global science solutions RIVERSIDE

U.S. Army Corps of Engineers, Omaha District

In Association with Nebraska Silver Jackets

PROJECT COMPLETION REPORT

Regulated Flood Frequency Analysis for the North Platte River at North Platte, NE

Contract W9128F-13-T-0011

Prepared by

Riverside Technology, inc.

October 14th, 2013

Table of Contents

Table of Figures

Table of Tables

1 Executive Summary

The Omaha District of the United States Army Corps of Engineers (USACE) as well as the other agencies involved with the Nebraska Silver Jackets program are focused on understanding and reducing flood risk. In order to better quantify the flood risk for the North Platte River, Riverside Technology, inc. (Riverside) was tasked with developing regulated flood frequency curves at several points along the North Platte in Nebraska. These curves can be used along with hydraulic models of the area to determine the probability of flooding to various depths. The Upper Mississippi River System Flow Frequency Study (USACE 2004) was used as an example of a regulated flow frequency study, especially the section relating to the Missouri River (Appendix F).

For this project, Riverside used basin and reservoir models previously calibrated for the National Weather Service (NWS) Missouri Basin River Forecast Center (MBRFC) for the North Platte River from the headwaters to the City of North Platte, NE. Reservoir and other regulation models were analyzed and updated as needed to match current operations, especially as demonstrated during the high-runoff year of 2011.

The hydrologic basin models were used to generate simulated unregulated flows throughout the basin and these flows were input into a flood frequency analysis to get unregulated flood frequency curves at the desired points. The unregulated flows were used along with reservoir, diversion, and routing models to generate regulated flows, and these regulated flows were used along with the unregulated frequency curves to create regulated frequency curves. By increasing the precipitation input to the hydrologic models, larger events were generated to extend the regulated flow frequency curves. Table 1-1 shows the results of the analysis for instantaneous regulated peak flows.

Table 1-1. Instantaneous regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	22600	23100	25500	26200	25600	19300	19400
0.005	20000	20400	21000	21300	21500	17300	17600
0.01	18300	18800	18900	18800	19200	13700	14700
0.02	15100	15700	15700	16100	16800	11400	11600
0.05	11600	11900	12100	12500	12700	8240	9130
0.10	9060	9670	9540	9730	9980	6290	6690
0.20	5680	5950	6110	6170	6790	3480	4740
0.50	2660	3050	3300	3450	3630	2700	2590
0.80	1630	2170	2330	2400	2500	2310	2130
0.90	1210	1760	1870	1870	1980	1980	1860
0.95	960	1400	1460	1440	1490	1640	1610
0.99	840	1170	1180	1280	1370	1160	1020

The project area is shown below in Figure 1-1. The basin boundaries for the North Platte River are shown in black, and each sub-basin is labeled according to the naming conventions used by the MBRFC. The City of North Platte is located at the far eastern end of the map, in the NPTN1 sub-basin.

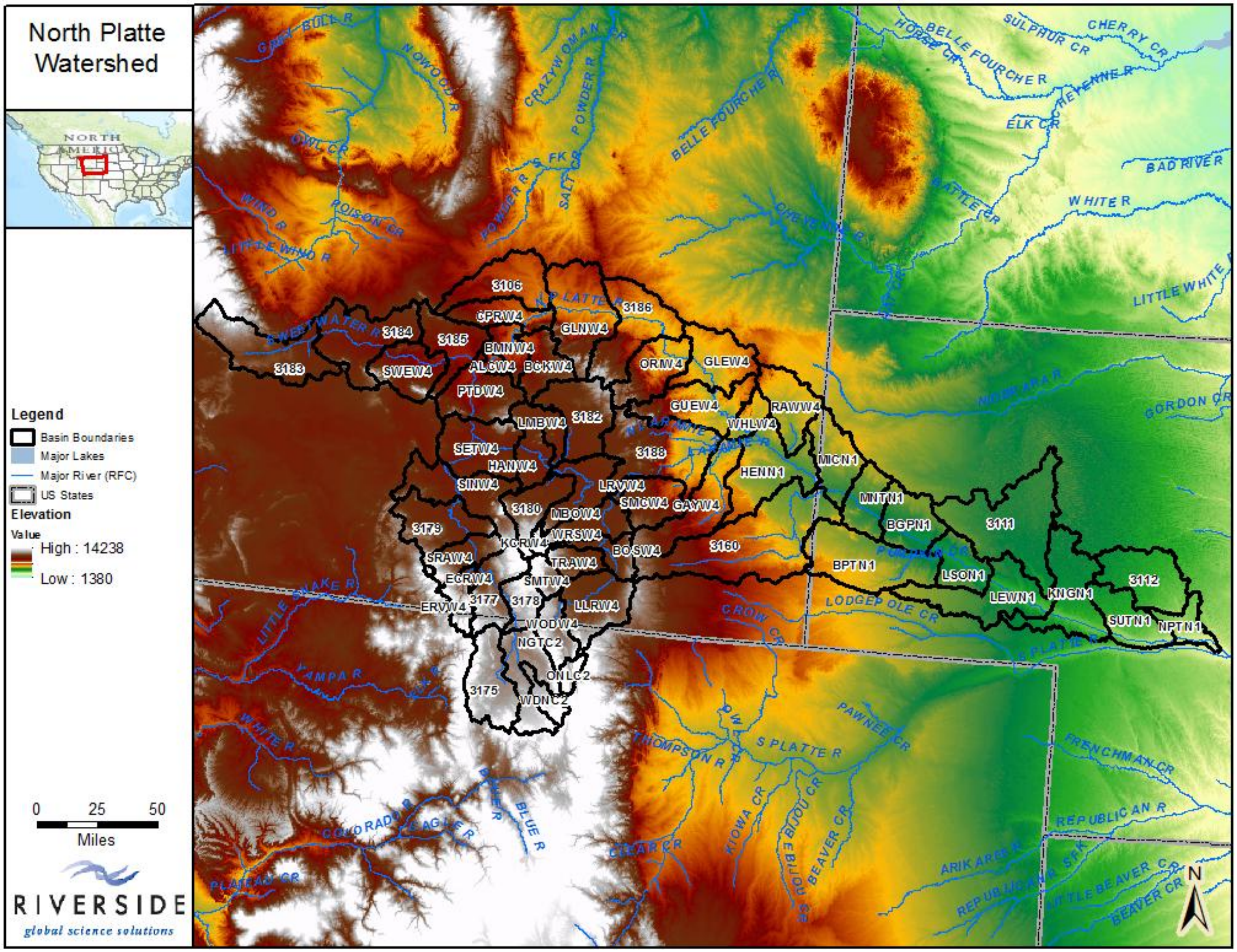

Figure 1-1. North Platte Watershed

2 Data Collection

Data were collected for this project from a variety of sources. Collected data include climatology (precipitation and temperature), streamflow, diversions, reservoir pool elevations, reservoir releases, up-to-date copies of previously calibrated model files, and verbal and written descriptions of reservoir operations. See Appendix A for a listing and description of the data files collected.

2.1 Climatology Data

Precipitation and temperature data covering the entire North Platte River watershed were provided to Riverside by the MBRFC on February 13, 2013. The period of record for these data is October 1948 through September 2012, covering 64 complete water years. Because the hydrologic models used in the project are driven by these 2 data sets, the period of record for the flood frequency analysis was set to match the climatology data.

The data were provided as mean areal precipitation (MAP) and mean areal temperature (MAT). Each time series represents the average precipitation or temperature over the sub-basin. The time series were created by the MBRFC using station data from many climate stations in and near the North Platte basin. The time series have a 6-hour time step and have no missing data.

2.2 Streamflow Data

Observed historical streamflow data were used in the calibration of the regulation models. Data were collected during Riverside's two previous calibration projects with the MBRFC in 2008-2010 (Riverside 2009, 2010). The calibration effort in those projects had a period of record ending in September 2004, and much of the observed data collected for those projects ended then as well. For this project, streamflow data through the end of 2012 were collected where available and appended to the previous time series.

Streamflow data were obtained from the United States Geological Survey (USGS) and Nebraska Department of Natural Resources (NDNR). USGS data were available online from the National Water Information System (NWIS) website at http://waterdata.usgs.gov/nwis/sw. Tools previously developed by Riverside were used to download and process the data in March, 2013. The website used in the previous projects to download NDNR data was no longer available, and extended streamflow data for sites in Nebraska were obtained in spreadsheet format by contacting NDNR personnel directly in April, 2013.

Table 2-1 shows the USGS gage IDs and associated MBRFC sub-basin ID for the data that were collected. Not all gages listed had data available for recent years. Table 2-2 shows the NDNR data collected. All NDNR time series had recent data available, with some small missing periods.

Table 2-1. USGS Streamflow Data

USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID
6620000	NGTC2	6636000	abvPTDW4	6657000	WHLW4	6665790	SMCW4
6617100	WDNC2	6641000	blwPTDW4	6657500	ONLC2	6670500	FLAW4
6625000	ECRW4	6642000	ALCW4	6659501	WOPW4	6671000	RAWW4
6627000	SRAW4	6643000	BCKW4	6659502	WODW4	6674500	HENN1
6630000	SINW4	6643500	BMNW4	6660000	LLRW4	6631500	3180

USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID	USGS Gage ID	Sub-basin ID
6632400	KCRW4	6645000	CPRW4	6661000	SMTW4	6638090	3183
6634620	LMBW4_1	6646800	GLNW4	6661500	TRAW4	6644500	3106
6634600	LMBW4_2	6652000	ORIW4	6661585	BOSW4	6650000	3186
6635000	HANW4	6652800	GLEW4	6662000	WRSW4		
6639000	SWEW4	6656000	GUEW4	6663500	LRVW4		

Table 2-2. Nebraska DNR Streamflow Data

NDNR Gage ID	Sub-basin ID
6679500	MICN1
6682000	MNTN1
6684500	BGPN1
6685000	BPTN1
6686000	LSON1
6687500	LEWN1
6690500	KNGN1
6691000	SUTN1
6693000	NPTN1
6677500	3160
6687000	3111
6692000	3112

2.3 Diversion Data

Observed historical diversion data were obtained where available for large diversions from the North Platte and tributaries. The data were used to check the calibrations of the consumptive use models and other diversion models. Because detailed calibration of these models was done in the two previous projects, work in this project was limited to checking the models against recent data to ensure the models were still operating reasonably. In the previous project, an effort was made to digitize data for diversions on the Laramie River, but no additional digitization was done for this project due to the limited scope and small relative impact of Laramie River diversions on peak flows in Nebraska.

Diversion data were obtained from the United States Bureau of Reclamation (USBR) and the NDNR. USBR data were downloaded from the Great Plains Region Hydromet archive at http://www.usbr.gov/gp/hydromet/hydromet_arcread.html on March 20, 2013. The NDNR diversion data were obtained at the same time as the streamflow data. Table 2-3 lists the USBR data collected, and Table 2-4 lists the NDNR data.

Table 2-3. USBR Diversion Data

USBR ID	Description
CAWY	Casper Canal
FCNE	Fort Laramie Canal at milepost 0.8, WY
FCWY	Fort Laramie Canal at milepost 85.3, NE
ICWY	Interstate Canal

USBR ID	Description
MGNE	Mitchell-Gering Canal
TSNE	Tristate Dam

Table 2-4. Nebraska DNR Diversion Data

NDNR Gage ID	Description
6764900	Korty Canal
138000	Sutherland Canal

2.4 Reservoir Data

Data were collected from the USBR, Central Nebraska Public Power and Irrigation District (CNPPID), and State of Wyoming to support the reservoir modeling portion of the project. Data types collected include pool elevation, releases, and inflows. Information on reservoir operations was also provided by the USACE, USBR, and CNPPID for the reservoirs they operate.

2.4.1 Time Series Data

Reservoir data were obtained from the USBR at the same time as the diversion data, from the same website. The five reservoirs on the mainstem of the North Platte in Wyoming all had data available from the USBR, as shown in Table 2-5.

Table 2-5. USBR Reservoir Data

Reservoir	USBR ID	Data Type	USBR Data Type ID
Seminoe	SEMR	Storage	AF
Seminoe	SEMR	Pool Elevation	FB
Seminoe	SEMR	Inflow	IN
Seminoe	SEMR	Release	QD
Pathfinder	PATR	Storage	AF
Pathfinder	PATR	Pool Elevation	FB
Pathfinder	PATR	Inflow	IN
Pathfinder	PATR	Release	QD
Alcova	ALCR	Storage	AF
Alcova	ALCR	Pool Elevation	FB
Alcova	ALCR	Inflow	IN
Alcova	ALCR	Release	QD
Glendo	GLER	Storage	AF
Glendo	GLER	Pool Elevation	FB
Glendo	GLER	Inflow	IN
Glendo	GLER	Release	QD
Guernsey	GUER	Storage	AF
Guernsey	GUER	Pool Elevation	FB
Guernsey	GUER	Inflow	IN
Guernsey	GUER	Release	QD

For the two modeled reservoirs on the Laramie River, Wheatland #2 and Grayrocks, some data were available on a new State of Wyoming website at http://seoflow.wyo.gov/wdportal/. The website provides pool elevation and release data for Wheatland #2, and release data for Grayrocks, which were downloaded in early April, 2013. Unfortunately, most of the data for 2011 (the primary year of interest for the model updating effort) were missing.

For Lake McConaughy, daily pool elevation and release data were provided by the CNPPID on February 15, 2013 in spreadsheet format. This data extended from 1942 through early 2013.

2.4.2 Operational Data

Guidance on how the reservoirs in the basin are operated was provided to Riverside by the reservoir operators, in both written form and through phone conversations.

The mainstem reservoirs in Wyoming are normally operated by the USBR. Glendo Reservoir is jointly operated by the USBR and the USACE, with the USBR operating the reservoir at normal pool levels, and the USACE taking over operations when the pool rises into the flood control zone (4635 ft). At very high pool elevations (above 4653 ft), the USBR resumes operation in order to operate according to dam safety needs. The reservoir operations and inflows are monitored year-round by the USACE, and the two agencies coordinate closely whenever flood control operations are forecasted.

Katie Seefus from the USACE provided information about flood control operations at Glendo Reservoir in a short written document on May 2, 2013. The document includes excerpts from the Glendo Water Control Manual. This document gives information about what factors the USACE considers when scheduling releases.

Aaron Thompson from the USBR provided a packet of information on May 2, 2013 relating to the USBR's operation of the Wyoming reservoirs (Seminoe, Pathfinder, Alcova, Glendo, and Guernsey). The packet contents are:

- A Water Supply and Utilization Report for the North Platte Basin from March 2013, showing reservoir content, storage ownership allocation, inflow forecasts, and snowpack information. This report was useful in showing what information the USBR looks at regularly, and also for showing which snow measurement stations are used in inflow forecast development.
- Documentation for the USBR's computer model of the North Platte, which runs on a monthly time step. This includes information about monthly storage targets, minimum flows, and irrigation demands.
- An updated storage-elevation curve for Glendo Reservoir. This curve is used by the USBR as of September 30, 2012 and is based on a 2003 sediment survey of the reservoir.
- A sample operating plan for April 2013. This plan details the monthly operational targets and a 12 month forecast of future operations for all of the reservoirs and powerplants in the basin.
- Time series information for releases and streamflow for select periods in 2010-2011.
- Other miscellaneous documents.

CNPPID provided much information about the operation of Lake McConaughy through phone conversations and emailed documents. Cory Steinke emailed Riverside a document on March 21, 2013 giving some information on release requirements in different conditions. Riverside staff participated in a phone call with CNPPID staff and USACE staff on April 17, 2013. There was extensive discussion of CNPPID's operational thought processes and limits imposed on reservoir operation by regulatory agencies and by downstream channel capacities. A summary of the information from this phone call is provided below:

- CNPPID has a Federal Energy Regulatory Commission (FERC) license for Lake McConaughy that limits the maximum pool elevation to 3265 ft. If conditions require it, they can apply for a short-term waiver to allow additional storage, usually 2 ft.

- The current channel capacity is 1600 cfs, above which damages will begin. In the past, flood damages began at 3000 cfs or higher.
- CNPPID monitors USBR water supply forecasts to predict inflow to the reservoir.
- One important goal during high-flow operations is to keep the City of North Platte below flood stage as much as possible given other constraints. Flood control is not an official objective of the reservoir, but CNPPID will attempt to minimize negative downstream impacts from reservoir operation. They will always attempt to keep the peak outflow less than the peak inflow.
- CNPPID will increase releases in late winter/early spring if the inflow forecast is high, to avoid excessively high pool elevations later in the year.
- The primary purpose of the reservoir is to provide water to downstream diversions for both irrigation and hydropower. CNPPID likes to fill the reservoir when possible. Some downstream water users can use water from the South Platte as well as from Lake McConaughy. South Platte water is typically used first.

2.5 Model Data

Riverside calibrated hydrologic and regulation models for sub-basins in the North Platte basin for the MBRFC from 2008-2010 (Riverside 2009, 2010). These models have been in use by the MBRFC since then and MBRFC staff have made changes to the models to improve forecasting ability and accuracy. For this study, the MBRFC provided up-to-date versions of all model files covering the North Platte on February 13, 2013. The files were re-formatted by Riverside to run on local computer systems and read/write the correct time series for this analysis.

3 Unregulated Flow Frequency Computation

The current calibrated hydrologic models provided by the MBRFC were used to generate simulated flows for many sub-basins in the North Platte basin (see Figure 1-1 for a map of sub-basins). The hydrologic model parameters were not changed as part of this project. The total simulated flows at each point of interest were treated as unregulated flow, and analyzed to determine flow frequency relationships.

3.1 Basin Modeling

Models simulating snow accumulation and melt (SNOW-17) as well as soil moisture accounting (SAC-SMA) were used to generate unregulated flow time series. Local flow generated using the models for each sub-basin was routed to the next downstream point and summed with the downstream local flow. The result is a simulation of total unregulated flow at many locations along the North Platte River. The time series include the effects of rain and snow, as well as soil moisture and channel storage. They do not include effects from irrigation diversions and returns or reservoir regulation.

In the initial calibration, observed regulation data for diversions and reservoirs were used to back calculate a natural flow to aid in calibration of the models. The models themselves do not require any observed regulation time series in order to produce simulated natural flows.

In 2002, there was a very large precipitation event near Ogallala, Nebraska in July. The high precipitation combined with a very low snowmelt peak for that year causes this convective thunderstorm to generate the largest modeled peak of the year for Keystone. Because all of the other annual peaks for all of the locations are generated by snowmelt, this event was removed from the analysis to avoid having a mixed population of peaks. Removing this event (while keeping the snowmelt peak from the same year) greatly improves the smoothness and regularity of the station statistics and resulting frequency curves. The event was removed by directly editing the precipitation time series, and using the edited precipitation to generate unregulated flow.

3.2 Flow Frequency Analysis

Flow frequency curves were developed for unregulated flows at the seven gaging locations listed in Table 3-1.

Table 3-1. Gage locations for analysis

Location	NWSID	River
Mitchell, NE	MICN1	North Platte
Minatare, NE	MNTN1	North Platte
Bridgeport, NE	BGPN1	North Platte
Lisco, NE	LSON1	North Platte
Lewellen, NE	LEWN1	North Platte
Keystone, NE	KEYN1	North Platte
North Platte, NE	NPTN1	North Platte

3.2.1 Procedure

Two types of frequency analysis were performed. The first is an annual instantaneous peak flow frequency analysis and follows the method outlined in Bulletin 17b (IACWD 1982). The second is a Volume-Duration-Frequency analysis that examines durations of 1, 3, 7, 15, and 30 days. This analysis follows the same general procedure as in Bulletin 17b but uses peak flows calculated for the appropriate duration. The USACE Hydrologic Engineering Center's (HEC) Statistical Software Package (SSP) was used because it has built-in functionality to perform both types of analysis. Appendix B has descriptions of the input and output time series used in HEC-SSP.

3.2.1.1 Instantaneous Peak Flow Analysis

HEC-SSP performs annual instantaneous peak flow frequency analyses as described by Bulletin 17b. The program requires annual peak time series as input. These time series were generated from the hydrologic model output by filtering the 6-hour output data to extract the annual peak for each water year (October – September). This extraction was done using the TSTool program developed by Riverside for the State of Colorado. TSTool can perform general time series manipulation and analysis. TSTool was also used to write the annual peak data to an HEC-DSS file for use in HEC-SSP. Tables of annual peak data are available in Appendix F.

HEC-SSP allows the user to specify the parameters for the analysis via a graphical interface. Table 3-2 shows the list of options selected for the seven locations. These options can be set on the "General" and "Options" tabs of the Bulletin 17b Editor window.

Table 3-2. Unregulated Bulletin 17b Analysis options

Option	Value
Generalized Skew	Use Regional Skew
Regional Skew	-0.293
Regional Skew MSE	0.104
Expected Probability Curve	Compute Expected Prob. Curve
Plotting Position	Weibull
Confidence Limits	Defaults (0.05, 0.95)
Time Window Modification	Full Period
Low Outlier Threshold	No override
Historic Period Data	No historic data used
User Specified Frequency Ordinates	Default values (0.2 – 99.0)

The regional skew method was selected to follow the recommendations of the Missouri River study (USACE 2004, Appendix F). To find the regional skew, the individual station skew values were calculated using HEC-SSP. These values ranged from -0.338 to -0.241. Since the range of individual station skew is small, a single regional skew was calculated by taking the average of all station skews. This average is -0.293 and was used for all locations.

Table 3-3 shows the statistics calculated for the instantaneous flow analysis for each location. Station skew was not used in the analysis. The mean and standard deviation transition smoothly from upstream to downstream, with the mean increasing and the standard deviation decreasing.

Table 3-3. Statistics for unregulated instantaneous flow analysis

Location	Mean (log cfs)	Standard Deviation (log cfs)	Station Skew
Mitchell	4.083	0.196	-0.338
Minatare	4.086	0.194	-0.330
Bridgeport	4.094	0.190	-0.310
Lisco	4.094	0.189	-0.301

Location	Mean (log cfs)	Standard Deviation (log cfs)	Station Skew
Lewellen	4.096	0.187	-0.284
Keystone	4.101	0.183	-0.250
North Platte	4.110	0.179	-0.241

3.2.1.2 Volume-Duration-Frequency Analysis

HEC-SSP performs annual volume-duration-frequency analysis based on a general frequency analysis approach. The program offers a large amount of flexibility in set up to support different types of analysis. Options for the analysis were chosen to be similar to the instantaneous flow analysis.

The durations analyzed were 1, 3, 7, 15, and 30 days. HEC-SSP was used to aggregate the 6-hour output from the hydrologic models to the selected durations, and extract the peaks from the aggregated time series. Tables of annual peak data are available in Appendix F.

Table 3-4 shows the options chosen for all locations for the volume-duration-frequency analysis. No graphical analysis was performed.

Table 3-4. Unregulated Volume Frequency Analysis options

Option	Value
Log Transform	Use Log Transform
Maximum or Minimum Analysis	Analyze Maximums
Year Specification	Water Year (starts Oct 1)
Plotting Position	Weibull
Time Window Modification	Full period used
Flow Durations	1, 3, 7, 15, and 30 days
Output Labeling	No changes
User Specified Frequency Ordinates	Default values (0.2 – 99.0)
Low Outlier Threshold	No override
Historic Period Data	No historic data used
Distribution	LogPearsonIII
Expected Probability Curve	Compute Expected Prob. Curve
Skew	Use Station Skew

The Missouri River study used regional average skew for duration analysis. This was necessary to smooth the curves from upstream to downstream. However, this study is using unregulated flows generated by the SAC-SMA model. These flows are more regular and smooth than unregulated flow back calculated from observations. The analysis resulted in smooth curves progressing downstream without needing to regionalize the station statistics.

Table 3-5 shows the statistics calculated for each duration and location. Generally for each location, the mean and standard deviation decrease as the duration increases, as expected. The skew also decreases with duration, except that for some locations, the 3-day skew is slightly larger than the 1-day skew.

Table 3-5. Statistics for unregulated volume-duration-frequency analysis

Location	Duration	Mean (log cfs)	Standard Deviation (log cfs)	Station Skew
Mitchell	1 Day	4.085	0.193	-0.329

Location	Duration	Mean (log cfs)	Standard Deviation (log cfs)	Station Skew
	3 Days	4.074	0.192	-0.332
	7 Days	4.048	0.190	-0.302
	15 Days	4.011	0.185	-0.217
	30 Days	3.964	0.187	-0.103
Minatare	1 Day	4.089	0.191	-0.318
	3 Days	4.078	0.190	-0.319
	7 Days	4.053	0.188	-0.288
	15 Days	4.016	0.183	-0.205
	30 Days	3.969	0.184	-0.093
Bridgeport	1 Day	4.096	0.187	-0.298
	3 Days	4.086	0.186	-0.298
	7 Days	4.062	0.184	-0.265
	15 Days	4.026	0.179	-0.185
	30 Days	3.980	0.180	-0.074
Lisco	1 Day	4.096	0.186	-0.288
	3 Days	4.087	0.185	-0.286
	7 Days	4.063	0.183	-0.254
	15 Days	4.028	0.178	-0.177
	30 Days	3.983	0.179	-0.070
Lewellen	1 Day	4.098	0.184	-0.272
	3 Days	4.090	0.184	-0.278
	7 Days	4.067	0.182	-0.252
	15 Days	4.032	0.177	-0.167
	30 Days	3.988	0.178	-0.063
Keystone	1 Day	4.100	0.183	-0.253
	3 Days	4.091	0.183	-0.261
	7 Days	4.068	0.182	-0.244
	15 Days	4.034	0.177	-0.162
	30 Days	3.989	0.178	-0.058
North Platte	1 Day	4.109	0.179	-0.241
	3 Days	4.101	0.179	-0.244
	7 Days	4.079	0.178	-0.232
	15 Days	4.045	0.173	-0.152
	30 Days	4.002	0.173	-0.047

3.2.2 Results

Results from the instantaneous flow analysis and the volume-duration-frequency analysis are given below.

3.2.2.1 Instantaneous Flow Analysis Results

Table 3-6 shows instantaneous flow associated with various probabilities at each location. In general, the flow for a given probability decreases from upstream to downstream at low probabilities, and increases at high probabilities. This may be because low-probability events are usually driven by high snowmelt, which attenuates as it travels down the river, while smaller events will have more influence from local runoff that enters the river between locations.

An example plot from the North Platte location is included as Figure 3-1. Plots for all locations are included in Appendix C.

Table 3-6. Instantaneous unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	37900	37700	37400	37200	37000	36600	36600
0.005	34200	34100	33900	33700	33500	33300	33300
0.01	31400	31300	31200	31000	30900	30700	30800
0.02	28500	28400	28400	28300	28100	28100	28200
0.05	24500	24500	24500	24400	24400	24300	24500
0.10	21300	21300	21400	21300	21300	21400	21600
0.20	17800	17800	18000	18000	18000	18100	18300
0.50	12400	12500	12700	12700	12700	12900	13200
0.80	8350	8440	8650	8670	8740	8920	9170
0.90	6710	6800	7000	7020	7090	7270	7510
0.95	5560	5650	5840	5860	5930	6100	6320
0.99	3850	3920	4090	4110	4180	4330	4520

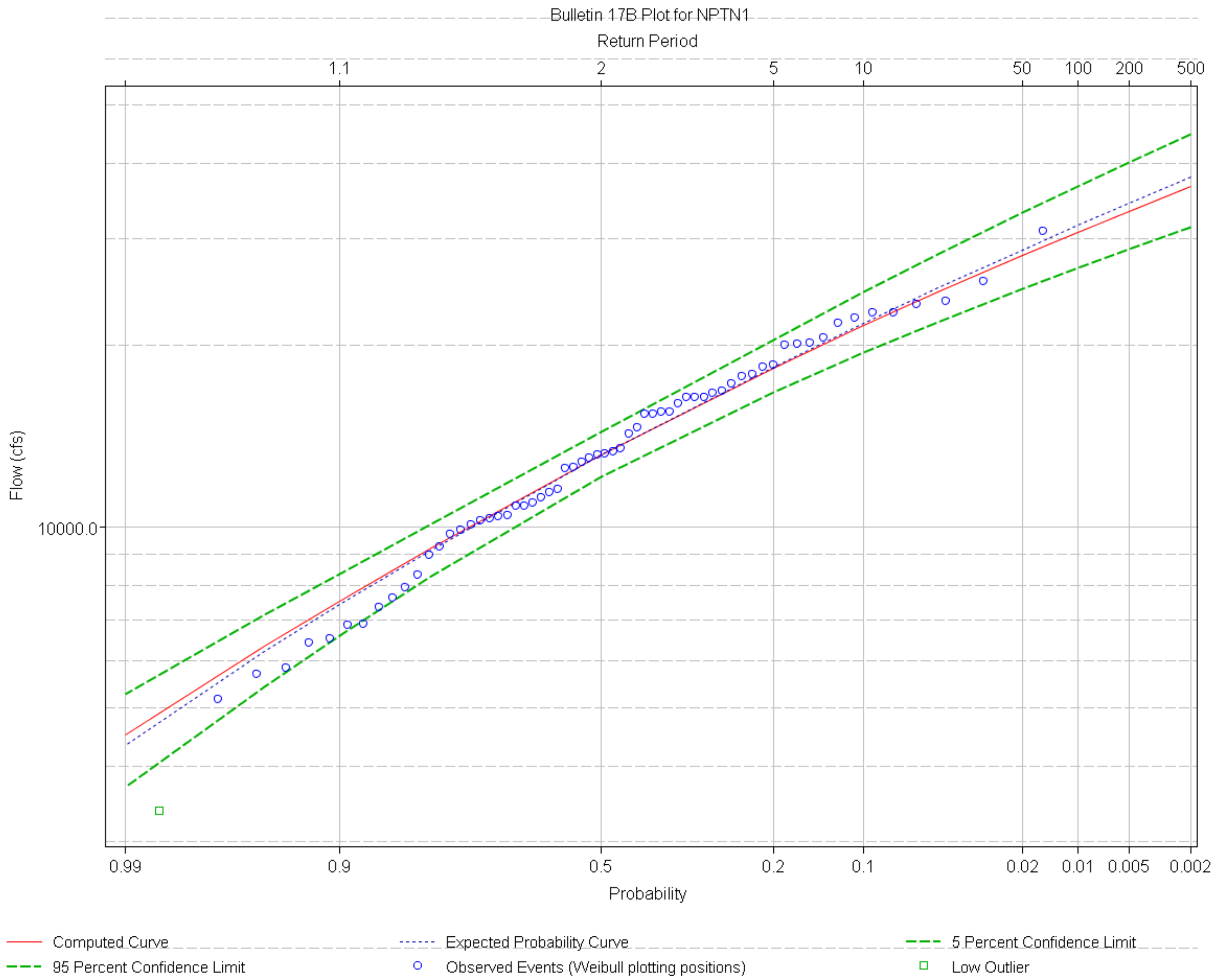

Figure 3-1. Instantaneous flow analysis results for North Platte

3.2.2.2 Volume-Duration-Frequency Results

The calculated probability results for each station are shown in Table 3-7 through Table 3-11. The flow for a given probability increases from upstream to downstream, and decreases as the duration increases.

Table 3-7. 1-day unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	36800	36800	37000	36900	37000	37300	37400
0.005	33400	33400	33600	33500	33600	33700	33900
0.01	30800	30800	30900	30900	30900	31000	31200
0.02	28000	28000	28200	28100	28200	28200	28400
0.05	24200	24300	24400	24300	24400	24400	24600
0.10	21200	21200	21300	21300	21300	21300	21600
0.20	17800	17900	18000	18000	18000	18000	18300
0.50	12500	12600	12700	12700	12800	12800	13100

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.80	8450	8540	8750	8770	8830	8880	9130
0.90	6790	6890	7100	7120	7200	7260	7500
0.95	5630	5730	5930	5970	6050	6110	6340
0.99	3890	3980	4170	4210	4290	4370	4570

Table 3-8. 3-day unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	35600	35700	35900	36000	36200	36400	36700
0.005	32300	32400	32600	32700	32800	33000	33300
0.01	29800	29900	30100	30100	30200	30300	30600
0.02	27200	27200	27400	27500	27500	27600	27900
0.05	23500	23600	23800	23800	23800	23900	24200
0.10	20500	20600	20800	20800	20900	20900	21200
0.20	17300	17400	17600	17600	17700	17700	17900
0.50	12200	12200	12500	12500	12500	12600	12800
0.80	8250	8350	8570	8600	8670	8710	8960
0.90	6640	6740	6960	7000	7070	7120	7360
0.95	5510	5610	5820	5860	5930	5990	6220
0.99	3810	3910	4100	4150	4210	4270	4480

Table 3-9. 7-day unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	33600	33700	34000	34200	34400	34500	34800
0.005	30500	30600	30800	31000	31100	31200	31500
0.01	28000	28100	28400	28500	28600	28700	29000
0.02	25500	25600	25800	26000	26100	26100	26400
0.05	22100	22200	22400	22400	22500	22600	22900
0.10	19300	19400	19600	19600	19700	19800	20000
0.20	16200	16300	16500	16600	16700	16700	17000
0.50	11400	11500	11700	11800	11900	11900	12200
0.80	7790	7900	8120	8170	8250	8280	8540
0.90	6300	6410	6630	6670	6750	6780	7030
0.95	5250	5360	5570	5620	5680	5720	5960
0.99	3670	3770	3970	4010	4070	4110	4310

Table 3-10. 15-day unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	31200	31400	31700	31900	32100	32200	32500
0.005	28200	28300	28500	28700	28900	29000	29300
0.01	25800	25900	26100	26300	26500	26500	26800
0.02	23400	23500	23700	23800	24000	24100	24400

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.05	20100	20200	20400	20500	20700	20700	21000
0.10	17500	17600	17800	17900	18000	18100	18400
0.20	14700	14800	15100	15100	15200	15300	15600
0.50	10400	10500	10700	10800	10900	10900	11200
0.80	7200	7310	7530	7580	7670	7710	7970
0.90	5880	5990	6210	6260	6340	6380	6620
0.95	4960	5070	5280	5320	5410	5440	5670
0.99	3550	3660	3850	3890	3970	4000	4200

Table 3-11. 30-day unregulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	30000	30100	30300	30500	30700	30800	31000
0.005	26700	26800	27000	27100	27300	27400	27600
0.01	24200	24300	24500	24600	24700	24800	25100
0.02	21700	21800	22000	22100	22200	22300	22600
0.05	18400	18500	18700	18800	18900	19000	19300
0.10	15900	16000	16200	16300	16400	16400	16700
0.20	13200	13300	13600	13600	13700	13800	14100
0.50	9260	9380	9600	9660	9760	9800	10100
0.80	6420	6530	6760	6800	6890	6930	7190
0.90	5280	5390	5600	5650	5730	5770	6010
0.95	4480	4590	4800	4840	4920	4950	5180
0.99	3280	3380	3570	3600	3680	3710	3910

Figure 3-2 is an example of the graphical results of the volume-duration-frequency analysis for North Platte. Notice how the curves do not intersect. Plots for the other locations are included in Appendix C.

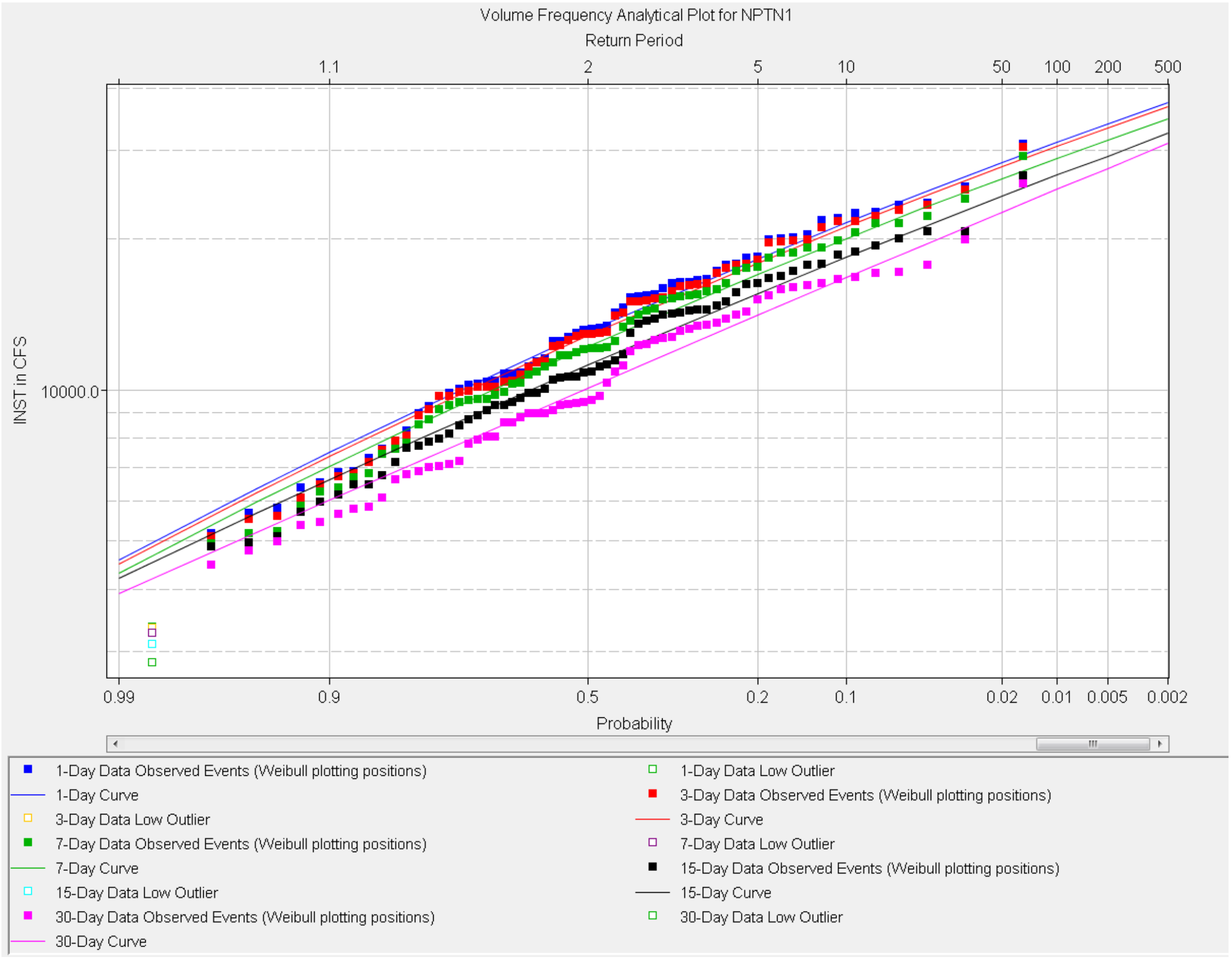

Figure 3-2. Volume-duration-frequency analysis results for North Platte.

4 Regulation modeling

The reservoir and streamflow regulation models calibrated for the MBRFC in 2008-2010 (Riverside 2009, 2010) were in operational use by the MBRFC during the 2011 runoff season, which had very high flows. Several of the reservoirs were operated differently than the models predicted. For this project, the reservoir models were re-examined in light of the 2011 operations, and model parameters were changed as needed. In addition to looking at actual operations from the most recent years, discussion with the reservoir operators helped identify operational criteria, possible modeling rules, and options for future operations (see Section 2.4.2).

The Wyoming reservoirs (Seminoe, Pathfinder, Alcova, Glendo, Guernsey, Wheatland #2, and Grayrocks) are modeled using the National Weather Service (NWS) RES-J model, and model parameters were refined as needed. Lake McConaughy in Nebraska was initially modeled in RES-J, but was transferred to the USACE HEC-ResSim model as part of this project. The ResSim model parameters were primarily taken from the initial RES-J model, with additions and changes based on recent operations and discussion with the reservoir operators at CNPPID.

In addition to the reservoir models, the overall basin modeling also includes regulation modeling for irrigation diversions and return flows. No changes were made to the existing diversion models.

The next sections describe the reservoirs, their operations, and how they are modeled. Detailed descriptions of modeling rules are included in Appendix D. See the RES-J model documentation (NWS 2008) for details about RES-J methods and parameters.

4.1 Seminoe Reservoir

Seminoe Dam is the upstream-most major dam on the North Platte mainstem. It is owned and operated by the USBR. The reservoir is part of the Kendrick Project, which supplies water for irrigation and hydropower generation in conjunction with Alcova Reservoir downstream.

The capacity in Seminoe Reservoir is over 1 million acre-feet, equal to a little over one year of average inflows. The dam is almost 300 ft high, with a crest elevation of 6361 ft. Dam construction was completed in 1939. Water can be released over the controlled spillway or through the power plant. The watershed above the dam is just over 9,000 mi^2, encompassing northern Colorado and southern Wyoming.

Water from Seminoe Reservoir is used for irrigation by the Casper-Alcova Irrigation District. This water is stored in Seminoe Reservoir, and then released downstream and withdrawn from Alcova Reservoir. Pathfinder Reservoir lies in between Seminoe and Alcova. These reservoirs are operated together to ensure optimal use of water. Seminoe Dam also provides flood control benefits as a secondary benefit.

4.1.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled.

The reservoir model is based on estimated hydrologic conditions, categorized as “Dry”, “Average”, “Wet”, or “Very Wet”. Snow accumulation in the mountains above the reservoir is used as the indicator for the current condition. The simulated snow-water equivalent (SWE) from two of the upstream modeled sub-basins is averaged to get a time series more representative of the basin above the reservoir. Only the higher elevation portion of these two sub-basins is used. It is important to note that the simulated SWE is an average over the modeled area, and often will not match measured values of SWE at a given snow course or SNOTEL station, which are a point measurement.

The simulated SWE is checked on the first day of the month between February and April. Based on this value, a wetness indicator time series (SWE_TRIGGER) is set to a value from 0 (very dry) to 5 (very wet). Values of 0 and 1 are considered to be “Dry” years, 2 and 3 are “Average” years, 4 is a “Wet” year, and 5 is a “Very Wet” year.

The model releases are set by a winter release table independent of the year type, and by one of four summer release tables depending on the current year type. All release tables are based on pool elevation and date. A trigger time series is used to decide when to switch from the winter table to the summer table. This trigger is activated by methods that look at pool elevation, year type, and a running average of the reservoir inflows over the previous 14 days. Once the trigger is active, it will stay active until the end of the modeled irrigation season (August 31).

The SWE is used to give the model an idea of what will happen in the future. A high SWE tells the model to start releasing earlier in the season to make room for the snowmelt, and a low SWE tells the model to hold back. This helps overcome inaccurate releases caused by looking only at current reservoir conditions.

For this project, the 2011 results showed that the model was not releasing high enough or early enough given the very high snowpack. The original reservoir calibration did not have a “Very Wet” classification, and stopped at level 4. The model was extended to include a level 5 for snowpack along with a new table specifying releases at that level. Release tables for the smaller snowpack years were adjusted as needed to improve simulation results in recent years.

Another change that was made was to switch from only looking at one upstream sub-basin for snowpack to looking at two and averaging the results. The NGTC2 sub-basin was originally used, and the SRAW4 sub-basin was added in this project. This change better represents the fact that the USBR looks at many snow stations to produce inflow forecasts. Simulation quality was improved through these changes.

4.1.2 Modeling Results

The model produces reasonable results. The classification into different year types usually works well. There are occasional years where the average SWE does not accurately represent the volume of actual inflows, and the year is misclassified. The model also does not always switch from winter to summer releases at the correct time. The timing of when the releases “turn on” is varied, and the model attempts to balance between turning on too early and too late.

Figure 4-1 shows the model results for 2011. The top plot shows flows, where the white line is observed releases, the purple line is simulated releases, and the yellow line is inflow. The bottom plot is pool elevation, where the white line is again observed, and the purple line is simulated. The model performs well in this year, although the day-to-day flows are not accurately modeled. The model switches from winter to summer releases on March 17, and due to increases in snowpack the year classification increases from 4 to 5 at the beginning of April. These changes can be seen in the plot where the simulated release line increases sharply. The pool elevation is drawn down to the correct level, though slightly early. The model releases are a bit too small when the pool elevation is low in May and June, and this causes the pool to rise too quickly relative to the observed operations. The modeled pool elevation rises high enough to cause substantially higher releases, which causes the modeled peak to be a bit high for the year. The model releases do not stop as abruptly as the observed releases, but end the year matching very well.

Looking at the snowpack and starting releases before the inflow increases provided a definite benefit to the simulation quality. Without this rule, the model would release too little water in the spring, and be forced to release too much during the summer.

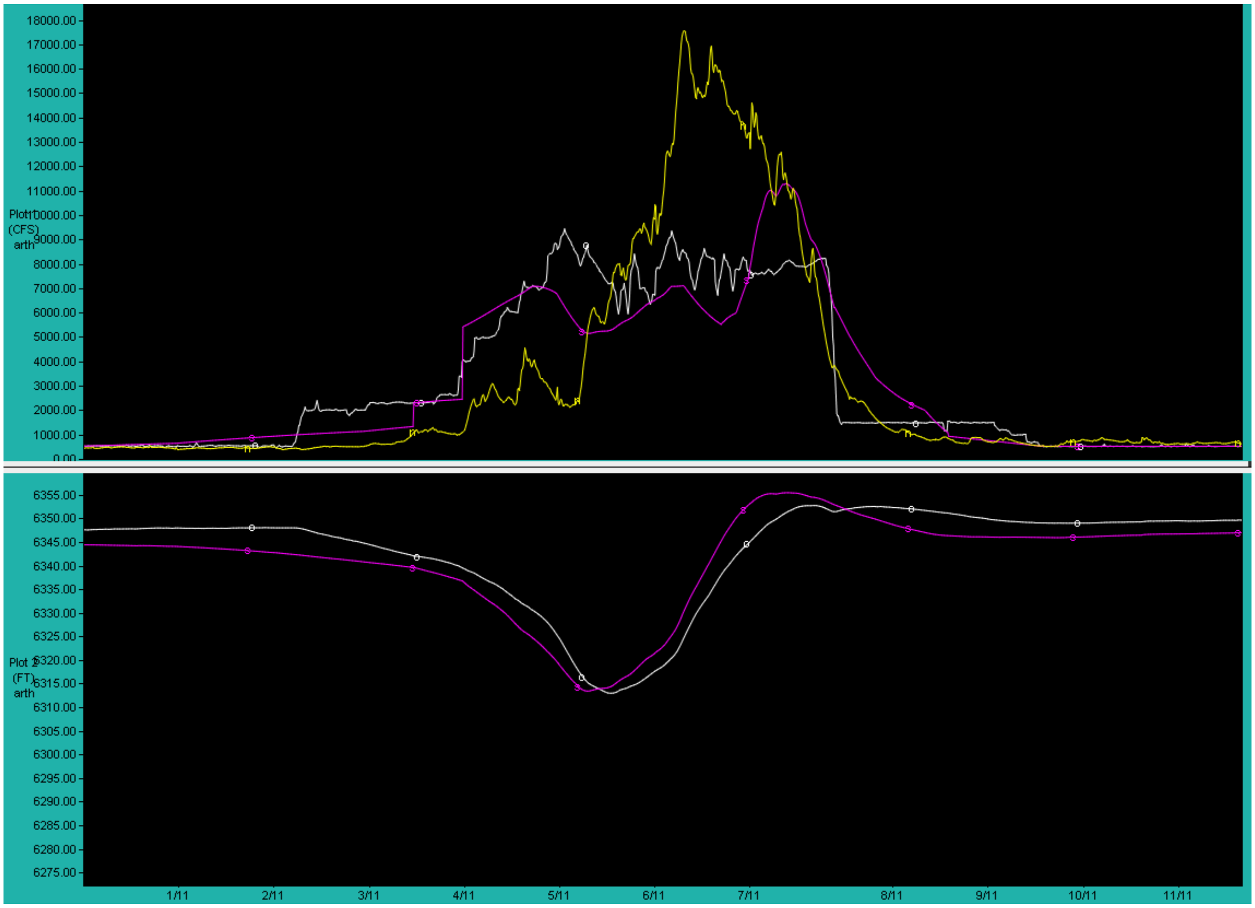

Figure 4-1. Simulation results for Seminoe Reservoir RES-J model

4.2 Pathfinder Reservoir

Pathfinder Dam is located on the North Platte below Seminoe Dam and Kortes Dam, about three miles below the confluence with the Sweetwater River. The USBR owns and operates the reservoir as part of the North Platte Project, along with Guernsey Reservoir downstream. The North Platte Project primarily provides irrigation water, and secondarily provides hydropower, flood control, and recreation benefits.

Pathfinder Reservoir has a capacity of 1.2 million acre-feet and an upstream watershed of 14,600 mi^2. The dam is 214 ft high and is constructed from granite blocks, with construction completed in 1909. The uncontrolled spillway crest elevation is 5850.0 ft.

Pathfinder Reservoir is the primary storage facility for the North Platte Project. Water released from Pathfinder Reservoir passes through Glendo Dam and Guernsey Dam, before being diverted at Whalen Diversion Dam. The North Platte Project is operated in conjunction with other projects such as Kendrick and Pick-Sloan in order to use the water of the North Platte efficiently.

4.2.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled.

The reservoir simulation is primarily controlled by a "normal" release table. This table prescribes releases based on pool elevation and date. The releases were defined through calibration with historical data. In addition to this table, the uncontrolled spillway is modeled. The parameters for the spillway curve were taken from a USBR chart detailing the spillway capacity at different elevations.

Changes made to the reservoir modeling in this project were limited to changing the values in the release table. The overall modeling worked reasonably well in recent years, and no need was seen for additional rules or complexity.

4.2.2 Modeling Results

Results from 2011 are shown in Figure 4-2. As before, the upper plot has observed releases (white), simulated releases (purple), and inflows (yellow). The bottom plot has observed (white) and simulated (purple) pool elevation. The inflows are simulated, and mostly composed of releases from Seminoe Dam. The peak release for the year is too high, mainly because the peak inflow coming from the Seminoe releases is too high. Pathfinder Dam spilled in 2011, and so mainly passed the inflows from upstream. The model releases too little early in the year, but matches the observed data well in the fall.

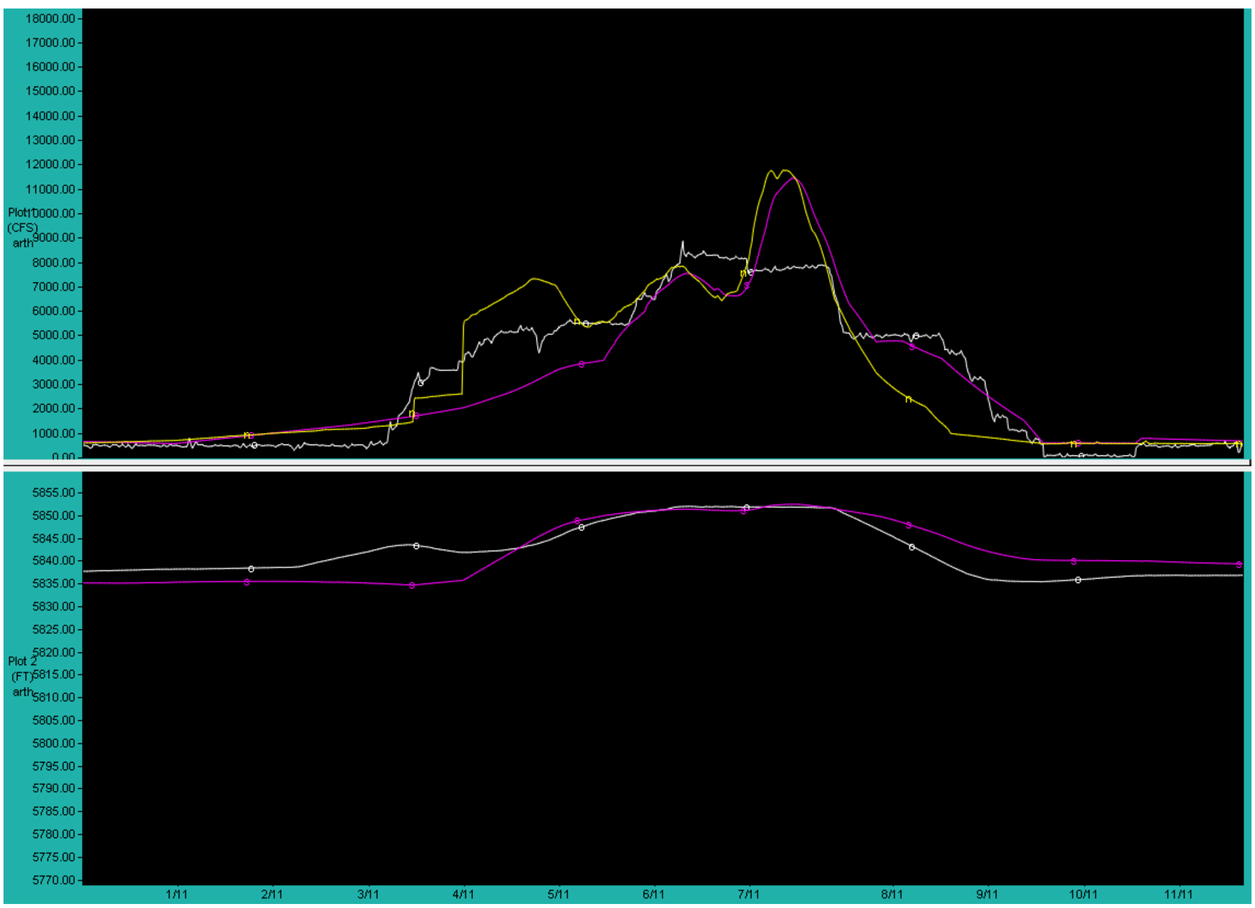

Figure 4-2. Simulation results for Pathfinder Reservoir RES-J model

4.3 Alcova Reservoir

Alcova Reservoir is located about 10 miles below Pathfinder Dam on the North Platte. The reservoir is part of the Kendrick Project and is owned and operated by the USBR. The main purpose of Alcova Reservoir is to supply water to Casper Canal.

Alcova is a relatively small reservoir, with a capacity of 184,000 ac-ft. This is equal to about 9 weeks of average inflow. Only the top 30,000 ac-ft of this storage is active. The dam is 265 ft high with a maximum head on the power plant of 165 ft. The maximum surface area is about 2500 acres. The spillway is gated and extends for the entire usable elevation.

The withdrawal point for Casper Canal is located within Alcova Reservoir. Water is diverted directly from the reservoir for use in the canal. Most water storage is handled at Seminoe Reservoir, with Alcova acting mainly as a large diversion dam.

4.3.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled.

A seasonal SetElevation table is the only release method in the Alcova Reservoir simulation. This method keeps the reservoir at 5488.25 ft in the winter and 5498.5 ft in the summer. No spillway method is included as the SetElevation method will release whatever is necessary. The only changes made to the model for this project were to increase the guide curve elevations from 5488 to 5488.25, and from 5498 to 5498.5, to more exactly match recent operations.

Withdrawals to Casper Canal are modeled along with the reservoir model. A consumptive use model is run prior to RES-J to generate an irrigation demand time series based on temperature, precipitation, and date. The temperature and precipitation that drive the consumptive use model are for the CPRW4 sub-basin, where the irrigated lands supplied by Casper Canal are located. The final simulated demand is then passed into the RES-J operation. This demand is withdrawn from the reservoir using a SetWithdraw method.

4.3.2 Modeling Results

The model produces very good results, especially in more recent years. In earlier years, the pool elevation varied some from year to year, while in recent years the operations have been very consistent. Releases are very similar to inflows due to the small storage space.

Figure 4-3 shows the results from 2011 with the same color scheme as the previous plots. Releases are too high in July, again caused by the high inflow that was passed through Pathfinder Reservoir after being released by the Seminoe Reservoir model.

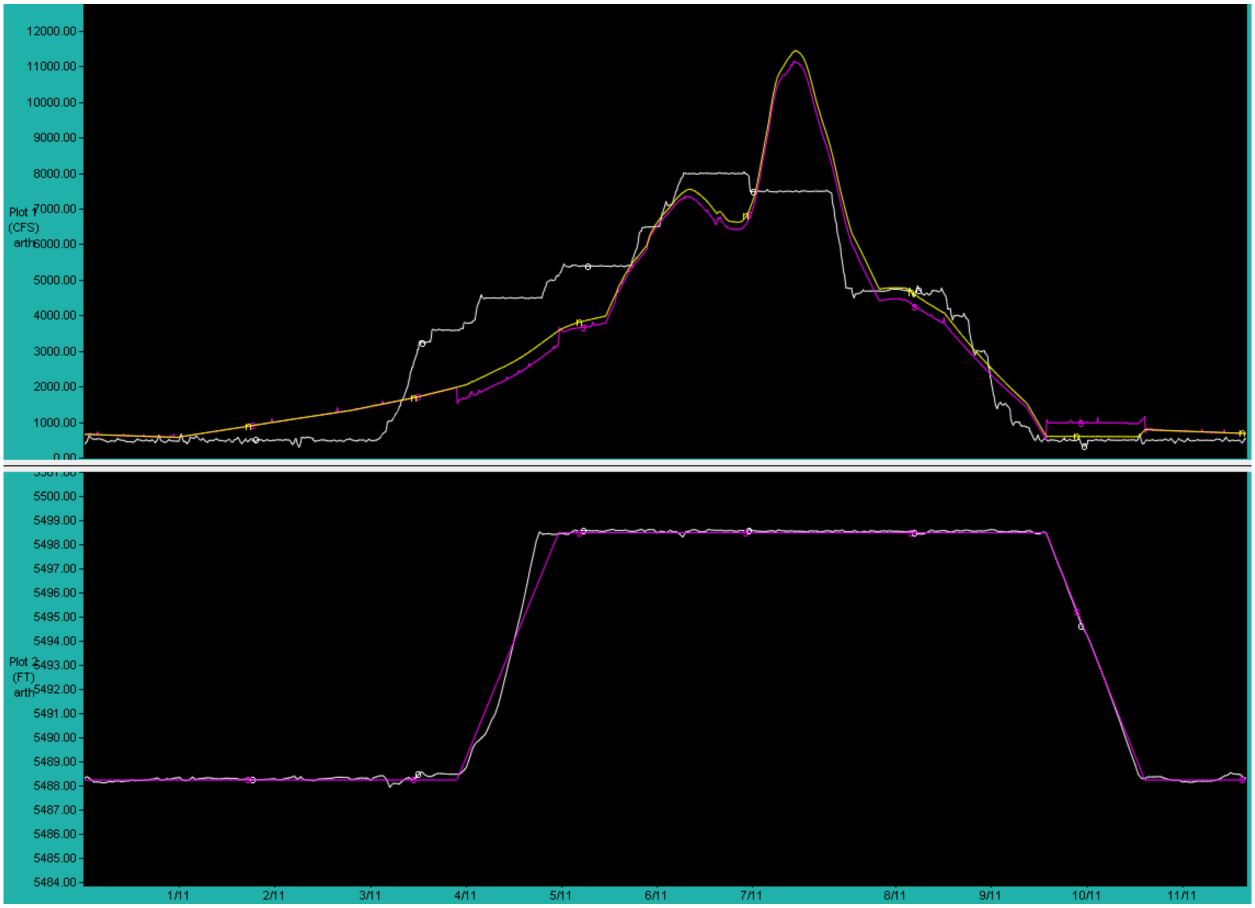

Figure 4-3. Simulation results for Alcova Reservoir RES-J model

4.4 Glendo and Guernsey Reservoirs

Glendo Dam is on the North Platte River downstream of Alcova Reservoir. The dam is part of the Pick-Sloan Missouri Basin Program, and is owned by the USBR and operated jointly by the USBR and USACE depending on the pool elevation. The reservoir provides irrigation water and hydropower as its primary goals.

The dam is 167 ft high with a crest length of 2,096 ft. The uncontrolled emergency spillway has a maximum capacity of 10,355 cfs. The outlet works passes water to the power plant and has a maximum discharge of 11,200 cfs. The dam controls a watershed area of over 17,000 mi^2.

Glendo Reservoir is used to store and re-regulate flows from upstream power plants. It is also used to provide irrigation water to 37,000 acres, and electricity to three states. Flood control and other benefits such as sediment retention are secondary.

Guernsey Reservoir is on the main stem of the North Platte, 25 miles below Glendo Dam. Owned and operated by the USBR as part of the North Platte Project, Guernsey Reservoir provides reregulation and temporary storage of irrigation water, as well as hydropower.

The reservoir is small with a maximum capacity of 45,600 ac-ft and surface area of 2400 acres. Average annual inflow is 1.15 million ac-ft, which gives the reservoir a total storage of only 2 weeks of average inflows. The power plant has a capacity of 6,400 kW between its two generators. There are two gated spillways, with crest elevations of 4405 and 4405.5 ft.

