Barton Springs Groundwater Model Development and Application

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Texas Water Development Board

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Topics

- Background and Objective
- Summary of Model Development
- Calibration Results
- Application

BSEACD Area Models

- BEG model calibrated from 1989-1998
- BSEACD established DFCs based on "drought-of-record" (DOR -1950s)
- BSEACD expressed concern regarding calibration period of BEG model
  - Developed separate model that ostensibly covered DOR
  - Review of BSEACD model revealed that it was also not "calibrated" to DOR

Options

- Use BEG Model (despite calibration period mismatch)
- Use BSEACD Model (despite calibration issues)
- Use “Water Budget Approach” (Analytical)
- Develop “New” Model

Question

- Can BEG model be quickly and easily updated/recalibrated to cover DOR period?

Key Issues

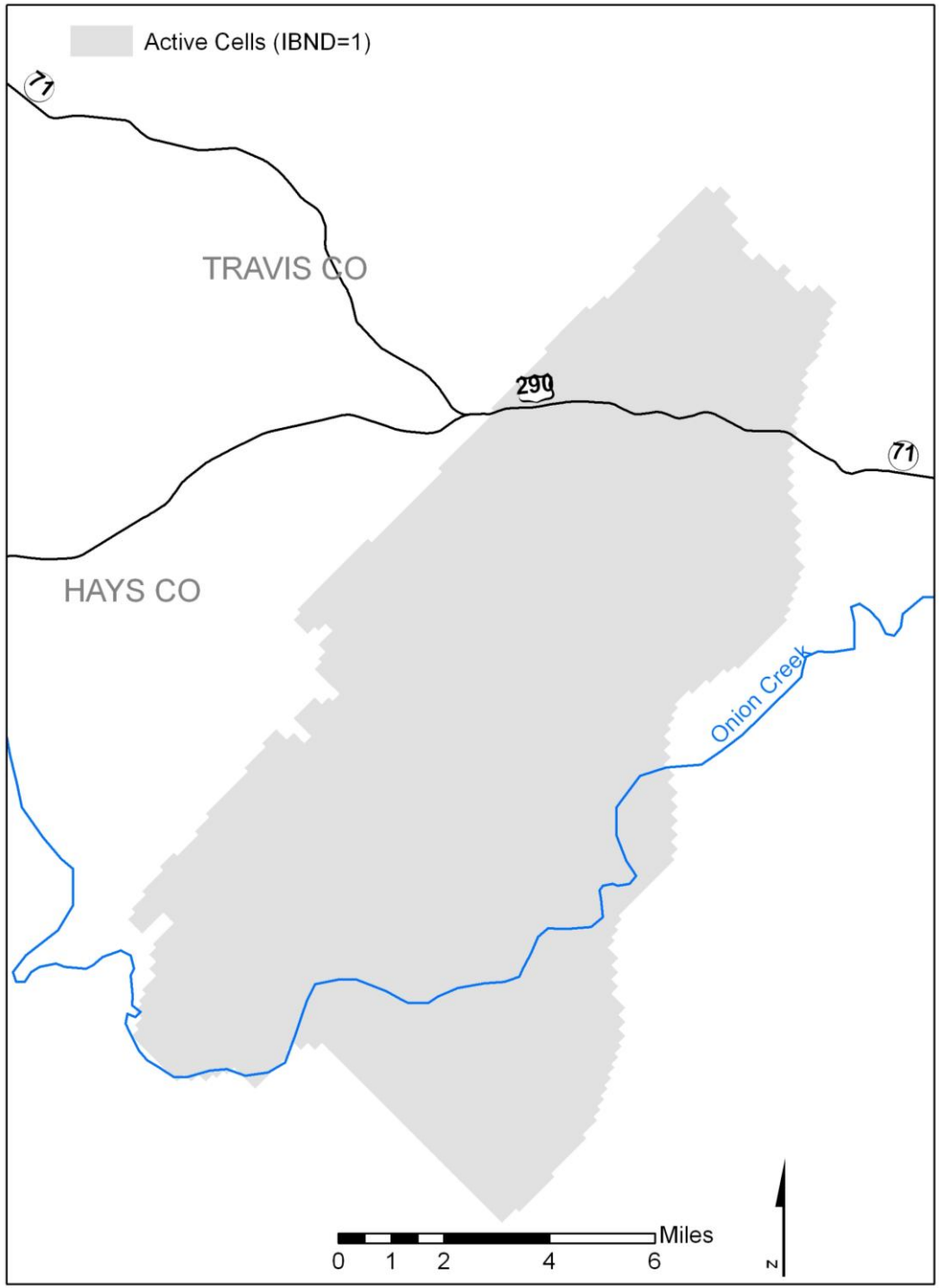
- “Backwards” extrapolation of recharge estimates
- Extension of pumping estimates

Model Summary (MF2K)

- BAS
- DIS
- LPF
- WEL
- DRN
- HFB
- RCH

BAS

- Same IBOUND as BEG model
- Starting Head Array
  - Assigned based on early runs


Active Cells (IBND=1)
71
TRAVIS CO
290
71
HAYS CO
Onion Creek
Miles
0 1 2 4 6
N

DIS - Spatial

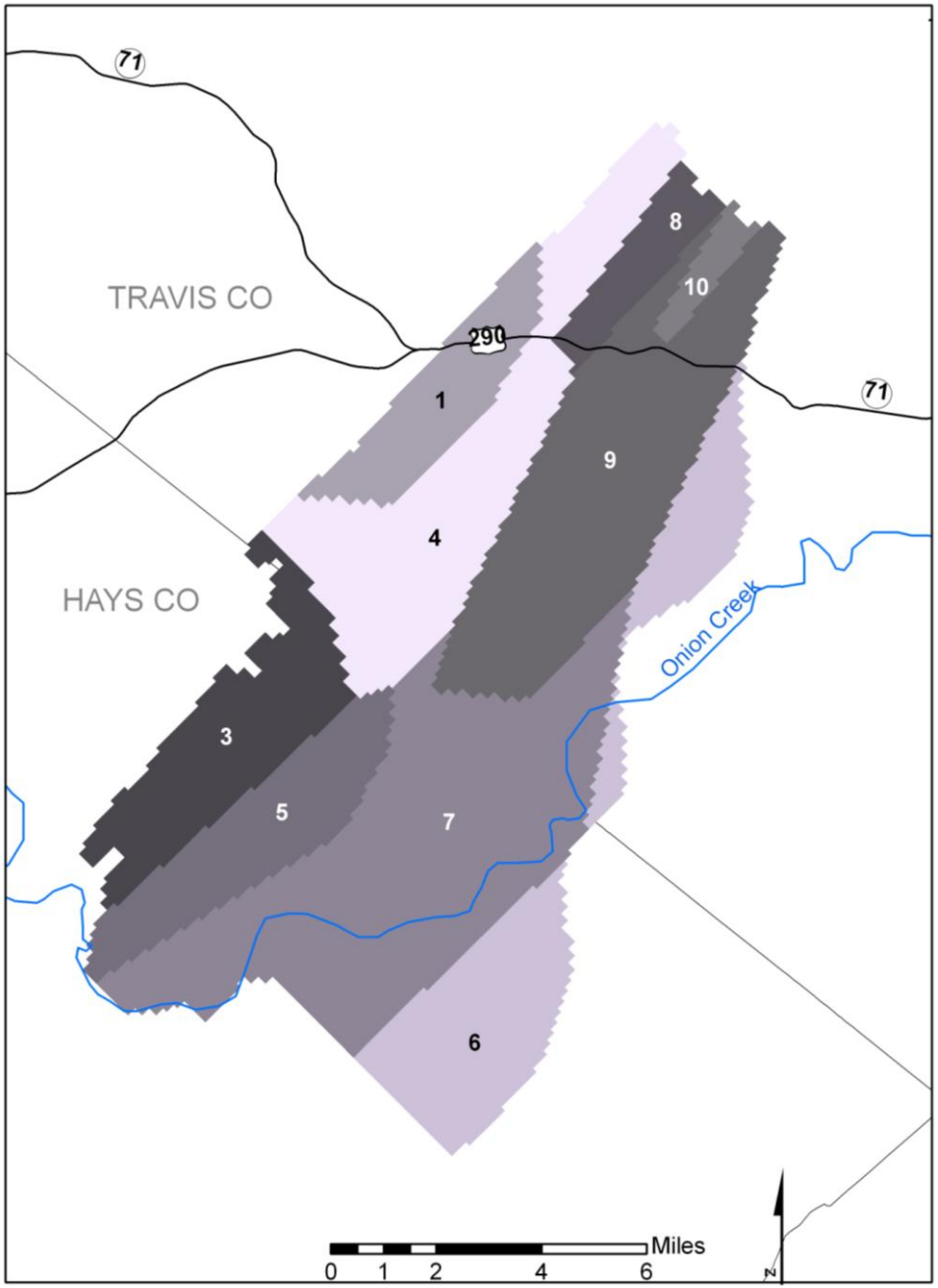
- 120 Rows x 120 Columns
- One Layer
- Cell Size = 1000 ft by 500 ft (Same as BEG)
- Top and Bottom Elevations
  - Same as BEG (with some corrections)

DIS - Temporal

- Initial Steady State Stress Period
- Monthly Stress Periods
  - January 1943 to December 2004
  - All months = 30 days
- 745 Stress Periods

LPF

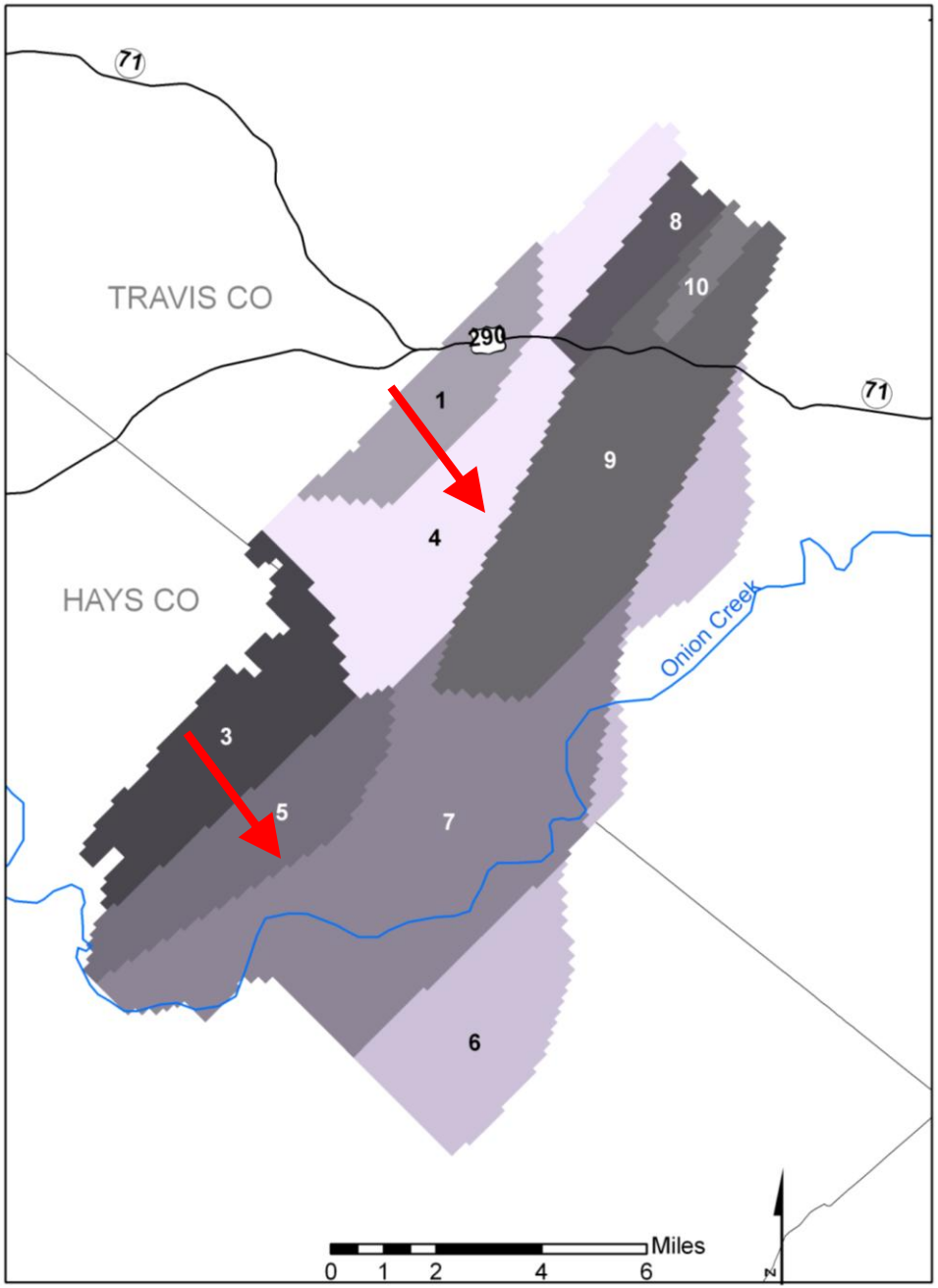
- K and S Zones same as BEG
- Added anisotropy



Hydraulic Conductivity

Zone	New Model			BEG
	Kx	**Ky**	**Kx/Ky**	**Kx=Ky**
1	0.2	0.3	0.6	1
3	0.1	7.2	0.01	3
4	0.1	15.0	0.01	3.5
5	1.3	4.1	0.3	4.5
6	52.2	5.0	10.4	39
7	176.0	85.8	2.1	93
8	20.0	27.3	0.7	100
9	172.0	227.0	0.8	320
10	1855.9	2000.0	0.9	1236

All values in ft/day



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	Kx	**Ky**	**Kx/Ky**	**Kx=Ky**
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4	0.1	15.0	0.01	3.5
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6	52.2	5.0	10.4	39
7	176.0	85.8	2.1	93
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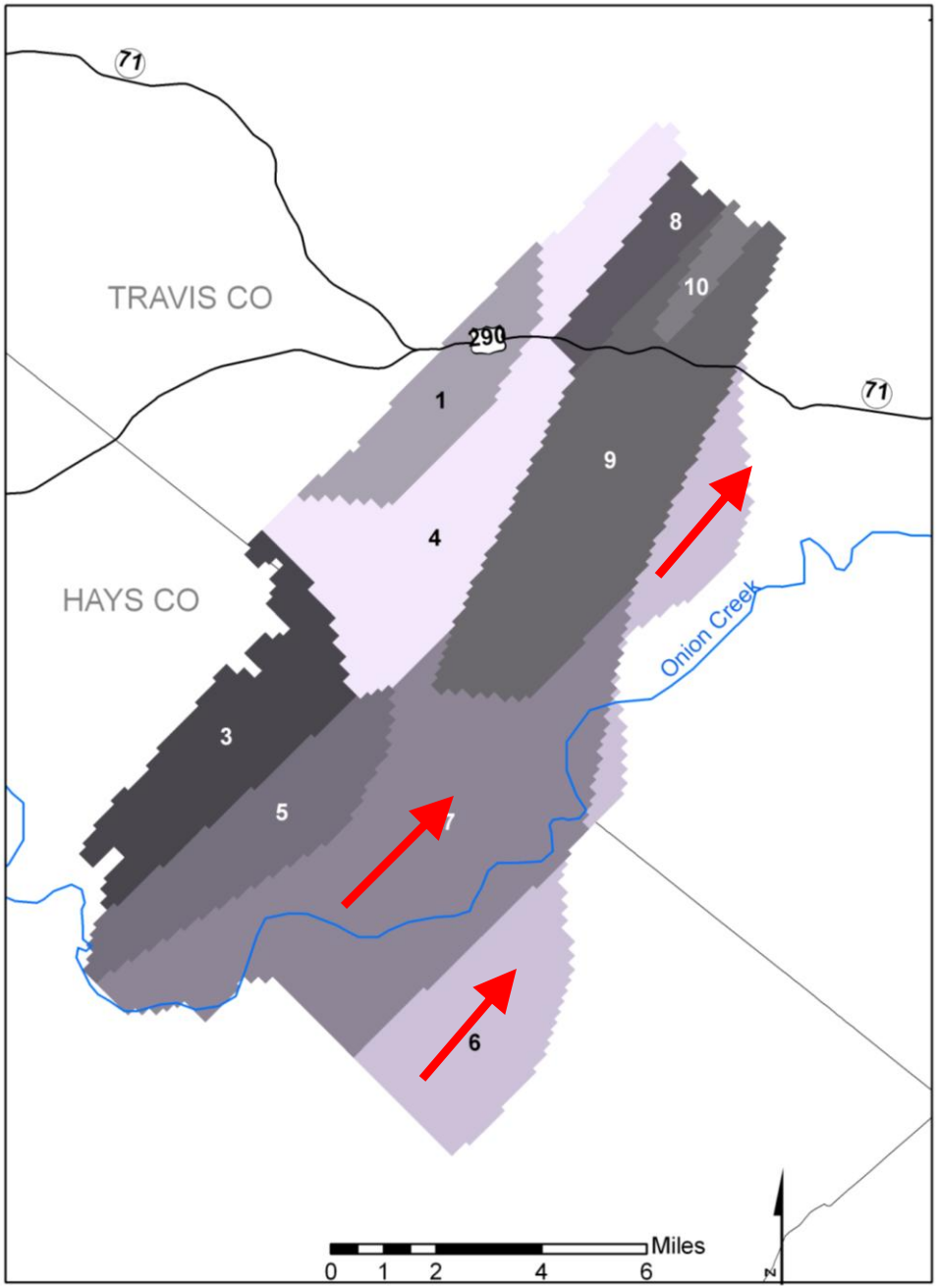

Hydraulic Conductivity

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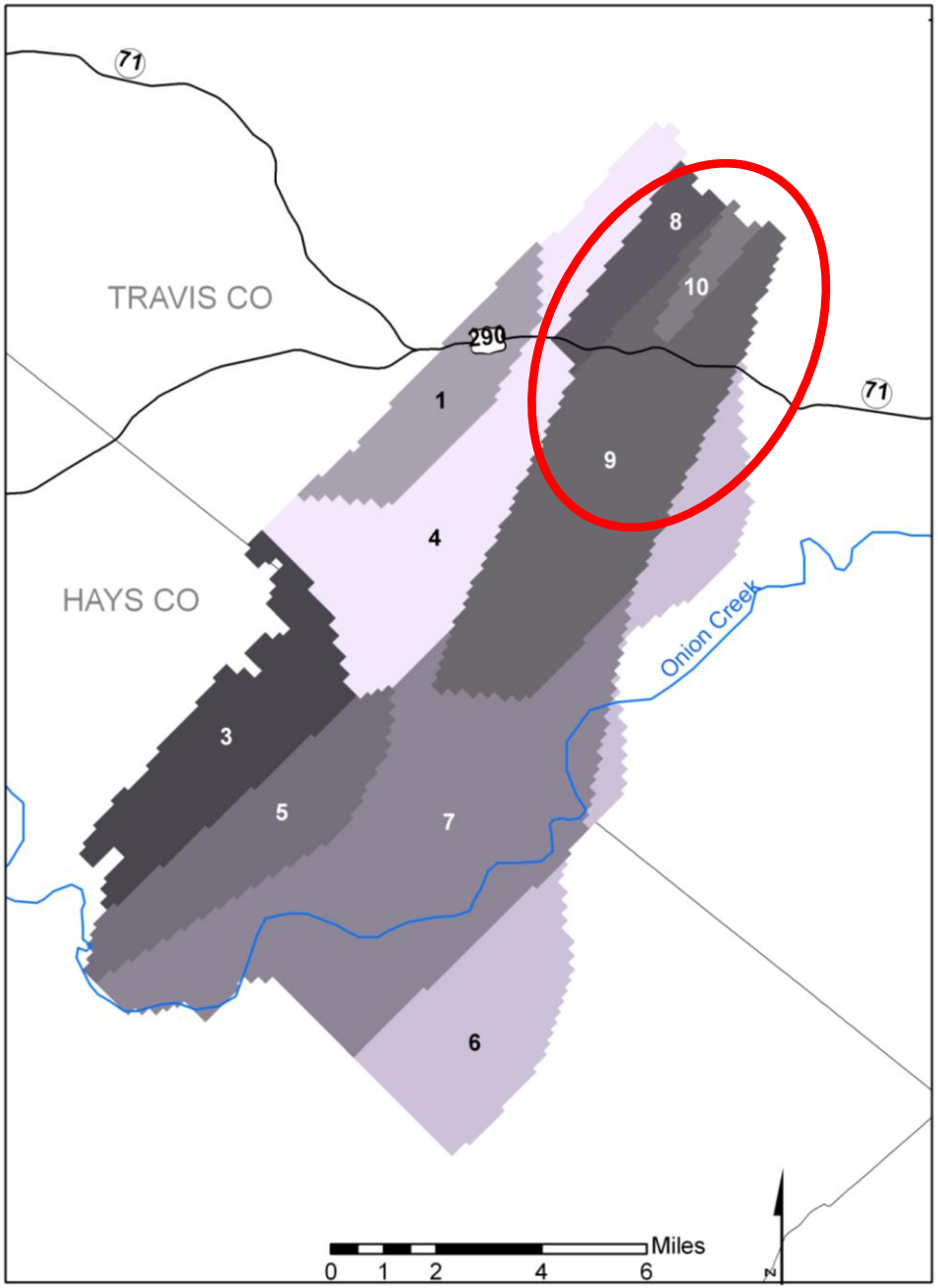
All values in ft/day



Hydraulic Conductivity

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1	0.2	0.3	0.6	1
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4	0.1	15.0	0.01	3.5
5	1.3	4.1	0.3	4.5
6	52.2	5.0	10.4	39
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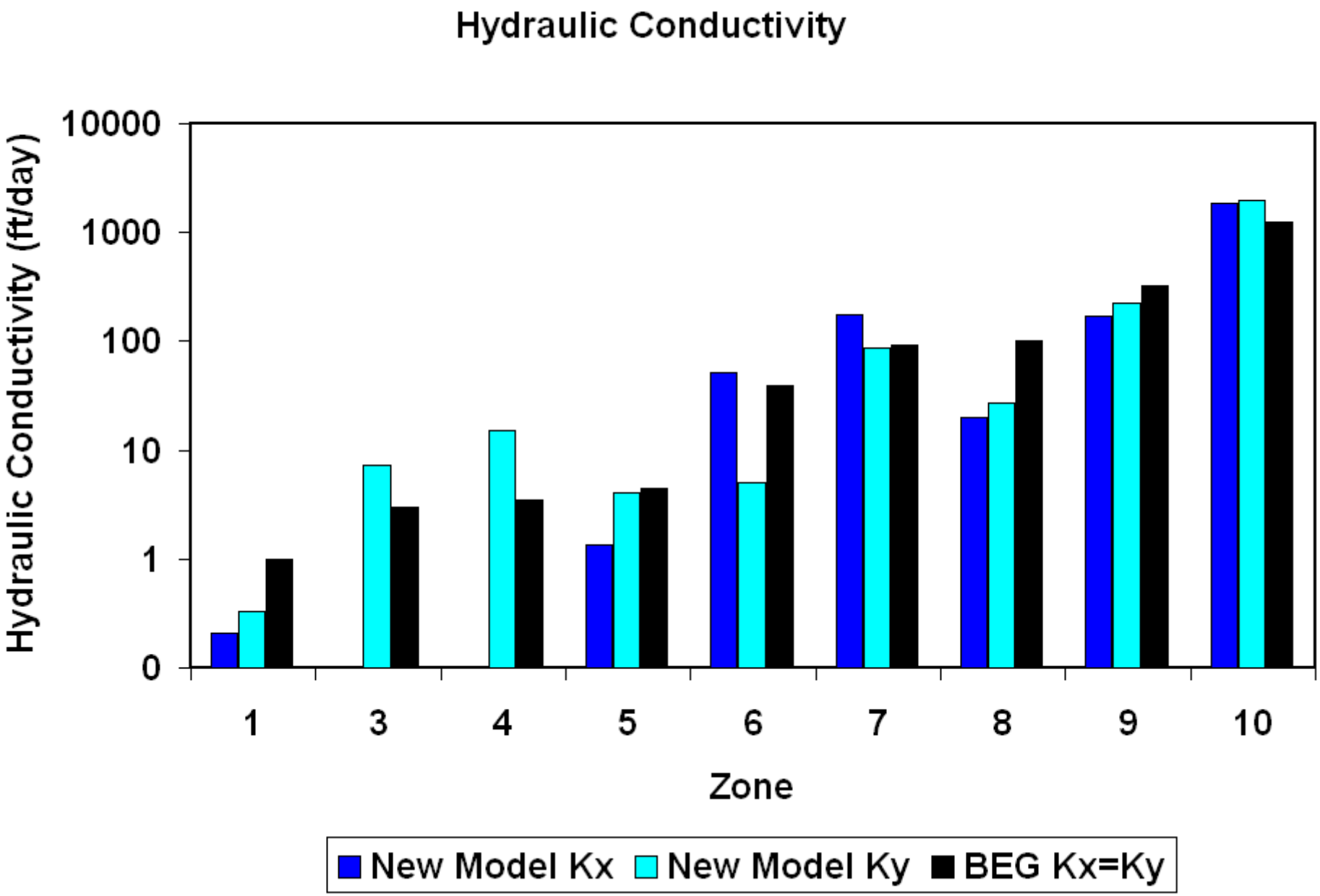
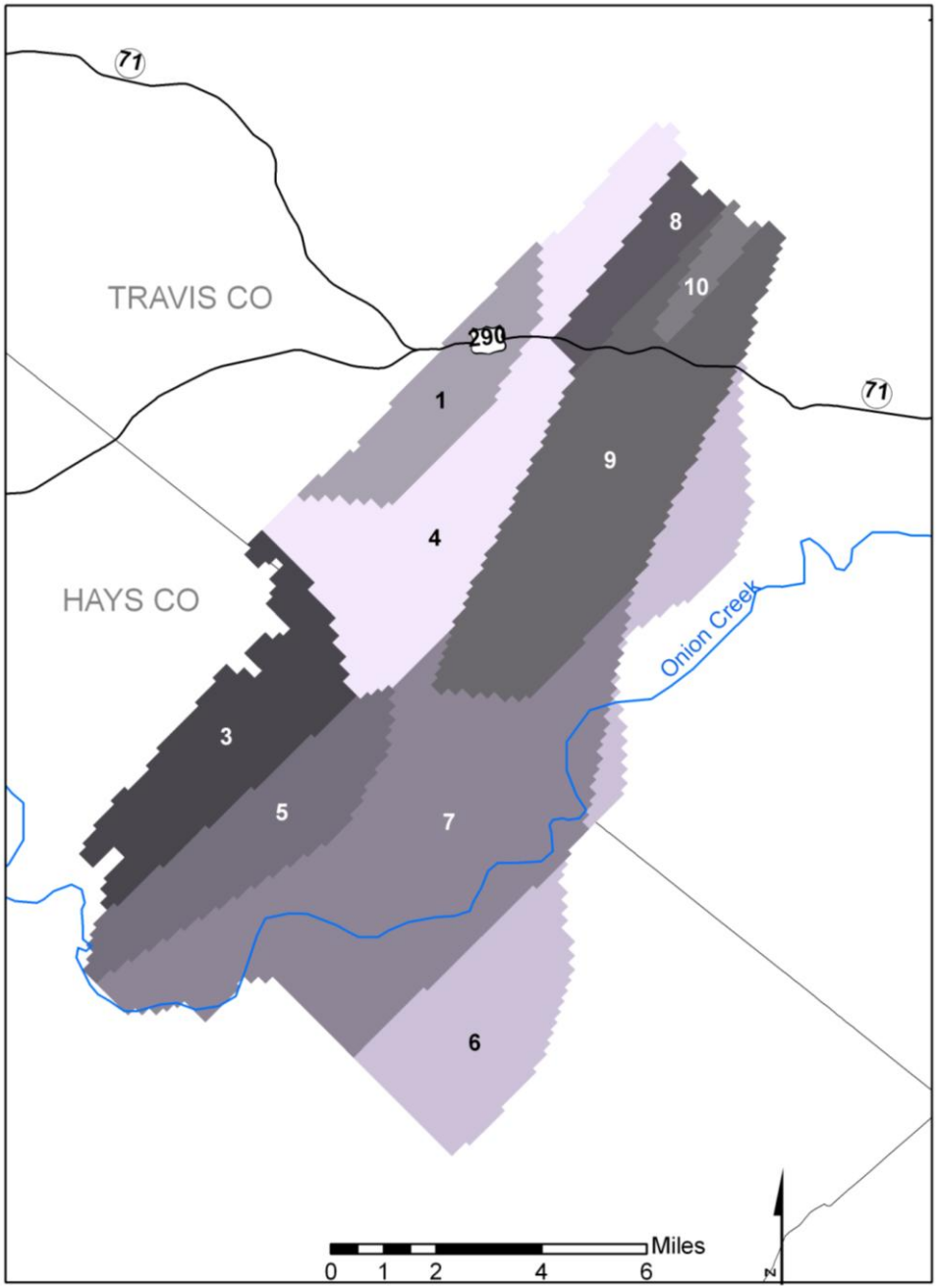
All values in ft/day


Hydraulic Conductivity
Hydraulic Conductivity (ft/day)
10000
1000
100
10
1
0
1
3
4
5
6
7
8
9
10
Zone
New Model Kx
New Model Ky
BEG Kx=Ky



Storativity and Specific Yield

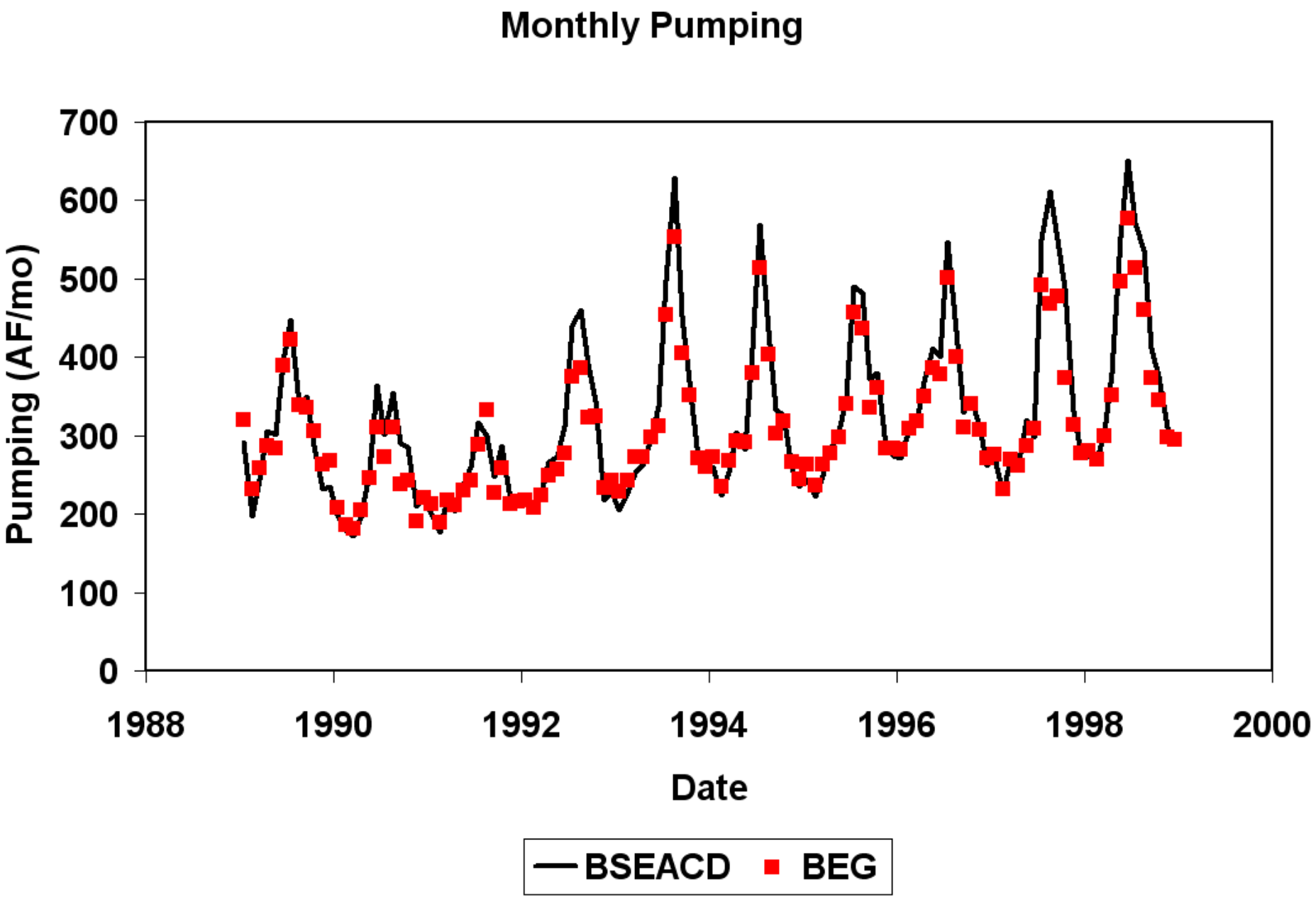
Zone	New Model	
	S_s	S_y
1	1.72E-05	7.56E-02
3	7.16E-05	2.00E-01
4	3.22E-06	1.47E-03
5	1.33E-05	7.45E-03
6	2.19E-07	1.73E-02
7	1.12E-05	1.93E-03
8	1.66E-04	6.79E-02
9	8.74E-08	7.44E-04
10	1.15E-03	1.73E-01

