

West Basin Facility Plan Project 7054

PART 3 - TECHNICAL MEMORANDUM

Conveyance Planning Basis (Design Criteria, Design Storm Update, and Climate Sensitivity)

FINAL/ October 2025

Produced by:

Jacobs
carollo®





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PART3 - TECHNICAL MEMORANDUM 2

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FINAL / October 2025

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Abbreviations

cfs	Cubic feet per second
CIRC	Climate Impacts Research Consortium
DDF	Depth-Duration-Frequency
DEQ	Department of Environmental Quality
DS+	Design Storm with Climate Depth Adjustment
DS+INT	Design Storm with Climate Intensity Adjustment
EPA	Environmental Protection Agency
gpcd	Gallons per capita per day
HGL	Hydraulic Gradeline
HYDRA	Portland, Rainfall Network
ICM	Integrated Catchment Model
JMP	JMP Statistical Discovery Software
MG	Million gallons
mg/L	Milligrams per liter
mgd	Million gallons per day
NOAA	National Oceanic and Atmospheric Administration
OCAR	Oregon Climate Assessment Report
OCCRI	Oregon Climate Change Research Institute
psi	Pounds per square inch
PWB	Portland Water Bureau
SCADA	Supervisory Control and Data Acquisition
SSOAP	Sanitary Sewer Overflow Analysis and Planning Toolbox
TM	Technical Memorandum

CONVEYANCE BASIS OF PLANNING

2.1 Objective

This technical memorandum (TM) summarizes conveyance system criteria for identifying capacity limitations and system improvement requirements for the Clean Water Services' (District's) West Basin Master Plan.

The objectives of this document include:

- Documentation of conveyance hydraulic design criteria to identify system capacity deficiencies.
- Summary of approach and recommendations for defining and selecting a design storm event to minimize risk of sanitary sewer overflows.
- Summary of climate intensification and how future climate trends are applied to the design storm event for system improvement sizing.

2.2 Summary

System criteria for defining conveyance capacity limitations and improvement sizing were confirmed including allowable surcharging above the gravity pipe crown during a wet weather design storm event. For pump stations, the criteria focus on pumping peak wet weather flows with the largest pump out of service (firm capacity).

The District reviewed level of service and risk of sanitary overflows in selecting a design storm event to meet the Oregon Department of Environmental Quality (DEQ) guidelines (*Oregon Administrative Rule 340-041-0009*). Factors were applied for climate intensification over a 50-year period to the design storm to ensure adequate level of service and sizing for the life span of new pipeline infrastructure.

The system criteria, design storm, and climate intensified storm were used to evaluate rainfall derived infiltration and inflow (RDI/I), risk of sanitary sewer overflows, and provide the basis for system improvement analysis documented in *Part 3, TM 5, Conveyance System Analysis – Existing System Deficiencies; TM 6, Conveyance System Analysis – Infiltration and Inflow; and TM 7, Conveyance System – Alternatives Analysis*.

2.3 Capacity Criteria

The District criteria for establishing collection system deficiencies are presented in Table 2.1 and Table 2.2. For sanitary sewer pipelines, the criteria focus on allowable surcharging above the pipe crown during a wet weather design storm event. For pump stations, the criteria focus on pumping peak wet weather flows with the largest pump out of service (firm capacity). Maximum velocity and minimum scouring velocity are considered secondary criteria and are indicative of undersized or oversized piping, respectively.

The deficiency criteria for this plan assume a high risk to property and health when the surcharged pipeline hydraulic gradeline (HGL) is within 3 feet of the ground surface and a moderate to low risk when the surcharged HGL is within 10 feet of the ground surface during the 5-year design storm. The District HGL criteria are summarized in Table 2.2 based on allowable freeboard during the design storm event and District HGL deficiency codes.

Table 2.1 District Collection System Design Criteria for Establishing System Deficiencies and Improvements

Standard	Category	Criteria	Explanation
Primary	Maximum water depth to diameter ratio during dry weather conditions	0.8	When the depth to diameter ratio exceeds 0.9, the pipe begins to lose gravity capacity due to greater frictional loss
	Minimum freeboard during 5-year design storm, (clearance from water surface to manhole rim)	3 feet minimum, HGL categories determine risk (Table 2.2)	The District standard considers level of risk when prioritizing improvements
	Pump station firm capacity	Pump stations have capacity to pump at flows greater than or equal to peak hour flows with largest pump out of service	The firm capacity criteria protect against loss of service during equipment failure and allows for pump cycling for longer equipment life
	Maximum force main velocity	8.0 fps	The velocity criteria protect against excessive head loss and allows pumps to operate efficiently
Secondary	Maximum gravity pipeline velocity	< 15.0 fps or anchored appropriately for extreme slopes	The maximum velocity criterion protects pipelines from turbulent flow conditions and excessive air entrainment
	Minimum cleansing/scouring velocity, gravity pipeline	2.0 fps	Pipe diameters and minimum slopes should be selected to prevent solids deposition
	Minimum cleansing/scouring velocity of force mains	3.5 fps	Pipe diameters should be selected to prevent solids deposition, with a minimum pipe diameter of 4 inches

fps = feet per second.

Table 2.2 District Freeboard Criteria and Hydraulic Gradeline Codes for Wet Weather Deficiencies

HGL Status	Description ¹	Risk Level	Action	Color Code
LS	Overflow or pressure with significant HGL increase	High	Improve	Red
LH	Overflow or pressure	High	Improve	Yellow
HS	Less than 3 feet freeboard with significant HGL increase	High	Improve	Orange
HH	Less than 3 feet freeboard	High	Improve	Brown
IS	3 to 10 feet freeboard with significant HGL increase	Low	Improve ²	Purple
IH	3 to 10 feet freeboard	Low	None	Pink
DS	Greater than 10 feet freeboard with significant HGL increase	Negligible	None	Light Blue
DH	Greater than 10 feet freeboard	Negligible	None	Dark Green
OK	HGL below pipe crown	Negligible	None	Light Green

Notes:

(1) A significant increase in HGL indicates that the peak flow rate exceeds the full flow capacity of the pipeline. This designation is given to pipelines where the HGL slope exceeds the pipeline slope by greater than 5%, causing a backwater impact in the upstream system.

(2) Improve in some cases. Improvement decision based on review of localized risks.

2.4 Design Storm Criteria

Oregon Department of Environmental Quality (DEQ) guidelines (*Oregon Administrative Rule 340-041-0009*) indicate that sanitary sewer overflows are prohibited except during a winter storm event exceeding the one in five-year frequency and a summer storm event exceeding the one in ten-year frequency.

Washington County is located west of the Cascades where heavy winter rainfall typically controls sanitary sewer capacity limitations, and the one-in-five-year frequency storm event is the standard in the Portland Metro area for evaluating collection system capacity for separated sewer systems.

The previous West Basin 5-year design storm was developed in 2012 and is a synthetic storm lasting 72-hours with back-to-back storms. For the West Basin Master Plan, the District wanted to reevaluate the design storm by considering additional candidate historical storm events and generate unique events for each treatment basin, Rock Creek, Hillsboro, and Forest Grove. The design storms were selected through a comprehensive historical rainfall analysis considering storm frequency and depth at varied durations and associated system impacts throughout each basin.

2.4.1 Historic Design Storm Summary

The 2012 synthetic design storm, which is illustrated in Figure 2.1, was developed to represent precipitation patterns in the Rock Creek Basin, based on Clean Water Services (District) rain gauges. To generate this design storm, 50 events with varied storm characteristics were selected, and simulated within the Rock Creek collection system model. The model results were used to generate flow and depth frequencies by subbasin to review system impacts. The hydraulic model performance subject to these candidate storms was simultaneously compared to known issues within the network, to confirm the model accuracy. A similar effort was performed in the East Basin (Durham and Fanno Basins). Since the 2012 design storm deployment, there has been noticeable changes in frequency of large storm events.

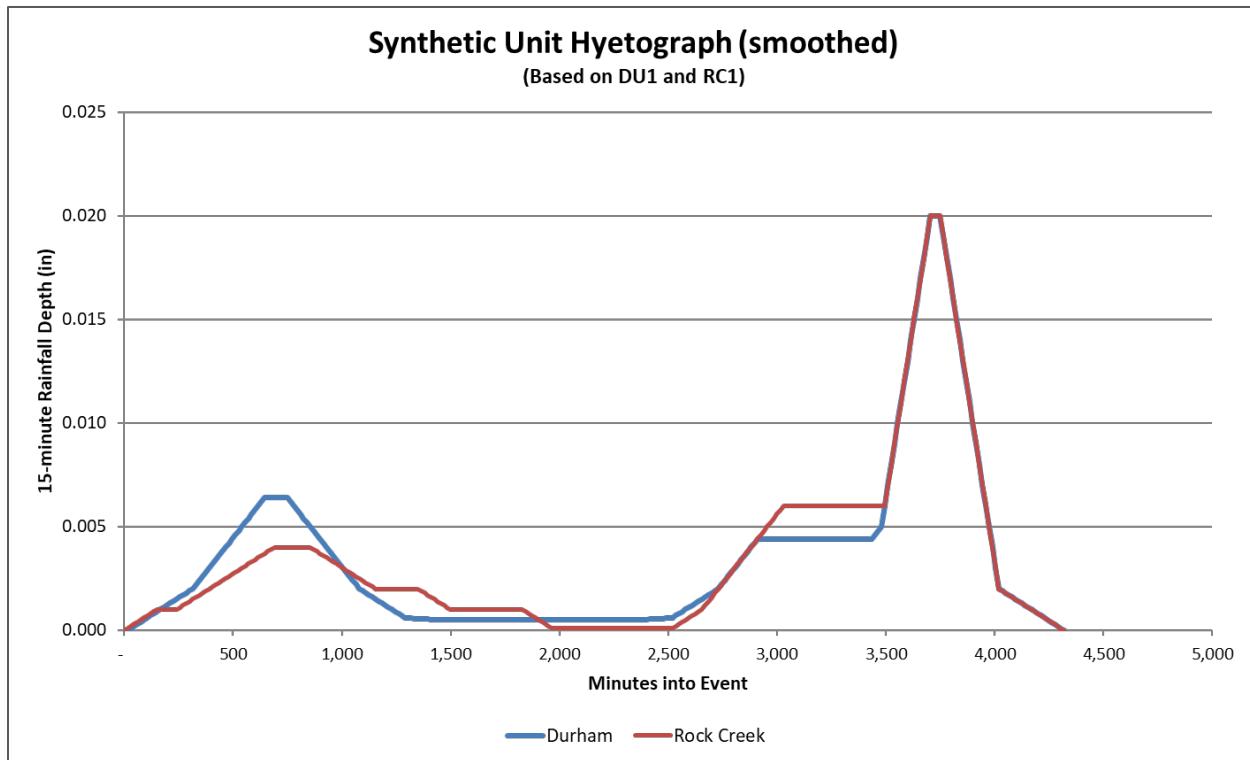


Figure 2.1 2012 East and West Basin Synthetic Design Storms

2.4.2 Design Storm Selection Methodology

The objective of the design storm analysis was to identify design storms specific to each treatment-plant-delineated model basin: Forest Grove, Hillsboro, and Rock Creek. The East Basin design storm (Durham and Fanno) was also evaluated at the same time. A methodological approach was identified and a high-level overview of the sequential steps is shown within Figure 2.2.



Figure 2.2 Methodology for Design Storm Development

2.4.2.1 Precipitation Data Review

Gage Identification and Data Accumulation

A total of 30 rain gages were used for the analysis, all of which have variable time periods of rainfall data coverage, and associated overlap. The analysis consisted of 14 local District rain gages, 7 Portland HYDRA Network rain gages, and 9 Western Regional Climate Center/National Oceanic and Atmospheric Administration (WRCC/NOAA) regional gages. Table 2.3 documents the location and period of record for each gage. Figure 2.3 illustrates the location of each District and Portland HYDRA gage, in relation to the network/model basins. Figure 2.4, from the WRCC/NOAA, shows the locations of regional gages throughout the state of Oregon, as well as bordering regions.

The raw data (precipitation accumulated depth) for all gages was aggregated into 1-hour, 6-hour, 12-hour, 24-hour, 48-hour, and 96-hour durations for the period of record.

Table 2.3 Precipitation Gage Information (see Appendices for additional details)

Gage ID	Gage Ownership	Min. Raw Data Timestep	Min. Coverage Date	Max. Coverage Date	(Location Description --) Address	Latitude	Longitude	Elevation (Ft. AD)
BKR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Banks Pump Station -- 42660 NW CEDAR CANYON RD, BANKS, OR 97106	45.6210	-123.1171	197.8
BNR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Butternut (Aloha 3 Pump Station) -- 4860 SW 209TH AVE, BEAVERTON, OR 97007	45.4849	-122.8926	171.7
CHR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Cedar Hills -- 2025 SW MERLO CT, BEAVERTON, OR 97006	45.5043	-122.8463	196.1
CMR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Cedar Mill -- 11216 NW BLACKHAWK DR, PORTLAND, OR 97229	45.5399	-122.7926	542.3
DPR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Durham Plant -- 16580 SW 85TH AVE, TIGARD, OR 97224	45.3996	-122.7634	160.1
FGR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Forest Grove Plant -- 1345 SW FERN HILL ROAD, FOREST GROVE, OR 97116	45.5117	-123.0908	164.1
HWR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Hillsboro Plant -- 770 S 1ST AVE, HILLSBORO, OR 97123	45.5140	-122.9897	154.2
LTR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Lower Tualatin (Sherwood Pump Station) -- 18967 SW PACIFIC HWY, SHERWOOD, OR 97140	45.3827	-122.8247	133.7
MTR	District Local Gage	15-Min.	1/2/2007	12/25/2022	Metzger (Tigard City Hall) -- 13125 SW HALL BLVD, TIGARD, OR 97223	45.4250	-122.7674	153.9
RCR	District Local Gage	15-Min.	1/2/2019	1/1/2023	Rock Creek Plant -- 3235 SE RIVER RD, HILLSBORO, OR 97123	45.4963	-122.9437	166.4
RVR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Reedville (Fire Station at Farmington and Merlo) -- 13810 SW FARMINGTON RD, BEAVERTON, OR 97005	45.4864	-122.8191	197.2
SSR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Sunset (Fire Station at 185th and Hwy 26) -- 3355 NW 185TH AVE, PORTLAND, OR 97229	45.5433	-122.8682	232.2
TCR	District Local Gage	15-Min.	1/2/2007	1/1/2023	Dawson Creek Pump Station -- 25350 NE CORNELL RD, HILLSBORO, OR 97124	45.5322	-122.9383	181.0
WHR	District Local Gage	15-Min.	11/14/2014	1/1/2023	West Hills -- 3425 SW 103RD AVE, BEAVERTON, OR 97005	45.4954	-122.7834	252.1
BUXTON MOUNTAINDALE OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/5/1974	Address Information Unavailable	45.6833	-123.0667	360.9
BUXTON OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/24/2013	Address Information Unavailable	45.6833	-123.1833	331.0
DIXIE MOUNTAIN OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	10/4/1975	12/23/2013	Address Information Unavailable	45.7000	-122.9333	1430.1
GLENWOOD 2 WNW OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/24/2013	Address Information Unavailable	45.6500	-123.2667	479.0
PORTLAND INTERNATIONAL AIRPORT OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/24/2013	Address Information Unavailable	45.6000	-122.6000	21.0
PORTLAND KGW TV OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	7/21/1973	2/10/2007	Address Information Unavailable	45.5167	-122.6833	159.1
REX 1 S OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/24/2013	Address Information Unavailable	45.3000	-122.9167	512.1
SAUVIES ISLAND OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	1/4/1970	12/24/2013	Address Information Unavailable	45.6500	-122.8333	40.0
SCOGGINS DAM 2 OR US (1)	WRCC/NOAA Regional Gage	1-Hr.	2/25/1973	4/27/1985	Address Information Unavailable	45.4833	-123.2000	360.9
Sylvania PCC	Portland HYDRA Network Gage	1-Hr.	6/5/1998	6/20/2023	12000 SW 49TH AVE. PORTLAND, OR 97219	45.4376	-122.7315	644.7
Vermont Hills	Portland HYDRA Network Gage	1-Hr.	6/5/1998	7/9/2002	5730 SW IDAHO ST. PORTLAND, OR 97221	45.4773	-122.7364	277.4

Gage ID	Gage Ownership	Min. Raw Data Timestep	Min. Coverage Date	Max. Coverage Date	(Location Description --) Address	Latitude	Longitude	Elevation (Ft. AD)
Sylvan School	Portland HYDRA Network Gage	1-Hr.	3/23/2000	6/25/2023	1849 SW 58TH AVE. PORTLAND, OR 97221	45.5099	-122.7370	814.4
Maplewood Elementary	Portland HYDRA Network Gage	1-Hr.	6/1/2002	6/21/2023	7452 SW 52ND AVE. PORTLAND, OR 97219	45.4708	-122.7300	395.1
Bonny Slope BSD	Portland HYDRA Network Gage	1-Hr.	4/20/2019	6/22/2023	11775 NW McDANIEL RD. PORTLAND, OR 97229	45.5396	-122.7977	558.6
Bonny Slope School	Portland HYDRA Network Gage	1-Hr.	6/10/1998	3/9/2017	10351 NW THOMPSON RD. PORTLAND, OR 97229	45.5455	-122.7838	626.6
Skyline School	Portland HYDRA Network Gage	1-Hr.	9/18/1998	5/16/2023	11536 NW SKYLINE BLVD. PORTLAND, OR 97231	45.6076	-122.8565	723.2

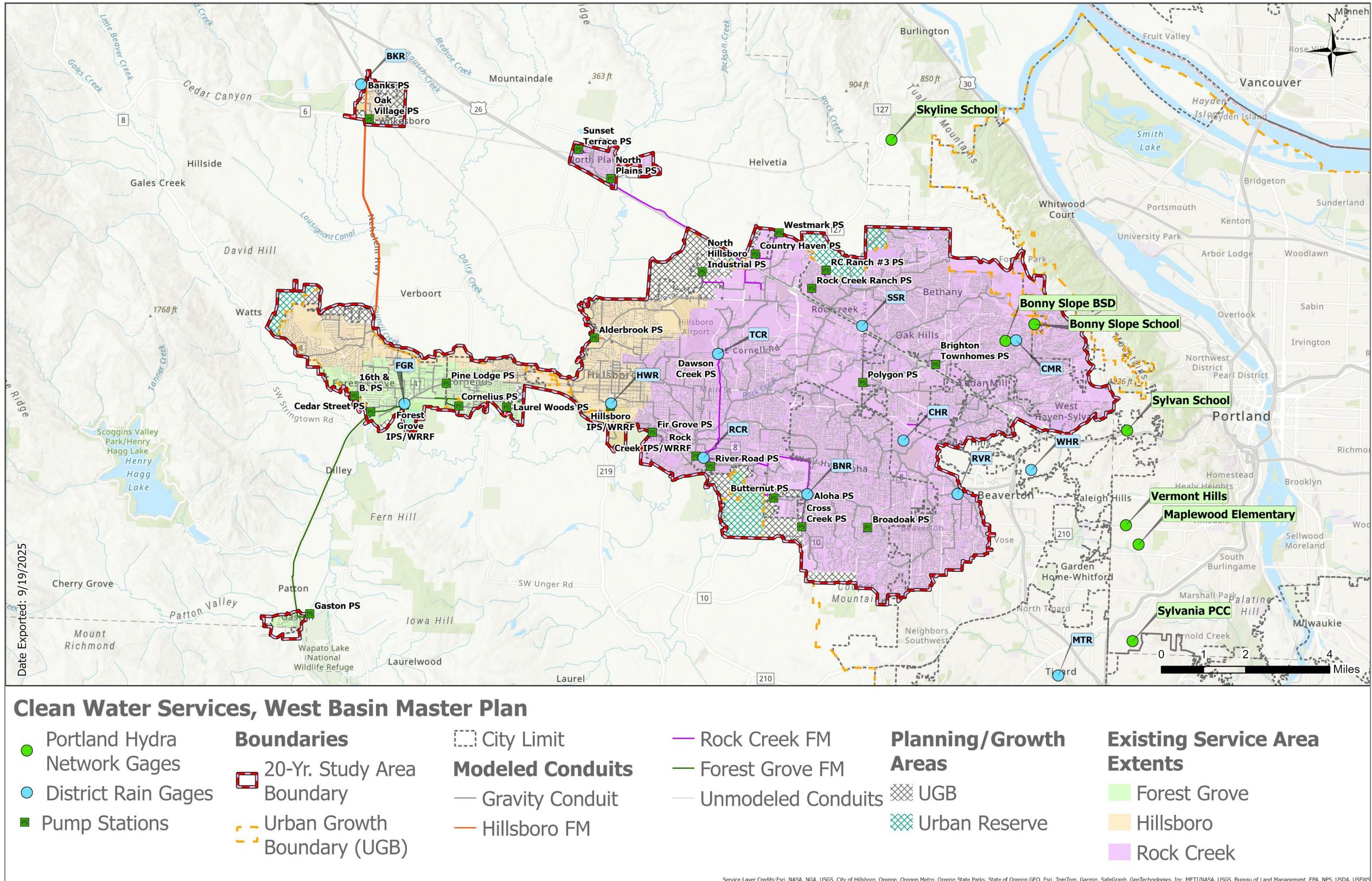
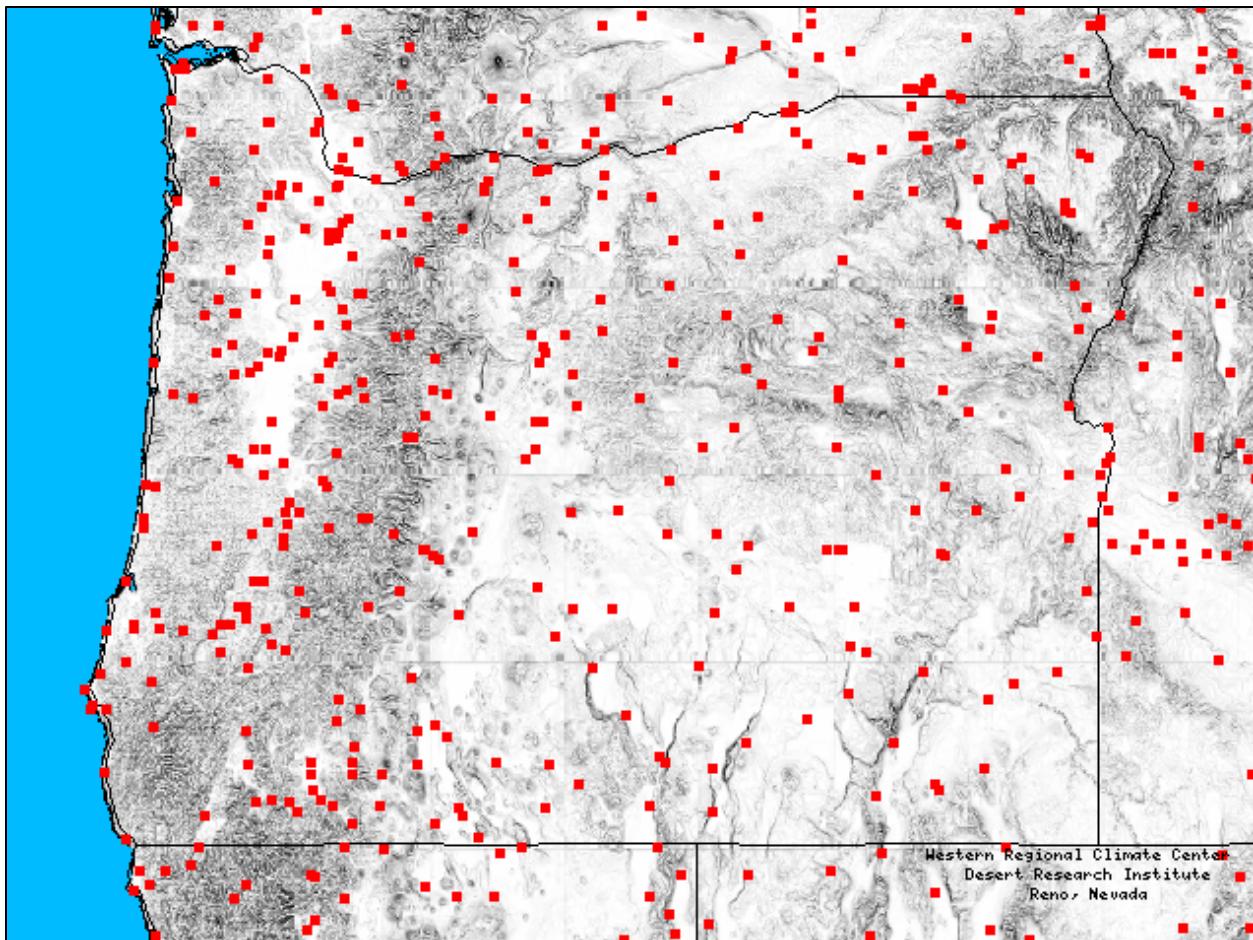


Figure 2.3 District Local Gage and Portland HYDRA Network Gage Locations, in Relation to West Basin Study Area



<https://wrcc.dri.edu/summary/Climsmor.html>

Figure 2.4 WRCC/NOAA Gage Locations Within Oregon and Bordering Regions

Local Gage Correlation and Composite Representative Datasets

Composite rainfall datasets for each local District precipitation gage were developed back to 1970, through best-fit linear correlation with other regional and HYDRA gages. This was achieved by reviewing the relationship between common data for each two-gage combination to define linear best-fit correlations. Relationships with the highest R^2 (i.e. the best linear correlation fit) were selected to backfill missing data periods. The priority of gage data used for the analysis and the details of the data compilation including applied correlations are presented in Appendix 2A. Tier 1 indicates priority gage data, if data is available. Tier 2 and Tier 3 are priorities for backfilling missing data using correlation analysis in order of priority respectively. An example of the correlation between two gages is presented in Figure 2.5. A spreadsheet tool which includes all applicable correlation plots is also referenced in Appendix 2A.

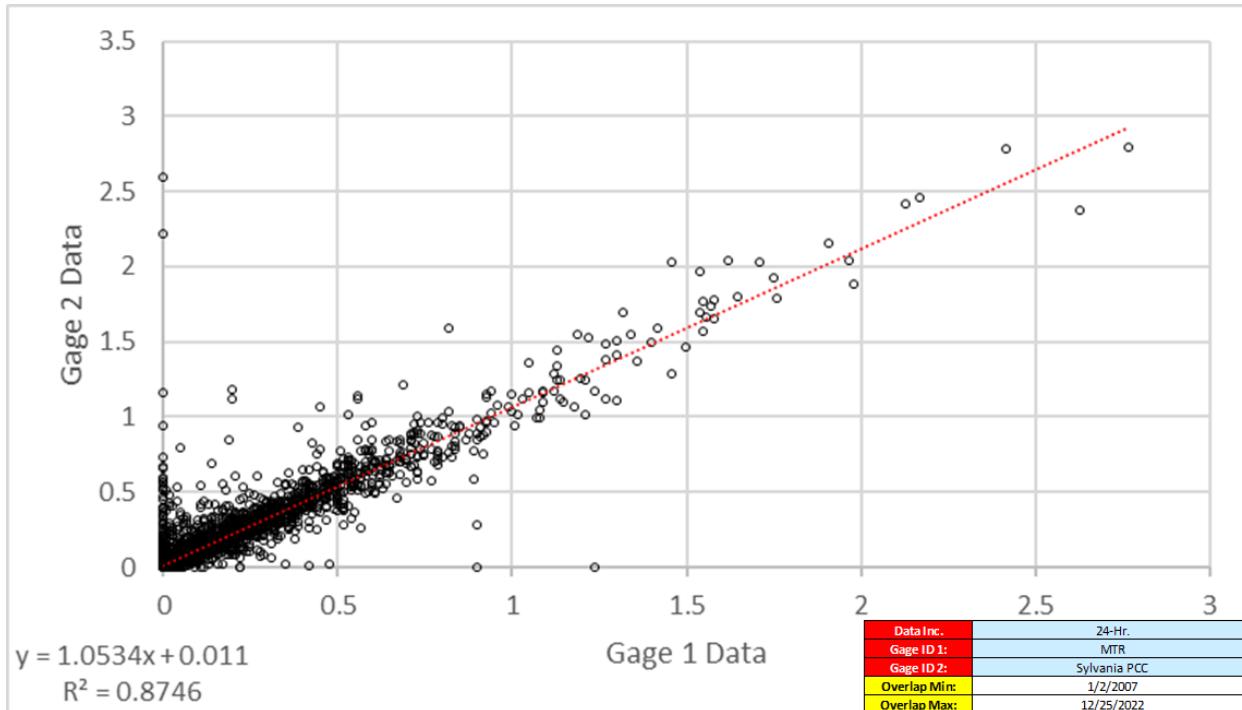


Figure 2.5 Example Correlation for MTR and Sylvania PCC, 24-Hr. Rainfall Duration

2.4.2.2 System Discretization

The system was discretized into individual subbasins to perform flow frequency and model result interpretation. The discretization included a total of 58 individual subbasins (shown in Figure 2.6 and detailed in Appendix 2B, including the East Basin). The subbasins correspond with the flow monitor subbasins, such that they align with model's hydrologic calibration and representative wet weather flow response (illustrated in Figure 2.7). Model rainfall time series (profiles) for subbasins were generated via intersection-based area-weighting of rainfall from the correlated local District gage datasets using the subbasin geometries, and District gage Theissen polygons (shown in Figure 2.8). The number of subbasins for each model basin are as follows:

- Rock Creek (West Basin): 22
- Hillsboro (West Basin): 10
- Forest Grove (West Basin): 6
- Durham/Fanno (East Basin): 20

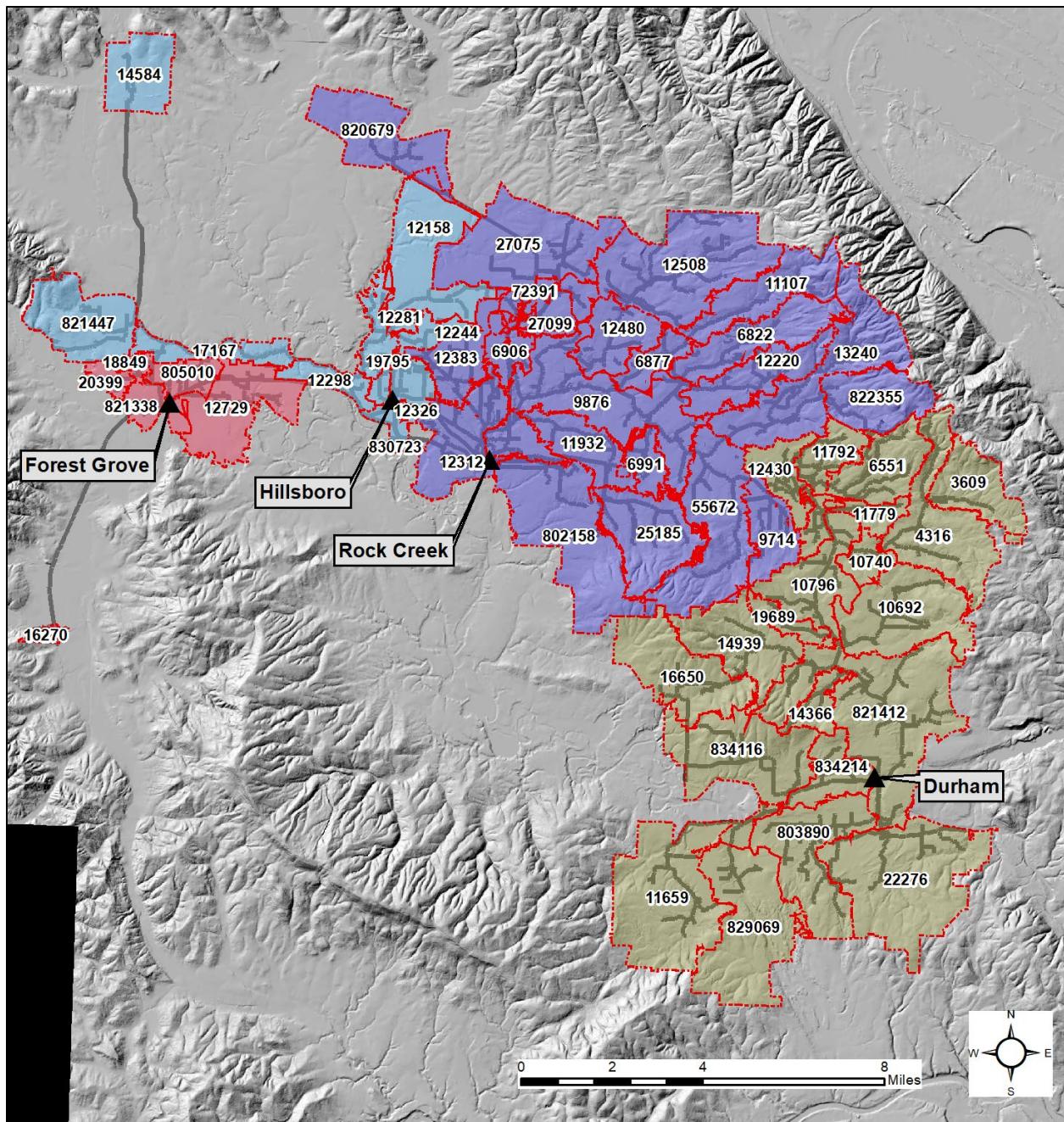


Figure 2.6 System Discretization: Subbasin Boundaries

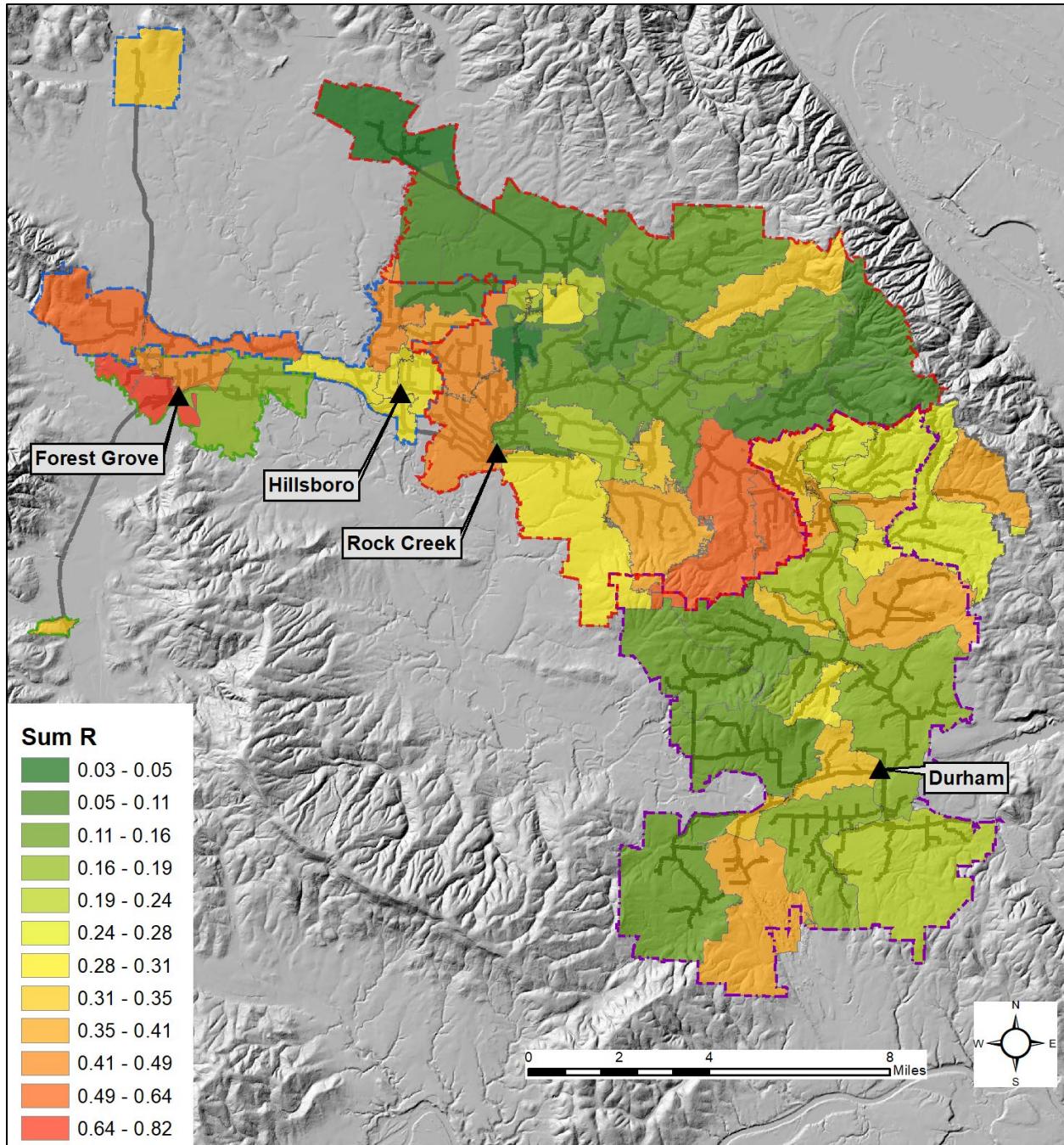


Figure 2.7 Area-weighted Total R Associated with Subbasins

Notes: Total R is the sum of R1, R2, and R3 within the RTK unit hydrograph hydrologic modeling approach. Effectively, Total R is the percentage of rainfall falling on a catchment that enters the conveyance system.

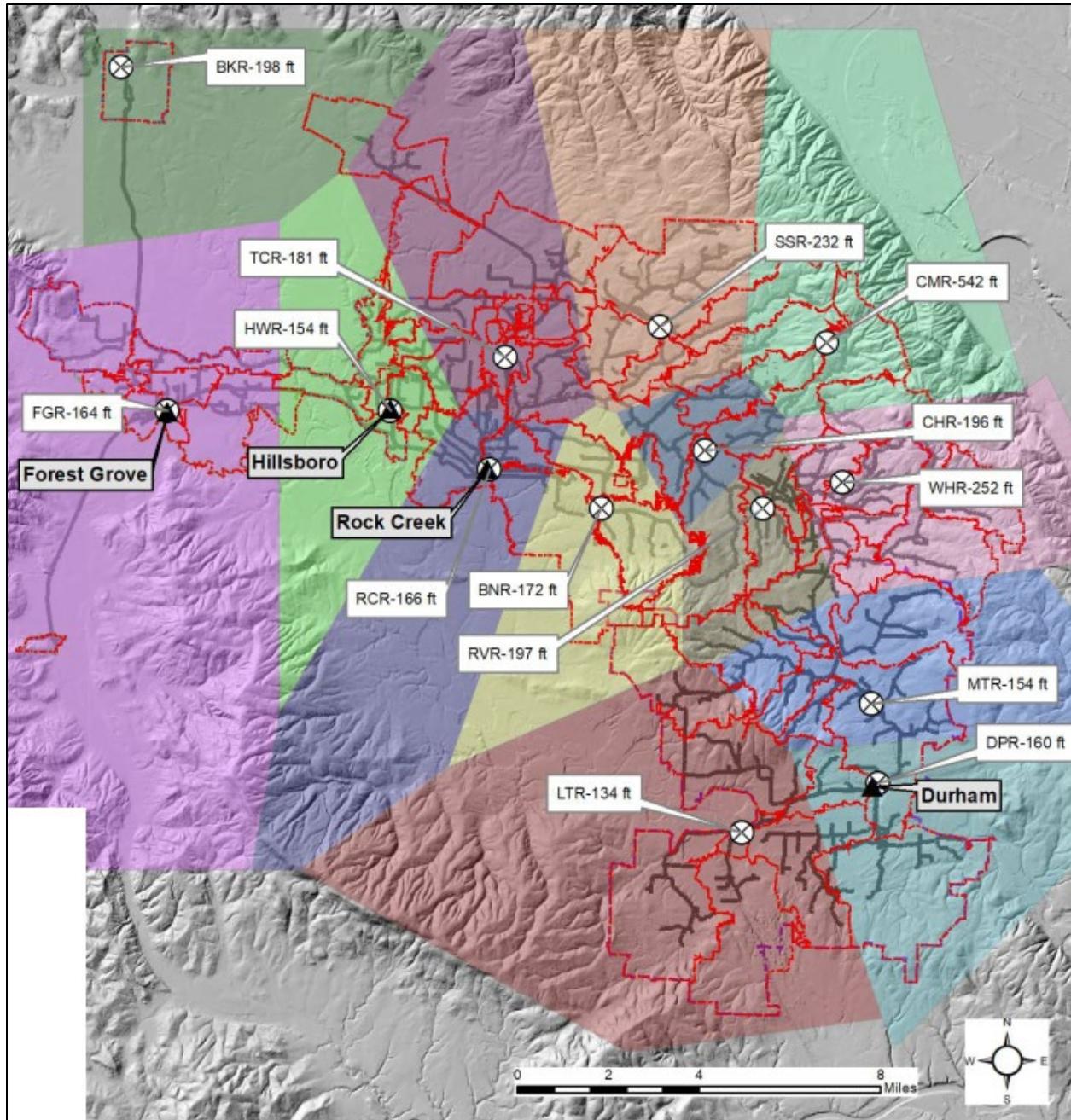


Figure 2.8 Subbasin Boundaries and District Local Theissen Polygons

2.4.2.3 Depth-Duration-Frequency Curve Generation

Depth-Duration-Frequency (DDF) curves are essential tools used within hydrologic analyses to describe the relationship between the accumulated precipitation depth, storm event duration, and the frequency of occurrence (recurrence interval or return period (e.g. a 5-Yr. Storm, 10-Yr. Storm, etc)]. These curves are used to evaluate level of service and risk related to sanitary sewer overflows.

DDF curves were generated for each correlated local District gage dataset, as well as the individual subbasin rainfall profiles at 1, 6, 12, 24, 48 and 96-hour durations, and 2, 5, 10 and 25-year recurrence intervals.

The curves are developed by isolating the depths associated with all rainfall events within the 52-year period and for each duration. The largest event for each year is used to define rainfall frequency. Outlier rainfall years within ± 2 standard deviations were removed and assumed to have erroneous or skewed rainfall accumulation.

After the removal of outlier events, recurrence intervals for each duration are calculated. Two different methodologies were utilized for calculating the recurrence interval from the datasets: 'return period', and 'percent rank', as shown below:

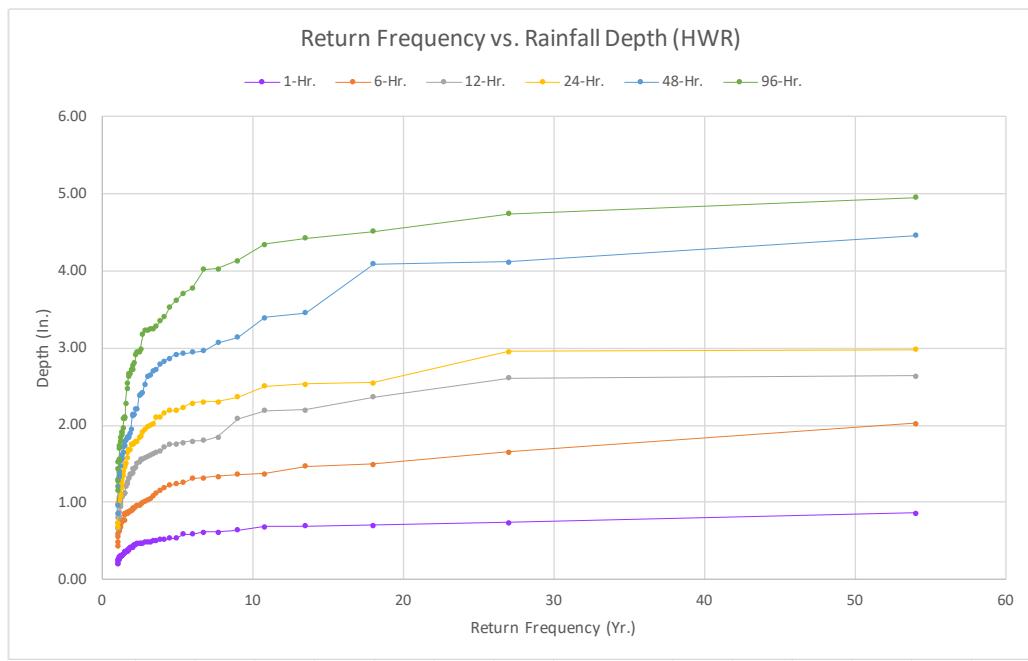
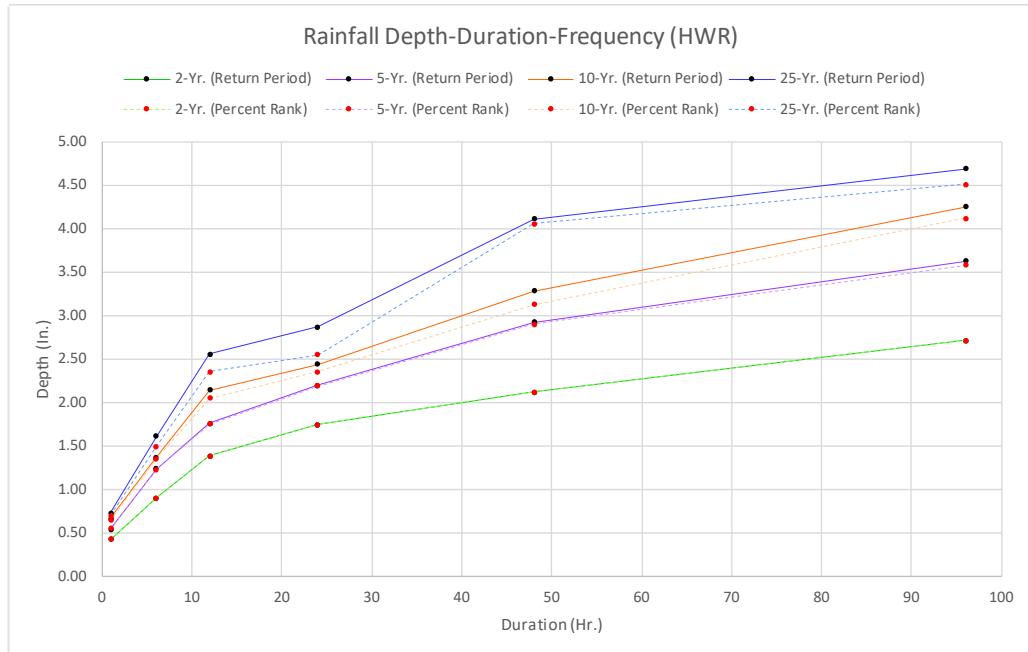
- (Standard) Return Period: $\frac{N+1}{M}$
 - » N : Number of years on record.
 - » M : Rank of observed occurrences, when arranged in descending order.
- (1 –) Percent Rank: $1 - \frac{(f_b + \frac{1}{2}f_w)}{N}$
 - » f_b : Frequency below; the number of occurrences less than the value of interest.
 - » f_w : Frequency within; the number of occurrences equal to the value of interest.
 - » N : The number of observed occurrences within the dataset being ranked.

The exact conversion between these two methods is a function of the size of the dataset being analyzed, and may be generalized as follows:

- 5-Yr. Return Period ≈ 0.2 Percent Rank (80th Percentile)
- 10-Yr. Return Period ≈ 0.1 Percent Rank (90th Percentile)

An Example DDF curve is provided in Figure 2.9. Appendix 2A and Appendix 2B contain DDF curves, as well as relevant details, for each correlated/backfilled local District gage dataset, and individual subbasin rainfall profiles, respectively. A spreadsheet tool with the catalog of curves is referenced in the appendices.

Return Period							Percent Rank							
Return Period	HWR						Percent Rank	HWR						
	Duration (Hr.)							Duration (Hr.)						
	1	6	12	24	48	96		1	6	12	24	48	96	
Depth (In.)							Depth (In.)							
2	0.43	0.91	1.39	1.75	2.12	2.72	2.00	0.43	0.91	1.39	1.75	2.12	2.72	
5	0.55	1.24	1.77	2.20	2.92	3.63	5.00	0.55	1.23	1.76	2.19	2.90	3.59	
10	0.67	1.37	2.15	2.45	3.28	4.26	10.00	0.64	1.36	2.05	2.36	3.13	4.12	
25	0.73	1.62	2.56	2.87	4.11	4.69	25.00	0.70	1.50	2.36	2.55	4.06	4.52	



Return Period							Percent Rank							
Return Period	HWR						Percent Rank	HWR						
	Duration (Hr.)							Duration (Hr.)						
	1	6	12	24	48	96		1	6	12	24	48	96	
Depth (In.)							Depth (In.)							
2	0.43	0.91	1.39	1.75	2.12	2.72	2.00	0.43	0.91	1.39	1.75	2.12	2.72	
5	0.55	1.24	1.77	2.20	2.92	3.63	5.00	0.55	1.23	1.76	2.19	2.90	3.59	
10	0.67	1.37	2.15	2.45	3.28	4.26	10.00	0.64	1.36	2.05	2.36	3.13	4.12	
25	0.73	1.62	2.56	2.87	4.11	4.69	25.00	0.70	1.50	2.36	2.55	4.06	4.52	

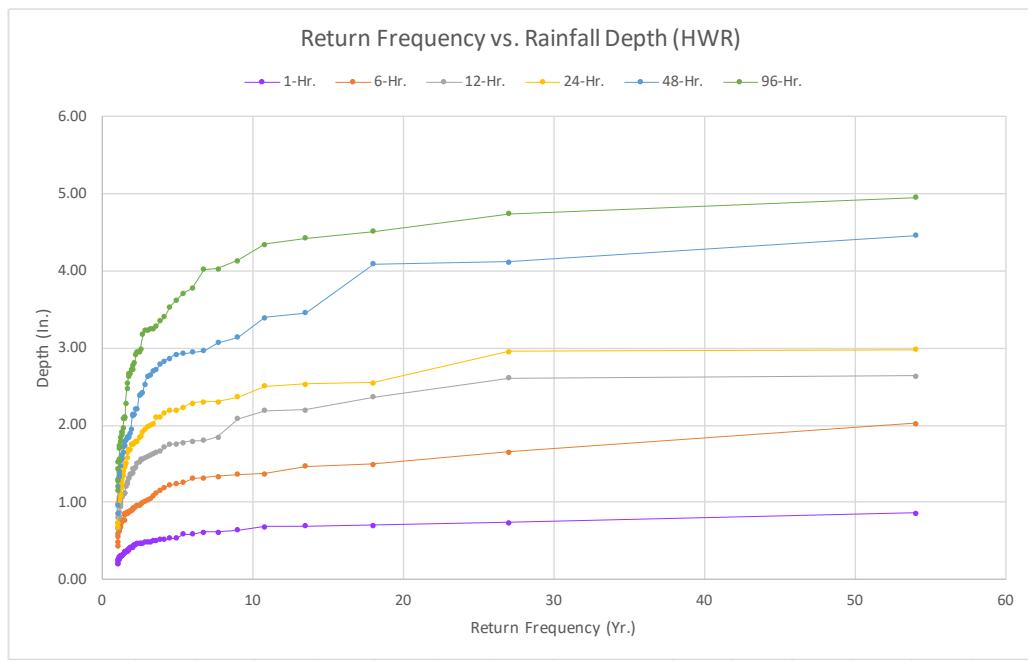
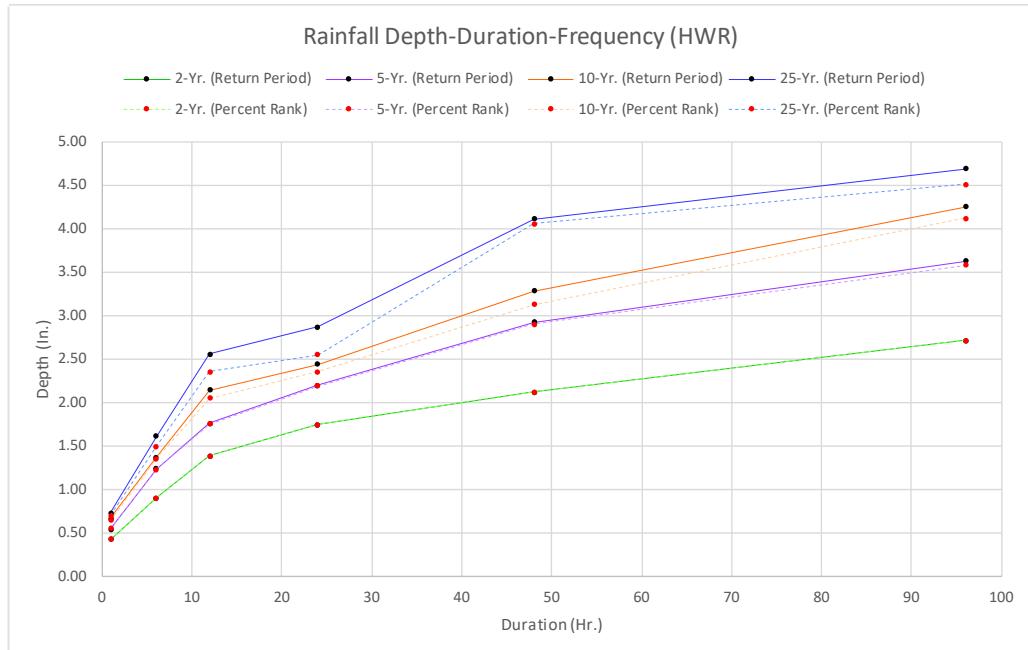


Figure 2.9 Example Depth-Duration-Frequency Curve Output (no curve smoothing, curve smooth also available in spreadsheet tool)

2.4.2.4 Event Selection for Modeling System Response

The Environmental Protection Agency's (EPA) Sanitary Sewer Overflow Analysis and Planning (SSOAP) Toolbox was utilized to extract and characterize all events for each correlated District gage dataset. The list of events was filtered down to those of representative characteristics that would be of more interest, from a maximum peak intensity, total volume, and recurrence interval perspective, as potential design storm candidates. The number and ranges of events associated with the comprehensive and filtered lists, for each gage, are detailed in Table 2.4.

