

“Nature always wears the colors of the spirit” —EMERSON



Ecologically Sustainable Management of Water Supply Reservoirs

Southeast Aquatic Resource
Partnership

Southern Instream Flow Network
June 23-24, 2008



Freshwater Resources of the Eastern U.S.



Adirondacks, New York



Low Flow Conditions in Massachusetts, USA



Fish Brook, Boxford



Sudbury River, Hopkinton



Natural variations in precipitation can result in shortages for water supplies



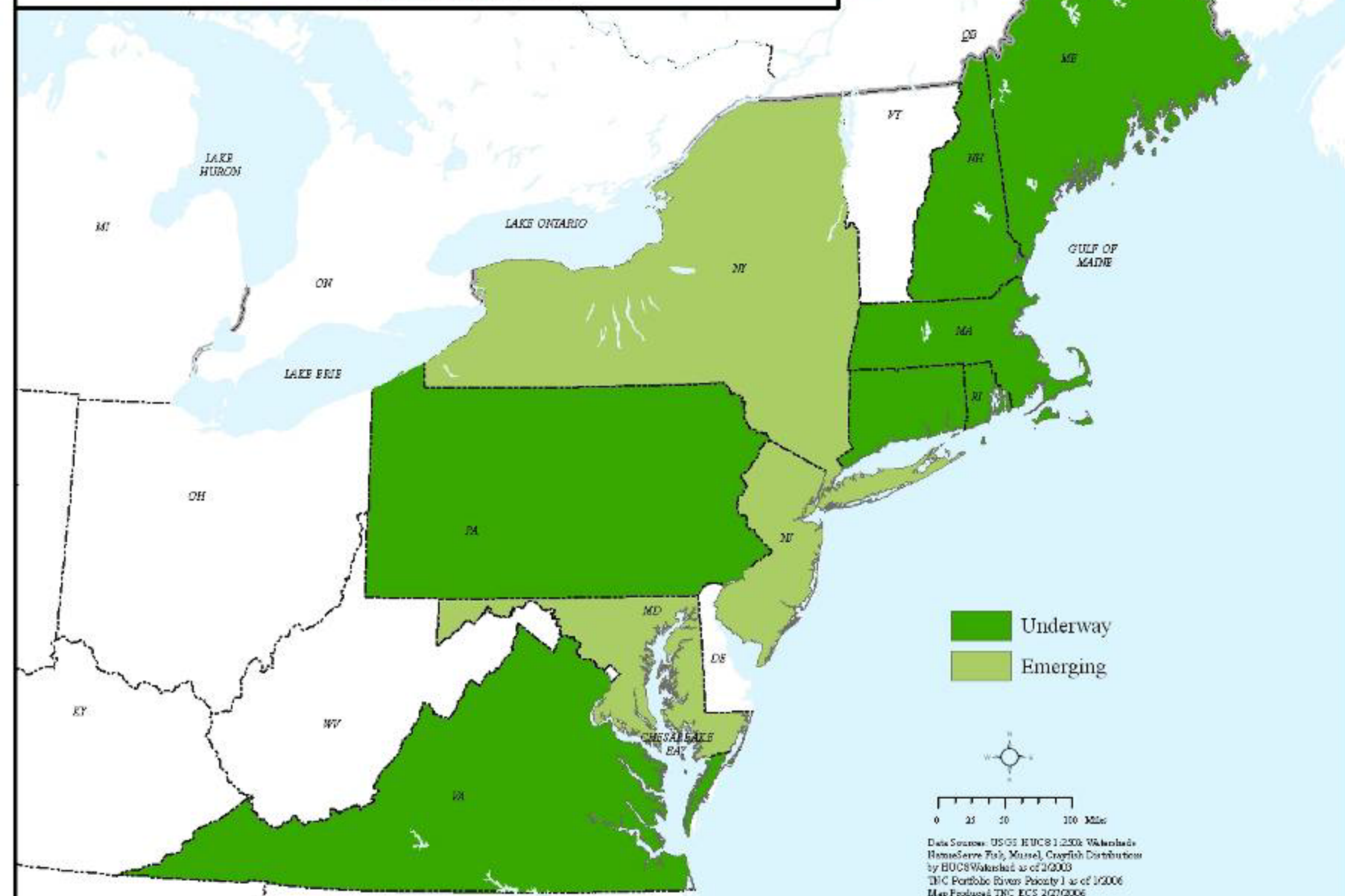
Middleton Pond,
Massachusetts



Wenham Lake
Massachusetts

States Working on Instream Flow Policy

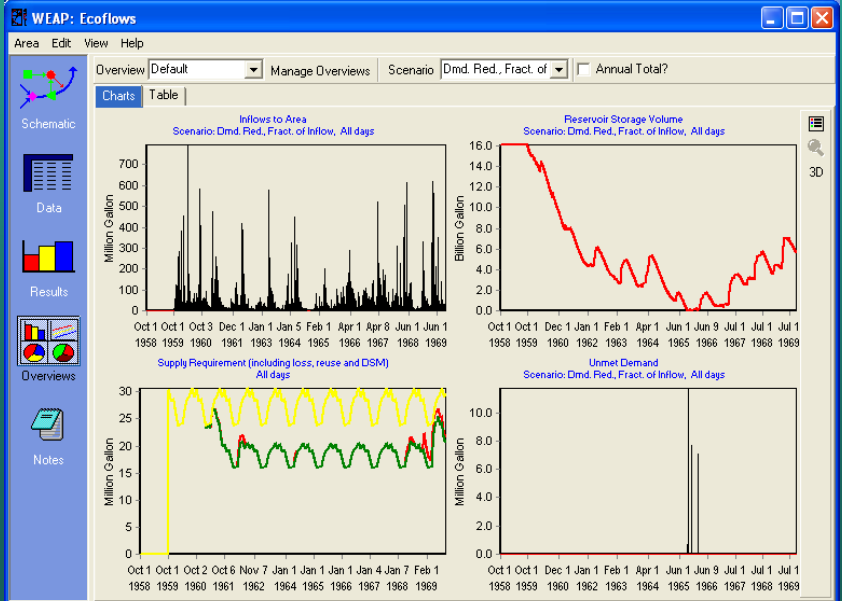
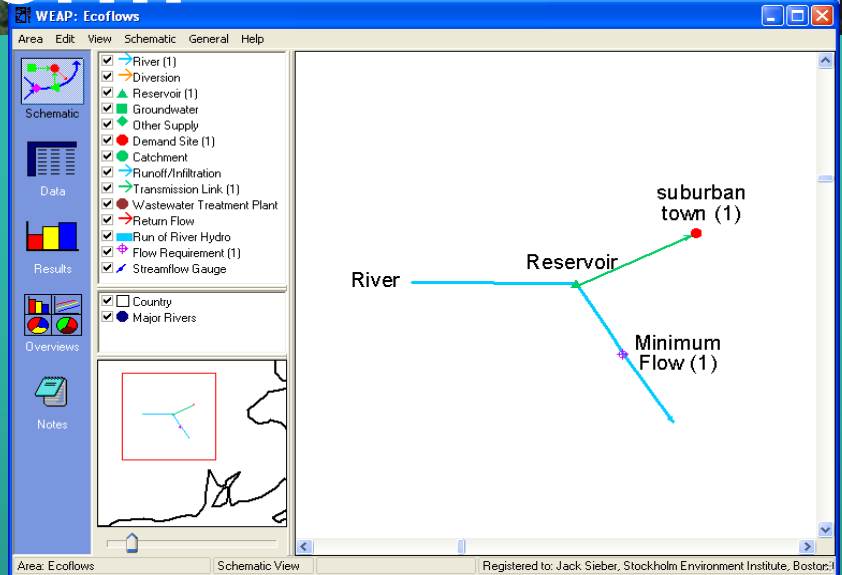
DRAFT OF 10/1/2006