Guernsey Reservoir releases closely match inflows, with small variations throughout the year and larger variations used to alter the pool elevation and flush silt from the reservoir. Water released from Guernsey Reservoir is diverted for irrigation at Whalen Diversion Dam.

4.4.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled for both reservoirs.

Glendo and Guernsey Reservoirs are modeled together in a single RES-J model. This allows the Glendo Reservoir model to use pool elevation at Guernsey when making release decisions.

Releases from Glendo Reservoir are defined primarily by a consumptive use model. The demand is determined prior to RES-J. The irrigation demand was calibrated to the reservoir releases rather than any specific downstream diversion.

The simulated demand is passed into RES-J. A node (DECIDE_REL) takes the demand and scales it up or down depending on pool elevation to account for the fact that irrigation releases will necessarily be reduced during dry years, and can be increased above their average during high-storage years. Another pair of methods on the same node adds or subtracts an amount to the scaled demand, depending on date and on the Guernsey Reservoir pool elevation. This amount accounts for release variations that depend on date, including the sharp changes in releases seen most years as part of a silt-flushing operation at Guernsey Reservoir. This scaled and augmented demand is then set as the reservoir release, subject to a minimum flow of 27 cfs.

There is a spillway method parameterized based on the listed maximum flow. All values below the maximum were estimated.

Guernsey Reservoir is modeled based on the fact that the pool elevation follows the same basic pattern most years. A SetElevation curve was developed based on the average elevation during the most recent 20 years of data in the original calibration in 2009. Most years, Glendo Reservoir releases will drop significantly in early July for a few days. Releases will then return to normal levels. A couple weeks later releases will increase for a few days and then again return to normal. Guernsey releases do not follow along with these changes. This difference significantly alters the Guernsey pool elevation, lowering it when inflows drop and then raising it again when inflows spike. In order to constrain the simulated releases prescribed by the SetElevation method, a minimum release and maximum release table are used. These two tables were also based on historical average data.

A spillway method is used, and was parameterized based on estimates from the calibration. The spillway method allows the simulation to exceed the maximum release table value when necessary due to very high inflows.

The original calibration for these reservoirs used two separate RES-J models with no joint operations. The release spike from Glendo in late July was strictly modeled and occurred every year whether it was needed or not. This worked well in the calibration period, but did not perform well in 2010 and 2011, when the silt run at Guernsey was not done according to the normal schedule. In these years the Glendo model released too much water that was passed downstream and caused downstream sub-basins to simulate flood conditions unnecessarily.

To better capture this situation the models were combined into a single joint model. This allows Glendo to check the pool elevation at Guernsey and reduce or eliminate the typical release spike if Guernsey is already full. This significantly improves the simulation results during 2010 and 2011.

4.4.2 Modeling Results

Figure 4-4 shows 2011 results for Glendo Reservoir, and Figure 4-5 shows results for Guernsey. In 2011, the silt run occurred, but was about a month later than normal. The updated joint model handles this much better than the individual models did. The Glendo model matches observed releases well, with the exception of a large drop in July, as the model attempted to initiate the silt run. This drop only decreased the pool elevation at Guernsey a few feet, due to the generally high inflows that year. The Guernsey model absorbs the error in Glendo releases, and the simulated releases from Guernsey are close to the observed releases, except for being a bit high when the silt run was actually initiated in August.

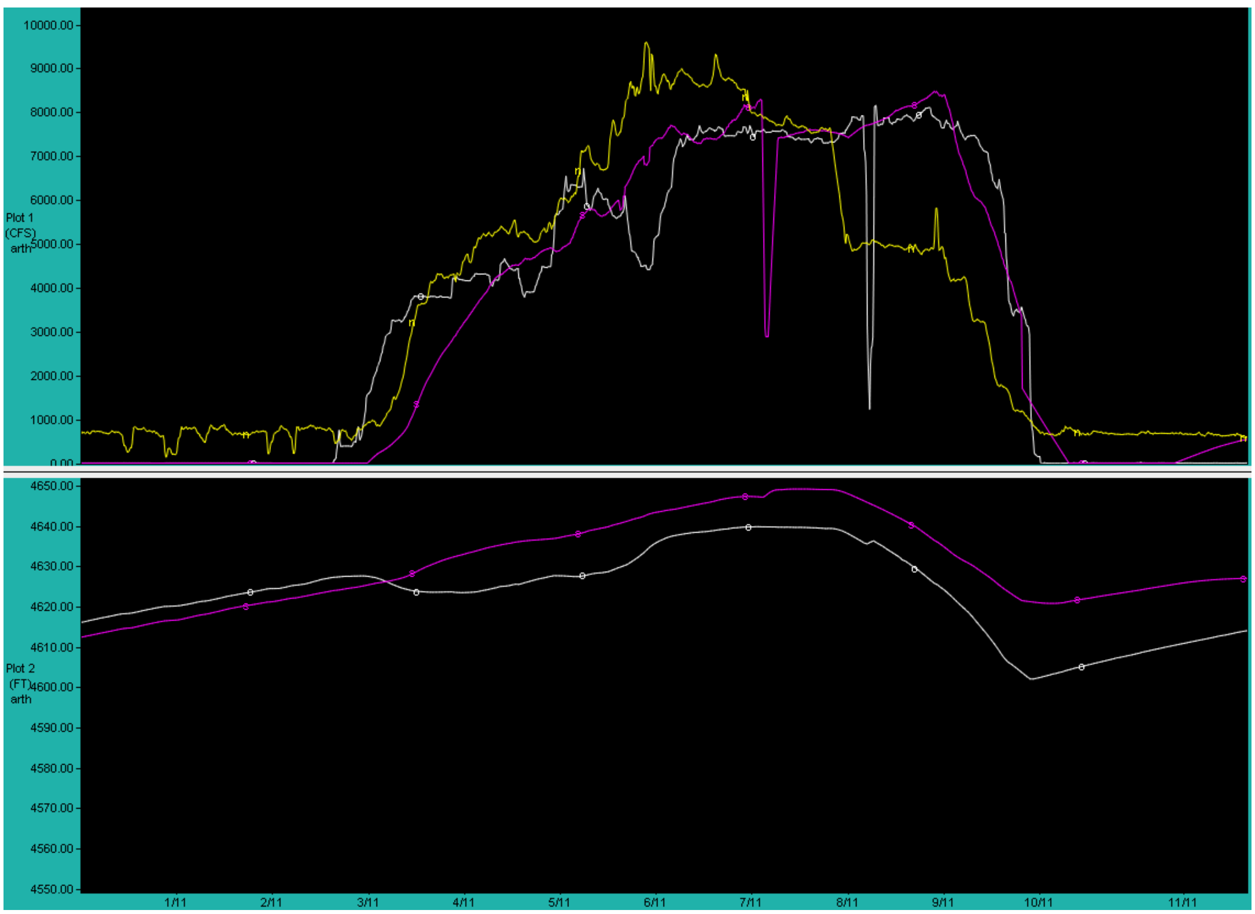

Figure 4-4. Simulation results for Glendo Reservoir RES-J model

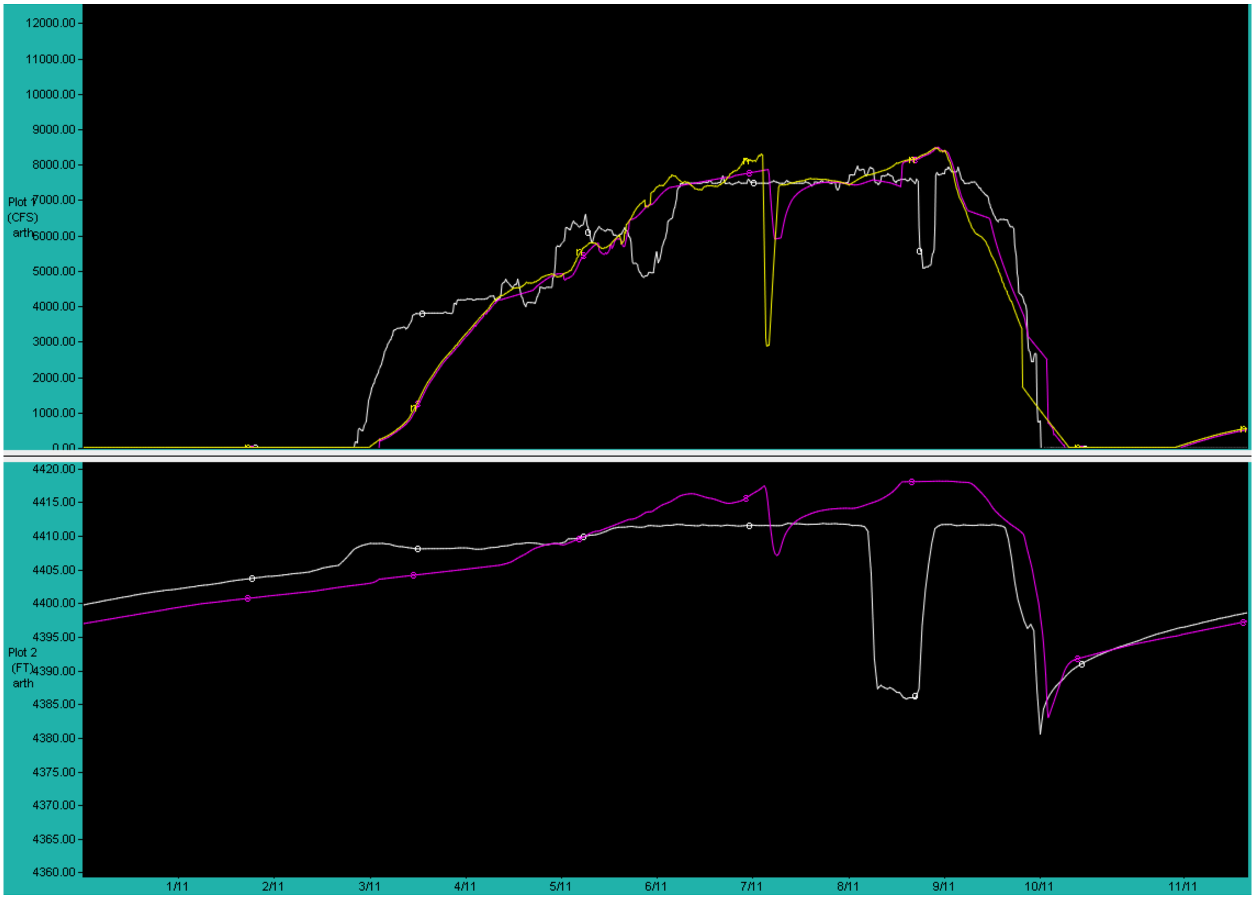

Figure 4-5. Simulation results for Guernsey Reservoir RES-J model

4.5 Wheatland Reservoir

Wheatland Reservoir #2 is owned by the Wheatland Irrigation District and is located on the Laramie River. The reservoir provides water to irrigate land downstream. The Wheatland Irrigation District has two other off-channel reservoirs (#1 and #3) that also store water for irrigation.

The dam is 36.6 ft high and over 8,000 ft long. The crest of the dam is at an elevation of 6971.7 ft. The outlet works have a maximum capacity of 1,320 cfs. There are two gated spillways with crests at 6954 and 6956 ft. The spillway capacities are 1,520 and 4,210 cfs, respectively. Reservoir capacity is approximately 100,000 ac-ft, which is enough space to store 1.4 years of average inflows.

Irrigation water released from Wheatland Reservoir #2 is diverted from the Laramie River to Sybille Creek a short distance below the dam. Typically, only a small minimum flow of about 20 cfs stays in the Laramie.

4.5.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled.

A consumptive use model is used before RES-J to develop a simulated irrigation demand. The temperature and precipitation time series used to drive the CU model are from the 3188 sub-basin, where most of the irrigation takes place.

The simulated demand is passed into RES-J. The demand is scaled up or down depending on pool elevation to account for available storage. A spillway method is included that uses parameters estimated during calibration. A minimum release of 20 cfs is modeled based on streamflow gage observations downstream of the reservoir.

Due to the sparse data availability for years after the original calibration period, especially 2011, no changes were made to the original calibration. No observed pool elevations were available before 2012, and observed releases began in March 2011 but were missing June-October.

4.6 Grayrocks Reservoir

Grayrocks reservoir is downstream of Wheatland Reservoir #2 on the Laramie River. It is owned by Basin Electric Power Cooperative (BEPC). The reservoir is used to provide steam and cooling water to the Laramie River Station power plant.

Grayrocks dam is 94 ft high and 2,555 ft long. The dam has a primary spillway outlet and an emergency spillway. Spillway capacity is 144,500 cfs. The total storage volume is 125,000 ac-ft, giving the reservoir the capacity to store over 2 years of average inflows.

BEPC uses water from Grayrocks Reservoir in the power plant nearby. BEPC also releases water from the reservoir to satisfy downstream water rights. Reservoir releases are constrained by the North Platte Decree, as described in the Decree and the Wyoming Platte River Basin Water Plan. Generally speaking, there is a minimum release based on the time of year and the “natural inflow” to the reservoir. There is also a maximum release of 200 cfs.

4.6.1 Modeling Approach

Rain and evaporation on the reservoir surface are modeled.

A very simple table is used to determine “normal” releases, based on pool elevation only. From October through April, this normal release is used, subject to a minimum flow of 40 cfs October through March, and 50 cfs in April. During May through September, the normal release is still used, but the minimum flow is constrained to the larger of 40 cfs or 75% of the inflow. There is also a maximum flow of 200 cfs during this time.

A spillway method is used when the pool elevation is above 4405 ft. The spillway parameters were estimated during calibration.

4.6.2 Modeling Results

Observed releases were available for most of 2011 and 2012, as seen in Figure 4-6. No observed pool elevation was available. The original calibration matched observed releases in the last two years quite well, and no changes were needed.

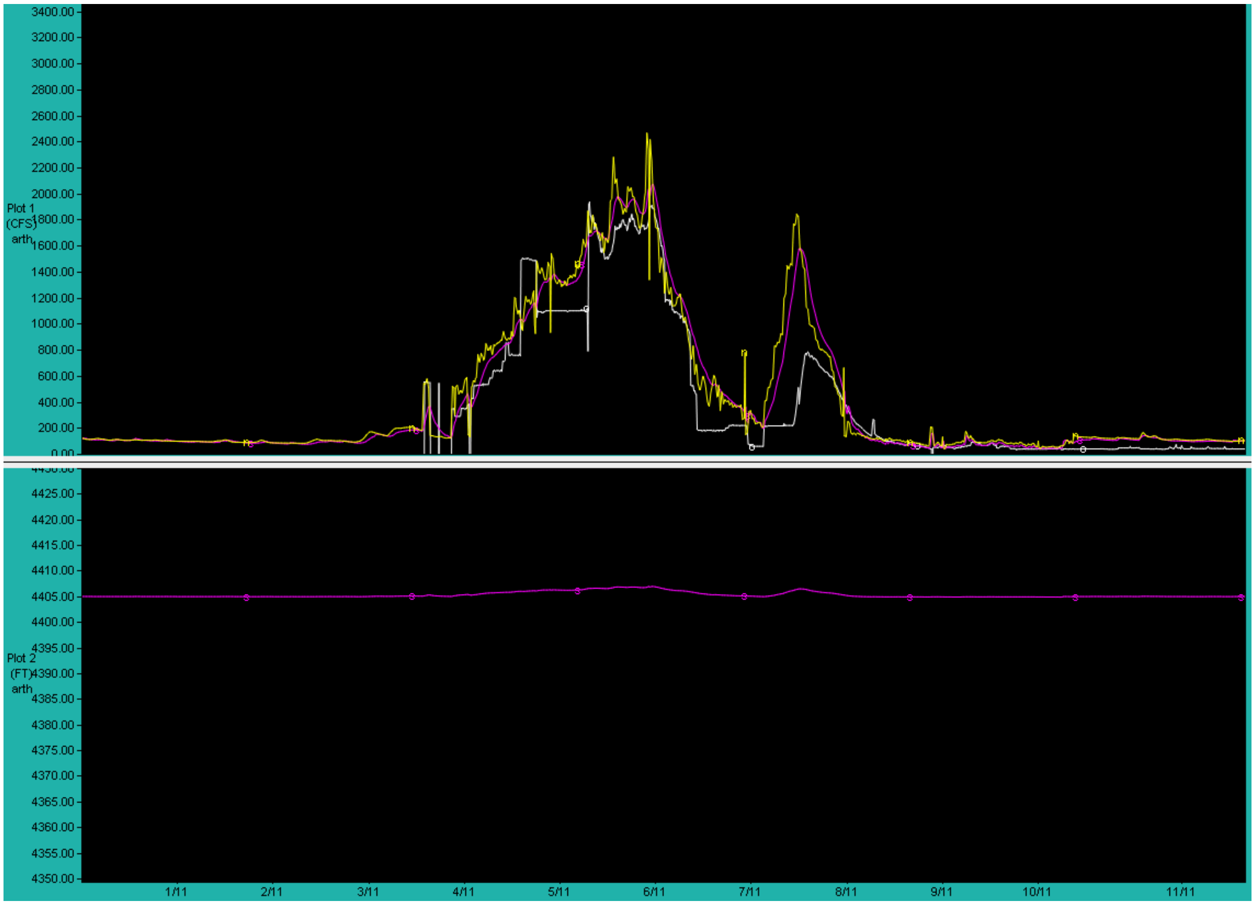

Figure 4-6. Simulation results for Grayrocks Reservoir RES-J model

4.7 Lake McConaughy

Lake McConaughy is formed by Kingsley Dam on the North Platte River and is the largest reservoir in Nebraska. Kingsley Dam has released water through hydropower turbines since 1994, with releases through the outlet tower before that. A Howell Bunger valve has been used periodically since 1997 to aerate the releases. A gated morning glory spillway is present but has never been used. Lake Ogallala is formed by Keystone Diversion Dam immediately downstream of Lake McConaughy. The Sutherland Canal diverts from Lake Ogallala.

The CNPPID operates Lake McConaughy primarily for irrigation and hydropower. Power is generated through turbines at the dam as well as multiple hydroplants fed by the Sutherland Canal and the downstream Tri-County Supply Canal. Over 100,000 acres are irrigated from the Tri-County Supply Canal. Environmental concerns are also important as there are several endangered species along the North Platte and Platte below the dam. Storage is provided in an Environmental Account in the reservoir for occasional releases to meet these needs. See Section 2.4.2 for more information on how Lake McConaughy is operated during high flows.

4.7.1 Modeling Approach

The original calibration of Lake McConaughy was done with the RES-J model. For this project, the model was transfered to HEC-ResSim, and improvements were made to the calibration as needed. The HEC-ResSim manual (USACE 2007) contains details of parameterizing and running the model.

ResSim functions very differently from RES-J both as a software application and as a model, and required some effort to setup properly. ResSim models are based on a “Watershed” which contains a stream network, reservoirs, and any other physical features. A watershed was created for Lake McConaughy with the reservoir as the only main feature, along with a portion of the upstream river network for visual appeal as shown in Figure 4-7. The physical properties of the reservoir were entered including the storage-elevation-area curves and the outlet and spillway capacities. ResSim will automatically limit releases based on these capacities.

The RES-J models for the North Platte all model rain and evaporation on the reservoir surface, so functionality was added to the ResSim model to account for net evaporation. Net evaporation was defined as a monthly varying average evaporation with actual precipitation subtracted. This results in water being added to the reservoir during heavy rains.

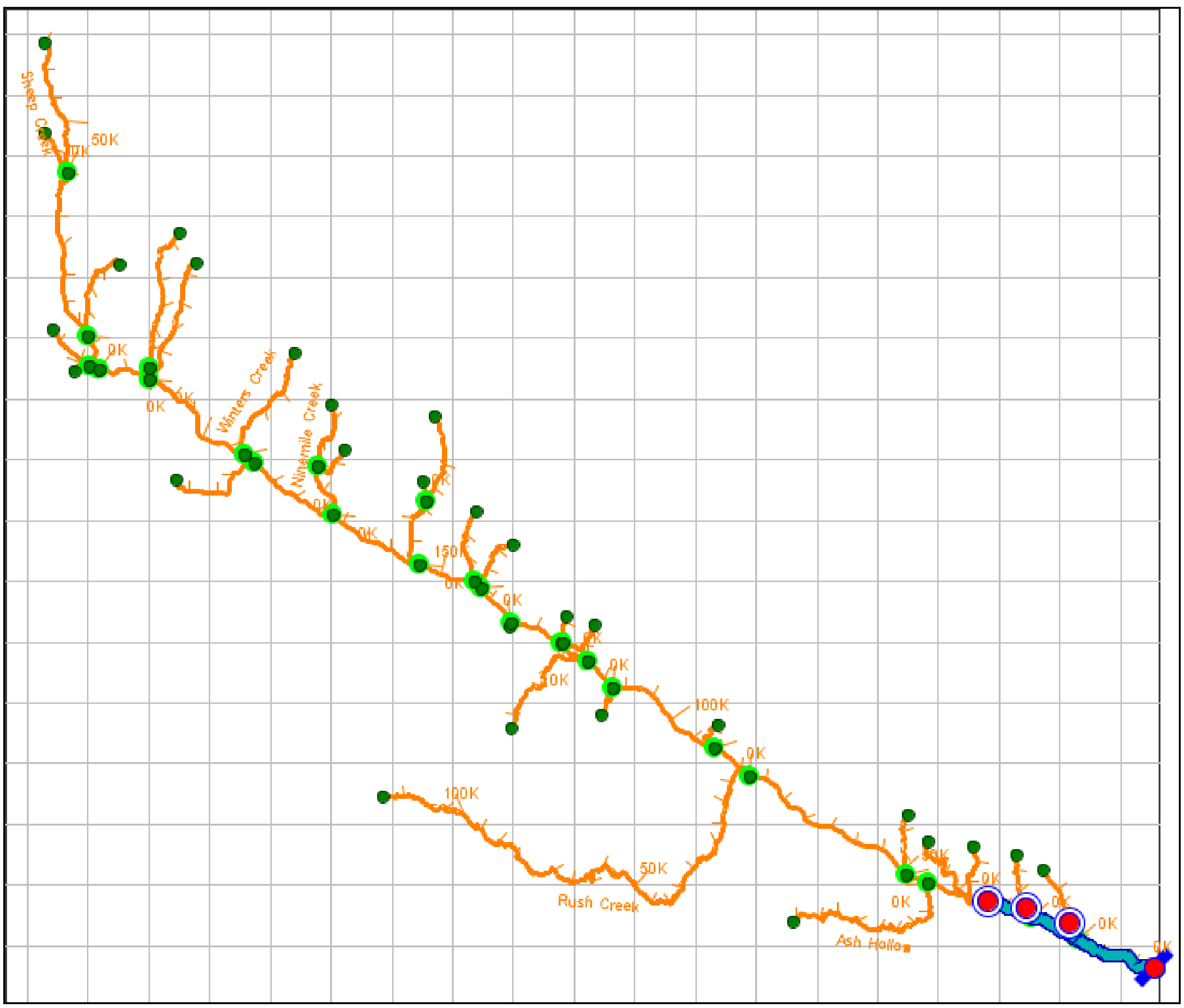

Figure 4-7. Lake McConaughy ResSim model display

The pool elevation at Lake McConaughy was divided into zones, which ResSim requires, and rules were added to these zones. The “Inactive” zone was set to 3131 ft, and no operation is possible below this level. The top of the “Conservation” zone was set to 3265 ft, which is the upper limit for the reservoir’s FERC license. A “Flood Control” zone was defined between 3265 and 3267 ft, to account for additional storage that is sometimes used during very large events. Finally, an “Emergency Flood Control” zone was defined as extending to elevation 3282 ft, which is the top of the storage-elevation curve. These zones are not meant to exactly match operational or legal zones in use by CNPPID, but rather to allow better modeling results.

In the Conservation and Flood Control zones, operations are similar. In the winter (October – April) releases are determined by pool elevation and date, similar to the original RES-J model. During the rest of the year, releases are based on consumptive use demand, scaled according to pool elevation as in several of the other RES-J models.

The RES-J model used simulated flow within Korty Canal (on the South Platte River) as a basis to reduce releases from Lake McConaughy. The more water in Korty Canal, the lower the release from Lake McConaughy when irrigation releases are controlling. For this project, the South Platte was not simulated, and so the average flow in Korty Canal for each day was calculated using historical data, in place of simulated canal flow.

At any time of year, the reservoir will switch to high flow mode based on pool elevation and a running average of the last 7 days of inflow. High flow mode begins if the average inflow is above 4000 cfs and the pool elevation is above a threshold that varies between 3255 and 3264.5 depending on the date. This threshold was determined from analysis of previous operations.

When in high flow mode, the reservoir will release based on the 7-day average inflow, generally keeping releases below inflow until the pool elevation is near 3265 ft. Above this level releases will increase up to 15,000 cfs for very high inflows. If the pool elevation increases above 3267 ft, emergency releases are made. During emergency releases, the reservoir will pass 90% of the current inflow, or the previous release, whichever is larger. This rule is meant to model the type of operations CNPPID might consider in a hypothetical very large event. CNPPID staff indicated their goal during a very large event would be to keep releases below inflow, and they would also like to keep the pool elevation below the FERC license limit as much as possible. The rule ensures that the peak releases will be less than peak inflow, but lowers the pool as fast as possible within that constraint.

4.7.2 Modeling Results

Figure 4-8 shows the model results for 2011. In this graph, the upper plot shows pool elevation, with observed data in red and simulated in green. The bottom plot shows flow, with observed releases in red, simulated releases in green, and inflows in black. The purple lines on the top plot mark the top of the Conservation and Flood Control zones.

In general the simulation performs well. The peak simulated release is very close to the peak observed release. The model holds releases lower in the spring than the observed data because the model does not have a method to look at forecasted inflow. Once the pool elevation rises high enough at the beginning of April, high flow mode turns on and model releases track average inflow, and are a bit higher than the historical releases. The pool elevation is generally held two to three feet lower in the model than in the observed data during the peak of the inflow.

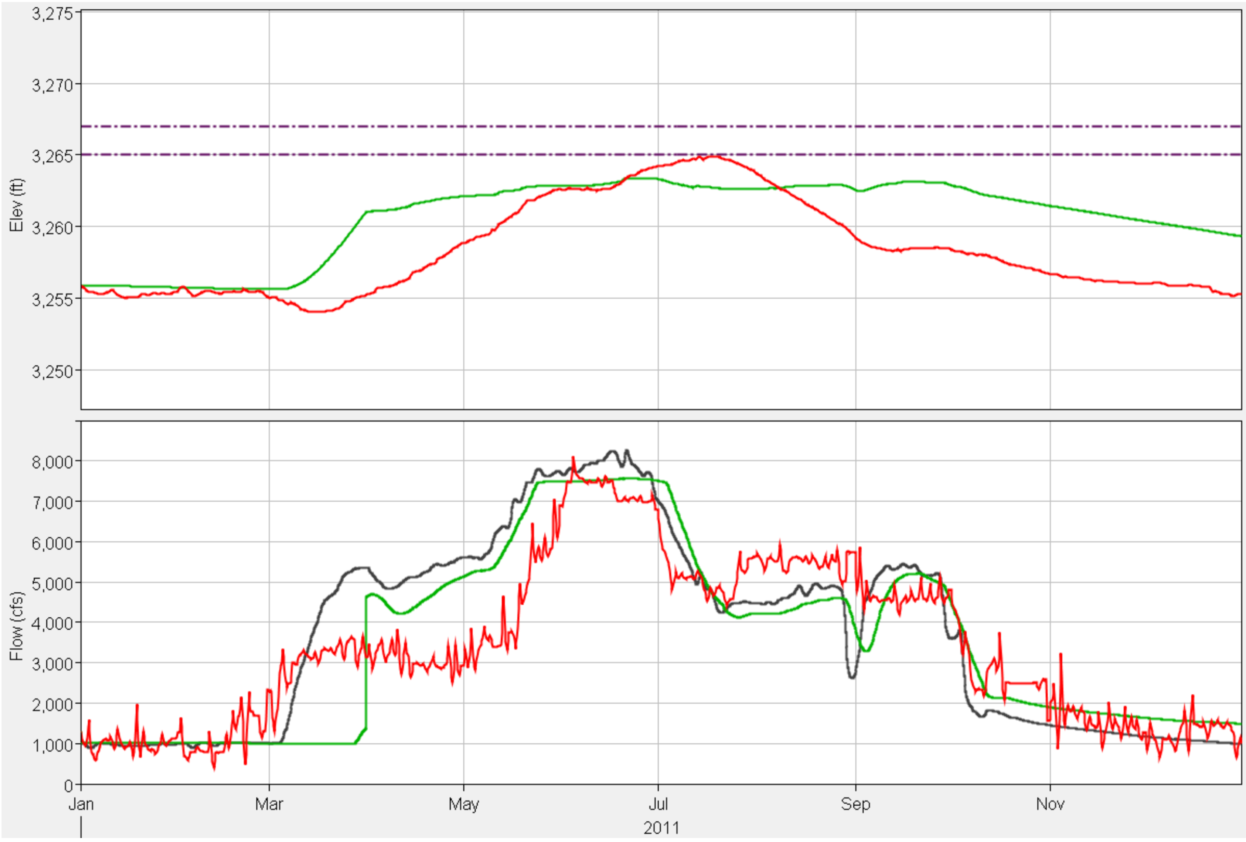

Figure 4-8. Simulation results for Lake McConaughy ResSim model

5 Regulated flow frequency computations

The regulated flows produced by the combination of the hydrologic and regulation models were used to generate regulated flow frequency curves. The reservoir models (RES-J and ResSim) along with the regulation models for irrigation diversion and returns were used to translate unregulated flow into regulated flow. By increasing the precipitation input, larger events were produced that allowed the frequency curves to be extended to include lower-probability events.

5.1 Procedure

The models were run for the entire period of record and the regulated and unregulated flows for each location of interest were read using TSTool and saved into a spreadsheet. To create more and larger peaks, the models were run five times. For each run, the input precipitation for the hydrologic models was increased uniformly for all sub-basins. Runs were made with the original MAP time series, and sets of time series increased by factors of 1.1, 1.2, 1.3, and 1.5.

The flows were aggregated to the needed durations using Microsoft Excel, and the annual peaks for each duration were extracted. The peaks from all of the different model runs were combined to get a set of 320 (64 years and 5 MAP sets) peaks for each location and duration. Regulated and unregulated peaks were both saved and aggregated. Appendix F contains tables listing the annual regulated peaks, starting at Table F-8. These peaks were generated using the original unscaled MAPs.

The probability associated with each unregulated peak was determined using the flow frequency curves described in Section 3.2.2. The equation used to calculate probability using flow is:

$$LogQ = \bar{X} + kS$$

Where: Q = flow
$\bar{X}$ = mean of logarithms of annual peak flow
k = factor that is a function of skew and exeedance probability
S = standard deviation of logarithms

The logarithmic mean ($\bar{X}$) and standard deviation of logarithms (S) were calculated by HEC-SSP for each location and duration and are shown in Table 3-3 and Table 3-5. For each unregulated peak Q, the equation was solved for the probability factor k.

Bulletin 17b provides a table of k values for many possible skew and exceedance probabilities as Appendix 3. Using this table, the appropriate skew, and the calculated k values for each unregulated peak the exeedance probability for each peak was calculated. Some peaks, especially from the runs with the 1.5 MAP factor, were so large that the calculated probability was less than 0.0001, or greater than a 10,000 year return interval. The table in Bulletin 17b does not extend to lower probabilities than this, so these peaks were not used in the resulting regulated frequency curve development. The regulated peaks from each year were initially assigned the same probability as the unregulated peak from that year.

5.2 Results

Several results were created for each location and duration. First, a plot of regulated vs. unregulated flow was produced to visually show the effects of regulation. Figure 5-1 is an example of these plots for North Platte, with all durations shown. Additional plots for the other locations are included in Appendix E. Peaks developed using unscaled MAPs are generally in the far bottom left of the plots, and represent the size of actual historical peaks in the analysis period. Most of the larger peaks were generated using the increased precipitation time series.

These plots do not show simple relationships between regulated and unregulated flows, but rather a complex relationship that varies depending on the size of the event, the shape of the event (high but short events will give a different regulated response than lower but longer events), and the antecedent conditions in the basin including total reservoir storage. Because the regulation was modeled using rule-based reservoir models and calibrated diversion models, a simple relationship between regulated and unregulated flow was not required.

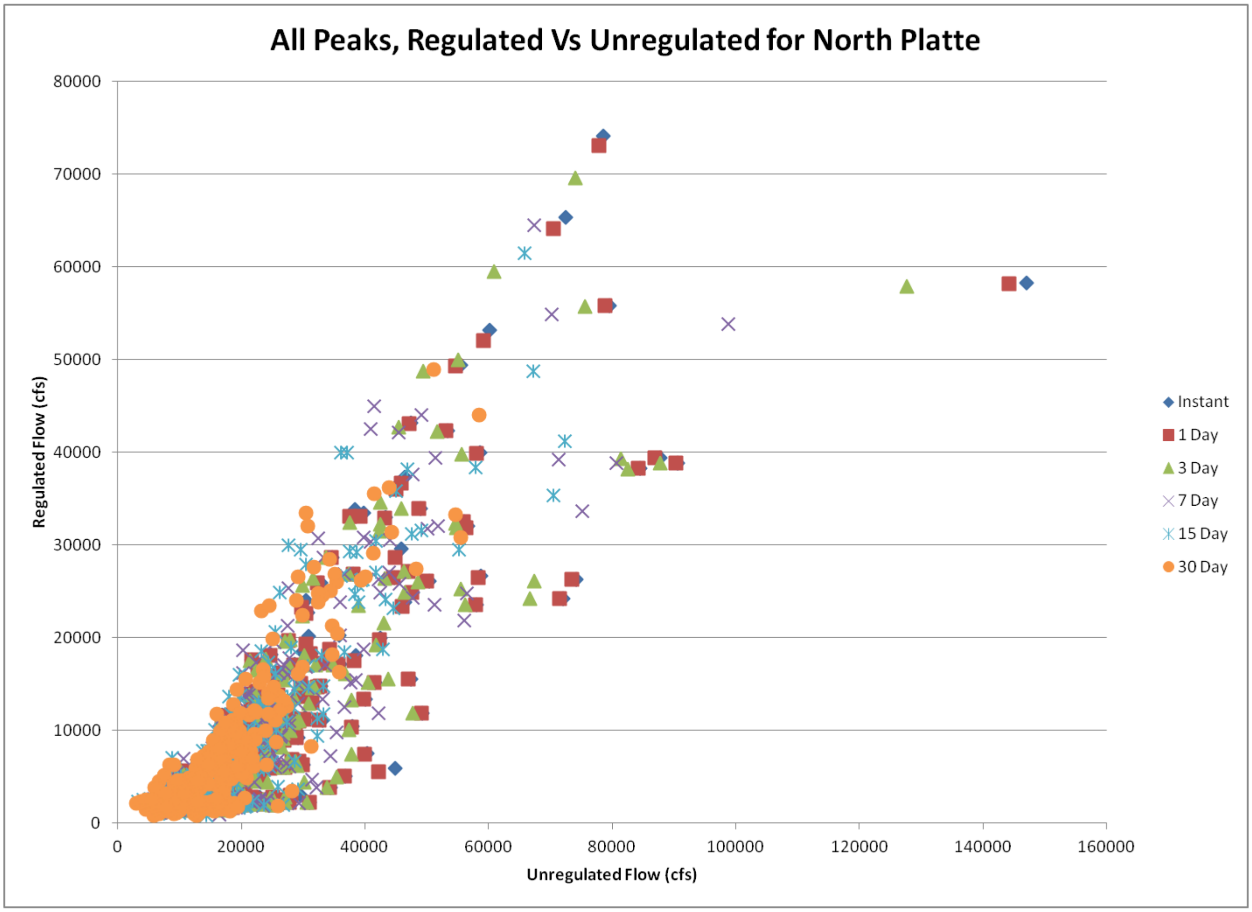

Figure 5-1. Regulated vs. unregulated peaks for North Platte

This is one area where the present study differs from the Missouri Flow Frequency Study. That study used plots similar to Figure 5-1 to determine a relationship between regulated and unregulated flows and then used that relationship to transform the unregulated frequency curve into a regulated frequency curve. This study used models to transform unregulated flow to regulated flow, and plotted the resulting relationship, but did not use it to determine the regulated frequency curve.

Figure 5-2 shows regulated peaks as a function of probability, using the probability estimated for the corresponding unregulated peak. This plot separates the peaks by which MAP scaling factor was used to generate them, to show the probability range that resulted from each scaling factor.

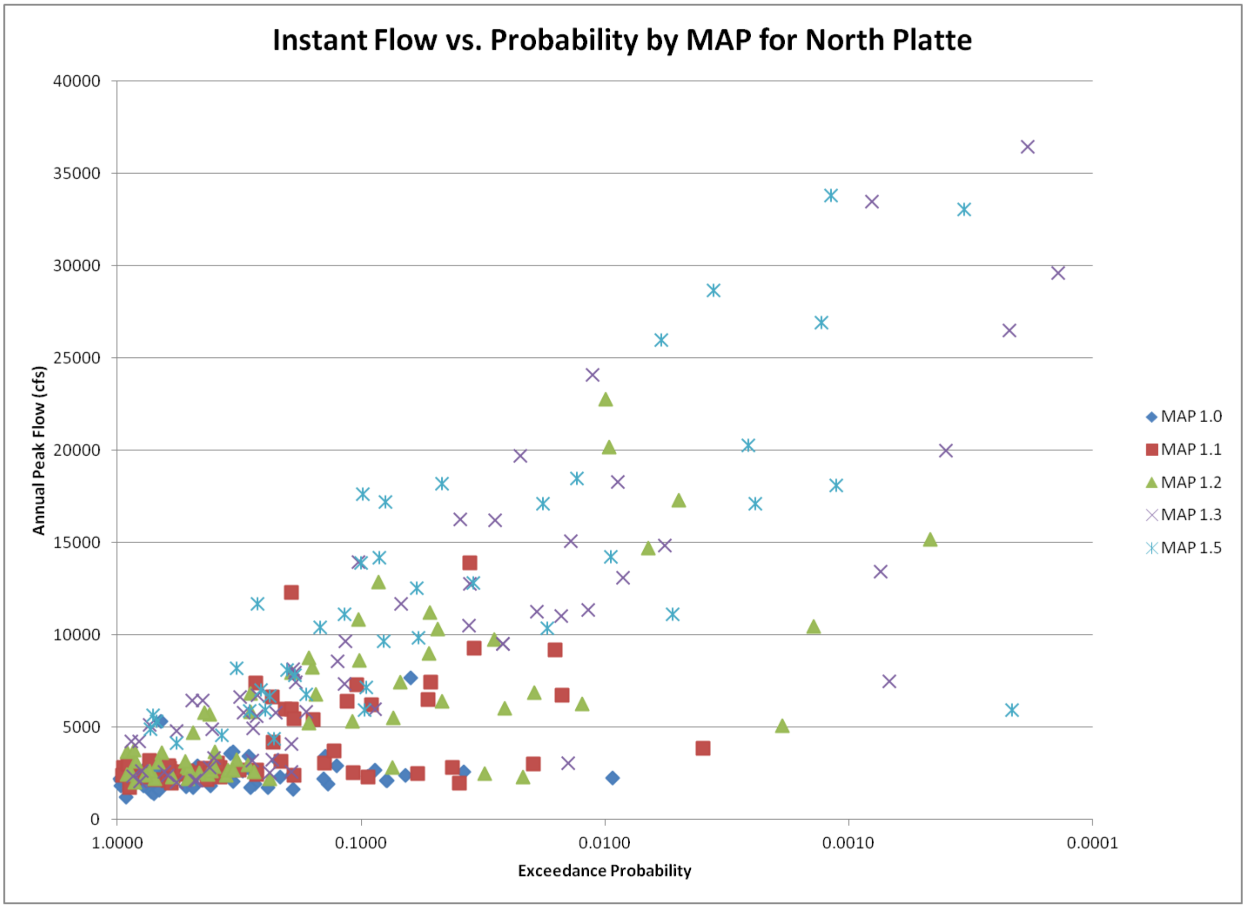

Figure 5-2. Regulated peaks at North Platte vs. probability

The assumption that was made in Figure 5-2 was that the exceedance probability for each regulated peak was the same as the exceedance probability for the corresponding unregulated peak. There are many variables other than peak inflow that impact the resulting regulated peak, e.g. initial reservoir storage, inflow volume and duration, etc. For example, a very flashy event could produce an unregulated peak with a small exceedance probability, but result in a small regulated peak if the reservoir is able to absorb the event. In the other direction, a smaller unregulated event with higher probability could cause a relatively large regulated peak if the reservoir was full at the start of the event.

To address this issue, a similar method to the one used in the Missouri River study was used re-order the regulated peak vs. probability relationships, as seen in Figure 5-3. The blue dots are the same points shown in Figure 5-2, and the red dots are those points sorted by rank. The smallest exceedance probabilities are paired with the largest regulated flows and vice-versa. As seen in the plot, the rank-ordered curve cuts through the middle of the scatter in the year-ordered curve.

Also shown in Figure 5-3 is the unregulated frequency curve. It can be seen that the regulated frequency curve (rank-ordered) is slowly approaching the unregulated curve as the probabilities get smaller. The curves do not meet even at very low probabilities, indicating that the North Platte has a large capacity for regulation and it is very difficult to completely overload the system.

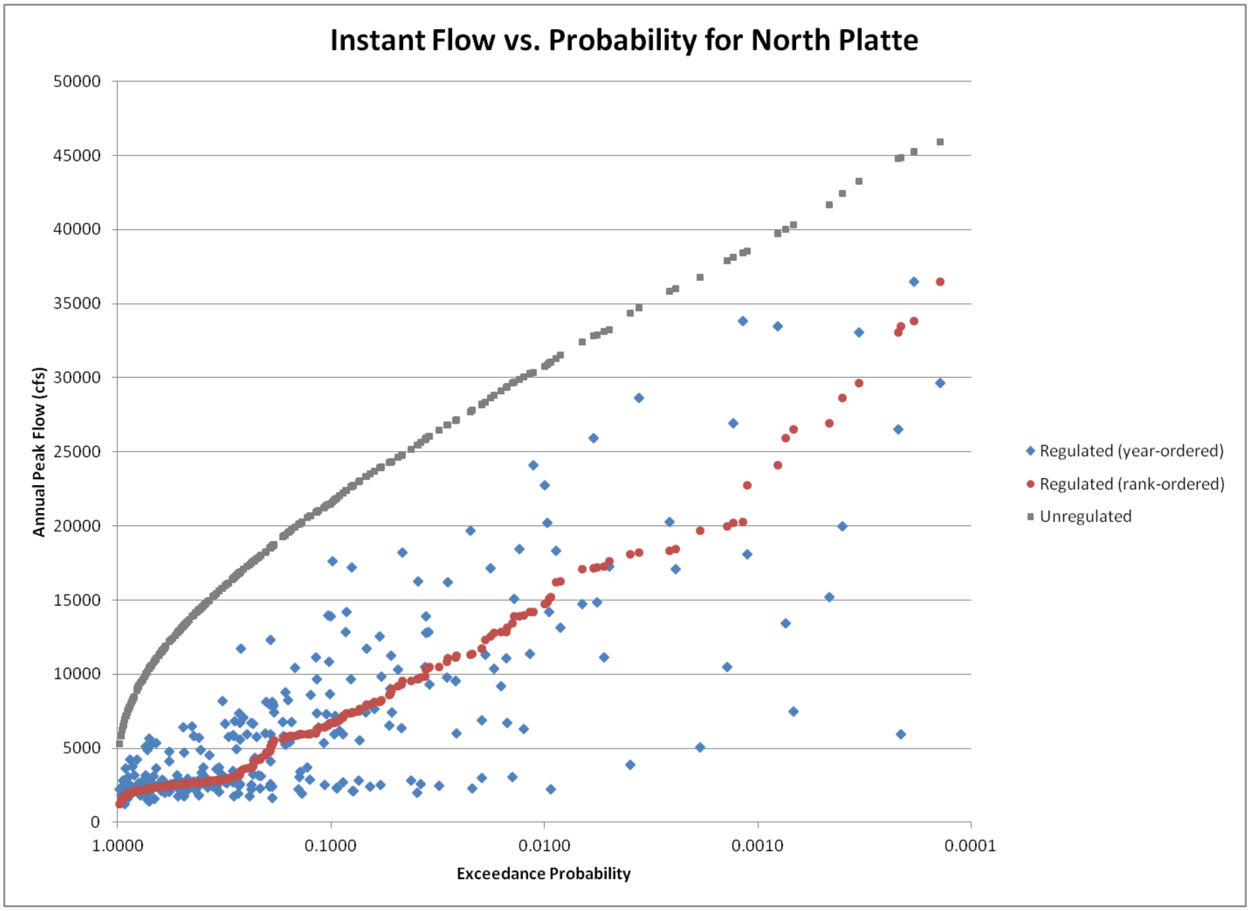

Figure 5-3. Regulated flow vs. probability for North Platte, rank ordered

By plotting all of the duration-frequency curves for a location, the trends between durations can be clearly seen as in Figure 5-4. This plot shows that the frequency curves are relatively well-ordered at lower flows, but as the flow increases and probability decreases, the curves become less smooth and more mixed. At North Platte, it appears that 7 days is the critical duration which results in the largest regulated flows. However, the critical duration is likely dependent on the specific rules in the reservoir models, and may be different in an actual event. Note that the duration-frequency curves for a given location may cross, especially at lower probabilities where the results are less consistent and more random. This further supports the idea that the critical duration may be different for different events.

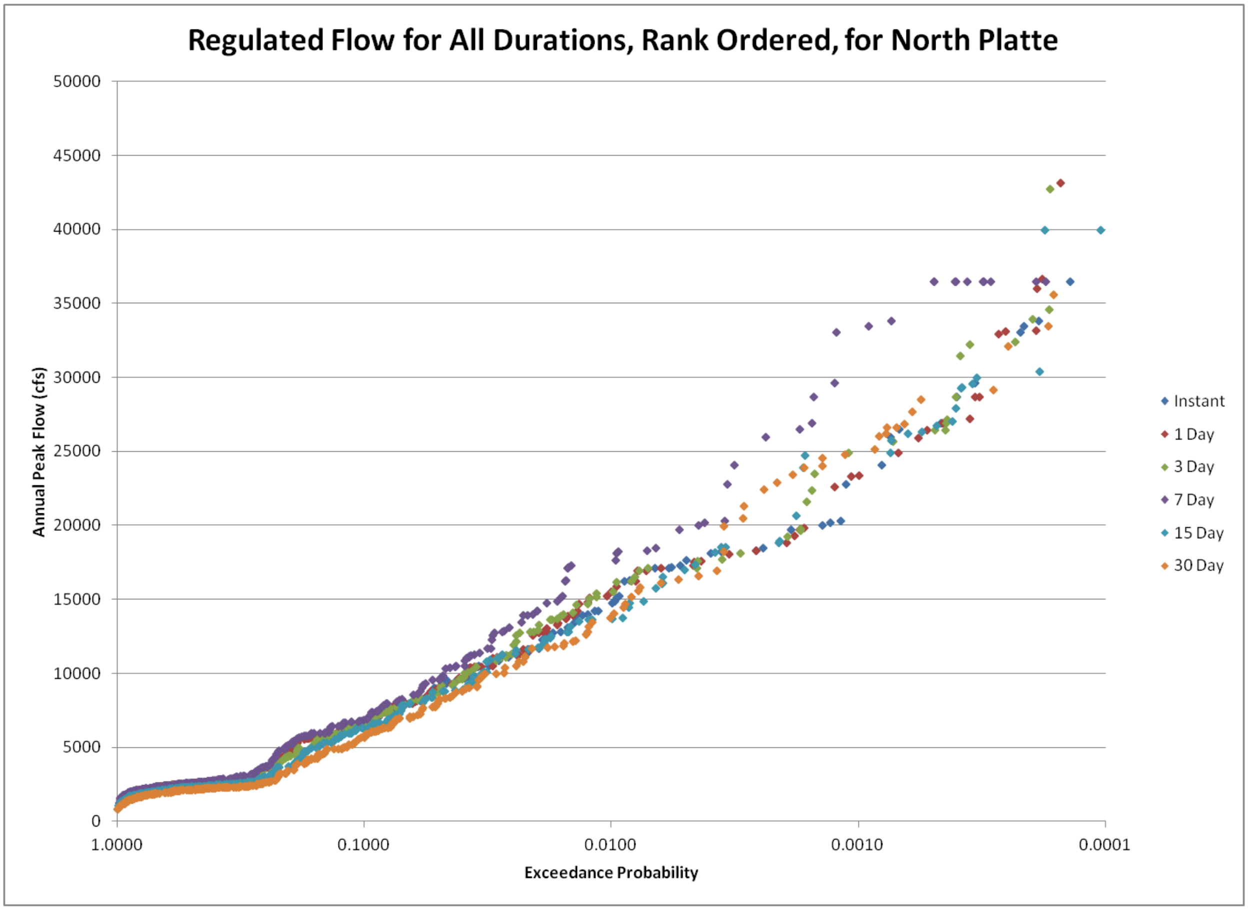

Figure 5-4. Regulated flow frequency curves for all durations at North Platte

Another way of looking at the data is shown in Figure 5-5. This plot shows the instantaneous regulated frequency curves at all locations. Lewellen is seen to have the largest regulated flows for a given probability, for events up to about a 100 year return interval. For larger events, the curves become more variable and no one location is consistently largest for a given probability.

Another interesting point in Figure 5-5 is that Keystone and North Platte have noticeably lower curves than the other locations. This shows the impact of Lake McConaughy, which is downstream from the other locations. Again however, for extremely large flows, the lines become mixed and the impact from Lake McConaughy is less clear.

A full set of plots for all locations and durations is included in Appendix E.

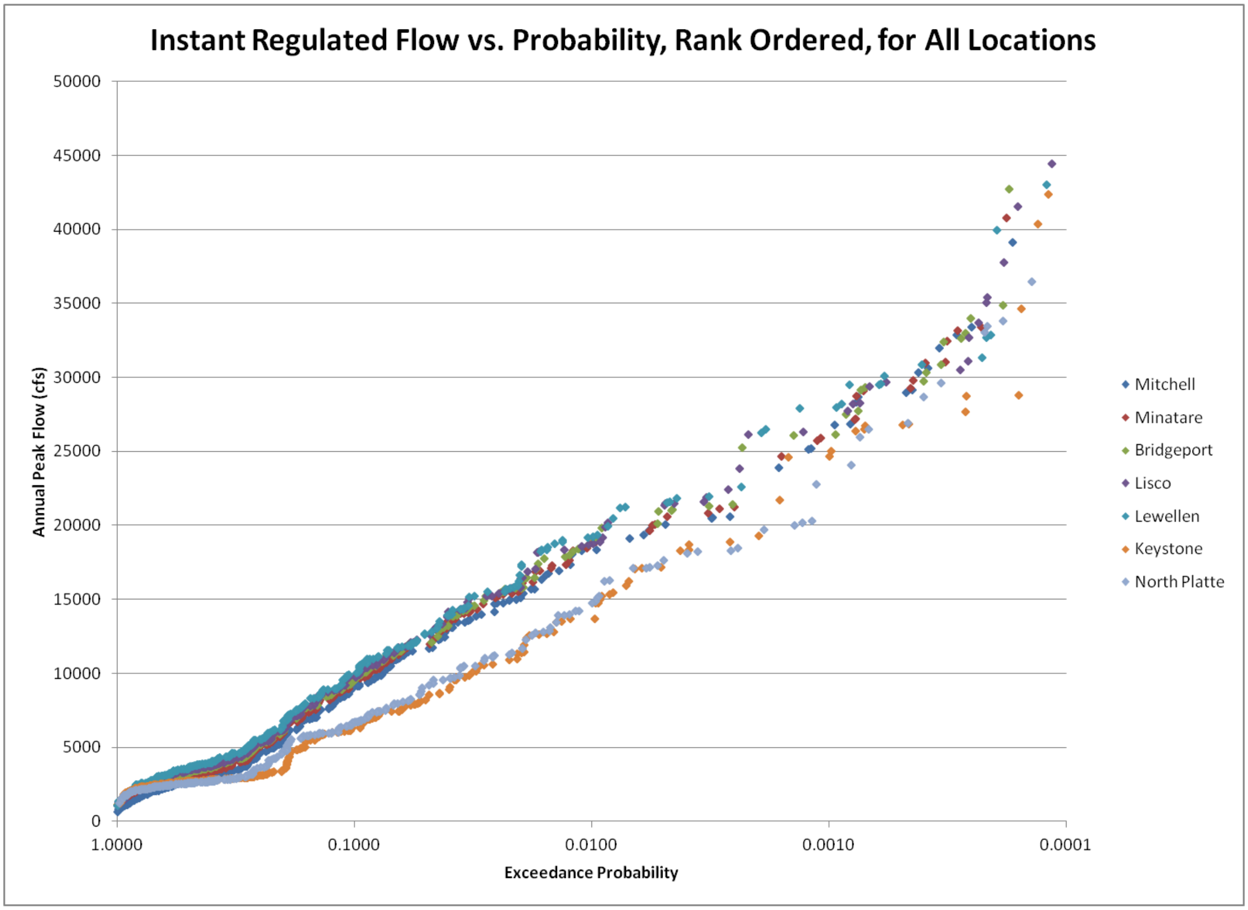

Figure 5-5. Regulated flow frequency curves for instantaneous peaks at all locations

For each location and duration, the regulated flow frequency curves are defined as the rank-ordered flow vs. frequency curves. These curves are detailed below in Table 5-1 through Table 5-6. The rank-ordered curves were chosen with the assumption that they were a good representation of the probability associated with each regulated peak. The rank-ordered curves help manage the variability in the regulated response described above.

Table 5-1. Instantaneous regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	22600	23100	25500	26200	25600	19300	19400
0.005	20000	20400	21000	21300	21500	17300	17600
0.01	18300	18800	18900	18800	19200	13700	14700
0.02	15100	15700	15700	16100	16800	11400	11600
0.05	11600	11900	12100	12500	12700	8240	9130
0.10	9060	9670	9540	9730	9980	6290	6690
0.20	5680	5950	6110	6170	6790	3480	4740
0.50	2660	3050	3300	3450	3630	2700	2590
0.80	1630	2170	2330	2400	2500	2310	2130

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.90	1210	1760	1870	1870	1980	1980	1860
0.95	960	1400	1460	1440	1490	1640	1610
0.99	840	1170	1180	1280	1370	1160	1020

Table 5-2. 1-day regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	23100	21200	25200	25300	25600	18700	18800
0.005	19400	19600	20100	21100	21400	17000	17200
0.01	18300	18400	18700	18600	19200	15200	15500
0.02	14900	15500	15700	15900	17200	11900	12700
0.05	11600	11900	12100	12600	12900	8550	9010
0.10	8970	9580	9470	9710	9970	6230	6680
0.20	5680	6380	6220	6110	6770	3540	4790
0.50	2650	3070	3320	3450	3650	2690	2570
0.80	1660	2180	2350	2460	2580	2290	2120
0.90	1210	1760	1890	1910	1980	1960	1860
0.95	1000	1390	1460	1440	1500	1600	1600
0.99	810	1140	1180	1270	1370	1060	1030

Table 5-3. 3-day regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	20400	21000	21200	24700	23900	19900	19200
0.005	18200	18700	19400	20100	21100	17700	17100
0.01	17800	18300	18400	18400	18400	15200	15500
0.02	15200	15900	16200	16200	16500	12600	12900
0.05	11800	12400	12400	12200	12600	8600	8760
0.10	8840	9400	9620	9660	9850	6440	6690
0.20	5480	6000	6290	6380	6530	3830	4430
0.50	2620	2950	3180	3310	3510	2650	2520
0.80	1480	2080	2250	2270	2400	2240	2070
0.90	1140	1660	1800	1790	1860	1930	1860
0.95	900	1300	1430	1370	1440	1580	1580
0.99	750	1040	1140	1230	1300	970	970

Table 5-4. 7-day regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	22900	24100	23500	21200	21000	18900	18700
0.005	17800	18600	18800	18700	19400	17300	16800
0.01	16200	16600	17100	17200	17700	15300	15200
0.02	14800	15300	15500	15600	15700	12600	12800
0.05	10900	11300	11500	11500	11500	8580	8450
0.10	8480	8940	9160	9170	9390	6470	6540
0.20	5050	5640	5810	6010	6270	4160	4130
0.50	2450	2760	3040	3160	3390	2590	2460
0.80	1240	1780	1930	2040	2210	2200	1990
0.90	1040	1450	1630	1620	1700	1940	1810
0.95	860	1190	1330	1310	1390	1640	1570
0.99	690	940	1090	1100	1170	1090	870

Table 5-5. 15-day regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	23400	23500	23800	24700	24900	19600	19400
0.005	18600	18400	17900	18100	18500	17100	17000
0.01	15400	15700	15900	15600	16300	14600	13700
0.02	13600	14300	14700	14600	14900	12200	11700
0.05	10100	10600	10800	10900	11100	8780	8770
0.10	7390	7970	8210	8280	8450	6120	6320
0.20	4600	5040	5250	5320	5570	3450	3700
0.50	2340	2640	2990	3160	3300	2500	2330
0.80	1090	1510	1790	1820	1910	2030	1880
0.90	850	1250	1400	1460	1530	1840	1680
0.95	700	1050	1180	1220	1280	1490	1390
0.99	620	910	1050	1040	1090	1070	1080

Table 5-6. 30-day regulated flow frequency values (cfs)

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.002	23400	23800	24400	24300	24900	23700	23100
0.005	20000	20600	21500	21600	19300	16400	16400
0.01	15400	15500	14900	14200	14400	13400	13900
0.02	12500	13000	13400	13600	14000	11800	11700
0.05	9850	10200	10500	10600	10700	8170	8090
0.10	6790	7040	7250	7170	7320	5620	5660

Exceedance Probability	Mitchell	Minatare	Bridgeport	Lisco	Lewellen	Keystone	North Platte
0.20	4040	4640	4860	5090	5260	3260	3430
0.50	2130	2460	2810	2890	2960	2260	2140
0.80	910	1350	1600	1650	1740	1800	1680
0.90	720	1130	1300	1300	1360	1570	1430
0.95	610	970	1080	1090	1140	1180	1170
0.99	550	900	990	980	1080	870	890

6 Summary

Riverside performed a regulated flow frequency study for the North Platte River in Nebraska. The study leveraged previous hydrologic, streamflow regulation, and reservoir modeling work performed for the National Weather Service. The models were updated as needed to take into account new data available since the original calibration and to better represent current and possible future operations at the reservoirs in the basin.

These models were used to generate unregulated and regulated flows at seven locations along the North Platte. The flows were aggregated into six different durations ranging from instantaneous flow to 30-day volumes. The unregulated flows were used in a Bulletin 17b style flow frequency study to generate flow frequency curves for each location and duration. The unregulated flow frequency curves were used along with the regulated flows to derive regulated flow frequency curves. These curves can be used by the US Army Corps of Engineers and others to better understand the impact of reservoir operations on the flow frequency relationship in the North Platte watershed.

7 References

Interagency Advisory Committee on Water Data (IACWD). 1982. *Guidelines for determining flood flow frequency*: Bulletin 17B of the Hydrology Subcommittee (revised and corrected). U.S. Geological Survey, Office of Water Data Coordination, Reston, VA.

National Weather Service (NWS). 2008. RES-J Joint Reservoir Regulation Operation Methods Descriptions. Available from http://www.nws.noaa.gov/oh/hrl/nwsrfs/users_manual/part2/_pdf/24resj.pdf.

Riverside Technology, inc. (Riverside). 2009. *Task Completion Report: Task 8-0013 MBRFC North Platte Calibration*. Submitted to National Weather Service/NOAA Office of Hydrologic Development, Silver Spring, MD, June 2009.

Riverside Technology, inc. (Riverside). 2010. *Task Completion Report: Task 9-0011 Calibration of the Lower North Platte River Basins, the Platte River Basins upstream of Kearney, Nebraska, and the Upper Republican Basins for the Missouri Basin River Forecast Center*. Submitted to National Weather Service/NOAA Office of Hydrologic Development, Silver Spring, MD, June 2010.

United States Army Corps of Engineers (USACE). 2004. *Upper Mississippi River System Flow Frequency Study: Final Report*. January 2004.

