HEC-5 Modeling of ACF Interim Operation by Mobile District

July 12, 2006

Model Settings

- Demands
  - Hydropower
    - Schedule based most recent operation
  - Water Supply
    - 2001 actual net for Chattahoochee and Flint Basins
    - 1993 actual net for Apalachicola River
  - Agricultural
    - Flint River provided by FWS STELLA modeling
    - Chattahoochee and Apalachicola 2000 projected
  - Required Flow
    - Atlanta
    - Columbus
    - Jim Woodruff Outflow; spawn and non-spawning season
- Operation
  - Balanced 4 federal reservoirs
  - Based on Comp Study Black & White model
  - Down Ramping Rate Restriction

Changes to B&W Model

- JW
  - Increased outlet capacity at elevation 75 (8600 to 18600)
  - Increase storage for Zone 4 (76.5 to 76.74); results in WF George sending water earlier for balancing Zone 4
- WF George
  - Added hydropower demand on weekend to assist with balance releases (PD)
- System
  - Removed equivalent level for reservoir balancing (J2.4)
  - Recycle through solution twice (J2.4)

Hydropower Demand

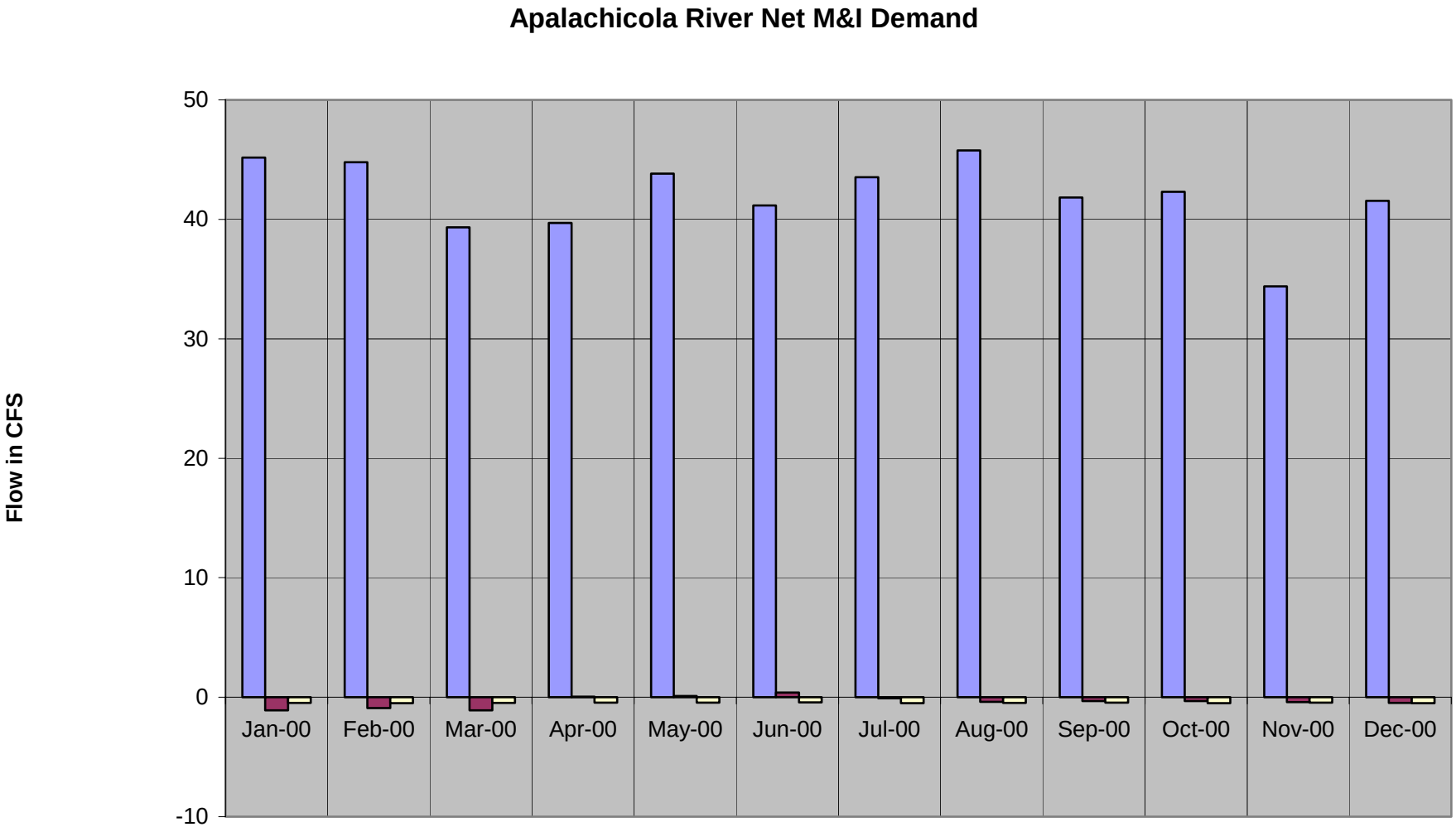
- Hydropower demand is a function of available storage. As the storage diminishes the demand reduces. Storage Zones described in the ACF Water Control manual dated 1989 used as the bases to assign the hydropower demand. Values developed from examining hydropower generation over the last few years.

IOP Model	Buford	West Point	WF George
Zone	(hours use)	(hours use)	(hours use)
1	3	4	4
2	2	2	2
3	2	2	2
4	0	0	0

Water Supply

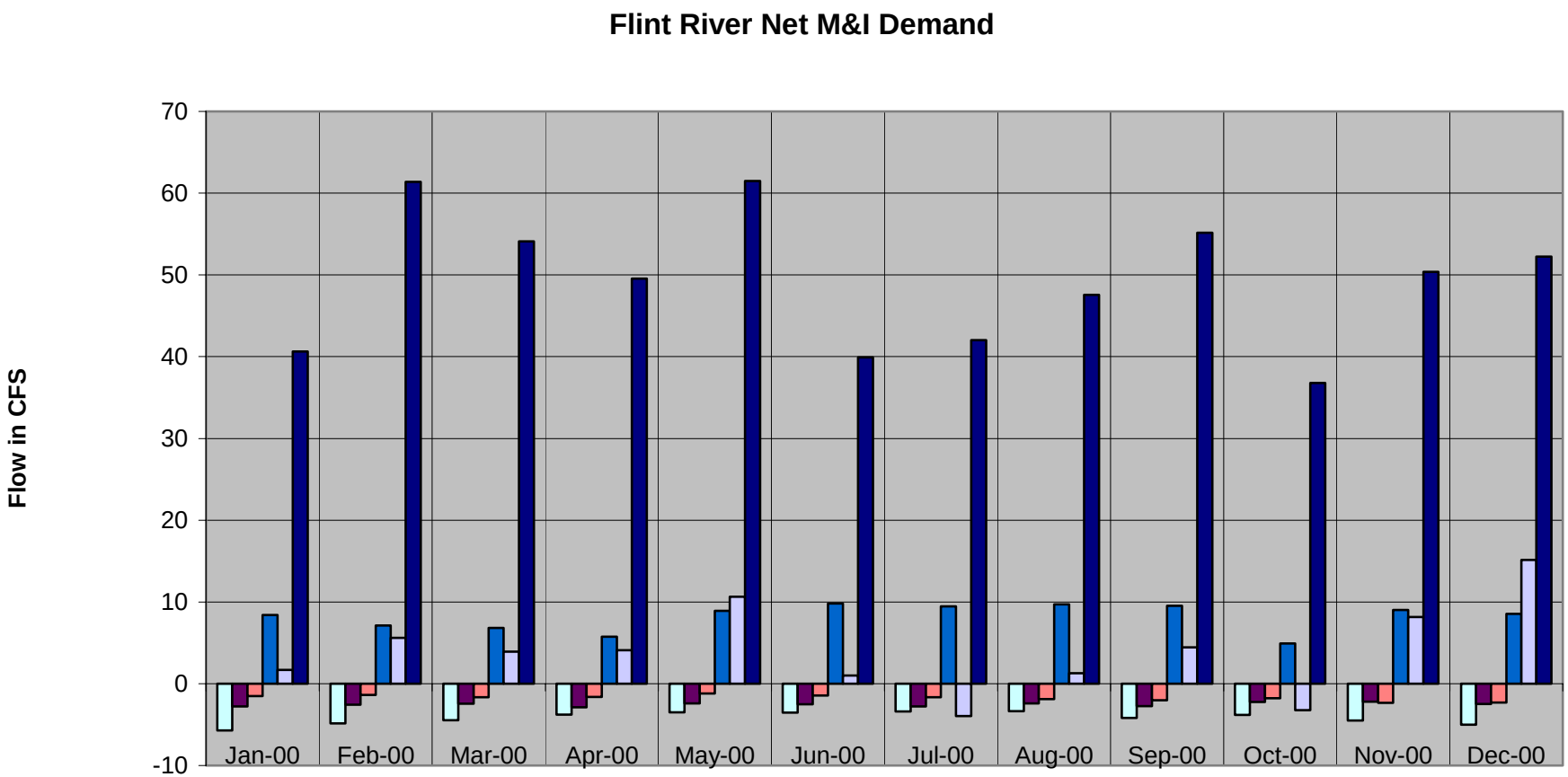
- The actual 2000 net water use provided by the states Georgia and Alabama used as the municipal and industrial demand for the Chattahoochee and Flint basin. The actual 1993 net water used for the Apalachicola River.

Water Supply-Apalachicola



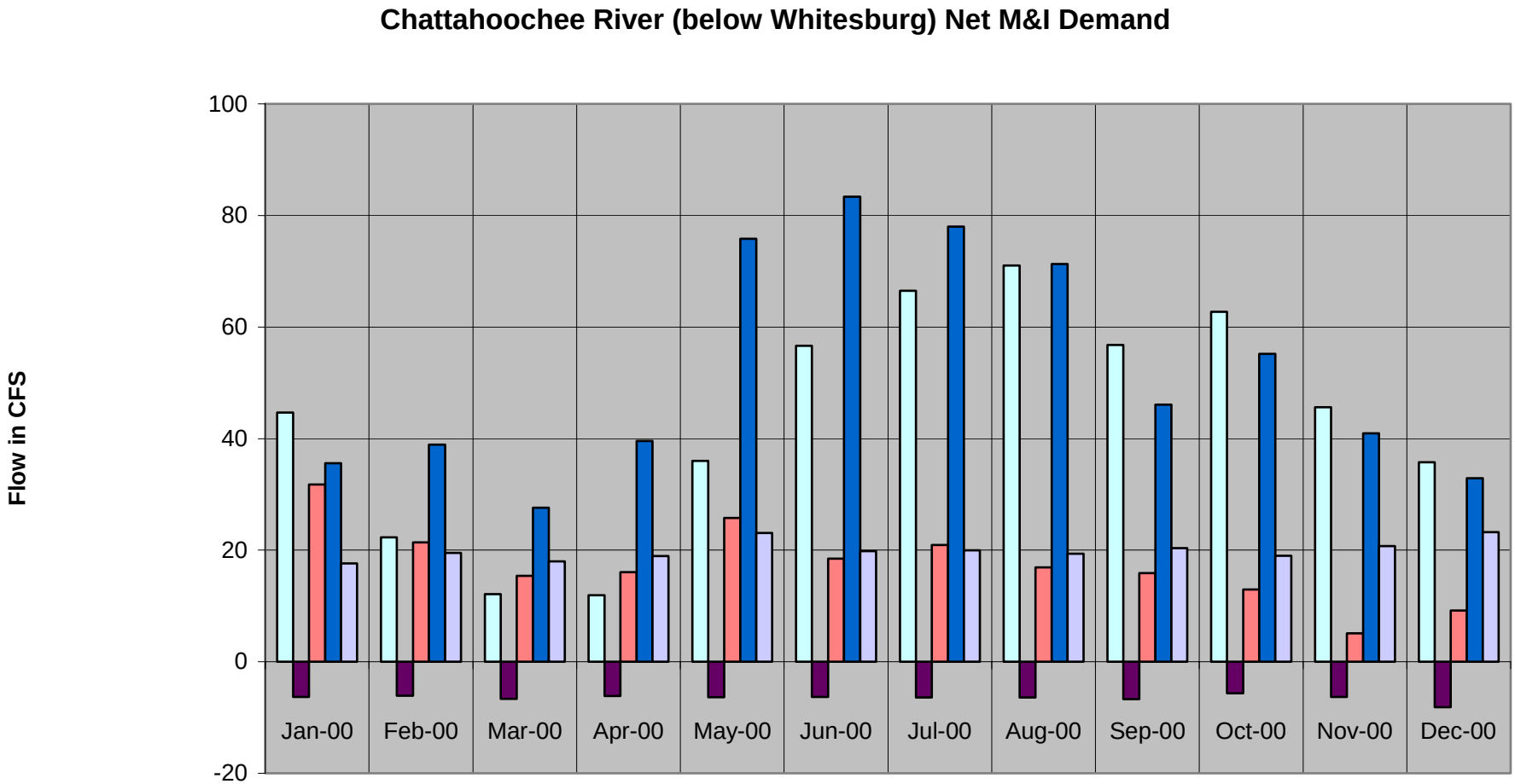
	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
Sumatra	45.18	44.78	39.34	39.7	43.83	41.17	43.53	45.76	41.82	42.31	34.38	41.56
Blountstown	-1.09	-0.92	-1.09	0.05	0.09	0.39	-0.09	-0.39	-0.32	-0.31	-0.4	-0.47
Chattahoochee	-0.47	-0.5	-0.48	-0.46	-0.46	-0.43	-0.5	-0.47	-0.46	-0.51	-0.46	-0.5

Water Supply-Flint



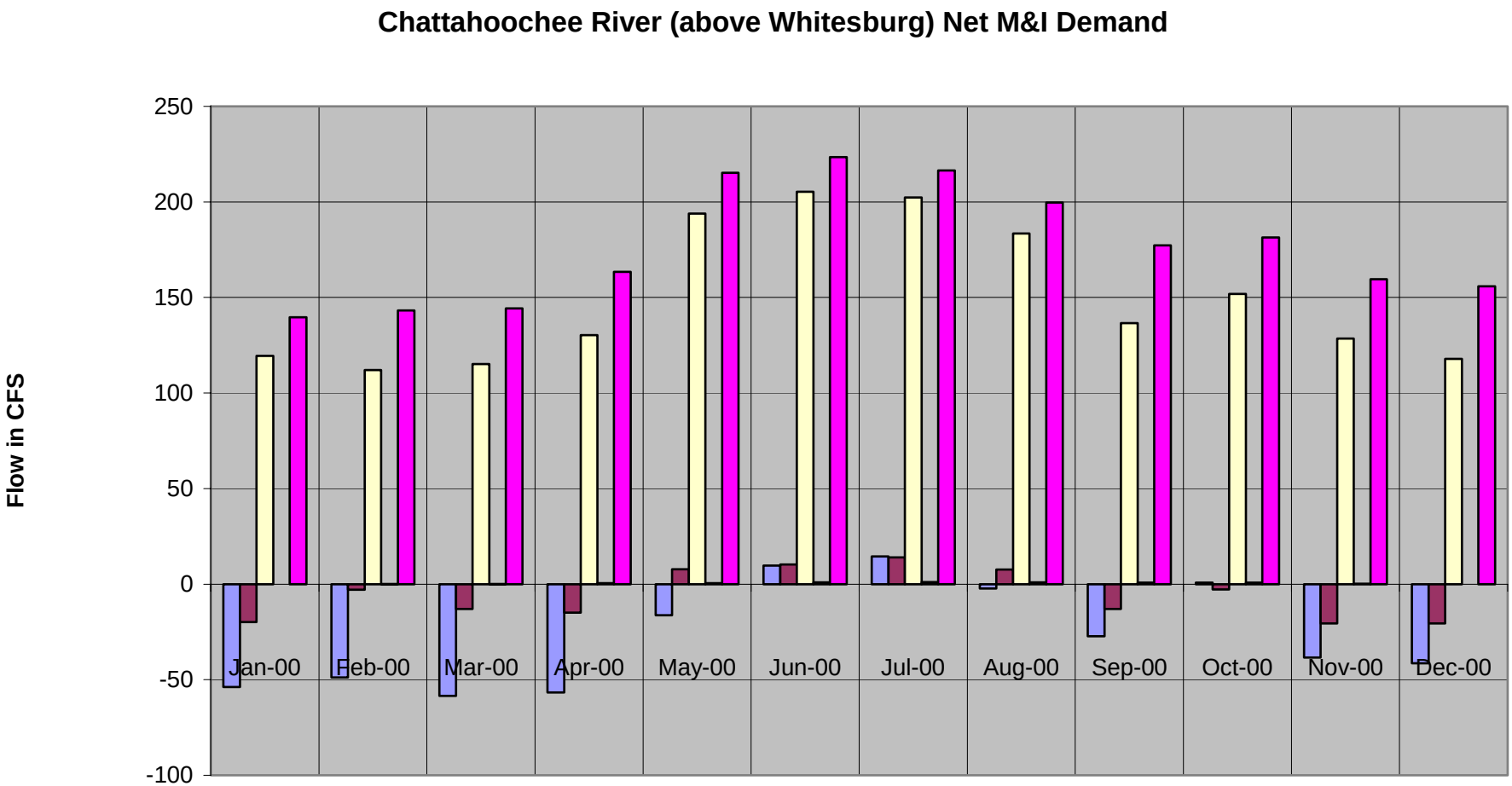
	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
JW Flint	-5.72	-4.87	-4.46	-3.79	-3.51	-3.52	-3.38	-3.36	-4.19	-3.8	-4.49	-5.01
Bainbridge	-2.77	-2.55	-2.44	-2.89	-2.4	-2.52	-2.78	-2.4	-2.72	-2.22	-2.2	-2.49
Newton	-1.53	-1.36	-1.65	-1.61	-1.19	-1.43	-1.66	-1.87	-2.02	-1.76	-2.34	-2.3
Albany	8.41	7.11	6.81	5.75	8.92	9.81	9.45	9.71	9.54	4.91	9.01	8.55
Montezuma	1.68	5.61	3.91	4.11	10.65	1.01	-3.97	1.28	4.45	-3.24	8.15	15.14
Griffin	40.63	61.36	54.1	49.54	61.49	39.9	42.01	47.58	55.15	36.78	50.37	52.24

Water Supply-Chattahoochee below Whitesburg



	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
JW Chattahooche	44.68	22.31	12.11	11.92	36.01	56.63	66.49	71.04	56.76	62.75	45.65	35.76
George Andrews	-6.29	-6.09	-6.67	-6.13	-6.37	-6.3	-6.41	-6.43	-6.73	-5.62	-6.33	-8.12
WF George	31.78	21.37	15.4	16.05	25.75	18.51	20.94	16.93	15.9	12.92	5.12	9.19
Columbus	35.61	38.91	27.59	39.55	75.83	83.33	78.03	71.29	46.08	55.19	40.95	32.88
West Point Dam	17.62	19.49	18	18.95	23.08	19.8	19.97	19.34	20.39	19	20.73	23.2

Water Supply-Chattahoochee above Whitesburg

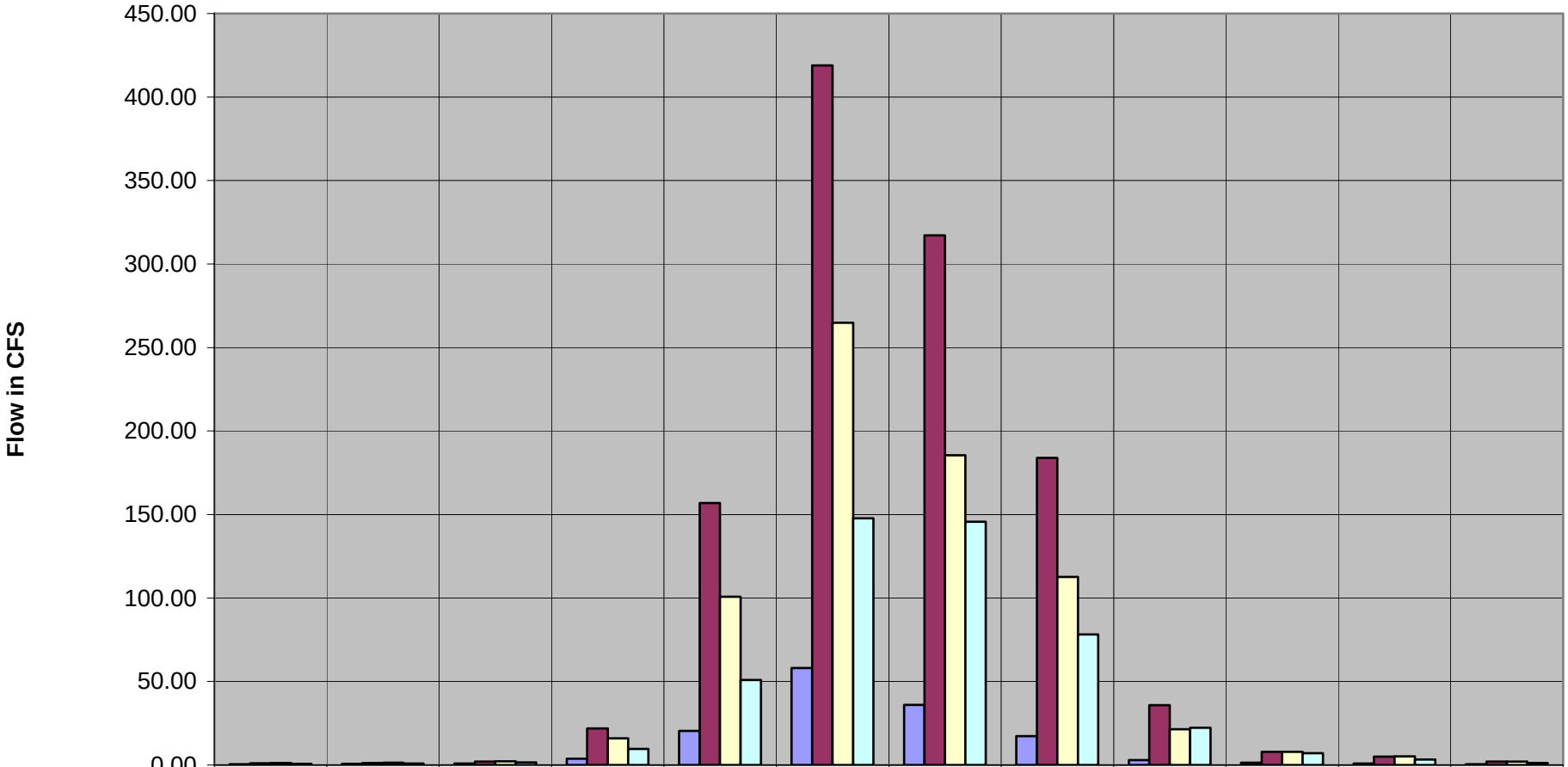


	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
Whiteburg	-53.81	-48.82	-58.48	-56.59	-16.2	9.77	14.54	-2.34	-27.28	0.83	-38.44	-41.41
Atlanta	-19.78	-2.92	-13.02	-14.85	7.77	10.27	13.99	7.61	-12.98	-2.78	-20.53	-20.57
Morgan Falls	119.45	112.11	115.13	130.31	193.83	205.36	202.33	183.54	136.54	151.79	128.53	117.86
Norcross	-0.05	0.03	0.03	0.56	0.48	1	1.11	1.05	0.77	0.79	0.3	-0.01
Buford	139.67	143.27	144.24	163.49	215.21	223.45	216.37	199.63	177.27	181.41	159.6	155.87

Agricultural Demand

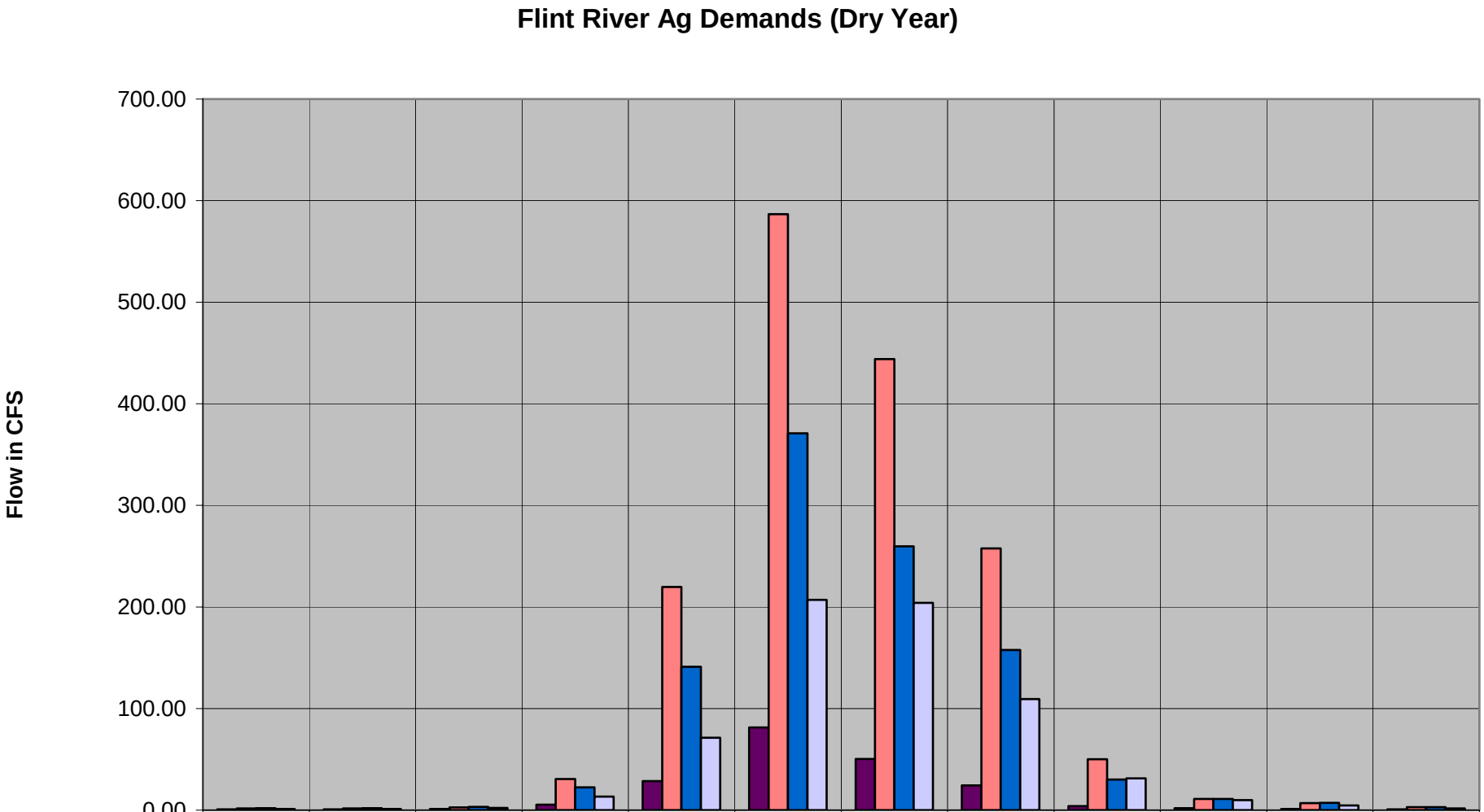
- Flint River Ag demands provided by the FWS STELLA model. Acreages equal to 621,000 and dry year multiplier of 1.4.
- Rest of basin based on NRCS year 2000 projected use. Data developed during the ACT/ACF Comprehensive Study.