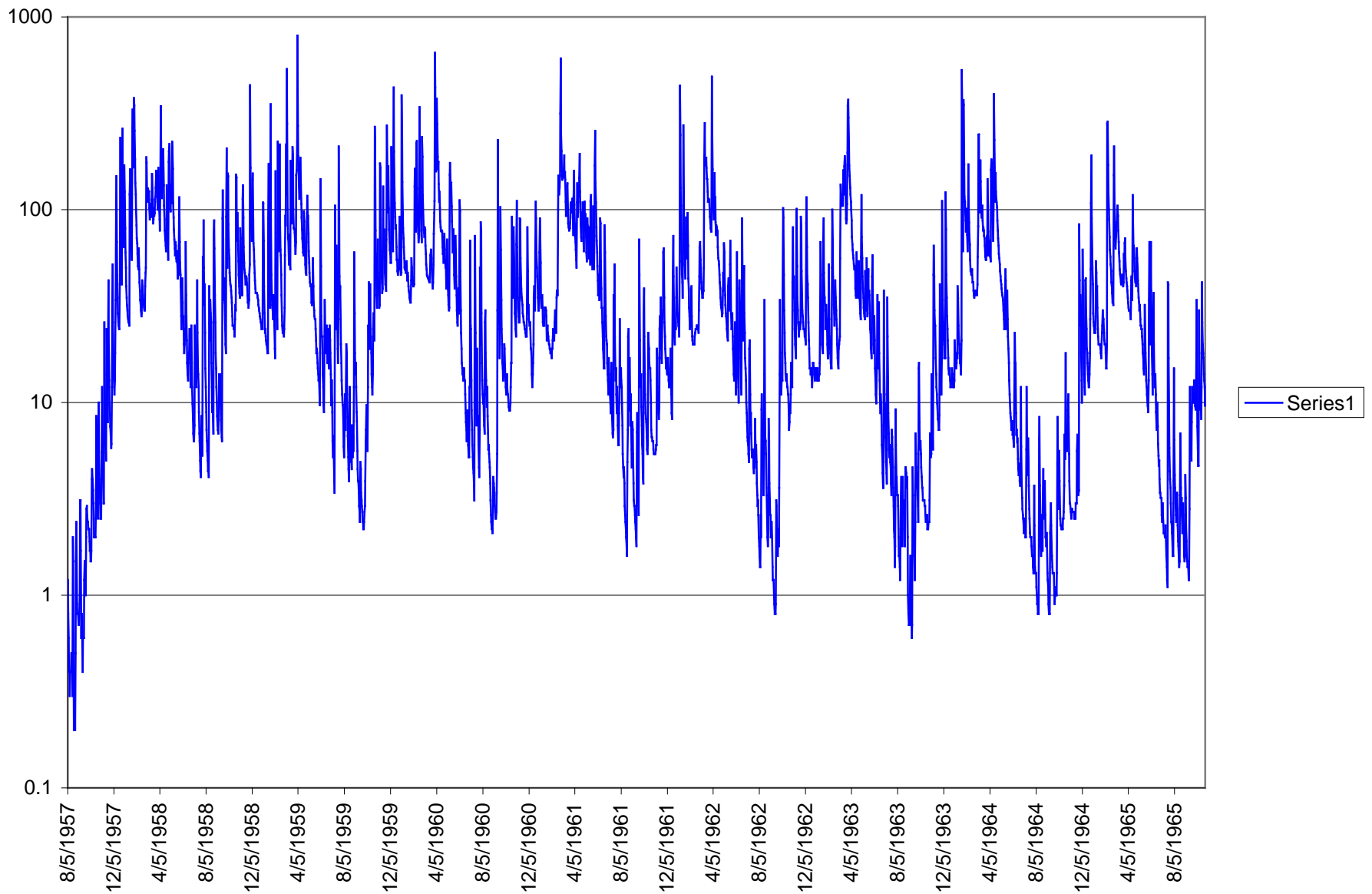
Model Platform

Water Evaluation and Planning model (WEAP)