Table 2.4 Candidate Design Storm Event Ranges in Duration (hour, hr), Total Volume (inches, in), and Peak Intensity (inches/hour, in/hr)

Gage ID	Tier 1 (Comprehensive From SSOAP)				Tier 2 (Filtered From SSOAP)			
	Events (#)	Duration Range (Hr.)	Total Volume Range (In.)	Peak Intensity Range (In./Hr.)	Events (#)	Duration Range (Hr.)	Total Volume Range (In.)	Peak Intensity Range (In./Hr.)
BKR	6878	1—123	0—6.47	0—1.46	118	1—123	0.59—6.47	0.29—1.46
BNR	7410	1—230	0—5.22	0—1.11	133	3—230	0.42—5.22	0.02—1.11
CMR	7602	1—221	0—5.26	0—1.27	134	1—221	0.44—5.26	0.03—1.27
DPR	7374	1—110	0—6.11	0—1.33	119	3—110	0.55—6.11	0.27—1.33
FGR	7422	1—131	0—5.85	0—1.27	110	2—131	0.48—5.85	0.08—1.27
HWR	7342	1—238	0—5.49	0—1.22	133	1—238	0.45—5.49	0.03—1.22
LTR ¹	6481	1—210	0—4.8	0—4.57	168	1—210	0.43—4.8	0.03—4.57
MTR ¹	6613	1—328	0—4.91	0—4.91	175	1—328	0.4—4.91	0.03—4.91
RCR	6632	1—238	0—6.33	0—1.45	149	1—238	0.49—6.33	0.06—1.45
RVR	7522	1—110	0—6.17	0—1.35	123	3—110	0.55—6.17	0.04—1.35
SSR	7531	1—118	0—5.5	0—1.18	132	3—118	0.49—5.5	0.04—1.18
TCR	7516	1—115	0—5.49	0—1.17	128	2—115	0.42—5.49	0.25—1.17
WHR	7507	1—110	0—6.7	0—1.48	138	3—110	0.6—6.7	0.24—1.48

¹ 4-5 inches per hour peak intensity represents errors in data accumulation.

Statistical analysis (data partitioning) of 328 events was performed using the JMP Statistical Discovery model to characterize 31 representative events and rainfall characteristics to predict rainfall frequency (see Figure 2.10 for characteristics with strong predictive benefits, also see Appendix 2C for statistical analysis graphics). Two representative events with unique characteristics were identified for subsequent modeling and system response review for each duration and frequency. These two representative events were chosen to typify a longer-duration/higher-volume storm and a shorter-duration/higher-intensity storm with potential to generate similar flow response.

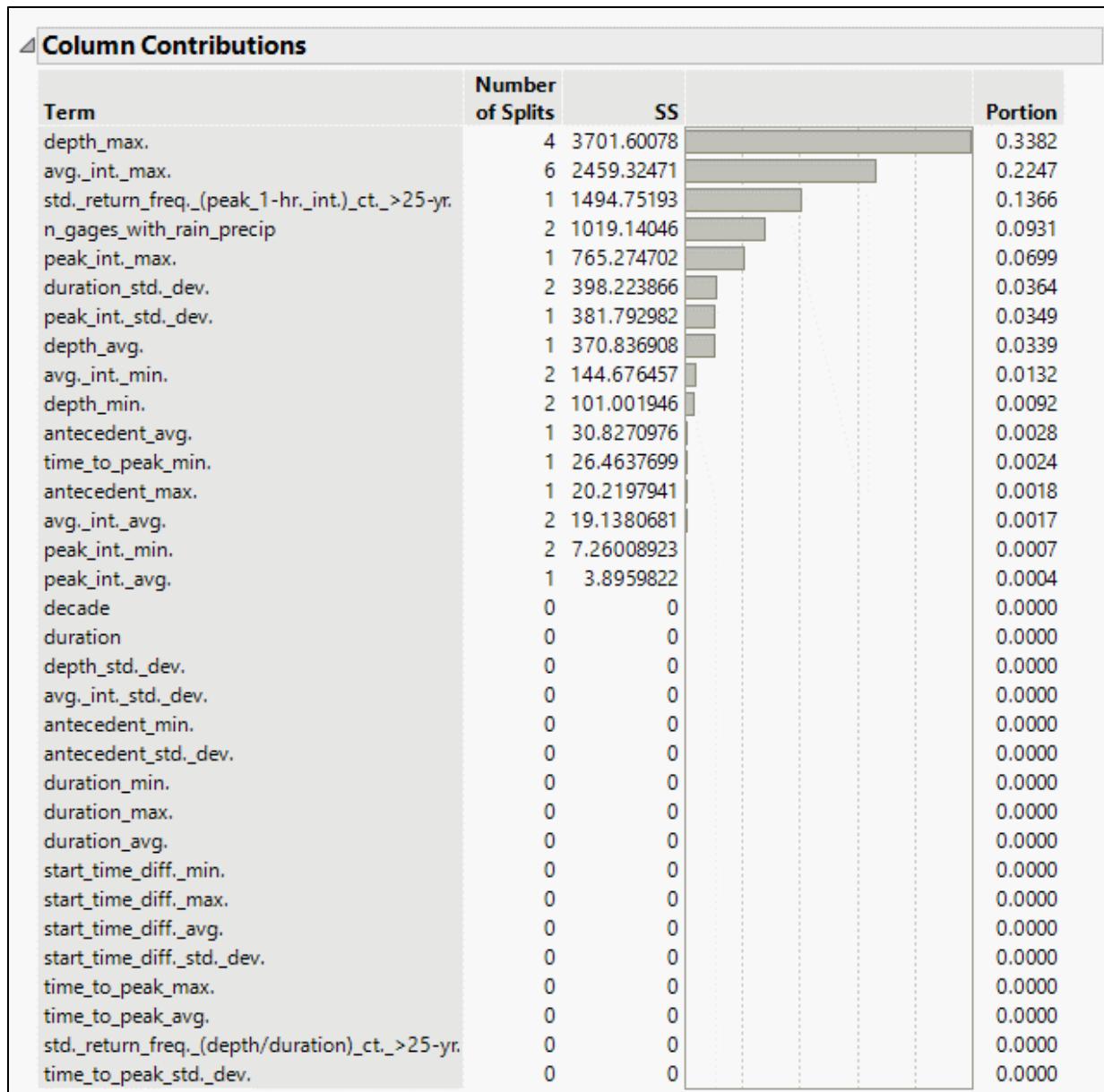


Figure 2.10 JMP Dependent Input Rainfall Statistics Contributing to Rainfall Frequency Prediction (higher portion/SS indicates more influence on prediction of flow response, see Appendix 2C)

2.4.2.5 Event Modeling and Flow Frequency

Each of the characteristic storm events were modeled for system flow response by discretized subbasin using spatially varied rainfall. The model results were reported for flow response and subsequently a percent-ranked flow frequency was developed to determine both the magnitude of response related to each storm, and the variability of system response with respect to the library of spatially varied storms. An example of the flow or response frequency across multiple subbasins is provided in Figure 2.11.

From this flow frequency, a refined statistical analysis (data partition) was performed within JMP to determine the rainfall characteristics associated with predicting system flow response. Ten distinct families of storms and system response were selected from the statistical analysis. Of these, fifteen storms were isolated and analyzed as candidate design storm events.

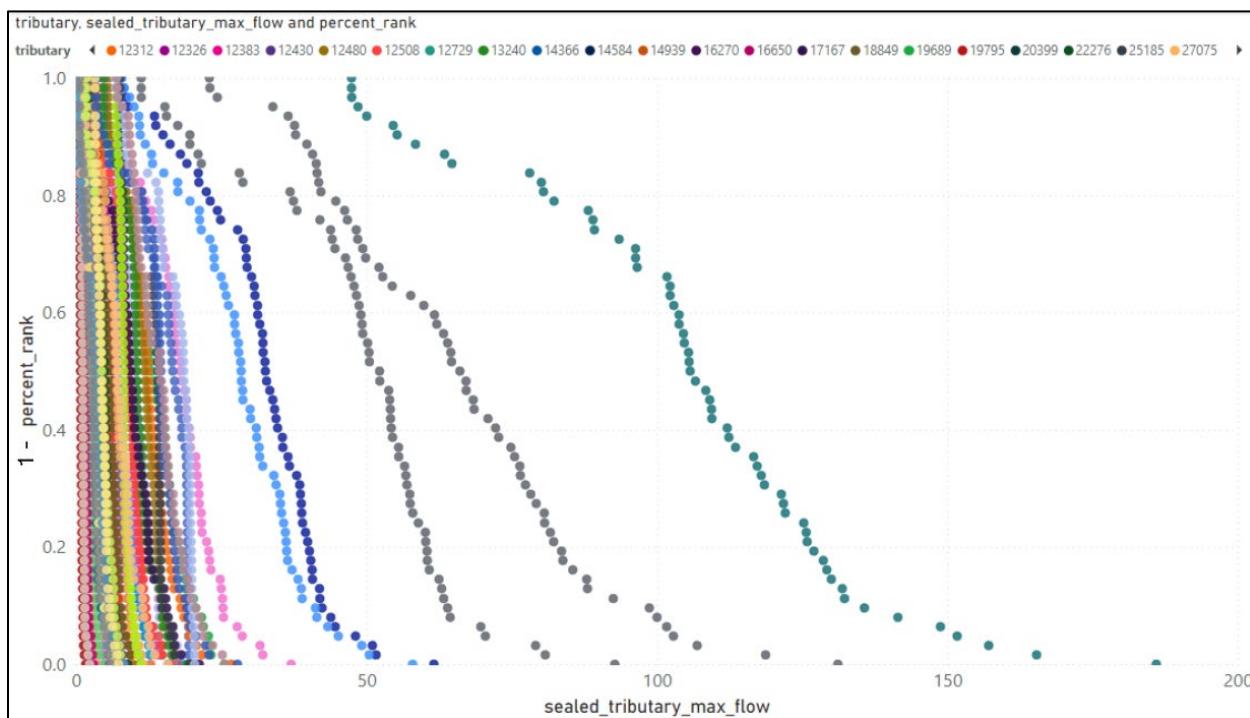


Figure 2.11 Flow Frequencies and Flow Response by Subbasin

2.4.2.6 Design Storm Selection

The following criteria were discussed with District staff as part of the design storm event selection from the fifteen storms in each treatment/collection basin:

- Uniform or variable system response across each treatment/collection basin.
 - » Uniform storm events were preferred to demonstrate the cumulative flow impact in the downstream collection and treatment systems.
 - » Higher intensity storm events were preferred to demonstrate local capacity deficiencies.
- Minimum precipitation frequency of 5-year return interval (required).
- Average flow response frequency between 5-year and 10-year return intervals (preferred).
- Minimum flow response frequency between 5-year and 10-year return intervals (considered as conservative standard and high level of service).
- Visual review of candidate storm event impact for each treatment/collection basin against known areas of limited capacity.

Box-and-whisker plots for each treatment/collection basin were used to demonstrate uniform or varied response across the subbasins and differentiate between the fifteen candidate storms. The plots for the Rock Creek, Hillsboro, and Forest Grove Basins are presented in Figure 2.12, Figure 2.13, and Figure 2.14, respectively. The three storms that most closely reflected the selection criteria are highlighted by event number in each plot.

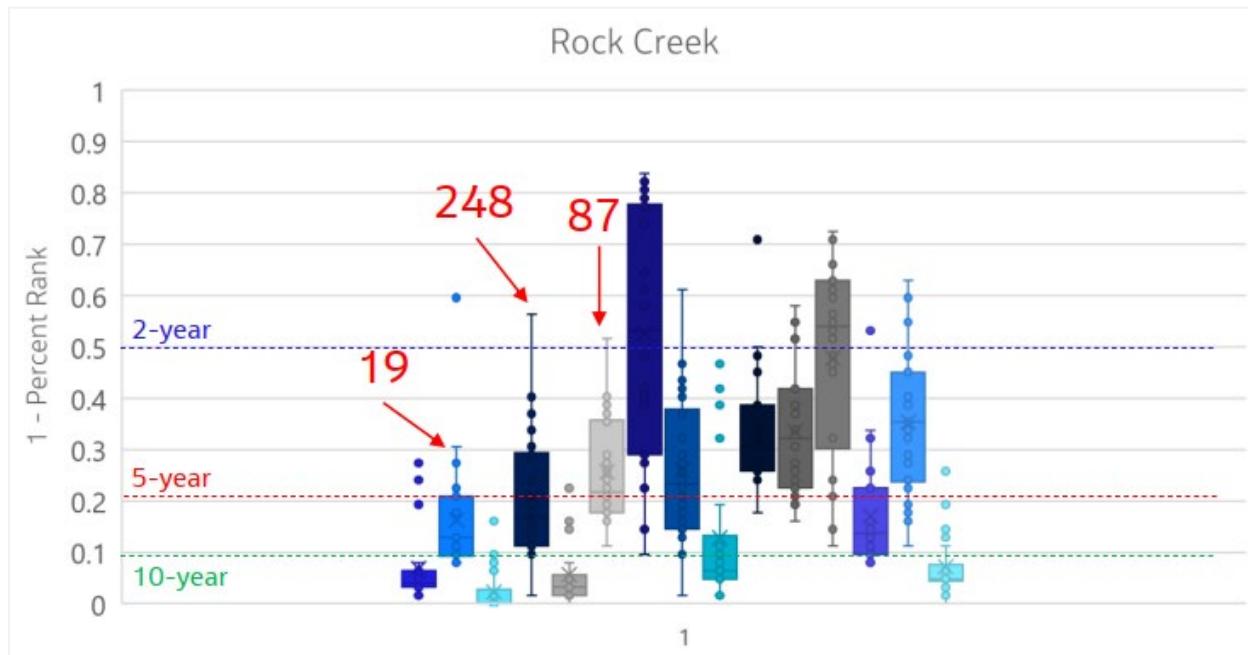


Figure 2.12 Spatially Varied Candidate Design Storms, Rock Creek Basin, Flow Frequency by Subbasin Box-and-Whisker

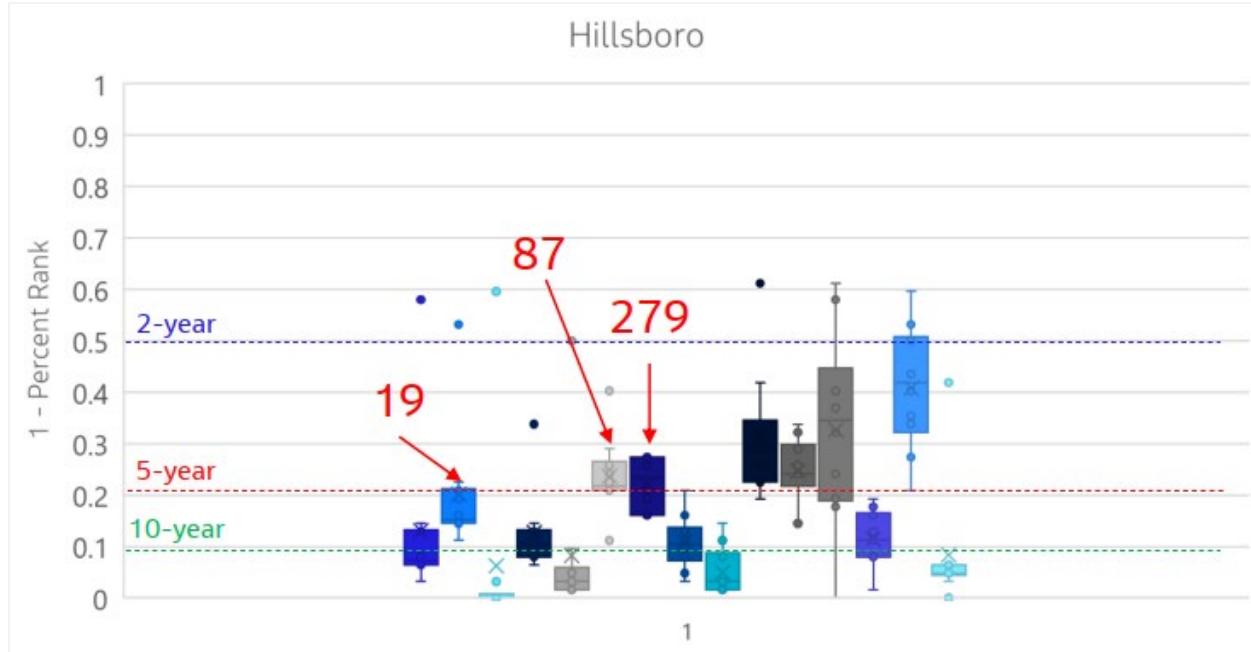


Figure 2.13 Spatially Varied Candidate Design Storms, Hillsboro Basin, Flow Frequency by Subbasin Box-and-Whisker

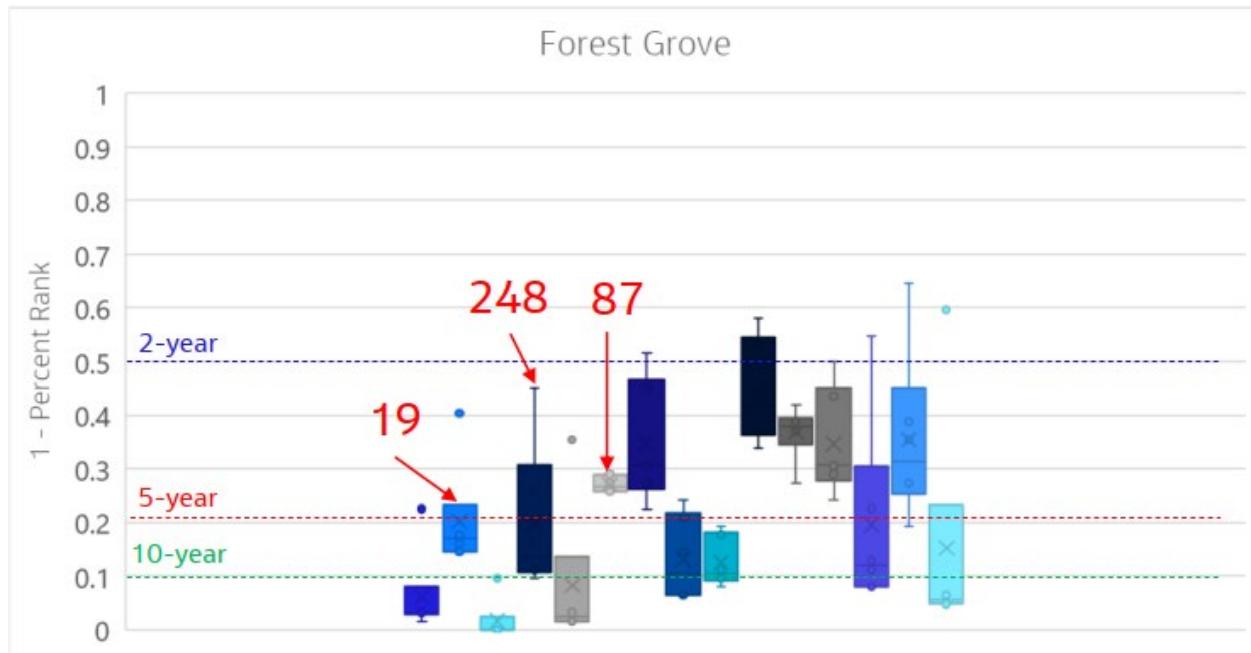


Figure 2.14 Spatially Varied Candidate Design Storms, Hillsboro Basin, Flow Frequency by Subbasin Box-and-Whisker

Uniform (i.e. not spatially varied) rainfall profiles of the final three candidate storms in each basin were then generated, and re-run through the model. Similarly, subbasin flow frequency box-and-whisker plots were generated for these uniform versions of the candidate design storms and compared to the previous 5-year design storm. These plots for the Rock Creek, Hillsboro, Forest Grove, Basins are presented in Figure 2.15, Figure 2.18, and Figure 2.21 respectively. The rainfall accumulation for each of the candidate storm events and the historic design storm is presented in Figure 2.16, Figure 2.19, and Figure 2.22 respectively. The inflow hydrograph at each treatment facility for each of the final candidate storm events and the historic design storm is presented in Figure 2.17, Figure 2.20, and Figure 2.23 respectively.

Additionally details on the design storm selection including capacity mapping for each candidate storm is provided in Appendix 2D.

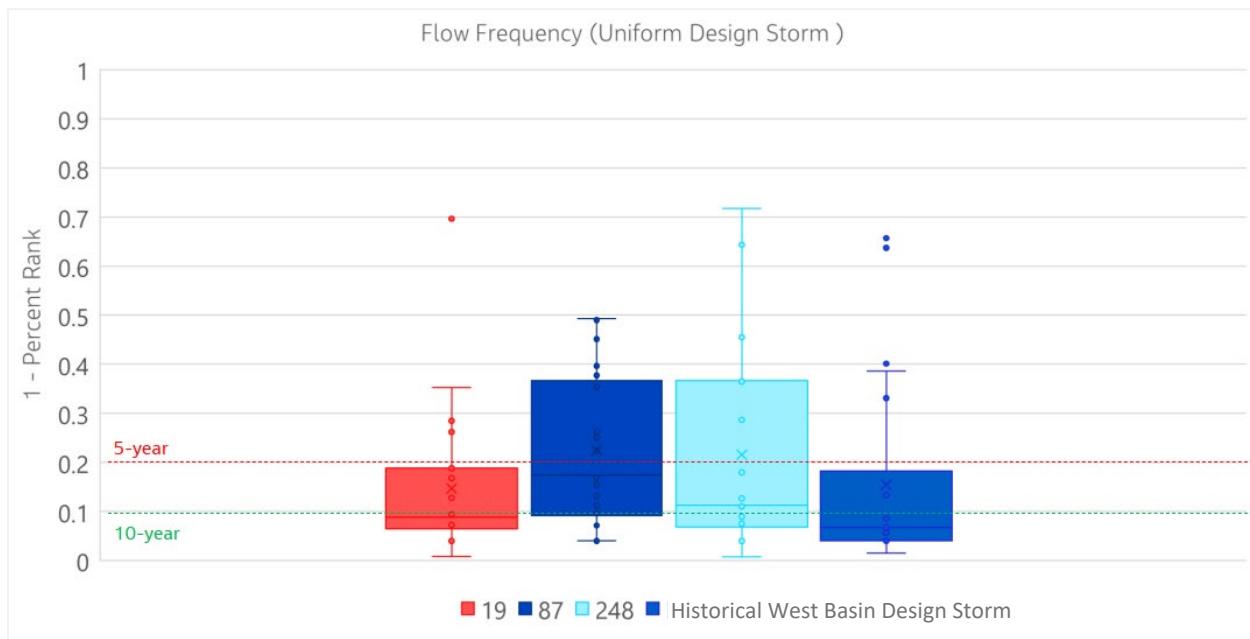


Figure 2.15 Uniform Candidate Design Storms and Historic Design Storm, Rock Creek Basin, Flow Frequency by Subbasin, Box-and-Whisker

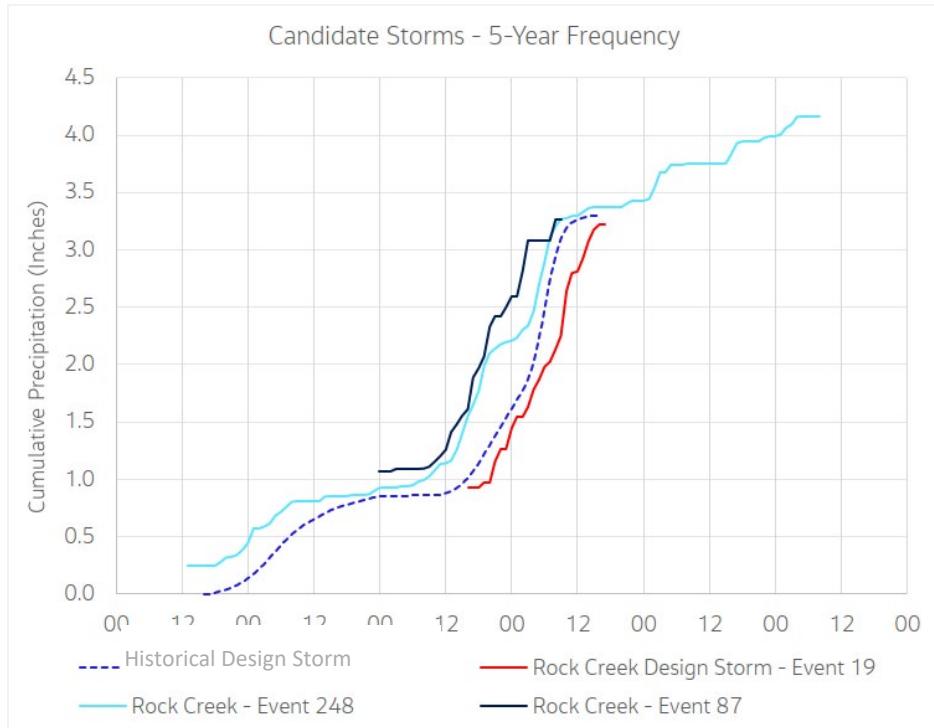


Figure 2.16 Rock Creek Basin, Uniform Candidate Design Storm Cumulative Precipitation

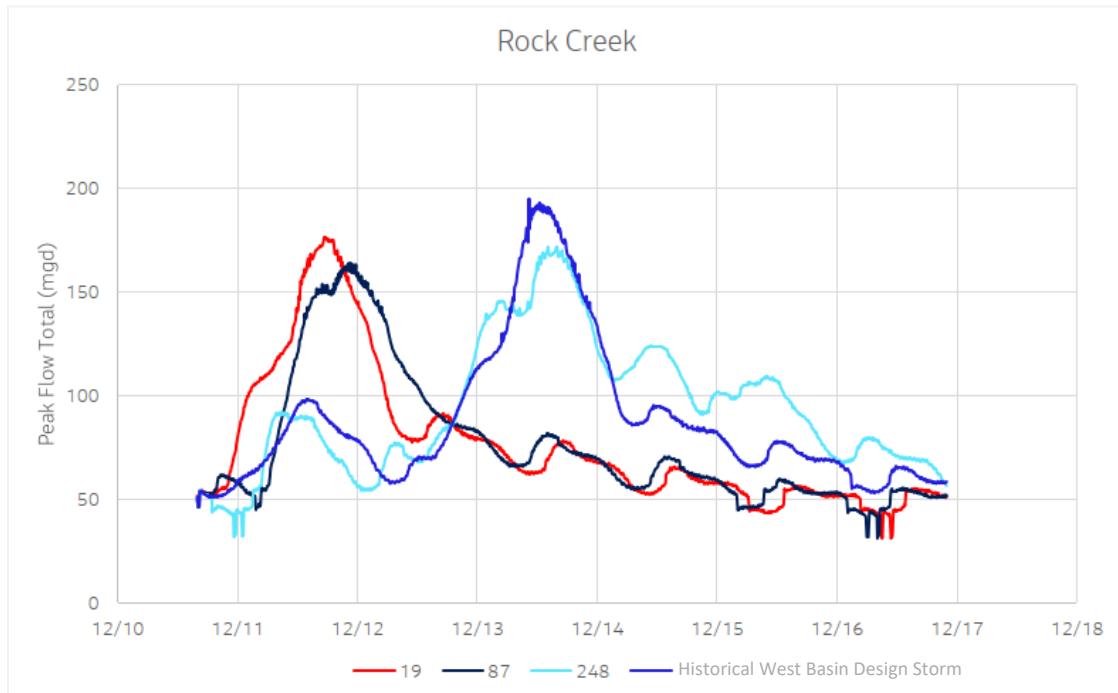


Figure 2.17 Rock Creek Basin, Uniform Candidate Design Storm Inflow Hydrograph

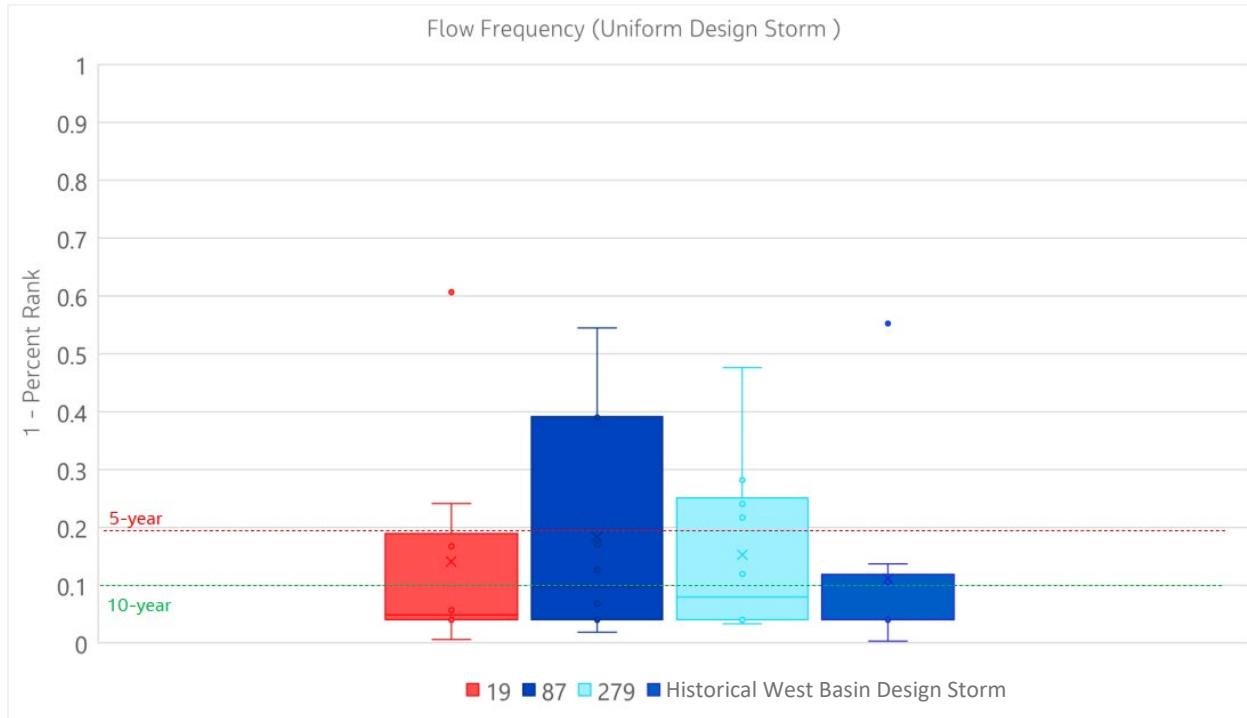


Figure 2.18 Uniform Candidate Design Storms and Historic Design Storm, Hillsboro Basin, Flow Frequency by Subbasin, Box-and-Whisker

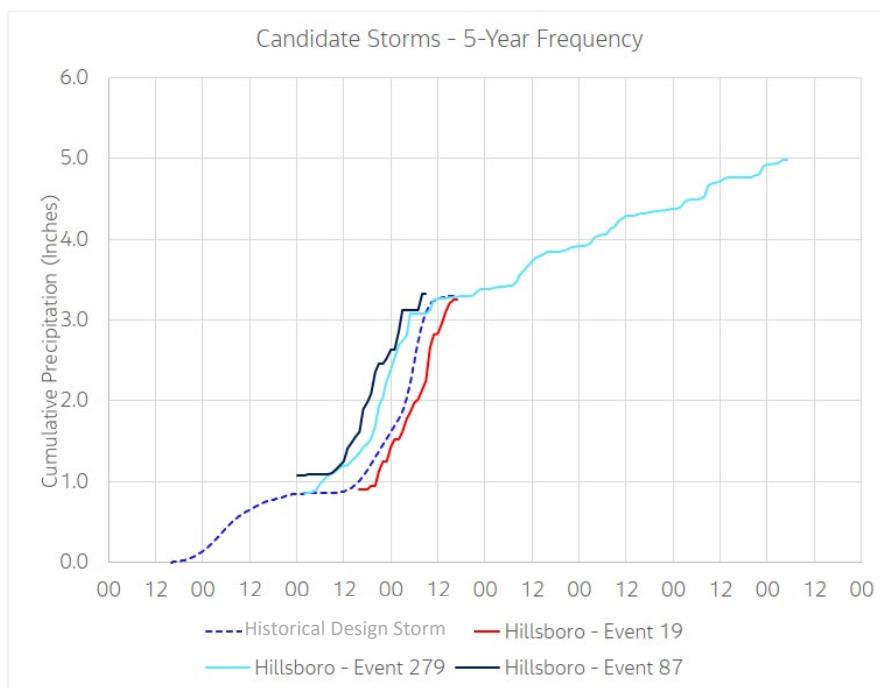


Figure 2.19 Hillsboro Basin, Uniform Candidate Design Storm Cumulative Precipitation

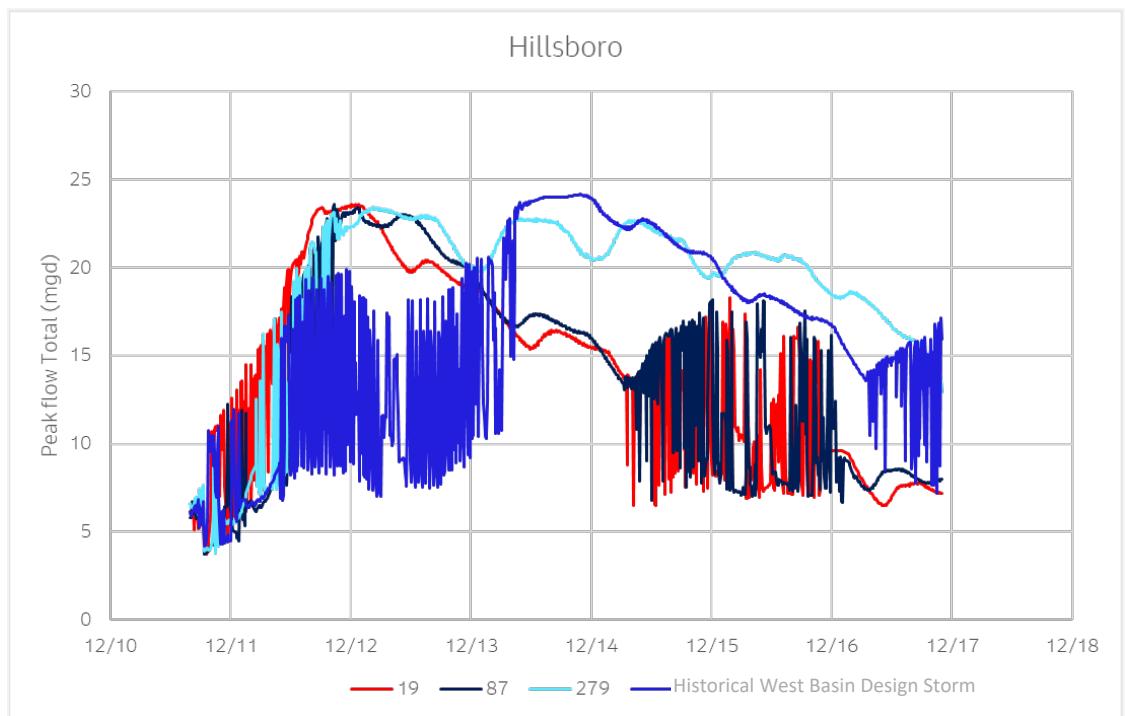


Figure 2.20 Hillsboro Basin, Uniform Candidate Design Storm Cumulative Inflow Hydrograph

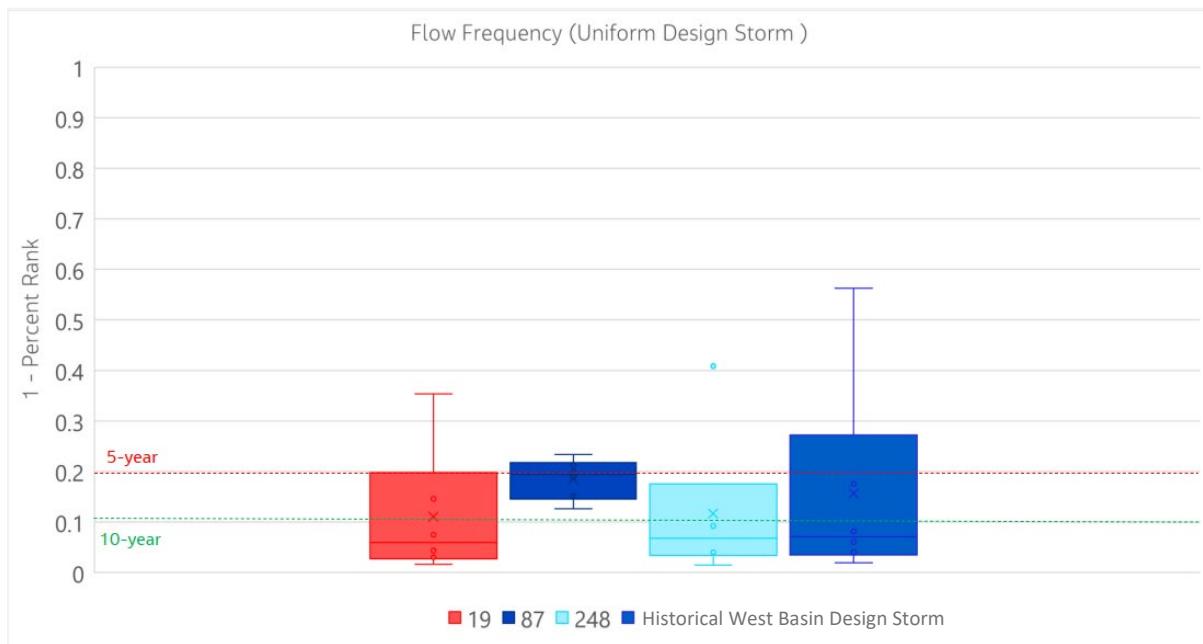


Figure 2.21 Uniform Candidate Design Storms and Historic Design Storm, Forest Grove Basin, Flow Frequency by Subbasin

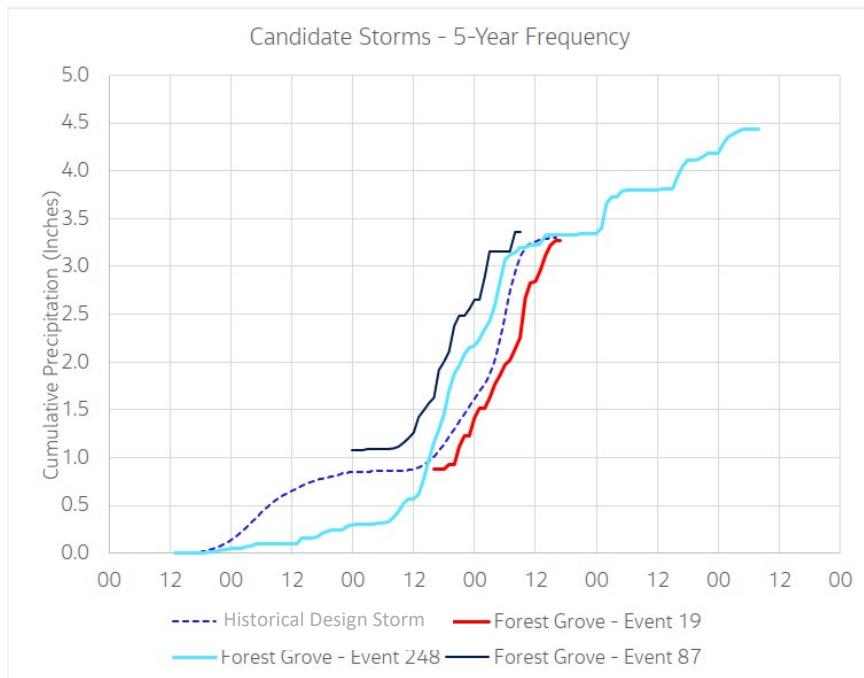


Figure 2.22 Forest Grove Basin, Uniform Candidate Design Storm Cumulative Precipitation

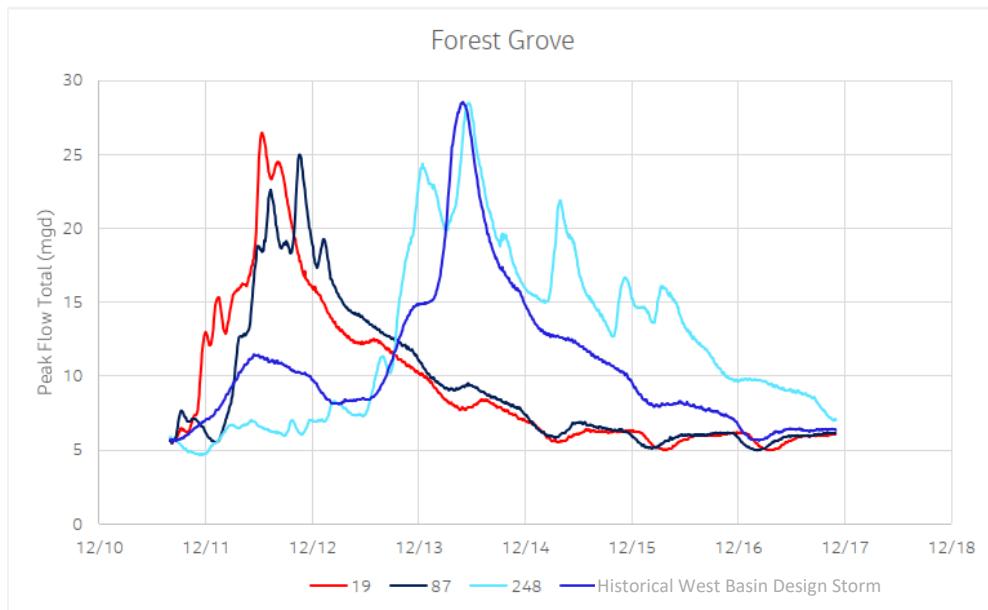


Figure 2.23 Forest Grove Basin, Uniform Candidate Design Storm Inflow Hydrograph

In coordination with District staff, the storm selection at the end of this analysis for each treatment/collection basin was as follows:

- Rock Creek: Utilize Existing/Historic Design Storm (1.2-inch maximum 6-hour accumulation, 2.4-inch maximum 24-hour accumulation, peak hour intensity = 0.3 inches per hour)
 - » The historic design storm provides more uniform risk across the subbasins for beneficial analysis for cumulative impact to downstream infrastructure.
 - » The selected storm event satisfies the requirement of 5-year precipitation frequency based on 52-year precipitation record.
 - » The selected storm event satisfies the 5-year to 10-year flow frequency in most subbasins (high level of service).
 - » The selected storm event generates known deficiencies through critical infrastructure including the Beaverton Creek Trunk and tributary trunk system.
- Hillsboro: Implement Storm Event 19 (1.0-inch maximum 6-hour accumulation, 2.4-inch maximum 24-hour accumulation, peak hour intensity = 0.4 inches per hour)
 - » The historic design storm, originally evaluated for the Rock Creek Basin generates a conservative level of service when applied to the Hillsboro Basin, typically greater than 10-year flow frequency.
 - » The selected storm event (19) satisfies the requirement of 5-year precipitation frequency based on 52-year precipitation record.
 - » The selected storm event satisfies the 5-year to 10-year flow frequency in most subbasins (high level of service without being overly conservative).
 - » The selected storm event generates known deficiencies through critical infrastructure including the Lower Hillsboro Trunk.
- Forest Grove: Implement Storm Event 19 (1.0-inch maximum 6-hour accumulation, 2.4-inch maximum 24-hour accumulation, peak hour intensity = 0.4 inches per hour)
 - » The historic design storm, originally evaluated for the Rock Creek Basin, generates a similar level of service to storm event 19.
 - » Storm event 19 was selected to maintain consistency with the Hillsboro Basin. The planning analysis includes options to realign the Hillsboro and Forest Grove Basins and a common design storm with a high level of service provides consistency for the analysis.
 - » The selected storm event (19) satisfies the requirement of 5-year precipitation frequency based on 52-year precipitation record.
 - » The selected storm event satisfies the 5-year to 10-year flow frequency in most subbasins (high level of service without being overly conservative).
 - » The selected storm event generates known deficiencies through critical infrastructure including wet weather volume impacts at the Forest Grove Water Resource Recovery Facility (WRRF).

In addition to the selected 5-year design storms, factors to adjust precipitation depth for a 2-year, 10-year, and 25-year frequency storm were developed to perform sensitivity analysis to understand the severity of system capacity deficiencies and prioritize system improvements. The full set of design storms at varied frequencies were provided in a spreadsheet tool (see Appendix 2E).

2.5 Climate Sensitivity

2.5.1 Background

This section documents the expected impacts and the recommended approach to address climate change in the Forest Grove, Hillsboro, and Rock Creek Basins by applying 50- year climate intensification factors to the selected design storm events. The climate intensification factors were used to consider increases in accumulated depth, changes to frequency of large storm events, and increased peak hour rainfall intensity.

The District is performing additional work to evaluate temperature and rainfall impacts of climate change that will be used to update climate intensification factors and assumptions for future work. This additional work includes a Climate Change Feasibility Study (Carollo, 2024-2025), participation in a Climate Change Downscaling Project for Washington County, and on-going internal work to define a Climate Action Plan Roadmap.

2.5.2 Climate Change Impacts in the Willamette Valley

The state of Oregon has two local resources for climate change related information and downscaled projections, including:

- Oregon Climate Change Research Institute (OCCRI), which produces the Oregon Climate Assessment Report (OCAR). The OCCRI, created by the state legislature (House Bill 3543, 2007), includes a small staff housed at Oregon State University (OSU) and a larger network of more than 150 researchers both inside and outside the state of Oregon. The OCCRI's intent is to prepare the Northwest United States by building a climate knowledge network, inform communities, and advance the understanding of regional climate, impacts, and adaptation.
- Climate Impacts Research Consortium (CIRC), which provides regular updates on climate science and impacts for Oregon, Washington, Idaho, and western Montana. The CIRC team is funded by the National Oceanic and Atmospheric Administration (NOAA) and is based at OSU and hosted by the OCCRI and the College of Earth, Ocean, and Atmospheric Sciences.

2.5.2.1 Precipitation Events

The fourth OCAR, completed in 2019, provides a comprehensive assessment of the state of climate change science, summarizing physical, biological, and social dimensions. The first chapter summarizes the state of knowledge of physical changes in climate and hydrology, focusing on the period since the previous (third) OCAR completed in 2017 (Dalton et al. 2017). The second chapter of the third OCAR covers the impacts and is, verbatim, the Northwest chapter of the Fourth National Climate Assessment (NCA4) which was released by the federal government November 23, 2018. The findings relative to annual precipitation and extreme events are as follows:

- Total annual precipitation is not projected to change significantly, showing:
 - » Slight increases in winter precipitation (December to February).
 - » Slight decreases in summer precipitation (June to August).

- Extreme events are projected to increase by ~10 percent in frequency in western Oregon by mid-century. Additionally, the frequency of the "wettest day in 100 days" is expected to increase by ~6 percent for areas west of the Cascades.

Unlike the certainty in temperature projections for the region, precipitation projections for the Pacific Northwest do not have a high degree of confidence. Because there is only low to moderate confidence in these estimated projections (indicating a high level of uncertainty), it is not recommended to directly apply the projected changes to historical data. In these circumstances, it is recommended to perform a stress test of the system to evaluate performance under a range of volume and intensity levels to identify system deficiencies and potential improvement upsizing.

The conveyance planning efforts use the following criteria related to the selected design storm events and adjustments to these events for climate intensification:

- The 5-year design storm, as documented in Section 2.3 of this TM, is used for design purposes, to define deficiencies and provide preliminary sizing of improvements.
- A 5-year sensitivity storm (design storm+, DS+) is used to understand additional system risk from climate intensification associated with increased storm frequency and may be considered for oversizing system improvements. The 5-year sensitivity storm utilizes the design storm distribution with an increased depth to account for 10-percent frequency change by 2050.
- An additional sensitivity storm (design storm + intensity, DS+INT) is used to understand additional system risk associated with increased storm intensity and may be considered for oversizing system improvements. The additional sensitivity storm increases the maximum hour intensity of the design storm by 20-percent.

The selected design storms and climate-intensified sensitivity storms for the Rock Creek, Hillsboro, and Forest Grove Basins are shown Figure 2.24, Figure 2.25 and Figure 2.26 respectively. Storm event total rainfall depths and peak intensities are also summarized in Table 2.5.

In addition to the intensified 5-year design storms, factors to adjust precipitation depth for a 2-year, 10-year, and 25-year frequency storm with climate intensification were developed. The full set of design storms with climate intensification at varied frequencies were provided in a spreadsheet tool (see Appendix 2E).

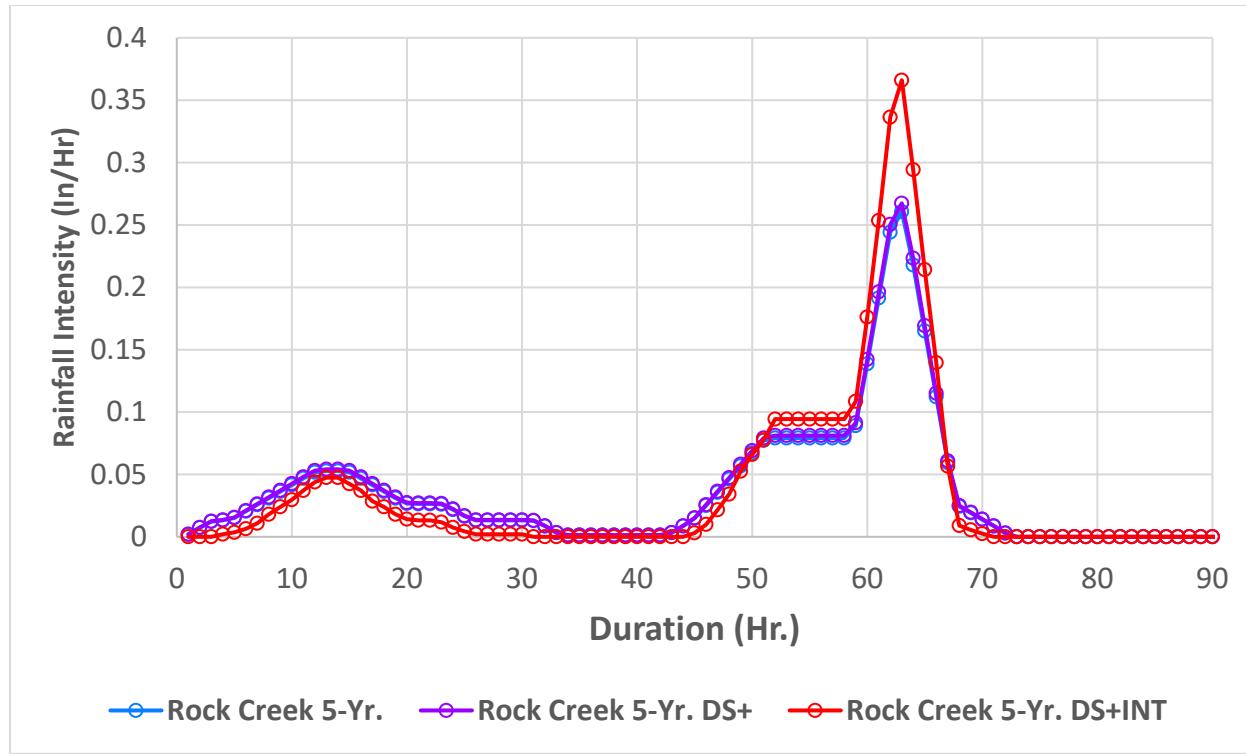


Figure 2.24 Rock Creek Basin Climate Intensified Design Storms

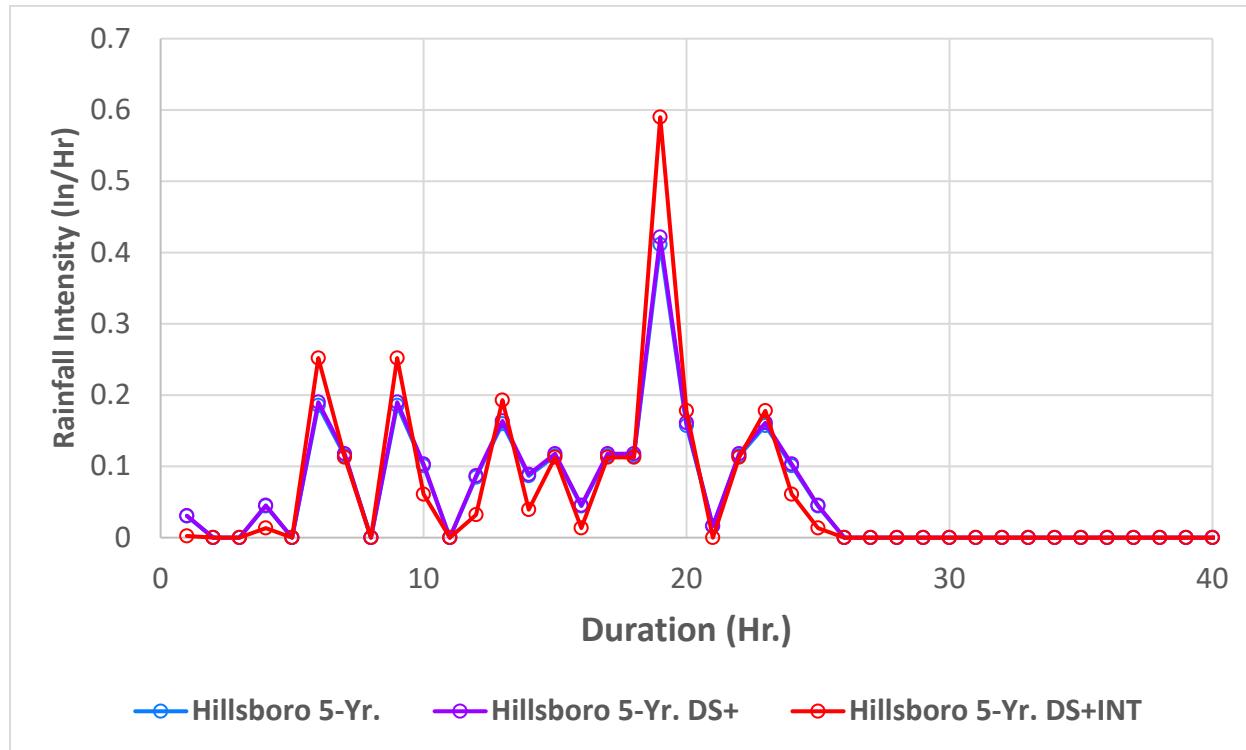


Figure 2.25 Hillsboro Basin Climate Intensified Design Storms

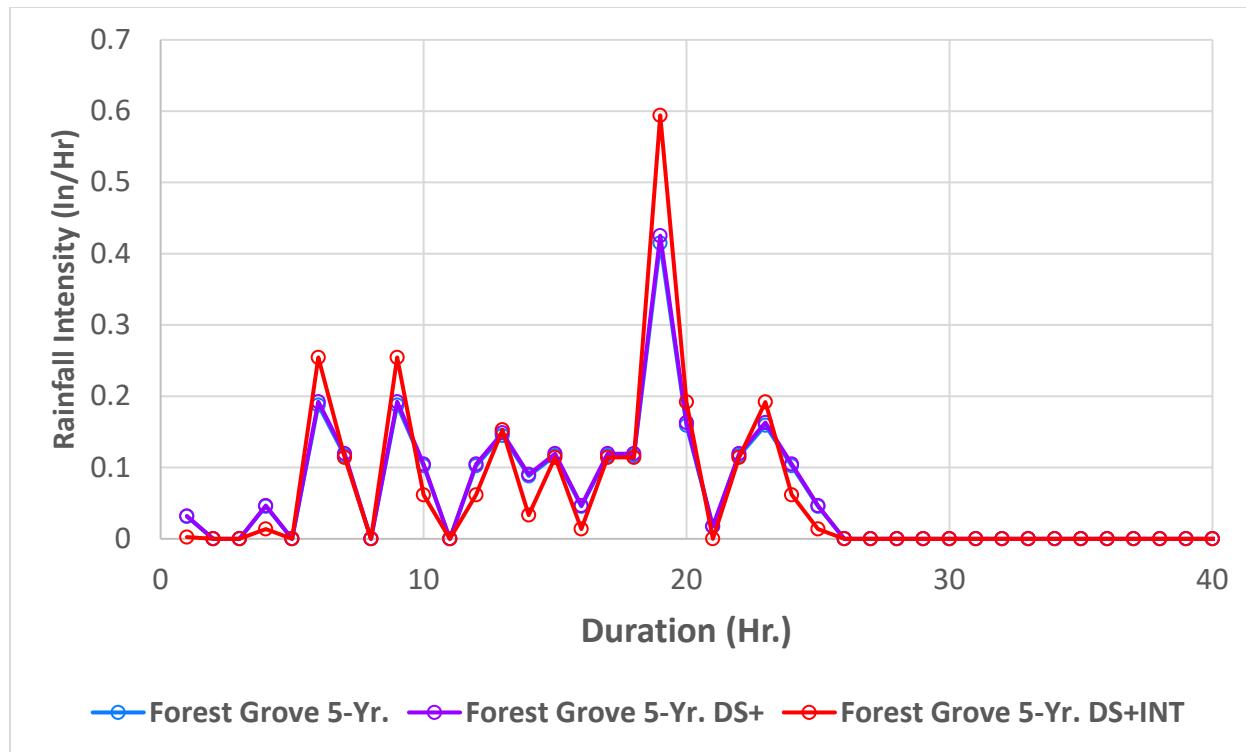


Figure 2.26 Forest Grove Basin Climate Intensified Design Storms

Table 2.5 Climate Intensified Design Storm Characteristics

Storm ID	Duration (Hr.)	Peak Intensity (In./Hr.)	Total Rainfall Depth (In.)
Rock Creek 5-Yr.	72	0.26	3.30
Rock Creek 5-Yr. DS+	72	0.27	3.38
Rock Creek 5-Yr. DS+INT	72	0.37	3.38
Hillsboro 5-Yr.	25	0.41	2.38
Hillsboro 5-Yr. DS+	25	0.42	2.44
Hillsboro 5-Yr. DS+INT	25	0.59	2.44
Forest Grove 5-Yr.	25	0.41	2.42
Forest Grove 5-Yr. DS+	25	0.43	2.48
Forest Grove 5-Yr. DS+INT	25	0.59	2.47

APPENDIX 2A

Gage Correlation Excel Tool and Rain Gage Data

See Spreadsheet Tool: CWSDesignStormAnalysis_GageCorrelation_202308XX.xlsb

Table 2A.1 Precipitation Gages Utilized for Candidate Correlation Within Tiered Approach

Dataset Class	Gage ID	Tier 1	Tier 2	Tier 3
District Local Gages	BKR	1		
	BNR	1		
	CHR	1		
	CMR	1		
	DPR	1		
	FGR	1		
	HWR	1		
	LTR	1		
	MTR	1		
	RCR	1		
	RVR	1		
	SSR	1		
WRCC/NOAA Regional Gages	TCR	1		
	WHR	1		
	BUXTON MOUNTAINDALE OR US (1)	1	1	1
	BUXTON OR US (1)	1	1	1
	DIXIE MOUNTAIN OR US (1)	1	1	1
	GLENWOOD 2 WNW OR US (1)	1	1	1
	PORTLAND INTERNATIONAL AIRPORT OR US (1)	1	1	1
	PORTLAND KGW TV OR US (1)	1	1	1
	REX 1 S OR US (1)	1	1	1
Portland HYDRA Network Gages	SAUVIES ISLAND OR US (1)	1	1	1
	SCOGGINS DAM 2 OR US (1)	1	1	1
	Sylvania PCC	1	1	
	Vermont Hills	1	1	
	Sylvan School	1	1	
	Maplewood Elementary	1	1	
Portland HYDRA Network Gages	Bonny Slope BSD	1	1	
	Bonny Slope School	1	1	

Dataset Class	Gage ID	Tier 1	Tier 2	Tier 3
Correlated Datasets	Skyline School	1	1	
	BNR_Full			1
	CHR_Full			1
	CMR_Full			1
	DPR_Full			1
	FGR_Full			1
	HWR_Full			1
	LTR_Full			1
	MTR_Full			1
	RVR_Full			1
	SSR_Full			1
	TCR_Full			1

Table 2A.2 Tiered Precipitation Gage Correlations, and Periods Utilized

$R^2 = 0$: The correlation does not explain any of the variance in the dependent variable.

