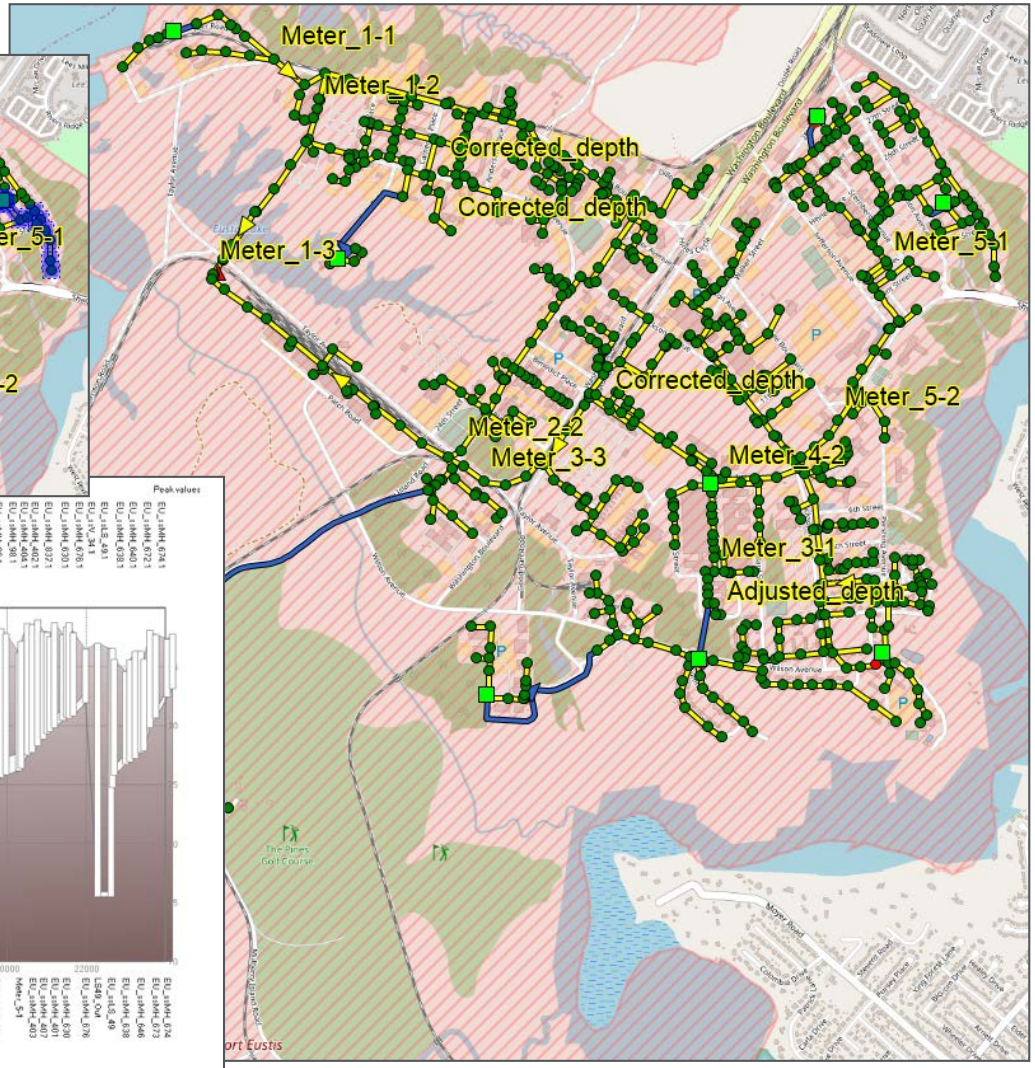
- Used buffers to define loading areas
- Uniform definition of R values
- Reproducible!



MODELING PERFORMED IN PCSWMM







WHAT WAS MODELED?

- 52 Sub basins
- 824 Manholes
- 834 Pipes
- 16 Pump Stations

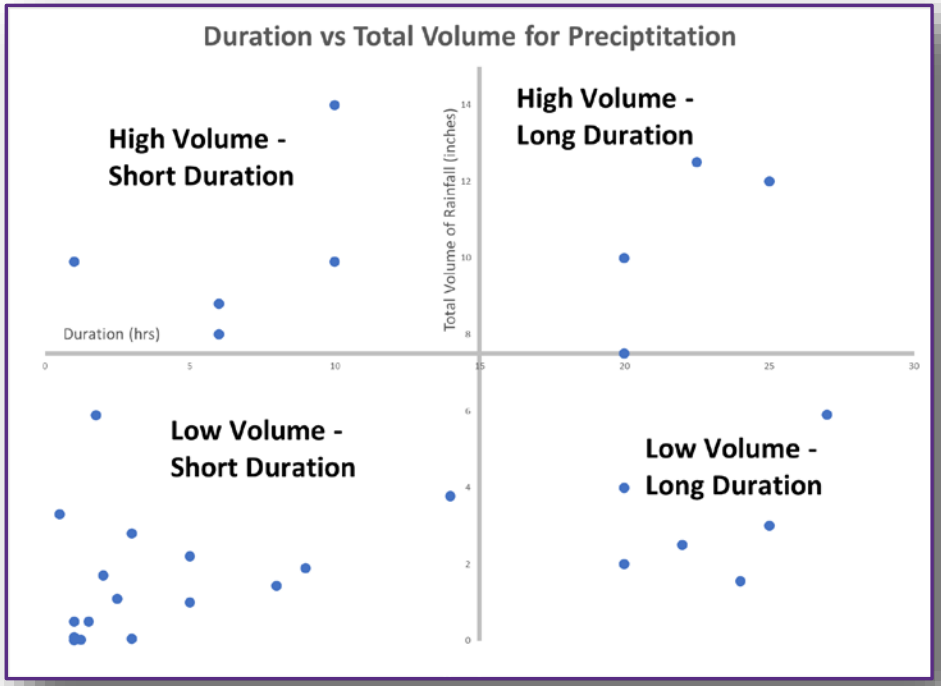
```
**************
Element Count
**************
Number of rain gages ...... 2
Number of subcatchments ... 52
Number of nodes ........... 824
Number of links ........... 834
Number of pollutants ...... 0
Number of land uses ....... 0
```

Pumps

Name	Inlet Node	Outlet Node
EU_ssLS_9.1	EU_ssLS_9	LS9_Out
EU_ssLS_46.1	EU_ssLS_46	LS46_Out
EU_ssLS_5.1	EU_ssLS_5	LS5_Out
EU_ssLS_47.1	EU_ssLS_47	LS47_Out
EU_ssLS_31.1	EU_ssLS_31	LS31_Out
EU_ssLS_51.1	EU_ssLS_51	LS51_Out
EU_ssLS_1.1	EU_ssLS_1	LS1_Out
EU_ssLS_2.1	EU_ssLS_2	LS2_Out
EU_ssLS_49.1	EU_ssLS_49	LS49_Out
EU_ssLS_10.1	EU_ssLS_10	LS10_Out
EU_ssLS_1.2	EU_ssLS_1	LS1_Out
EU_ssLS_2.2	EU_ssLS_2	LS2_Out
EU_ssLS_31.2	EU_ssLS_31	LS31_Out
EU_ssLS_46.2	EU_ssLS_46	LS46_Out
EU_ssLS_47.2	EU_ssLS_47	LS47_Out
EU_ssLS_49.2	EU_ssLS_49	LS49_Out
EU_ssLS_9.2	EU_ssLS_9	LS9_Out
EU_ssLS_51.2	EU_ssLS_51	LS51_Out
EU_ssLS_5.2	EU_ssLS_5	LS5_Out
EU_ssLS_10.2	EU_ssLS_10	LS10_Out