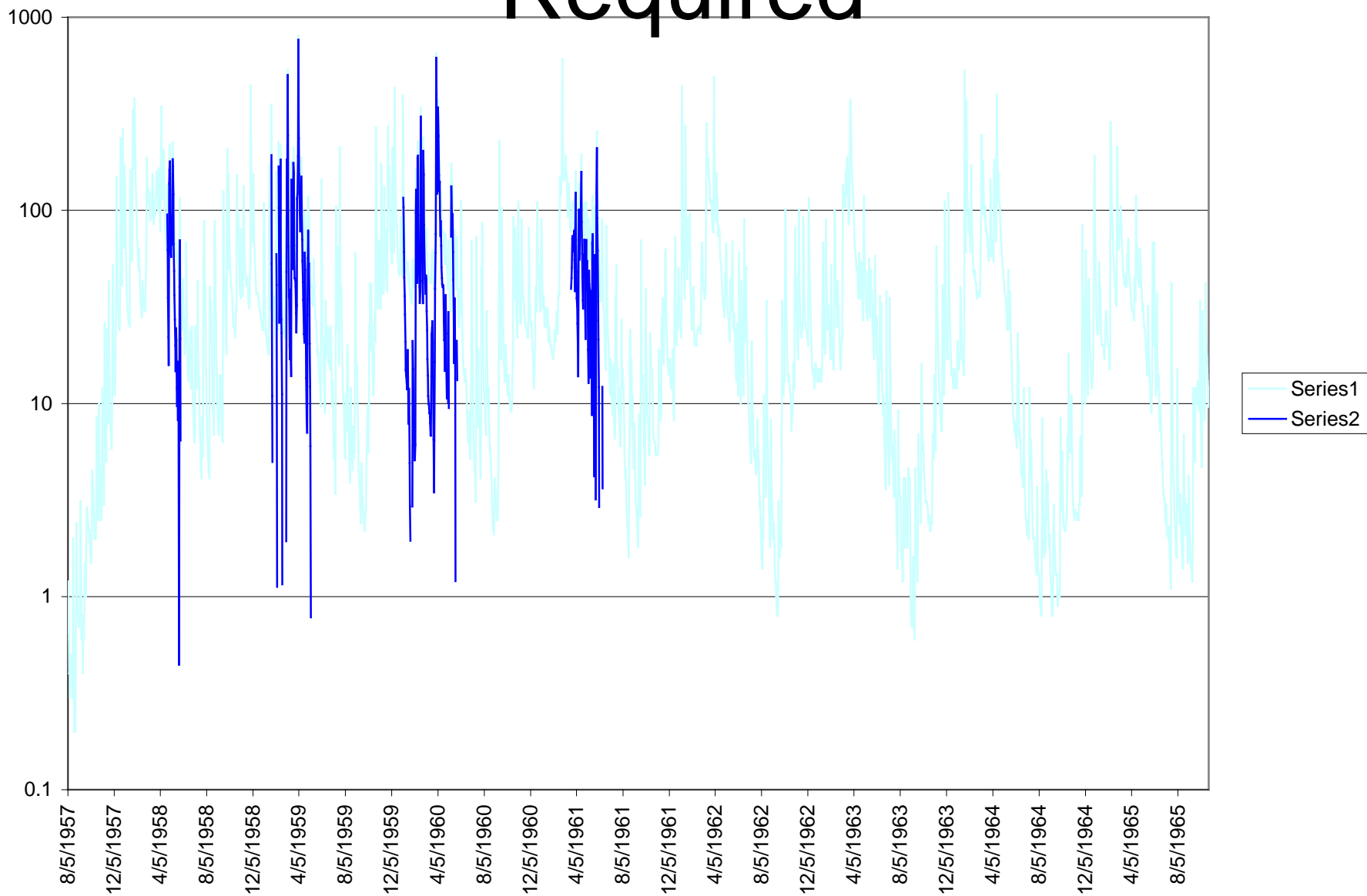
Developed by Stockholm Environment



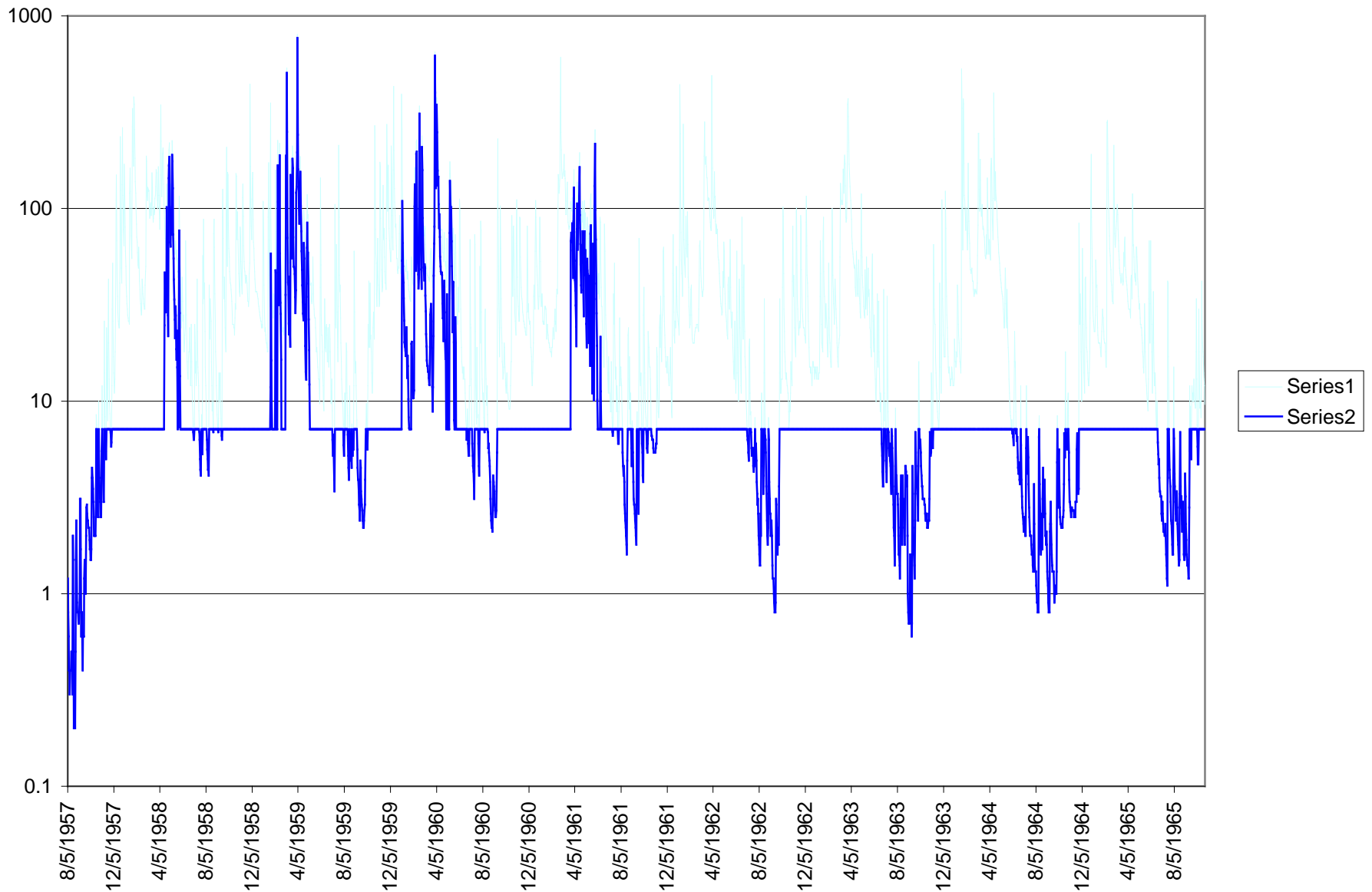
Inflows – Unaltered Flows



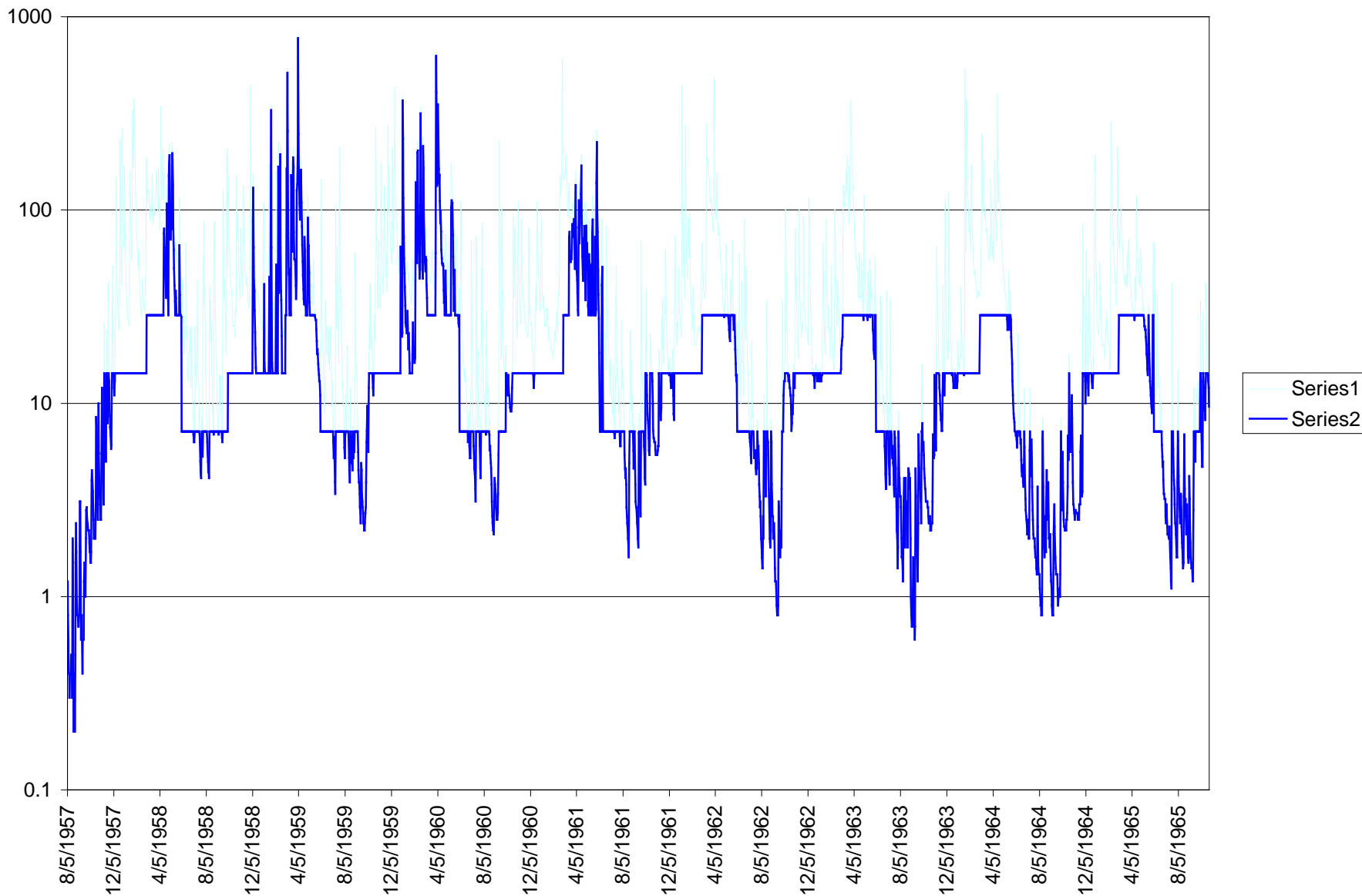
Flow Policy: No Release Required



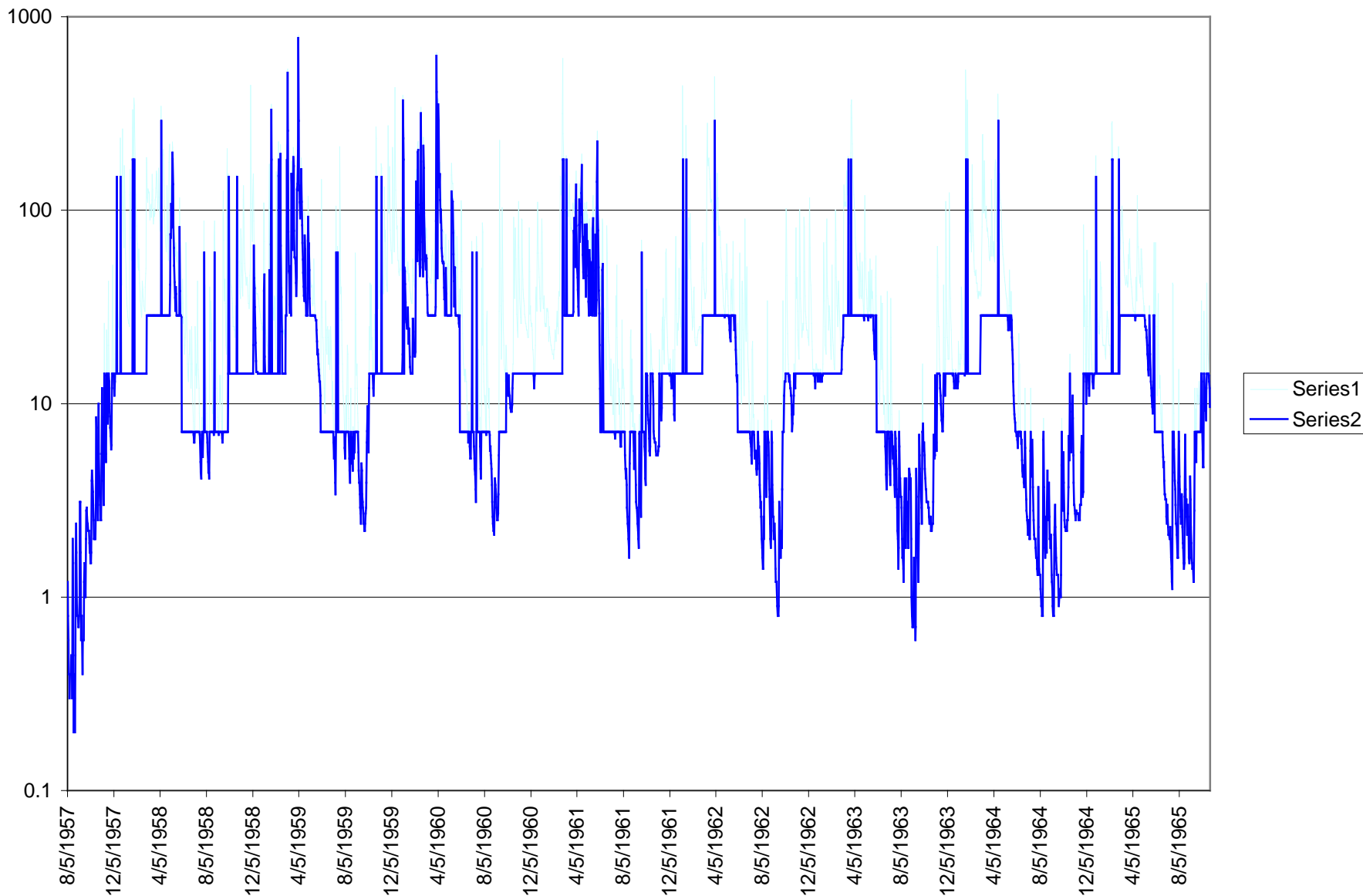
Flow Policy: Minimum Release



Flow Policy: Seasonal Release