$0 < R^2 < 1$: The correlation explains some of the variance in the dependent variable, but not all. The closer the R^2 value is to 1, the better the correlation is in the regression.

The closer the R^2 value is to 1, the better the correlation explains the variance. Backfill data entries of "N/A" indicate that the Case 2 correlation does not provide a good fit.

Backfill date entries of "N/A" indicate that the Gage 2 correlation does not provide any additional timespan coverage.

APPENDIX 2B

Correlated Gage Frequency-Depth-Duration Excel Tool

See Spreadsheet Tool:

[CWSDesignStormAnalysis_FDD_CWSGages_20231226.xlsb](#) (rainfall frequency-depth-duration by rain gauge)

[CWSDesignStormAnalysis_FDD_Tributaries_202308XX.xlsb](#) (meter basin specific frequency-depth-duration)

Table 2B.1 Discretized Sub-basin Characteristics

Sub-basin ID (Tributary-to Node ID)	Model Basin	Average Gravity Conduit Diameter (In.)	Total Gravity Conduit Length (Mi.)	Total Sewershed Area (Ac.)	Area-Weighted Total R	Representative Rain Gage (Maximum from Theissen Polygon Intersect)	Composite Soil Type (Area-Weighted Assignment)	Minimum Elevation (Ft. AD)	Maximum Elevation (Ft. AD)	Mean Elevation (Ft. AD)	Total Area (Ac.)
3609	Durham	10	10.8	28.5	0.41	WHR	C	236.4	974.8	460.2	1538.1
4316	Durham	10	37.5	99.0	0.25	WHR	C	197.4	1042.2	398.0	2934.3
6551	Durham	10	48.6	128.0	0.28	WHR	C	181.6	968.6	395.3	1656.7
10692	Durham	10	55.5	146.0	0.37	MTR	B	154.8	789.9	321.6	2912.8
10740	Durham	10	15.4	40.2	0.30	WHR	B	184.2	338.7	237.4	578.6
10796	Durham	10	46.5	122.0	0.21	RVR	D	155.5	416.3	221.8	2019.3
11659	Durham	10	51.1	135.0	0.14	LTR	B	120.1	588.9	236.1	4187.3
11779	Durham	10	27.9	72.9	0.37	WHR	D	168.9	340.2	231.7	922.6
11792	Durham	10	23.1	60.6	0.27	WHR	B	173.3	475.8	290.2	924.3
12430	Durham	10	29.0	76.0	0.34	RVR	D	164.3	280.5	201.3	1000.4
14366	Durham	10	17.5	46.2	0.30	MTR	B	144.5	568.0	293.6	627.8
14939	Durham	10	54.5	144.8	0.16	MTR	B	164.1	746.6	342.4	2215.7
16650	Durham	10	37.6	101.0	0.16	LTR	C	186.2	777.9	376.5	2617.0
19689	Durham	10	15.5	40.6	0.34	MTR	D	156.2	411.8	245.5	532.0
22276	Durham	10	46.5	123.0	0.22	DPR	B	99.8	504.6	266.9	4682.5
803890	Durham	12	33.6	88.3	0.19	LTR	B	82.8	354.1	191.2	2928.9
821412	Durham	10	121.4	318.9	0.19	MTR	B	75.7	732.5	233.3	5573.6
829069	Durham	10	20.0	52.8	0.37	LTR	B	23.8	733.8	266.9	3730.7
834116	Durham	10	57.7	153.3	0.12	LTR	B	108.3	715.8	291.6	3135.9
834214	Durham	15	27.4	71.7	0.35	DPR	B	97.6	409.3	170.9	1458.5
12729	Forest Grove	10	31.6	82.8	0.19	FGR	B	134.2	191.2	167.4	2312.3
16270	Forest Grove	10	5.1	13.3	0.33	FGR	B	170.8	468.2	246.4	168.2
18849	Forest Grove	12	3.6	9.3	0.46	FGR	C	174.3	214.5	189.1	138.4
20399	Forest Grove	10	7.2	18.9	0.82	FGR	B	162.7	254.4	208.6	345.8
805010	Forest Grove	12	18.1	47.2	0.47	FGR	C	164.0	199.4	179.2	727.1
821338	Forest Grove	12	12.0	30.8	0.71	FGR	B	151.3	223.3	176.6	646.7
12158	Hillsboro	10	17.0	45.2	0.10	TCR	D	142.4	221.1	186.6	2713.2
12244	Hillsboro	10	13.1	34.2	0.38	HWR	D	147.0	213.9	190.4	487.3
12281	Hillsboro	10	23.8	62.6	0.45	HWR	D	131.7	197.0	173.3	994.2
12298	Hillsboro	15	8.8	22.7	0.31	HWR	B	127.7	196.3	168.3	660.3
12326	Hillsboro	10	18.9	49.3	0.31	HWR	D	132.0	200.5	183.7	636.0
14584	Hillsboro	10	4.4	11.7	0.35	BKR	D	182.9	274.7	208.3	788.2
17167	Hillsboro	12	17.4	45.4	0.57	FGR	B	140.2	485.5	215.7	1710.7
19795	Hillsboro	10	7.3	19.1	0.31	HWR	B	147.4	198.8	185.9	282.2
821447	Hillsboro	10	34.8	90.9	0.64	FGR	B	167.0	776.1	273.6	2227.3
830723	Hillsboro	24	3.1	7.7	0.31	HWR	D	125.3	182.6	137.5	367.0
6822	Rock Creek	10	51.4	136.0	0.13	CMR	B	166.7	726.5	322.9	1973.0
6877	Rock Creek	12	9.6	25.3	0.13	SSR	D	142.0	252.1	201.2	736.9
6906	Rock Creek	12	10.2	26.7	0.05	TCR	D	144.3	212.7	190.8	605.1
6991	Rock Creek	10	21.2	55.4	0.32	BNR	B	152.2	240.5	207.2	650.5
9714	Rock Creek	10	35.4	93.2	0.63	RVR	B	167.5	419.2	240.1	1231.1
9876	Rock Creek	10	124.2	329.2	0.13	TCR	D	124.6	234.9	185.9	4552.1
11107	Rock Creek	10	40.2	106.6	0.32	CMR	B	182.9	1083.1	397.8	1990.5
11932	Rock Creek	10	38.6	101.4	0.23	BNR	D	129.2	237.3	205.3	1343.6
12220	Rock Creek	10	40.6	107.3	0.15	CHR	D	169.7	647.0	283.4	1663.1
12312	Rock Creek	10	48.0	125.1	0.49	RCR	D	118.5	243.0	172.4	2268.4
12383	Rock Creek	10	27.8	72.9	0.47	TCR	C/D	141.4	225.5	191.5	1335.3
12480	Rock Creek	10	20.6	54.7	0.10	SSR	D	140.1	248.9	196.3	1386.5
12508	Rock Creek	10	95.4	253.3	0.15	SSR	B	154.5	476.6	254.8	4253.8
13240	Rock Creek	10	62.0	163.7	0.10	CMR	B	173.6	1176.8	472.5	3566.5
25185	Rock Creek	10	75.9	200.9	0.37	BNR	B	162.8	772.3	294.1	2334.4
27075	Rock Creek	15	16.8	43.7	0.11	TCR	B	154.0	262.4	203.9	4120.5
27099	Rock Creek	27	4.5	11.7	0.30	TCR	B	166.2	234.5	205.8	489.2
55672	Rock Creek	10	91.2	241.9	0.63	RVR	B	158.1	799.9	302.5	3473.8
72391	Rock Creek	12	8.1	21.2	0.24	TCR	B	167.1	236.3	211.6	722.8
802158	Rock Creek	10	33.3	89.0	0.31	BNR	B	119.5	770.9	251.1	4060.4
820679	Rock Creek	10	20.8	54.2	0.03	TCR	B	153.9	236.1	196.2	2293.0
822355	Rock Creek	10	37.2	99.3	0.09	WHR	C	213.3	1228.3	581.8	1731.6

APPENDIX 2C

Design Storm Statistical Evaluation

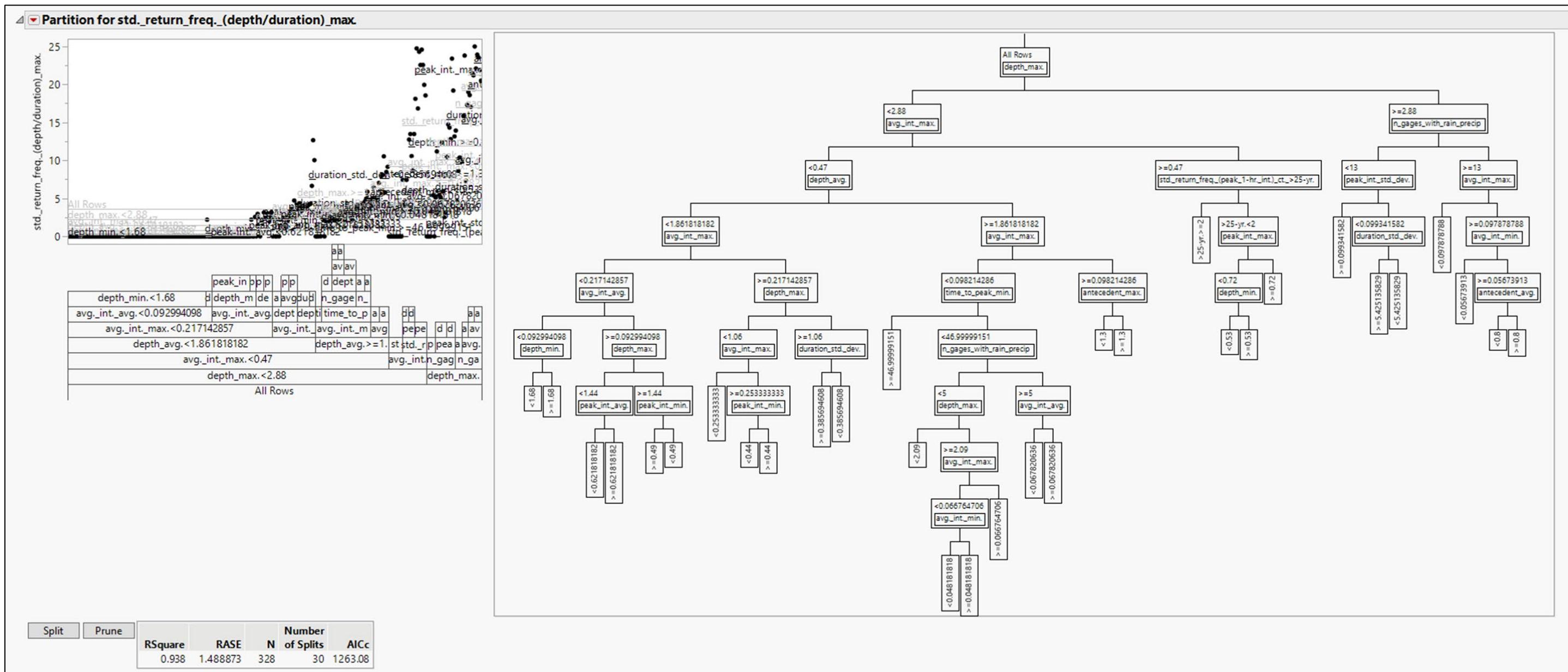


Figure 2C.1 JMP Recurrence Interval Partitioning Leaves and Associated Statistical Scoring

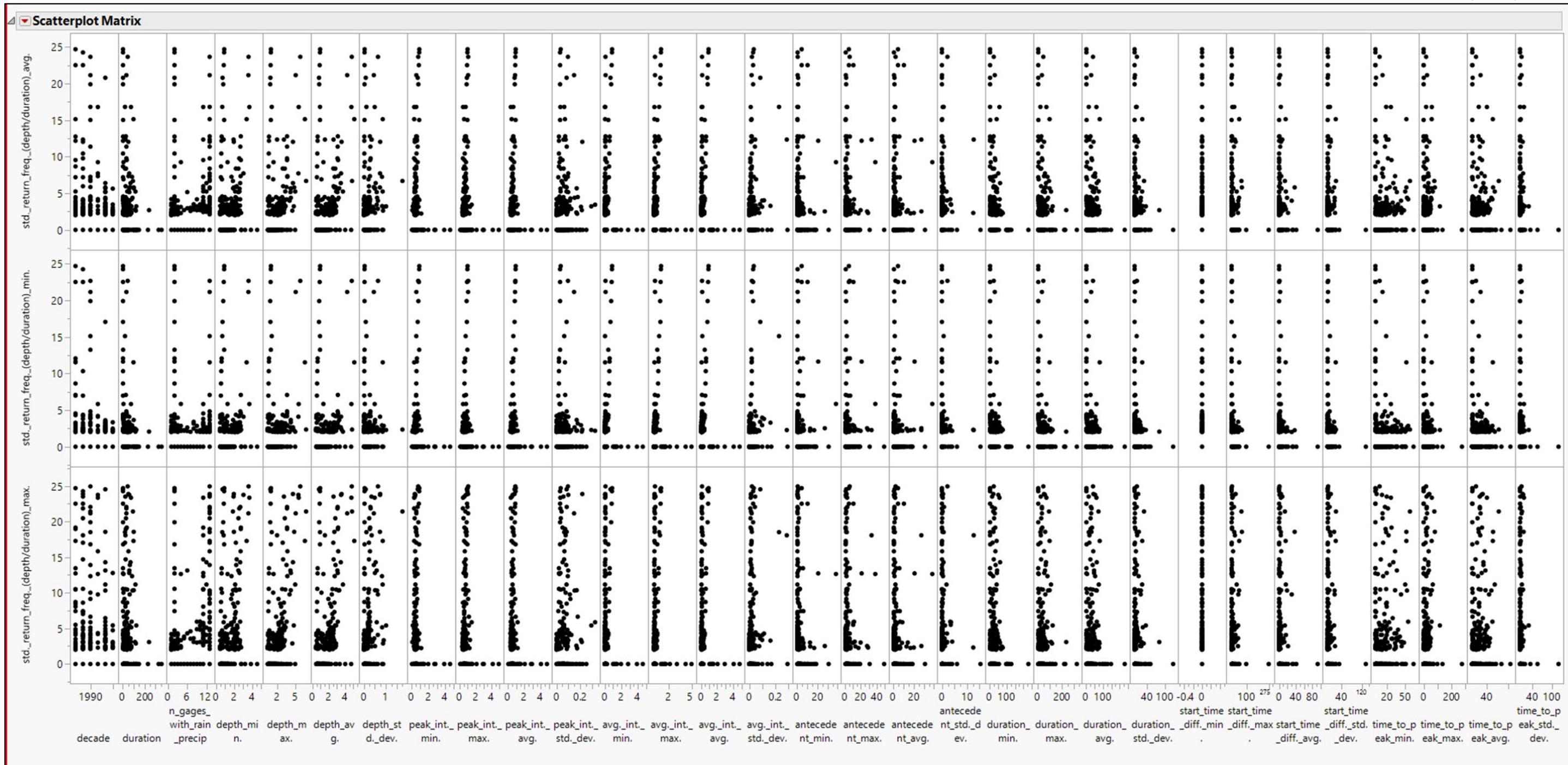


Figure 2C.27 JMP Dependent Input Variable Relationships to Recurrence Intervals

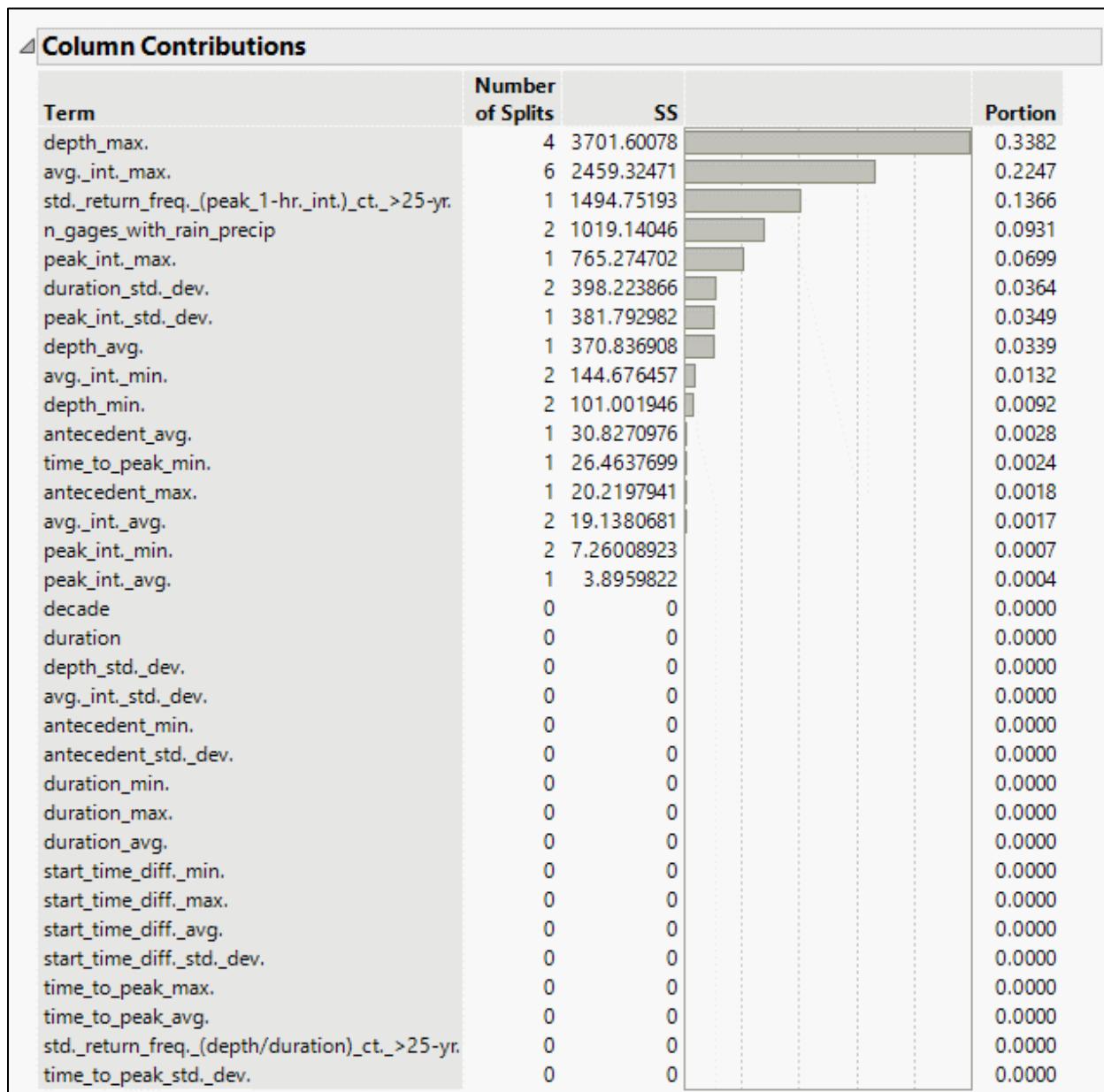


Figure 2C.3 JMP Dependent Input Variable Contributions to Recurrence Interval Partitioning

Table 2C.1 Events Selected via JMP Partition for ICM Modeling of Flow Frequency; Key Characteristics

Event ID	Date/Time Start	Date/Time End	Duration (Hr.)	Gages With Precip. (Ct.)	Depth (Min.) (In.)	Depth (Max.) (In.)	Depth (Avg.) (In.)	Peak Intensity (Min.) (In./Hr.)	Peak Intensity (Max.) (In./Hr.)	Peak Intensity (Avg.) (In./Hr.)	Avg. Intensity (Min.) (In./Hr.)	Avg. Intensity (Max.) (In./Hr.)	Avg. Intensity (Avg.) (In./Hr.)	Min. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Min. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)
11	1/10/1972 18:00	1/11/1972 14:00	20	2	2.08	2.22	2.15	0.44	0.47	0.46	0.10	0.11	0.11	3.43	4.26	3.85	3.84	4.16	4.00
15	9/9/1972 6:00	9/9/1972 17:00	11	11	0.97	1.29	1.12	0.53	0.72	0.62	0.09	0.12	0.10	0.00	0.00	0.00	6.98	8.95	8.17
16	12/19/1972 16:00	12/19/1972 17:00	1	2	0.53	0.57	0.55	0.53	0.57	0.55	0.53	0.57	0.55	8.03	9.35	8.69	8.03	9.35	8.69
19	11/8/1973 13:00	11/9/1973 14:00	25	11	2.15	2.79	2.44	0.50	0.67	0.58	0.09	0.11	0.10	2.56	13.40	4.85	4.90	6.54	5.90
22	1/12/1974 18:00	1/16/1974 19:00	97	13	3.39	6.50	5.12	0.28	0.52	0.43	0.05	0.10	0.07	12.81	18.19	16.16	2.00	2.55	2.17
25	7/8/1974 16:00	7/8/1974 23:00	7	11	0.89	1.19	1.03	0.48	0.65	0.56	0.13	0.23	0.16	3.10	3.66	3.38	4.48	5.59	5.10
32	11/14/1975 16:00	11/15/1975 9:00	17	8	0.52	0.65	0.58	0.39	0.55	0.47	0.03	0.06	0.04	0.00	0.00	0.00	2.00	3.32	2.45
34	12/3/1975 4:00	12/4/1975 12:00	32	13	1.77	2.27	1.97	0.44	0.58	0.51	0.06	0.07	0.06	2.30	3.12	2.61	2.96	6.86	3.87
41	8/23/1977 11:00	8/24/1977 4:00	17	3	1.63	1.70	1.66	0.59	0.60	0.59	0.10	0.10	0.10	2.34	2.34	2.34	3.97	4.28	4.08
42	8/26/1977 10:00	8/26/1977 11:00	1	2	1.01	1.08	1.05	1.01	1.08	1.05	1.01	1.08	1.05	0.00	0.00	0.00	0.00	0.00	0.00
47	12/12/1977 13:00	12/13/1977 16:00	27	13	2.74	3.59	3.11	0.52	0.76	0.63	0.10	0.15	0.12	7.73	24.66	14.27	6.43	20.18	8.48
55	12/20/1978 16:00	12/20/1978 17:00	1	2	0.51	0.54	0.53	0.51	0.54	0.53	0.51	0.54	0.53	6.90	7.49	7.19	6.90	7.49	7.19
65	9/13/1980 15:00	9/13/1980 16:00	1	1	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	2.21	2.21	2.21	2.21	2.21	2.21
69	12/1/1980 16:00	12/2/1980 14:00	22	13	1.93	3.08	2.57	0.36	0.55	0.46	0.09	0.24	0.19	2.42	24.95	16.25	2.28	3.13	2.69
71	10/5/1981 11:00	10/6/1981 20:00	33	3	1.79	1.91	1.86	0.40	0.45	0.43	0.06	0.09	0.07	2.16	2.16	2.16	2.56	3.05	2.81
74	12/4/1981 21:00	12/6/1981 5:00	32	11	2.07	2.64	2.34	0.36	0.66	0.46	0.07	0.09	0.08	2.12	4.96	3.16	13.86	20.86	17.36
75	1/22/1982 2:00	1/24/1982 4:00	50	4	1.18	2.26	1.69	0.42	0.49	0.45	0.04	0.20	0.12	2.15	2.56	2.36	4.48	4.72	4.60
77	7/30/1982 2:00	7/30/1982 6:00	4	11	0.61	0.82	0.71	0.45	0.62	0.53	0.15	0.21	0.18	0.00	0.00	0.00	3.56	4.49	4.15
83	4/10/1983 5:00	4/10/1983 6:00	1	2	0.56	0.60	0.58	0.56	0.60	0.58	0.56	0.60	0.58	9.72	12.67	11.19	9.72	12.67	11.19
85	7/8/1983 11:00	7/8/1983 19:00	8	11	0.58	0.77	0.67	0.55	0.75	0.65	0.07	0.38	0.13	3.86	4.36	4.11	8.64	12.07	9.96
87	11/2/1983 16:00	11/4/1983 1:00	33	11	2.11	2.72	2.43	0.25	0.52	0.33	0.06	0.12	0.08	2.16	7.89	3.84	5.21	6.24	5.73
92	6/20/1984 1:00	6/21/1984 11:00	34	3	1.77	2.26	1.97	0.32	0.53	0.45	0.06	0.07	0.06	3.01	3.01	3.01	6.34	6.86	6.60
96	11/26/1984 21:00	11/28/1984 12:00	39	13	2.40	3.07	2.68	0.29	0.38	0.34	0.06	0.08	0.07	2.66	9.98	4.39	0.00	0.00	0.00
97	6/5/1985 22:00	6/7/1985 14:00	40	2	2.11	2.25	2.18	0.49	0.50	0.50	0.05	0.06	0.05	2.56	2.56	2.56	2.36	2.36	2.36
98	9/9/1985 22:00	9/10/1985 12:00	14	11	1.66	2.18	1.90	0.39	0.52	0.45	0.12	0.16	0.14	2.05	7.17	3.72	2.00	2.55	2.17
103	2/14/1986 13:00	2/17/1986 8:00	67	1	2.48	2.48	2.48	0.37	0.37	0.37	0.04	0.04	0.04	2.07	2.07	2.07	0.00	0.00	0.00
104	7/4/1986 3:00	7/4/1986 6:00	3	2	0.64	0.68	0.66	0.54	0.58	0.56	0.21	0.23	0.22	2.28	2.28	2.28	8.59	9.97	9.28
115	9/18/1988 21:00	9/19/1988 20:00	23	11	0.82	1.96	1.51	0.61	0.83	0.72	0.06	0.82	0.21	2.30	24.37	16.74	18.12	24.37	22.13

Event ID	Date/Time Start	Date/Time End	Duration (Hr.)	Gages With Precip. (Ct.)	Depth (Min.) (In.)	Depth (Max.) (In.)	Depth (Avg.) (In.)	Peak Intensity (Min.) (In./Hr.)	Peak Intensity (Max.) (In./Hr.)	Peak Intensity (Avg.) (In./Hr.)	Avg. Intensity (Min.) (In./Hr.)	Avg. Intensity (Max.) (In./Hr.)	Avg. Intensity (Avg.) (In./Hr.)	Min. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Min. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)
122	1/14/1991 23:00	1/15/1991 2:00	3	13	0.43	0.77	0.63	0.43	0.72	0.59	0.19	0.26	0.22	2.13	2.13	2.13	3.52	9.55	7.50
123	2/20/1991 0:00	2/20/1991 12:00	12	11	1.23	1.61	1.40	0.58	0.78	0.68	0.10	0.13	0.12	3.01	3.01	3.01	11.42	18.68	14.74
138	1/19/1993 9:00	1/20/1993 21:00	36	2	1.84	1.97	1.91	0.43	0.46	0.45	0.05	0.05	0.05	0.00	0.00	0.00	3.52	3.89	3.70
146	10/26/1994 11:00	10/28/1994 7:00	44	13	3.61	5.75	4.82	0.76	1.04	0.88	0.10	0.17	0.12	0.00	0.00	0.00	23.69	23.69	23.69
147	10/30/1994 23:00	11/2/1994 0:00	49	12	2.37	3.05	2.59	0.31	0.52	0.43	0.05	0.09	0.06	2.01	5.46	3.19	2.00	2.55	2.17
163	12/28/1996 18:00	12/29/1996 22:00	28	1	1.73	1.73	1.73	0.49	0.49	0.49	0.06	0.06	0.06	0.00	0.00	0.00	2.36	2.36	2.36
166	5/23/1997 15:00	5/24/1997 7:00	16	13	0.52	0.97	0.79	0.43	0.97	0.78	0.12	0.95	0.26	0.00	0.00	0.00	3.52	3.89	3.70
168	5/31/1997 5:00	5/31/1997 13:00	8	13	0.95	1.80	1.48	0.54	1.13	0.92	0.12	0.23	0.18	3.26	7.81	4.79	8.59	9.97	9.28
171	10/8/1997 14:00	10/8/1997 16:00	2	3	0.44	0.49	0.47	0.44	0.49	0.47	0.25	0.47	0.39	3.84	4.16	4.00	2.36	4.16	3.46
172	10/28/1997 14:00	10/29/1997 9:00	19	13	0.67	1.09	0.91	0.53	0.72	0.63	0.04	0.71	0.16	17.37	17.37	17.37	6.98	17.37	8.94
196	1/5/2002 2:00	1/8/2002 7:00	77	7	1.69	2.67	2.00	0.42	0.66	0.55	0.03	0.06	0.04	0.00	0.00	0.00	2.65	7.52	6.12
208	8/29/2005 15:00	8/29/2005 20:00	5	4	1.26	1.38	1.33	0.69	0.76	0.73	0.25	0.28	0.27	6.53	15.67	10.59	0.00	0.00	0.00
228	12/31/2008 14:00	1/2/2009 17:00	51	13	2.72	3.65	3.15	0.39	0.61	0.49	0.05	0.10	0.08	2.87	17.09	7.89	3.26	10.35	5.20
234	6/6/2010 5:00	6/7/2010 1:00	20	8	1.11	1.87	1.56	0.44	0.58	0.52	0.08	0.11	0.09	3.23	3.23	3.23	2.17	11.64	5.18
237	10/23/2010 8:00	10/26/2010 12:00	76	2	2.12	2.81	2.47	0.26	0.45	0.36	0.03	0.04	0.03	2.45	2.45	2.45	3.55	3.55	3.55
239	12/7/2010 15:00	12/10/2010 13:00	70	11	1.27	2.71	2.06	0.44	0.67	0.53	0.04	0.06	0.05	2.16	3.64	2.90	3.23	8.68	5.03
241	2/27/2011 16:00	3/1/2011 15:00	47	3	2.39	2.49	2.45	0.25	0.40	0.35	0.05	0.05	0.05	2.40	3.19	2.78	2.21	2.21	2.21
243	11/21/2011 4:00	11/24/2011 2:00	70	12	2.67	4.55	3.46	0.38	0.53	0.45	0.04	0.07	0.06	2.69	15.32	6.78	2.15	6.79	3.80
247	6/4/2012 19:00	6/5/2012 4:00	9	5	0.93	1.20	1.05	0.59	0.92	0.76	0.12	0.15	0.13	0.00	0.00	0.00	9.16	20.34	16.14
248	11/16/2012 22:00	11/21/2012 17:00	115	12	2.11	4.92	3.73	0.43	0.73	0.54	0.04	0.07	0.05	2.06	11.94	5.47	2.28	14.03	6.52
250	6/12/2013 16:00	6/12/2013 19:00	3	1	0.68	0.68	0.68	0.52	0.52	0.52	0.23	0.23	0.23	2.48	2.48	2.48	5.34	5.34	5.34
258	5/28/2014 14:00	5/28/2014 17:00	3	1	0.76	0.76	0.76	0.73	0.73	0.73	0.25	0.25	0.25	2.34	2.34	2.34	22.34	22.34	22.34
259	6/25/2014 18:00	6/26/2014 17:00	23	3	0.82	1.74	1.15	0.80	1.27	0.98	0.08	0.30	0.22	2.98	3.44	3.21	0.00	0.00	0.00
264	1/17/2015 5:00	1/18/2015 3:00	22	2	1.77	1.83	1.80	0.38	0.39	0.39	0.08	0.08	0.08	2.21	2.21	2.21	2.24	2.24	2.24
271	12/5/2015 6:00	12/9/2015 9:00	99	13	1.97	4.76	2.67	0.49	0.84	0.58	0.06	0.12	0.09	2.27	19.75	6.35	2.15	24.17	7.61
274	3/11/2016 11:00	3/16/2016 11:00	120	6	1.53	2.22	1.91	0.22	0.38	0.29	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
275	4/29/2016 10:00	4/29/2016 21:00	11	1	0.57	0.57	0.57	0.44	0.44	0.44	0.05	0.05	0.05	0.00	0.00	0.00	3.33	3.33	3.33
279	10/12/2016 22:00	10/18/2016 1:00	123	10	1.30	4.69	2.88	0.11	1.13	0.53	0.01	0.08	0.05	2.30	5.78	3.31	2.29	4.18	3.07
282	1/17/2017 11:00	1/18/2017 23:00	36	5	2.11	2.40	2.22	0.24	0.40	0.31	0.06	0.08	0.07	2.26	3.70	2.73	2.26	2.26	2.26
296	8/10/2019 16:00	8/10/2019 22:00	6	1	0.76	0.76	0.76	0.56	0.56	0.56	0.13	0.13	0.13	0.00	0.00	0.00	5.02	5.02	5.02

Event ID	Date/Time Start	Date/Time End	Duration (Hr.)	Gages With Precip. (Ct.)	Depth (Min.) (In.)	Depth (Max.) (In.)	Depth (Avg.) (In.)	Peak Intensity (Min.) (In./Hr.)	Peak Intensity (Max.) (In./Hr.)	Peak Intensity (Avg.) (In./Hr.)	Avg. Intensity (Min.) (In./Hr.)	Avg. Intensity (Max.) (In./Hr.)	Avg. Intensity (Avg.) (In./Hr.)	Min. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Depth/Duration-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Min. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Max. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)	Avg. (Peak-1-Hr.-Int.-DDF-Derived) Percent Rank Rec. Int. (Yr.)
300	12/19/2019 10:00	12/21/2019 21:00	59	4	1.02	3.23	2.55	0.21	0.48	0.32	0.04	0.06	0.05	2.89	3.38	3.17	2.17	2.17	2.17
310	1/11/2021 9:00	1/13/2021 4:00	43	13	2.19	3.13	2.58	0.35	0.54	0.44	0.05	0.08	0.06	2.07	4.84	3.10	2.95	7.46	4.75
314	9/18/2021 0:00	9/19/2021 7:00	31	2	1.92	2.32	2.12	0.48	0.50	0.49	0.06	0.07	0.07	2.55	2.55	2.55	3.23	4.63	3.93
321	2/26/2022 14:00	3/3/2022 5:00	111	8	2.02	3.12	2.58	0.44	0.67	0.53	0.03	0.05	0.04	2.49	3.13	2.81	2.17	12.67	5.90
328	12/25/2022 19:00	12/28/2022 5:00	58	11	2.60	4.21	3.09	0.35	0.46	0.41	0.05	0.09	0.07	3.37	13.73	5.82	3.03	3.03	3.03

The minimum, average, and maximum values recorded here are across all 14 correlated/backfilled District gage datasets.

APPENDIX 2D

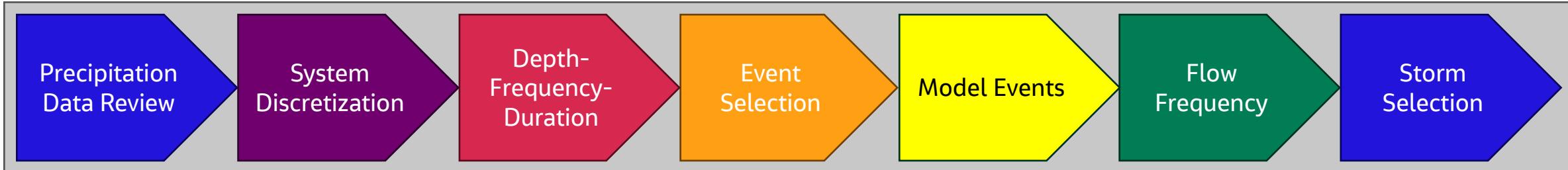
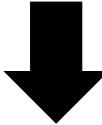
Candidate Storms, System Impacts



Design Storm Selection

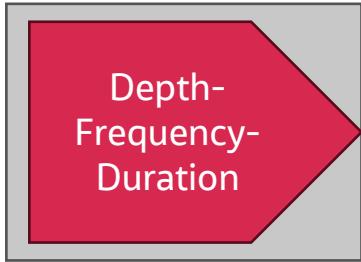
West Basin Master Plan
September 25, 2023

Design Storm Approach

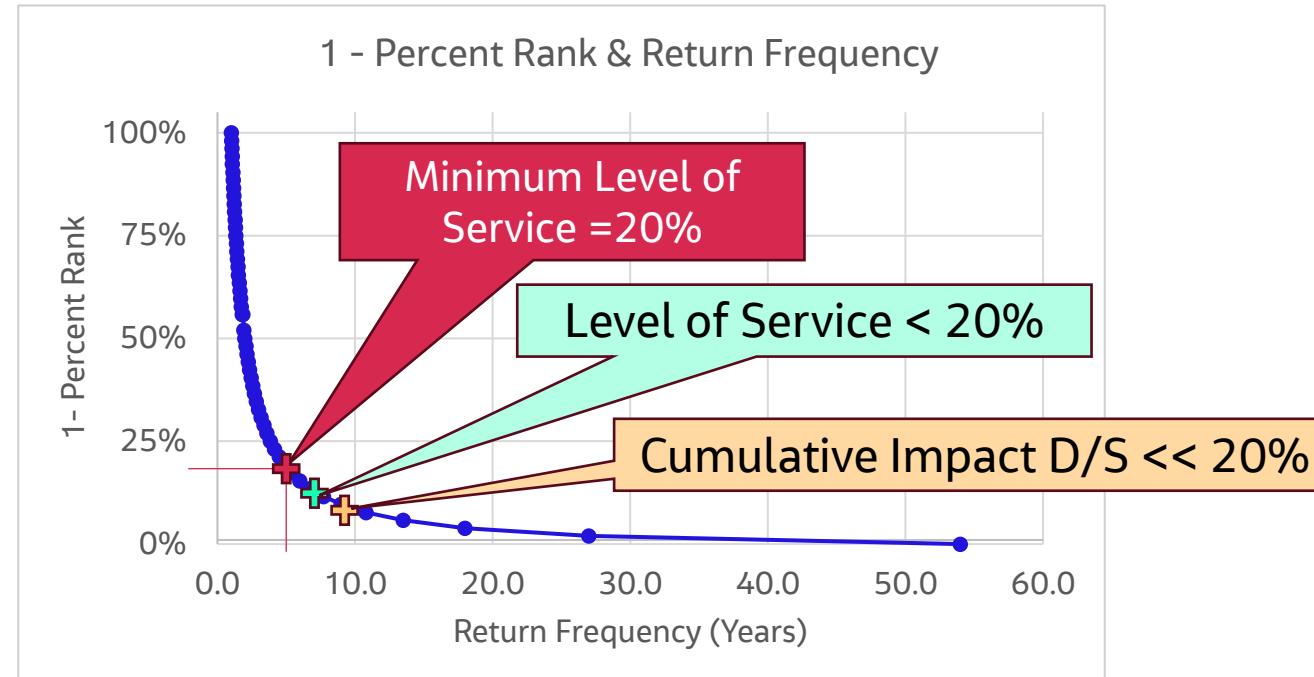


- ❖ Develop data for local gages using relationship to regional gages (1970-2023)
- ❖ Break the system into 55 subbasins
- ❖ Precipitation depth-frequency-duration curves for each subbasin based on 53-years
- ❖ Outlier Review/Fix
- ❖ Select unique characteristic events at varied duration and intensity (~50 events)
- ❖ Simulate events in each model (spatially varied rainfall by subbasin)
- ❖ Evaluate system response (flow and depth frequency by subbasin)
- ❖ Select storm event(s) that generate minimum 5-year impact in system
- ❖ Consider variable vs uniform response

Level of Service



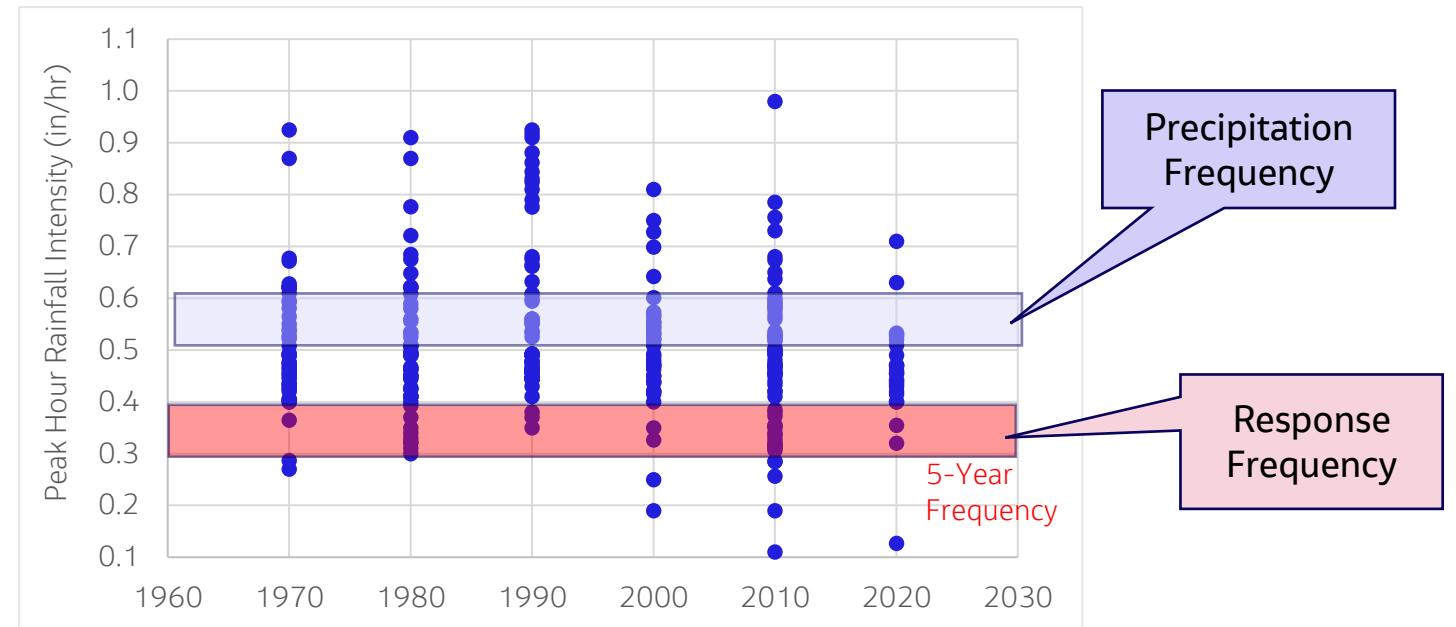
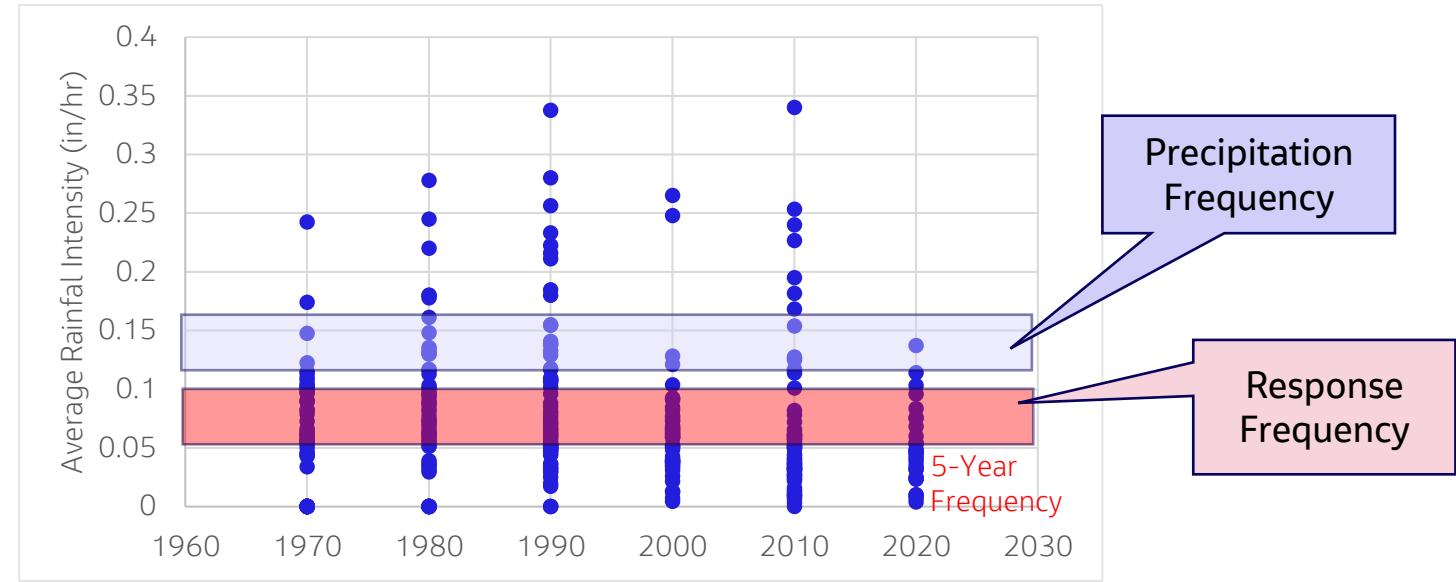
- District level of service storm selection in 2012 fell between 10% and 20%
- Cumulative impact downstream is closer to 10% (application of uniform storm)



Variability by Decade

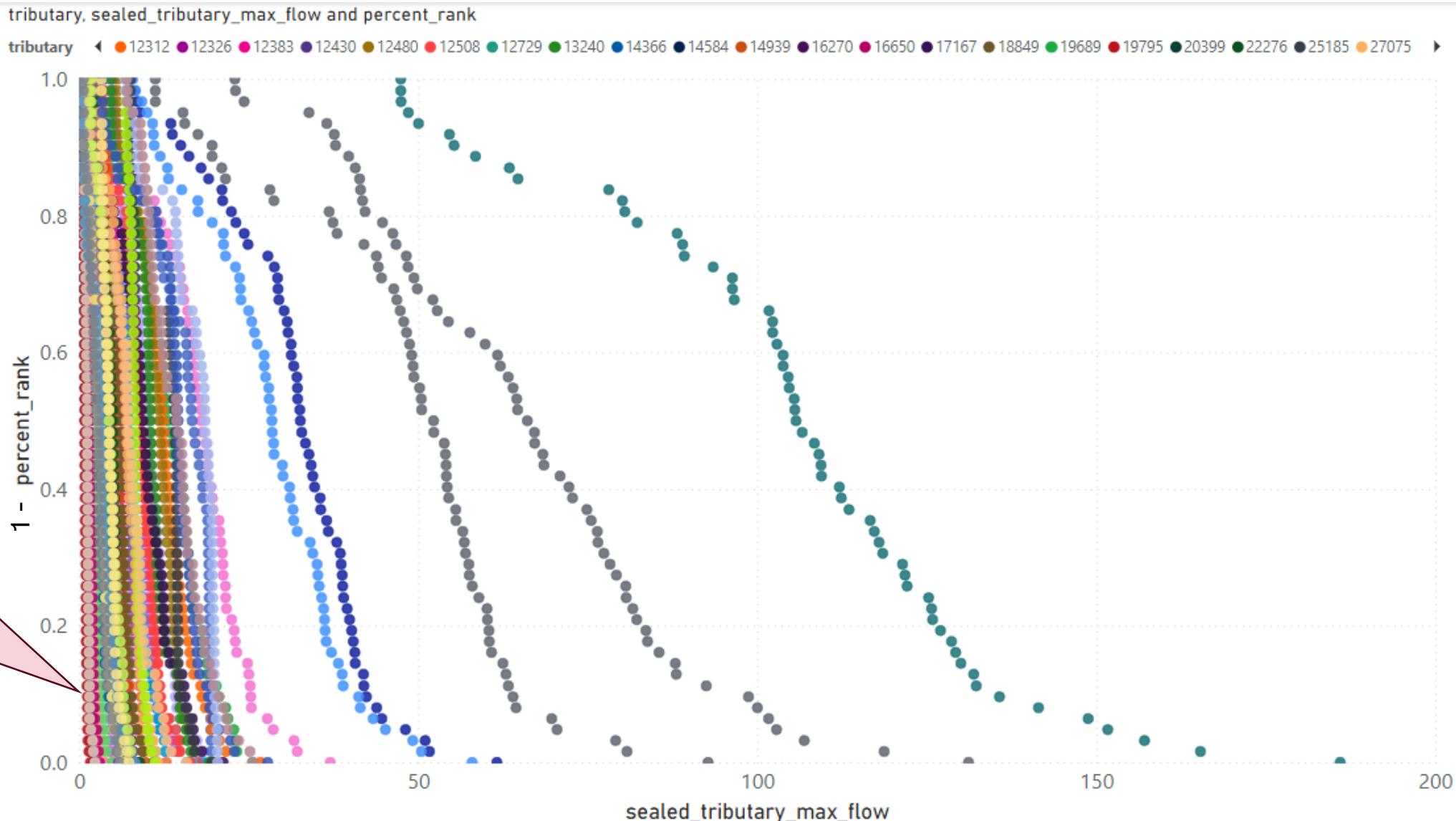


- Precipitation frequency tied to precipitation duration
- Response frequency independent of precipitation duration