Ag Demand Flint River (normal year)



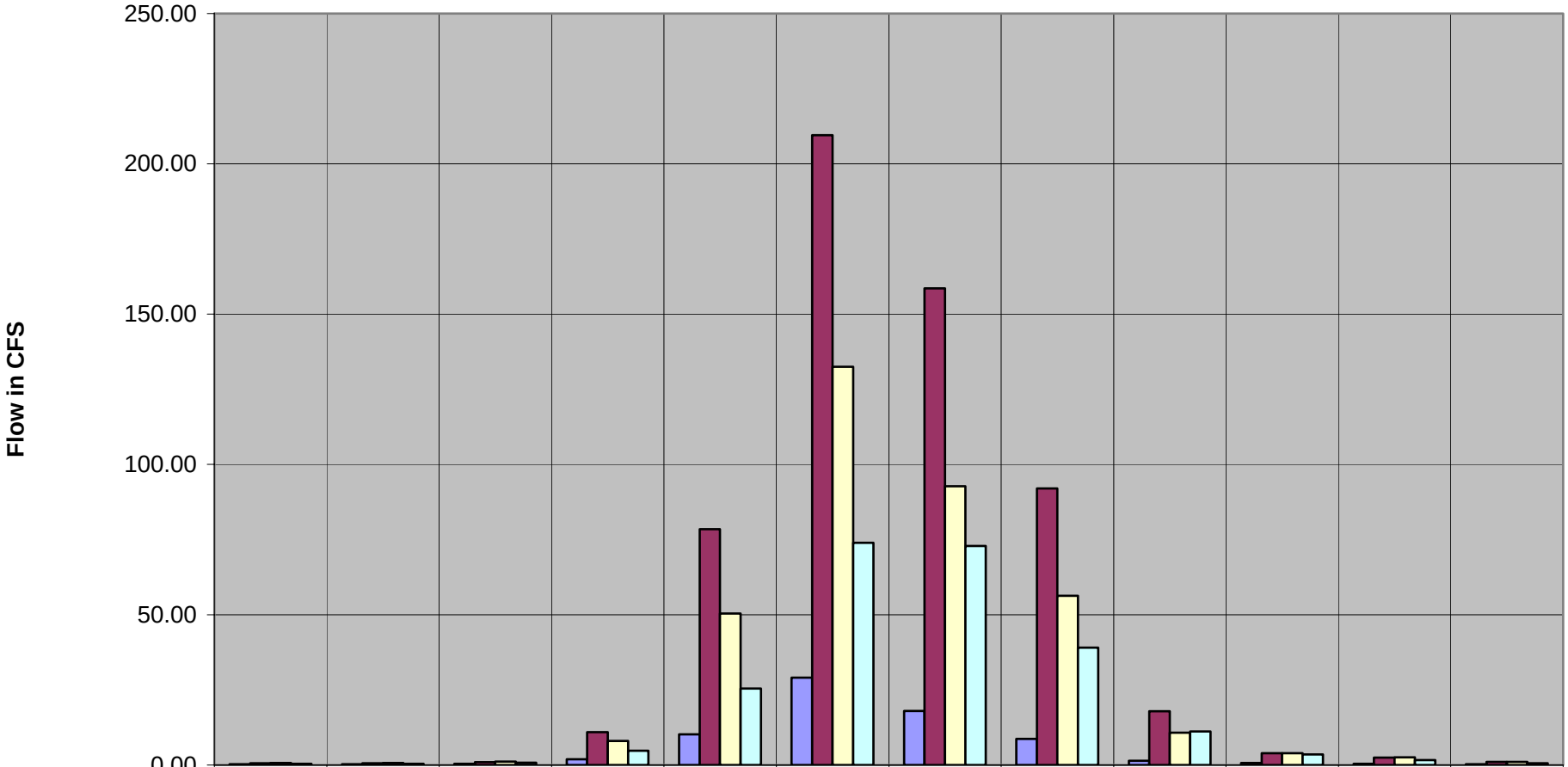
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Montezuma	0.60	0.66	0.77	3.81	20.41	58.14	36.01	17.27	2.91	1.31	0.79	0.59
Newton	1.08	1.19	1.98	21.98	156.89	419.03	317.22	184.02	35.85	7.85	4.98	2.02
Bainbridge	1.25	1.38	2.28	16.02	100.79	264.92	185.44	112.66	21.50	7.84	5.10	2.07
Jiw Woodruff	0.72	0.79	1.62	9.54	50.93	147.85	145.70	78.14	22.29	7.08	3.30	1.12

Ag Demand Flint River (dry year)



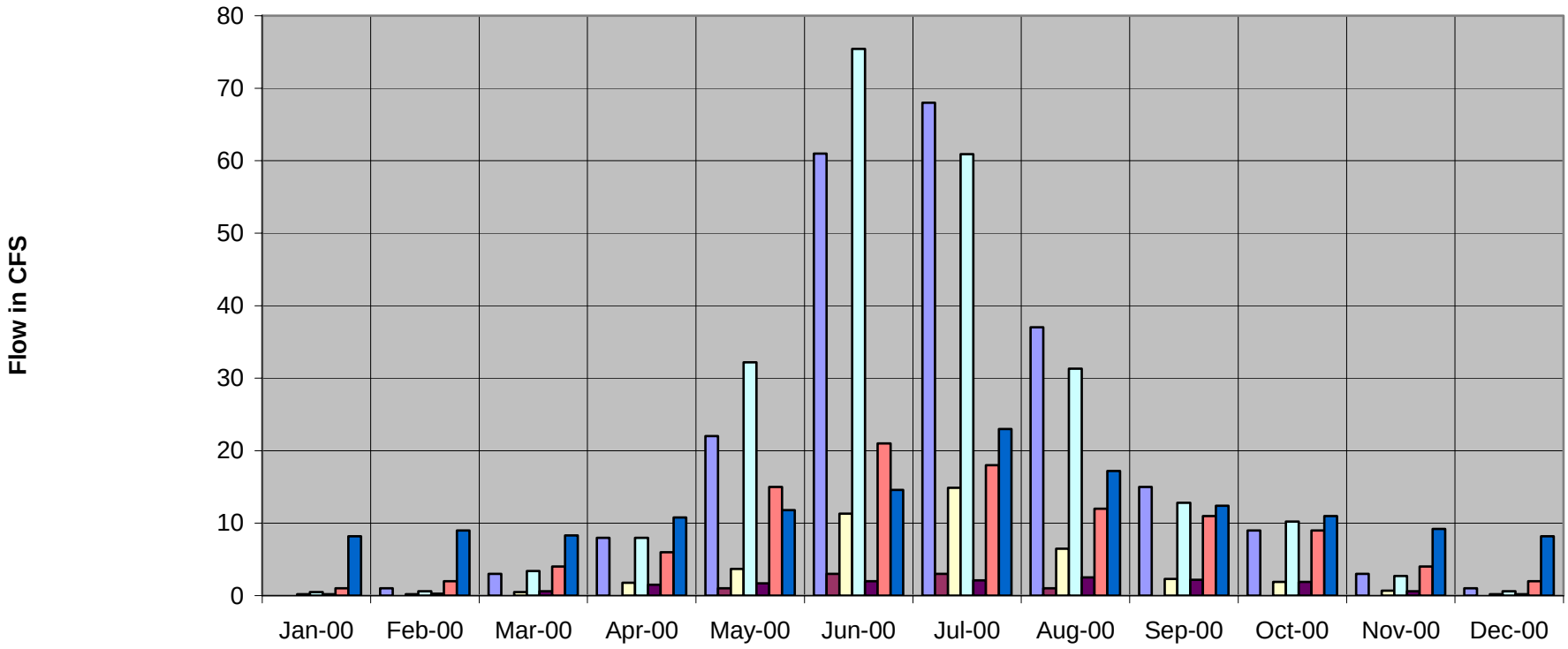
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Montezuma	0.84	0.93	1.08	5.34	28.57	81.40	50.41	24.18	4.07	1.84	1.11	0.83
Newton	1.52	1.67	2.77	30.78	219.64	586.64	444.11	257.63	50.19	10.99	6.97	2.83
Bainbridge	1.75	1.94	3.19	22.43	141.10	370.88	259.61	157.72	30.10	10.98	7.15	2.90
Jiw Woodruff	1.01	1.11	2.27	13.36	71.30	207.00	203.98	109.39	31.20	9.92	4.63	1.57

Ag Demand Flint River (wet year)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Montezuma	0.30	0.33	0.39	1.91	10.20	29.07	18.00	8.64	1.45	0.66	0.40	0.30
Newton	0.54	0.60	0.99	10.99	78.44	209.51	158.61	92.01	17.93	3.93	2.49	1.01
Bainbridge	0.63	0.69	1.14	8.01	50.39	132.46	92.72	56.33	10.75	3.92	2.55	1.03
Jiw Woodruff	0.36	0.40	0.81	4.77	25.47	73.93	72.85	39.07	11.14	3.54	1.65	0.56

Ag Demand Apalachicola-Chattahoochee River



	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
Sumatra	0	1	3	8	22	61	68	37	15	9	3	1
Bloutstown	0	0	0	0	1	3	3	1	0	0	0	0
George Andrews	0	0	1	2	4	11	15	7	2	2	1	0
WF George	1	1	3	8	32	75	61	31	13	10	3	1
Columbus	0	0	1	2	2	2	2	3	2	2	1	0
West Point	1	2	4	6	15	21	18	12	11	9	4	2
Buford	8	9	8	11	12	15	23	17	12	11	9	8

Required Flow

- Minimum flow requirement
  - Atlanta 750 cfs
  - Columbus
    - 1,850 cfs if West Point > 621.6
    - 1,200 cfs if West Point < 621.6
- Continuous Release
  - Buford 450 cfs (small unit)
  - West Point 675 cfs (small unit)
  - Jim Woodruff 100 cfs (lockages/leakages)

Jim Woodruff Release

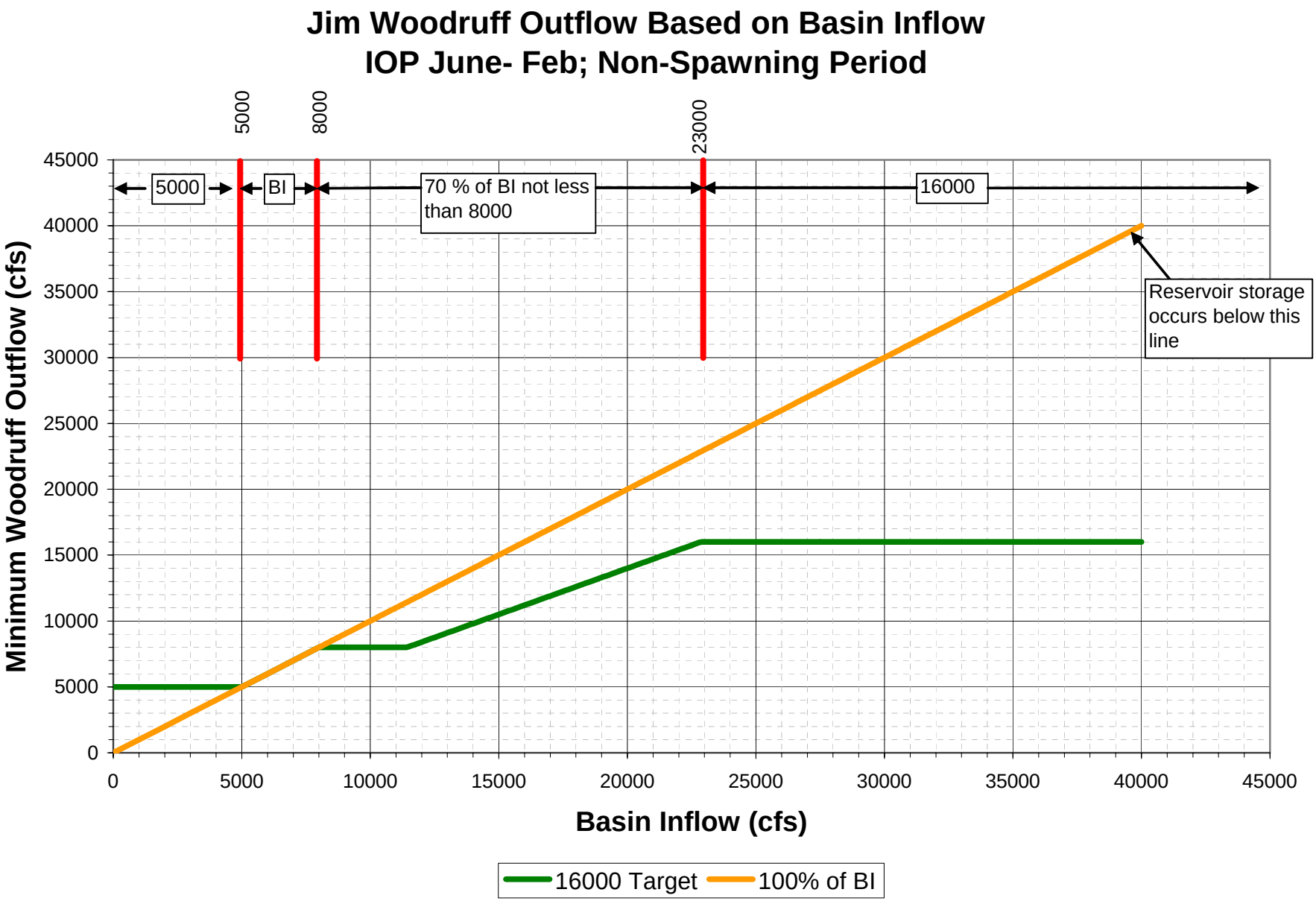
Months	Basin Inflow	Releases from JW
June- February	>= 23,000	not less than 16,000
	>= 8,000 and <23,000	>=70% of BI; but not less than 8,000
	< 8,000	>= BI; not less than 5,000
March - May	>= 37,400	not less than 37,400
	>= 20,400 and <37,000	>=70% of BI; but not less than 20,400
	< 20,400	>= BI; not less than 5,000

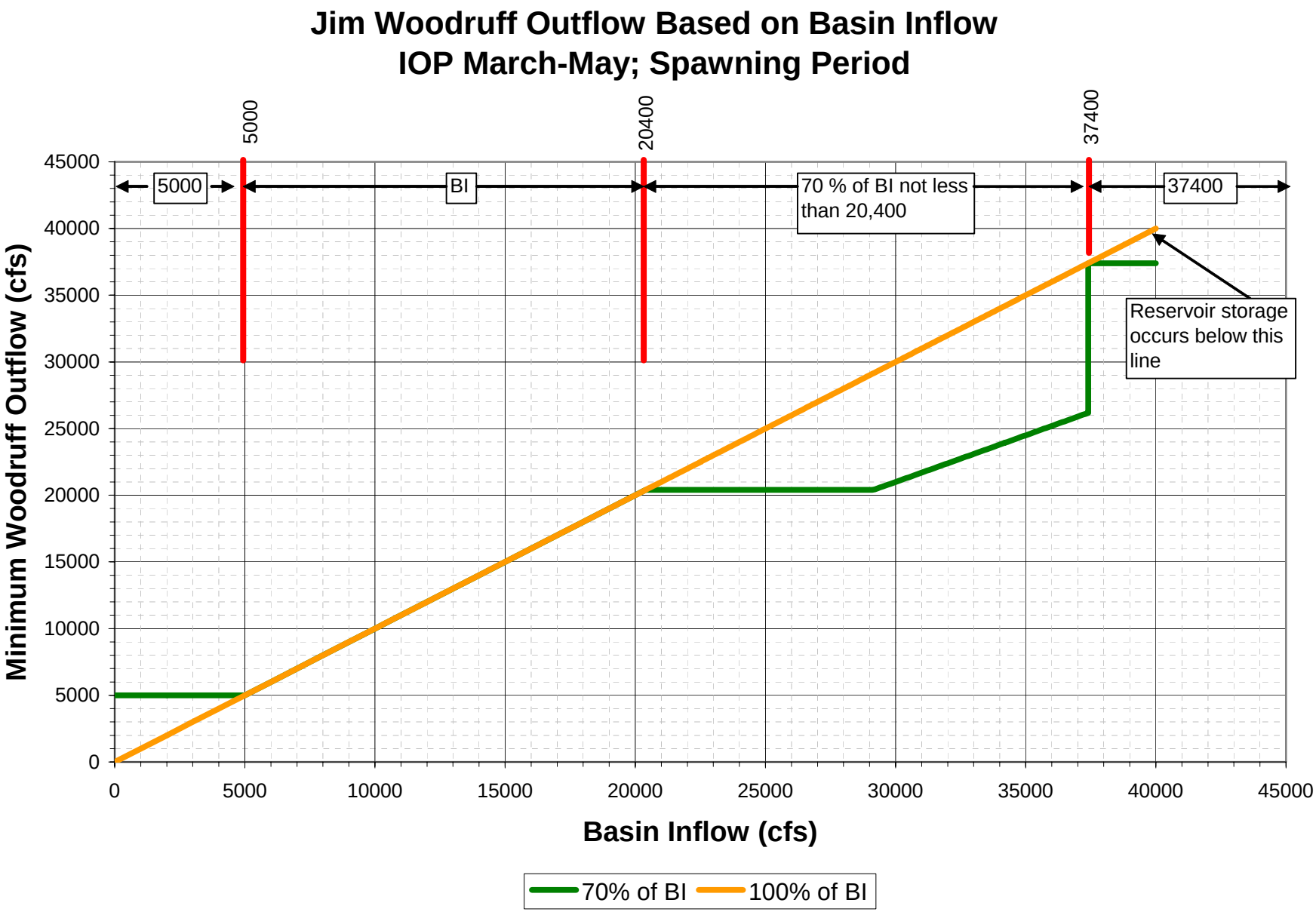
Woodruff Required Outflow

- Preprocess Spreadsheet (JWoutflows.xls)
  - Based on Basin Inflows (BI)
    - 7-day moving average
  - 2 Seasons
    - March – May (spawning)
    - June – February
  - Storage Ratio
    - 70% release

JWoutflow.xls

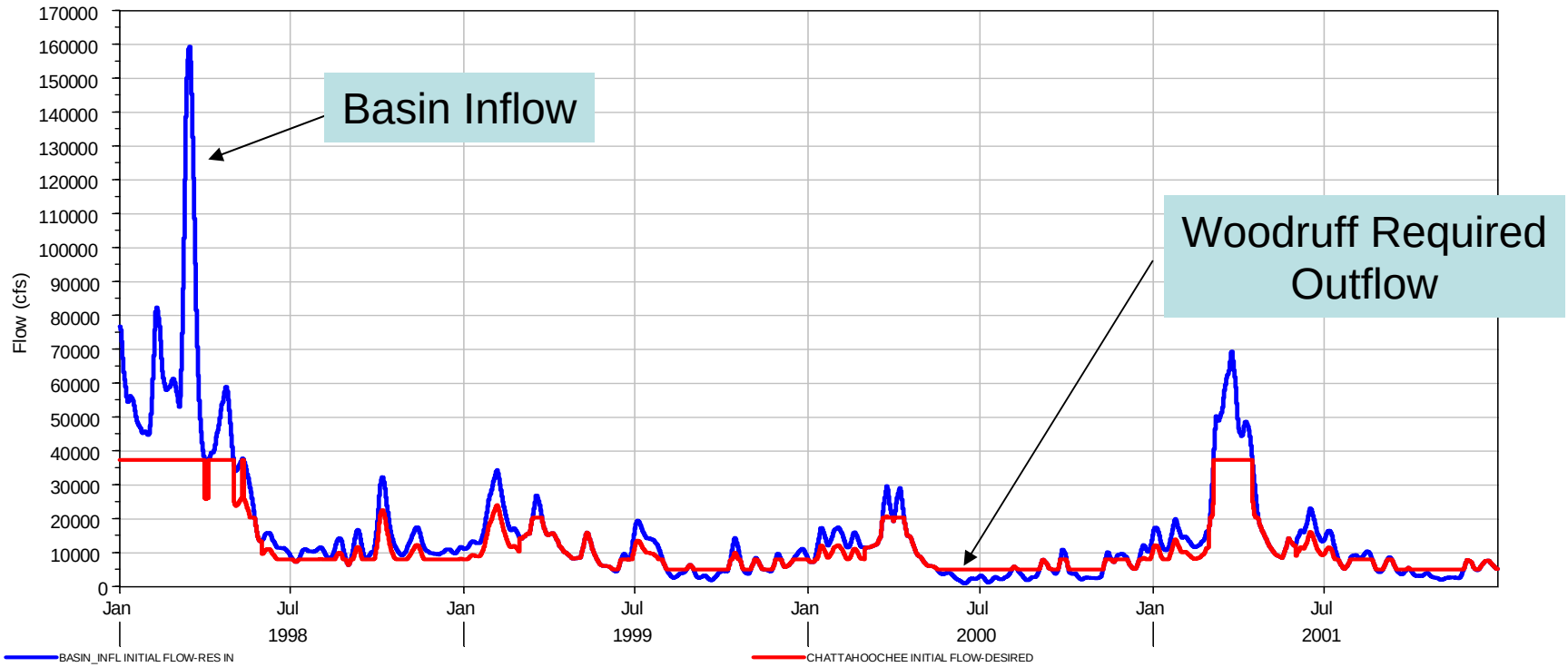
	B	C	D	E	F	G	H
1		APALACHICOLA	BI Limits	Non-Spaw	Spawn		
2		JIM WOODRUFF	Upper	37400	37400		
3		FLOW_CUM	Middle	8000	20400		
4			Lower	5000	5000		
5		1DAY					
6		STELLA-JW 7DAY	Storage Ratio	90%			
7		1-Jan-39					
8		2400					
9		31-Dec-01					
10		2400					
11		CFS					
12	**Index**	PER-AVER	Season	BI Bracket	Outflow 1	Outflow 2	Pre Endangered Release
13	01/01/1939	0	Non-Spawn	4	5,000	0	5000
14	01/02/1939	1,112.56	Non-Spawn	4	5,000	0	5000