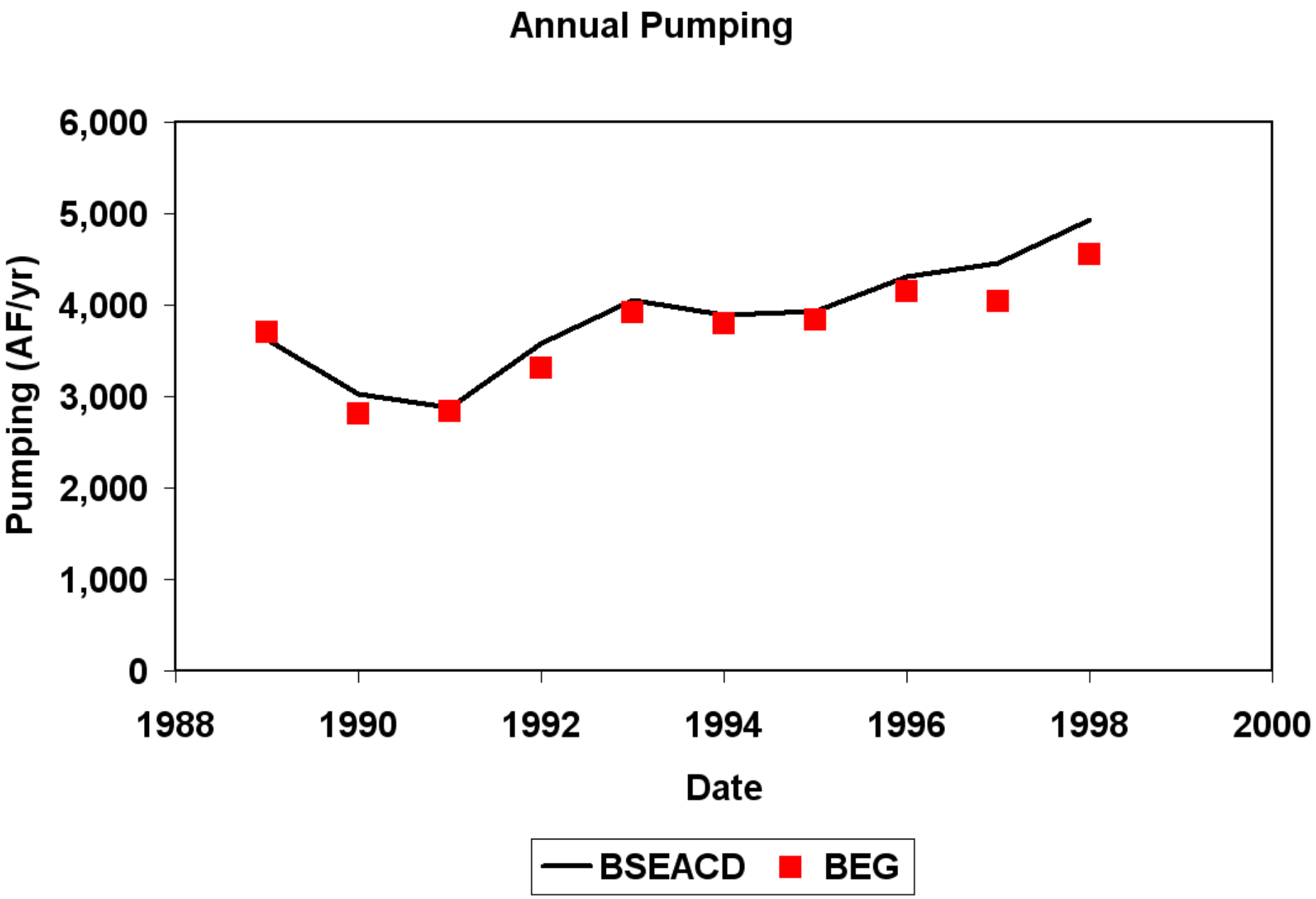
S_s in ft-1

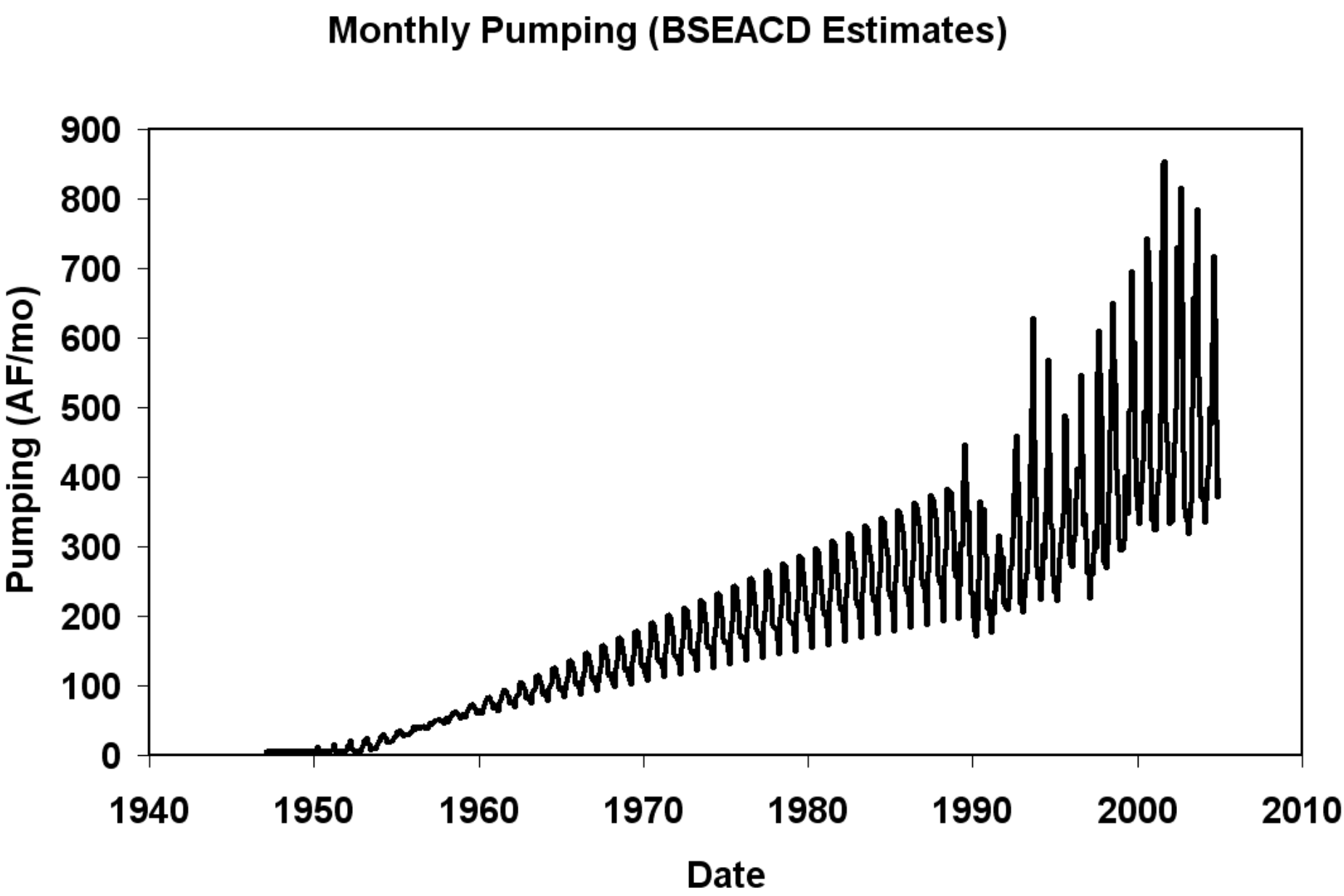
S_y dimensionless

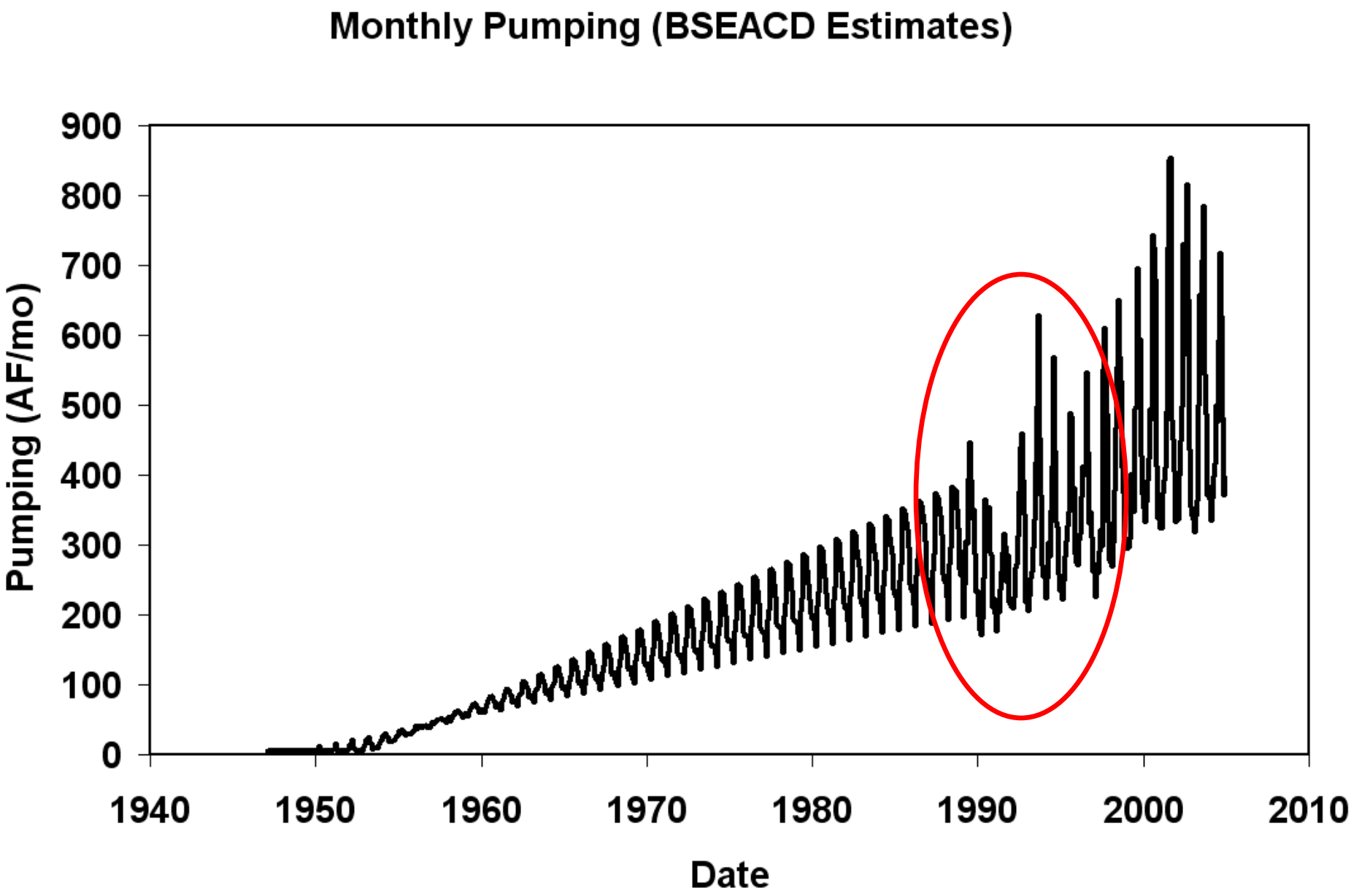
WEL

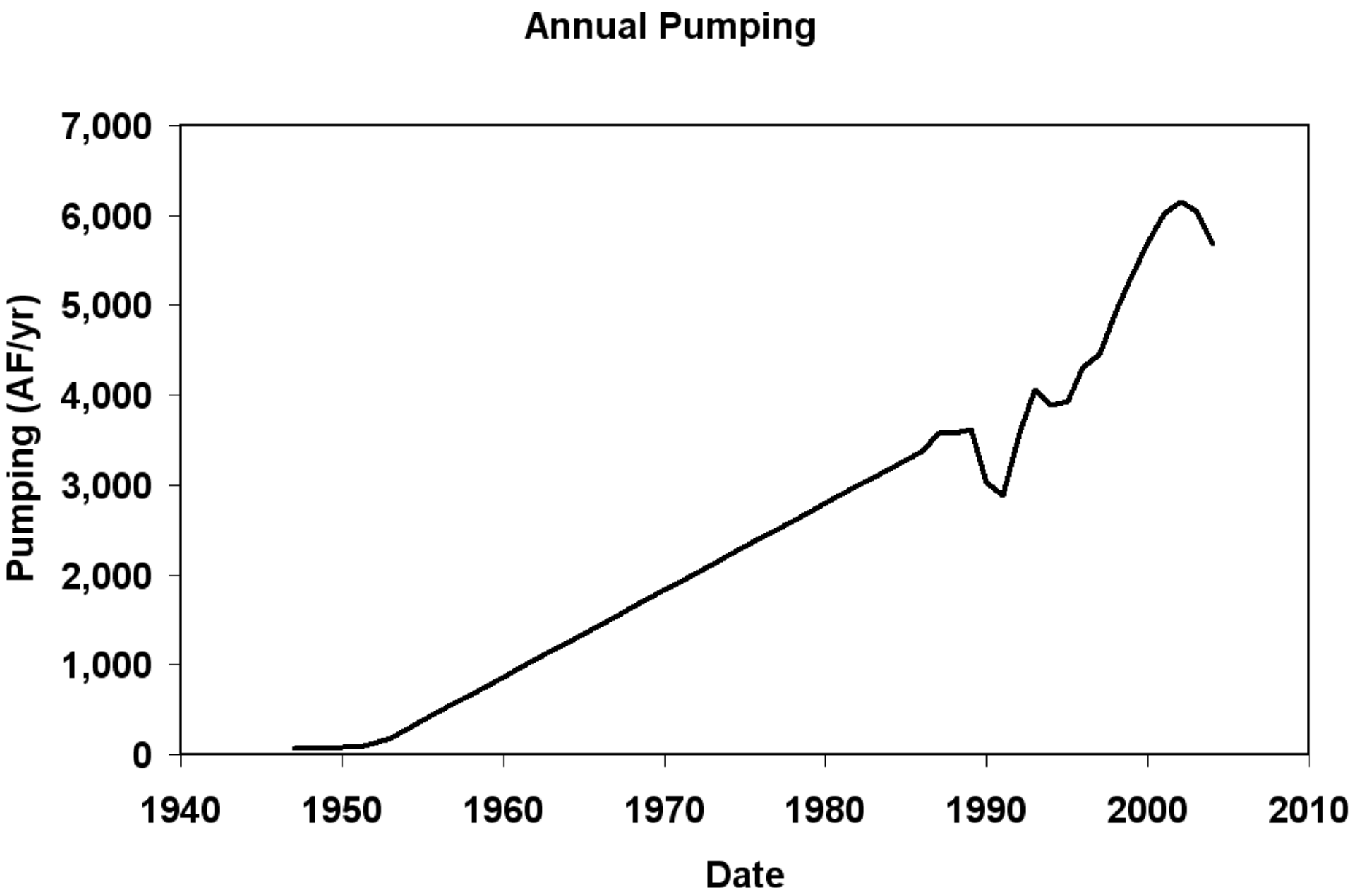
- BEG/BSEACD Estimates
- “Rural” vs. “Point” Pumping


Monthly Pumping
Pumping (AF/mo)
700
600
500
400
300
200
100
0
1988
1990
1992
1994
1996
1998
2000
Date
BSEACD
BEG


Annual Pumping
6,000
5,000
4,000
3,000
2,000
1,000
0
Pumping (AF/yr)
1988
1990
1992
1994
1996
1998
2000
Date
BSEACD
BEG

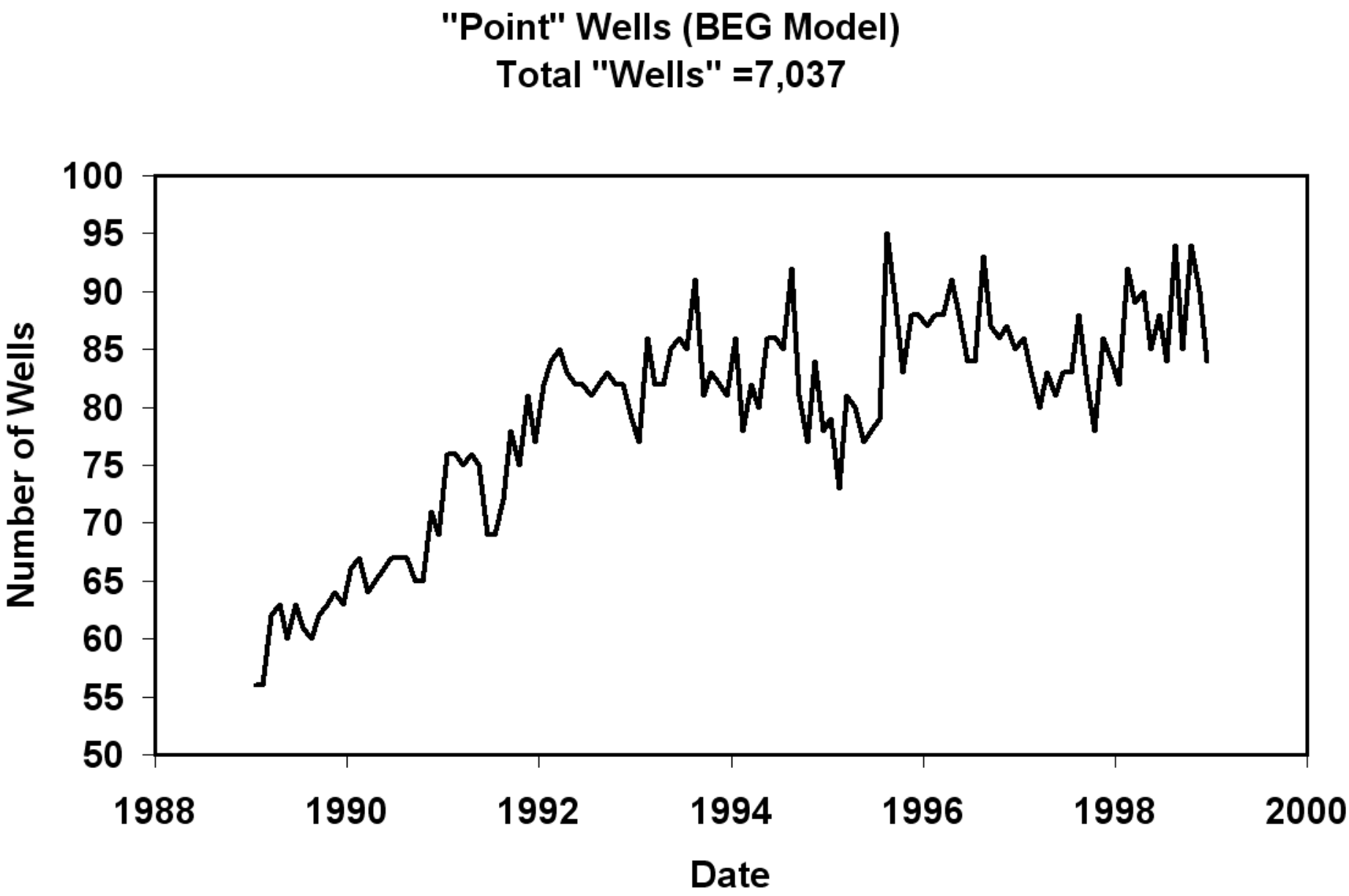

Monthly Pumping (BSEACD Estimates)
Pumping (AF/mo)
900
800
700
600
500
400
300
200
100
0
1940
1950
1960
1970
1980
1990
2000
2010
Date

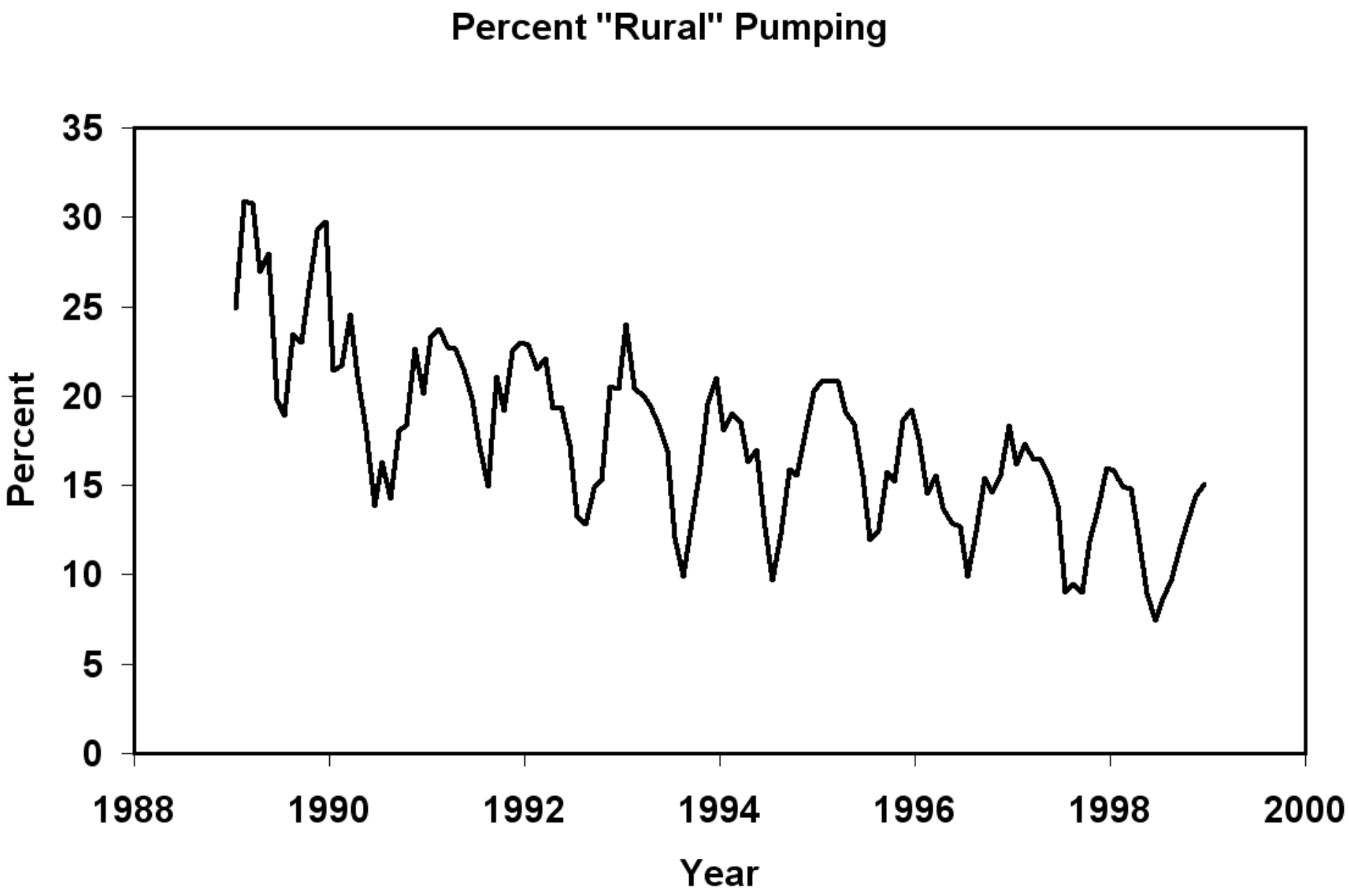

Monthly Pumping (BSEACD Estimates)
Pumping (AF/mo)
900
800
700
600
500
400
300
200
100
0
1940
1950
1960
1970
1980
1990
2000
2010
Date


Annual Pumping
Pumping (AF/yr)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1940
1950
1960
1970
1980
1990
2000
2010
Date

1943-1988, 1999-2004 Extrapolation

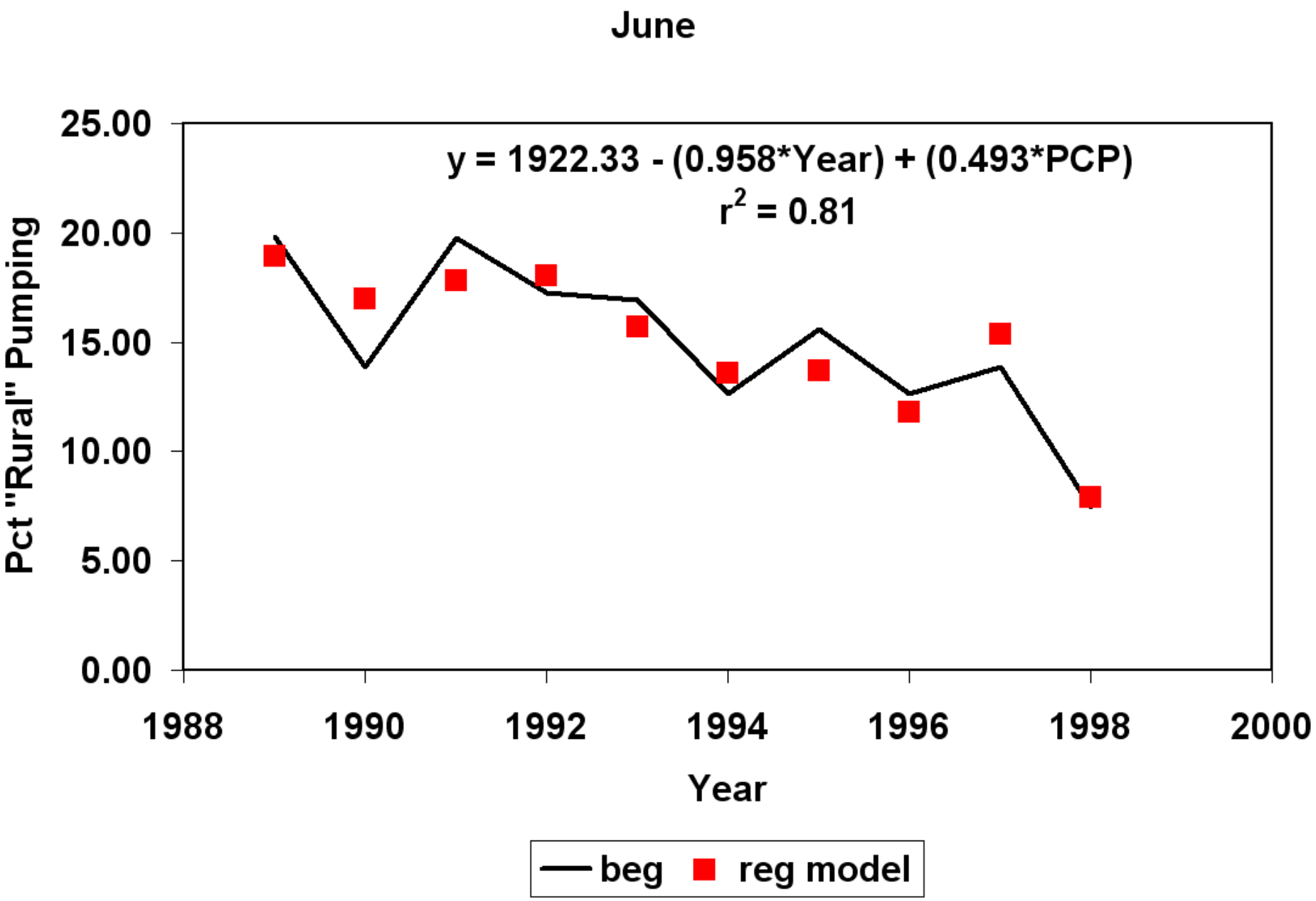
- Use BSEACD estimated pumping totals
- Distribute based on “rural” and “point” distribution
- Use BEG spatial distribution based on month

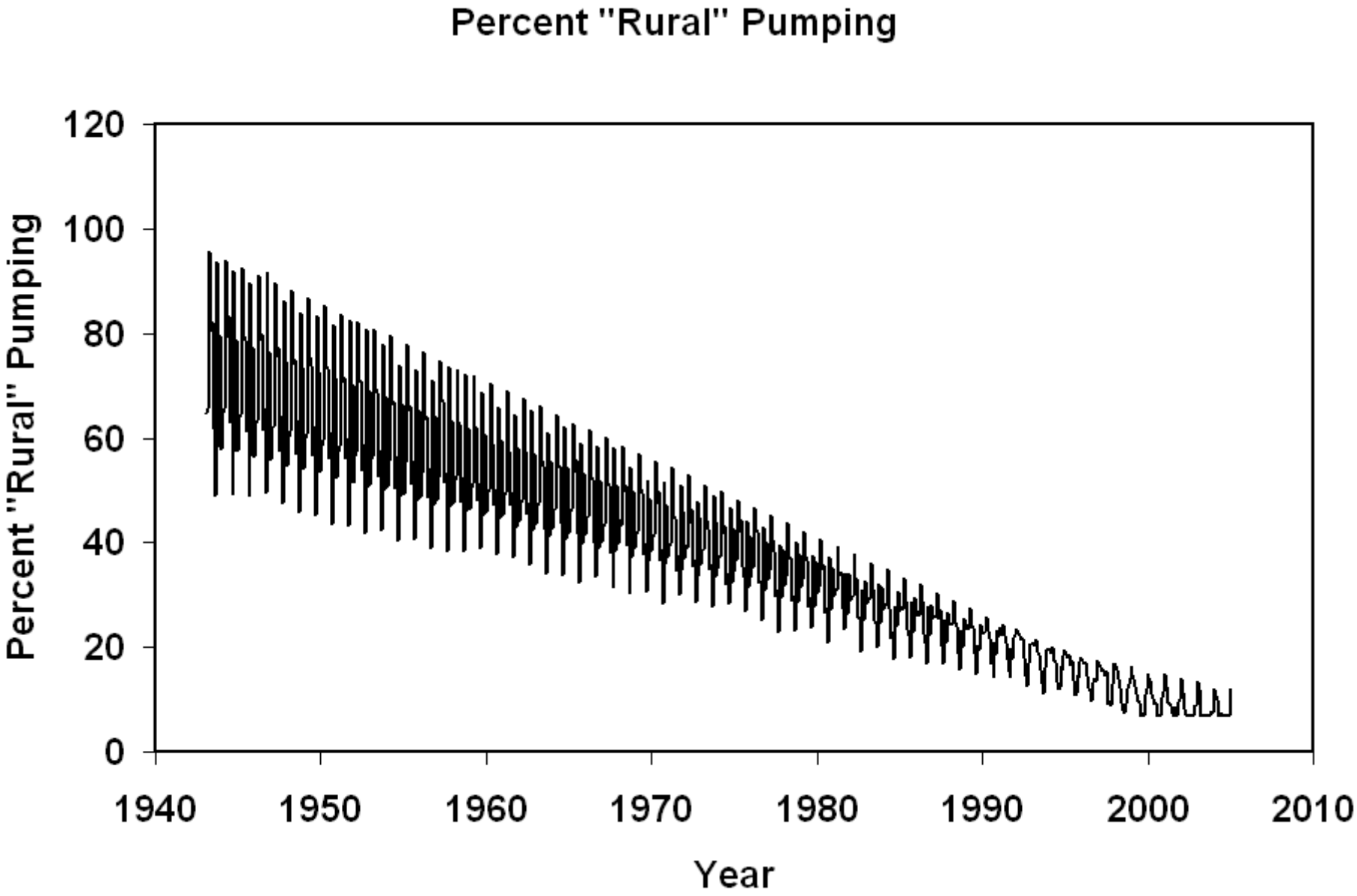

"Point" Wells (BEG Model)
Total "Wells" =7,037
Number of Wells
100
95
90
85
80
75
70
65
60
55
50
1988
1990
1992
1994
1996
1998
2000
Date


Percent "Rural" Pumping
35
30
25
20
15
10
5
0
Percent
1988
1990
1992
1994
1996
1998
2000
Year

“Rural” vs. “Point”

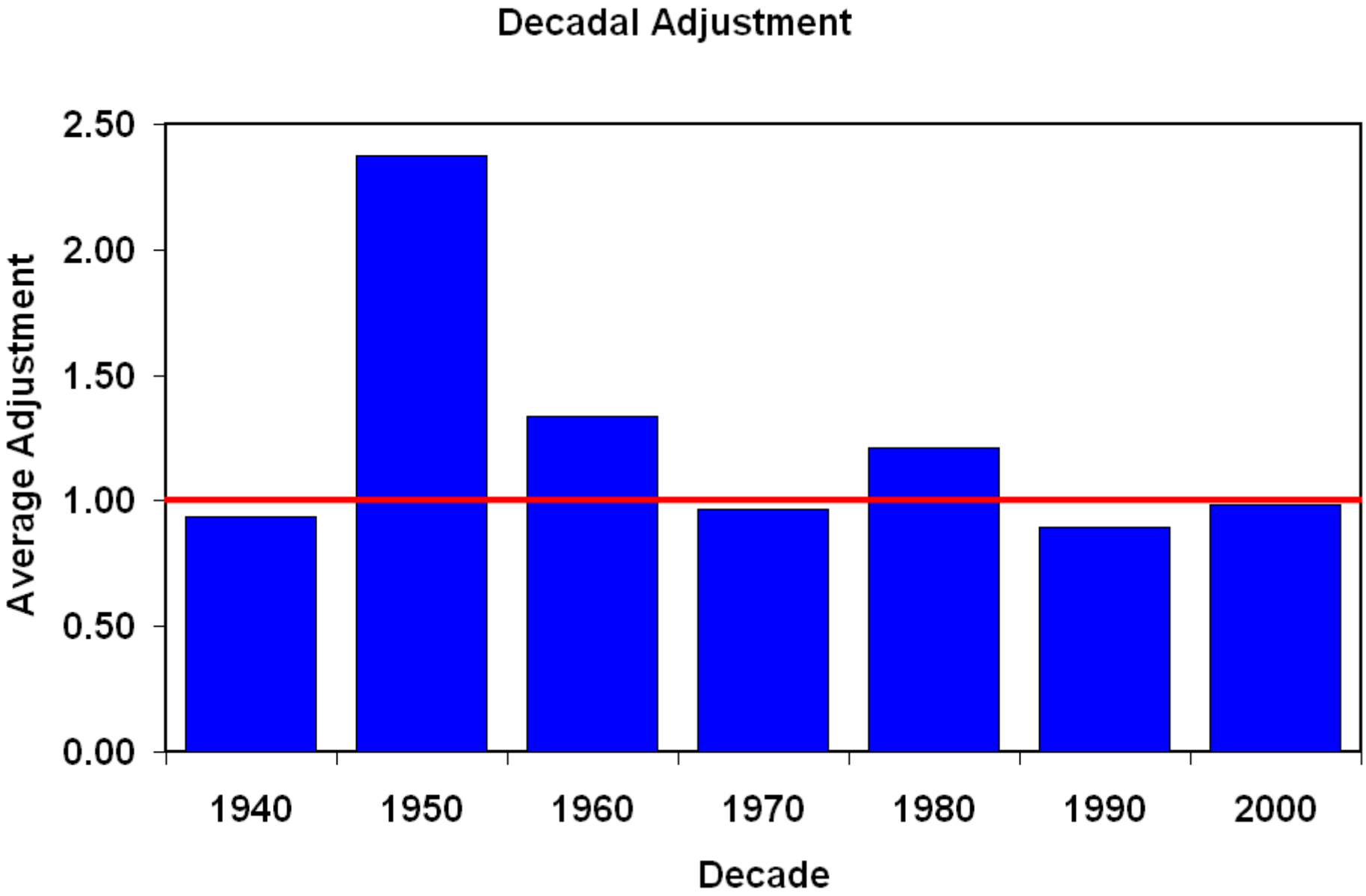
- 12 Months
- 12 Regression Equations
  - Year and Precipitation independent variables

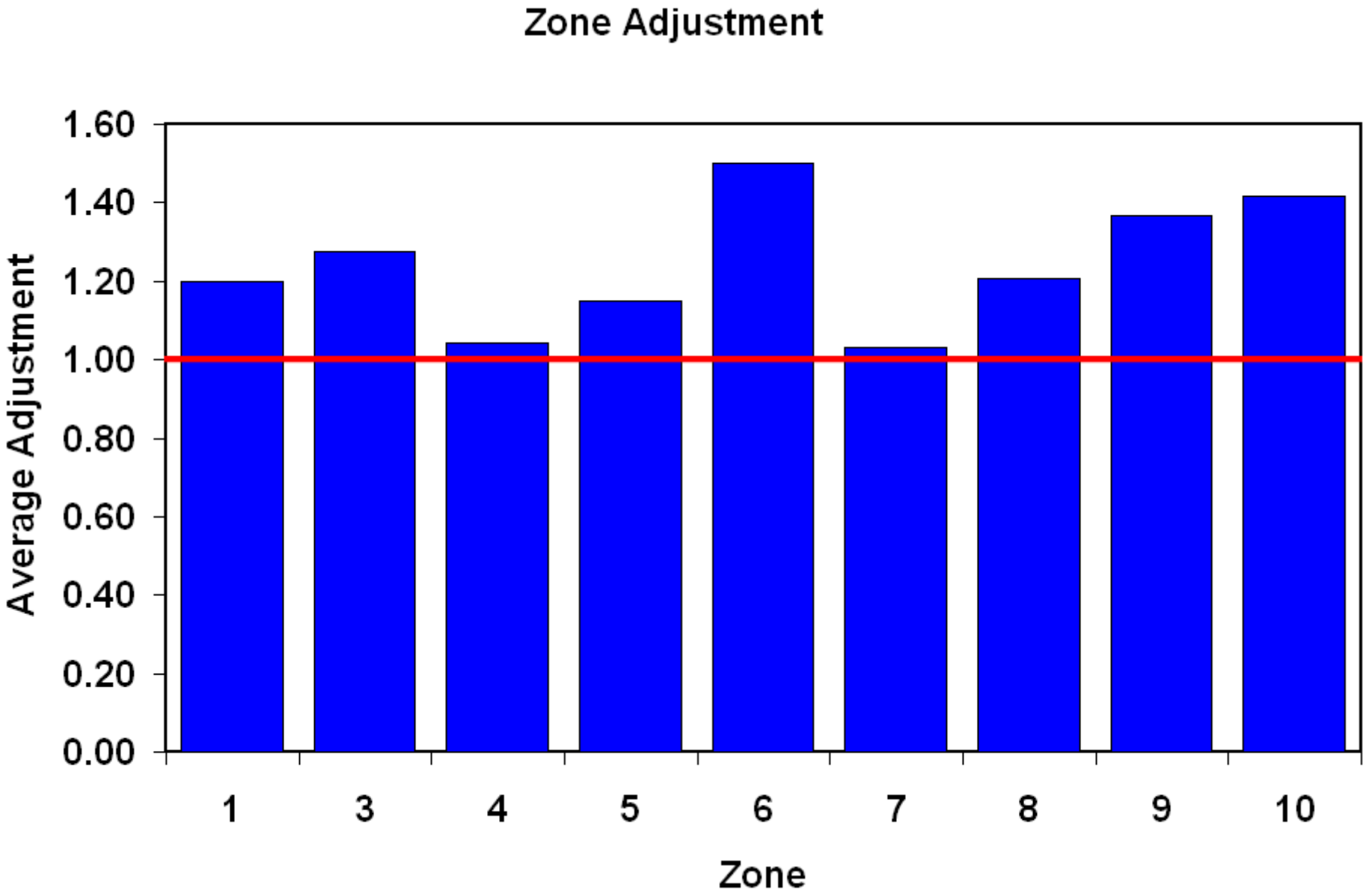

June
y = 1922.33 - (0.958*Year) + (0.493*PCP)
r2 = 0.81
Pct "Rural" Pumping
25.00
20.00
15.00
10.00
5.00
0.00
1988
1990
1992
1994
1996
1998
2000
Year
beg
reg model

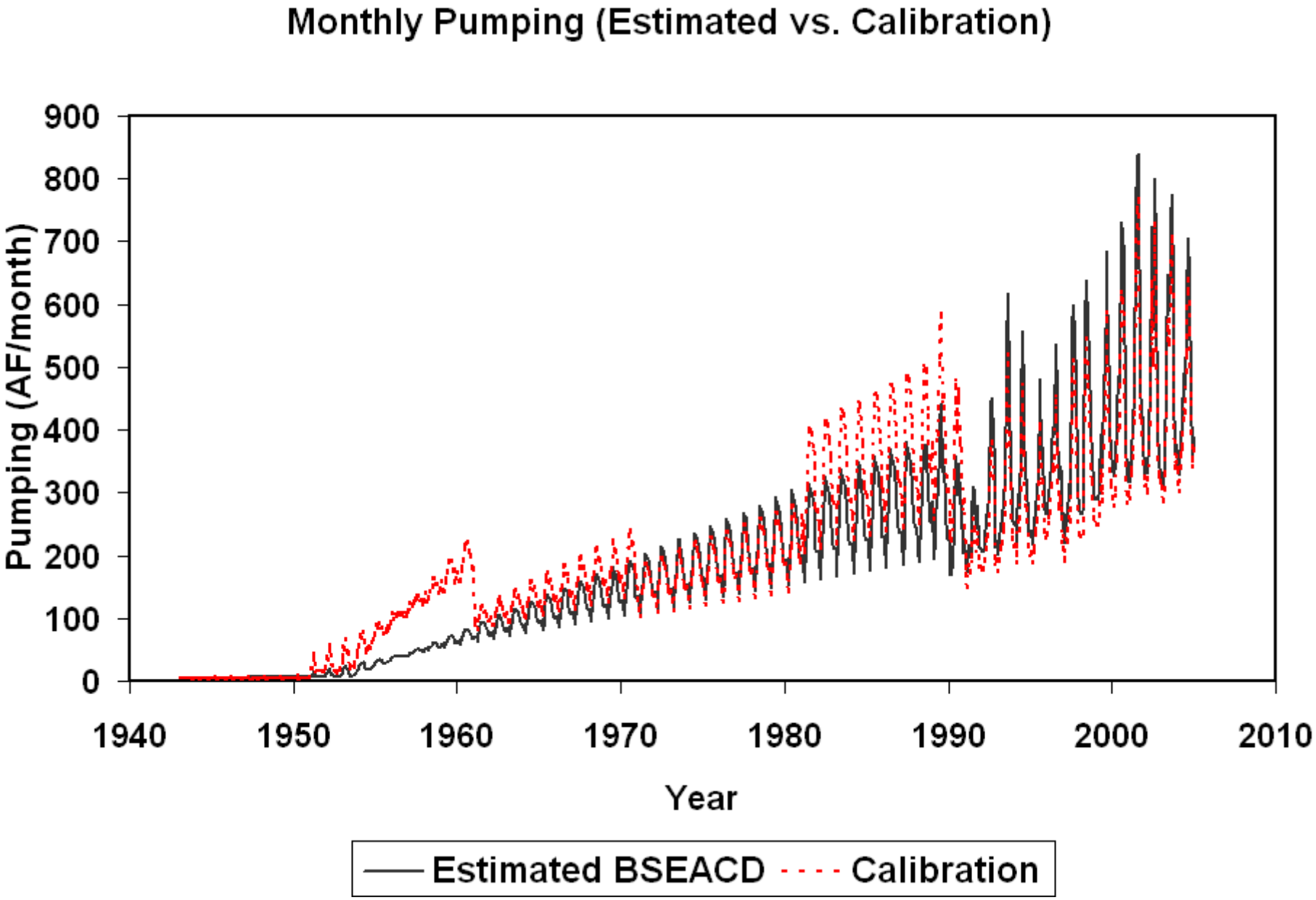

Percent "Rural" Pumping
Percent "Rural" Pumping
120
100
80
60
40
20
0
1940
1950
1960
1970
1980
1990
2000
2010
Year

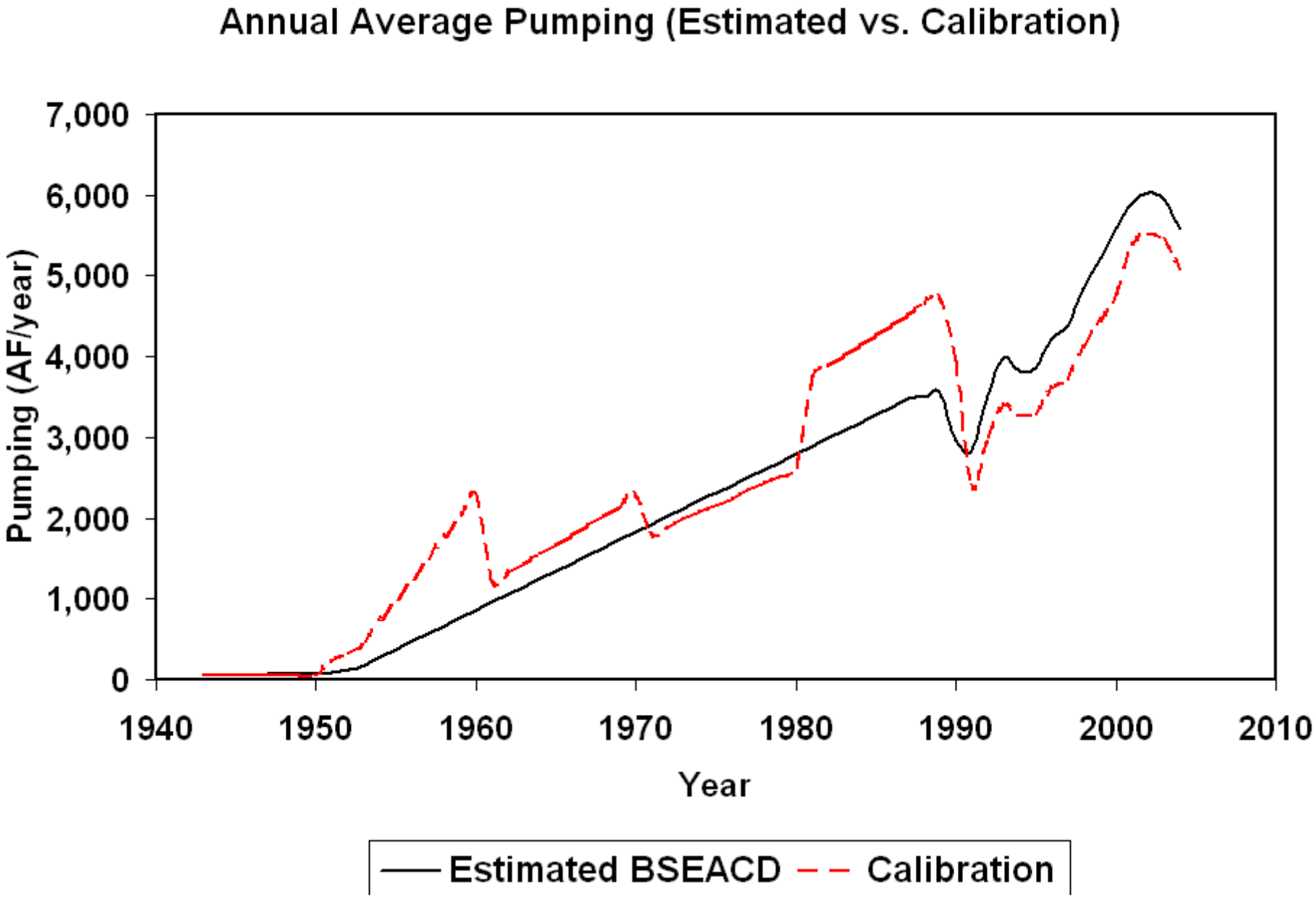
Calibration Adjustments

- Adjust by decade (40s to 00s)
  - 7 “decades”
- Adjust by K&S zone
  - 9 zones


Decadal Adjustment
Average Adjustment
2.50
2.00
1.50
1.00
0.50
0.00
1940
1950
1960
1970
1980
1990
2000
Decade