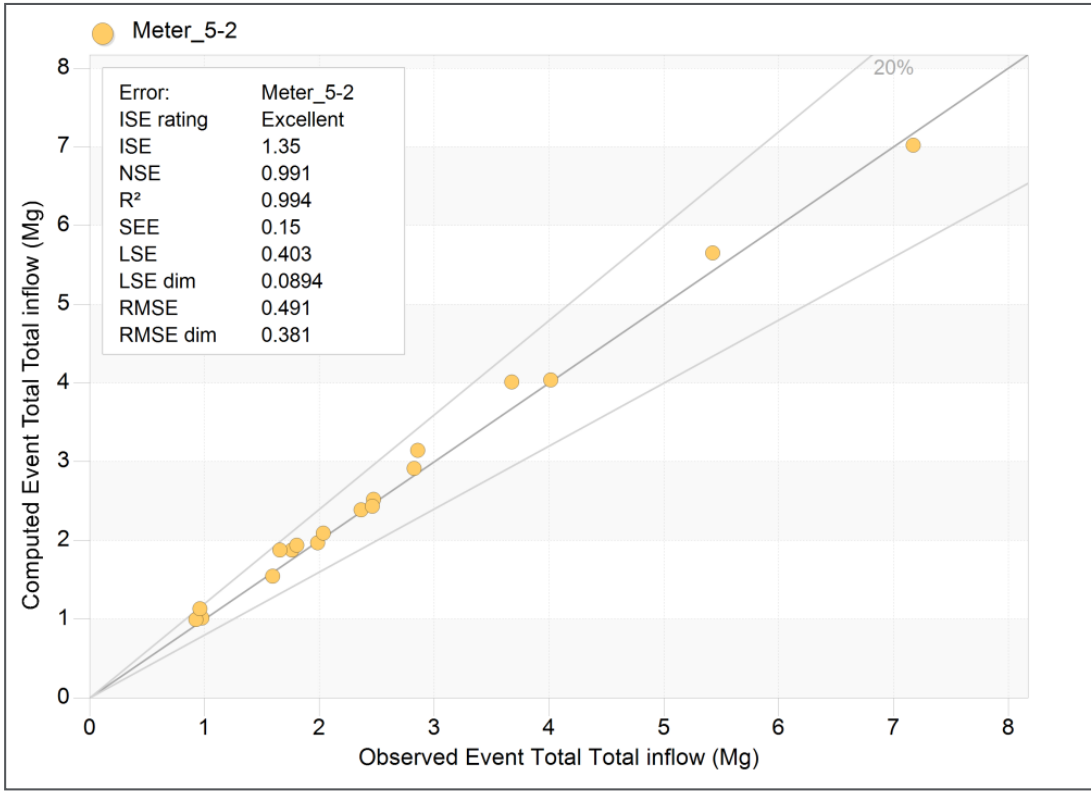
PREFERRED CALIBRATION METHODOLOGY

- Calibrate to multiple events over various antecedent conditions
- Calibrate to multiple rainfall events of varying totals, intensities, and durations



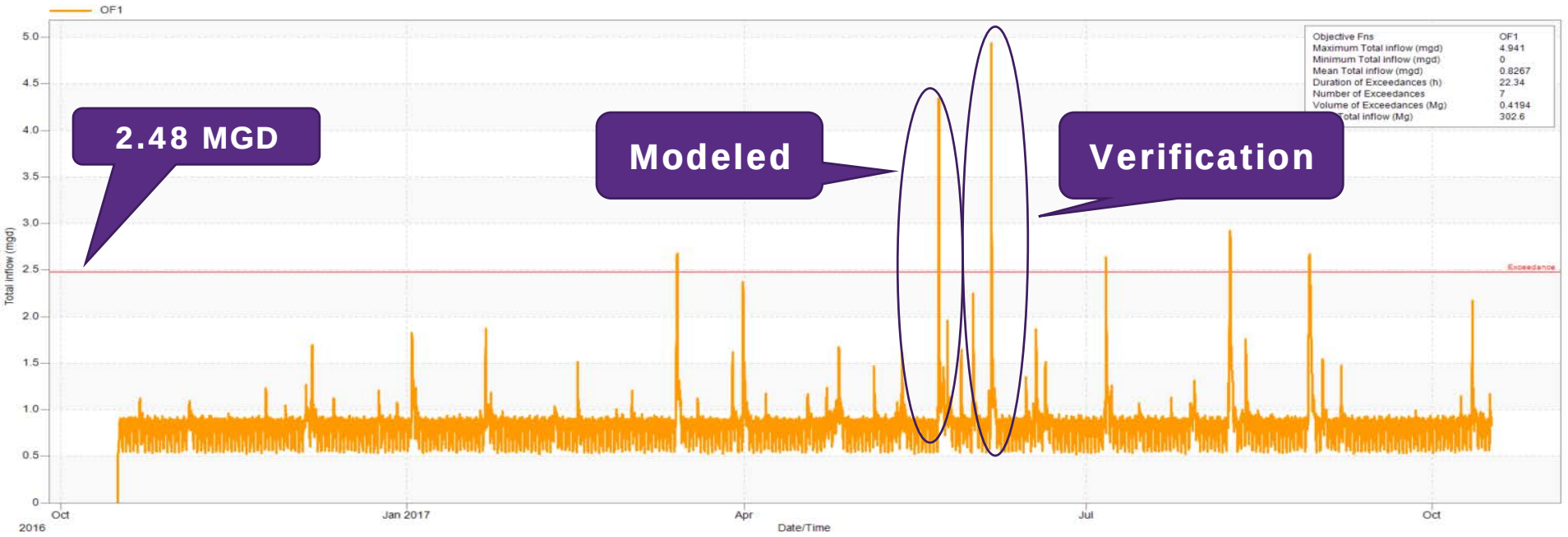
MODEL CALIBRATION

- Over 12 month monitoring period
- Multi-event calibration
  - 18 dry events
  - 21 wet events
- Emphasis on meeting WaPUG standards
- However, HRSD was expecting something else…