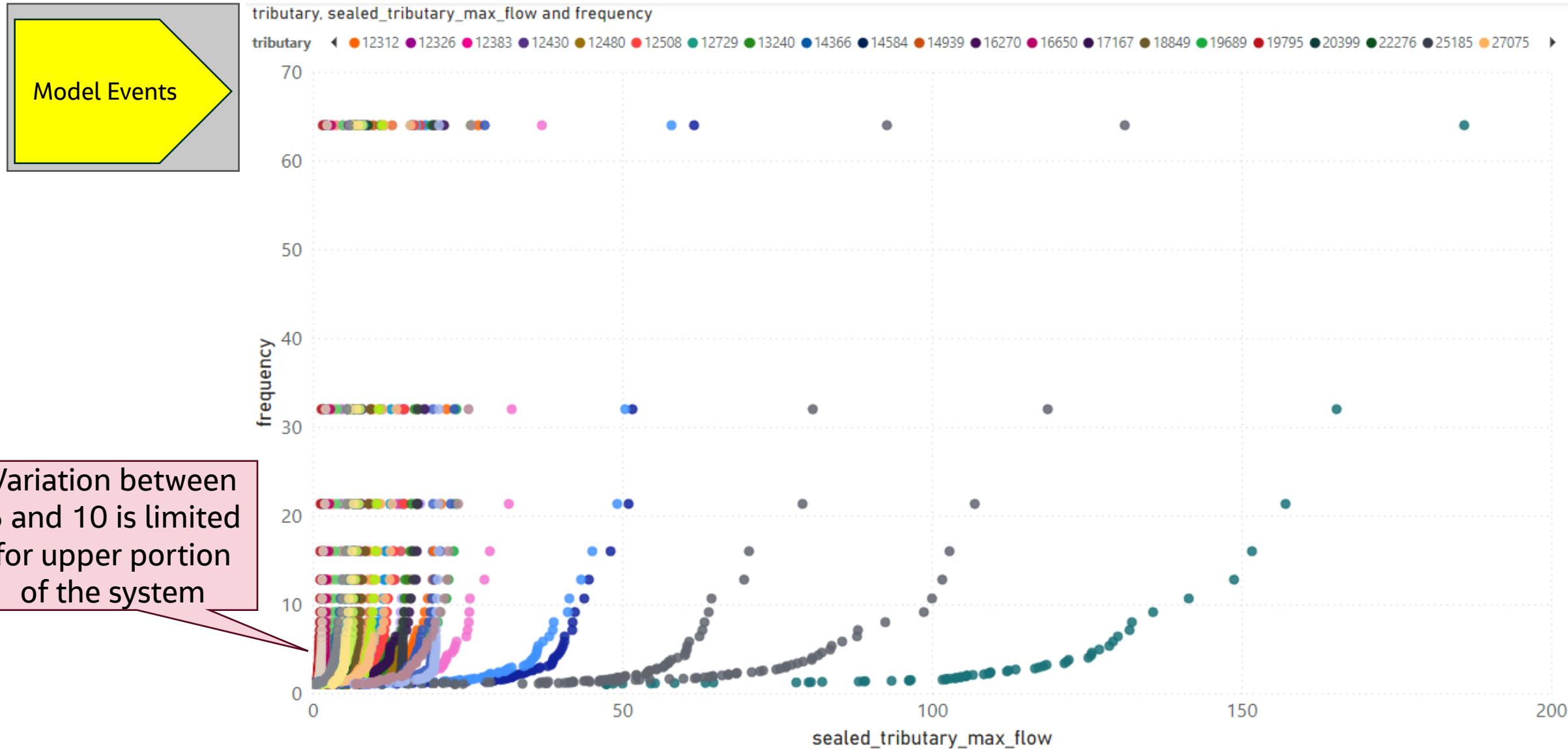


Model Events in ICM → Estimate Flow Frequency

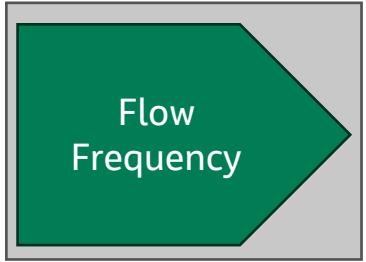
Model Events



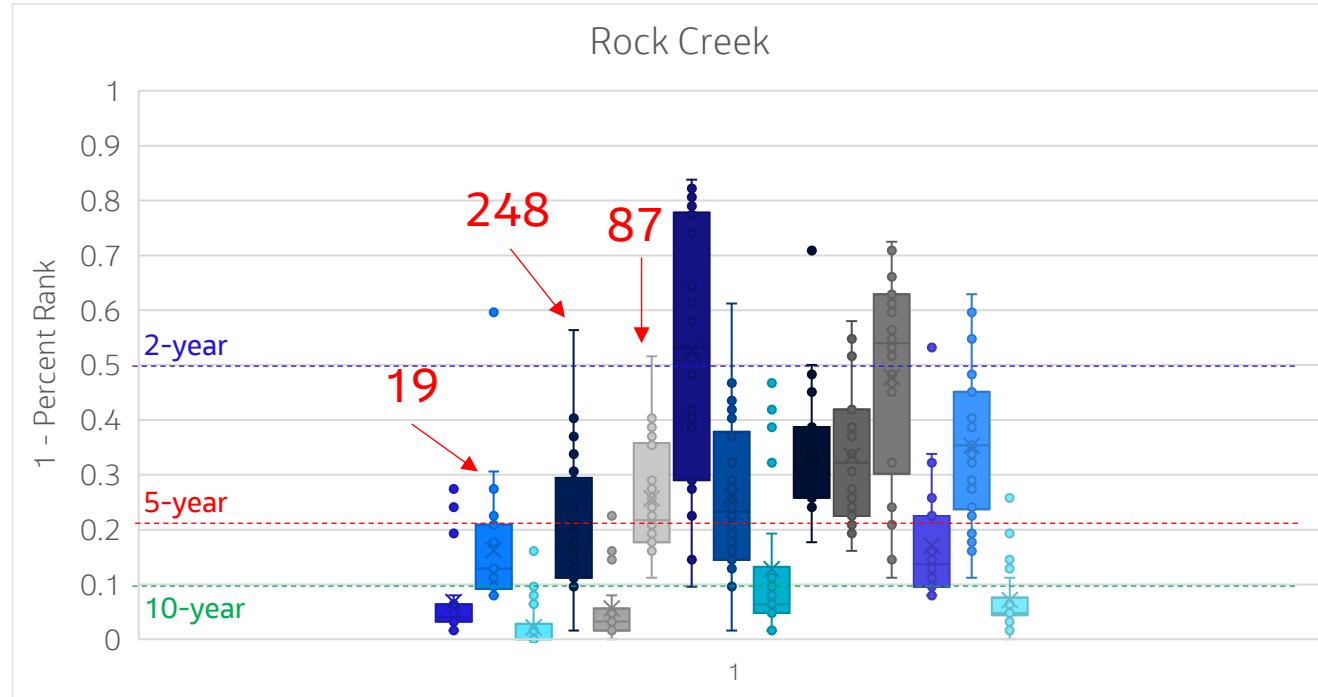
Model Events in ICM → Estimate Flow Frequency



Flow Frequency – Events of Interest – Rock Creek



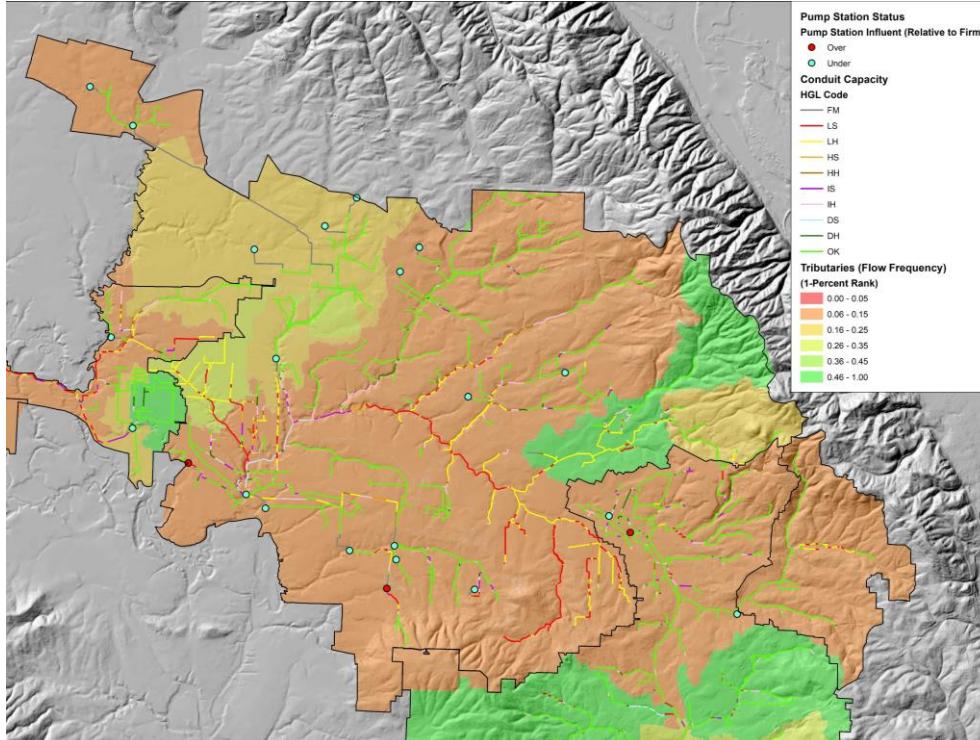
- High flow and spatial variability for some events
- Less variability and more system-wide impact for 5-year to 10-year flow frequency (similar to existing design storm)



Frequency – Events of Interest – Spatial Variability - Rock Creek

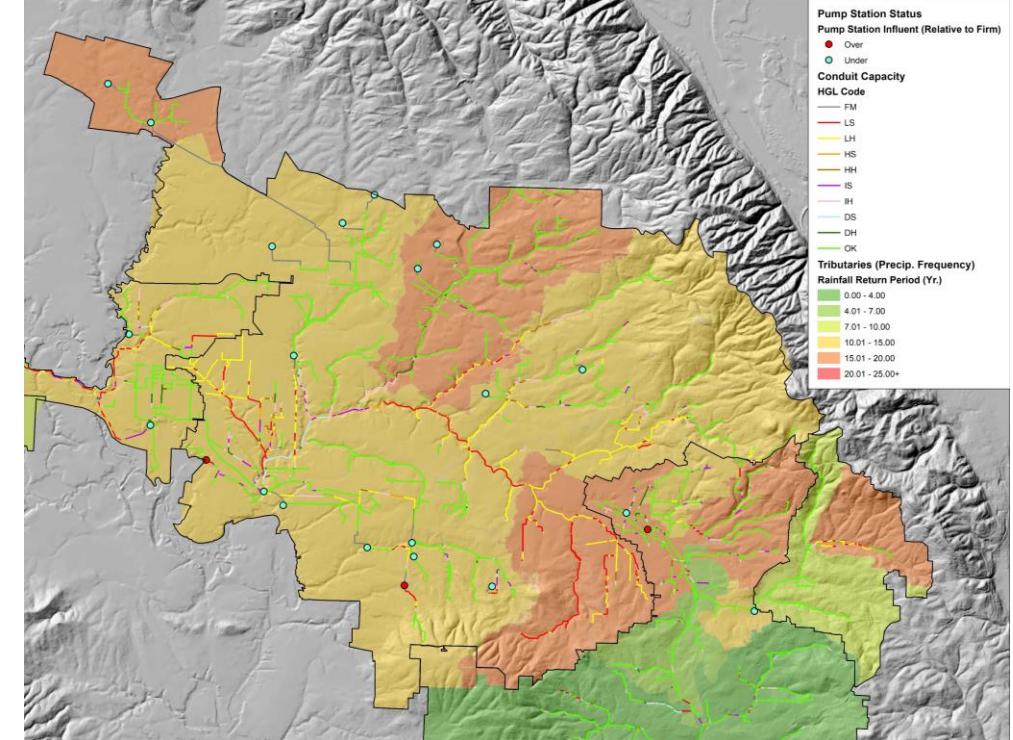
Flow Frequency

Flow Frequency



Event 19

Precipitation Frequency

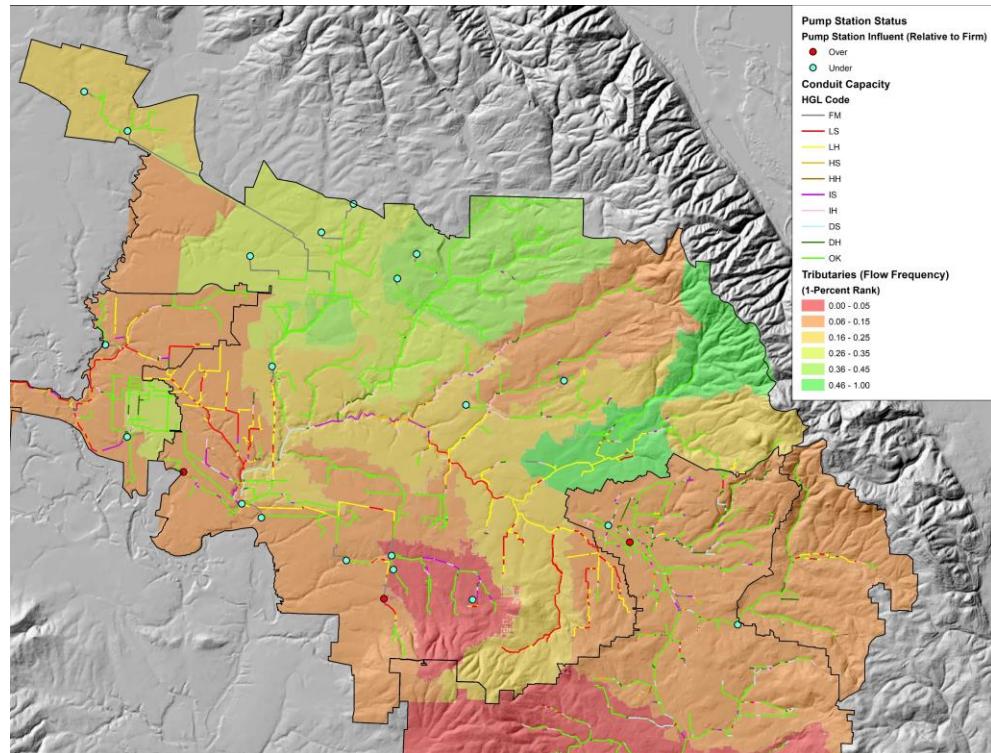


- 24-hour event
- 2.15- to 2.56- inch depth (2.3- inch avg)
- 7.2-year average flow frequency
- Design storm = 2.4- inch in 24 hours

Frequency – Events of Interest – Spatial Variability Rock Creek

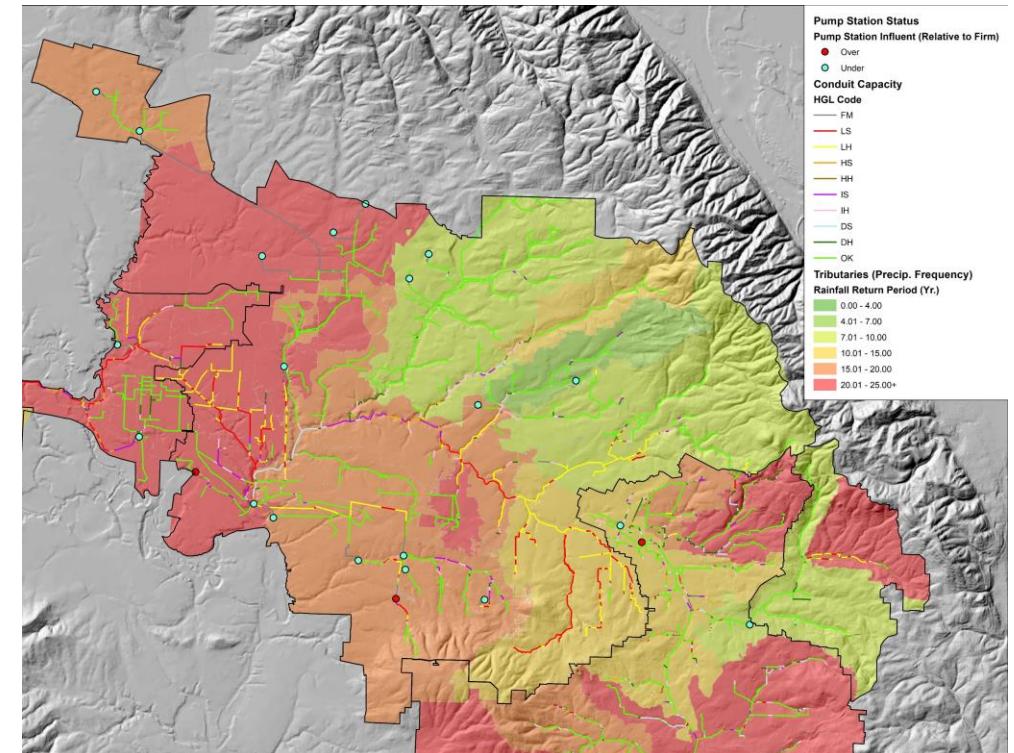
Flow Frequency

Flow Frequency



Event 248

Precipitation Frequency

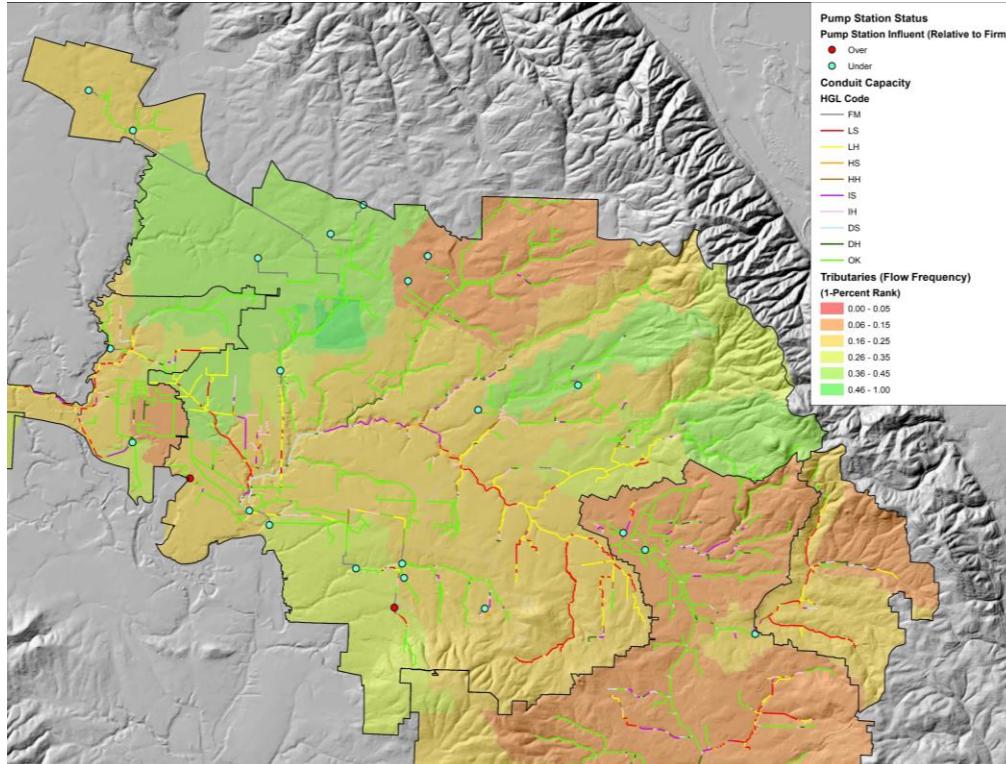


- 72-hour event
- 3.34- to 4.65- inch depth (3.92-inch avg)
- 6.7-year average flow frequency
- Design storm = 3.3- inch in 72 hours

Frequency – Events of Interest – Spatial Variability Rock Creek

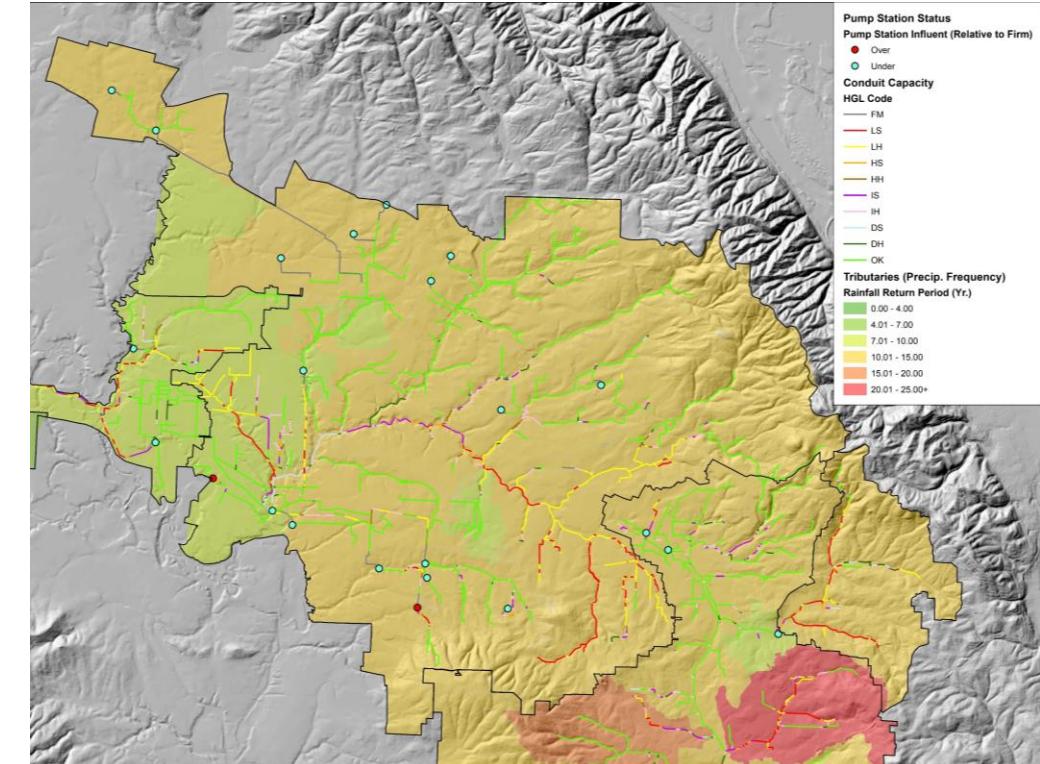
Flow Frequency

Flow Frequency



Event 87

Precipitation Frequency

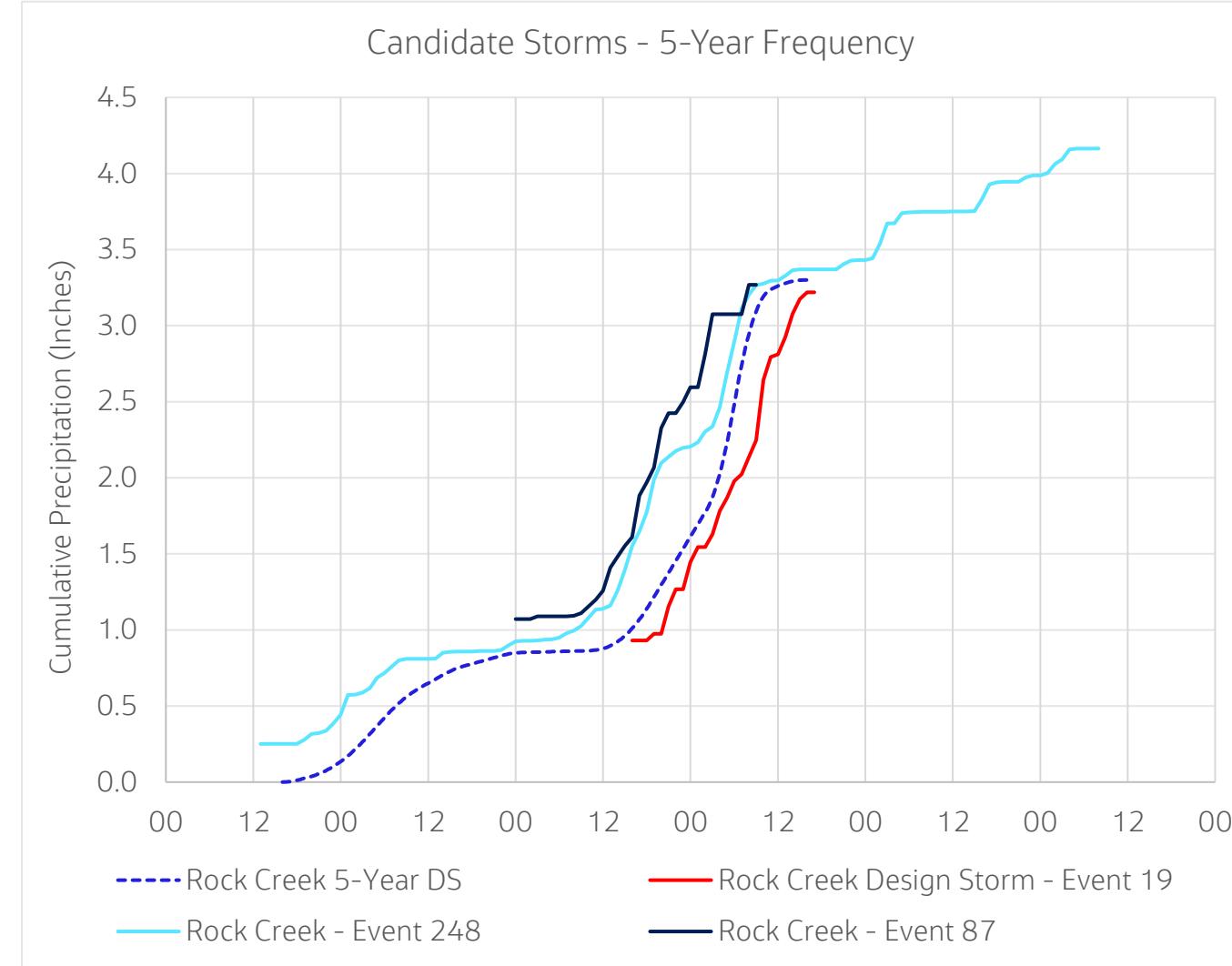


- 24-hour event
- 2.11- to 2.50- inch depth (2.26-inch avg)
- 4.3-year average flow frequency
- Design storm = 2.4- inch in 24 hours

Select Storm Event(s) – Candidate Storms – Rock Creek



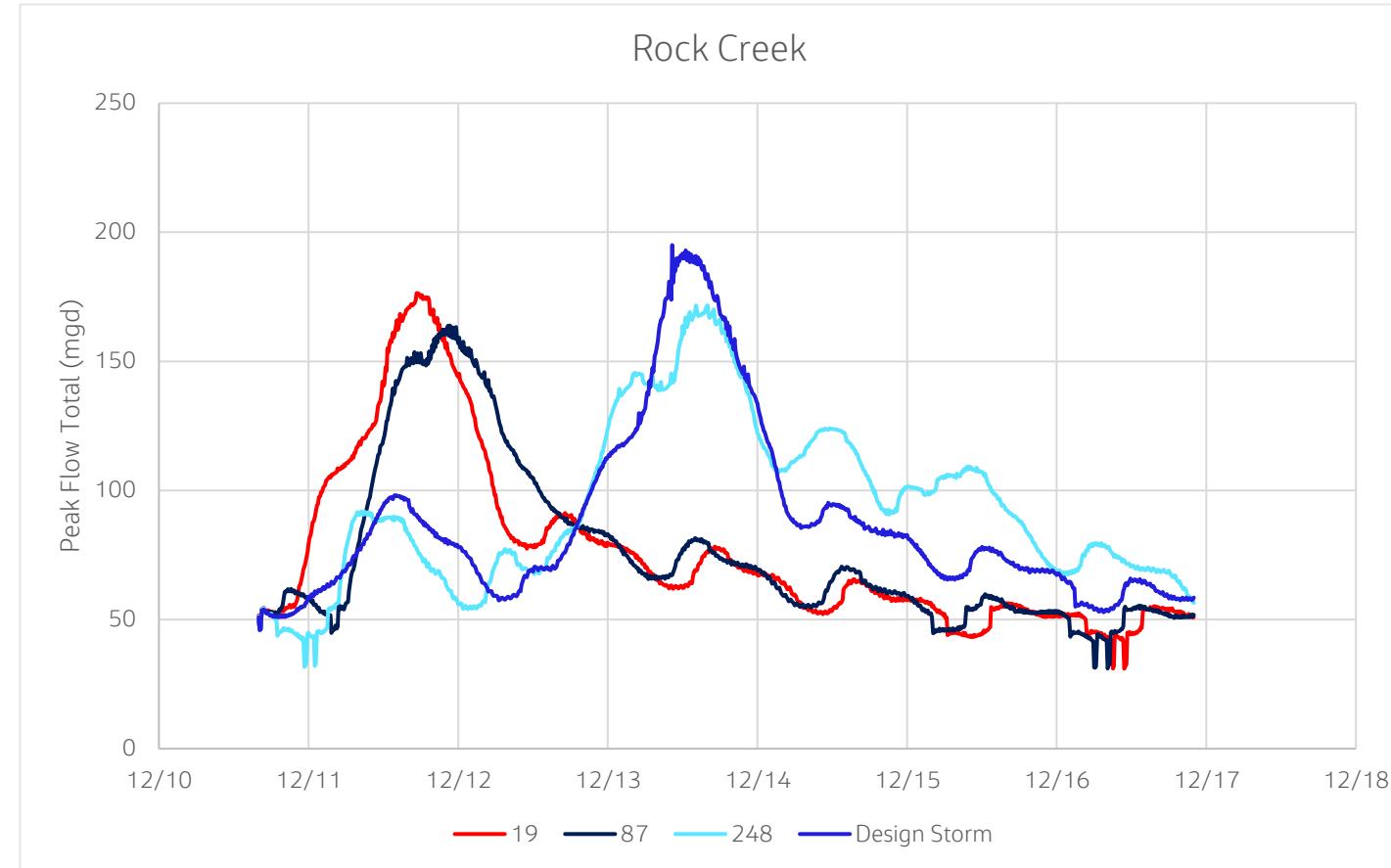
- Event 19 & 248 = higher level of service, 6-7 year frequency
- Event 87 = lower level of services, 4-5 year frequency



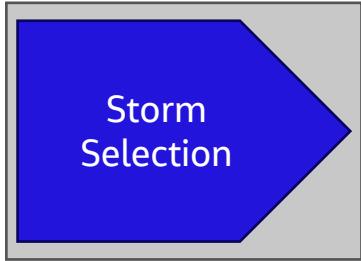
Select Storm Event(s) – Candidate Storms – Rock Creek



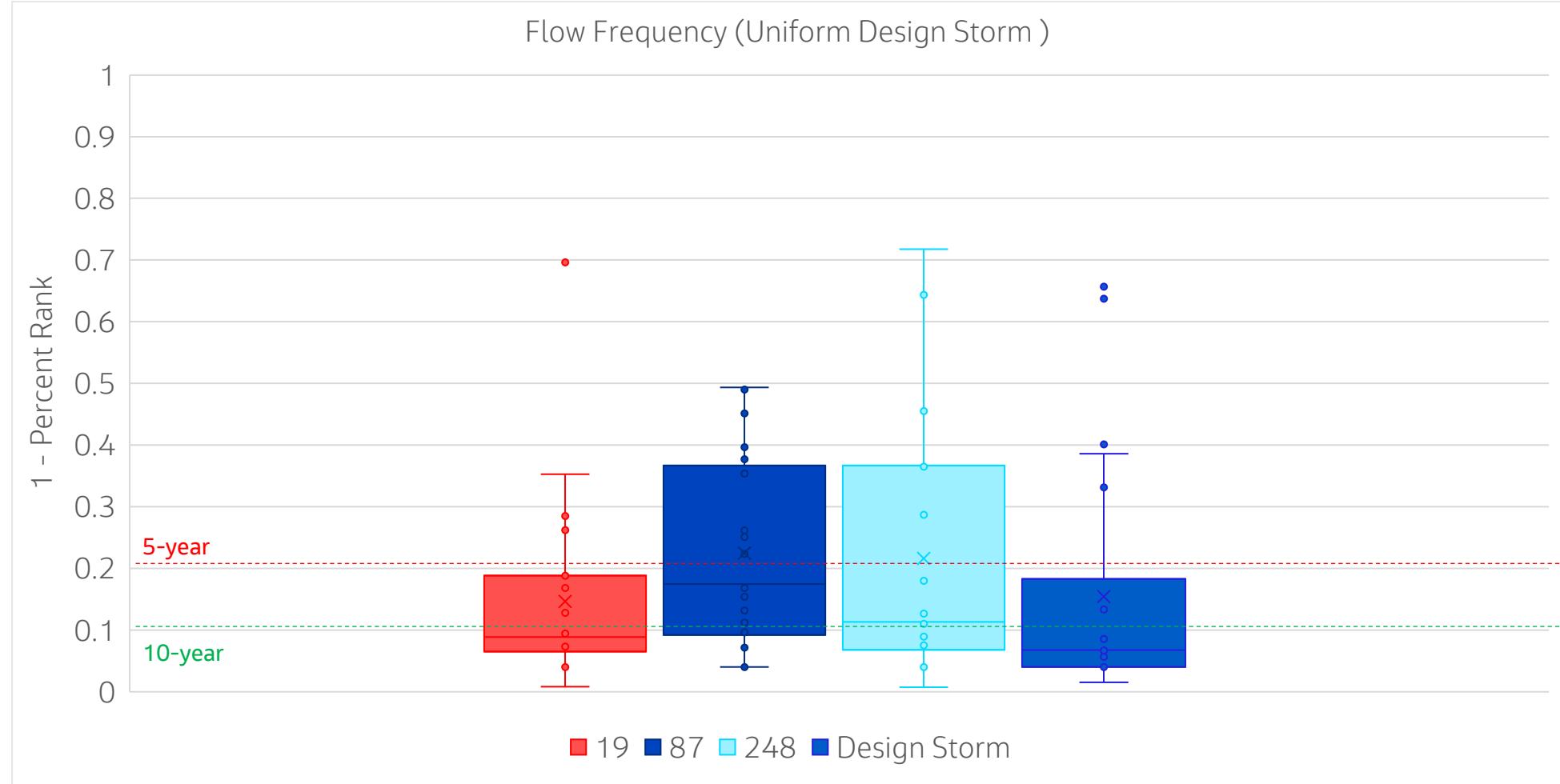
- Event 19 & 248 = higher level of service, 6-7 year frequency
- Event 87 = lower level of services, 4-5 year frequency



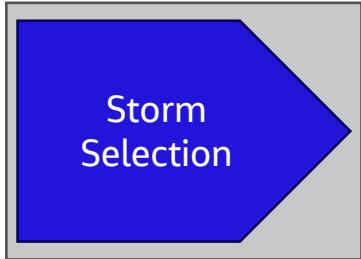
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



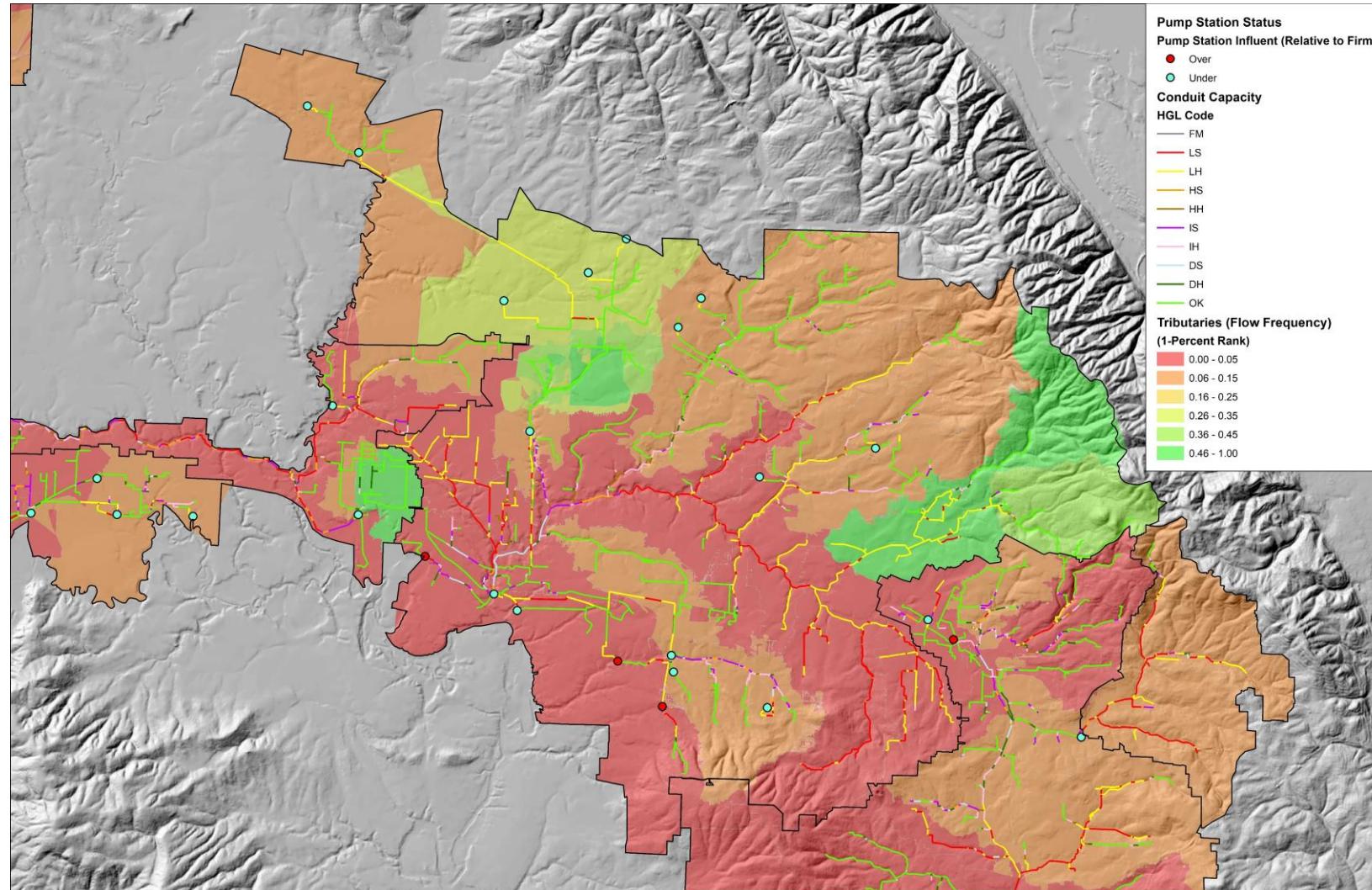
- Events 19, 248, and 87 compared to existing design storm
- Uniform Application



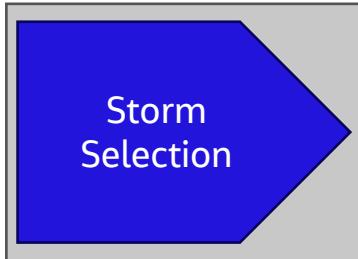
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



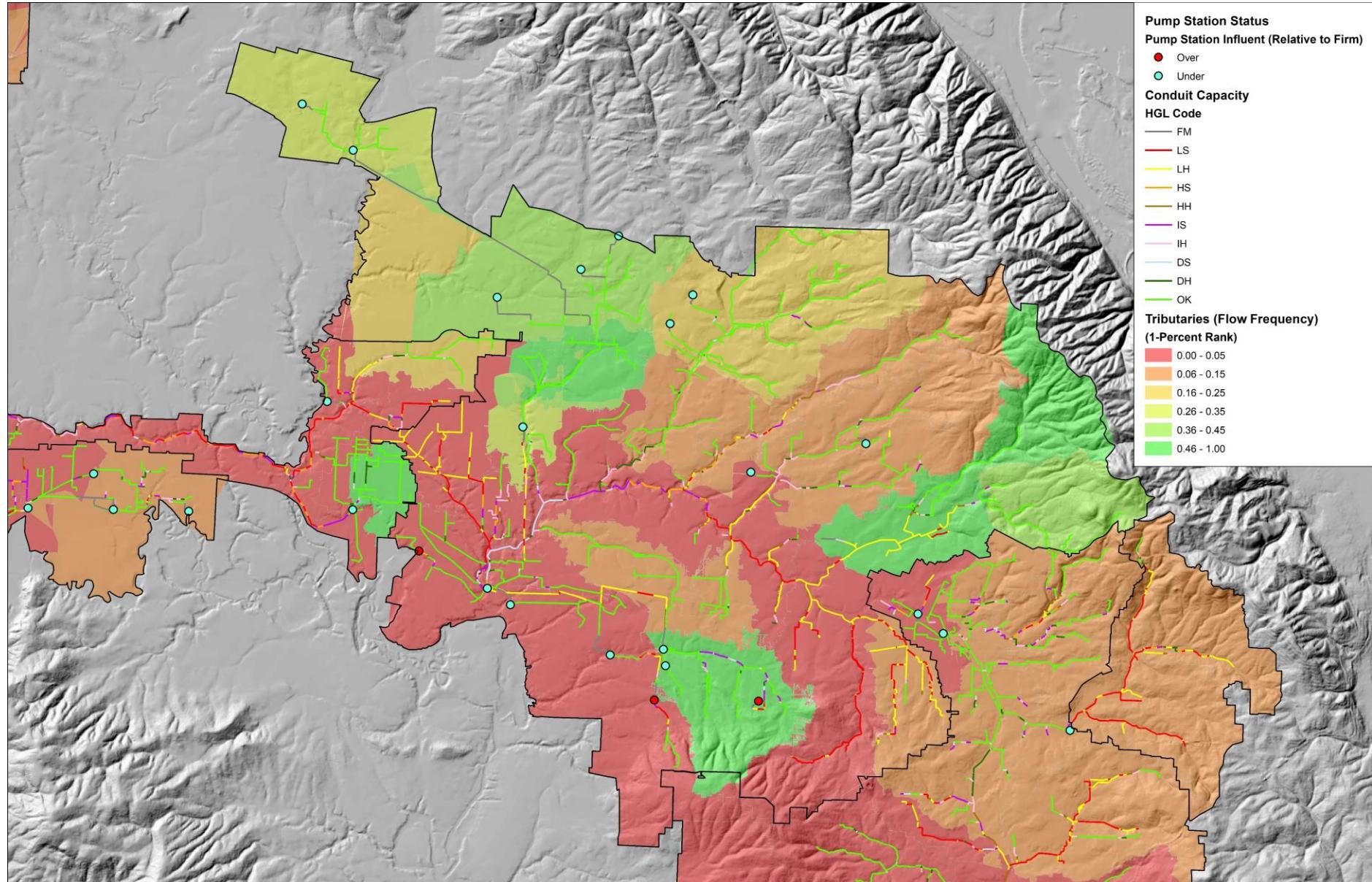
- Existing Design Storm
- Uniform Application



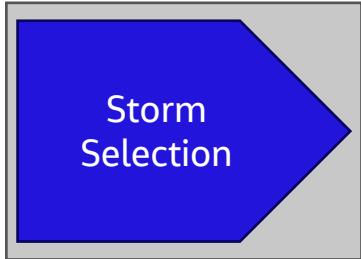
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



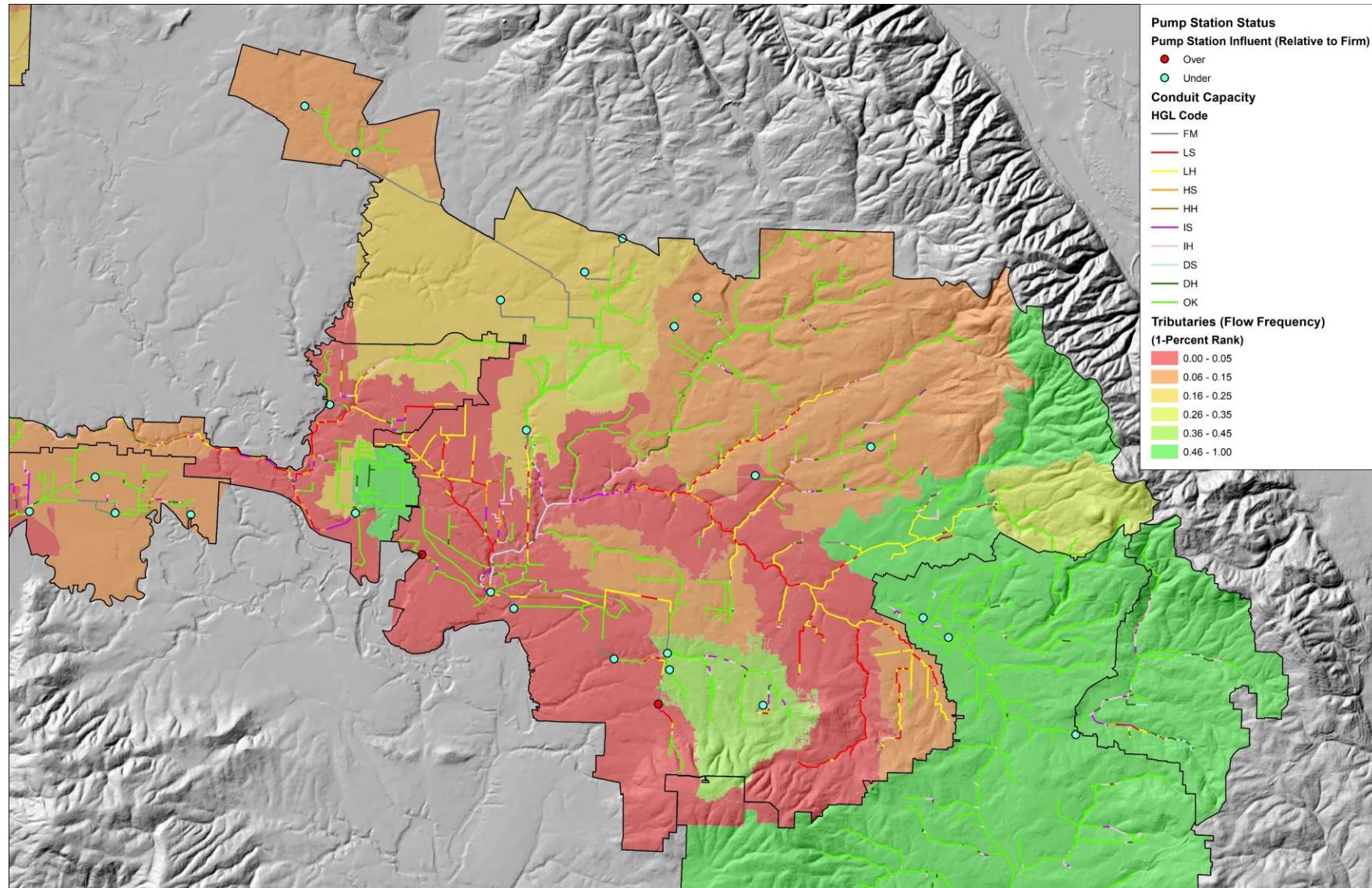
- Event 248
- Uniform Application



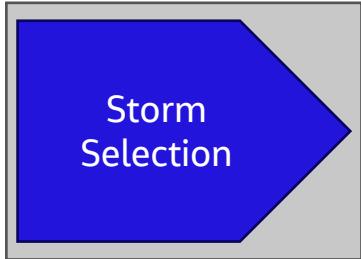
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



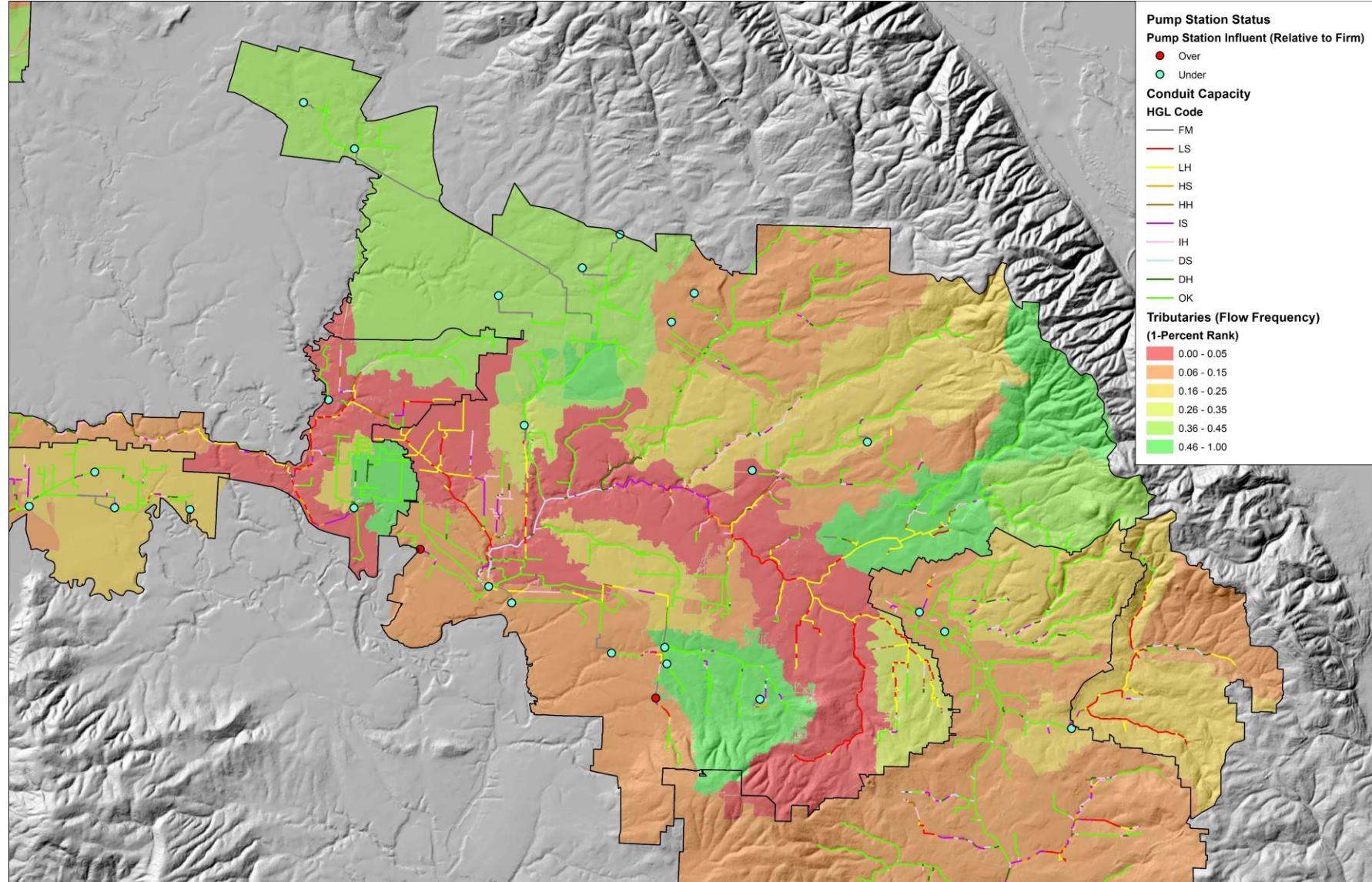
- Event 19
- Uniform Application



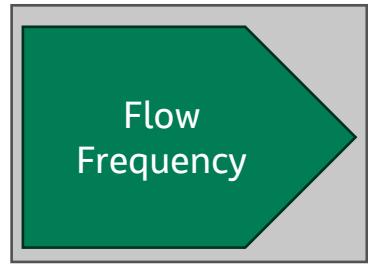
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



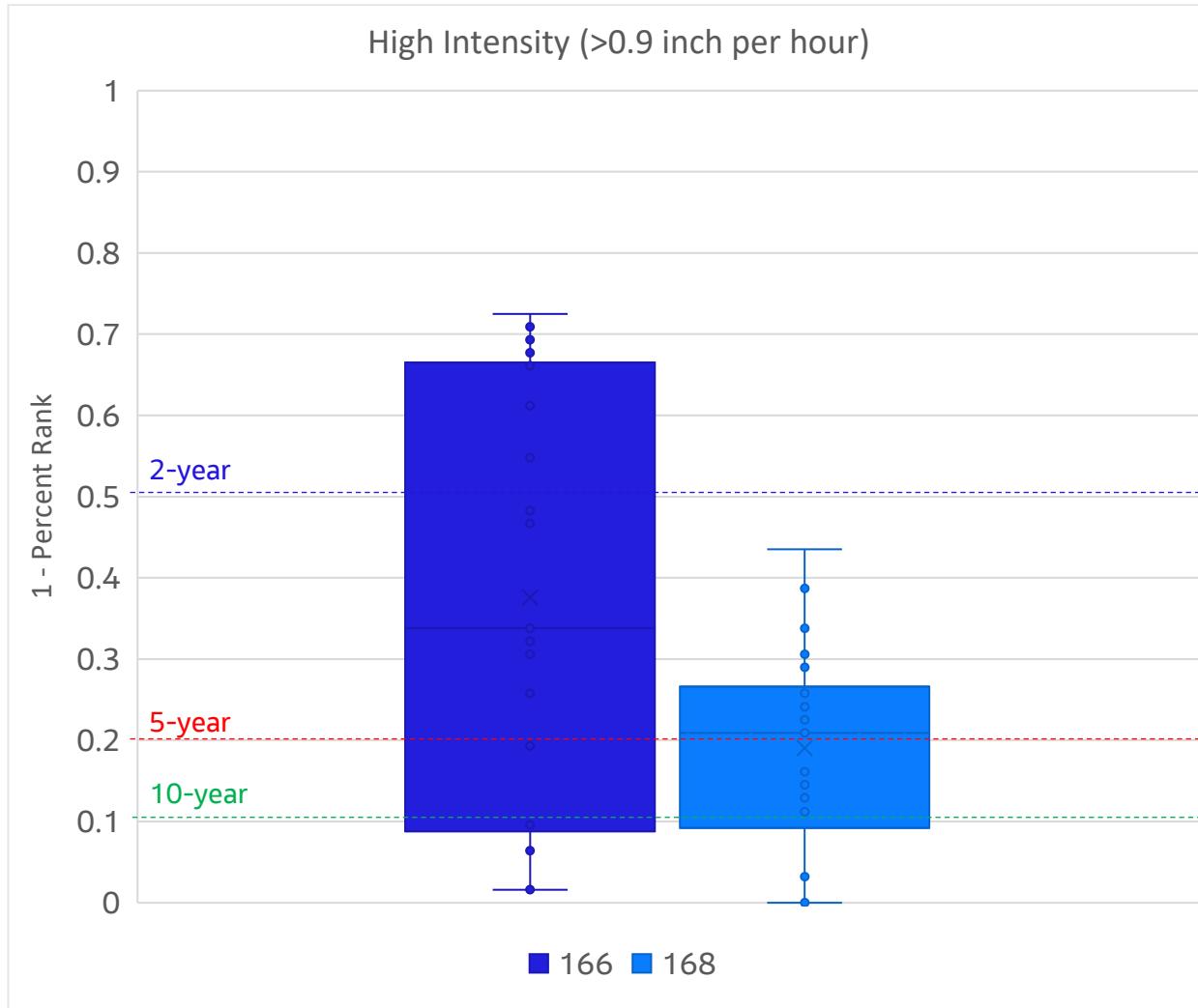
- Event 87
- Uniform Application



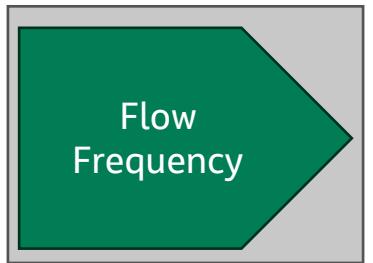
High Intensity Assessment – Rock Creek



- Events with some subbasins at 0.9 inch/hour
- <6-hour duration (cloud burst)