United States Army Corps of Engineers (USACE). 2007. *HEC-ResSim Reservoir System Simulation: User's Manual, Version 3.0*. Davis, CA. April 2007.

Appendix A Associated File Descriptions

A number of files were included in the "North Platte Flow Frequency Study 2013.zip" file to supplement this report. This Appendix lists these files along with brief descriptions, sorted by folder.

- "Useful reports and references" This folder contains pdf format copies of the references listed above. It also includes several other useful reports used during the project.
- "Data Collected" This folder contains copies of all data collected during the project. Contents include data provided to Riverside as well as data downloaded from online sources or available from past Riverside projects.
  - "CNPPID" This folder contains time series information for Lake McConaughy in spreadsheet format and operational information in pdf format.
  - "MBRFC" This folder contains precipitation (MAP) and temperature (MAT) time series for all modeled sub-basins. Also included are model input files automatically produced from the MBRFC's operational forecast system.
  - "NDNR" This folder contains time series for streamflow and diversions on the North Platte obtained from the Nebraska DNR.
  - "USACE" This folder contains operational information for Glendo Reservoir.
  - "USBR" This folder contains time series downloaded from the USBR archive as well as information about the operation of the USBR's reservoirs in Wyoming.
  - "USGS" This folder contains streamflow time series as downloaded from the USGS website.
  - "Wyoming SEO" This folder contains time series information for Laramie River reservoirs downloaded from the State of Wyoming website.
- "Model Data" This folder holds the model input files and time series needed to run all basin, regulation, and reservoir models for the North Platte.
  - "NWSRFS" This folder contains two compressed files.
    - The NWSRFS_Models.tar.gz file contains all of the National Weather Service model input files needed to run the basin and RES-J models. These input files are in text format, and can be run using NWS River Forecast System software on Linux operating systems.
    - The NWSRFS_Model_timeseries.tar.gz file contains all of the input time series needed to run the models, as well as all of the output time series generated by the models as ran by Riverside. The time series are in NWS CARD format and are ASCII based.
  - "ResSim" This folder contains all of the files and time series needed to run the Lake McConaughy ResSim model. If HEC-ResSim is configured to point to the "ResSim" folder as a "Watershed Location" the model will be available.
    - Input time series are contained in \base\McConaughy\McConaughyData.dss as well as in \base\McConaughy\rss\Full_Period_Simulation\simulation.dss
    - Output time series are contained in \base\McConaughy\rss\Full_Period_Simulation\simulation.dss
- "Unregulated Flow Frequency" This folder contains input time series used in HEC-SSP for the flow frequency analysis. Time series are described in detail in Appendix B. Also included are Bulletin 17b report tables in spreadsheet format. Using these time series along with the options detailed in Table 3-2 and Table 3-4 in HEC-SSP should reproduce the results shown in this report for the unregulated flow frequency analysis.

- “Regulated Flow Frequency” This folder contains regulated and unregulated flow data in text format for all analysis locations, generated using all MAP scaling factors used in the study. The folder also contains spreadsheets which process and analyze the flow data.
    - Each location folder contains the flow data files and spreadsheets. The “[AAAA1]_1.x.xlsm” spreadsheets process the data related to each MAP scaling factor. The “[AAAA1] All.xlsx” spreadsheet summarizes the results from the other five spreadsheets and creates some of the plots included in Appendix E.
    - In the root directory, the “All.xlsx” spreadsheet summarizes and plots the data from all locations. This spreadsheet was used to create the rest of the Appendix E plots as well as the tables in Appendix F.

Appendix B HEC-SSP DSS Data Description

Input time series and output time series for the unregulated frequency curve analysis are available in the HEC-DSS file named NPlatte_Final.dss. This appendix contains a description of the contents of that DSS file. The HEC-DSSVue software can be used to view this file.

1. There are two input time series for each location.
   a. **/NPLATTE/[location ID]N/INST-VAL//6HOUR/UNREG/**
      This is the time series that is output from the modeling system that generates the unregulated flows. Values are unregulated flow at a 6-hour time step. The period for each of these time series is October 1, 1948 – September 30, 2012.
   b. **/NPLATTE/[location ID]N/INST-VAL//IR-YEAR/PEAK/**
      This is an annual time series of instantaneous peak flow values, used in the 17b analysis. There is one value per year, given a date of December 31. This time series was created from the first time series above by extracting the annual peaks. The period for these time series is 1949-2012.
2. There are 22 output time series for each location.
   a. **/NPLATTE/[location ID]N/FREQ-FLOW///BULLETIN 17B_[location ID] EVENTS/**
      This record contains the annual peak events, sorted by rank and listed along with the Weibull plotting position for each event.
   b. **/NPLATTE/[location ID]/FREQ-FLOW/MAX ANALYTICAL//BULLETIN 17B_[location ID] ANALYTIC-DATA/**
      This record contains results from the 17b analysis. The computed frequency curve along with the expected probability curve and confidence intervals are included.
   c. **/NPLATTE/[location ID]N/INST-VAL//6HOUR/VOL_DUR_[location ID]_[duration]-DAY FLOW/**
      This record contains the running average calculated by HEC-SSP for the given duration. A value is given every 6 hours, representing the average associated with that time step. There are 5 of these time series per location, 1 for each duration.
   d. **/NPLATTE/[location ID]N/INST-VAL-PERAVG//IR-CENTURY/VOL-DUR_[location ID]_[duration]-DAY MAX/**
      This record contains the maximum value for each year, for the given duration. The date of each maximum is the actual date the maximum average value was reached. There are 5 of these time series per location, 1 for each duration.
   e. **/NPLATTE/[location ID]N/FREQ-INST///VOL-DUR_[location ID]_[duration]-DAY MAX EVENTS/**
      This record contains the annual maximums as above, sorted by rank and associated with a probability, given by the Weibull plotting position. There are 5 of these time series per location, 1 for each duration.
   f. **/NPLATTE/[location ID]N/FREQ-INST/MAX ANALYTICAL//VOL-DUR_[location ID]_[duration]-DAY MAX ANALYTIC-DATA/**
      This record contains results from the volume-duration-frequency analysis. The computed frequency curve along with the expected probability curve and confidence intervals are included. There are 5 of these time series per location, 1 for each duration.

Appendix C Unregulated Flow Frequency Plots

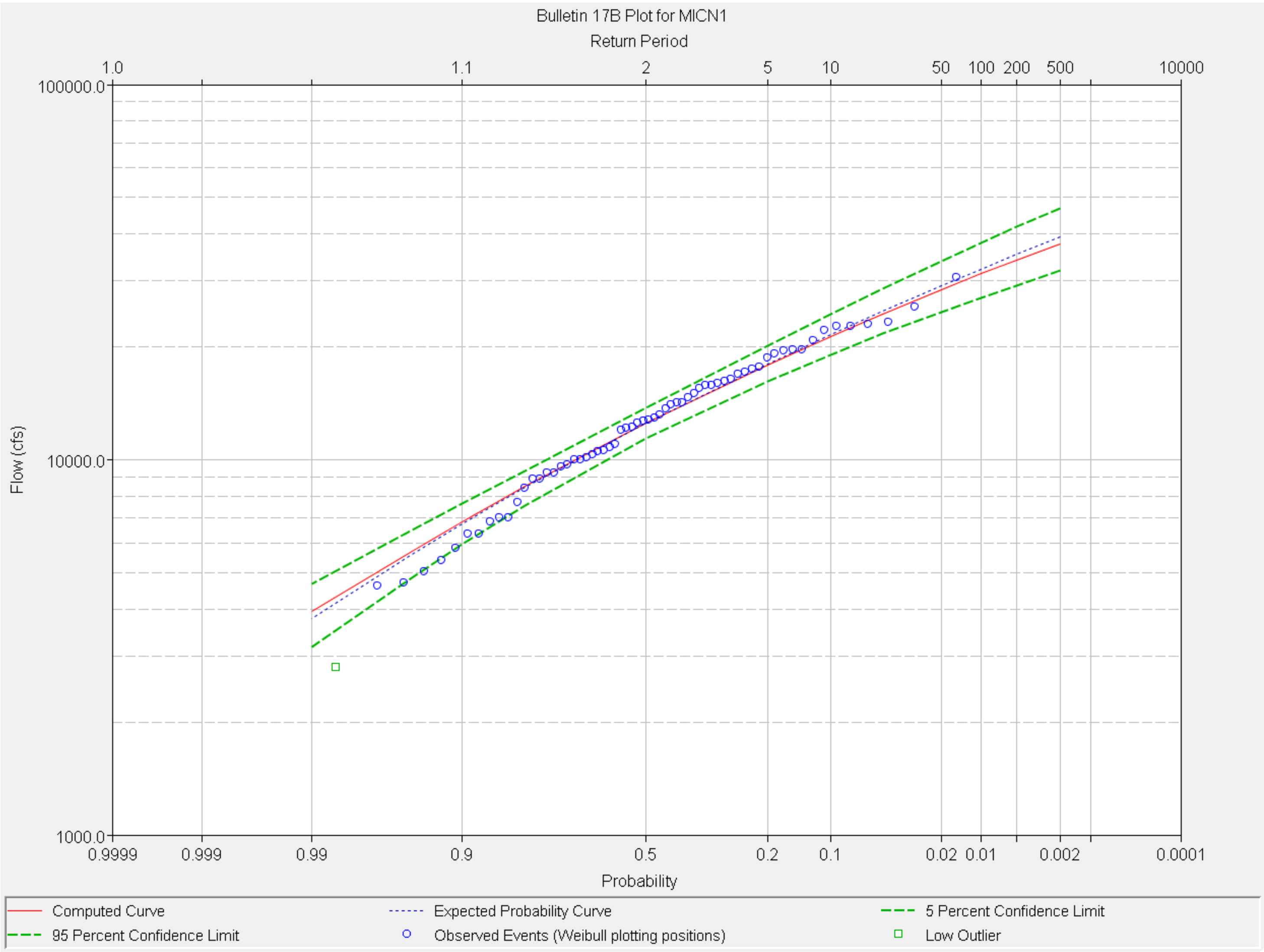

Figure C-1. Bulletin 17B plot for Mitchell

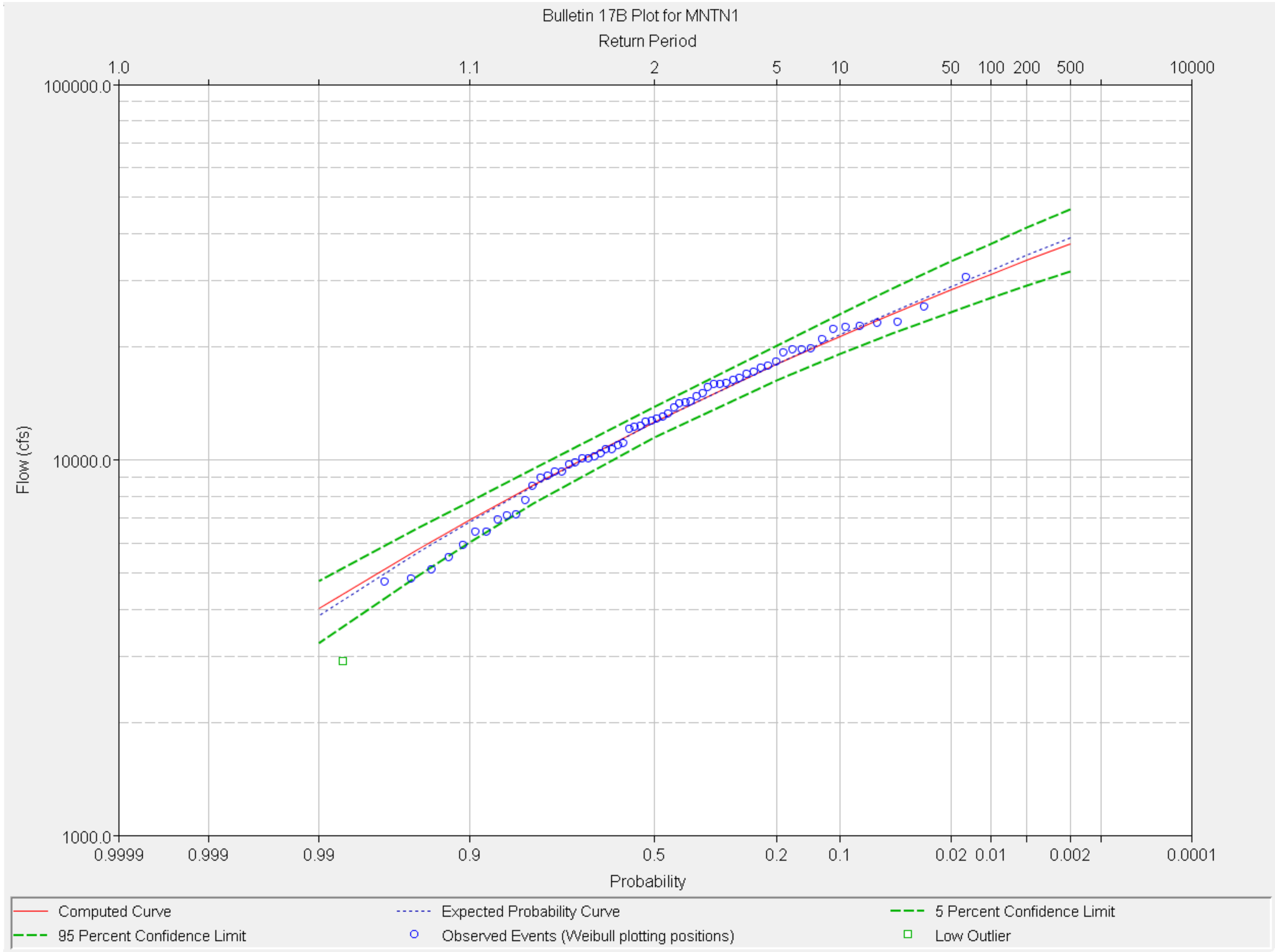

Figure C-2. Bulletin 17B plot for Minatare

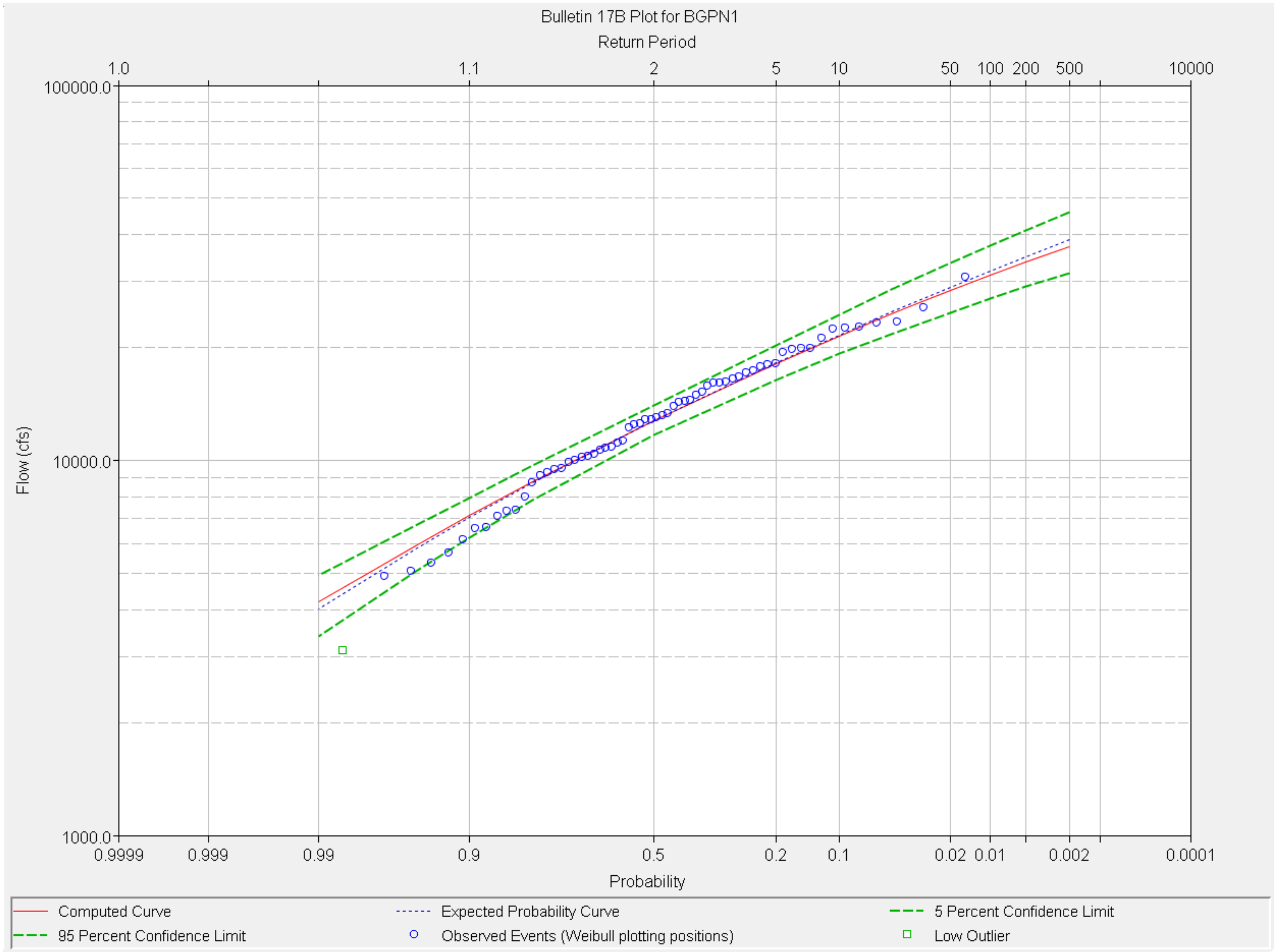

Figure C-3. Bulletin 17B plot for Bridgeport

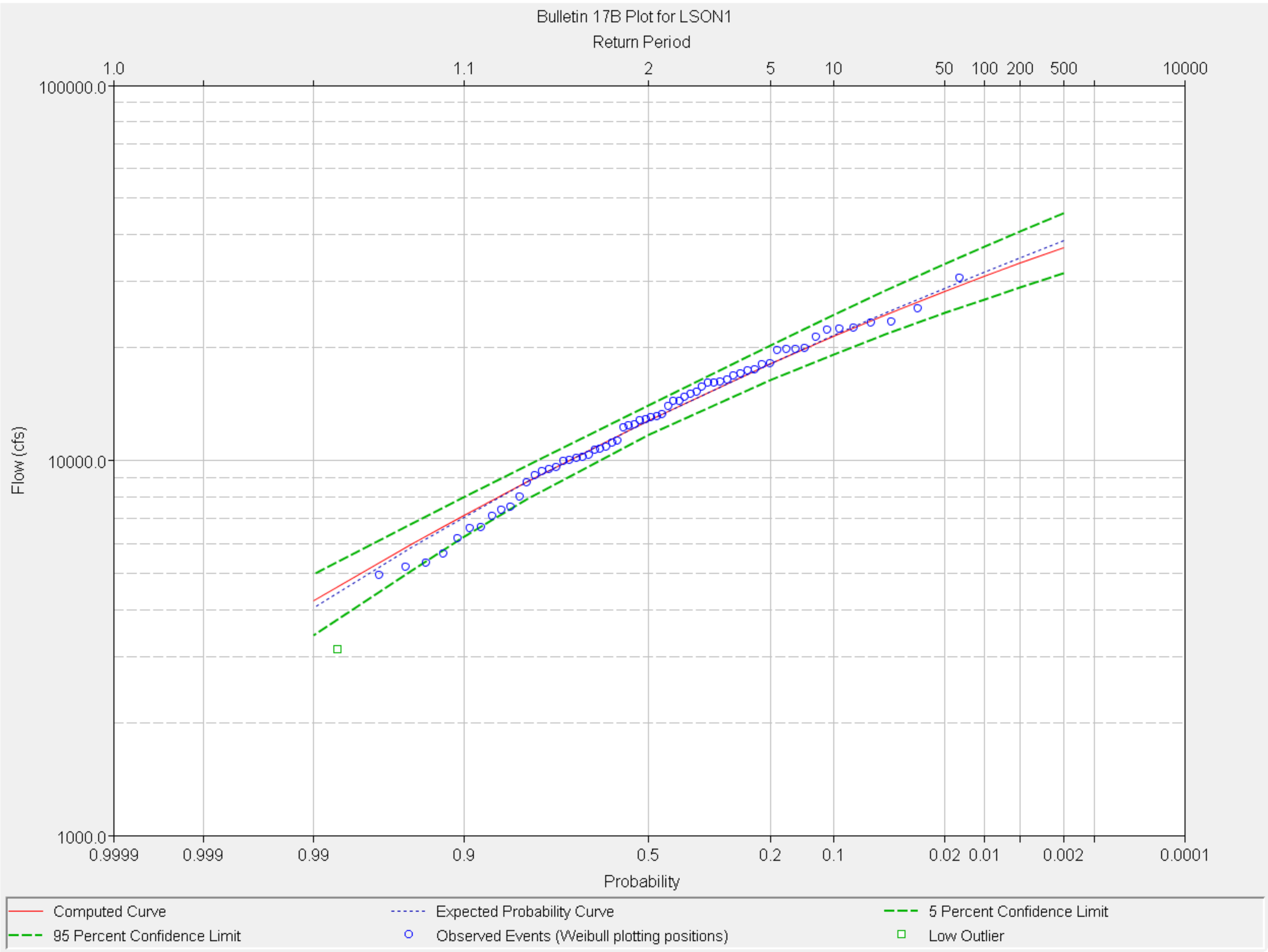

Figure C-4. Bulletin 17B plot for Lisco

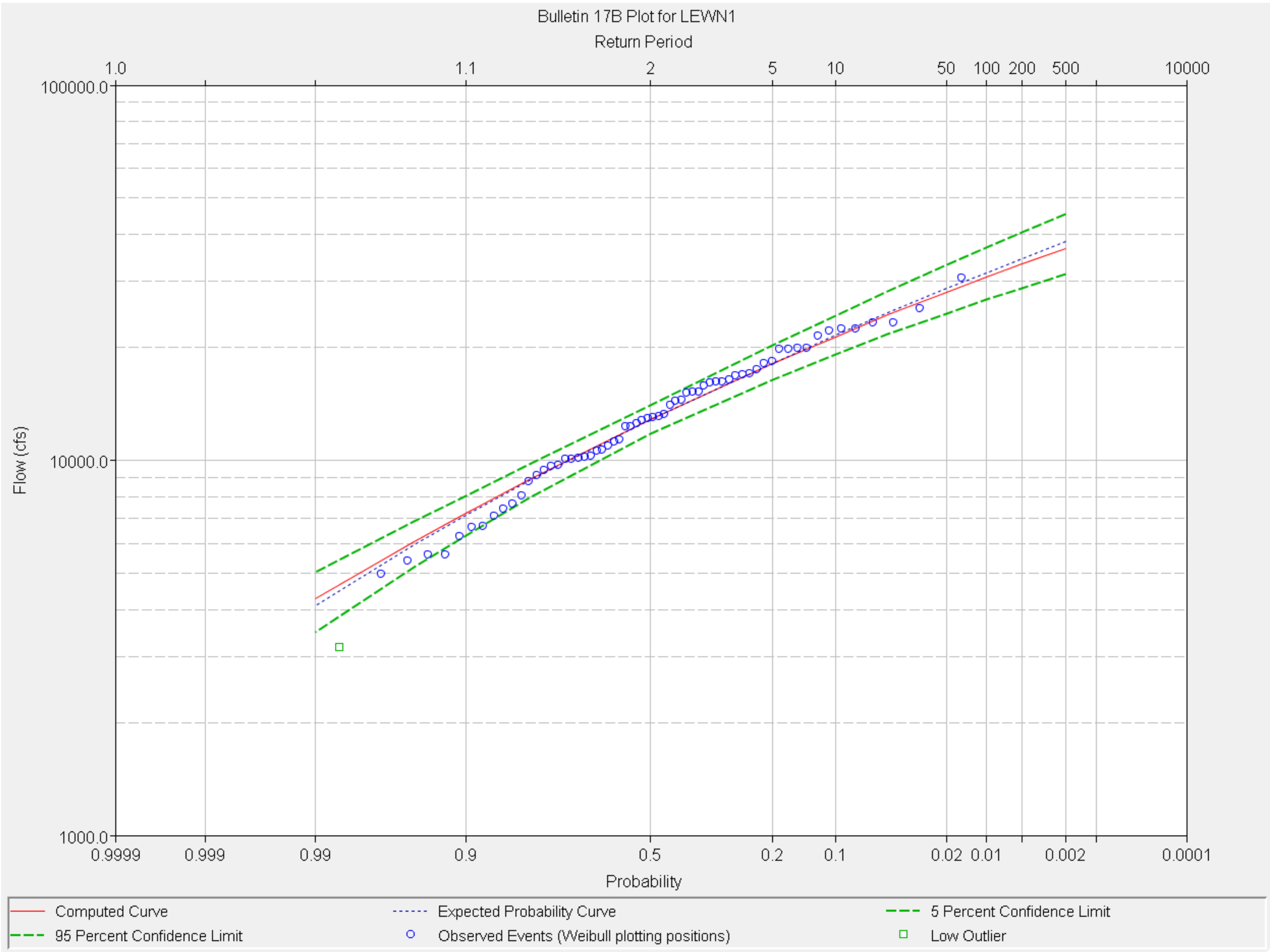

Figure C-5. Bulletin 17B plot for Lewellen

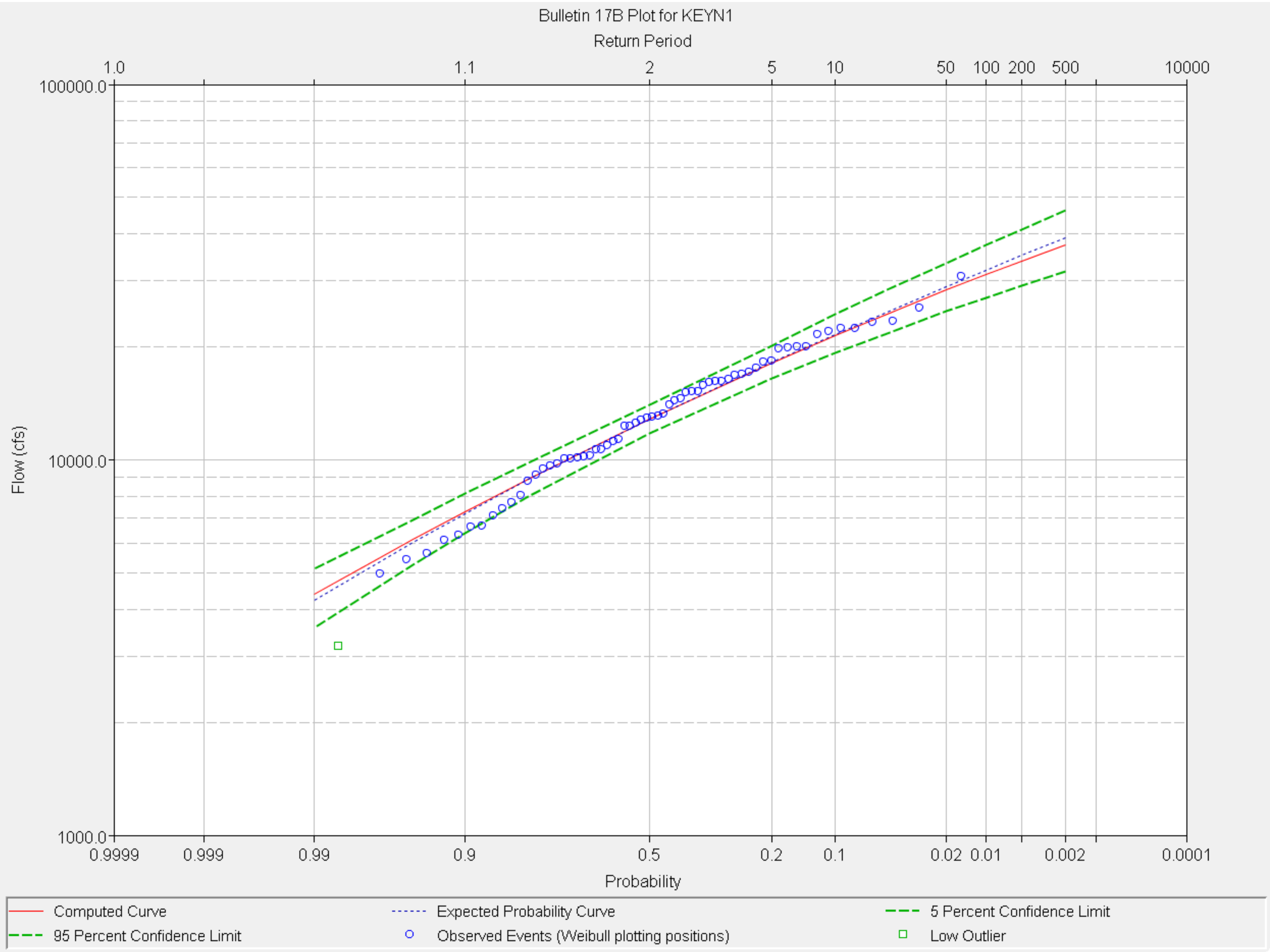

Figure C-6. Bulletin 17B plot for Keystone

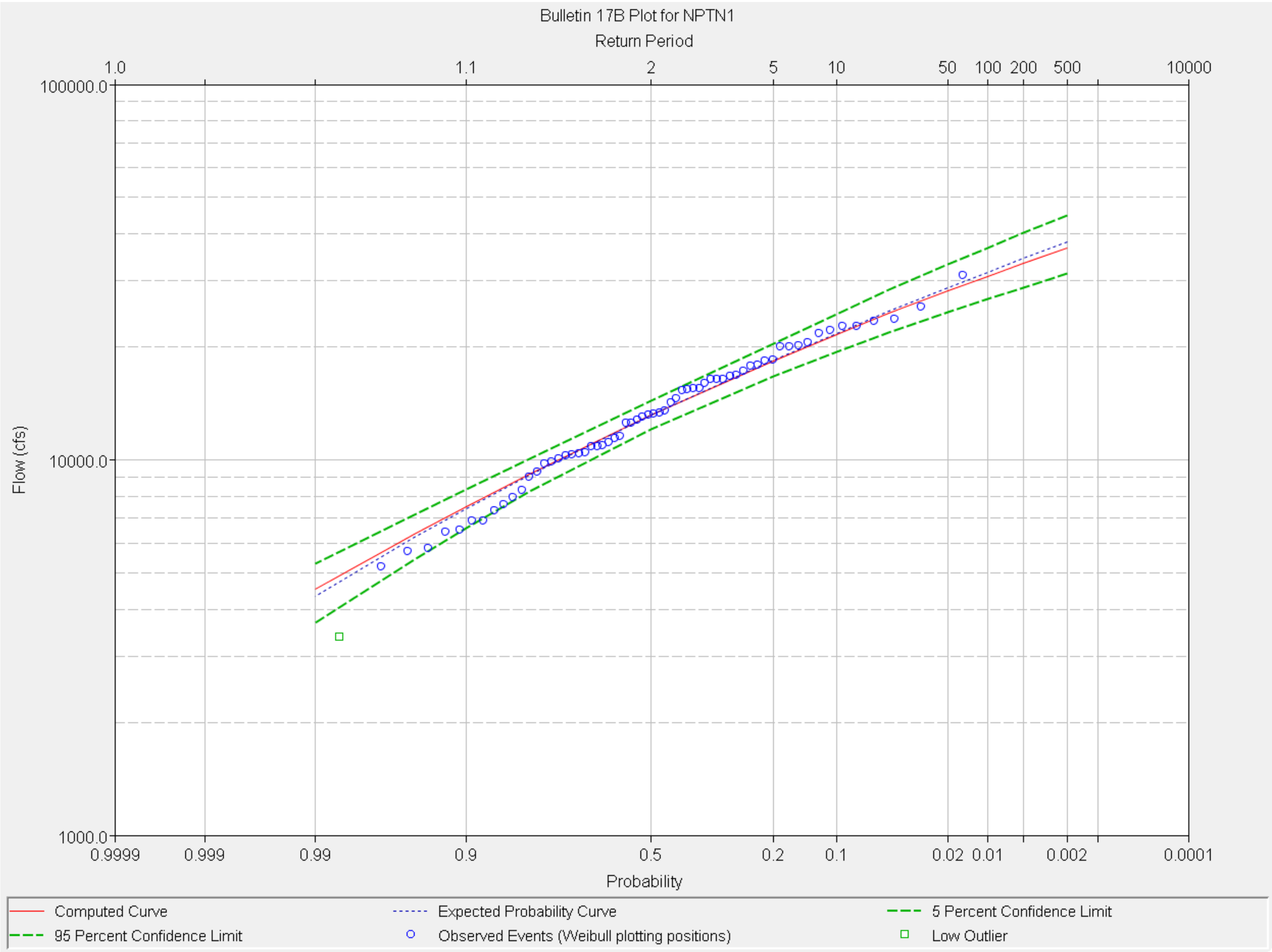

Figure C-7. Bulletin 17B plot for North Platte

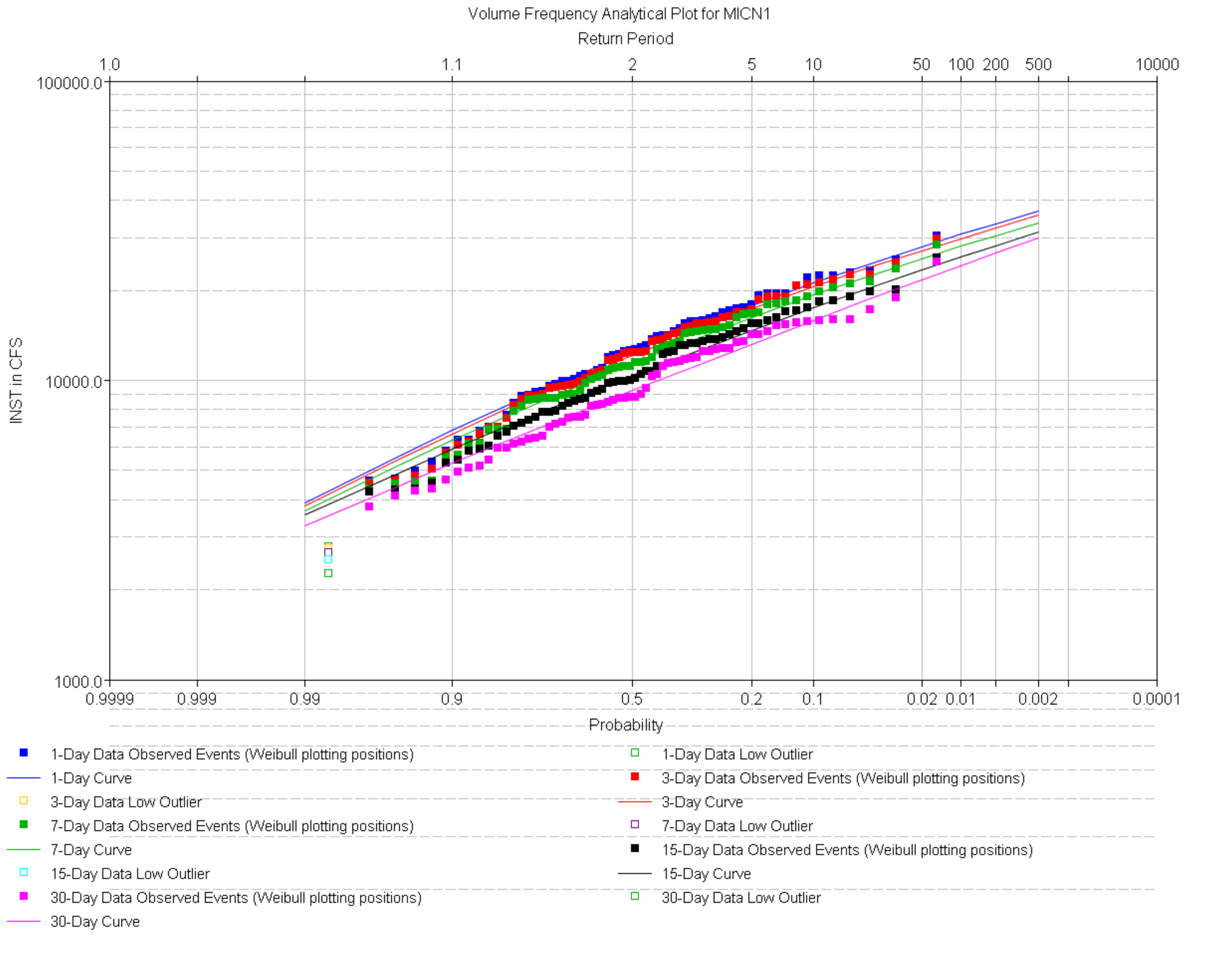

Figure C-8. Volume-Duration-Frequency curves for Mitchell

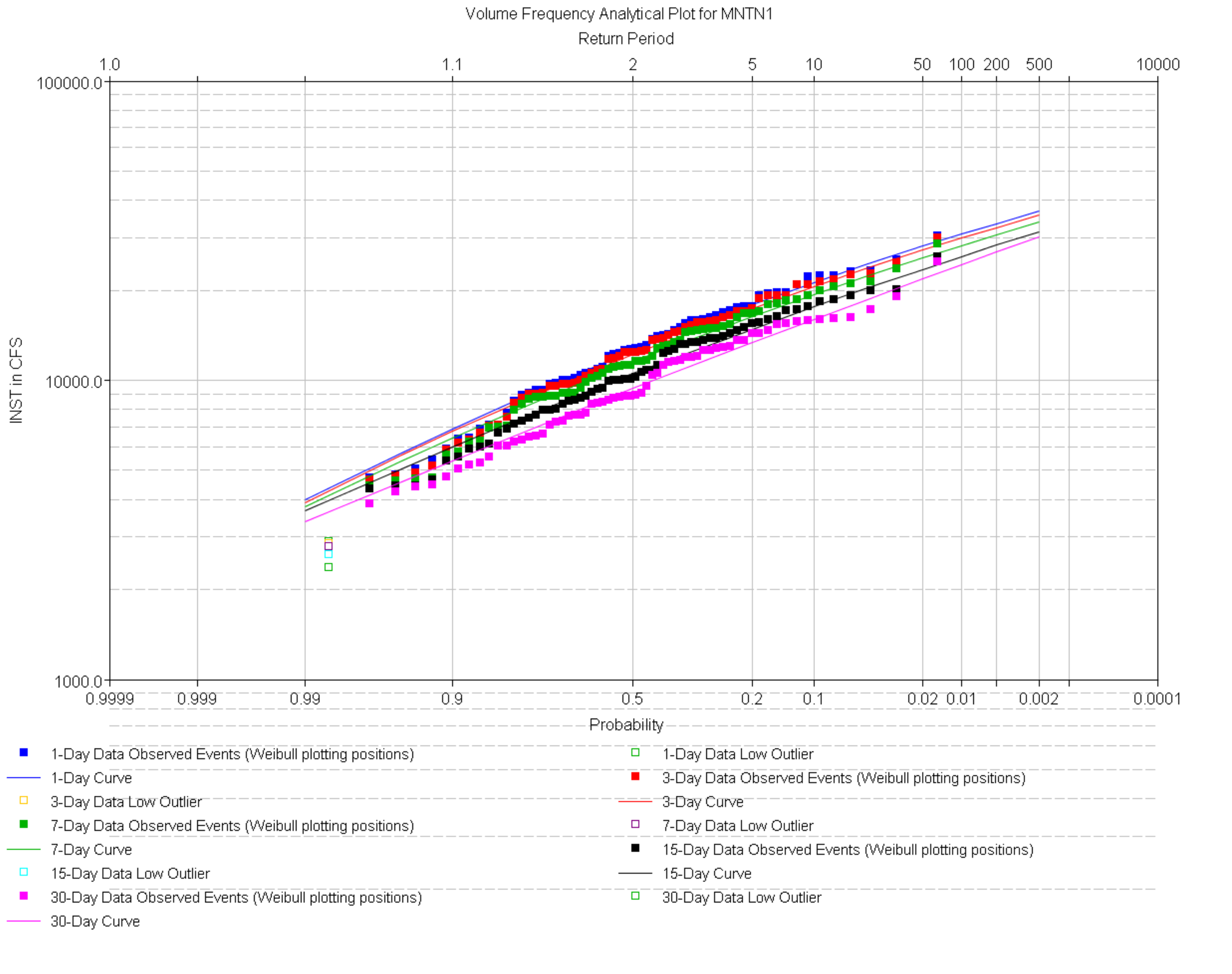

Figure C-9. Volume-Duration-Frequency curves for Minatare

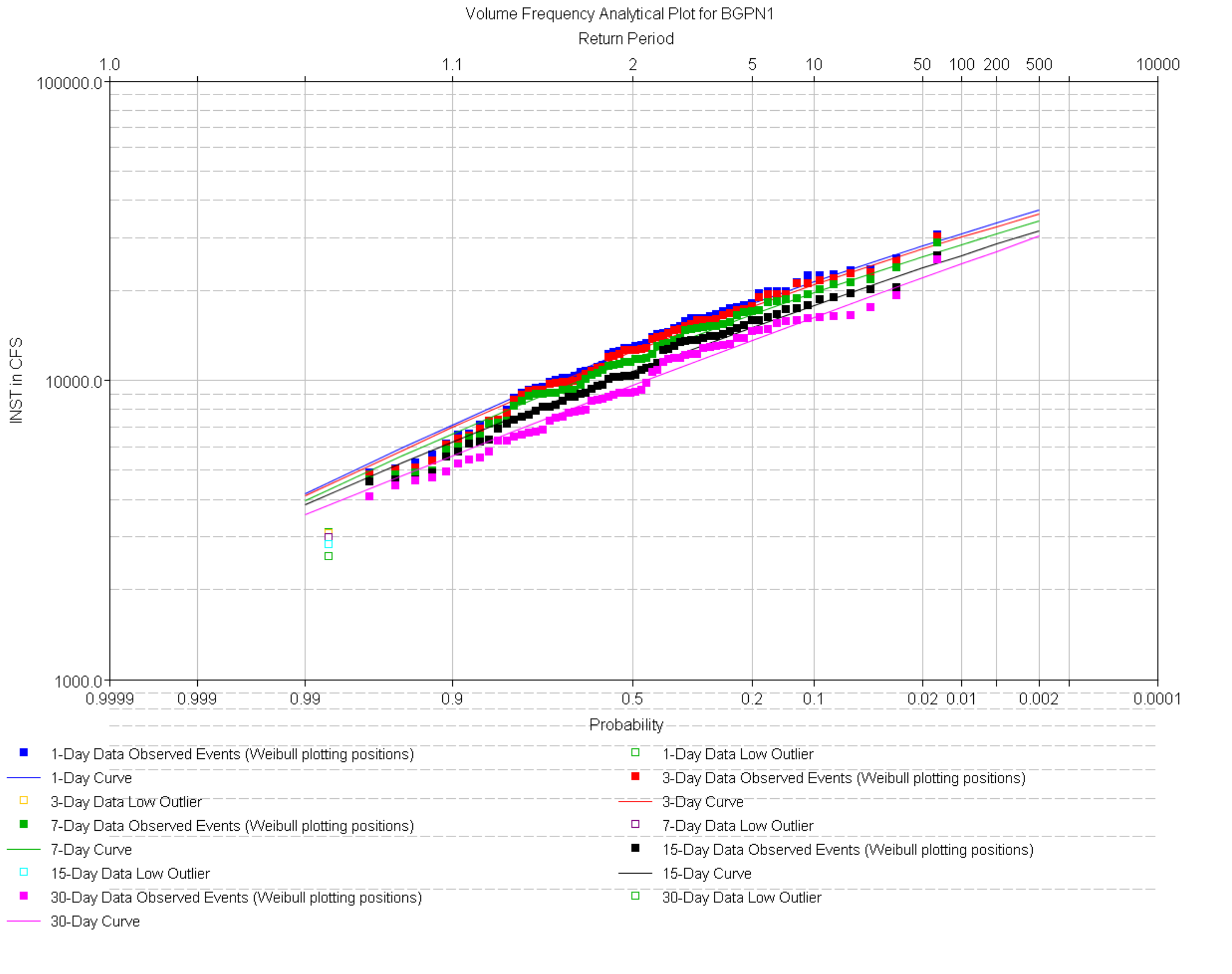

Figure C-10. Volume-Duration-Frequency curves for Bridgeport

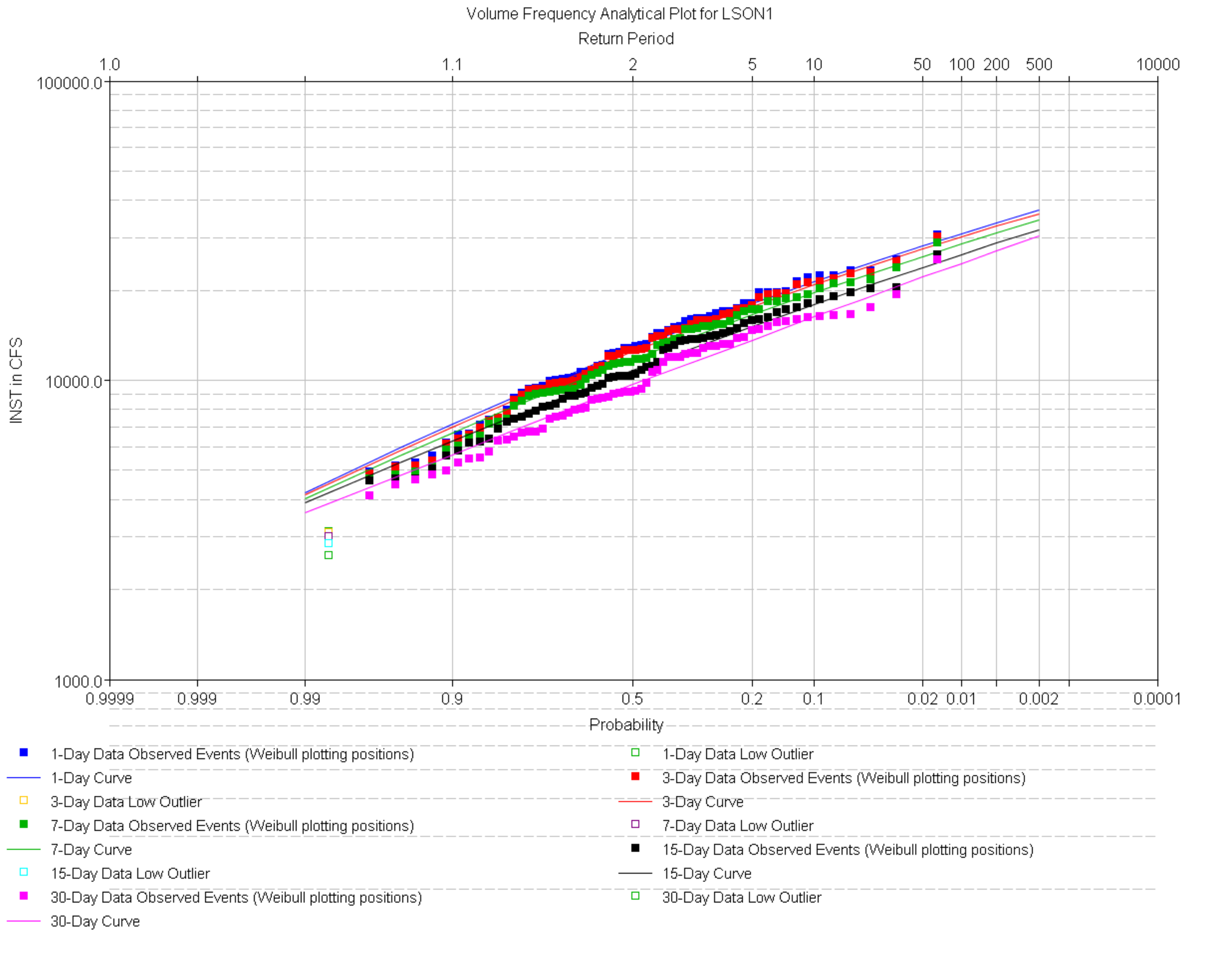

Figure C-11. Volume-Duration-Frequency curves for Lisco

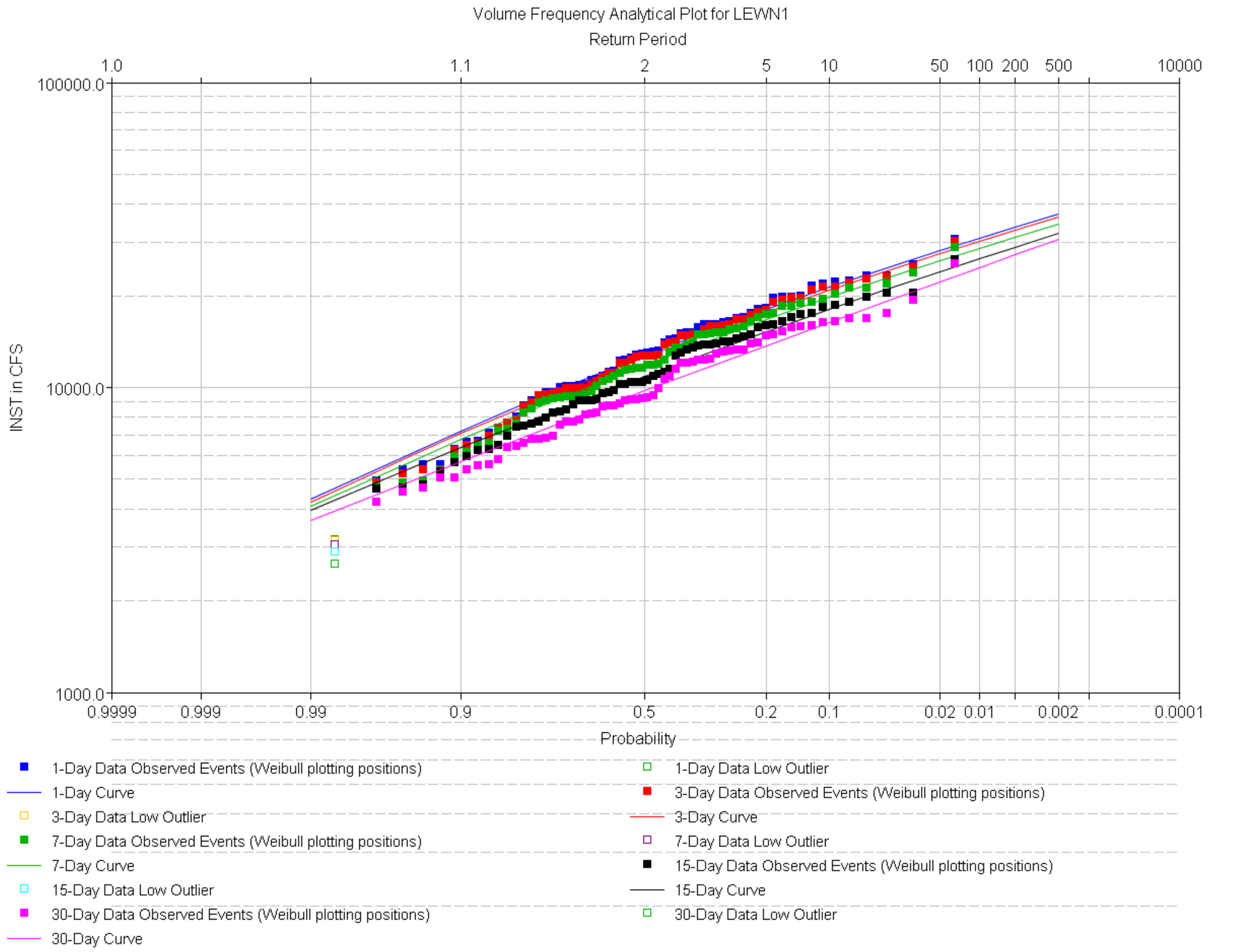

Figure C-12. Volume-Duration-Frequency curves for Lewellen

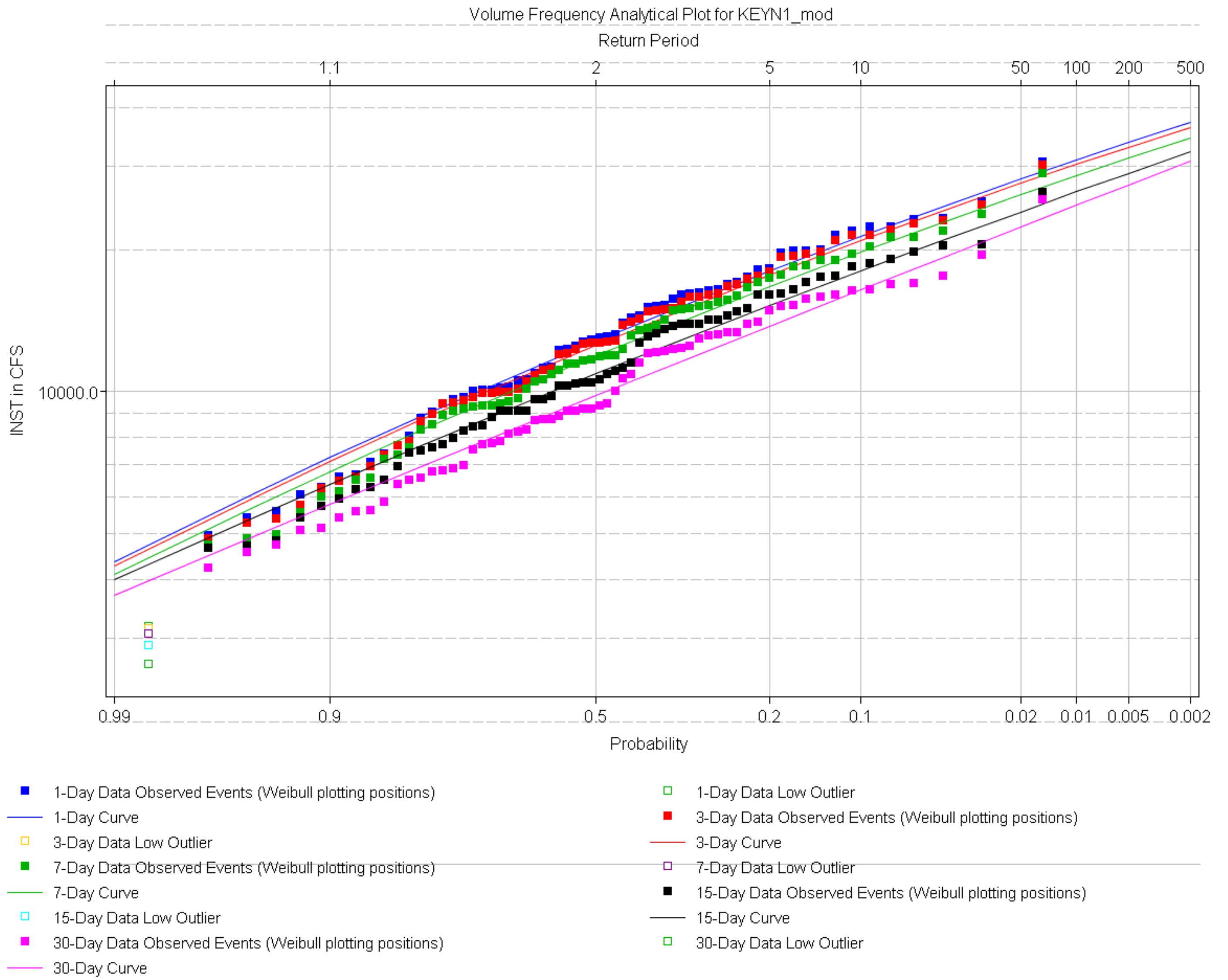

Figure C-13. Volume-Duration-Frequency curves for Keystone

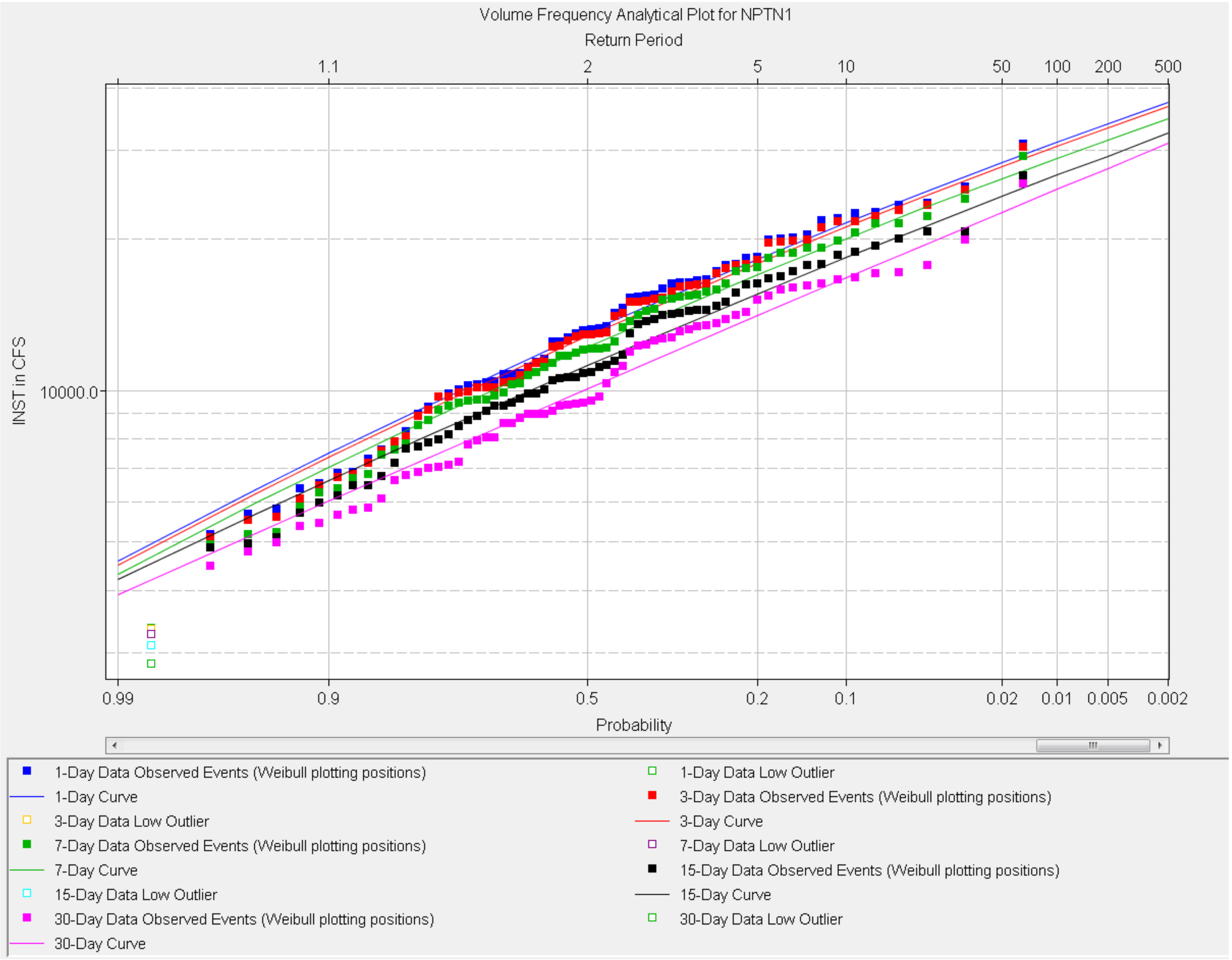

Figure C-14. Volume-Duration-Frequency curves for North Platte

Appendix D Reservoir Modeling Rules

SETW4 – Seminoe Reservoir

Operations Prior to RES-J

1. *LOOKUP AVG_IN_1* converts the positive inflow time series to an INFW data type for using in the following unit hydrograph operation.
2. *UNIT-HG AVG_IN_2* accumulates the total inflow over a running 14 day period.
3. *LOOKUP AVG_IN_3* scales down the accumulated inflow to get a final 14-day running average of reservoir inflows.
4. *WEIGH-TS SWE* averages two SWE time series (NGTC2UP2 and SRAW4UP2) for input to RES-J.

RES-J Model Components

1. NODE SWE_TRIGGER sets a value used to estimate how much inflow the year will have.
2. NODE REL_TRIGGER sets a value that determines when to switch from winter to summer releases.
3. RESERVOIR SET represents Seminoe Reservoir.
4. NODE ROOT has no purpose other than to provide a downstream connection point for all components as required by RES-J.