Zone Adjustment
Average Adjustment
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1
3
4
5
6
7
8
9
10
Zone


Monthly Pumping (Estimated vs. Calibration)
Pumping (AF/month)
900
800
700
600
500
400
300
200
100
0
1940
1950
1960
1970
1980
1990
2000
2010
Year
Estimated BSEACD
Calibration


Annual Average Pumping (Estimated vs. Calibration)
Pumping (AF/year)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1940
1950
1960
1970
1980
1990
2000
2010
Year
Estimated BSEACD
Calibration

DRN

- Barton Springs
- Cold Springs
- Calibration Parameter: Conductance

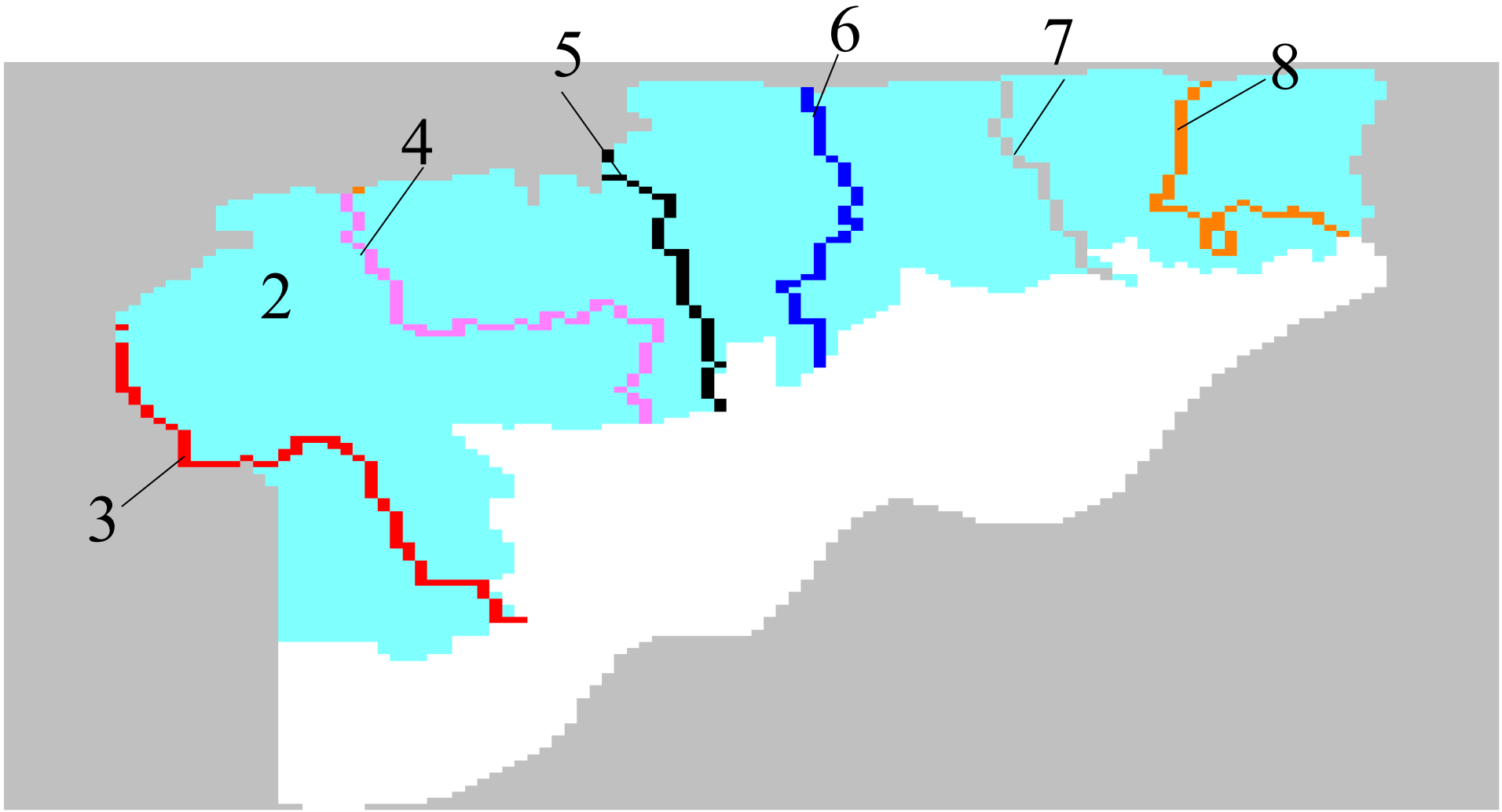
HFB

- Same location and conductance as BEG

RCH

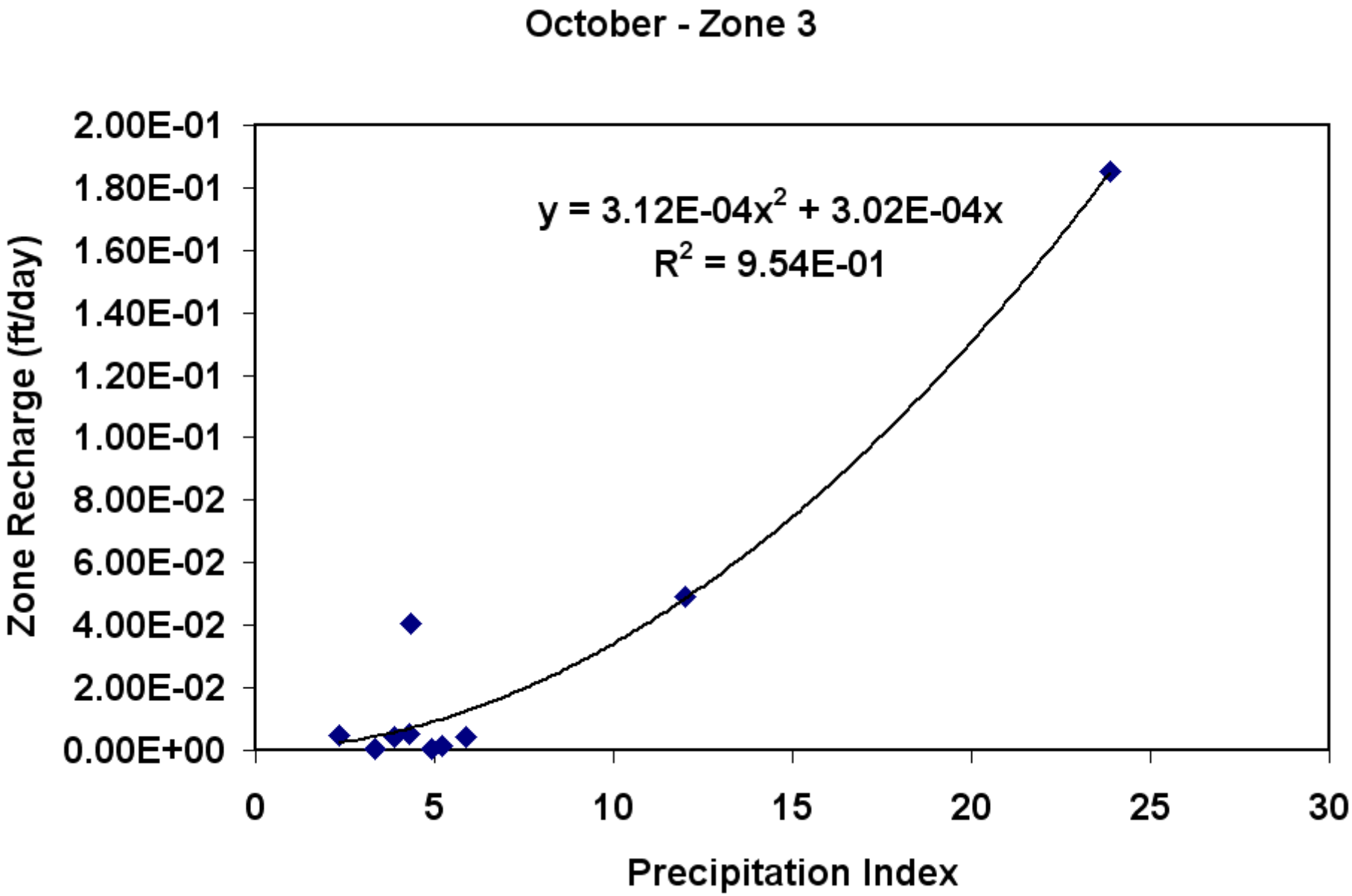
- Extrapolation based on BEG model
  - 7 zones
  - 12 months
  - 84 Regression Relationships
- Adjusted during calibration

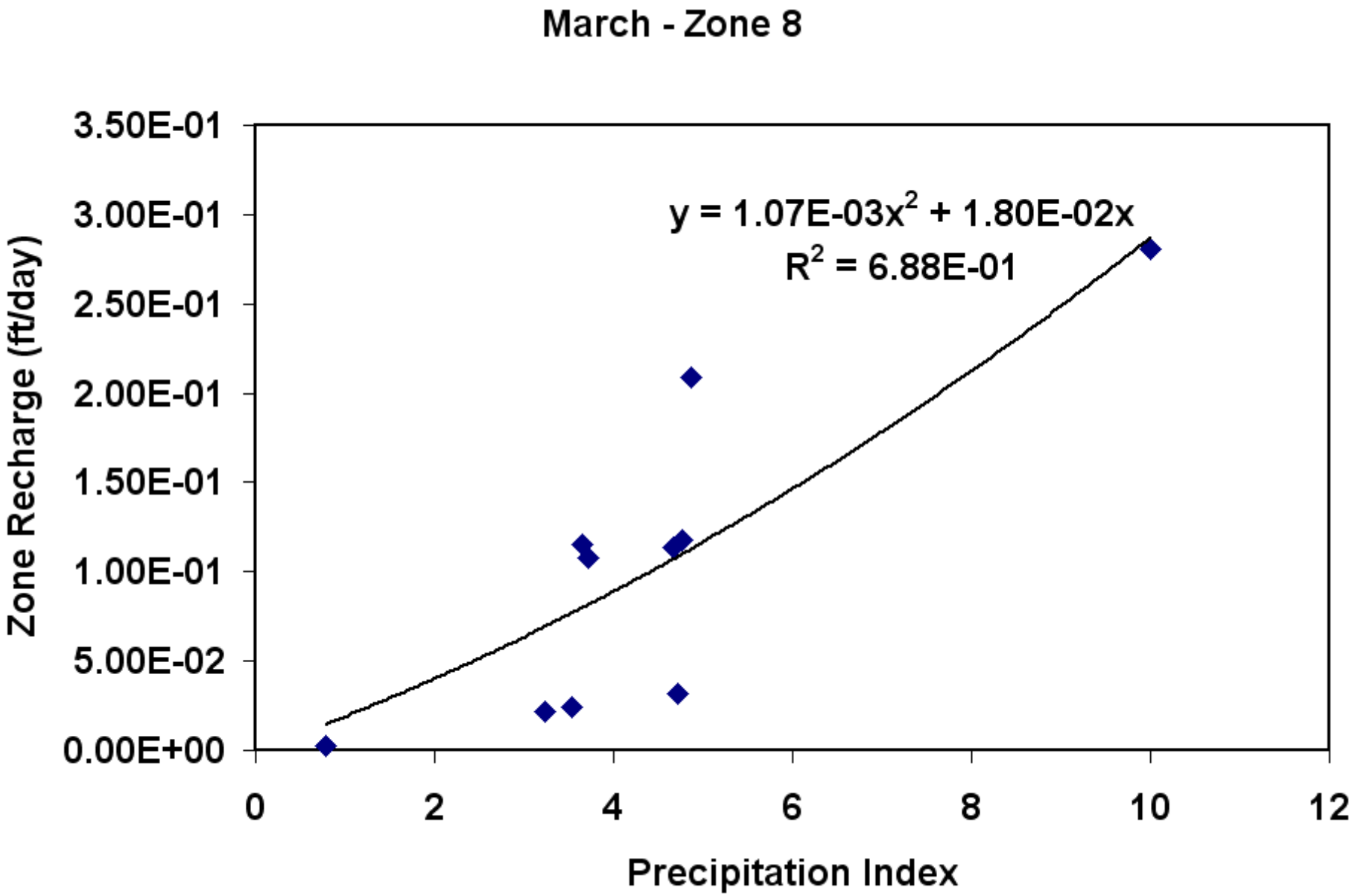
7 Recharge “Zones”

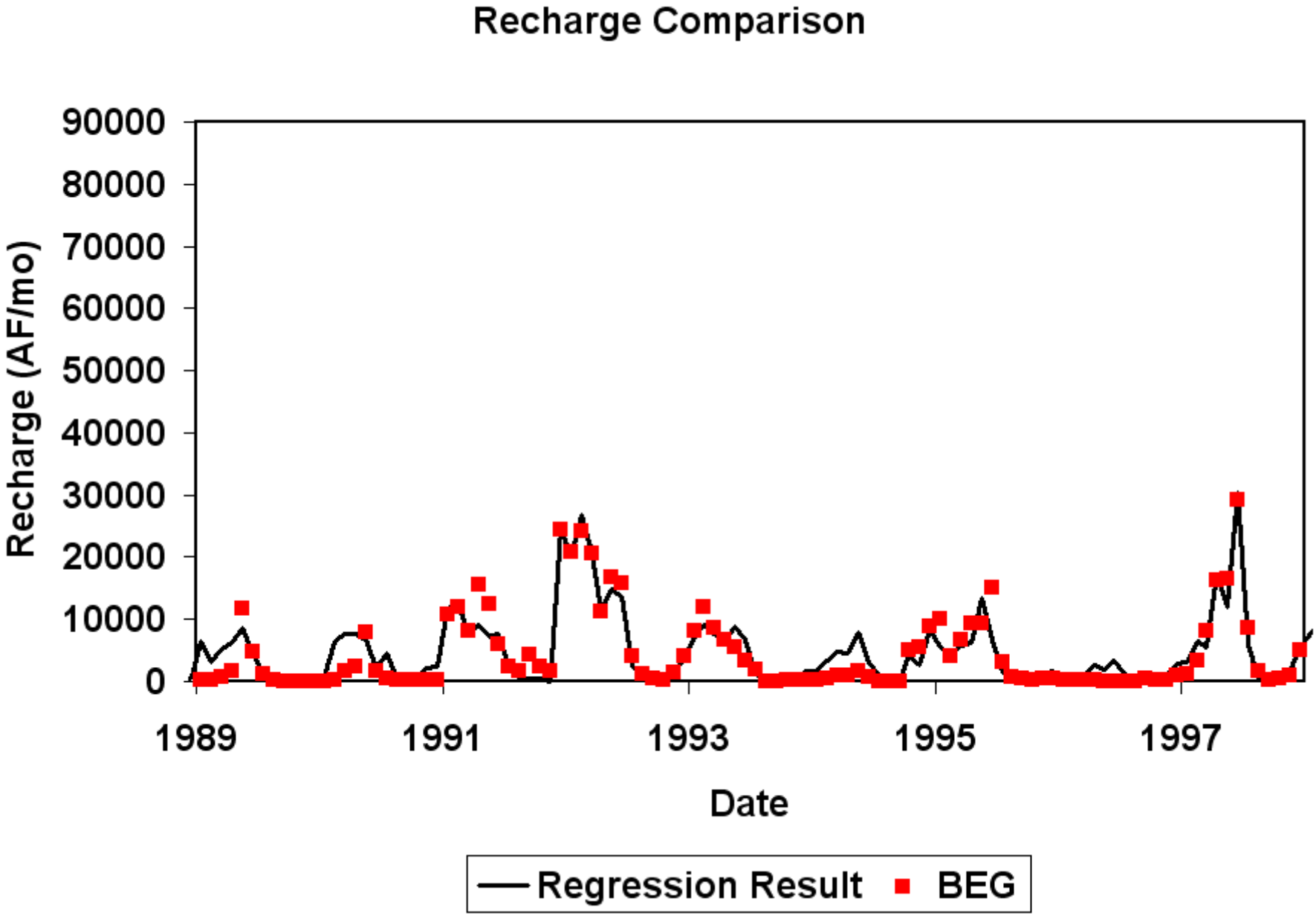


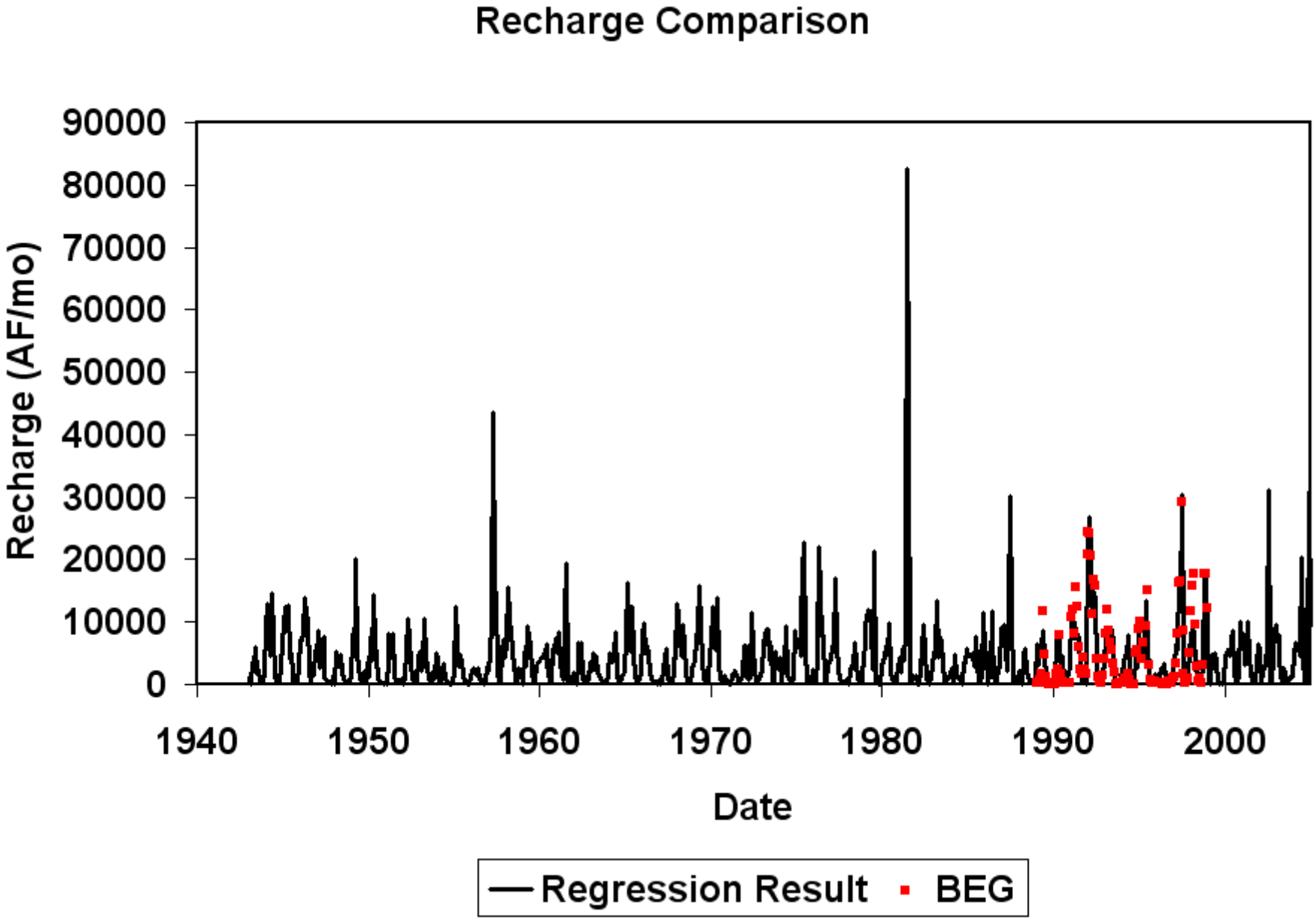
Precipitation Index

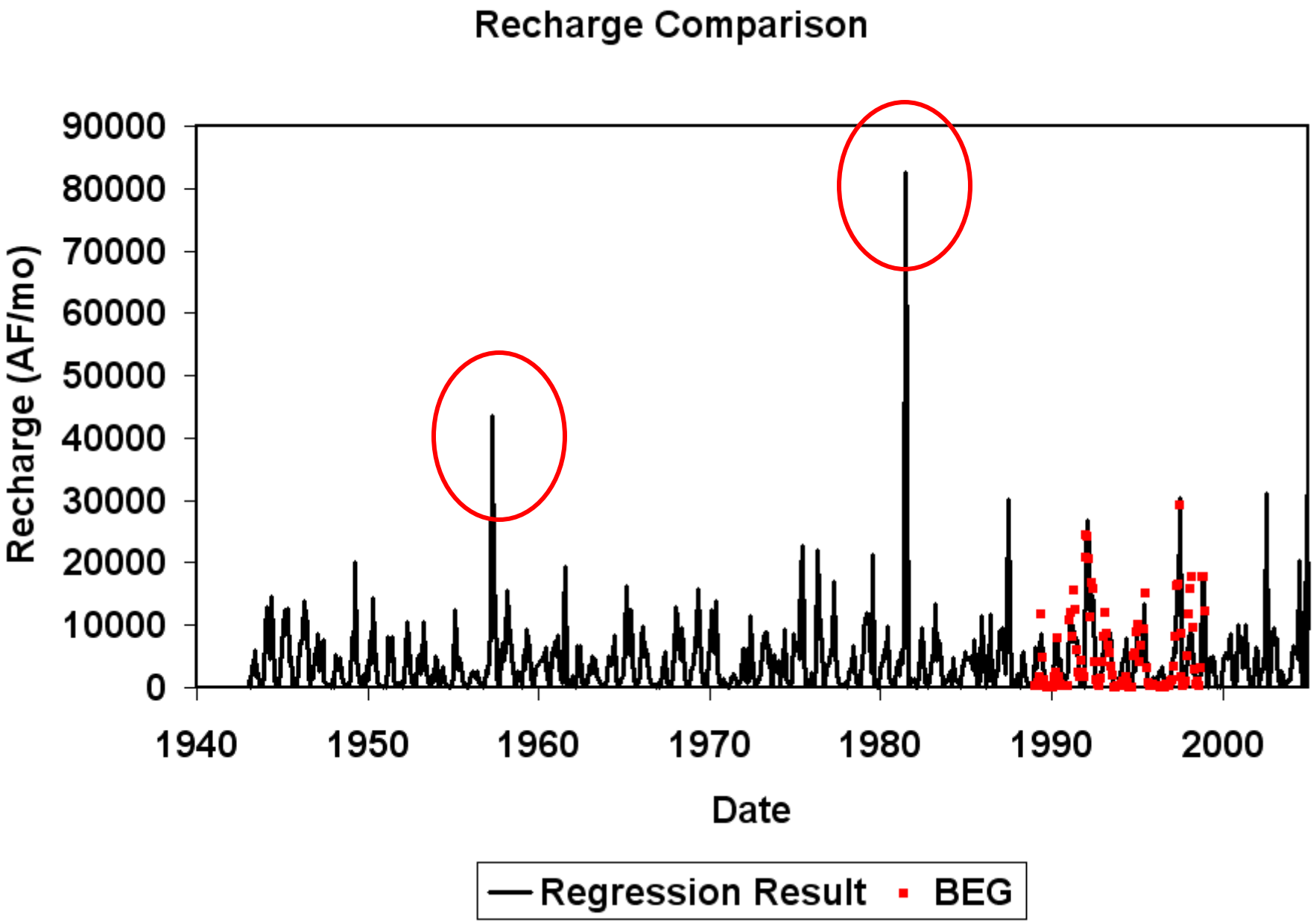
- Average of San Marcos and Austin Airport
- Current Month + ½ Month(-1) + ¼ Month(-2)


October - Zone 3
y = 3.12E-04x2 + 3.02E-04x
R2 = 9.54E-01
Zone Recharge (ft/day)
2.00E-01
1.80E-01
1.60E-01
1.40E-01
1.20E-01
1.00E-01
8.00E-02
6.00E-02
4.00E-02
2.00E-02
0.00E+00
0
5
10
15
20
25
30
Precipitation Index


March - Zone 8
y = 1.07E-03x2 + 1.80E-02x
R2 = 6.88E-01
Zone Recharge (ft/day)
3.50E-01
3.00E-01
2.50E-01
2.00E-01
1.50E-01
1.00E-01
5.00E-02
0.00E+00
0
2
4
6
8
10
12
Precipitation Index


Recharge Comparison
Recharge (AF/mo)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1989
1991
1993
1995
1997
Date
Regression Result
BEG


Recharge Comparison
Recharge (AF/mo)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1940
1950
1960
1970
1980
1990
2000
Date
Regression Result
BEG


Recharge Comparison
Recharge (AF/mo)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1940
1950
1960
1970
1980
1990
2000
Date
Regression Result
BEG

Calibration Parameters

- Adjust maximum recharge (by zone)
- Wet year adjustment (by month)
- Dry year adjustment (by month)
- Decadal adjustment (by decade)

Maximum Recharge

Zone	Max Recharge Rate (ft/day)
2	2.00E-03
3	2.00E-01
4	5.00E-02
5	1.97E-01
6	6.26E-02
7	3.01E-02
8	1.80E-01

Dry Year Factors

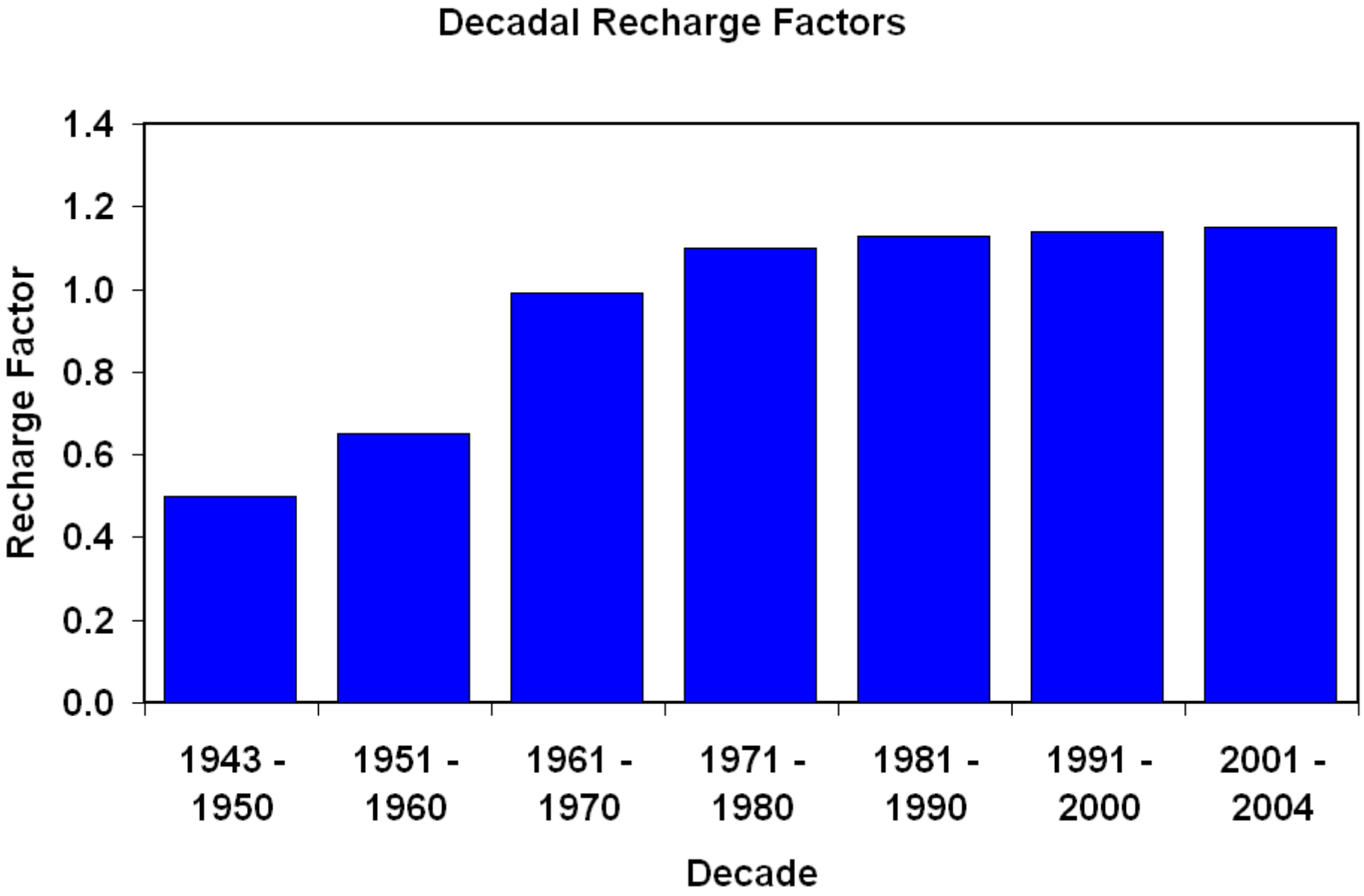
Month	Dry Threshold	Factor
1	4	0.143
2	4	0.1
3	4	0.1
4	5	0.1
5	4	0.1
6	6	0.1
7	4	0.1
8	4	0.1
9	4	0.1
10	7	0.1
11	6	0.1
12	5	0.1

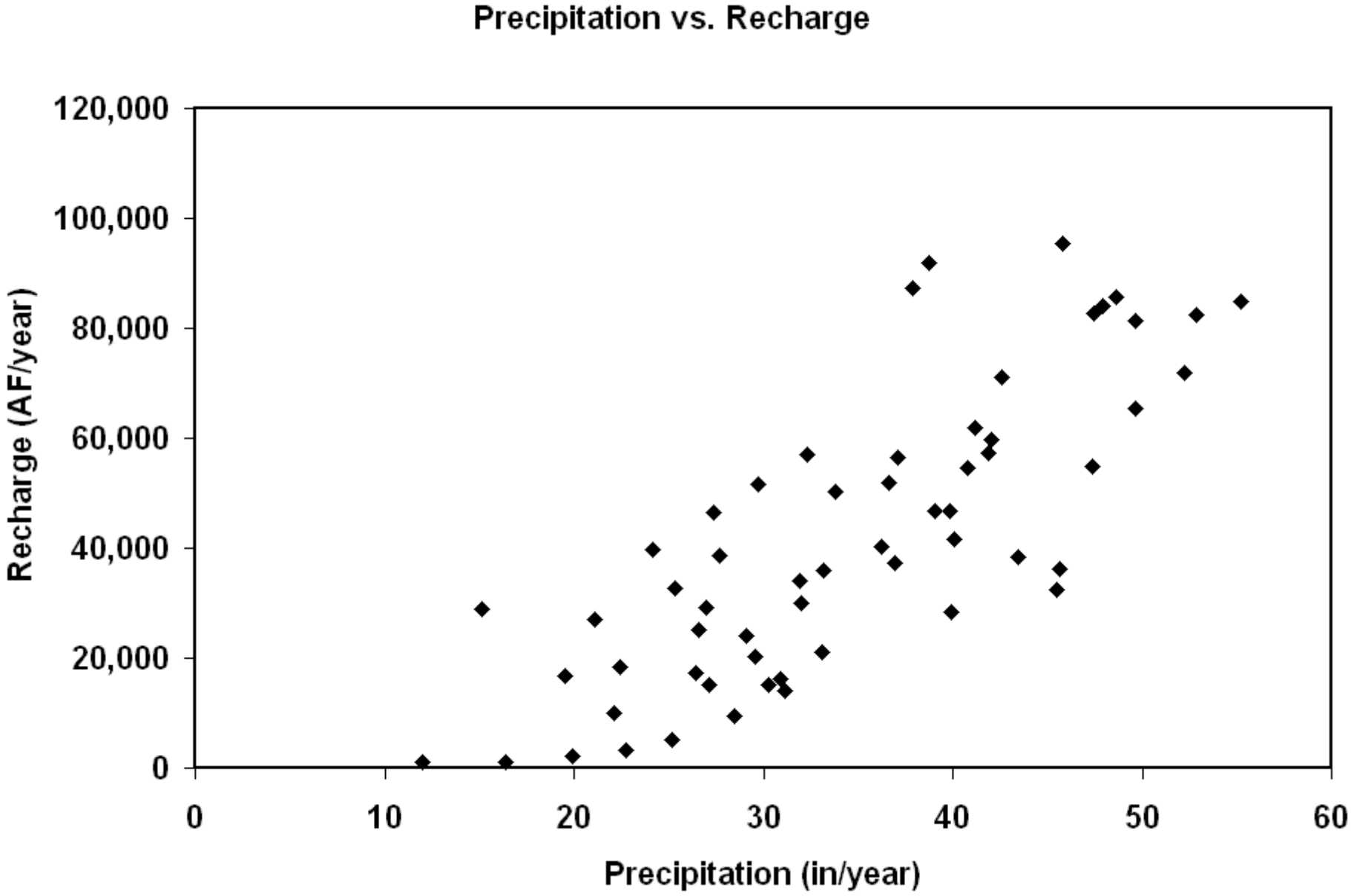
Wet Year Factors

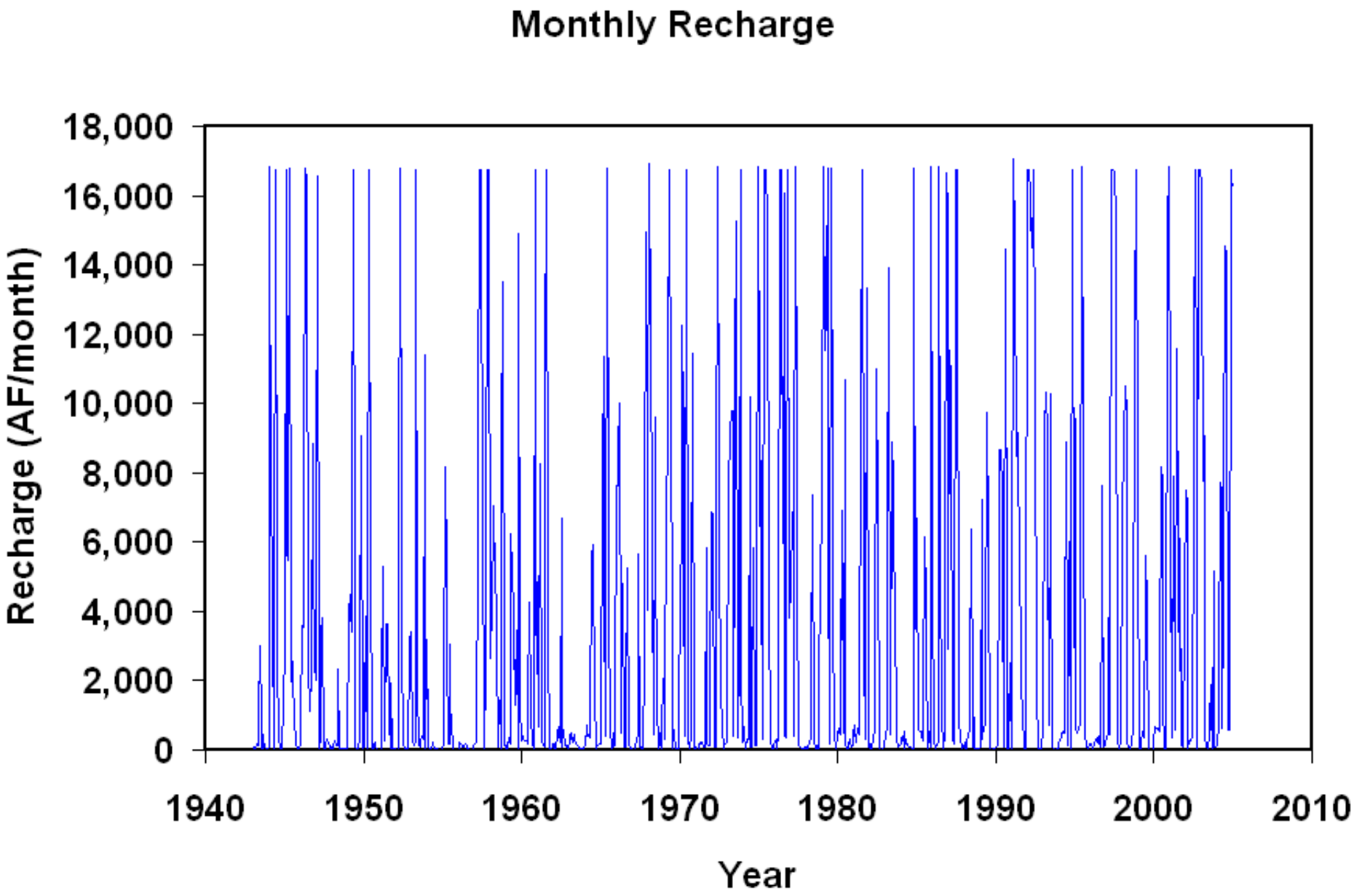
Month	Wet Threshold	Factor
1	6	9.5
2	7	0.7
3	8	0.7
4	6	6.7
5	9	6.5
6	8	0.7
7	7	4.5
8	6	9
9	8	10.5
10	7	8.5
11	9	10.5
12	9	2.5