Flow Policy: Seasonal w/Pulses



Reservoir Yield



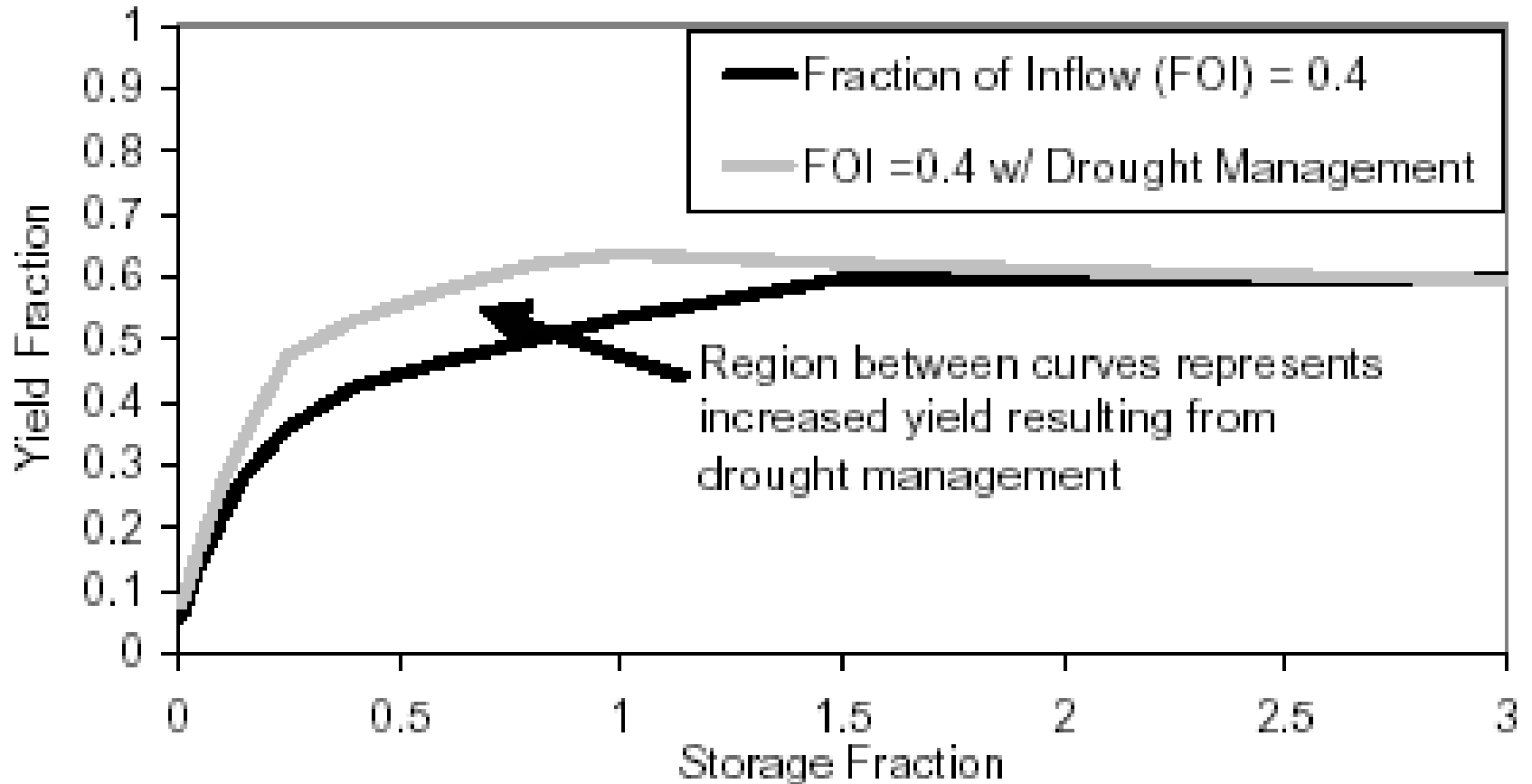
<u>Policy</u>	<u>Yield</u>	
	<u>Fraction</u>	<u>mgd</u>
No Release	0.76	26.5
Minimum	0.65	22.4
Adaptive seasonal	0.62	21.7
Fraction	0.53	18.7
Seasonal	0.52	17.7
Fraction w/min	0.51	17.0
Seasonal w/pulse	0.49	16.4