RES-J Methods

1. **LOOKUP3 SWE_TRIGGER REPEAT** repeats the previous trigger value. This is accomplished by setting the ending discharge for the SWE_TRIGGER node equal to the starting discharge. Starting discharge values in the rows are decreased slightly (i.e. 1 is represented by 0.99) to avoid rounding errors by RES-J. This method executes every time step.
2. **LOOKUP3 SWE_TRIGGER YEAR_TYPE** sets the year type as 0 (dry) to 5 (very wet). Classification is based on the date and the average simulated SWE between the NGTC2UPR and SRAW4UPR sub-basins. This method runs on the first day of the month from February through April. The rule that activates this method is setup using a date format of: MM/DD_HH where M=Month, D=Day, H=Hour. Using a 7-hour range for each date (as can be seen in the rule) ensures that at least one 6-hour time step is included within the range.
3. **LOOKUP3 REL_TRIGGER TURN_ON_DRY** sets the release trigger to one when conditions are right. The average inflow must exceed a certain value that changes based on pool elevation. The inflow/pool table is calibrated based on a dry year type. This method runs between February 1 and July 1, when SWE_TRIGGER is 0 or 1, and the release trigger has not yet been activated.
4. **LOOKUP3 REL_TRIGGER TURN_ON_AVG** sets the release trigger to one when conditions are right. The average inflow must exceed a certain value that changes based on pool elevation. The inflow/pool table is calibrated based on an average year type. This method runs between February 1 and July 1, when SWE_TRIGGER is 2 or 3, and the release trigger has not yet been activated.
5. **LOOKUP3 REL_TRIGGER TURN_ON_WET** sets the release trigger to one when conditions are right. The average inflow must exceed a certain value that changes based on pool elevation. The inflow/pool table is calibrated based on a wet year type. This method runs between February 1 and July 1, when SWE_TRIGGER is 4, and the release trigger has not yet been activated.
6. **LOOKUP3 REL_TRIGGER TURN_ON_VWET** sets the release trigger to one when conditions are right. The average inflow must exceed a certain value that changes based on pool elevation. The inflow/pool table is calibrated based on a very wet year type. This method runs between

February 1 and July 1, when SWE_TRIGGER is 5, and the release trigger has not yet been activated.

7. **LOOKUP3 REL_TRIGGER KEEP_ON** sets the trigger to a value of one. This method runs between February 1 and August 30, whenever the release trigger was active at the end of the previous time step.
8. **SETSUM SET WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:
    a. **LOOKUP3 SET PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
    b. **LOOKUP3 SET EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
9. **LOOKUP3 SET WINT_RELEASE** prescribes a release for normal off-season operations based on pool elevation and date. This method runs whenever REL_TRIGGER equals zero.
10. **LOOKUP3 SET SUMM_REL_DRY** sets a release during the summer release season based on pool elevation and date. This method is calibrated for dry years and runs whenever REL_TRIGGER is one and SWE_TRIGGER is 0 or 1.
11. **LOOKUP3 SET SUMM_REL_AVG** sets a release during the summer release season based on pool elevation and date. This method is calibrated for average years and runs whenever REL_TRIGGER is one and SWE_TRIGGER is 2 or 3.
12. **LOOKUP3 SET SUMM_REL_WET** sets a release during the summer release season based on pool elevation and date. This method is calibrated for wet years and runs whenever REL_TRIGGER is one and SWE_TRIGGER is 4.
13. **LOOKUP3 SET SUM_REL_VWET** sets a release during the summer release season based on pool elevation and date. This method is calibrated for very wet years and runs whenever REL_TRIGGER is one and SWE_TRIGGER is 5.
14. **SPILLWAY SET SPILL** specifies supplemental releases when the pool elevation is high. The physical spillway is gated, so the parameters were estimated based on historical values and the listed maximum spill. This method executes whenever the pool elevation is greater than 6352 ft.
15. **ADJUST SET SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.
16. **ADJUST SET ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

PTDW4 – Pathfinder Reservoir

Operations Prior to RES-J

None.

RES-J Model Components

1. RESERVOIR PTD represents Pathfinder Reservoir.

RES-J Methods

1. **SETSUM PTD WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:
    a. **LOOKUP3 PTD PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
    b. **LOOKUP3 PTD EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
2. **SETRELEASE PTD NORMAL** prescribes releases based on typical reservoir operations. This method executes every time step.
3. **SPILLWAY PTD HIGH_SPILL** specifies supplemental releases when the pool elevation is high. The physical spillway is uncontrolled, and the parameters were taken from a USBR chart detailing the spillway rating curve. This method executes whenever the pool elevation is greater than 5849.5 ft.
4. **ADJUST PTD SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.
5. **ADJUST PTD ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

ALCW4 – Alcova Reservoir

Operations Prior to RES-J

1. *Consumptive Use* model. See calibration project report from Riverside (2009) for details on the standard consumptive use modeling template.

RES-J Model Components

1. RESERVOIR ALC represents Alcova Reservoir.

RES-J Methods

1. **SETSUM ALC WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following four methods:
    a. **SETWITHDRAW ALC CU_DIVERSION** withdraws the simulated consumptive use demand calculated prior to RES-J. This demand is not scaled or altered in any way within RES-J.
    b. **LOOKUP3 ALC PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
    c. **LOOKUP3 ALC EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
2. **SETELEVATION ALC SEASONAL** sets the reservoir elevation to 5488.25 ft from November through March, and 5498.5 from May through September. April and October are a linear transition from one elevation to the other. This method executes every time step.
3. **ADJUST ALC SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.

4. **ADJUST ALC ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

GLEW4 – Glendo Reservoir and GUEW4 – Guernsey Reservoir

Operations Prior to RES-J

1. *Consumptive Use* model. See calibration project report from Riverside (2009) for details on the standard consumptive use modeling template.

RES-J Model Components

1. NODE CUDEMAND echoes the value of the simulated consumptive use demand calculated prior to RES-J.
2. NODE DECIDE_REL sets a value that guides the reservoir releases. The value is based on pool elevation at both reservoirs, date, and CU demand.
3. RESERVOIR GLE represents Glendo Reservoir.
4. REACH GLE_GUE represents the reach between Glendo and Guernsey reservoirs.
5. RESERVOIR GUE represent Guernsey Reservoir.
6. NODE ROOT has no purpose other than to provide a downstream connection point for all components as required by RES-J.

RES-J Methods

1. **SETMIN DECIDE_REL MIN_FLOW** executes every time step. The output of the DECIDE_REL node is set to the smaller of the two contained methods. Because RES-J treats node augmentations as negative diversions, this SETMIN method actually performs as a SETMAX method, in that it outputs the largest augmentation between the two methods. Augmentations are stored internally as negative values, so the SETMIN method takes the more negative of the two, which corresponds to the largest augmentation.
    a. **SETSUM DECIDE_REL TOTAL_REL** adds together the flows specified by the following three methods:
        i. **LOOKUP3 DECIDE_REL CU_DEMAND** outputs the simulated CU demand scaled up or down according to pool elevation and magnitude of the demand.
        ii. **LOOKUP3 DECIDE_REL AUGMENT** outputs a number between -4100 cfs and +9500 cfs, in order to alter the scaled CU demand based on date and pool elevation. This method is used to include date as a decision variable. The output from this method is added to the CU_DEMAND method above to create a total release recommendation.
        iii. **LOOKUP3 DECIDE_REL REDUCE_AUG** looks at the pool elevation at Guernsey Reservoir and if it is high enough (> 4405) will reduce the recommended release from Glendo to avoid having Glendo release to fill Guernsey when Guernsey is already full.
    b. **LOOKUP3 DECIDE_REL MINFLOW** sets a value of zero at all times. As part of the SETMIN, this method ensures that the final result of this node is never negative.
2. **SETSUM GLE WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:

   a. **LOOKUP3 GLE PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
   b. **LOOKUP3 GLE EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
3. **LOOKUP3 GLE RELEASE** causes the reservoir to release whatever value the DECIDE_REL node outputs. This release is never allowed to go below 27 cfs, regardless of what the node output is. This method executes every time step.
4. **SPILLWAY GLE HIGH_SPILL** specifies supplemental releases when the pool elevation is high. The physical spillway is uncontrolled, and the maximum flow was found on the USBR website. All other parameters were estimated based on the maximum flow. This method executes whenever the pool elevation is greater than 4652 ft.
5. **ADJUST GLE SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.
6. **ADJUST GLE ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.
7. **LAGK GLE_GUE GUEW4_LAGK** executes every time step and routes releases from Glendo Reservoir downstream to Guernsey Reservoir. The routing method is lag and attenuation, with a constant lag of 6 hours and constant attenuation of 6 hours. The parameters were translated from the calibrated Tatum routing model used by the MBRFC for this reach. Local inflows for the Glendo to Guernsey reach are added to the Glendo releases prior to routing.
8. **SETSUM GUE WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:
   a. **LOOKUP3 GUE PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
   b. **LOOKUP3 GUE EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
9. **SETMAX GUE NORMAL** executes every time step and sets the release from the reservoir to the larger of the following two methods:
   a. **SETRELEASE GUE MIN_RELEASE** specifies a minimum release based on date. This method was paramaterized using typical historical minimum flows.
   b. **SETMIN GUE NORMAL** takes the smaller of the two included methods, which ensures that the output will never be larger than the maximum specified release:
      i. **SETRELEASE GUE MAX_RELEASE** specifies a maximum release based on historical patterns. The maximum releases do not include spill.
      ii. **SETELEVATION GUE NORMAL** sets the elevation of the reservoir to a value matching the historical average based on date.
10. **SPILLWAY GUE HIGH_SPILL** specifies supplemental releases when the pool elevation is high. The physical spillway is gated. All parameters were estimated based on calibration. This method executes whenever the pool elevation is greater than 4417.5 ft.
11. **ADJUST GUE SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.

12. **ADJUST GUE ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

LRVW4 – Wheatland Reservoir #2

Operations Prior to RES-J

1. *Consumptive Use* model. See calibration project report from Riverside (2009) for details on the standard consumptive use modeling template.

RES-J Model Components

1. RESERVOIR WTR represents Wheatland Reservoir #2.

RES-J Methods

1. **SETSUM WTR WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:
    a. **LOOKUP3 WTR PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
    b. **LOOKUP3 WTR EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
2. **LOOKUP3 WTR DEMAND** scales the consumptive use demand determined prior to RES-J based on pool elevation and the magnitude of the demand. A minimum flow of 20 cfs is applied except when the pool elevation is low (below 6955). This method executes every time step.
3. **SPILLWAY WTR HIGH_SPILL** specifies supplemental releases when the pool elevation is high. There are two physical spillways, both gated. All parameters were estimated based on calibration. This method executes whenever the pool elevation is greater than 6963 ft.
4. **ADJUST WTR SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.
5. **ADJUST WTR ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

GAYW4 – Grayrocks Reservoir

Operations Prior to RES-J

None.

RES-J Model Components

1. RESERVOIR GAY represents Grayrocks Reservoir.

RES-J Methods

1. **SETSUM GAY WITHDRAWALS** executes every time step and prescribes a total withdrawal from the reservoir by summing the specified withdrawals from the following three methods:

   a. **LOOKUP3 GAY PRECIP** augments the reservoir (equal to a negative withdrawal) with the observed precipitation. The total augmentation volume is determined by the precipitation amount and the reservoir surface area (estimated using pool elevation).
   b. **LOOKUP3 GAY EVAP** withdraws simulated evaporation from the reservoir surface based on the pool elevation (as a surrogate for surface area), date, and estimated evaporation depths.
2. **SETMAX GAY MINFLOW1** executes from Oct 1 to May 1 and sets the release to the larger of the following two methods:
   a. **LOOKUP3 GAY MINFLOW1** prescribes a legal minimum release of 40 cfs from October through March, and 50 cfs during April. If the pool elevation is below 4385 ft the minimum flow is zero.
   b. **LOOKUP3 GAY NORMAL** prescribes a nearly constant release. The release is small when the pool elevation is below 4405 ft, but increases significantly above that elevation.
3. **SETMIN GAY MAXFLOW** executes from May 1 through Sep 30 and sets the release to the smaller of the following two methods. Put together with the SETMAX method below, this method constrains the release to be between the minimum flow (MINFLOW2) and the maximum flow (MAXFLOW):
   a. **SETMAX GAY MINFLOW2** selects the larger of the following two methods:
      i. **LOOKUP3 GAY MINFLOW2** sets the release to zero when the pool elevation is below 4385 ft. Above that point the minimum flow is 40 cfs or 75% of the inflow, whichever is larger.
      ii. **LOOKUP3 GAY NORMAL** prescribes a nearly constant release. The release is small when the pool elevation is below 4405 ft, but increases significantly above that elevation.
   b. **LOOKUP3 GAY MAXFLOW** outputs a value of 200 cfs at all times. This is the listed legal maximum flow.
4. **SPILLWAY GAY HIGH_SPILL** specifies supplemental releases when the pool elevation is high. The physical spillway is uncontrolled, but no flow information was known. All parameters were estimated based on calibration. This method executes whenever the pool elevation is greater than 4404 ft.
5. **ADJUST GAY SET_TO_OBS** adjusts the reservoir release and pool elevation to observed values whenever possible. This method may be useful in operational forecasting. This method is not currently set to execute.
6. **ADJUST GAY ADJ_CO_SAVE** adjusts the reservoir pool elevation carryover states to observed values. This method may be useful in operational forecasting. This method is not currently set to execute.

KNGN1 – Lake McConaughy

Operations Prior to ResSim

1. A TSTool command file is used to create a monthly repeating pattern of average evaporation rates. Average rates were determined during the previous calibration project (Riverside 2010). Observed precipitation is subtracted from the monthly evaporation to get net evaporation at each time step. This time series is written to HEC-DSS format and input to the ResSim model as an evaporation time series.
2. Consumptive Use model run along with the KNGN1 hydrologic models. See calibration project report from Riverside (2010) for details on the standard consumptive use modeling template.

The final irrigation demand from the CU model is written to HEC-DSS and used by rules in the ResSim model.

ResSim State Variables

1. *EmergencyRelease*: This state variable calculates a recommended release from the reservoir based on current inflow and the previous release. The release is calculated as the greater of 90% of the current inflow, or the previous release.
2. *HighRelease*: This state variable calculates a recommended release based on inflow and pool elevation. The average inflow over the last 7 days (28 time steps) is used along with the current pool elevation.
3. *HighTrigger*: This state variable sets a value of 1 or 0 depending on date, current pool elevation, and a 7-day average of past inflows. The output is used to determine whether to follow the release recommendation from the *HighRelease* state variable.
4. *IrrigationDemand*: This state variable uses the irrigation demand calculated prior to ResSim along with the current pool elevation and date to determine a recommended release from the reservoir. The recommended release is adjusted downward depending on how much water is currently in Korty Canal. The model uses average daily flow in Korty Canal in place of observed or simulated values.

ResSim Model Operations

1. **Emergency Flood Control** Zone: This zone represents the highest storages physically possible, with a constant elevation equal to the dam crest.
    a. *Inflow > 20,000 cfs* If Condition: This condition is active when the current inflow is greater than or equal to 20,000 cfs or when the pool elevation is greater than or equal to 3270 ft. The Morning Glory spillway is used by the model in these conditions.
        i. **E_Release** Rule: This rule releases from all available outlets according to the value calculated in the EmergencyRelease state variable.
    b. **Emergency_Release** Rule: This rule releases according to the value calculated in the EmergencyRelease state variable. Releases are limited to the controlled outlet and will not use the Morning Glory spillway.
    c. **No_MorningGlory** Rule: This rule forces the flow from the Morning Glory spillway to be zero. This rule is present in the Emergency Flood Control, Flood Control, and Conservation zones.
2. **Flood Control** Zone: This zone represents storage that can be used in exceptional conditions with a license waiver from FERC. The top is set to a constant elevation of 3267 ft.
    a. *High Flow* If Condition: This condition is active when the value calculated by the HighTrigger state variable is equal to 1.
        i. **HighRelease** Rule: This rule sets the release from the reservoir equal to the value calculated by the HighRelease state variable. Releases are limited to the controlled outlet and will not use the Morning Glory spillway. This rule is present in both the Flood Control and Conservation zones.
    b. *Low Flow* If Condition: This condition is active whenever the High Flow If Condition is not active, i.e. when the value of the HighTrigger state variable is equal to 0.
        i. **Irrigation Release** Rule: This rule sets the release from the reservoir equal to the value calculated by the IrrigationDemand state variable. Releases are limited to the controlled outlet and will not use the Morning Glory spillway. This rule is present in both the Flood Control and Conservation zones.

   c. **No_MorningGlory** Rule: This rule forces the flow from the Morning Glory spillway to be zero. This rule is present in the Emergency Flood Control, Flood Control, and Conservation zones.
3. **Conservation** Zone: This zone represents the normal storage limit with a constant elevation of 3265 ft. This zone is set as the guide curve in ResSim.
   a. *HighFlow* If Condition: This condition is active when the value calculated by the HighTrigger state variable is equal to 1.
      i. **HighRelease** Rule: This rule sets the release from the reservoir equal to the value calculated by the HighRelease state variable. Releases are limited to the controlled outlet and will not use the Morning Glory spillway. This rule is present in both the Flood Control and Conservation zones.
   b. *Irrigation Season* If Condition: This condition is active when the current date is between May 1 and October 1.
      i. **Min Release** Rule: This rule sets a minimum release from the reservoir equal to 500 cfs year round. Releases are limited to the controlled outlet and will not use the Morning Glory spillway.
      ii. **Irrigation Release** Rule: This rule sets the release from the reservoir equal to the value calculated by the IrrigationDemand state variable. Releases are limited to the controlled outlet and will not use the Morning Glory spillway. This rule is present in both the Flood Control and Conservation zones.
   c. *Winter* If Condition: This condition is active whenever the HighFlow and Irrigation Season if conditions are not active, i.e. when the HighTrigger state variable is equal to 0 and the date is between October 2 and April 30.
      i. **WinterRelease** Rule: This rule specifies a release from the reservoir based on pool elevation and date. Releases are limited to the controlled outlet and will not use the Morning Glory spillway.
   d. **No_MorningGlory** Rule: This rule forces the flow from the Morning Glory spillway to be zero. This rule is present in the Emergency Flood Control, Flood Control, and Conservation zones.
4. **Inactive** Zone: This zone represents the bottom of the reservoir with a constant elevation of 3131 ft. The zone is special in ResSim and cannot contain any rules.
   a. No rules are defined for the zone.

