FES 2007 Stormwater Workshop

Stormwater Permitting Course-2007

The Omni Orlando Resort at ChampionsGate

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Devo Engineering

Outline Of Presentation

1. Today's presentation will tell a story which, since the mid 1990's, has been repeated many times by the author. However, it only gets serious attention from drainage engineers and regulators when we have significant cumulative rainfall surpluses or deficits

2. The range and magnitude of water level fluctuation in closed (a.k.a. land-locked) lakes, ponds (both wet & dry), and wetlands are linked closely to surpluses and deficits in cumulative rainfall over relatively long periods of time. A "long" period, in this sense, refers to a duration of 1 month to say 42 months. The "critical duration" for a land-locked basin depends on the characteristics of the contributing watershed (time lag before ground water enters) and the geology and geometry of the "pond".

Outline Of Presentation

(Continued)

3. Current regulations (FDOT & SRWMD) model storm events up to 10 days in duration which don't reflect the true "critical duration" for these closed basins. After all, is 24.11 inches of rainfall in one month for critical than 10.6 inches of rain in 1 day? Is 220 inches of rainfall in 36 months (3 years) more critical than the design 100 yr storm event?

4. First data slide will show a plot of recent ground water level trends to get a feel for the actual range of water table fluctuation measured on a Clermont sand ridge over the past 13 years (1994 to the present). This period was somewhat wild and covers 2 major droughts (2001, 2007) and several periods of high rainfall including Tropical Storm Gordon, 1994-1996, El Nino Rains in early 1998, troika of hurricanes in 2004, and record monthly rainfall total in June 2005.

Outline Of Presentation

(Continued)

5. Analyze cumulative rainfall patterns over the last 100 years at 2 rainfall stations in Central Florida (Orlando International Airport and Clermont) and mark their peaks and valleys for various "critical durations" ranging from 1 month to 48 months. Compare the 1 month totals to the FDOT 100 yr/10 day storm which is the highest rainfall storm currently regulated.

6. A quick comparison is done for a site in Seminole County (Lake Sylvan) to compare to cumulative rainfall patterns at OIA. The purpose of this is to show trend similarity between rainfall stations 25 miles apart.

7. A summary of the regulatory criteria for each agency will be presented. How applicable are these criteria for providing true regulation of peak stages and duration in these systems?

Outline Of Presentation

(Continued)

8. Examples of recent flooding in land-locked lakes. Show a rainfall trending analysis and high water stage correlation for 2 lakes which flooded in the Lake Wales area of Polk County (SWFWMD).

9. Long-term continuous simulation modeling: discuss the conceptual models, technology and software

10. Show some real-world applications of continuous simulation modeling

11. Geotechnical Pitfalls in stormwater design - will discuss some of these bonus slides if time permits

Part 1

Review of Long Term Cumulative Rainfall Patterns & Recent Trends in Central Florida

Part 2

Applicability of Current Regulatory Criteria for Ensuring Flood Protection in Land-Locked Drainage Systems

Part 3

Long-term and short-term continuous simulation modeling of stormwater management systems.

Part 4

Some Screen Shots of PONDS 3.2 Software Continuous Simulation Hydrograph Generator

Part 5

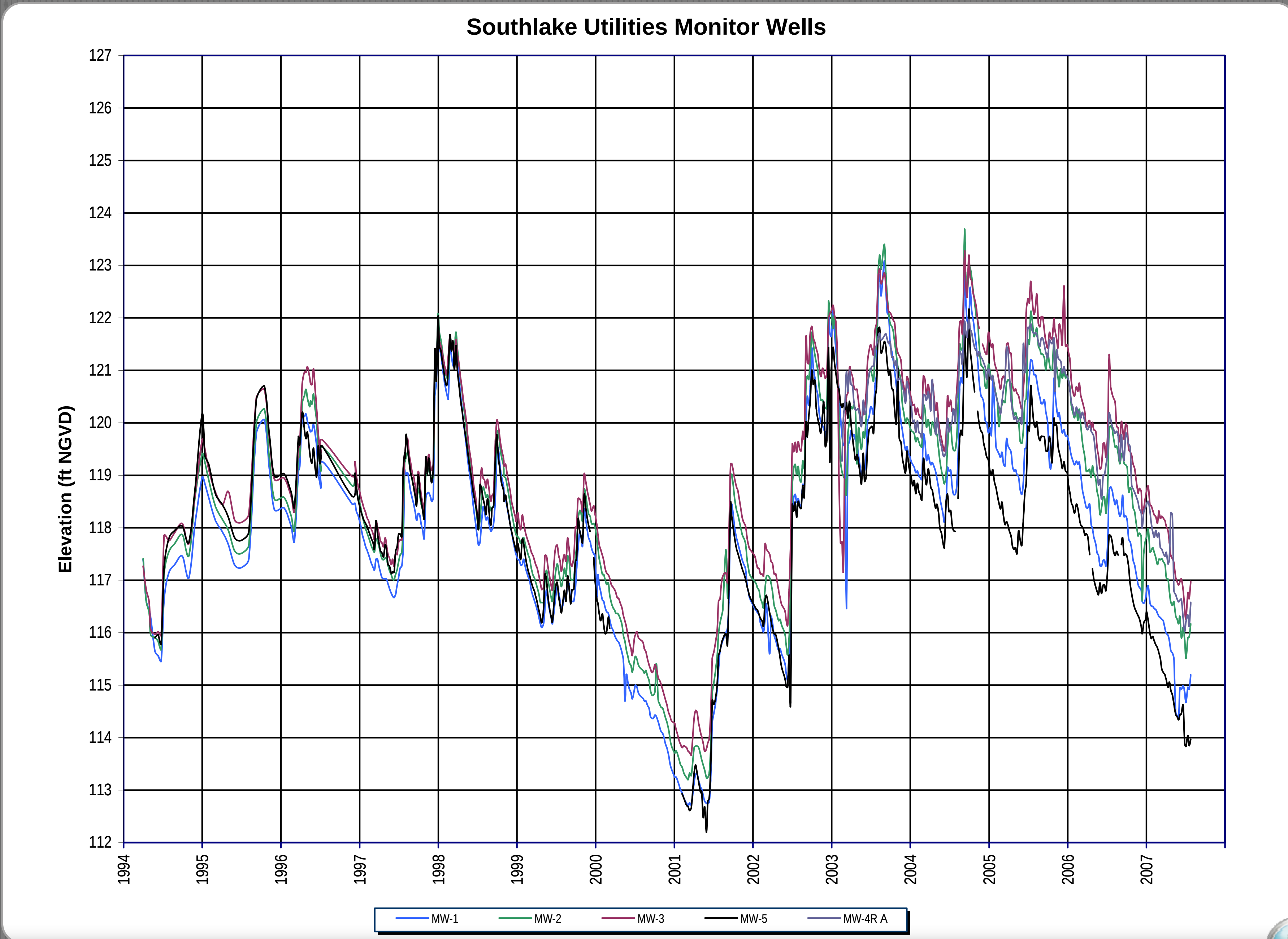
Some lessons in stormwater management design learned from post-mortem investigations

Part 1

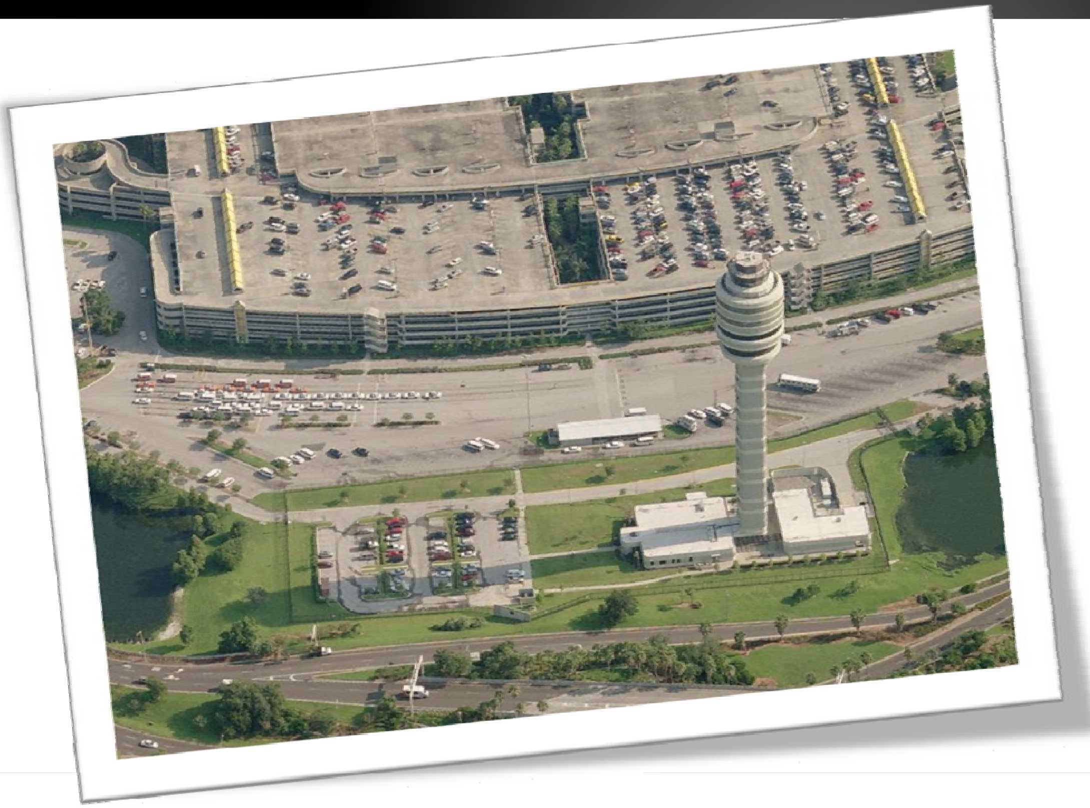
Review of Long Term Cumulative Rainfall Patterns & Recent Trends in Central Florida

Groundwater Levels at Southlake Utilities on Lake Wales Ridge

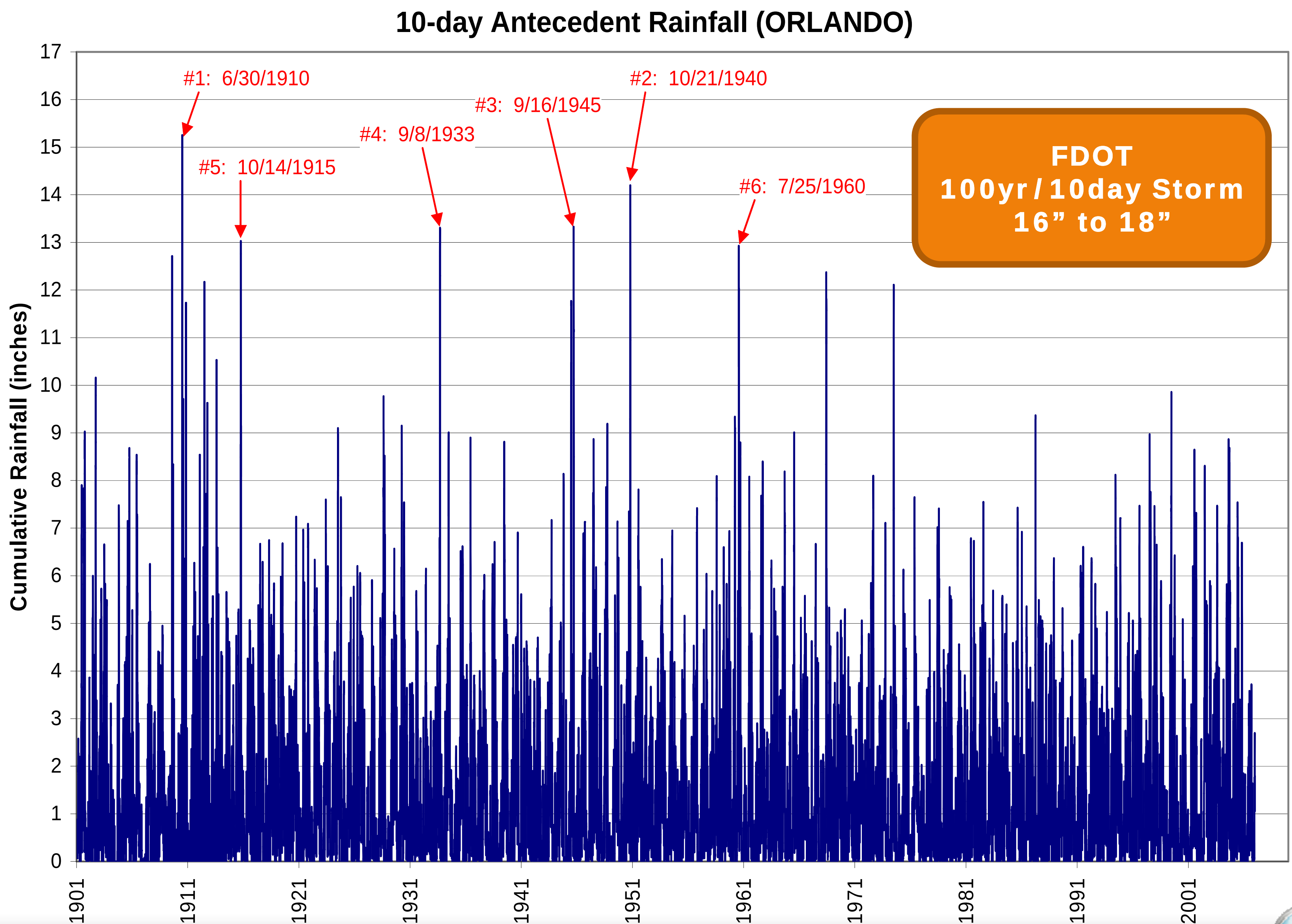
What has been the measured groundwater level fluctuation on the Central Florida ridge for the past 13 years? Let us look at the trends on a sandhill site which has been continuously monitored since 1994.


Southlake Utilities Monitor Wells
Elevation (ft NGVD)
127
126
125
124
123
122
121
120
119
118
117
116
115
114
113
112
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
MW-1
MW-2
MW-3
MW-5
MW-4R A

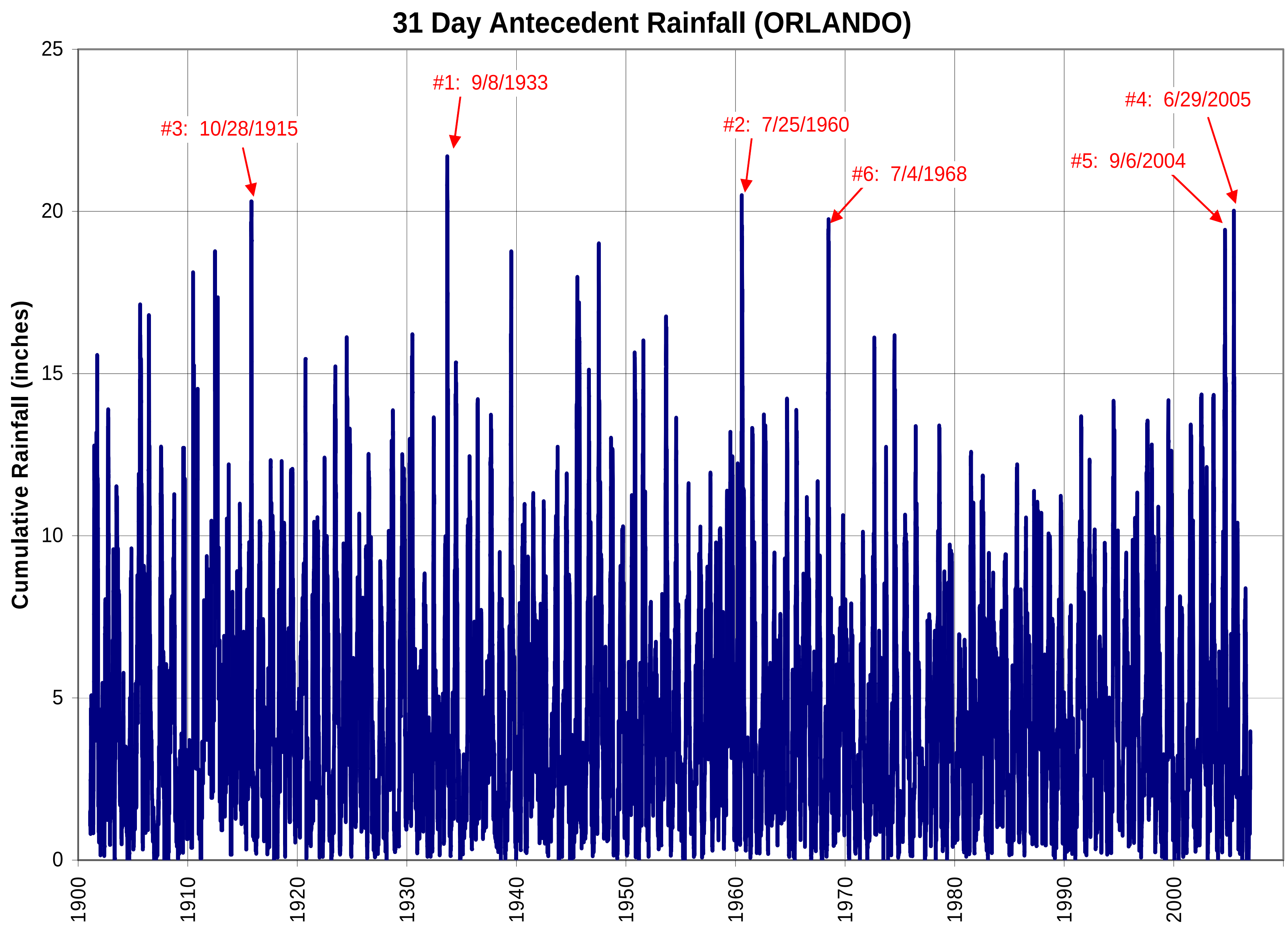
106 Years of Rainfall Data at OIA



Yearly Cumulative Rainfall (Orlando)



10-day Antecedent Rainfall (ORLANDO)
Cumulative Rainfall (inches)
#1: 6/30/1910
#2: 10/21/1940
#3: 9/16/1945
#4: 9/8/1933
#5: 10/14/1915
#6: 7/25/1960
FDOT
100yr / 10day Storm
16" to 18"
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1901
1911
1921
1931
1941
1951
1961
1971
1981
1991
2001

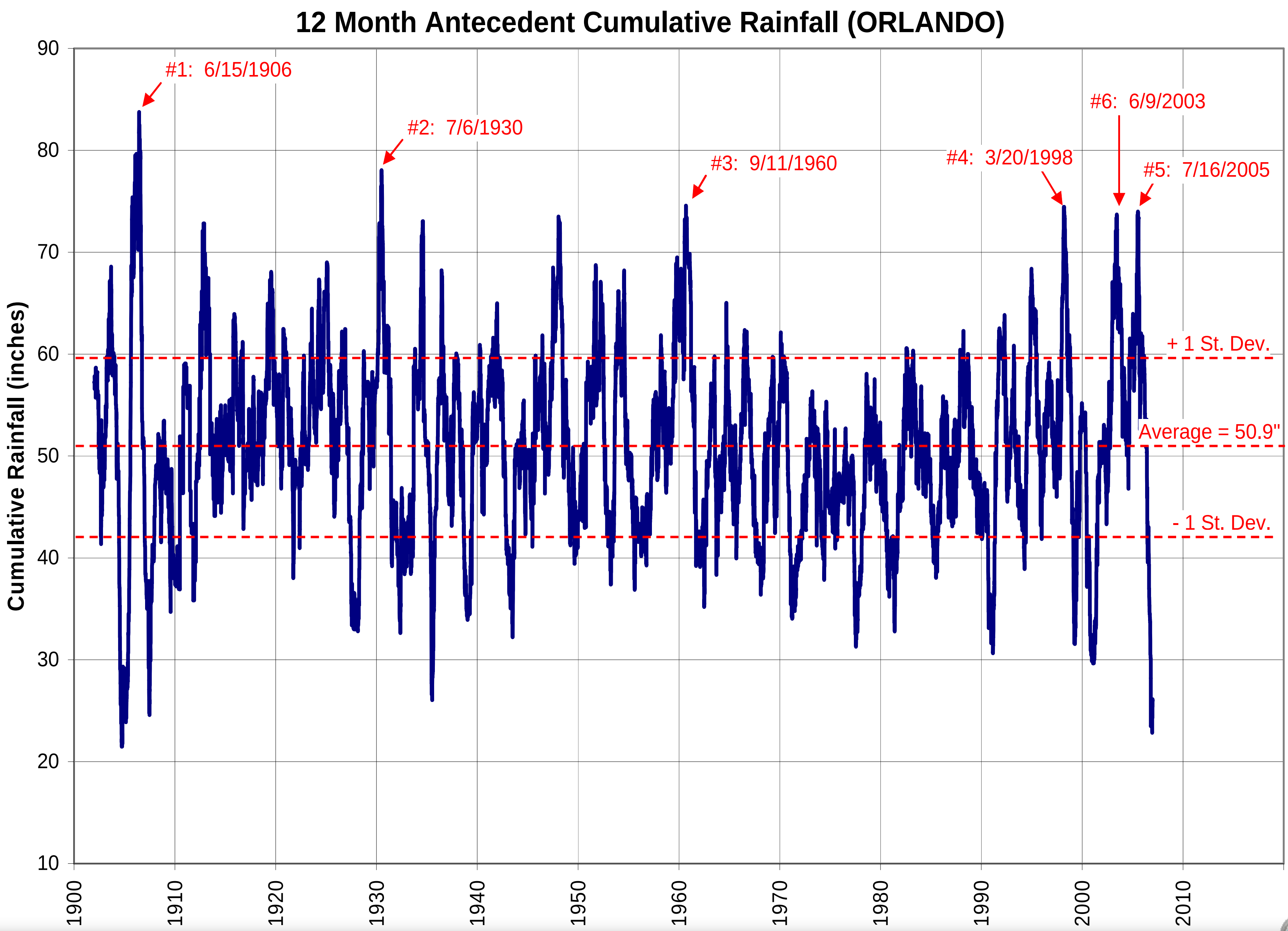


31 Day Antecedent Rainfall (ORLANDO)
Cumulative Rainfall (inches)
0
5
10
15
20
25
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
#1: 9/8/1933
#2: 7/25/1960
#3: 10/28/1915
#4: 6/29/2005
#5: 9/6/2004
#6: 7/4/1968