Jim Woodruff Outflow Based on Basin Inflow
IOP June- Feb; Non-Spawning Period
5000
8000
23000
5000
BI
70 % of BI not less than 8000
16000
Reservoir storage occurs below this line
Minimum Woodruff Outflow (cfs)
Basin Inflow (cfs)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
16000 Target
100% of BI


Jim Woodruff Outflow Based on Basin Inflow
IOP March-May; Spawning Period
5000
20400
37400
5000
BI
70 % of BI not less than 20,400
37400
Reservoir storage occurs below this line
Minimum Woodruff Outflow (cfs)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
Basin Inflow (cfs)
70% of BI
100% of BI

Woodruff Required Outflow

- Values imported to DSS
- HEC-5 Chattahoochee minimum flow requirement

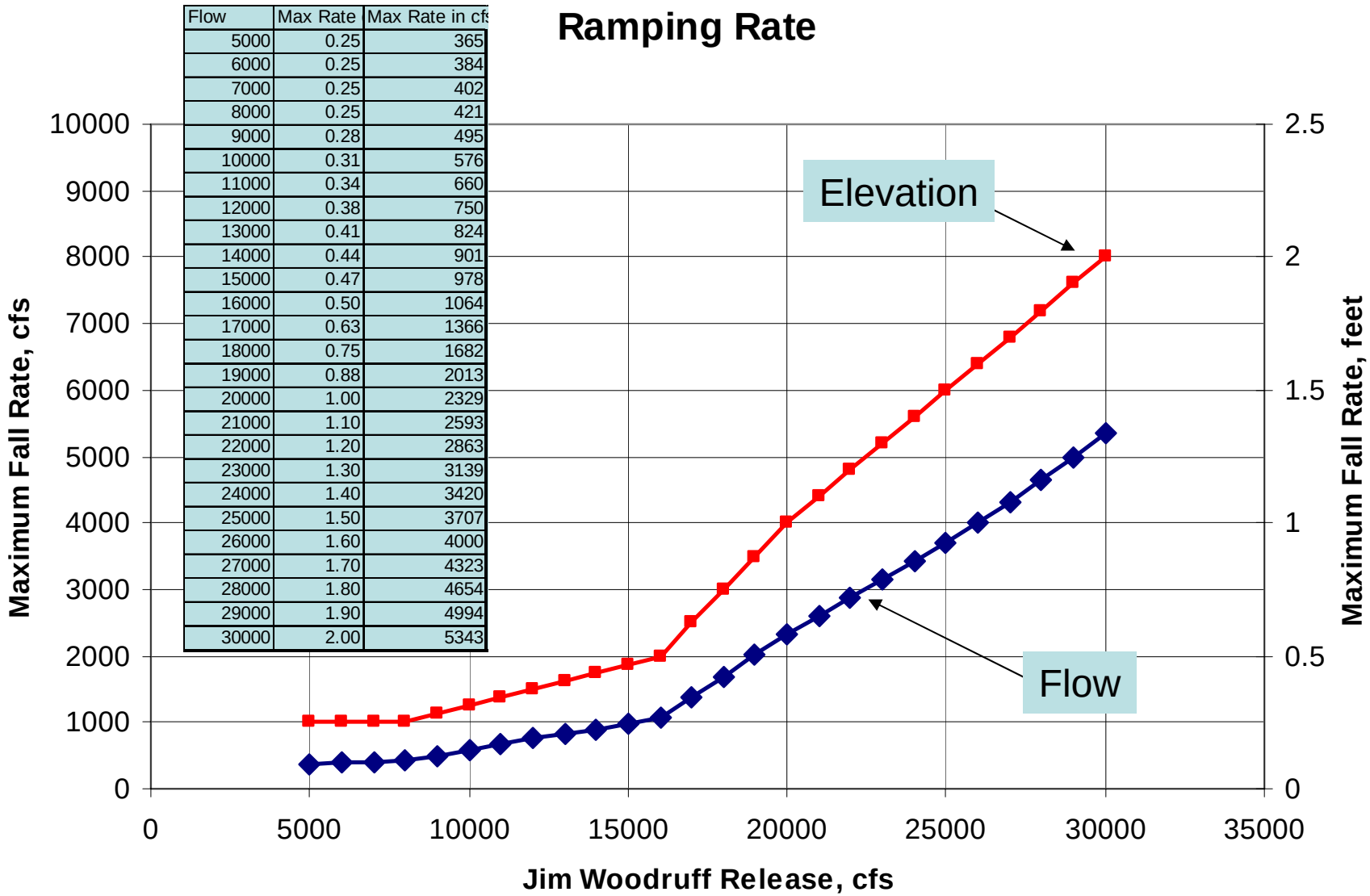


Down Ramping Rates

Release Range	Maximum Fall Rate (ft/day) measurse at Chattahoocee
> 30,000	none
> 20,000 and <= 30,000	1.0 to 2.0
> 16,000 and <= 20,000	0.5 to 1.0
> 8,000 and <= 16,000	0.25 to 0.5
<= 8,000	0.25

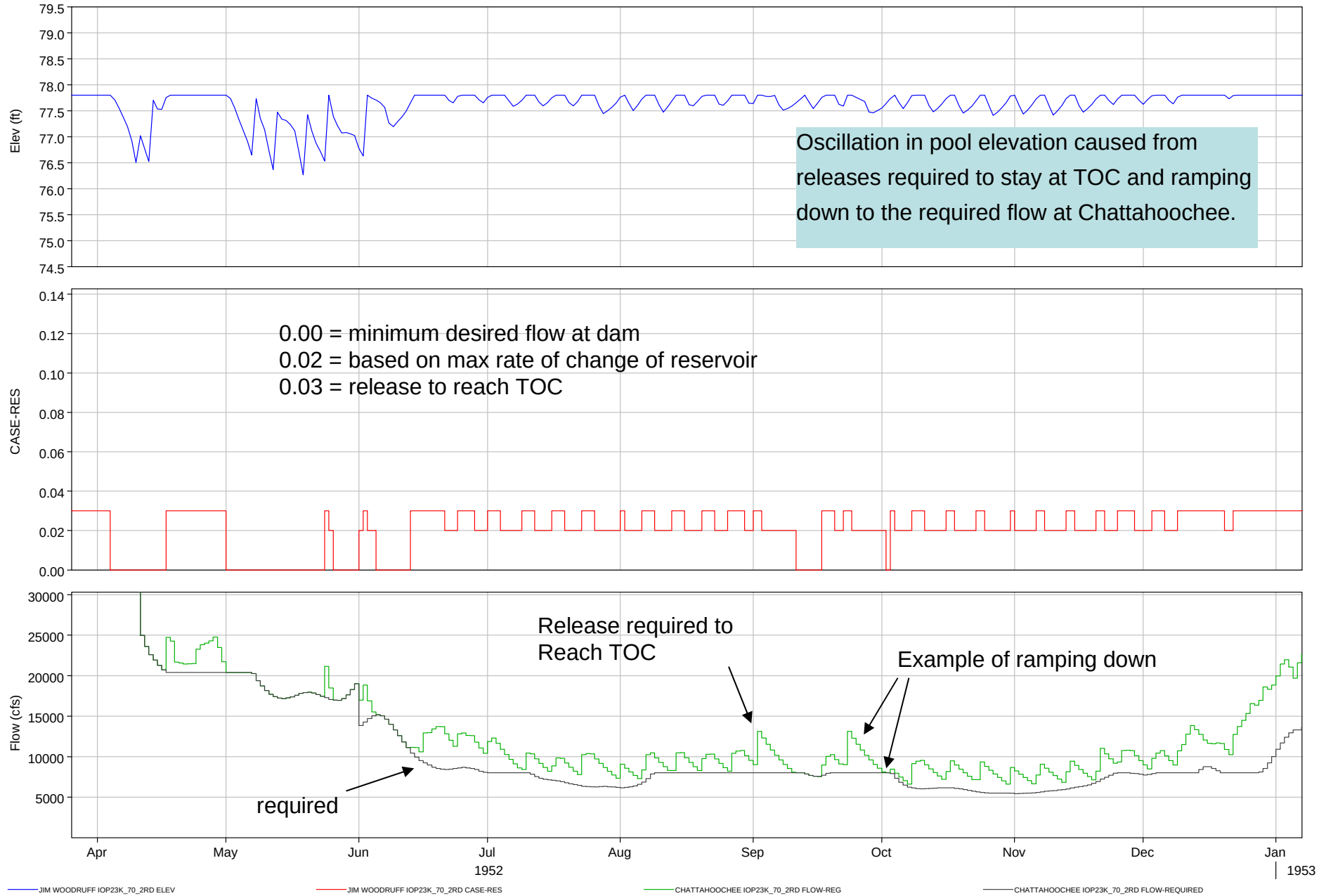
Maximum Fall Rate in Model

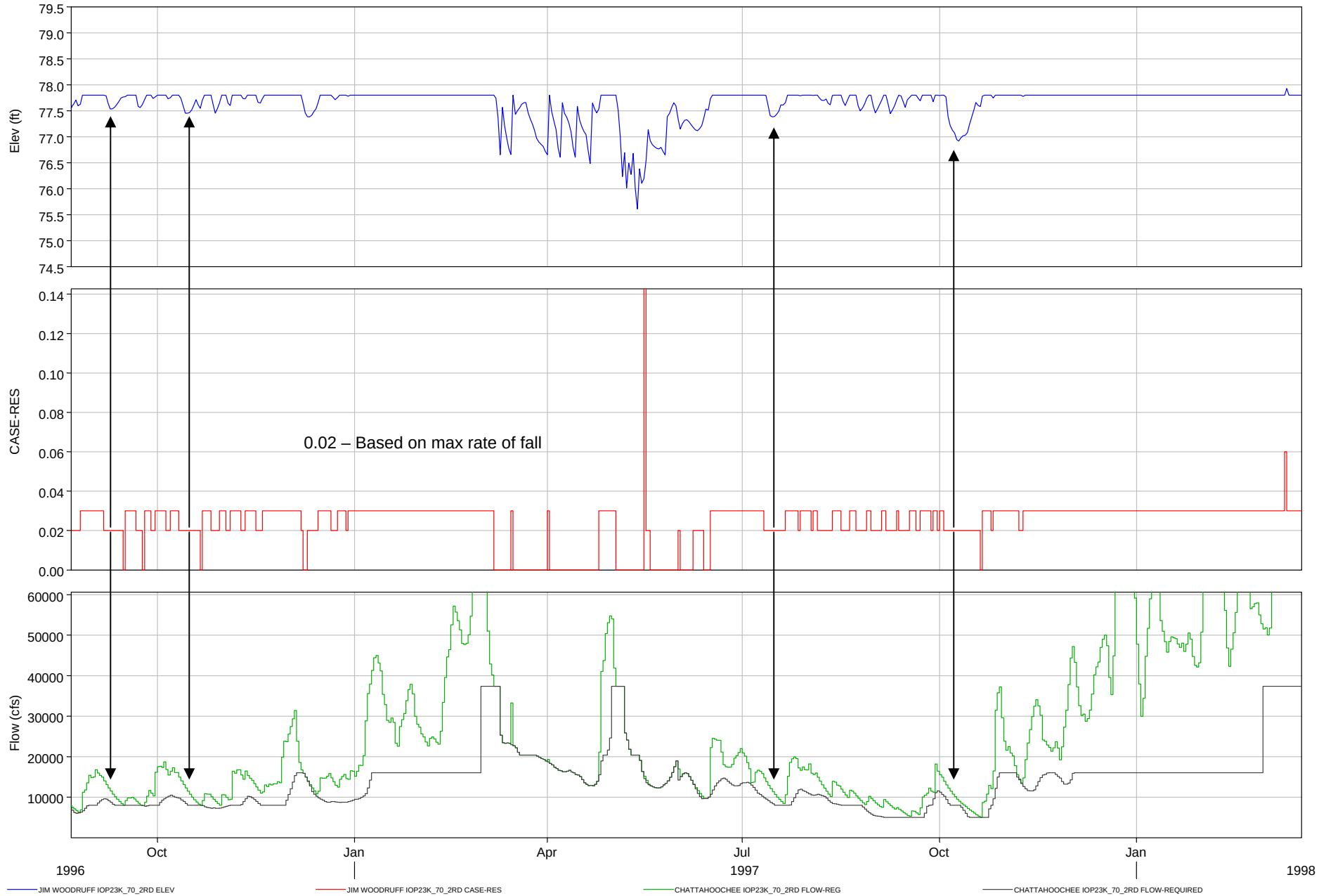
Flow	Max Rate	Max Rate in cfs
5000	0.25	365
6000	0.25	384
7000	0.25	402
8000	0.25	421
9000	0.28	495
10000	0.31	576
11000	0.34	660
12000	0.38	750
13000	0.41	824
14000	0.44	901
15000	0.47	978
16000	0.50	1064
17000	0.63	1366
18000	0.75	1682
19000	0.88	2013
20000	1.00	2329
21000	1.10	2593
22000	1.20	2863
23000	1.30	3139
24000	1.40	3420
25000	1.50	3707
26000	1.60	4000
27000	1.70	4323
28000	1.80	4654
29000	1.90	4994
30000	2.00	5343



Modeling Down Ramping Rate

- Down ramping rate is a function of previous day flow
- HEC-5 does not allow a release decision based on previous day flow
- Iterations are required to capture down ramping rate
- Basin inflow used as initial estimate of previous day release
- Each subsequent model run uses Jim Woodruff release (from previous model run) shifted forward 1 day to determine ramp rate
- ~~5~~ 10 iterations required for acceptable convergence of Jim Woodruff discharge


Elev (ft)
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
75.5
75.0
74.5
Oscillation in pool elevation caused from releases required to stay at TOC and ramping down to the required flow at Chattahoochee.
CASE-RES
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.00 = minimum desired flow at dam
0.02 = based on max rate of change of reservoir
0.03 = release to reach TOC
Flow (cfs)
30000
25000
20000
15000
10000
5000
Release required to Reach TOC
Example of ramping down
required
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
1952
1953
JIM WOODRUFF IOP23K_70_2RD ELEV
JIM WOODRUFF IOP23K_70_2RD CASE-RES
CHATTAHOOCHEE IOP23K_70_2RD FLOW-REG
CHATTAHOOCHEE IOP23K_70_2RD FLOW-REQUIRED


Elev (ft)
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
75.5
75.0
74.5
CASE-RES
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0.02 – Based on max rate of fall
Flow (cfs)
60000
50000
40000
30000
20000
10000
Oct
Jan
Apr
Jul
Oct
Jan
1996
1997
1998
JIM WOODRUFF IOP23K_70_2RD ELEV
JIM WOODRUFF IOP23K_70_2RD CASE-RES
CHATTAHOOCHEE IOP23K_70_2RD FLOW-REG
CHATTAHOOCHEE IOP23K_70_2RD FLOW-REQUIRED

Modeling Notes

- Balanced operation based on Zones assignments from ACF Draft Water Control Plan
- Release decision based on highest demand
  - Minimum flow requirement
  - Water supply
  - Balance downstream reservoir
  - Hydropower
  - Reach top of rule curve
- Down ramping rate captured through iterations
- Basin Inflow provide by FWS STELLA modeling team. This ensures that the Jim Woodruff minimum release computation is based on the same data set.
- Jim Woodruff minimum release based on basin inflow is preprocessed outside of modeling in a spreadsheet. Used in the model as minimum flow requirement at Chattahoochee.
- The model does not capture the volumetric adjustment as described in “Adjustments to IOP” document. This is a periodic refinement in the operation that will be captured in real operation.

Summary

- Model captures
  - Basin Inflow – Woodruff discharge relationship
  - Fall ramping rate
  - Balanced operation, with greatest demand on downstream reservoirs West Point and WF George

Hydropower Demand

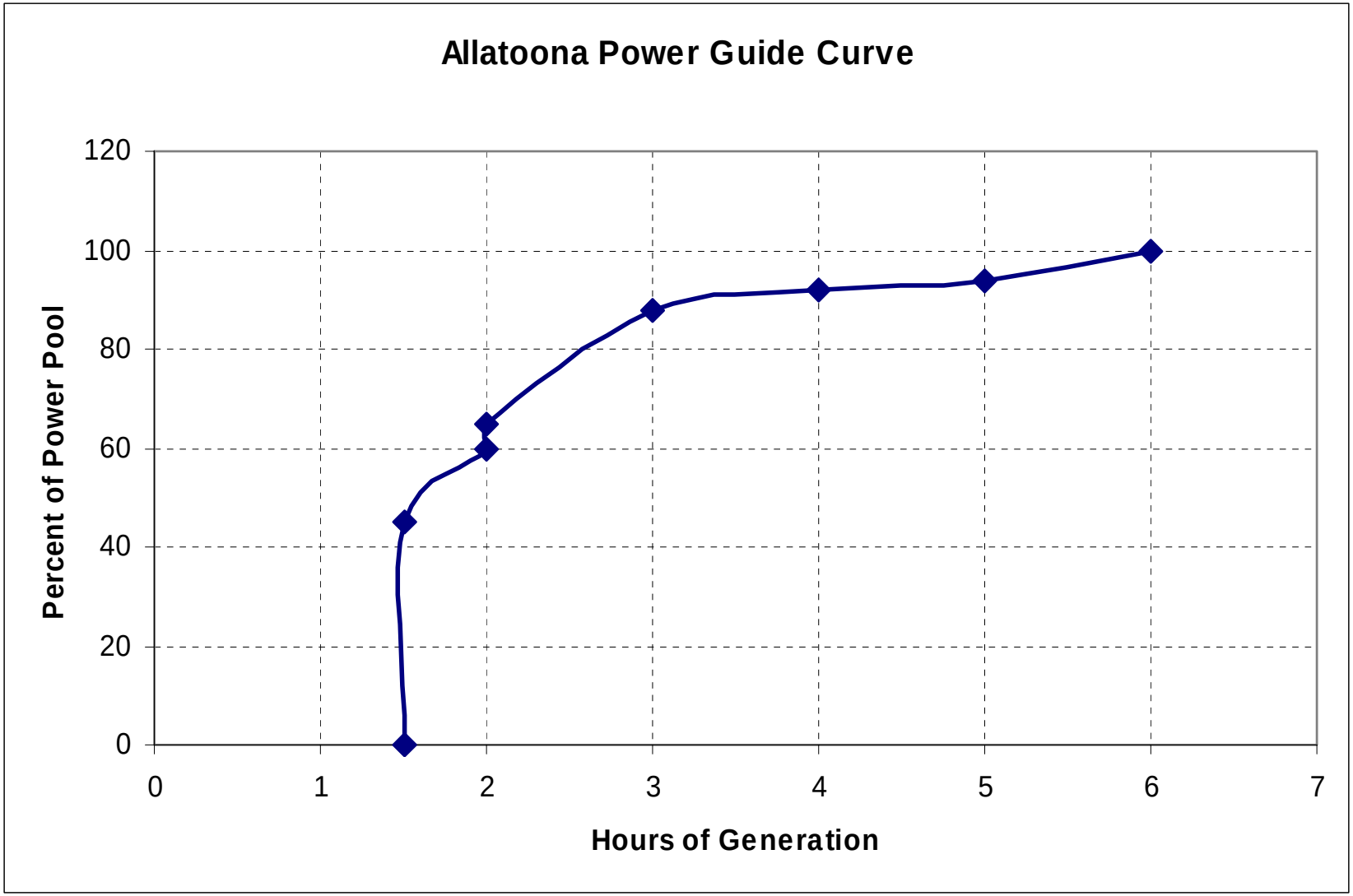
- Hydropower demand is a function of available storage. As the storage diminishes the demand reduces. Storage Zones described in the ACF Water Control manual dated 1989 used as the bases to assign the hydropower demand. Values developed from examining hydropower generation over the last few years.

IOP Model	Buford	West Point	WF George
Zone	(hours use)	(hours use)	(hours use)
1	3	4	4
2	2	2	2
3	2	2	2
4	0	0	0

HEC-5 Power Guide Curve

- PC and PF record
  - PC percent of conservation storage
  - PF plant factor (% time generating)
- Hydropower demand function of remaining conservation storage
- PR and PD record become multipliers
  - PR monthly
  - PD daily
- PC recorded use to approximate ZONES from ACF Water Control Plan