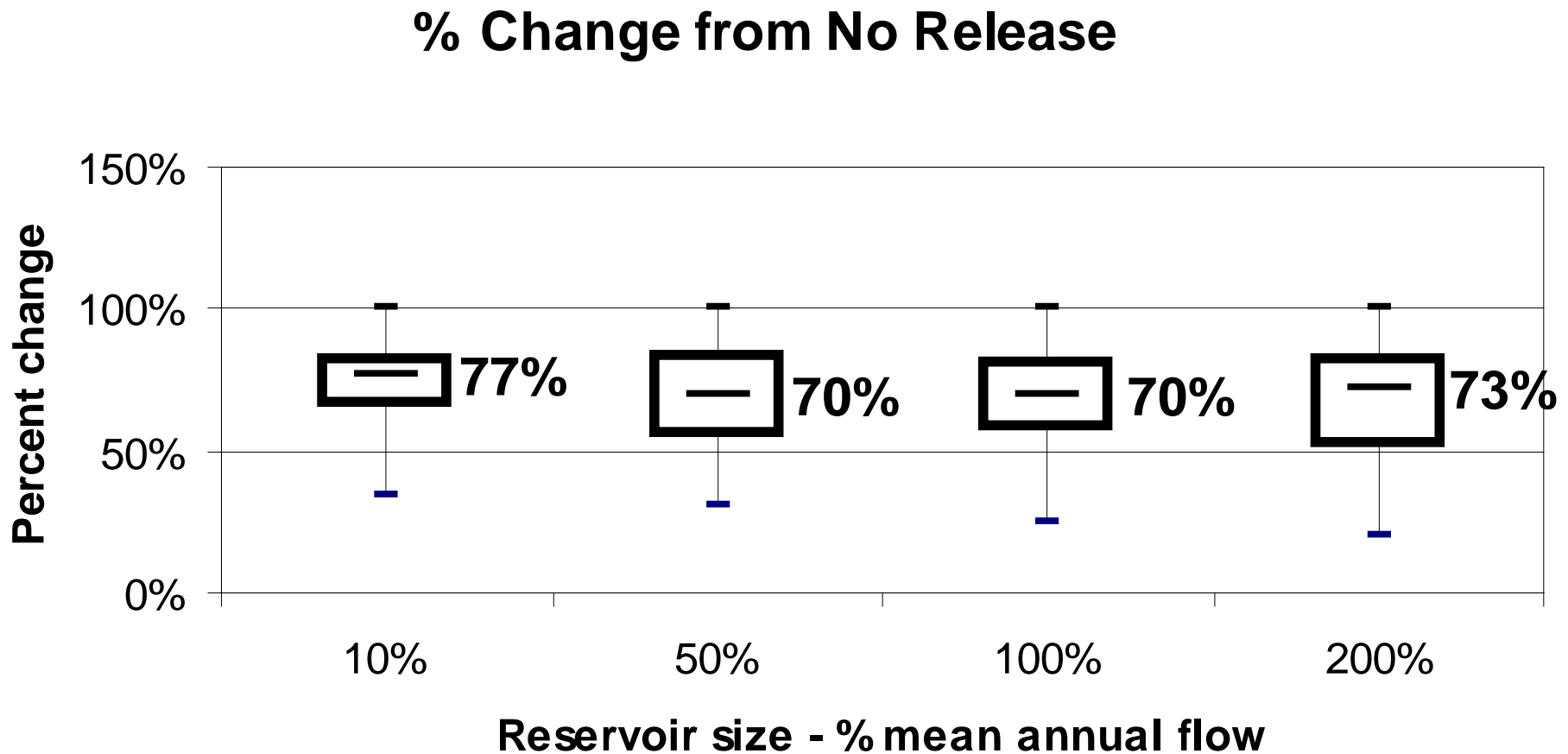
Drought management

Reservoir Level	Demand Reduction
60-100%	0
40-59%	20%
0-39%	40%

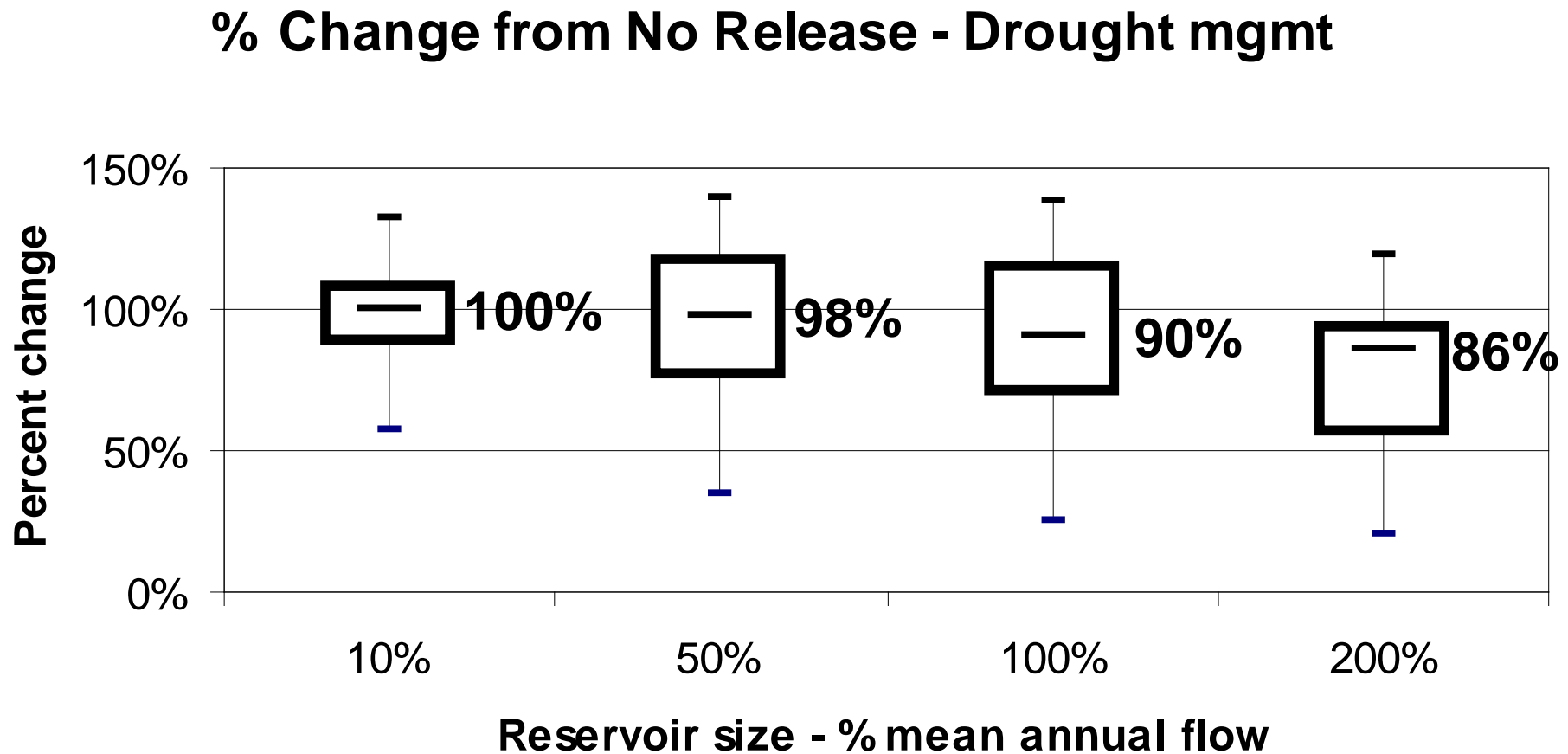
Demand Management Increases the Yield of Water Supplies