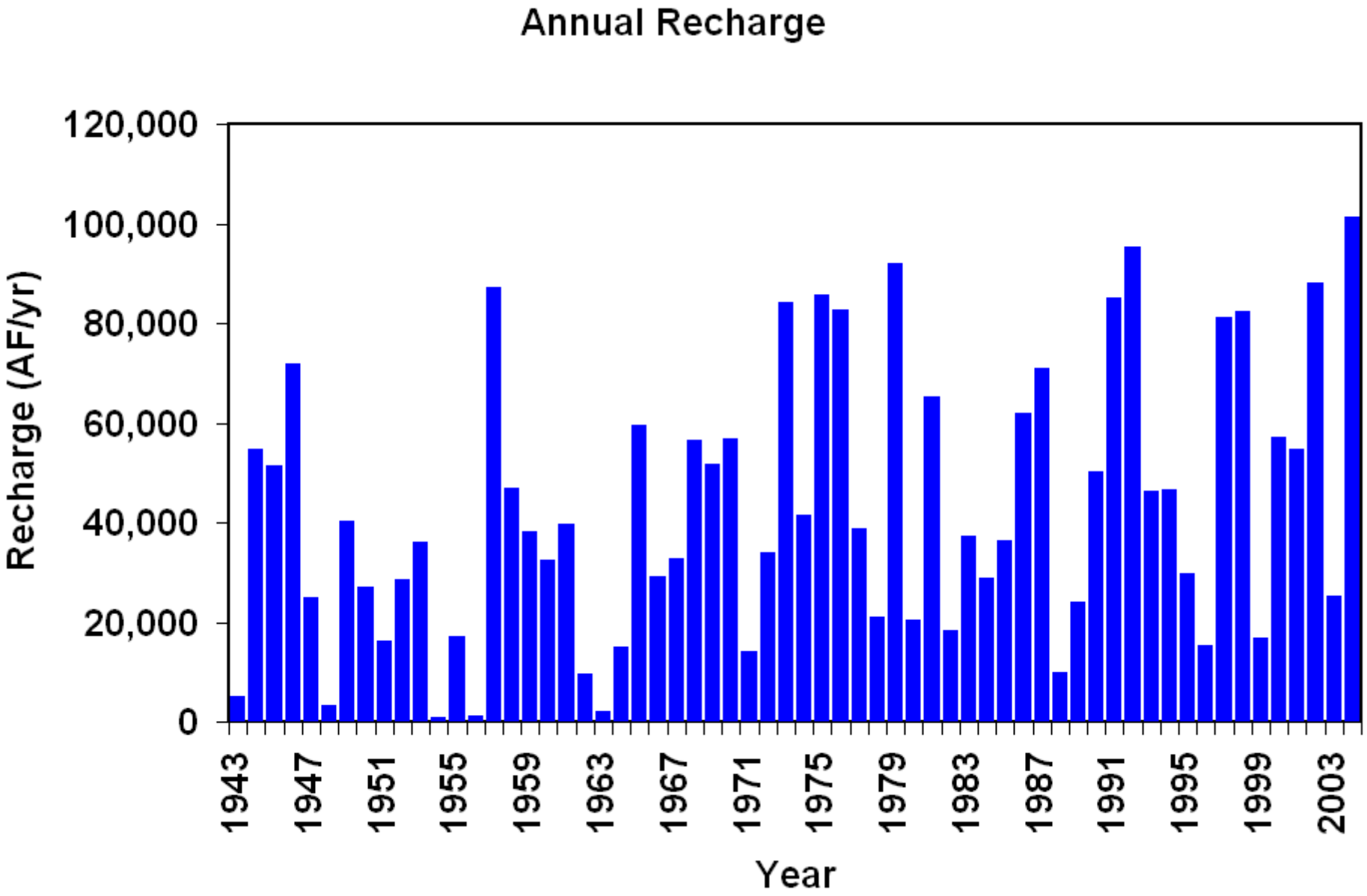
Decadal Factors

Decade	Factor
1943 - 1950	0.50
1951 - 1960	0.65
1961 - 1970	0.99
1971 - 1980	1.10
1981 - 1990	1.13
1991 - 2000	1.14
2001 - 2004	1.15


Decadal Recharge Factors
Recharge Factor
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1943 - 1950
1951 - 1960
1961 - 1970
1971 - 1980
1981 - 1990
1991 - 2000
2001 - 2004
Decade


Precipitation vs. Recharge
Recharge (AF/year)
120,000
100,000
80,000
60,000
40,000
20,000
0
0
10
20
30
40
50
60
Precipitation (in/year)


Monthly Recharge
Recharge (AF/month)
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1940
1950
1960
1970
1980
1990
2000
2010
Year


Annual Recharge
Recharge (AF/yr)
120,000
100,000
80,000
60,000
40,000
20,000
0
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
Year

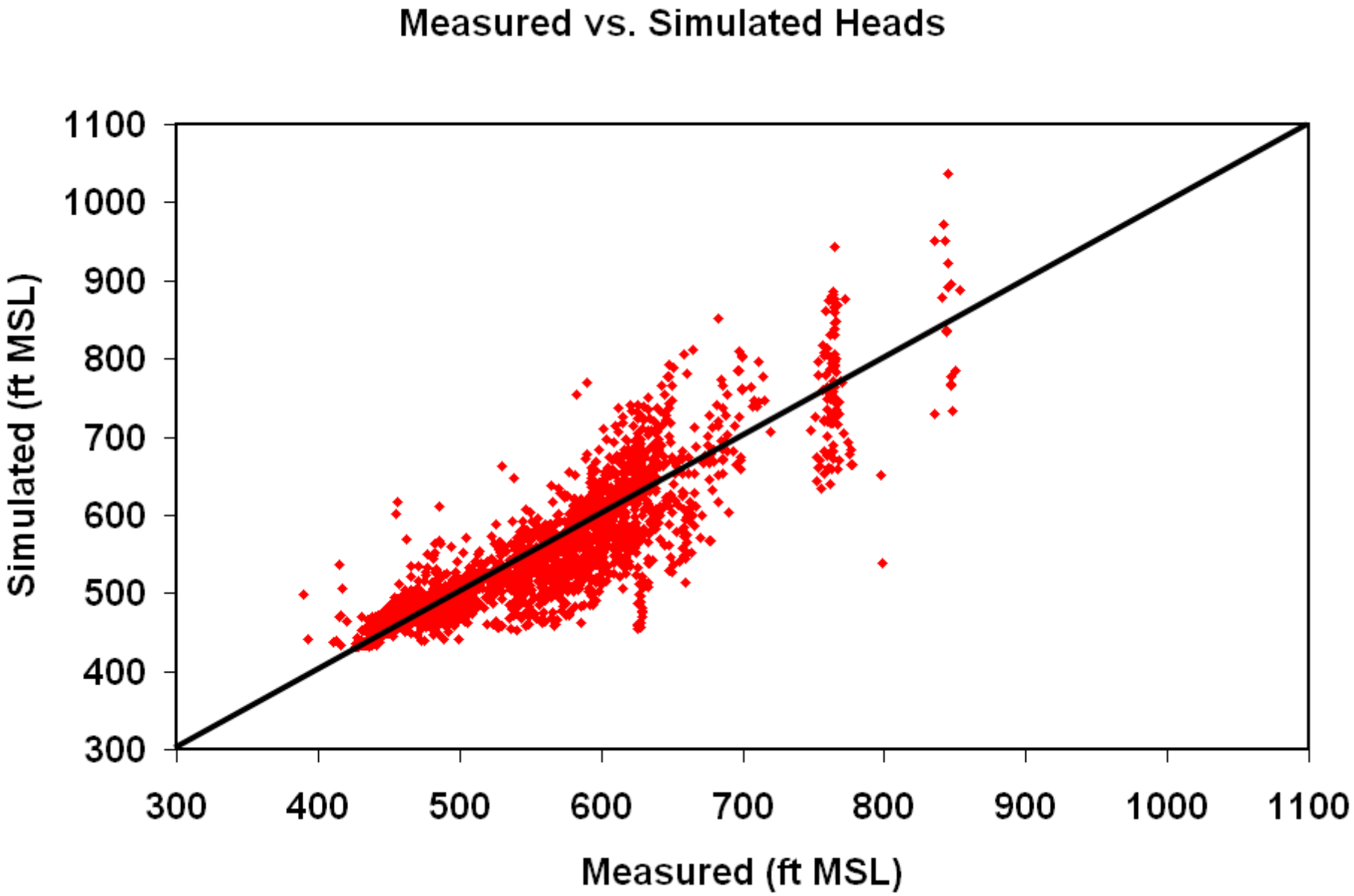
Calibration Targets

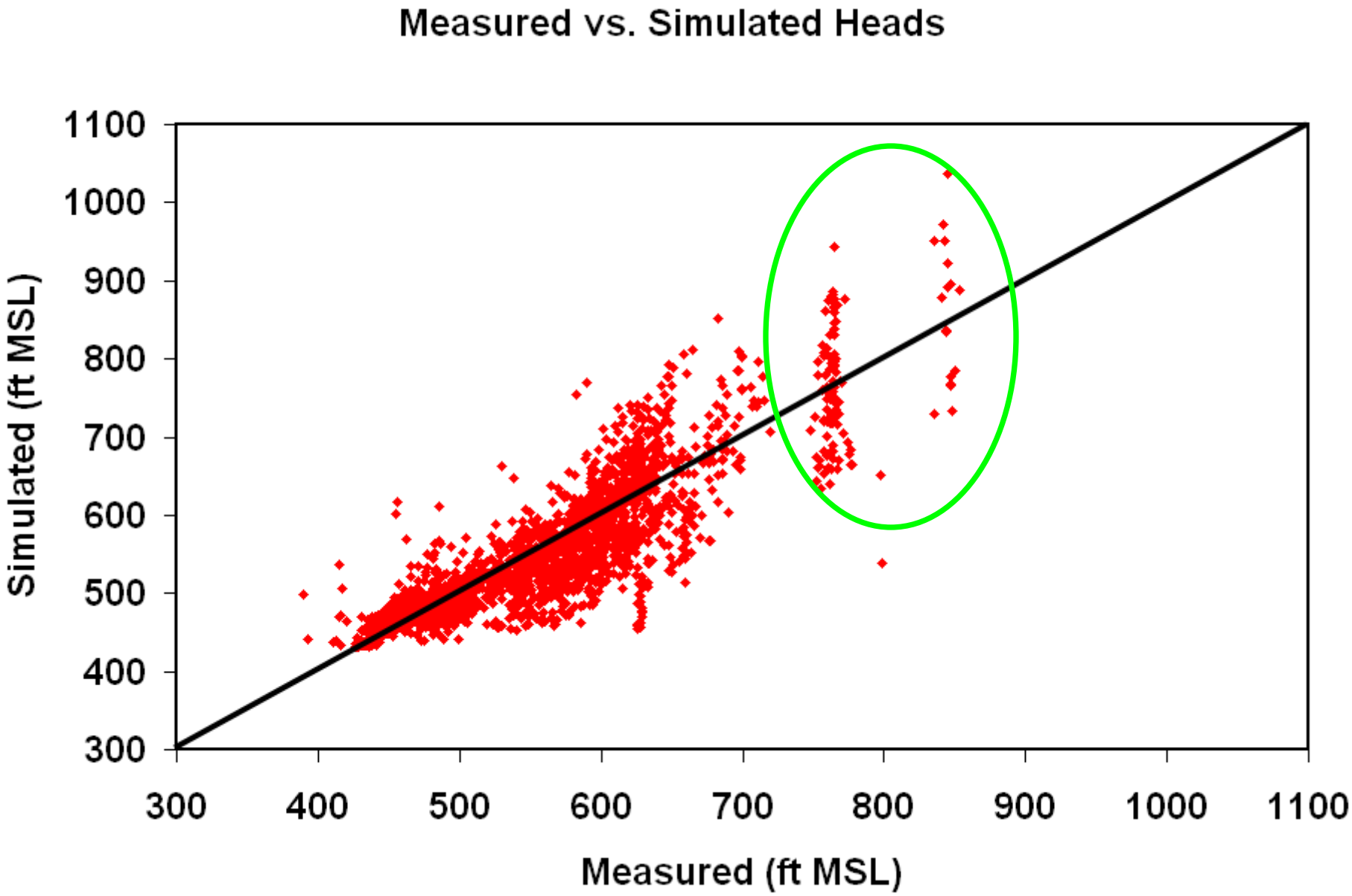
- 153 Wells
- 2246 Head Measurements
- 744 Barton Spring Flow “Measurements”

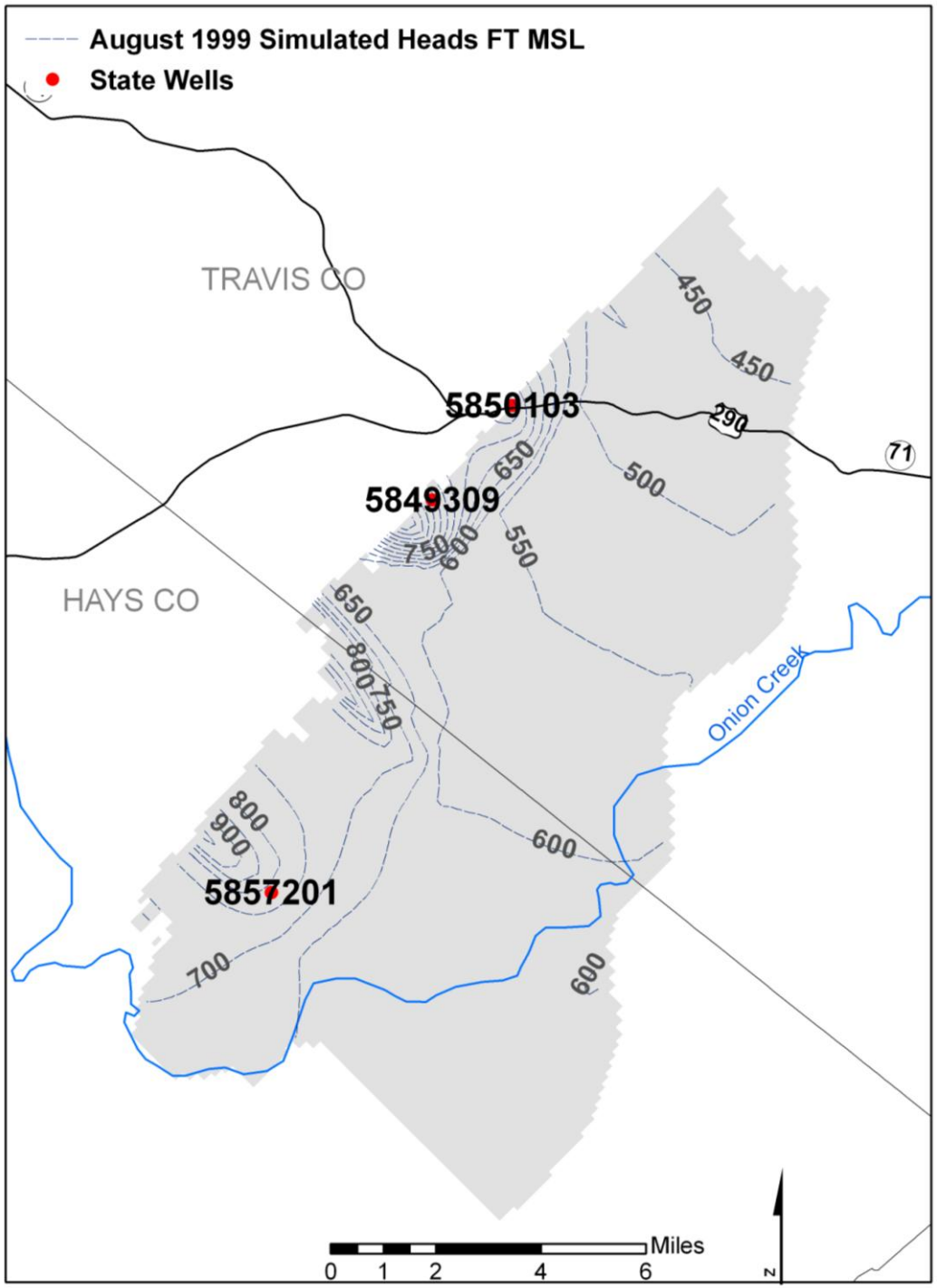
Calibration Summary

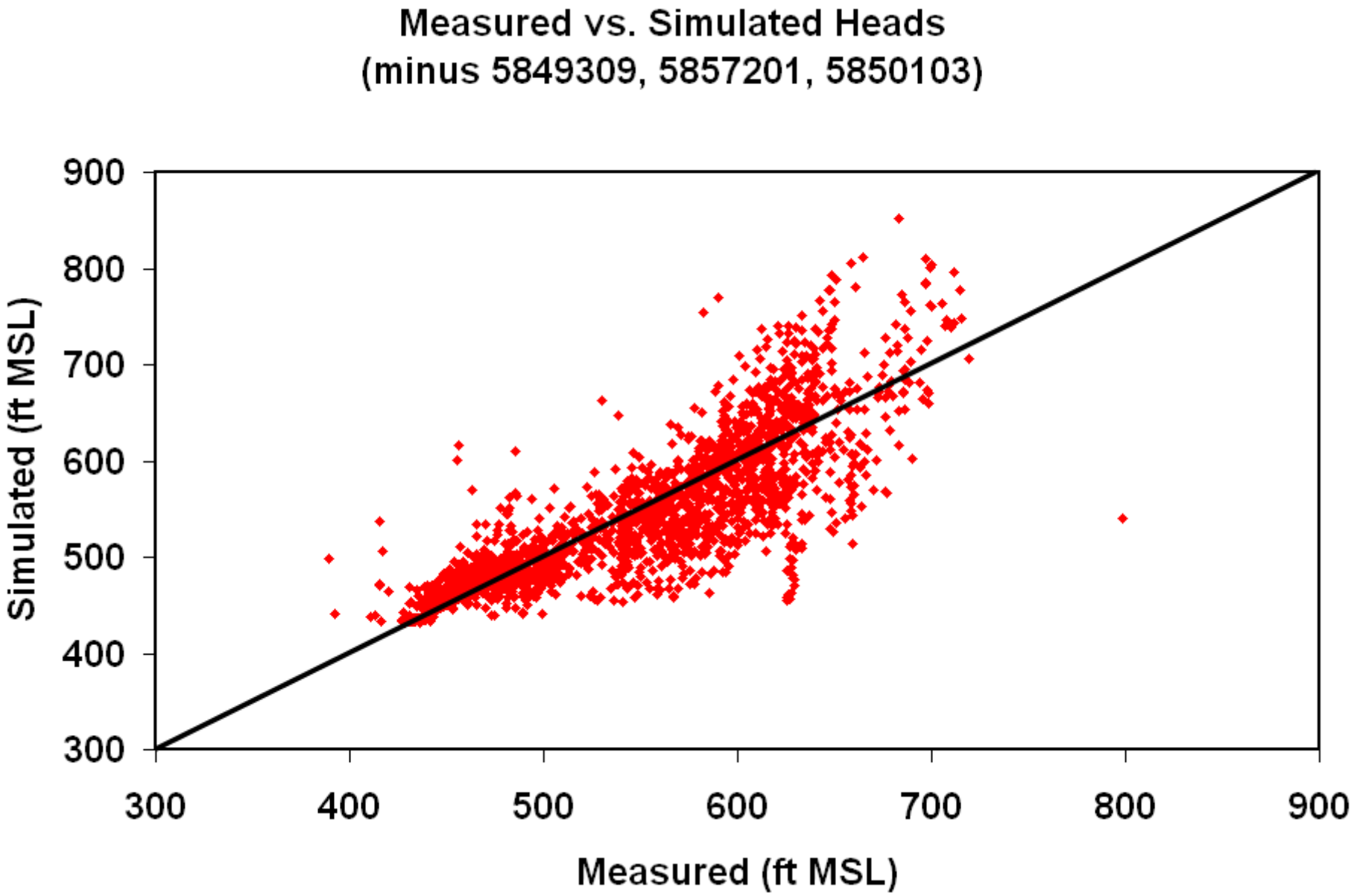
	New Model	BEG Model
Simulation Period	1943-2004	1989-1998
Number of Stress Periods	744	120
Error of Head Drop Across Model	7%	10-22%*

*March/April 1994 July/Aug 1996 July/Aug 1998


Measured vs. Simulated Heads
Simulated (ft MSL)
1100
1000
900
800
700
600
500
400
300
300
400
500
600
700
800
900
1000
1100
Measured (ft MSL)


Measured vs. Simulated Heads
Simulated (ft MSL)
1100
1000
900
800
700
600
500
400
300
300
400
500
600
700
800
900
1000
1100
Measured (ft MSL)


August 1999 Simulated Heads FT MSL
State Wells
TRAVIS CO
HAYS CO
5850103
5849309
5857201
450
450
290
71
500
650
600
550
750
650
800
750
800
900
600
700
600
Onion Creek
Miles
0 1 2 4 6
N


Measured vs. Simulated Heads
(minus 5849309, 5857201, 5850103)
Simulated (ft MSL)
900
800
700
600
500
400
300
300
400
500
600
700
800
900
Measured (ft MSL)

Comparison

	All Wells	All Wells less 3
Range	464	409
Standard Deviation of Residuals	44.69	42.43
Standard Deviation/Range	0.096	0.104

Comparison

	All Wells	All Wells less 3
Range	464	409
Standard Deviation of Residuals	44.69	42.43
Standard Deviation/Range	0.096	0.104

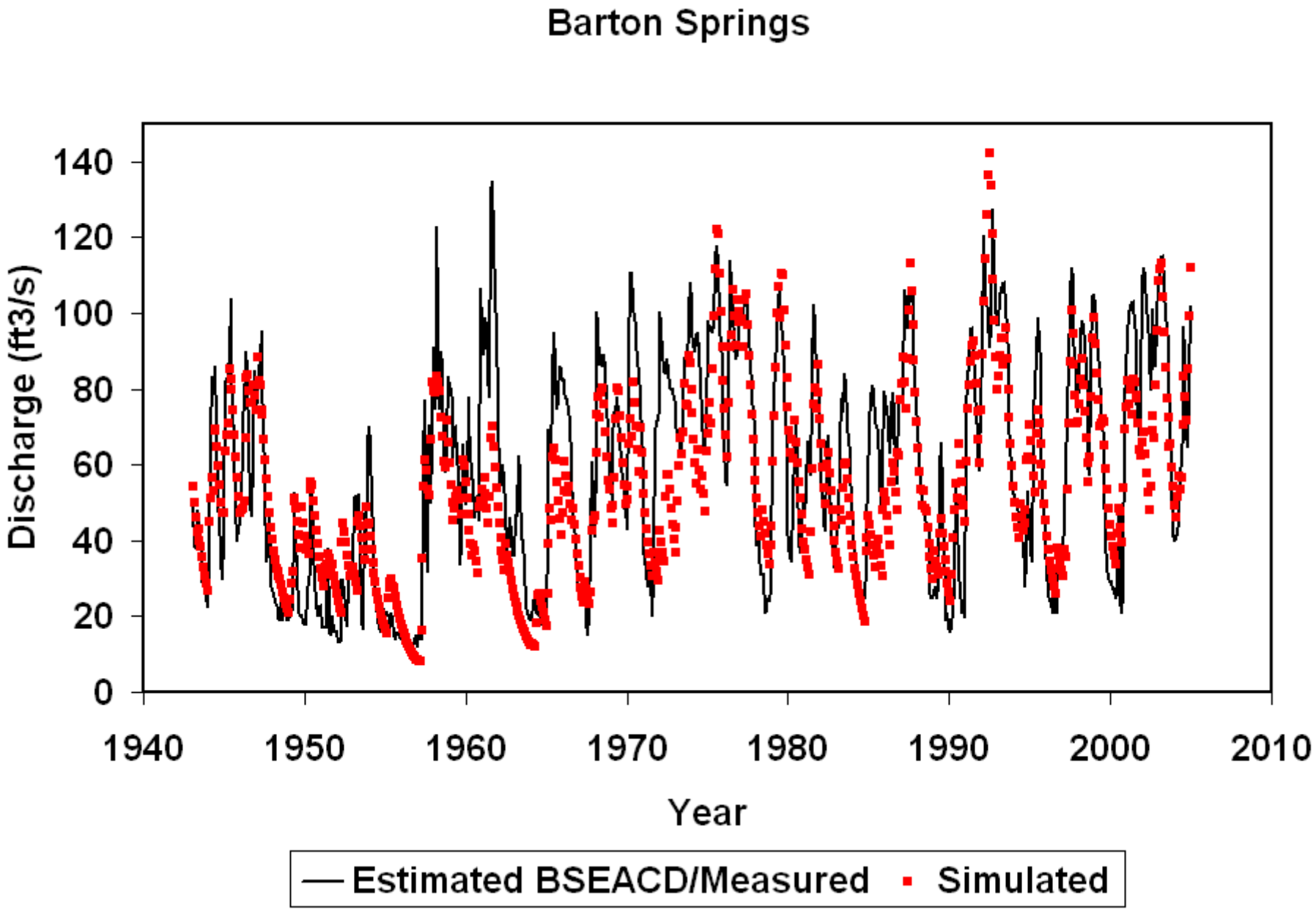
Comparison

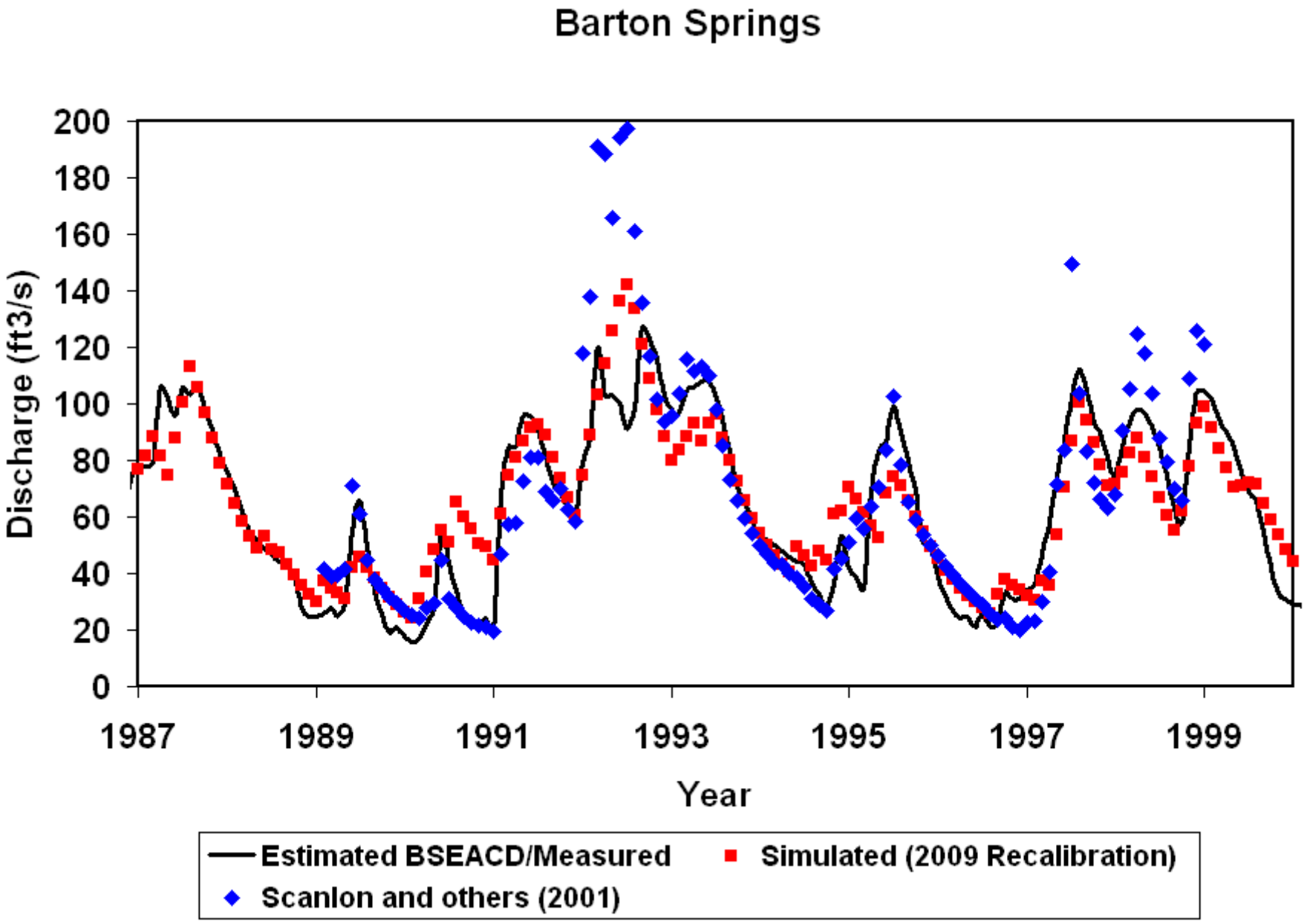
	All Wells	All Wells less 3
Range	464	409
Standard Deviation of Residuals	44.69	42.43
Standard Deviation/Range	0.096	0.104

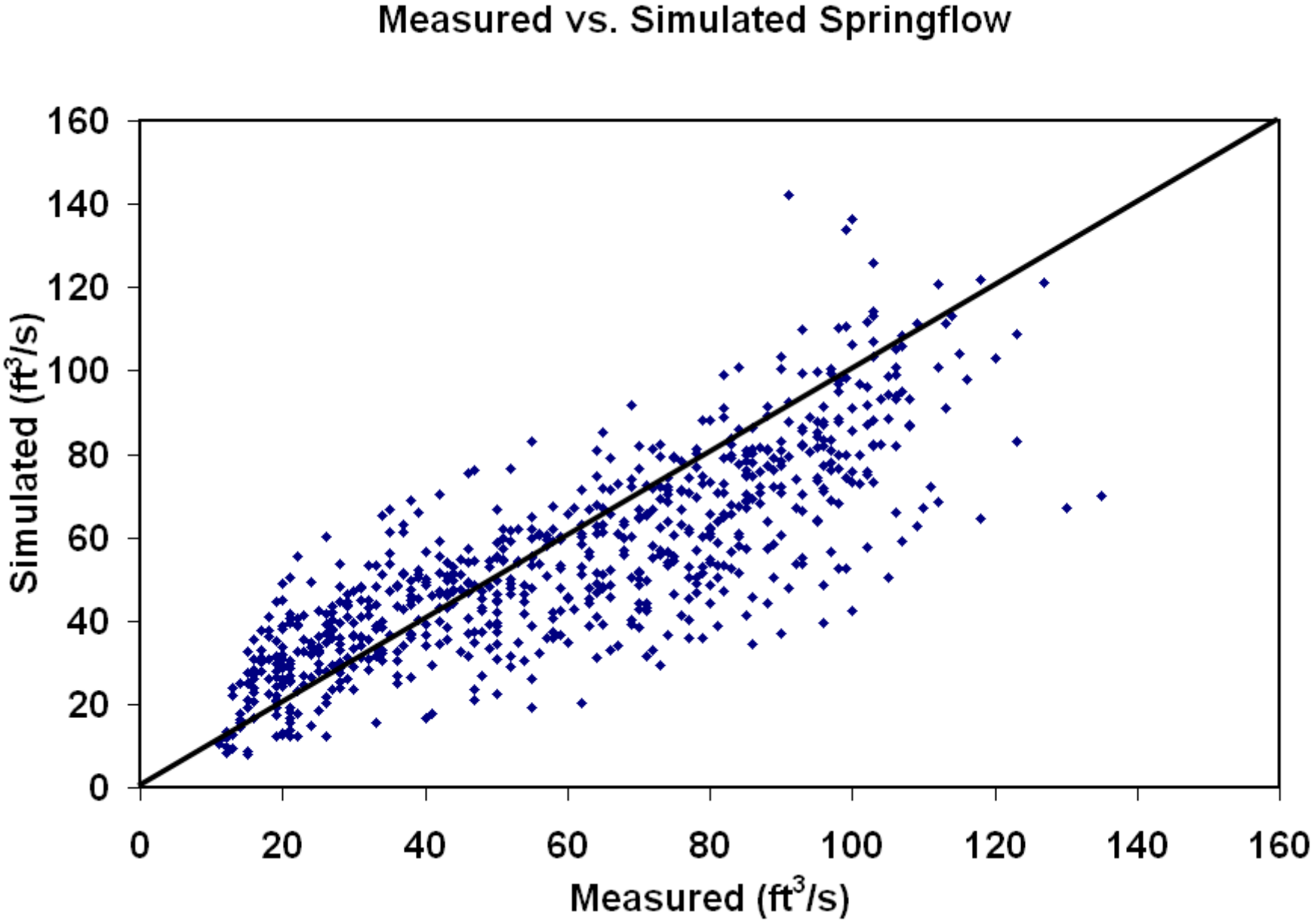
Comparison

	All Wells	All Wells less 3
Range	464	409
Standard Deviation of Residuals	44.69	42.43
Standard Deviation/Range	0.096	0.104

Standard < 0.10


Barton Springs
Discharge (ft3/s)
0
20
40
60
80
100
120
140
1940
1950
1960
1970
1980
1990
2000
2010
Year
Estimated BSEACD/Measured
Simulated


Barton Springs
Discharge (ft3/s)
200
180
160
140
120
100
80
60
40
20
0
1987
1989
1991
1993
1995
1997
1999
Year
Estimated BSEACD/Measured
Simulated (2009 Recalibration)
Scanlon and others (2001)

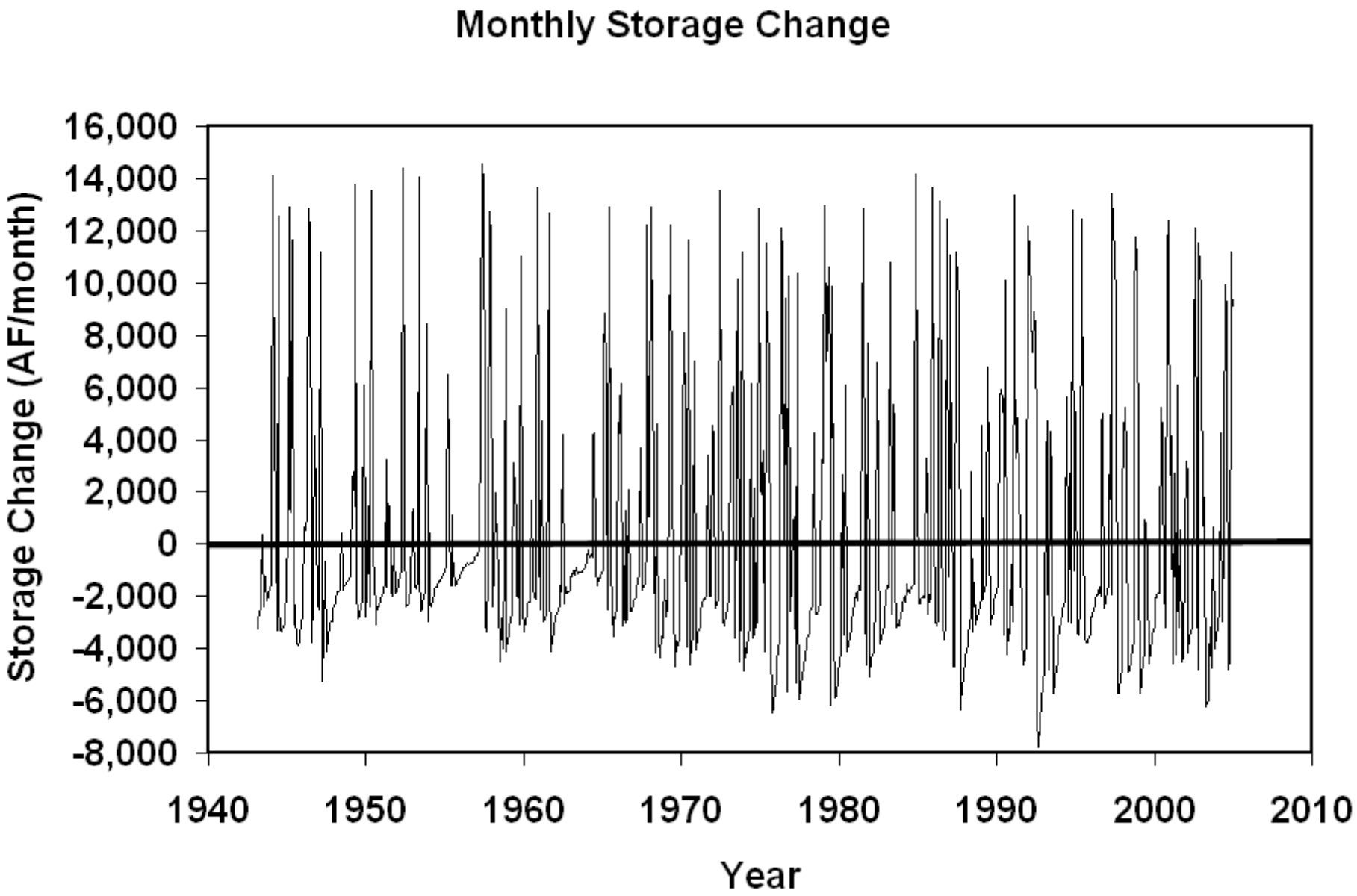

Measured vs. Simulated Springflow
Simulated (ft3/s)
Measured (ft3/s)
0
20
40
60
80
100
120
140
160

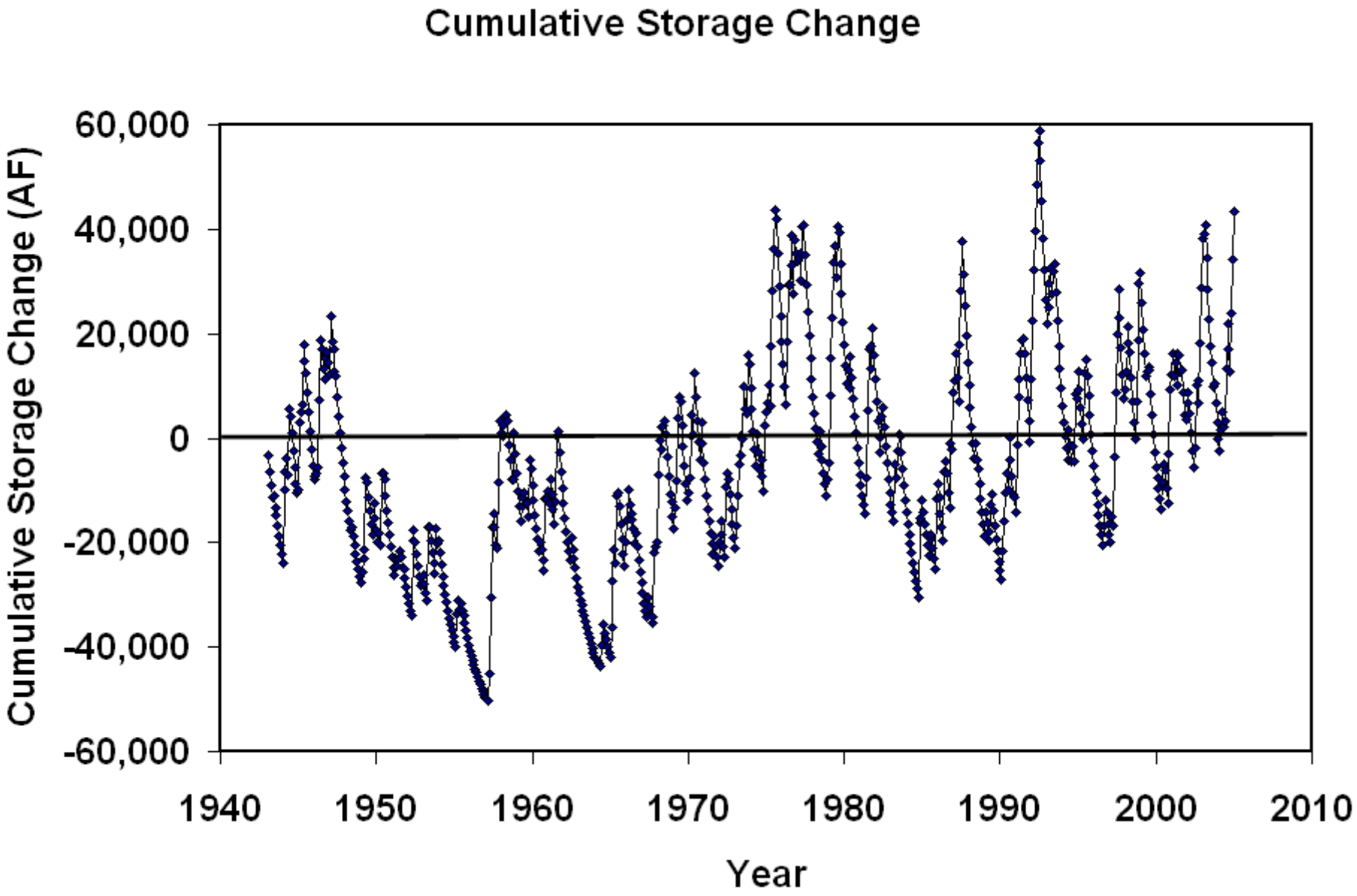
Calibration Statistics

	Barton Springs
Range (cfs)	134
Standard Deviation of Residuals	16.86
Standard Deviation/Range	0.126