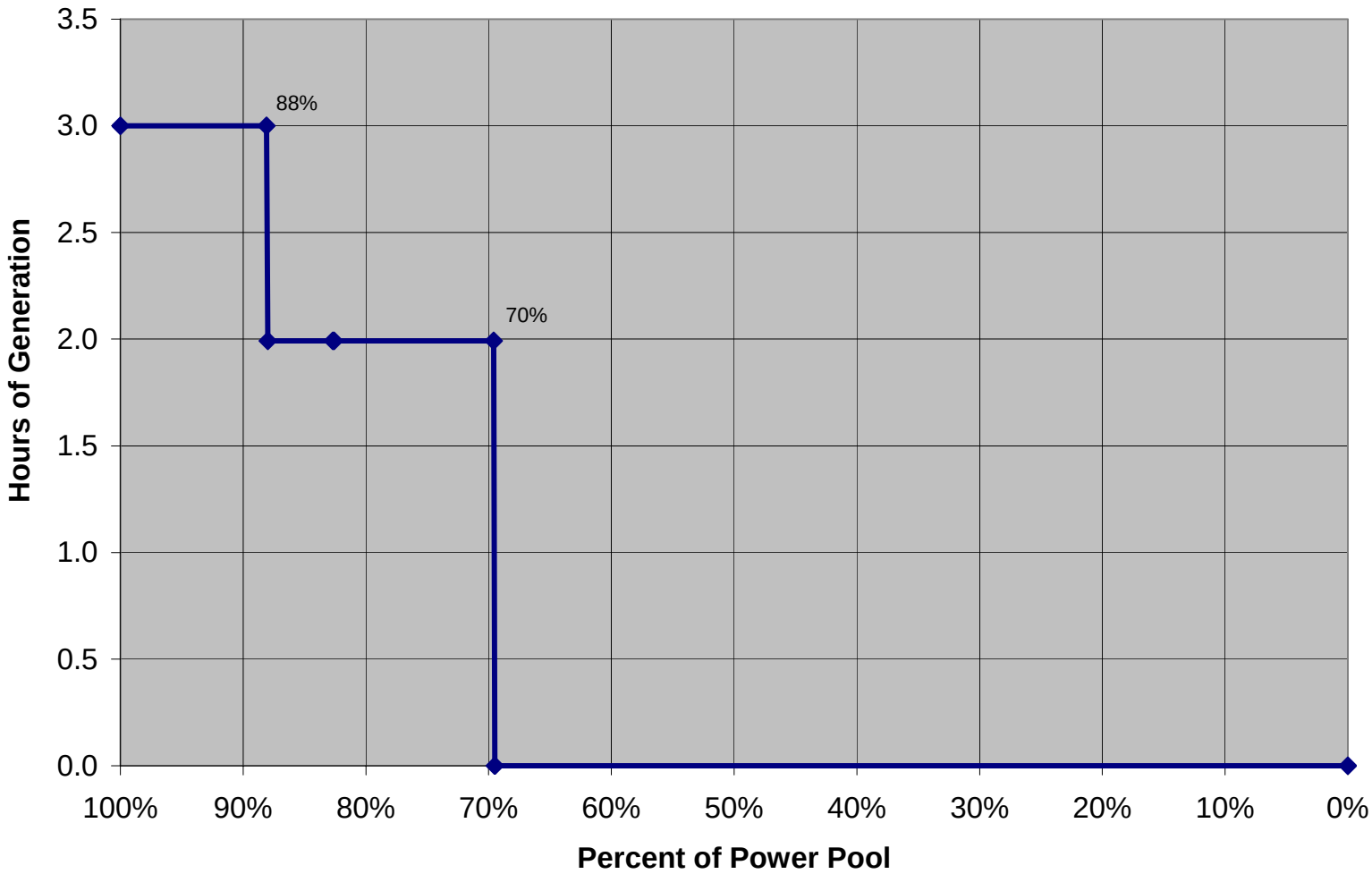
Hydropower Modeling

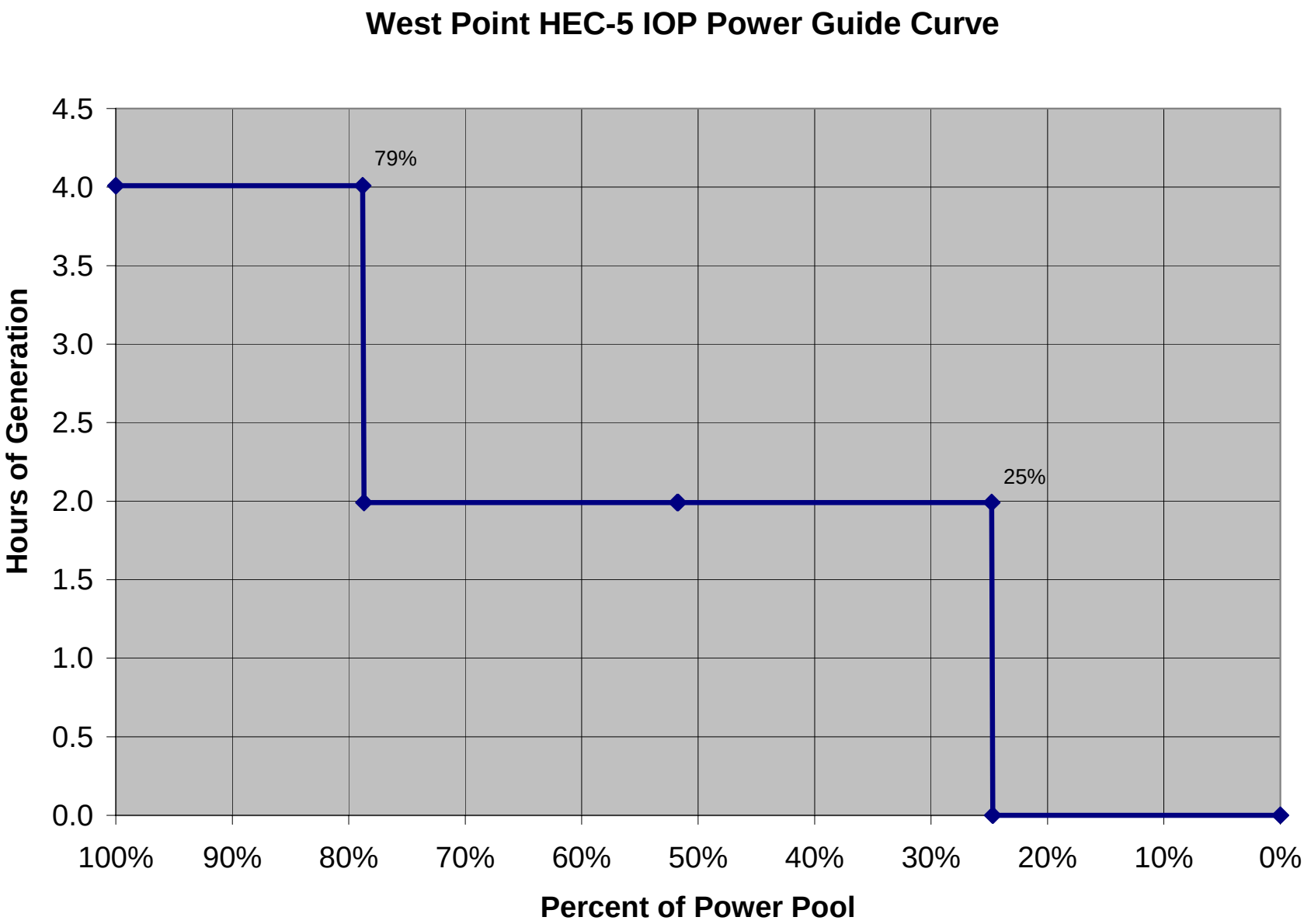


HEC-5 Power Guide Curve

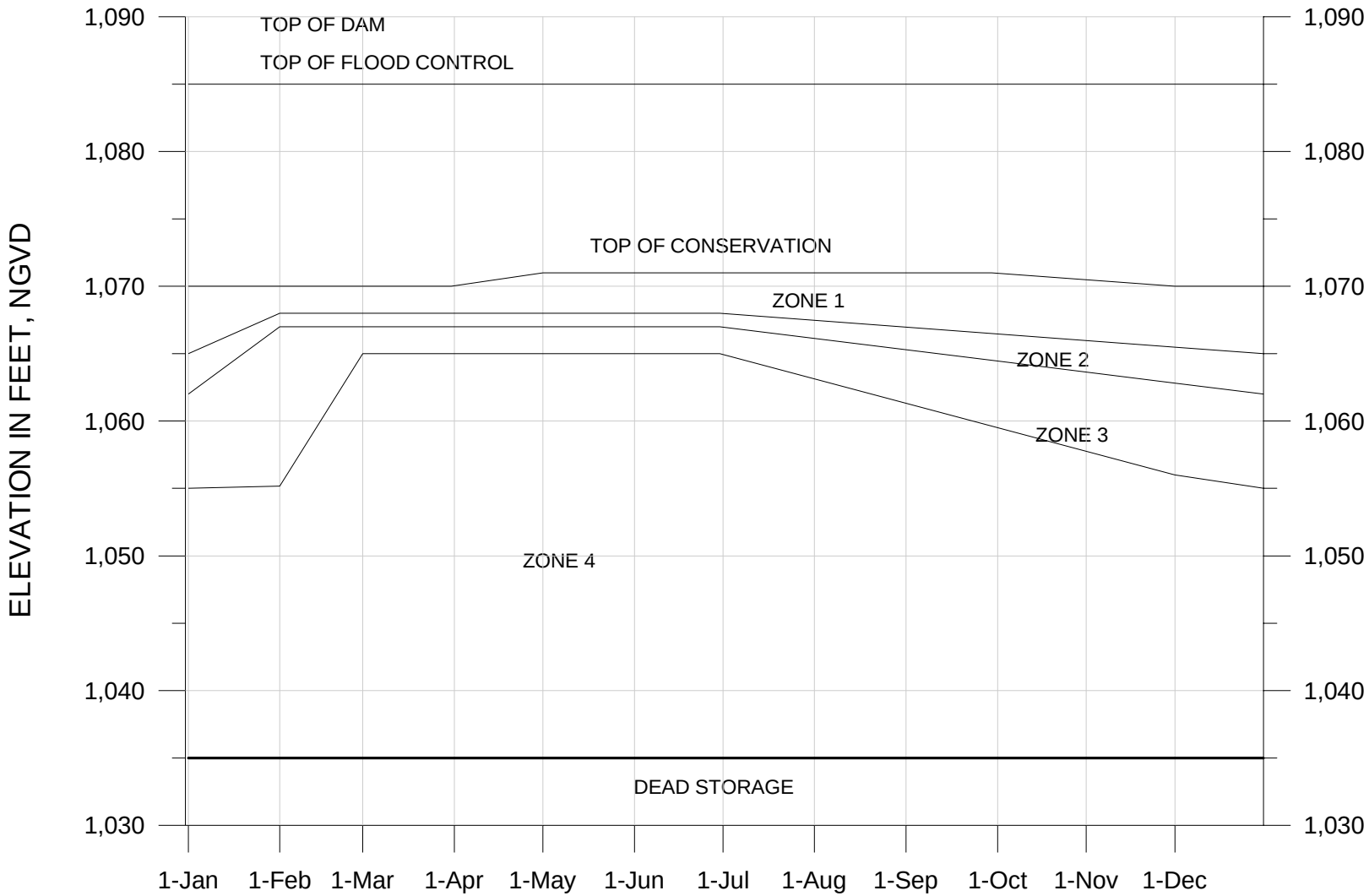
```
Buford
C "PC VALUES COMPUTED FROM AVERAGE POOL ELEVATION FOR EACH ZONE"
C PC     6       0    .826    .827    .880    .881     1.0
C "PC VALUES COMPUTED FROM TOP OF ZONES ON JUNE 1ST"
C Z1=1071 Z2=1068 Z3=1067 Z4=1065
PC     8       0    .796    .797    .862    .863    .896    .897     1.0
PF     8    .000    .000    .083    .083    .083    .083    .125    .125

West Point
C "PC VALUES COMPUTED FROM AVERAGE POOL ELEVATION FOR EACH ZONE"
C PC     7       0    .363    .364    .555    .556    .693    .694     1.0
C "PC VALUES COMPUTED FROM TOP OF ZONES ON JUNE 1ST"
C Z1=635 Z2=633 Z3=632 Z4=630
PC     8       0    .609    .610    .758    .759    .836    .837     1.0
PF     8    .000    .000    .083    .083    .083    .083    .167    .167

WF George
C "PC VALUES COMPUTED FROM AVERAGE POOL ELEVATION FOR EACH ZONE"
C PC     8       0    .247    .248    .517    .518    .787    .788     1.0
C "PC VALUES COMPUTED FROM TOP OF ZONES ON JUNE 1ST"
C Z1=190 Z2=189 Z3=188 Z4=186
PC     8       0    .309    .310    .643    .644    .818    .819     1.0
PF     8    .000    .000    .083    .083    .083    .083    .167    .167
```

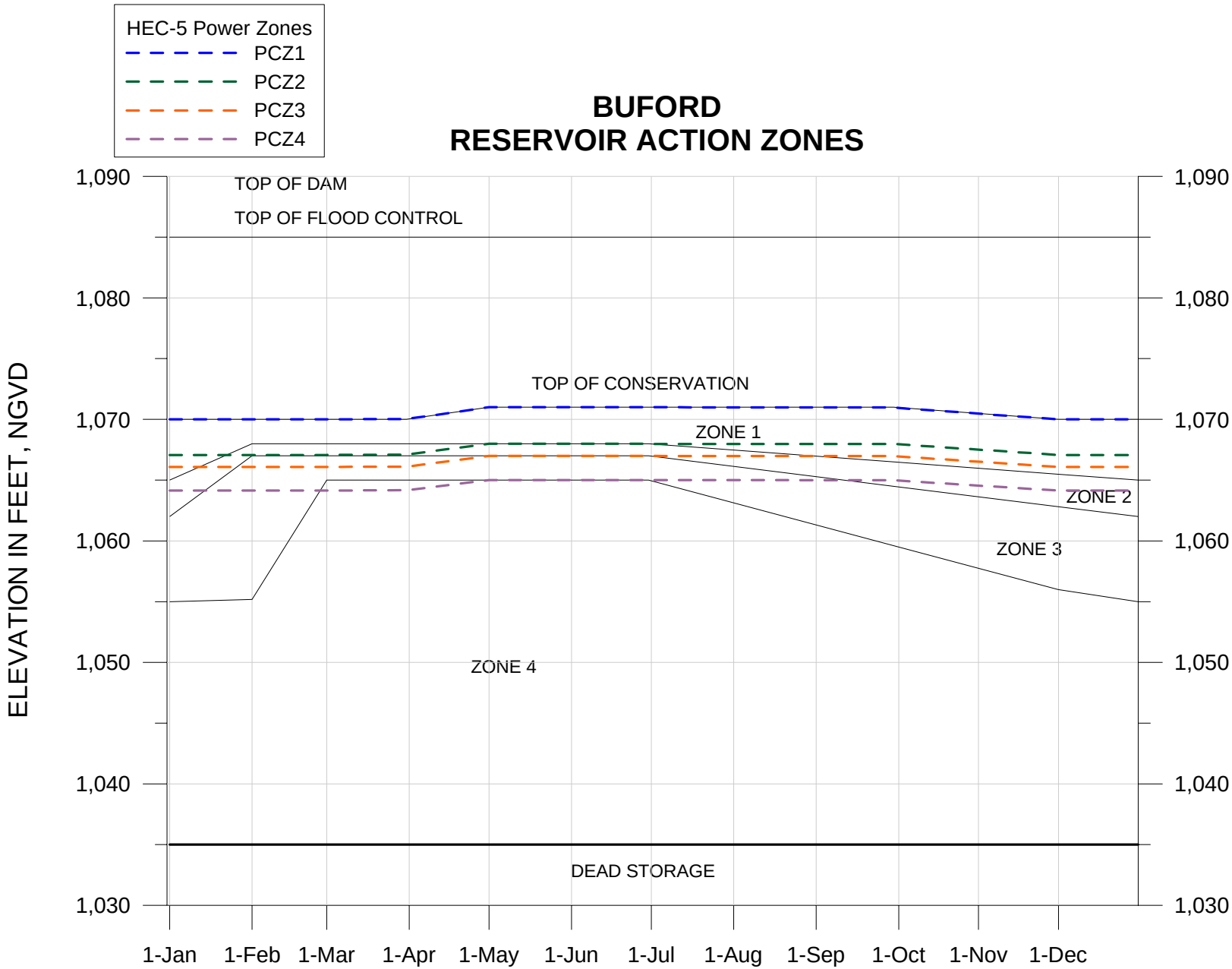
Buford HEC-5 IOP Power Guide Curve

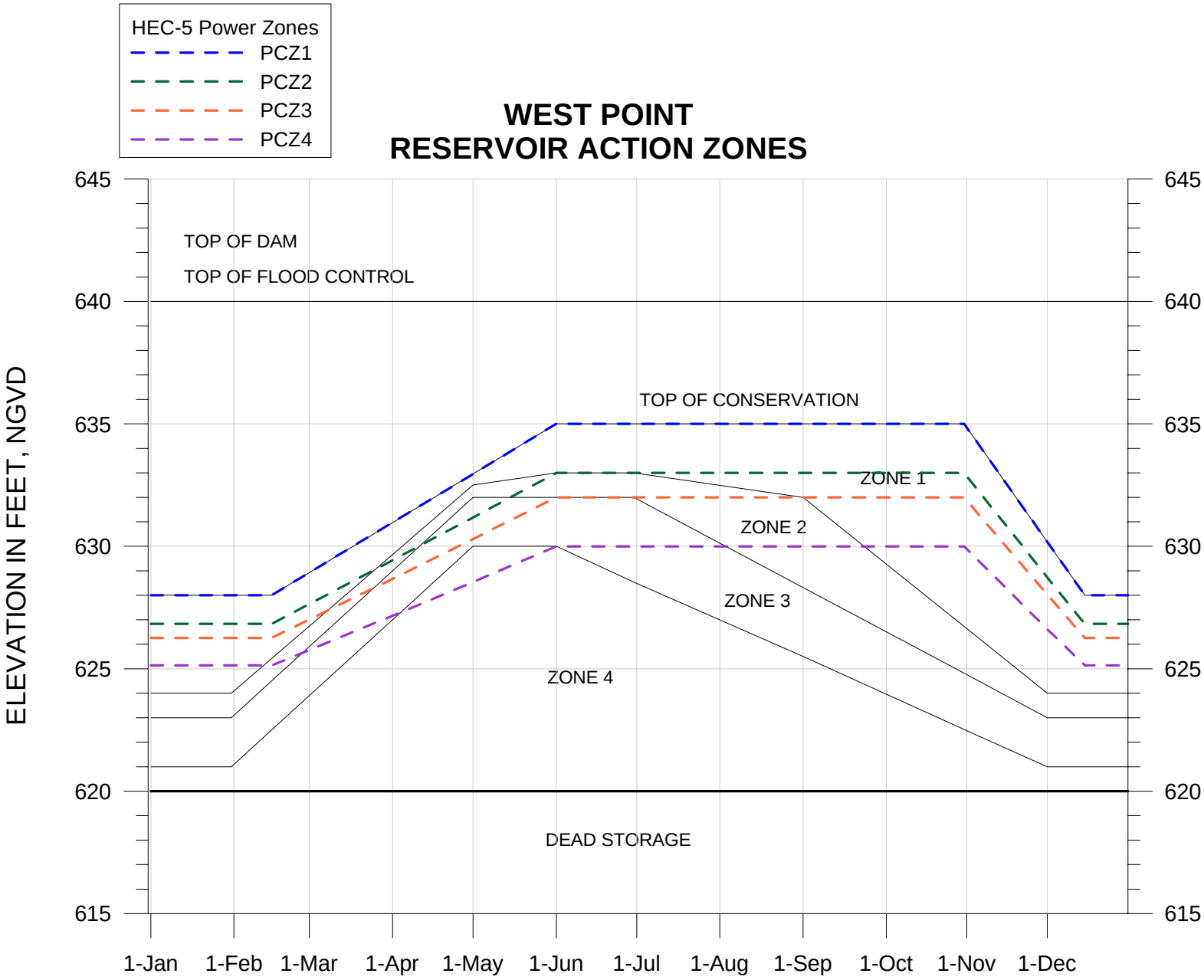


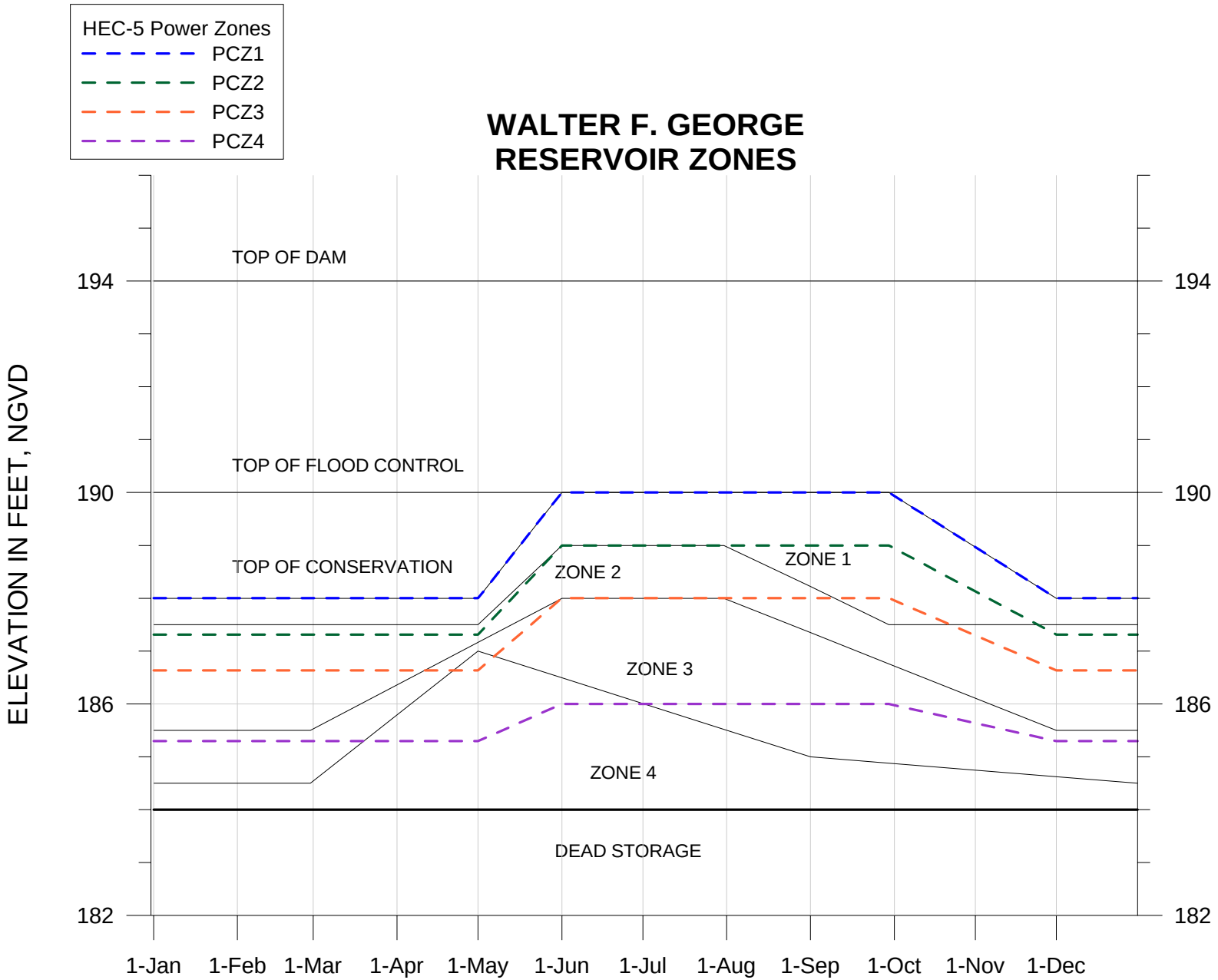

West Point HEC-5 IOP Power Guide Curve
Hours of Generation
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
79%
25%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percent of Power Pool

BUFORD
RESERVOIR ACTION ZONES

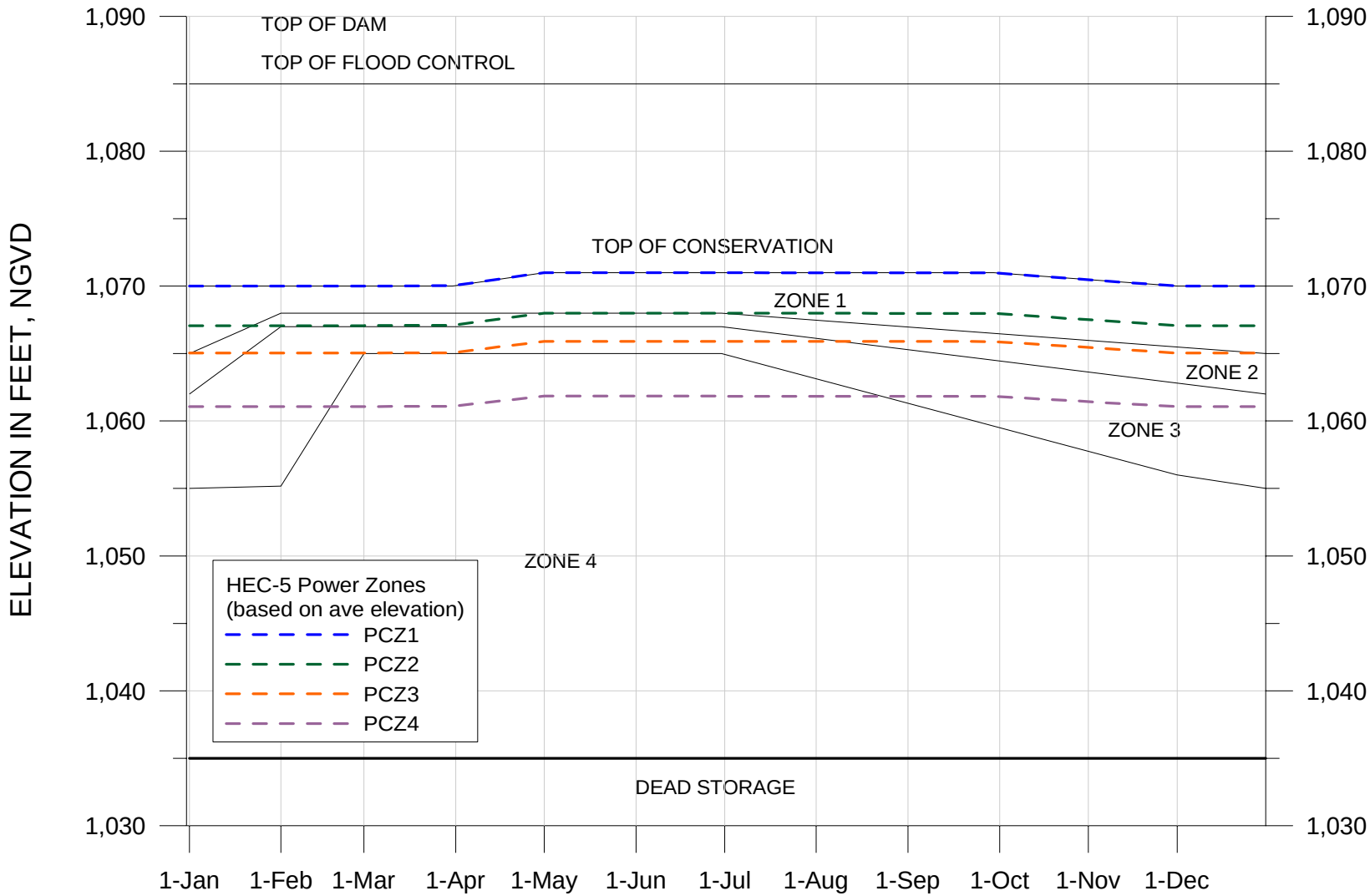



HEC-5 Power Zones
PCZ1
PCZ2
PCZ3
PCZ4
BUFORD
RESERVOIR ACTION ZONES
ELEVATION IN FEET, NGVD
1,090
1,080
1,070
1,060
1,050
1,040
1,030
TOP OF DAM
TOP OF FLOOD CONTROL
TOP OF CONSERVATION
ZONE 1
ZONE 2
ZONE 3
ZONE 4
DEAD STORAGE
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