Release rules can reduce reservoir yields by 24-30%



Drought management can allow for comparable yields to no releases





Relations among storage, yield, and instream flow

Richard M. Vogel,¹ Jack Sieber,² Stacey A. Archfield,¹ Mark P. Smith,³ Colin D. Apse,⁴ and Annette Huber-Lee⁵

Received 2 June 2006; revised 13 January 2007; accepted 29 January 2007; published 1 May 2007.

[1] An extensive literature documents relations between reservoir storage capacity and water supply yield and the properties of instream flow needed to support downstream aquatic ecosystems. However, the literature that evaluates the impact of reservoir operating rules on instream flow properties is limited to a few site-specific studies, and as a result, few general conclusions can be drawn to date. This study adapts the existing generalized water evaluation and planning model (WEAP) to enable general explorations of relations between reservoir storage, instream flow, and water supply yield for a wide class of reservoirs and operating rules. Generalized relationships among these variables document the types of instream flow policies that when combined with drought management strategies, are likely to provide compromise solutions to the ecological and human negotiations for water for different sized reservoir systems. The concept of a seasonal ecodeficit/ecosurplus is introduced for evaluating the impact of reservoir regulation on ecological flow regimes.

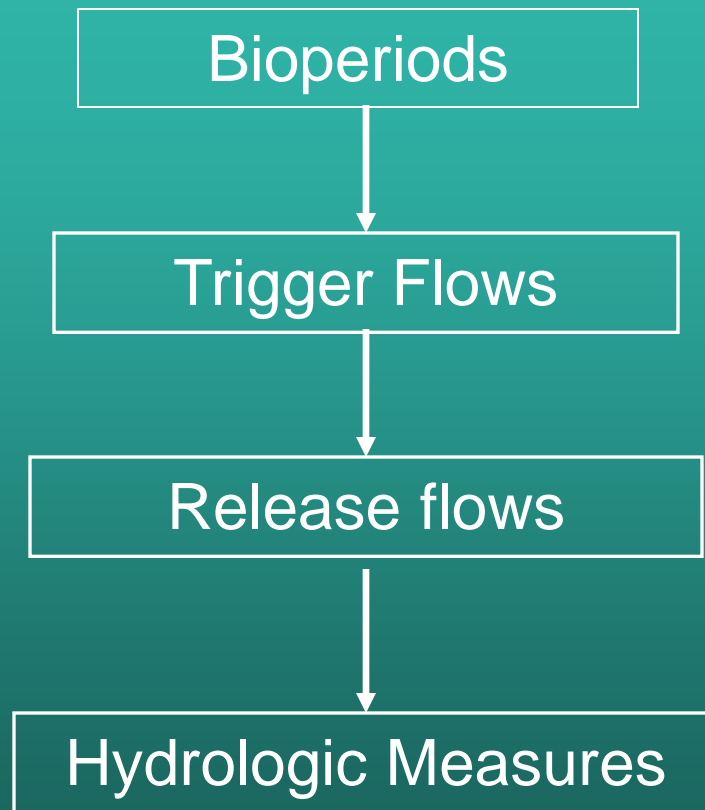
Citation: Vogel, R. M., J. Sieber, S. A. Archfield, M. P. Smith, C. D. Apse, and A. Huber-Lee (2007), Relations among storage, yield, and instream flow, *Water Resour. Res.*, 43, W05403, doi:10.1029/2006WR005226.



Connecticut Stream Flow Regulations

Developing standards for
withdrawals

Fishery statute updated in 2006 to
require new regulations



Adaptive Release Rule – Practical Application Step 1

Calculate Trigger Flows

Prep Work: Go to USGS web site and download relevant NATURAL flow statistics for Index Gage

Bioperiod	“Subsistence Flow”	“Base Flow”	“Wet Flow”
Overwinter (Dec-Feb)			
Habitat forming (Mar-Apr)			
Clupeid spawning (May)			
Resident spawning (June)			
Rearing and growth (July-Oct)			
Salmonid spawning (Nov)			

Adaptive Release Rule – Practical Application Step 1

Calculate Trigger Flows

Prep Work: Go to USGS web site and download relevant NATURAL flow statistics for Index Gage

Bioperiod	“Subsistence Flow”	“Base Flow”	“Wet Flow”
Overwinter (Dec-Feb)	< BQ90	BQ90-BQ25	> BQ25
Habitat forming (Mar-Apr)	< BQ90	BQ90-BQ25	> BQ25
Clupeid spawning (May)	< BQ90	BQ90-BQ25	> BQ25
Resident spawning (June)	< BQ90	BQ90-BQ25	> BQ25
Rearing and growth (July-Oct)	< BQ90	BQ90-BQ25	> BQ25
Salmonid spawning (Nov)	<BQ90	BQ90-BQ25	> BQ25

Adaptive Release Rule – Practical Application Step 1

Prep Work: Go to USGS web site and download relevant NATURAL flow statistics for Index Gage

Trigger Flows

Bioperiod	“Subsistence Flow”	“Base Flow”	“Wet Flow”
Overwinter (Dec-Feb)	< 2.7 cfs	2.8 – 9.5 cfs	> 9.6 cfs
Habitat forming (Mar-Apr)	< 5.1 cfs	5.2 – 17 cfs	> 17.1 cfs
Clupeid spawning (May)	< 3.5 cfs	3.6 – 11 cfs	> 11.1 cfs
Resident spawning (June)	< 1.5 cfs	1.6 – 6.1 cfs	> 6.2 cfs
Rearing and growth (July-Oct)	< 0.7 cfs	0.8 – 3.8 cfs	> 3.9 cfs
Salmonid spawning (Nov)	< 1.7cfs	1.8 – 9.0 cfs	> 9.1 cfs

Adaptive Release Rule – Practical Application Step 2

Calculate Release Flows

Prep Work: Go to USGS web site and download relevant NATURAL flow statistics for Dam location

Bioperiod	“Subsistence Flow”	"Base Flow"	Wet Period Flows
	Flow that occurs infrequently	Typical flows in most conditions	Occasionally occurs
Overwinter (Dec-Feb)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50
Habitat forming (Mar-Apr)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50
Clupeid spawning (May)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50
Resident spawning (June)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50
Rearing and growth (July-Oct)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50
Salmonid spawning (Nov)	Bioperiod Q95	Bioperiod Q75	Bioperiod Q50

Adaptive Release Rule – Practical Application Step 2

Prep Work: Go to USGS web site and download relevant NATURAL flow statistics for Dam location