HRSD STANDARDS

- One modeled storm and one verification storm

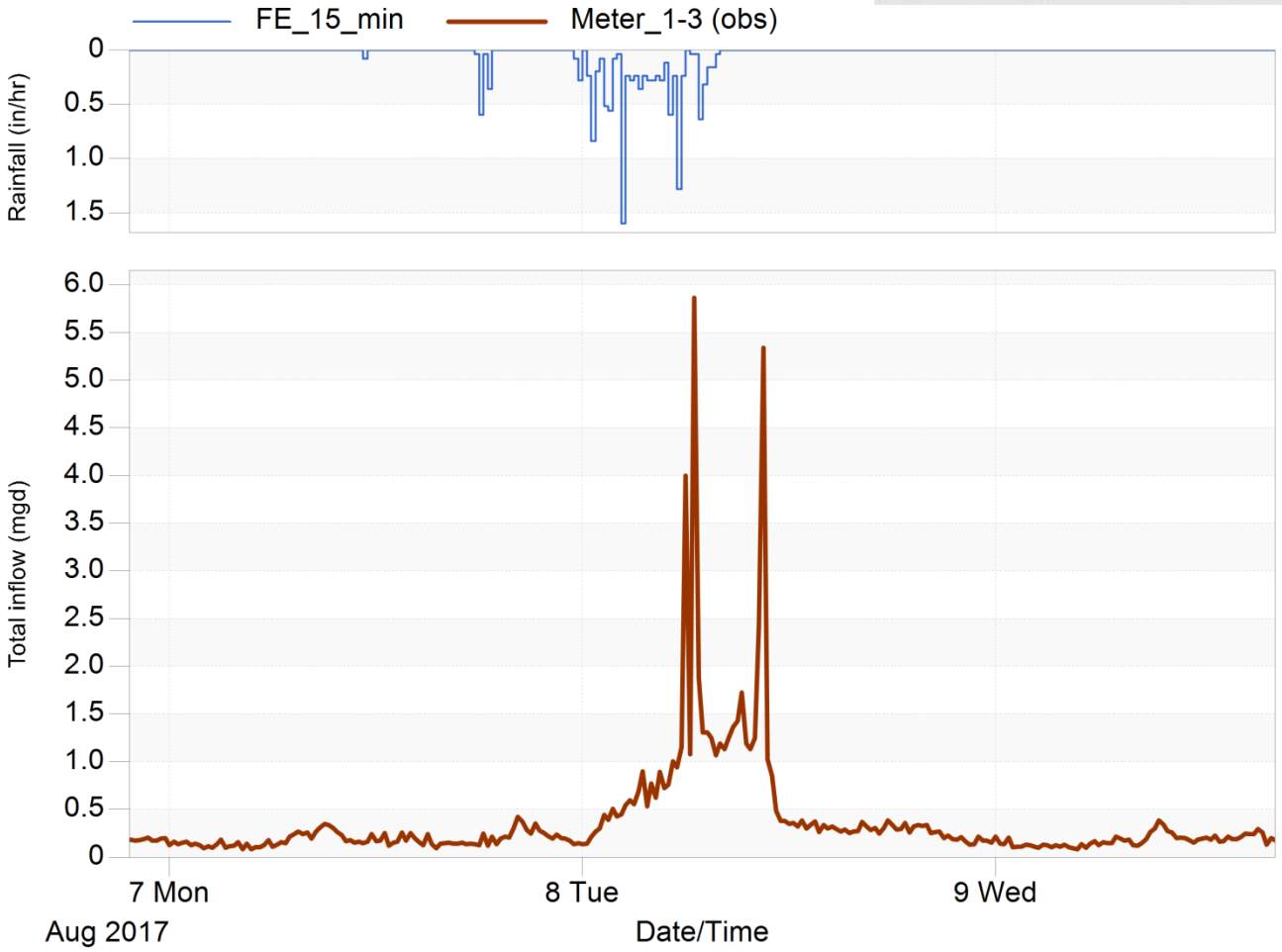


SINGLE CALIBRATION EVENT

	FE_15_min
Maximum Rainfall (in/hr)	1.6
Minimum Rainfall (in/hr)	0
Mean Rainfall (in/hr)	0.04492
Duration of Exceedances (h)	66.57
Duration of Deficits (h)	57.32
Number of Exceedances	1
Number of Deficits	6
Volume of Exceedances (in)	2.99
Volume of Deficits (in)	0
Total Rainfall (in)	2.99

From 8/6/2017 9:39:32 PM to 8/9/2017 4:13:41 PM (66.57 hours)

	Meter_1-3 (obs)
Maximum Total inflow (mgd)	5.864
Minimum Total inflow (mgd)	0.08
Mean Total inflow (mgd)	0.3695
Duration of Exceedances (h)	66.57
Duration of Deficits (h)	0
Number of Exceedances	1
Number of Deficits	0
Volume of Exceedances (Mg)	1.024
Volume of Deficits (Mg)	0
Total Total inflow (Mg)	1.025



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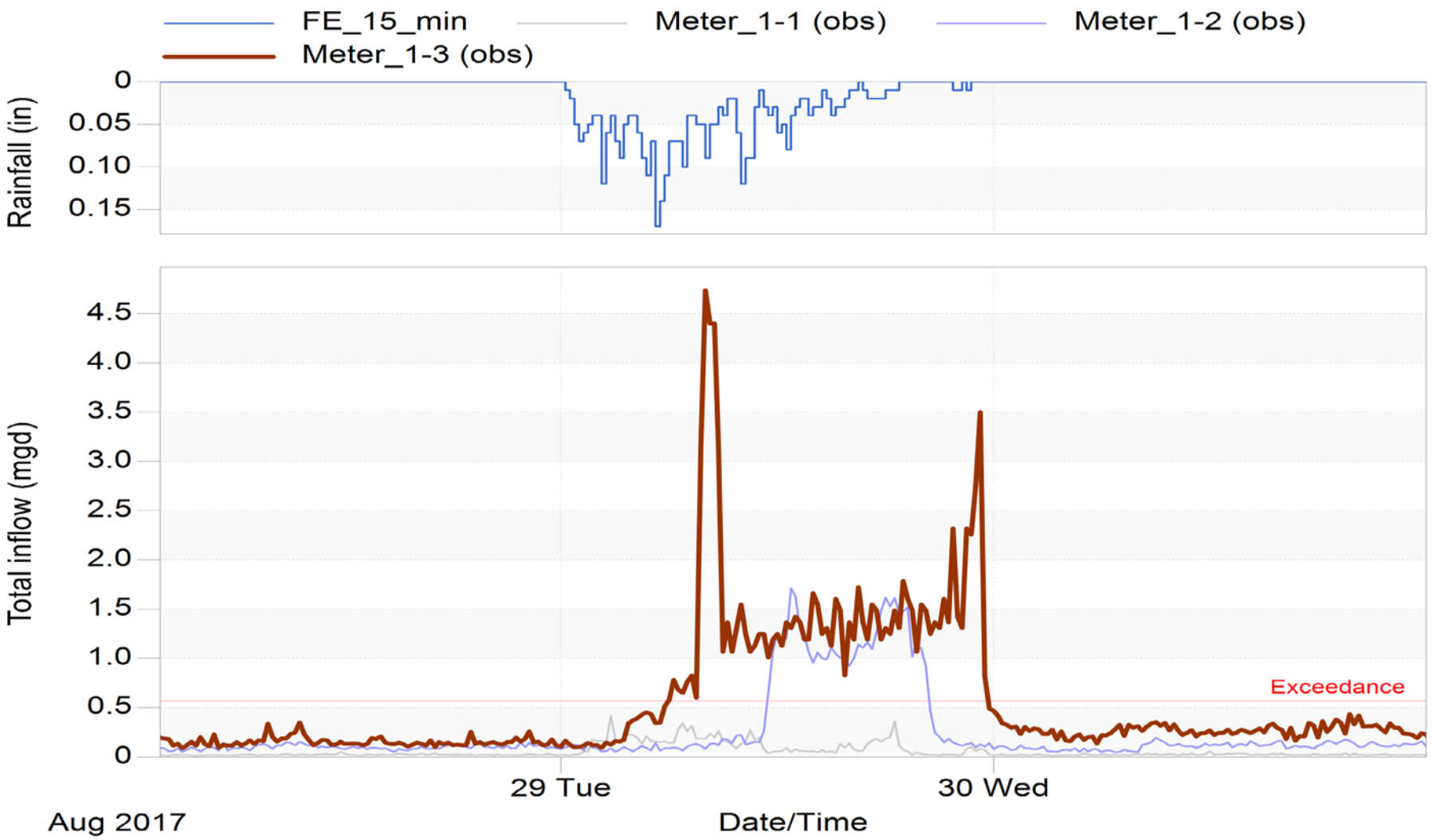
SINGLE VERIFICATION EVENT



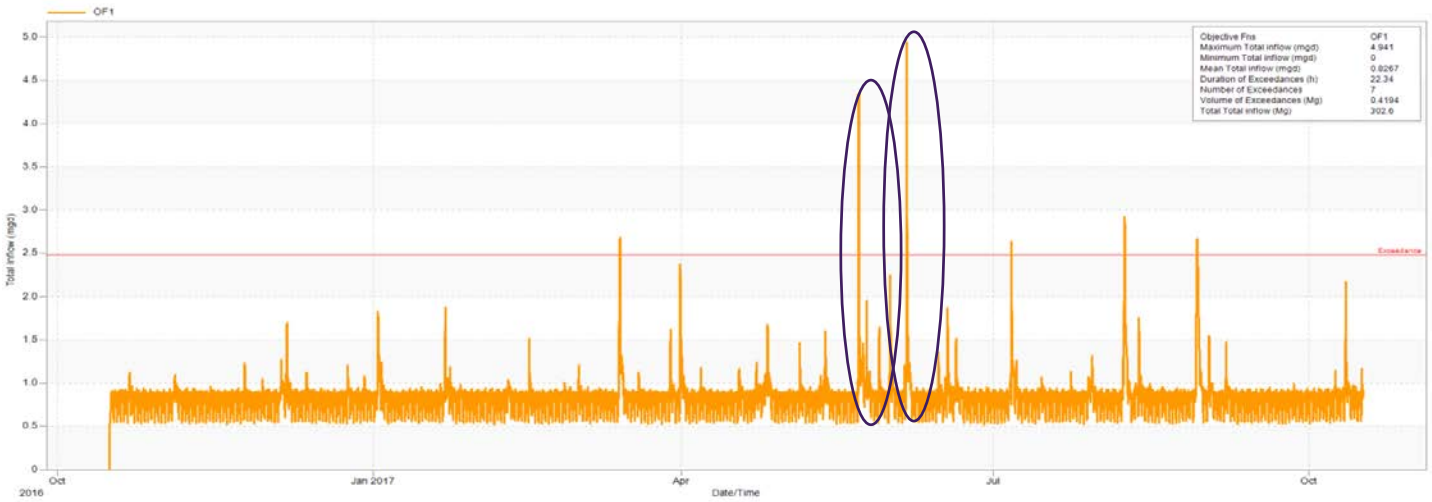
SO WHAT IS SOURCE?