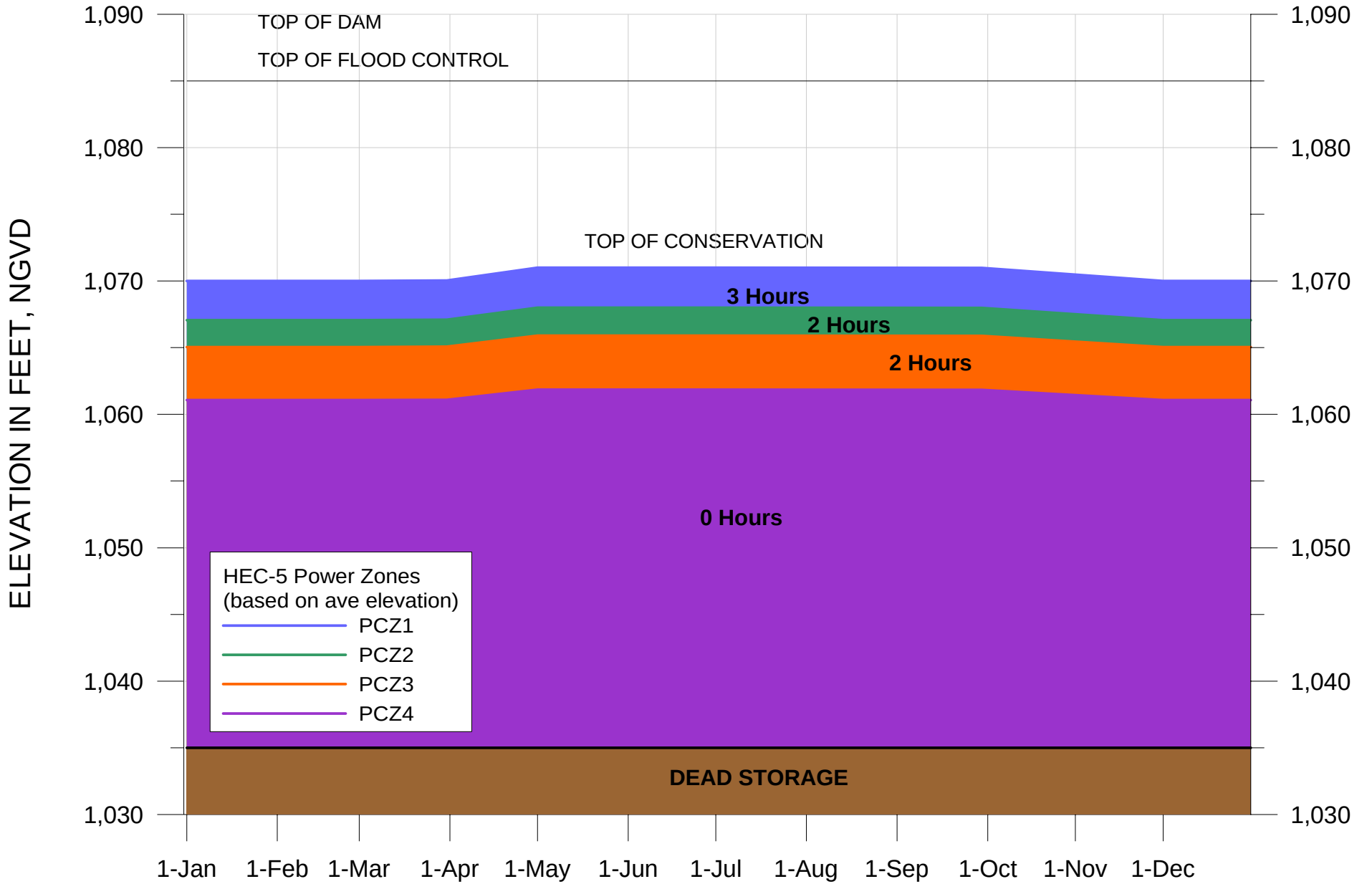

HEC-5 Power Zones
PCZ1
PCZ2
PCZ3
PCZ4
WEST POINT
RESERVOIR ACTION ZONES
ELEVATION IN FEET, NGVD
645
640
635
630
625
620
615
TOP OF DAM
TOP OF FLOOD CONTROL
TOP OF CONSERVATION
ZONE 1
ZONE 2
ZONE 3
ZONE 4
DEAD STORAGE
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

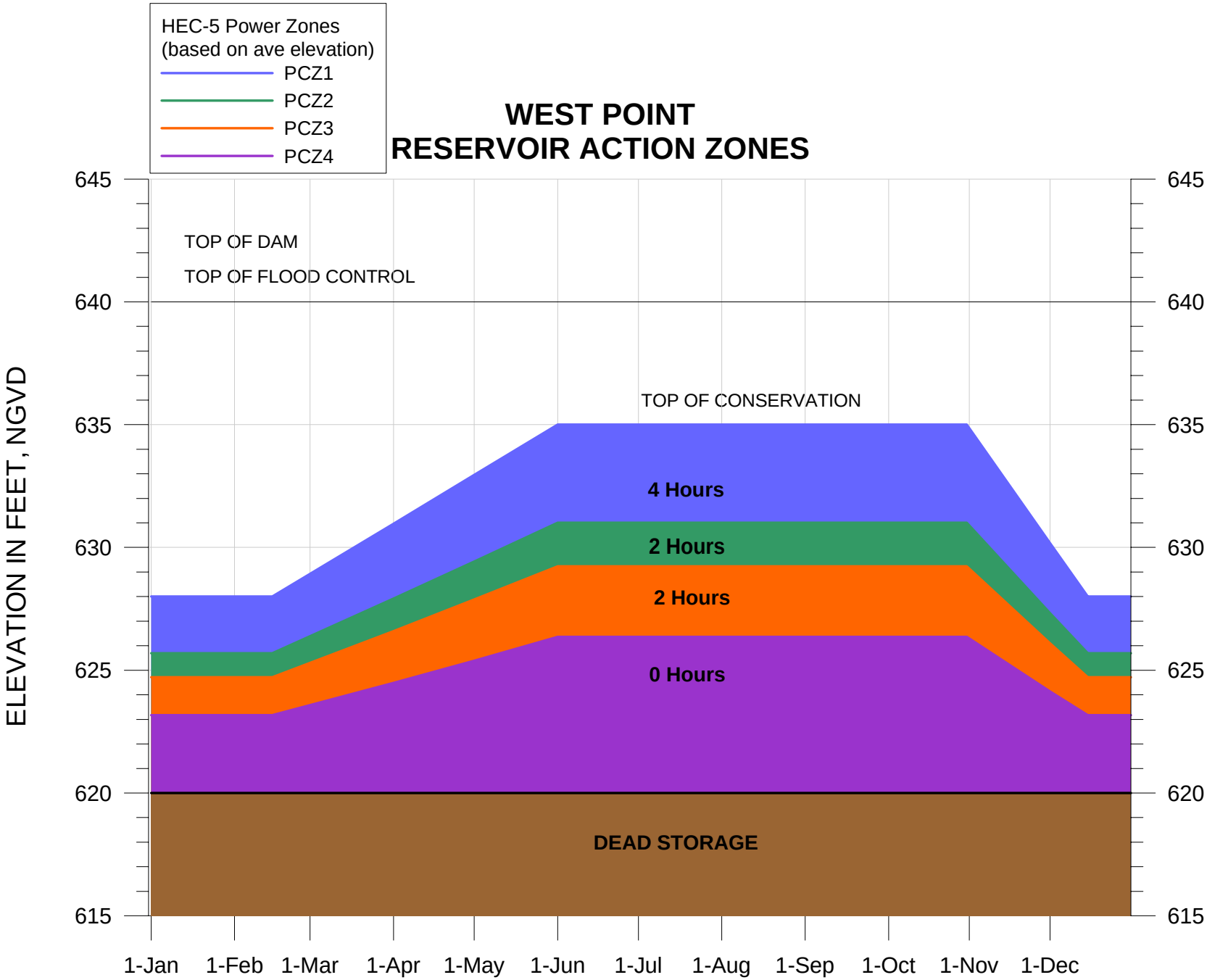

HEC-5 Power Zones
PCZ1
PCZ2
PCZ3
PCZ4
WALTER F. GEORGE
RESERVOIR ZONES
ELEVATION IN FEET, NGVD
TOP OF DAM
TOP OF FLOOD CONTROL
TOP OF CONSERVATION
ZONE 1
ZONE 2
ZONE 3
ZONE 4
DEAD STORAGE
194
190
186
182
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

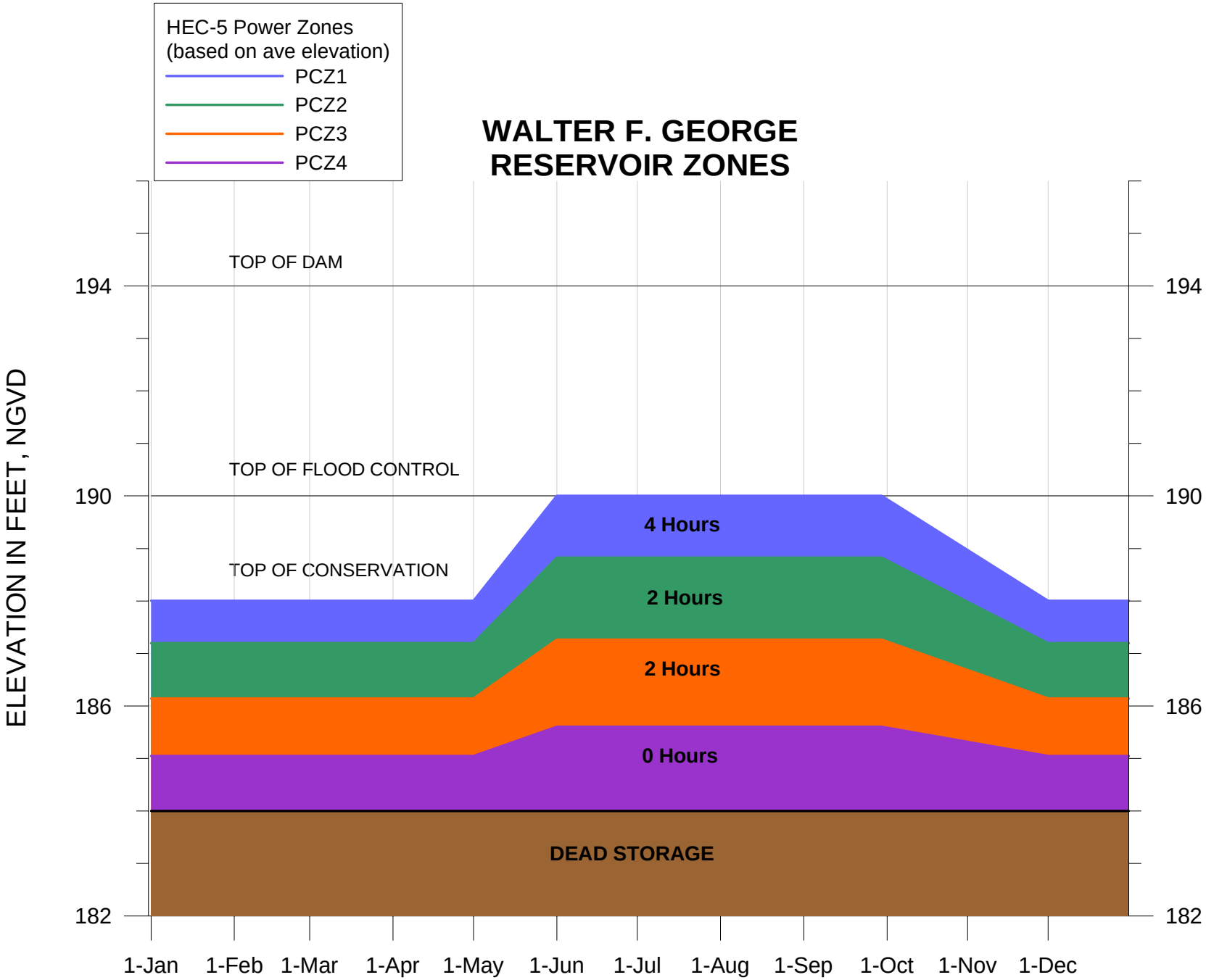
BUFORD
RESERVOIR ACTION ZONES



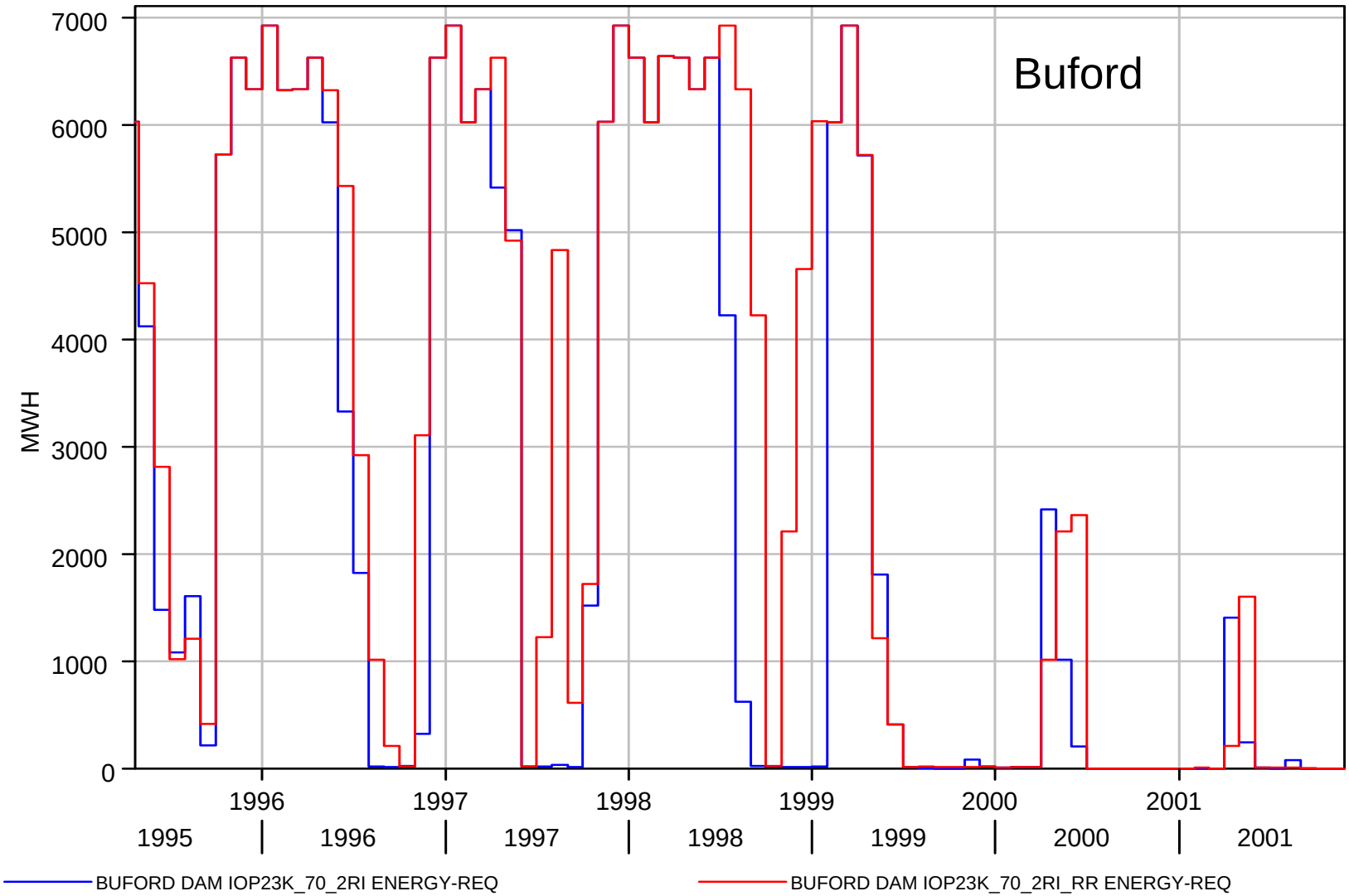
BUFORD
RESERVOIR ACTION ZONES



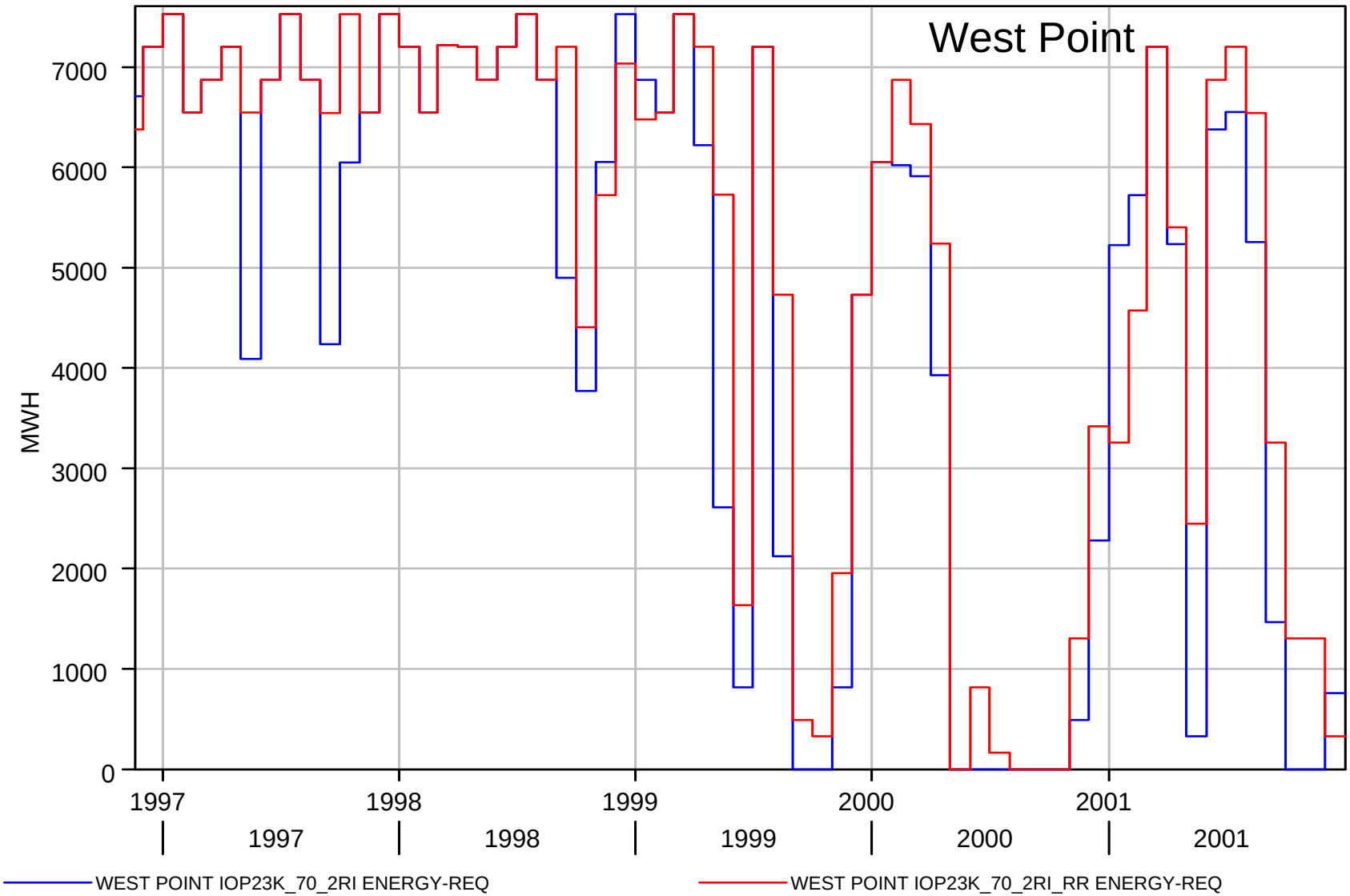

HEC-5 Power Zones
(based on ave elevation)
PCZ1
PCZ2
PCZ3
PCZ4
WEST POINT
RESERVOIR ACTION ZONES
TOP OF DAM
TOP OF FLOOD CONTROL
TOP OF CONSERVATION
4 Hours
2 Hours
2 Hours
0 Hours
DEAD STORAGE
ELEVATION IN FEET, NGVD
645
640
635
630
625
620
615
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec


HEC-5 Power Zones
(based on ave elevation)
PCZ1
PCZ2
PCZ3
PCZ4
WALTER F. GEORGE
RESERVOIR ZONES
TOP OF DAM
TOP OF FLOOD CONTROL
TOP OF CONSERVATION
4 Hours
2 Hours
2 Hours
0 Hours
DEAD STORAGE
ELEVATION IN FEET, NGVD
194
190
186
182
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec

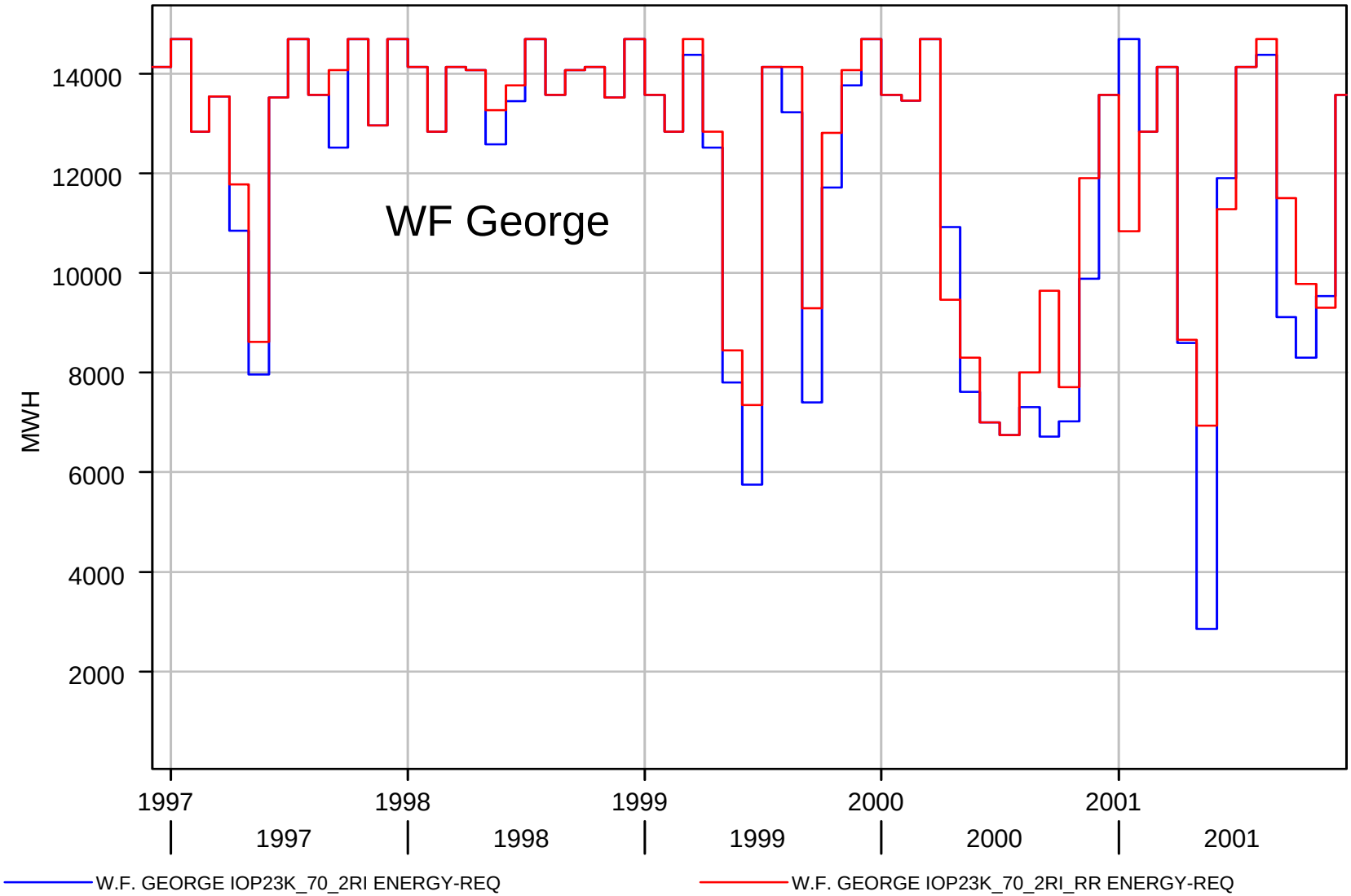
Difference in Energy Demand



Difference in Energy Demand

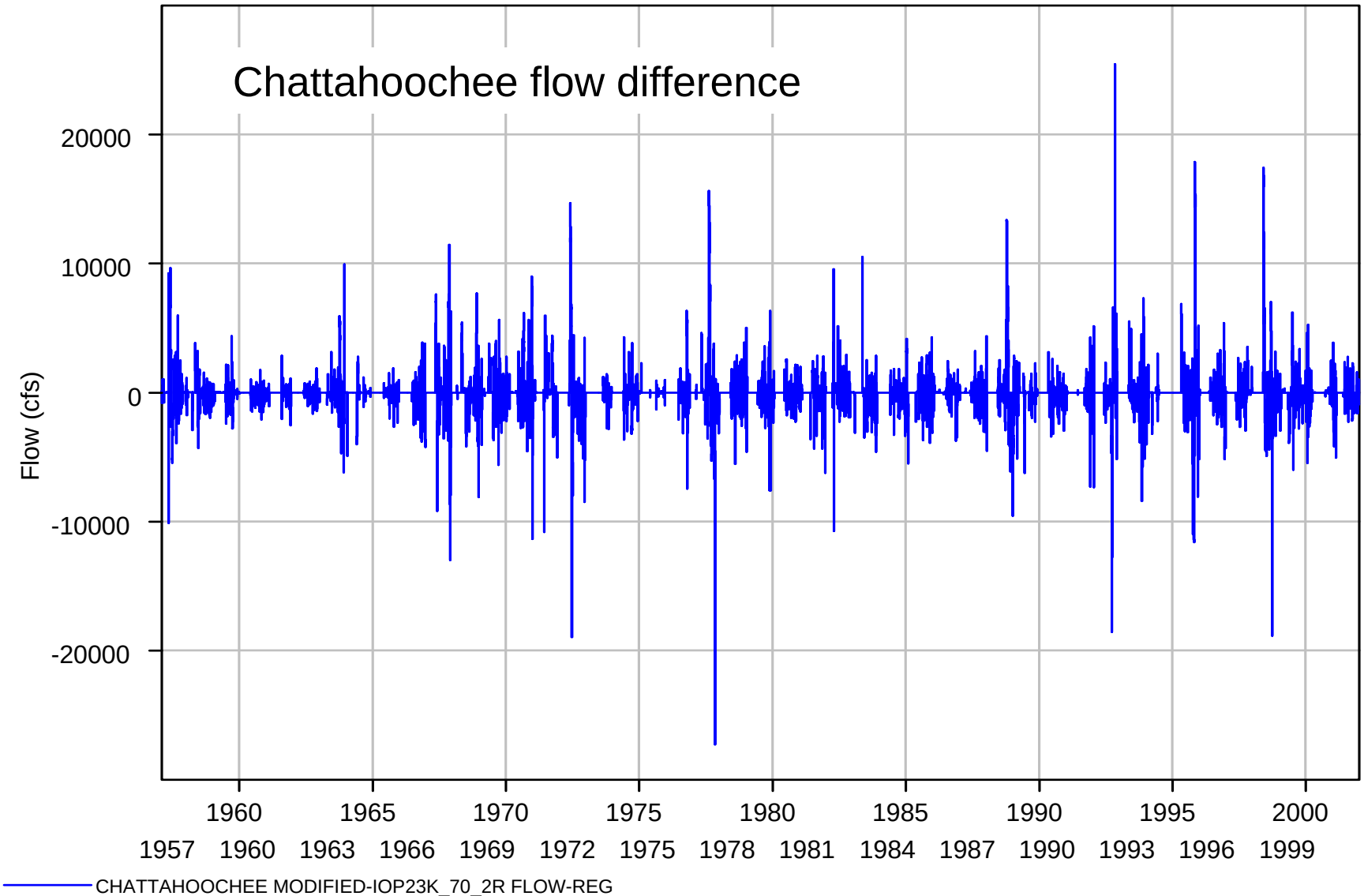


Difference in Energy Demand

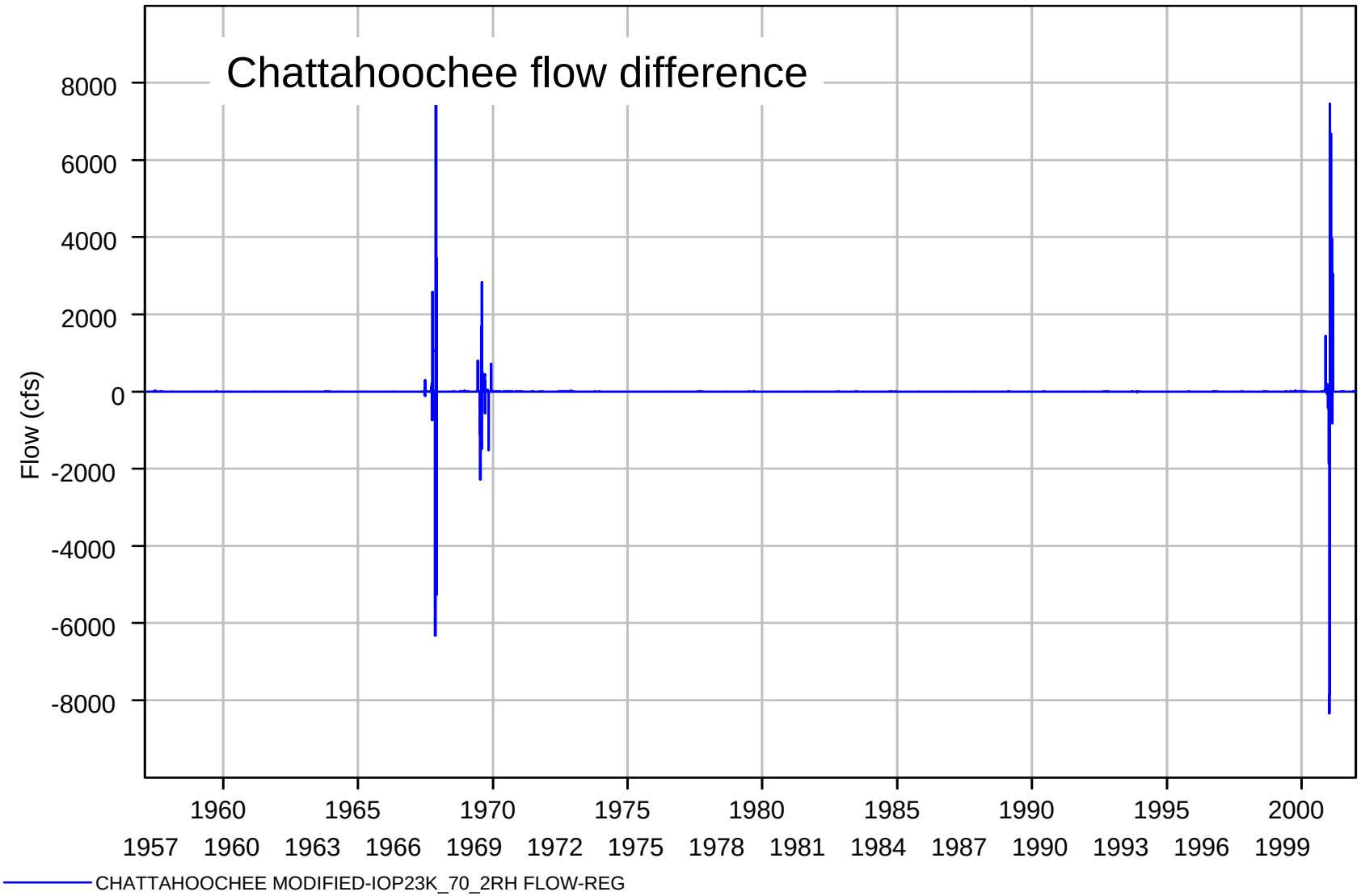


IOP HEC-5 Modeling Results

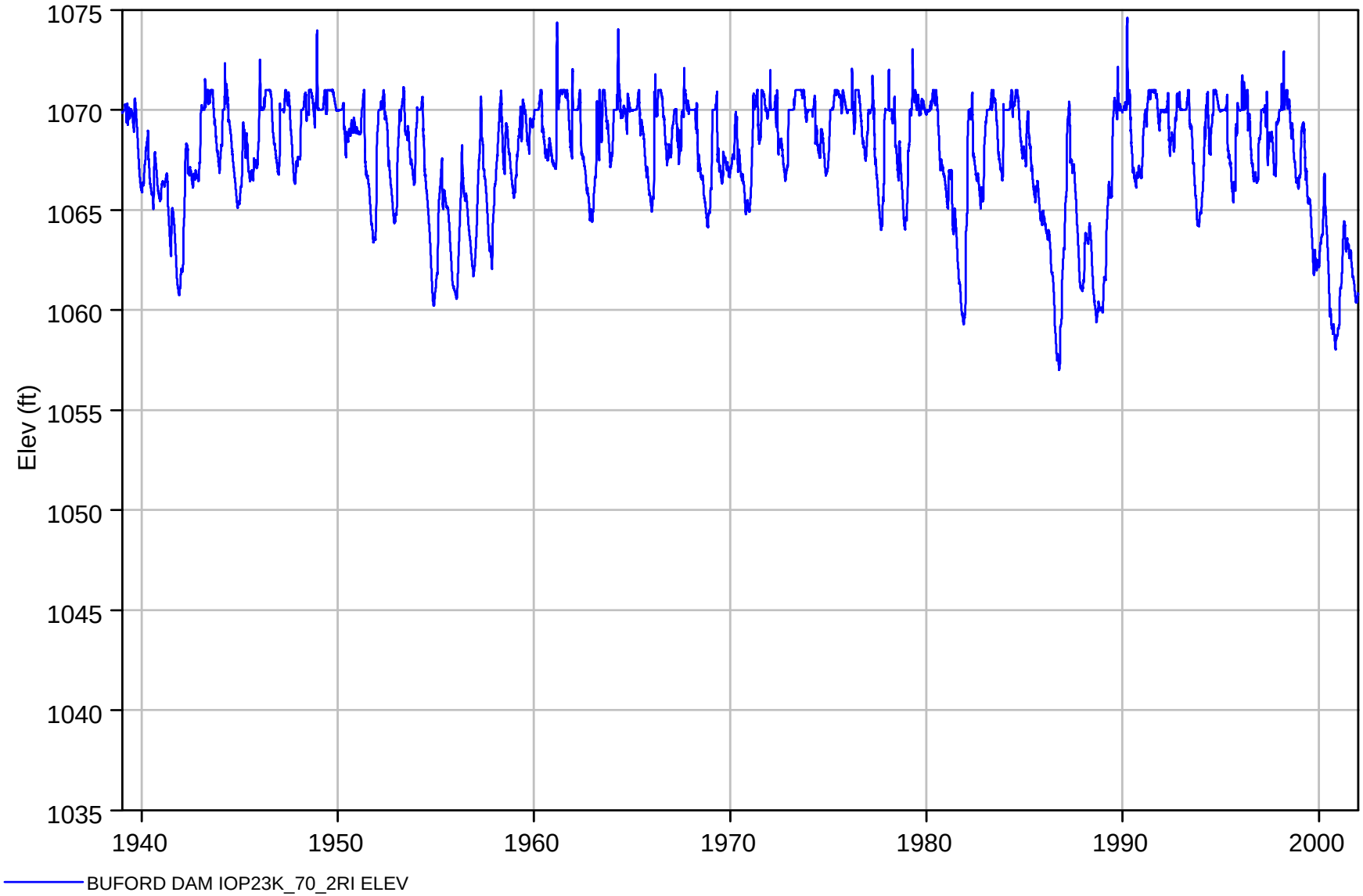
IOP Model Output – 2nd Iteration



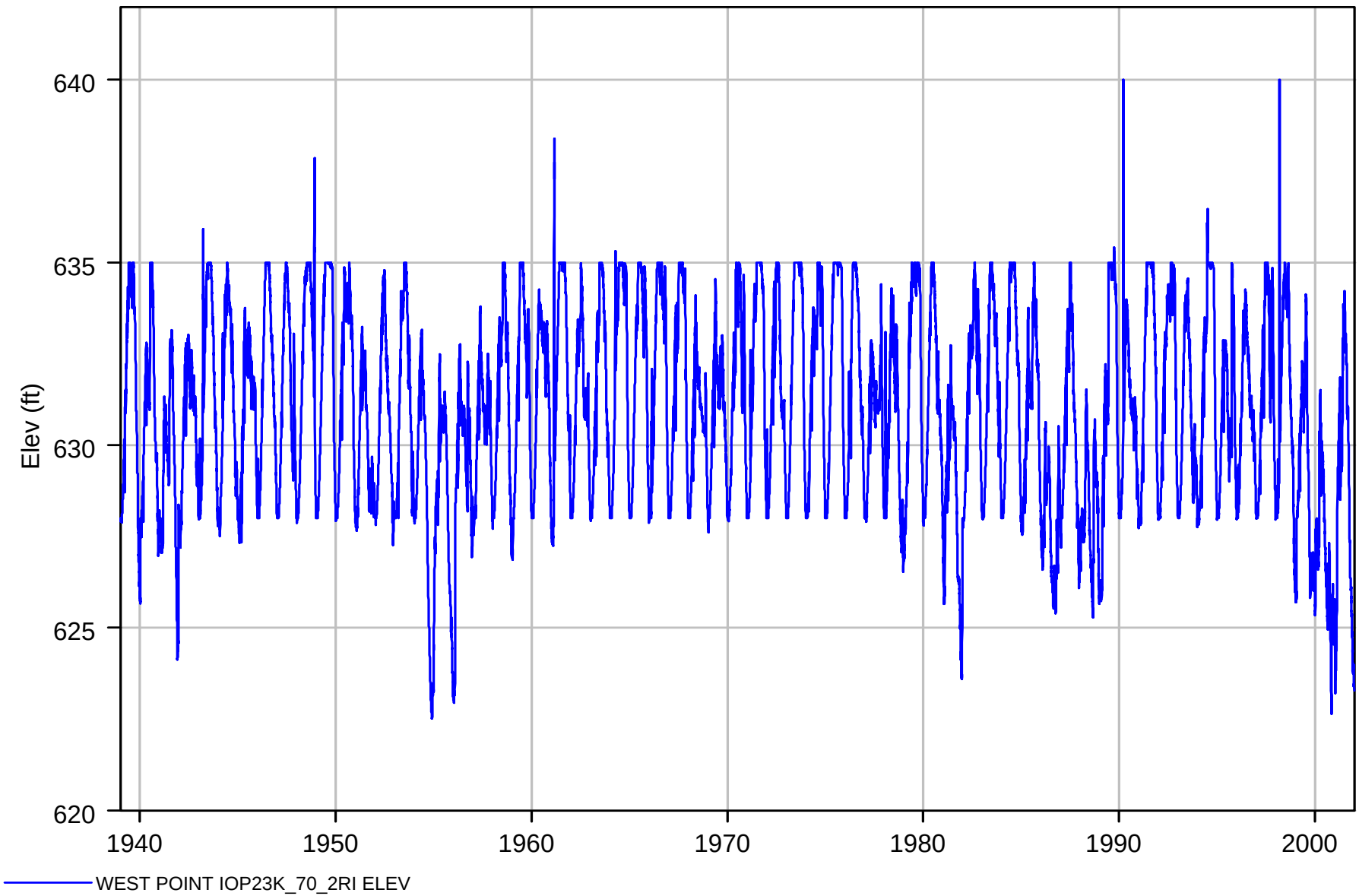
IOP Model Output - 10th Iteration



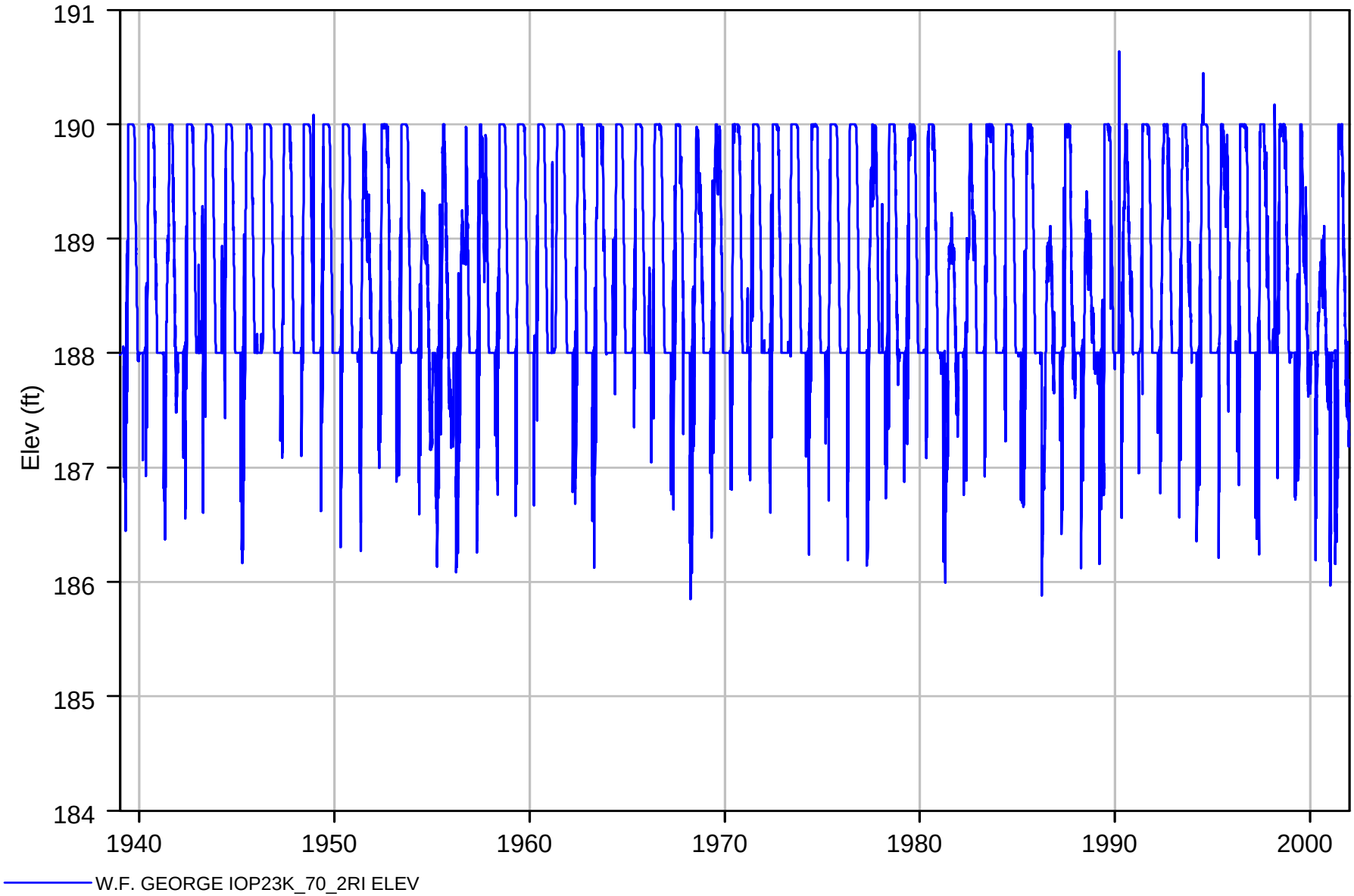
IOP Modeling Results – Buford Elevation



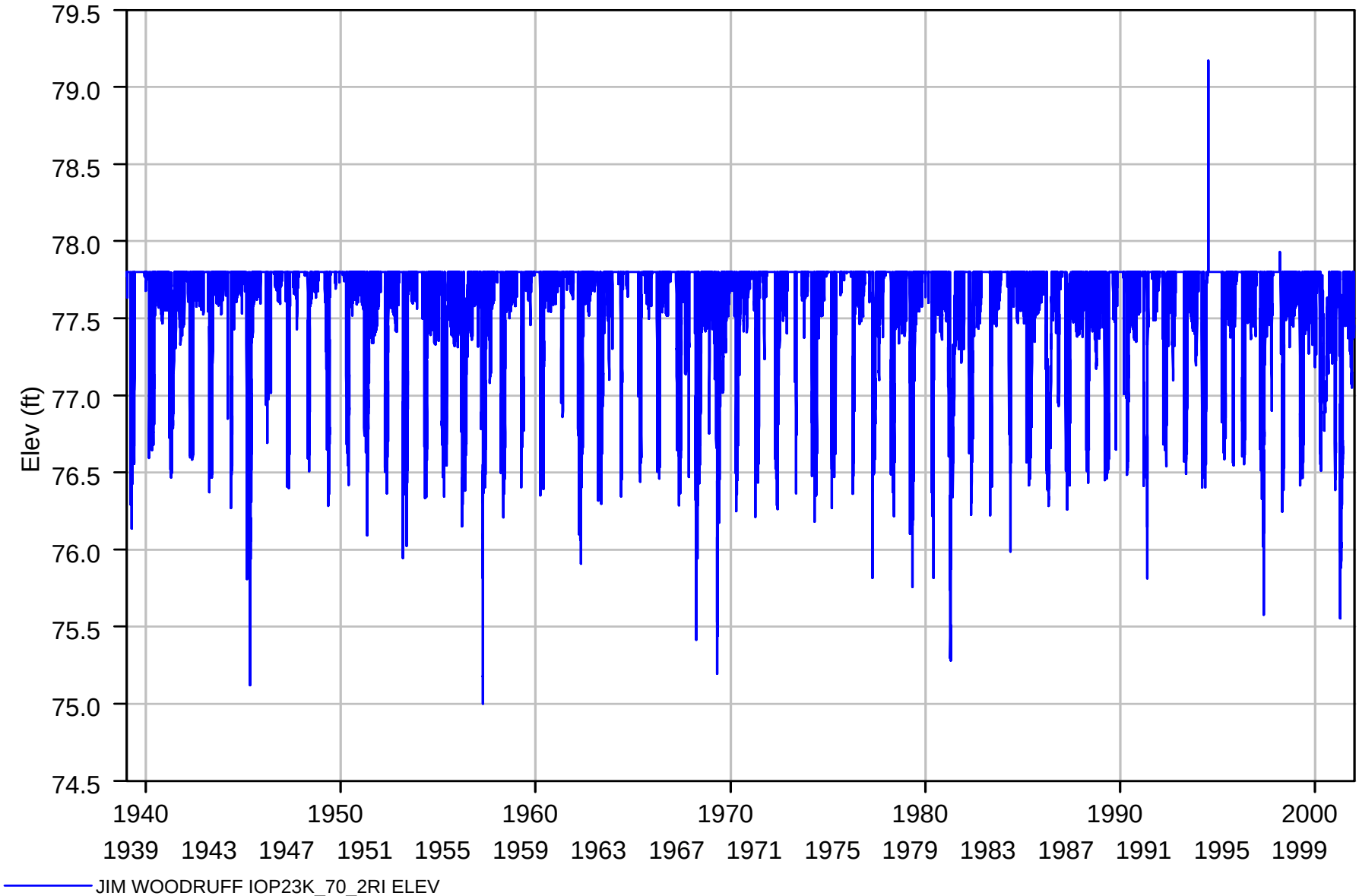
IOP Modeling Results – West Point Elevation