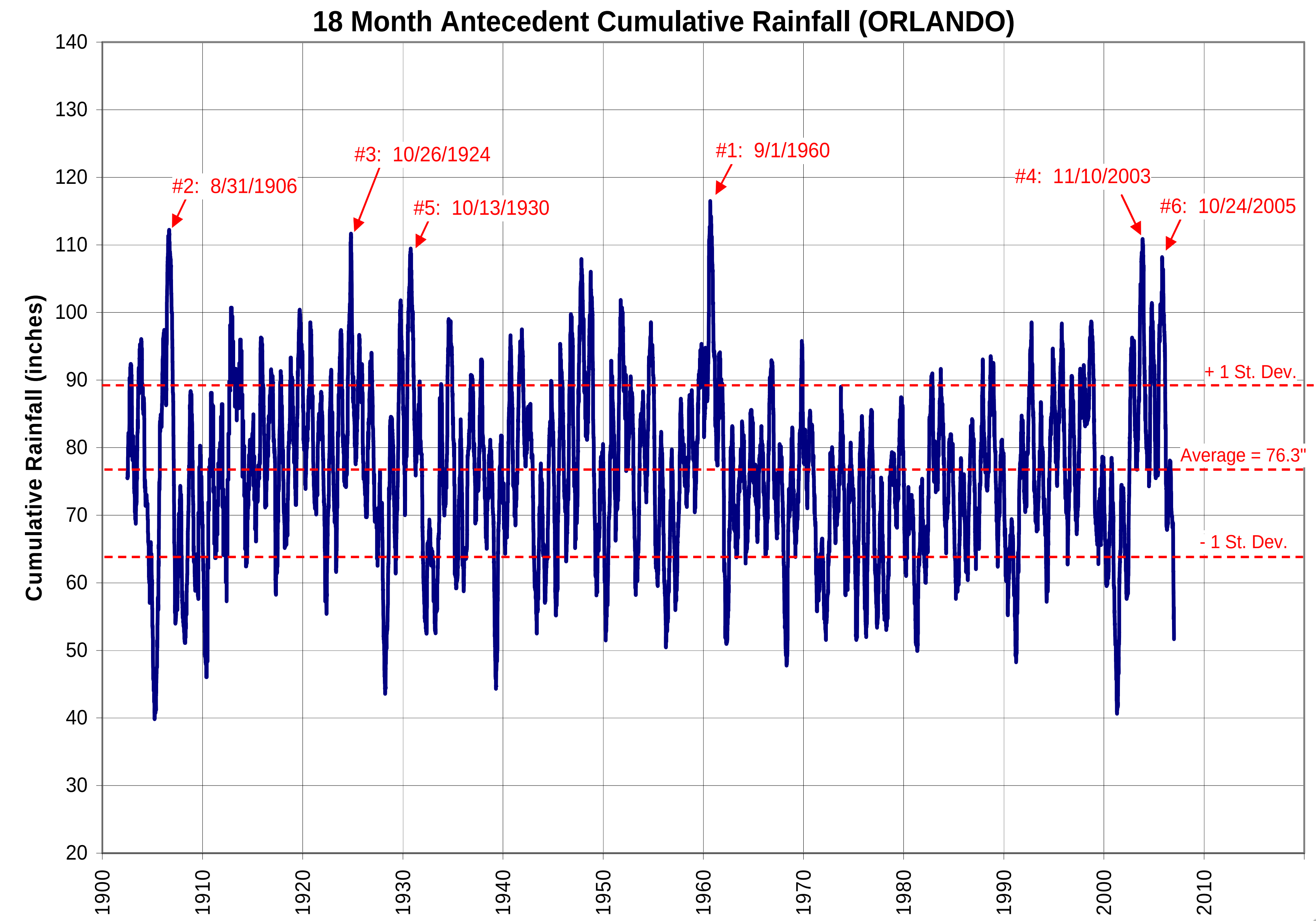
Comparison of Measured Rainfall to FDOT 100-yr / 24-hr Storm Event

OIA Peak 10-day & 31-day Rainfall		
Rank	10-day Antecedent Rainfall (inches)	31-day Antecedent Rainfall (inches)
1	15.25 (6/30/1910)	21.70 9/8/1933
2	14.20 (10/21/1940)	20.50 7/25/1960
3	13.33 (9/16/1945)	20.07 10/28/1915
4	13.31 (9/8/1933)	20.02 6/29/2005
5	13.03 (10/14/2015)	19.43 9/6/2004

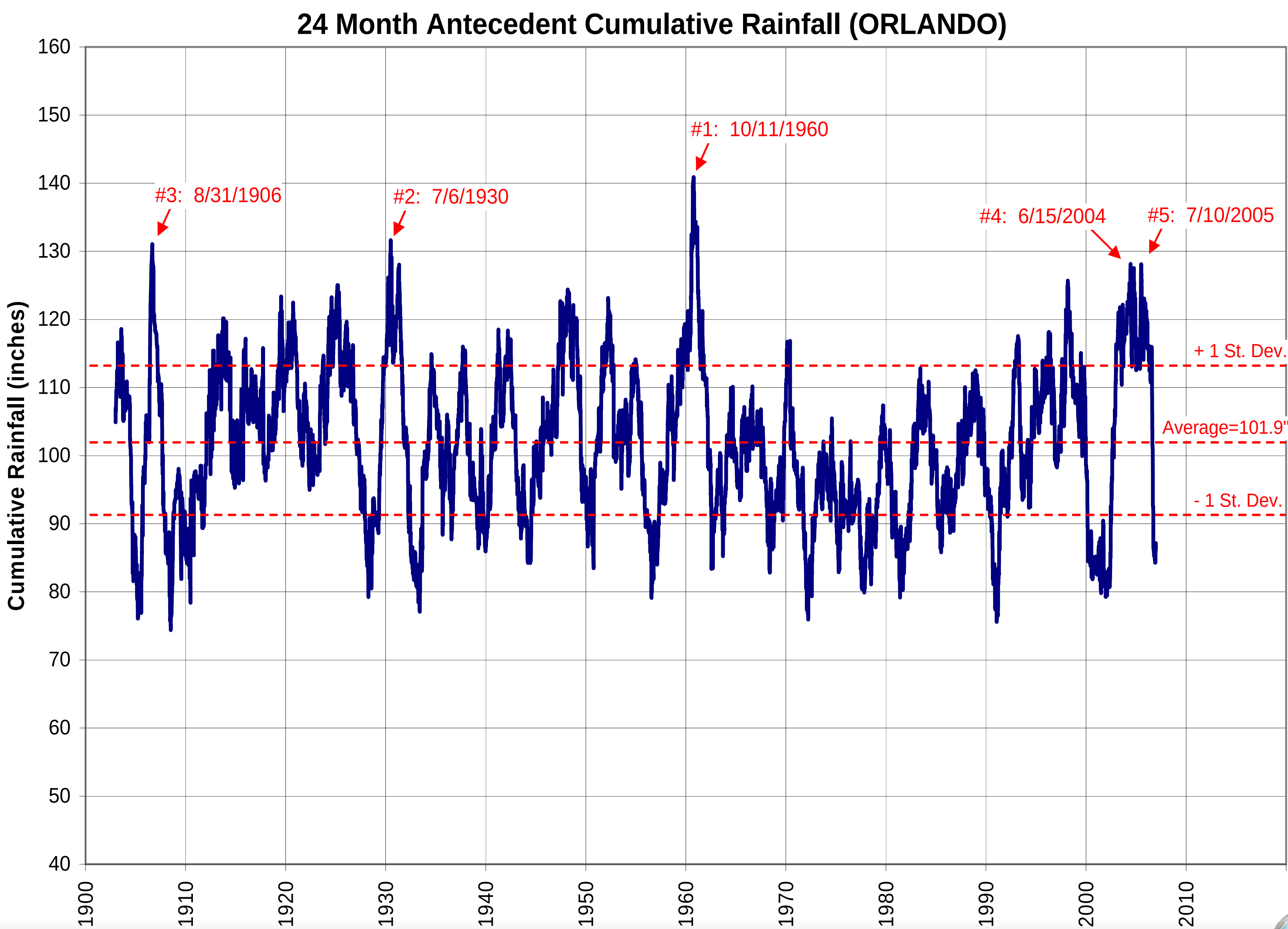
FDOT 100-yr / 10-day is 16 to 18 inches.



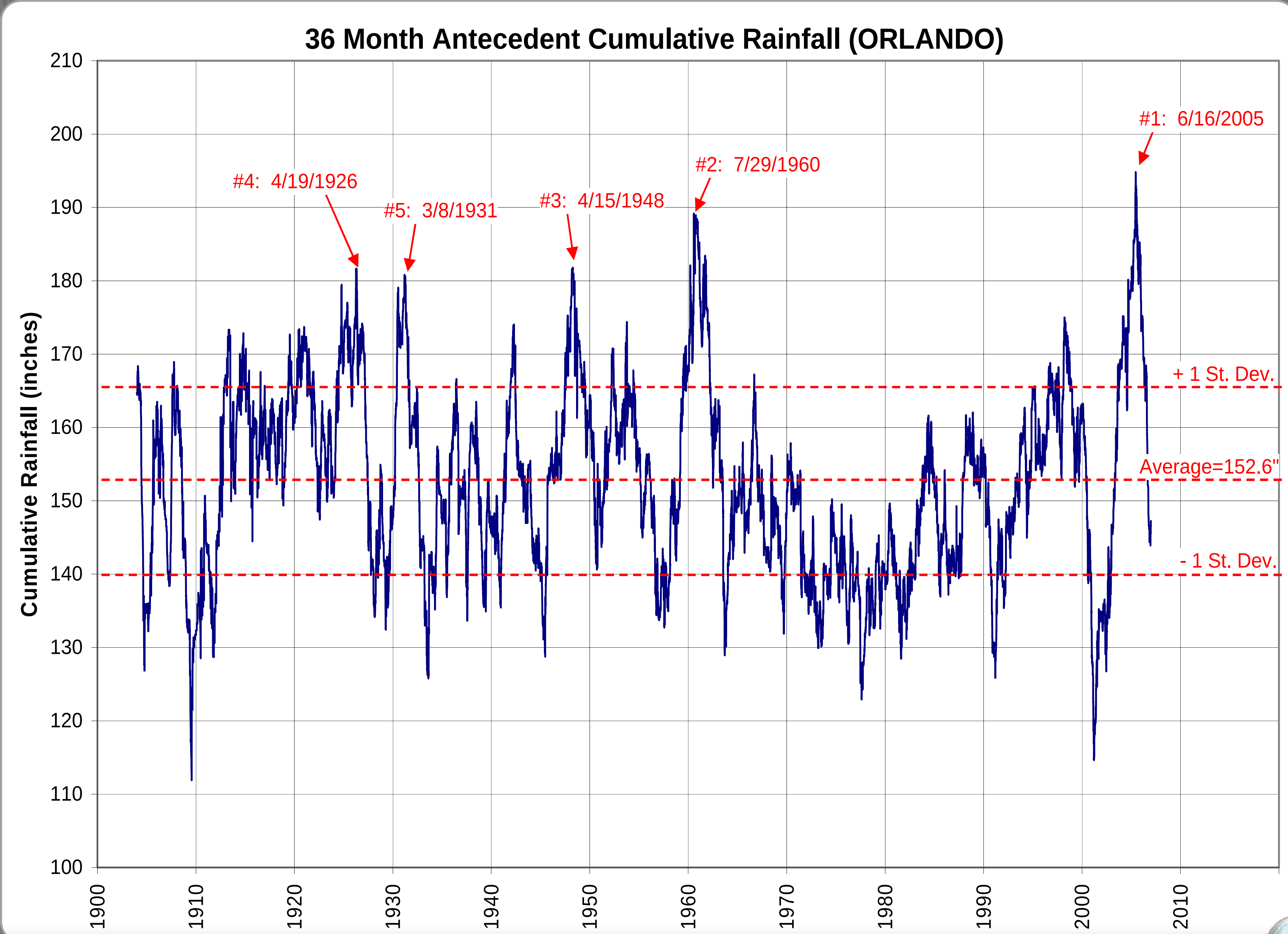
12 Month Antecedent Cumulative Rainfall (ORLANDO)
Cumulative Rainfall (inches)
90
80
70
60
50
40
30
20
10
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
#1: 6/15/1906
#2: 7/6/1930
#3: 9/11/1960
#4: 3/20/1998
#6: 6/9/2003
#5: 7/16/2005
+ 1 St. Dev.
Average = 50.9"
- 1 St. Dev.



18 Month Antecedent Cumulative Rainfall (ORLANDO)
Cumulative Rainfall (inches)
140
130
120
110
100
90
80
70
60
50
40
30
20
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
#2: 8/31/1906
#3: 10/26/1924
#5: 10/13/1930
#1: 9/1/1960
#4: 11/10/2003
#6: 10/24/2005
+ 1 St. Dev.
Average = 76.3"
- 1 St. Dev.



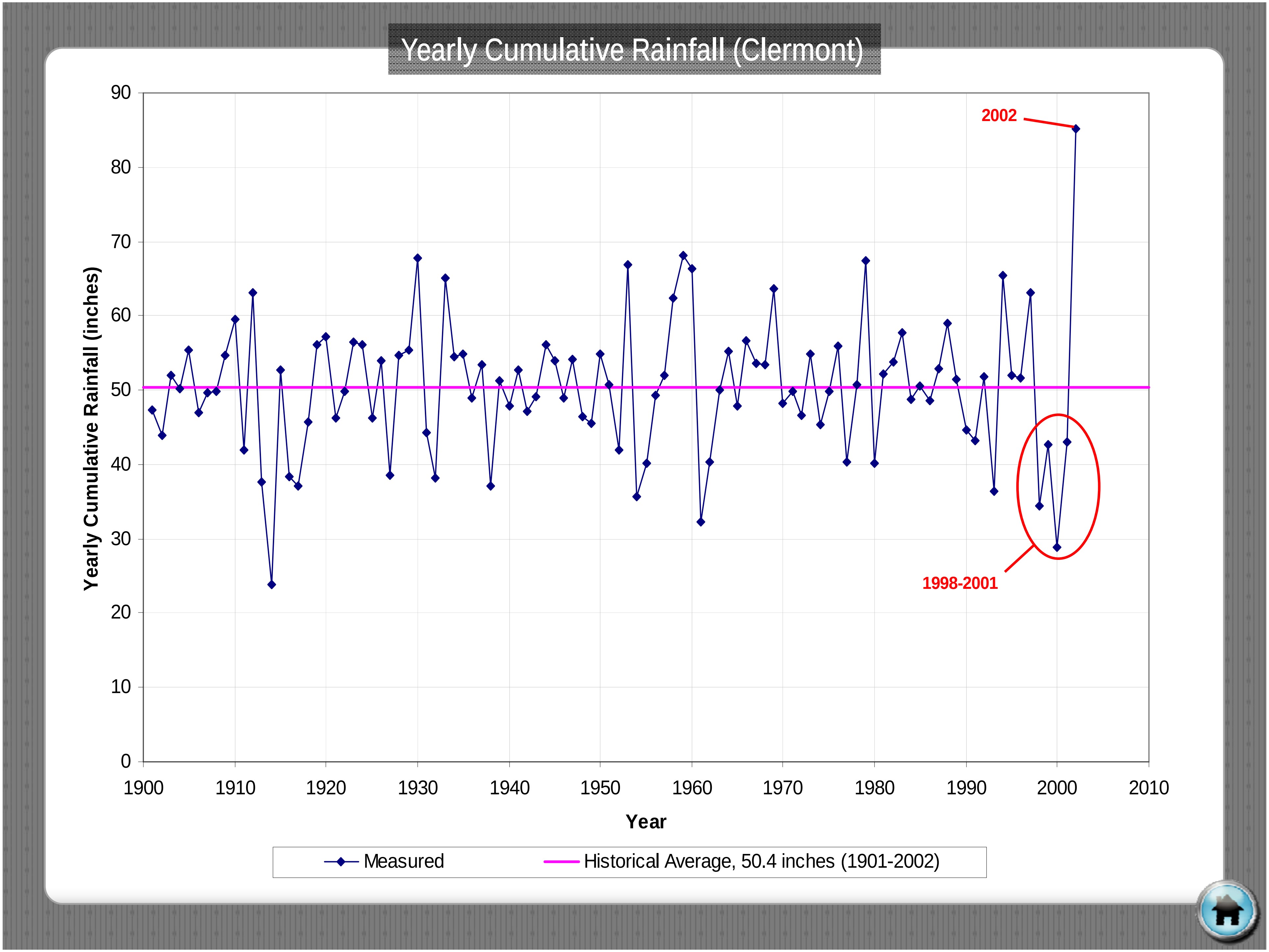
24 Month Antecedent Cumulative Rainfall (ORLANDO)
Cumulative Rainfall (inches)
160
150
140
130
120
110
100
90
80
70
60
50
40
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
#1: 10/11/1960
#2: 7/6/1930
#3: 8/31/1906
#4: 6/15/2004
#5: 7/10/2005
+ 1 St. Dev.
Average=101.9"
- 1 St. Dev.



36 Month Antecedent Cumulative Rainfall (ORLANDO)
Cumulative Rainfall (inches)
210
200
190
180
170
160
150
140
130
120
110
100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
#1: 6/16/2005
#2: 7/29/1960
#3: 4/15/1948
#4: 4/19/1926
#5: 3/8/1931
+ 1 St. Dev.
Average=152.6"
- 1 St. Dev.

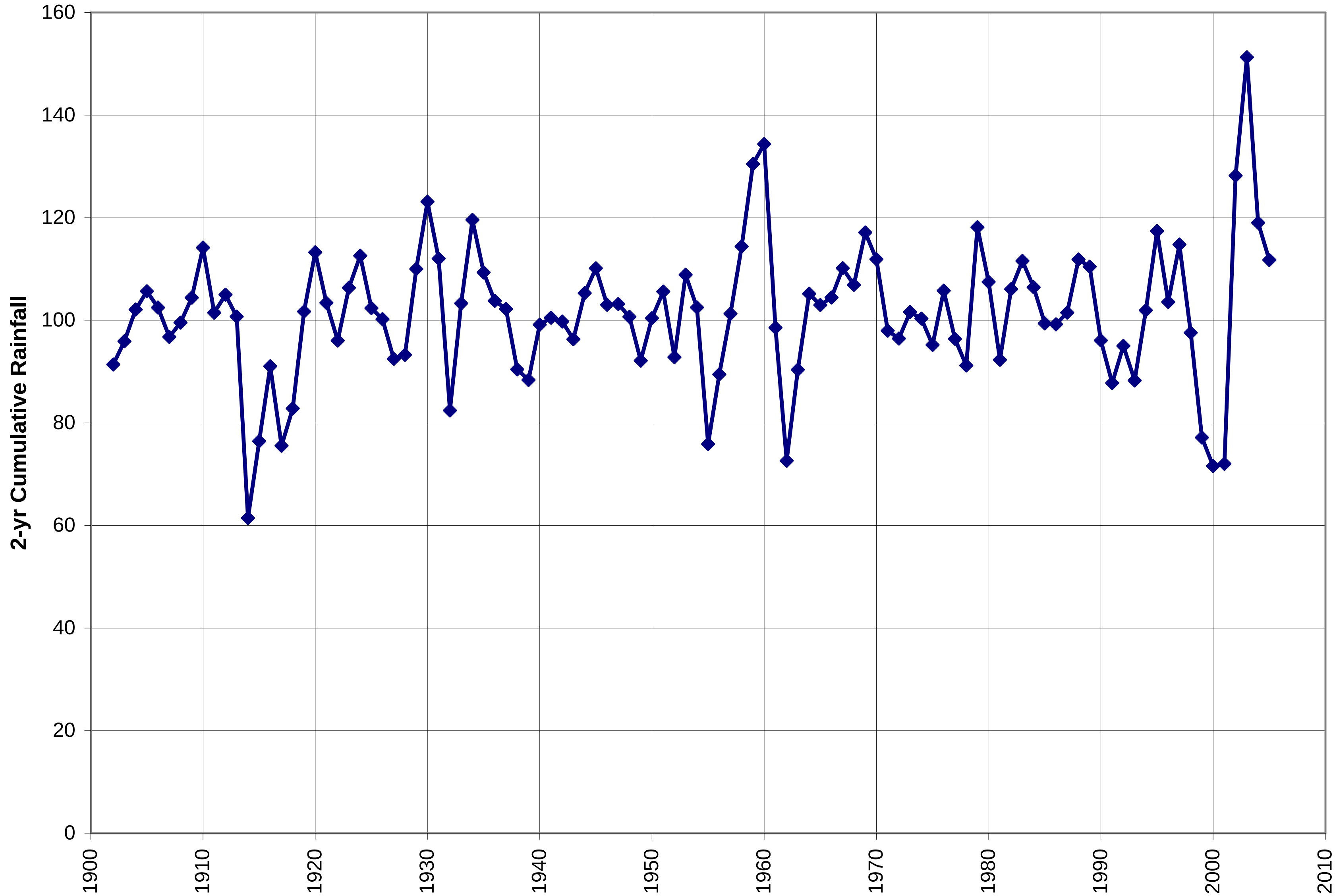
101 Years of Rainfall Data at Clermont Weather Station 1901 - 2002