Maybe tidal influence?

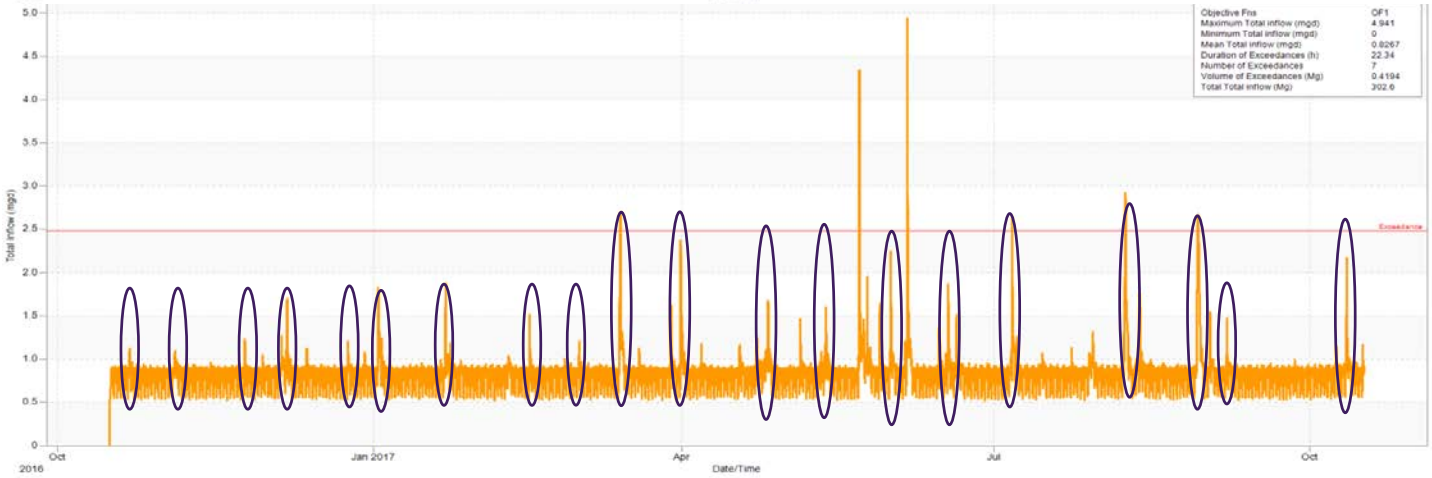
Maybe something else…

MULTI VS SINGLE EVENT CALIBRATION

Single Event



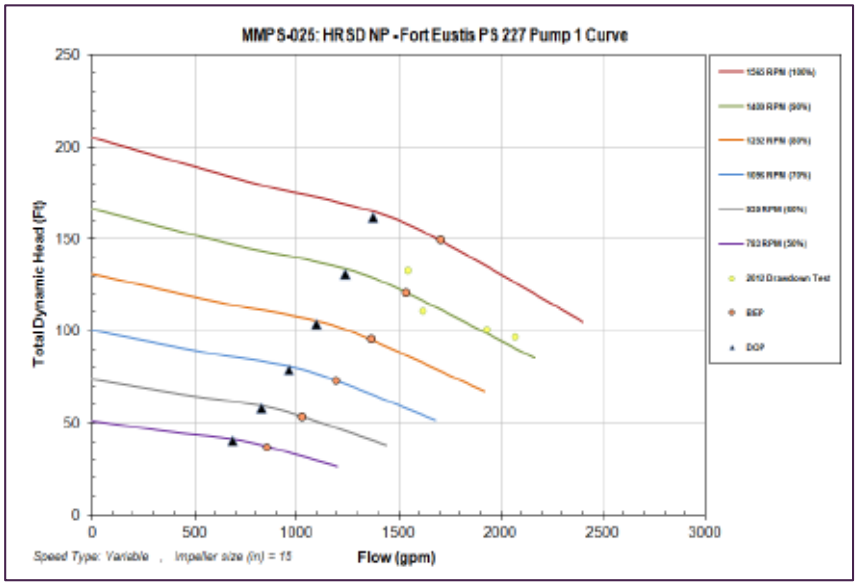
Multiple Events



HOW TO USE CALIBRATED MODEL—ROUND 1

- What are the HRSD pump station operational capacities?
- Drawdown data for HRSD pump station
  - Field testing showed that pump station flow capabilities ranged from 1.0 MGD up to 3.1 MGD

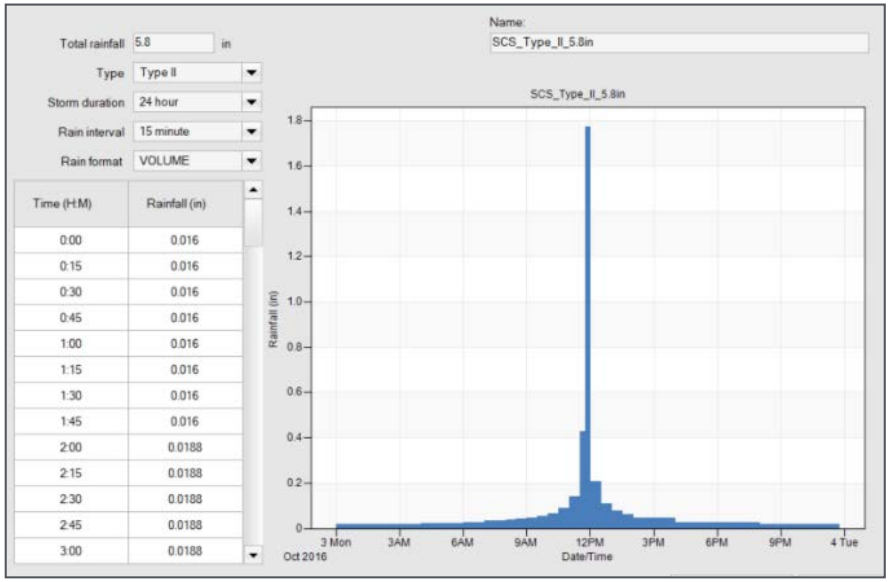
Figure 227-2. Fort Eustis Pump Station



HOW TO USE CALIBRATED MODEL—ROUND 1

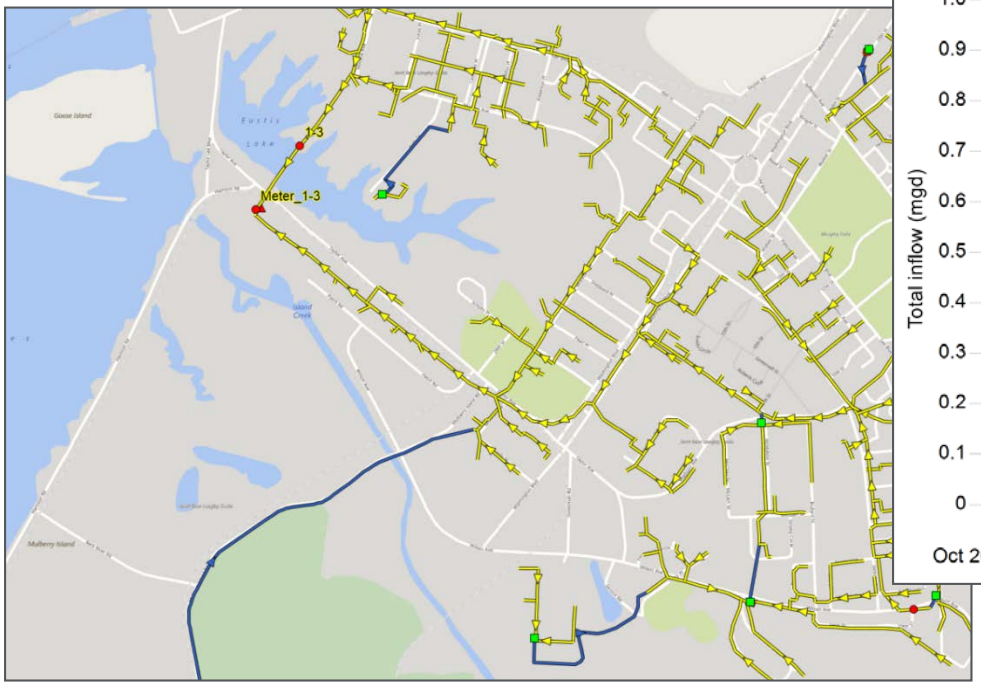
Test 10-year, 24-hour storm for three scenarios:

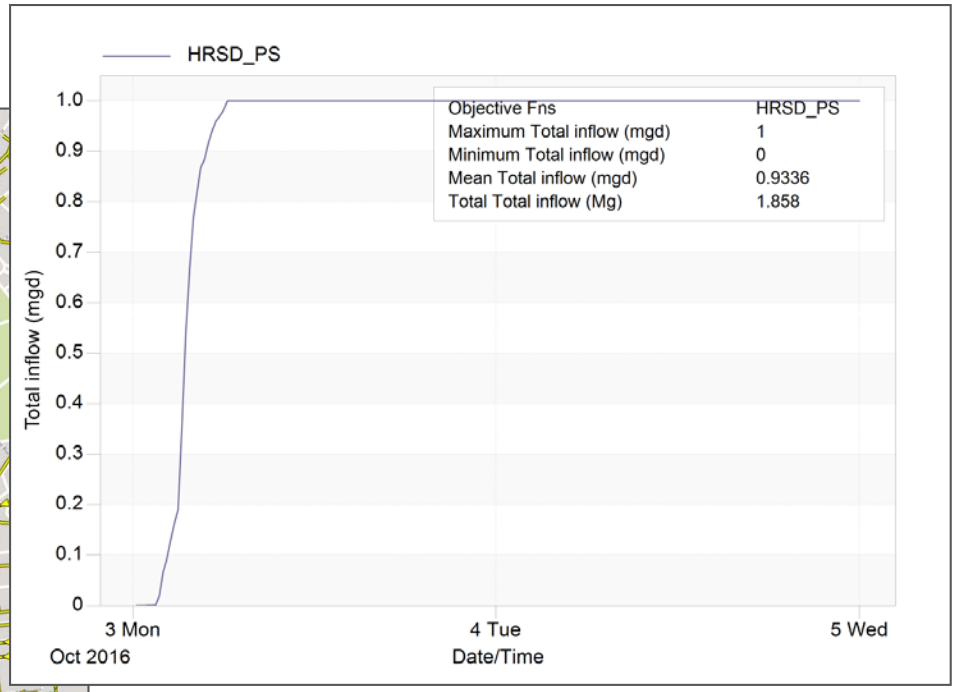
1) 1.0 MGD (lower limit from drawdown testing)
2) 2.48 MGD (3 X AAF)
3) Free discharge



10-YEAR 24-HOUR MODEL RUN RESULTS

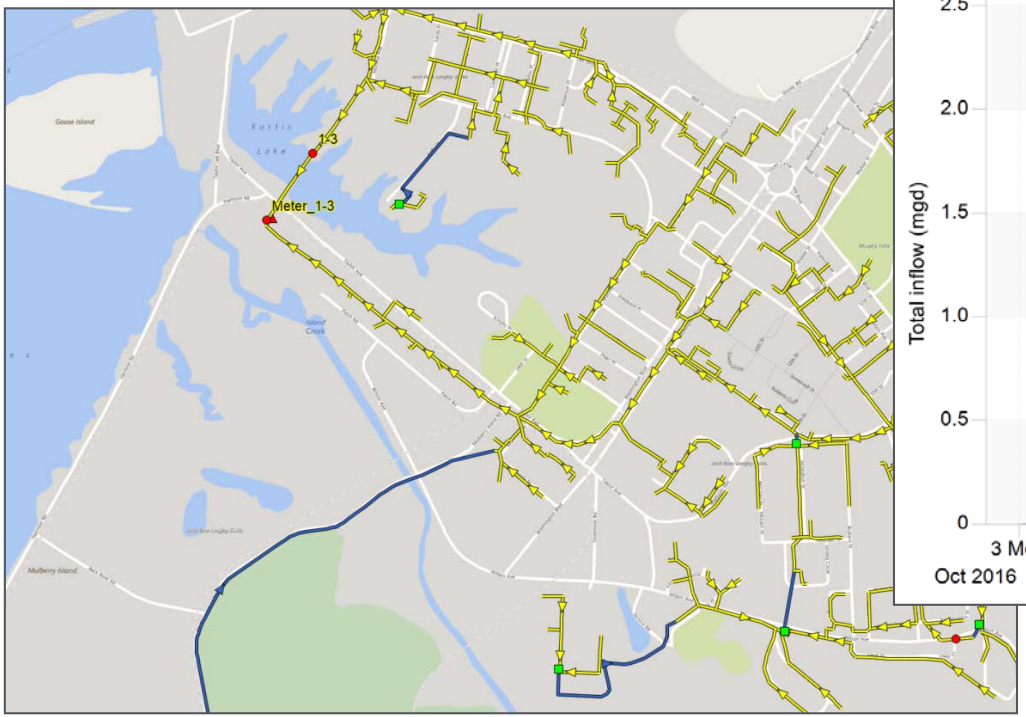
- HRSD – Assumed 1.0 MGD capacity based on drawdown performance
- 3 SSOs – 1.59 MG

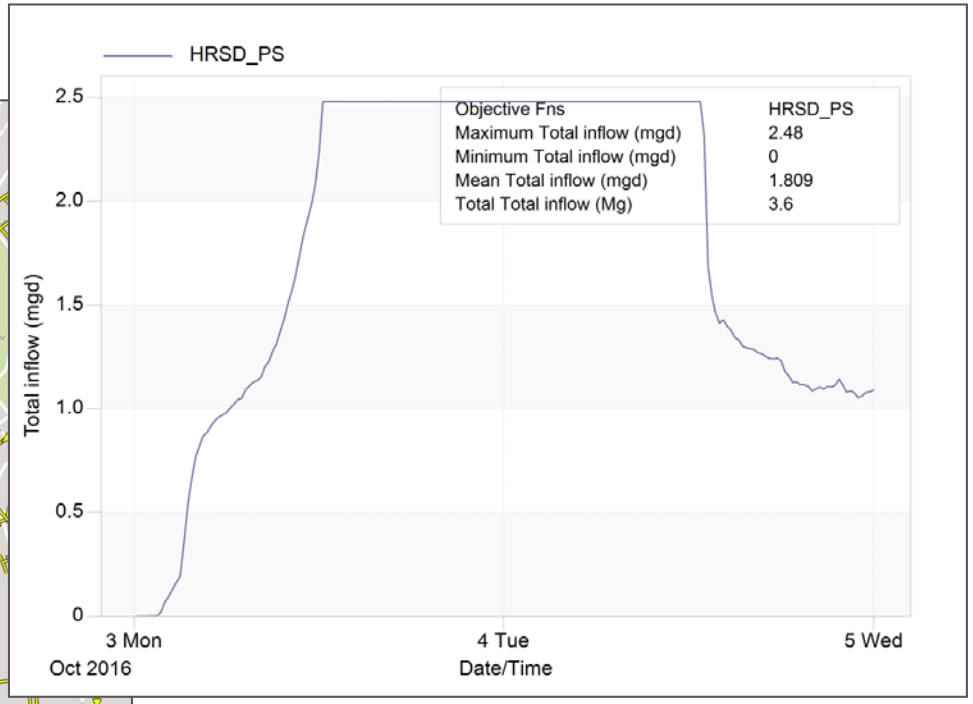




10-YEAR, 24-HOUR MODEL RUN RESULTS

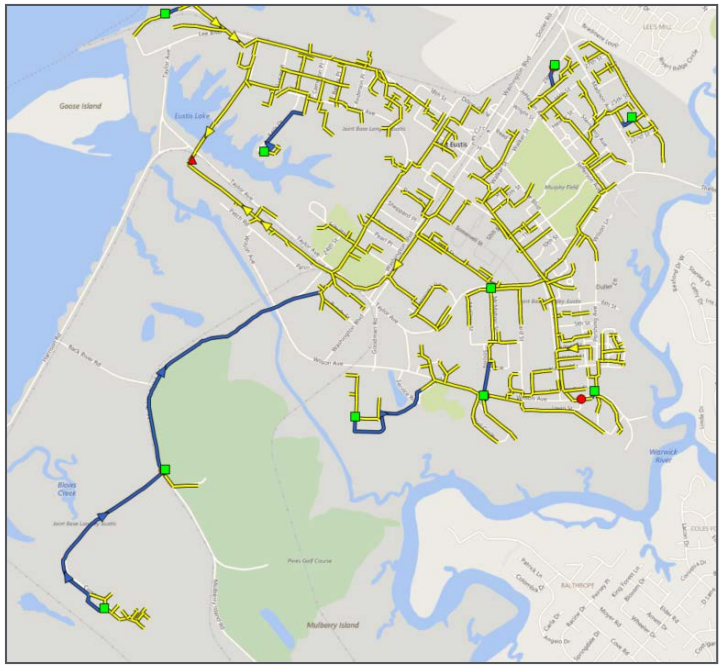
- HRSD – Assumed 2.48 MGD capacity based on 3 X AAF
- 3 SSOs – 0.301 MG