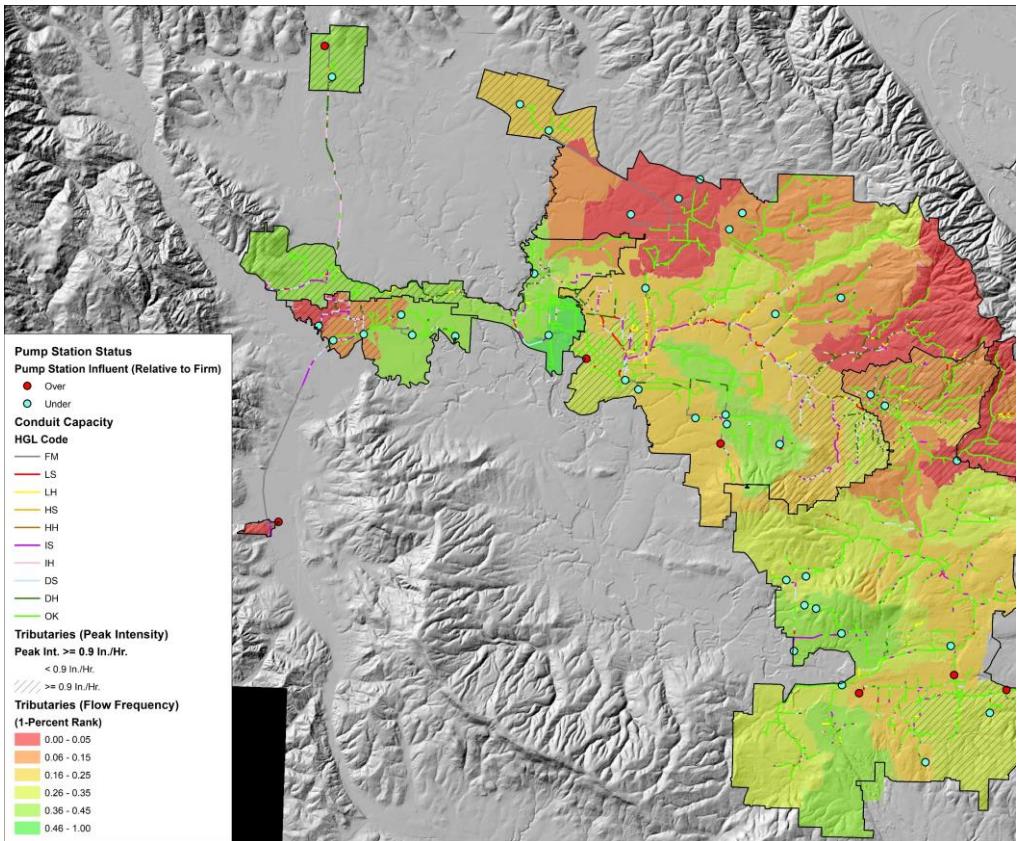


High Intensity Assessment – Rock Creek

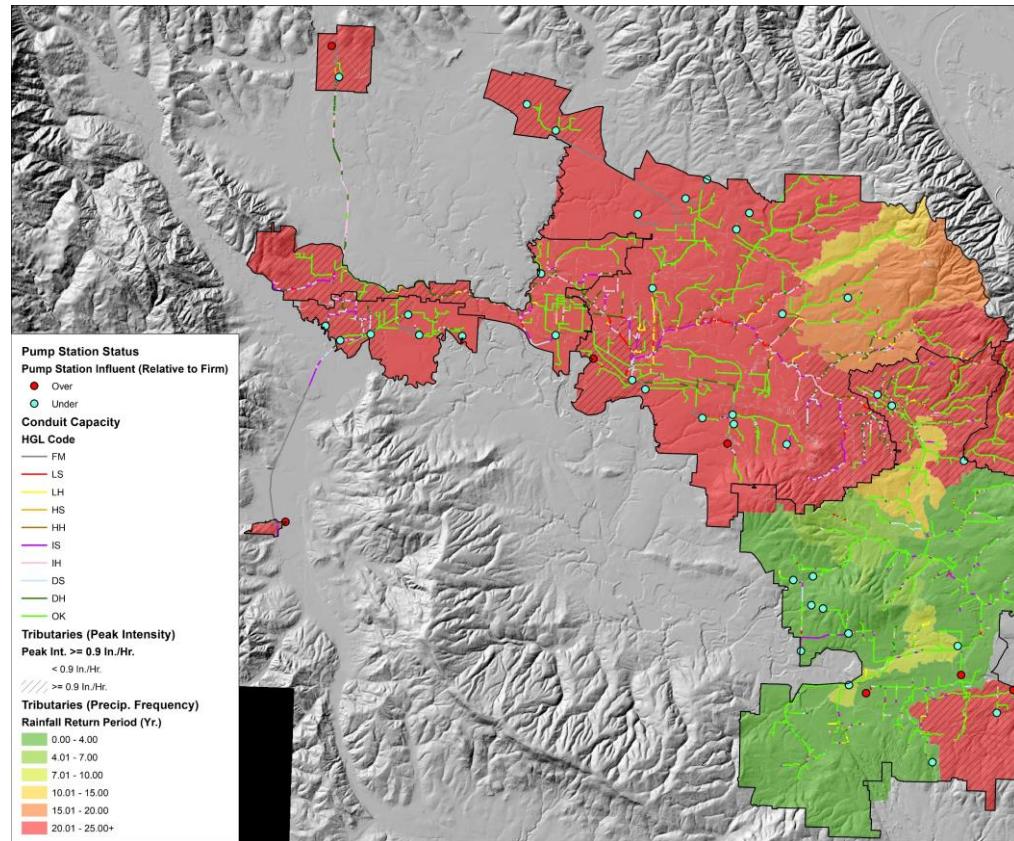


Event 168

Flow Frequency



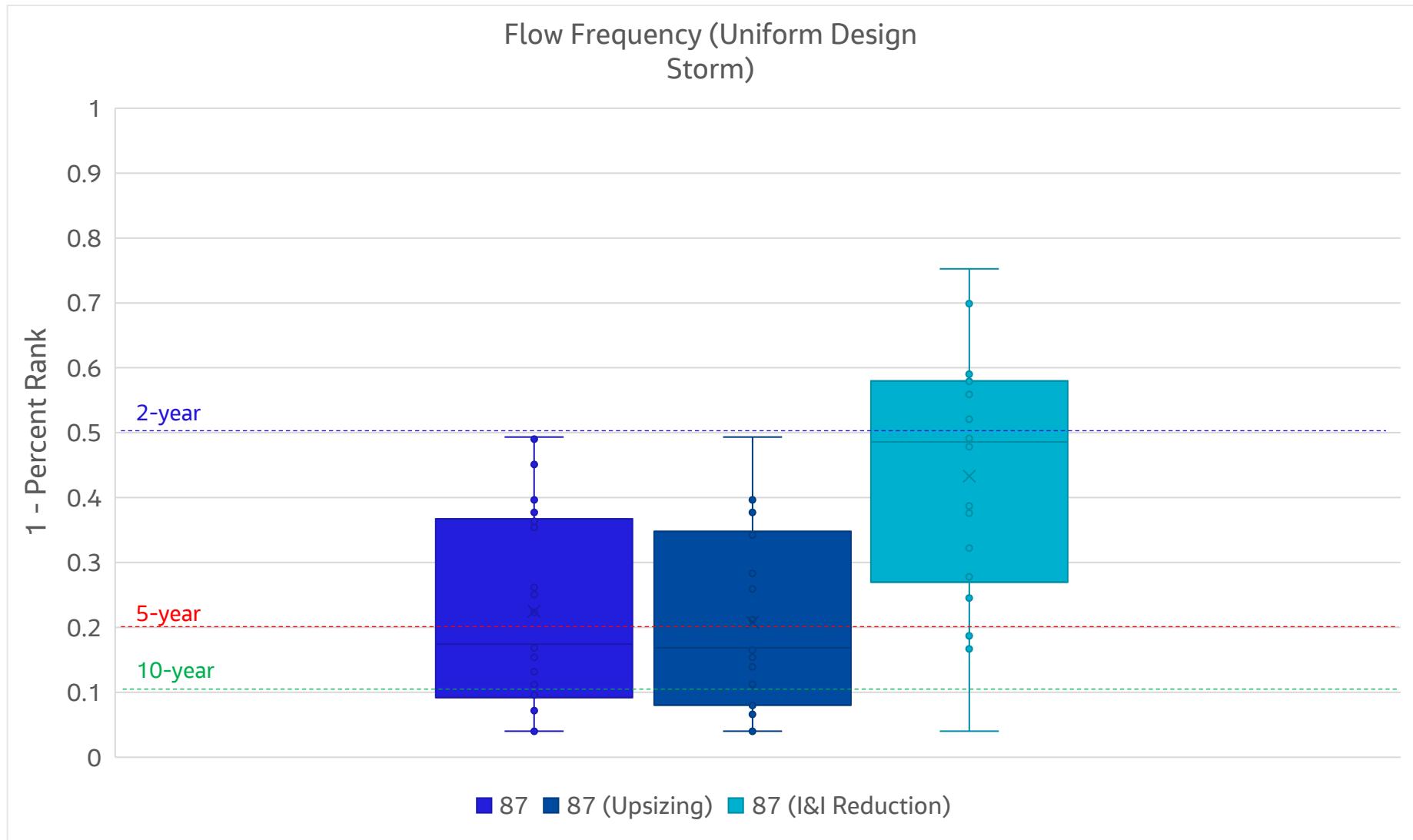
Precipitation Frequency



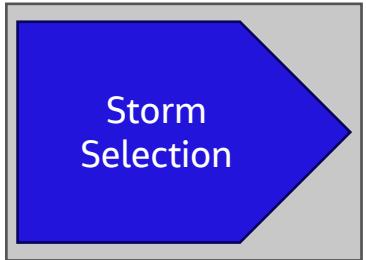
Sensitivity to Upsizing & RDI/I Reduction - Rock Creek



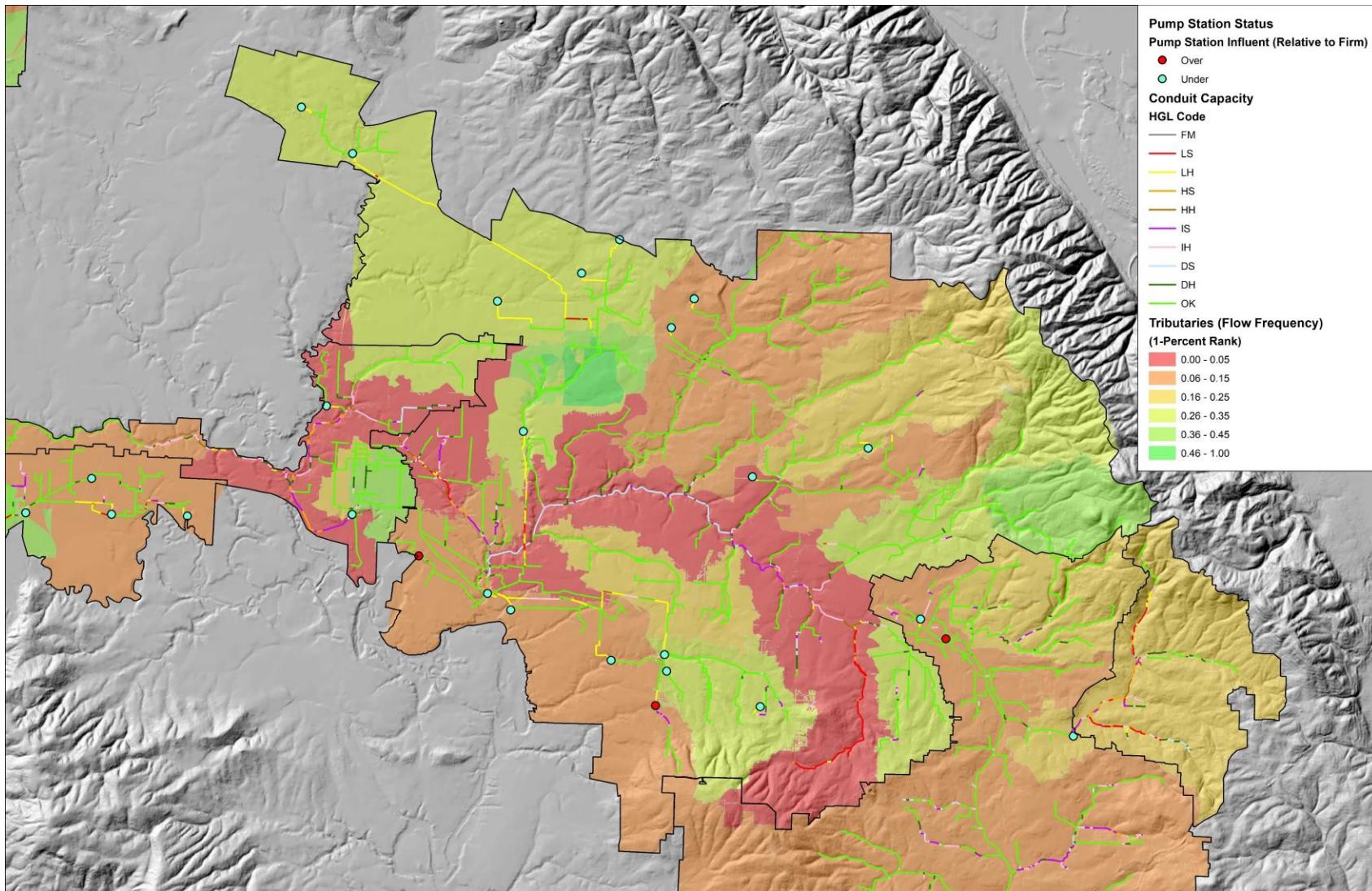
Event 87



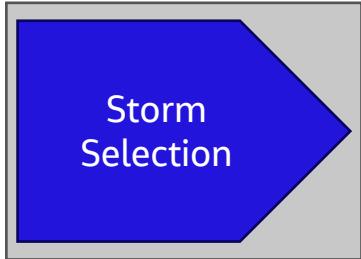
Sensitivity to Upsizing - Rock Creek



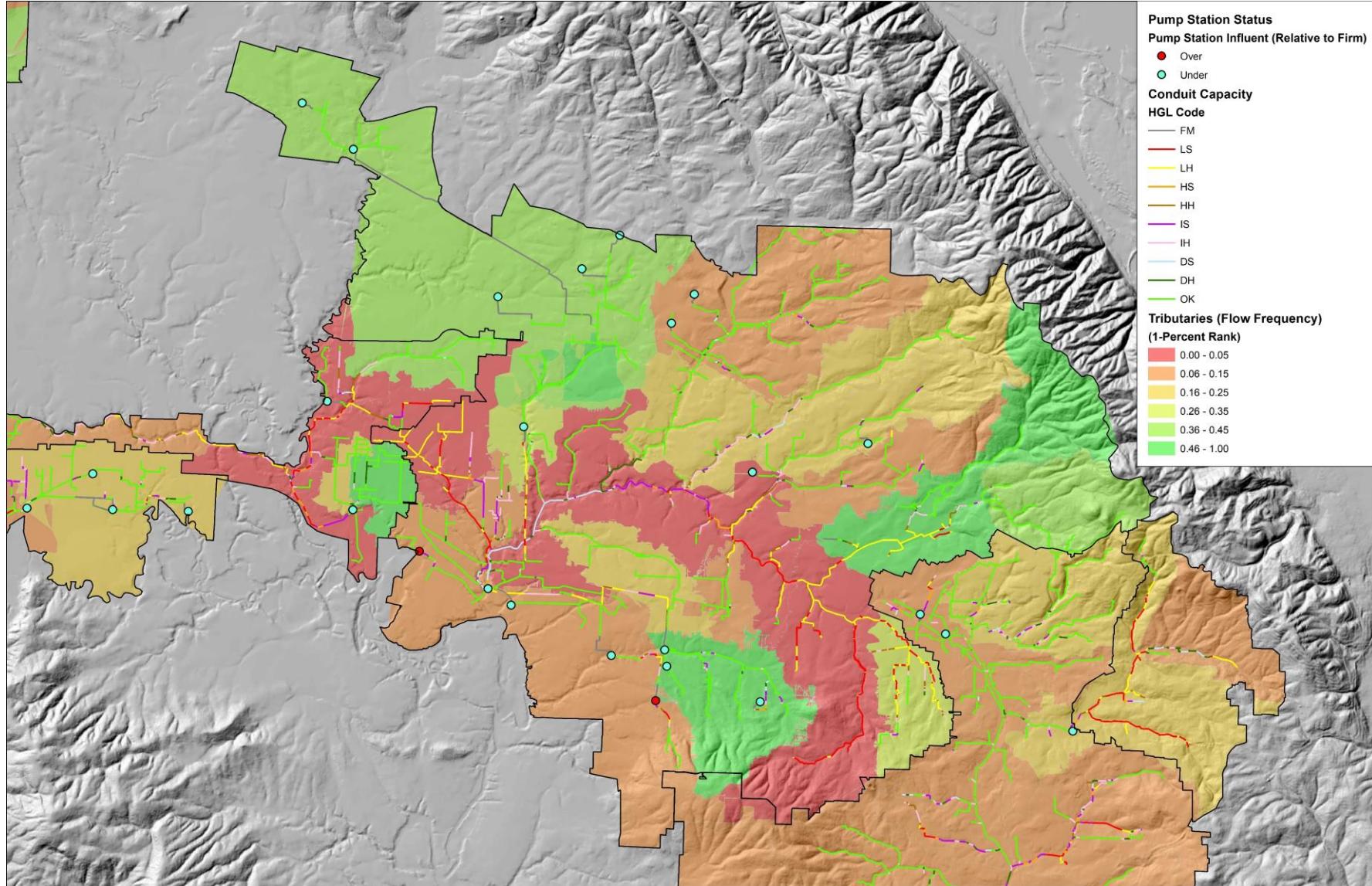
Event 87



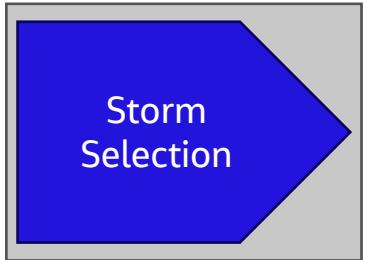
Select Storm Event(s) – Candidate Storms – Uniform - Rock Creek



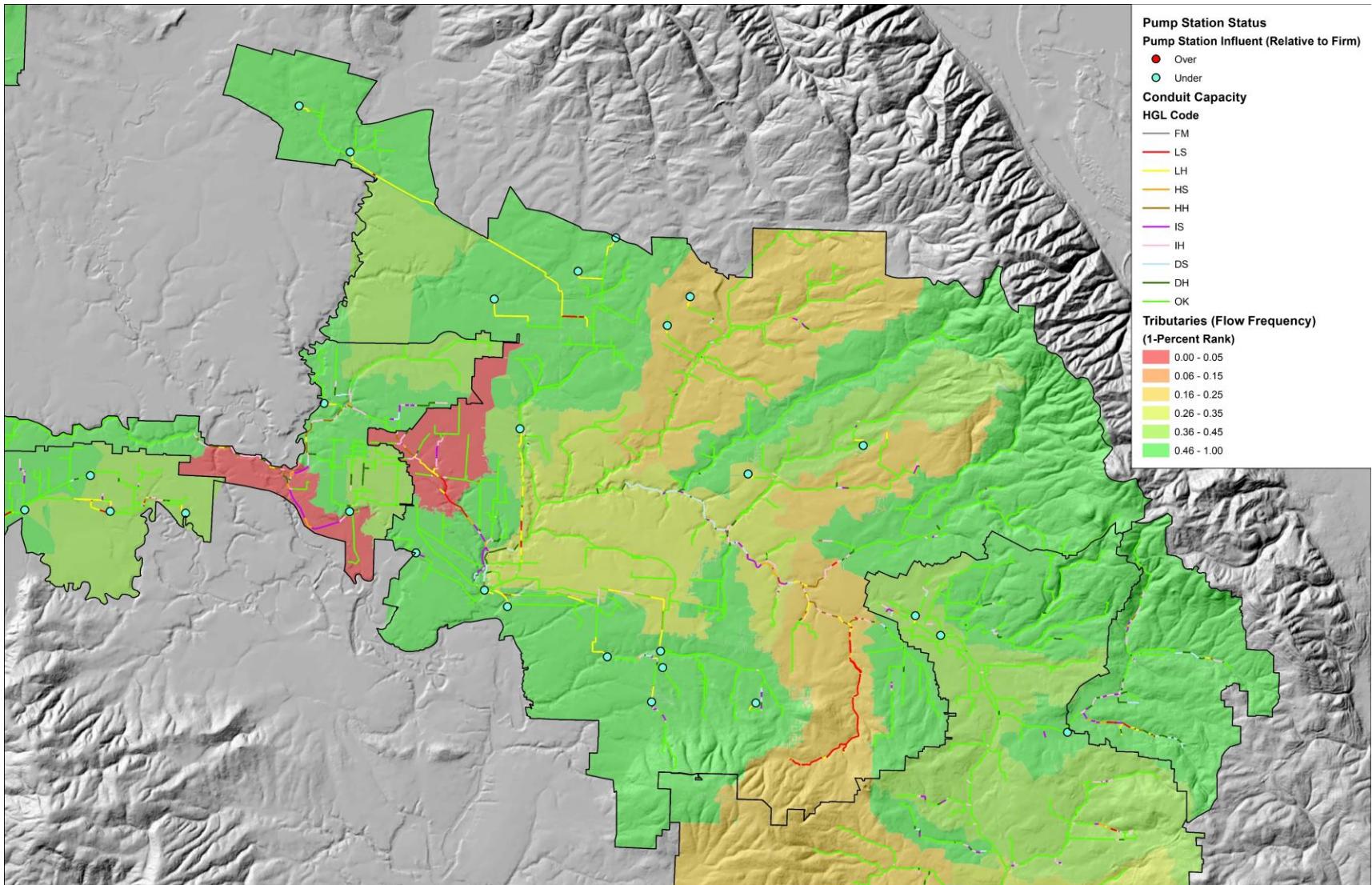
- Event 87
- Uniform Application



Sensitivity to RDI/I Reduction - Rock Creek

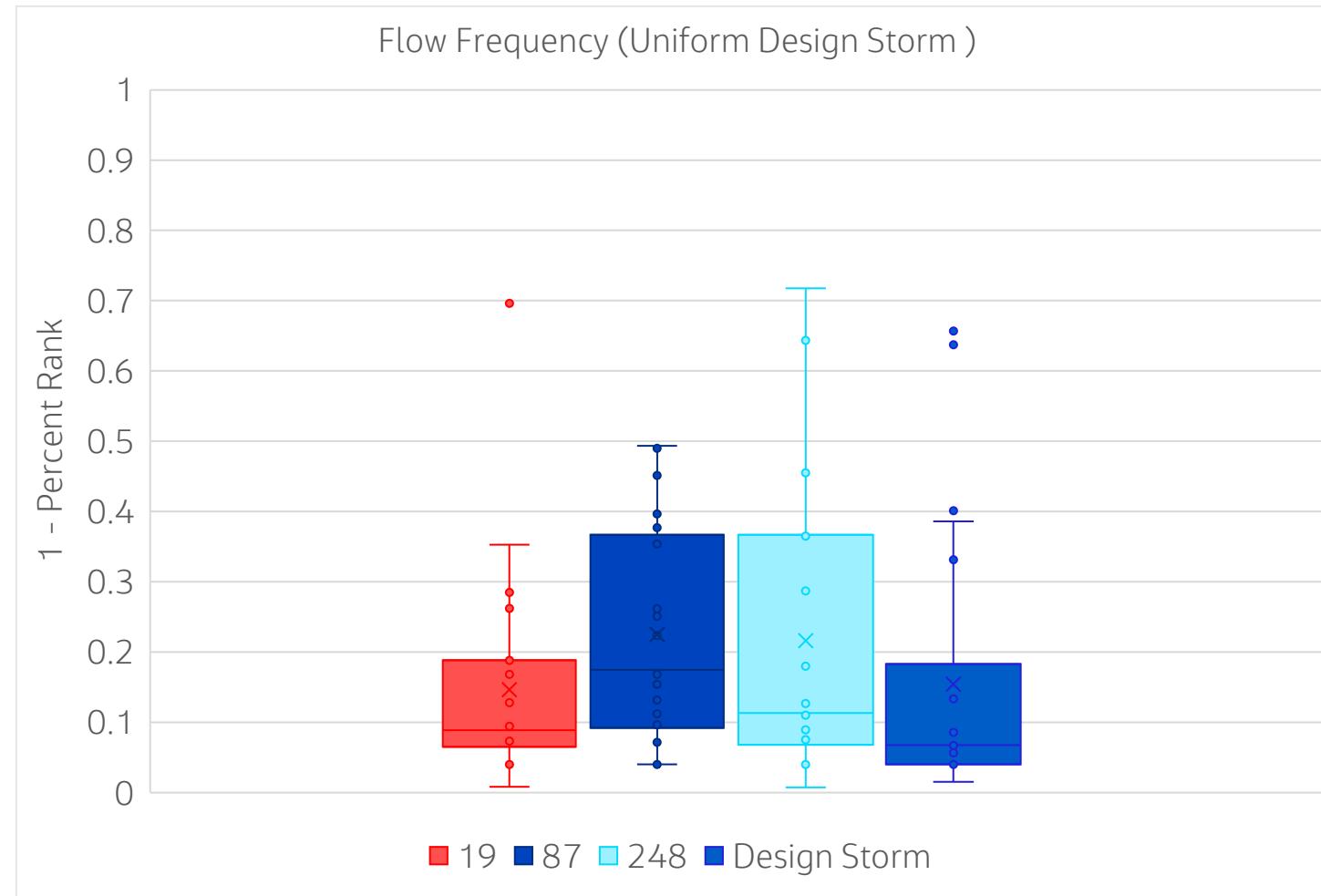


Event 87

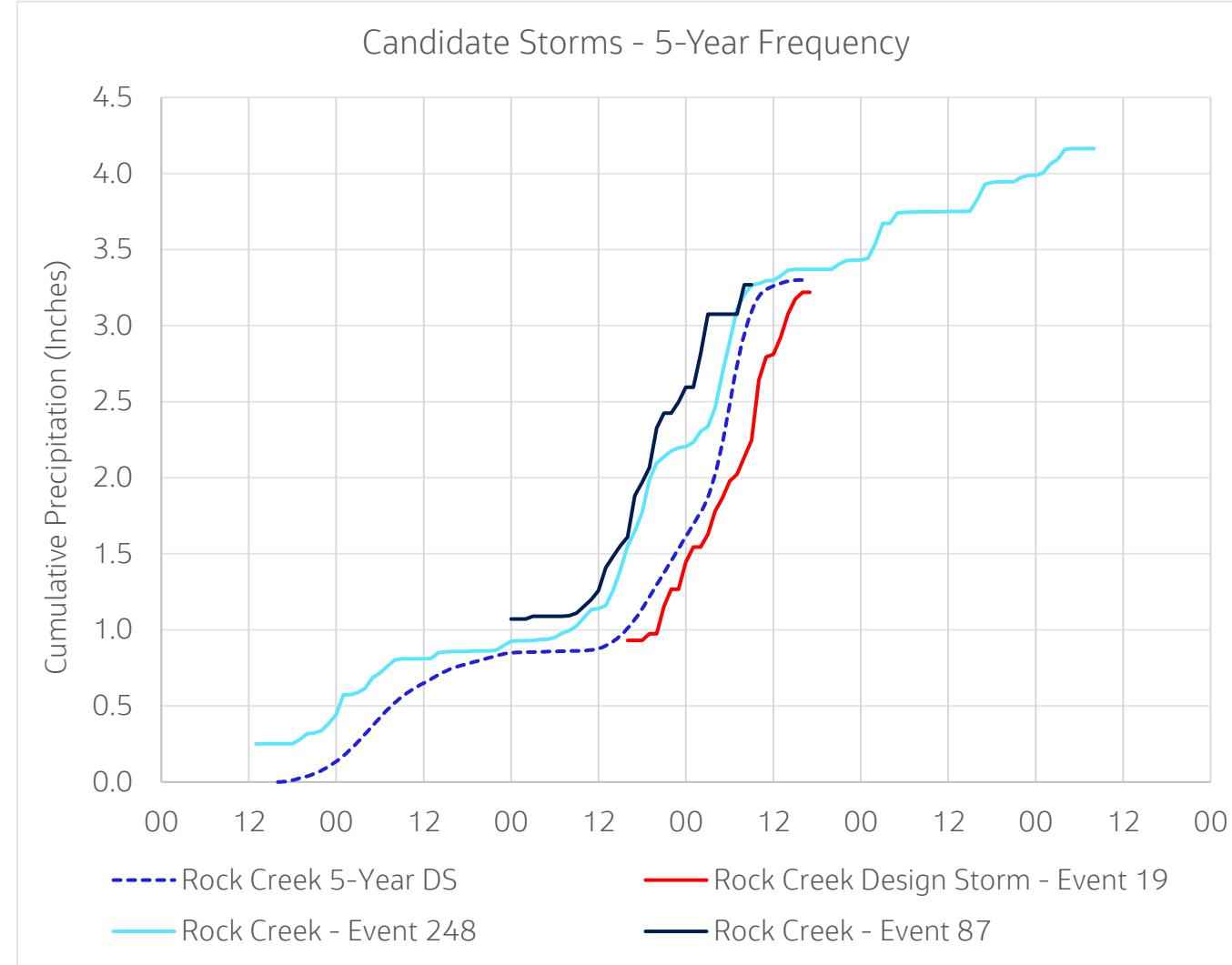
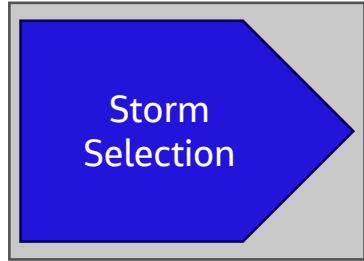


Rock Creek Recommendations

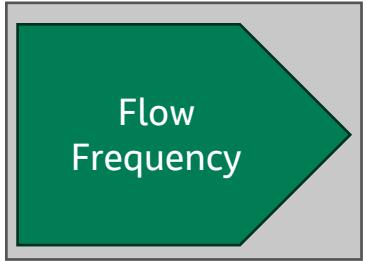
- Event 19 provides high level of service with fewest outliers
 - Adjust few outliers
- Not significantly different than using existing design storm
- Decision: District preference for existing design storm (keep it simple approach)



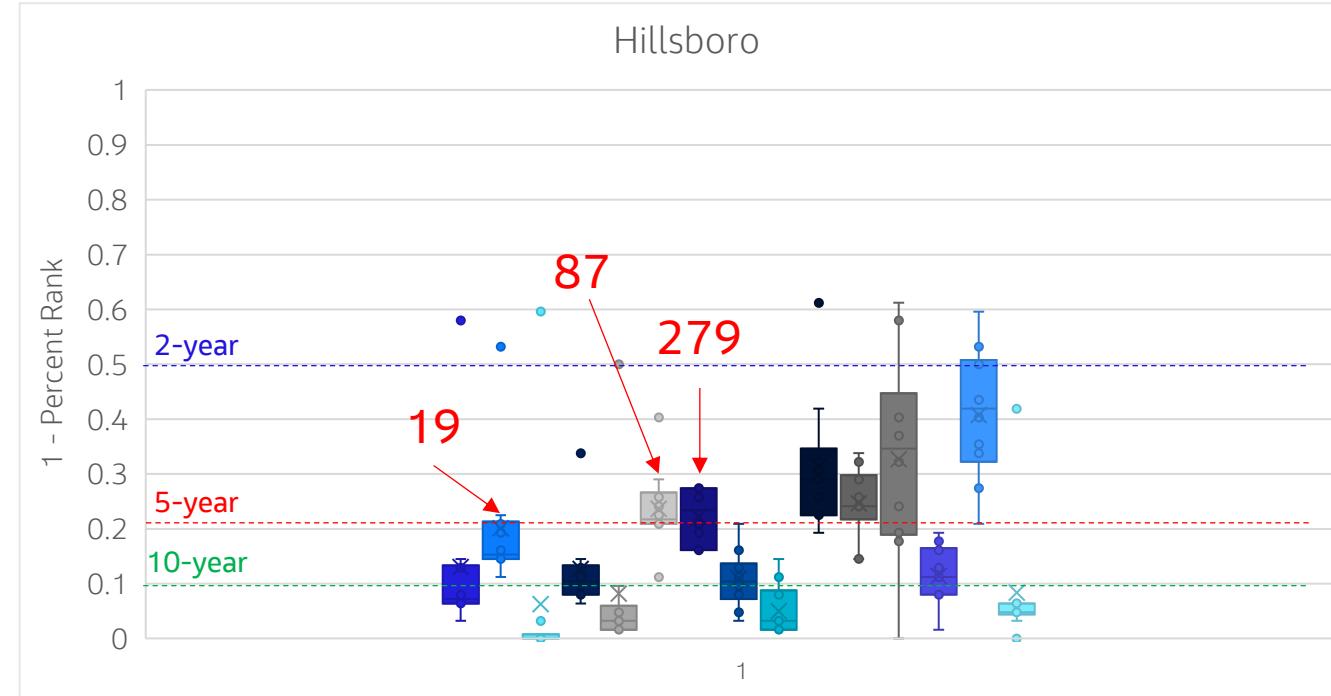
Select Storm Event(s) – Candidate Storms – Rock Creek



Flow Frequency – Events of Interest – Hillsboro



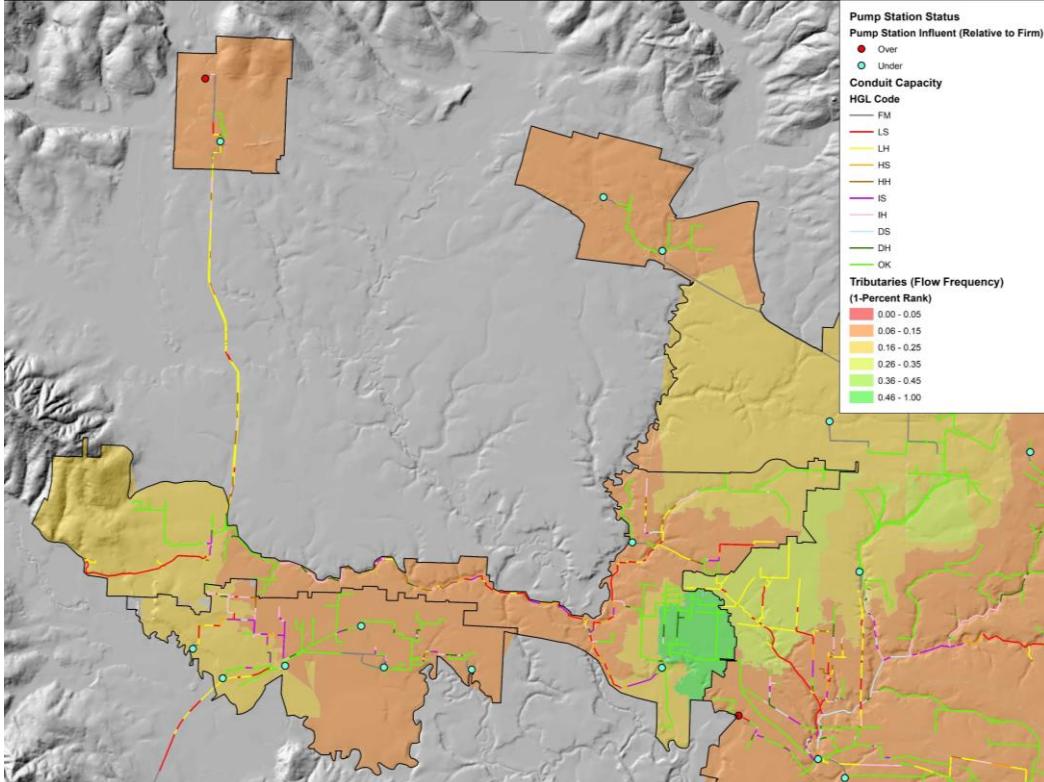
- High flow and spatial variability for some events
- Less variability and more system-wide impact for 5-year to 10-year flow frequency (similar to existing design storm)



Frequency – Events of Interest – Spatial Variability - Hillsboro

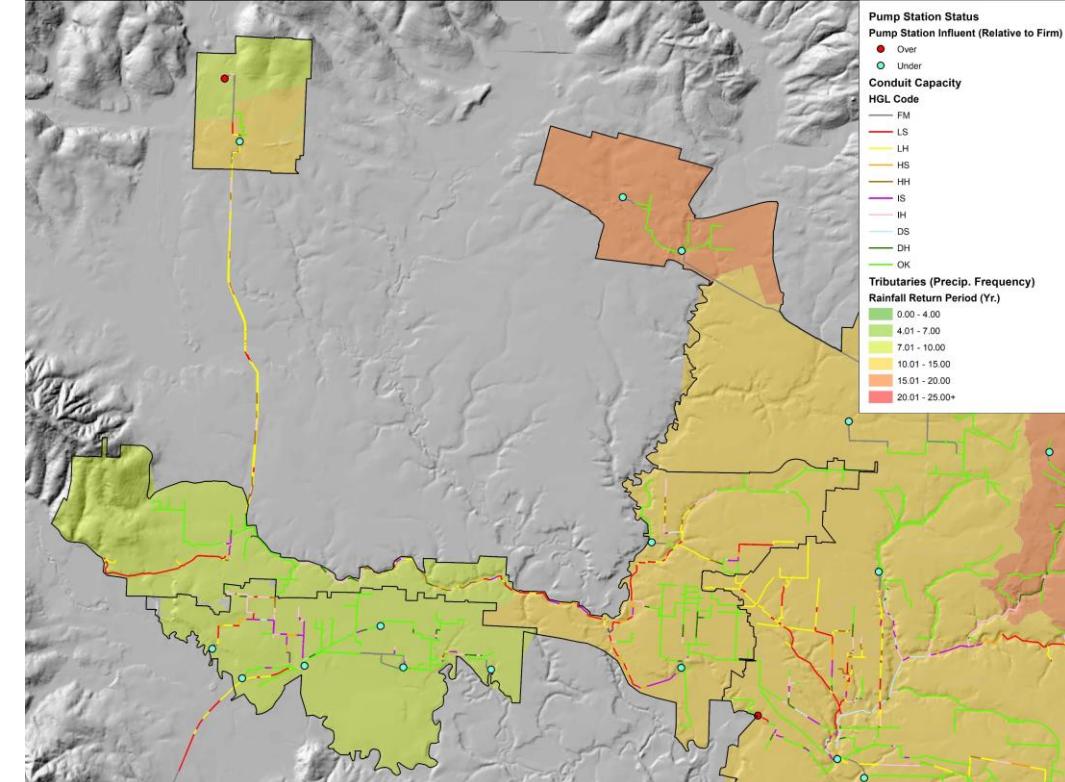
Flow Frequency

Flow Frequency



Event 19

Precipitation Frequency



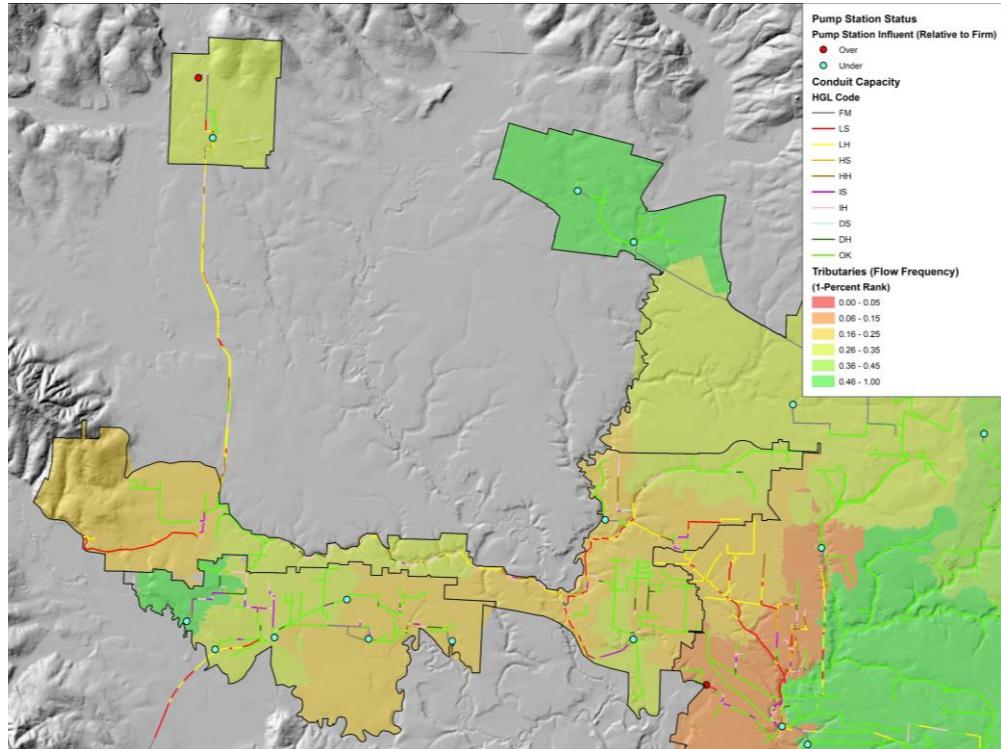
- 24-hour event
- 2.26- to 2.71- inch depth (2.4- inch avg)
- 5.5-year avg flow frequency
- Design storm = 2.4- inch in 24 hours

Frequency – Events of Interest – Spatial Variability - Hillsboro

Flow Frequency

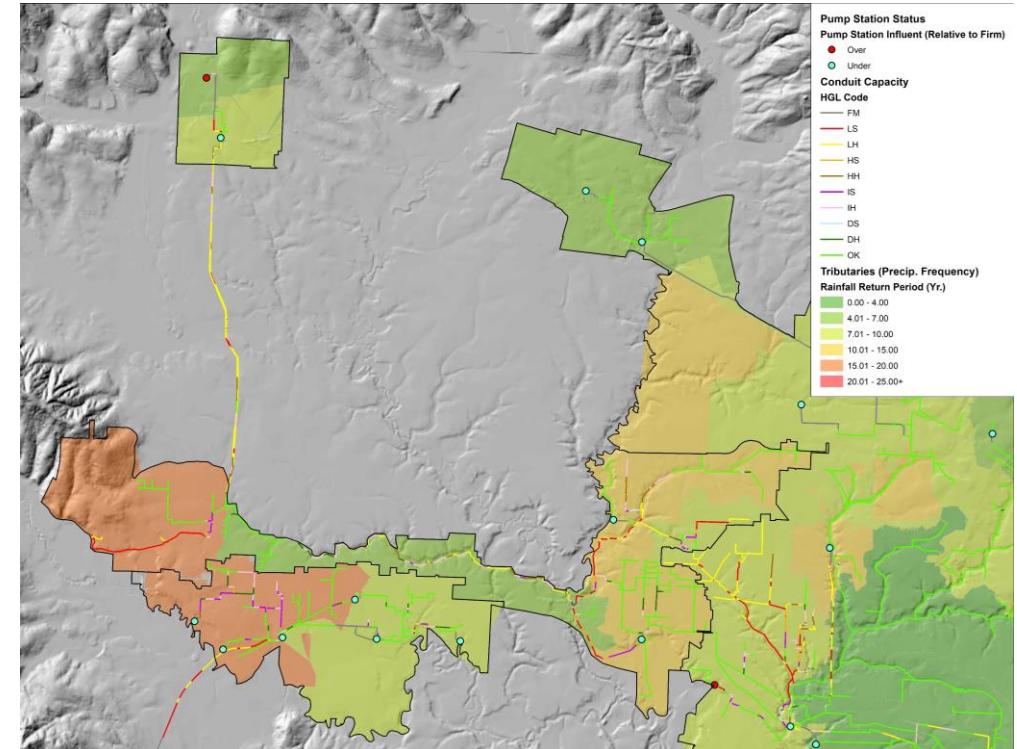
- 72-hour event
- 3.71- to 4.69- inch depth (4.0- inch avg)
- 4.5-year avg flow frequency
- Design storm = 3.3- inch in 72 hours

Flow Frequency

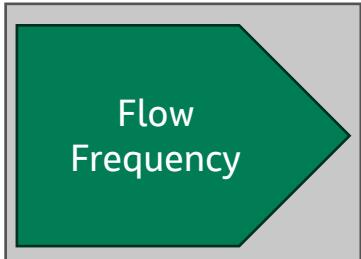


Event 279

Precipitation Frequency

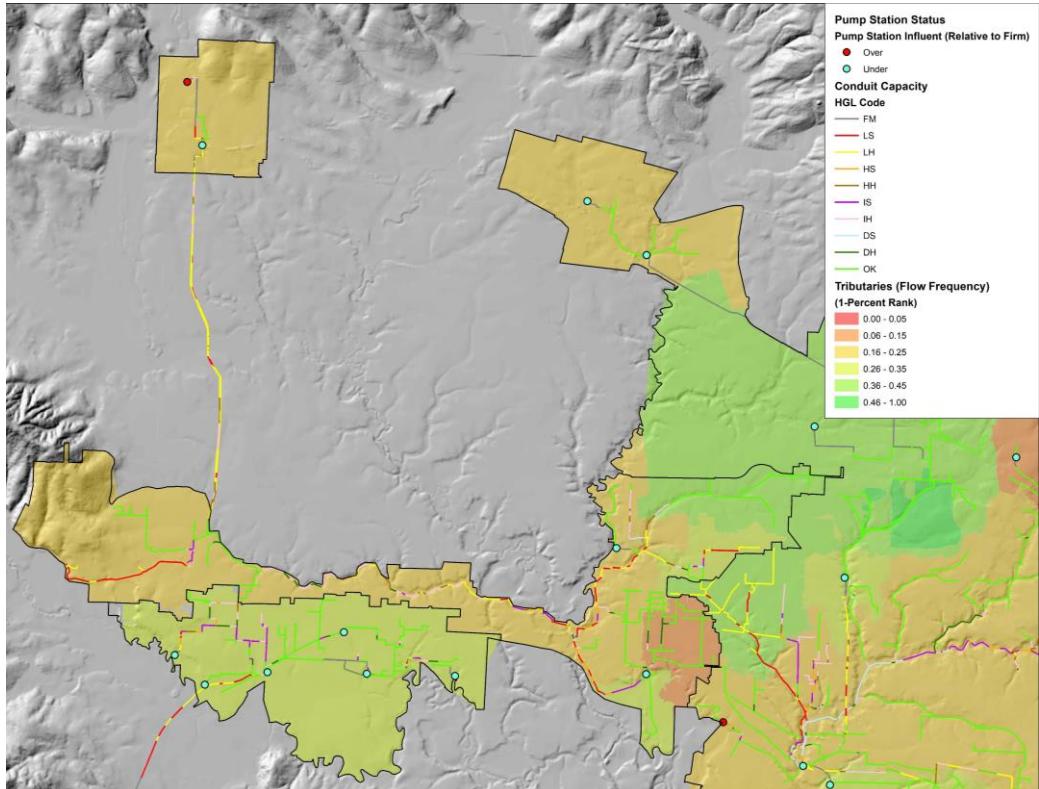


Frequency – Events of Interest – Spatial Variability - Hillsboro



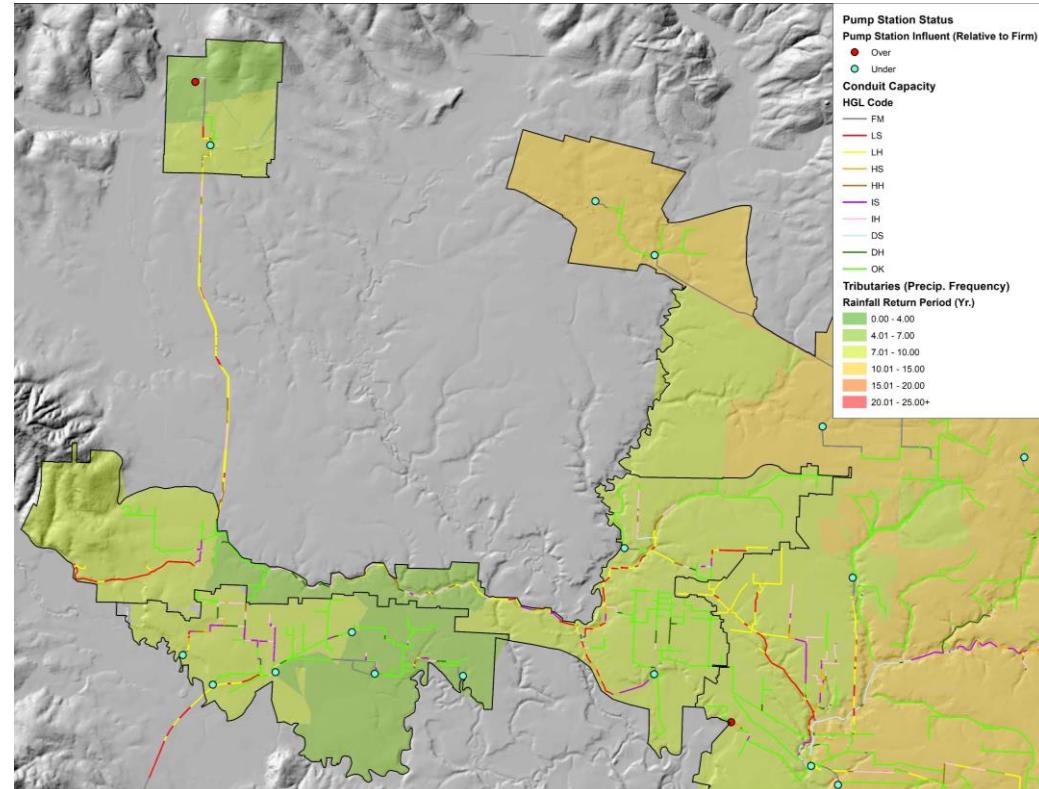
- 24-hour event
- 2.22- to 2.63- inch depth (2.3- inch avg)
- 4.4-year avg flow frequency
- Design storm = 2.4- inch in 24 hours

Flow Frequency



Event 87

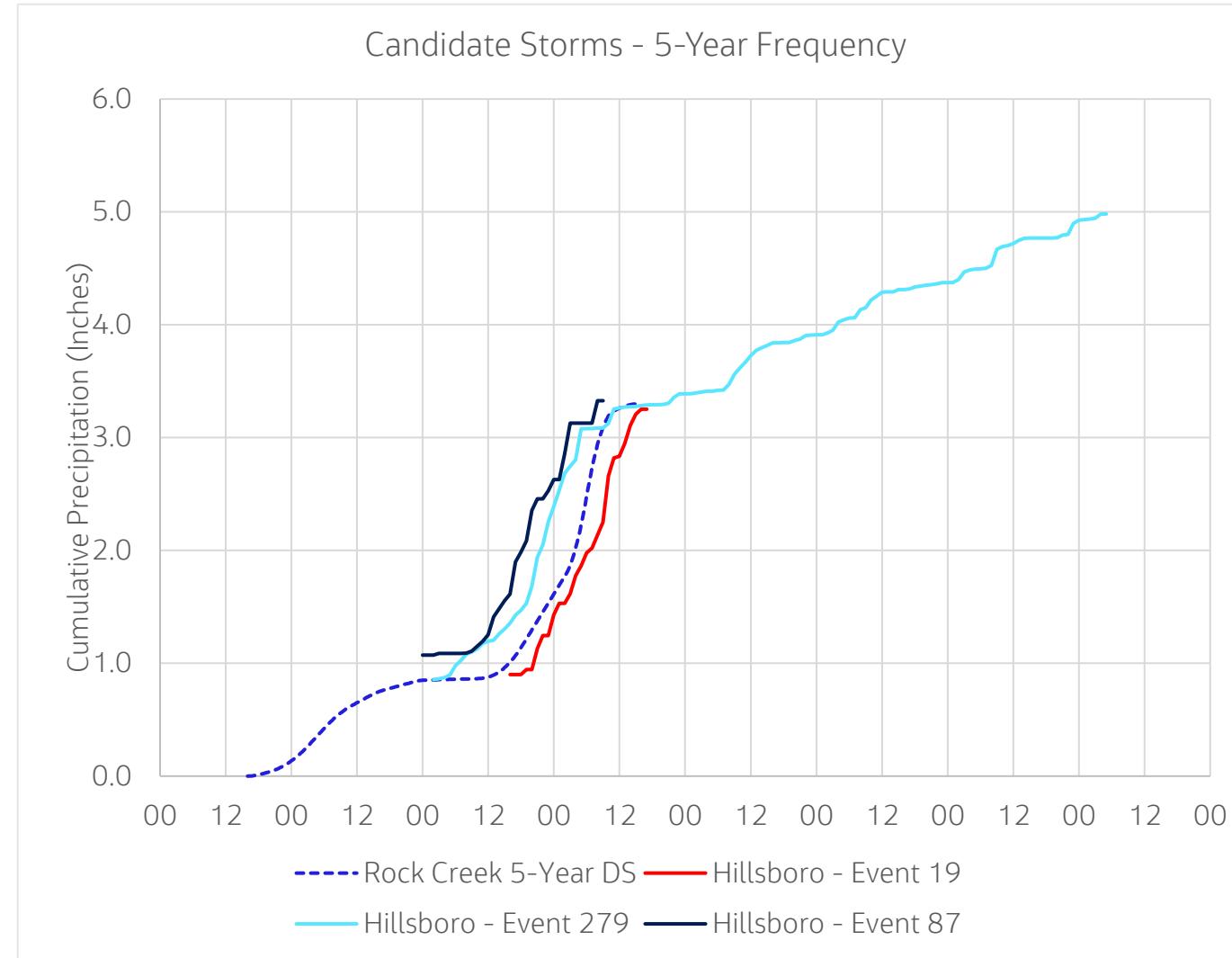
Precipitation Frequency



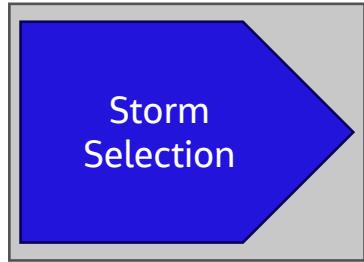
Select Storm Event(s) – Candidate Storms – Hillsboro