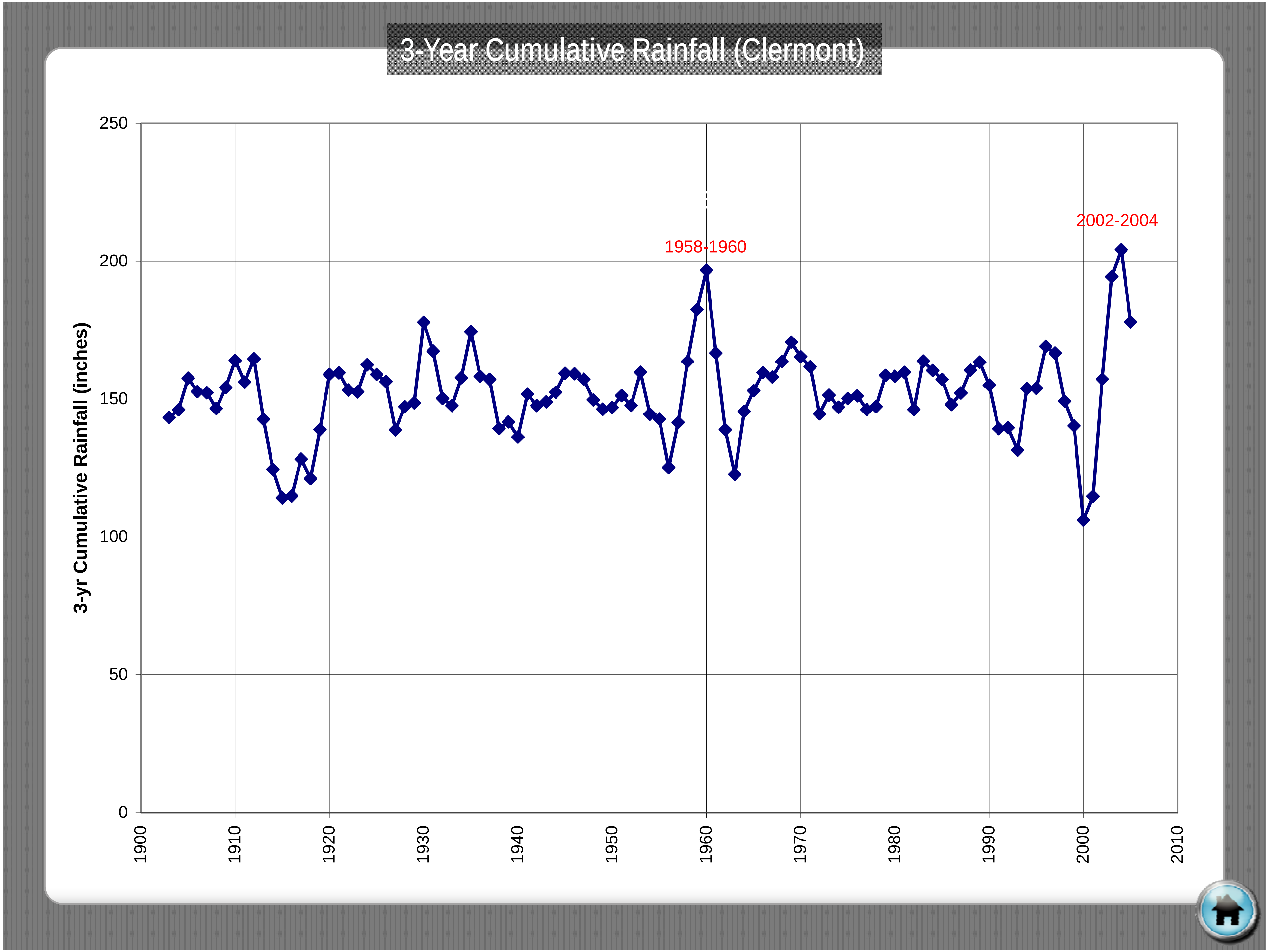
Yearly Cumulative Rainfall (Clermont)



Yearly Cumulative Rainfall (Clermont)
Yearly Cumulative Rainfall (inches)
90
80
70
60
50
40
30
20
10
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
2002
1998-2001
Measured
Historical Average, 50.4 inches (1901-2002)

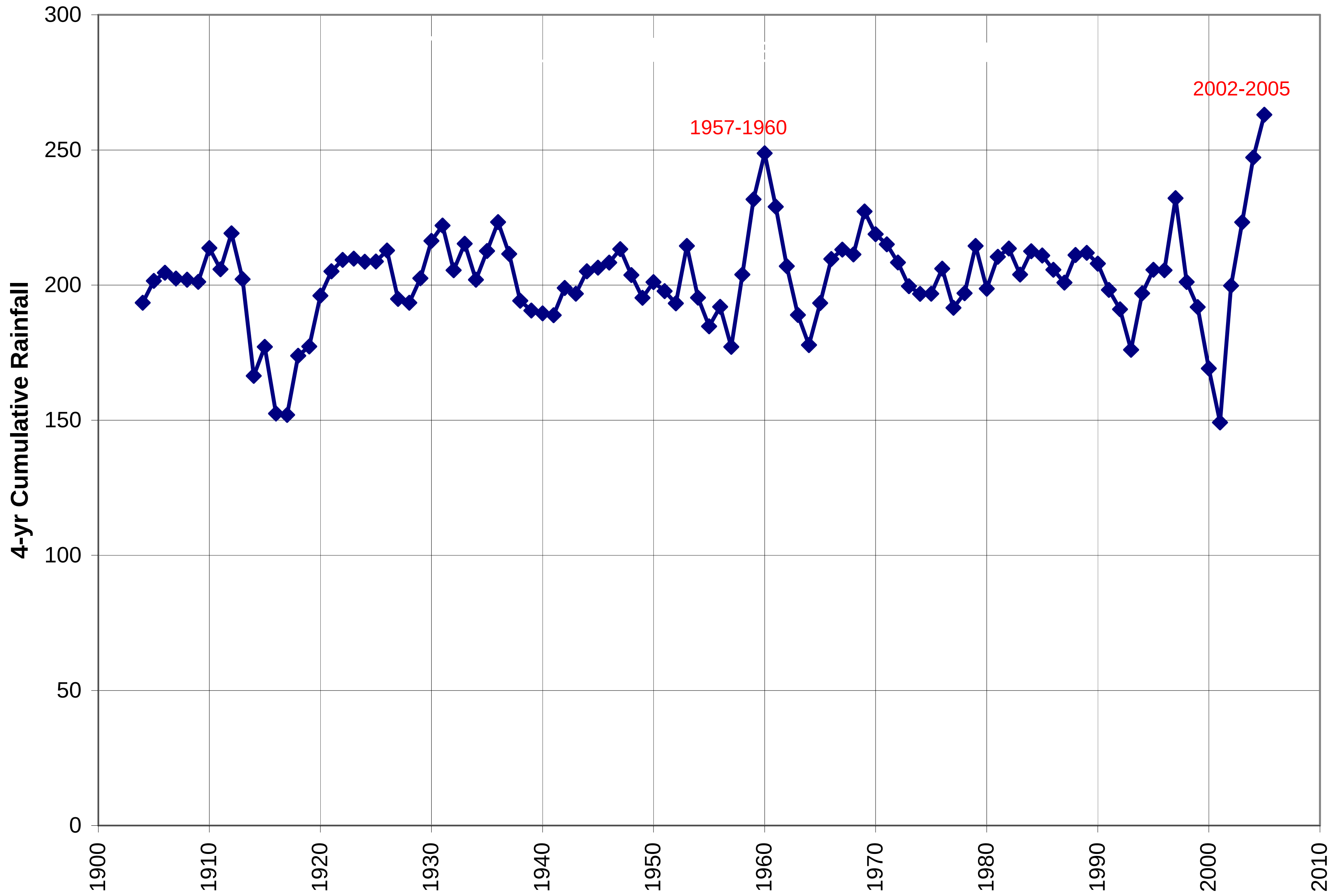
2-Year Cumulative Rainfall (Clermont)





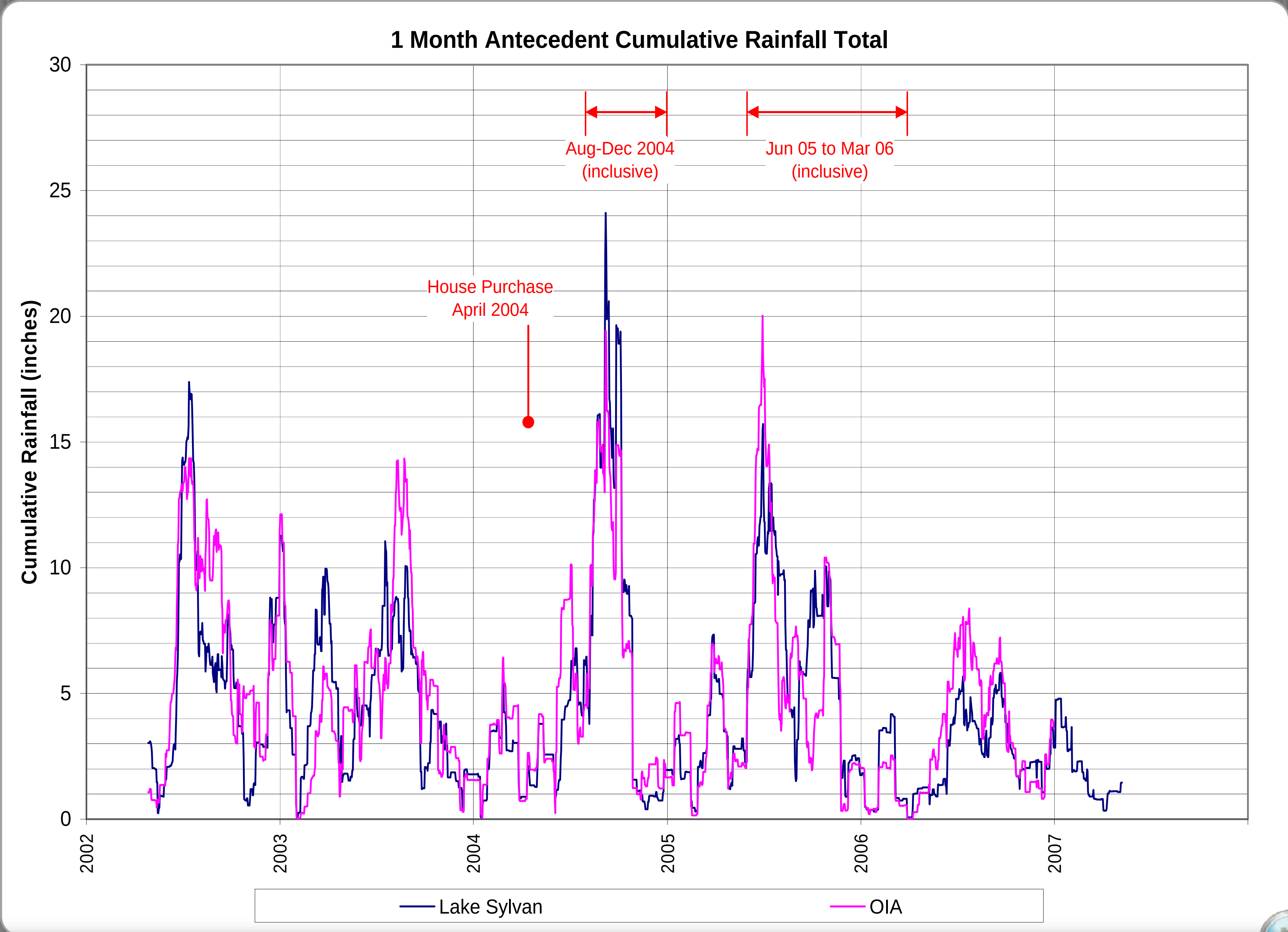
3-Year Cumulative Rainfall (Clermont)
3-yr Cumulative Rainfall (inches)
0
50
100
150
200
250
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
1958-1960
2002-2004

4-Year Cumulative Rainfall (Clermont)

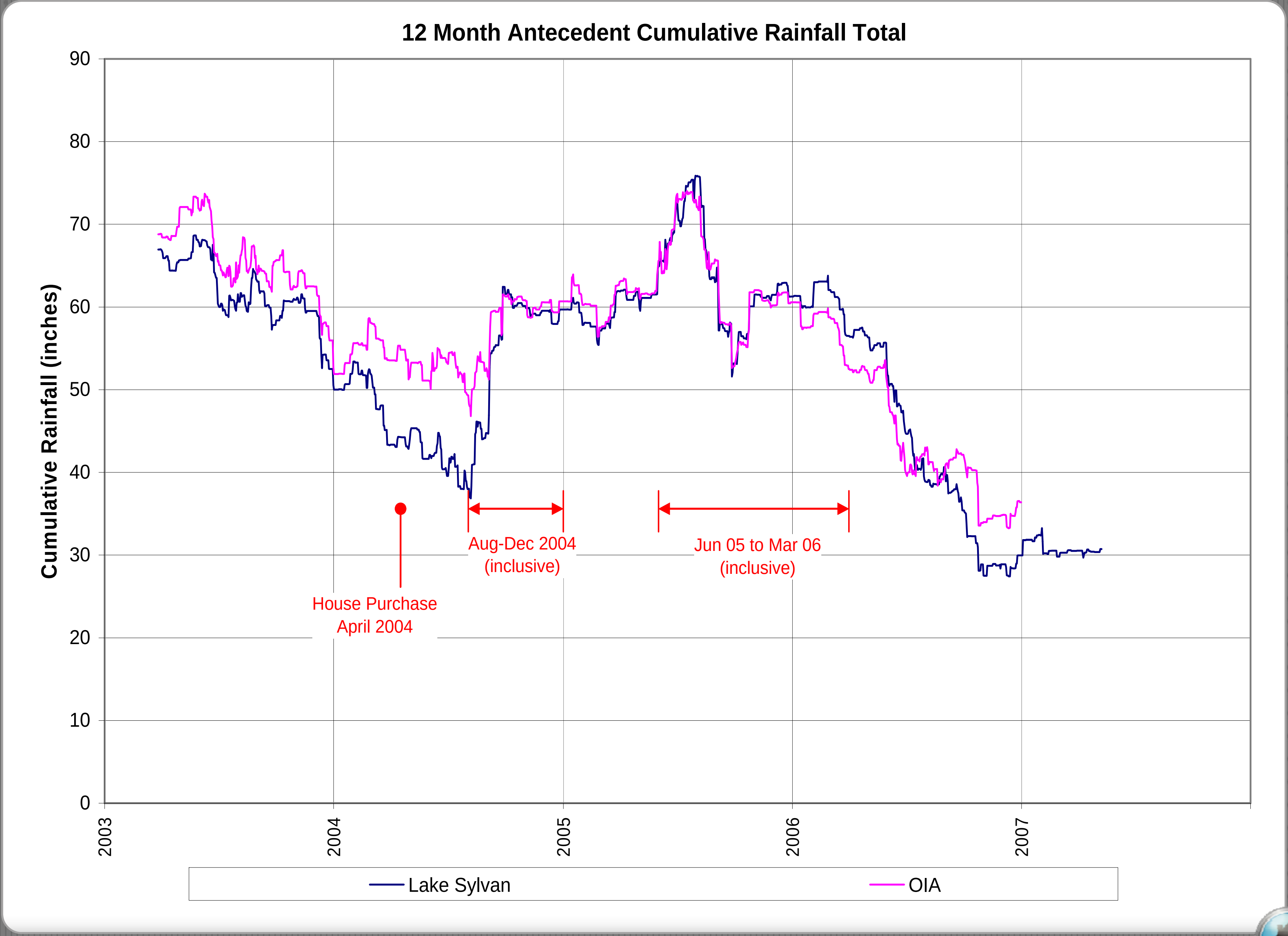


Rainfall at Lake Sylvan

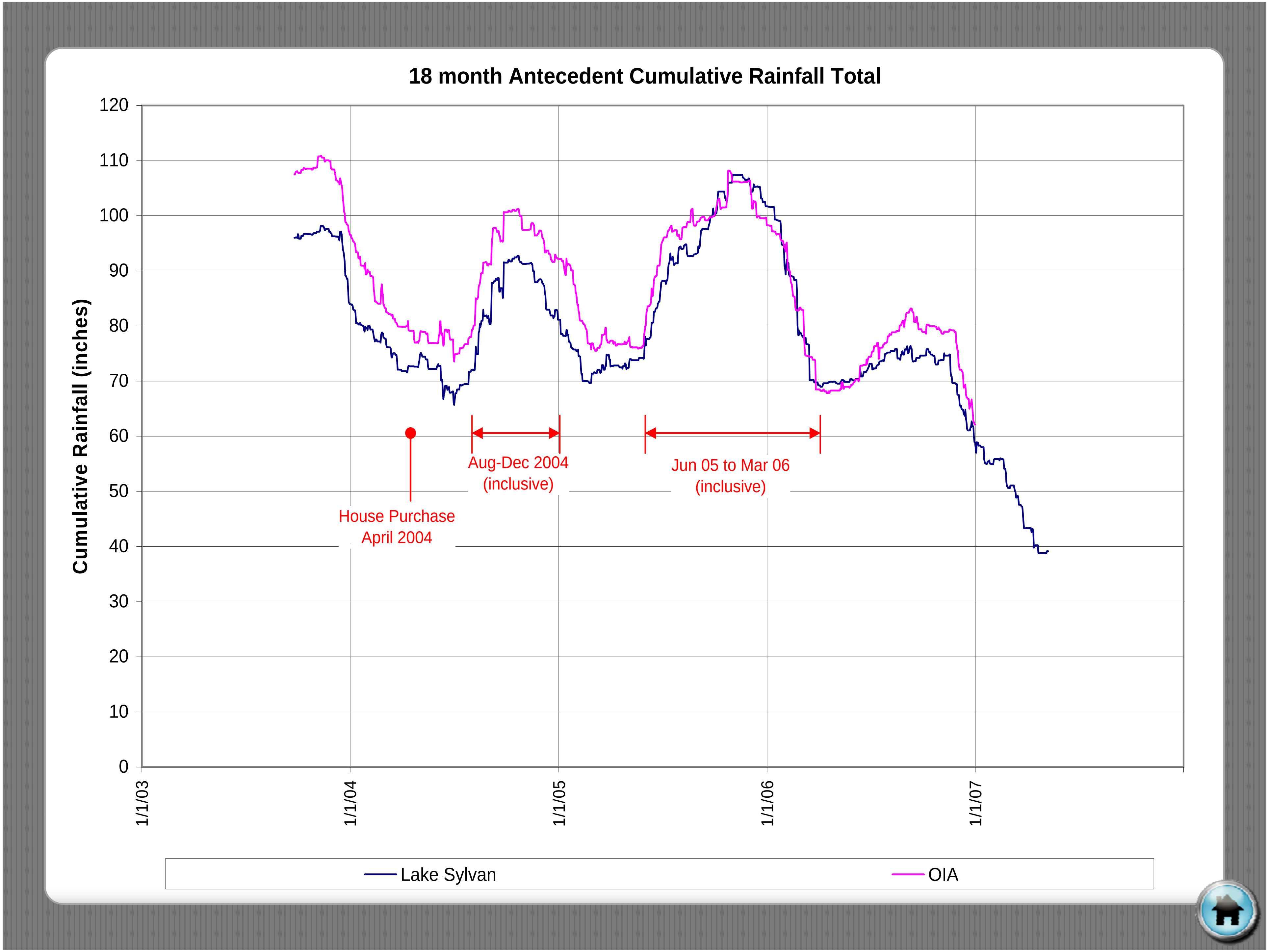
The Lake Sylvan site is located near the Heathrow community in Seminole County. The purpose of this exercise was to compare the rainfall patterns at OIA and Lake Sylvan to see if their trends were consistent from a long term standpoint or vastly different.