Appendix E Regulated Flow Frequency Plots

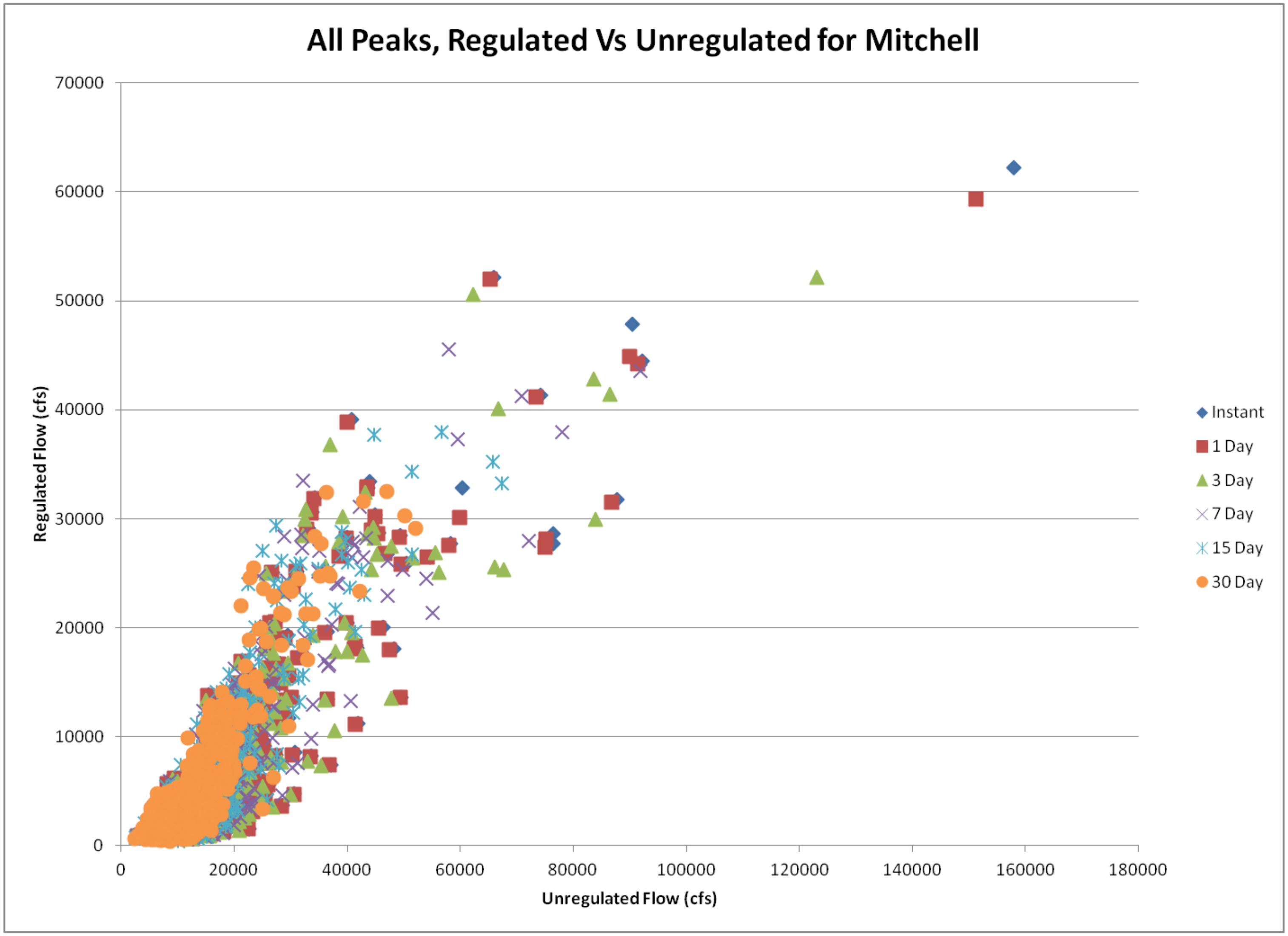

Figure E-1. Regulated vs. Unregulated peaks for Mitchell

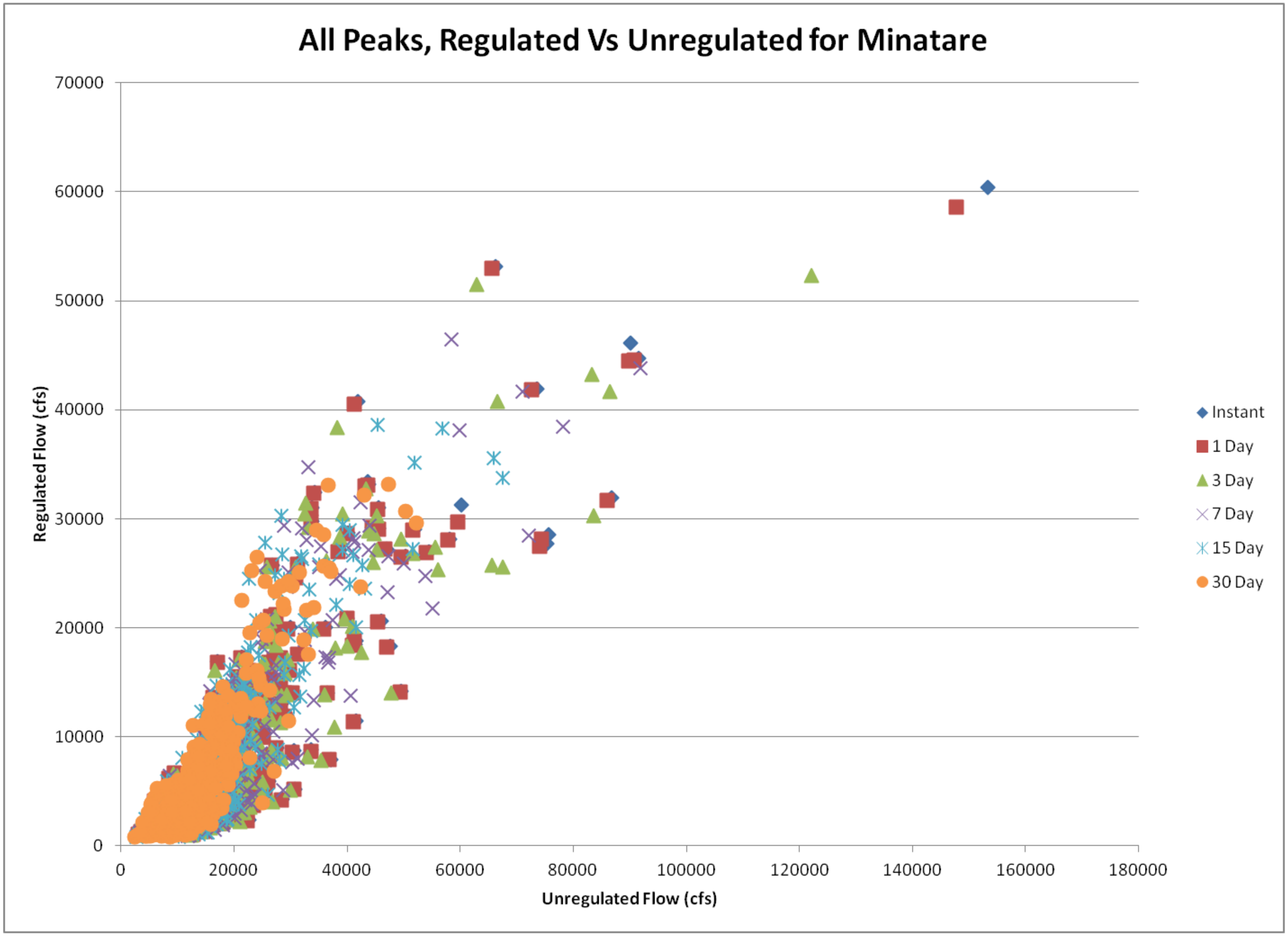

Figure E-2. Regulated vs. Unregulated peaks for Minatare

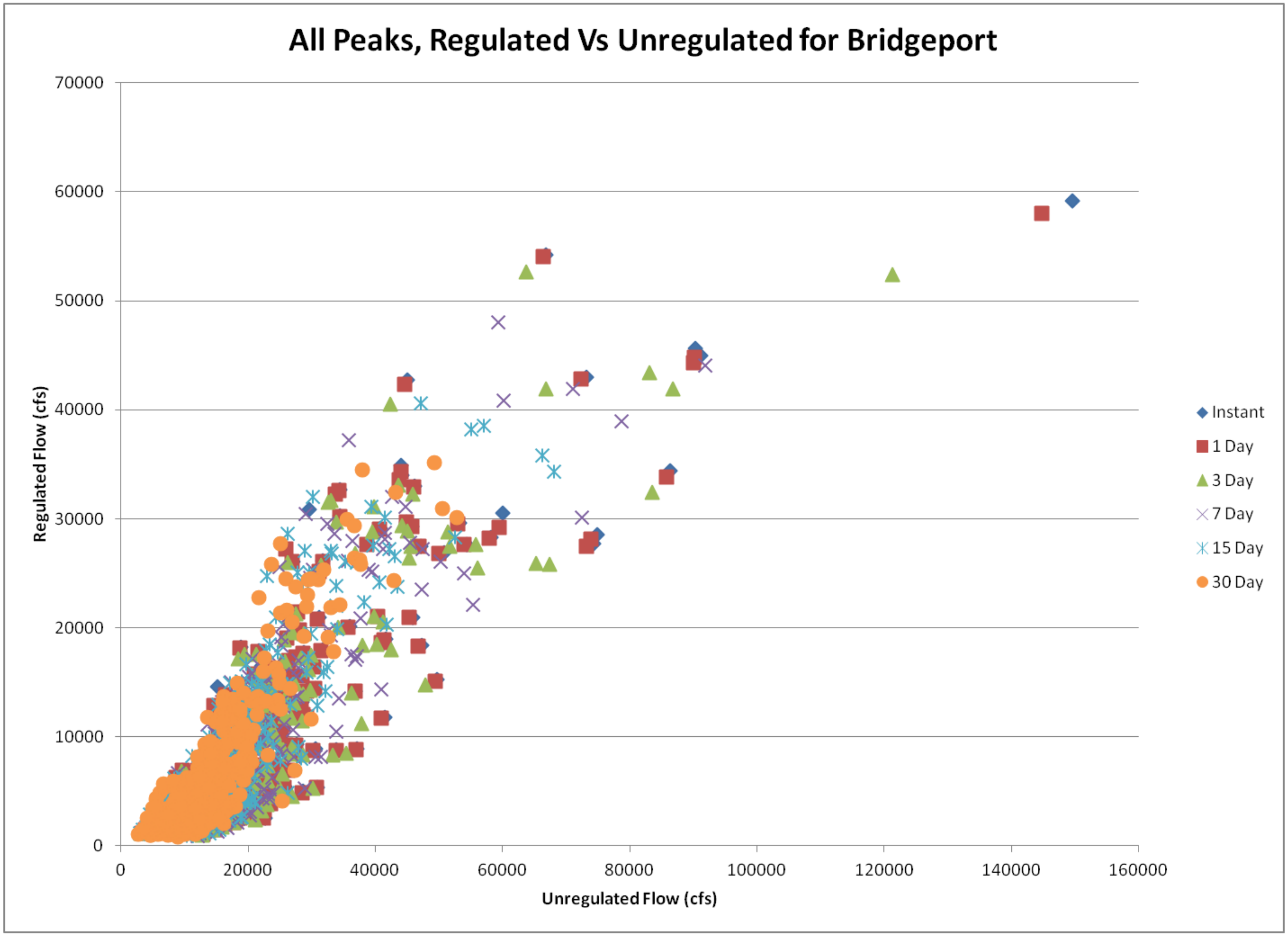

Figure E-3. Regulated vs. Unregulated peaks for Bridgeport

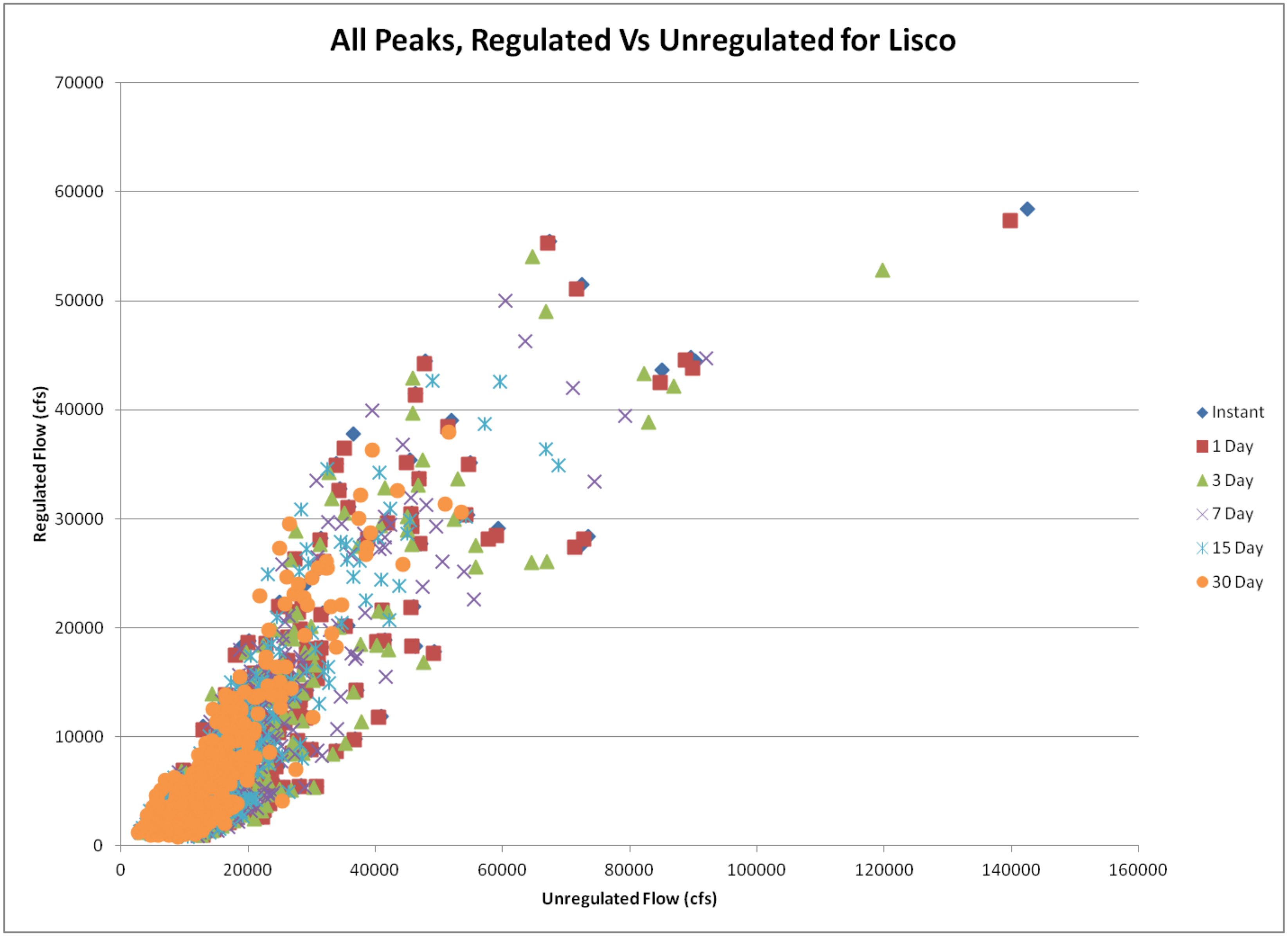

Figure E-4. Regulated vs. Unregulated peaks for Lisco

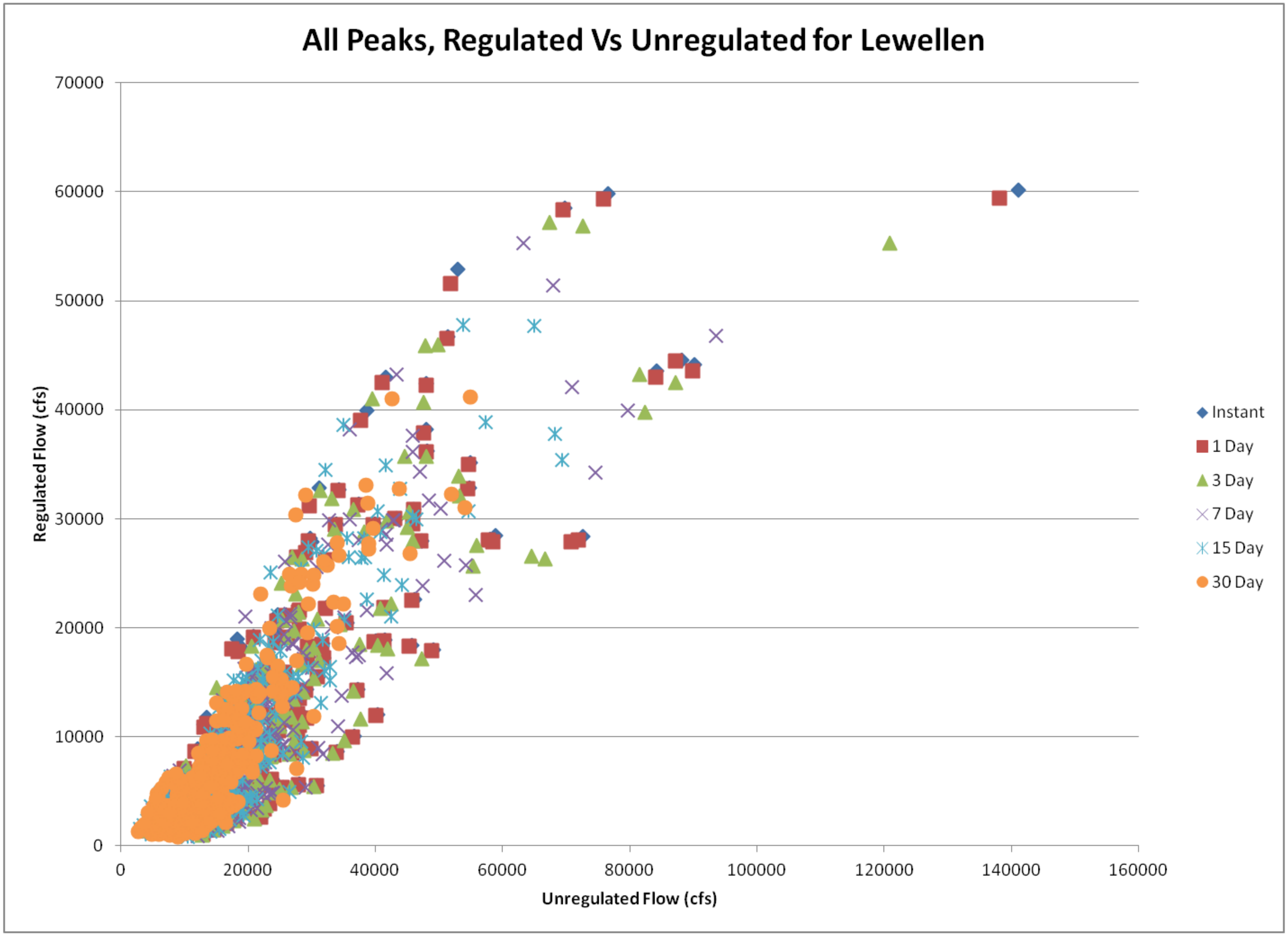

Figure E-5. Regulated vs. Unregulated peaks for Lewellen

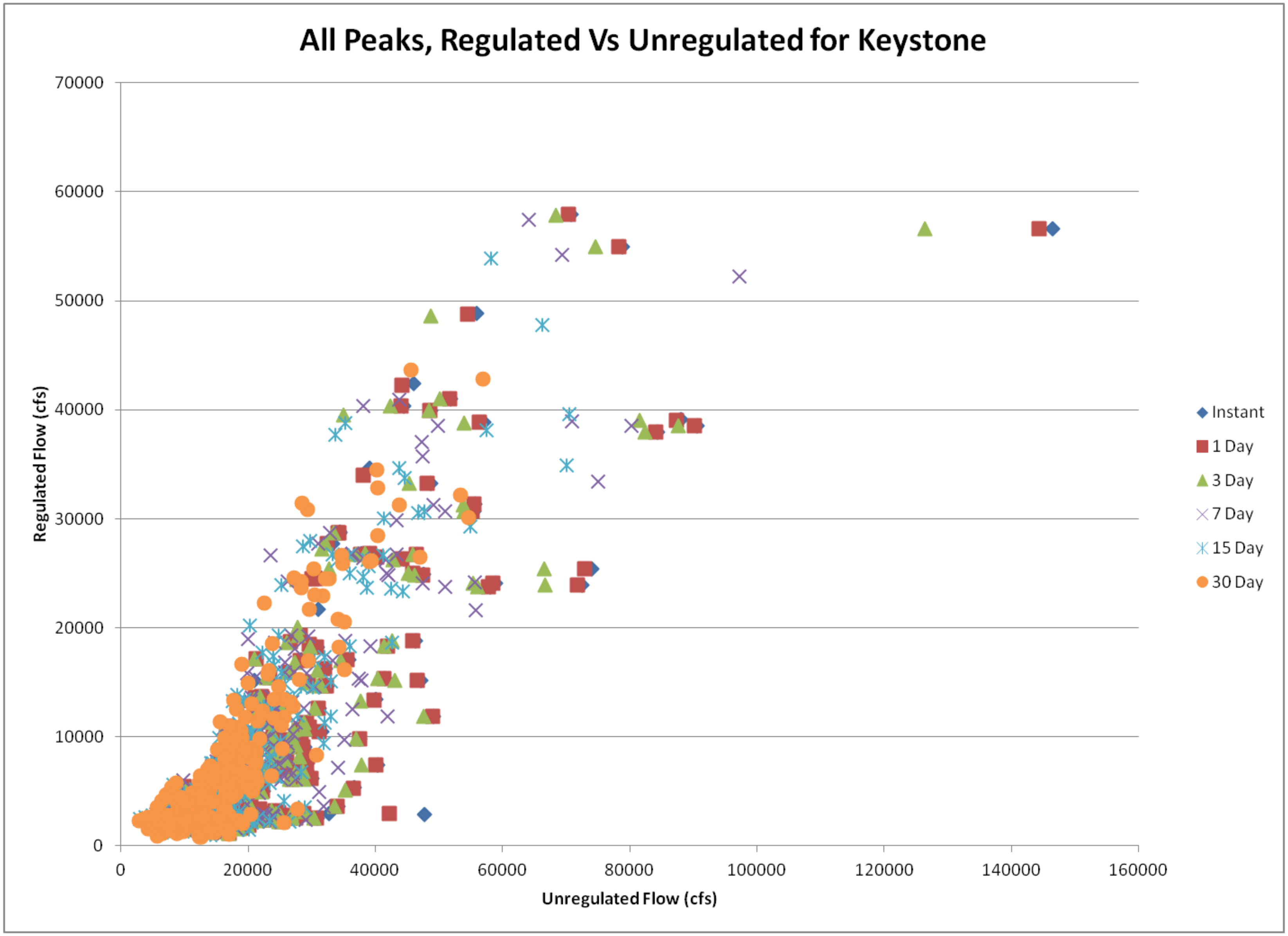

Figure E-6. Regulated vs. Unregulated peaks for Keystone

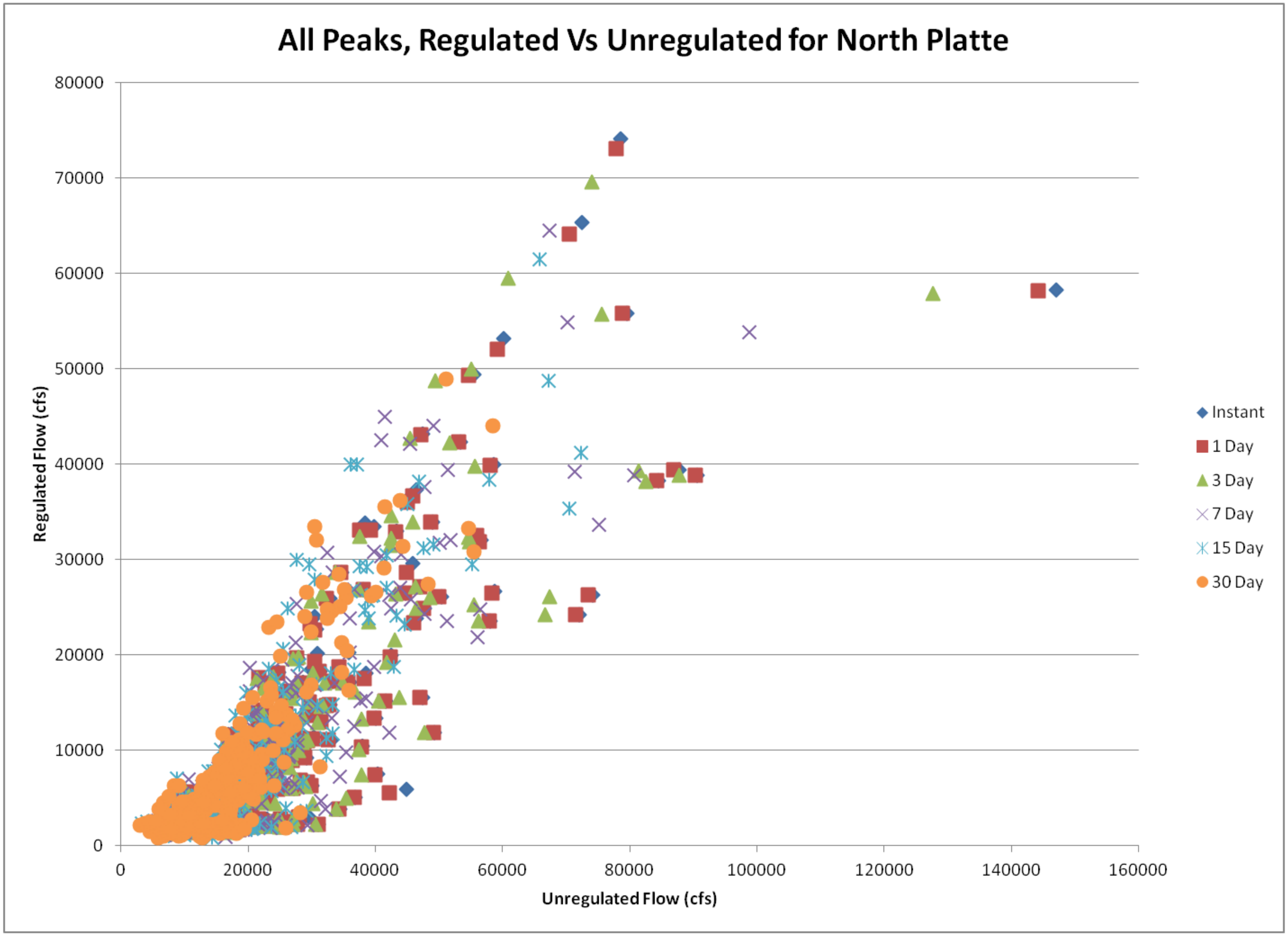

Figure E-7. Regulated vs. Unregulated peaks for North Platte

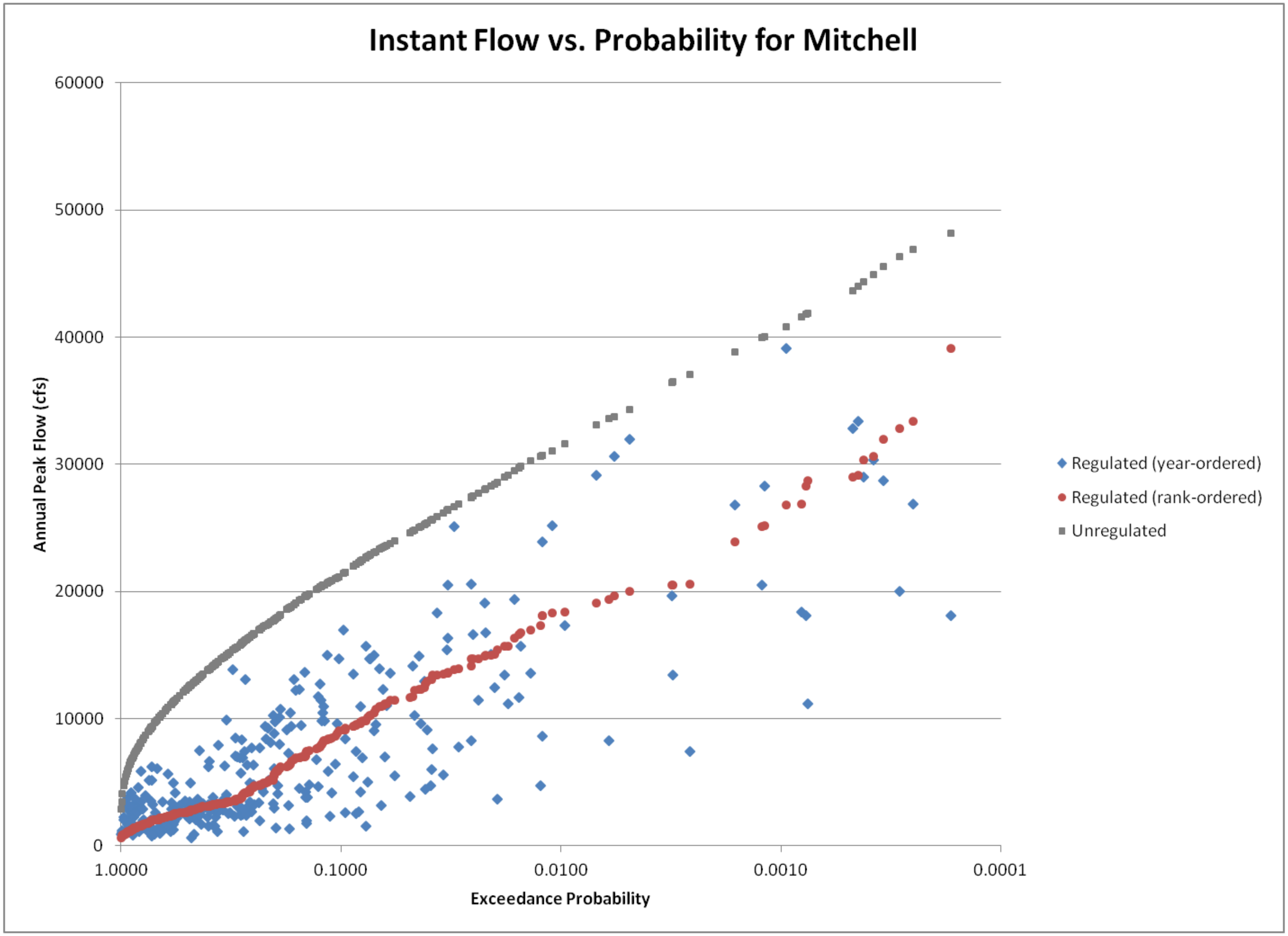

Figure E-8. Instantaneous peaks vs. probability for Mitchell

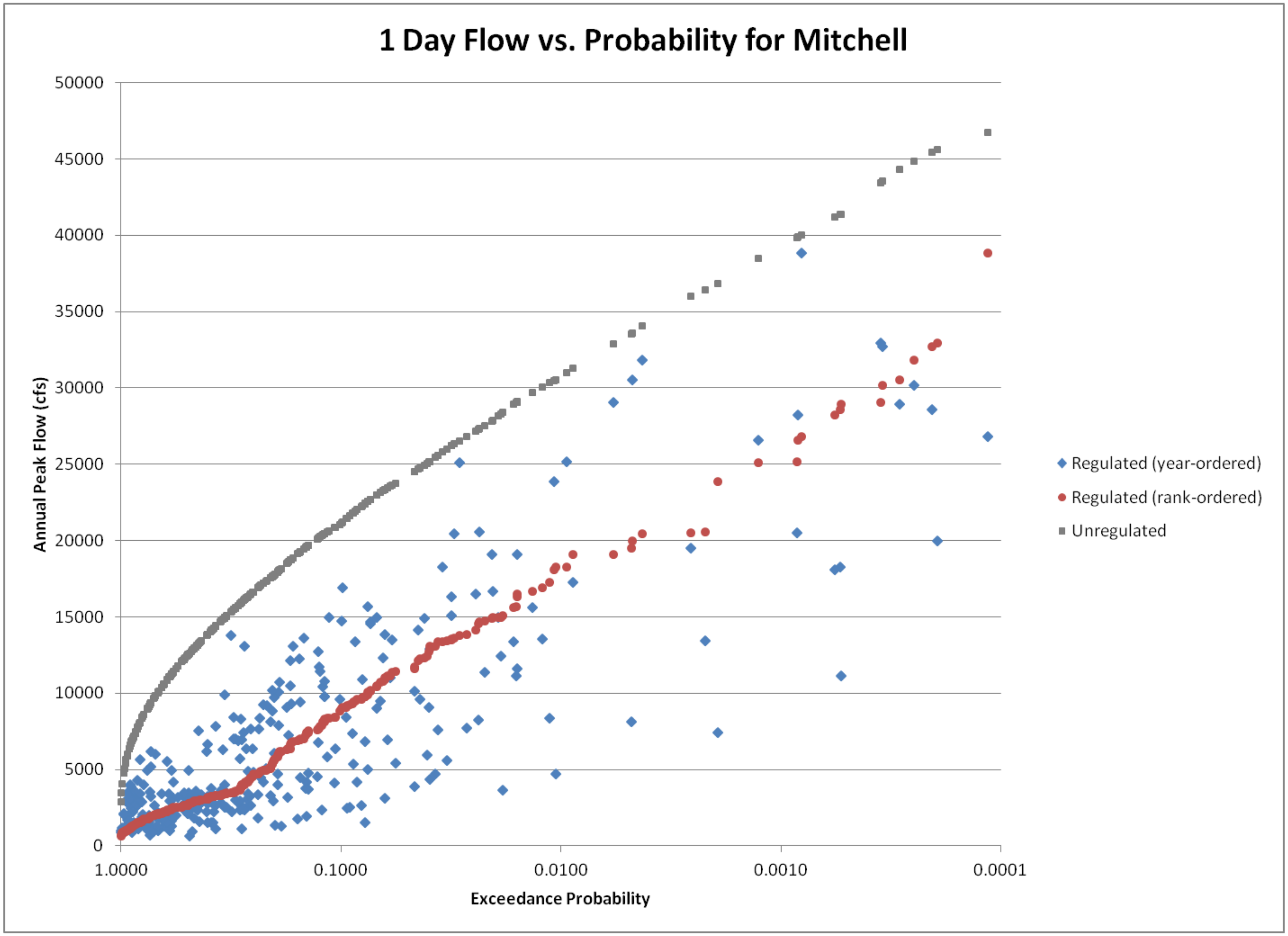

Figure E-9. 1 day peaks vs. probability for Mitchell

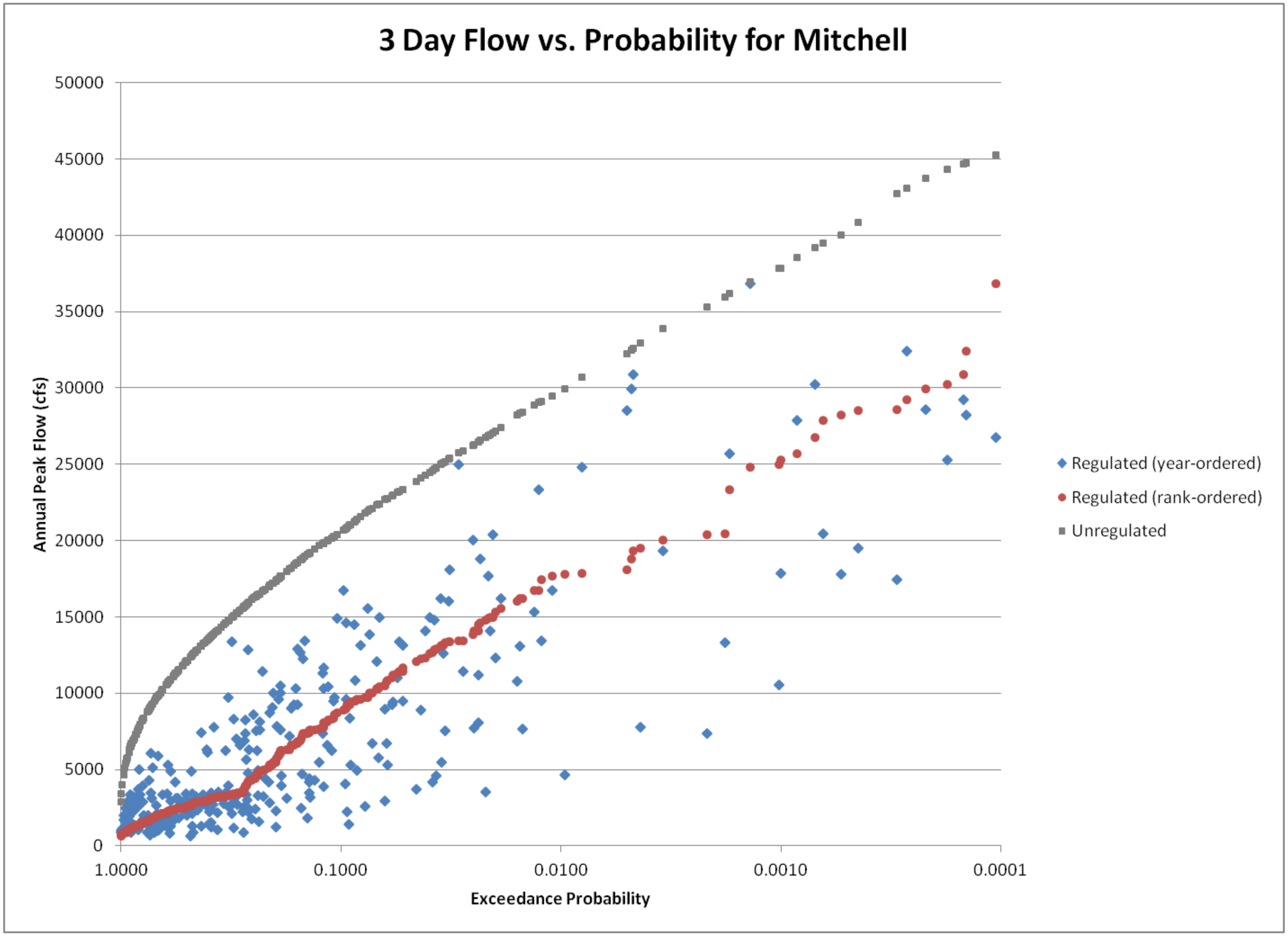

Figure E-10. 3 day peaks vs. probability for Mitchell

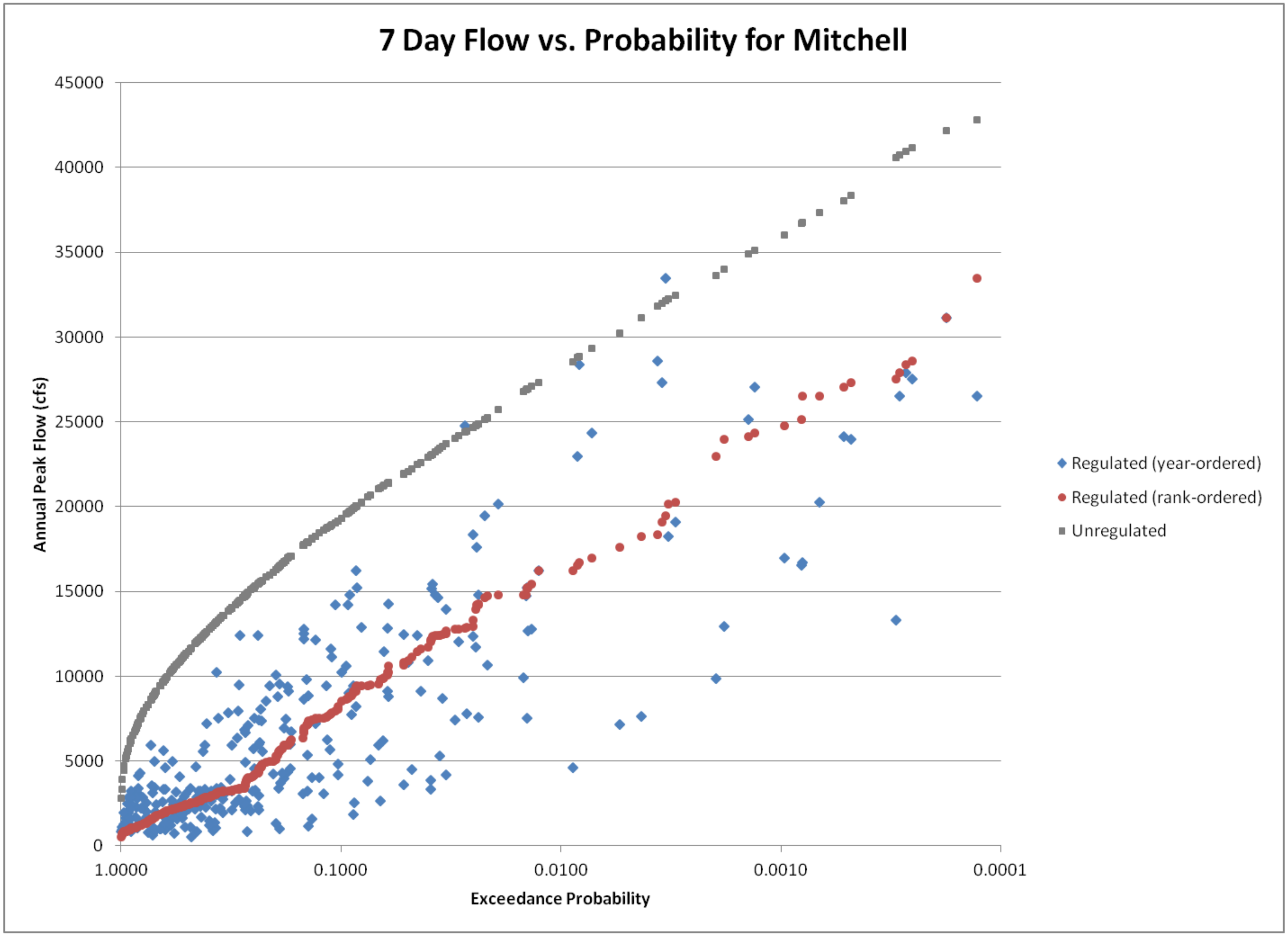

Figure E-11. 7 day peaks vs. probability for Mitchell

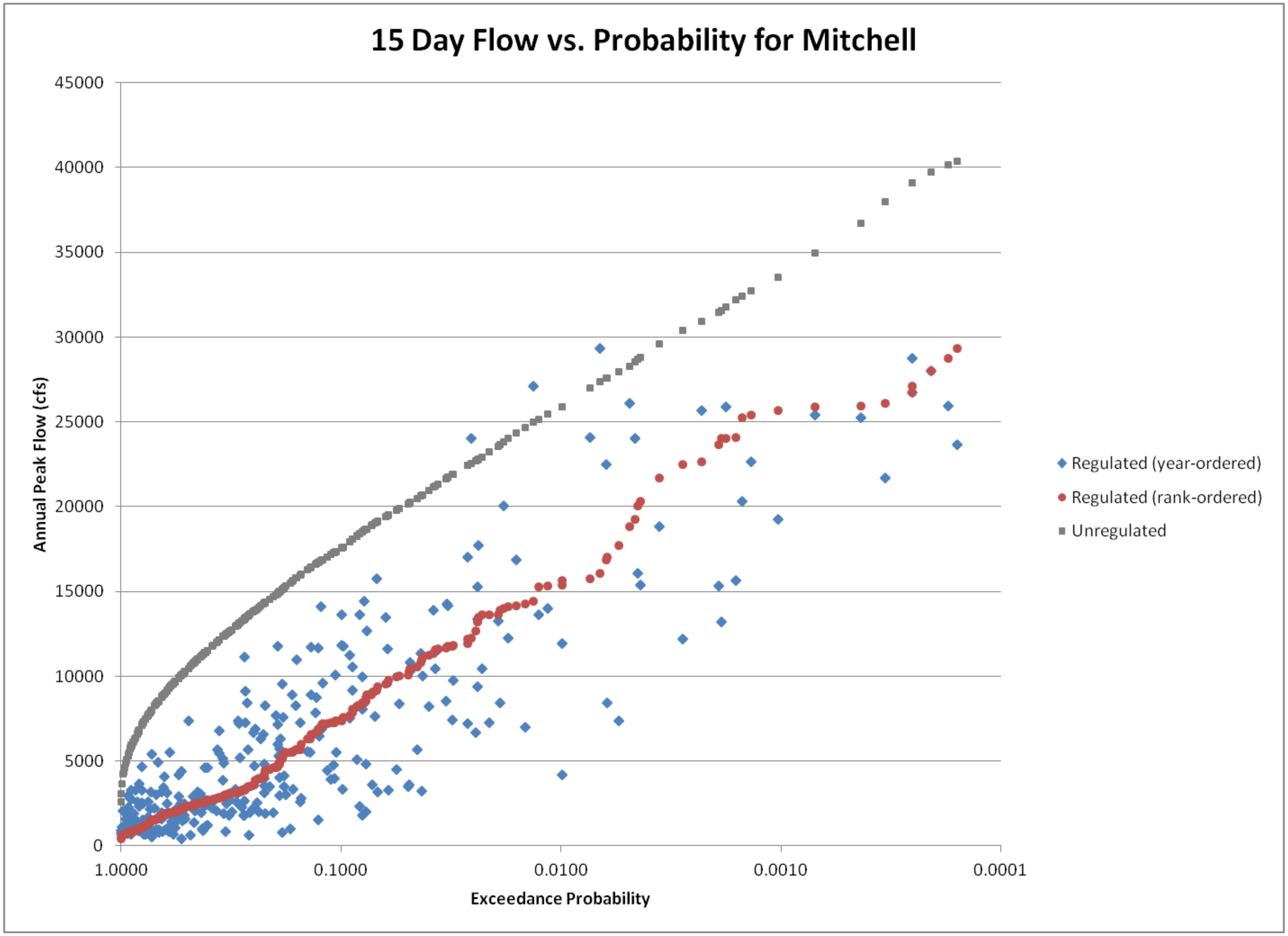

Figure E-12. 15 day peaks vs. probability for Mitchell

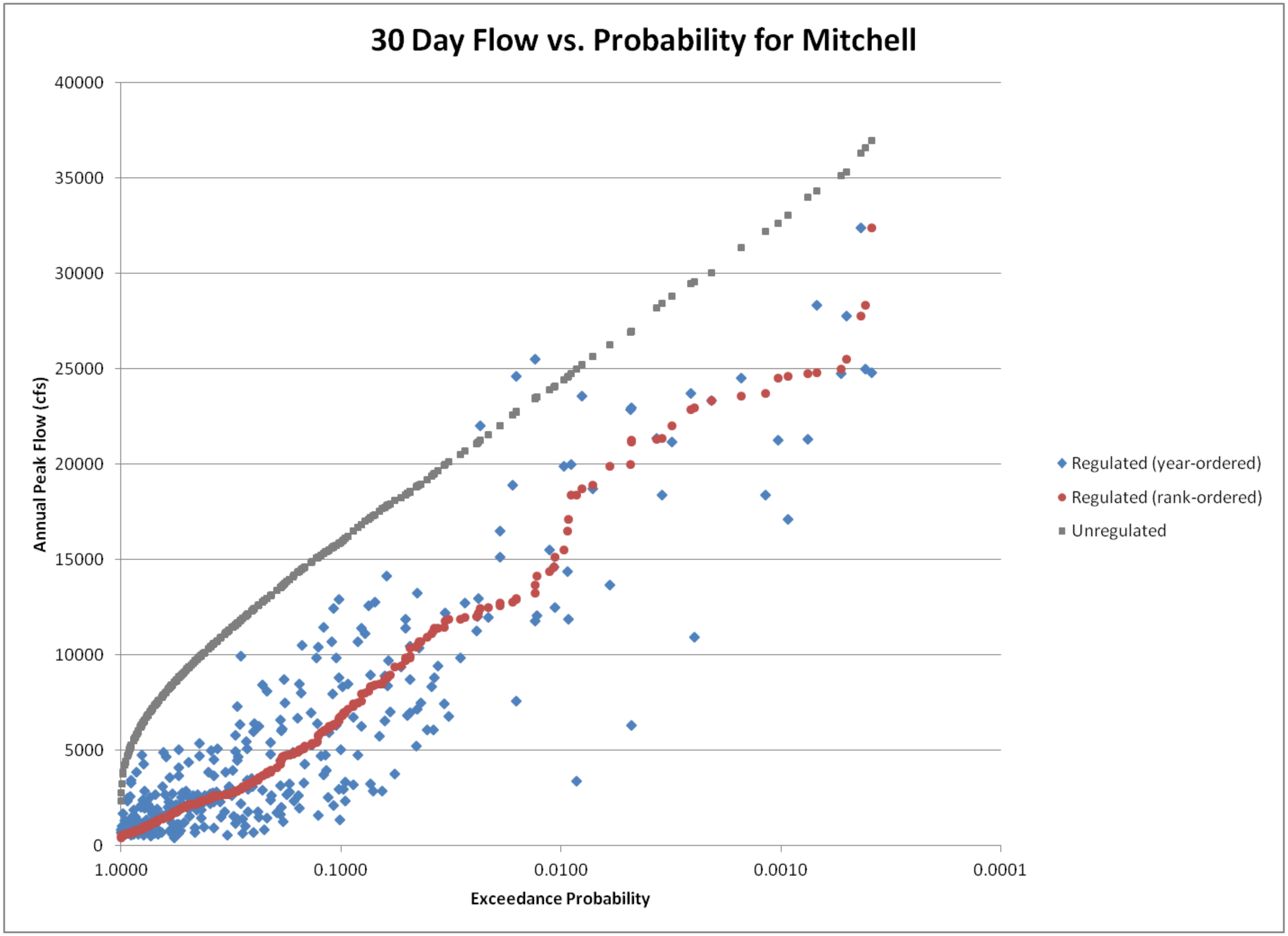

Figure E-13. 30 day peaks vs. probability for Mitchell

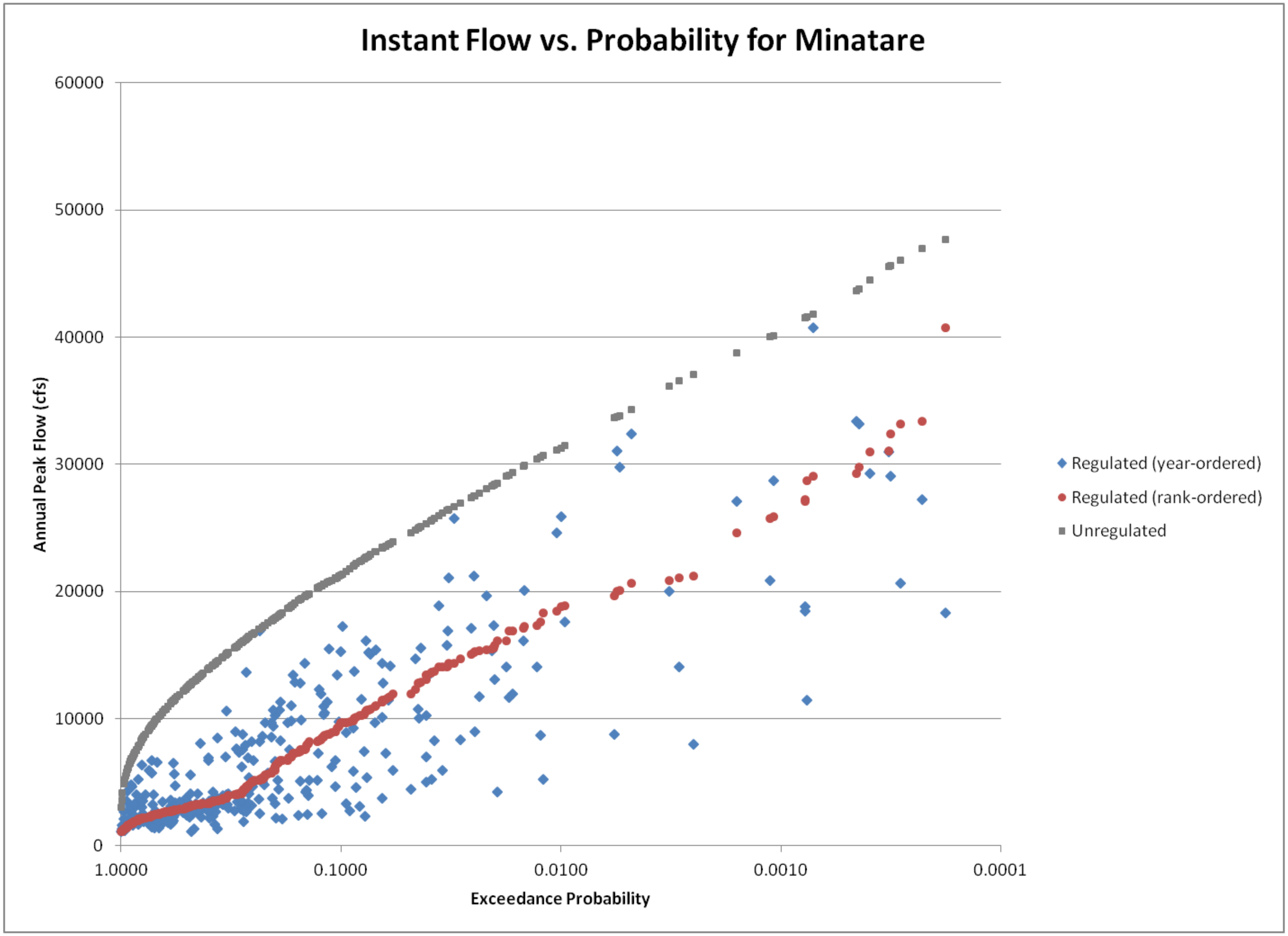

Figure E-14. Instantaneous peaks vs. probability for Minatare

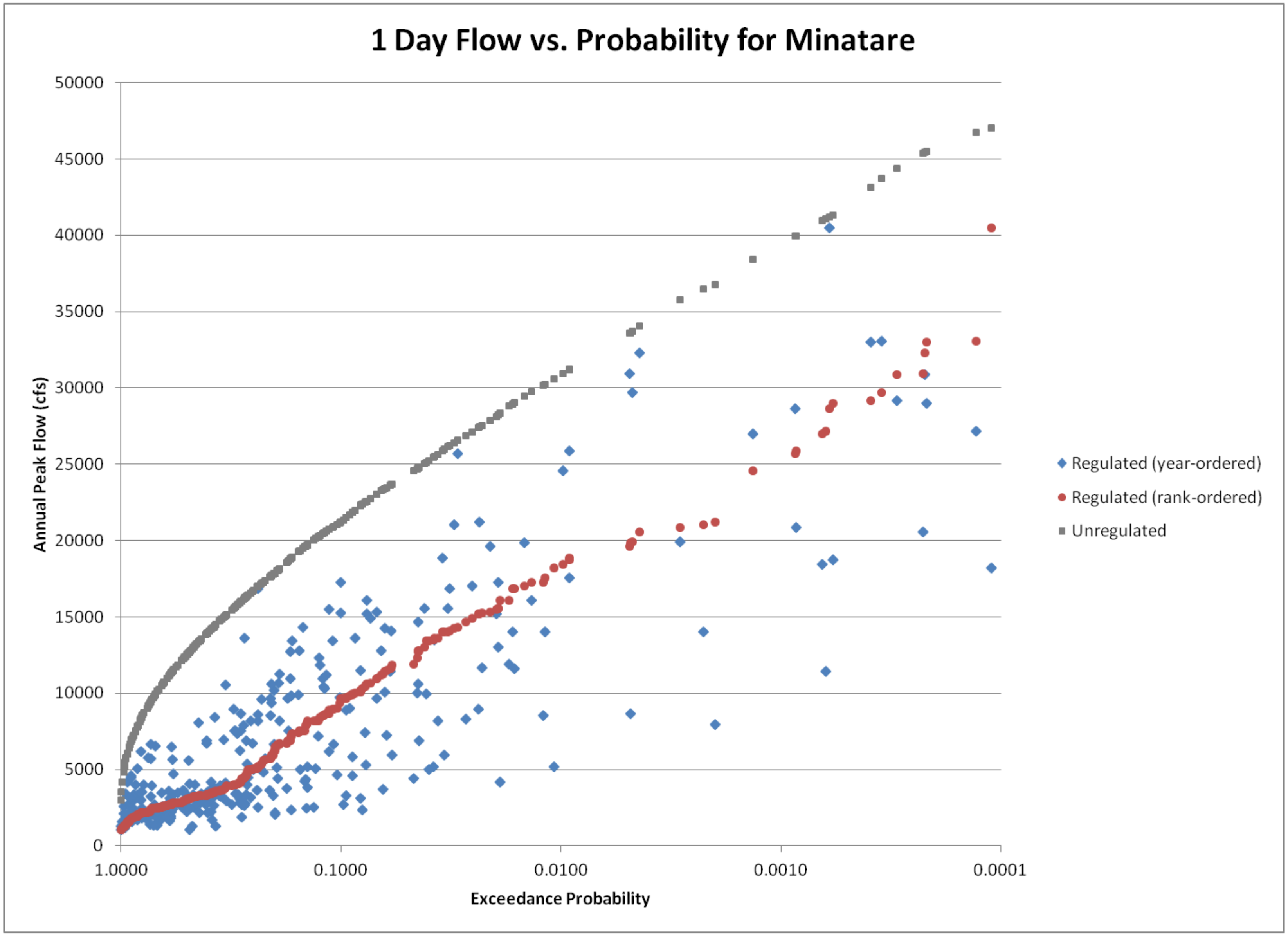

Figure E-15. 1 day peaks vs. probability for Minatare

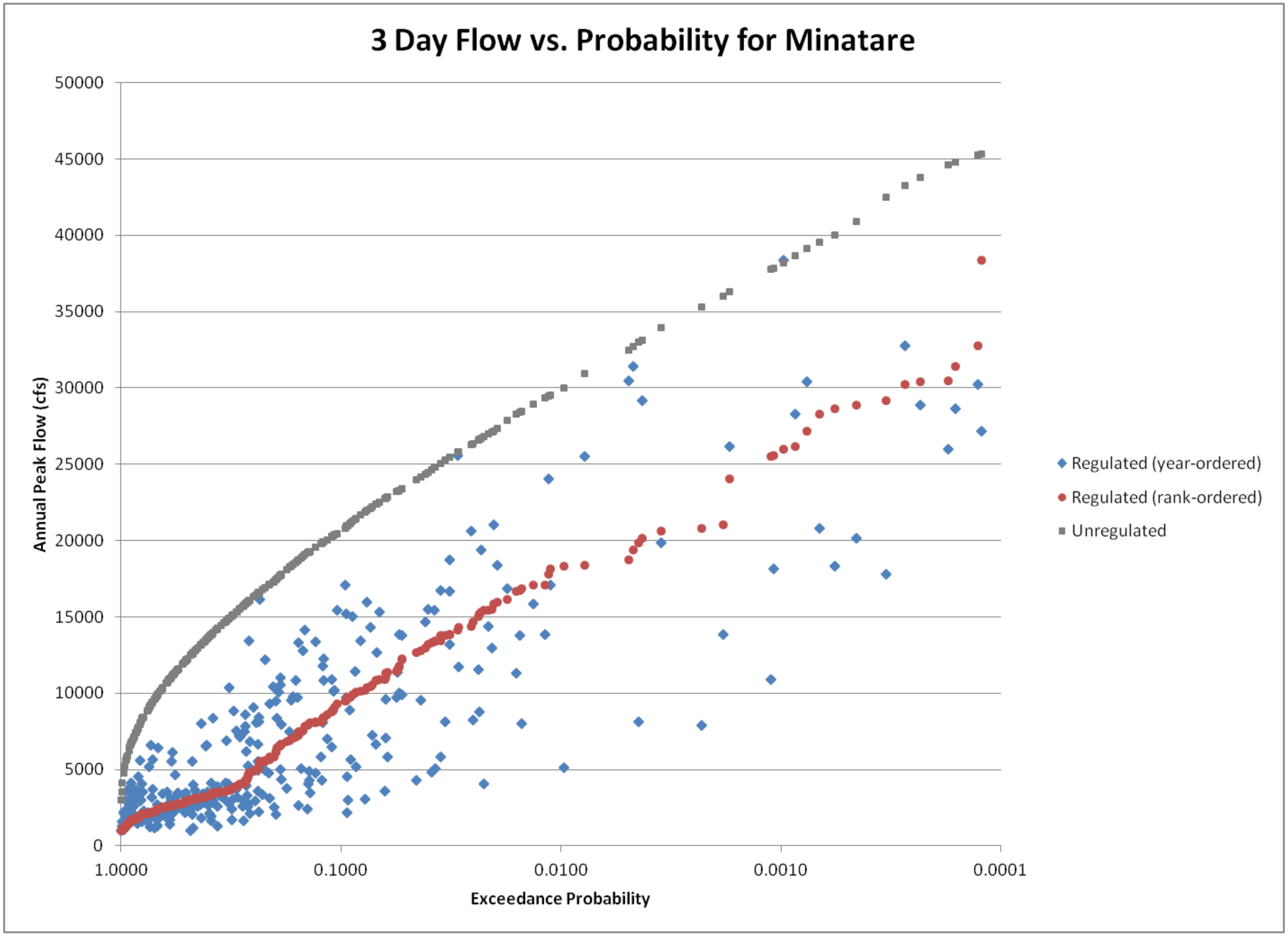

Figure E-16. 3 day peaks vs. probability for Minatare

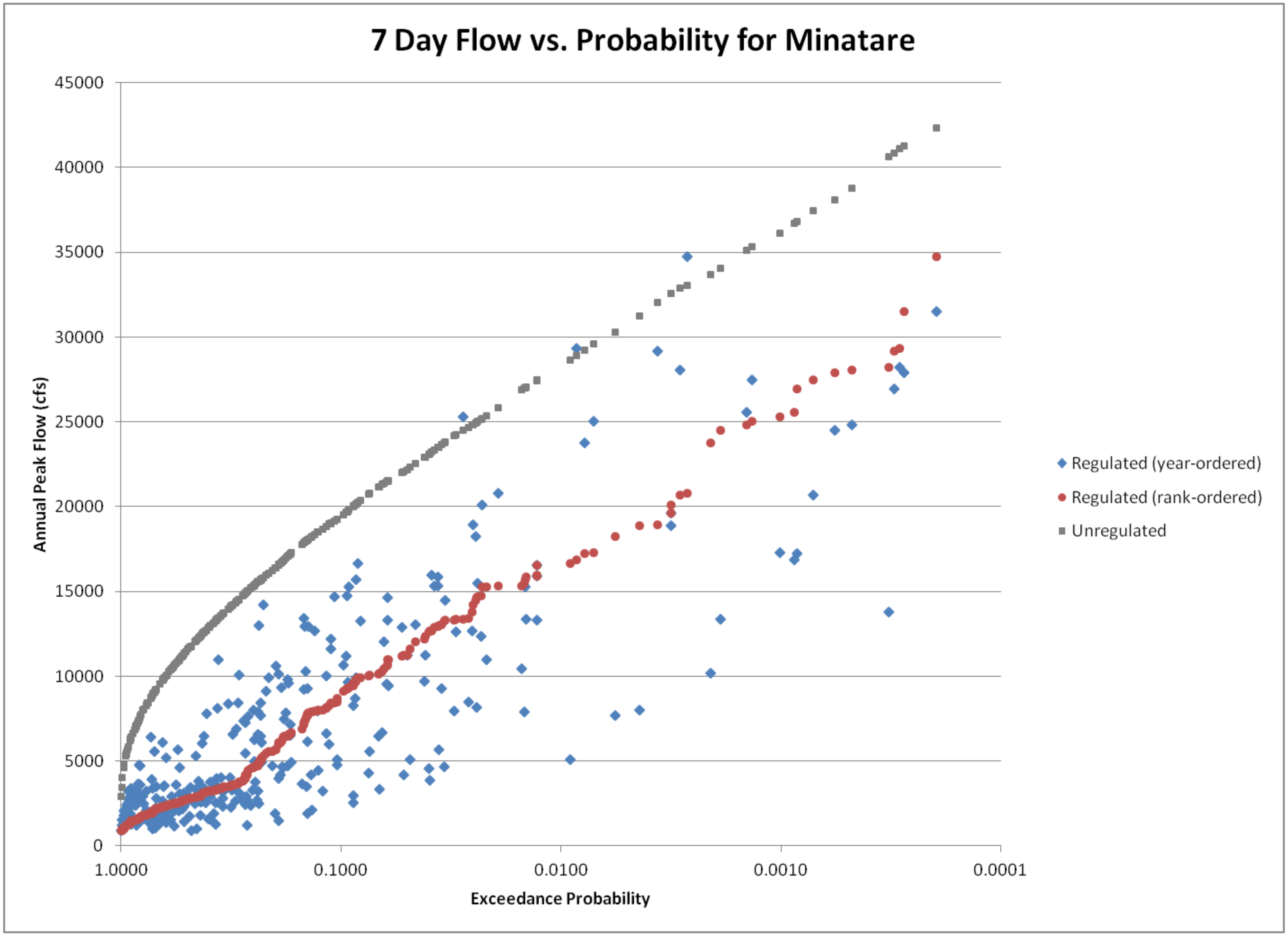

Figure E-17. 7 day peaks vs. probability for Minatare

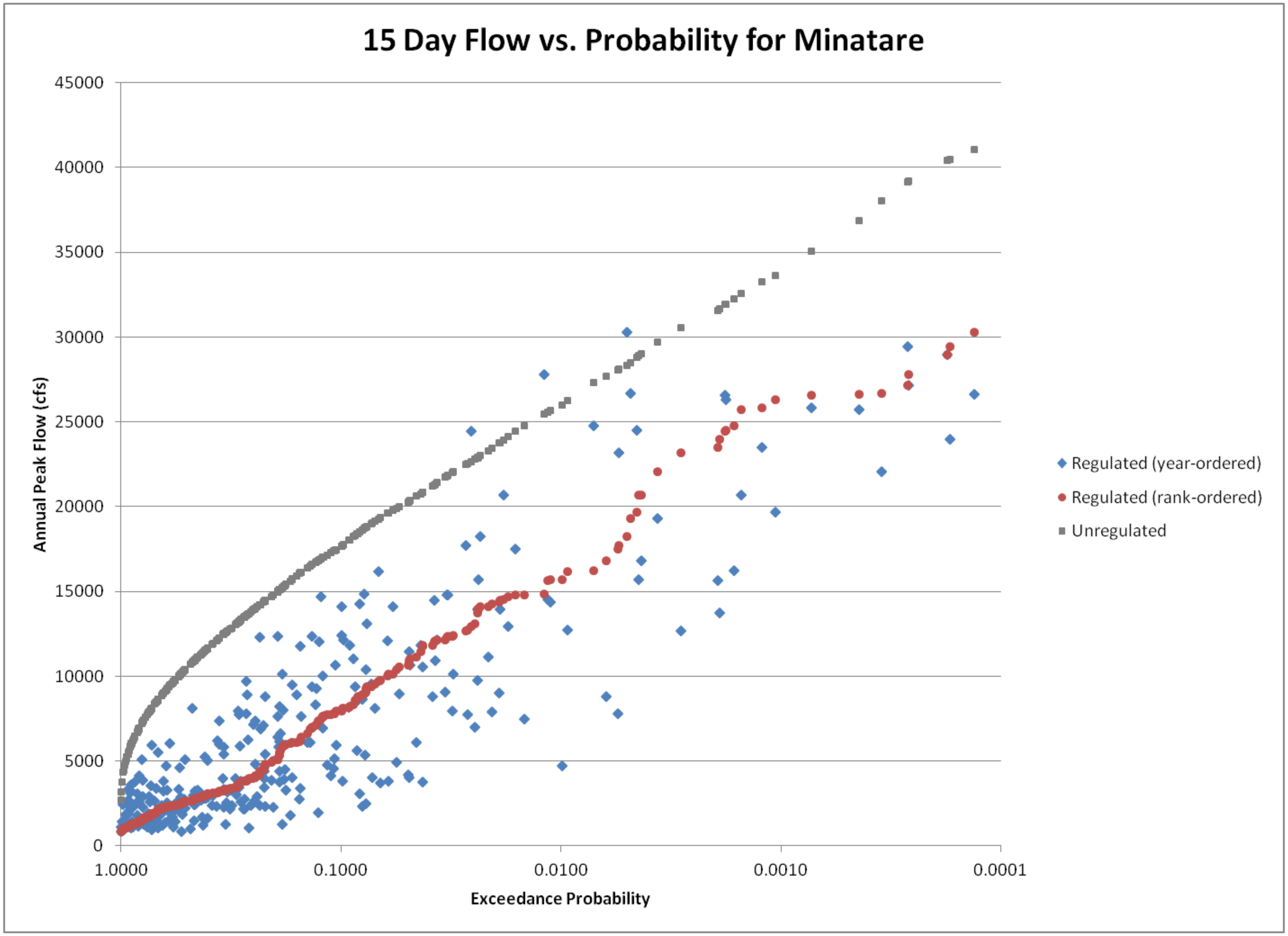

Figure E-18. 15 day peaks vs. probability for Minatare

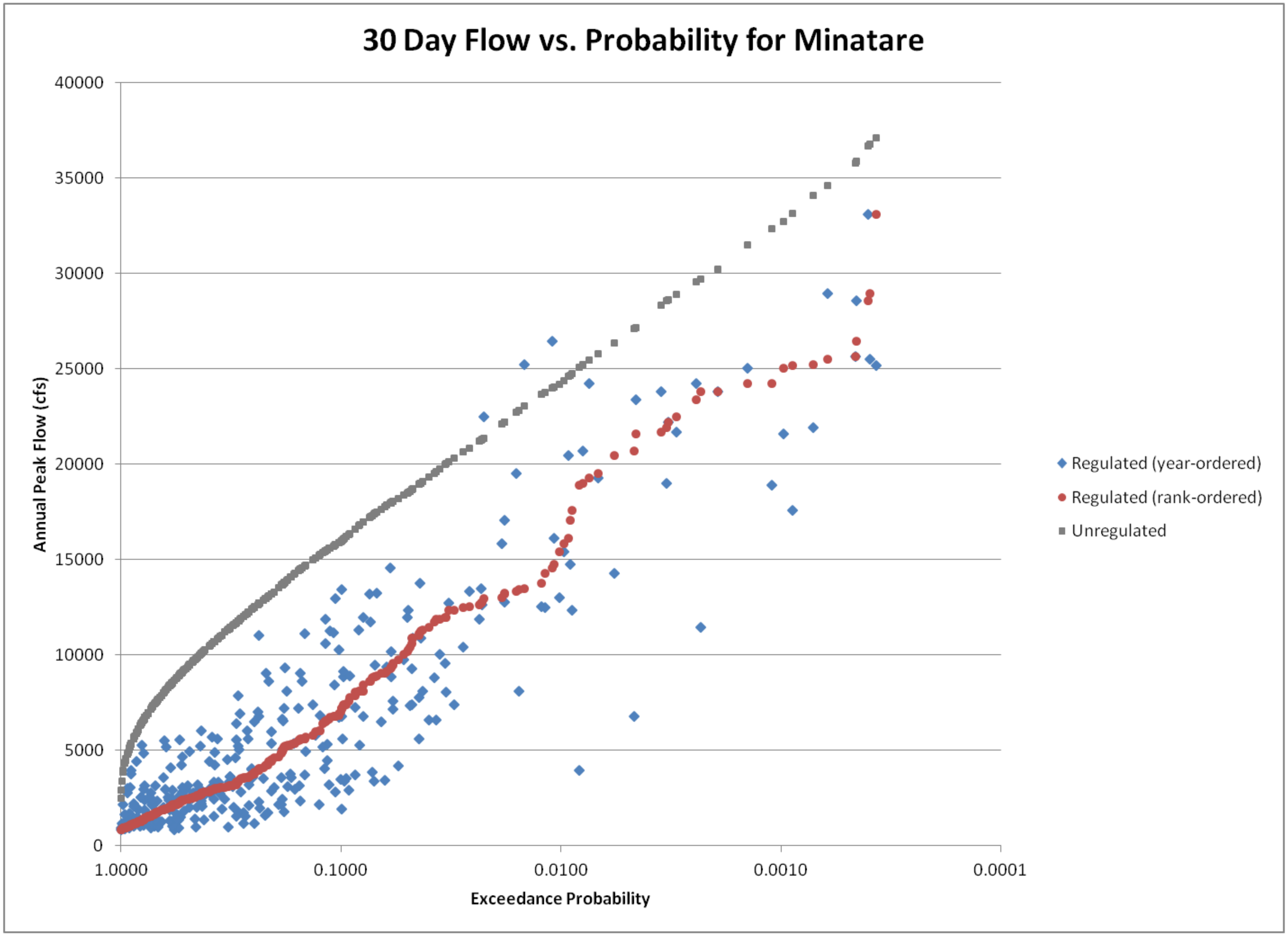

Figure E-19. 30 day peaks vs. probability for Minatare

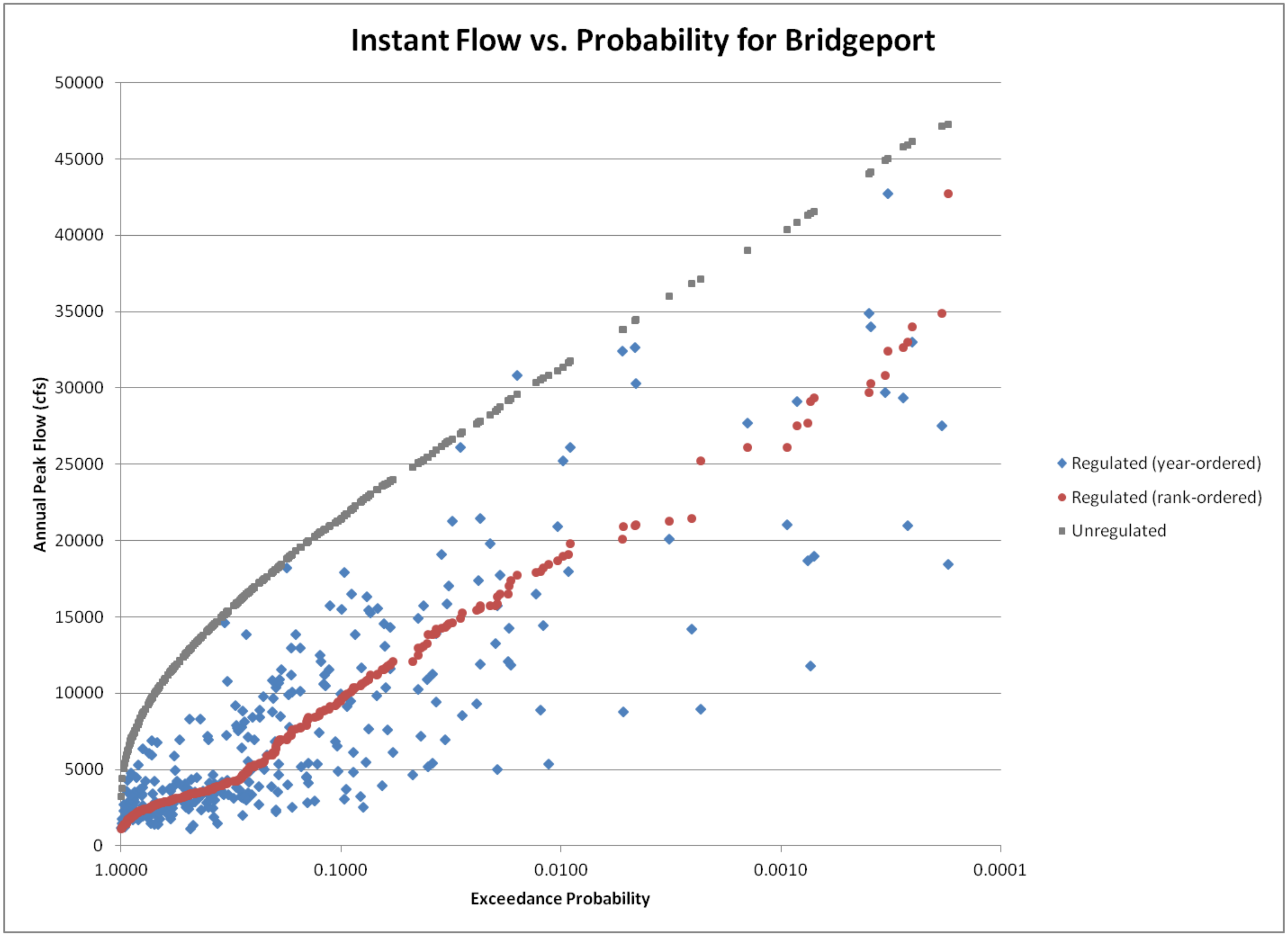

Figure E-20. Instantaneous peaks vs. probability for Bridgeport

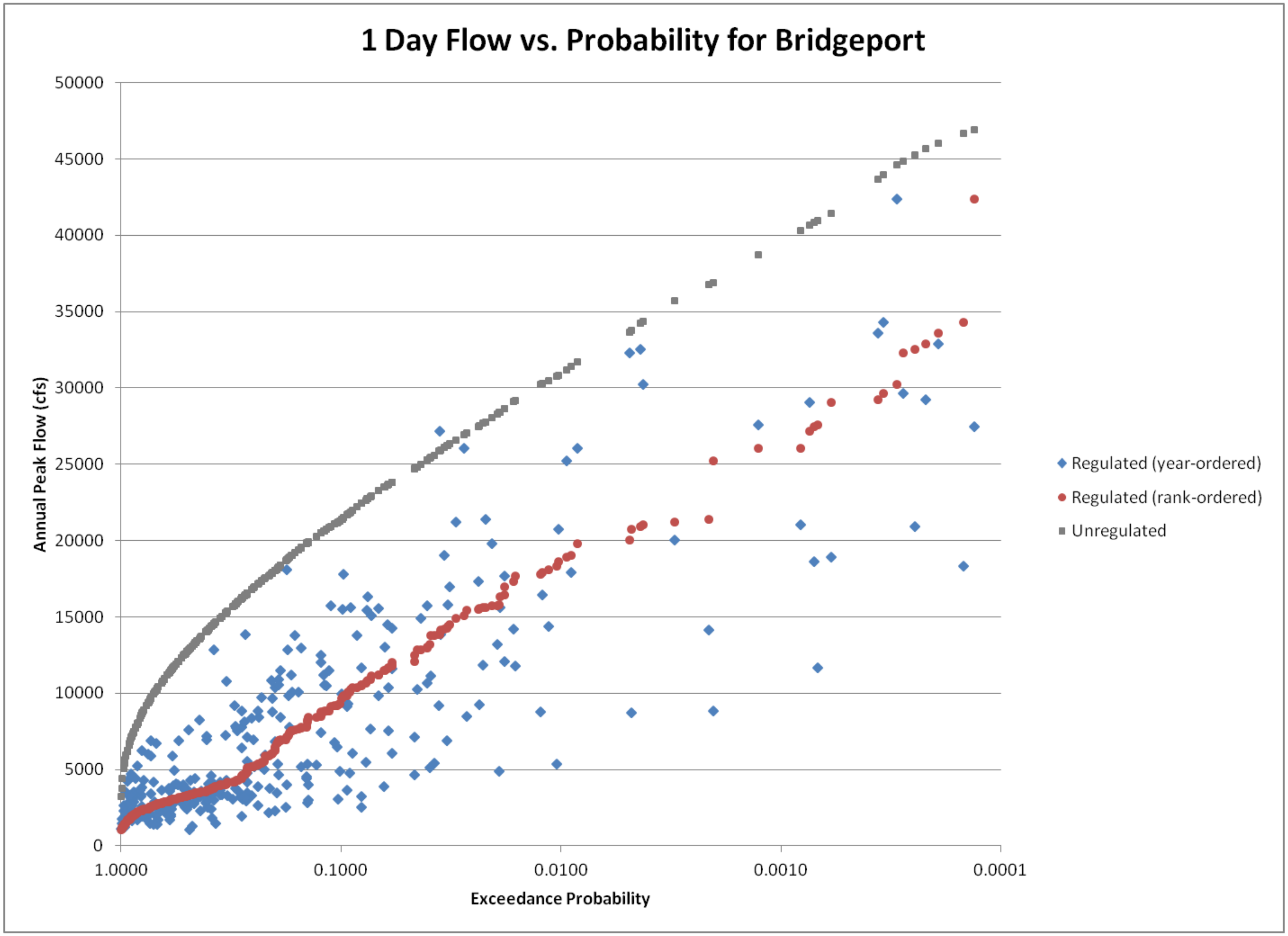

Figure E-21. 1 day peaks vs. probability for Bridgeport

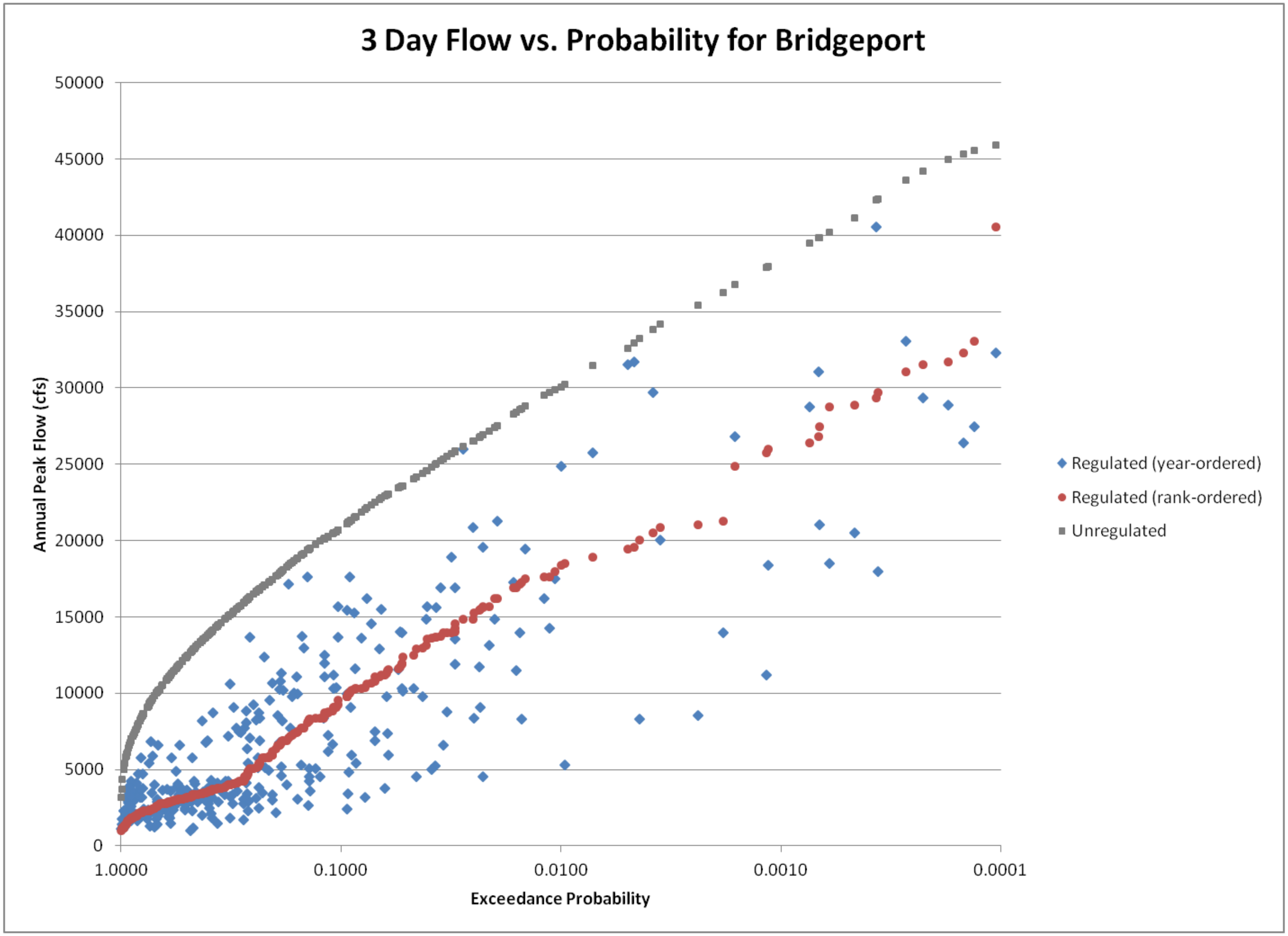

Figure E-22. 3 day peaks vs. probability for Bridgeport

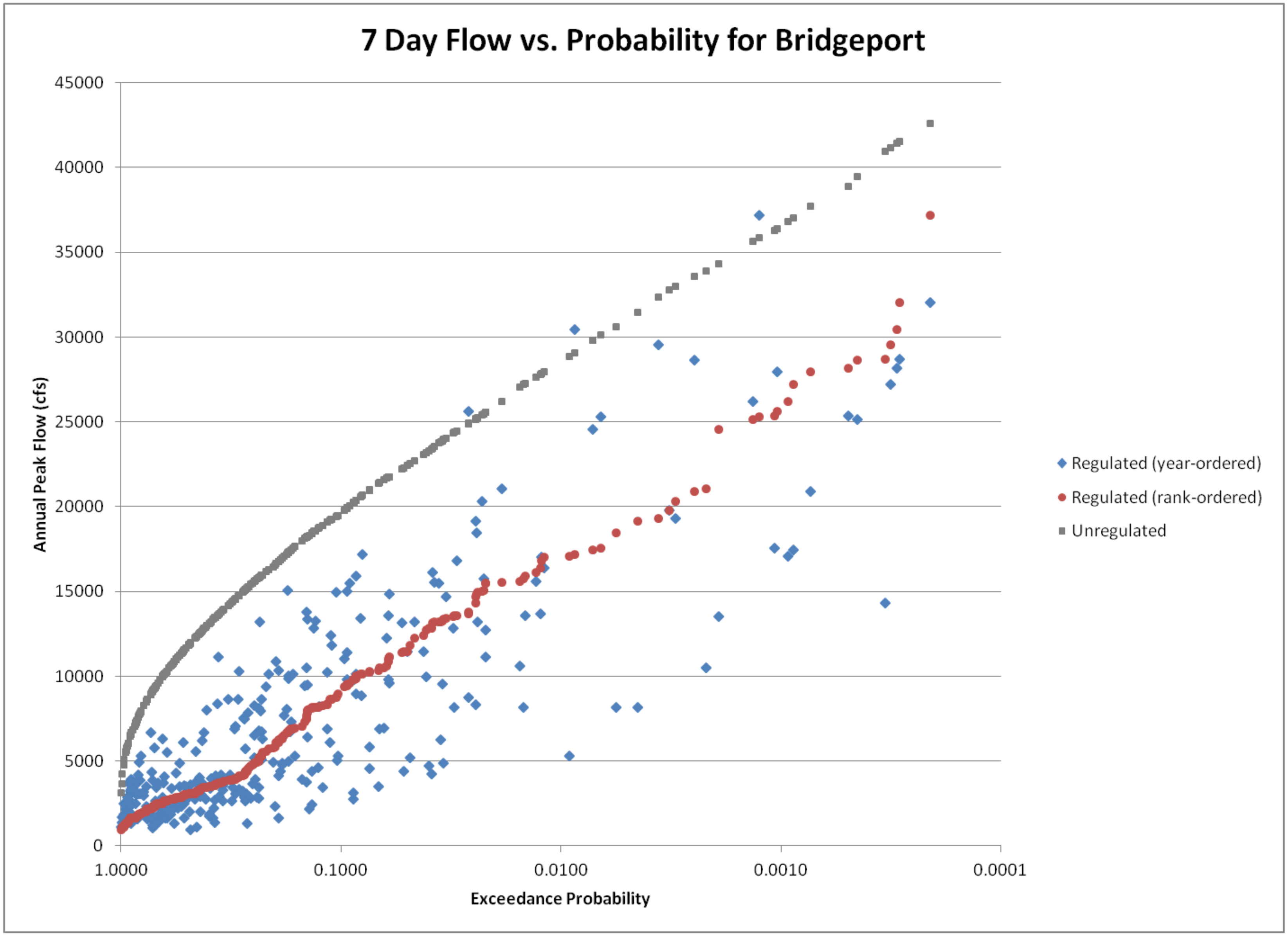

Figure E-23. 7 day peaks vs. probability for Bridgeport

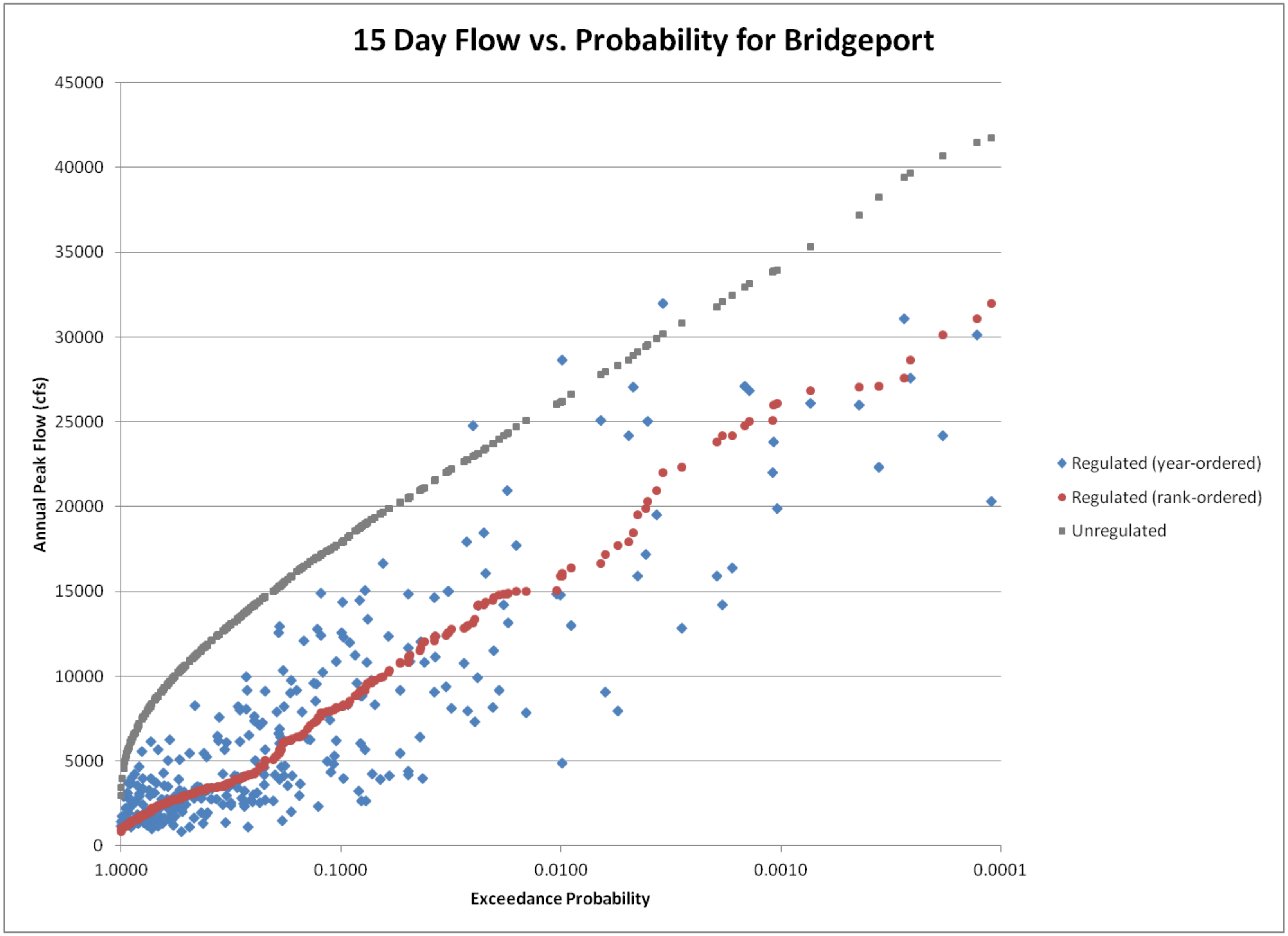

Figure E-24. 15 day peaks vs. probability for Bridgeport

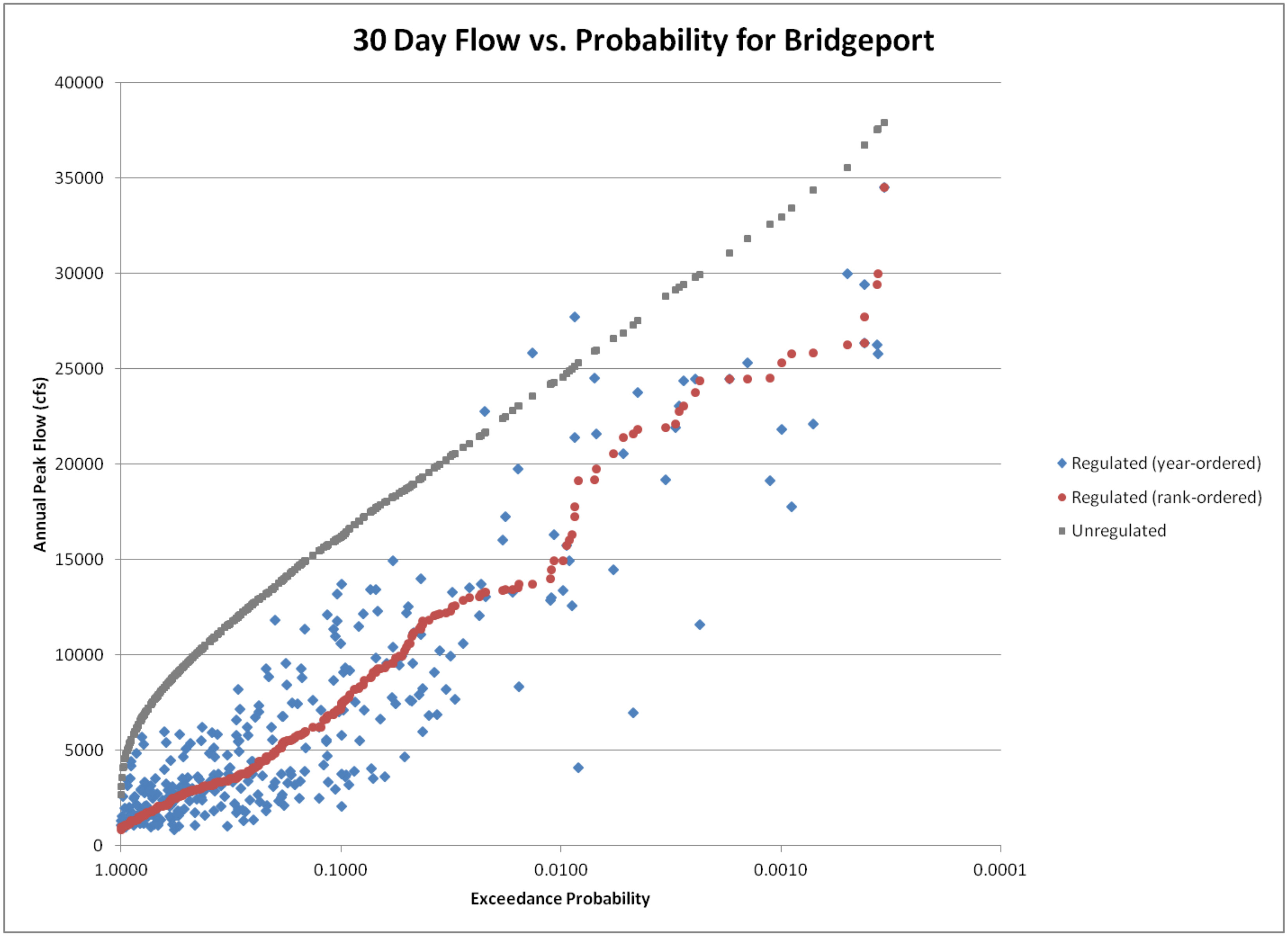

Figure E-25. 30 day peaks vs. probability for Bridgeport

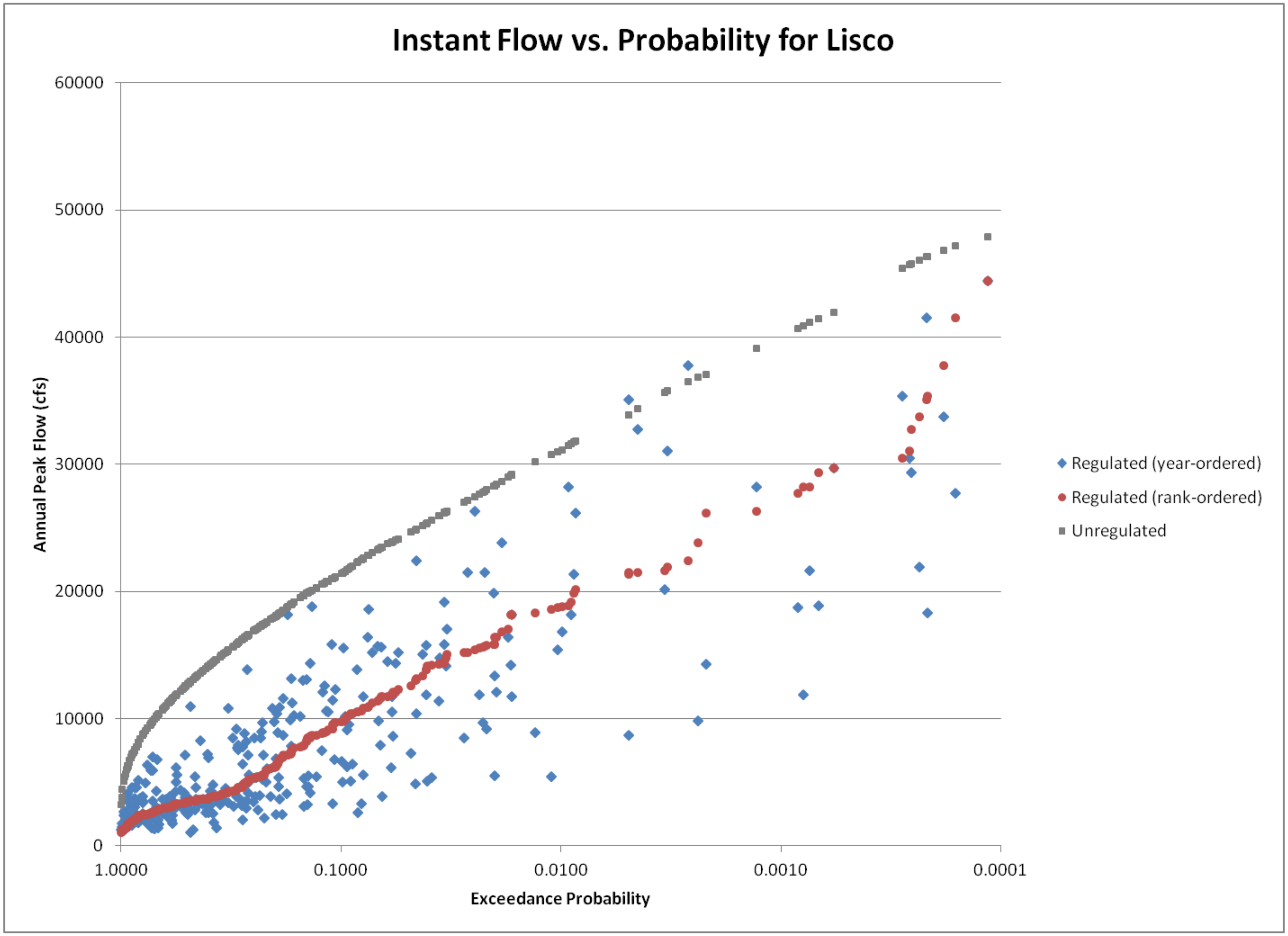

Figure E-26. Instantaneous peaks vs. probability for Lisco

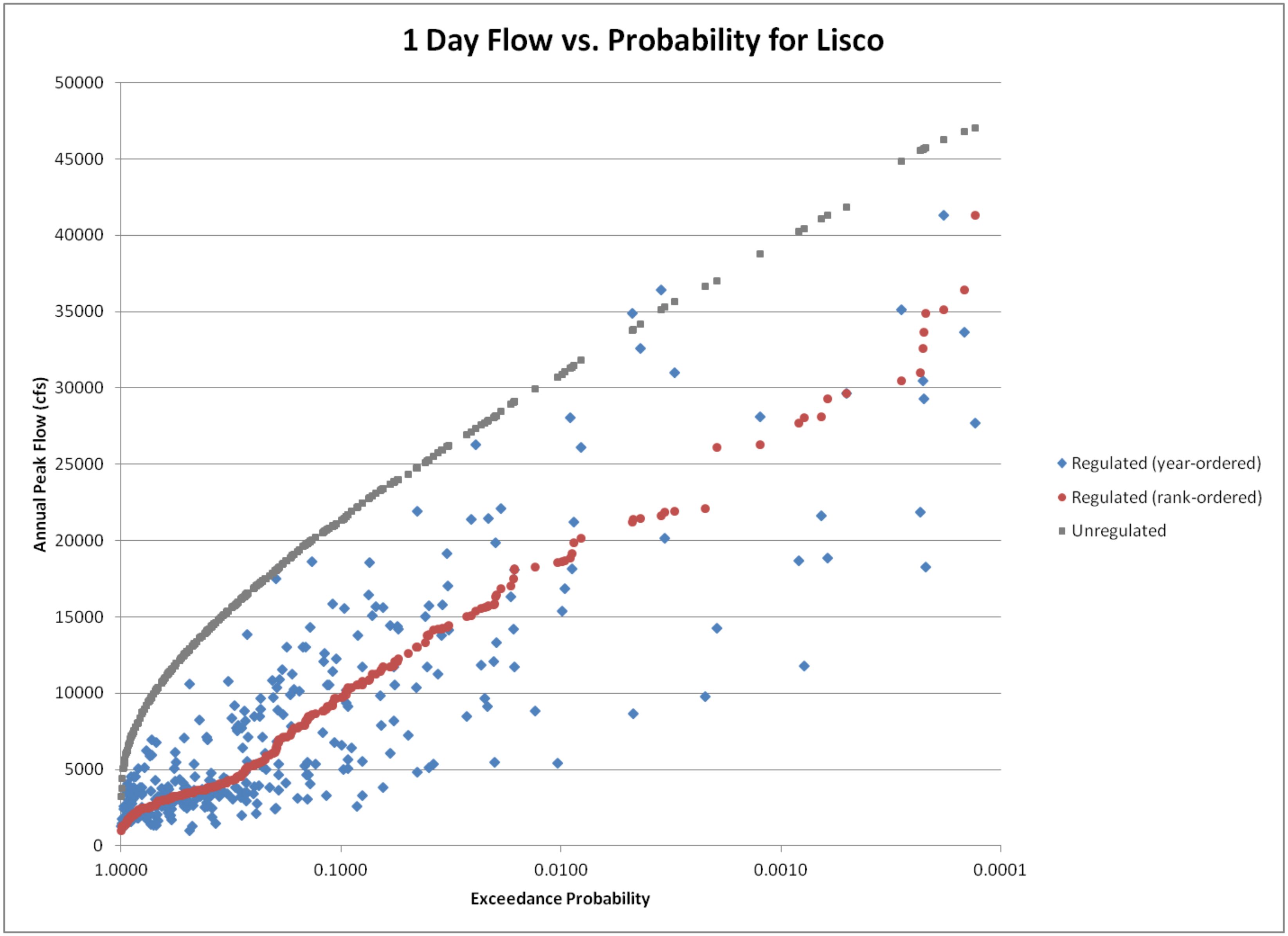

Figure E-27. 1 day peaks vs. probability for Lisco

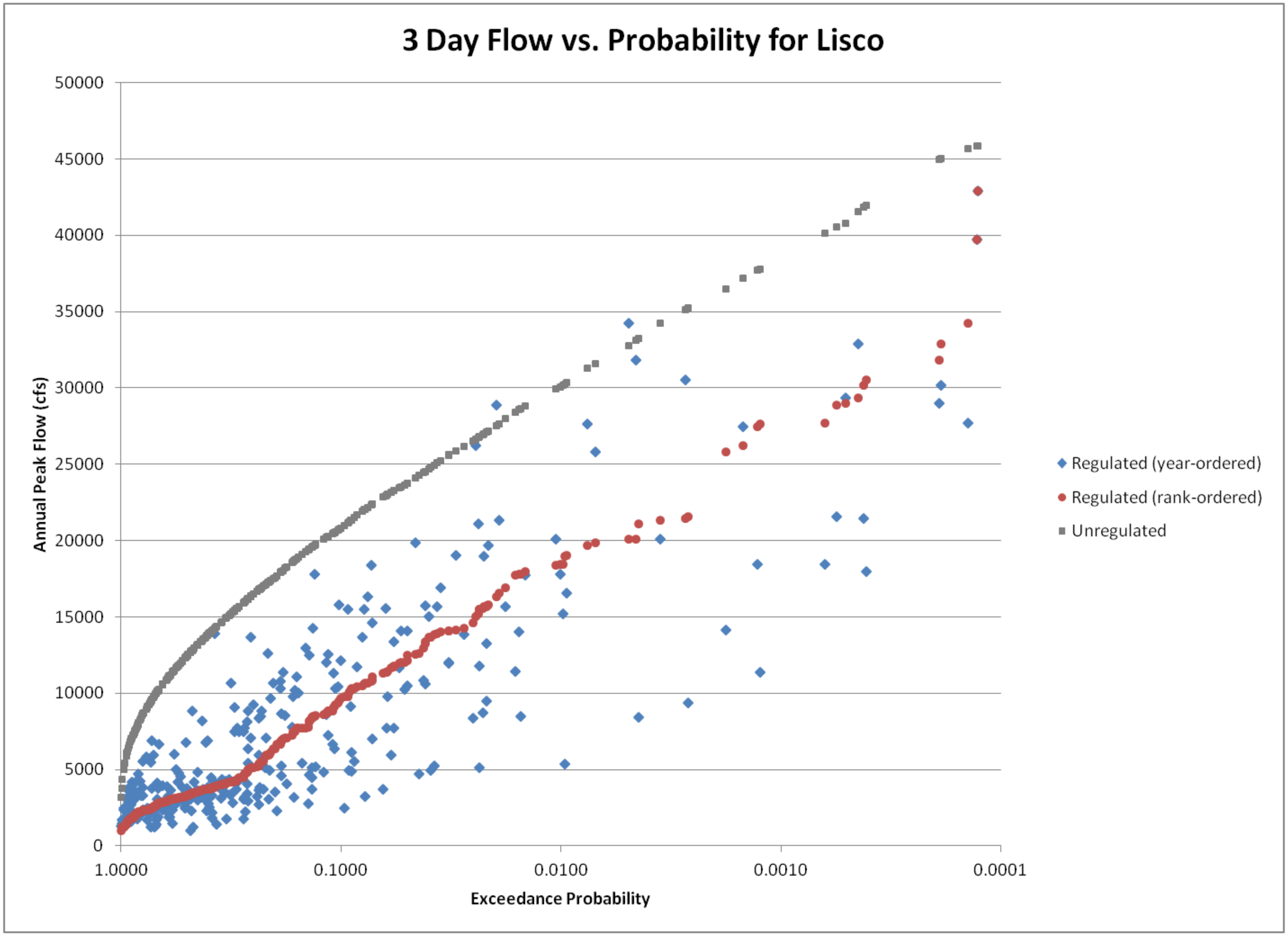

Figure E-28. 3 day peaks vs. probability for Lisco

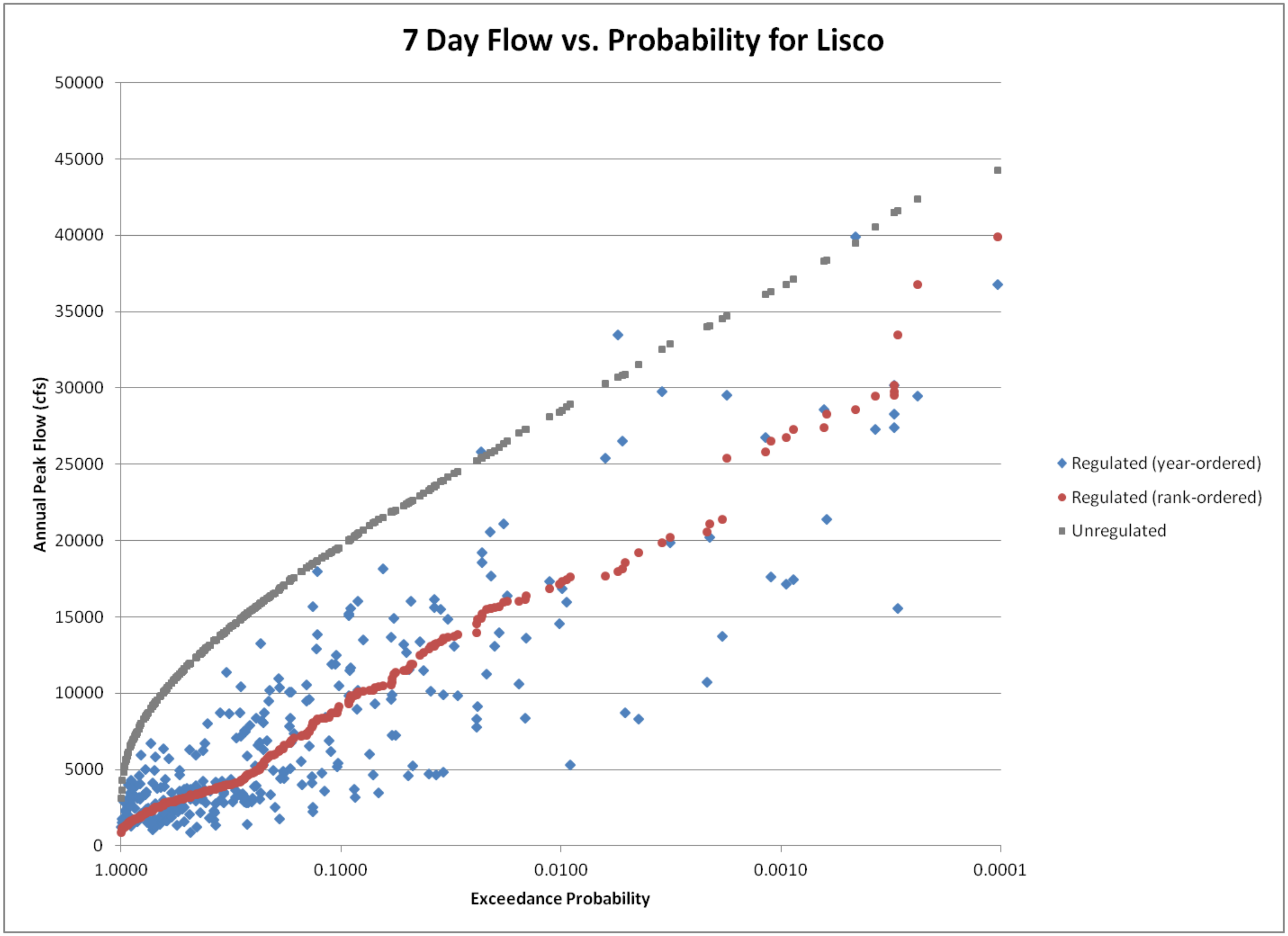

Figure E-29. 7 day peaks vs. probability for Lisco

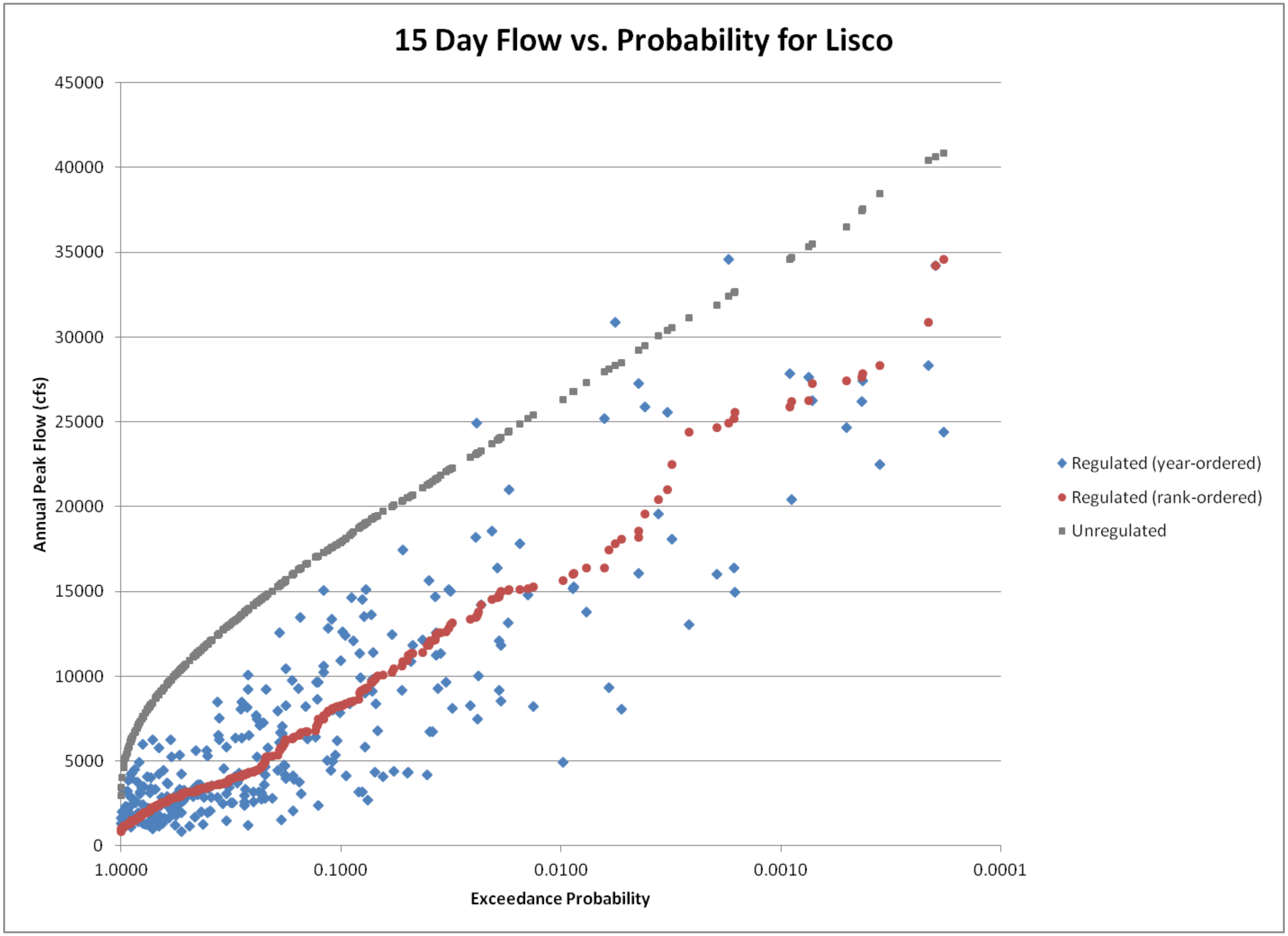

Figure E-30. 15 day peaks vs. probability for Lisco

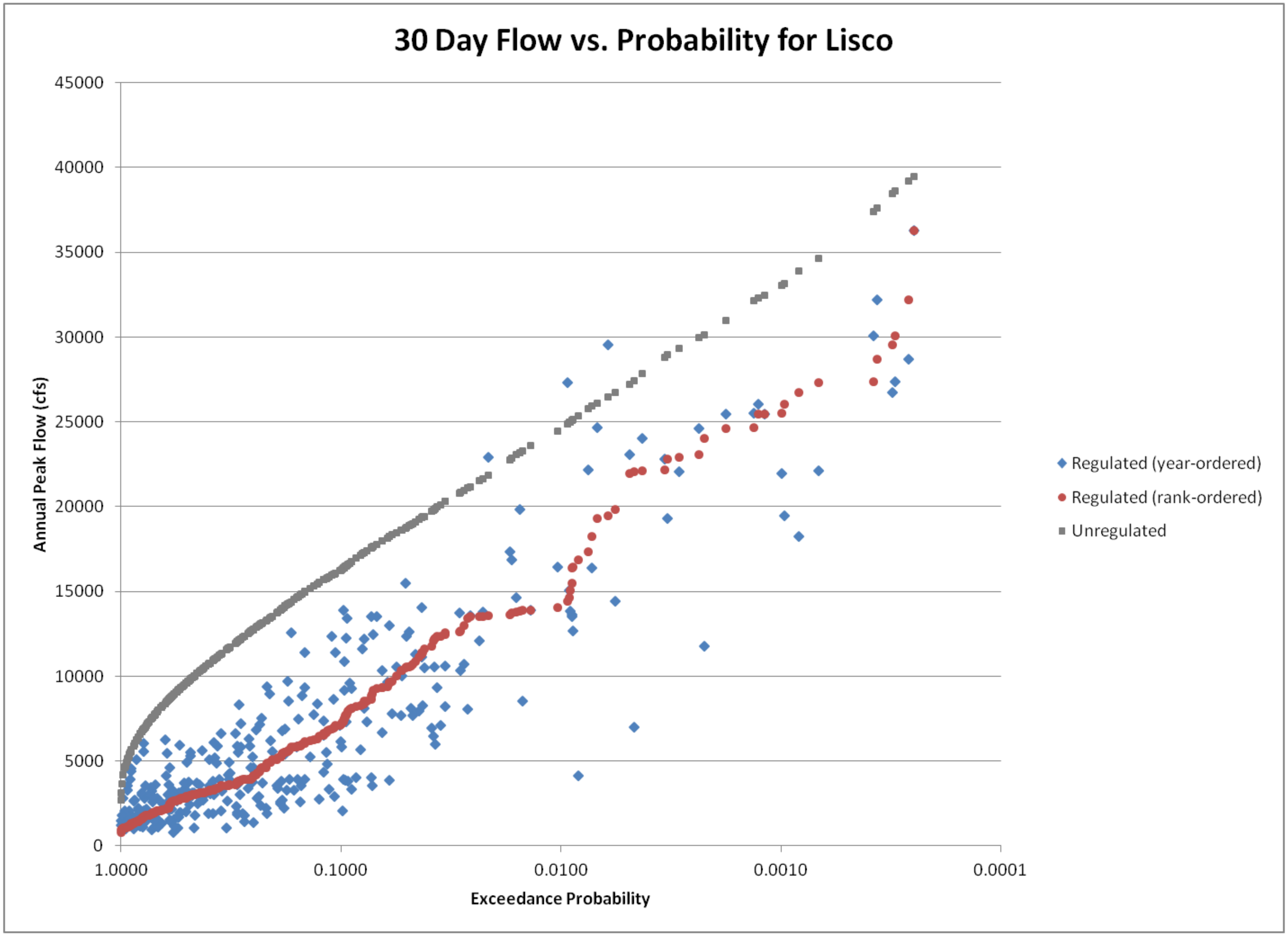

Figure E-31. 30 day peaks vs. probability for Lisco

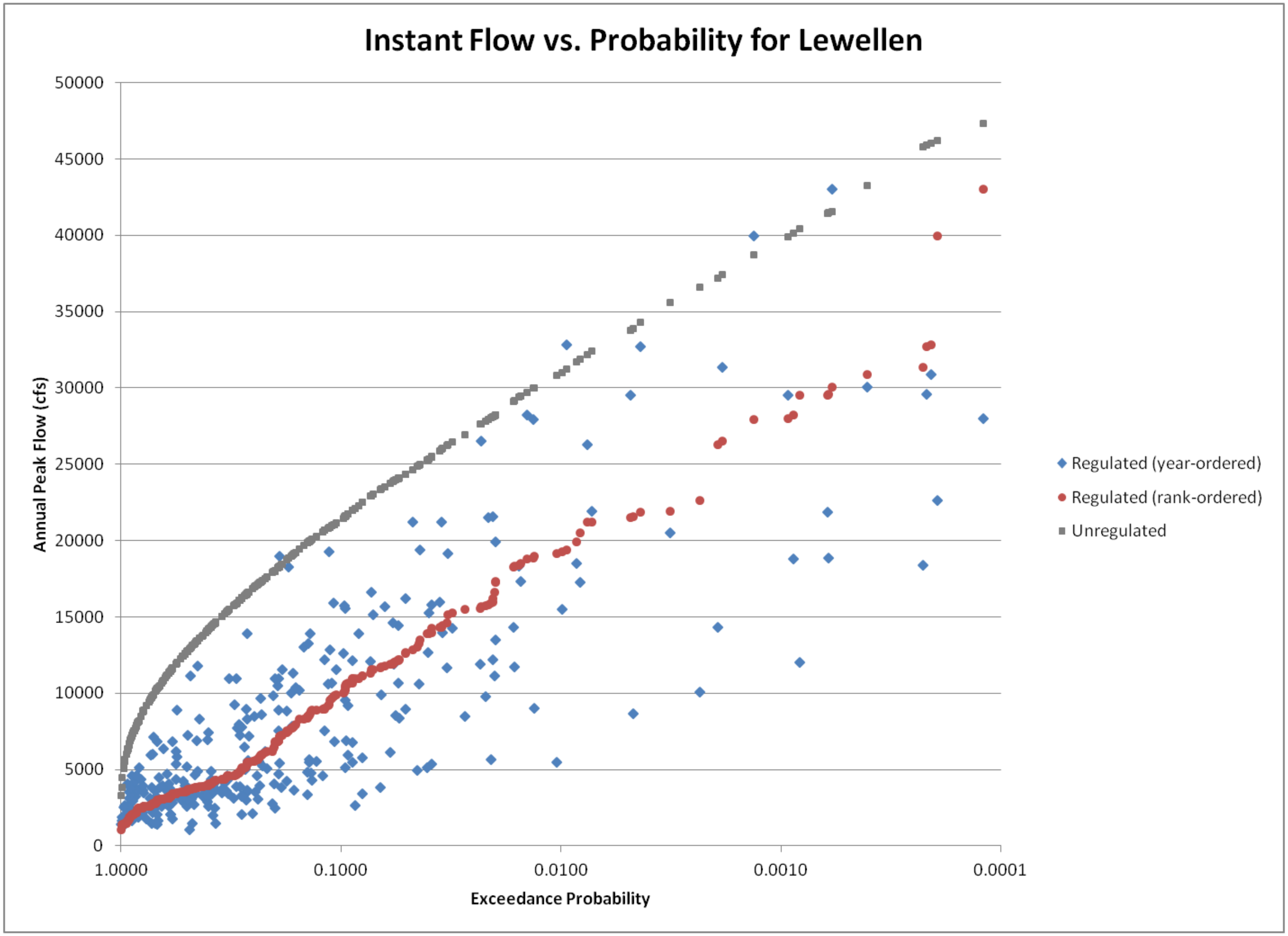

Figure E-32. Instantaneous peaks vs. probability for Lewellen

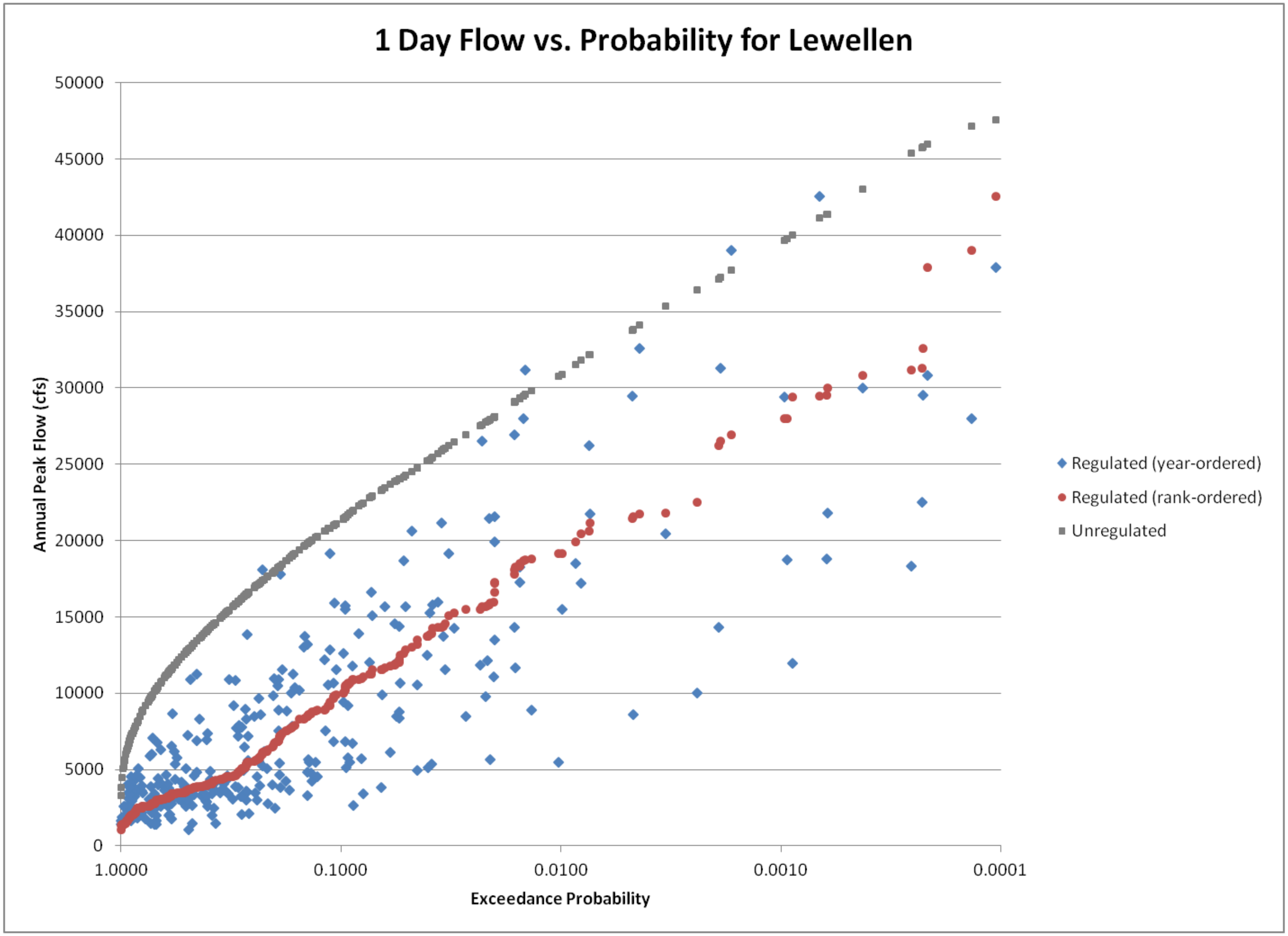

Figure E-33. 1 day peaks vs. probability for Lewellen

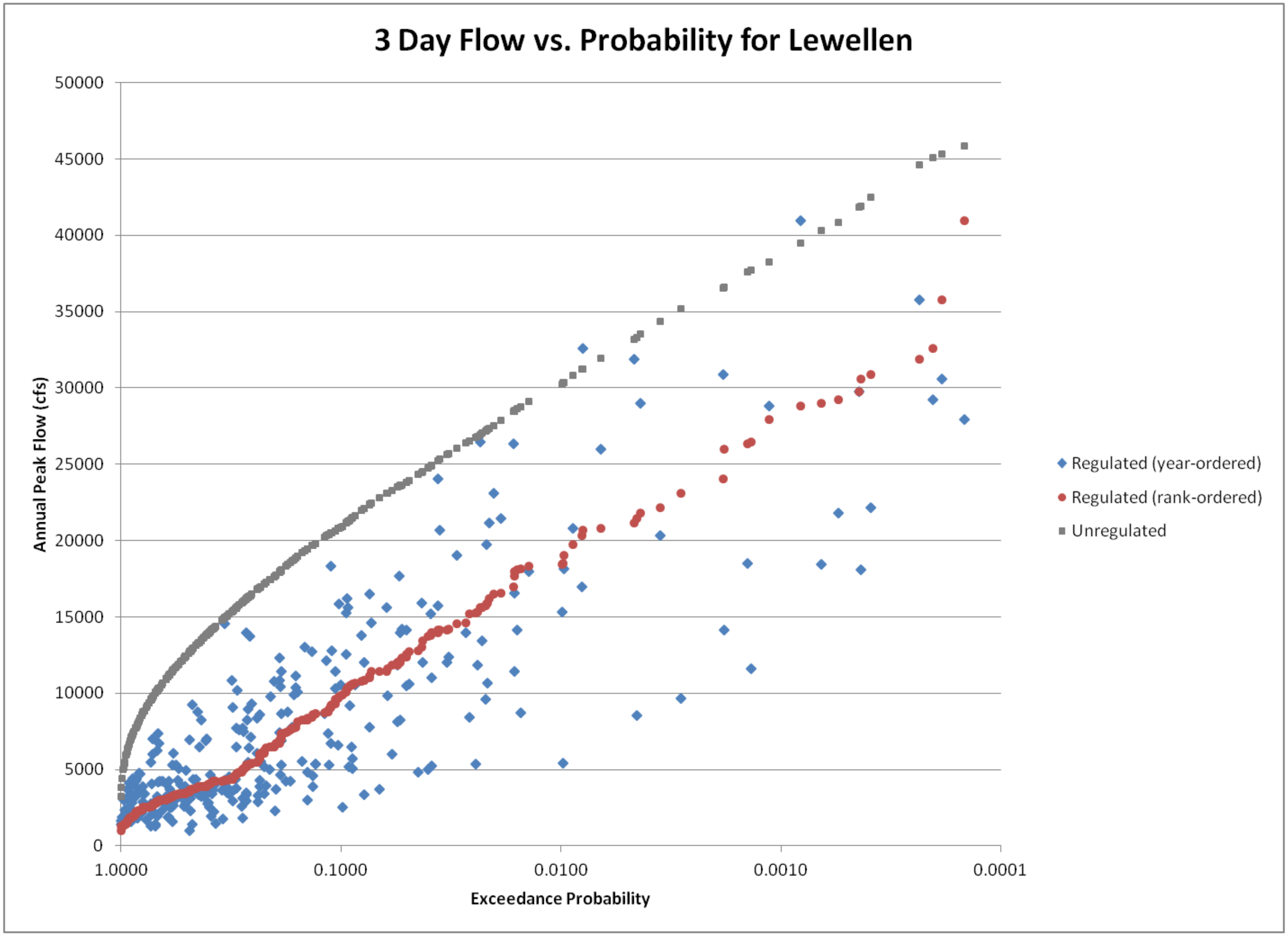

Figure E-34. 3 day peaks vs. probability for Lewellen

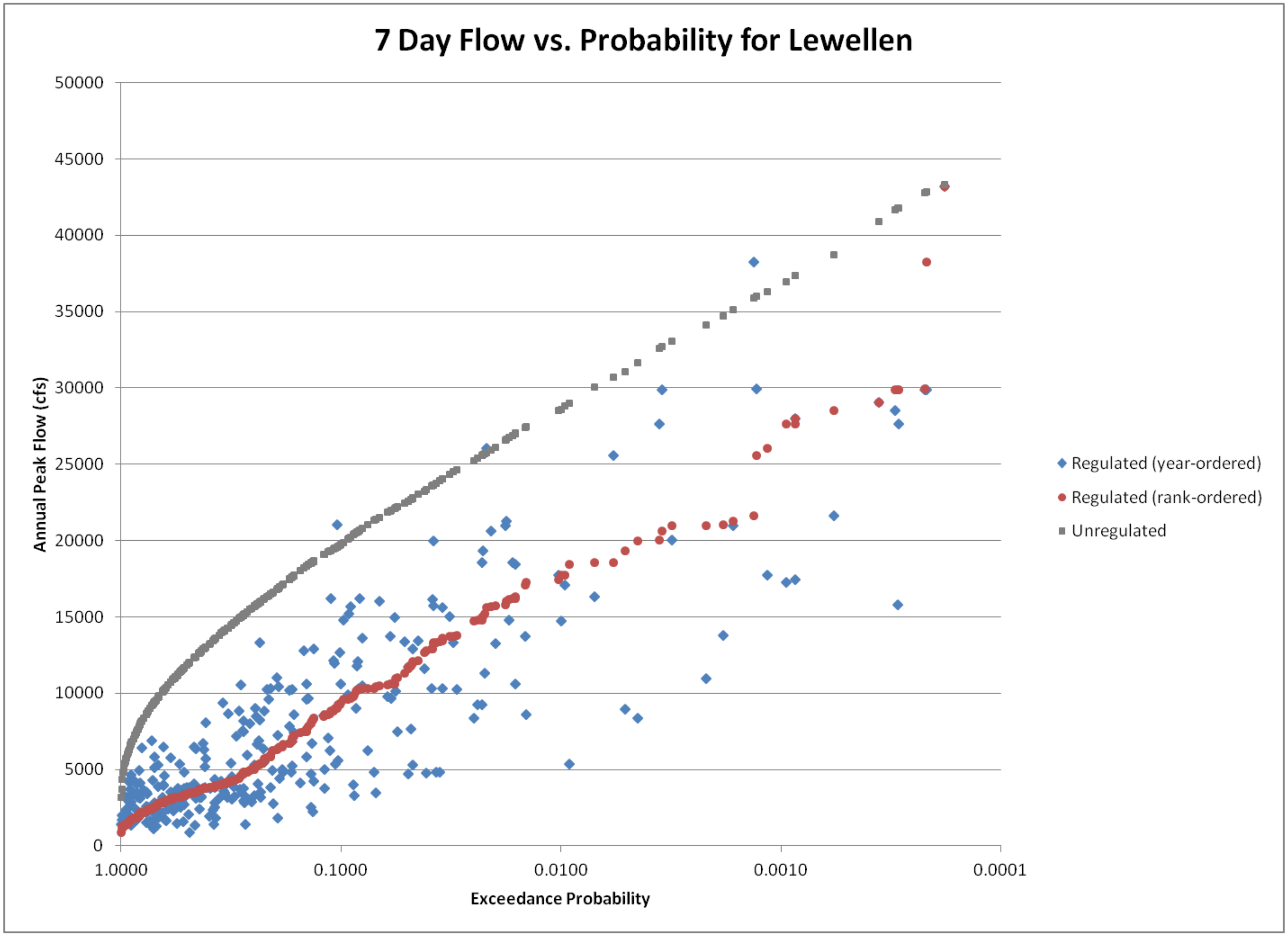

Figure E-35. 7 day peaks vs. probability for Lewellen

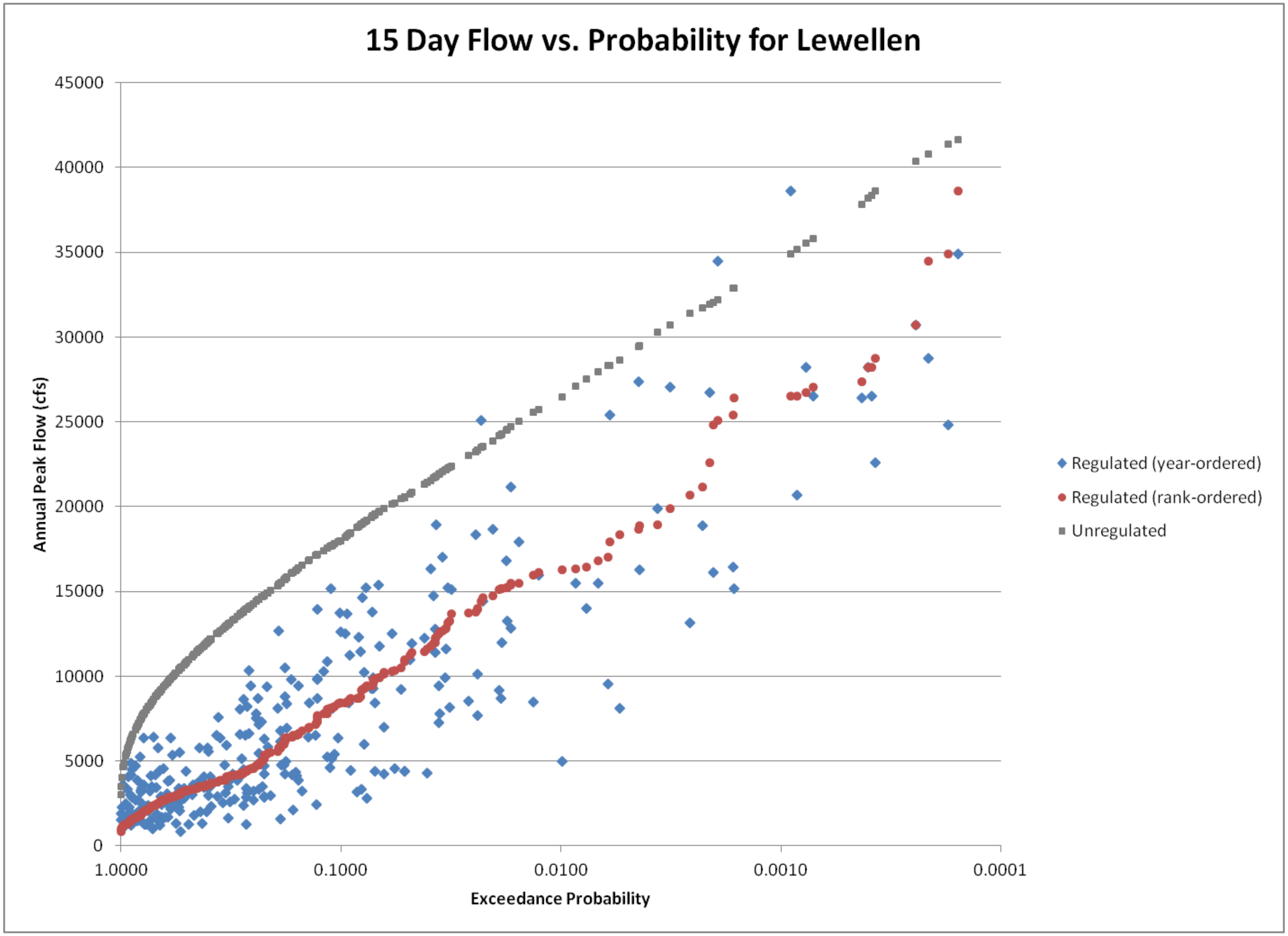

Figure E-36. 15 day peaks vs. probability for Lewellen

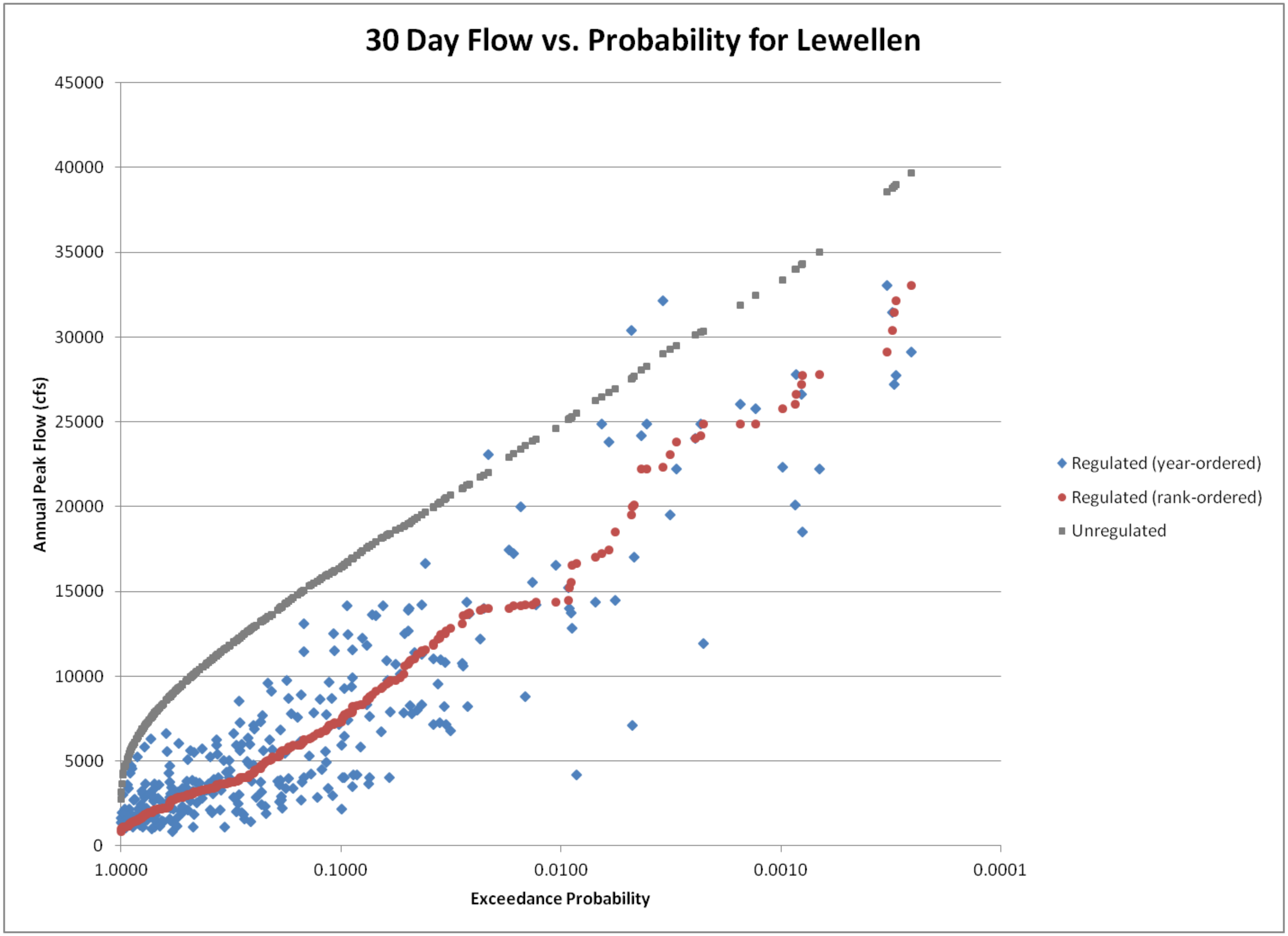

Figure E-37. 30 day peaks vs. probability for Lewellen

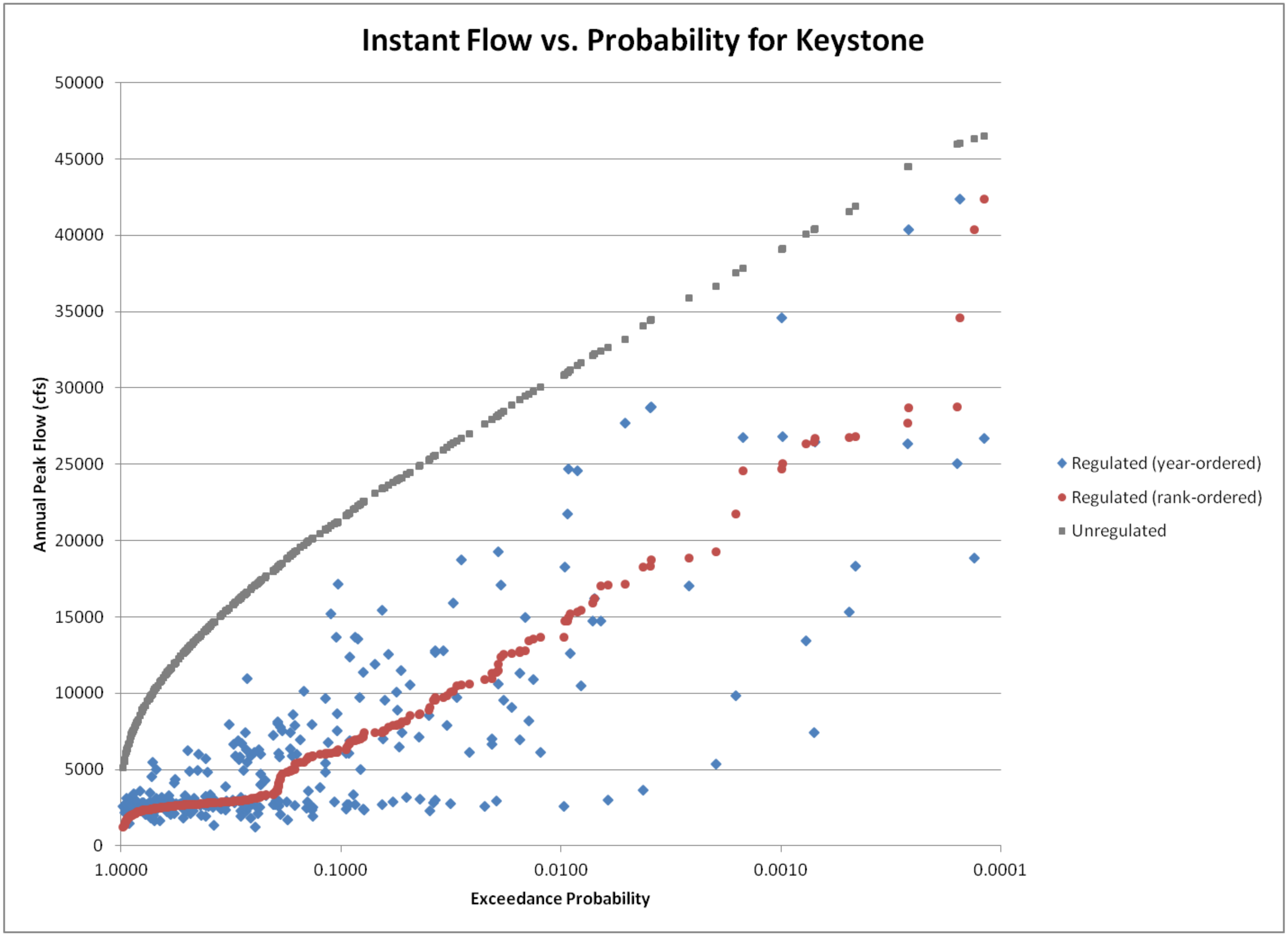

Figure E-38. Instantaneous peaks vs. probability for Keystone

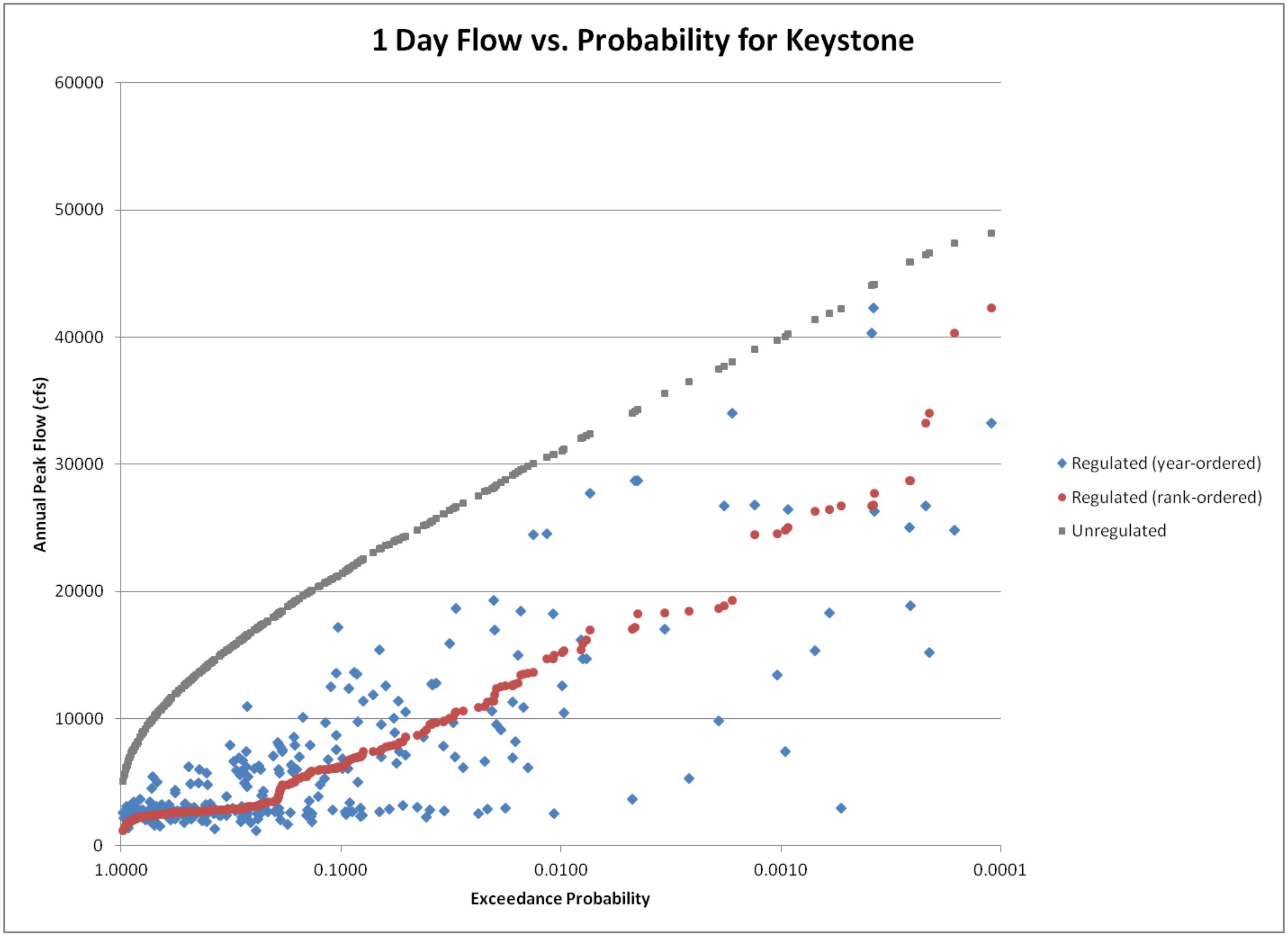

Figure E-39. 1 day peaks vs. probability for Keystone

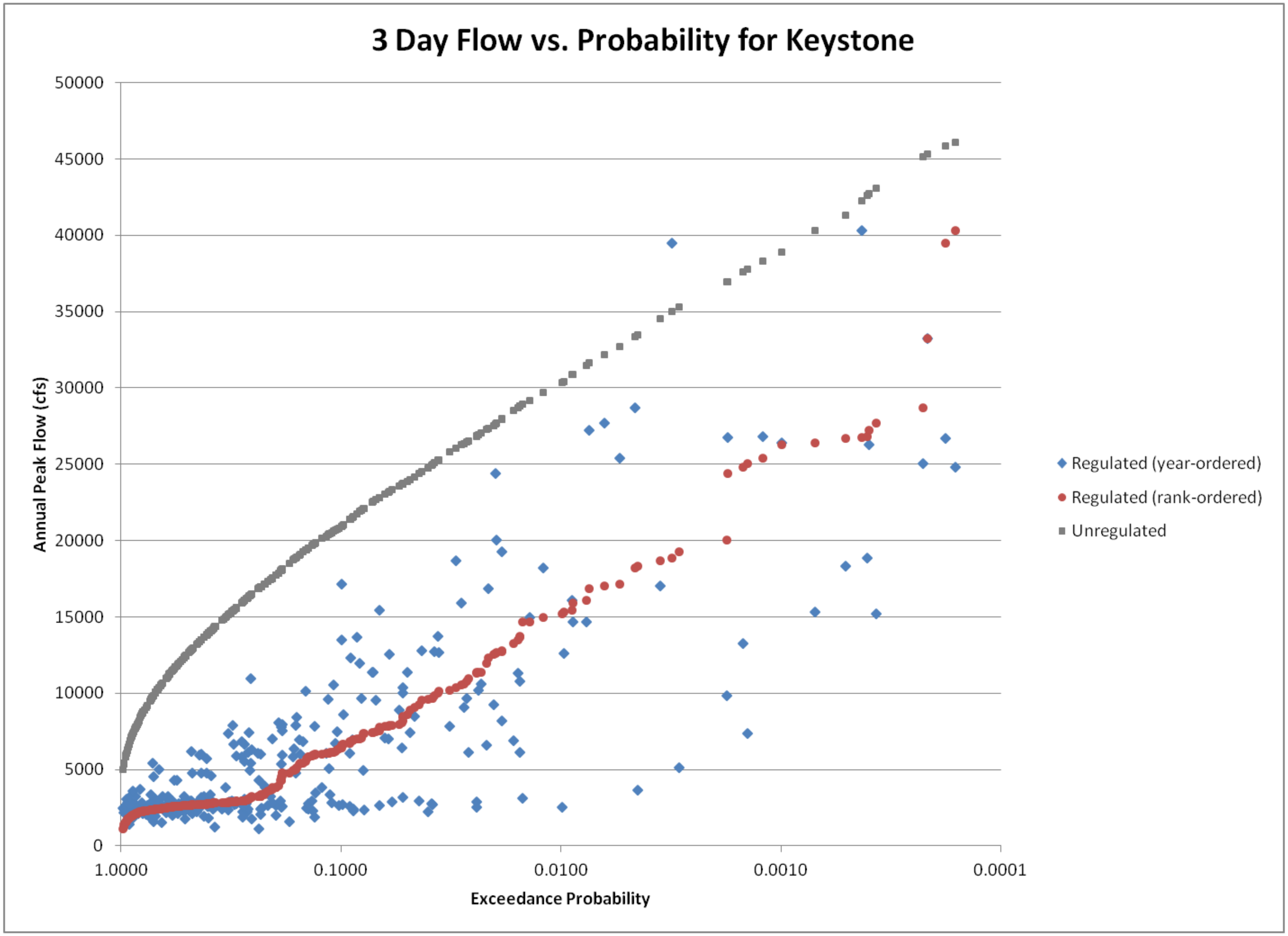

Figure E-40. 3 day peaks vs. probability for Keystone

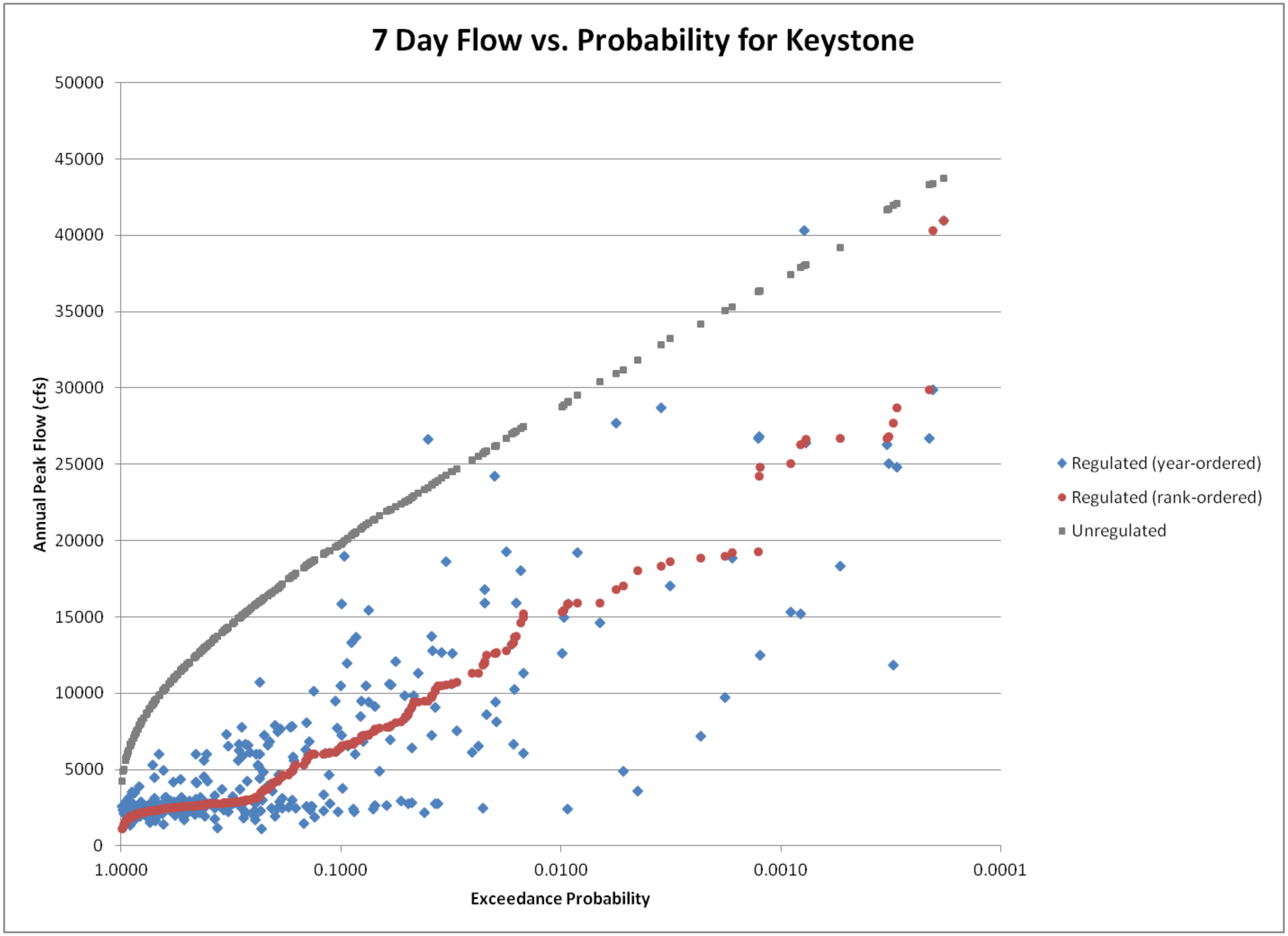

Figure E-41. 7 day peaks vs. probability for Keystone

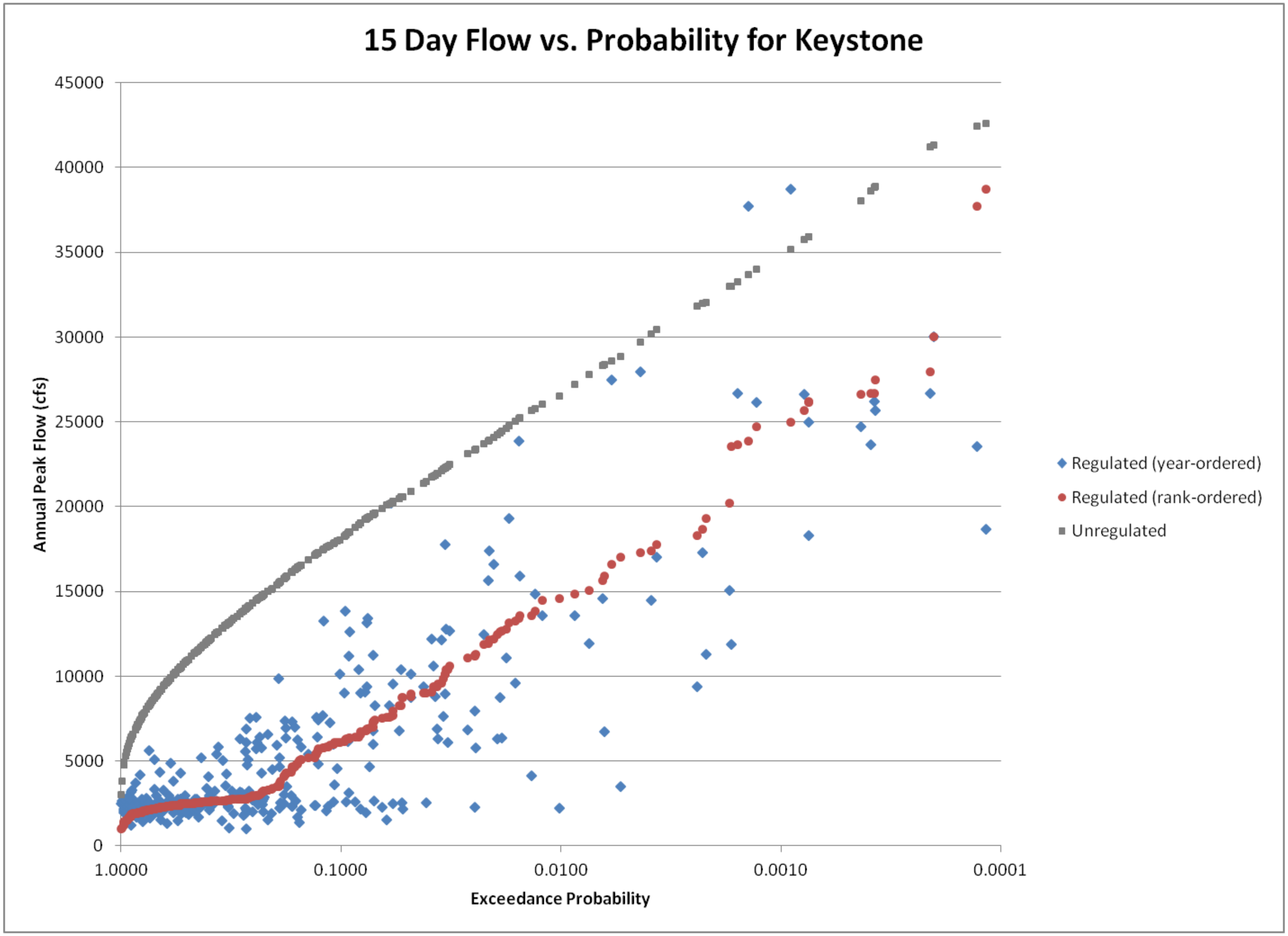

Figure E-42. 15 day peaks vs. probability for Keystone

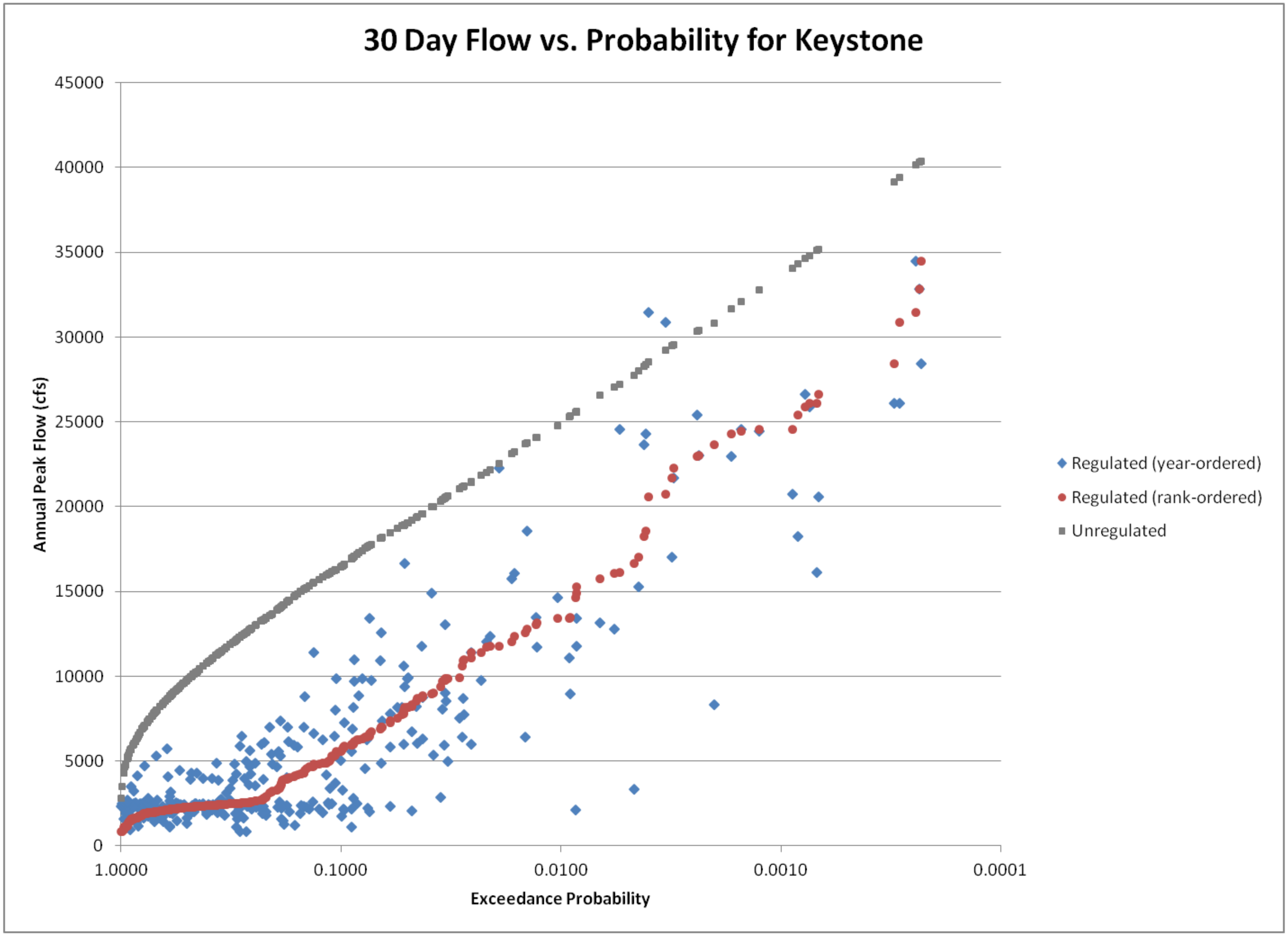

Figure E-43. 30 day peaks vs. probability for Keystone

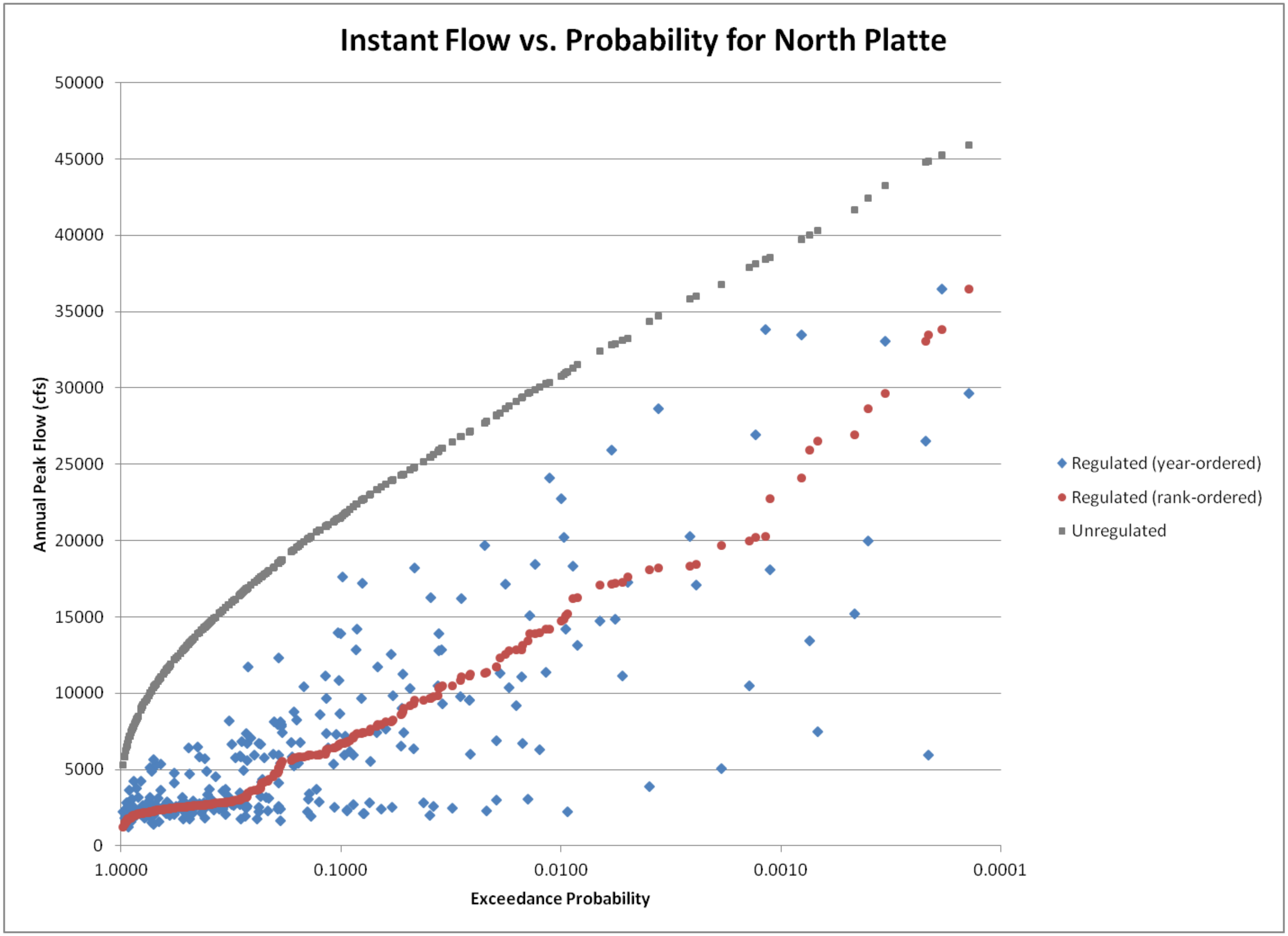

Figure E-44. Instantaneous peaks vs. probability for North Platte

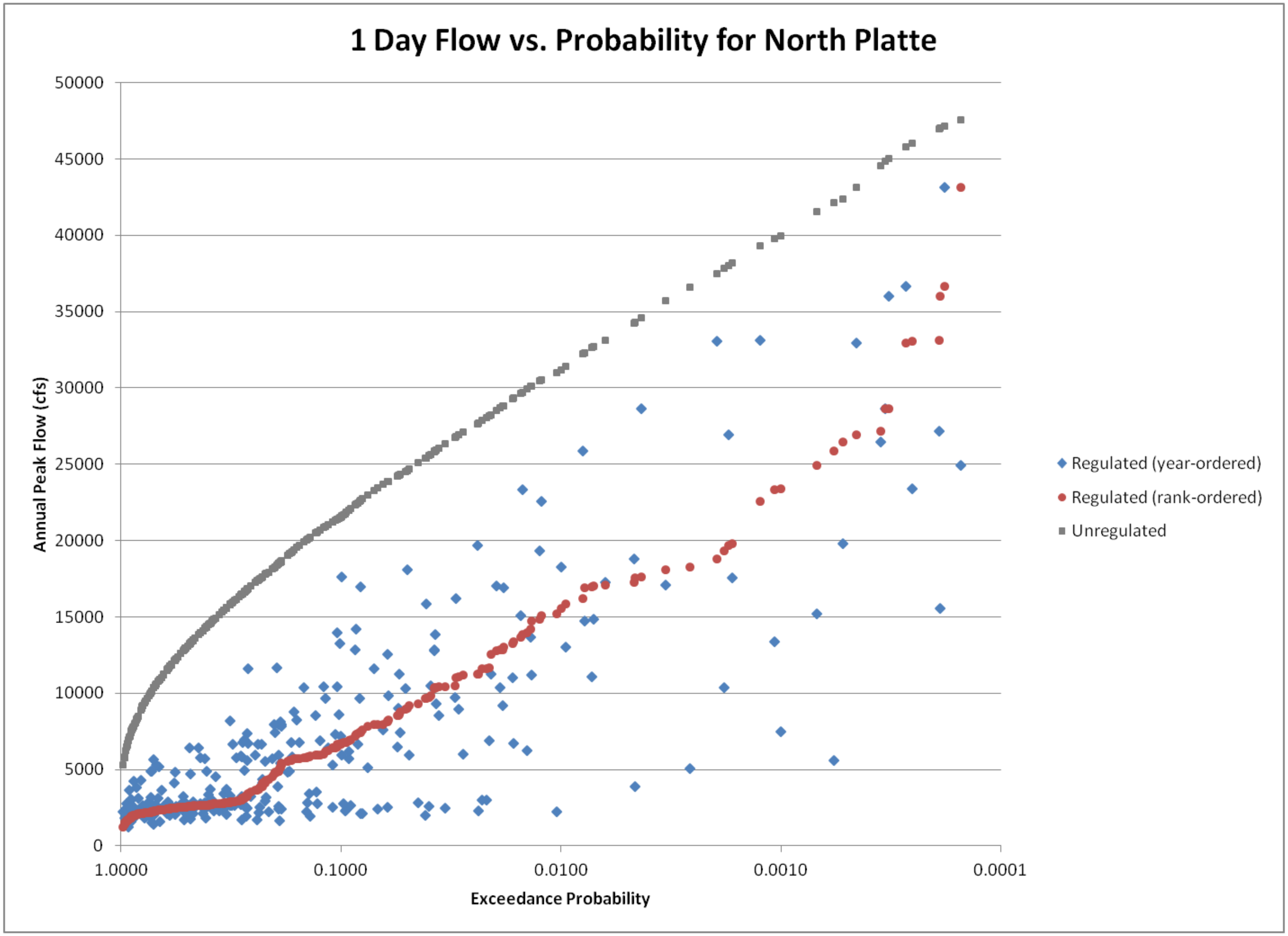

Figure E-45. 1 day peaks vs. probability for North Platte

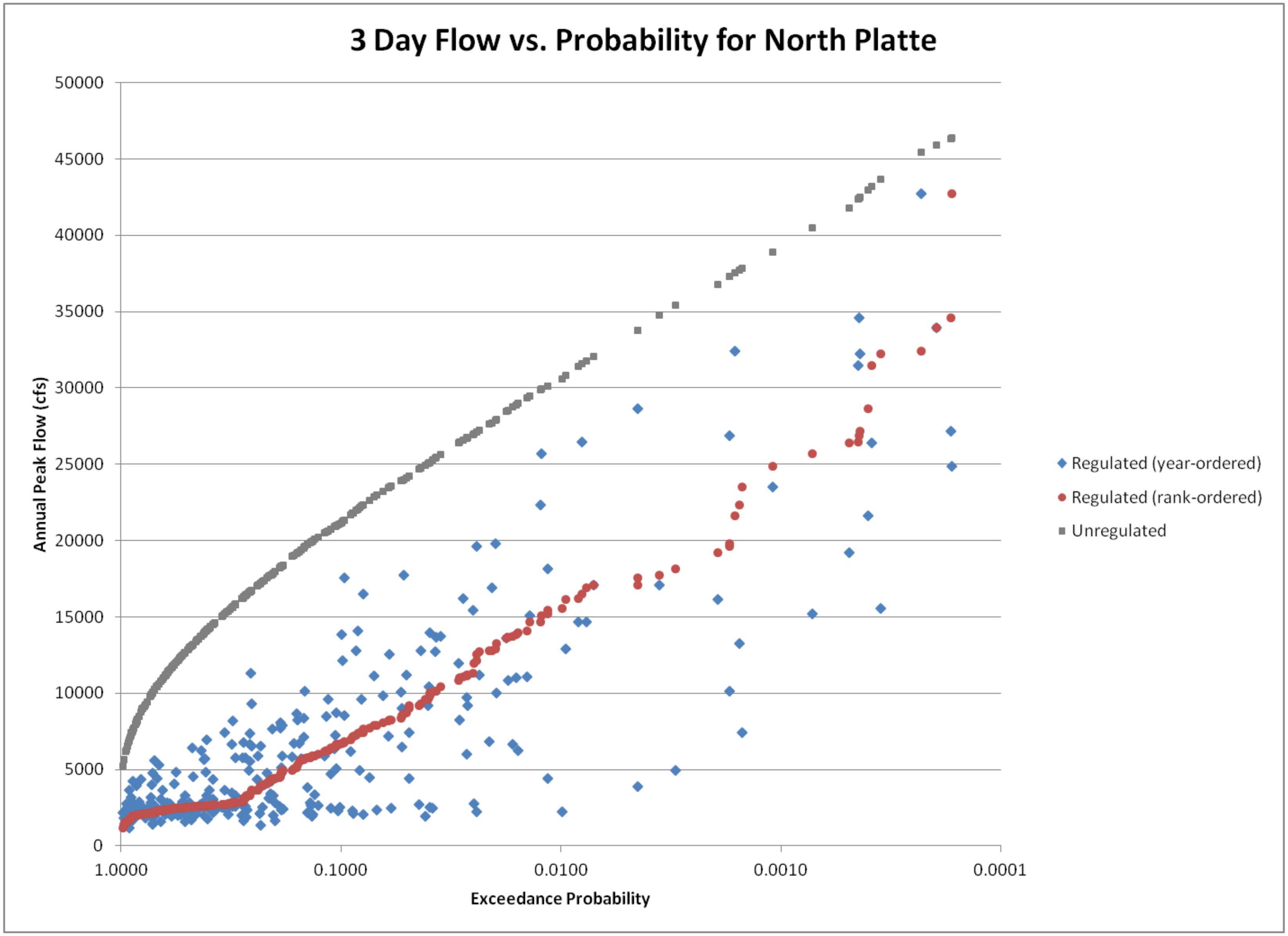

Figure E-46. 3 day peaks vs. probability for North Platte

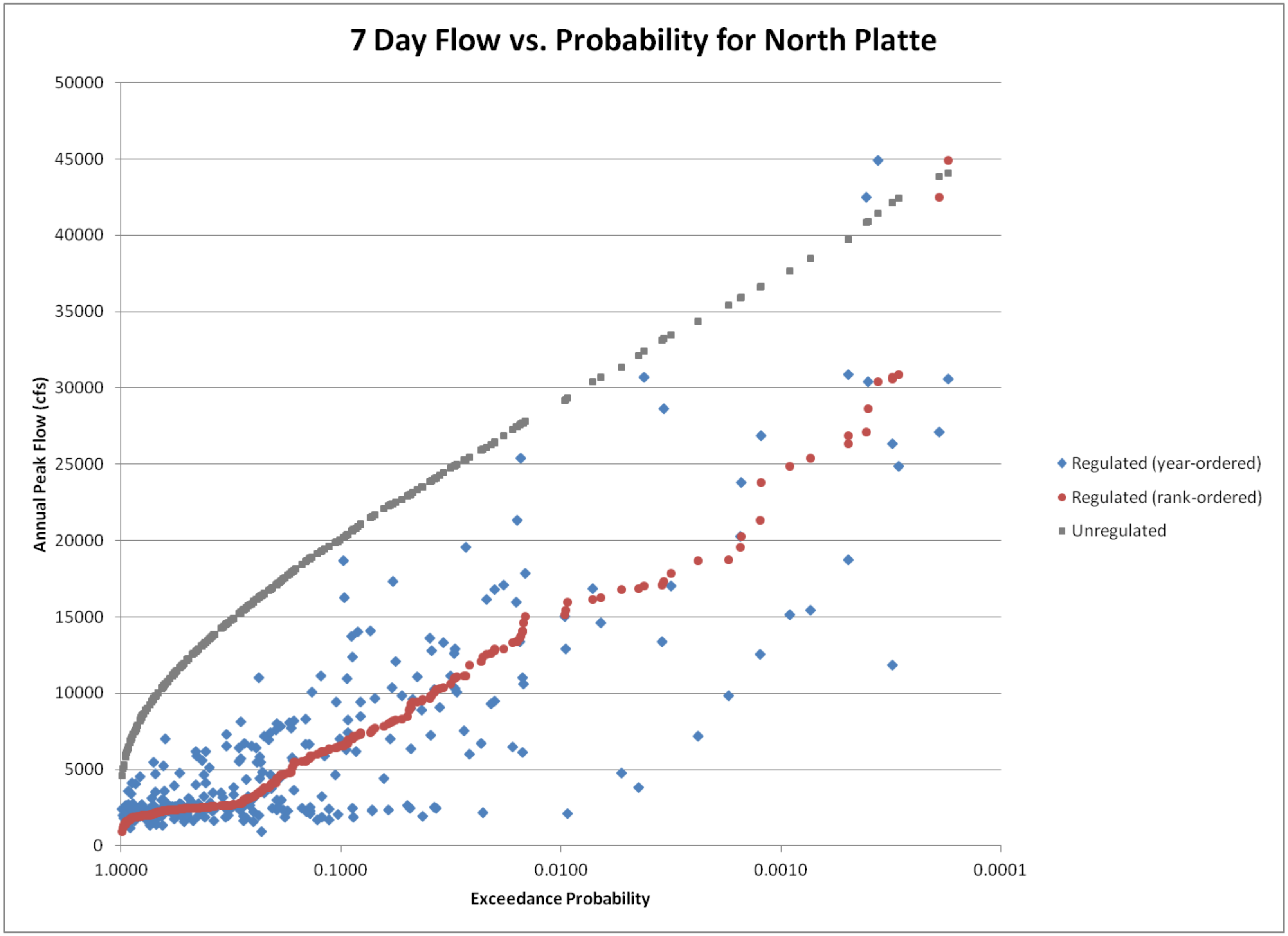

Figure E-47. 7 day peaks vs. probability for North Platte

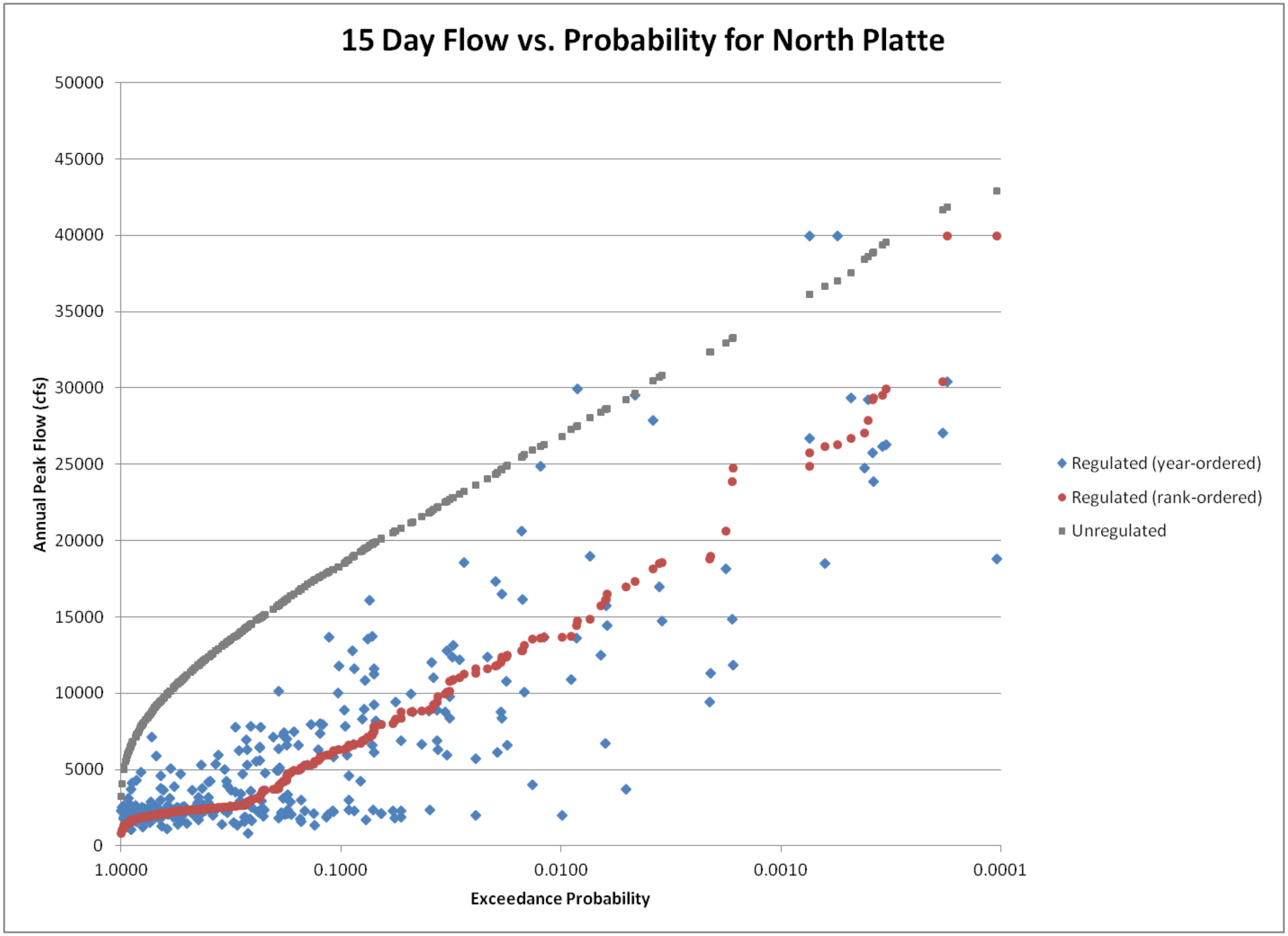

Figure E-48. 15 day peaks vs. probability for North Platte

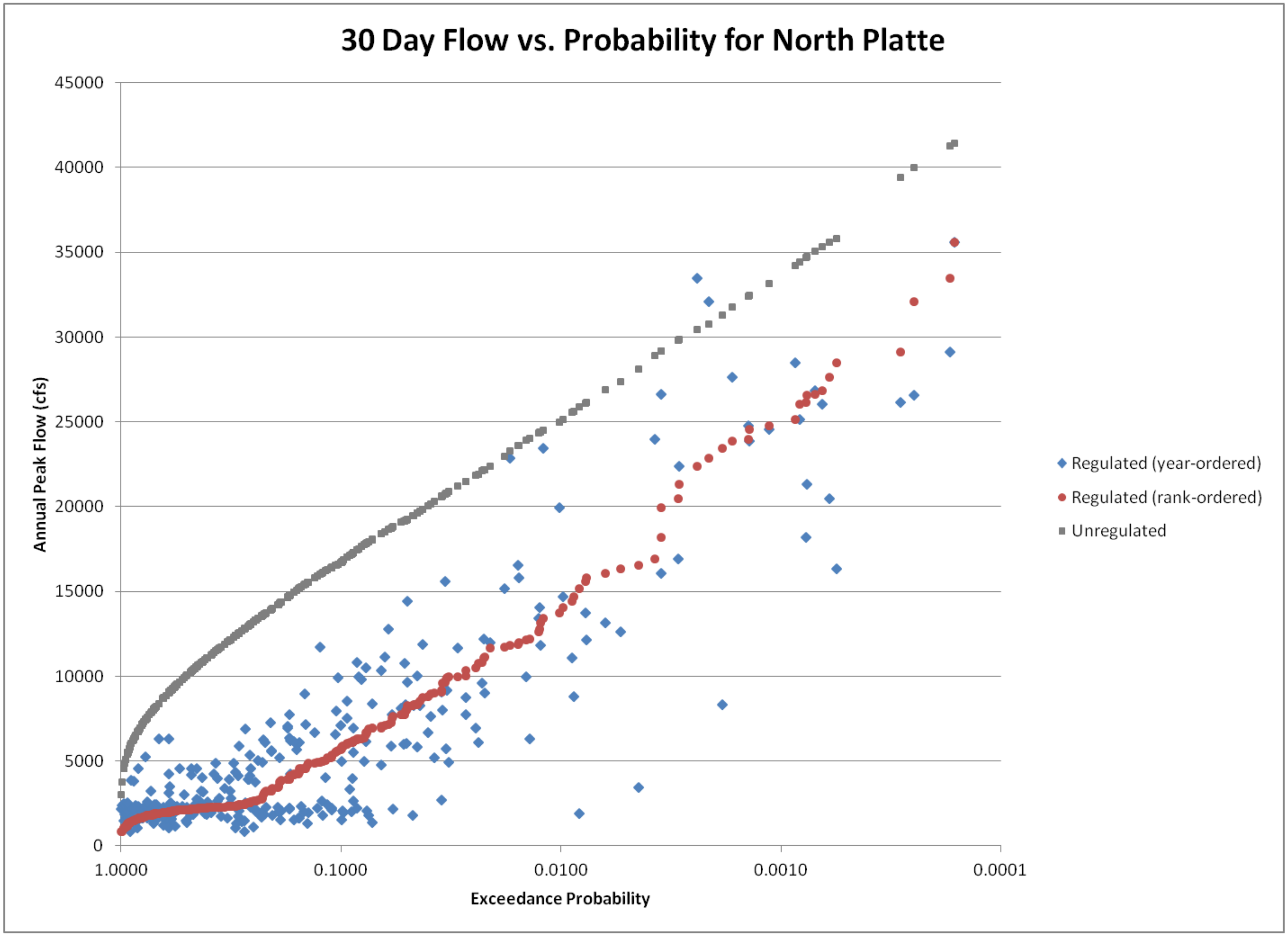

Figure E-49. 30 day peaks vs. probability for North Platte

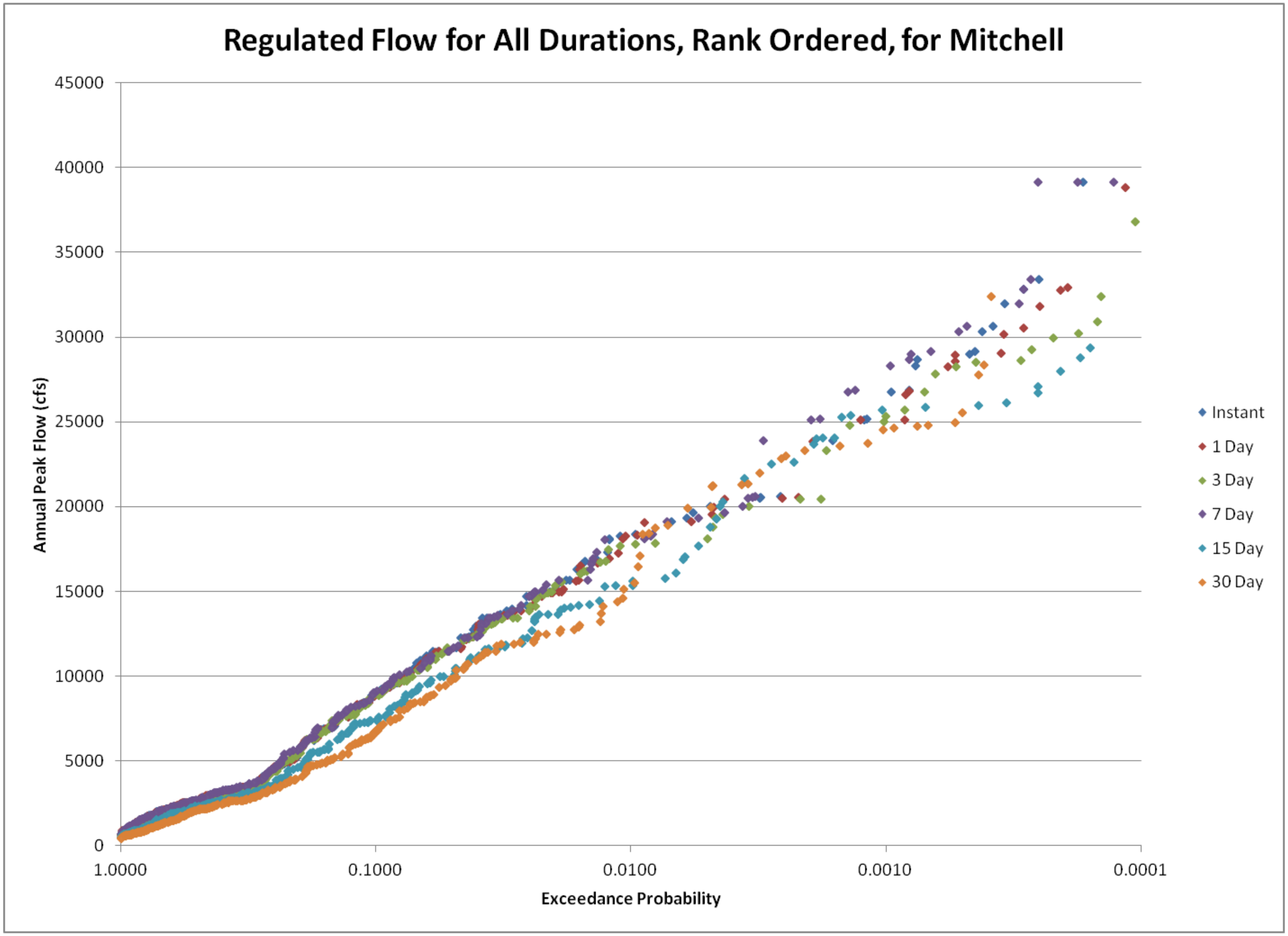

Figure E-50. Regulated flow frequency curves for all durations at Mitchell

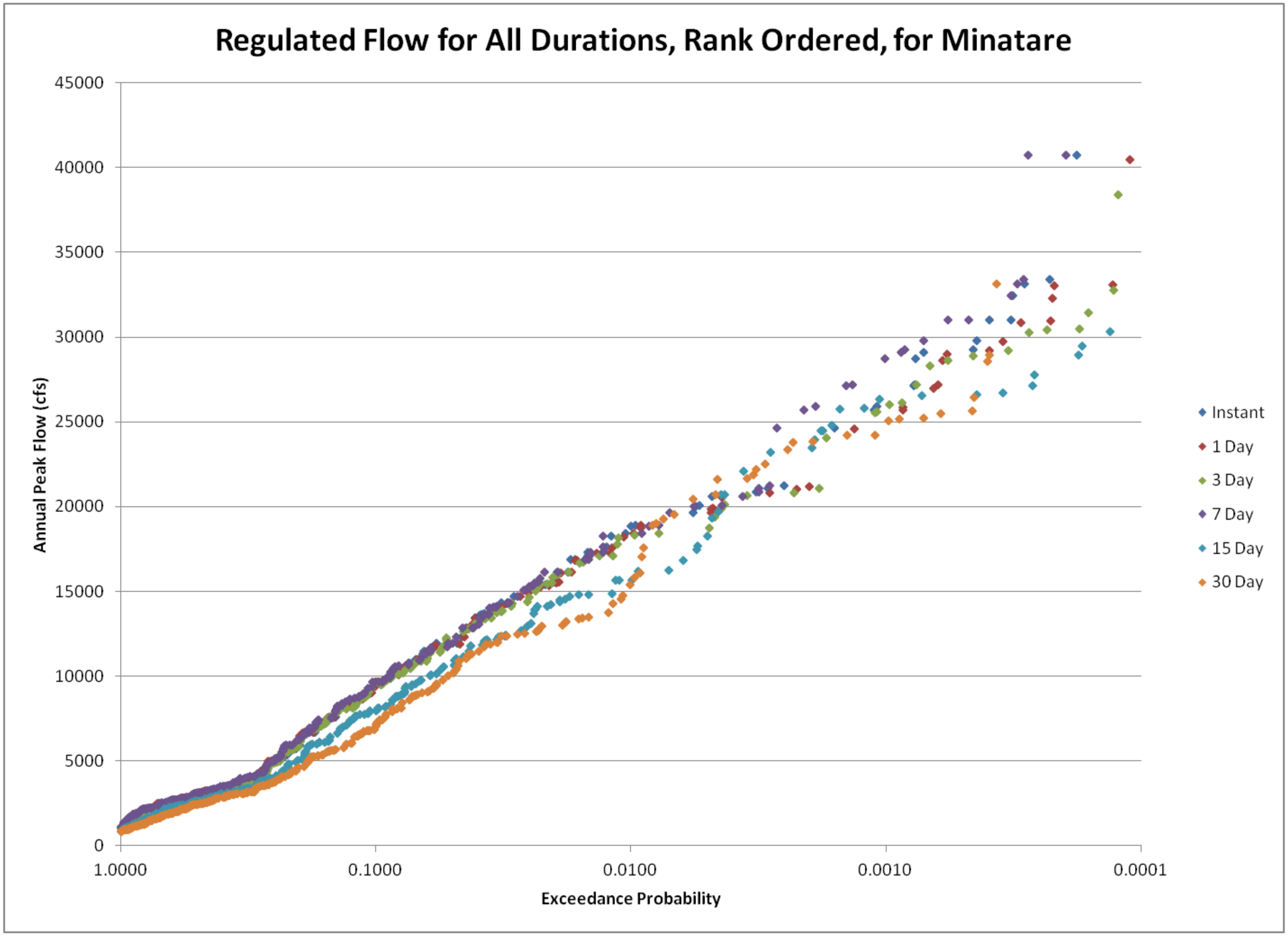

Figure E-51. Regulated flow frequency curves for all durations at Minatare

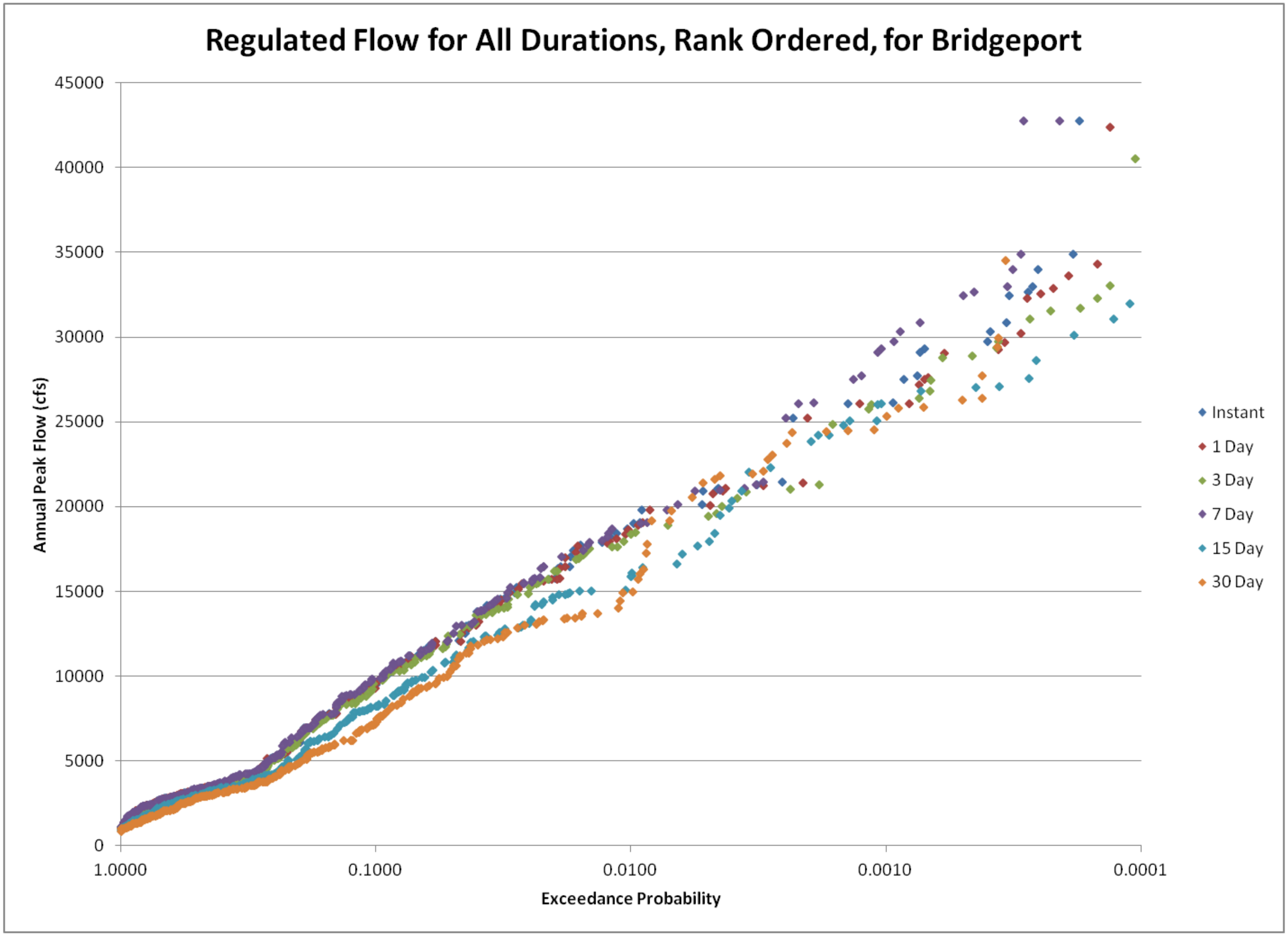

Figure E-52. Regulated flow frequency curves for all durations at Bridgeport

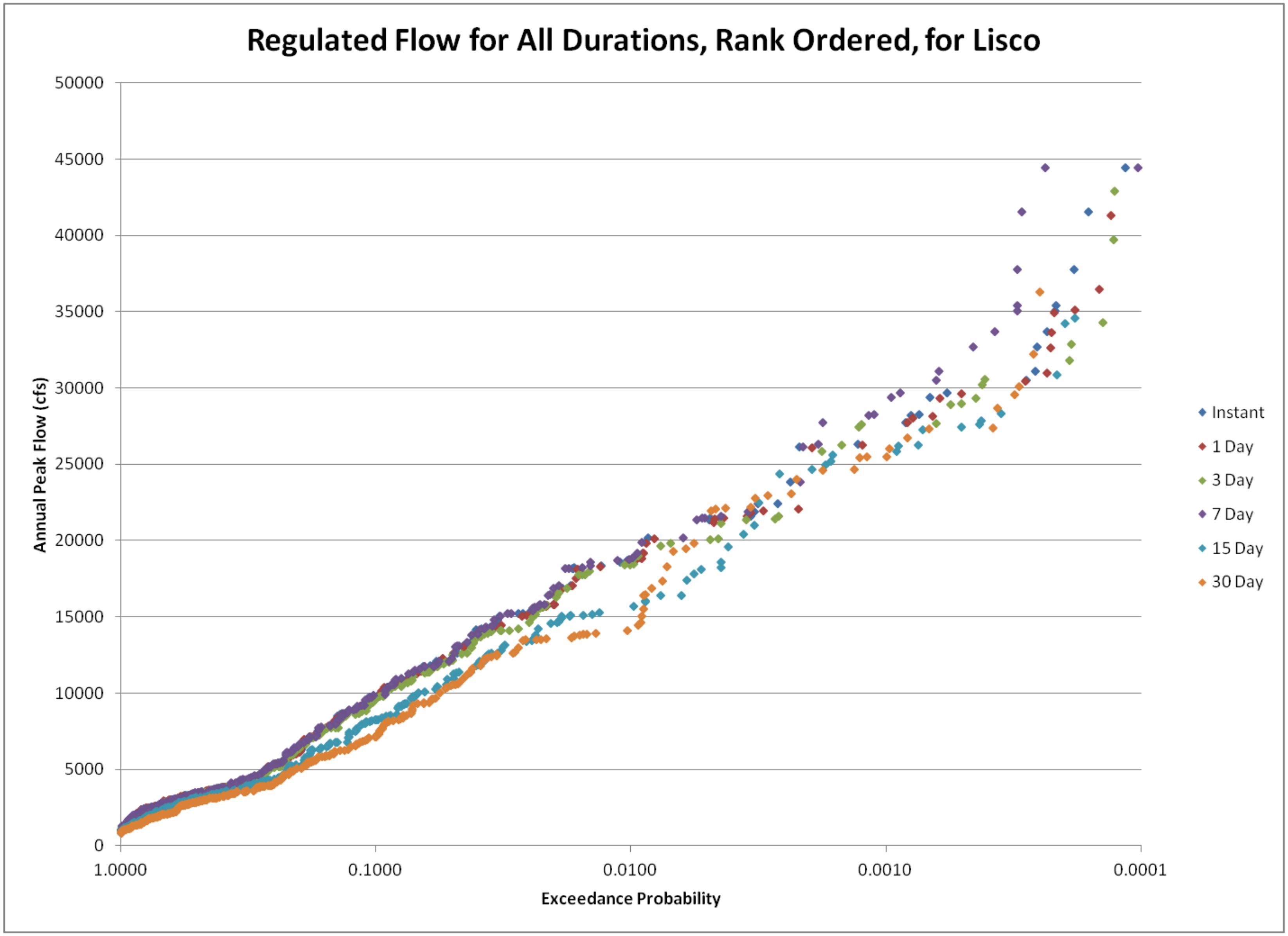

Figure E-53. Regulated flow frequency curves for all durations at Lisco

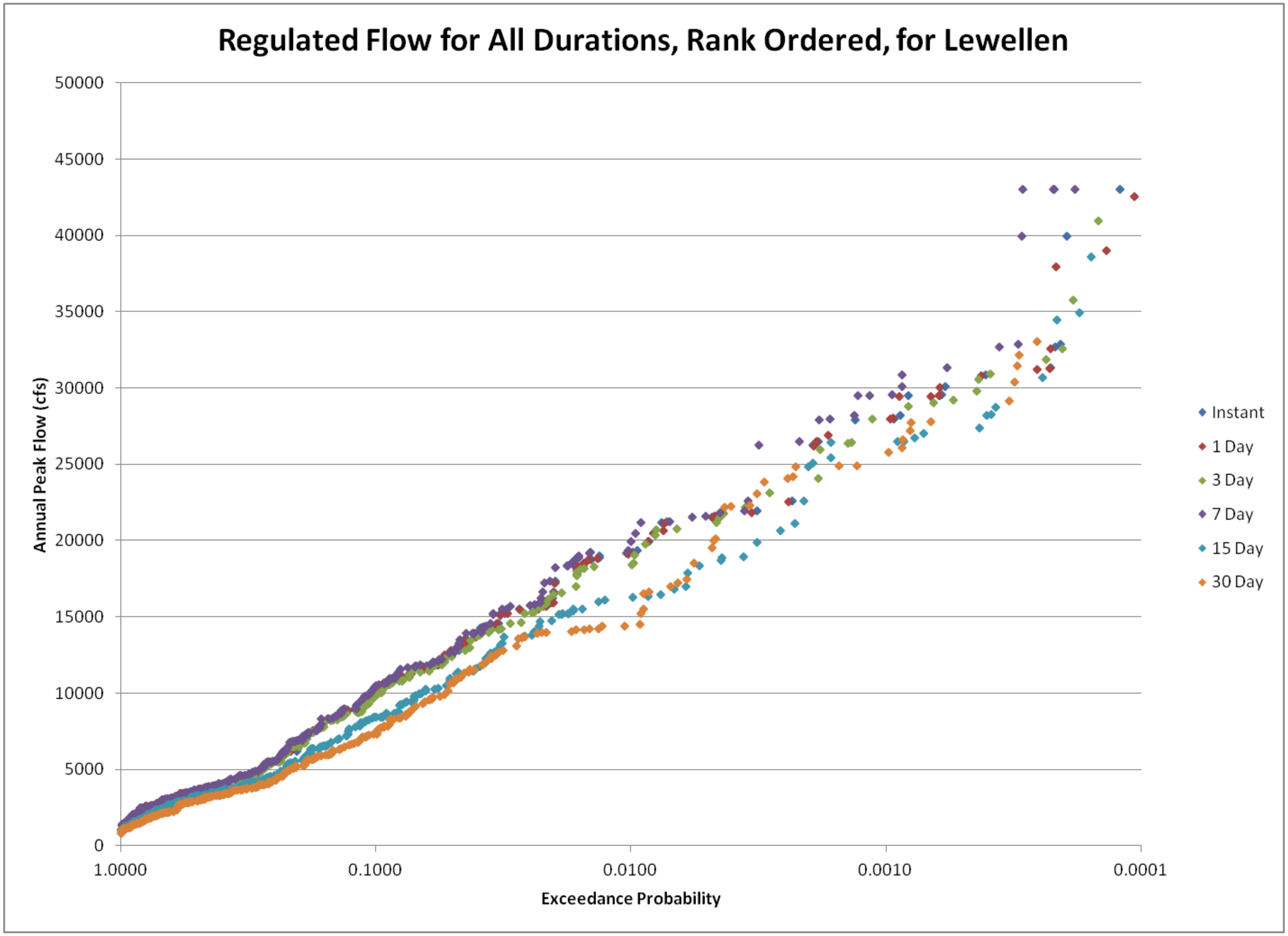

Figure E-54. Regulated flow frequency curves for all durations at Lewellen

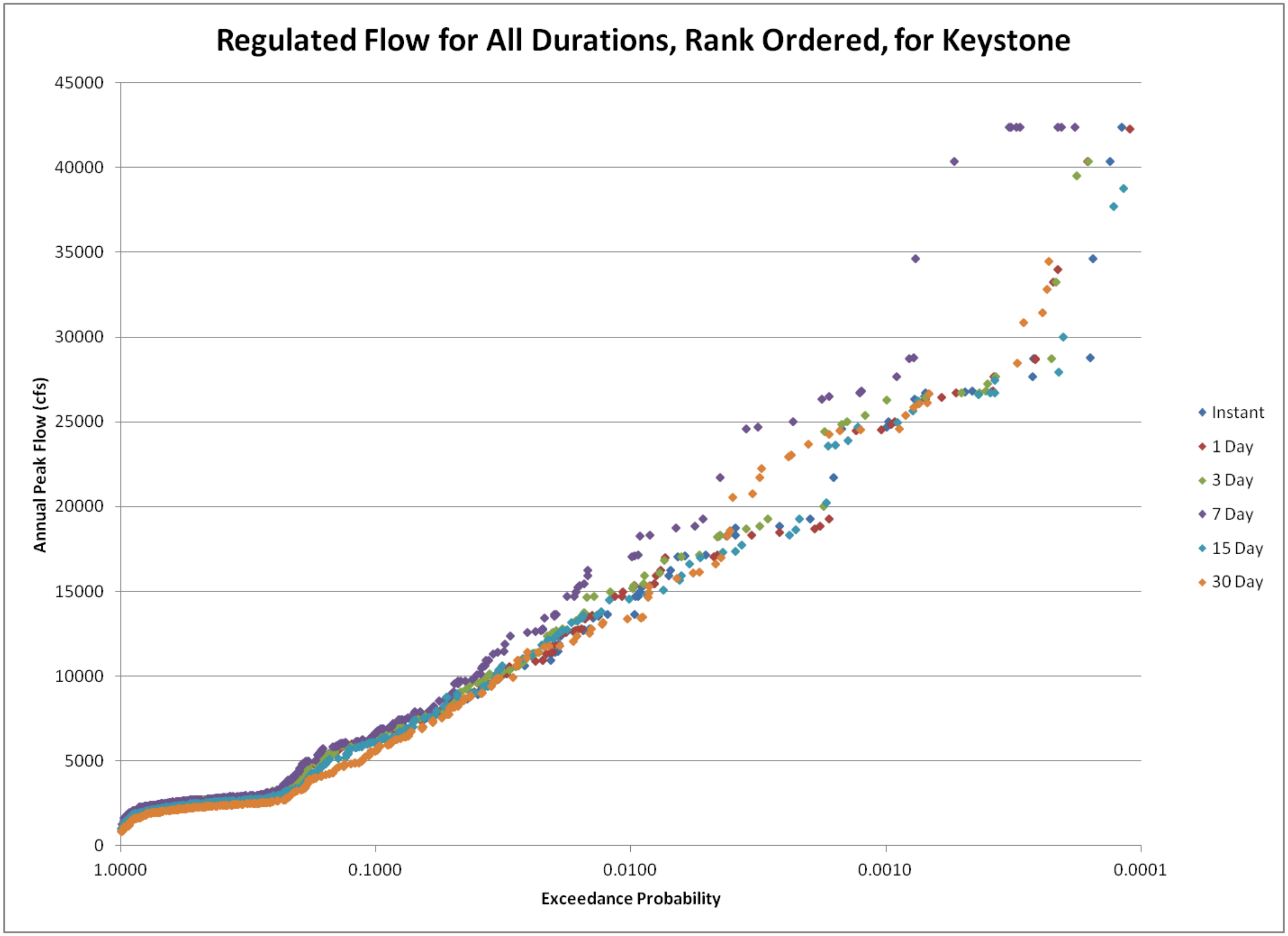

Figure E-55. Regulated flow frequency curves for all durations at Keystone

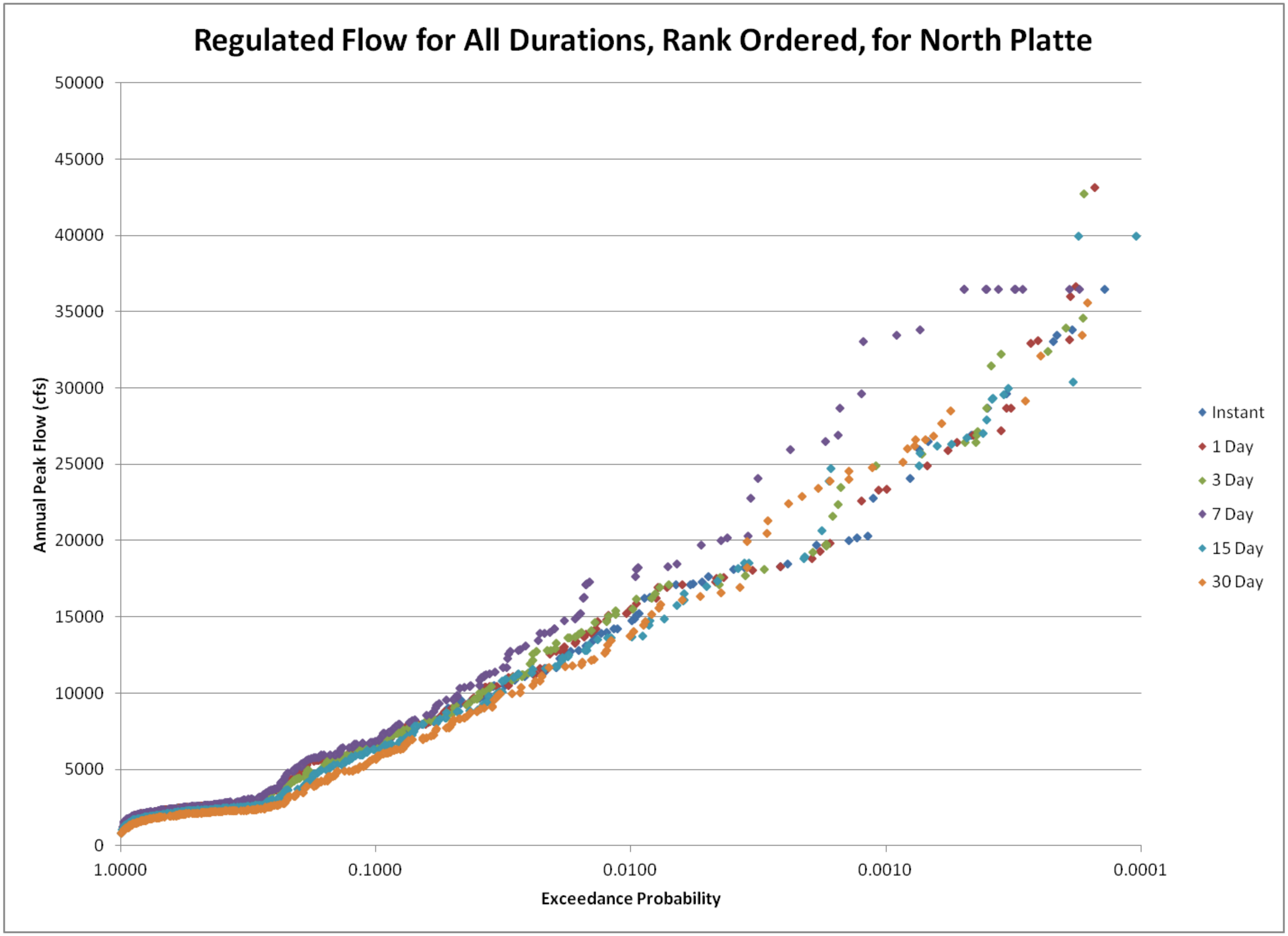

Figure E-56. Regulated flow frequency curves for all durations at North Platte

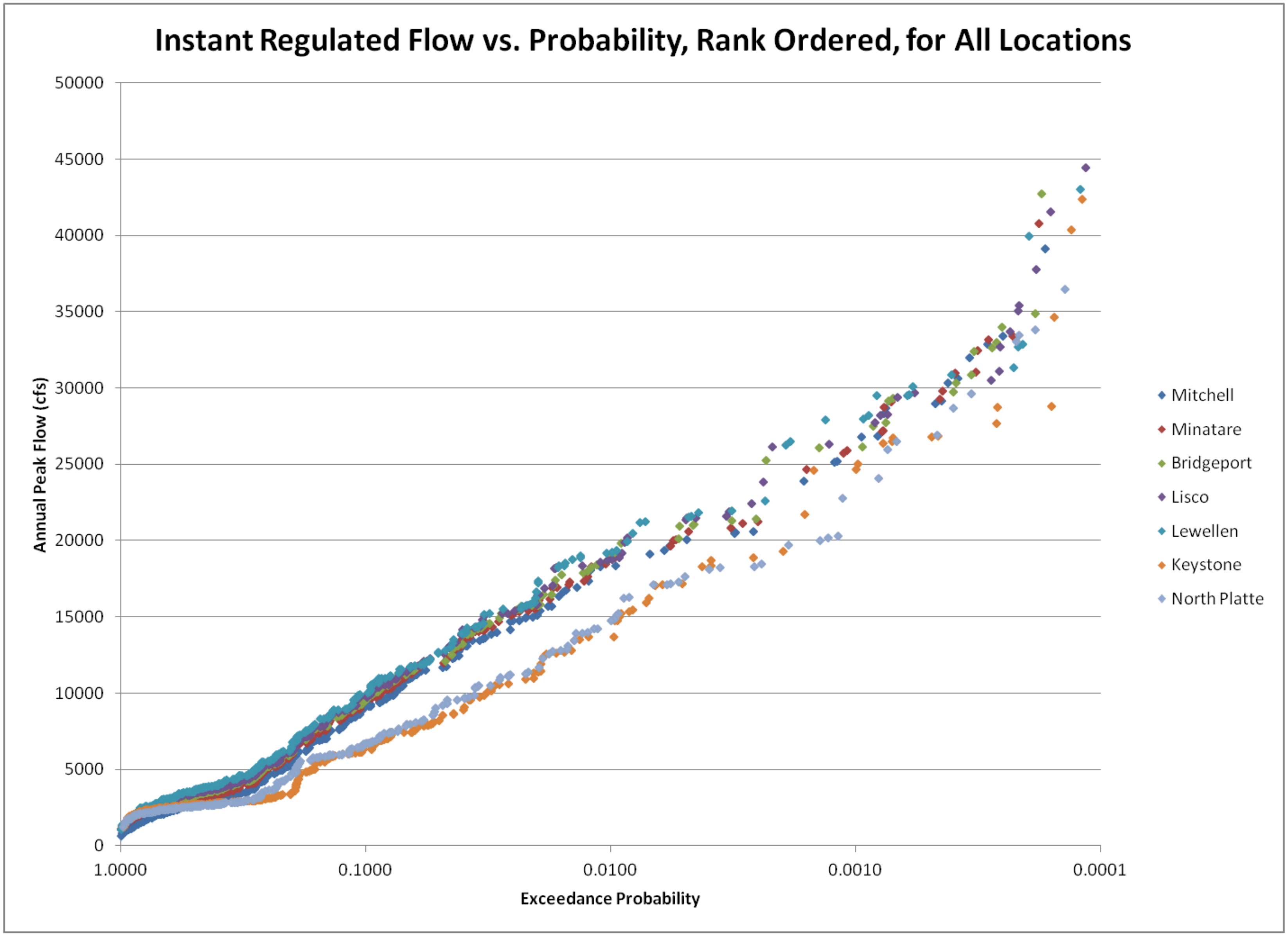

Figure E-57. Instantaneous regulated flow frequency curves for all locations

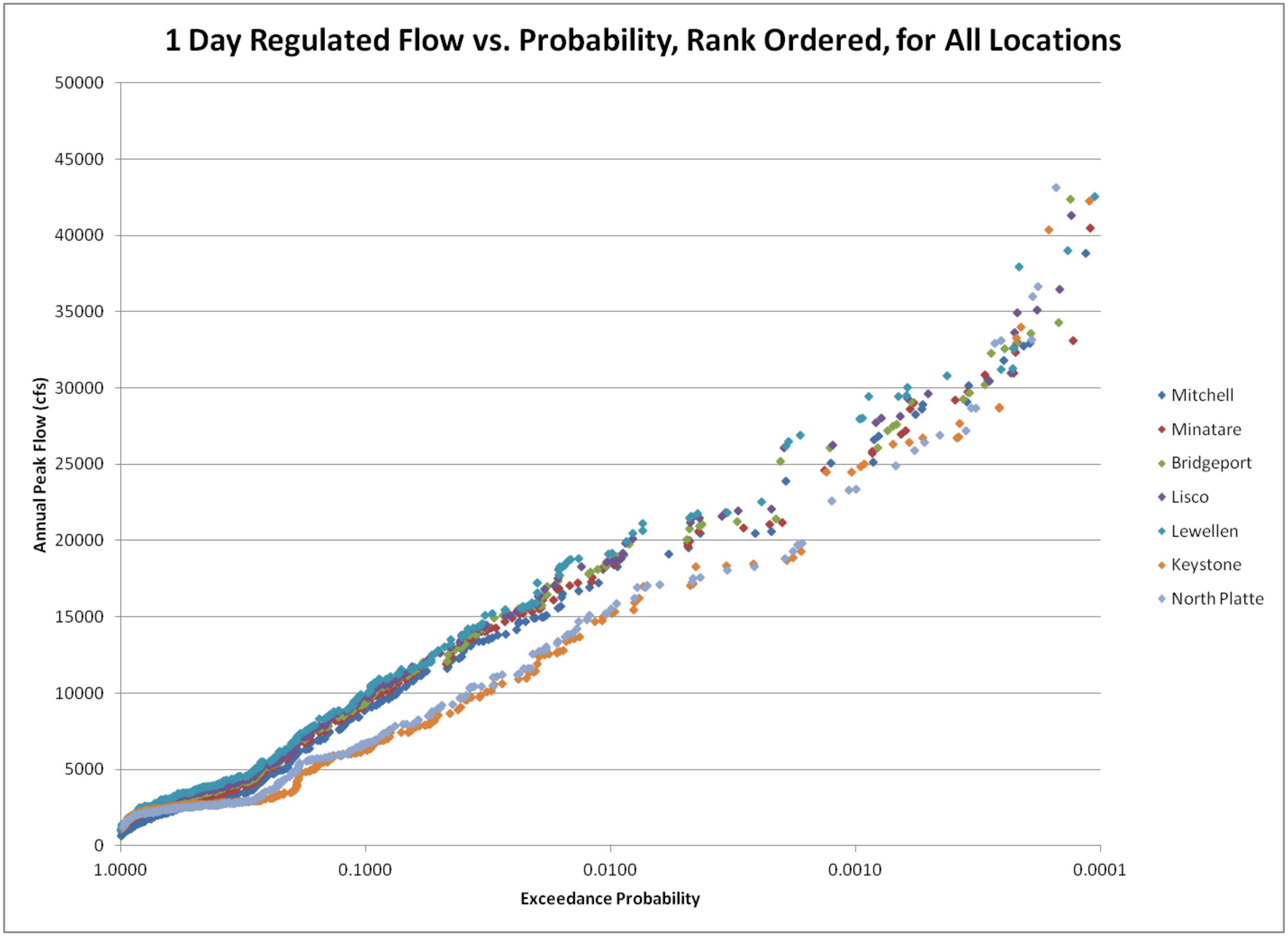

Figure E-58. 1 day regulated flow frequency curves for all locations

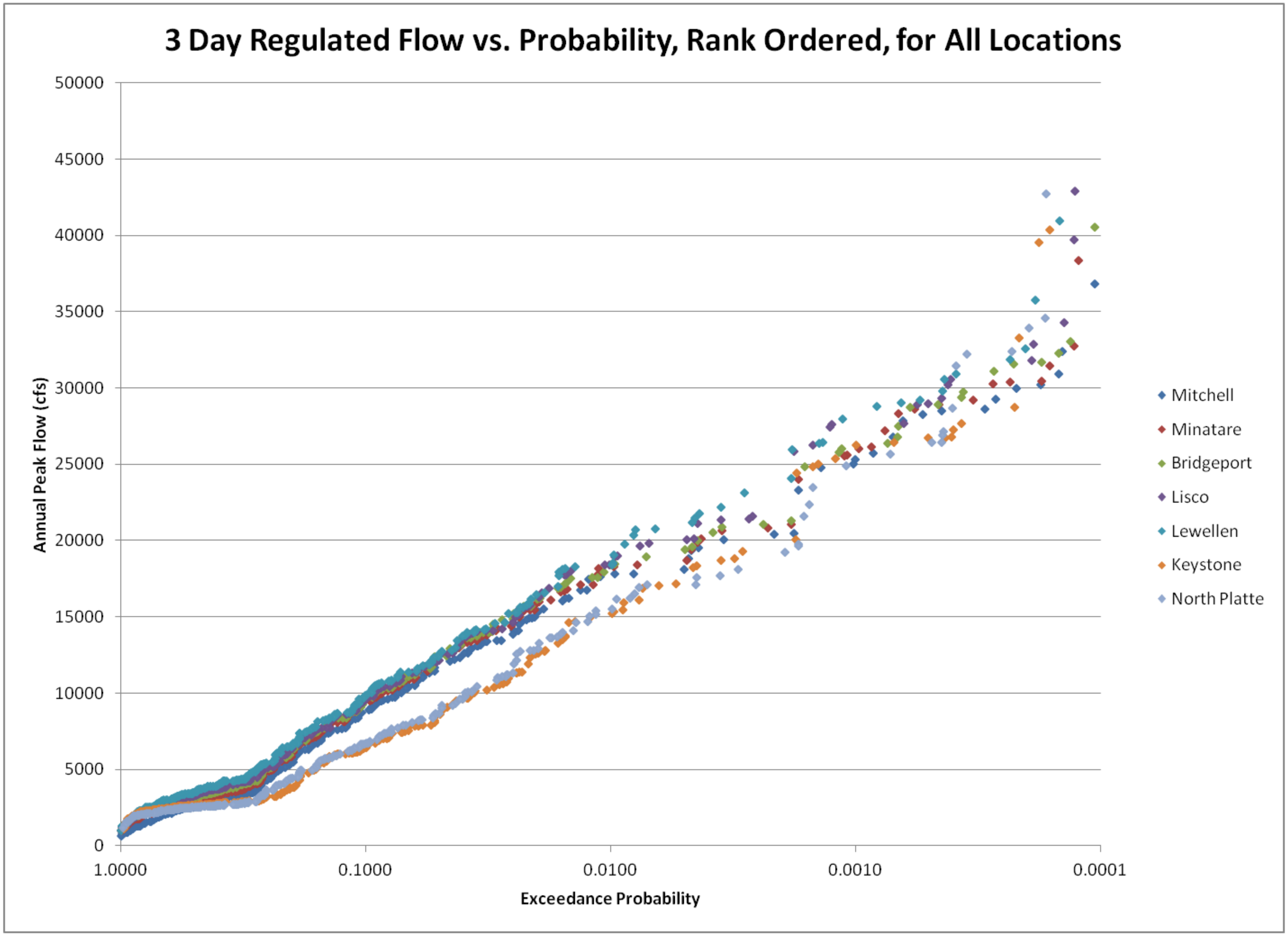

Figure E-59. 3 day regulated flow frequency curves for all locations

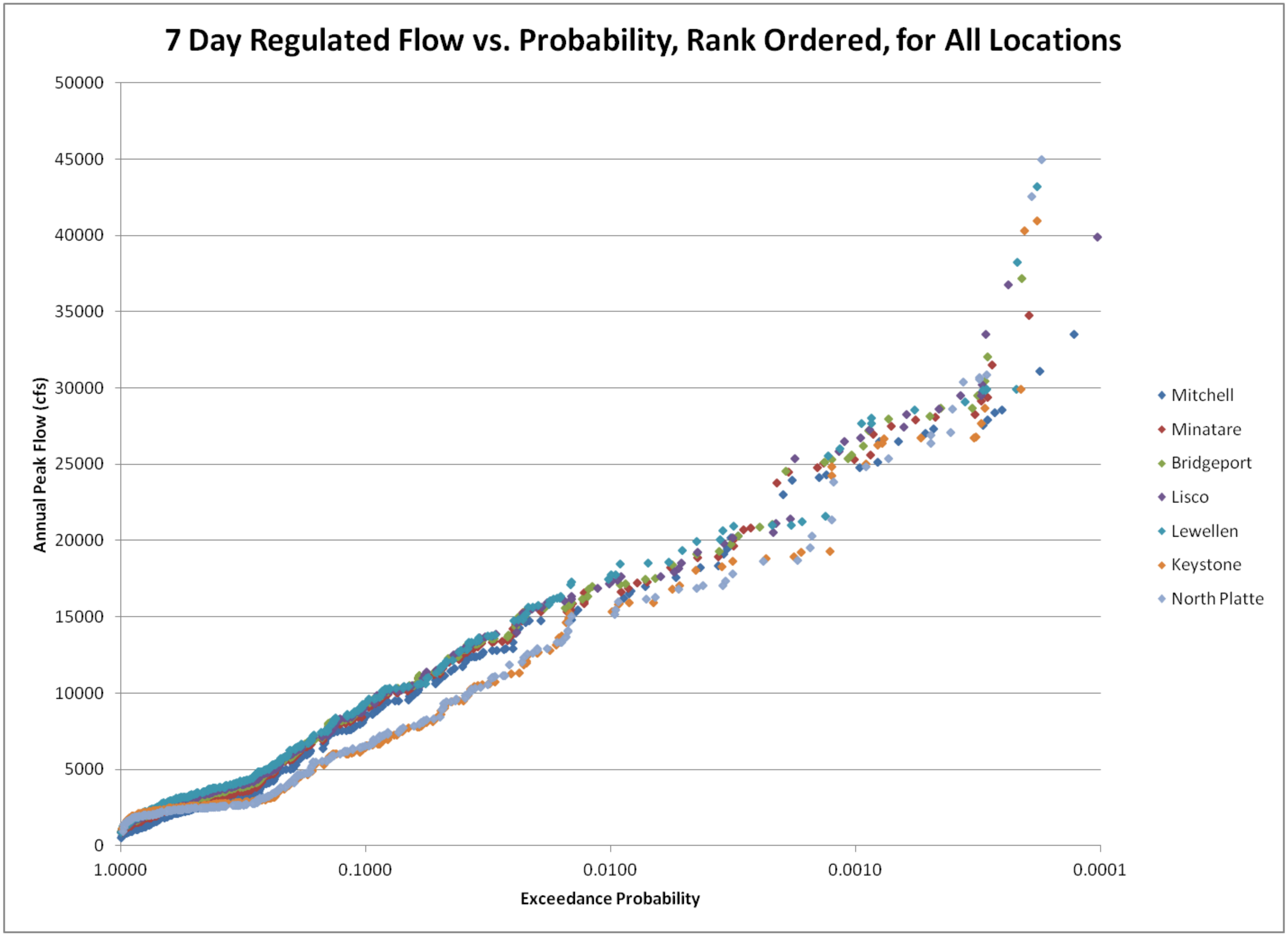

Figure E-60. 7 day regulated flow frequency curves for all locations

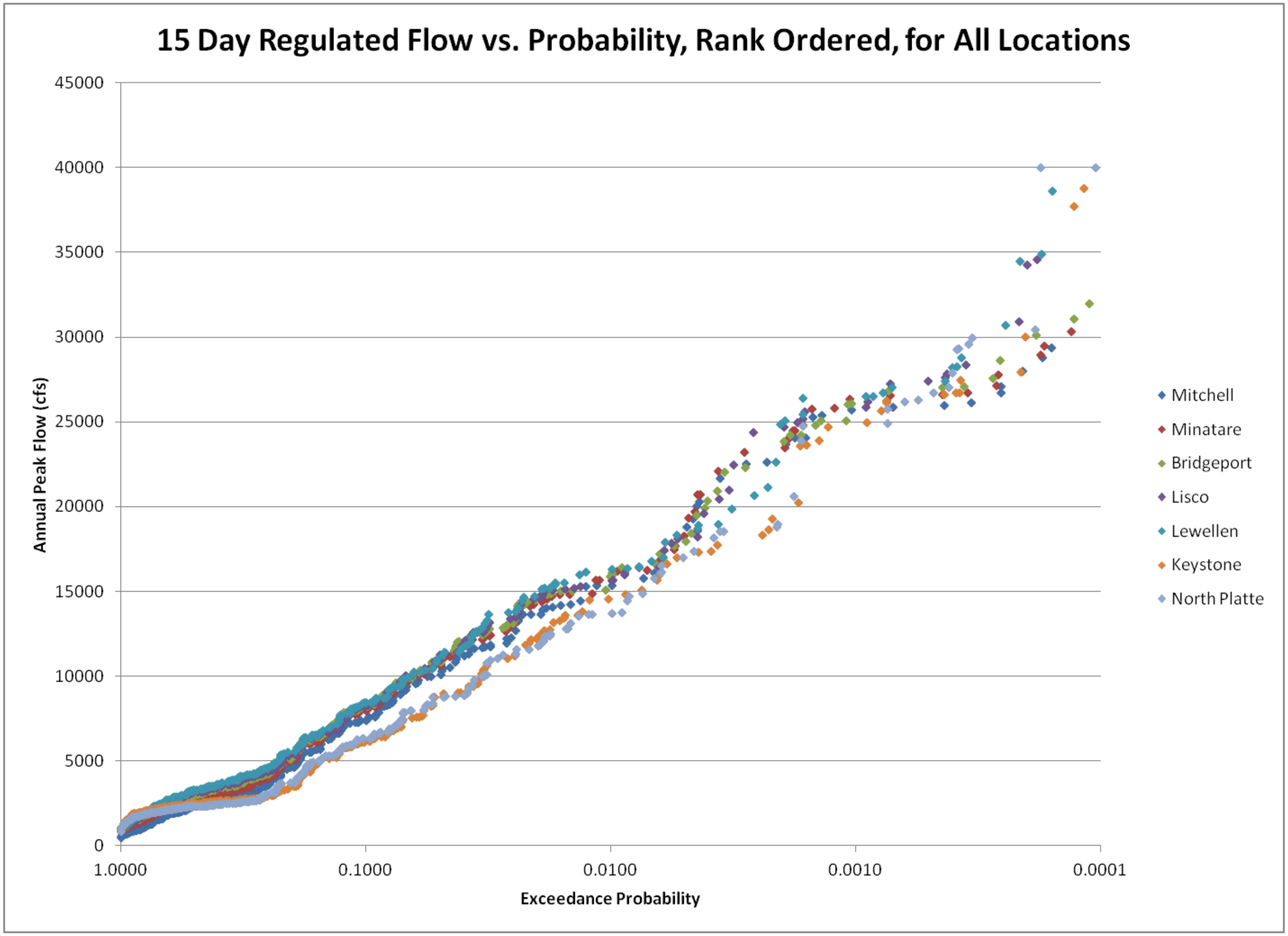

Figure E-61. 15 day regulated flow frequency curves for all locations

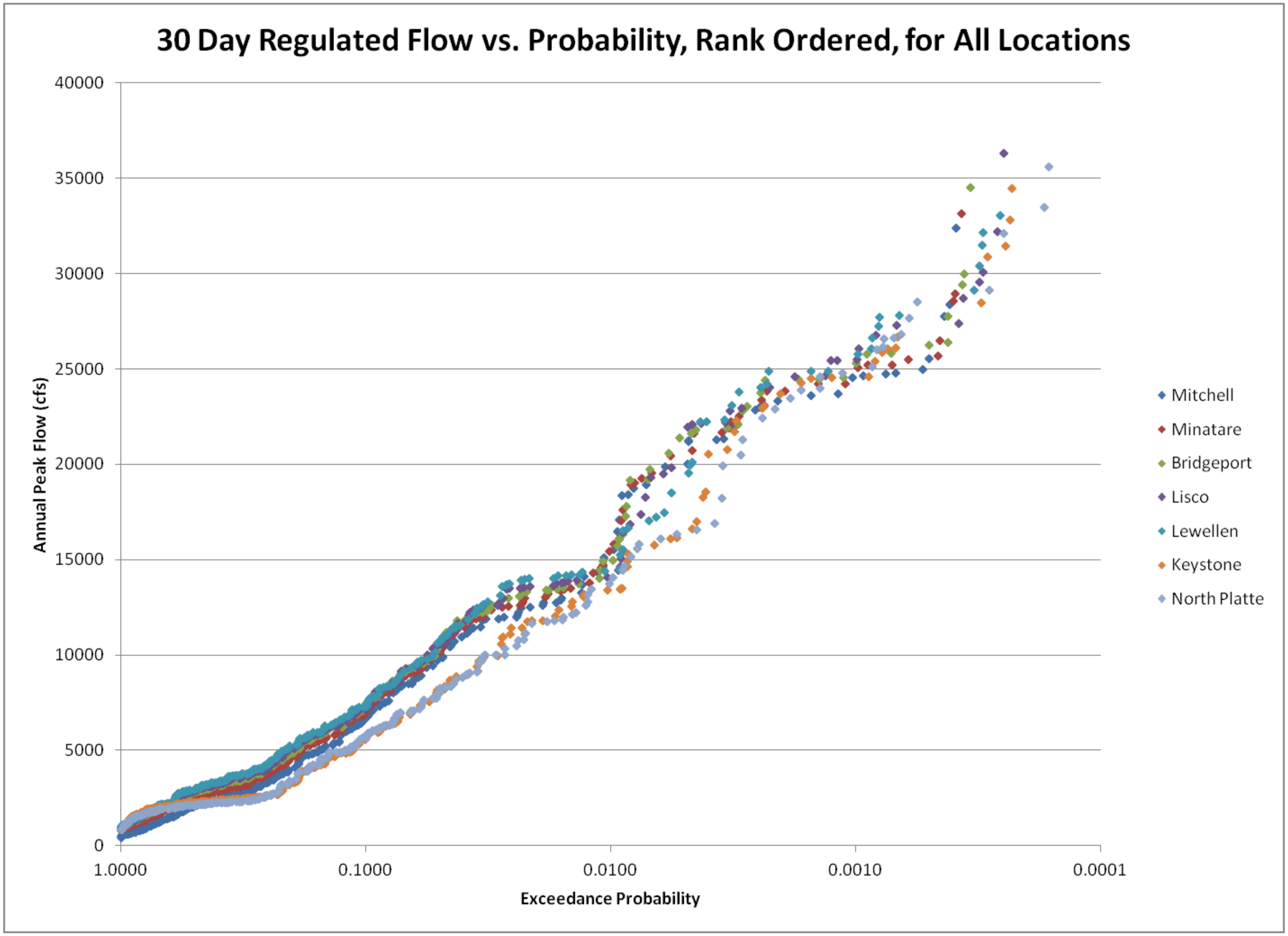

Figure E-62. 30 day regulated flow frequency curves for all locations

Appendix F Tables of Annual Peaks

Table F-1. Annual unregulated peaks for Mitchell (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30700	30500	29900	28600	25900	25000
1950	12300	12200	11900	10900	10800	10400
1951	17000	16900	16500	16300	14700	12900
1952	23400	23300	22700	21100	18400	15700
1953	10700	10600	10000	9050	8750	8350
1954	10200	10200	9770	9060	7630	6220
1955	4830	4800	4740	4690	4630	4440
1956	16000	16000	15600	14900	13600	11200
1957	22300	22200	21800	19900	18700	15900
1958	12300	12300	12000	11300	9880	8270
1959	7140	7130	7090	6940	6670	6460
1960	7780	7750	7530	6960	6100	5040
1961	9340	9300	9070	8790	8020	7070
1962	14100	14100	13700	13000	12400	11900
1963	5110	5090	4900	4550	4430	4370
1964	6920	6890	6690	6270	5910	5540
1965	16500	16500	16300	15400	13200	11500
1966	5460	5420	5130	4640	4380	3850
1967	9300	9260	8980	8840	8530	7780
1968	9840	9820	9700	9430	8860	7590
1969	10100	10100	9780	8830	7960	7350
1970	19700	19700	19200	18600	16000	14400
1971	22700	22600	21400	19100	17000	15300
1972	8500	8480	8350	7950	7130	6610
1973	25600	25500	24700	23700	20200	17300
1974	15100	15000	14600	13400	13200	12800
1975	12100	12100	11800	11200	10300	9070
1976	14200	14200	13800	12800	10800	8800
1977	18700	18200	15100	11300	7910	6010
1978	22700	22400	21000	17900	15500	12900
1979	13000	13000	12500	11600	11200	10600
1980	15900	15800	15700	15100	14400	13500
1981	13300	13200	12500	11000	9140	7210
1982	10600	10600	10500	10200	9430	8910
1983	17200	17200	17000	16800	15600	15500
1984	19600	19600	19200	18100	17200	16100

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1985	11100	11100	10900	10300	10000	8880
1986	17600	17600	17400	16700	16400	14600
1987	7070	7050	6970	6960	6810	6270
1988	9050	9040	9020	8870	8300	7650
1989	4750	4740	4670	4480	4370	4240
1990	9010	8970	8770	8340	7500	6520
1991	16300	16300	15800	14800	13800	11900
1992	10100	10100	9590	8660	7300	6040
1993	13800	13800	13600	13200	12400	11700
1994	10400	10400	10300	9820	9290	8430
1995	19300	19300	19200	18400	17600	16000
1996	14800	14700	14500	14400	14000	13600
1997	20900	20800	20800	20600	19100	16100
1998	12800	12700	12500	11600	10000	9560
1999	15600	15600	15300	14600	13800	12600
2000	10900	10900	10800	10500	10000	8690
2001	5880	5870	5800	5710	5510	5180
2002	2910	2910	2870	2790	2620	2370
2003	12700	12600	12400	11700	10100	8580
2004	6410	6390	6300	6180	5950	5260
2005	17800	17700	17000	14900	12600	11600
2006	12800	12800	12600	12000	10600	8810
2007	9660	9640	9500	9030	8550	7590
2008	15900	15900	15600	14700	13400	12000
2009	14300	14300	14100	13600	13300	12600
2010	19800	19700	18800	17000	15000	14400
2011	23100	23000	22700	21400	19900	19000
2012	6380	6350	6140	5590	5320	4710

Table F-2. Annual unregulated peaks for Minatare (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30700	30600	30000	28600	26000	25100
1950	12300	12300	11900	11000	10900	10500
1951	17100	17000	16600	16400	14800	13000
1952	23400	23400	22700	21200	18500	15800
1953	10800	10700	10100	9160	8870	8500
1954	10300	10200	9860	9170	7740	6330
1955	4930	4910	4870	4830	4760	4570
1956	16100	16100	15700	15000	13700	11300

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1957	22300	22300	21900	20000	18800	16000
1958	12400	12400	12100	11400	9990	8390
1959	7250	7240	7200	7050	6770	6570
1960	7870	7840	7630	7070	6200	5150
1961	9420	9390	9180	8900	8130	7180
1962	14200	14200	13800	13100	12600	12000
1963	5230	5210	5010	4660	4550	4480
1964	7010	6980	6790	6370	6020	5640
1965	16600	16600	16400	15500	13300	11600
1966	5530	5490	5220	4750	4490	3950
1967	9390	9350	9090	8950	8650	7880
1968	9930	9920	9800	9530	8970	7690
1969	10200	10100	9840	8910	8060	7450
1970	19800	19700	19300	18700	16100	14500
1971	22700	22600	21400	19300	17200	15400
1972	8600	8580	8450	8060	7240	6720
1973	25600	25500	24800	23800	20300	17400
1974	15200	15100	14700	13600	13300	12900
1975	12200	12100	11900	11300	10400	9170
1976	14300	14200	13800	12900	10900	8920
1977	18300	17900	15000	11300	8010	6120
1978	22600	22400	21000	18000	15600	13000
1979	13100	13000	12600	11700	11300	10700
1980	16000	15900	15800	15200	14500	13600
1981	13300	13200	12500	11100	9250	7320
1982	10700	10700	10600	10300	9540	9030