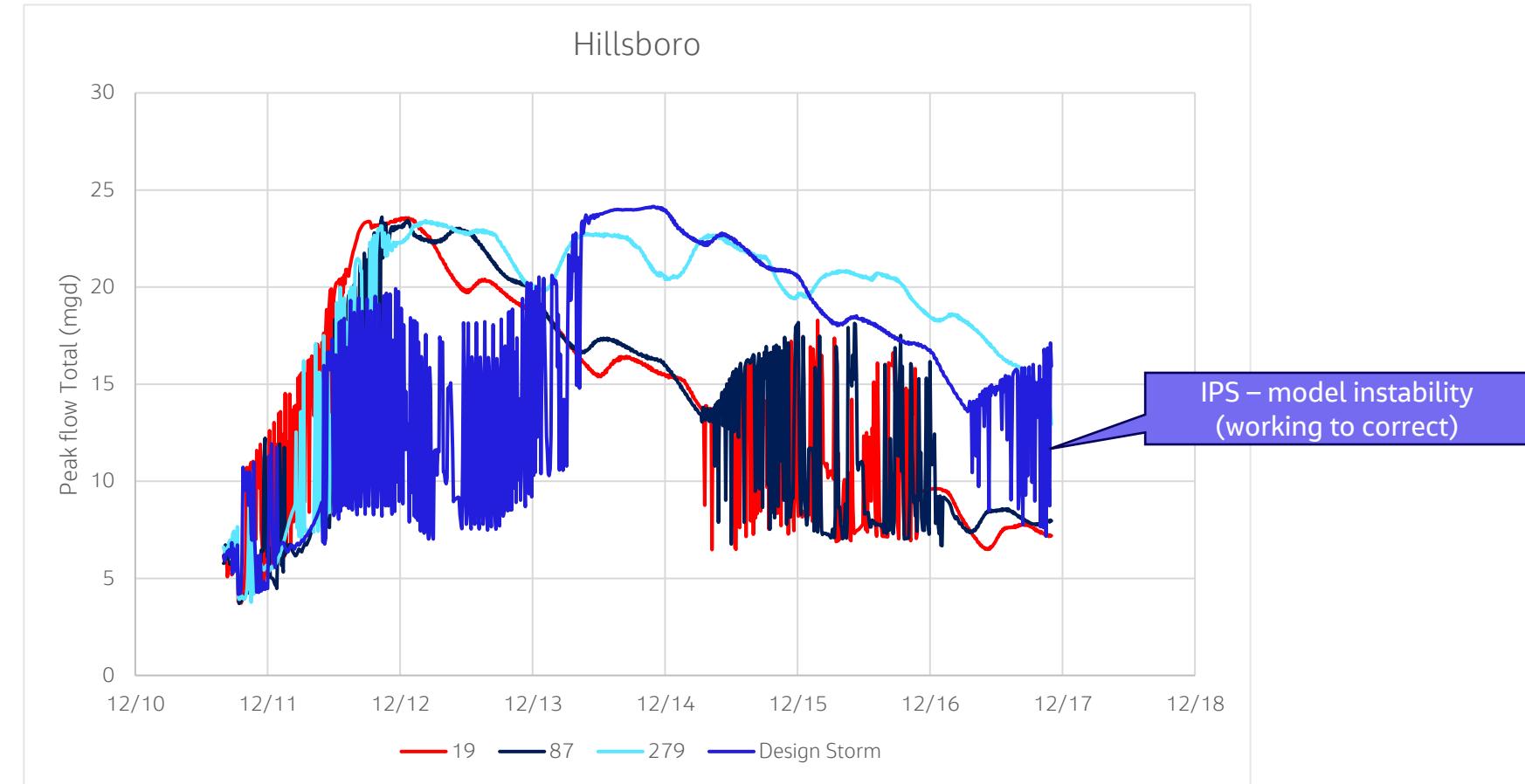
- Event 19 = slightly higher level of service, 5-6 year frequency
- Event 279 & 87 = slightly lower level of service, 4-5 year frequency



Select Storm Event(s) – Candidate Storms – Hillsboro



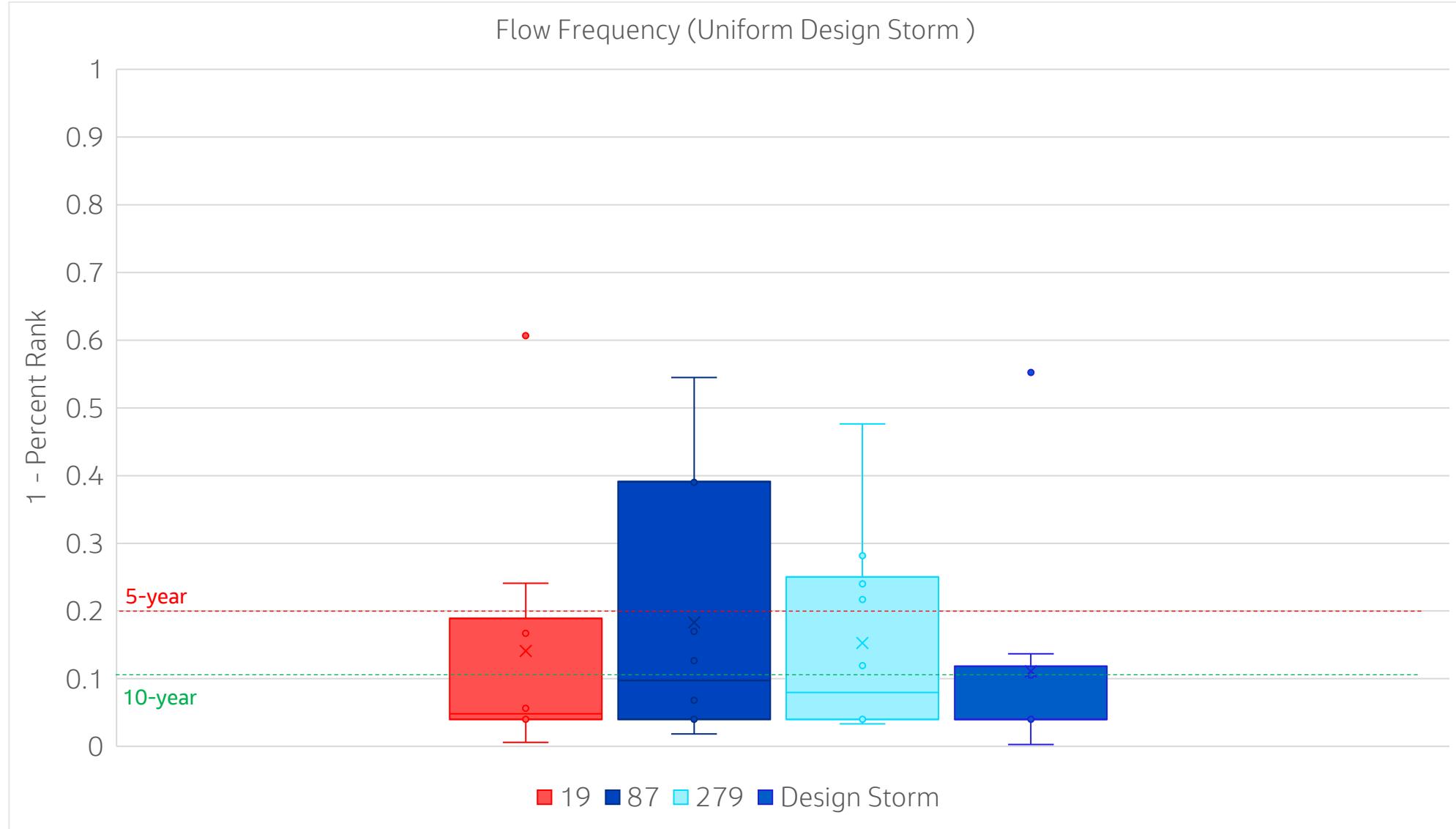
- Event 19 = slightly higher level of service, 5-6 year frequency
- Event 279 & 87 = slightly lower level of service, 4-5 year frequency



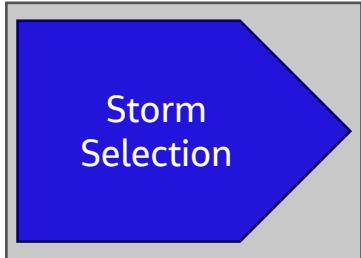
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



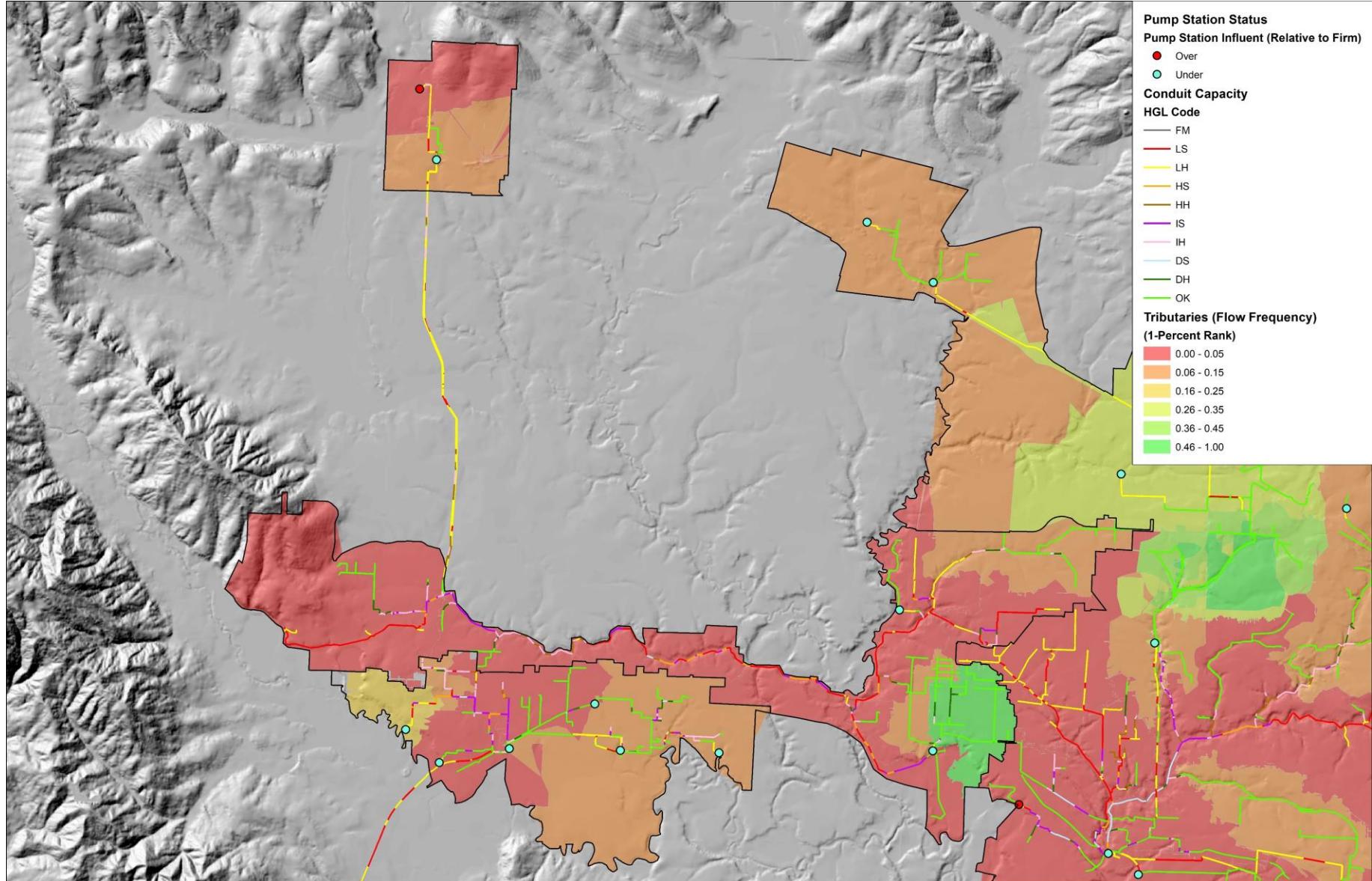
- Events 19, 279, and 87 compared to existing design storm
- Uniform Application



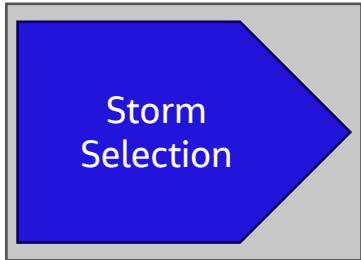
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



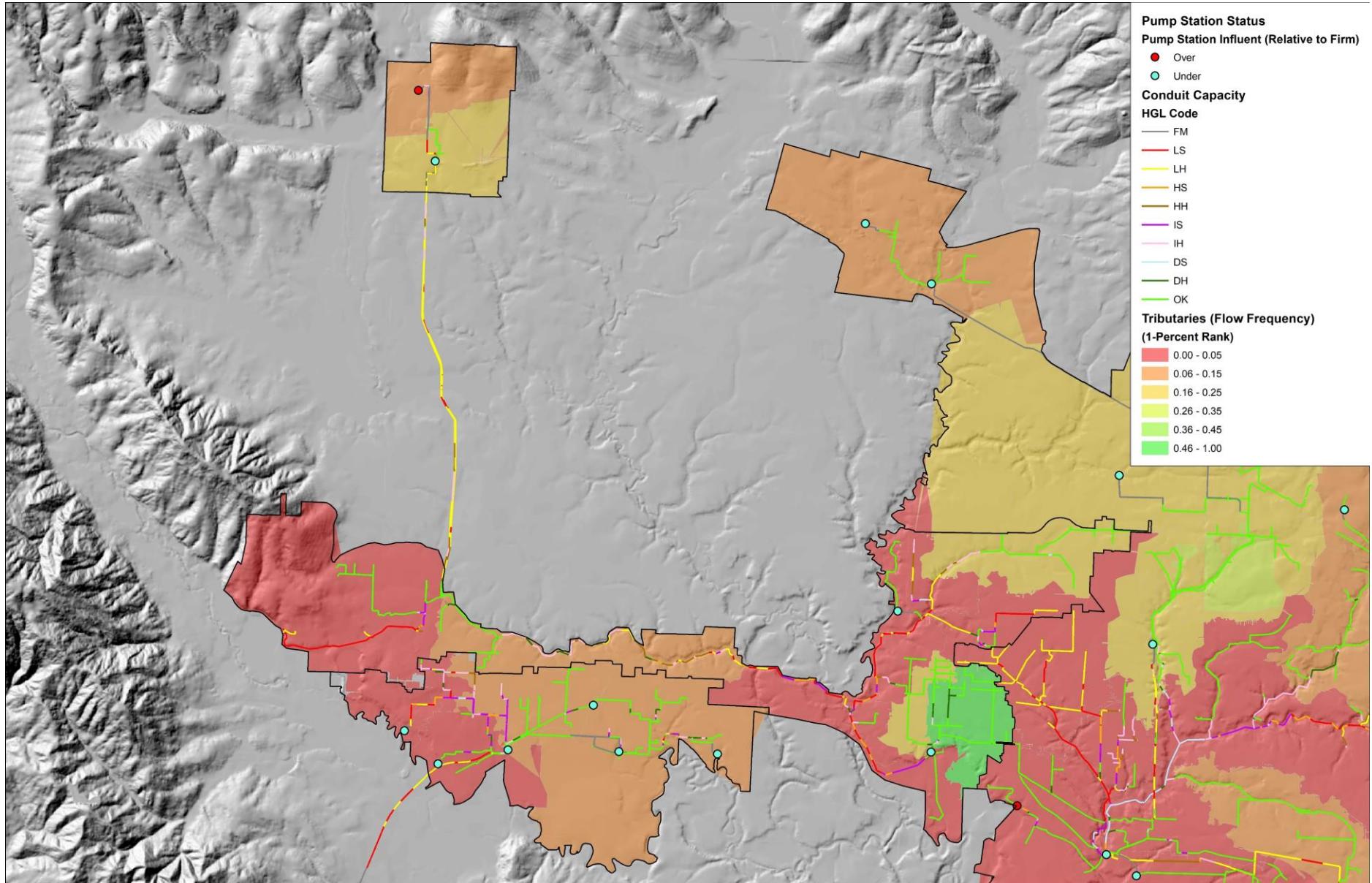
- Existing Design Storm
- Uniform Application



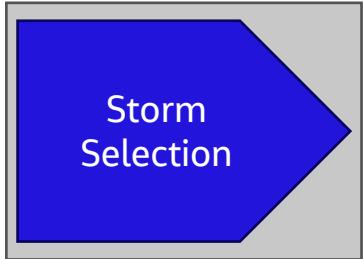
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



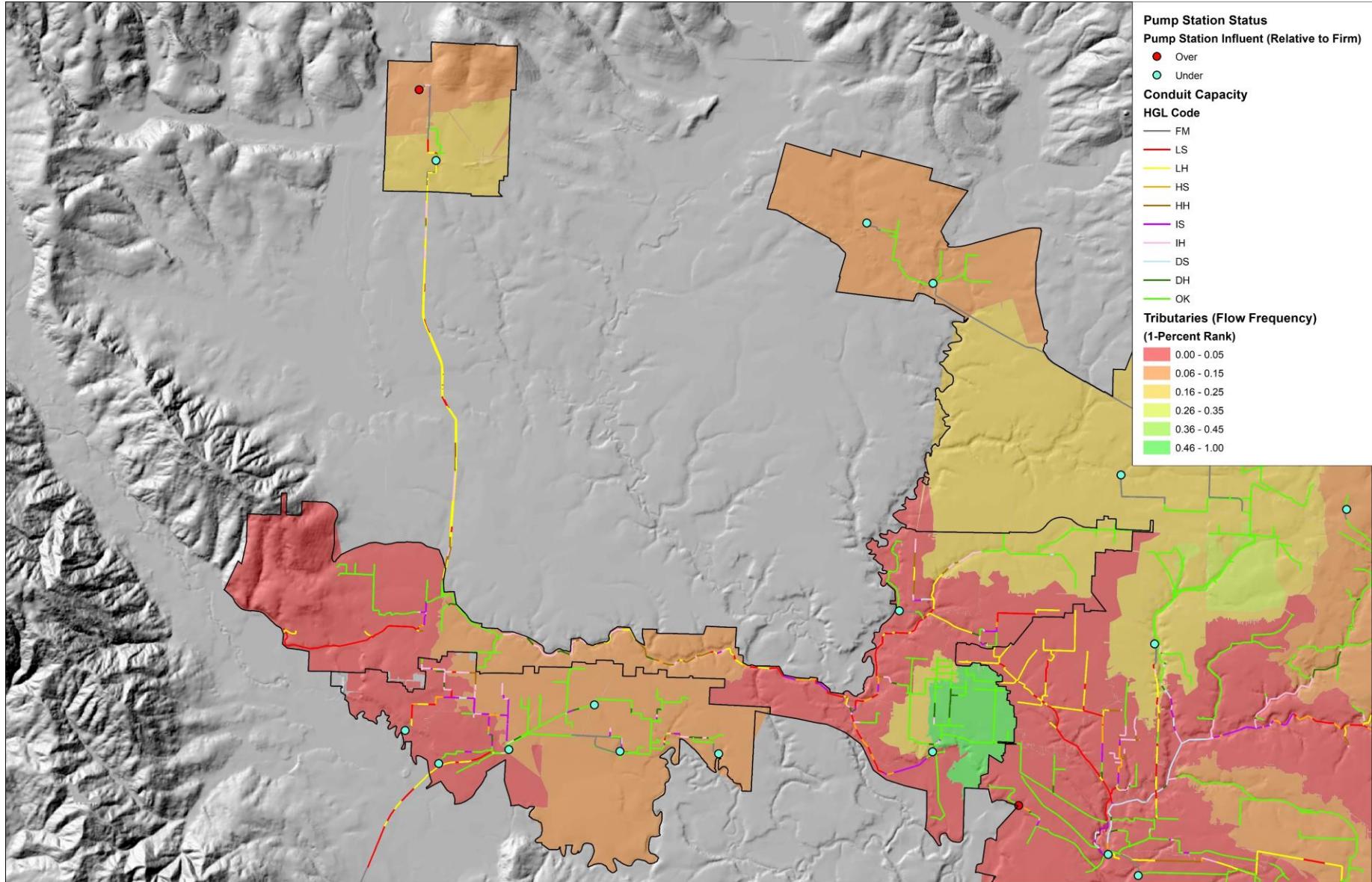
- Event 19
- Uniform Application



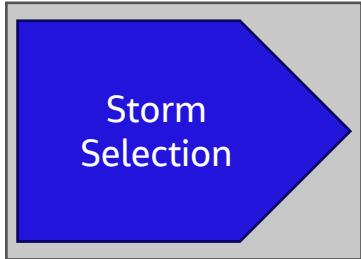
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



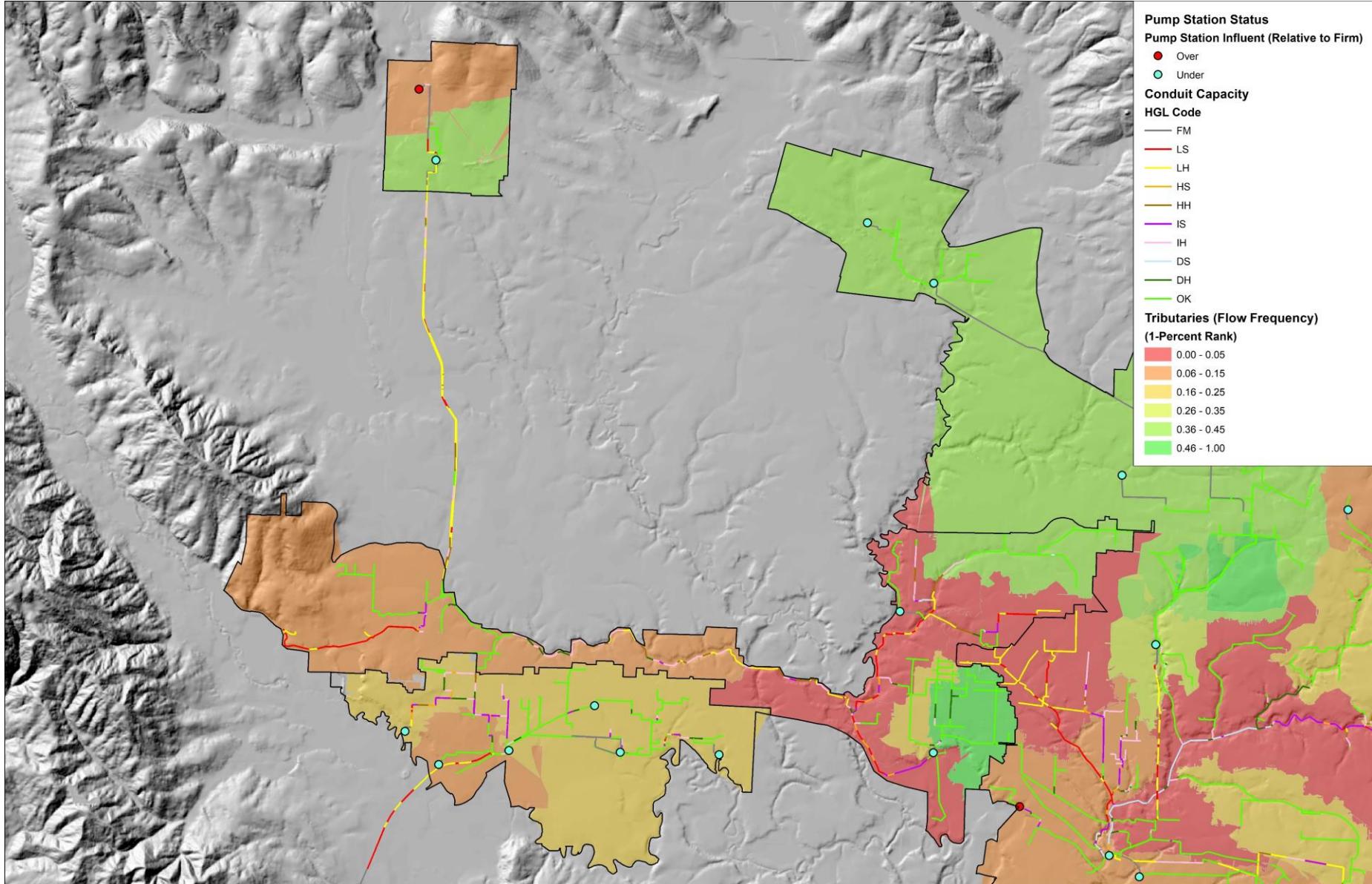
- Event 279
- Uniform Application



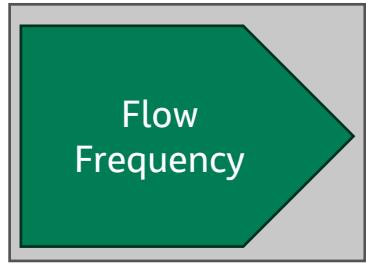
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



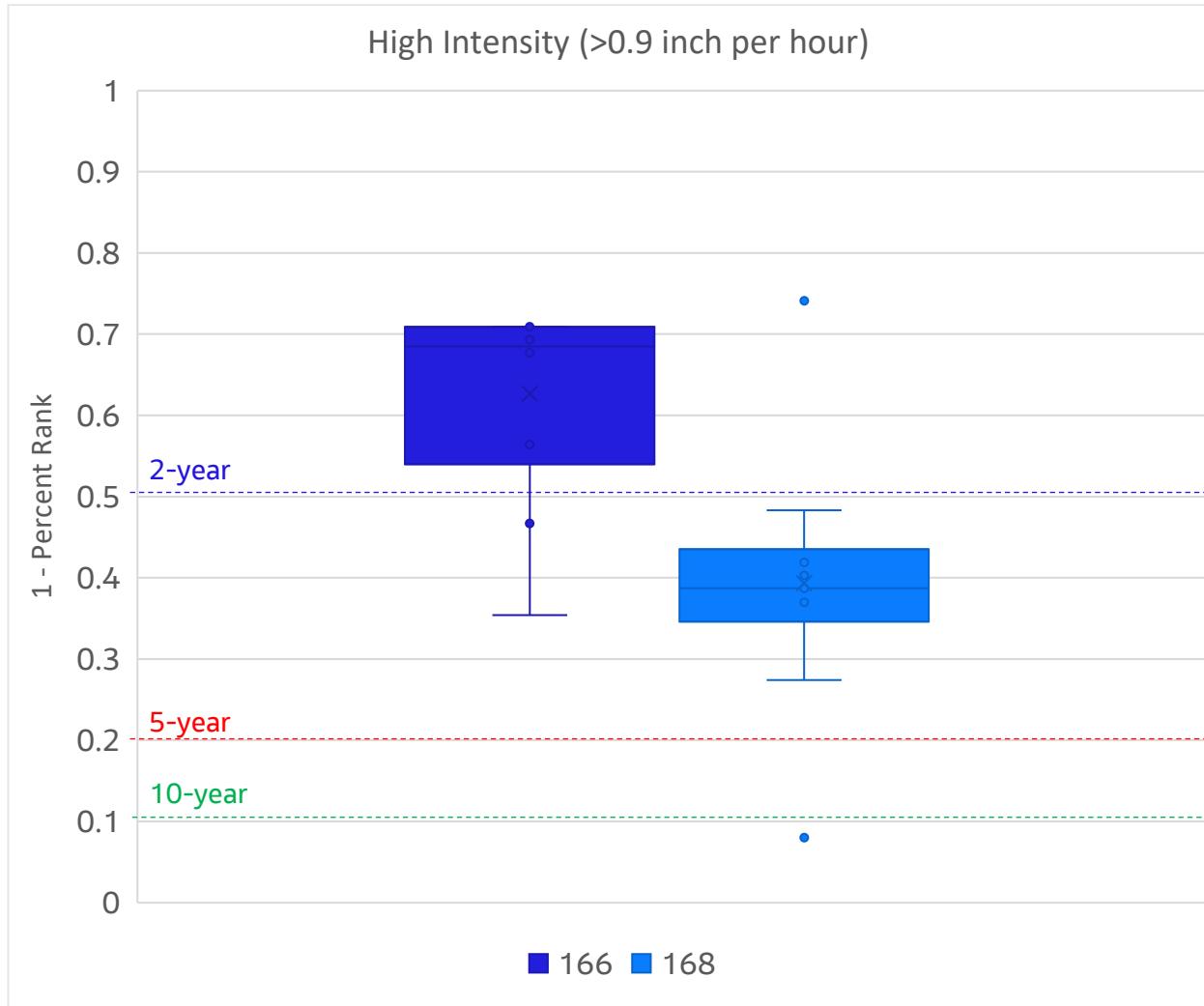
- Event 87
- Uniform Application



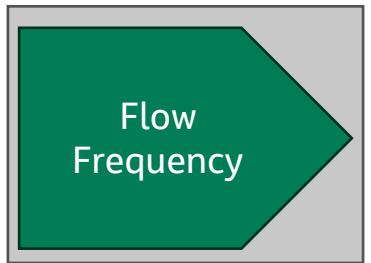
High Intensity Assessment – Hillsboro



- Events with some subbasins at 0.9 inch/hour
- <6-hour duration (cloud burst)

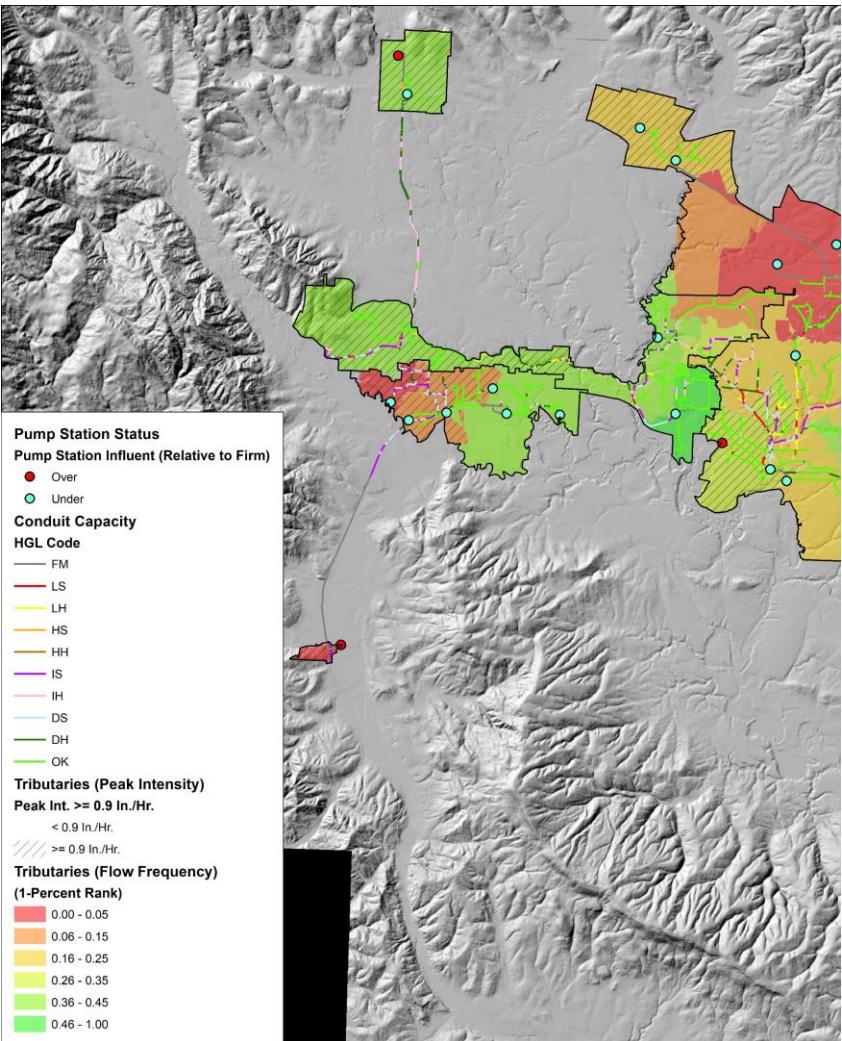


High Intensity Assessment – Hillsboro

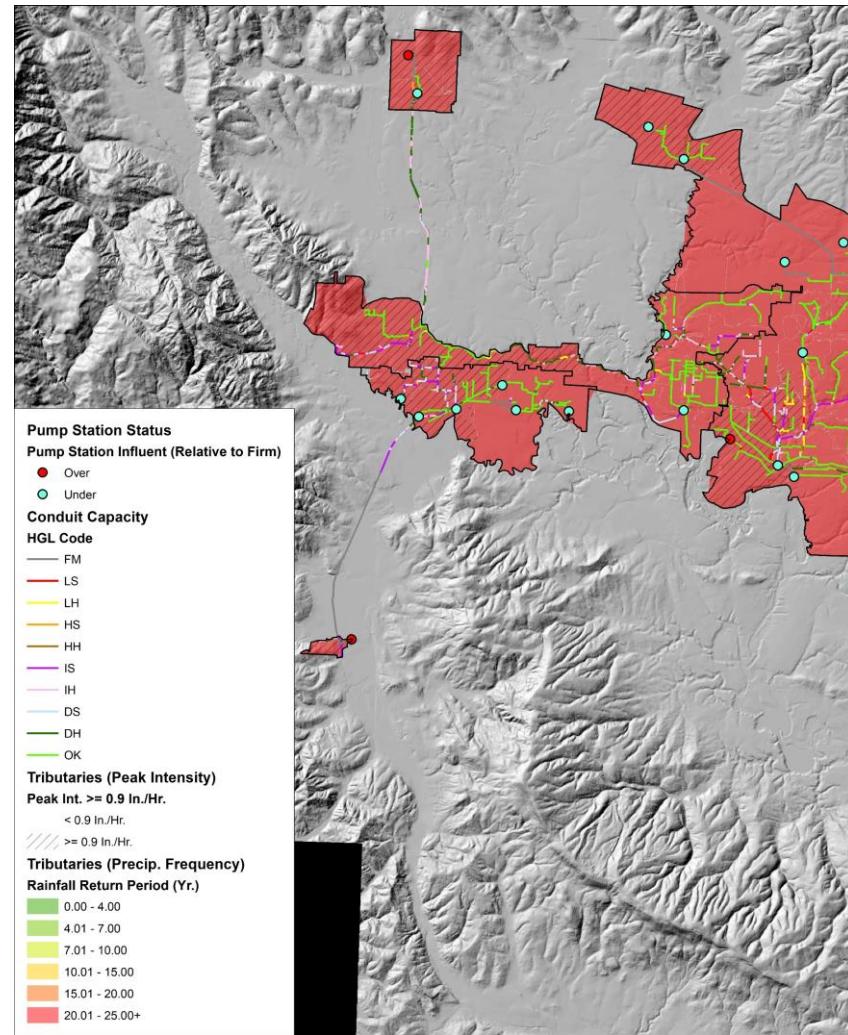


Event 168

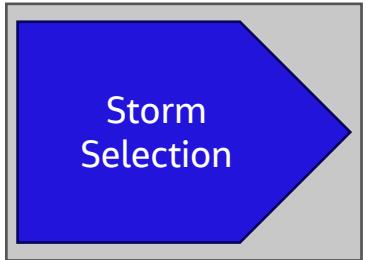
Flow Frequency



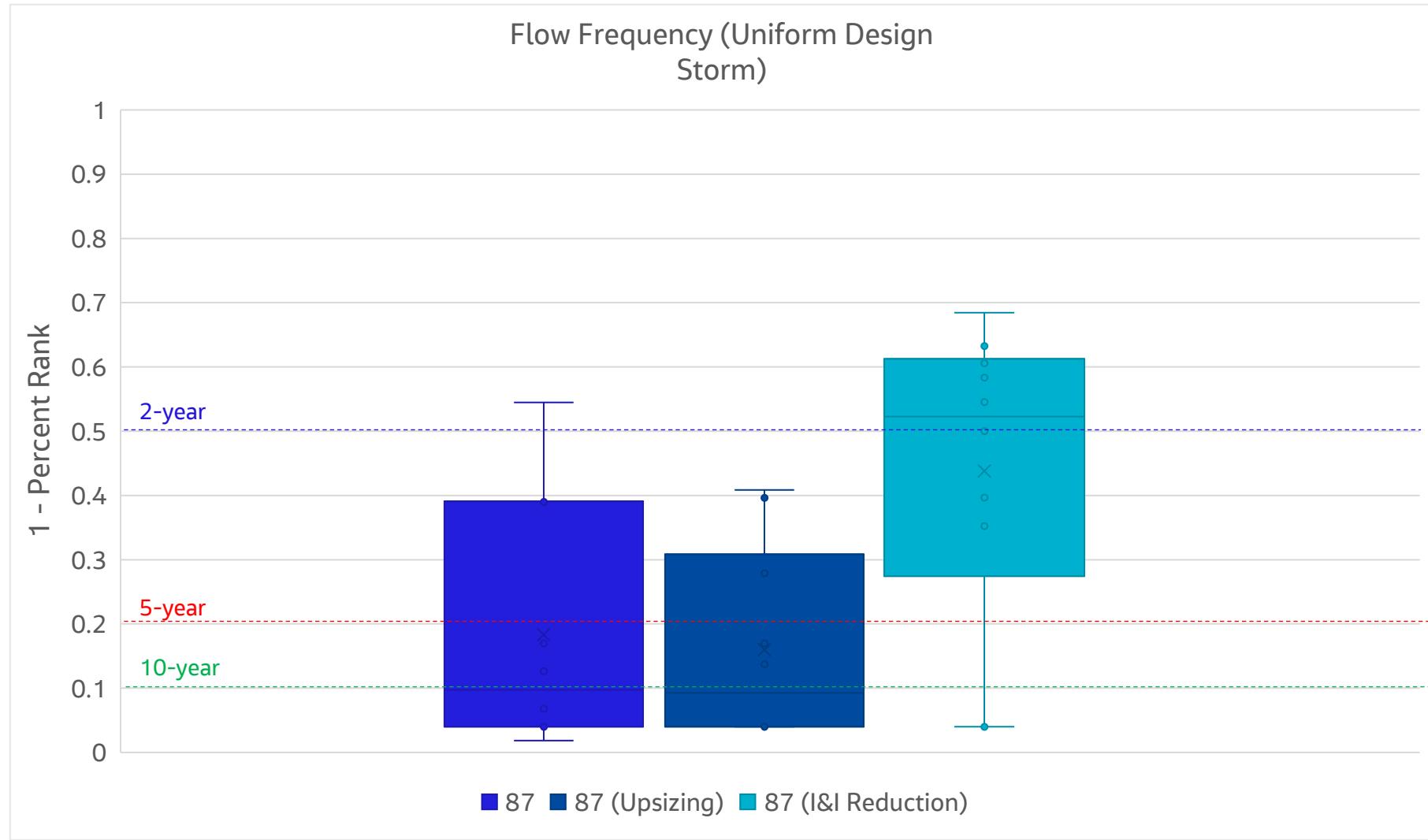
Precipitation Frequency



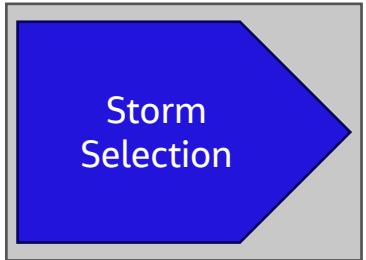
Sensitivity to Upsizing & RDI/I Reduction - Hillsboro



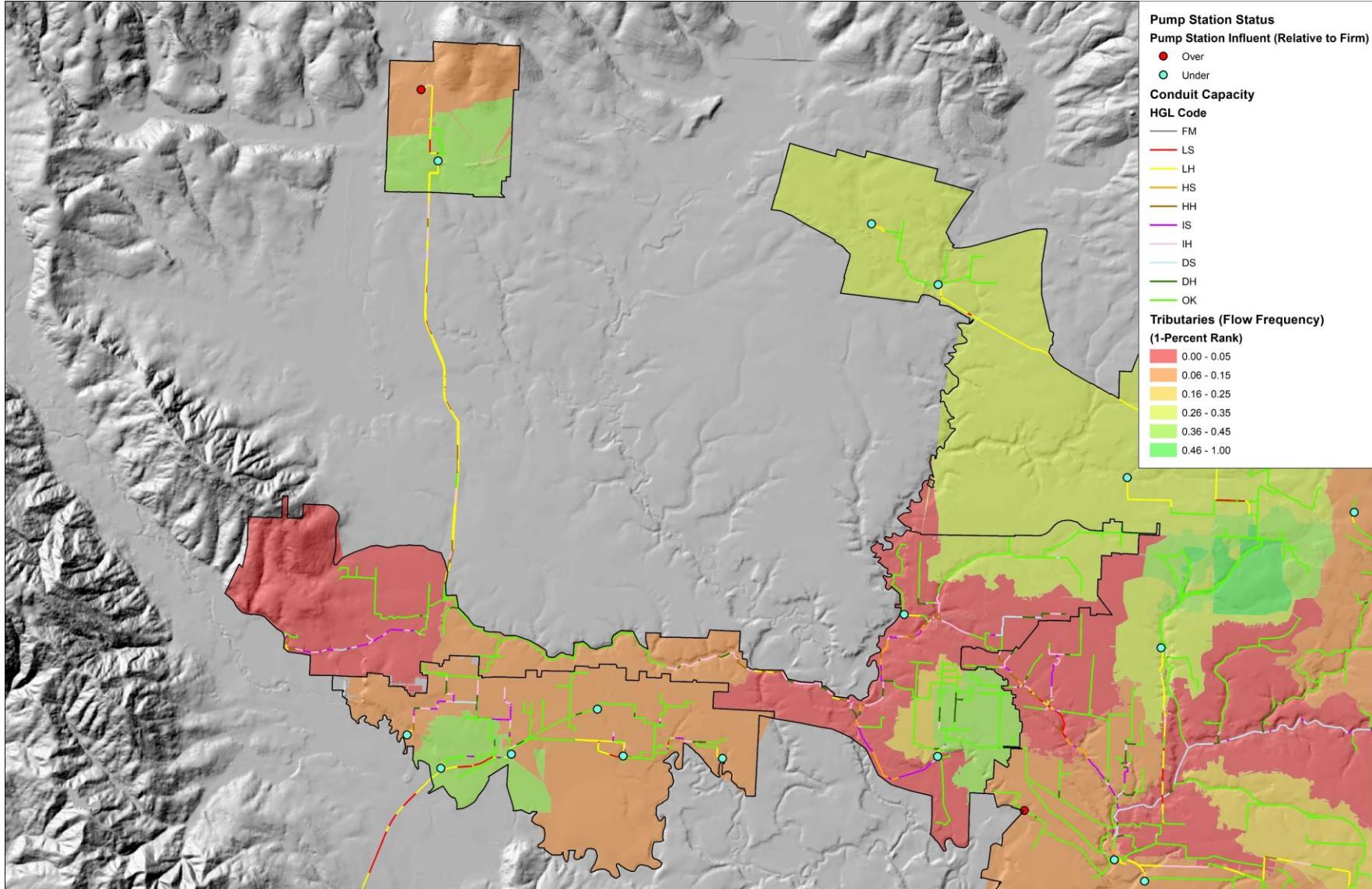
Event 87



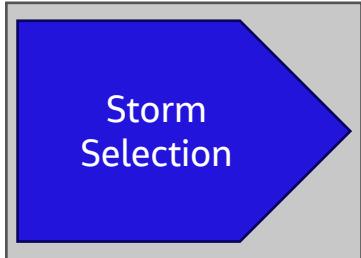
Sensitivity to Upsizing - Hillsboro



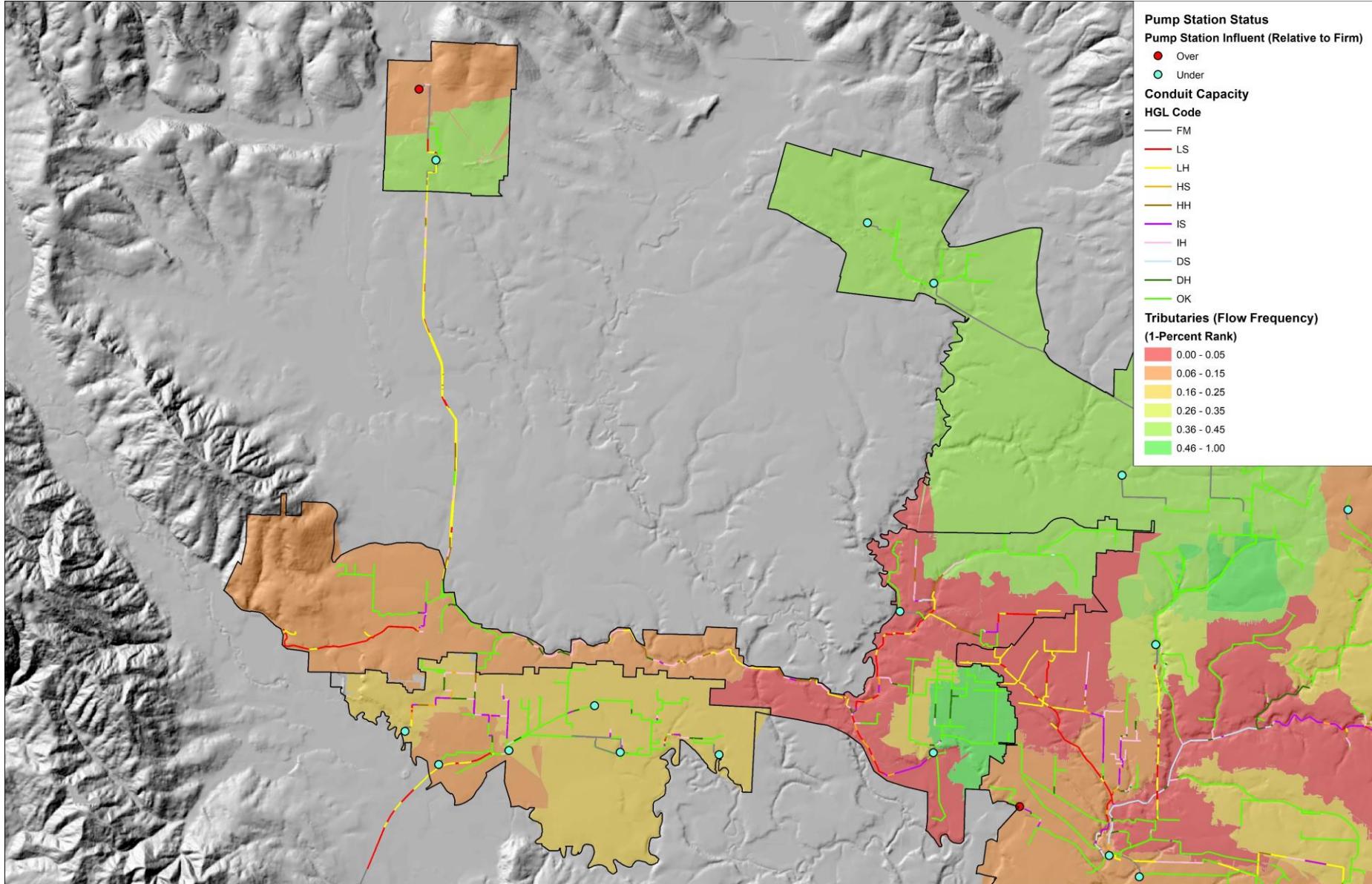
Event 87



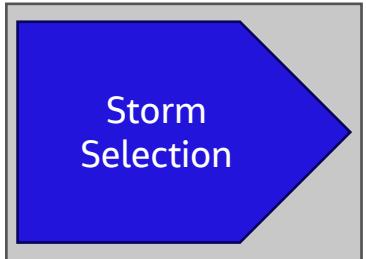
Select Storm Event(s) – Candidate Storms – Uniform - Hillsboro



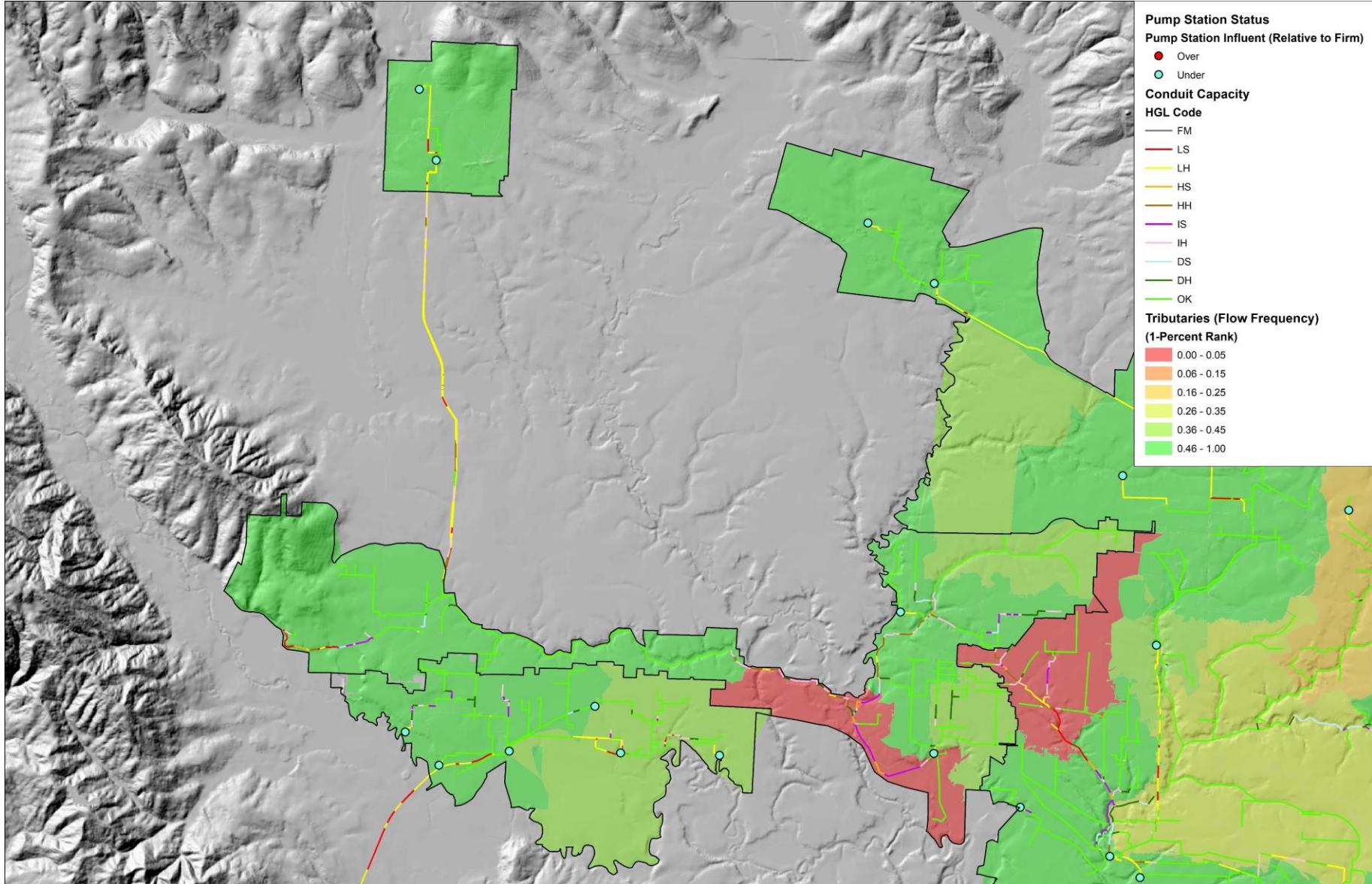
- Event 87
- Uniform Application



Sensitivity to RDI/I Reduction - Hillsboro

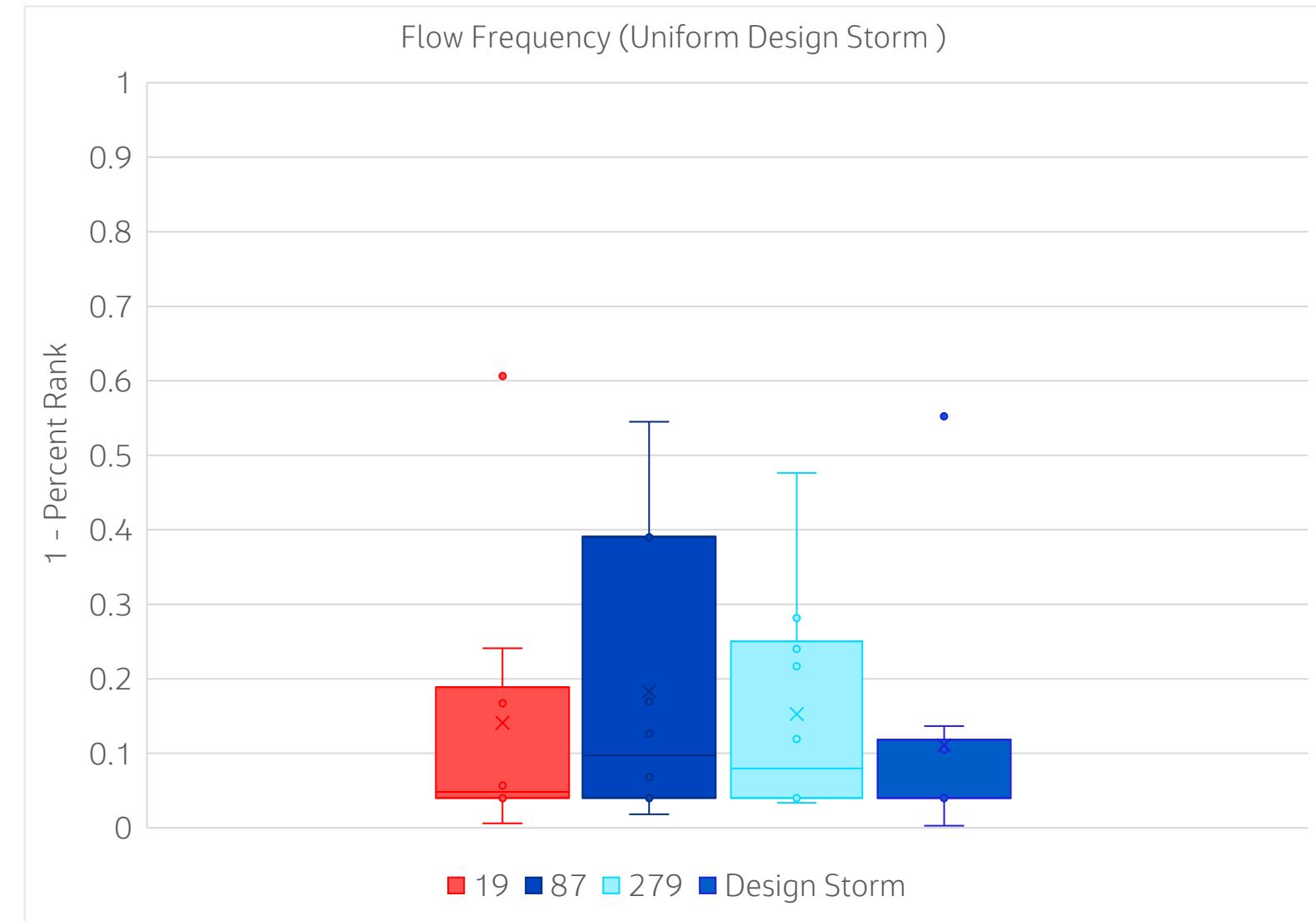


Event 87

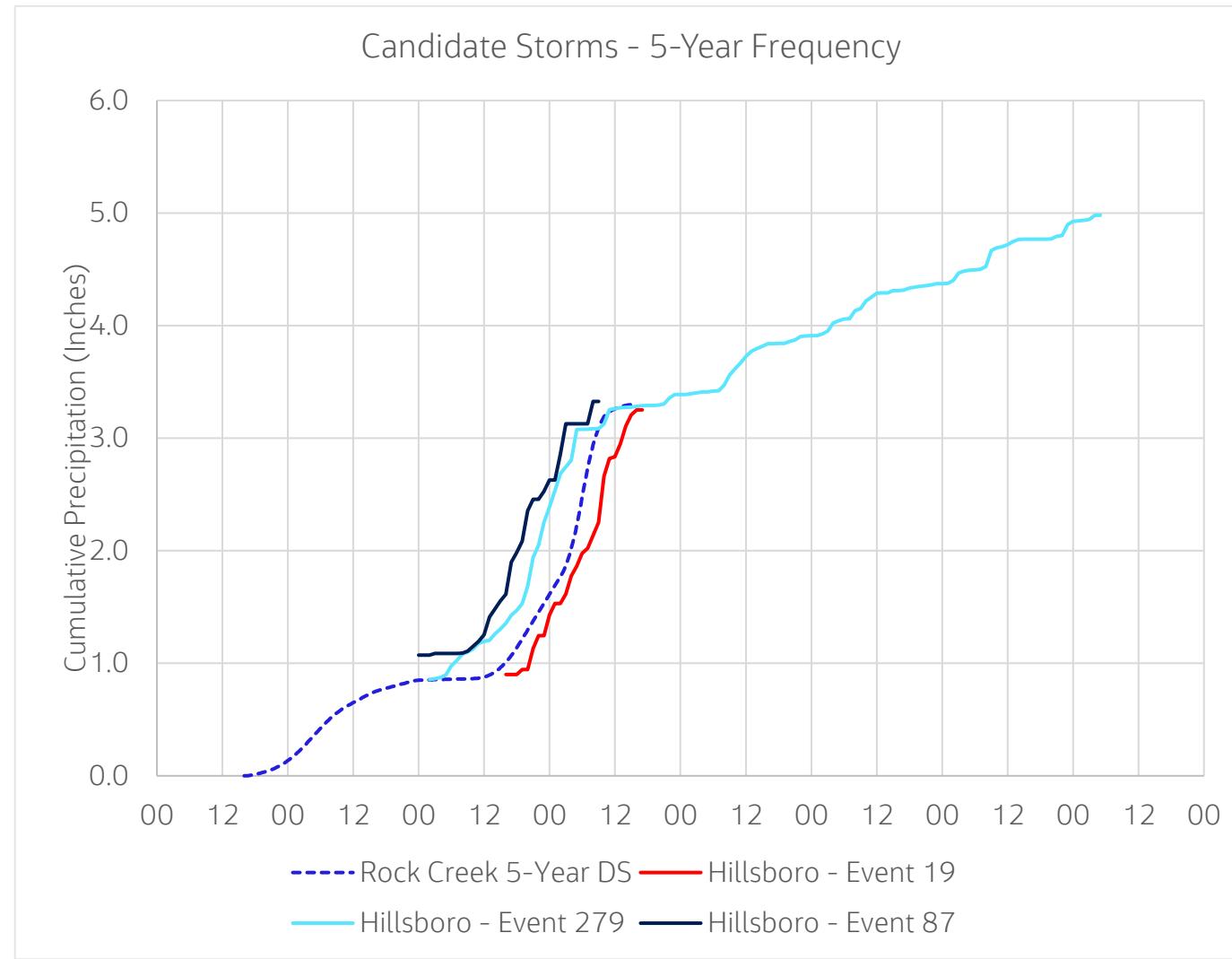


Hillsboro Recommendations

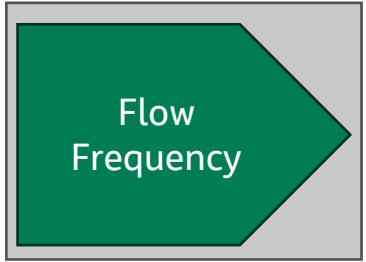
- Event 19 provides high level of service with fewest outliers
 - Adjust few outliers
- Less conservative than using existing design storm
- Decision: District preference for storm 19, (existing Rock DS overly conservative)