1 Month Antecedent Cumulative Rainfall Total
Cumulative Rainfall (inches)
30
25
20
15
10
5
0
2002
2003
2004
2005
2006
2007
House Purchase
April 2004
Aug-Dec 2004
(inclusive)
Jun 05 to Mar 06
(inclusive)
Lake Sylvan
OIA

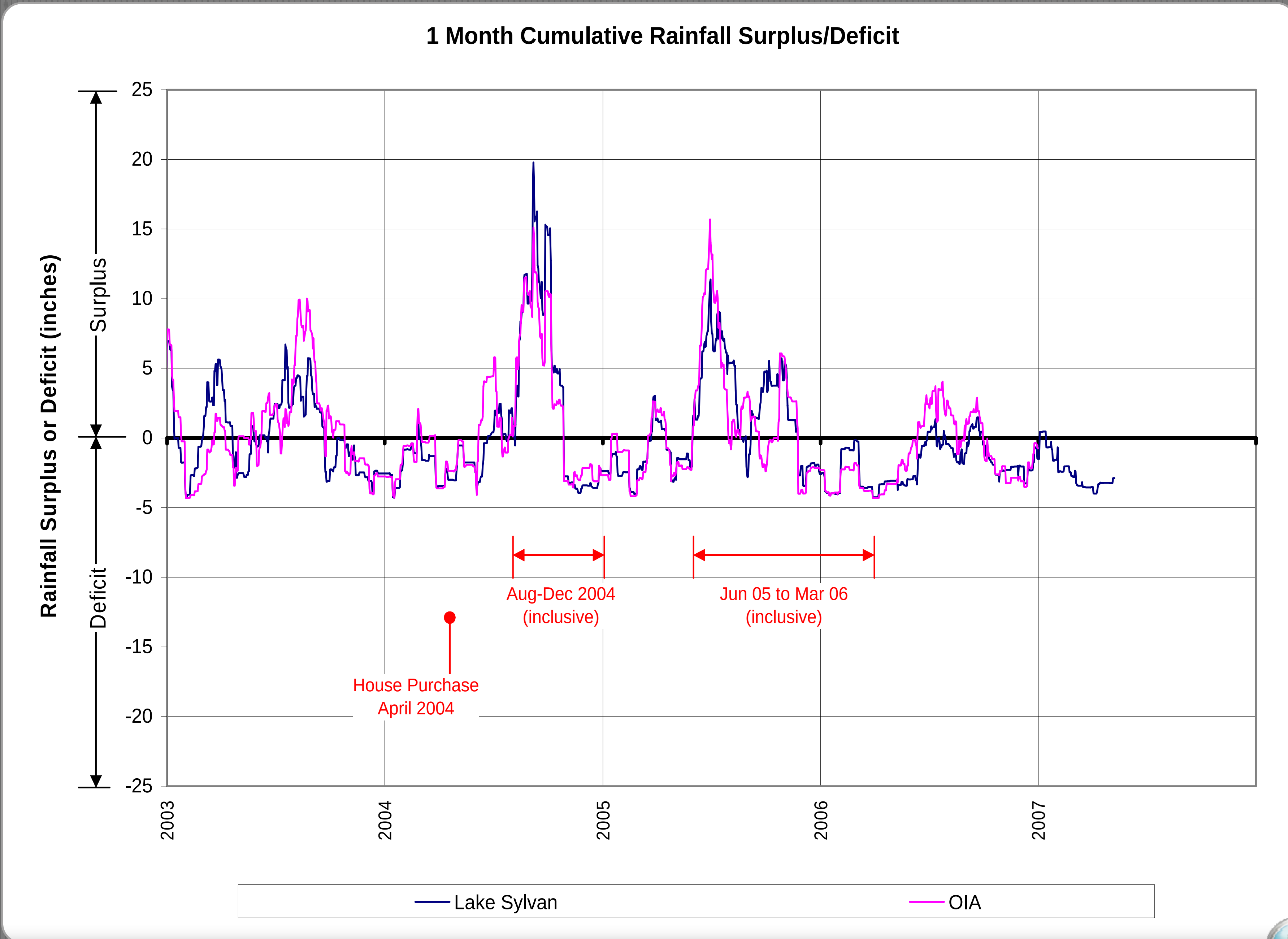


12 Month Antecedent Cumulative Rainfall Total
Cumulative Rainfall (inches)
90
80
70
60
50
40
30
20
10
0
2003
2004
2005
2006
2007
House Purchase
April 2004
Aug-Dec 2004
(inclusive)
Jun 05 to Mar 06
(inclusive)
Lake Sylvan
OIA



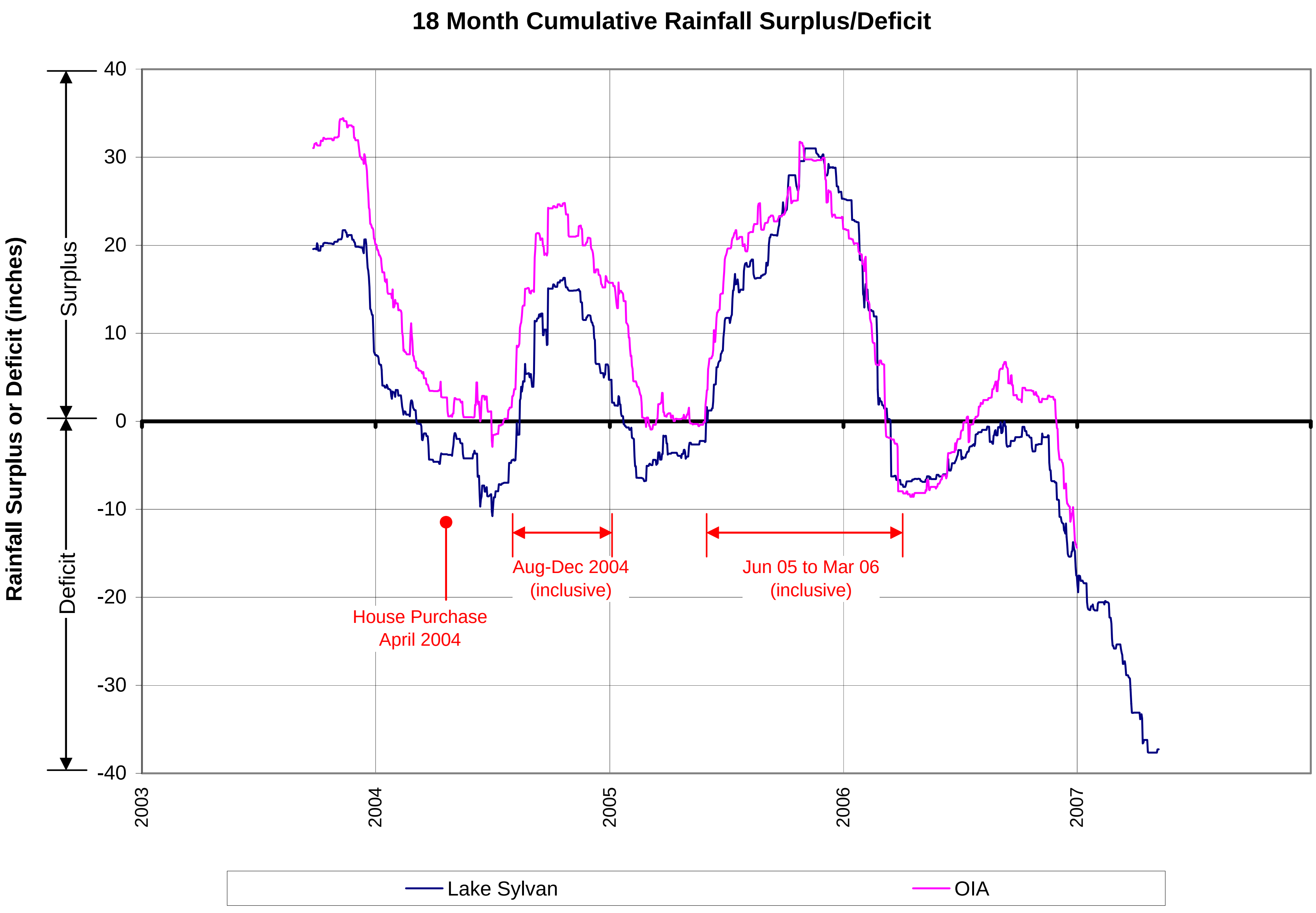
18 month Antecedent Cumulative Rainfall Total
Cumulative Rainfall (inches)
120
110
100
90
80
70
60
50
40
30
20
10
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
House Purchase
April 2004
Aug-Dec 2004
(inclusive)
Jun 05 to Mar 06
(inclusive)
Lake Sylvan
OIA

Rainfall Surplus/Deficit at Lake Sylvan



1 Month Cumulative Rainfall Surplus/Deficit
Rainfall Surplus or Deficit (inches)
Surplus
Deficit
25
20
15
10
5
0
-5
-10
-15
-20
-25
2003
2004
2005
2006
2007
Aug-Dec 2004
(inclusive)
Jun 05 to Mar 06
(inclusive)
House Purchase
April 2004
Lake Sylvan
OIA

12 Month Cumulative Rainfall Surplus/Deficit


18 Month Cumulative Rainfall Surplus/Deficit
Rainfall Surplus or Deficit (inches)
Surplus
Deficit
40
30
20
10
0
-10
-20
-30
-40
2003
2004
2005
2006
2007
House Purchase
April 2004
Aug-Dec 2004
(inclusive)
Jun 05 to Mar 06
(inclusive)
Lake Sylvan
OIA

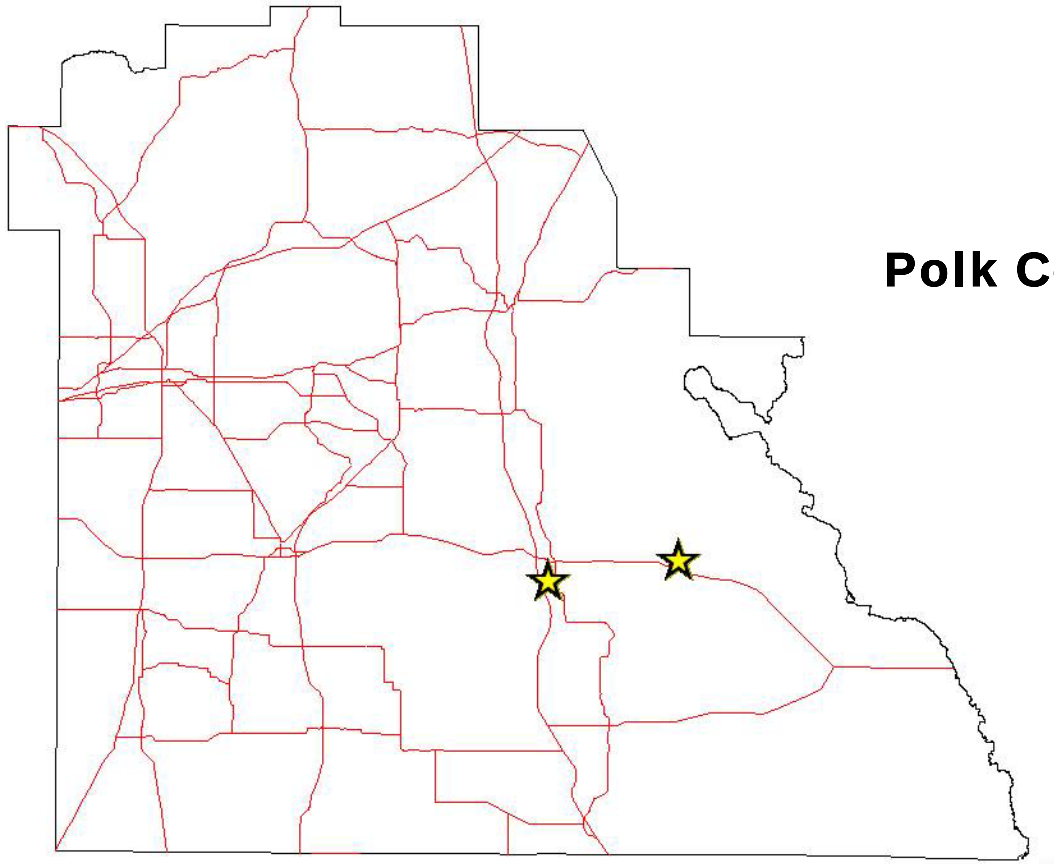
Part 2

Applicability of Current Regulatory Criteria for Ensuring Flood Protection in Land-Locked Drainage Systems

SUMMARY OF REGULATORY CRITERIA FOR LAND-LOCKED BASINS			
Agency	**Initial Stage for routing**	**Design Storm Event to compute runoff volume**	**Recovery Criteria**
SWFWMD	stage after 36 hr of recovery following slug loading of water quality volume. if dry, seasonal high water table	100 yr/24 hr	none
SJRWMD	the pond bottom or the elevation at which the water quality volume is recovered to; on a case by case basis, the seasonal high water table may be used	25 yr/96 hr on a case by case basis, the 100 yr/24 hr storm may be used	14 days on a case by case basis, back to back storms may be analyzed if full recovery cannot be achieved in 14 days
SFWMD	average wet season water table	100 yr/72 hr	no separate criteria for land locked basins since there are so few in SFWMD
SRWMD	seasonal high water table	critical duration but usually the critical one for maximum runoff volume is: 100 yr/240 hr storm	50% of the retention volume to be recovered in 7 days, with the total volume to be available in 30 days
NWFWMD	seasonal high water table	25 yr/96 hr	None
FDOT	Lowest elevation of available storage above the seasonal high water table	critical duration/frequency that yields highest pre-post runoff volume. max duration of 240 hr	50% of the retention volume to be recovered in 7 days, with the total volume to be available in 30 days
FEMA	seasonal high water table	100 yr/96 hr storm, or 100 yr/24 hr preceded by a mean annual storm (2.33 yr/24 hr)	none
Orange County	seasonal high water table not more than 50% of water quality volume	100 yr/24 hr	14 day recovery natural seepage or bleed-down