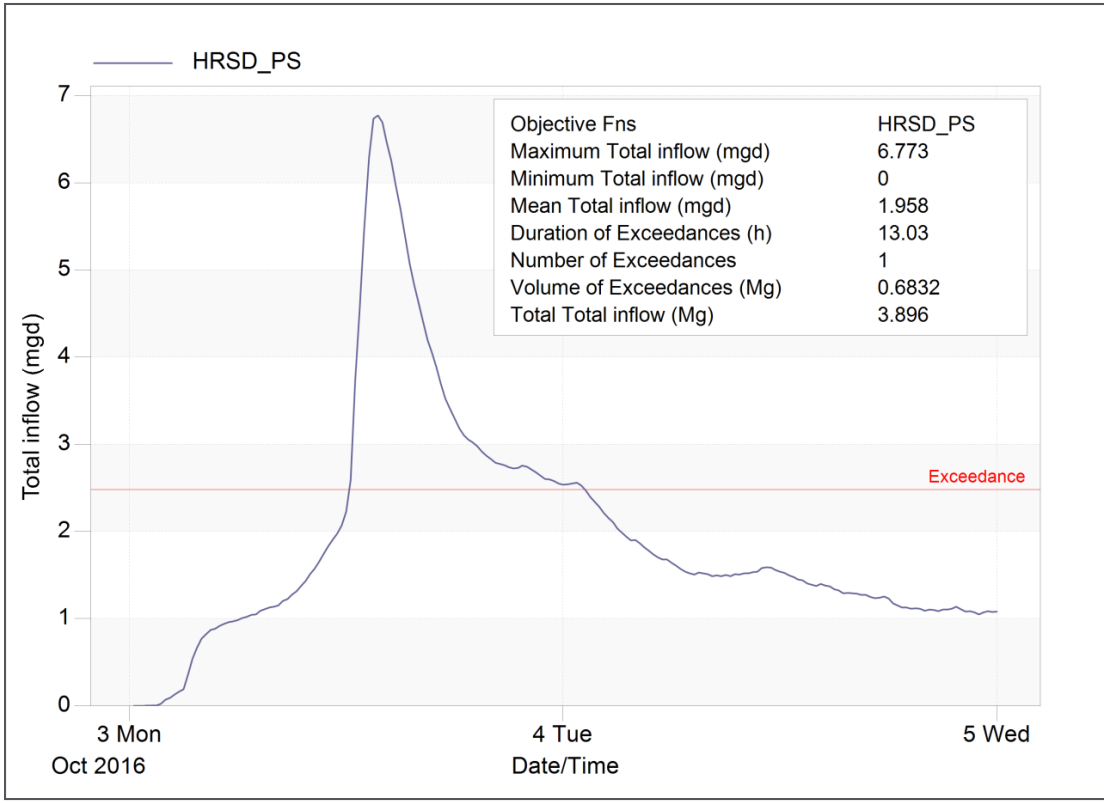




10-YEAR, 24-HOUR MODEL RUN RESULTS

- HRSD - Free Discharge
- 6.77 MGD Peak
- 8 x's AAF
- 1 SSO-0.002 MG





MODEL EVALUATION—ROUND 2

- HRSD requires Log-Pearson III(LPIII) analysis of flows, which is not specific to an intensity or total rainfall
- The LPIII distribution is a statistical technique for fitting frequency distribution data to predict a design flood

$$f_X(x) = \frac{1}{\alpha\Gamma(\beta)}\left(\frac{x-\varepsilon}{\alpha}\right)^{\beta-1} e^{-\left(\frac{x-\varepsilon}{\alpha}\right)}, \quad \varepsilon \le x < +\infty$$

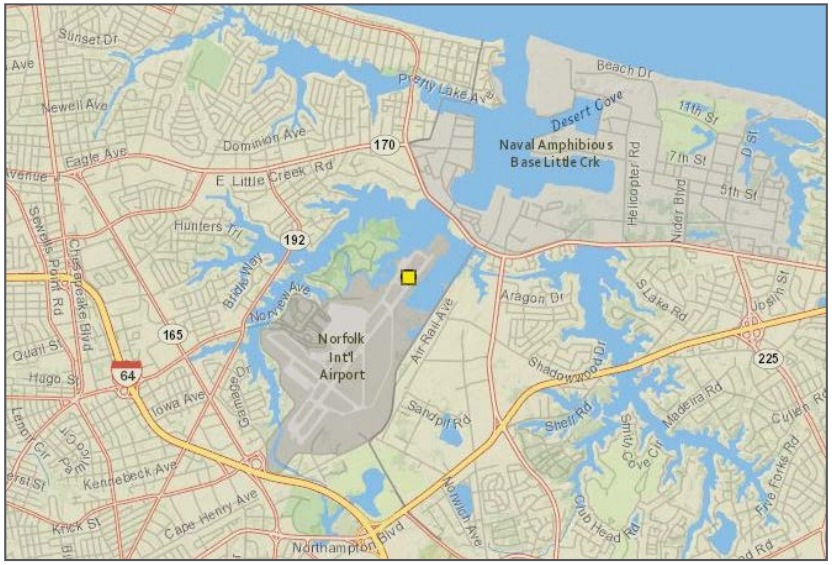
$$\alpha = \frac{\sigma}{\sqrt{\beta}} \qquad \beta = \left(\frac{2}{\gamma}\right)^2 \qquad \varepsilon = \mu - \sigma\sqrt{\beta}$$

μ , σ and γ are the mean, standard deviation and skewness coefficient of X, respectively.

It reduces to Gamma distribution if $\varepsilon = 0$.

LONG-TERM RAINFALL STUDY

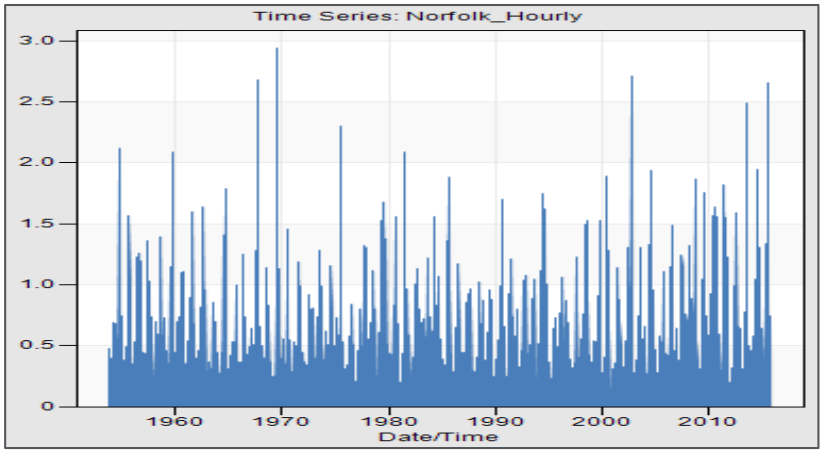
- Evaluated 1960-Present at Norfolk International
- Time period of 1960-Present
  - Over 9,194 rainfall events of over 0.1 in of rain
  - Over 860 rainfall events over 1.0 in of rain