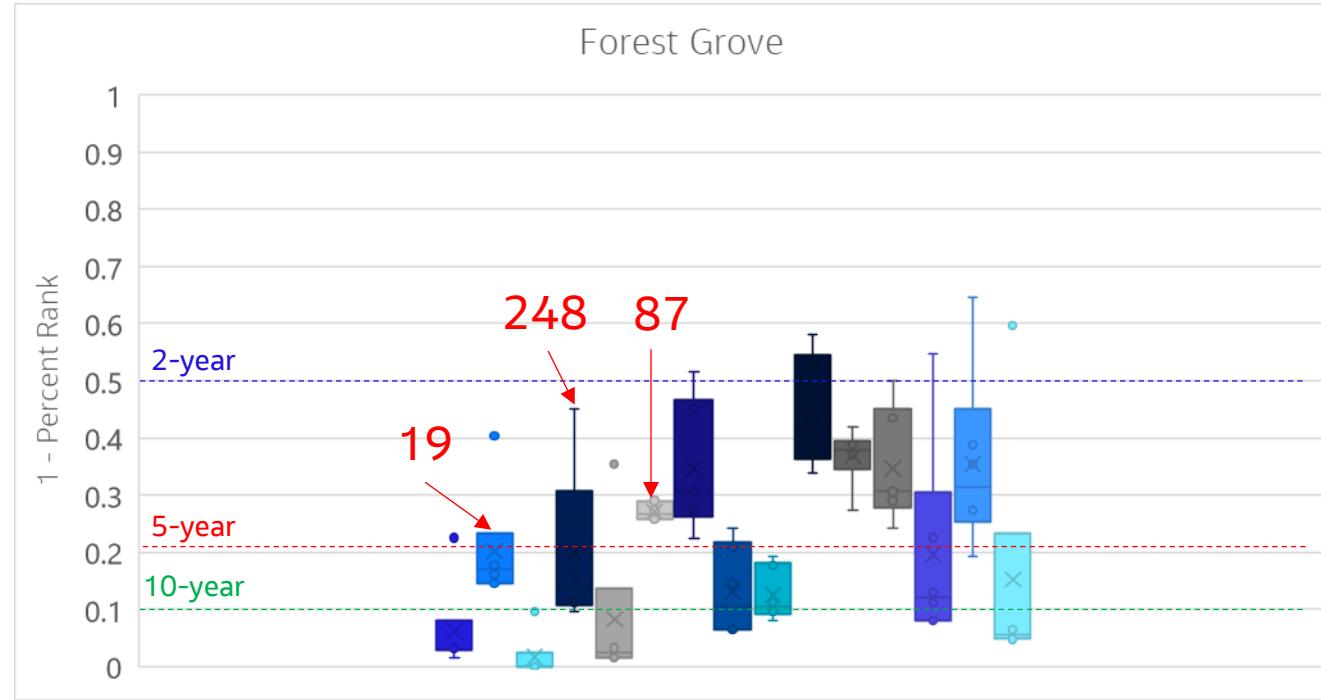
Select Storm Event(s) – Candidate Storms – Hillsboro



Flow Frequency – Events of Interest – Forest Grove



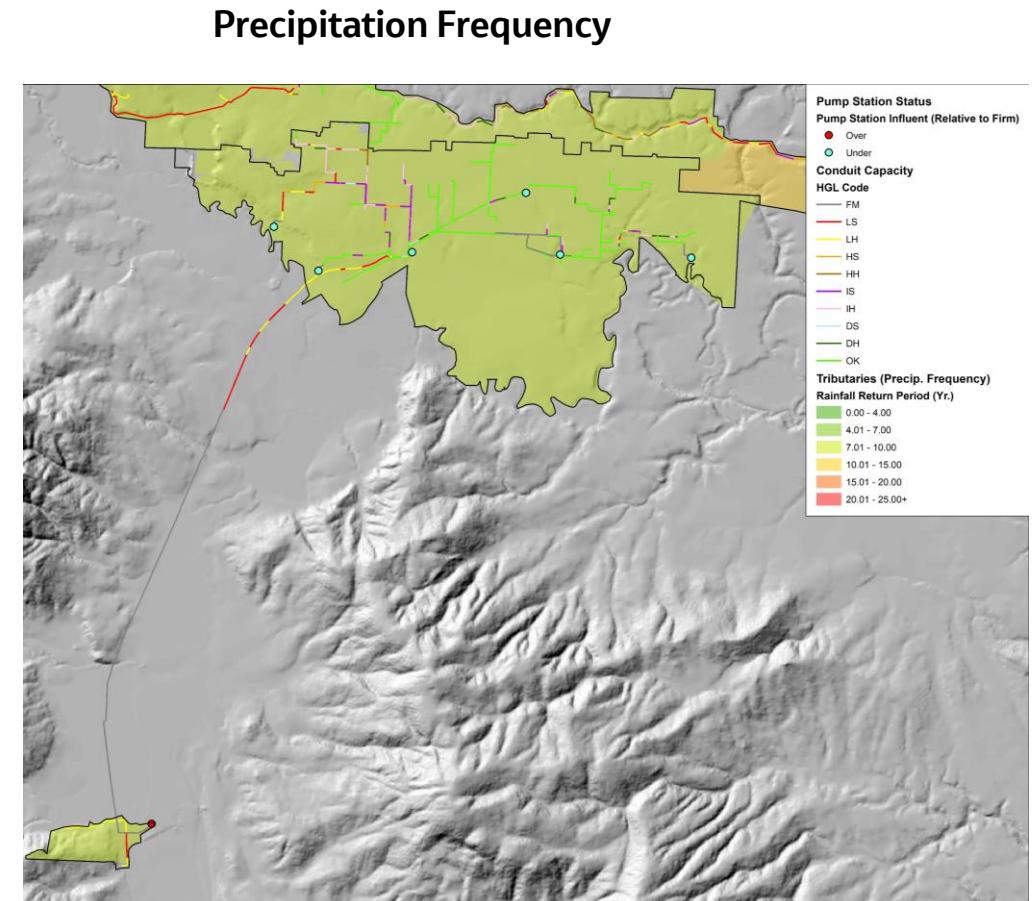
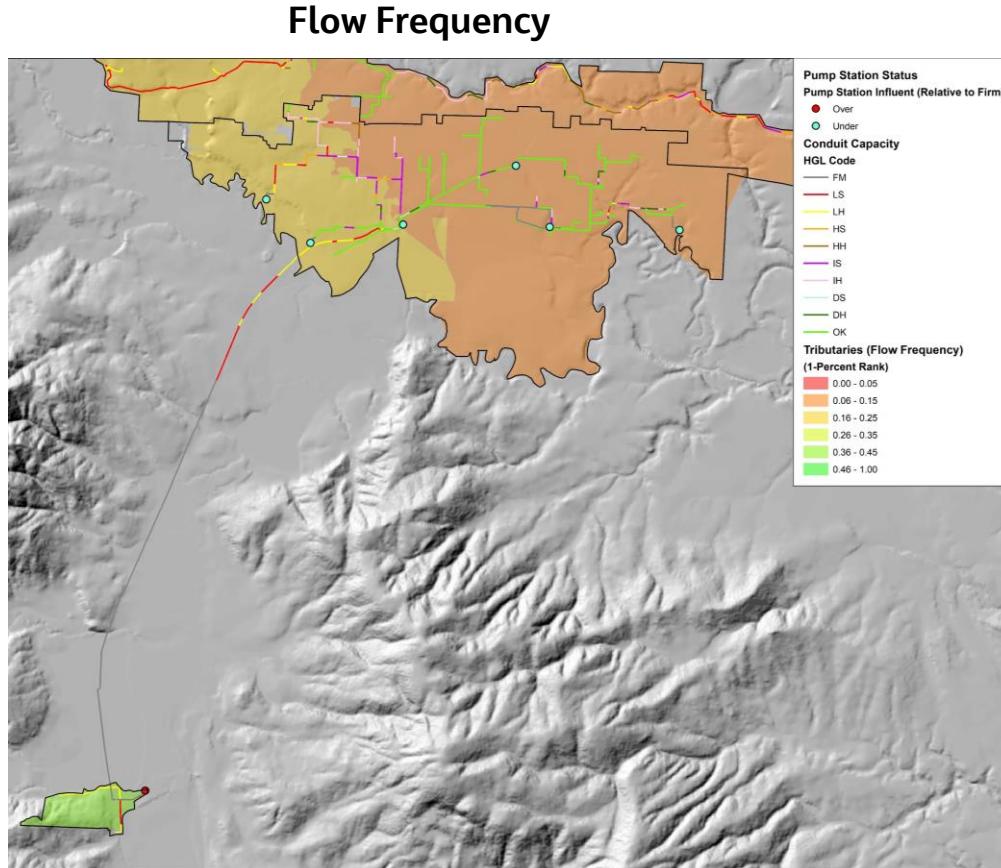
- High flow and spatial variability for some events maxing out around 10-year flow frequency



Frequency – Events of Interest – Spatial Variability - Forest Grove

Flow Frequency

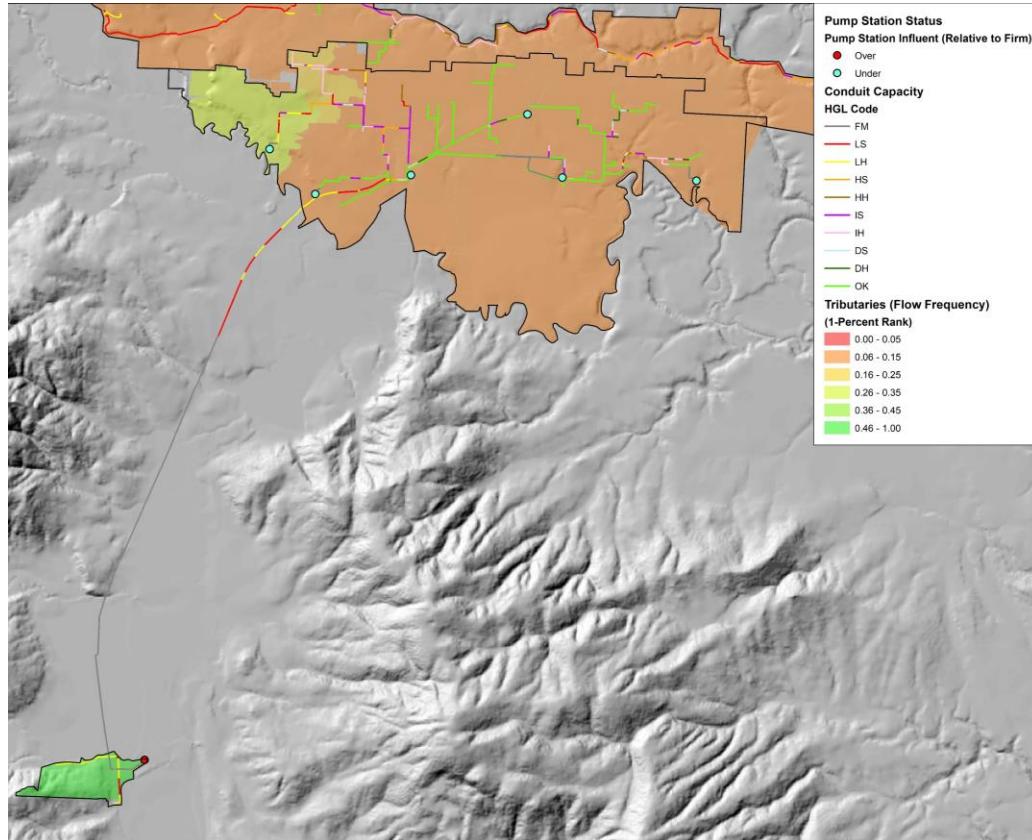
- 24-hour event
- 2.41- to 2.42- inch depth (2.42- inch avg)
- 5.3-year average flow frequency
- Design storm = 2.4- inch in 24 hours



Frequency – Events of Interest – Spatial Variability - Forest Grove

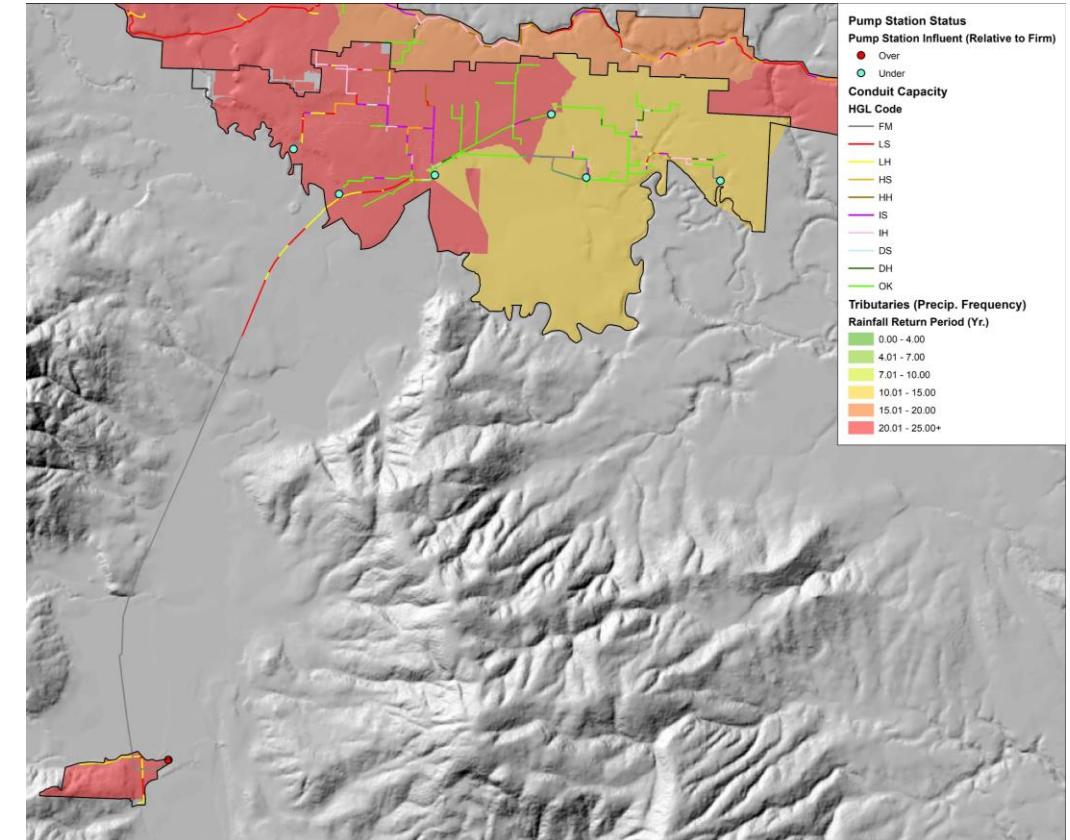
Flow Frequency

Flow Frequency



Event 248

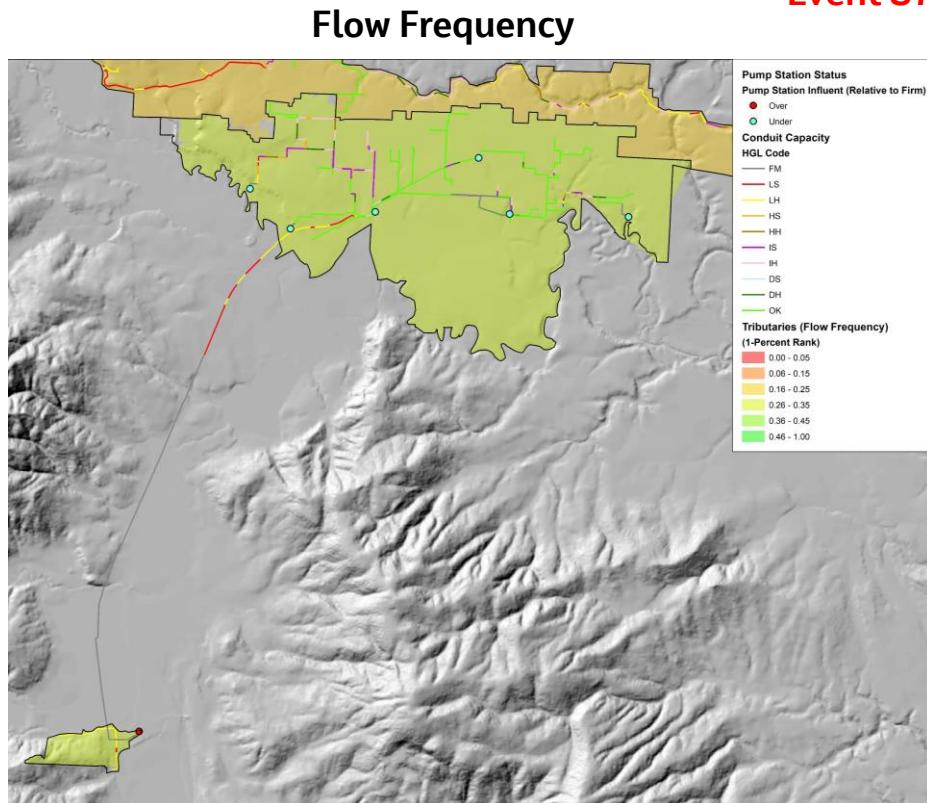
Precipitation Frequency



- 72-hour event
- 4.42- to 4.45- inch depth (4.44-inch avg)
- 6.2-year average flow frequency
- Design storm = 3.3- inch in 72 hours

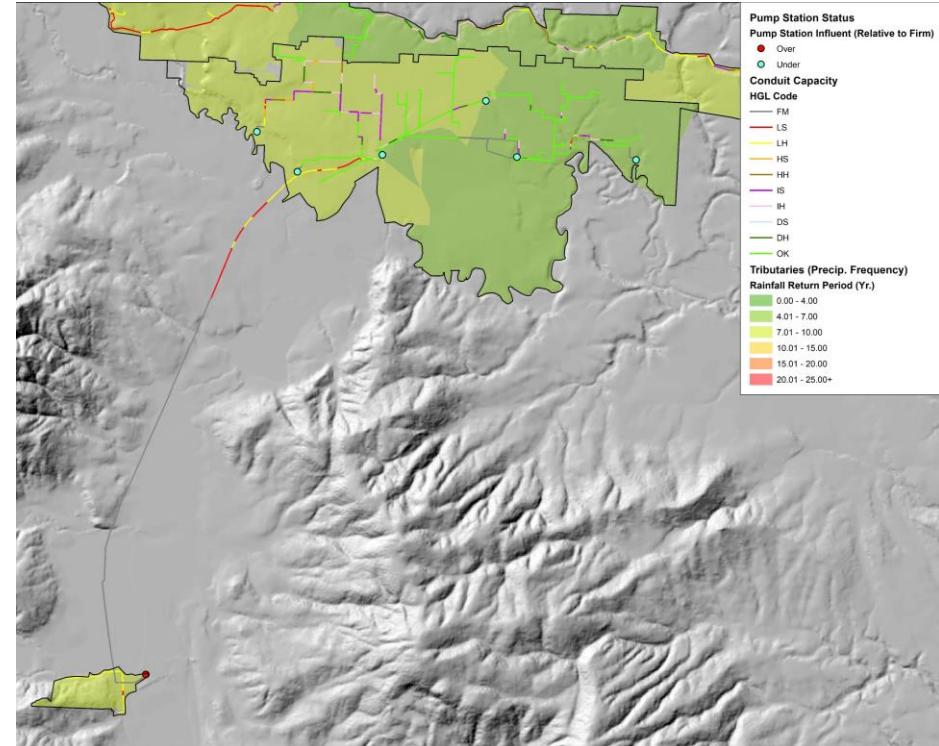
Frequency – Events of Interest – Spatial Variability - Forest Grove

Flow Frequency



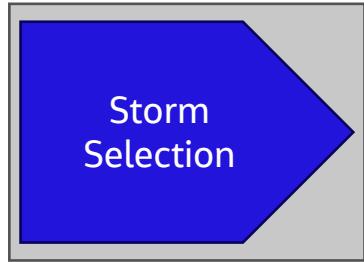
Event 87

Precipitation Frequency

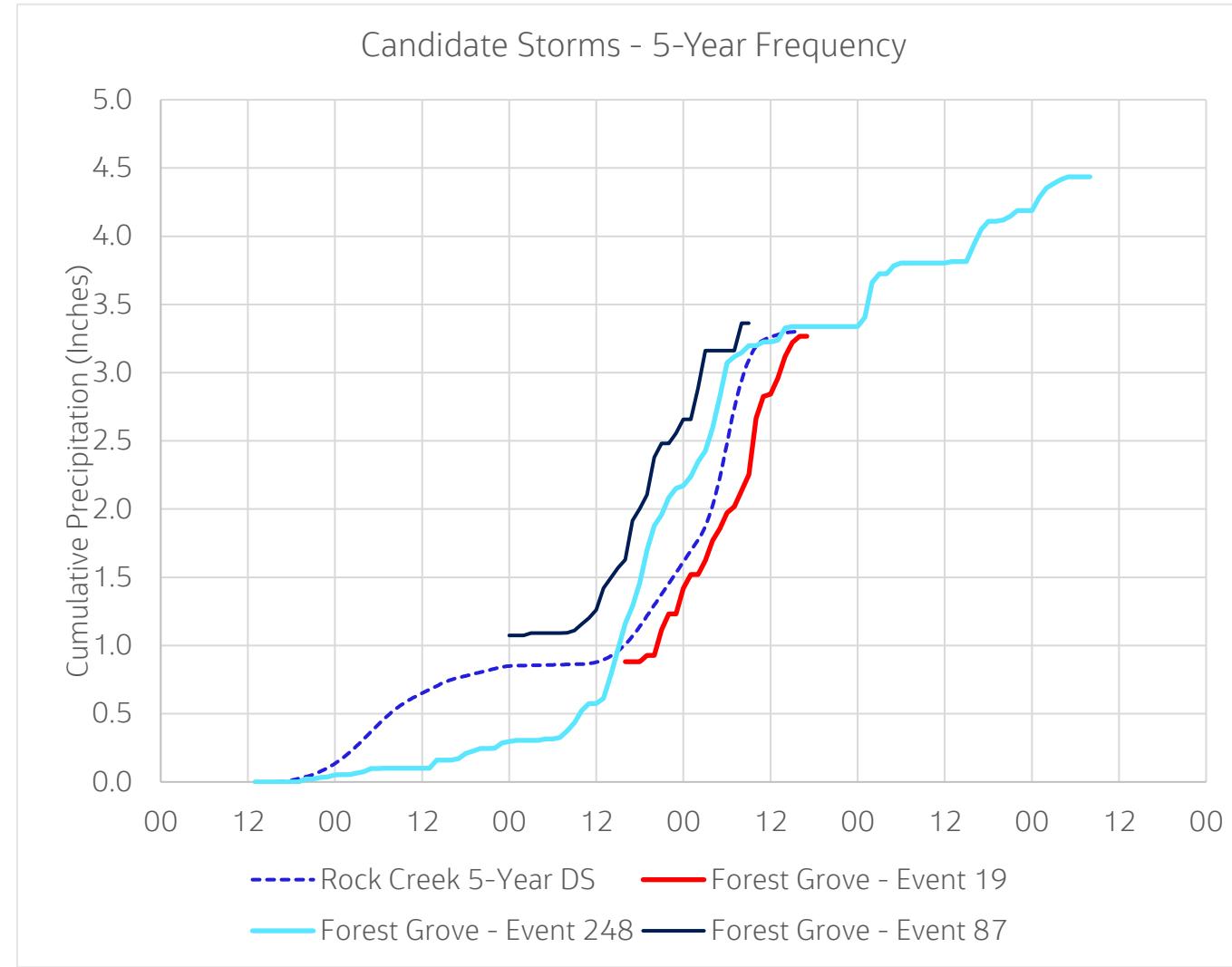


- 24-hour event
- 2.36- to 2.37- inch depth (2.37-inch avg)
- 3.6-year average flow frequency
- Design storm = 2.4- inch in 24 hours

Select Storm Event(s) – Candidate Storms – Forest Grove



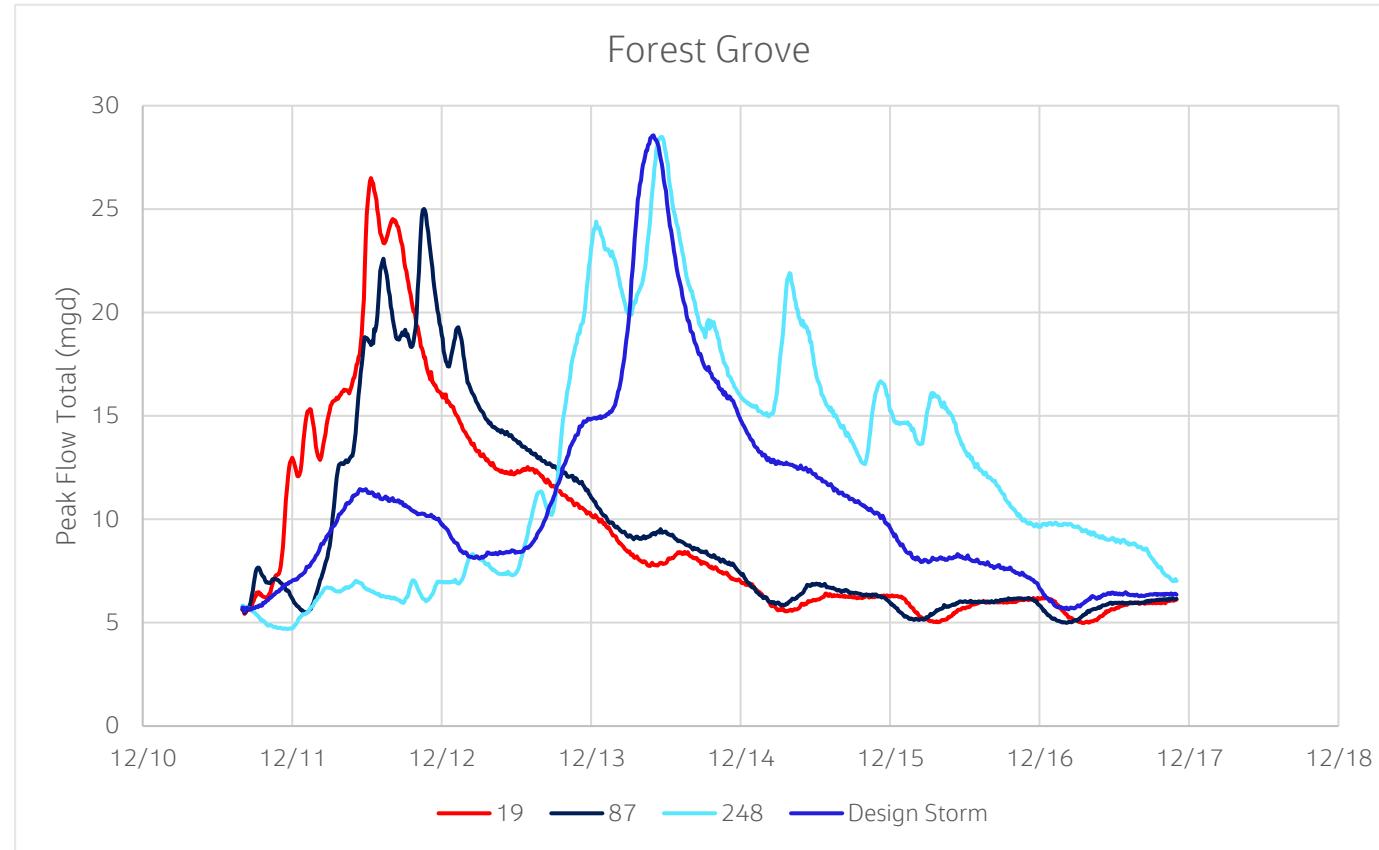
- Events 19 and 248 approximate a 5-year storm specific to Forest Grove Basin



Select Storm Event(s) – Candidate Storms – Forest Grove



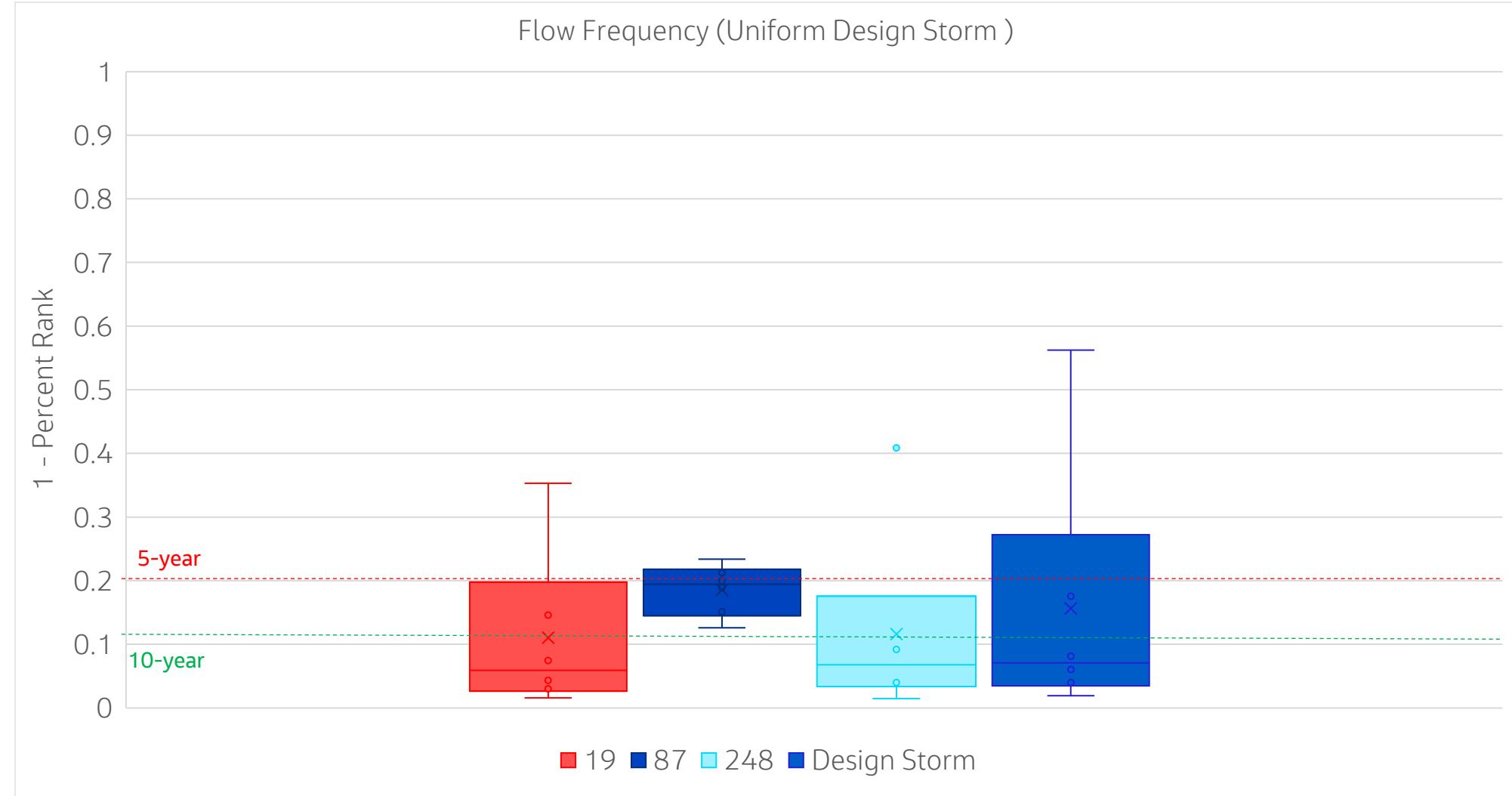
- Events 19 and 248 approximate a 5-year storm specific to Forest Grove Basin



Select Storm Event(s) – Candidate Storms – Uniform - Forest Grove



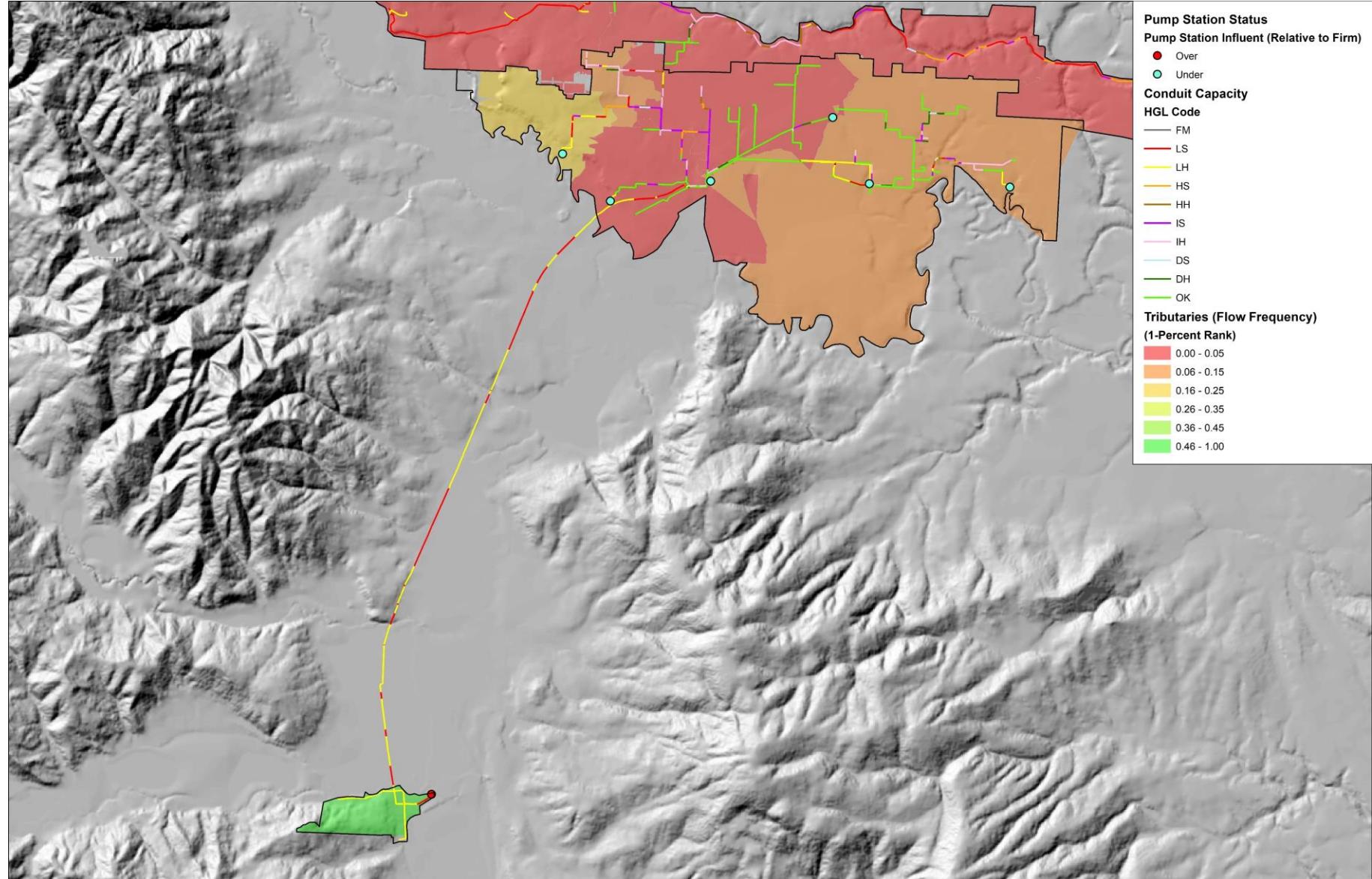
- Events 19, 87, and 248 compared to existing design storm
- Uniform Application



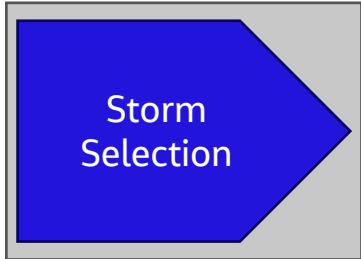
Select Storm Event(s) – Candidate Storms – Uniform – Forest Grove



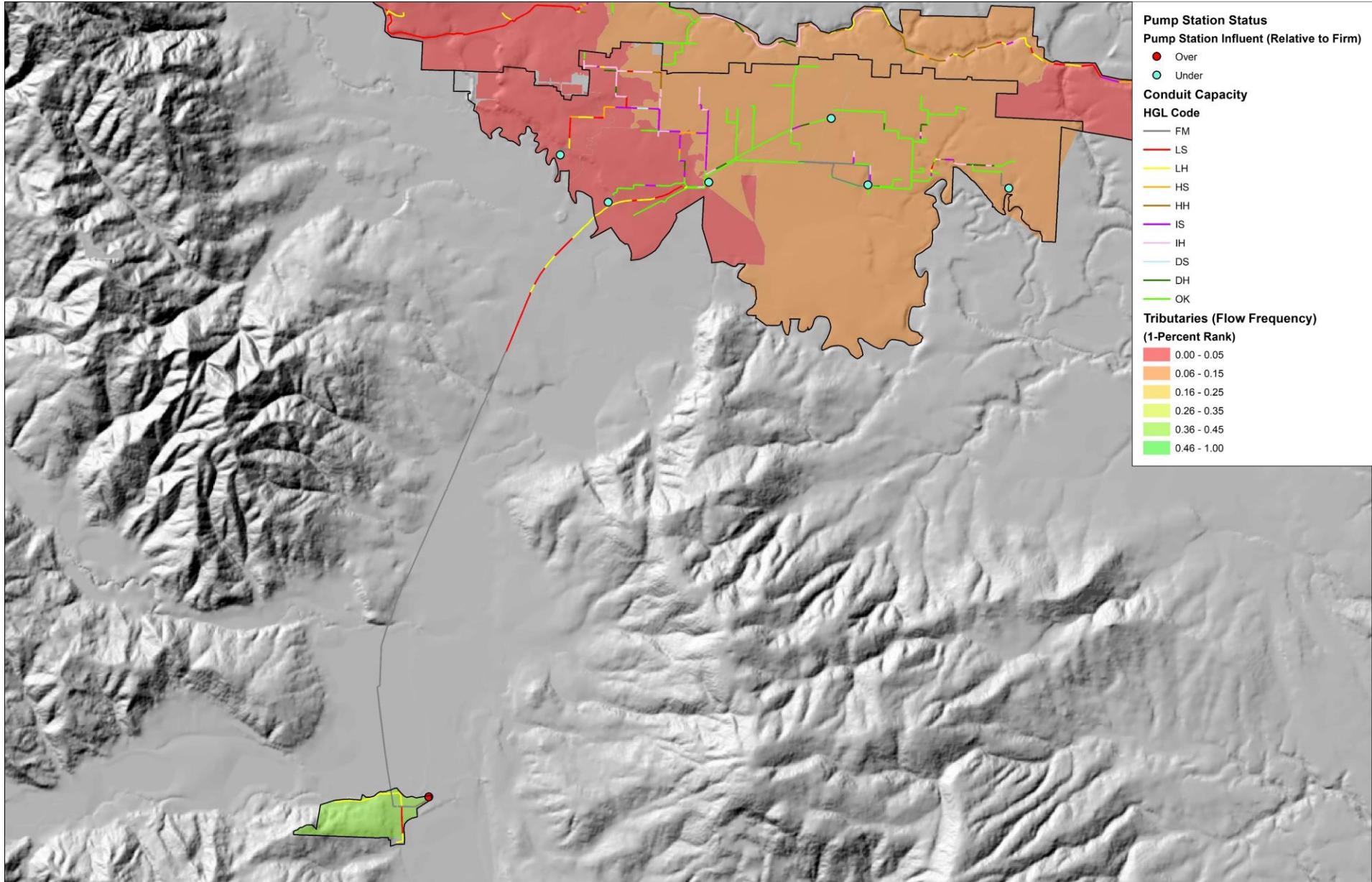
- Existing Design Storm
- Uniform Application



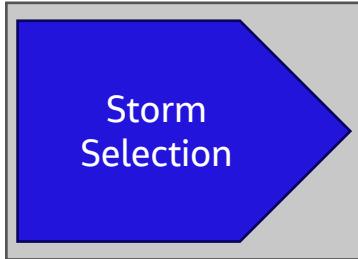
Select Storm Event(s) – Candidate Storms – Uniform – Forest Grove



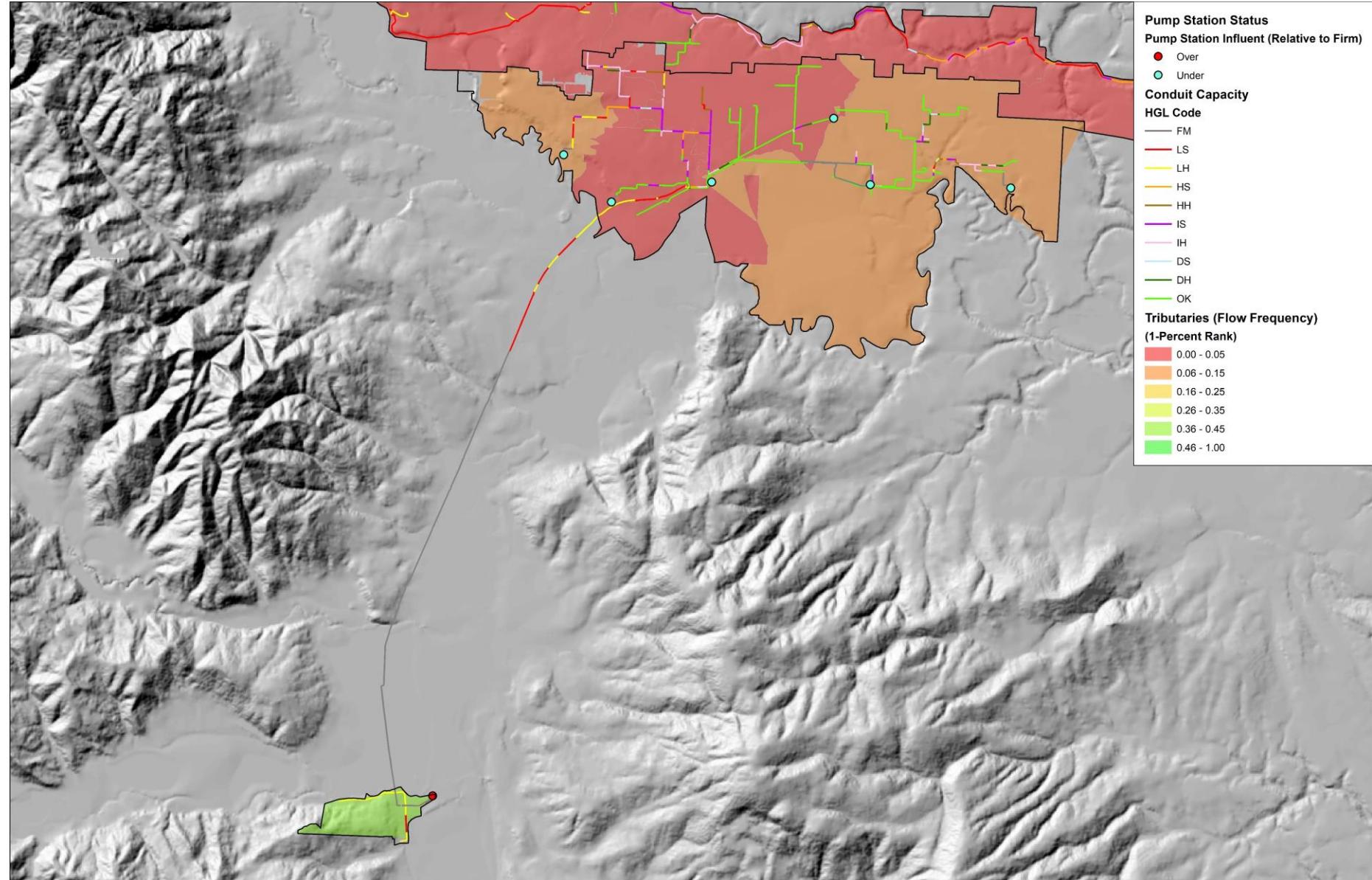
- Event 19
- Uniform Application



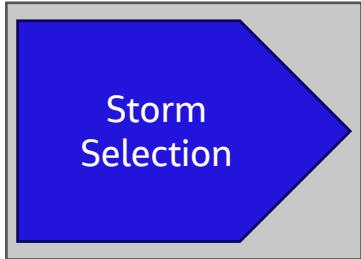
Select Storm Event(s) – Candidate Storms – Uniform – Forest Grove



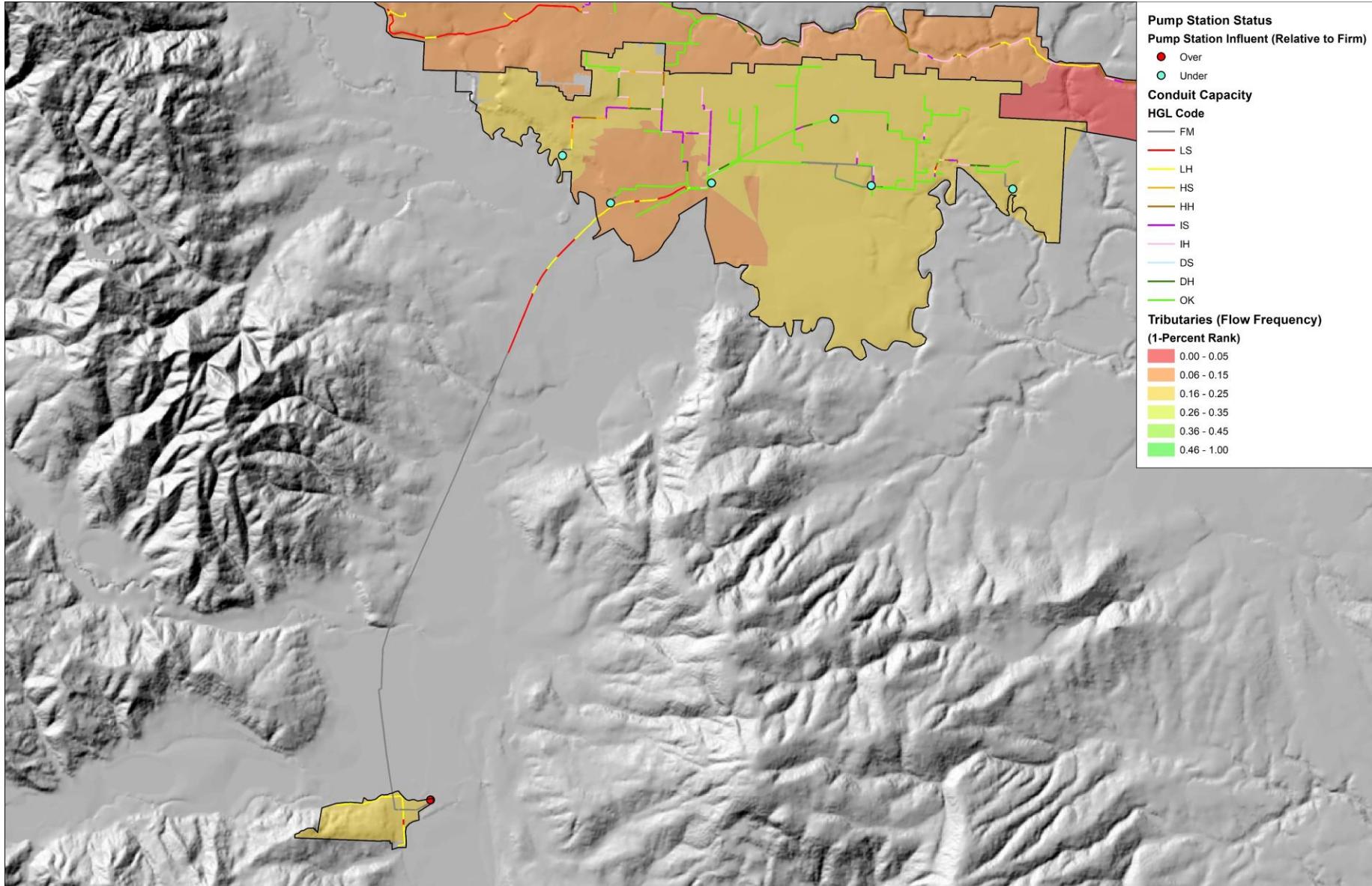
- Event 248
- Uniform Application



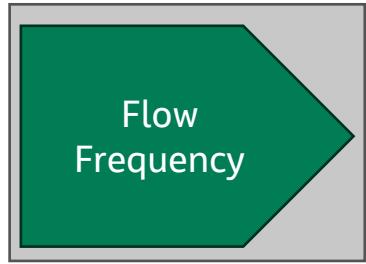
Select Storm Event(s) – Candidate Storms – Uniform – Forest Grove