1983	17300	17300	17100	16800	15700	15600
1984	19700	19700	19300	18200	17300	16200
1985	11200	11200	11000	10400	10100	8980
1986	17700	17700	17500	16800	16500	14700
1987	7190	7180	7130	7100	6950	6400
1988	9170	9160	9140	8990	8420	7780
1989	4850	4840	4780	4590	4480	4350
1990	9080	9040	8860	8430	7600	6620
1991	16400	16300	15900	15000	13900	12000
1992	10200	10100	9670	8760	7410	6150
1993	13900	13800	13700	13300	12500	11800
1994	10500	10500	10400	9930	9400	8540
1995	19400	19300	19300	18500	17700	16100

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1996	14900	14800	14600	14500	14100	13700
1997	21100	21000	21000	20800	19300	16300
1998	12800	12800	12600	11700	10100	9670
1999	15700	15700	15300	14700	14000	12700
2000	11000	11000	10900	10600	10200	8810
2001	5990	5980	5910	5830	5630	5300
2002	3020	3010	2970	2890	2730	2480
2003	12700	12700	12500	11800	10200	8680
2004	6500	6490	6400	6280	6060	5370
2005	17900	17800	17100	15000	12800	11700
2006	12900	12900	12700	12100	10700	8920
2007	9750	9740	9600	9140	8650	7700
2008	16000	16000	15700	14800	13500	12100
2009	14400	14300	14200	13700	13500	12700
2010	19800	19700	18900	17100	15100	14500
2011	23100	23100	22800	21500	20000	19100
2012	6450	6420	6230	5690	5410	4800

Table F-3. Annual unregulated peaks for Bridgeport (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30800	30800	30200	28900	26200	25300
1950	12500	12500	12100	11200	11100	10700
1951	17200	17200	16800	16600	15000	13300
1952	23600	23500	22900	21400	18700	16000
1953	10900	10800	10300	9360	9090	8720
1954	10500	10400	10100	9370	7960	6550
1955	5150	5140	5110	5070	5000	4800
1956	16300	16200	15900	15200	13900	11600
1957	22500	22500	22000	20200	19000	16200
1958	12600	12600	12300	11600	10200	8610
1959	7460	7460	7420	7260	6980	6780
1960	8060	8030	7830	7280	6420	5360
1961	9620	9590	9400	9120	8350	7410
1962	14400	14400	14000	13300	12800	12300
1963	5440	5410	5230	4870	4770	4700
1964	7200	7180	7000	6590	6240	5860
1965	16800	16800	16600	15700	13600	11800
1966	5720	5670	5420	4960	4710	4170
1967	9580	9540	9300	9170	8870	8090

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1968	10100	10100	10000	9740	9170	7880
1969	10300	10300	10000	9100	8250	7660
1970	20000	19900	19500	18900	16300	14700
1971	22800	22700	21600	19500	17400	15600
1972	8810	8790	8660	8270	7460	6940
1973	25700	25600	25000	24000	20500	17600
1974	15400	15300	14900	13800	13500	13100
1975	12400	12300	12100	11500	10600	9370
1976	14500	14400	14100	13100	11200	9140
1977	18100	17700	15100	11500	8230	6330
1978	22700	22400	21100	18300	15900	13200
1979	13300	13200	12800	11900	11600	10900
1980	16200	16100	16000	15400	14700	13900
1981	13400	13300	12700	11300	9460	7540
1982	10900	10900	10900	10500	9770	9250
1983	17500	17500	17300	17000	15900	15800
1984	19900	19800	19400	18400	17500	16400
1985	11400	11400	11200	10600	10300	9200
1986	17900	17900	17700	17100	16700	14900
1987	7450	7440	7420	7360	7200	6640
1988	9400	9390	9370	9220	8660	8020
1989	5060	5050	4980	4800	4690	4560
1990	9250	9220	9050	8620	7800	6820
1991	16600	16500	16100	15200	14100	12200
1992	10300	10300	9850	8960	7620	6370
1993	14000	14000	13900	13400	12700	12000
1994	10700	10700	10600	10100	9620	8760
1995	19600	19500	19500	18700	17900	16400
1996	15100	15000	14800	14800	14300	13900
1997	21300	21300	21200	21000	19600	16600
1998	13000	12900	12700	11900	10300	9880
1999	15900	15800	15500	14900	14200	12900
2000	11200	11200	11100	10900	10400	9030
2001	6210	6200	6140	6050	5850	5520
2002	3230	3230	3190	3110	2940	2690
2003	12900	12900	12700	12000	10400	8890
2004	6700	6690	6610	6500	6270	5580
2005	18200	18100	17400	15300	13100	11900
2006	13100	13100	12900	12300	10900	9140

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2007	9960	9950	9810	9360	8860	7910
2008	16200	16200	15900	15000	13700	12300
2009	14600	14600	14500	13900	13700	13000
2010	20000	19900	19100	17300	15400	14700
2011	23300	23300	23000	21800	20200	19300
2012	6620	6600	6410	5890	5590	4990

Table F-4. Annual unregulated peaks for Lisco (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30800	30700	30300	28900	26300	25400
1950	12500	12400	12100	11200	11100	10700
1951	17100	17100	16800	16600	15000	13300
1952	23500	23400	22800	21400	18700	16000
1953	10800	10800	10300	9410	9140	8770
1954	10400	10400	10000	9380	7990	6580
1955	5290	5290	5260	5230	5140	4930
1956	16300	16200	15900	15200	13900	11600
1957	22500	22500	22100	20300	19100	16300
1958	12600	12500	12300	11600	10200	8650
1959	7490	7480	7440	7290	7010	6820
1960	8050	8020	7840	7310	6460	5400
1961	9670	9640	9470	9200	8440	7510
1962	14500	14400	14100	13400	12900	12400
1963	5460	5430	5260	4900	4810	4730
1964	7190	7170	7010	6620	6270	5890
1965	16900	16900	16700	15900	13800	12000
1966	5680	5650	5420	4990	4730	4200
1967	9580	9560	9370	9230	8950	8180
1968	10100	10100	10000	9760	9190	7900
1969	10300	10300	9990	9120	8270	7700
1970	20000	20000	19600	19000	16400	14800
1971	22600	22500	21500	19500	17400	15700
1972	8810	8790	8670	8290	7490	6970
1973	25600	25500	25000	23900	20500	17600
1974	15300	15300	14900	13800	13600	13100
1975	12400	12300	12100	11500	10600	9430
1976	14500	14400	14100	13100	11200	9200
1977	17400	17000	15000	11500	8270	6370
1978	22300	22200	21000	18500	16000	13300

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1979	13200	13200	12800	11900	11600	10900
1980	16200	16100	16000	15500	14700	13900
1981	13300	13300	12700	11400	9520	7600
1982	11000	10900	10900	10500	9810	9320
1983	17600	17500	17300	17100	16000	15900
1984	19800	19800	19400	18500	17600	16500
1985	11400	11400	11200	10700	10300	9230
1986	18200	18100	18000	17300	17000	15200
1987	7560	7560	7540	7470	7310	6750
1988	9480	9480	9450	9300	8760	8140
1989	5080	5070	5010	4830	4730	4600
1990	9230	9210	9070	8640	7820	6850
1991	16500	16500	16100	15200	14200	12300
1992	10200	10200	9800	8960	7640	6390
1993	14100	14000	13900	13500	12700	12000
1994	10700	10700	10600	10200	9630	8770
1995	19700	19700	19600	18900	18100	16600
1996	15100	15100	14900	14800	14400	14000
1997	21400	21400	21400	21100	19700	16700
1998	12900	12900	12700	11900	10400	9910
1999	15800	15800	15500	15000	14200	12900
2000	11200	11200	11100	10900	10400	9070
2001	6260	6250	6200	6110	5910	5570
2002	3250	3240	3210	3130	2960	2710
2003	12900	12900	12700	12000	10400	8910
2004	6700	6690	6620	6510	6280	5600
2005	18300	18200	17600	15500	13200	12000
2006	13100	13100	12900	12300	10900	9160
2007	10000	9980	9850	9410	8930	7980
2008	16200	16200	15900	15100	13800	12400
2009	14900	14800	14600	13900	13800	13100
2010	19900	19800	19100	17400	15600	14800
2011	23300	23300	23000	21800	20300	19400
2012	6610	6590	6420	5910	5630	5020

Table F-5. Annual unregulated peaks for Lewellen (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30800	30800	30300	29000	26500	25500
1950	12400	12400	12100	11200	11200	10800

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1951	17200	17100	16800	16600	15100	13400
1952	23400	23300	22800	21400	18800	16100
1953	10800	10700	10200	9430	9180	8820
1954	10400	10300	10000	9400	8040	6640
1955	5660	5650	5460	5430	5370	5130
1956	16200	16200	16000	15200	14000	11600
1957	22500	22500	22100	20400	19200	16400
1958	12600	12600	12400	11700	10400	8760
1959	7530	7520	7480	7330	7050	6870
1960	8110	8090	7910	7410	6560	5480
1961	9740	9710	9570	9300	8550	7630
1962	14600	14500	14300	13600	13100	12500
1963	5520	5500	5340	4970	4890	4780
1964	7210	7190	7040	6670	6320	5930
1965	17000	17000	16800	16000	14000	12200
1966	5660	5630	5420	5010	4760	4270
1967	9810	9790	9640	9480	9160	8380
1968	10200	10200	10100	9810	9240	7950
1969	10300	10300	10000	9190	8370	7810
1970	20100	20000	19700	19100	16500	15000
1971	22500	22400	21500	19600	17500	15800
1972	8840	8830	8710	8340	7560	7040
1973	25500	25400	24900	23900	20500	17600
1974	15400	15300	14900	13900	13700	13200
1975	12400	12400	12200	11600	10700	9520
1976	14500	14400	14100	13200	11300	9280
1977	16900	16600	14800	11600	8380	6480
1978	22100	22000	20900	18600	16100	13400
1979	13200	13100	12800	11900	11600	11000
1980	16200	16200	16100	15600	14800	14000
1981	13300	13300	12700	11500	9650	7770
1982	11000	11000	10900	10600	9880	9400
1983	17600	17600	17400	17100	16100	16000
1984	19800	19800	19500	18500	17600	16600
1985	11400	11400	11200	10700	10400	9270
1986	18300	18200	18100	17500	17100	15300
1987	7730	7730	7720	7640	7470	6910
1988	9550	9550	9530	9370	8880	8290
1989	5080	5080	5020	4850	4780	4650

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1990	9210	9190	9060	8640	7860	6910
1991	16600	16500	16200	15300	14300	12400
1992	10200	10200	9830	9020	7720	6450
1993	14100	14100	13900	13600	12800	12100
1994	10700	10700	10600	10200	9670	8830
1995	19900	19900	19800	19100	18500	17000
1996	15200	15200	15000	15000	14500	14100
1997	21600	21600	21500	21300	19900	16900
1998	13000	13000	12800	12000	10500	10000
1999	15900	15800	15600	15000	14300	13000
2000	11300	11300	11200	11000	10500	9160
2001	6350	6340	6300	6210	6010	5670
2002	3290	3280	3250	3180	3000	2750
2003	12900	12900	12700	12000	10500	8970
2004	6730	6720	6660	6550	6320	5640
2005	18400	18300	17700	15700	13400	12200
2006	13100	13100	12900	12400	11000	9220
2007	10100	10100	9990	9560	9120	8180
2008	16200	16200	16000	15100	13800	12400
2009	15300	15300	15100	14300	13900	13300
2010	20000	19900	19200	17600	15800	15000
2011	23400	23400	23100	22000	20500	19500
2012	6660	6640	6480	6000	5720	5110

Table F-6. Annual unregulated peaks for Keystone (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	30900	30800	30400	29100	26500	25600
1950	12400	12400	12100	11300	11200	10800
1951	17200	17200	17000	16700	15100	13400
1952	23400	23300	22800	21400	18800	16200
1953	10800	10700	10300	9460	9210	8850
1954	10400	10300	10100	9420	8060	6660
1955	6180	6140	5840	5640	5510	5240
1956	16300	16200	16000	15200	14000	11600
1957	22500	22500	22100	20500	19300	16500
1958	12600	12600	12400	11700	10400	8790
1959	7540	7530	7490	7340	7070	6890
1960	8130	8110	7940	7440	6590	5510
1961	9750	9730	9590	9320	8570	7650

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1962	14700	14600	14400	13700	13200	12600
1963	5560	5530	5380	5010	4940	4820
1964	7220	7200	7050	6680	6330	5940
1965	17100	17100	16900	16100	14000	12300
1966	5670	5640	5440	5030	4780	4310
1967	9860	9840	9700	9530	9210	8420
1968	10200	10200	10100	9820	9250	7960
1969	10300	10300	10000	9210	8390	7840
1970	20100	20100	19700	19100	16600	15000
1971	22600	22400	21600	19700	17600	15800
1972	8870	8850	8740	8370	7590	7070
1973	25500	25400	24900	23900	20600	17700
1974	15400	15300	15000	14000	13700	13200
1975	12400	12400	12200	11600	10700	9550
1976	14500	14500	14200	13200	11300	9300
1977	16900	16600	14900	11700	8530	6580