Groundwater Budget

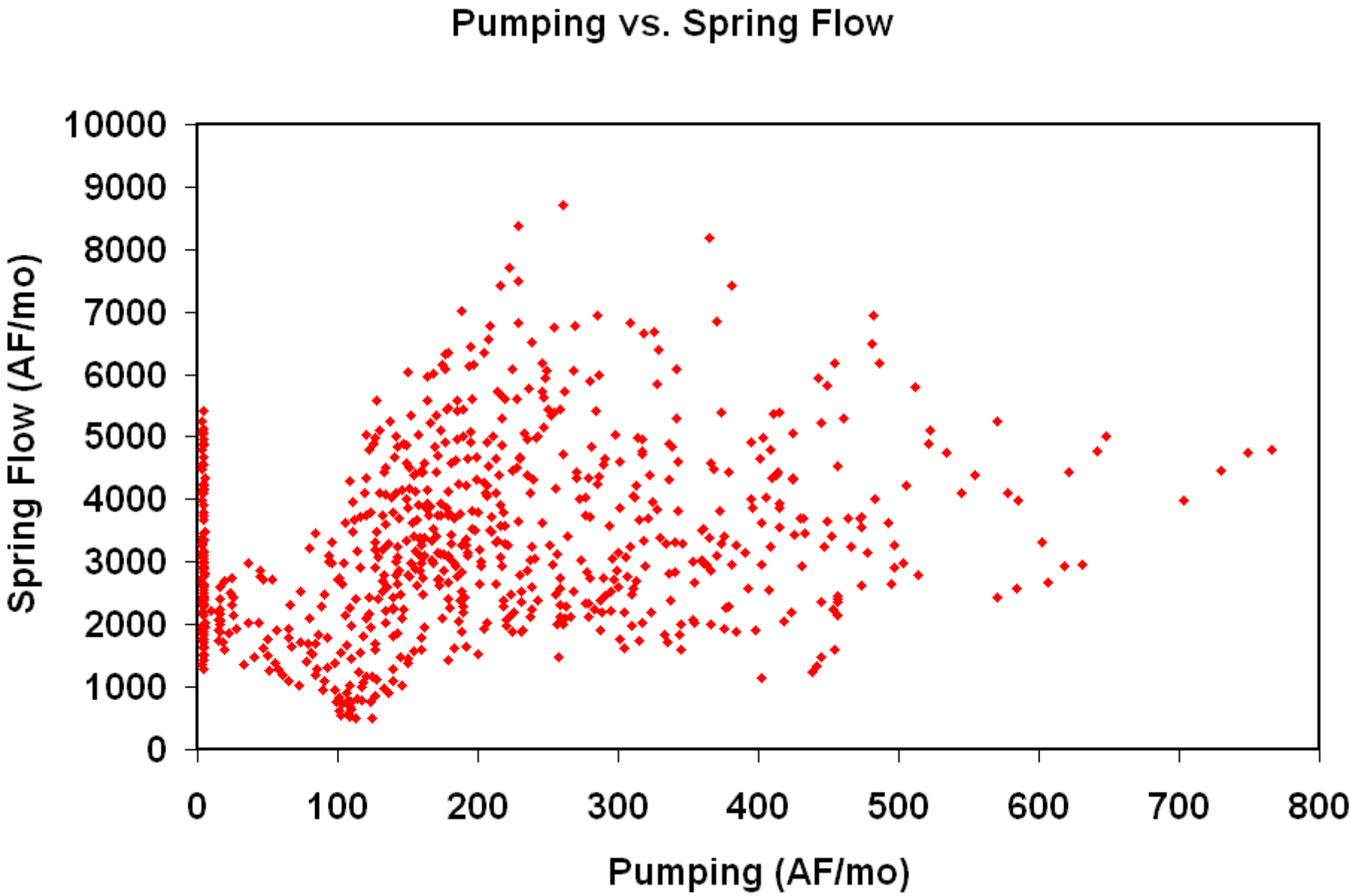
- Monthly
  - Recharge, Pumping, Spring Flow
  - Storage Change
  - Cumulative Storage Change
  - Cross Plots
- Annual

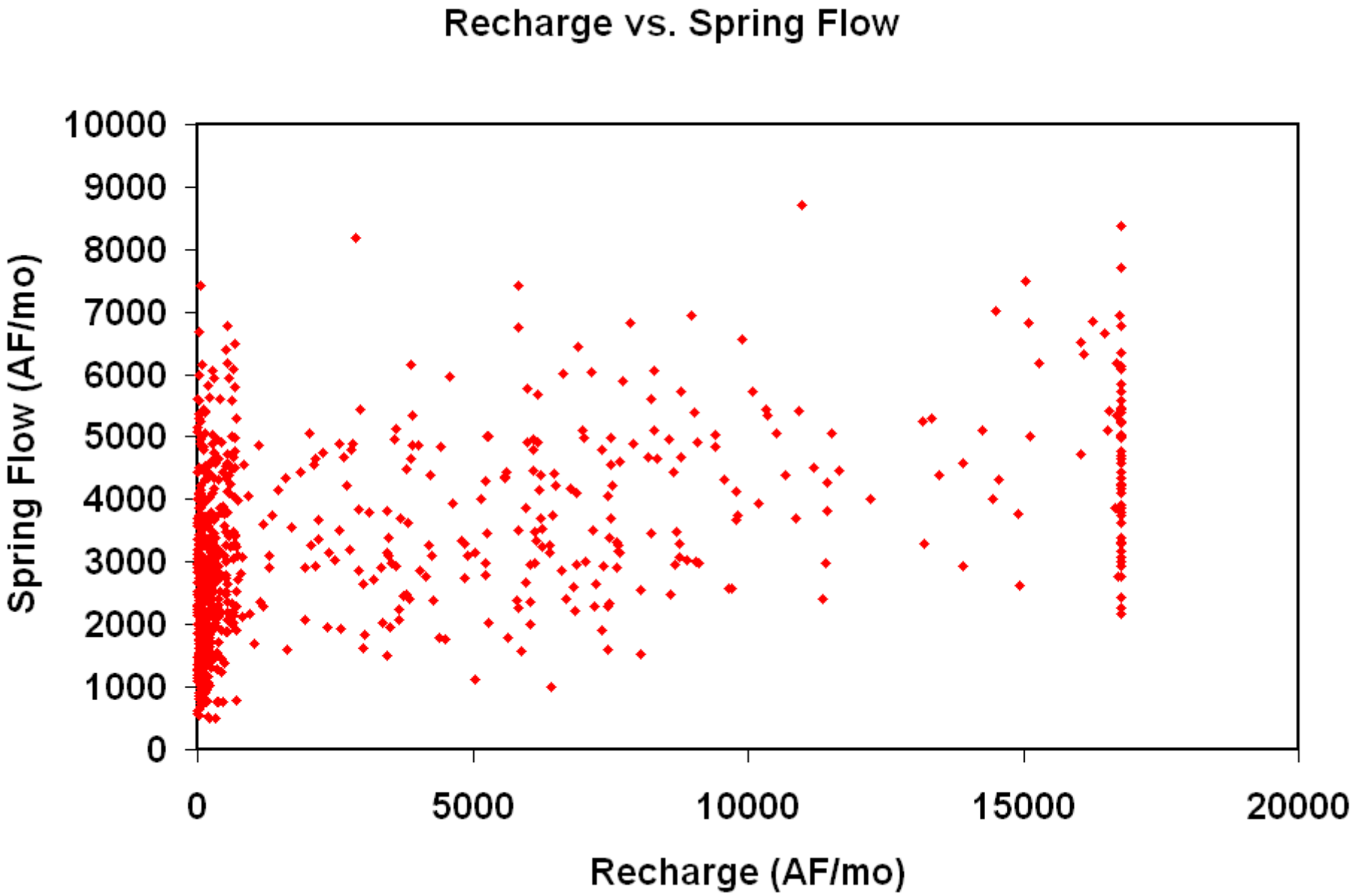

Monthly Storage Change
Storage Change (AF/month)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
-6,000
-8,000
1940
1950
1960
1970
1980
1990
2000
2010
Year

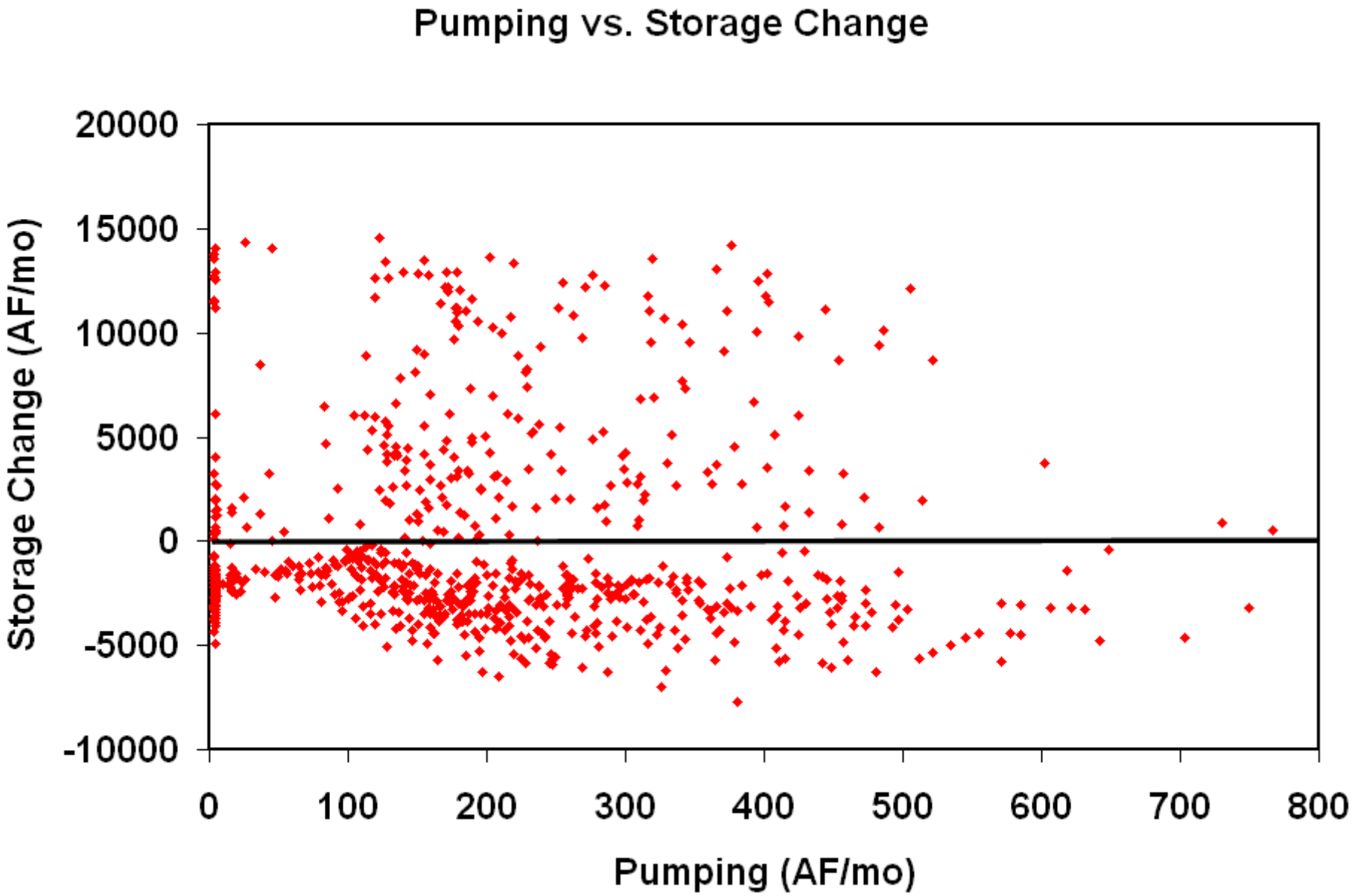

Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year

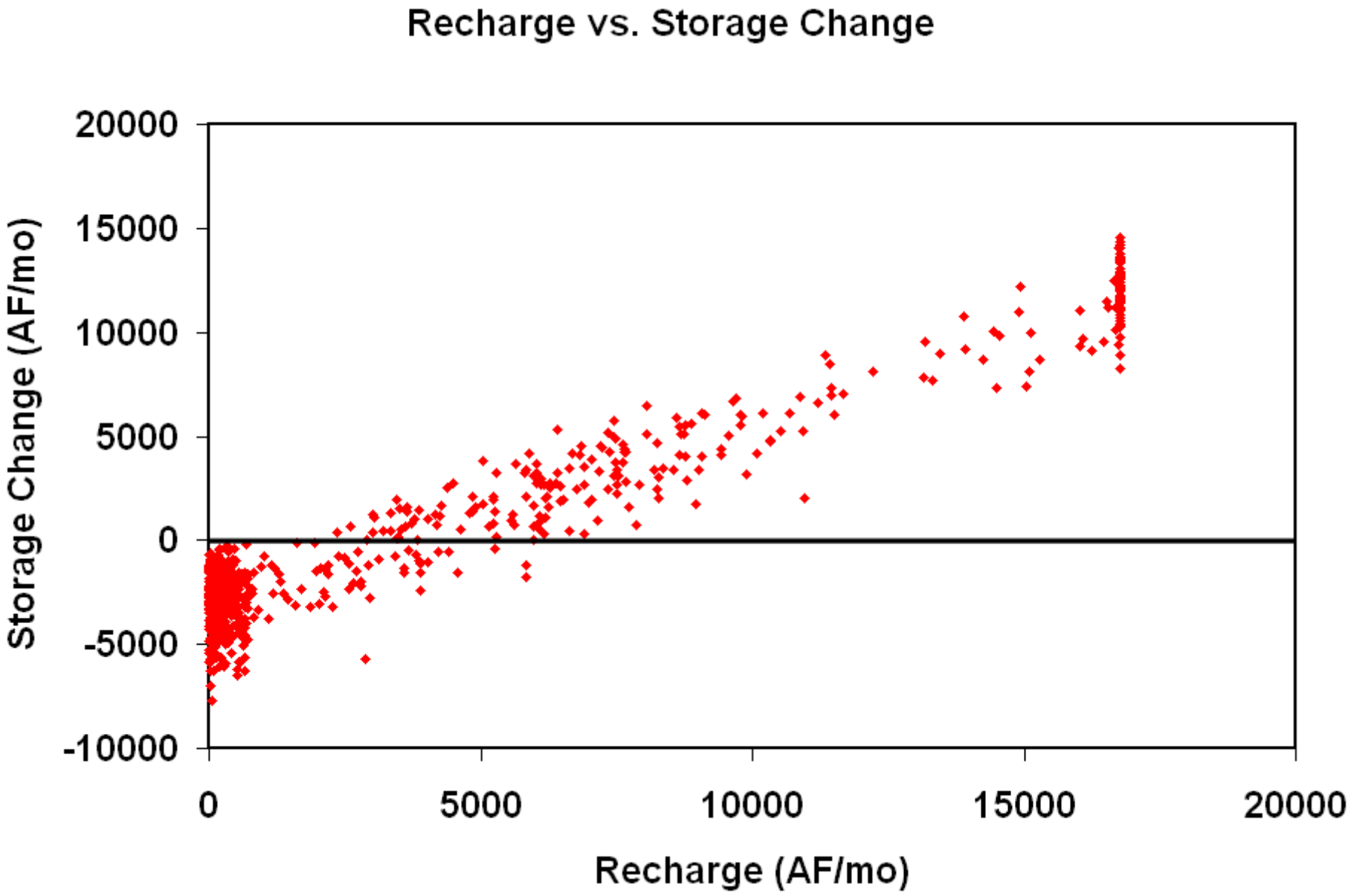
Cross Plots

- Changes in Spring Flow
  - Pumping
  - Recharge
- Changes in Storage
  - Pumping
  - Recharge


Pumping vs. Spring Flow
Spring Flow (AF/mo)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
100
200
300
400
500
600
700
800
Pumping (AF/mo)

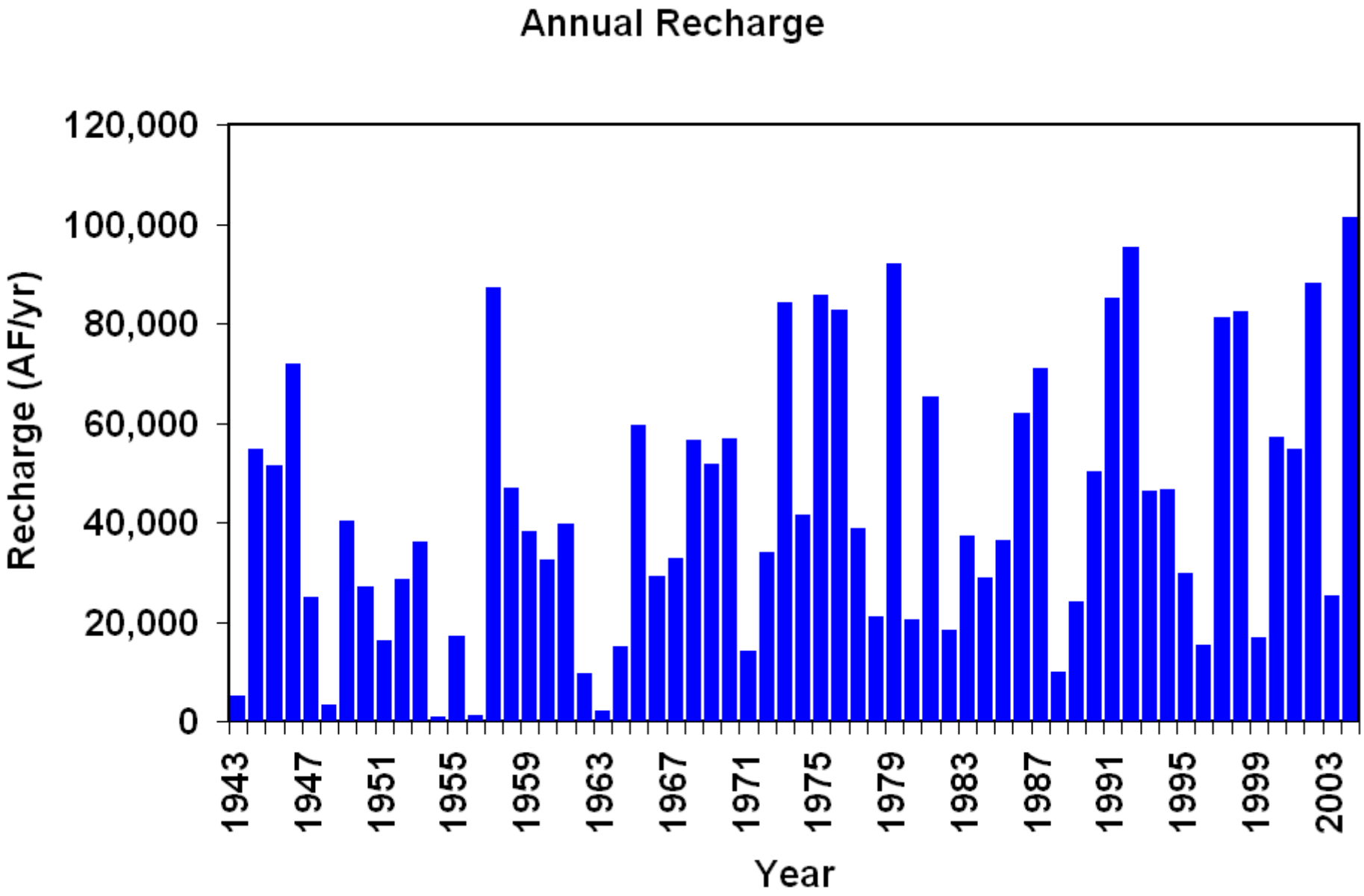

Recharge vs. Spring Flow
Spring Flow (AF/mo)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5000
10000
15000
20000
Recharge (AF/mo)

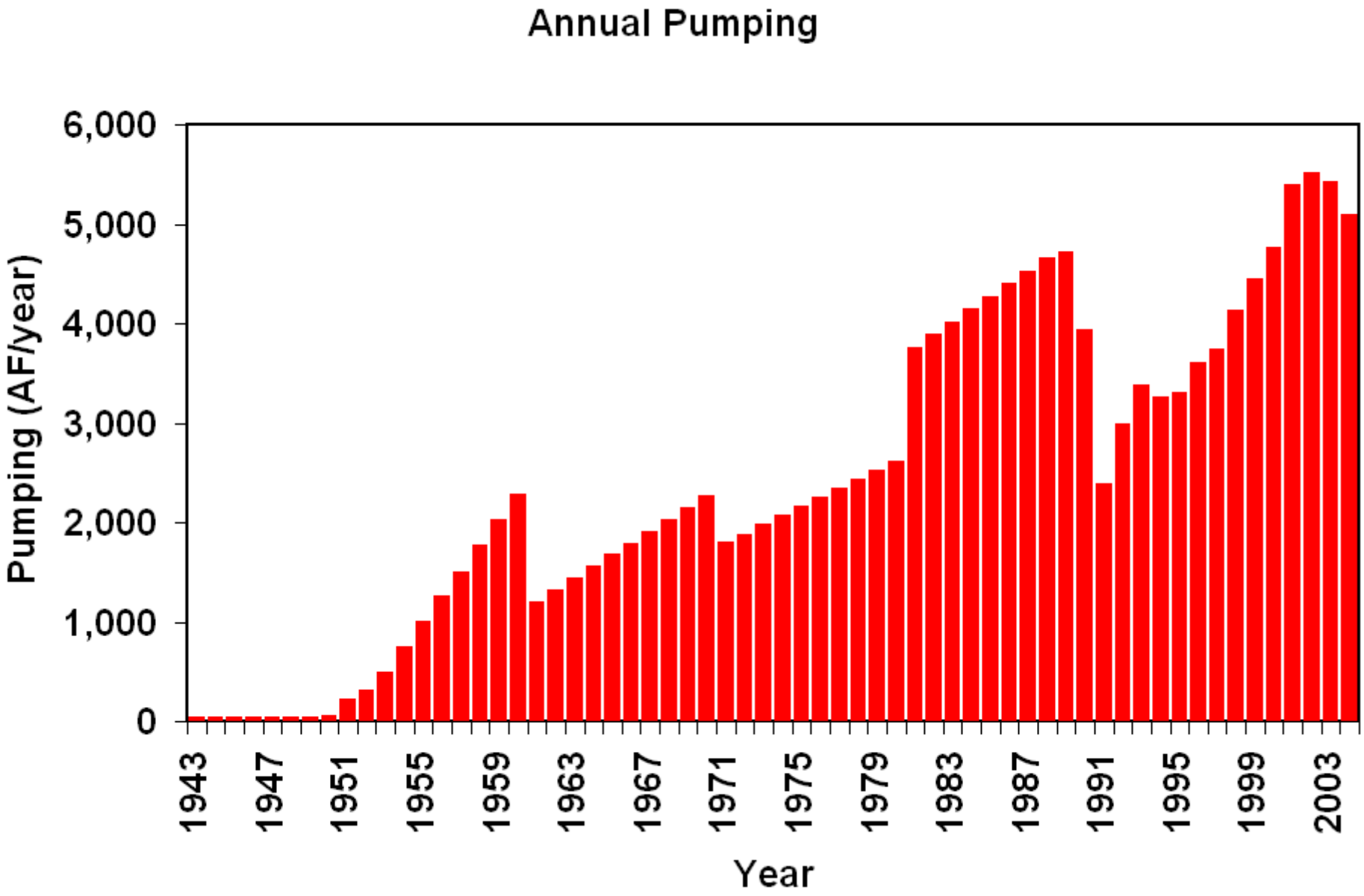

Pumping vs. Storage Change
Storage Change (AF/mo)
20000
15000
10000
5000
0
-5000
-10000
0
100
200
300
400
500
600
700
800
Pumping (AF/mo)

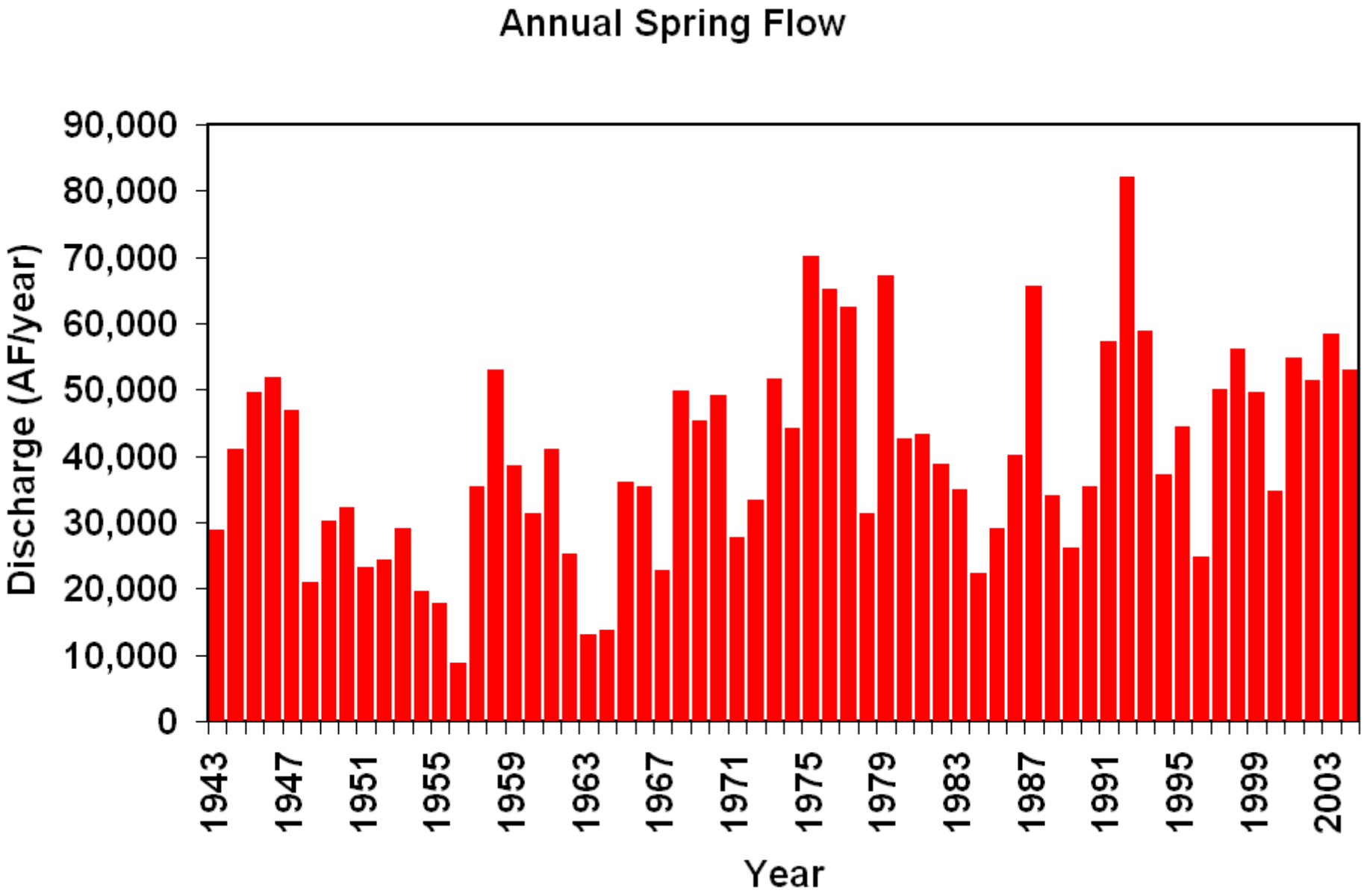

Recharge vs. Storage Change
Storage Change (AF/mo)
20000
15000
10000
5000
0
-5000
-10000
0
5000
10000
15000
20000
Recharge (AF/mo)

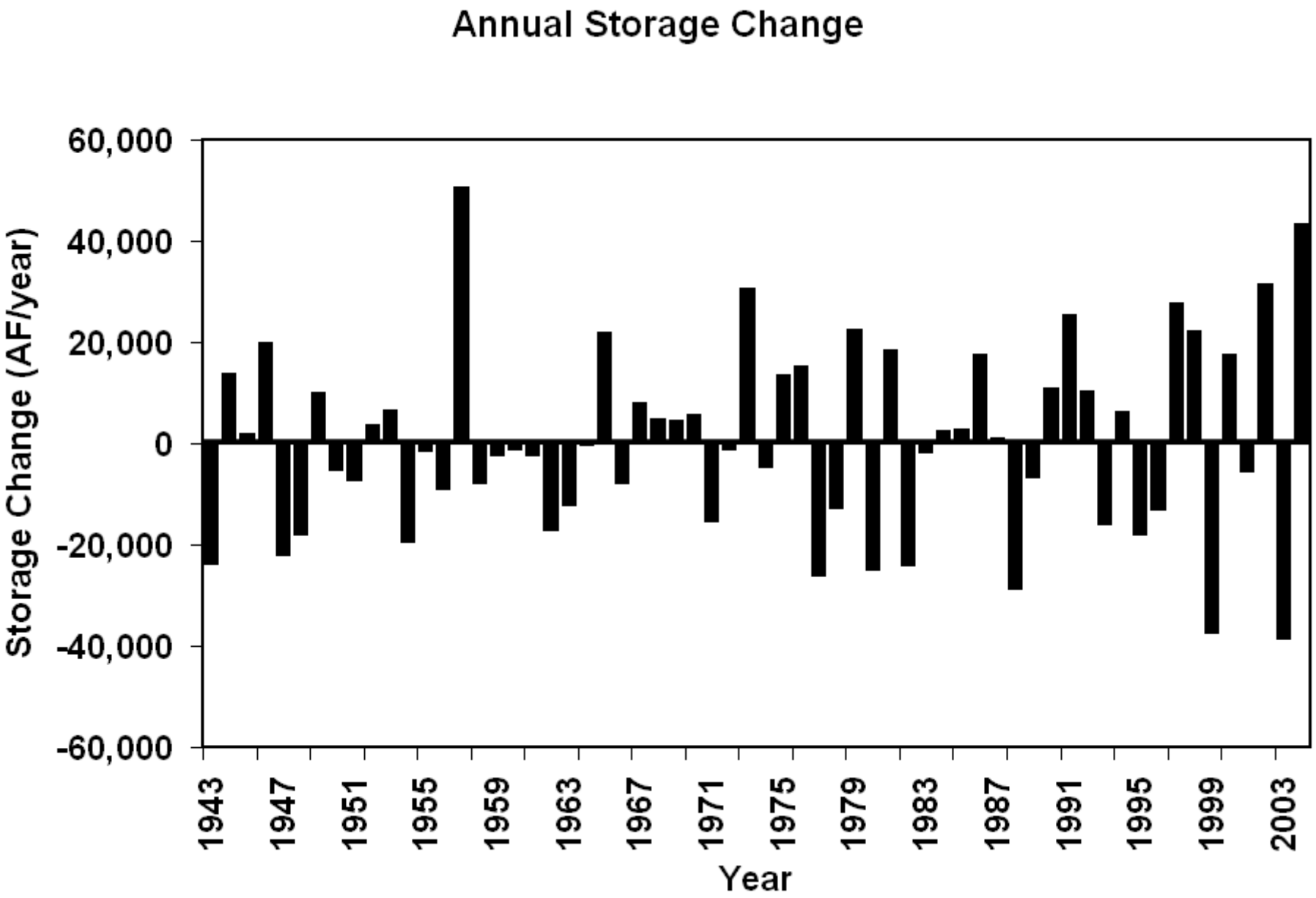
Groundwater Budget

- Monthly
- Annual
  - Recharge
  - Pumping
  - Spring Flow
  - Storage Change
  - Cross Plots


Annual Recharge
Recharge (AF/yr)
120,000
100,000
80,000
60,000
40,000
20,000
0
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
Year

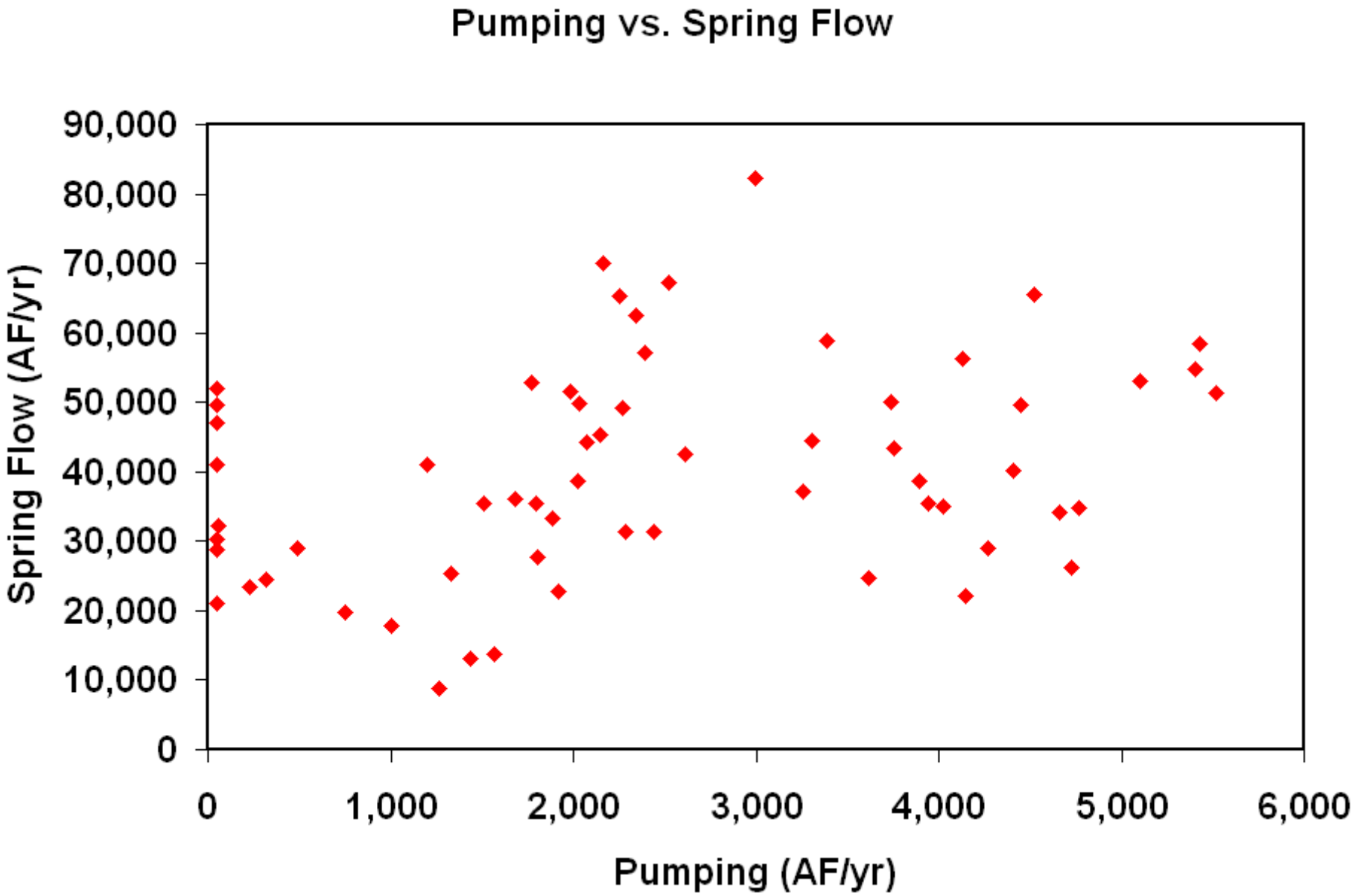

Annual Pumping
Pumping (AF/year)
6,000
5,000
4,000
3,000
2,000
1,000
0
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
Year

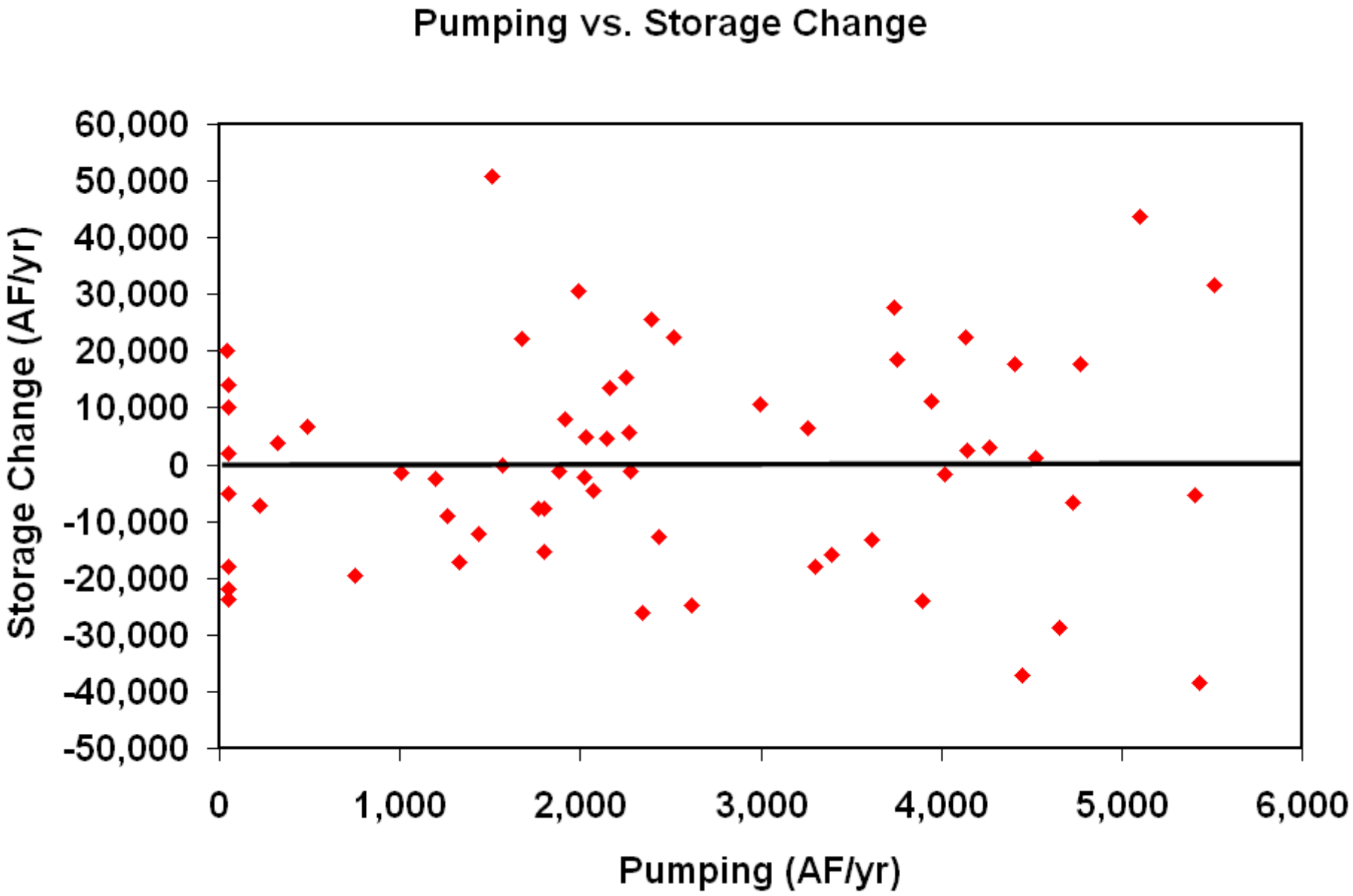

Annual Spring Flow
Discharge (AF/year)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
Year