Release Flows

Bioperiod	"Subsistence Flow"	"Base Flow"	Wet Period Flows
	Flow that occurs infrequently	Typical flows in most conditions	Occasionally occurs
Overwinter (Dec-Feb)	2.2 cfs	4.1 cfs	5.9 cfs
Habitat forming (Mar-Apr)	4.3 cfs	7.4 cfs	10.0 cfs
Clupeid spawning (May)	3.0 cfs	5.1 cfs	7.2 cfs
Resident spawning (June)	1.3 cfs	2.4 cfs	3.7 cfs
Rearing and growth (July-Oct)	0.7 cfs	1.3 cfs	2.2 cfs
Salmonid spawning (Nov)	1.4 cfs	3.4 cfs	5.4 cfs

Example:

Overwinter Bioperiod

Date	Release Flow	Flow
1/29	5.9 cfs	6.1
1/30	5.9 cfs	6
1/31	5.9 cfs	5.1
2/1	5.9 cfs	3
2/2	5.9 cfs	2
2/3	5.9 cfs	2
2/4	5.9 cfs	2
2/5	5.9 cfs	2
2/6	5.9 cfs	2
2/7	5.9 cfs	2.1
2/8	5.9 cfs	2.1
2/9	5.9 cfs	8
2/10	5.9 cfs	8
2/11	5.9 cfs	8

Date	Flow
1/1	10
1/2	9
1/3	11
1/4	13
1/5	25
1/6	16
1/7	12
1/8	9
1/9	8.8
1/10	8.1
1/11	7.7
1/12	7.3
1/13	7
1/14	6.7

Date	Release Flow	Flow
1/15	4.1 cfs	10
1/16	4.1 cfs	12
1/17	4.1 cfs	16
1/18	4.1 cfs	25
1/19	4.1 cfs	25
1/20	4.1 cfs	16
1/21	4.1 cfs	12
1/22	4.1 cfs	12
1/23	4.1 cfs	16
1/24	4.1 cfs	25
1/25	4.1 cfs	35
1/26	4.1 cfs	16
1/27	4.1 cfs	16
1/28	4.1 cfs	6.7

Trigger Flows

Median **2.55**

Median **9.00**

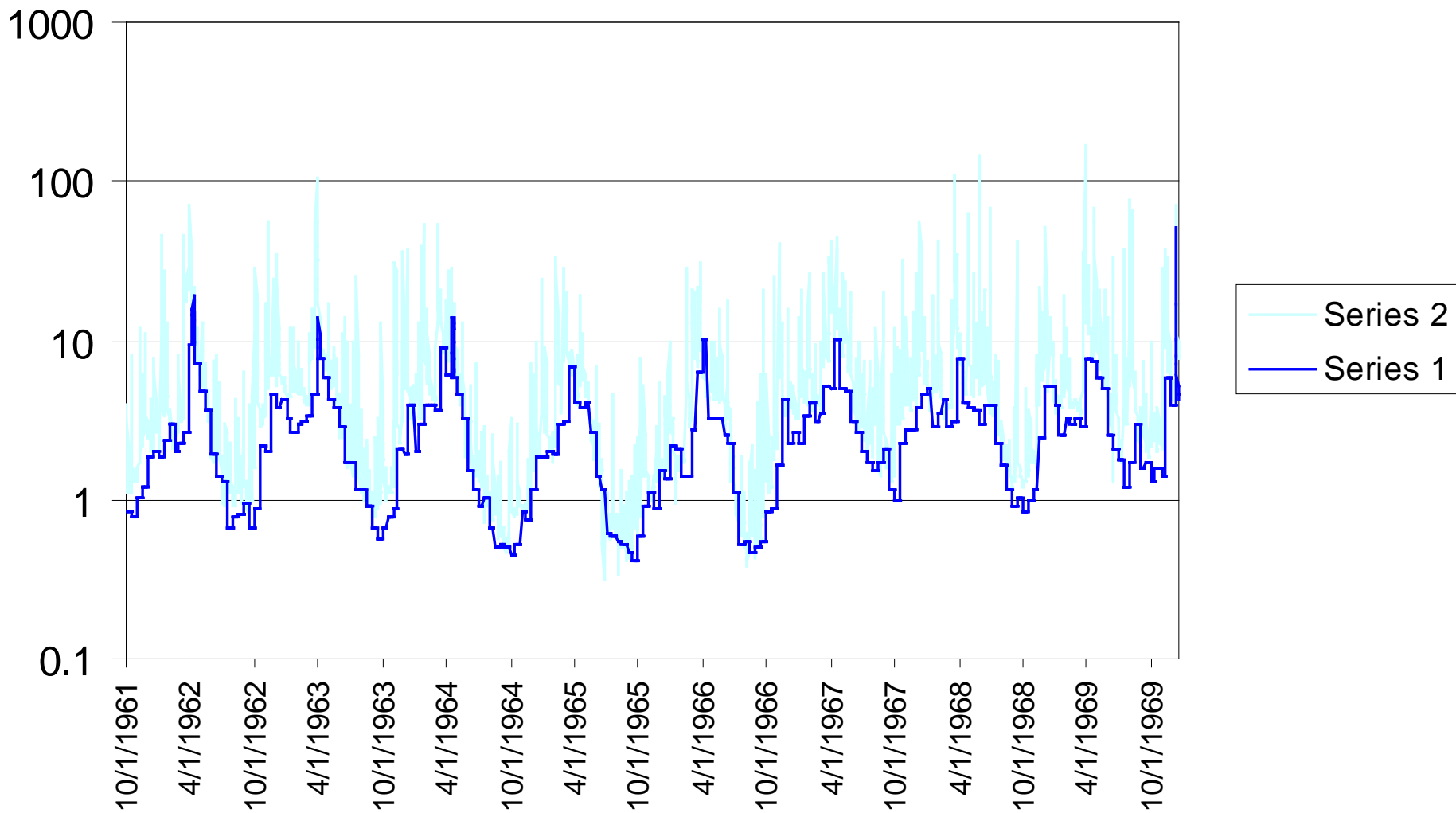
Median **16.00**

Bioperiod	Release "Subsistence Flow" When 14-day median is less than	Release "Base Flow" When 14-day median is between	Release "Wet Period Flow" When 14-day median is greater than
Overwinter (Dec-Feb)	< 2.7 cfs	2.8 - 9.5 cfs	> 9.6 cfs

Release Flows

Bioperiod	"Subsistence Flow"	"Base Flow"	Wet Period Flows
	Flow that occurs infrequently	Typical flows in most conditions	Occasionally occurs
Overwinter (Dec-Feb)	2.2 cfs	4.1 cfs	5.9 cfs

Policy: Bioperiod Adaptive Release



Stream flow Statistics

- (A) annual runoff;
- (B) monthly average streamflow for January;
- (C) monthly average streamflow for March;
- (D) monthly average streamflow for May;
- (E) monthly average streamflow for June;
- (F) monthly average streamflow for August;
- (G) monthly average streamflow for November;
- (H) low flood pulse count;
- (I) variability in low pulse duration;
- (J) base flow;
- (K) julian date of annual minimum streamflow;
- (L) high flood pulse count;
- (M) high streamflow duration;
- (N) high streamflow magnitude;
- (O) variability in streamflow reversals;