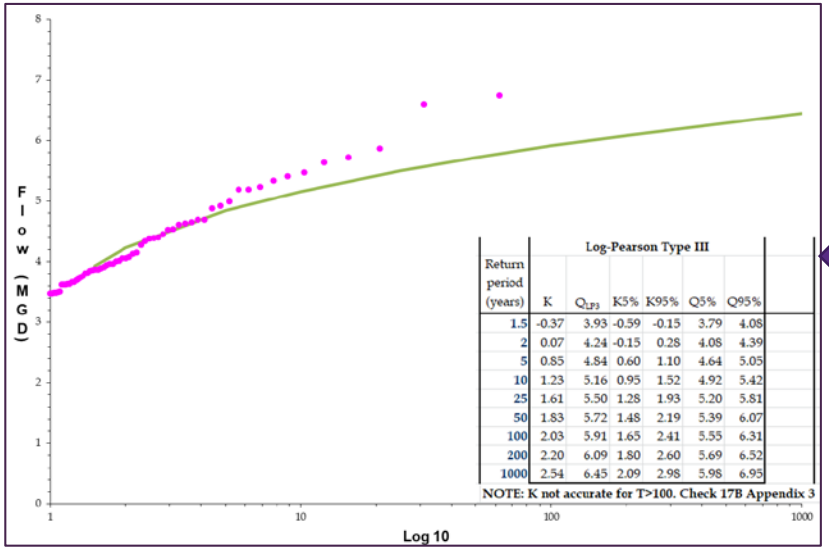
Date	Duration (h)	Total Rainfall (in)
5/16/2014	9	8.848
6/26/2006	45	8.727
9/8/2014	15.25	8.688
8/9/2016	2	8.562
6/14/2006	21	8.45
9/19/2016	7.42	8.401
9/16/2002	9.33	8.4
7/18/2015	2.5	8.303
10/24/2007	42.67	7.978
11/12/2006	17.08	7.94

RAINFALL TO 10-YEAR FLOW?

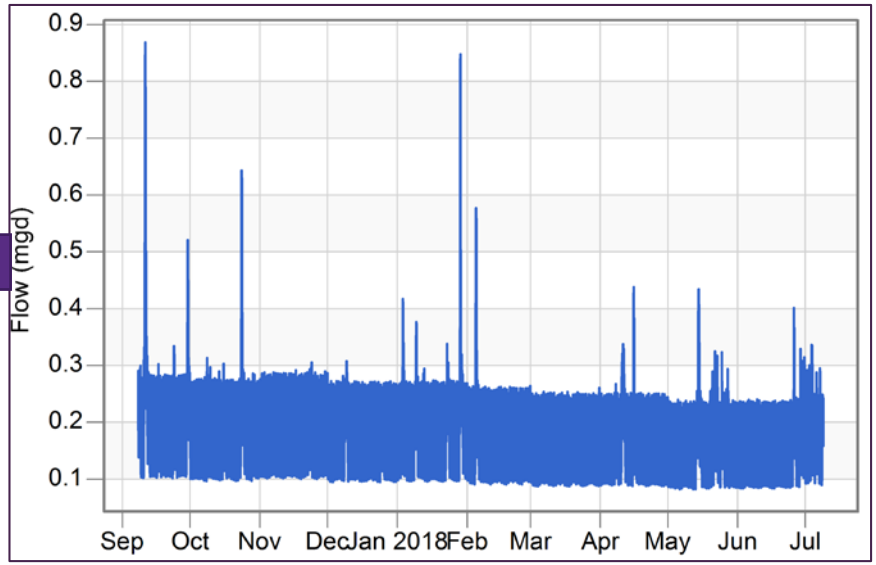
Long-term Rainfall



Calibrated Model

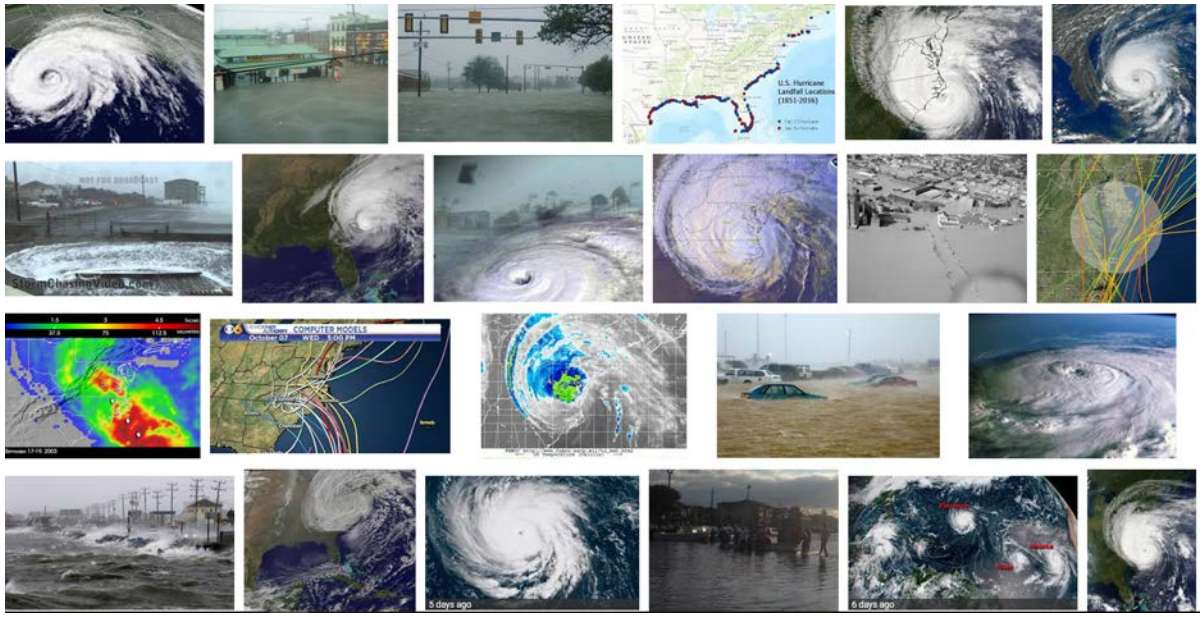


LPIII



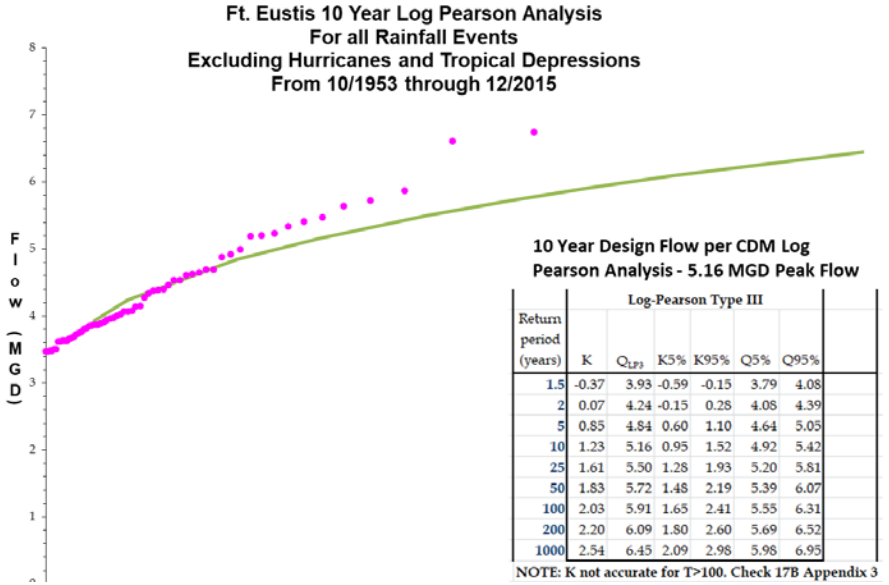
ONE QUESTION ON LOG PEARSON?

- EPA specifically states that we do not have to design for tropical cyclones
- Can Log Pearson eliminate those events???