Some Examples of Recent Flooding Problems

Lake Belle, Tractor Lake, & Saddlebag Lake



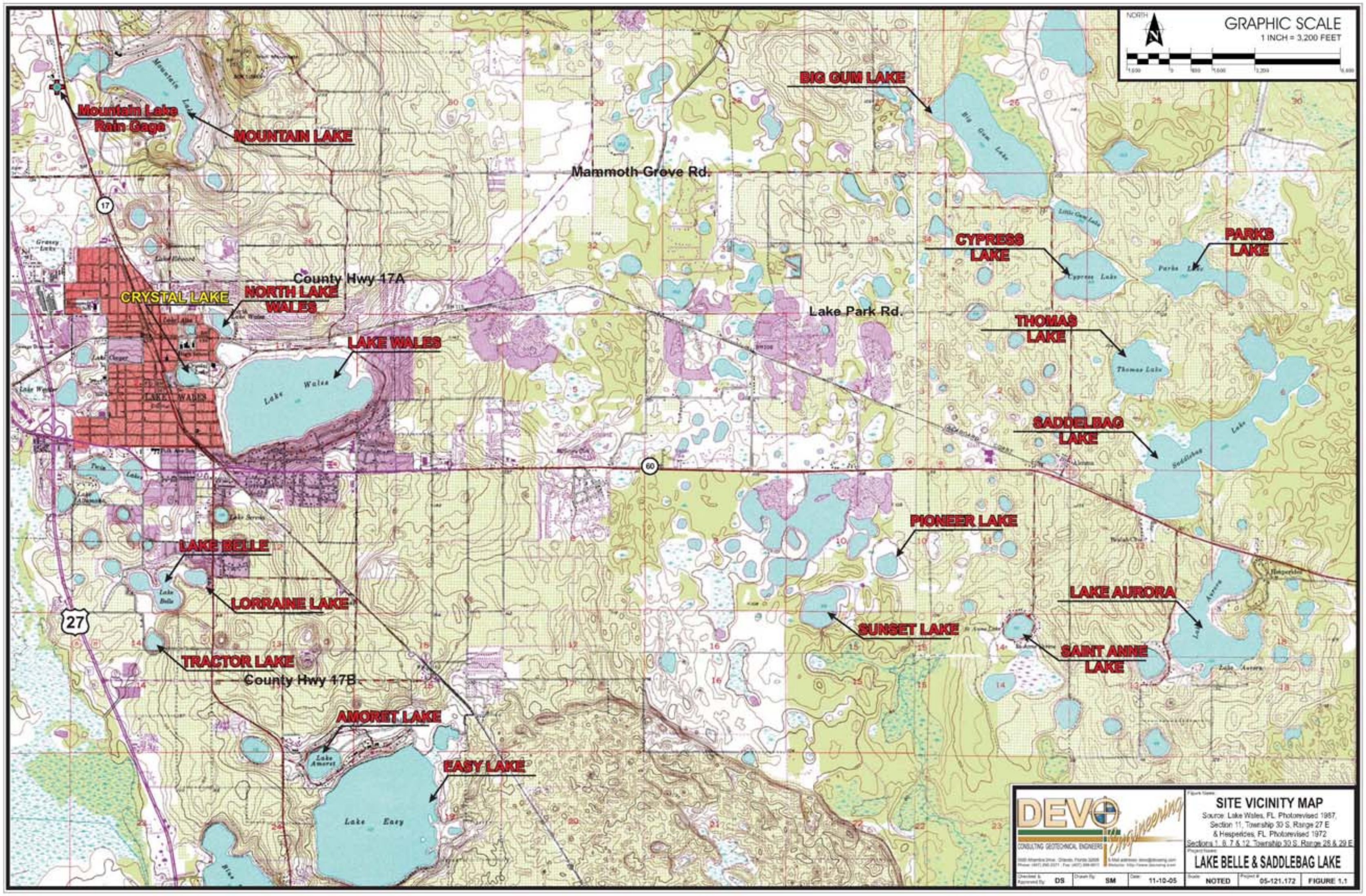
Polk County

Saddlebag Lake

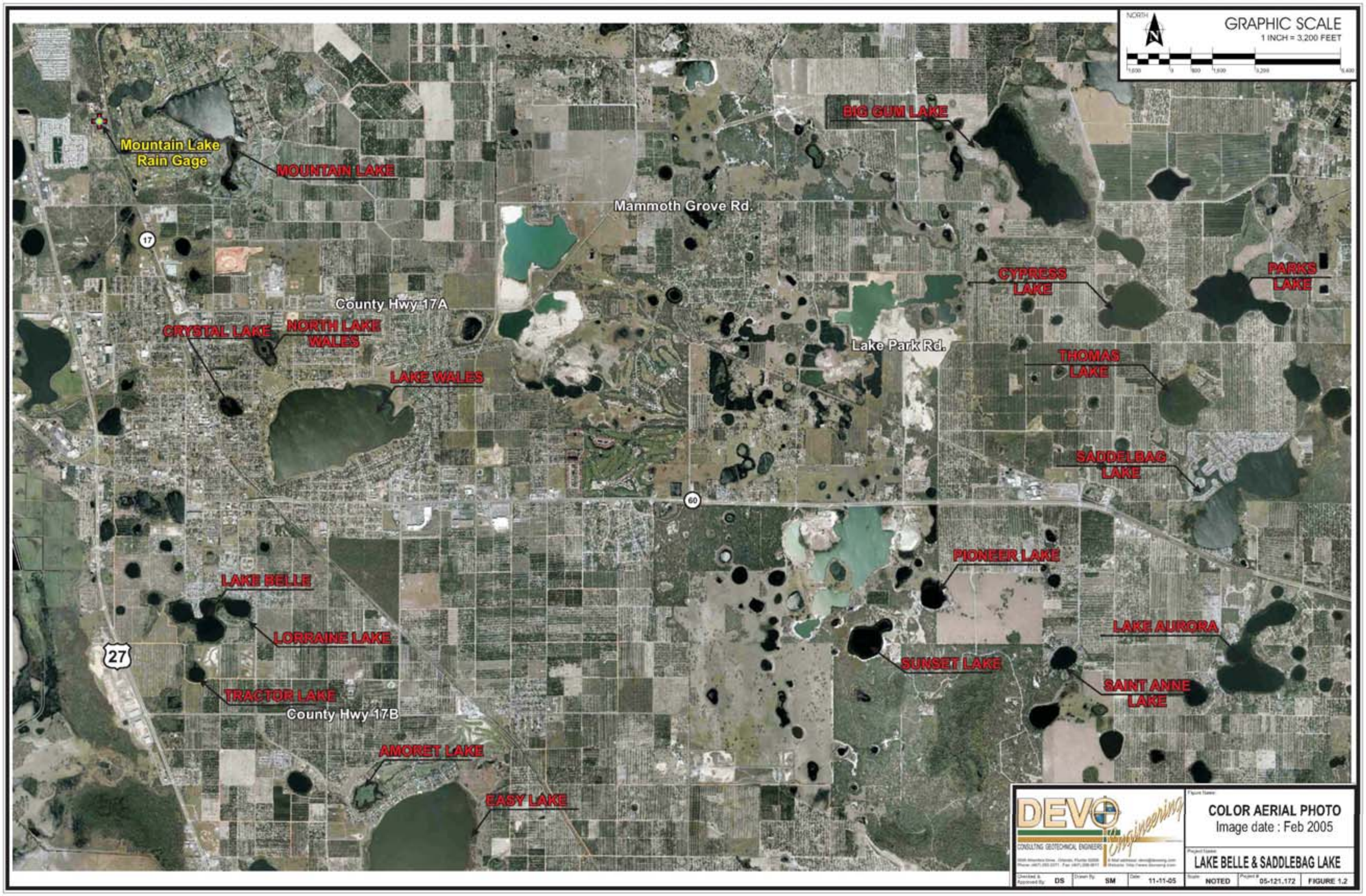
Saddlebag Lake

Lake Belle

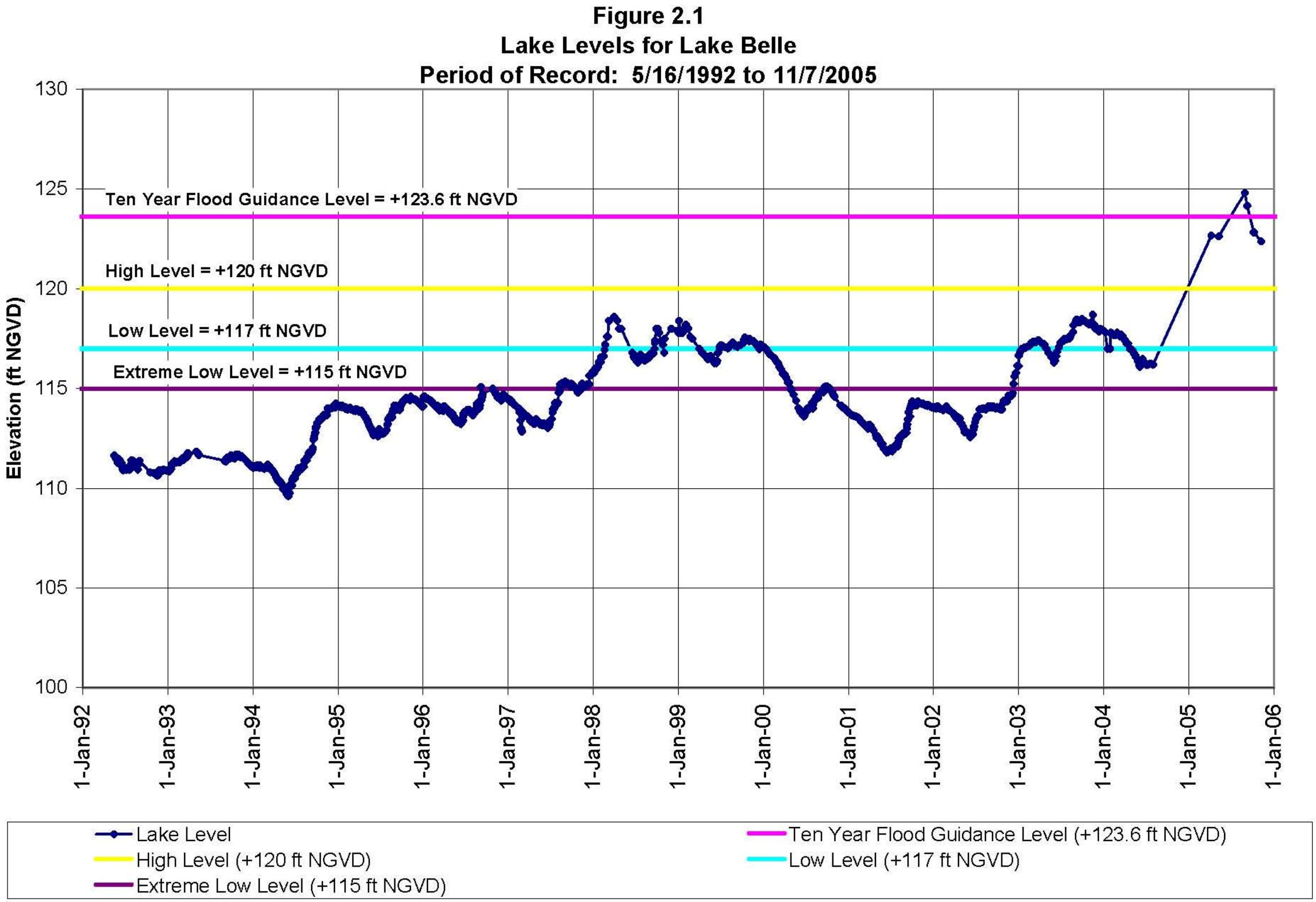
Site Vicinity Map



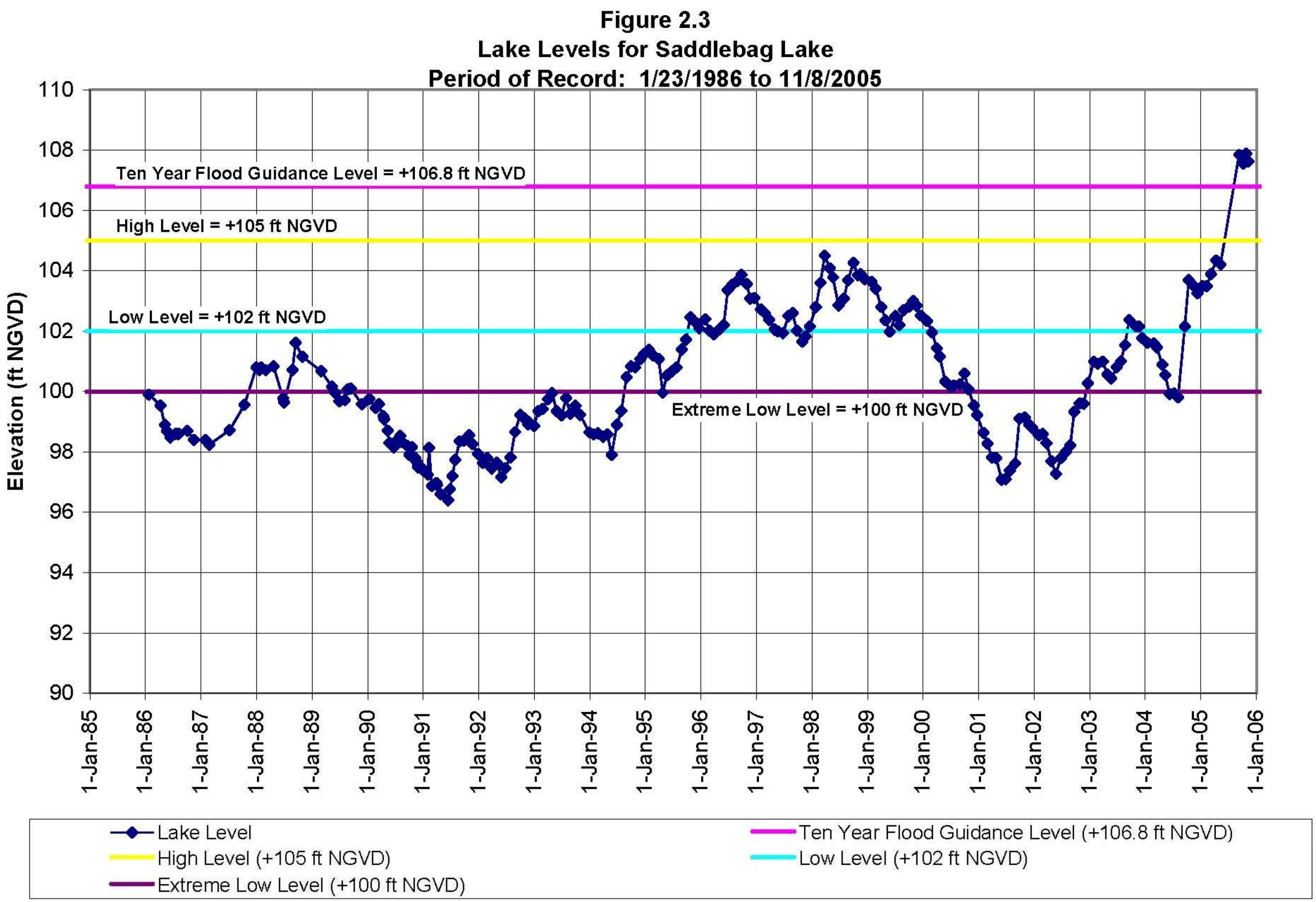
Aerial Map


GRAPHIC SCALE
1 INCH = 3,200 FEET
NORTH
N
BIG GUM LAKE
Mountain Lake
Rain Gage
MOUNTAIN LAKE
Mammoth Grove Rd.
17
County Hwy 17A
CYPRESS
LAKE
PARKS
LAKE
CRYSTAL LAKE
NORTH LAKE
WALES
Lake Park Rd.
LAKE WALES
THOMAS
LAKE
SADDLEBAG
LAKE
60
PIONEER LAKE
LAKE BELLE
LORRAINE LAKE
LAKE AURORA
27
SUNSET LAKE
SAINT ANNE
LAKE
TRACTOR LAKE
County Hwy 17B
AMORET LAKE
EASY LAKE
DEVO Engineering
CONSULTING GEOTECHNICAL ENGINEERS
COLOR AERIAL PHOTO
Image date : Feb 2005
LAKE BELLE & SADDLEBAG LAKE
DS
SM
11-11-05
NOTED
05-121.172
FIGURE 1.2