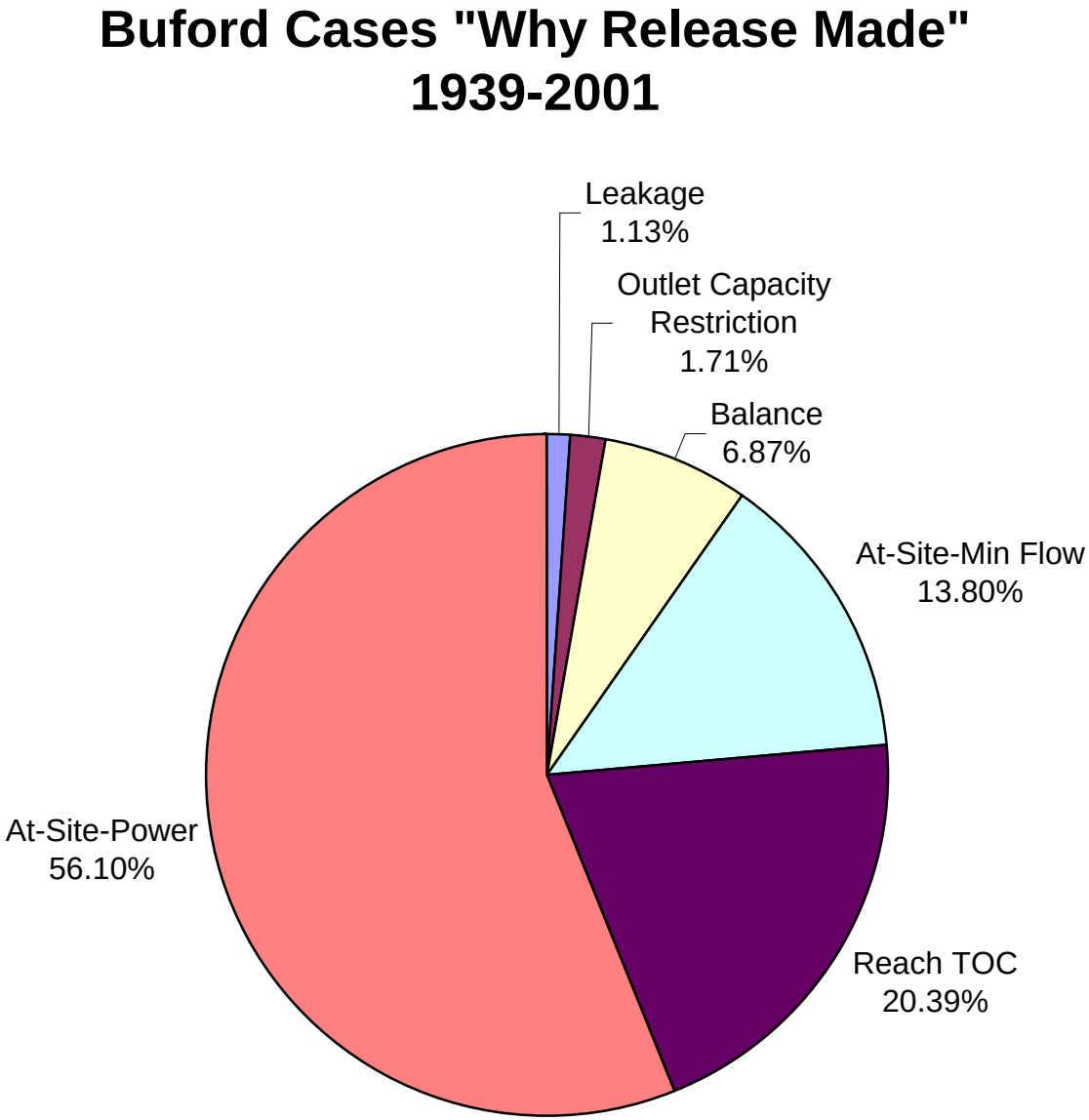
IOP Modeling Results – WF George Elevation