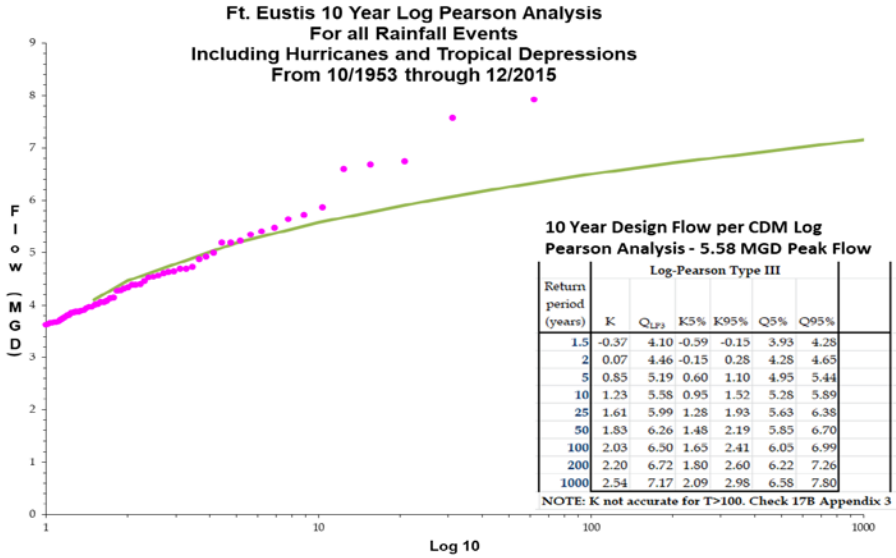


LOG PEARSON RESULTS (TWO SETS)

- Analysis without Hurricanes – 5.16 MGD



- Analysis with Hurricanes – 5.58 MGD



PEAK FLOW COMMITMENT

- Per the FFTS, if the projected 10-year peak hour flow recurrence is greater than 6 X the AAF, minimum reduction in the basin shall be 60%

AAF = 0.83 MGD

Peak Flow Threshold = 3 x 0.83 MGD = 2.48 MGD

10-year projected peak hour flow (LPIII) = 5.16 MGD

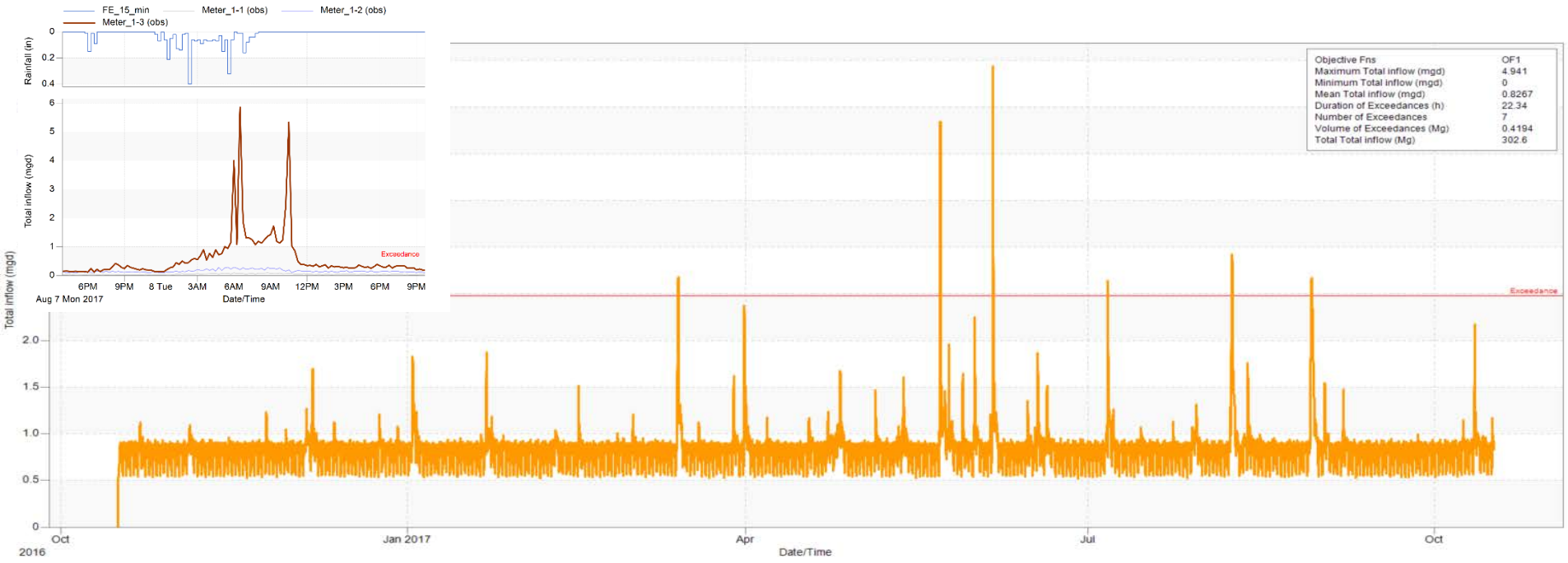
6 x AAF = 6 x 0.83 MGD = 4.96 MGD

Peak Flow Commitment = 5.16 MGD - (5.16 MGD - 0.83 MGD) x 60%

= **2.56 MGD**

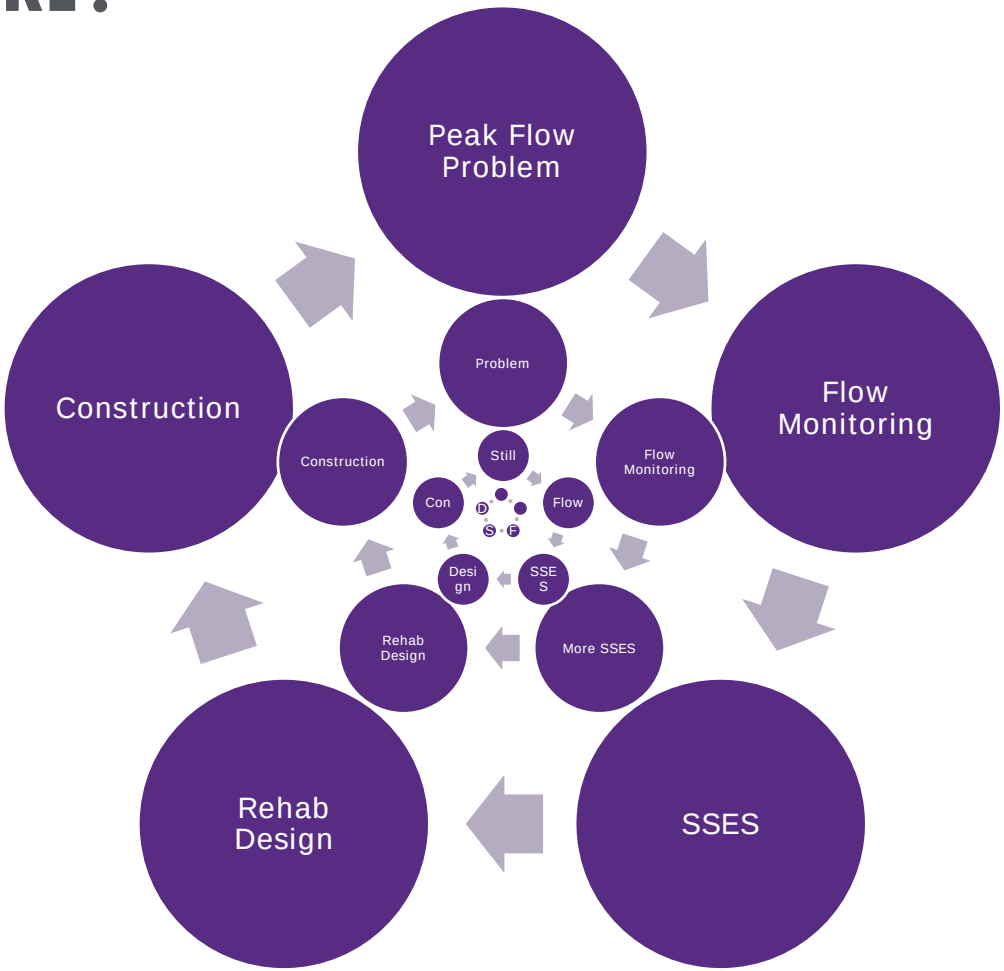
SINGLE EVENT CALIBRATION…WITH LPIII?

- Can lead to overly conservative designs
- Should not be combined with long term simulation



WHERE TO GO FROM HERE?

- Find source of massive inflow
- Continue to work with HRSD on pump station issues
  - Need SCADA!
- Size storage facility for 3x's dry weather flows
- Push for permanent flow meters
- Continue to use multiple event calibration and spread the word



And can the traditional wet weather planning approach loop be broken?

Thank you for the opportunity.

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