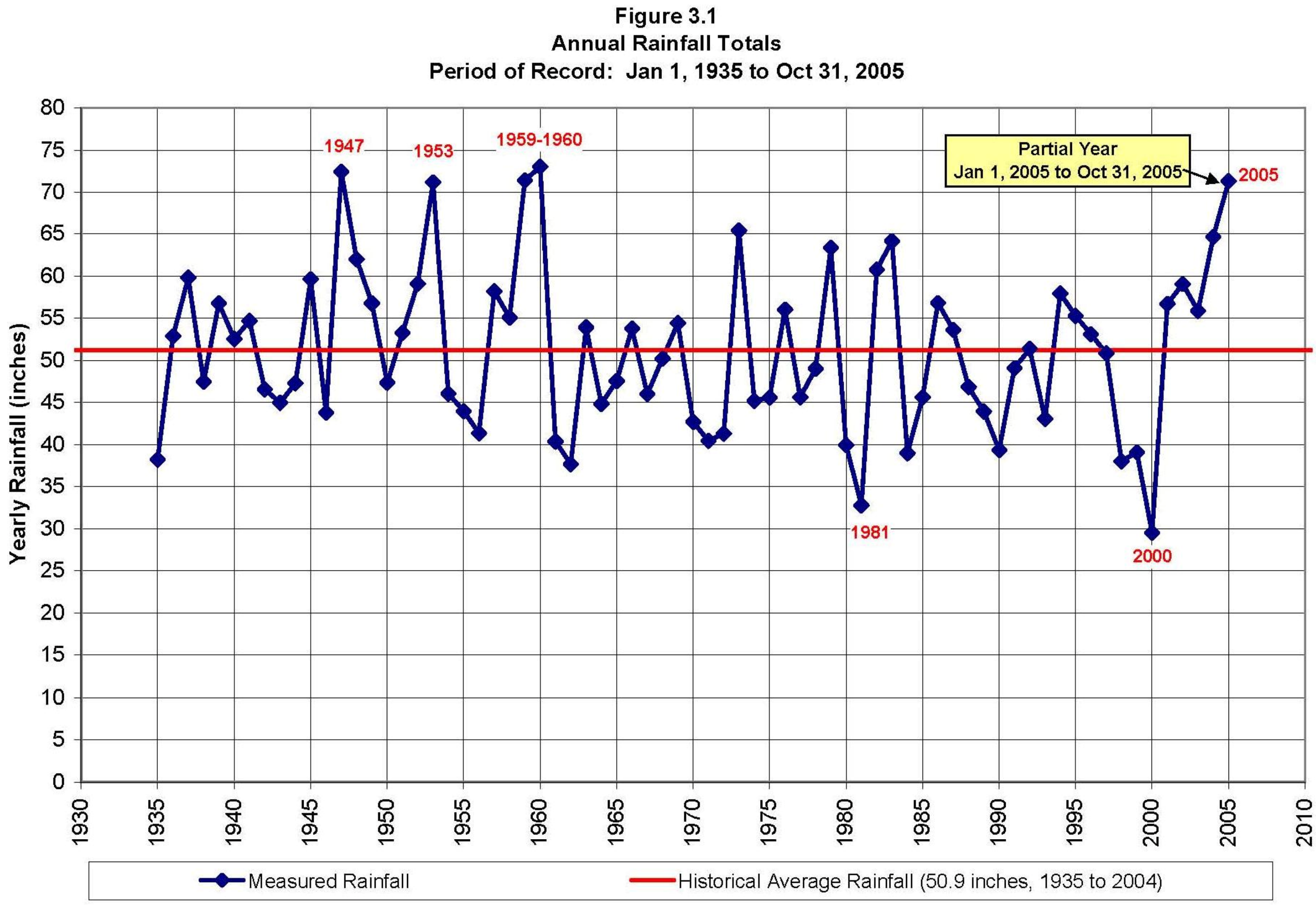
Lake Levels for Lake Belle



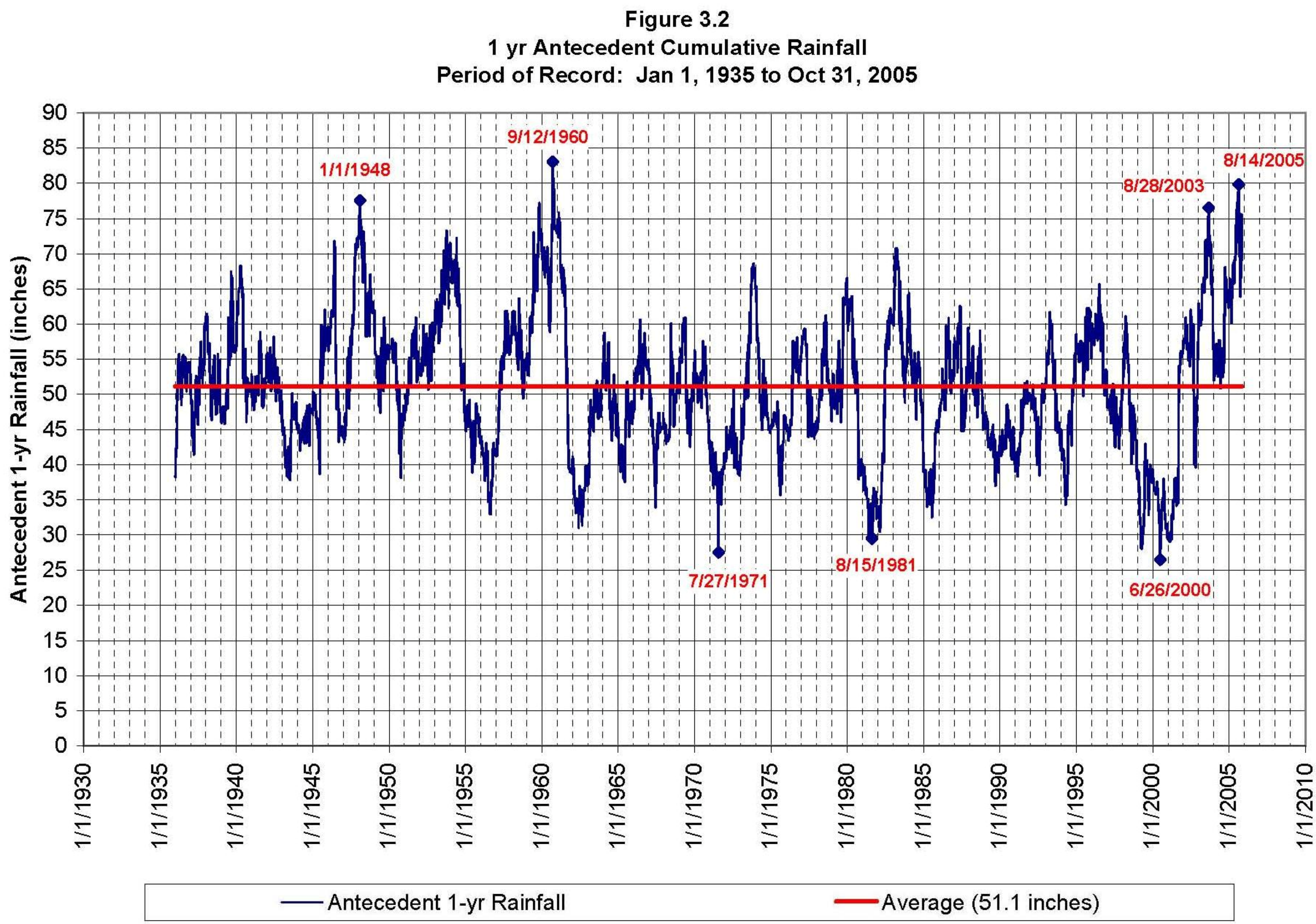
Lake Levels for Saddlebag Lake



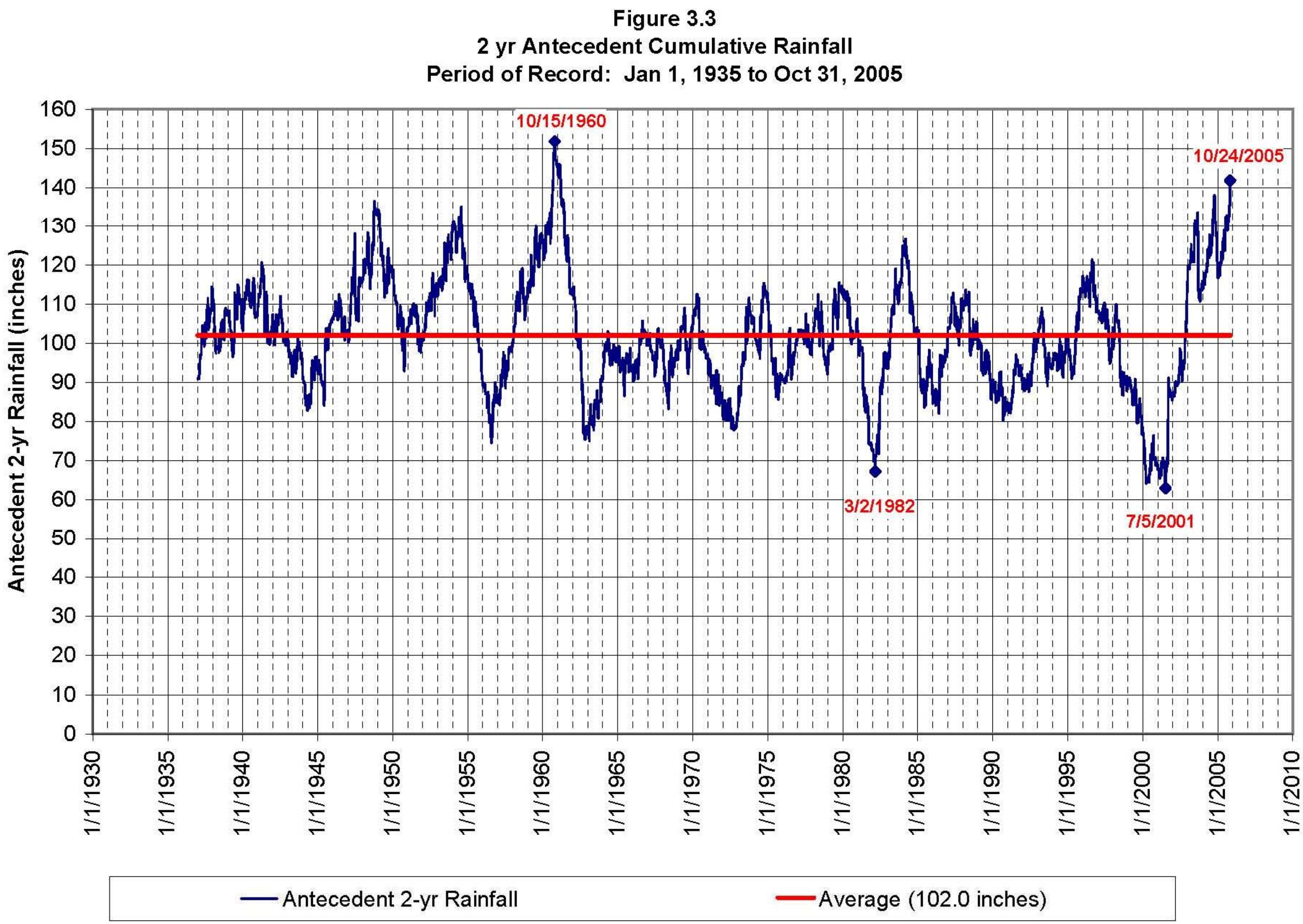
1-yr Antecedent Rainfall



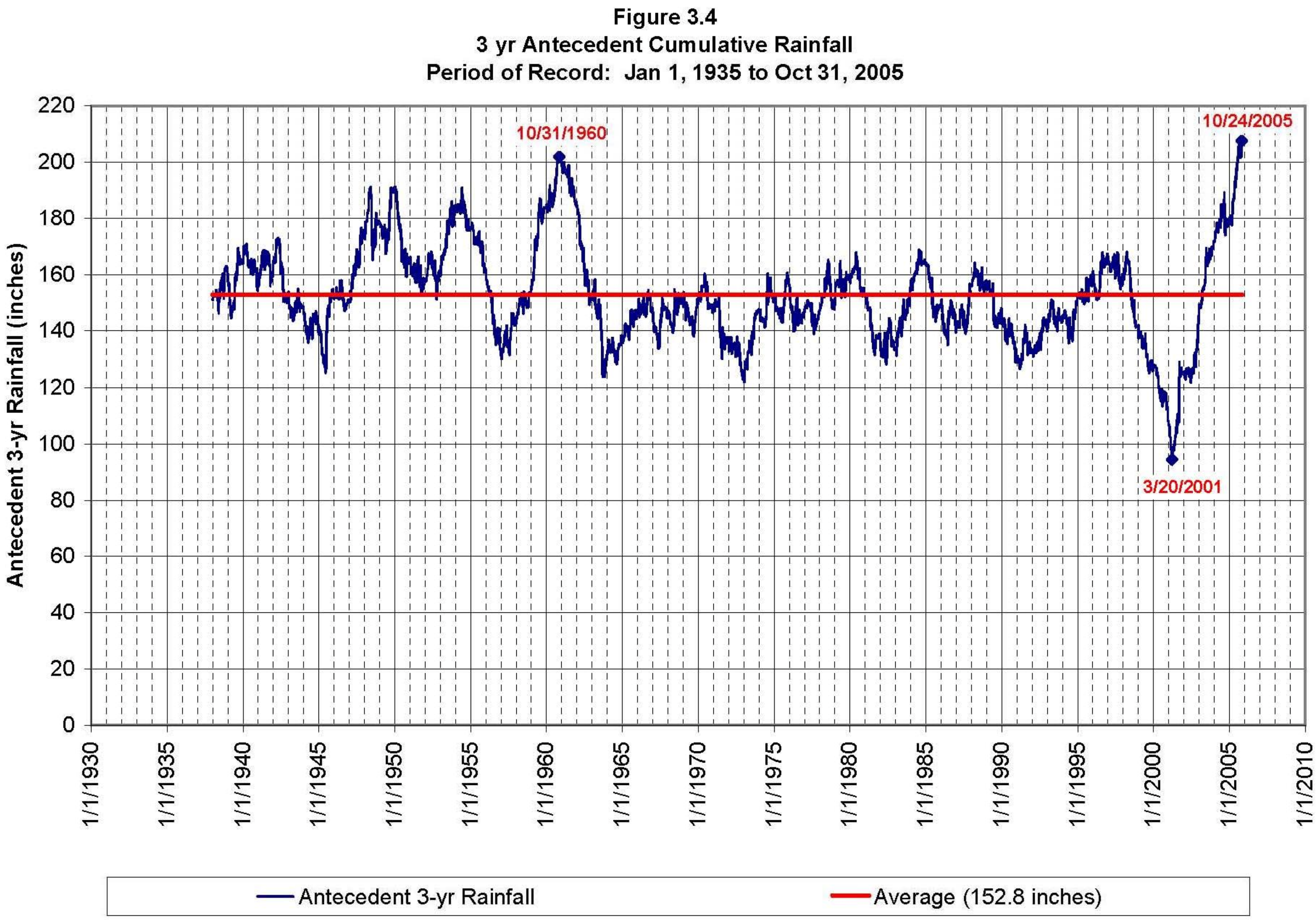
1-yr Antecedent Rainfall



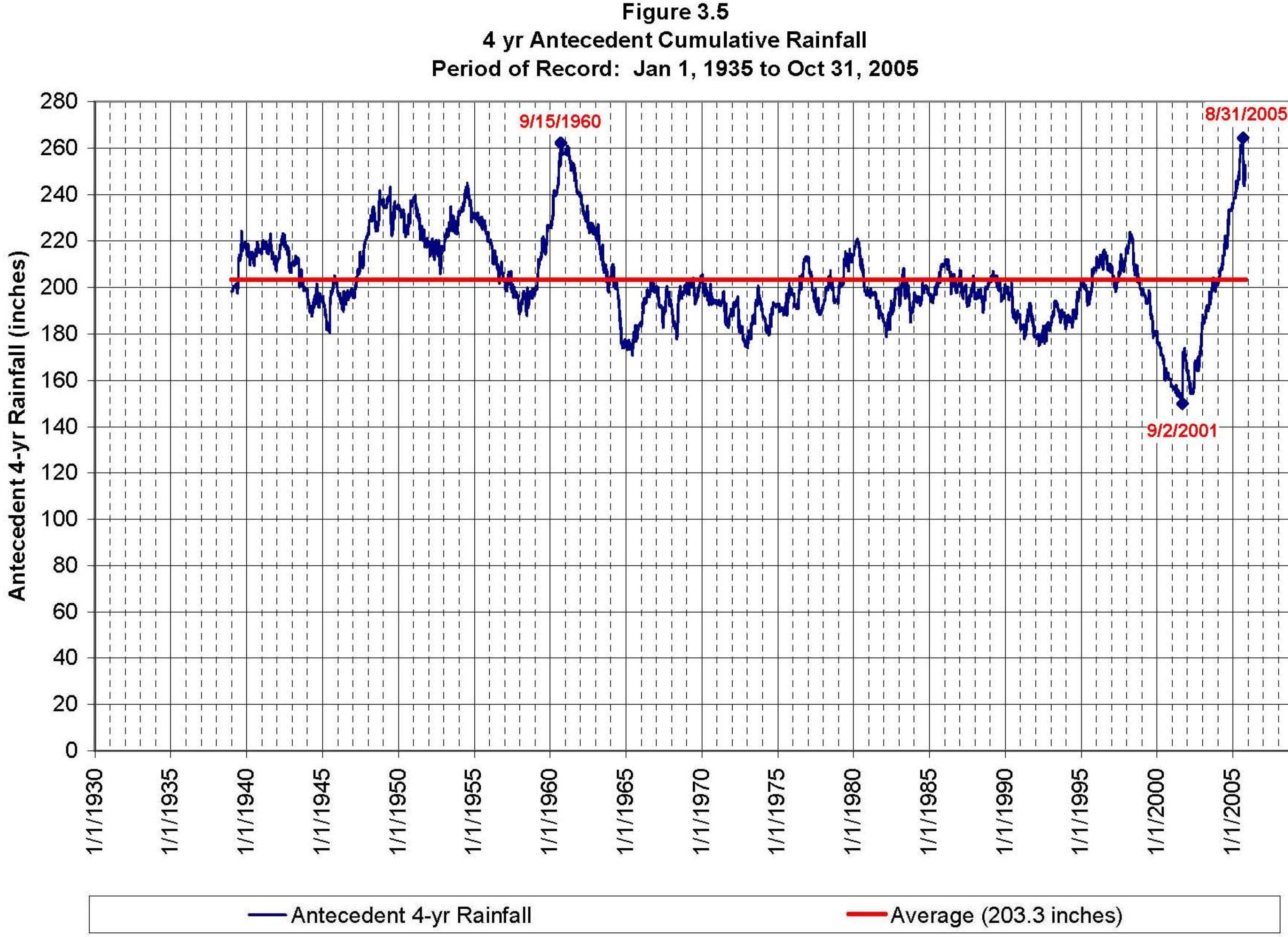
2-yr Antecedent Rainfall



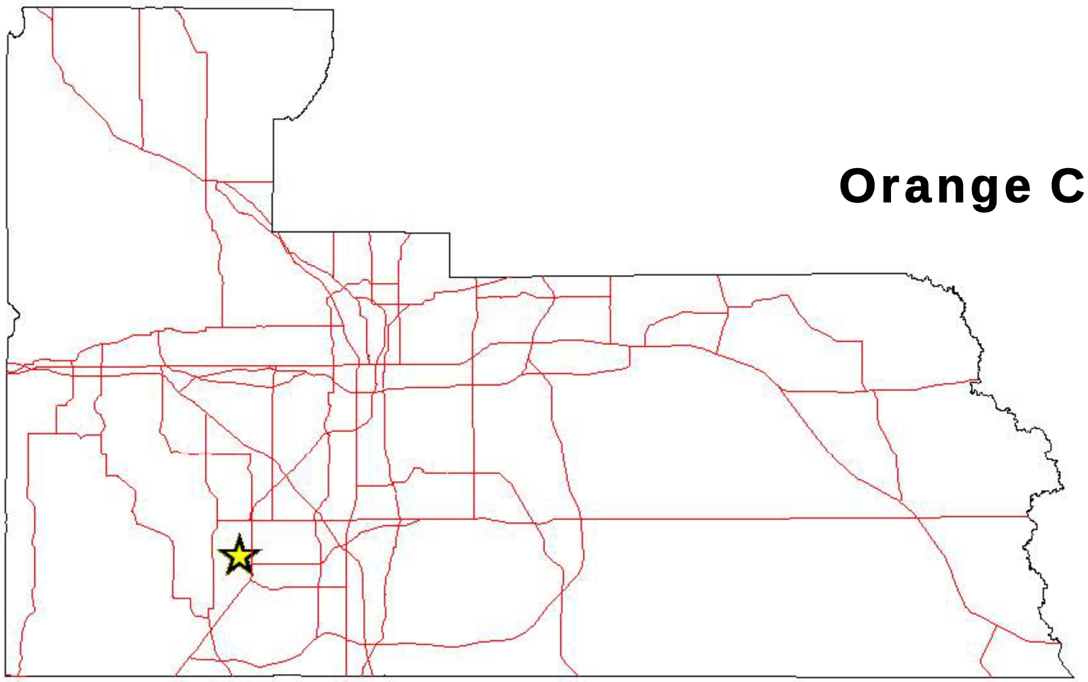
3-yr Antecedent Rainfall



4-yr Antecedent Rainfall



Big Sand Lake



Orange County

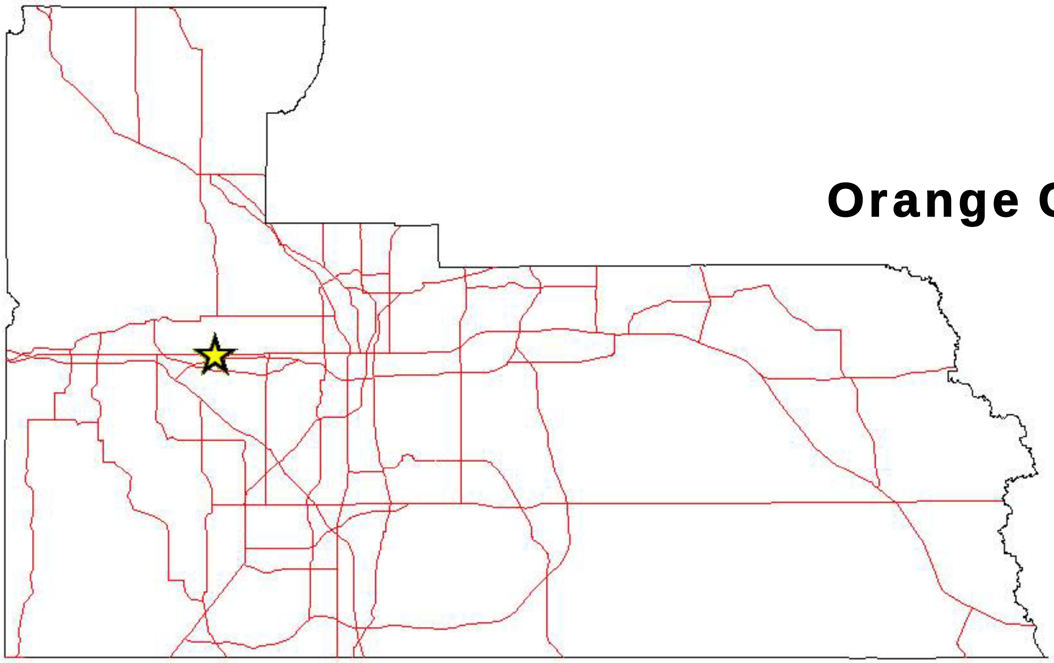
Big Sand Lake

Photo date: 2004

Big Sand Lake

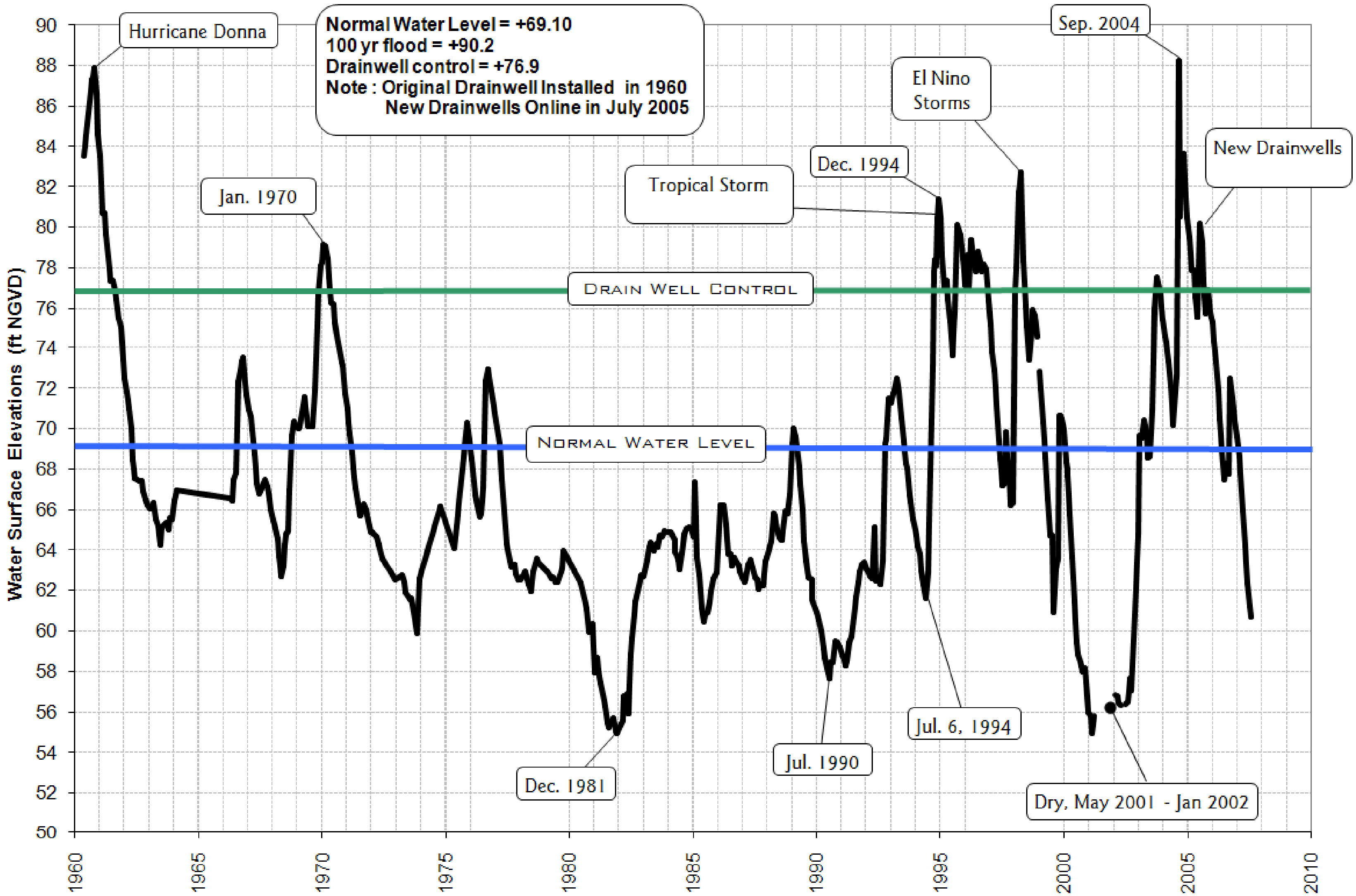
Photo date: 2004

Lake Sherwood



Orange County

Lake Sherwood



Lake Sherwood

Photo date: March 1998

Lake Sherwood

Photo date: March 1998

Lake Sherwood

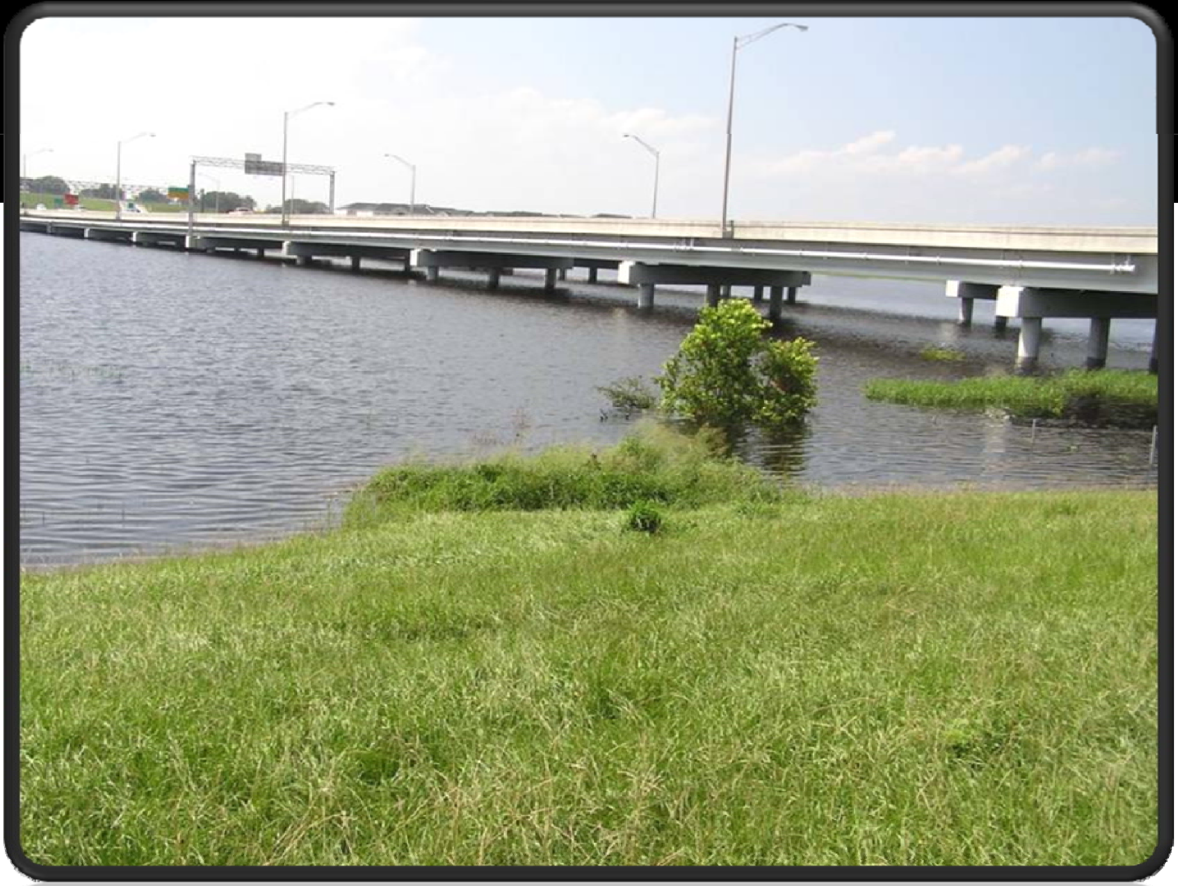
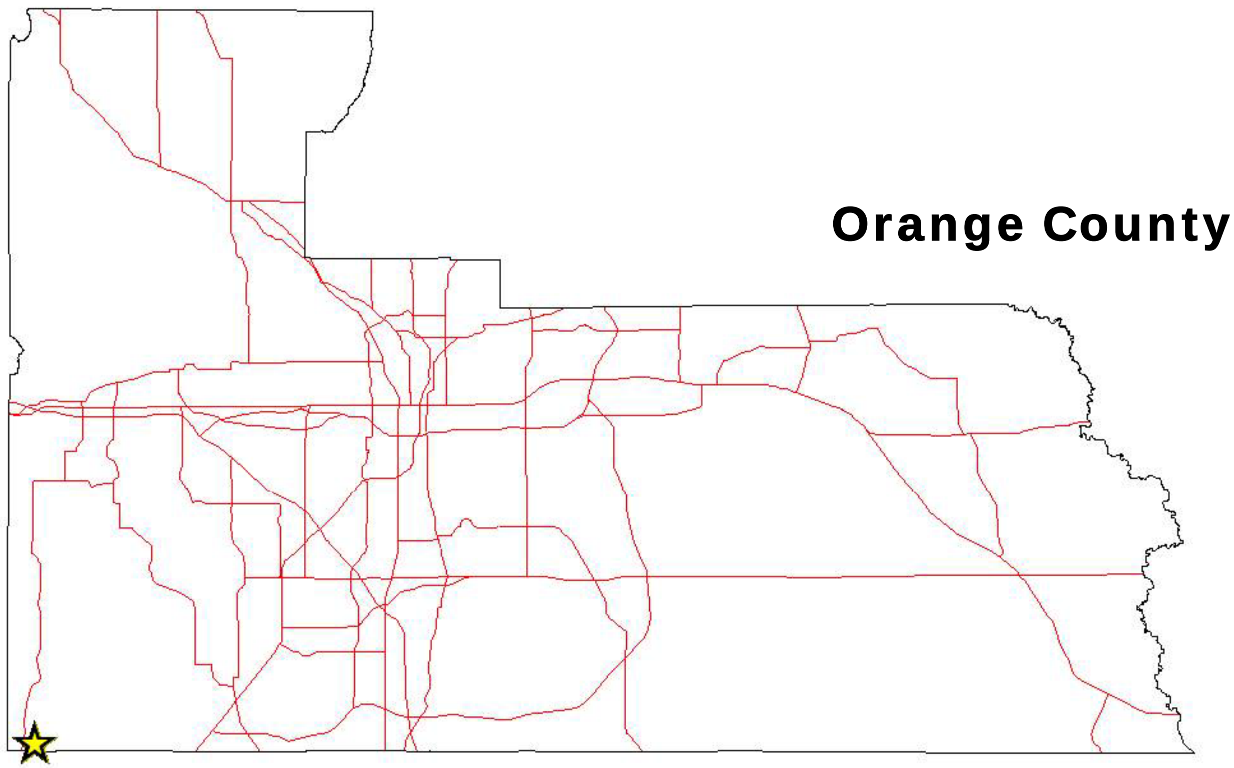