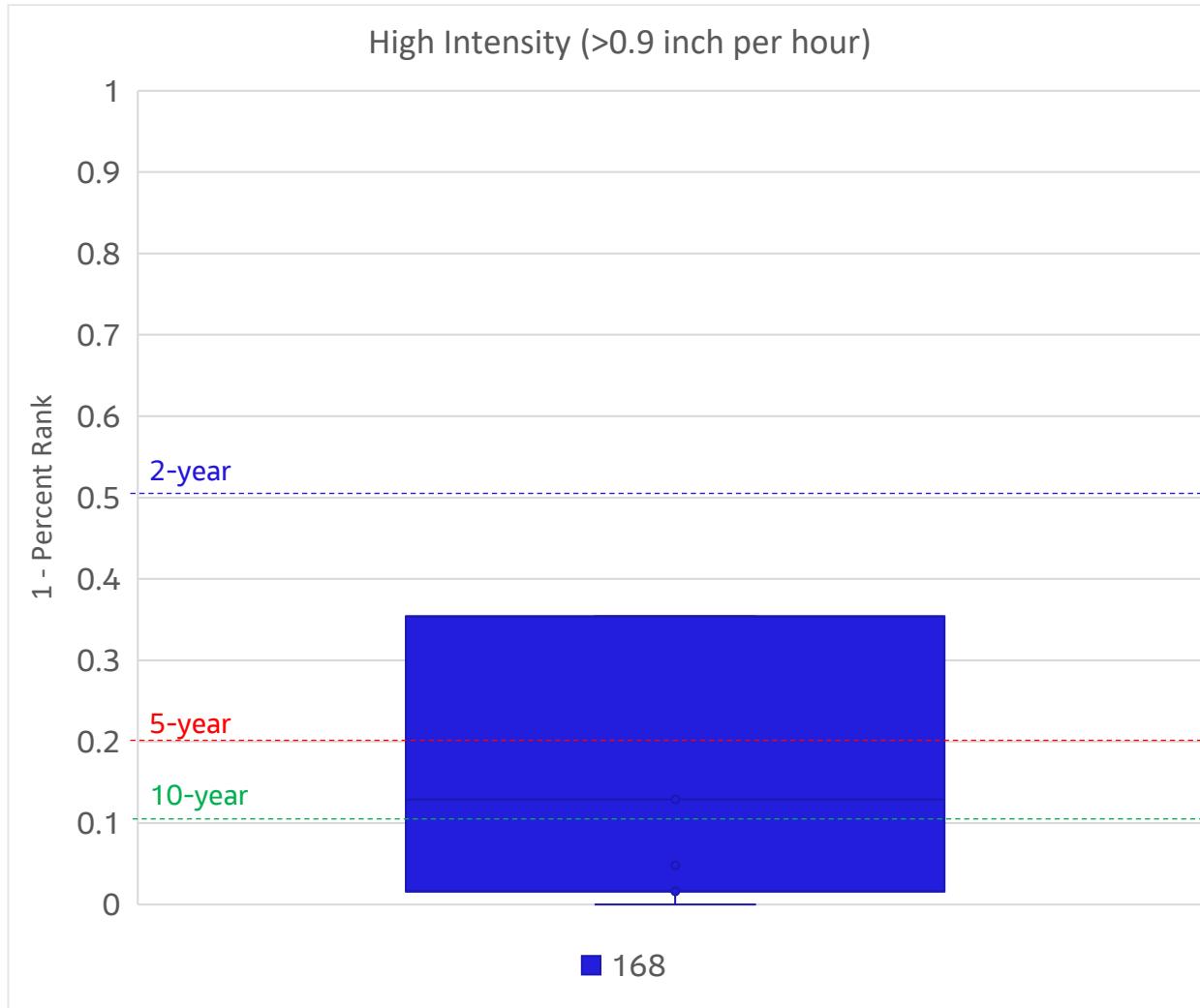
- Event 87
- Uniform Application



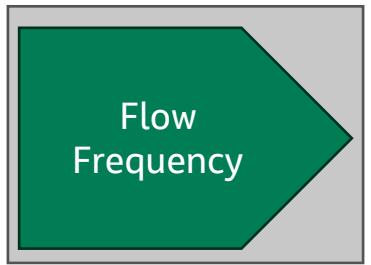
High Intensity Assessment – Forest Grove



- Events with some subbasins at 0.9 inch/hour
- <6-hour duration (cloud burst)

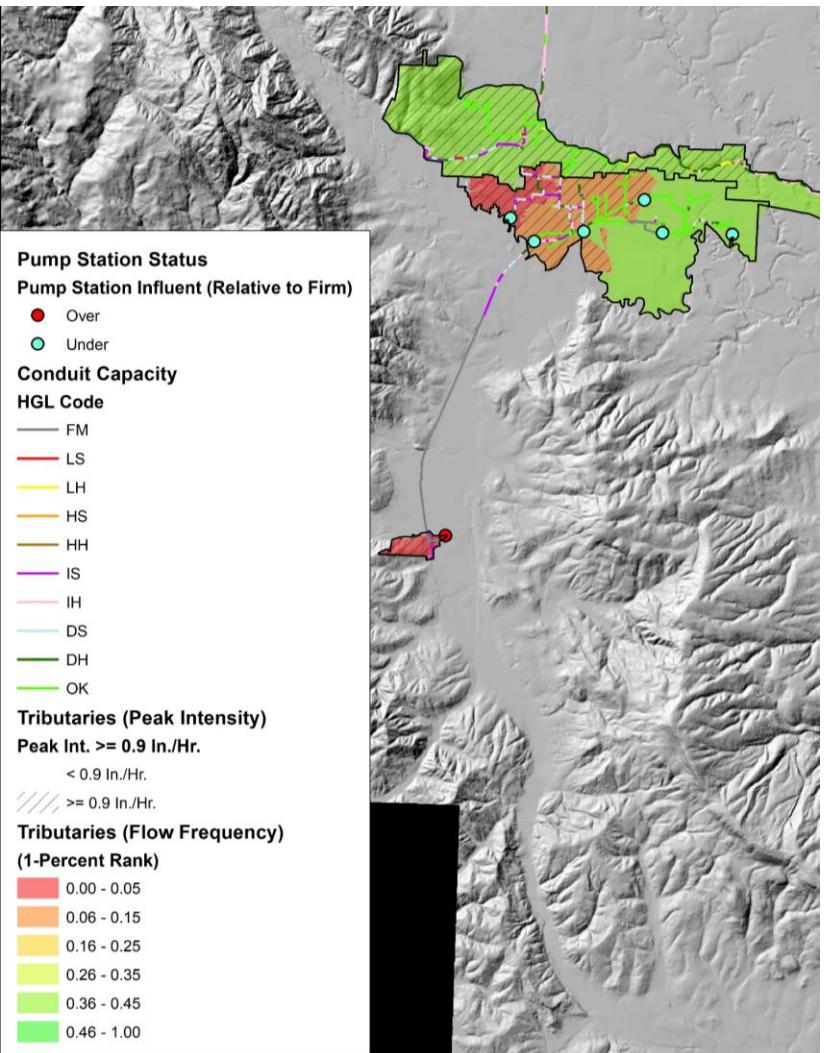


High Intensity Assessment – Forest Grove

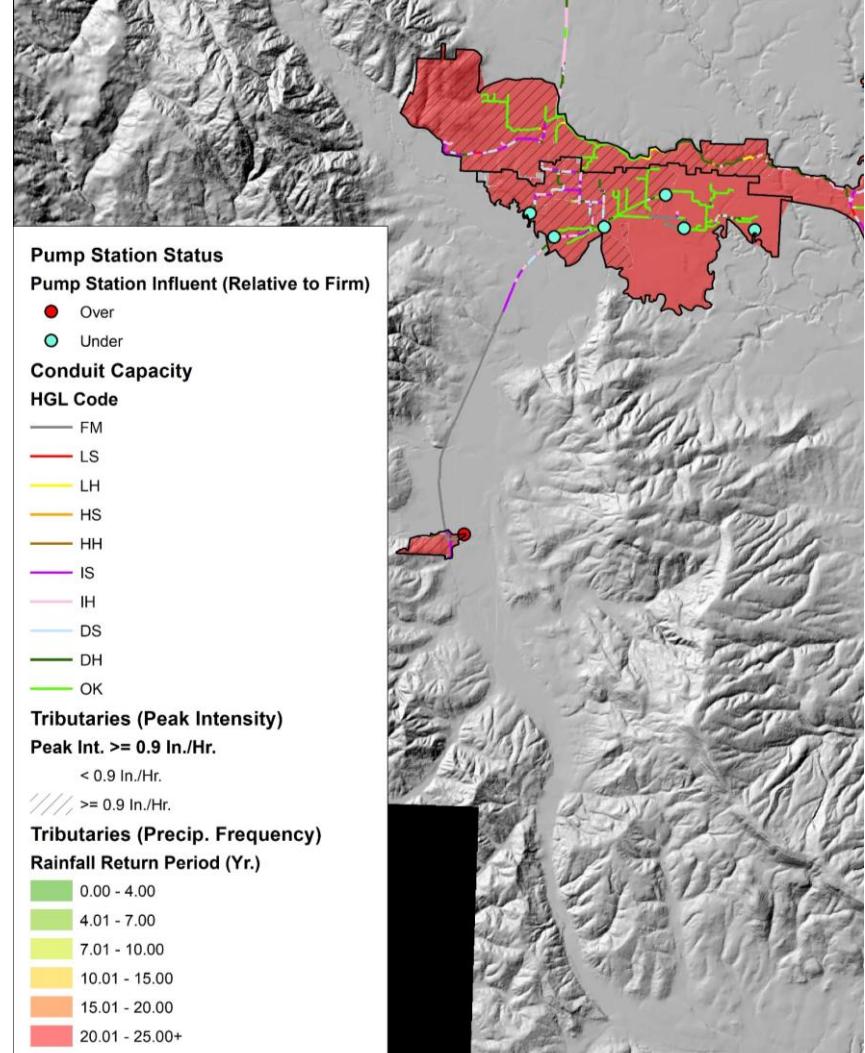


Event 168

Flow Frequency



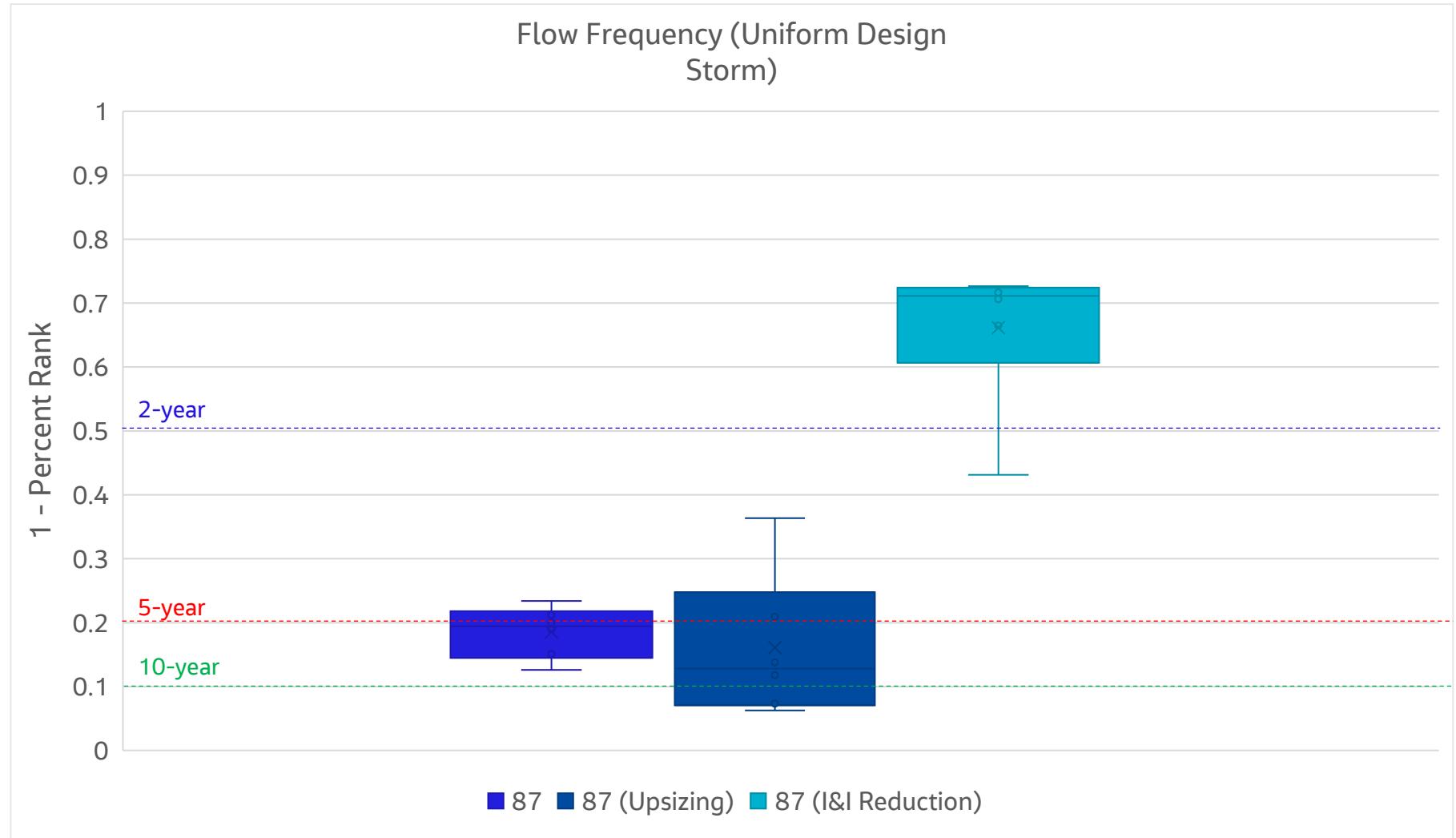
Precipitation Frequency



Sensitivity to Upsizing & RDI/I Reduction - Forest Grove



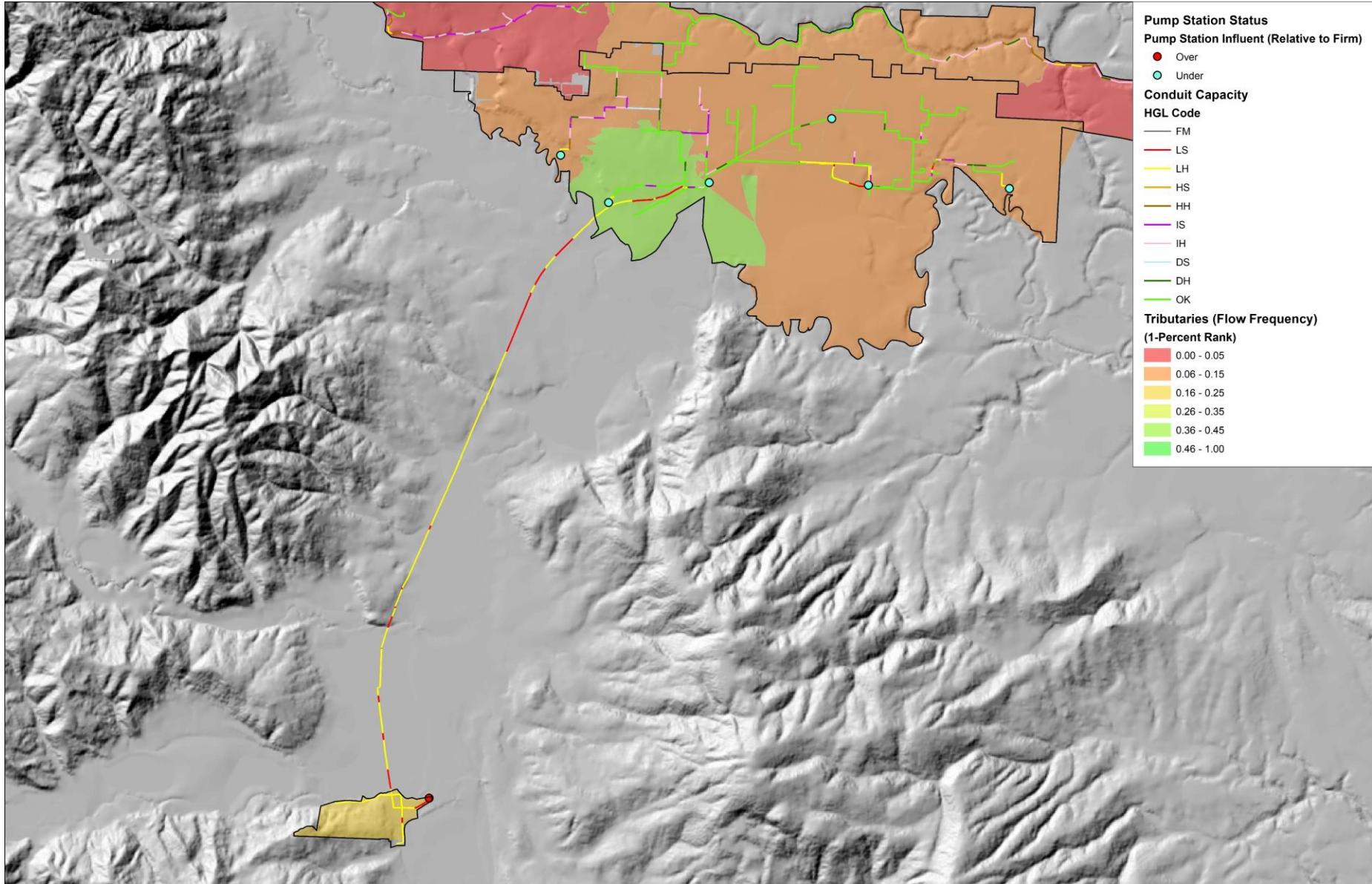
Event 87



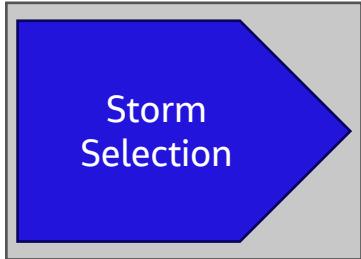
Sensitivity to Upsizing – Forest Grove



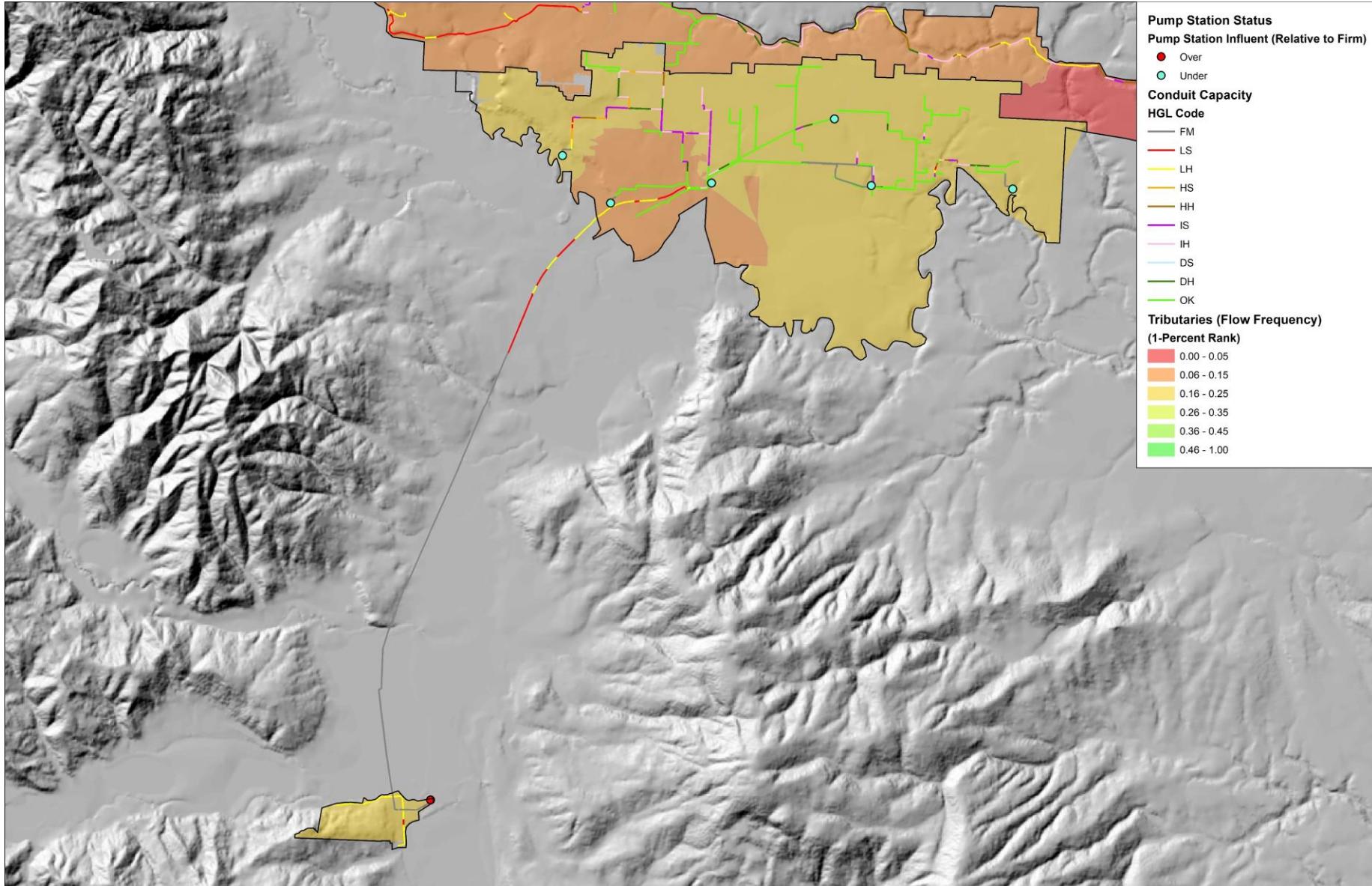
Event 87



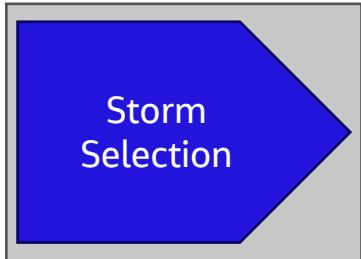
Select Storm Event(s) – Candidate Storms – Uniform – Forest Grove



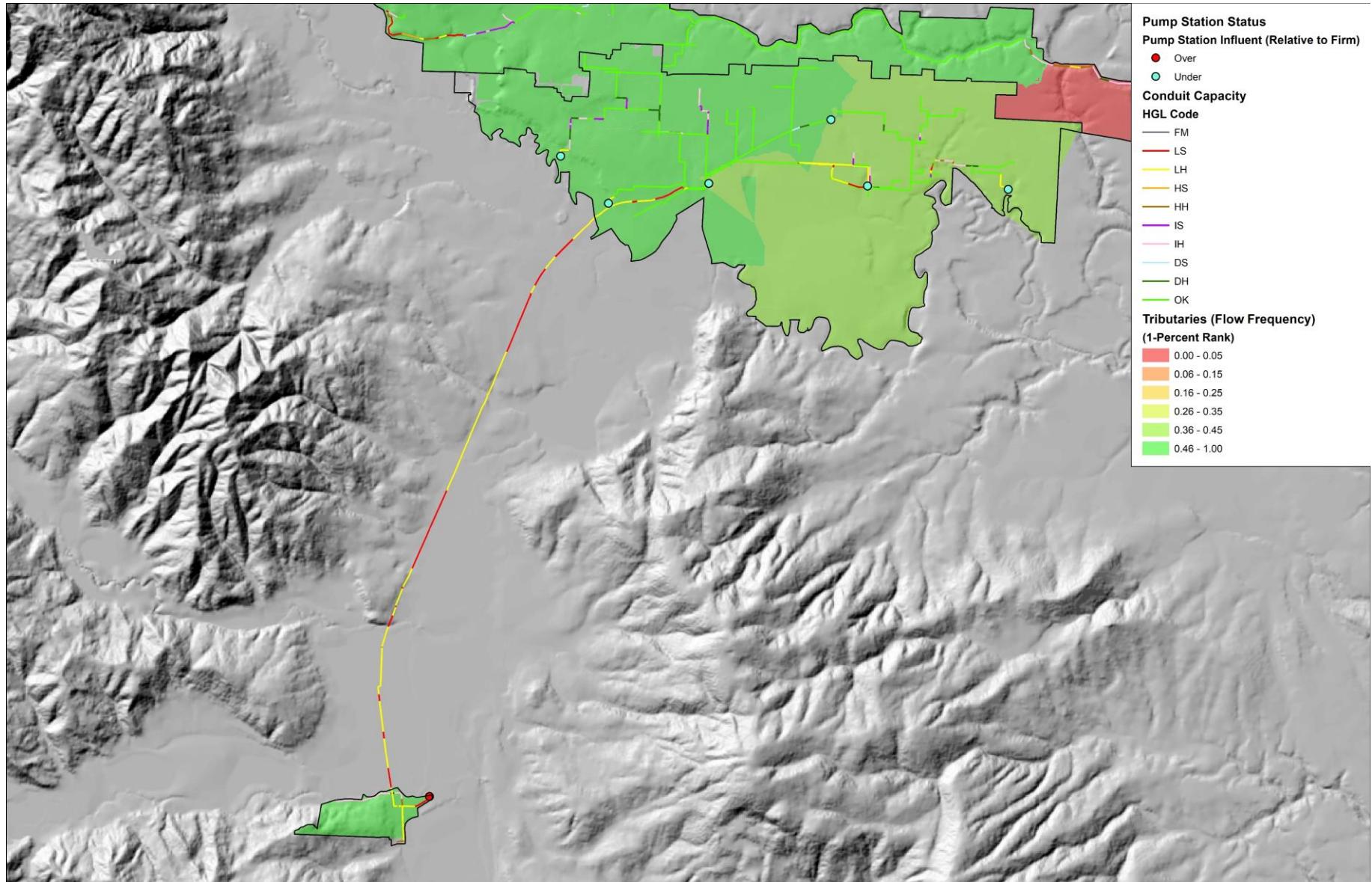
- Event 87
- Uniform Application



Sensitivity to RDI/I Reduction – Forest Grove

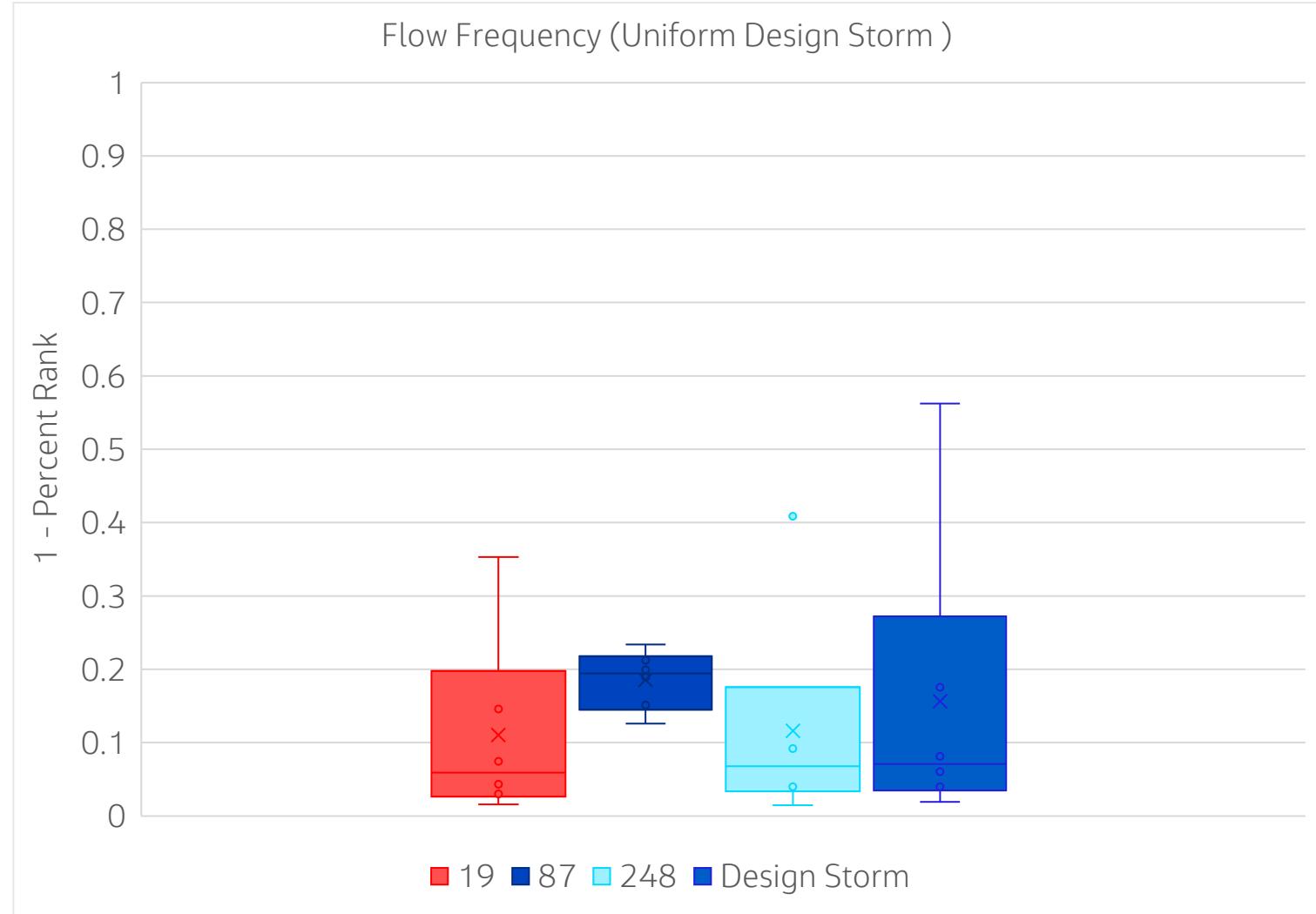


Event 87

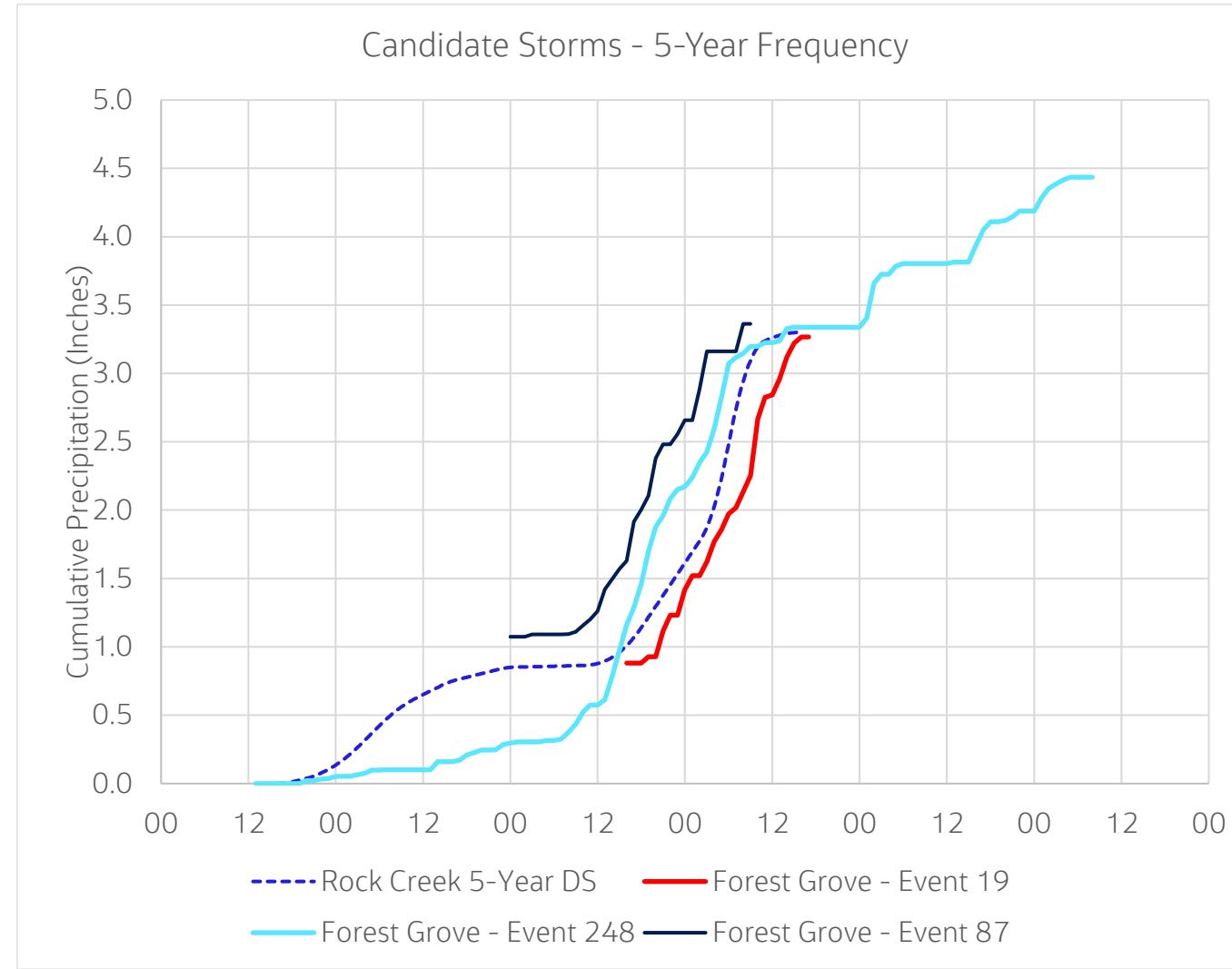
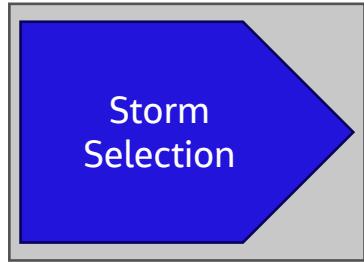


Forest Grove Recommendations

- Event 19 provides high level of service with fewest outliers
- Event 87 less conservative
- Decision: District preference for storm 19, (same storm as Hillsboro for simplicity, 19 is at least 5-year protection in all subareas)



Select Storm Event(s) – Candidate Storms – Forest Grove



APPENDIX 2E

Selected Design Storm Details

See Spreadsheet: WBMP_Design_Storm_&_Climate_Sensitivity_Storms_2024.08.15 - v3.xlsm

Table 2E.1 Rock Creek Basin, Selected Design Storm (5-year frequency) + Scaling for other Frequencies and Climate Sensitivity (arbitrary date assigned)

Time	2-Year	2-Year DS+	2-Year DS+INT	5-Year	5-Year DS+	5-Year DS+INT	10-Year	10-Year DS+	10-Year DS+INT	25-Year	50-Year	100-Year
12/10/1977 +16:00:00	0.0017	0.0018	0.0000	0.0020	0.0020	0.0000	0.0024	0.0025	0.0000	0.0028	0.0031	0.0031
12/10/1977 +17:00:00	0.0064	0.0064	0.0000	0.0073	0.0074	0.0000	0.0089	0.0090	0.0000	0.0102	0.0115	0.0115
12/10/1977 +18:00:00	0.0107	0.0108	0.0000	0.0122	0.0125	0.0000	0.0150	0.0152	0.0000	0.0171	0.0193	0.0194
12/10/1977 +19:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/10/1977 +20:00:00	0.0133	0.0135	0.0021	0.0152	0.0156	0.0024	0.0187	0.0189	0.0029	0.0213	0.0240	0.0241
12/10/1977 +21:00:00	0.0180	0.0182	0.0043	0.0205	0.0210	0.0050	0.0251	0.0254	0.0061	0.0287	0.0323	0.0325
12/10/1977 +22:00:00	0.0226	0.0229	0.0081	0.0257	0.0264	0.0093	0.0316	0.0320	0.0113	0.0361	0.0406	0.0408
12/10/1977 +23:00:00	0.0273	0.0275	0.0144	0.0310	0.0318	0.0166	0.0381	0.0385	0.0202	0.0436	0.0490	0.0492
12/11/1977 +00:00:00	0.0319	0.0322	0.0196	0.0363	0.0372	0.0227	0.0446	0.0451	0.0274	0.0510	0.0573	0.0576
12/11/1977 +01:00:00	0.0365	0.0369	0.0246	0.0416	0.0426	0.0284	0.0511	0.0516	0.0344	0.0584	0.0657	0.0660
12/11/1977 +02:00:00	0.0412	0.0416	0.0312	0.0469	0.0481	0.0361	0.0576	0.0582	0.0437	0.0658	0.0740	0.0743
12/11/1977 +03:00:00	0.0455	0.0460	0.0371	0.0518	0.0531	0.0429	0.0637	0.0643	0.0520	0.0727	0.0818	0.0822
12/11/1977 +04:00:00	0.0464	0.0469	0.0405	0.0528	0.0541	0.0468	0.0649	0.0656	0.0567	0.0741	0.0834	0.0837
12/11/1977 +05:00:00	0.0464	0.0469	0.0405	0.0528	0.0541	0.0468	0.0649	0.0656	0.0567	0.0741	0.0834	0.0837
12/11/1977 +06:00:00	0.0455	0.0460	0.0371	0.0518	0.0531	0.0414	0.0637	0.0643	0.0501	0.0727	0.0818	0.0822
12/11/1977 +07:00:00	0.0412	0.0416	0.0312	0.0469	0.0481	0.0361	0.0576	0.0582	0.0437	0.0658	0.0740	0.0743
12/11/1977 +08:00:00	0.0365	0.0369	0.0235	0.0416	0.0426	0.0272	0.0511	0.0516	0.0329	0.0584	0.0657	0.0660
12/11/1977 +09:00:00	0.0319	0.0322	0.0196	0.0363	0.0372	0.0227	0.0446	0.0451	0.0274	0.0510	0.0573	0.0576
12/11/1977 +10:00:00	0.0273	0.0275	0.0144	0.0310	0.0318	0.0166	0.0381	0.0385	0.0202	0.0436	0.0490	0.0492
12/11/1977 +11:00:00	0.0235	0.0237	0.0111	0.0267	0.0274	0.0128	0.0329	0.0332	0.0155	0.0375	0.0422	0.0424
12/11/1977 +12:00:00	0.0232	0.0234	0.0103	0.0264	0.0271	0.0119	0.0324	0.0328	0.0144	0.0371	0.0417	0.0419
12/11/1977 +13:00:00	0.0232	0.0234	0.0103	0.0264	0.0271	0.0119	0.0324	0.0328	0.0144	0.0371	0.0417	0.0419
12/11/1977 +14:00:00	0.0229	0.0231	0.0088	0.0261	0.0267	0.0102	0.0320	0.0324	0.0123	0.0366	0.0412	0.0414
12/11/1977 +15:00:00	0.0191	0.0193	0.0052	0.0218	0.0223	0.0060	0.0268	0.0271	0.0072	0.0306	0.0344	0.0345
12/11/1977 +16:00:00	0.0145	0.0146	0.0027	0.0165	0.0169	0.0031	0.0203	0.0205	0.0037	0.0232	0.0261	0.0262
12/11/1977 +17:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/11/1977 +18:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/11/1977 +19:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/11/1977 +20:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/11/1977 +21:00:00	0.0116	0.0117	0.0008	0.0132	0.0135	0.0009	0.0162	0.0164	0.0011	0.0185	0.0208	0.0209
12/11/1977 +22:00:00	0.0113	0.0114	0.0000	0.0129	0.0132	0.0000	0.0158	0.0160	0.0000	0.0181	0.0203	0.0204
12/11/1977 +23:00:00	0.0075	0.0076	0.0000	0.0086	0.0088	0.0000	0.0105	0.0107	0.0000	0.0120	0.0135	0.0136
12/12/1977 +00:00:00	0.0029	0.0029	0.0000	0.0033	0.0034	0.0000	0.0041	0.0041	0.0000	0.0046	0.0052	0.0052
12/12/1977 +01:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +02:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +03:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +04:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +05:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021

Time	2-Year	2-Year DS+	2-Year DS+INT	5-Year	5-Year DS+	5-Year DS+INT	10-Year	10-Year DS+	10-Year DS+INT	25-Year	50-Year	100-Year
12/12/1977 +06:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +07:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +08:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +09:00:00	0.0012	0.0012	0.0000	0.0013	0.0014	0.0000	0.0016	0.0016	0.0000	0.0019	0.0021	0.0021
12/12/1977 +10:00:00	0.0029	0.0029	0.0000	0.0033	0.0034	0.0000	0.0041	0.0041	0.0000	0.0046	0.0052	0.0052
12/12/1977 +11:00:00	0.0075	0.0076	0.0000	0.0086	0.0088	0.0000	0.0105	0.0107	0.0000	0.0120	0.0135	0.0136
12/12/1977 +12:00:00	0.0131	0.0132	0.0017	0.0149	0.0152	0.0019	0.0183	0.0184	0.0023	0.0209	0.0235	0.0236
12/12/1977 +13:00:00	0.0220	0.0223	0.0072	0.0251	0.0257	0.0083	0.0308	0.0311	0.0101	0.0352	0.0396	0.0398
12/12/1977 +14:00:00	0.0313	0.0316	0.0175	0.0356	0.0365	0.0202	0.0438	0.0443	0.0244	0.0500	0.0563	0.0565
12/12/1977 +15:00:00	0.0406	0.0410	0.0285	0.0462	0.0474	0.0329	0.0568	0.0574	0.0398	0.0649	0.0730	0.0733
12/12/1977 +16:00:00	0.0499	0.0504	0.0450	0.0568	0.0582	0.0520	0.0698	0.0705	0.0629	0.0797	0.0896	0.0900
12/12/1977 +17:00:00	0.0592	0.0598	0.0568	0.0673	0.0690	0.0655	0.0827	0.0836	0.0794	0.0945	0.1063	0.1068
12/12/1977 +18:00:00	0.0679	0.0686	0.0670	0.0772	0.0792	0.0774	0.0949	0.0959	0.0938	0.1084	0.1219	0.1225
12/12/1977 +19:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/12/1977 +20:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/12/1977 +21:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/12/1977 +22:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/12/1977 +23:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/13/1977 +00:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/13/1977 +01:00:00	0.0696	0.0703	0.0827	0.0792	0.0812	0.0956	0.0973	0.0984	0.1158	0.1112	0.1251	0.1256
12/13/1977 +02:00:00	0.0783	0.0791	0.0953	0.0891	0.0914	0.1101	0.1095	0.1107	0.1334	0.1251	0.1407	0.1413
12/13/1977 +03:00:00	0.1218	0.1231	0.1553	0.1386	0.1421	0.1794	0.1703	0.1721	0.2172	0.1946	0.2189	0.2198
12/13/1977 +04:00:00	0.1682	0.1699	0.2241	0.1914	0.1963	0.2588	0.2352	0.2377	0.3135	0.2687	0.3022	0.3036
12/13/1977 +05:00:00	0.2146	0.2168	0.2983	0.2442	0.2504	0.3445	0.3001	0.3033	0.4172	0.3429	0.3856	0.3873
12/13/1977 +06:00:00	0.2291	0.2315	0.3250	0.2607	0.2673	0.3754	0.3204	0.3238	0.4546	0.3660	0.4117	0.4135
12/13/1977 +07:00:00	0.1914	0.1934	0.2605	0.2178	0.2233	0.3009	0.2677	0.2705	0.3644	0.3058	0.3439	0.3455
12/13/1977 +08:00:00	0.1450	0.1465	0.1890	0.1650	0.1692	0.2183	0.2028	0.2049	0.2644	0.2317	0.2606	0.2617
12/13/1977 +09:00:00	0.0986	0.0996	0.1229	0.1122	0.1151	0.1419	0.1379	0.1393	0.1719	0.1575	0.1772	0.1780
12/13/1977 +10:00:00	0.0522	0.0527	0.0486	0.0594	0.0609	0.0561	0.0730	0.0738	0.0680	0.0834	0.0938	0.0942
12/13/1977 +11:00:00	0.0215	0.0217	0.0064	0.0244	0.0250	0.0074	0.0300	0.0303	0.0090	0.0343	0.0386	0.0387
12/13/1977 +12:00:00	0.0168	0.0170	0.0036	0.0191	0.0196	0.0041	0.0235	0.0238	0.0050	0.0269	0.0302	0.0304
12/13/1977 +13:00:00	0.0122	0.0123	0.0012	0.0139	0.0142	0.0014	0.0170	0.0172	0.0017	0.0195	0.0219	0.0220
12/13/1977 +14:00:00	0.0075	0.0076	0.0000	0.0086	0.0088	0.0000	0.0105	0.0107	0.0000	0.0120	0.0135	0.0136
12/13/1977 +15:00:00	0.0026	0.0026	0.0000	0.0030	0.0030	0.0000	0.0037	0.0037	0.0000	0.0042	0.0047	0.0047
12/13/1977 +16:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum, 1- hour (inches)	0.2291	0.2315	0.3250	0.2607	0.2673	0.3754	0.3204	0.3238	0.4546	0.3660	0.4117	0.4135
Maximum, 6- hours (inches)	1.0702	1.0811	1.4522	1.2177	1.2487	1.6773	1.4966	1.5124	2.0315	1.7097	1.9229	1.9315
Maximum, 12- hours (inches)	1.5255	1.5411	2.0014	1.7358	1.7800	2.3116	2.1333	2.1558	2.7998	2.4372	2.7411	2.7532
Maximum, 24- hours (inches)	2.0957	2.1171	2.5302	2.3846	2.4453	2.9223	2.9307	2.9616	3.5394	3.3481	3.7656	3.7823

Time	2-Year	2-Year DS+	2-Year DS+INT	5-Year	5-Year DS+	5-Year DS+INT	10-Year	10-Year DS+	10-Year DS+INT	25-Year	50-Year	100-Year
Maximum, 48 hours (inches)	2.2976	2.3210	2.5741	2.6143	2.6808	2.9731	3.2129	3.2468	3.6009	3.6706	4.1283	4.1466
Maximum, 72 hours (inches)	2.9002	2.9299	2.9345	3.3000	3.3840	3.3878	4.0557	4.0985	4.1032	4.6335	5.2112	5.2343

Table 2E.2 Hillsboro Basin, Selected Design Storm (5-year frequency) + Scaling for other Frequencies and Climate Sensitivity (arbitrary date assigned)

Time	2-Year	2-Year DS+	2-Year DS+INT	5-Year	5-Year DS+	5-Year DS+INT	10-Year	10-Year DS+	10-Year DS+INT	25-Year	50-Year	100-Year
12/10/1977 +16:00:00	0.0265	0.0267	0.0267	0.0301	0.0309	0.0309	0.0369	0.0373	0.0373	0.0421	0.0474	0.0476
12/10/1977 +17:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +18:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +19:00:00	0.0389	0.0393	0.0393	0.0442	0.0453	0.0453	0.0542	0.0548	0.0548	0.0619	0.0696	0.0699
12/10/1977 +20:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +21:00:00	0.1628	0.1645	0.1645	0.1854	0.1900	0.1900	0.2272	0.2296	0.2296	0.2594	0.2916	0.2929
12/10/1977 +22:00:00	0.1009	0.1019	0.1019	0.1148	0.1177	0.1177	0.1407	0.1422	0.1422	0.1606	0.1806	0.1814
12/10/1977 +23:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/11/1977 +00:00:00	0.1628	0.1645	0.1645	0.1854	0.1900	0.1900	0.2272	0.2296	0.2296	0.2594	0.2916	0.2929
12/11/1977 +01:00:00	0.0885	0.0894	0.0894	0.1007	0.1032	0.1032	0.1234	0.1247	0.1247	0.1409	0.1584	0.1591
12/11/1977 +02:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/11/1977 +03:00:00	0.0744	0.0752	0.0752	0.0847	0.0868	0.0868	0.1038	0.1049	0.1049	0.1185	0.1332	0.1338
12/11/1977 +04:00:00	0.1403	0.1417	0.1417	0.1597	0.1637	0.1637	0.1957	0.1978	0.1978	0.2235	0.2512	0.2523
12/11/1977 +05:00:00	0.0761	0.0768	0.0768	0.0866	0.0888	0.0888	0.1061	0.1072	0.1072	0.1211	0.1362	0.1368
12/11/1977 +06:00:00	0.1009	0.1019	0.1019	0.1148	0.1177	0.1177	0.1407	0.1422	0.1422	0.1606	0.1806	0.1814
12/11/1977 +07:00:00	0.0389	0.0393	0.0393	0.0442	0.0453	0.0453	0.0542	0.0548	0.0548	0.0619	0.0696	0.0699
12/11/1977 +08:00:00	0.1009	0.1019	0.1019	0.1148	0.1177	0.1177	0.1407	0.1422	0.1422	0.1606	0.1806	0.1814
12/11/1977 +09:00:00	0.1009	0.1019	0.1019	0.1148	0.1177	0.1177	0.1407	0.1422	0.1422	0.1606	0.1806	0.1814
12/11/1977 +10:00:00	0.3612	0.3649	0.3649	0.4112	0.4216	0.4216	0.5040	0.5093	0.5093	0.5754	0.6468	0.6496
12/11/1977 +11:00:00	0.1380	0.1395	0.1395	0.1572	0.1611	0.1611	0.1926	0.1946	0.1946	0.2199	0.2472	0.2483
12/11/1977 +12:00:00	0.0141	0.0142	0.0142	0.0160	0.0164	0.0164	0.0196	0.0198	0.0198	0.0224	0.0252	0.0253
12/11/1977 +13:00:00	0.1009	0.1019	0.1019	0.1148	0.1177	0.1177	0.1407	0.1422	0.1422	0.1606	0.1806	0.1814
12/11/1977 +14:00:00	0.1380	0.1395	0.1395	0.1572	0.1611	0.1611	0.1926	0.1946	0.1946	0.2199	0.2472	0.2483
12/11/1977 +15:00:00	0.0885	0.0894	0.0894	0.1007	0.1032	0.1032	0.1234	0.1247	0.1247	0.1409	0.1584	0.1591
12/11/1977 +16:00:00	0.0389	0.0393	0.0393	0.0442	0.0453	0.0453	0.0542	0.0548	0.0548	0.0619	0.0696	0.0699
12/11/1977 +17:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum, 1- hour (inches)	0.3612	0.3649	0.3649	0.4112	0.4216	0.4216	0.5040	0.5093	0.5093	0.5754	0.6468	0.6496
Maximum, 6- hours (inches)	0.8531	0.8618	0.8618	0.9712	0.9955	0.9955	1.1903	1.2028	1.2028	1.3589	1.5275	1.5342
Maximum, 12- hours (inches)	1.3984	1.4128	1.4128	1.5921	1.6320	1.6320	1.9512	1.9716	1.9716	2.2275	2.5039	2.5150
Maximum, 24- hours (inches)	2.0655	2.0867	2.0867	2.3515	2.4105	2.4105	2.8820	2.9122	2.9122	3.2902	3.6984	3.7147
Maximum, 48 hours (inches)	2.0920	2.1135	2.1135	2.3817	2.4414	2.4414	2.9189	2.9495	2.9495	3.3323	3.7458	3.7623
Maximum, 72 hours (inches)	2.0920	2.1135	2.1135	2.3817	2.4414	2.4414	2.9189	2.9495	2.9495	3.3323	3.7458	3.7623

Table 2E.3 Forest Grove Basin, Selected Design Storm (5-year frequency) + Scaling for other Frequencies and Climate Sensitivity (arbitrary date assigned)

Time	2-Year	2-Year DS+	2-Year DS+INT	5-Year	5-Year DS+	5-Year DS+INT	10-Year	10-Year DS+	10-Year DS+INT	25-Year	50-Year	100-Year
12/10/1977 +16:00:00	0.0275	0.0278	0.0278	0.0313	0.0321	0.0321	0.0383	0.0387	0.0387	0.0437	0.0491	0.0495
12/10/1977 +17:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +18:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +19:00:00	0.0400	0.0404	0.0404	0.0455	0.0466	0.0466	0.0557	0.0563	0.0563	0.0636	0.0714	0.0719
12/10/1977 +20:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/10/1977 +21:00:00	0.1648	0.1665	0.1665	0.1876	0.1923	0.1923	0.2296	0.2320	0.2320	0.2621	0.2945	0.2964
12/10/1977 +22:00:00	0.1024	0.1034	0.1034	0.1166	0.1195	0.1195	0.1427	0.1442	0.1442	0.1628	0.1830	0.1842
12/10/1977 +23:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/11/1977 +00:00:00	0.1648	0.1665	0.1665	0.1876	0.1923	0.1923	0.2296	0.2320	0.2320	0.2621	0.2945	0.2964
12/11/1977 +01:00:00	0.0899	0.0908	0.0908	0.1024	0.1049	0.1049	0.1253	0.1266	0.1266	0.1430	0.1607	0.1617
12/11/1977 +02:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12/11/1977 +03:00:00	0.0899	0.0908	0.0908	0.1024	0.1049	0.1049	0.1253	0.1266	0.1266	0.1430	0.1607	0.1617
12/11/1977 +04:00:00	0.1273	0.1286	0.1286	0.1450	0.1486	0.1486	0.1774	0.1793	0.1793	0.2025	0.2276	0.2291
12/11/1977 +05:00:00	0.0774	0.0782	0.0782	0.0881	0.0903	0.0903	0.1079	0.1090	0.1090	0.1231	0.1383	0.1393
12/11/1977 +06:00:00	0.1024	0.1034	0.1034	0.1166	0.1195	0.1195	0.1427	0.1442	0.1442	0.1628	0.1830	0.1842
12/11/1977 +07:00:00	0.0400	0.0404	0.0404	0.0455	0.0466	0.0466	0.0557	0.0563	0.0563	0.0636	0.0714	0.0719
12/11/1977 +08:00:00	0.1024	0.1034	0.1034	0.1166	0.1195	0.1195	0.1427	0.1442	0.1442	0.1628	0.1830	0.1842
12/11/1977 +09:00:00	0.1024	0.1034	0.1034	0.1166	0.1195	0.1195	0.1427	0.1442	0.1442	0.1628	0.1830	0.1842
12/11/1977 +10:00:00	0.3644	0.3682	0.3682	0.4150	0.4253	0.4253	0.5079	0.5132	0.5132	0.5796	0.6514	0.6557
12/11/1977 +11:00:00	0.1398	0.1412	0.1412	0.1592	0.1632	0.1632	0.1948	0.1969	0.1969	0.2224	0.2499	0.2515
12/11/1977 +12:00:00	0.0150	0.0152	0.0152	0.0171	0.0175	0.0175	0.0209	0.0211	0.0211	0.0239	0.0268	0.0270
12/11/1977 +13:00:00	0.1024	0.1034	0.1034	0.1166	0.1195	0.1195	0.1427	0.1442	0.1442	0.1628	0.1830	0.1842
12/11/1977 +14:00:00	0.1398	0.1412	0.1412	0.1592	0.1632	0.1632	0.1948	0.1969	0.1969	0.2224	0.2499	0.2515
12/11/1977 +15:00:00	0.0899	0.0908	0.0908	0.1024	0.1049	0.1049	0.1253	0.1266	0.1266	0.1430	0.1607	0.1617
12/11/1977 +16:00:00	0.0400	0.0404	0.0404	0.0455	0.0466	0.0466	0.0557	0.0563	0.0563	0.0636	0.0714	0.0719
12/11/1977 +17:00:00	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum, 1-hour (inches)	0.3644	0.3682	0.3682	0.4150	0.4253	0.4253	0.5079	0.5132	0.5132	0.5796	0.6514	0.6557
Maximum, 6-hours (inches)	0.8638	0.8726	0.8726	0.9836	1.0081	1.0081	1.2038	1.2164	1.2164	1.3739	1.5439	1.5541
Maximum, 12-hours (inches)	1.4031	1.4175	1.4175	1.5977	1.6375	1.6375	1.9554	1.9759	1.9759	2.2316	2.5078	2.5244
Maximum, 24-hours (inches)	2.0946	2.1162	2.1162	2.3853	2.4446	2.4446	2.9193	2.9498	2.9498	3.3316	3.7439	3.7687
Maximum, 48 hours (inches)	2.1221	2.1439	2.1439	2.4166	2.4767	2.4767	2.9576	2.9885	2.9885	3.3753	3.7931	3.8181
Maximum, 72 hours (inches)	2.1221	2.1439	2.1439	2.4166	2.4767	2.4767	2.9576	2.9885	2.9885	3.3753	3.7931	3.8181