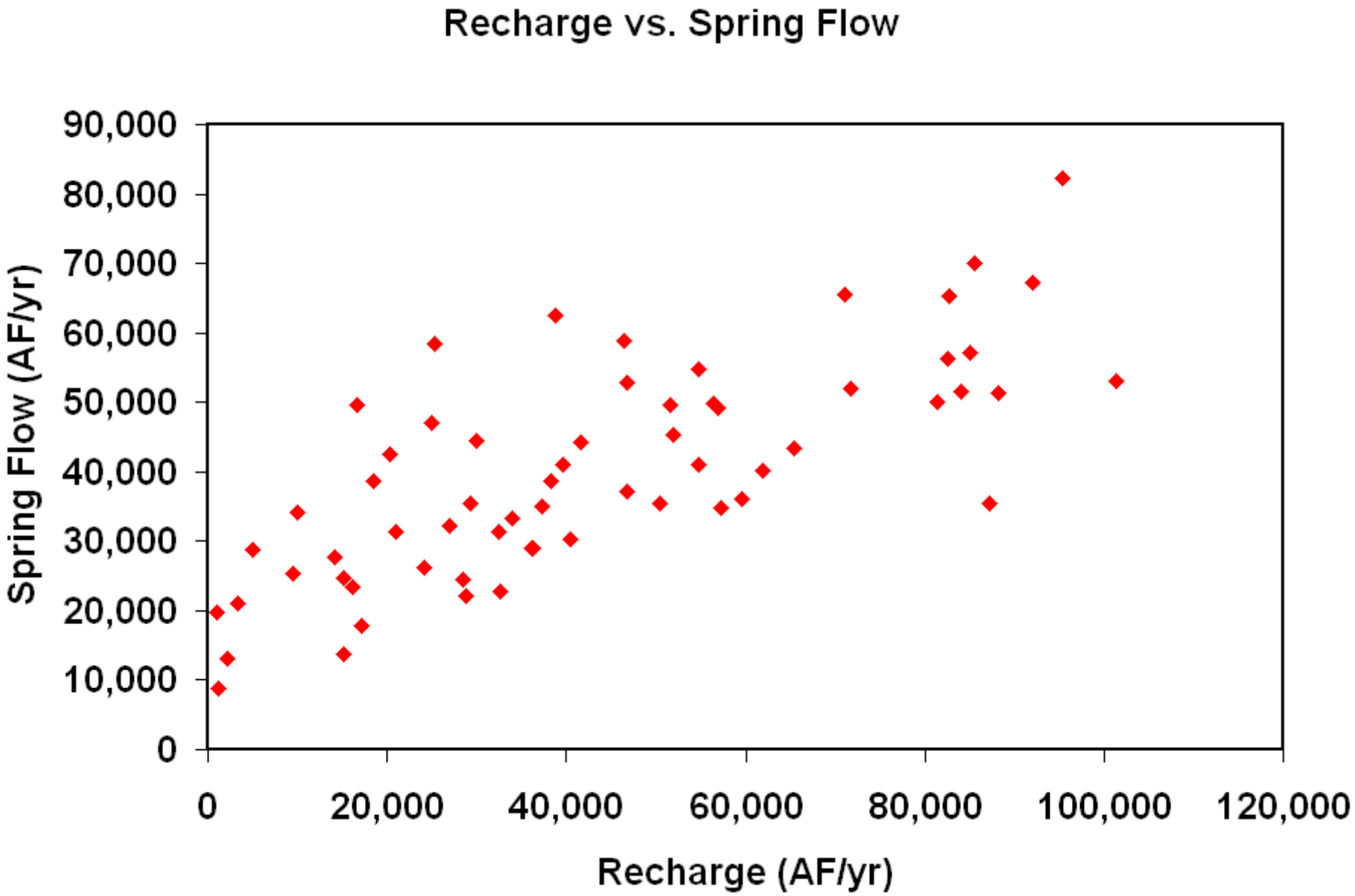

Annual Storage Change
Storage Change (AF/year)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1943
1947
1951
1955
1959
1963
1967
1971
1975
1979
1983
1987
1991
1995
1999
2003
Year

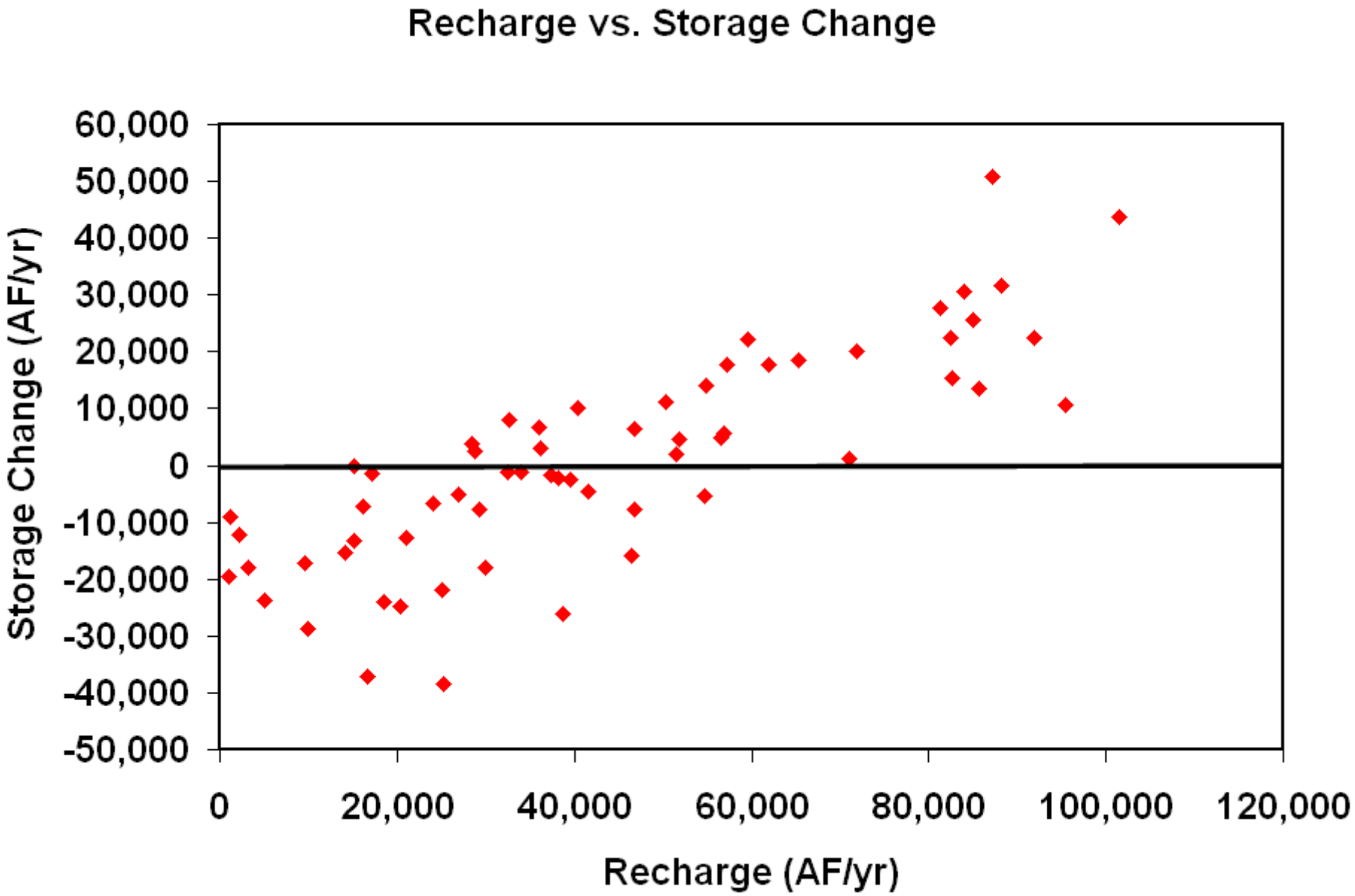
Cross Plots

- Pumping Impacts on
  - Spring Flow
  - Storage Change
- Recharge Impacts on
  - Spring Flow
  - Storage Change


Pumping vs. Spring Flow
Spring Flow (AF/yr)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
1,000
2,000
3,000
4,000
5,000
6,000
Pumping (AF/yr)


Pumping vs. Storage Change
Storage Change (AF/yr)
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
0
1,000
2,000
3,000
4,000
5,000
6,000
Pumping (AF/yr)


Recharge vs. Spring Flow
Spring Flow (AF/yr)
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0
20,000
40,000
60,000
80,000
100,000
120,000
Recharge (AF/yr)


Recharge vs. Storage Change
Storage Change (AF/yr)
60,000
50,000
40,000
30,000
20,000
10,000
0
-10,000
-20,000
-30,000
-40,000
-50,000
0
20,000
40,000
60,000
80,000
100,000
120,000
Recharge (AF/yr)

Groundwater Budget Summary

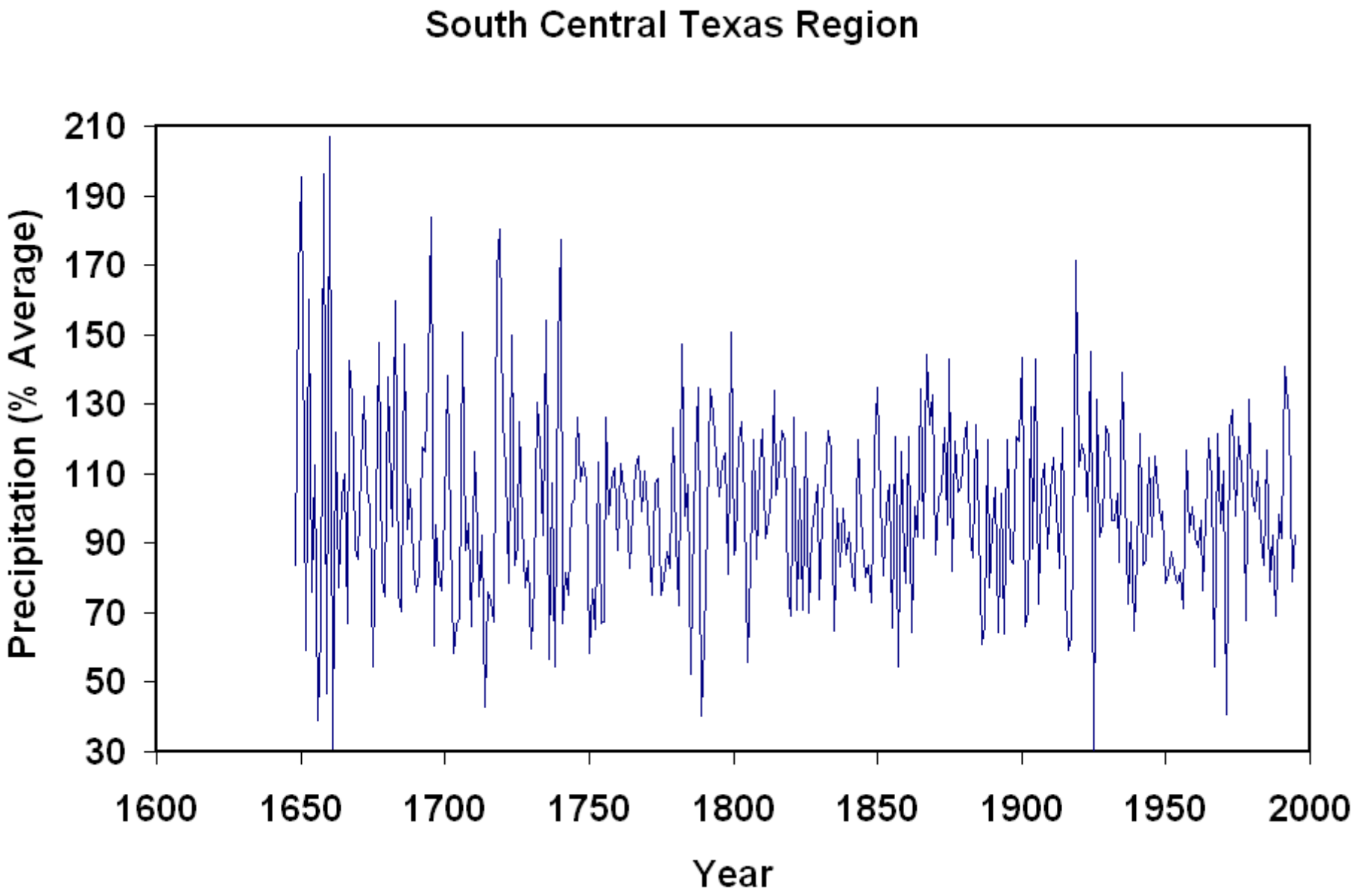
- Recharge vs. Storage Change
  - Monthly and Annual
- Recharge vs. Spring Flow
  - Annual
- Pumping impacts less significant

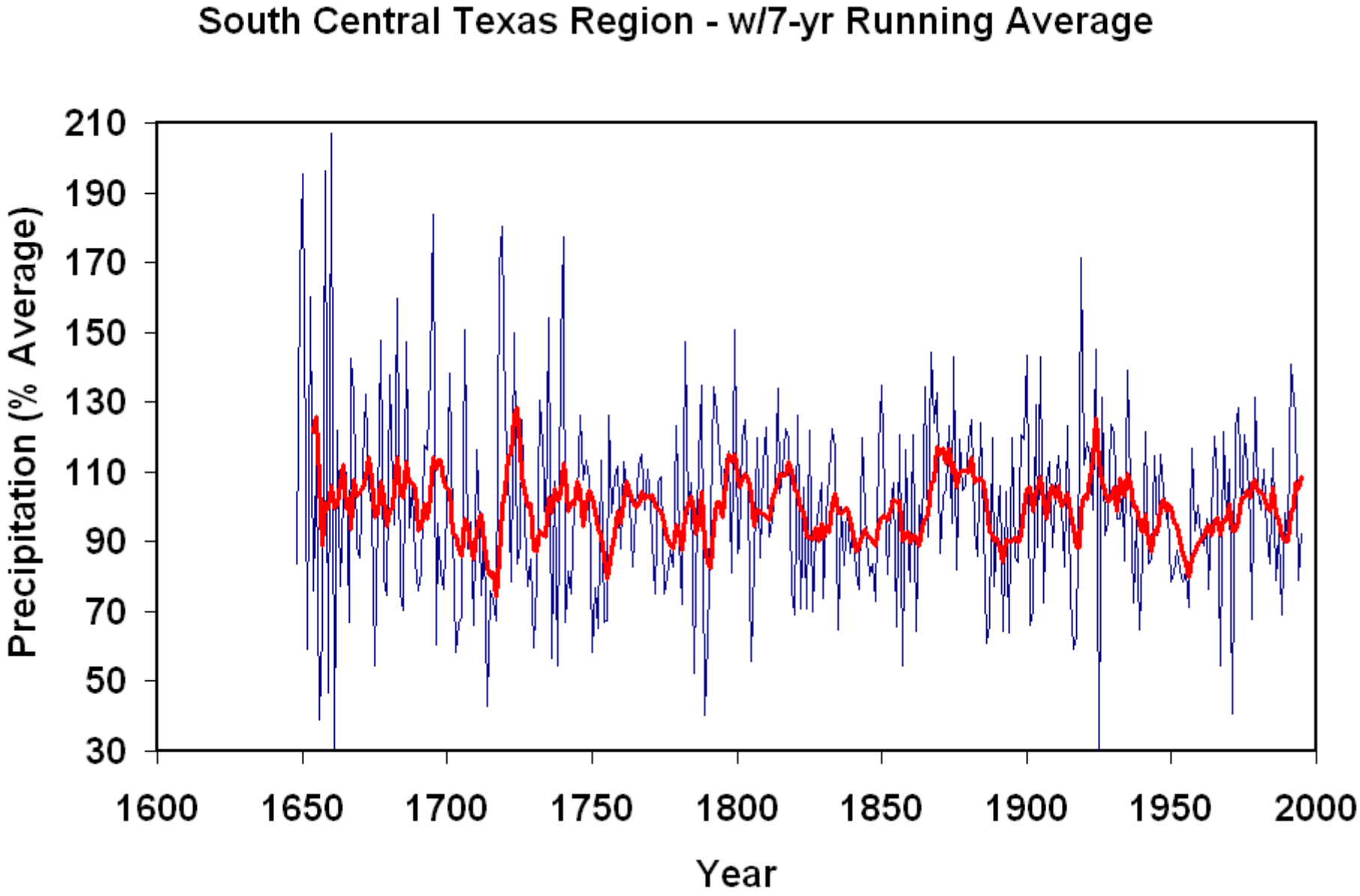
Model Application

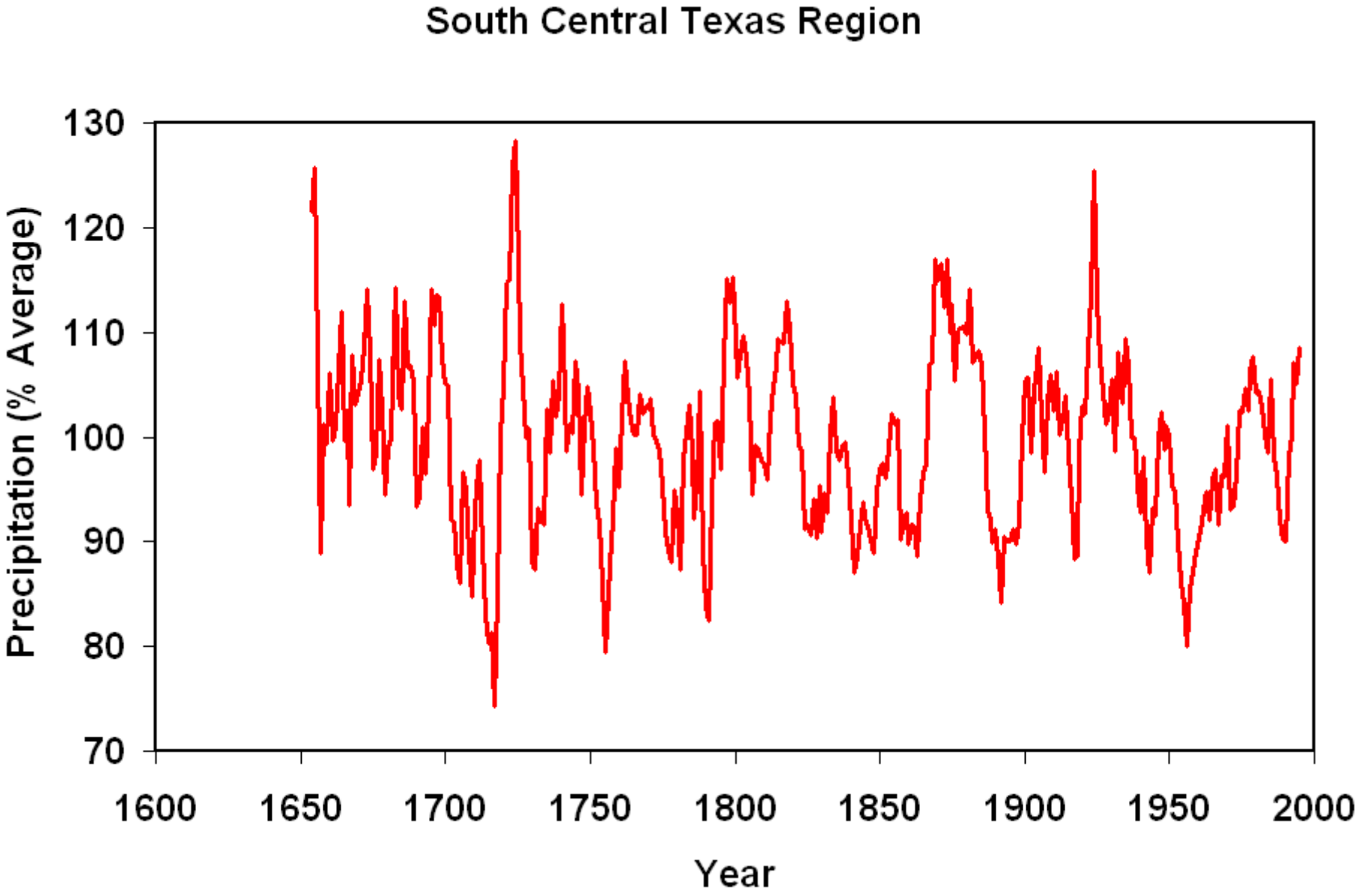
- DFC based on spring flow under drought conditions
- “Traditional” approach
  - 50 year run with 7 yr DOR as last 7 years
- “Variation” approach
  - Multiple 7-year simulations

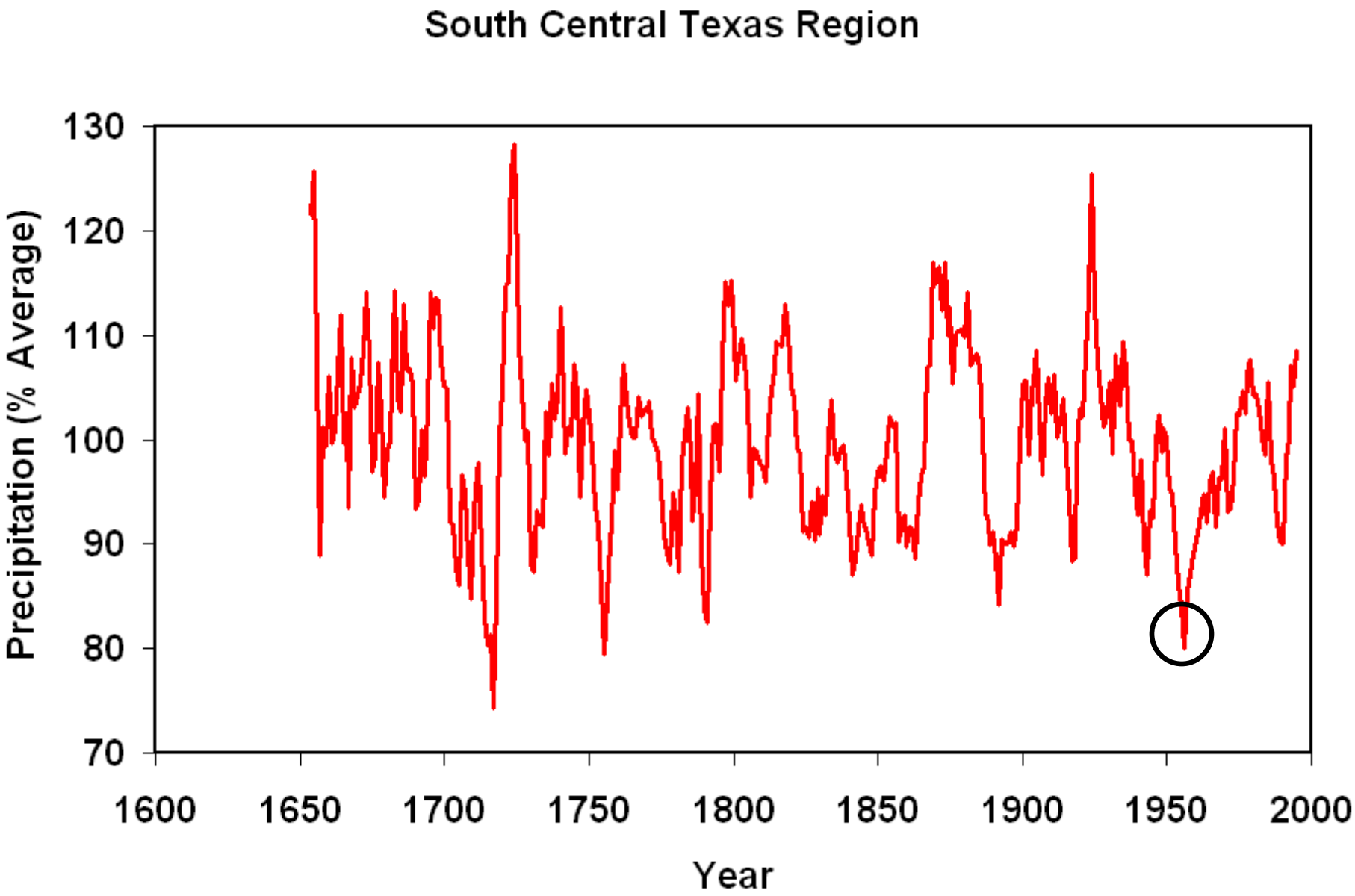
Extending Historic Record

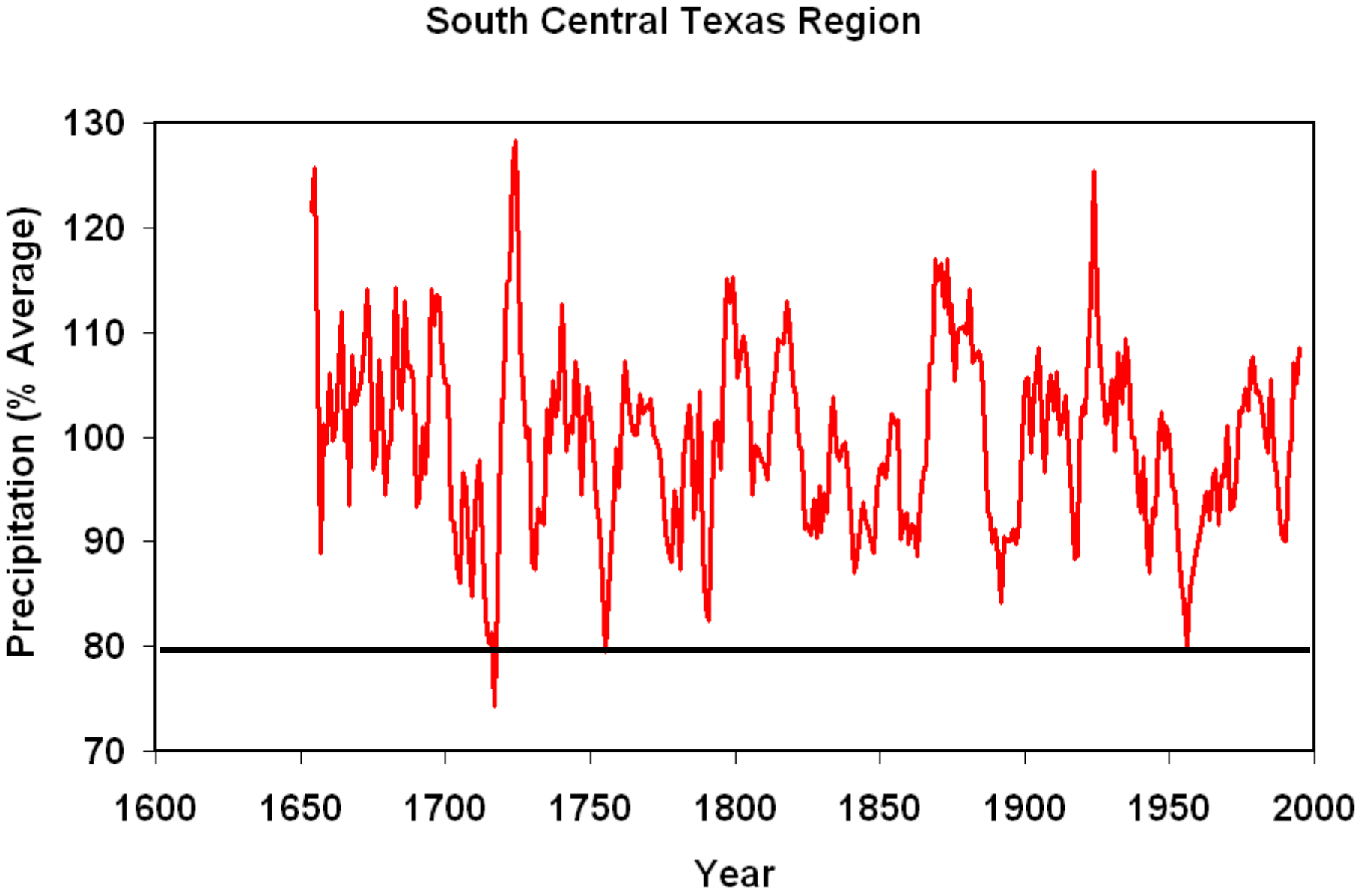
- University of Arkansas study (GBRA)
- Tree ring Record: 1648 – 1995

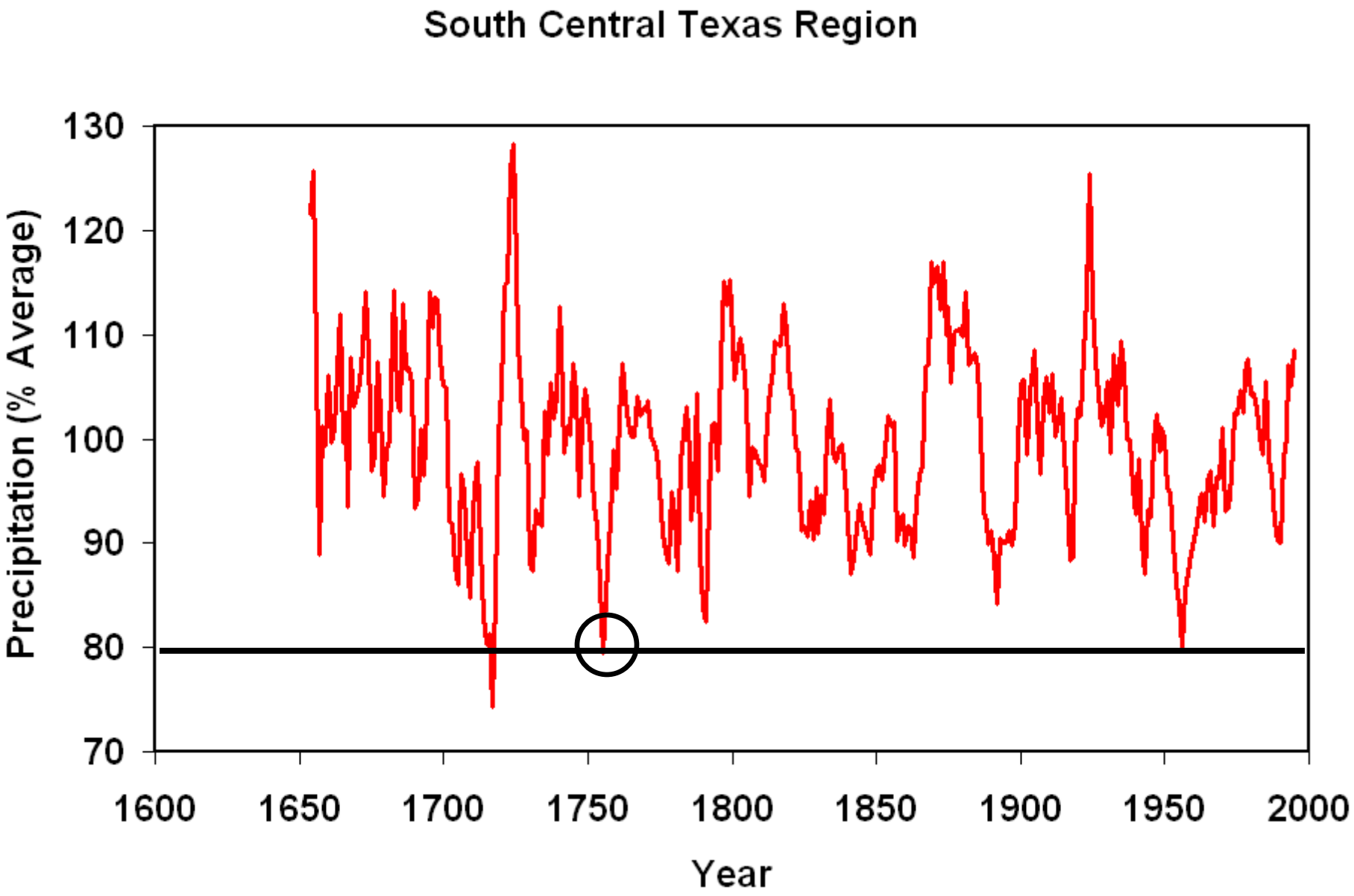

South Central Texas Region
Precipitation (% Average)
210
190
170
150
130
110
90
70
50
30
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

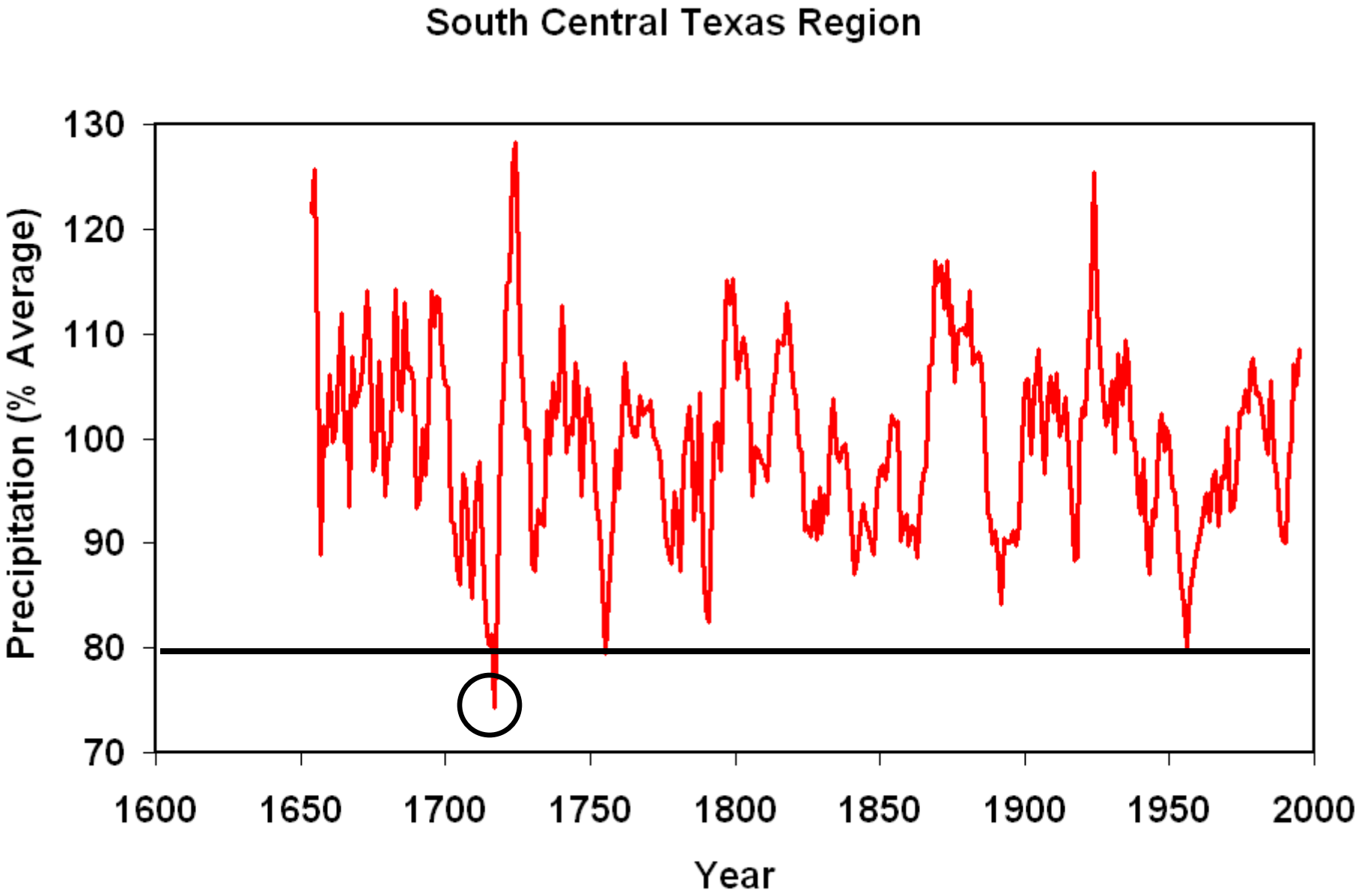

South Central Texas Region - w/7-yr Running Average
Precipitation (% Average)
210
190
170
150
130
110
90
70
50
30
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


South Central Texas Region
Precipitation (% Average)
130
120
110
100
90
80
70
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


South Central Texas Region
Precipitation (% Average)
130
120
110
100
90
80
70
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


South Central Texas Region
Precipitation (% Average)
130
120
110
100
90
80
70
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


South Central Texas Region
Precipitation (% Average)
130
120
110
100
90
80
70
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year


South Central Texas Region
Precipitation (% Average)
130
120
110
100
90
80
70
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

342 Recharge Scenarios

- 7-year scenarios

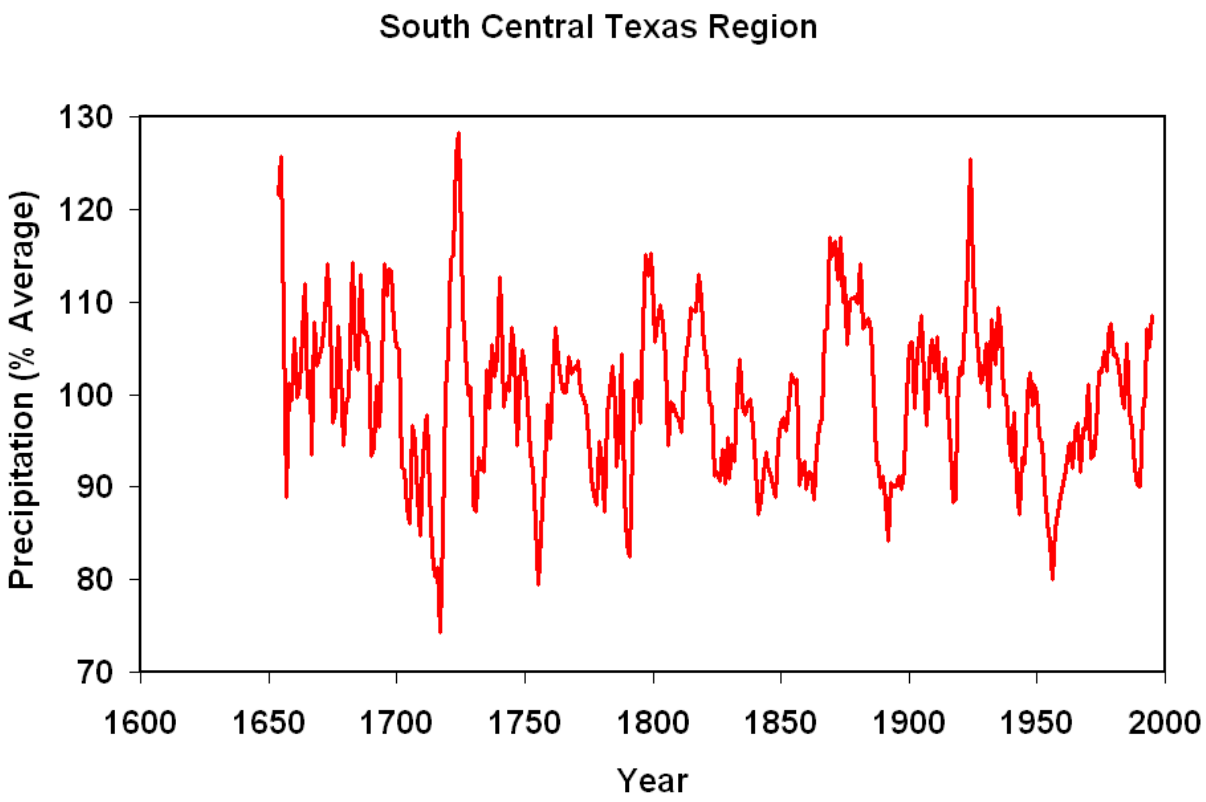
  1648 to 1654

  1649 to 1655

  :