1978	22100	22000	21000	18600	16200	13400
1979	13200	13200	12800	12000	11700	11000
1980	16300	16300	16100	15600	14800	14000
1981	13400	13300	12800	11500	9710	7830
1982	11000	11000	10900	10600	9900	9430
1983	17700	17600	17400	17100	16100	16000
1984	19900	19800	19500	18600	17700	16600
1985	11400	11400	11300	10700	10400	9290
1986	18300	18300	18100	17500	17200	15300
1987	7760	7760	7750	7670	7500	6940
1988	9590	9590	9570	9410	8930	8340
1989	5100	5090	5030	4870	4800	4670
1990	9220	9200	9080	8660	7870	6930
1991	16600	16500	16200	15300	14300	12400
1992	10200	10200	9830	9030	7730	6470
1993	14100	14100	13900	13600	12800	12100
1994	10700	10700	10600	10200	9690	8840
1995	20000	19900	19900	19100	18500	17000
1996	15200	15200	15100	15000	14600	14100
1997	21600	21600	21600	21400	19900	17000
1998	13100	13000	12900	12000	10600	10100
1999	15900	15900	15600	15100	14300	13100
2000	11300	11300	11200	11000	10500	9180

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2001	6370	6360	6310	6220	6030	5690
2002	12600	11000	7650	4260	3010	2790
2003	12900	12900	12700	12000	10500	8980
2004	6740	6730	6670	6570	6340	5660
2005	18400	18400	17700	15700	13400	12200
2006	13100	13100	12900	12400	11000	9230
2007	10200	10100	10000	9590	9150	8210
2008	16200	16200	16000	15100	13900	12500
2009	15400	15300	15100	14300	14000	13300
2010	20100	20100	19400	17800	16100	15200
2011	23400	23400	23200	22000	20500	19600
2012	6680	6660	6500	6020	5740	5130

Table F-7. Annual unregulated peaks for North Platte (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	31100	31000	30600	29300	26800	25900
1950	12600	12600	12300	11500	11400	11000
1951	18000	17900	17800	17600	15700	14000
1952	23500	23400	23000	21600	19000	16400
1953	10900	10900	10500	9670	9420	9070
1954	10500	10500	10200	9620	8260	6860
1955	6500	6450	6170	5940	5800	5530
1956	16400	16400	16200	15500	14500	12000
1957	22800	22700	22300	20700	19500	16800
1958	12900	12800	12700	12000	10700	9070
1959	7740	7740	7700	7560	7290	7120
1960	8370	8350	8170	7680	6830	5750
1961	10000	9970	9830	9560	8820	7900
1962	15500	15400	15100	14500	13800	13200
1963	5820	5800	5650	5280	5210	5070
1964	7430	7410	7270	6920	6560	6180
1965	17400	17400	17200	16400	14400	12800
1966	5880	5850	5660	5270	5010	4560
1967	10200	10200	10000	9860	9540	8730
1968	10400	10400	10300	10000	9440	8160
1969	10500	10500	10200	9430	8600	8060
1970	20300	20200	19900	19300	16800	15200
1971	22700	22600	21800	19900	17900	16100
1972	9070	9050	8940	8580	7820	7290

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1973	25600	25600	25100	24100	20800	17900
1974	15600	15600	15200	14300	14000	13500
1975	12600	12600	12400	11800	11000	9810
1976	14700	14600	14400	13500	11500	9530
1977	16900	16600	15000	12200	8950	6940
1978	22200	22100	21100	18800	16400	13700
1979	13400	13400	13000	12200	11900	11300
1980	16500	16400	16300	15800	15000	14200
1981	13600	13500	13000	11800	9950	8120
1982	11300	11200	11200	10800	10100	9650
1983	17900	17800	17700	17400	16400	16300
1984	20100	20100	19700	18800	17900	16800
1985	11600	11600	11500	11000	10600	9510
1986	18500	18500	18300	17700	17400	15600
1987	7990	7990	7980	7900	7730	7170
1988	9860	9860	9840	9680	9230	8690
1989	5290	5290	5230	5060	4990	4870
1990	9400	9380	9270	8860	8090	7150
1991	16800	16700	16400	15600	14600	12700
1992	10400	10400	10000	9250	7960	6710
1993	14300	14300	14200	13800	13100	12400
1994	10900	10900	10800	10400	9900	9060
1995	20200	20200	20100	19400	18700	17300
1996	15500	15400	15300	15200	14800	14400
1997	21900	21900	21800	21600	20100	17200
1998	13300	13300	13100	12300	10900	10400
1999	16100	16100	15800	15300	14600	13300
2000	11500	11500	11400	11200	10700	9390
2001	6600	6590	6550	6460	6260	5920
2002	11400	10600	7710	4570	3220	3010
2003	13100	13100	12900	12200	10700	9200
2004	6940	6930	6870	6770	6530	5860
2005	18600	18500	17900	16000	13700	12400
2006	13300	13300	13100	12600	11200	9430
2007	11000	10900	10500	10300	9680	8860
2008	16500	16500	16300	15500	14200	12800
2009	15600	15600	15400	14600	14300	13600
2010	20700	20600	19900	18400	17000	15900
2011	23700	23700	23400	22300	20800	20000

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2012	6920	6910	6750	6290	6010	5400

Table F-8. Annual modeled regulated peaks for Mitchell (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	4750	4740	4670	4620	4200	3400
1950	3300	3230	2860	2590	2080	2200
1951	1950	1850	1560	1350	1950	1470
1952	3150	3100	2920	2640	2360	2130
1953	2060	2050	2040	2000	1970	1890
1954	1030	1050	1010	940	810	720
1955	2250	2140	1730	1250	860	640
1956	1140	1100	890	820	660	560
1957	2670	2650	2570	2520	2020	1360
1958	2300	2300	2290	2260	2120	1790
1959	1630	1550	1380	1110	890	780
1960	1240	1250	1220	1190	1050	870
1961	800	720	680	630	540	500
1962	1610	1550	1240	910	870	650
1963	950	910	910	850	680	610
1964	880	900	900	870	710	600
1965	2670	2640	2410	2320	2260	1580
1966	1180	1170	1140	1180	1110	930
1967	1380	1350	1280	1060	820	720
1968	1240	1210	1050	990	840	610
1969	980	1010	990	900	750	660
1970	3840	3690	3160	3080	2590	2000
1971	5050	5020	4920	4810	4460	3710
1972	2080	2070	2030	2180	2570	1970
1973	4730	4710	4570	4160	3600	2890
1974	3500	3490	3480	3430	3230	2930
1975	2620	2590	2500	2340	2360	2160
1976	1570	1560	1530	1500	1370	1110
1977	1330	1320	1170	1110	980	830
1978	1550	1530	1430	1190	1030	870
1979	2070	1830	1290	1090	1020	930
1980	2430	2360	2280	2090	1920	1640
1981	2460	2430	2130	1980	1910	1630
1982	1380	1310	1280	1210	1190	790
1983	4220	4210	4150	3960	3330	2540

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1984	4210	4190	4150	4040	3930	3340
1985	2910	2950	2920	2710	2480	2180
1986	8160	8110	7860	6920	5520	4310
1987	2270	2260	2270	2280	2310	2140
1988	1510	1490	1360	950	900	790
1989	880	870	840	790	690	630
1990	1160	1060	900	770	670	570
1991	3110	3090	3020	2630	2160	1410
1992	1800	1760	1480	850	700	610
1993	2260	2250	2210	2190	1890	1400
1994	1810	1780	1520	930	820	720
1995	4520	4490	4400	4010	3360	2980
1996	2850	2840	2790	2760	2520	2050
1997	4150	4100	4060	3820	3170	2360
1998	2430	2430	2420	2400	2350	2210
1999	3130	2990	2730	2570	2250	1790
2000	2010	1970	1870	1770	1650	1770
2001	3740	3450	2880	1970	1290	1050
2002	900	890	870	820	740	690
2003	670	650	640	550	450	410
2004	2060	2050	1950	1210	740	550
2005	2970	2950	2800	2360	1800	1180
2006	930	930	900	840	650	630
2007	920	930	900	880	770	660
2008	2640	2620	2550	2330	1780	1060
2009	2270	2260	2190	1990	1820	1490
2010	4810	4790	4700	4350	4020	2640
2011	9030	9020	8950	8780	8350	7490
2012	2730	2710	2630	2470	2280	2500

Table F-9. Annual modeled regulated peaks for Minatare (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	5220	5210	5150	5110	4700	3940
1950	3730	3660	3340	3070	2440	2720
1951	2570	2510	2240	1920	2270	1720
1952	3780	3740	3580	3330	3050	2810
1953	2150	2130	2100	2240	2360	2240
1954	1650	1610	1340	1180	1100	1060
1955	2680	2590	2240	1810	1470	1270

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1956	1900	1870	1630	1230	1040	970
1957	3120	3110	3040	2960	2490	1950
1958	2370	2370	2360	2320	2210	1910
1959	2220	2180	2020	1560	1390	1190
1960	1720	1690	1460	1220	1090	940
1961	1450	1410	1220	1020	930	920
1962	2310	2260	1950	1440	1250	1180
1963	1220	1190	1070	1040	1000	930
1964	1630	1610	1570	1270	1050	1010
1965	3200	3160	2920	2690	2590	2040
1966	1780	1750	1660	1590	1310	1130
1967	2120	2100	2020	1560	1280	1260
1968	1970	1950	1760	1330	1220	1060
1969	1410	1370	1280	1070	1050	1030
1970	3950	3850	3450	3240	2780	2360
1971	5350	5320	5210	5110	4770	4070
1972	2160	2150	2120	2480	2870	2400
1973	5230	5210	5080	4680	4020	3390
1974	4110	4110	4100	4050	3840	3510
1975	2630	2610	2530	2550	2760	2620
1976	1700	1700	1670	1580	1470	1380
1977	2100	2060	1700	1430	1320	1220
1978	2350	2330	2200	1910	1790	1620
1979	2710	2540	2080	1740	1680	1570
1980	2890	2840	2630	2380	2330	2150
1981	3120	3090	2780	2230	2280	2120
1982	2020	1960	1880	1810	1660	1490
1983	4840	4830	4780	4590	4000	3190
1984	4360	4340	4300	4200	4150	3550
1985	3090	3140	3110	2920	2840	2650
1986	8590	8550	8340	7500	6090	4930
1987	2400	2470	2570	2600	2710	2550
1988	2240	2220	2120	1630	1310	1260
1989	1290	1260	1090	990	960	910
1990	1760	1690	1620	1440	1190	1070
1991	3390	3380	3310	2940	2470	1750
1992	2500	2460	2190	1560	1290	1250
1993	2720	2690	2630	2570	2280	1770
1994	2520	2500	2200	1660	1460	1290

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1995	5080	5030	4890	4460	3810	3390
1996	3240	3210	3150	3120	2890	2460
1997	4690	4650	4550	4300	3690	2920
1998	2480	2480	2460	2780	2780	2690
1999	3490	3410	3190	2870	2630	2330
2000	2200	2180	2110	2040	1970	2230
2001	4300	4150	3640	2770	2080	1660
2002	1120	1080	1010	910	860	840
2003	1130	1080	1000	900	850	830
2004	2710	2700	2580	1880	1430	1220
2005	3300	3280	3120	2700	2190	1570
2006	1360	1310	1180	1010	990	940
2007	1380	1350	1200	1050	1030	970
2008	3050	3040	2930	2690	2200	1540
2009	2650	2640	2570	2340	2190	2000
2010	5160	5160	5070	4730	4400	3150
2011	9670	9660	9590	9420	8980	8090
2012	2750	2730	2650	2500	2700	3030

Table F-10. Annual modeled regulated peaks for Bridgeport (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	5380	5370	5300	5280	4870	4100
1950	4090	4030	3740	3480	2830	3090
1951	2710	2650	2450	2340	2680	2110
1952	3930	3900	3750	3510	3220	2970
1953	2420	2400	2560	2670	2770	2620
1954	1750	1700	1440	1330	1220	1160
1955	2730	2640	2320	1880	1520	1330
1956	1980	1950	1710	1310	1120	1050
1957	3260	3260	3180	3130	2650	2060
1958	2520	2510	2500	2470	2360	2050
1959	2280	2260	2100	1640	1510	1290
1960	1730	1700	1630	1630	1500	1280
1961	1490	1450	1270	1070	1010	990
1962	2470	2430	2120	1630	1400	1340
1963	1230	1220	1200	1170	1110	1010
1964	1680	1670	1630	1340	1100	1080
1965	3340	3310	3100	2880	2790	2210
1966	1950	1930	1830	1760	1540	1300

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1967	2150	2140	2060	1610	1370	1370
1968	2010	1990	1790	1460	1340	1160
1969	1430	1430	1350	1230	1190	1140
1970	4110	4030	3580	3450	2970	2510
1971	5490	5470	5400	5300	4960	4250
1972	2310	2300	2260	2990	3280	2770
1973	5410	5400	5270	4870	4210	3550
1974	4280	4270	4260	4210	4010	3700
1975	2860	2860	2900	2980	3190	3030
1976	1860	1850	1820	1740	1650	1620
1977	2220	2170	1830	1630	1530	1390
1978	2560	2540	2410	2170	2030	1850
1979	2890	2740	2320	2020	1970	1860
1980	3250	3220	3020	2800	2730	2520
1981	3300	3270	2970	2690	2700	2510
1982	2780	2680	2280	2100	1910	1780
1983	5020	5000	4940	4750	4140	3330
1984	4560	4550	4520	4410	4360	3740
1985	3610	3610	3570	3370	3270	3050
1986	8790	8760	8550	7690	6280	5110
1987	2890	2910	3000	3000	3100	2930
1988	2370	2350	2210	1720	1420	1390
1989	1340	1310	1150	1130	1070	990
1990	1820	1780	1740	1570	1300	1160
1991	3490	3480	3420	3050	2590	1870