IOP Modeling Results – Jim Woodruff Elevation

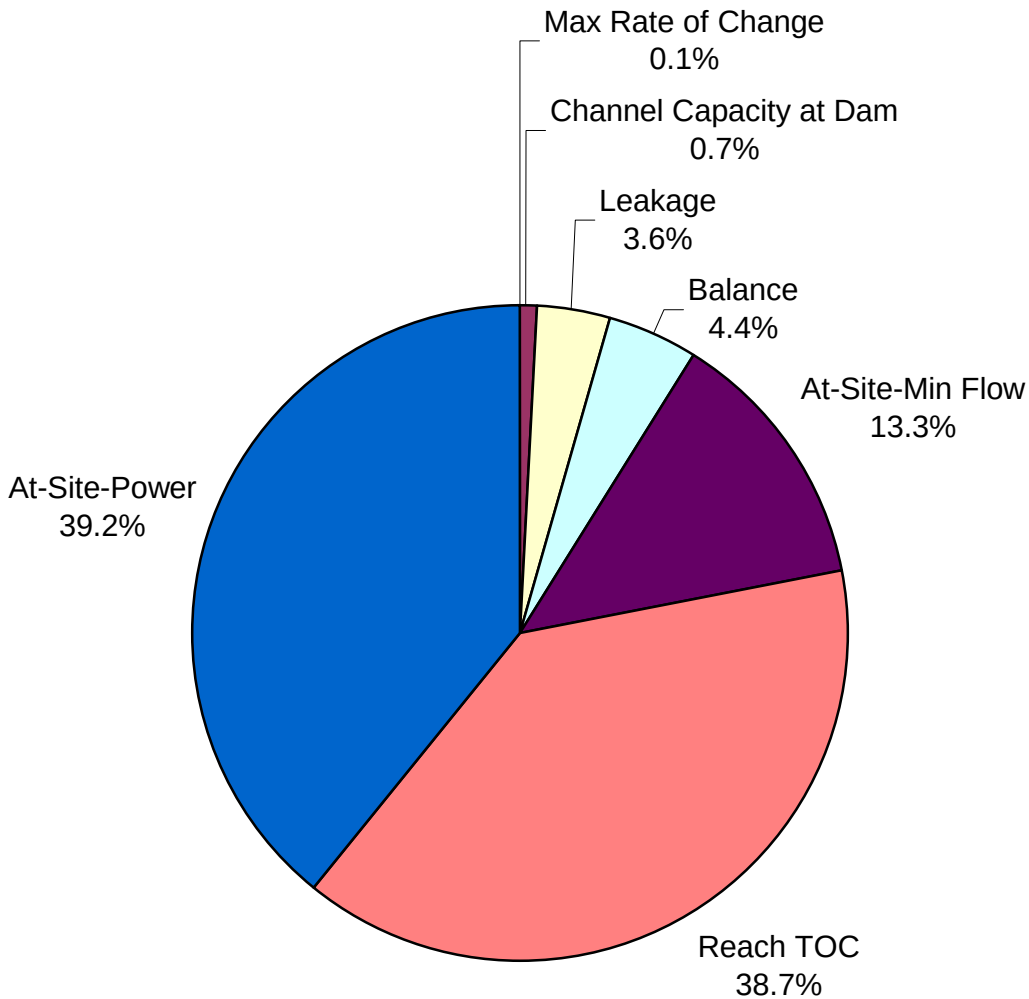


IOP Modeling Results



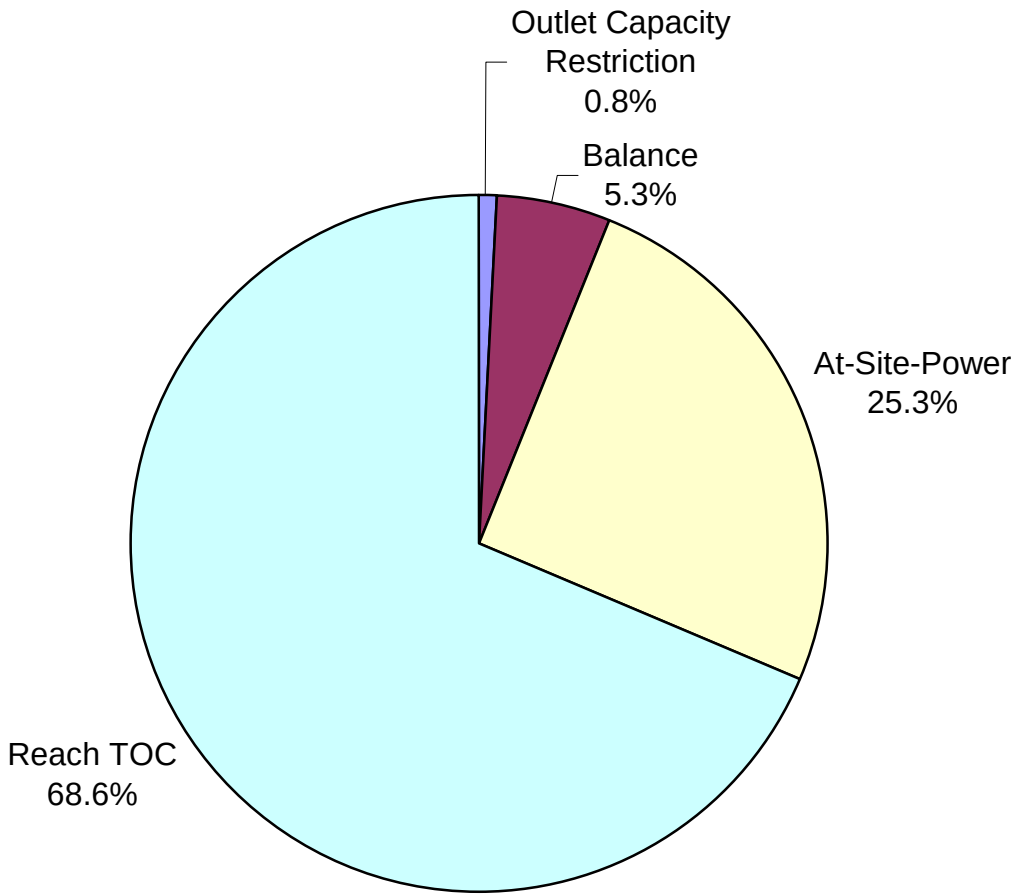
IOP Modeling Results

West Point Cases "Why Release Made" 1939-2001



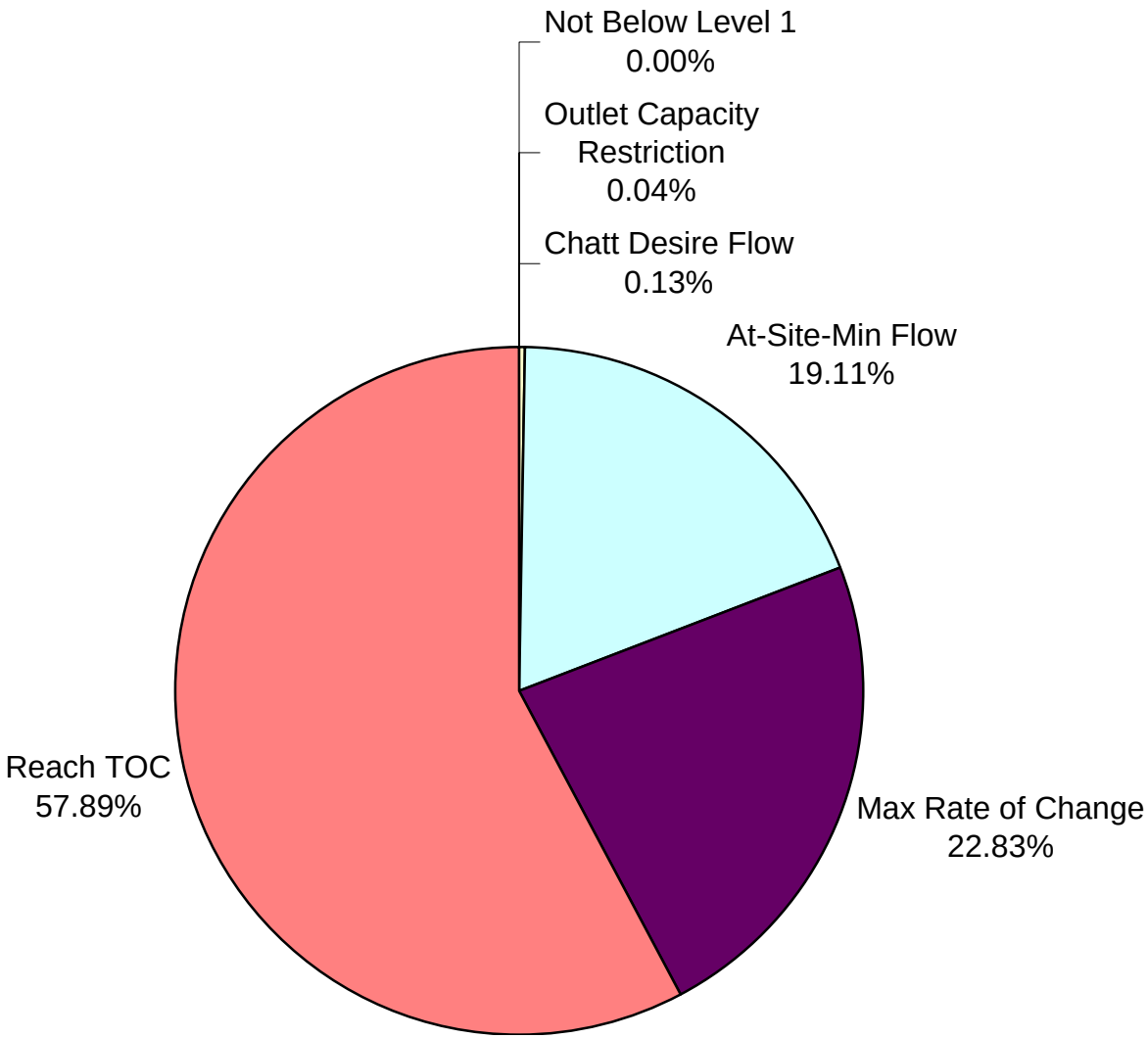
IOP Modeling Results

WF George Cases "Why Release Made"
1939-2001



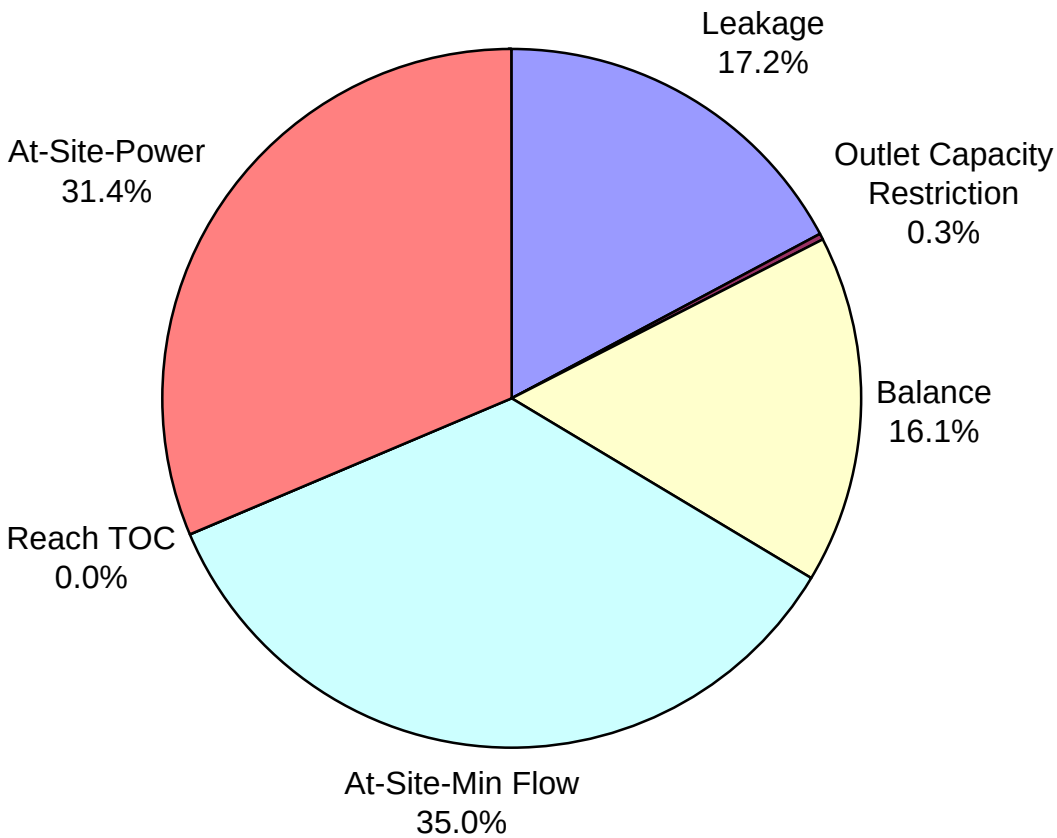
IOP Modeling Results

Jim Woodruff Cases "Why Release Made" 1939-2001

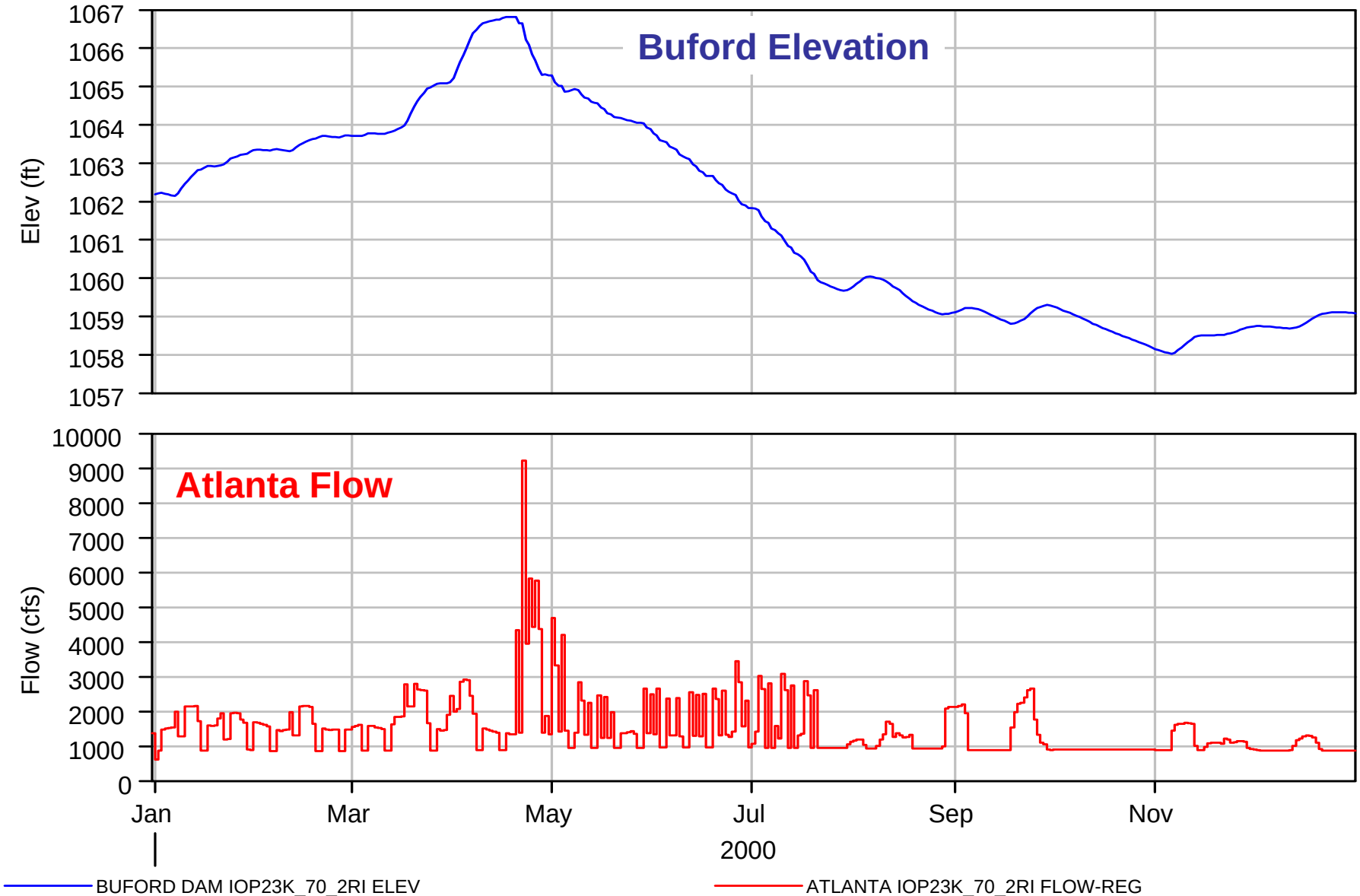


IOP Modeling Results

Buford Cases "Why Release Made"
Year 2000

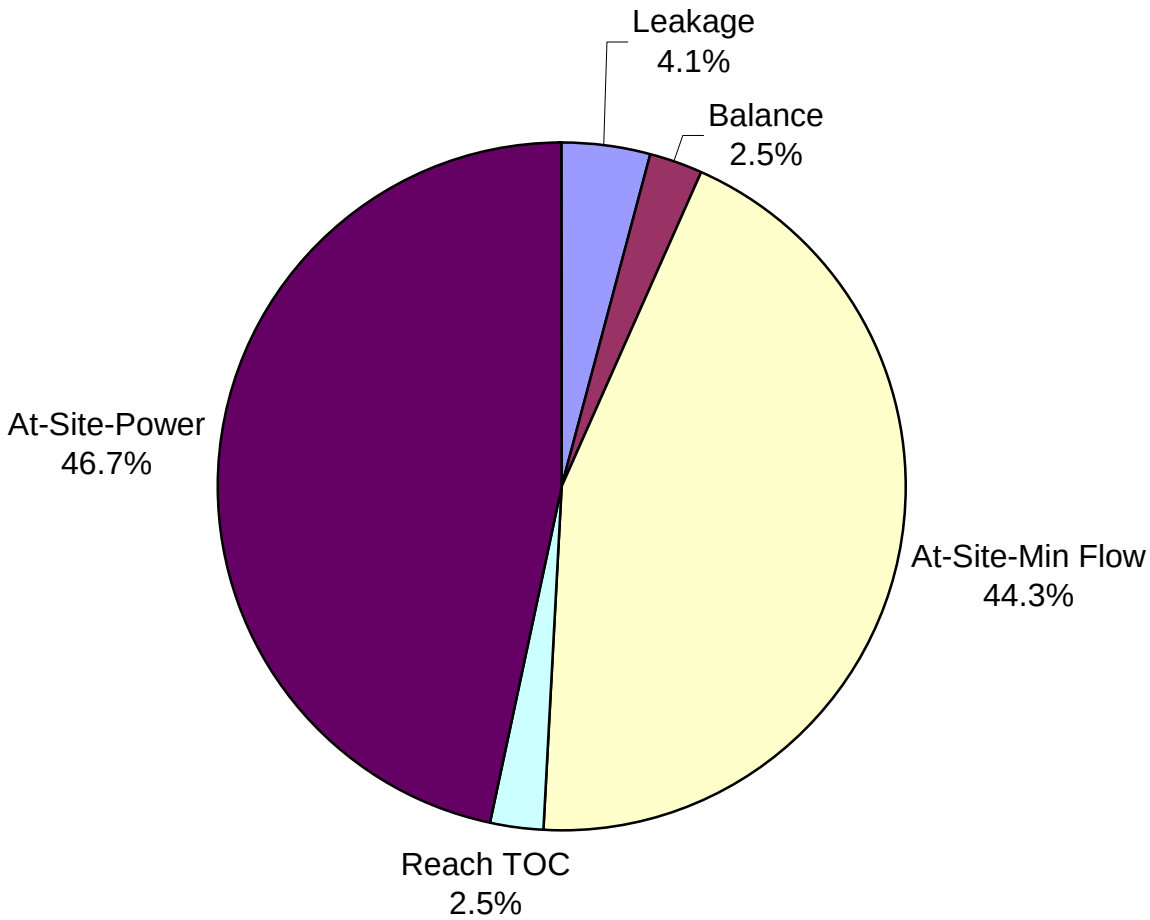


IOP Modeling Results

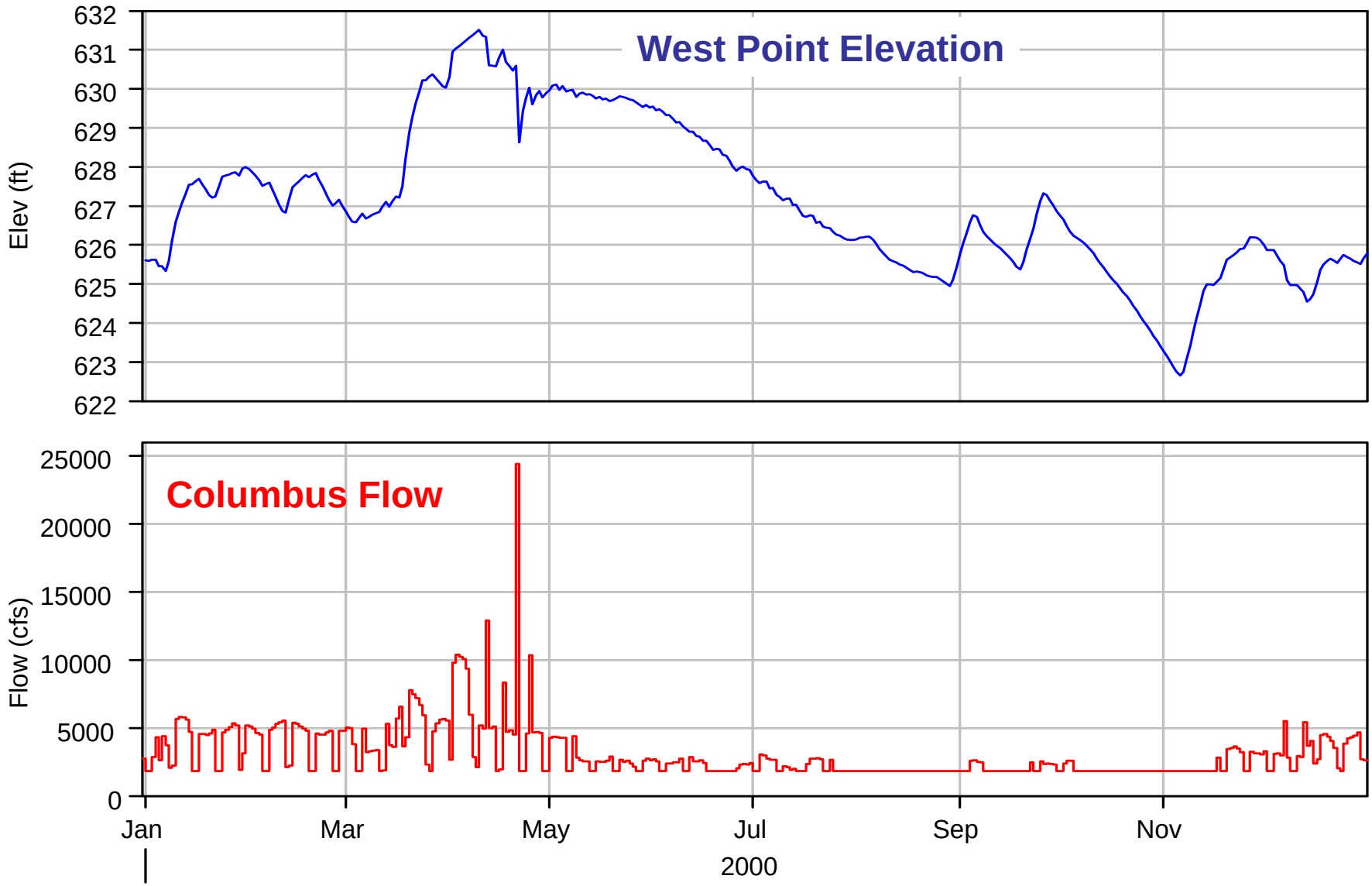


IOP Modeling Results

West Point Cases "Why Release Made"
Year 2000

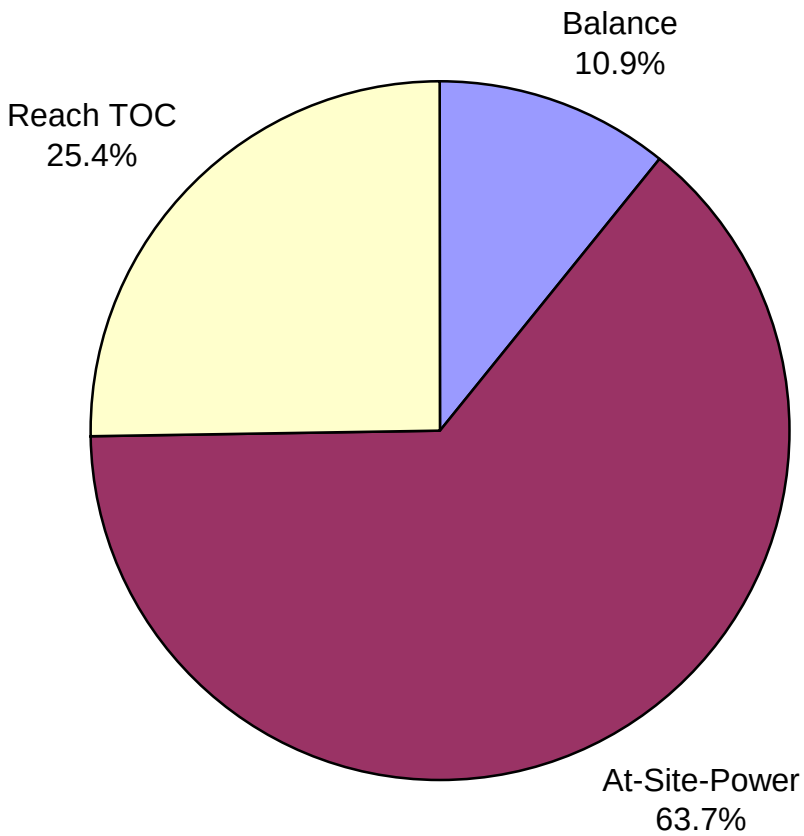


IOP Modeling Results



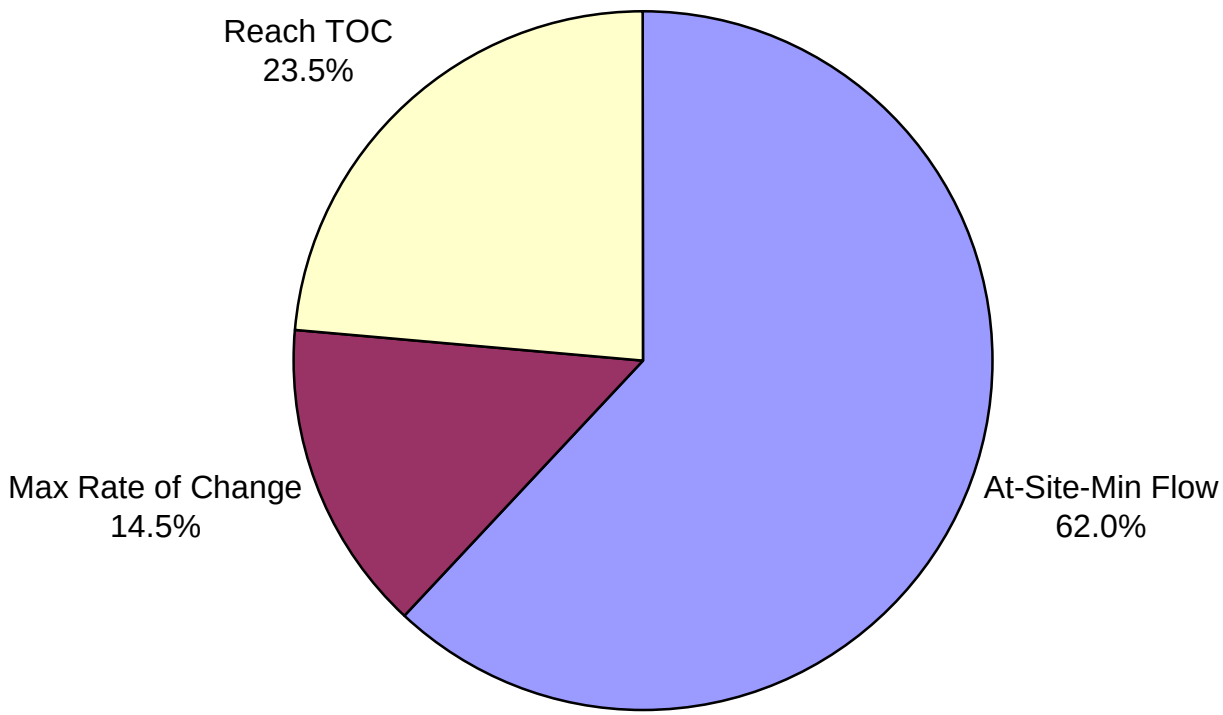
IOP Modeling Results

WF George Cases "Why Release Made"
Year 2000

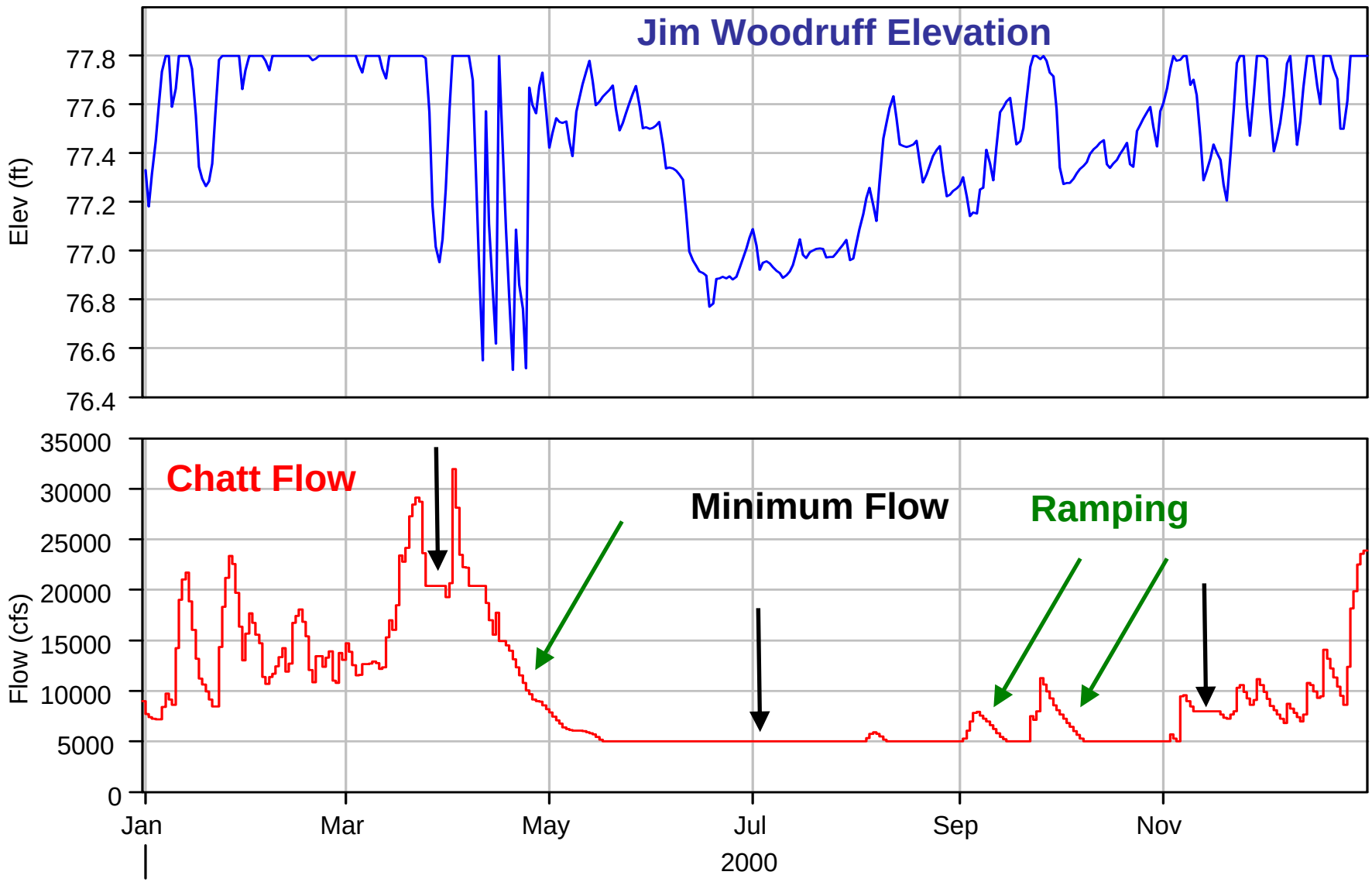


IOP Modeling Results

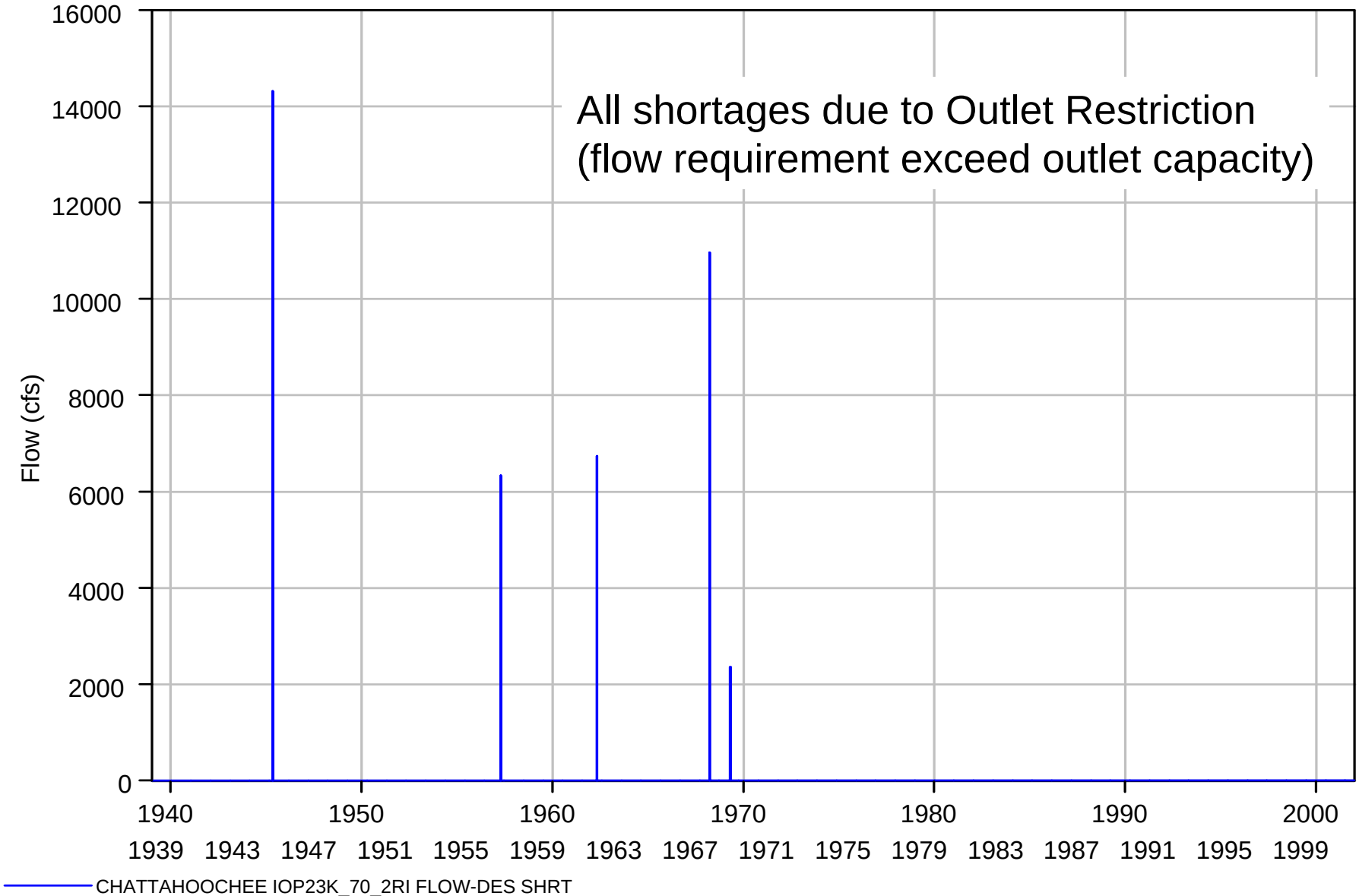
Jim Woodruff Cases "Why Release Made"
Year 2000



IOP Modeling Results

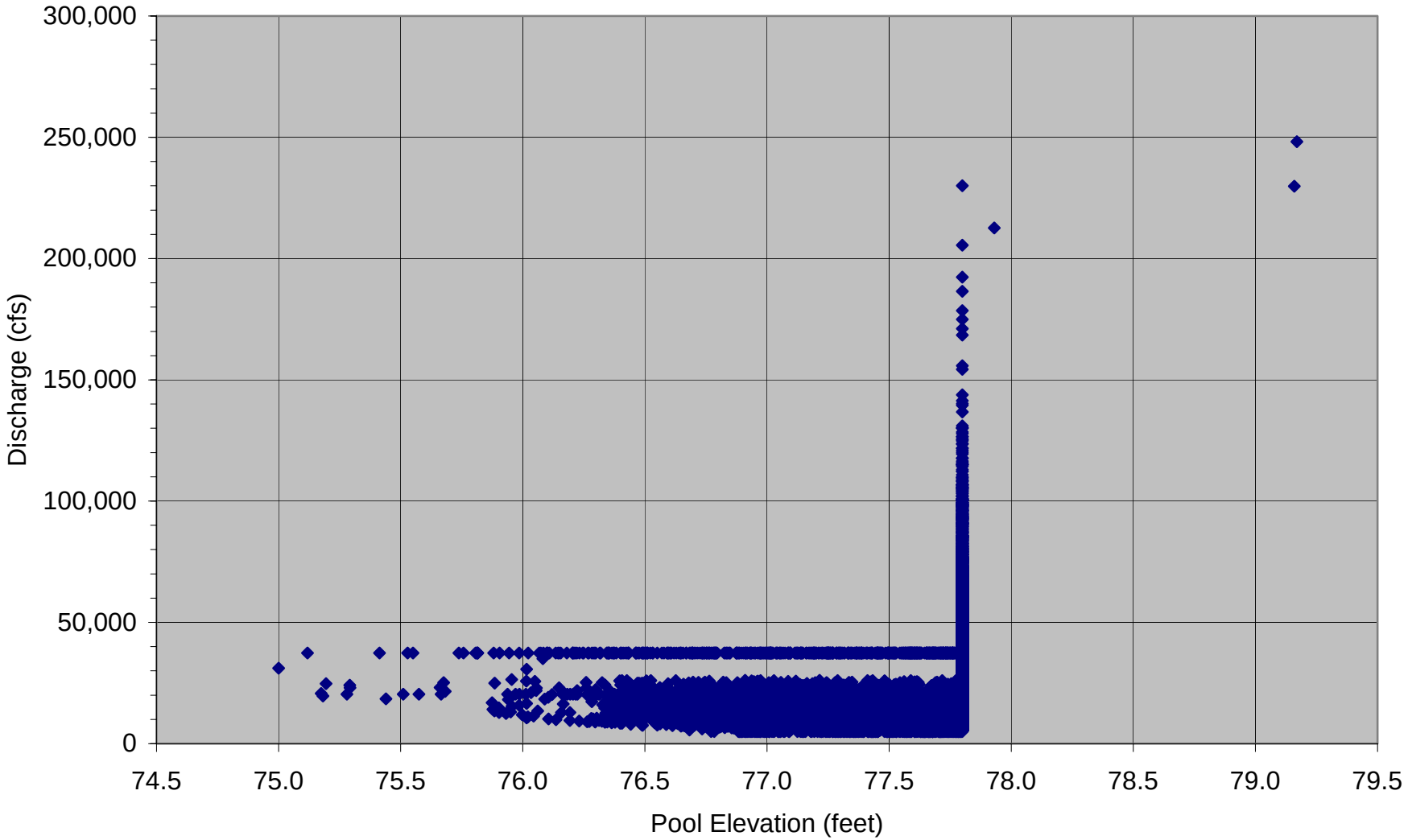


IOP Modeling Results – Chattahoochee Shortages

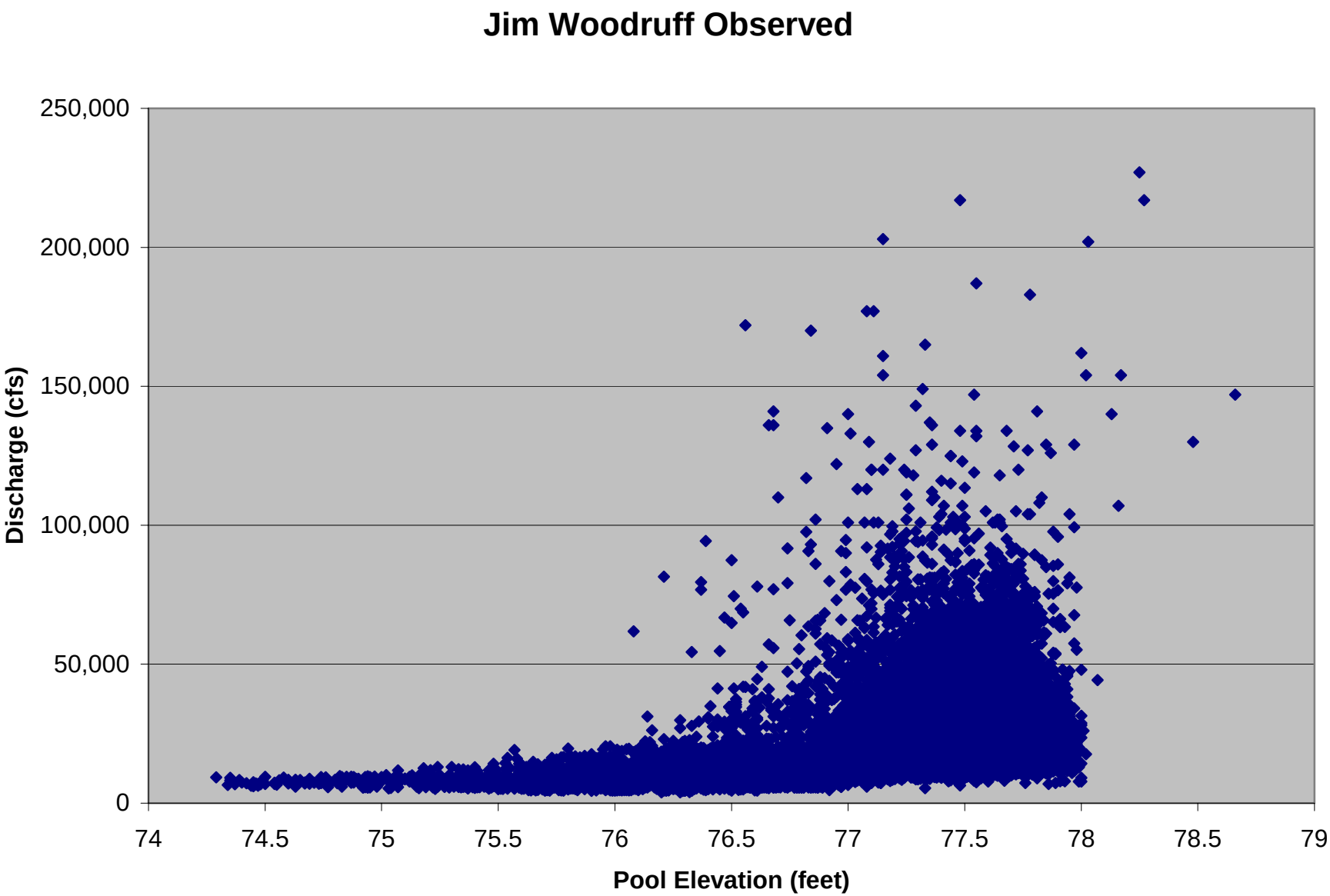


IOP Modeling Results

Jim Woodruff



Actual


Jim Woodruff Observed
250,000
200,000
150,000
100,000
50,000
0
Discharge (cfs)
74
74.5
75
75.5
76
76.5
77
77.5
78
78.5
79
Pool Elevation (feet)