Alteration of Key Statistics

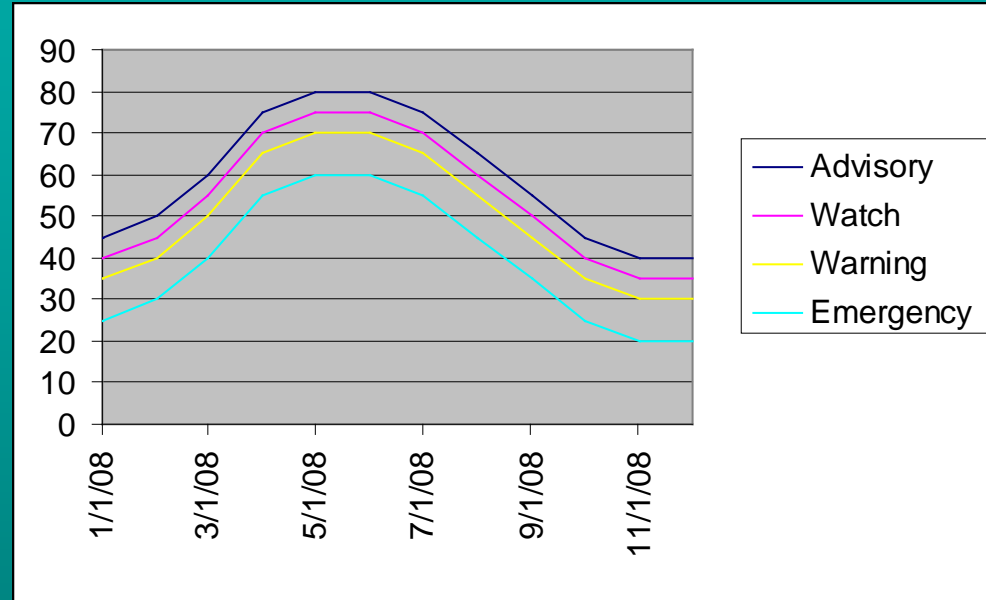
Safe Yield Fraction	Alternative	Average Flows [MAF/Watershed Area]	Low Flow Frequency [25th Percentile]**	Low Flow Frequency [10th Percentile]**	Low Flow Duration [25th Percentile]	Low Flow Duration [10th Percentile]	Low Flow Magnitude [1 day minimum]	Low Flow Magnitude [3 day minimum]	Low Flow Magnitude [7 day minimum]
0.640	Reference with Demand	-61.2	-30.0	-16.7	20.0	83.3	-100.00	-100.00	-100.00
0.543	Augmented Consant .2 cfm	-52.0	-50.0	-16.7	20.0	83.3	9.59	-4.76	-16.17
0.527	BAR2b1	-39.6	-80.0	-83.3	1580.0	1375.0	9.59	-4.76	-16.17
0.440	BAR%	-42.1	-70.00	-83.33	840.00	1083.33	12.33	-2.38	-14.07
0.415	BAR2g	-39.6	-80.0	-83.3	1730.0	1433.3	-4.11	-16.67	-26.65
0.413	BAR2c	-39.3	-60.0	-83.3	380.0	2966.7	-4.11	-16.67	-26.65
0.408	BAR2b	-39.1	-80.0	-83.3	1440.0	1333.3	9.59	-4.76	-16.17
0.392	BAR2b2	-39.6	-80.0	-80.0	1440.0	1440.0	36.99	19.05	4.79
0.390	BAR3b	-37.3	-70.00	-83.33	340.00	450.00	36.99	19.05	4.79
0.378	BAR2a	-36.1	-80.0	-100.0	1580.0	900.0	78.08	54.76	36.23
0.378	BAR2d	-34.7	-90.0	-100.0	2360.0	900.0	78.08	54.76	36.23

	≥ (-) 80%	High Risk
	(-) 40 to (-) 80 %	Moderate Risk
	< (-) 40%	Low Risk
	< 40%	Low Risk
	40 to 80 %	Moderate Risk
	≥ 80%	High Risk

Simulating Drought Triggers & Demand Management

Developed generic drought curves

Simulated demand management based on DPH regulations



Proposed Reductions in Demand Based on Drought Condition Level:

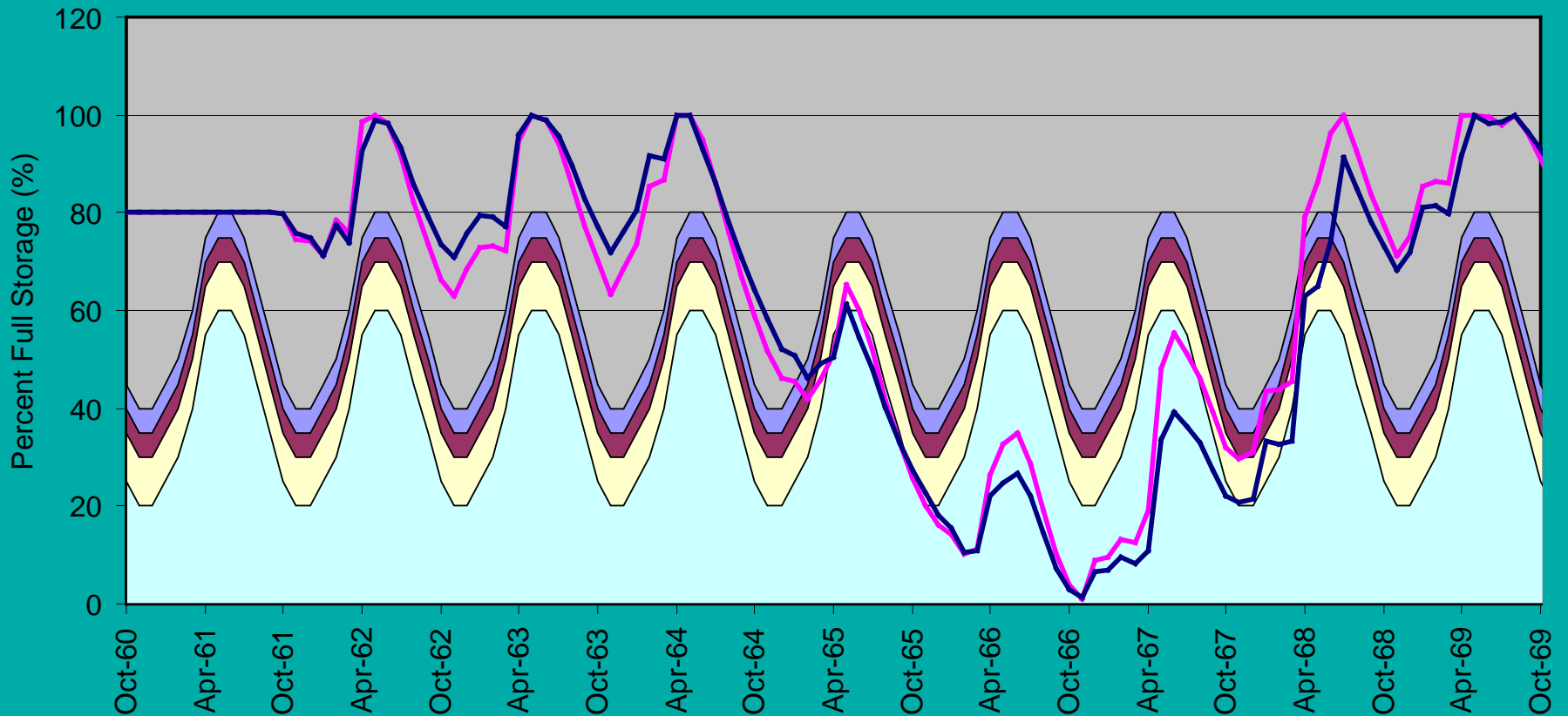
Drought Advisory	Voluntary	10% reduction from non-drought average for the month
Drought Watch	Voluntary	15% “
Drought Warning	Mandatory	20% “
Drought Emergency	Mandatory	25% “

Reservoir Levels for BAR3c vs. No Release Rule in 1960s

Storage Ratio of 0.6; Hubbard River Inflows

Yield Ratio: No Release= 0.59; BAR3c= 0.43

Advisory Watch Warning Emergency Reference with Demand BAR3c



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