1992	2560	2520	2250	1630	1360	1320
1993	2820	2810	2760	2720	2440	1930
1994	2650	2620	2340	1820	1610	1430
1995	5190	5170	5040	4630	3980	3610
1996	3390	3380	3330	3310	3110	2670
1997	4920	4890	4810	4560	3950	3200
1998	2790	2750	2860	3230	3160	3040
1999	3830	3770	3570	3250	3040	2700
2000	2380	2370	2300	2230	2370	2630
2001	4300	4210	3750	2910	2230	1810
2002	1150	1140	1130	1120	1180	1060
2003	1110	1080	1020	940	870	860
2004	2770	2760	2630	1940	1490	1260
2005	3520	3500	3350	2930	2360	1730

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2006	1350	1320	1190	1140	1110	1020
2007	1420	1390	1250	1190	1160	1070
2008	3200	3190	3090	2860	2360	1770
2009	3010	2990	2890	2640	2500	2320
2010	5390	5380	5300	4970	4660	3400
2011	9830	9830	9760	9590	9150	8260
2012	2930	2910	2840	2870	3120	3430

Table F-11. Annual modeled regulated peaks for Lisco (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	5420	5410	5360	5330	4920	4140
1950	4150	4100	3860	3600	2920	3190
1951	2810	2780	2680	2560	2820	2220
1952	3860	3840	3710	3470	3180	2940
1953	2530	2630	2760	2790	2870	2680
1954	1670	1640	1380	1330	1250	1160
1955	2680	2620	2330	1880	1500	1300
1956	2050	2020	1790	1390	1210	1080
1957	3310	3310	3240	3190	2710	2080
1958	2610	2600	2590	2560	2450	2140
1959	2240	2200	2050	1650	1480	1260
1960	1820	1810	1790	1780	1640	1410
1961	1430	1410	1240	1040	980	950
1962	2510	2470	2180	1690	1500	1410
1963	1300	1300	1290	1220	1070	990
1964	1620	1610	1580	1290	1130	1020
1965	3440	3410	3210	3060	2970	2350
1966	1970	1940	1840	1770	1650	1410
1967	2130	2120	2040	1600	1370	1330
1968	1940	1930	1720	1430	1300	1180
1969	1380	1370	1310	1240	1150	1100
1970	4160	4080	3730	3580	3090	2590
1971	5560	5550	5520	5410	5060	4330
1972	2360	2350	2330	3340	3380	2830
1973	5360	5340	5230	4840	4270	3550
1974	4280	4280	4270	4220	4020	3720
1975	2970	2980	3030	3080	3300	3100
1976	1860	1860	1840	1800	1710	1690
1977	2170	2130	1790	1600	1500	1360

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1978	2610	2600	2470	2230	2090	1890
1979	2790	2680	2310	2060	2010	1910
1980	3290	3260	3080	2890	2810	2590
1981	3360	3330	3040	2860	2810	2590
1982	3530	3450	2970	2230	2050	1960
1983	5010	5000	4950	4770	4140	3350
1984	4690	4680	4650	4540	4470	3850
1985	3720	3710	3680	3470	3360	3130
1986	8900	8870	8670	7820	6440	5240
1987	3070	3110	3150	3110	3200	3010
1988	2490	2460	2190	1780	1480	1360
1989	1270	1260	1230	1190	1140	1070
1990	1770	1750	1710	1530	1270	1120
1991	3500	3490	3430	3070	2610	1880
1992	2540	2510	2230	1610	1330	1300
1993	2830	2820	2770	2750	2480	1960
1994	2640	2610	2340	1840	1640	1440
1995	5280	5260	5150	4760	4130	3830
1996	3600	3570	3470	3360	3160	2730
1997	5000	4990	4920	4680	4070	3330
1998	2850	2900	3130	3410	3250	3110
1999	3880	3850	3690	3390	3180	2800
2000	2470	2460	2390	2310	2540	2760
2001	4130	4060	3680	2900	2260	1830
2002	1280	1280	1270	1260	1340	1210
2003	1030	1010	990	910	820	800
2004	2730	2720	2590	1910	1460	1220
2005	3660	3640	3520	3100	2530	1870
2006	1280	1280	1260	1220	1160	1040
2007	1360	1320	1230	1230	1180	1100
2008	3190	3180	3090	2870	2360	1800
2009	3260	3250	3140	2850	2620	2390
2010	5490	5480	5400	5080	4790	3530
2011	9830	9820	9760	9590	9160	8280
2012	2990	2980	2900	3050	3240	3540

Table F-12. Annual modeled regulated peaks for Lewellen (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	5490	5480	5430	5370	4980	4210

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1950	4220	4190	3980	3730	3010	3290
1951	3030	3000	2910	2770	2960	2350
1952	3850	3830	3720	3500	3210	2960
1953	2790	2830	2860	2840	2910	2710
1954	1650	1620	1410	1360	1280	1210
1955	2660	2610	2350	1920	1520	1320
1956	2060	2030	1820	1430	1290	1140
1957	3410	3400	3340	3300	2820	2160
1958	2740	2740	2730	2710	2590	2290
1959	2210	2190	2040	1630	1500	1310
1960	1880	1870	1850	1840	1710	1480
1961	1500	1470	1310	1090	1030	1010
1962	2500	2470	2210	1820	1640	1560
1963	1390	1390	1380	1290	1110	1080
1964	1640	1620	1580	1360	1220	1100
1965	3520	3490	3320	3190	3120	2510
1966	1990	1970	1880	1830	1770	1530
1967	2170	2160	2070	1750	1510	1440
1968	3560	3430	2920	2230	1710	1430
1969	1410	1410	1380	1310	1190	1130
1970	4290	4220	3920	3760	3260	2720
1971	5750	5740	5720	5610	5250	4500
1972	2460	2460	2860	3650	3450	2880
1973	5340	5330	5220	4850	4410	3680
1974	4310	4300	4290	4250	4060	3760
1975	3060	3080	3140	3150	3370	3140
1976	1990	1980	1970	1920	1820	1720
1977	2140	2100	1790	1610	1510	1390
1978	2660	2640	2510	2250	2120	1930
1979	2720	2650	2320	2080	2030	1940
1980	3290	3260	3120	2910	2840	2620
1981	3410	3370	3090	2920	2850	2620
1982	3720	3670	3220	2400	2170	2060
1983	5050	5040	5010	4820	4180	3410
1984	4840	4840	4810	4700	4620	4010
1985	3780	3780	3740	3520	3400	3160
1986	8890	8870	8680	7860	6500	5310
1987	3230	3250	3230	3190	3260	3070
1988	3100	3040	2740	2210	1790	1460

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1989	1350	1350	1320	1270	1220	1180
1990	1760	1740	1700	1530	1270	1130
1991	3550	3550	3480	3140	2690	1960
1992	2530	2490	2220	1650	1350	1330
1993	2900	2890	2850	2820	2540	2030
1994	2610	2580	2320	1840	1680	1470
1995	5480	5470	5360	5010	4430	4210
1996	4120	4090	3910	3690	3340	2900
1997	5140	5130	5060	4830	4220	3510
1998	3060	3150	3420	3540	3310	3170
1999	3900	3870	3740	3460	3250	2870
2000	2610	2600	2530	2450	2670	2830
2001	4060	4020	3690	2940	2280	1840
2002	1400	1400	1390	1400	1520	1350
2003	1070	1050	990	910	850	840
2004	2720	2720	2580	1940	1490	1250
2005	3860	3840	3720	3310	2750	2040
2006	1460	1460	1440	1370	1280	1180
2007	1450	1410	1290	1280	1230	1150
2008	3230	3220	3130	2930	2410	1830
2009	3620	3610	3500	3170	2870	2420
2010	5640	5630	5560	5260	4990	3760
2011	9890	9880	9820	9660	9240	8350
2012	3110	3090	3030	3200	3320	3630

Table F-13. Annual modeled regulated peaks for Keystone (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	2570	2560	2540	2400	2220	2120
1950	2610	2570	2530	2460	2270	1860
1951	2130	2120	2050	1950	1890	1780
1952	2740	2710	2680	2640	2610	2480
1953	2710	2700	2690	2650	2600	2470
1954	3140	3120	3090	3020	2810	2490
1955	2460	2410	2340	2310	2300	2220
1956	2310	2290	2250	2100	1900	1780
1957	2400	2380	2350	2210	1960	1730
1958	1810	1800	1770	1710	1490	1180
1959	2260	2260	2240	2200	2170	2020
1960	2470	2440	2400	2320	2250	2080

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1961	2000	2000	1990	1960	1850	1760
1962	1330	1310	1260	1210	1050	820
1963	2190	2180	2170	2140	2090	1920
1964	1990	1980	1930	1830	1760	1610
1965	1250	1190	1140	1110	990	860
1966	2490	2460	2420	2290	1980	1590
1967	1840	1800	1750	1670	1530	1410
1968	2370	2350	2340	2260	2080	1780
1969	2460	2420	2390	2110	1640	1440
1970	2360	2340	2310	2270	2100	1920
1971	2370	2350	2300	2250	2090	1970
1972	2820	2780	2730	2630	2490	2080
1973	2820	2800	2780	2760	2570	2230
1974	3890	3860	3810	3690	3190	2230
1975	2760	2750	2730	2670	2570	2370
1976	3010	2970	2900	2770	2650	2380
1977	2690	2660	2620	2510	2350	2170
1978	2710	2700	2690	2570	2330	2030
1979	2440	2410	2350	2270	2260	2130
1980	3160	3120	3070	3010	2850	2600
1981	3130	3070	2970	2840	2630	2160
1982	2720	2700	2630	2600	2560	2420
1983	3310	3290	3220	3140	2940	2530
1984	2470	2430	2390	2360	2330	2140
1985	3030	3010	2990	2940	2780	2500
1986	2630	2620	2590	2530	2360	2190
1987	2690	2690	2680	2650	2460	2150
1988	2800	2800	2790	2690	2480	2330
1989	2610	2590	2480	2330	2180	2090
1990	2060	2050	2030	1980	1960	1850
1991	2280	2260	2240	2190	2010	1760
1992	1630	1620	1570	1530	1420	1170
1993	1930	1890	1820	1740	1500	1110
1994	1650	1540	1500	1430	1350	1120
1995	3600	3540	3480	3360	3110	2820
1996	2630	2610	2550	2520	2430	2240
1997	2440	2440	2430	2420	2280	2160
1998	2960	2950	2940	2900	2730	2320
1999	2810	2790	2760	2730	2690	2260

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2000	3070	3040	2990	2910	2750	2540
2001	2600	2580	2570	2550	2500	2310
2002	2690	2680	2650	2580	2480	2310
2003	2340	2330	2320	2280	2140	1920
2004	1470	1440	1410	1370	1240	940
2005	2080	2050	2010	1940	1880	1600
2006	2130	2120	2110	2050	1840	1490
2007	1980	1960	1920	1870	1830	1660
2008	1960	1930	1890	1850	1780	1660
2009	2380	2370	2350	2260	2100	1880
2010	2550	2550	2500	2450	2340	2280
2011	7030	7020	7010	6960	6770	6330
2012	2960	2950	2950	2940	2870	2690

Table F-14. Annual modeled regulated peaks for North Platte (cfs)

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1949	2270	2260	2240	2140	1980	1890
1950	2510	2500	2460	2410	2240	1880
1951	2310	2230	1990	1900	1820	1810
1952	2420	2410	2380	2340	2320	2220
1953	2410	2410	2400	2370	2310	2220
1954	2700	2690	2670	2610	2430	2180
1955	2060	2050	2020	1990	1970	1900
1956	3460	3100	2020	1920	1740	1620
1957	2130	2120	2070	1910	1710	1550
1958	1780	1730	1610	1600	1440	1170
1959	2110	2100	2070	2010	1950	1780
1960	2180	2170	2140	2040	1940	1790
1961	1930	1930	1910	1840	1720	1580
1962	3600	3430	2550	1860	1370	1090
1963	1840	1840	1830	1810	1780	1630
1964	1610	1600	1590	1530	1500	1390
1965	1740	1680	1360	960	850	830
1966	2130	2120	2090	2000	1760	1460
1967	1510	1510	1490	1430	1310	1210
1968	1980	1980	1960	1900	1750	1500
1969	2220	2200	2150	1960	1540	1320
1970	1950	1950	1930	1890	1760	1620
1971	2110	2110	2090	2040	1900	1800

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
1972	2520	2510	2480	2420	2370	1980
1973	2590	2580	2520	2470	2320	2060
1974	3700	3690	3640	3480	2960	1980
1975	2710	2680	2650	2510	2420	2310
1976	2690	2670	2580	2460	2350	2140
1977	2600	2590	2520	2410	2270	2020
1978	2680	2660	2510	2310	2080	1870
1979	2300	2290	2190	2100	2010	1960
1980	2720	2710	2680	2630	2490	2270
1981	2940	2910	2830	2690	2510	2000
1982	2520	2510	2470	2290	2210	2150
1983	3180	3180	3110	3030	2860	2420
1984	2220	2210	2170	2140	2090	1940
1985	2650	2640	2640	2590	2530	2350
1986	2390	2390	2380	2310	2140	1990
1987	2370	2360	2360	2340	2180	1910
1988	2920	2910	2820	2650	2470	2270
1989	2230	2220	2150	2020	1890	1880
1990	1840	1840	1810	1750	1680	1620
1991	1940	1930	1890	1830	1670	1450
1992	1430	1410	1400	1350	1260	1070
1993	1820	1810	1760	1640	1400	1080
1994	1620	1600	1570	1380	1140	1060
1995	3440	3420	3370	3240	3020	2670
1996	2420	2400	2360	2350	2230	2080
1997	2360	2340	2320	2300	2120	2040
1998	2670	2670	2650	2630	2520	2180
1999	2630	2630	2600	2570	2540	2170
2000	2710	2700	2670	2600	2460	2330
2001	2800	2780	2710	2690	2630	2290
2002	2470	2460	2450	2400	2320	2160
2003	1930	1930	1920	1880	1780	1610
2004	1220	1210	1180	1160	1080	860
2005	1670	1660	1630	1570	1530	1300
2006	1750	1740	1730	1670	1490	1170
2007	5340	5190	4430	2980	2010	1650
2008	1740	1710	1660	1630	1610	1480
2009	2060	2050	2040	1990	1880	1720
2010	2900	2790	2630	2470	2290	2210

Year	Instant	1 Day	3 Day	7 Day	15 Day	30 Day
2011	7680	7580	7180	7010	6890	6670
2012	2650	2650	2640	2630	2580	2440