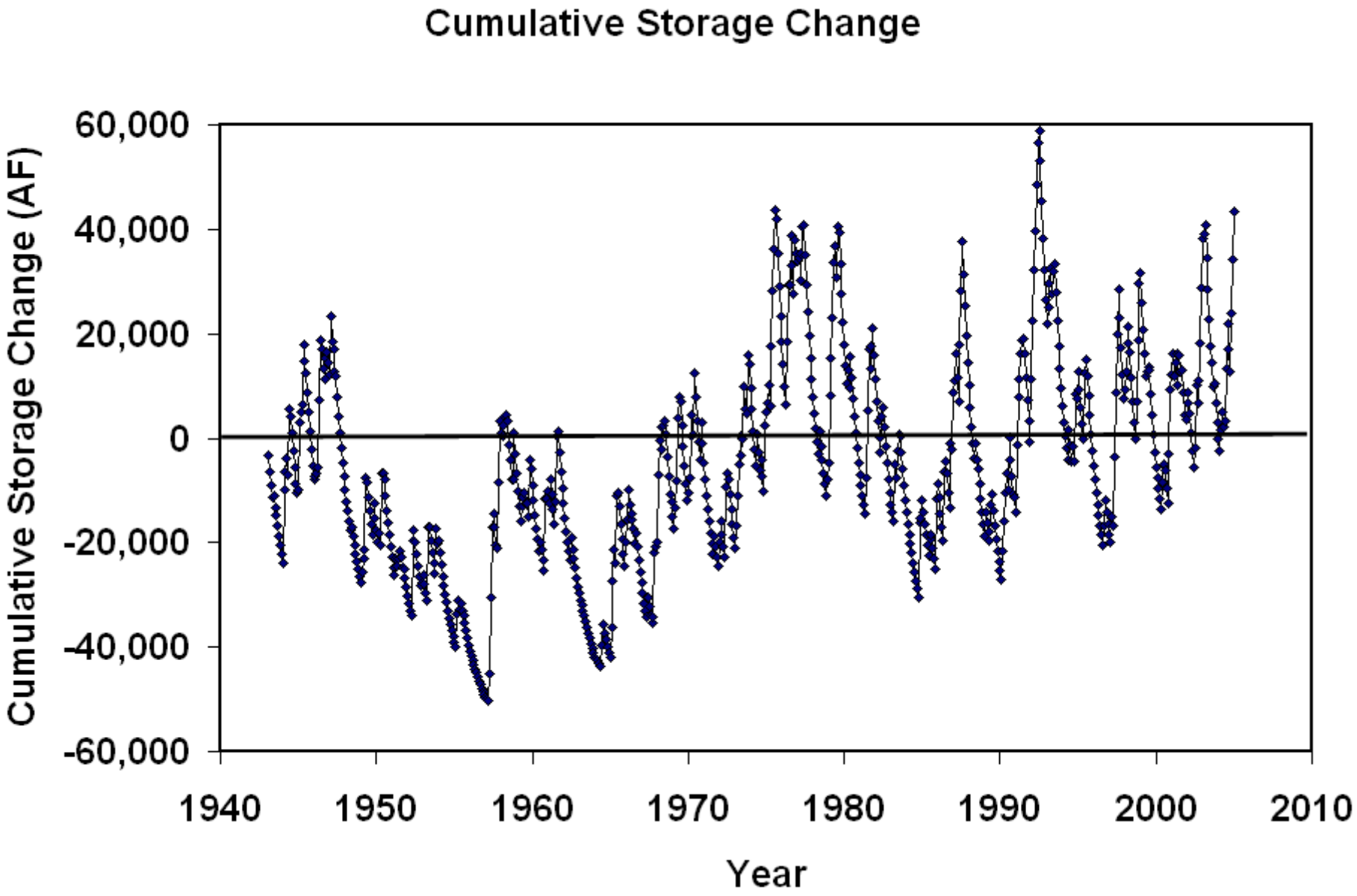
  :

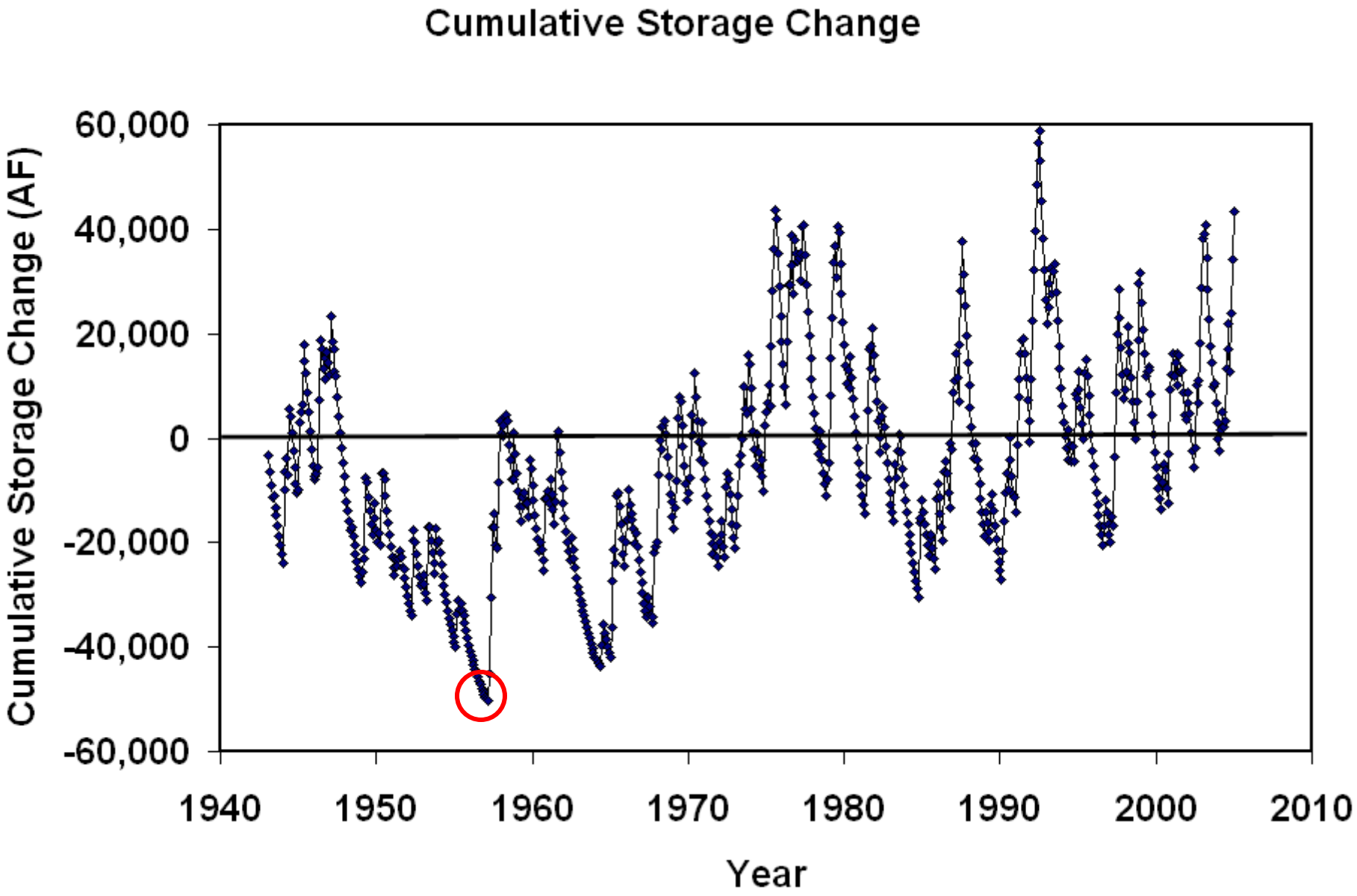
  1989 to 1995

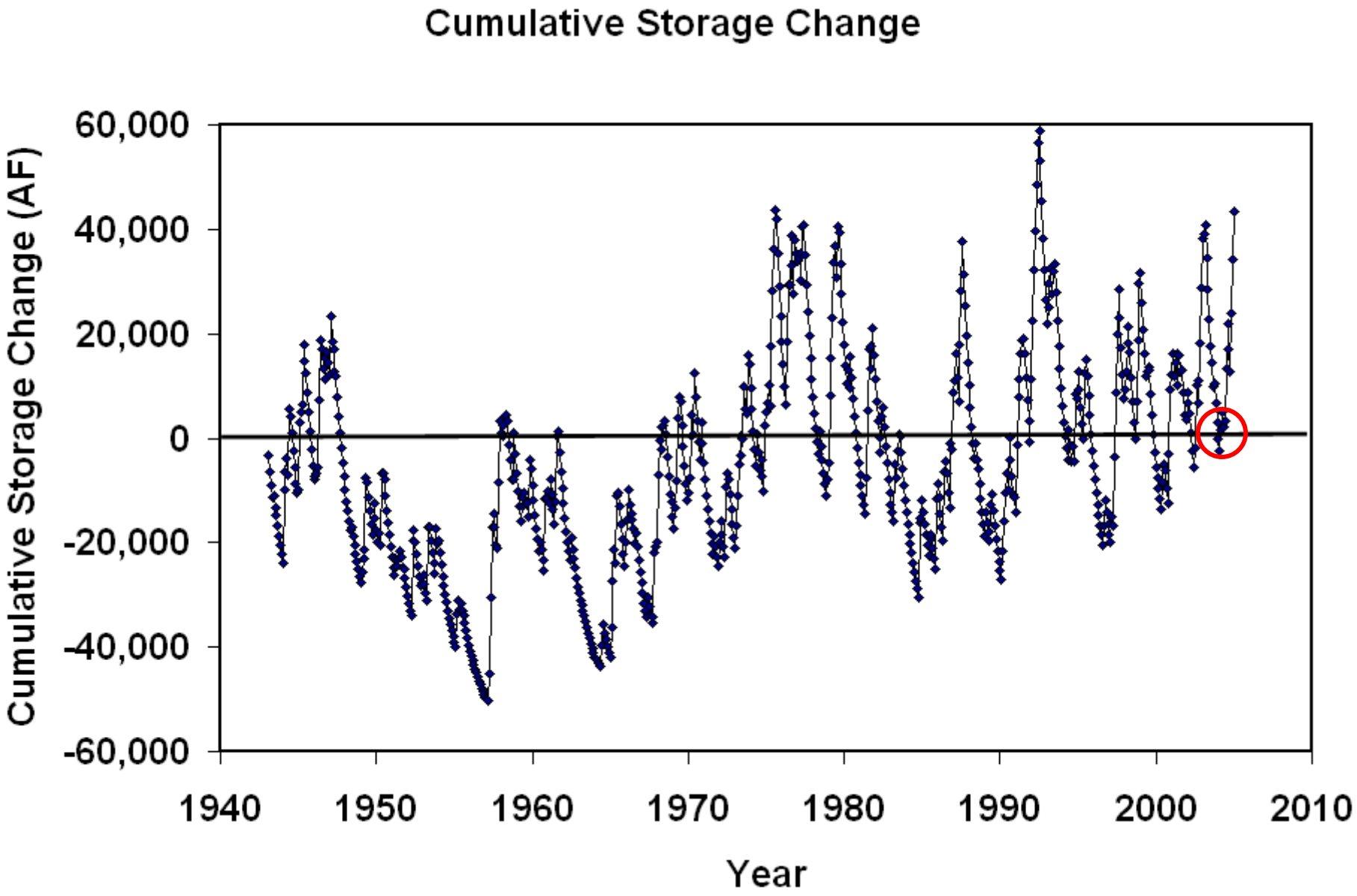


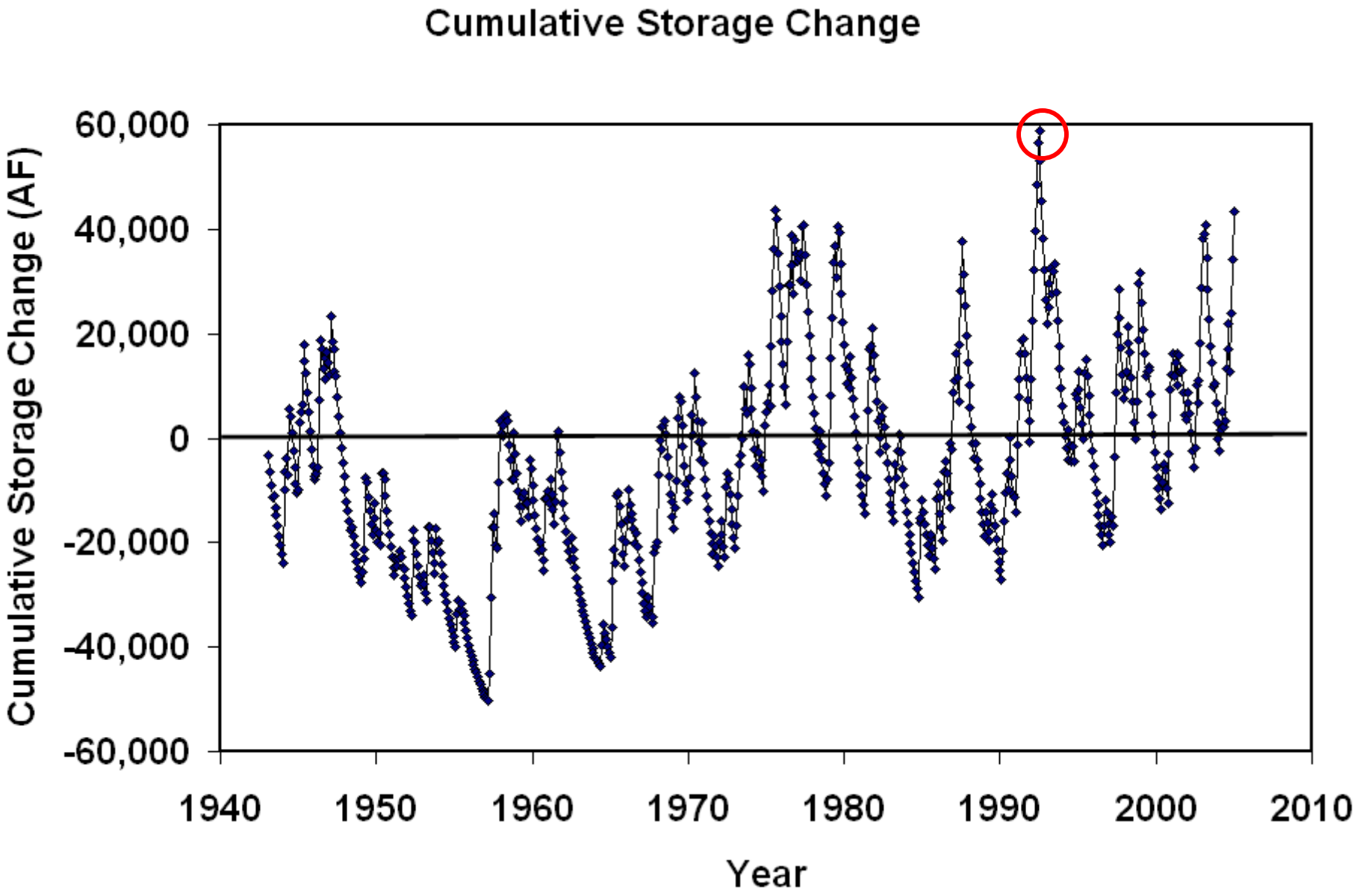
Variations on Recharge Scenarios

- Initial conditions
  - Low (1957)
  - Intermediate (2004)
  - High (1992)
- Pumping
  - 5 scenarios (3,800 to 16,300 AF/yr)
  - Current Pumping ~ 5,500 AF/yr


Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year


Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year


Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year

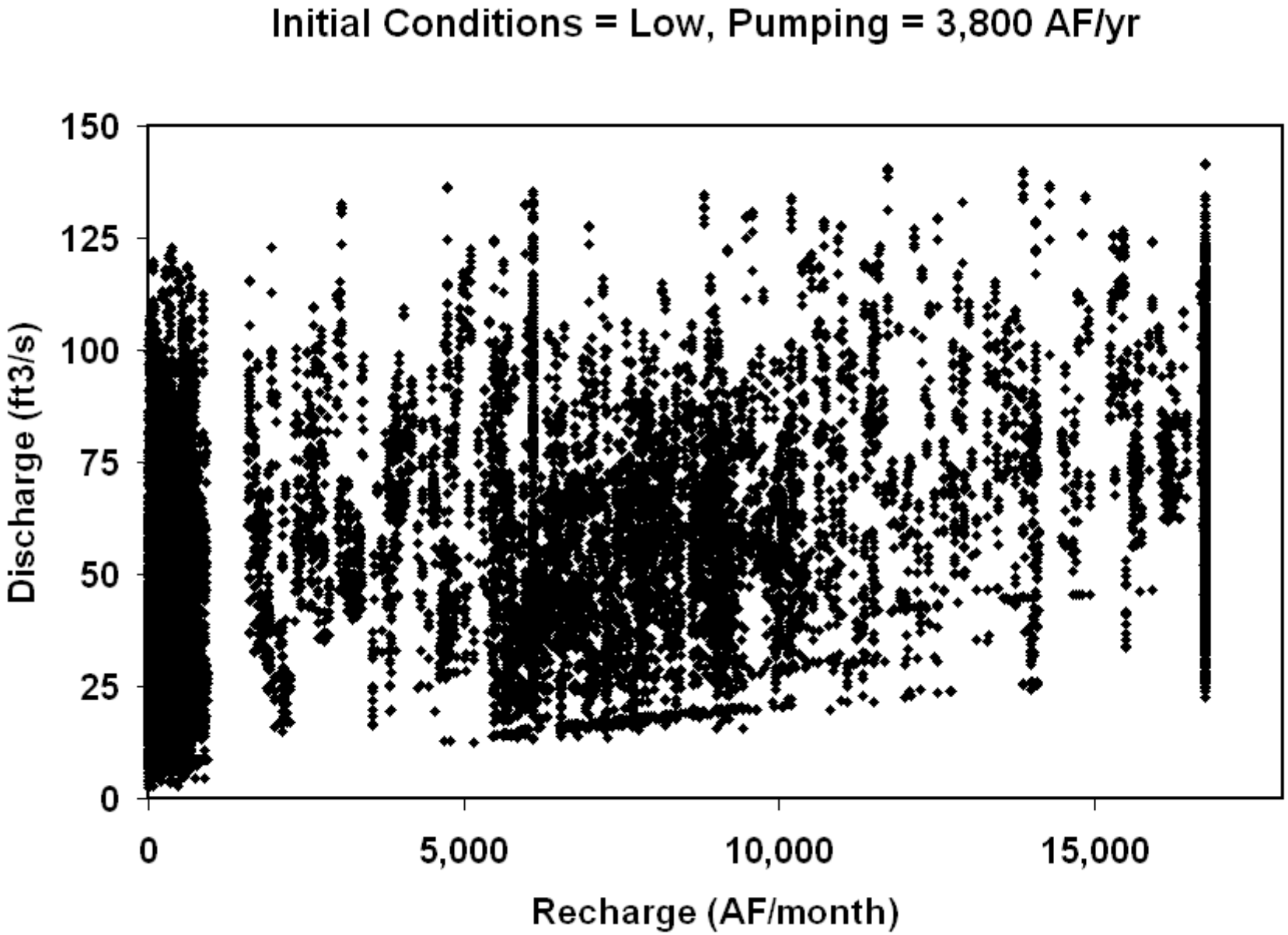

Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year

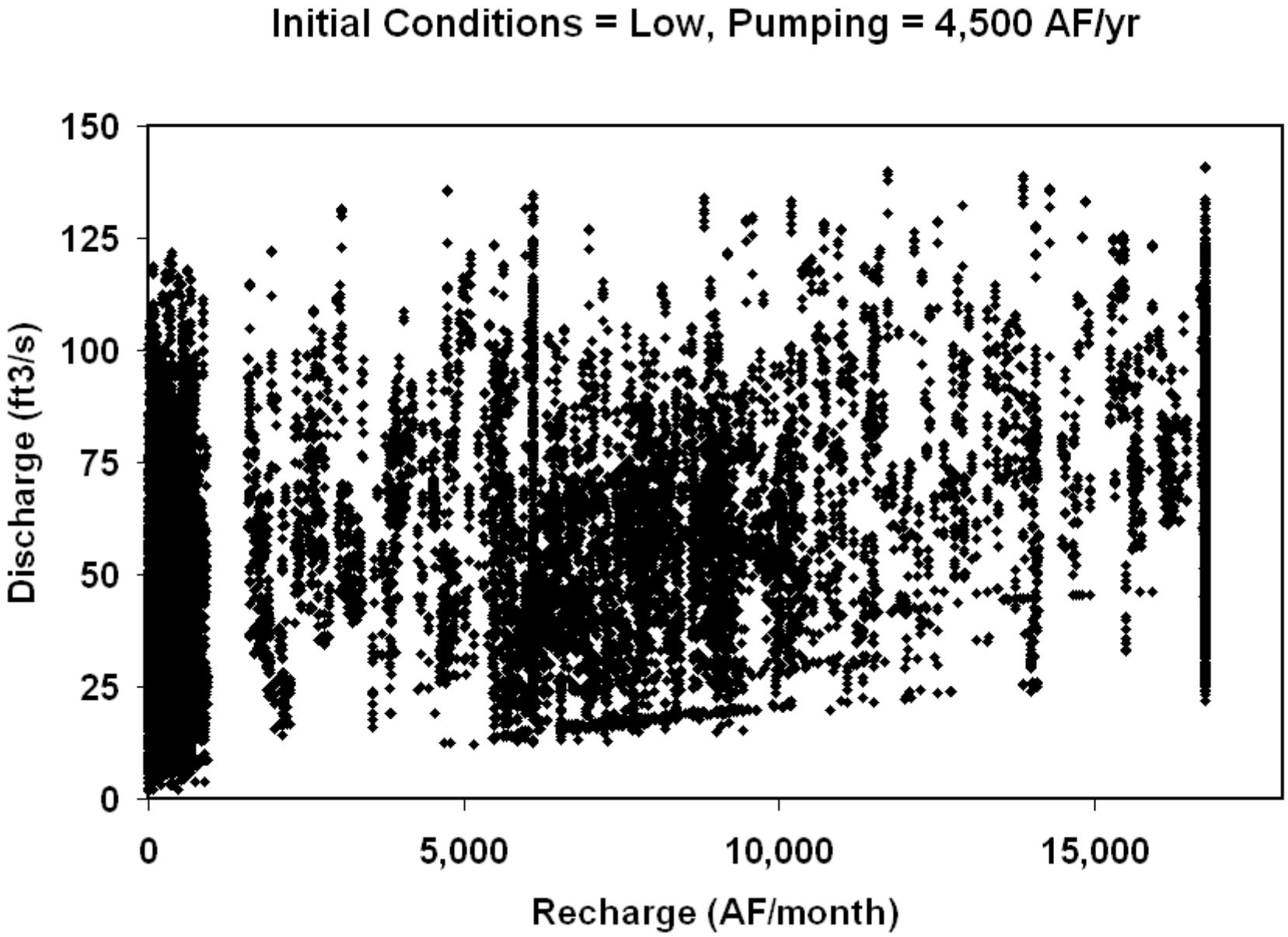
Summary of Simulations

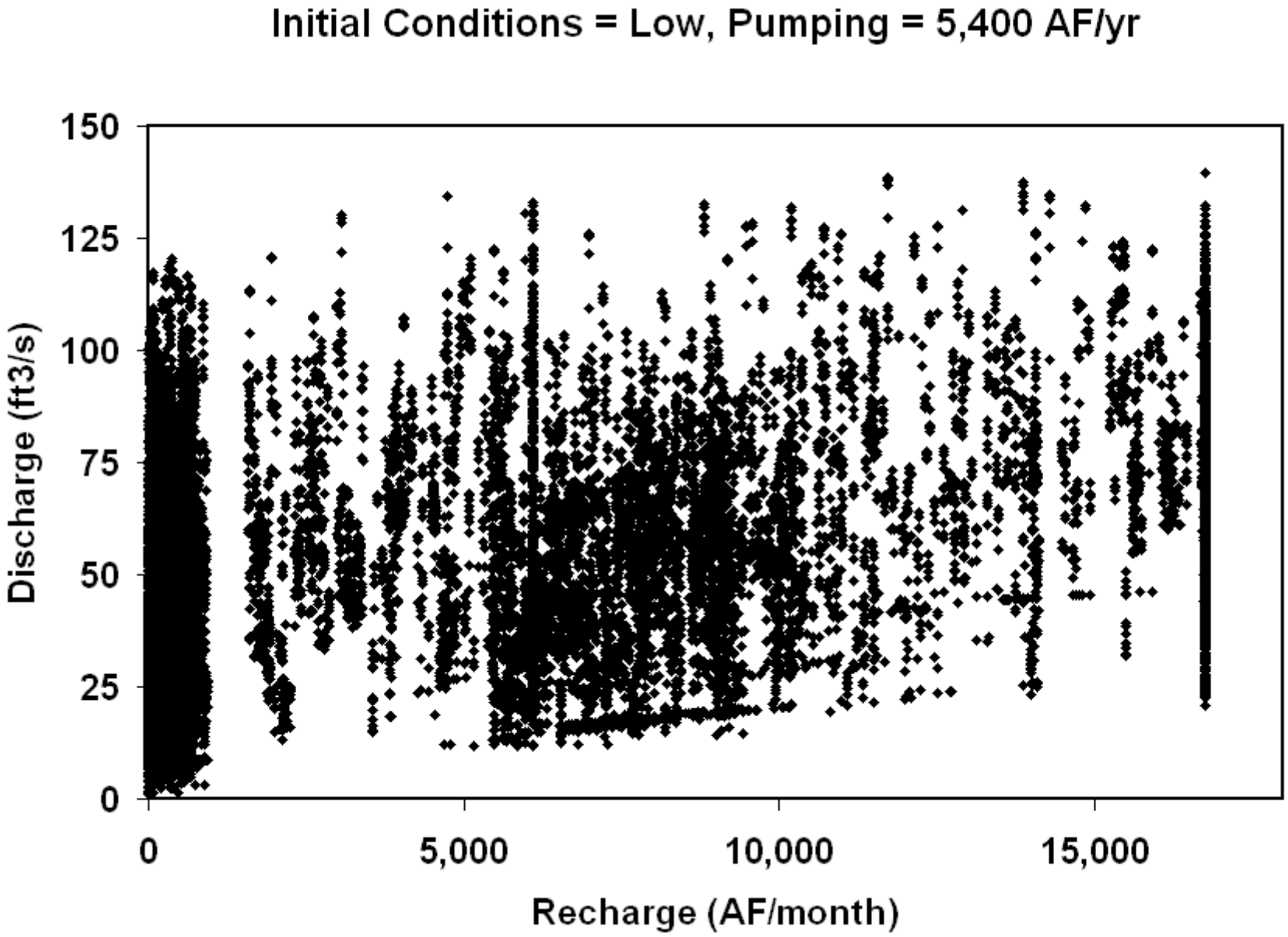
- 15 Scenarios
  - 3 Initial Conditions
  - 5 Pumping
- Each scenario = 342 7-year simulations
  - 28,728 months
- Initially – 5,130 7-year simulations

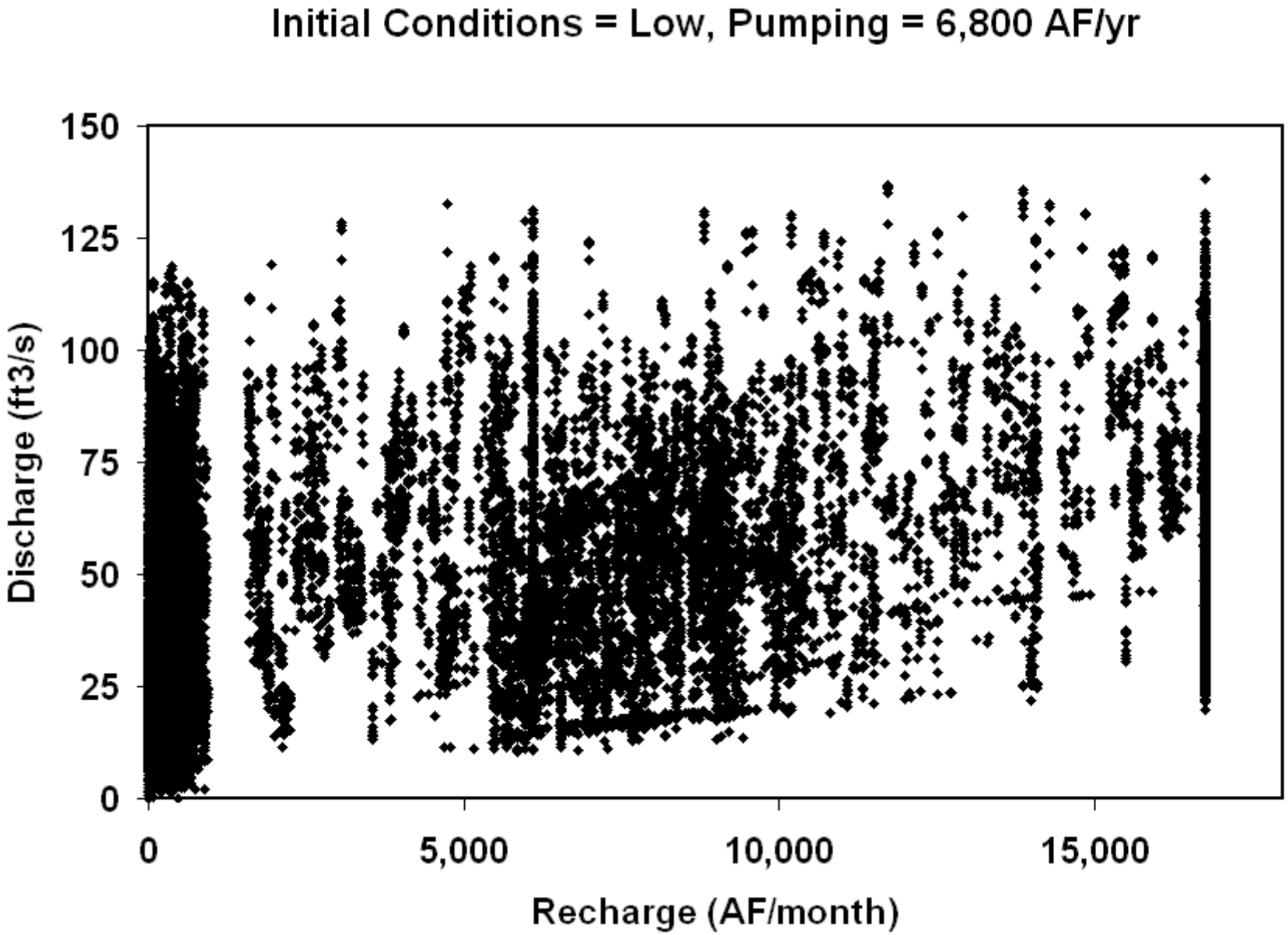
Results

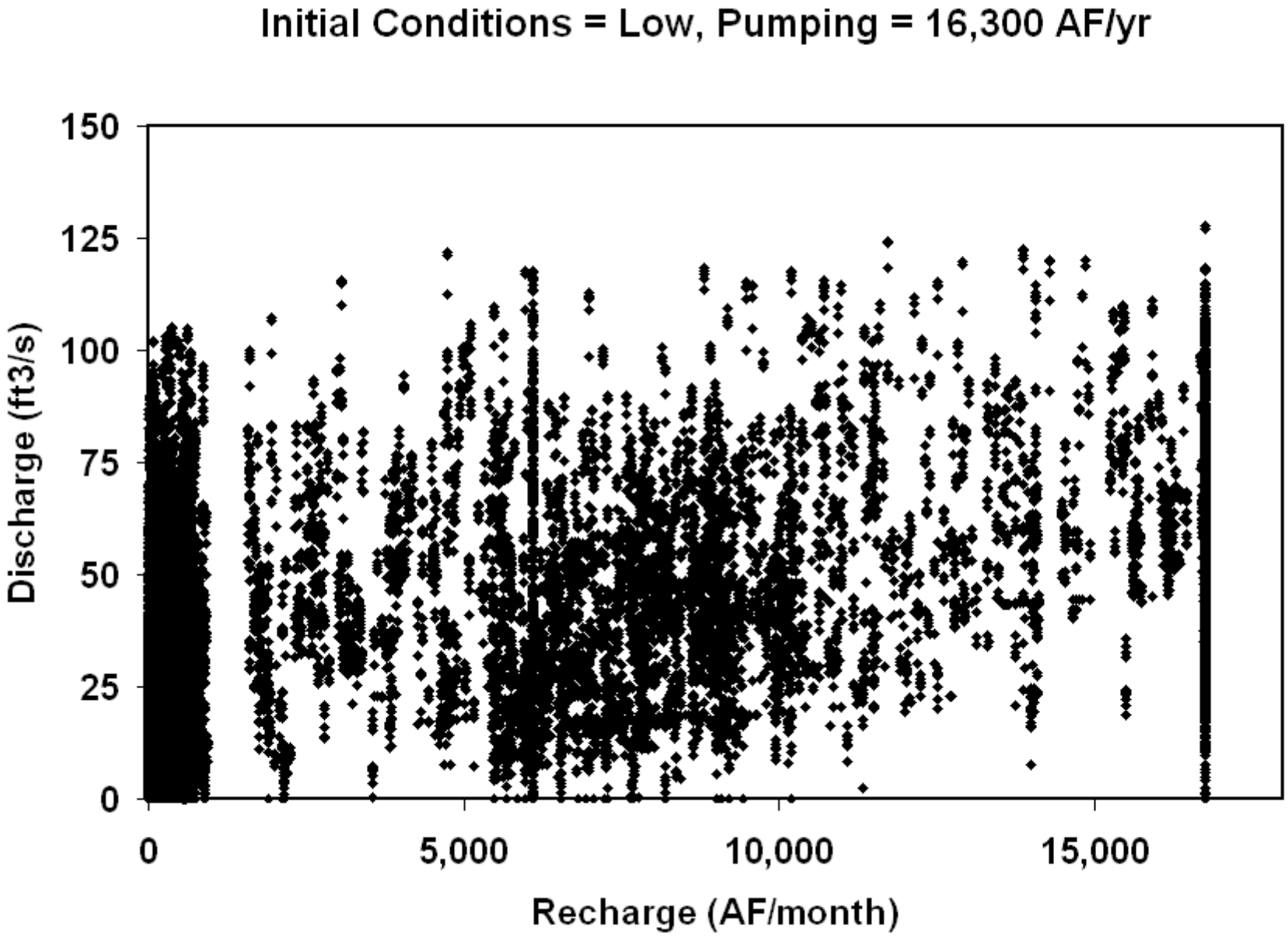
- 28,728 months
- Impacts of recharge on spring flow
- Impacts of pumping on spring flow

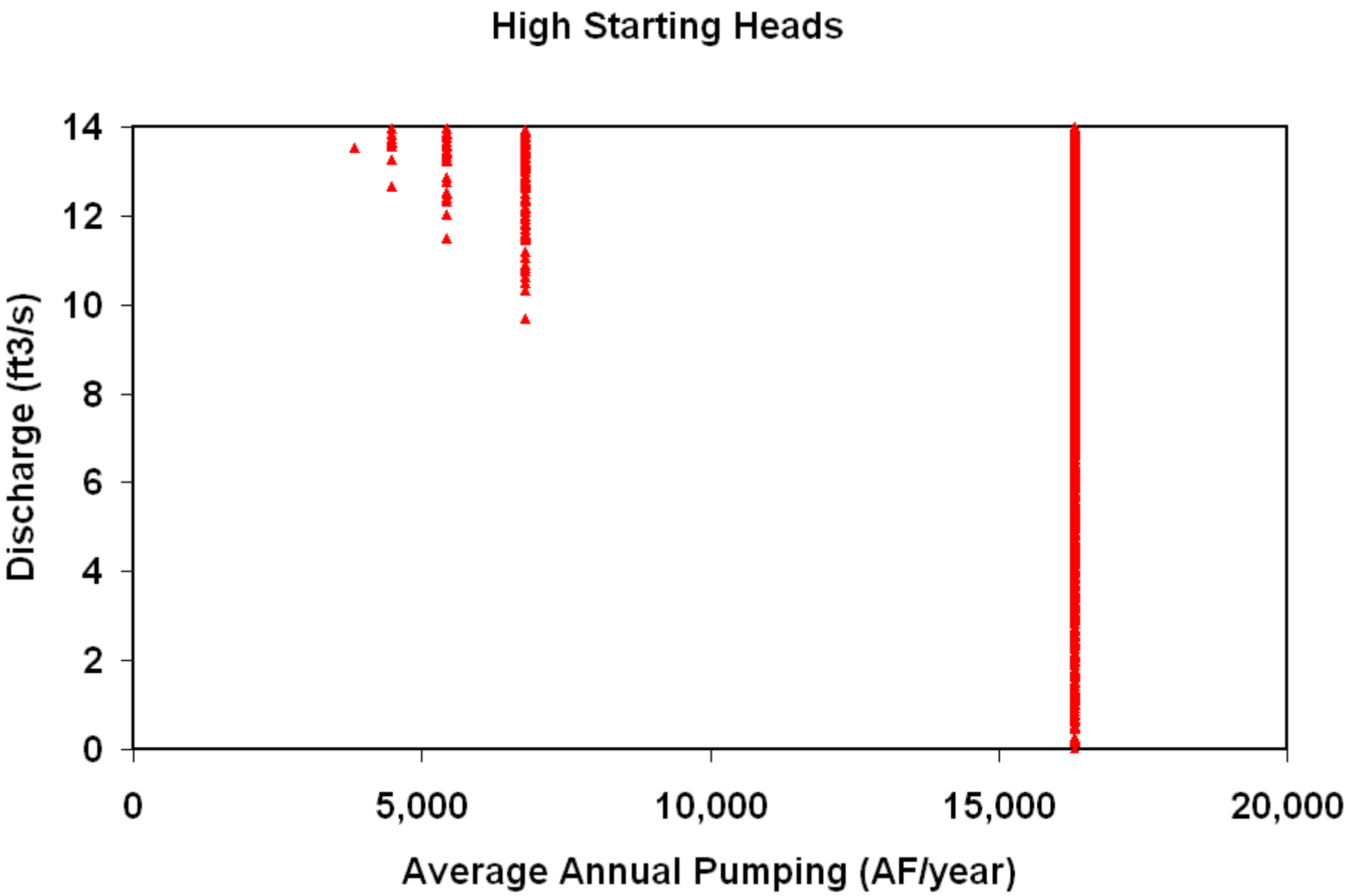

Initial Conditions = Low, Pumping = 3,800 AF/yr
Discharge (ft3/s)
150
125
100
75
50
25
0
0
5,000
10,000
15,000
Recharge (AF/month)

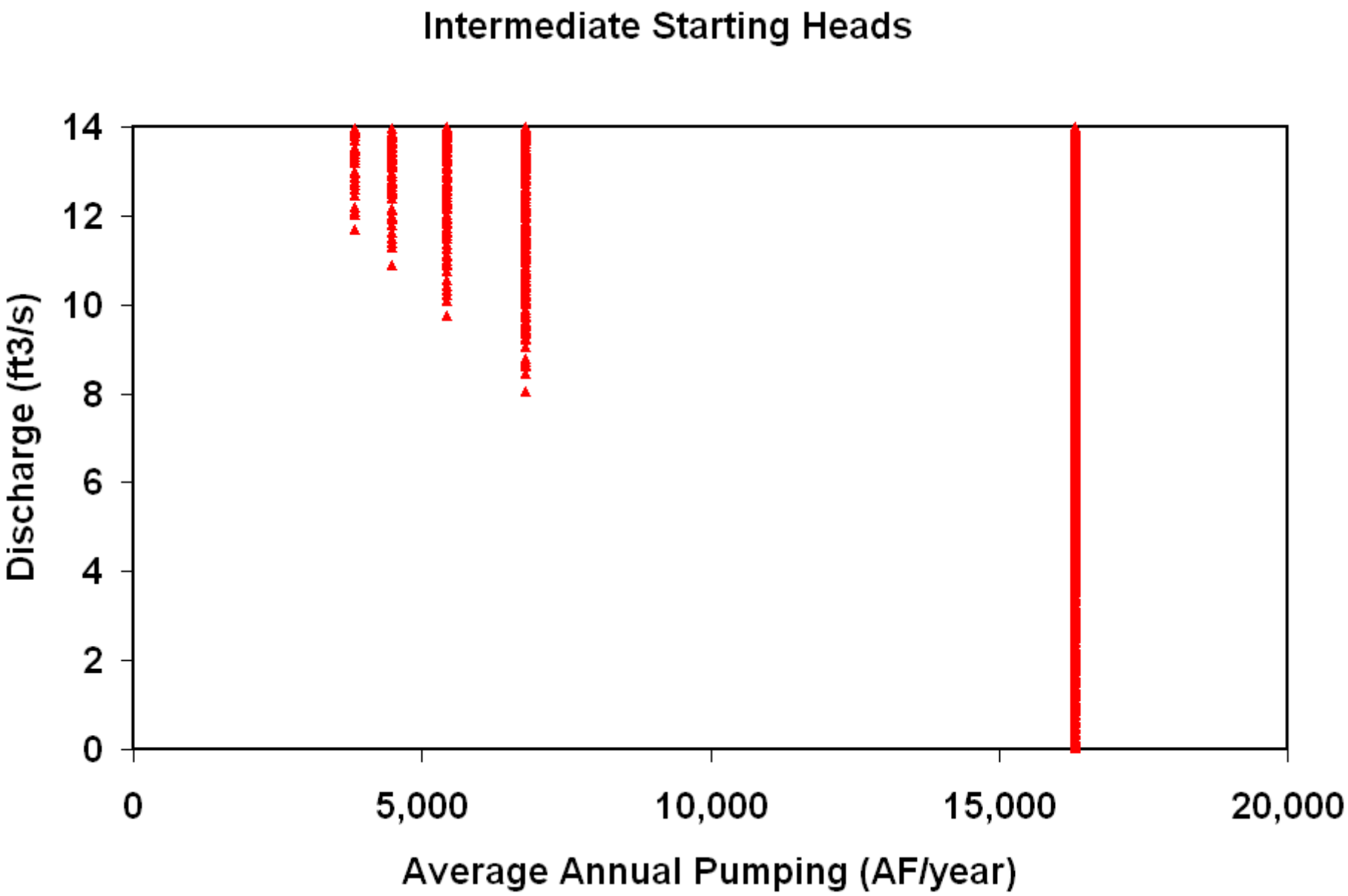

Initial Conditions = Low, Pumping = 4,500 AF/yr
Discharge (ft3/s)
150
125
100
75
50
25
0
0
5,000
10,000
15,000
Recharge (AF/month)

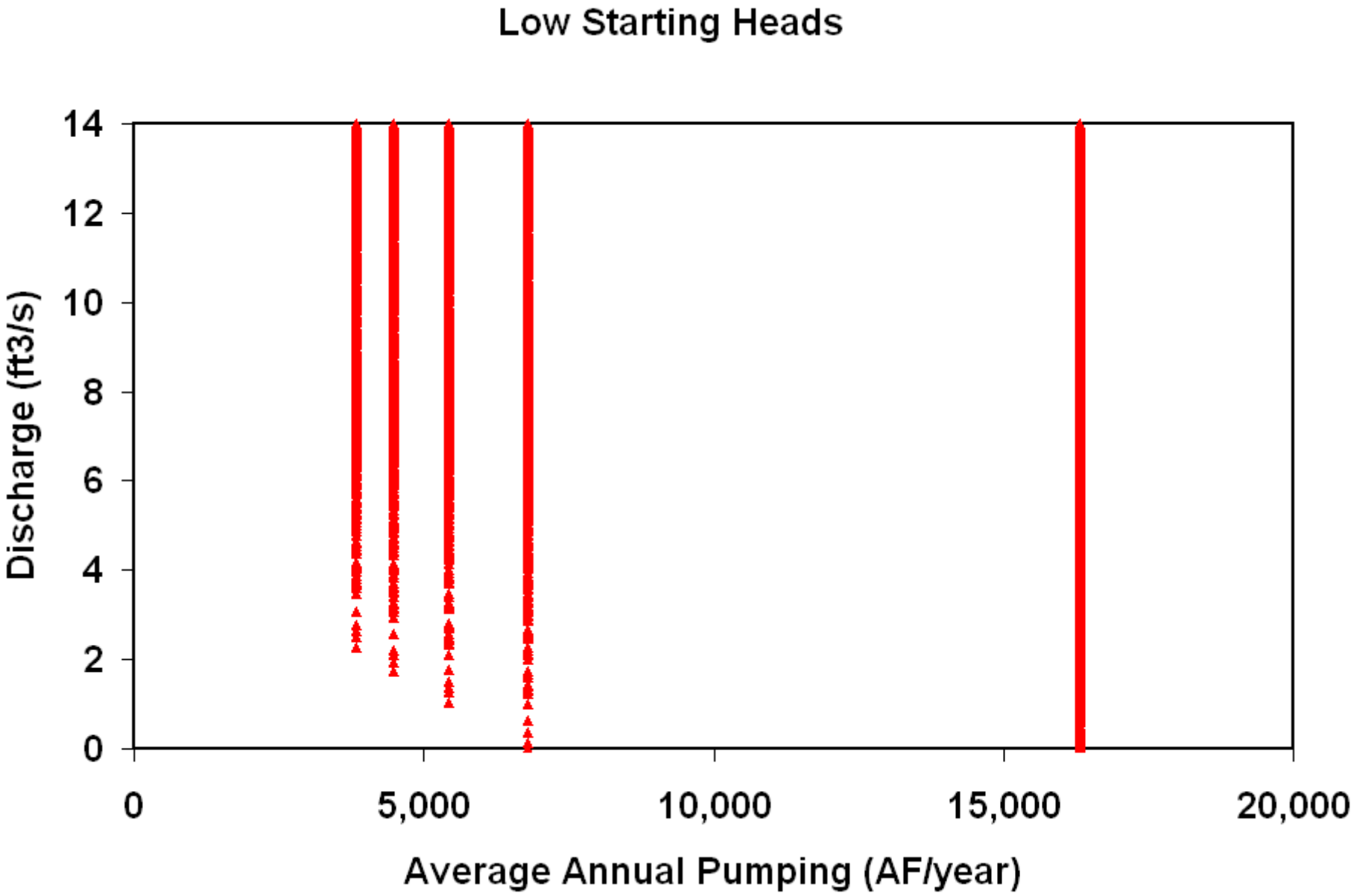

Initial Conditions = Low, Pumping = 5,400 AF/yr
Discharge (ft3/s)
150
125
100
75
50
25
0
0
5,000
10,000
15,000
Recharge (AF/month)

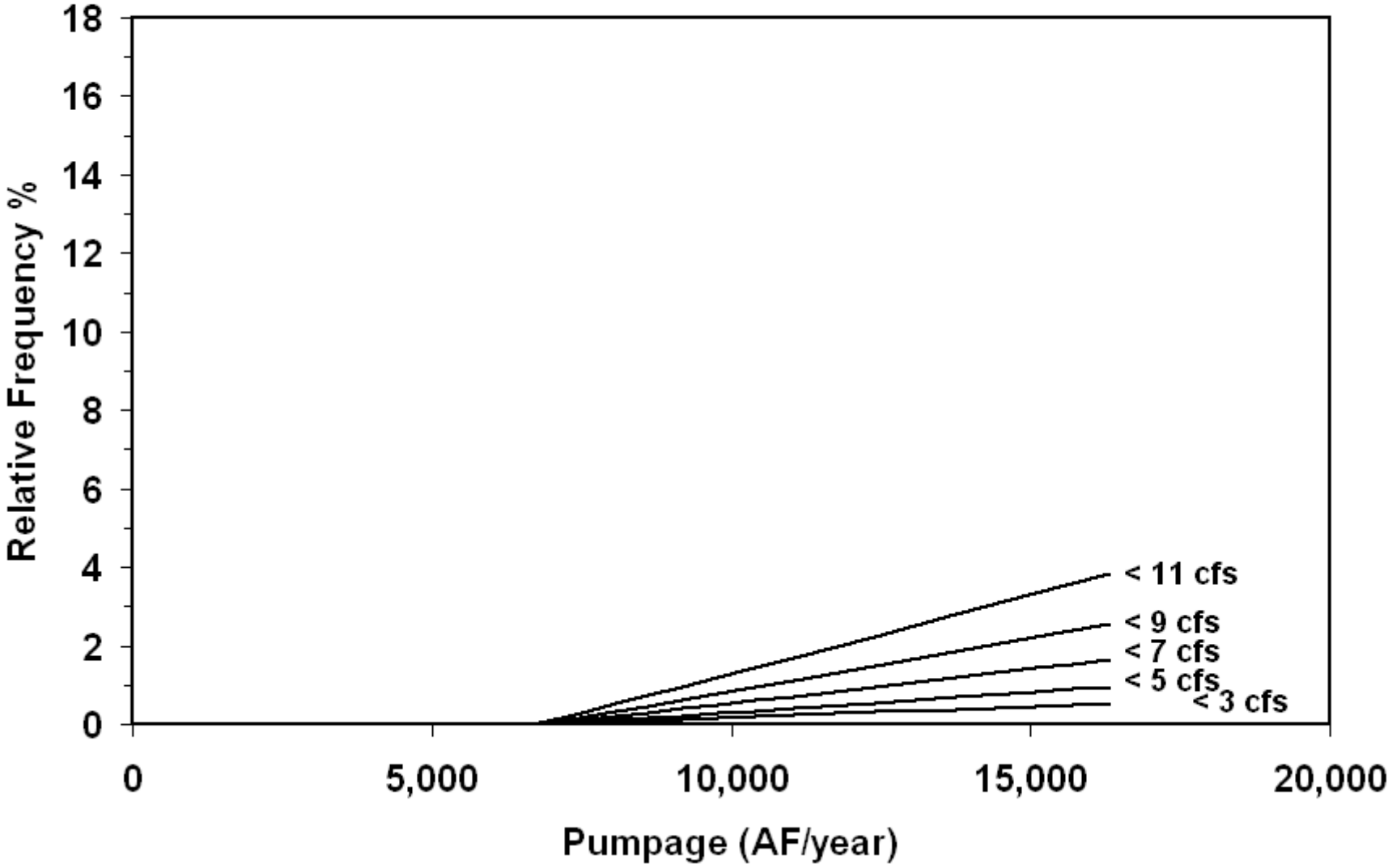

Initial Conditions = Low, Pumping = 6,800 AF/yr
Discharge (ft3/s)
150
125
100
75
50
25
0
0
5,000
10,000
15,000
Recharge (AF/month)

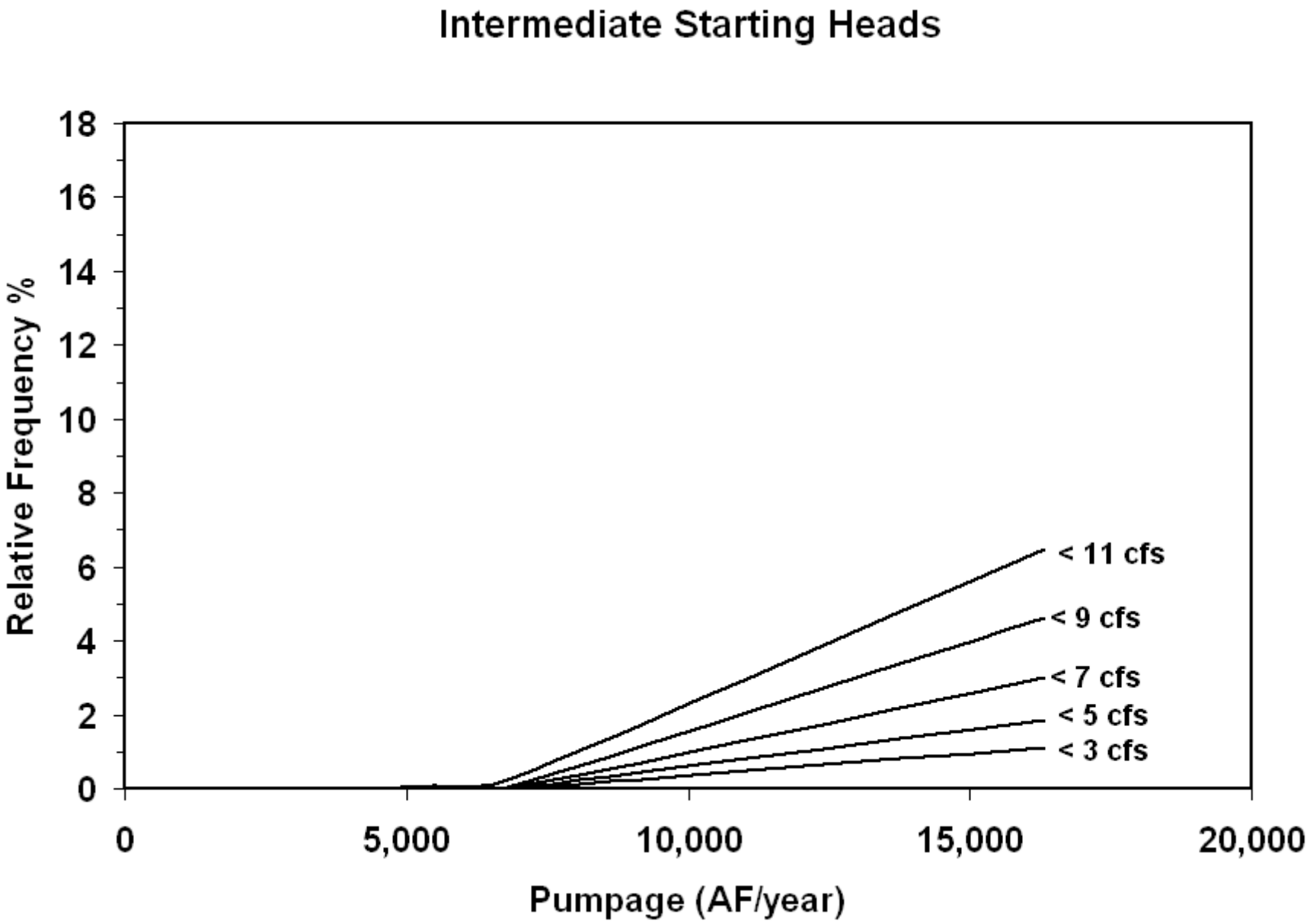

Initial Conditions = Low, Pumping = 16,300 AF/yr
Discharge (ft3/s)
150
125
100
75
50
25
0
0
5,000
10,000
15,000
Recharge (AF/month)

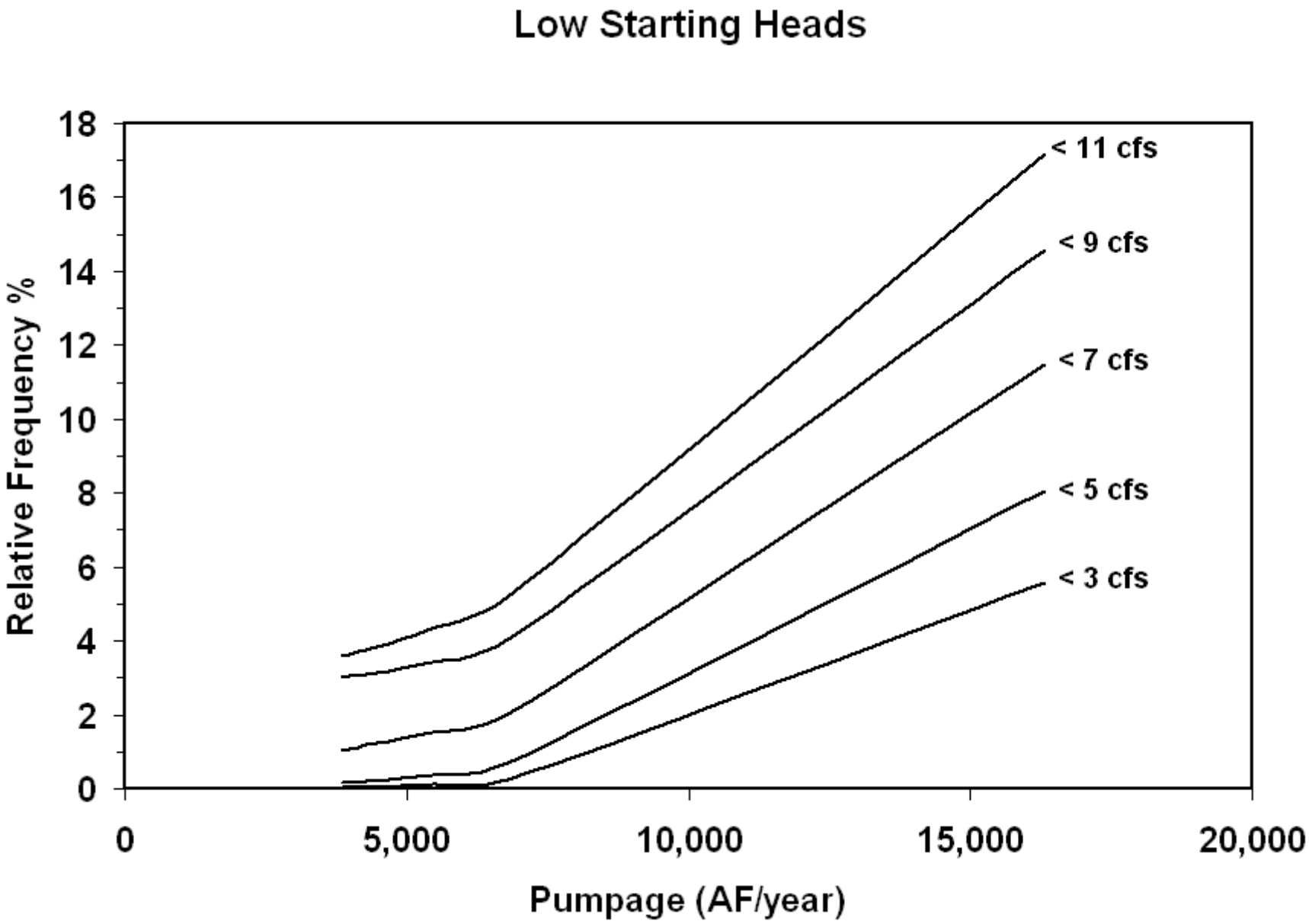

High Starting Heads
Discharge (ft3/s)
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Average Annual Pumping (AF/year)

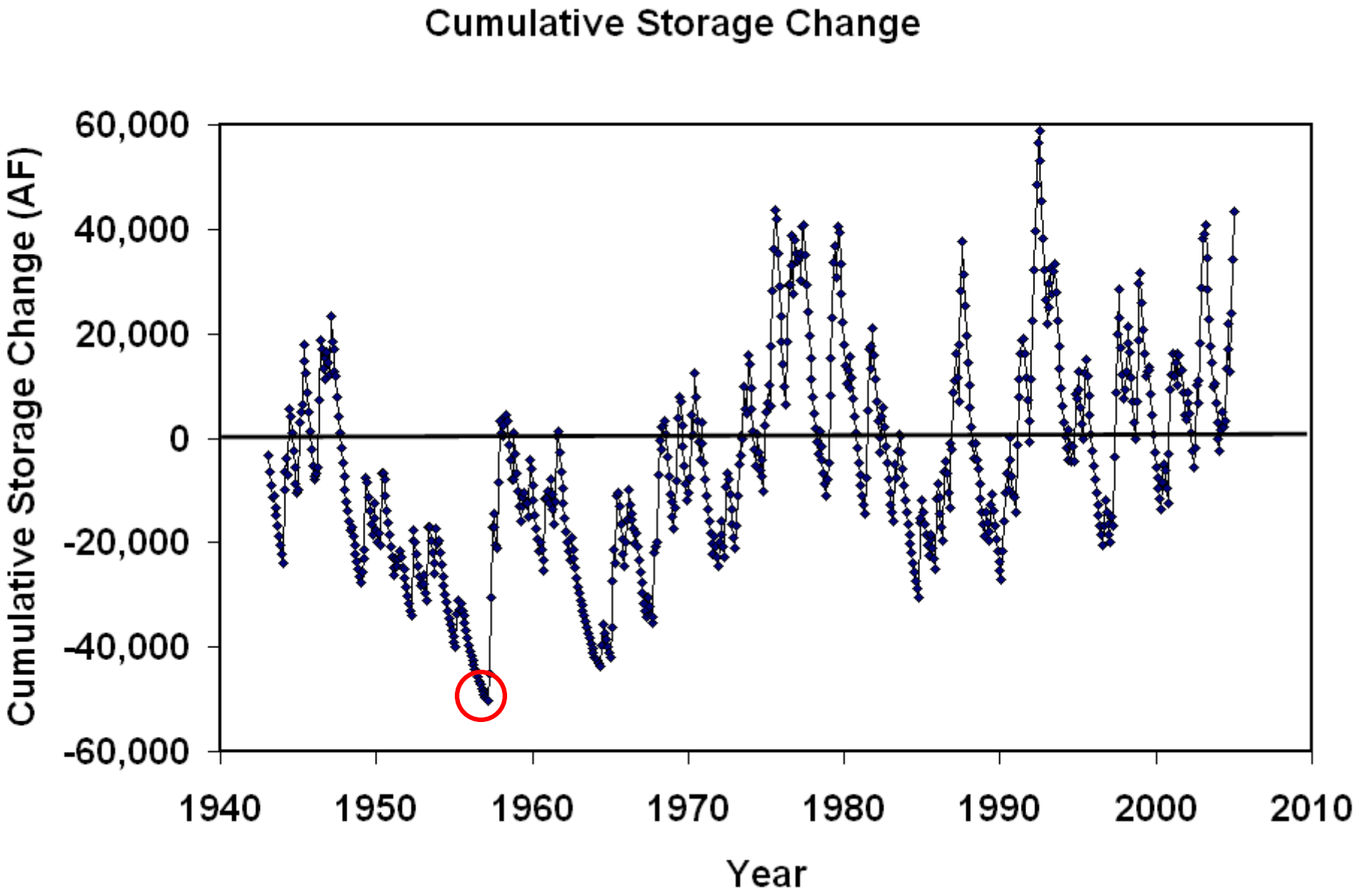

Intermediate Starting Heads
Discharge (ft3/s)
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Average Annual Pumping (AF/year)


Low Starting Heads
Discharge (ft3/s)
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Average Annual Pumping (AF/year)


High Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs


Intermediate Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs


Low Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs

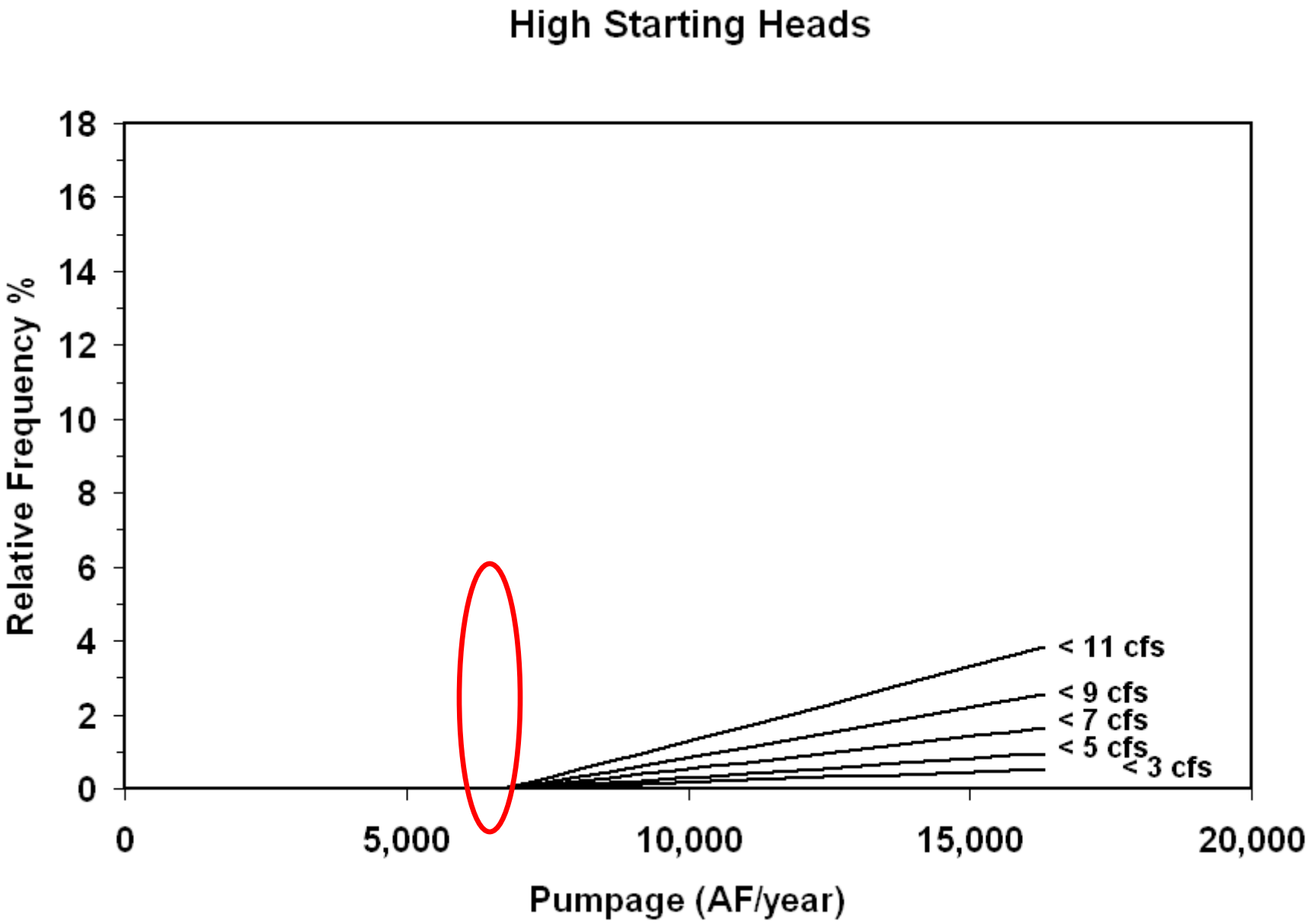

Cumulative Storage Change
Cumulative Storage Change (AF)
60,000
40,000
20,000
0
-20,000
-40,000
-60,000
1940
1950
1960
1970
1980
1990
2000
2010
Year

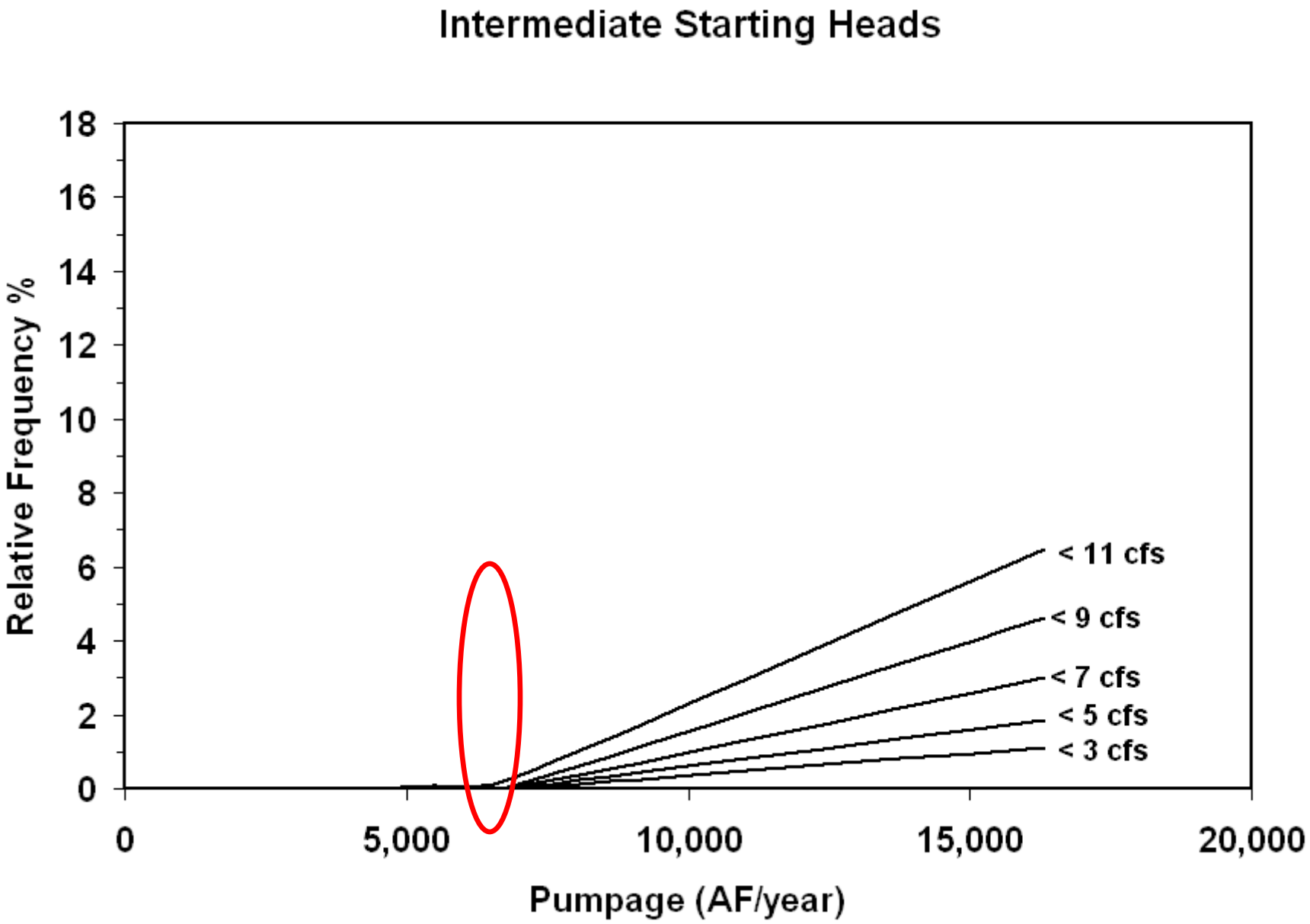
Summary

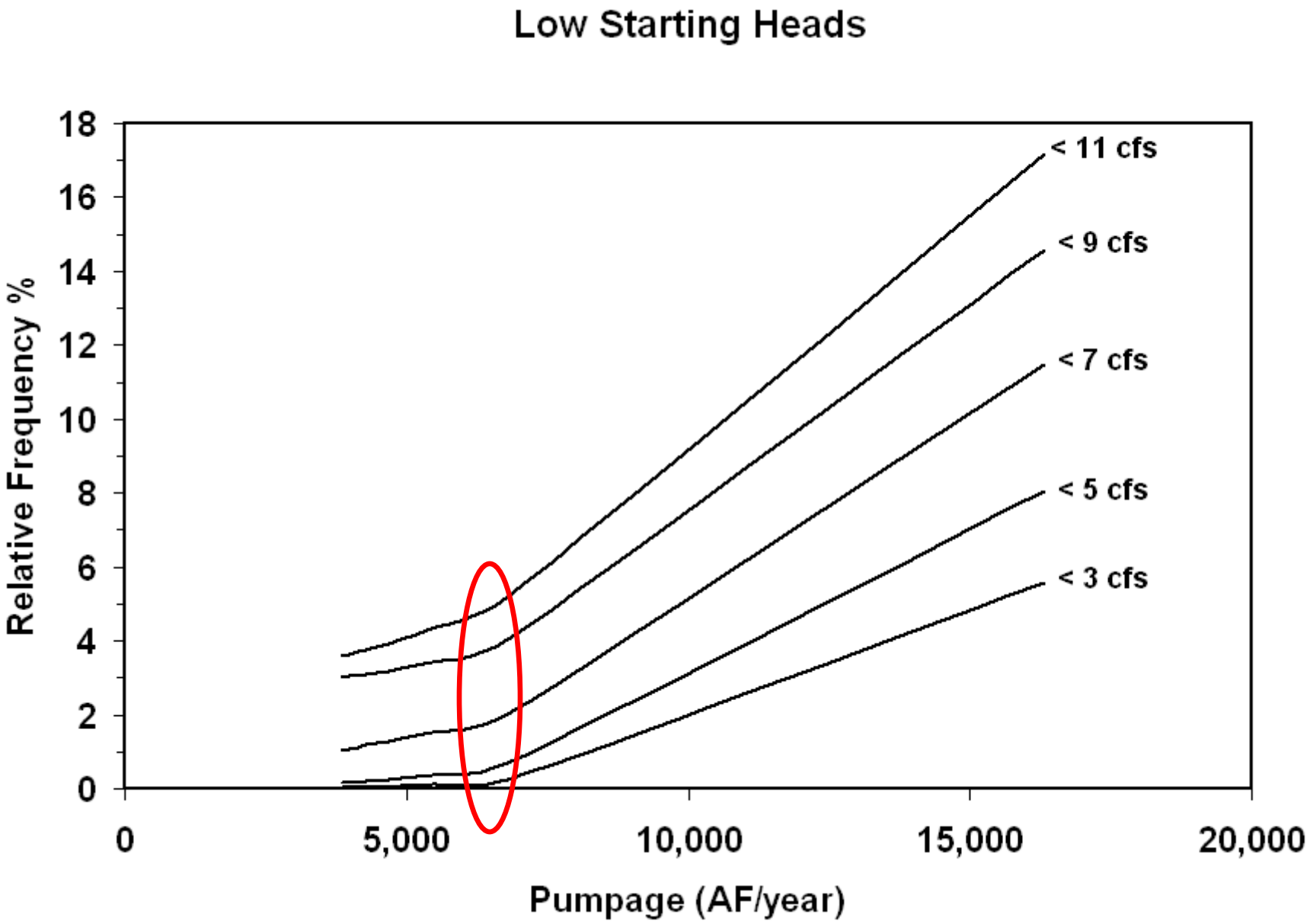
- Current pumping is relatively low compared to flow in system
- Relative impacts on spring flow
  - Initial Conditions
  - Recharge
  - Pumping
- Pumping assumed to be constant

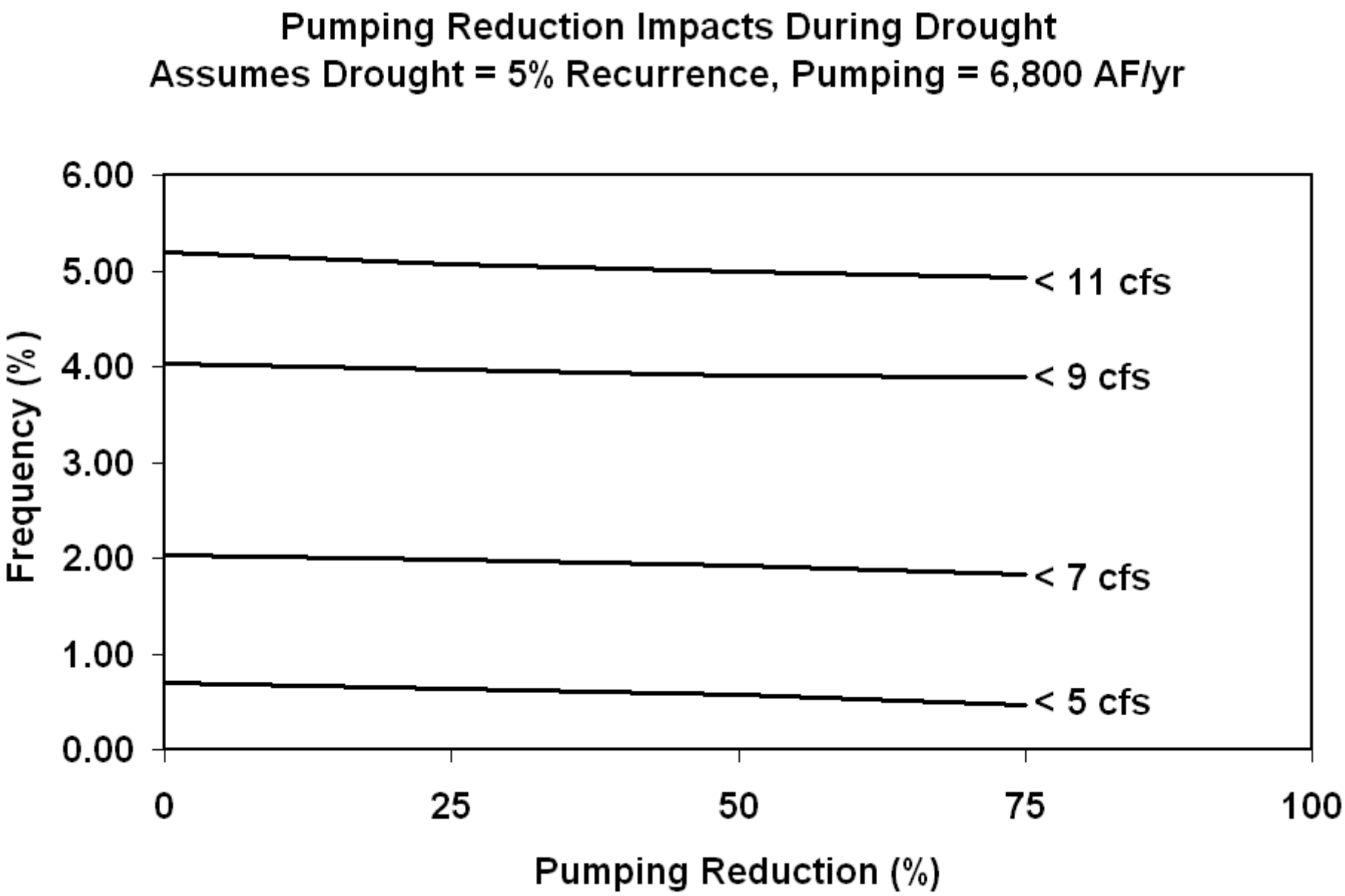
Pumping Reduction During Drought

- Assumed low initial conditions
- Assumed 6,800 AF/yr pumping
- Drought Threshold
  - 5%
  - 10%
- Pumping Reduction
  - 25%
  - 50%
  - 75%


High Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs


Intermediate Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs


Low Starting Heads
Relative Frequency %
18
16
14
12
10
8
6
4
2
0
0
5,000
10,000
15,000
20,000
Pumpage (AF/year)
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
< 3 cfs


Pumping Reduction Impacts During Drought
Assumes Drought = 5% Recurrence, Pumping = 6,800 AF/yr
Frequency (%)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
< 11 cfs
< 9 cfs
< 7 cfs
< 5 cfs
0
25
50
75
100
Pumping Reduction (%)

Summary

- New model better able to simulate drought conditions
- Tool to investigate spring flow impacts
  - Drought
  - Initial conditions
  - Annual pumping
  - Pumping reductions during drought

Desired Future Condition

- Policy decision/choice
- Minimum spring flow
  - Initial condition assumption?
  - 100% achievement?
  - 95% achievement?
  - 90% achievement?