Photo date: 2004

Lake Sherwood

Photo date: 2007

Lake Rexford and Lake Osage



Lake Rexford and Lake Osage

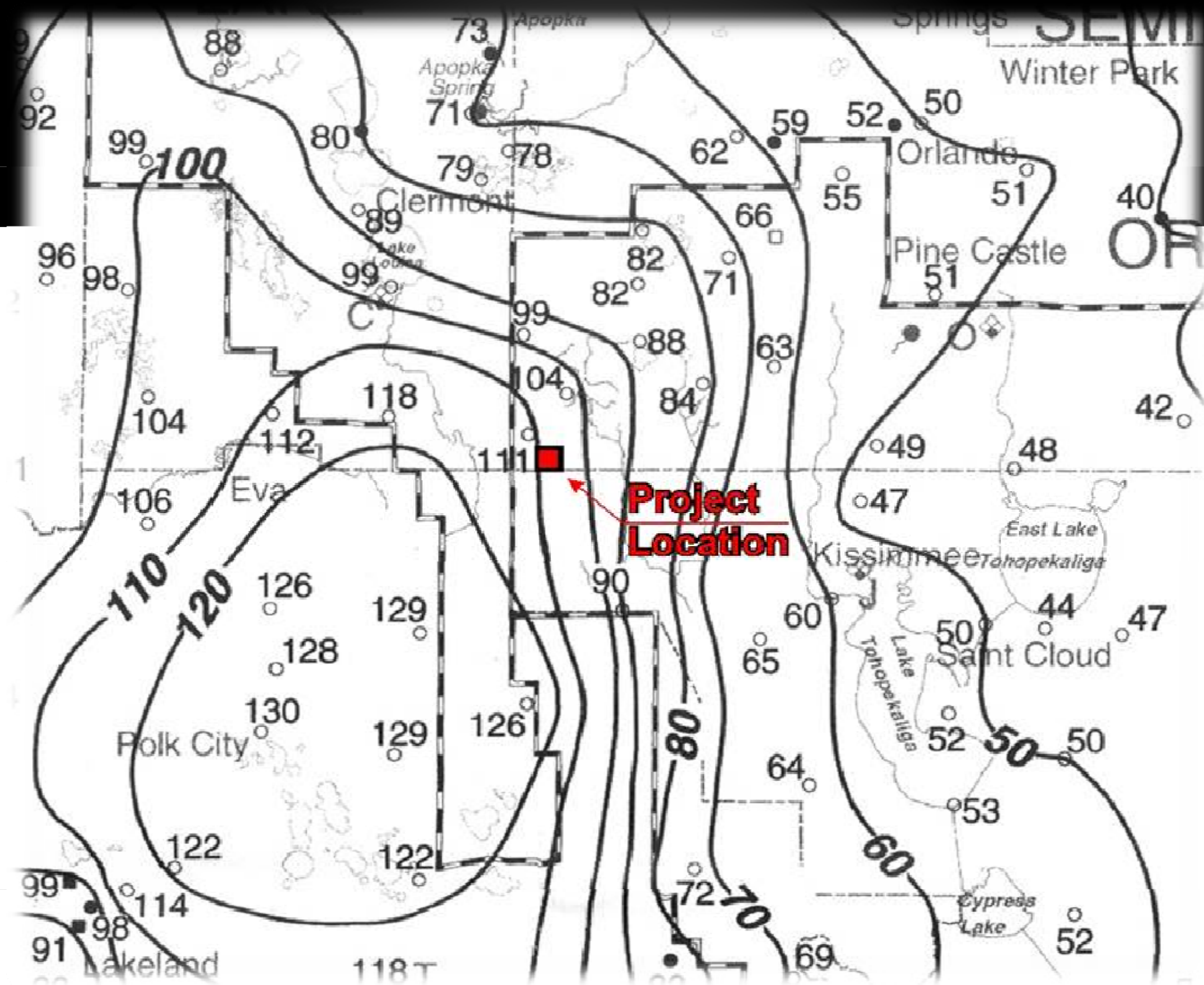
Lake Rexford and Lake Osage

Photo date: 2003

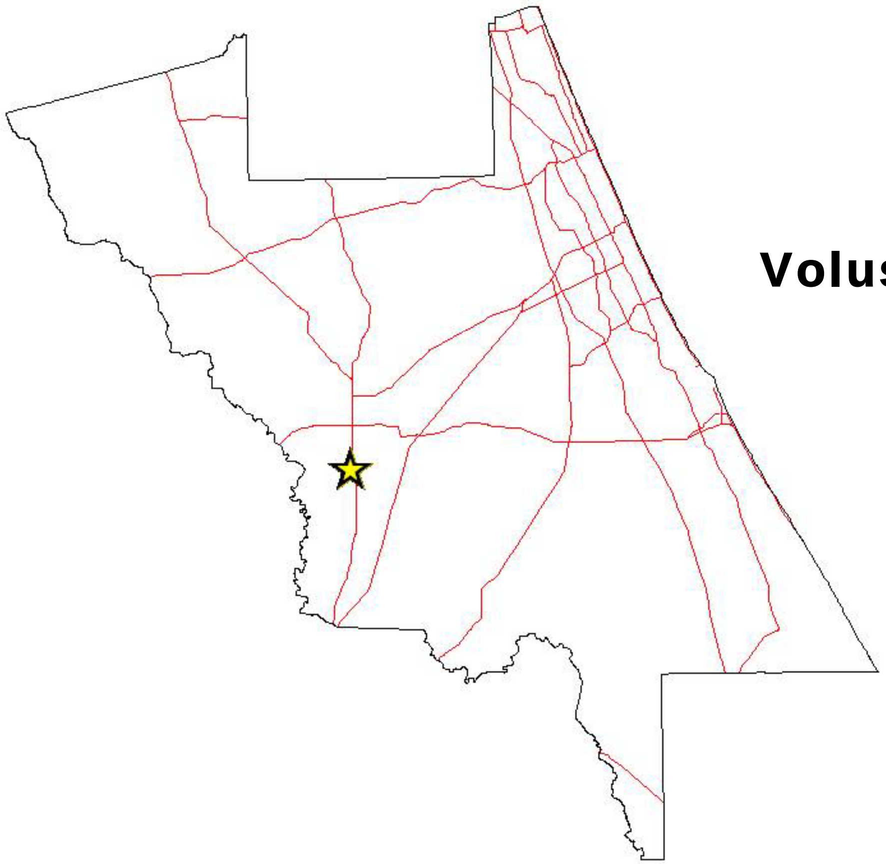
Lake Rexford and Lake Osage

Photo date: 2003

Lake Rexford and Lake Osage Potentiometric Surface Contours



Calvin Street and Crystal Cove



Volusia County

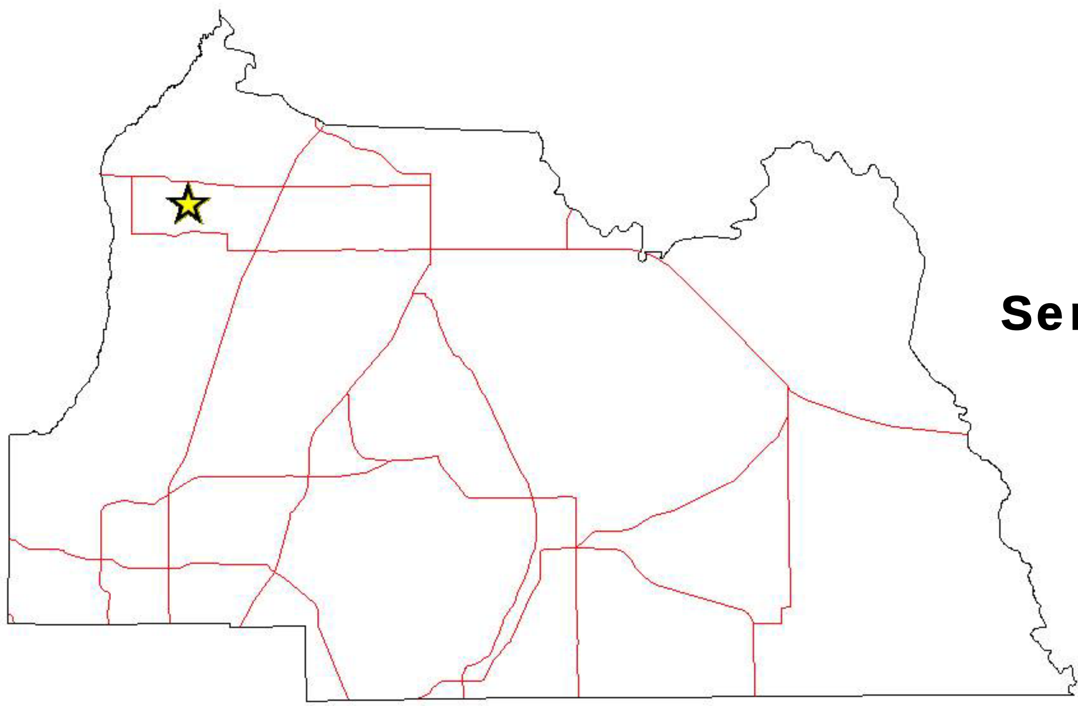
Calvin Street Depression, Deland Area

Photo date: 2005

Crystal Cove, Deland Area

Photo date: 2005

Lake Sylvan



Seminole County

Lake Sylvan

Part 3

Long-term and short-term continuous simulation modeling of stormwater management systems.

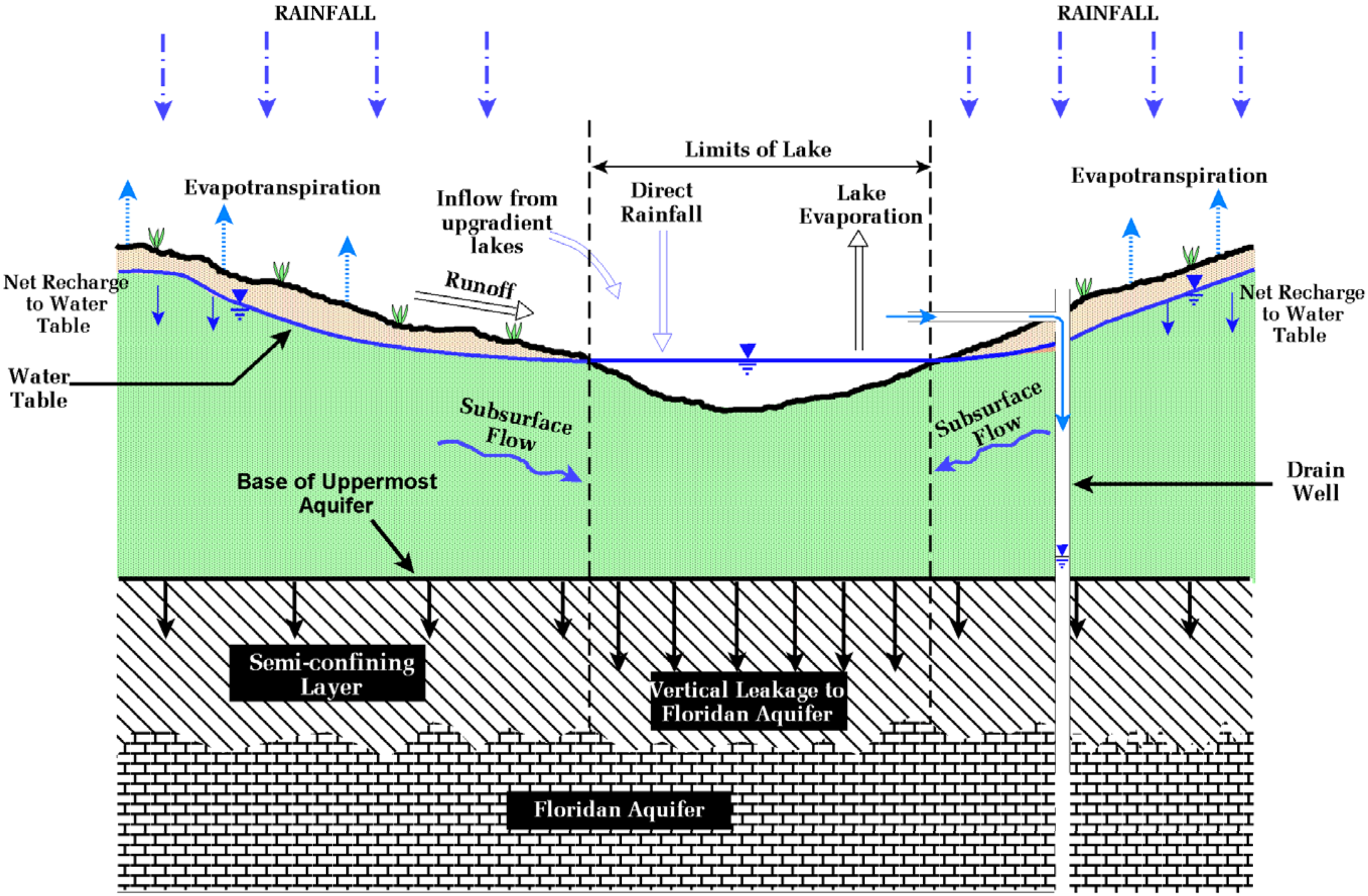
Is it time for its integration in stormwater management criteria?

Are the tools & technology available to practitioners?

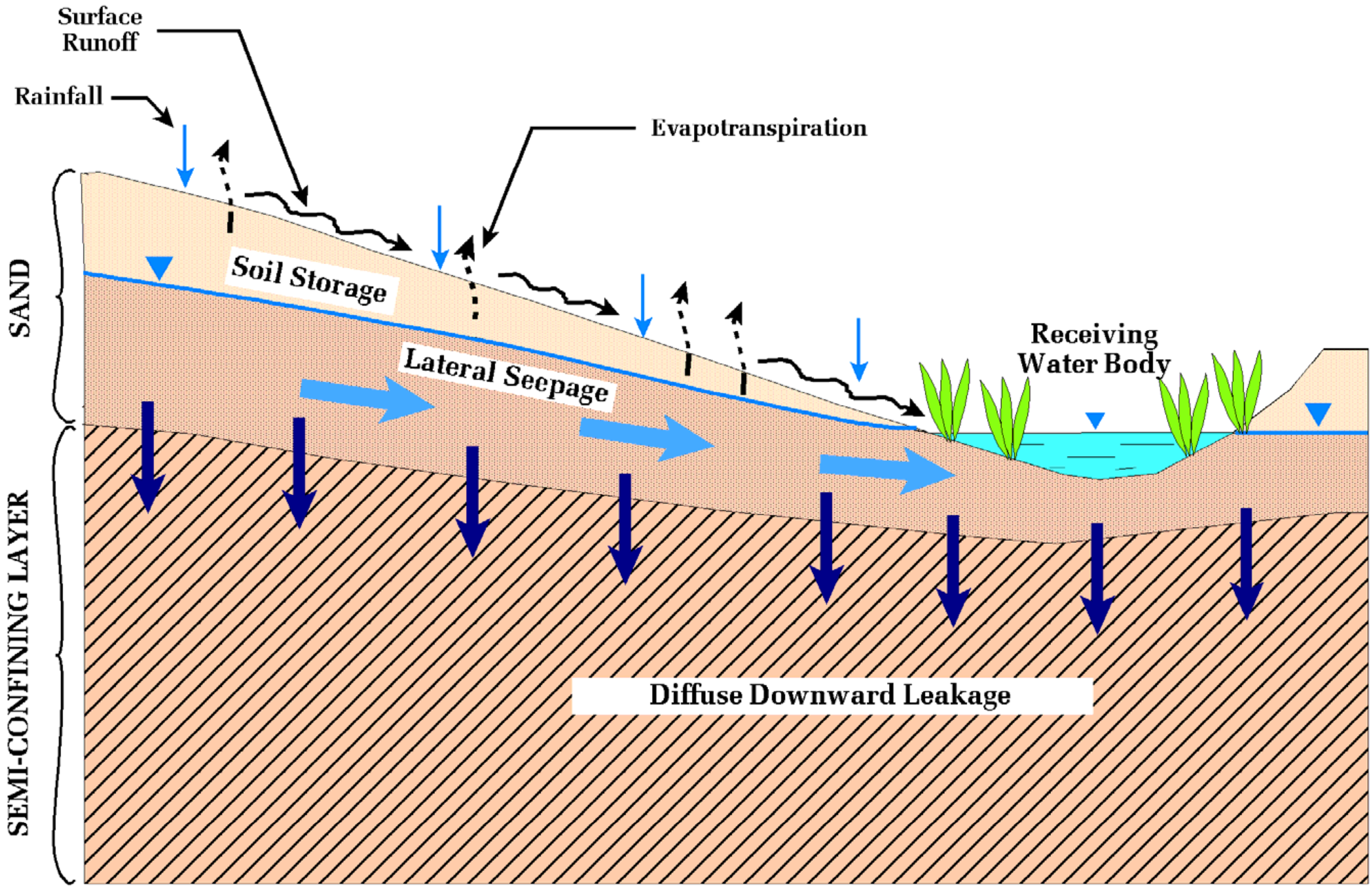
Continuous Simulation Modeling of Stormwater Ponds, Lakes, & Wetlands:

BUILT-IN INTO PONDS 3.2 – the continuous simulation hydrograph, what additional parameters do we need to consider?

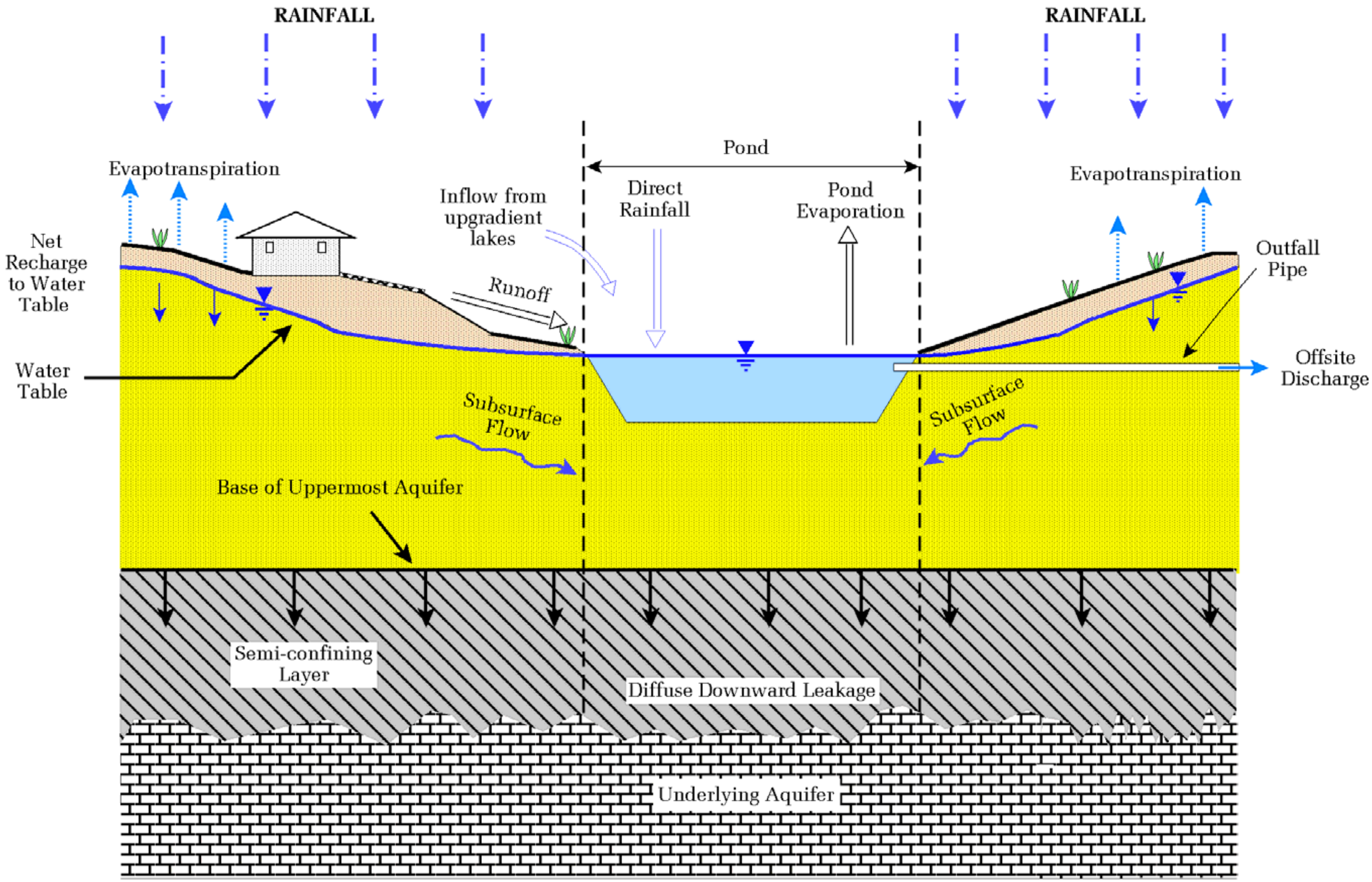
CONCEPTUAL MODEL FOR NATURAL DEPRESSIONS



CONCEPTUAL MODEL FOR PREDEVELOPMENT



CONCEPTUAL MODEL FOR POSTDEVELOPMENT



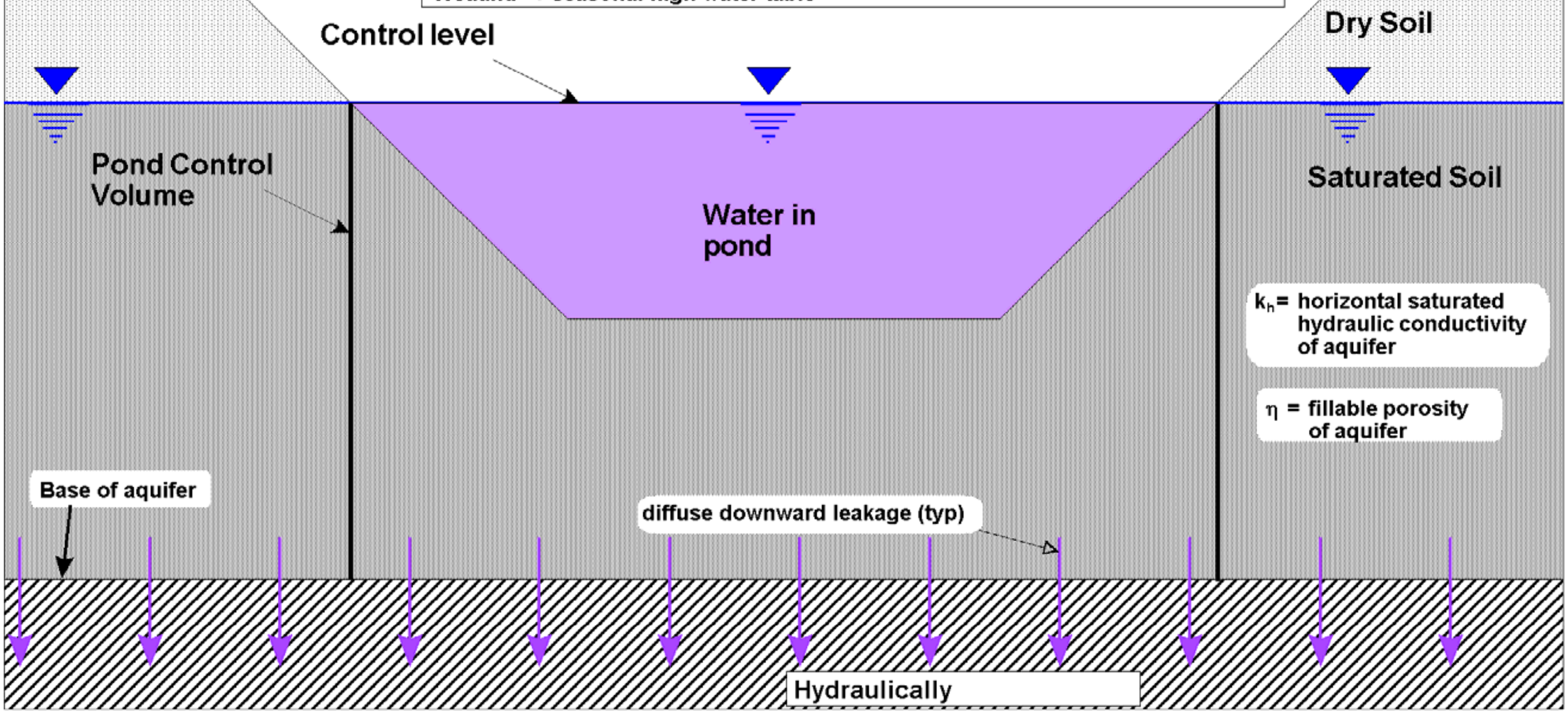
DEFINITIONS:

A_{open} = Area of water surface in pond, varies with stage
A_c = Area of water surface in pond at control level
η = Soil porosity or soil storage
S_b = Stage at physical bottom of pond
S_c = Stage at pond control level

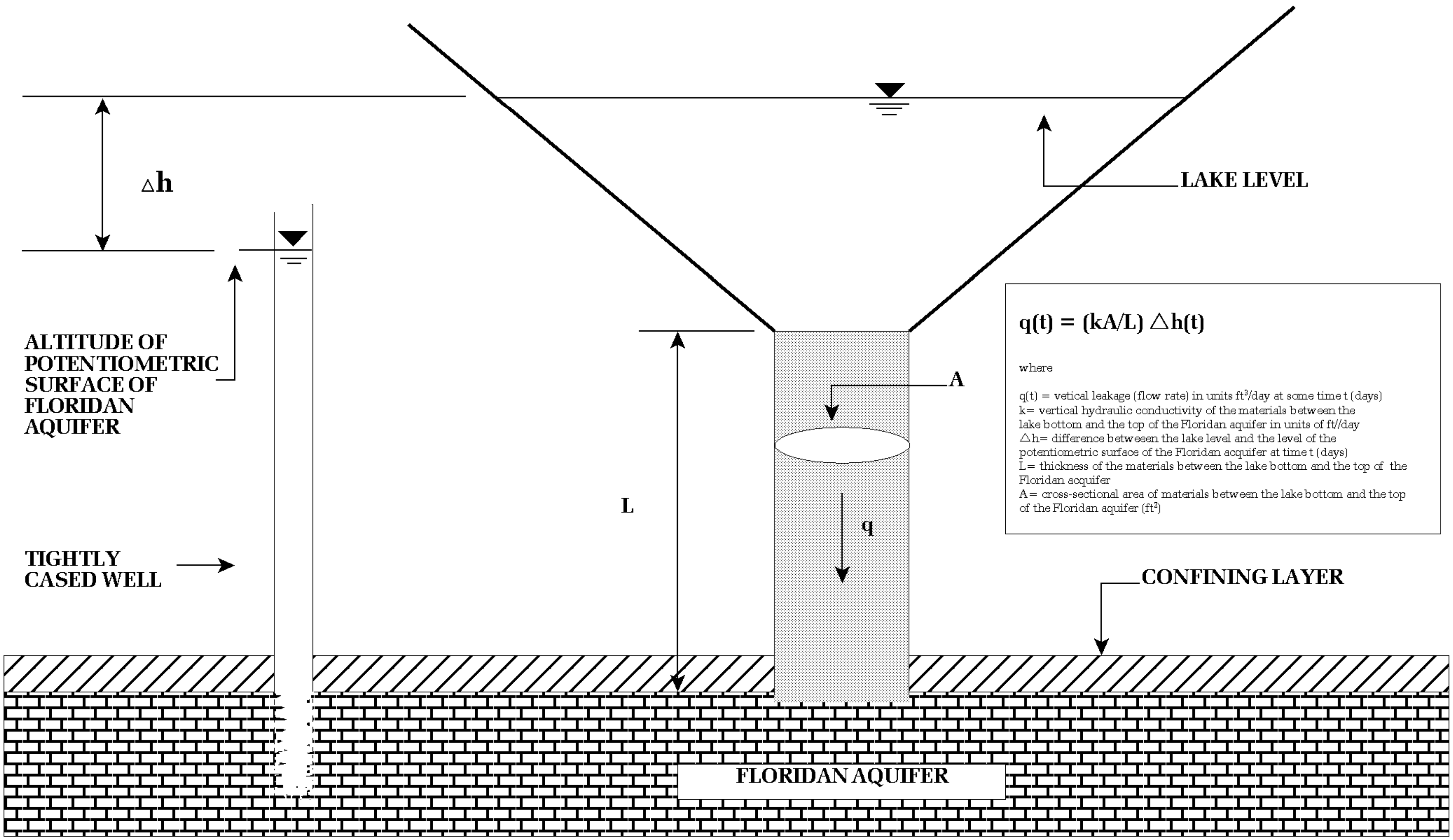
STAGE	AREA FOR MODEL
$> S_c$	A_{open}
S_c	$A_c = A_{open}$
$S_b \rightarrow S_c$	$[A_c - A_{open}]\ \eta + A_{open}$
$< S_b$	$A_c \times \eta$

How to pick control level for different types of stormwater management systems:

Wet Detention Pond With Outfall ➜ elevation of control device (orifice)
Wet Detention Pond or Lake Without Outfall ➜ normal water level
Dry Pond With Outfall ➜ top of water quality volume
Dry Pond or Depression Without Outfall ➜ top of design high water
Wetland ➜ seasonal high water table



MODELFORCOMPUTINGDISCHARGEFROMLAKEORPONDTO FLORIDAN



CONTINUOUS SIMULATION MODELING:
CONCEPTUAL MODELS DIFFUSE DOWNWARD LEAKAGE - THINK ABOUT THIS FIRST

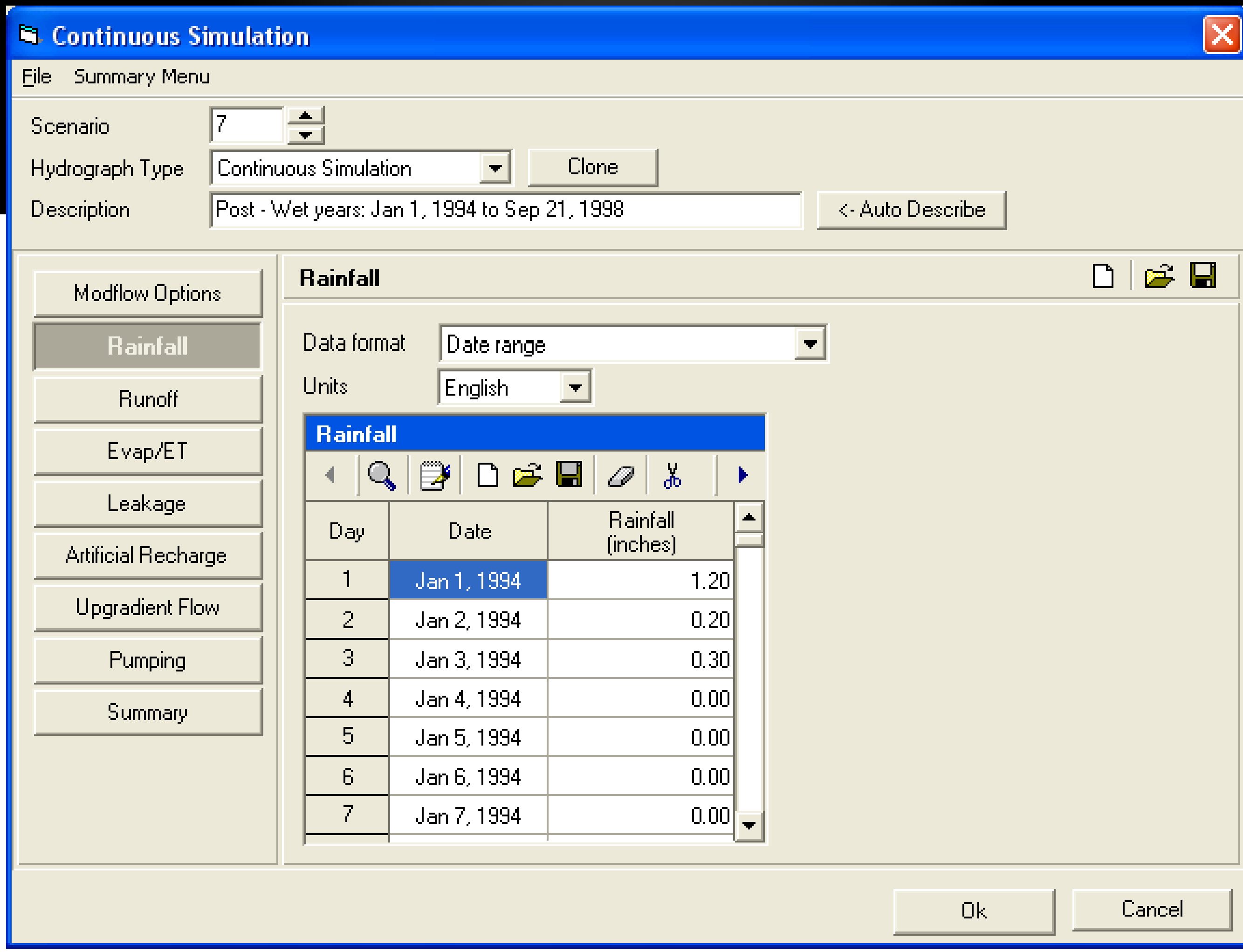
- Simple models are those where the vertical recharge rate (aka ”diffuse downward leakage”) is uniform with time. There are actual sites like this in the areas of very low recharge (for example, East Orange County).

- Less simple models are those where the diffuse downward leakage changes markedly with time based on rainfall and the water level (pot surface) in the underlying Floridan aquifer. These models require some calibration to back-compute the daily or monthly recharge rate. All other parameters are known.

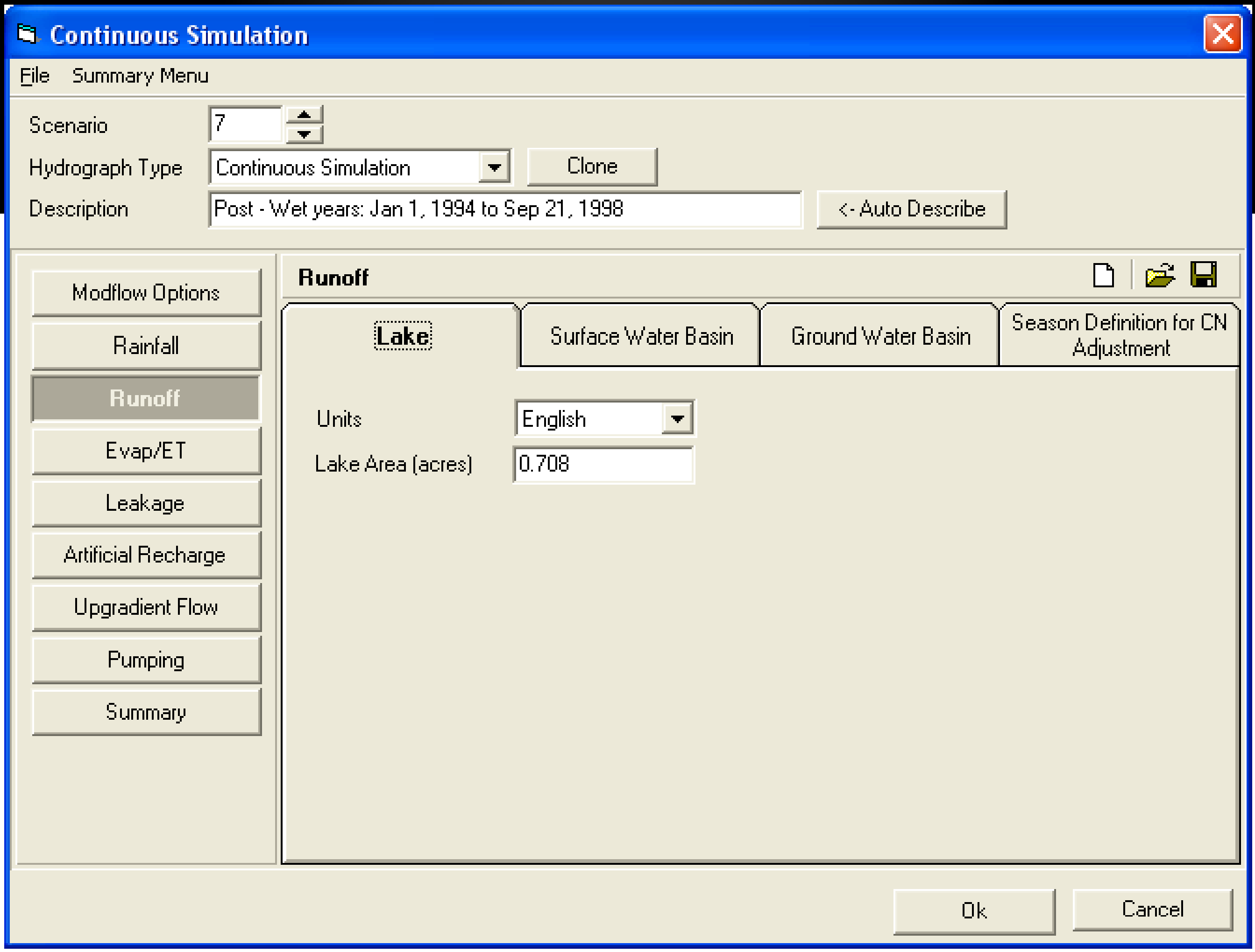
Part 4

Some Screen Shots of PONDS 3.2 Software Continuous Simulation Hydrograph Generator

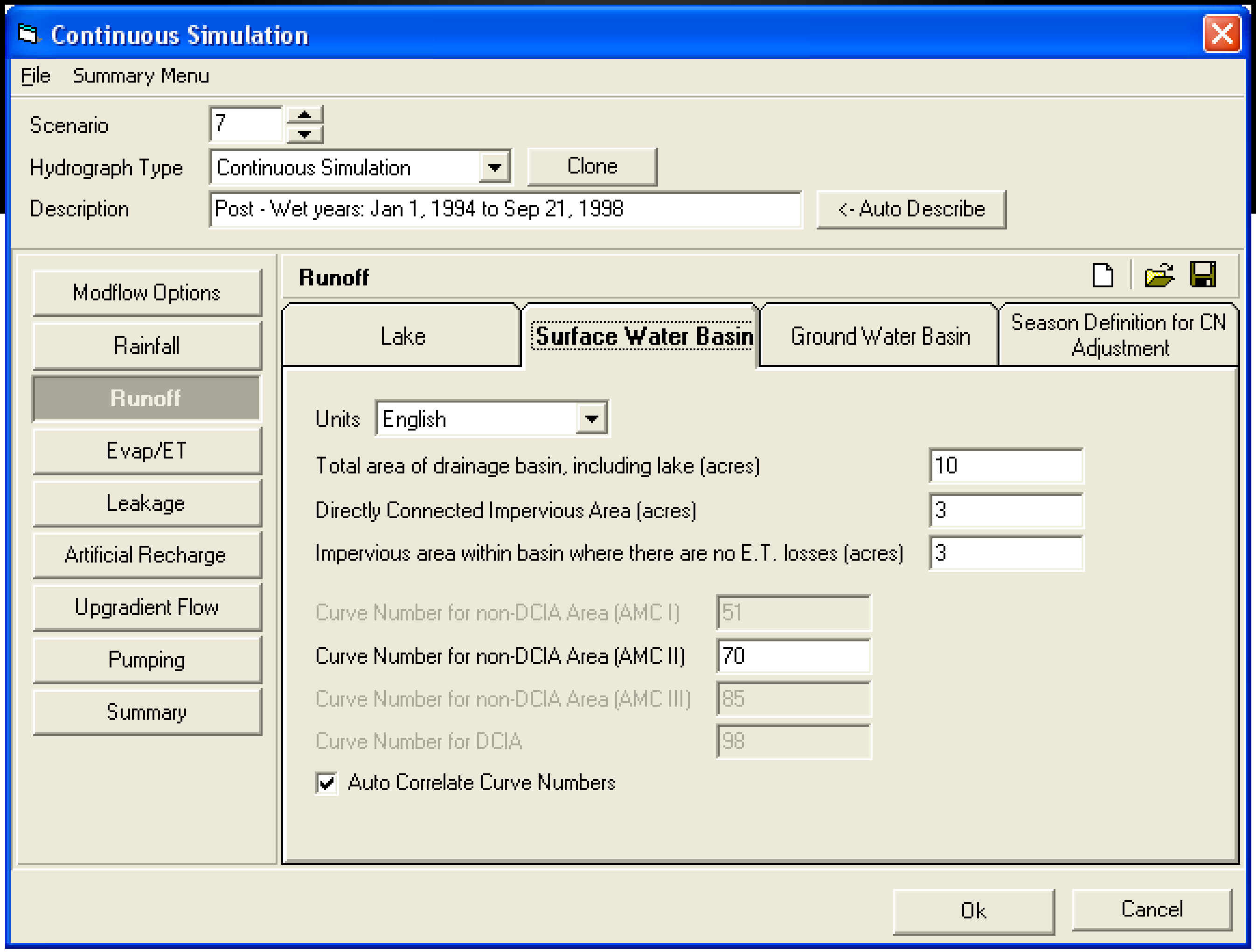
Continuous Simulation Hydrograph



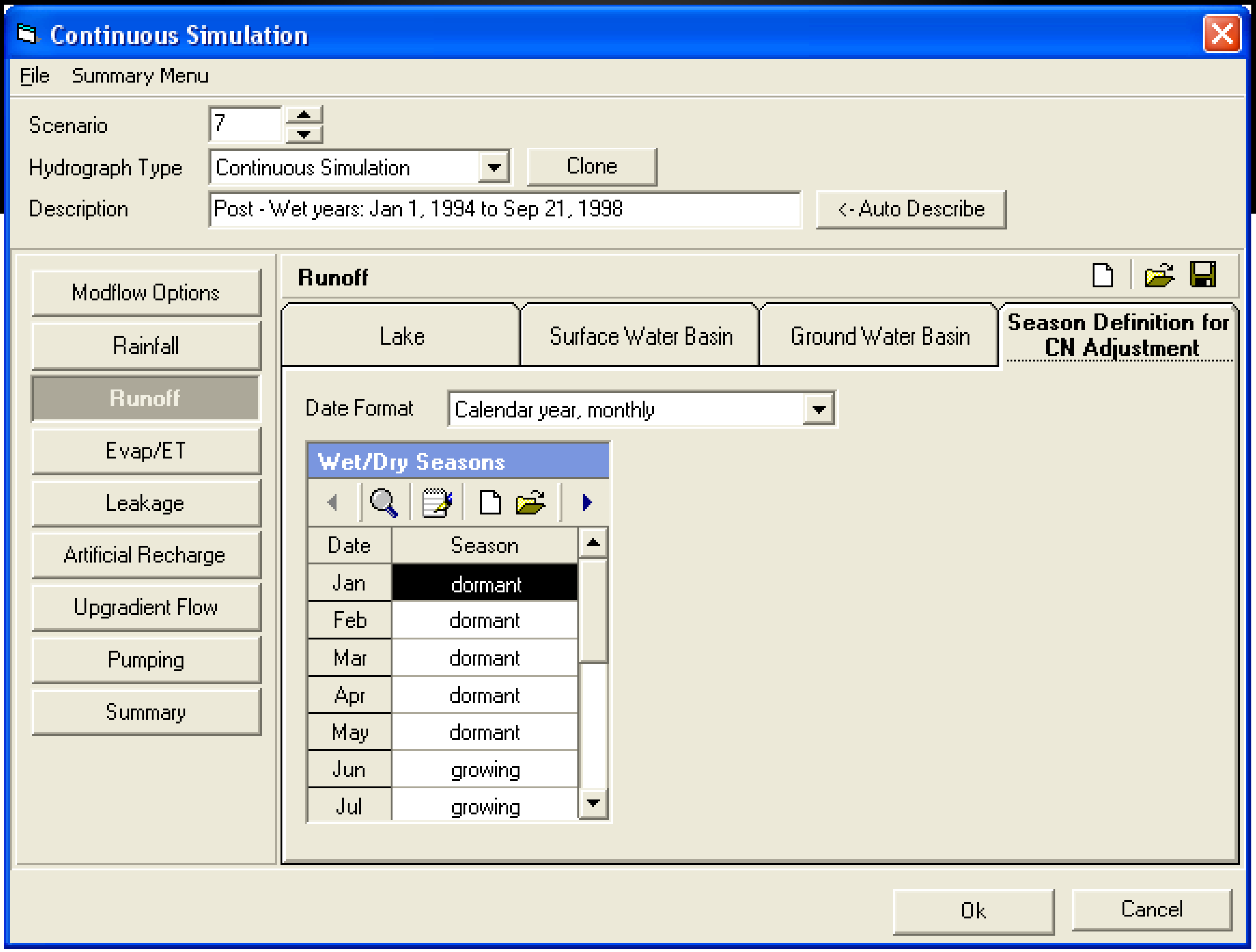
Continuous Simulation Hydrograph



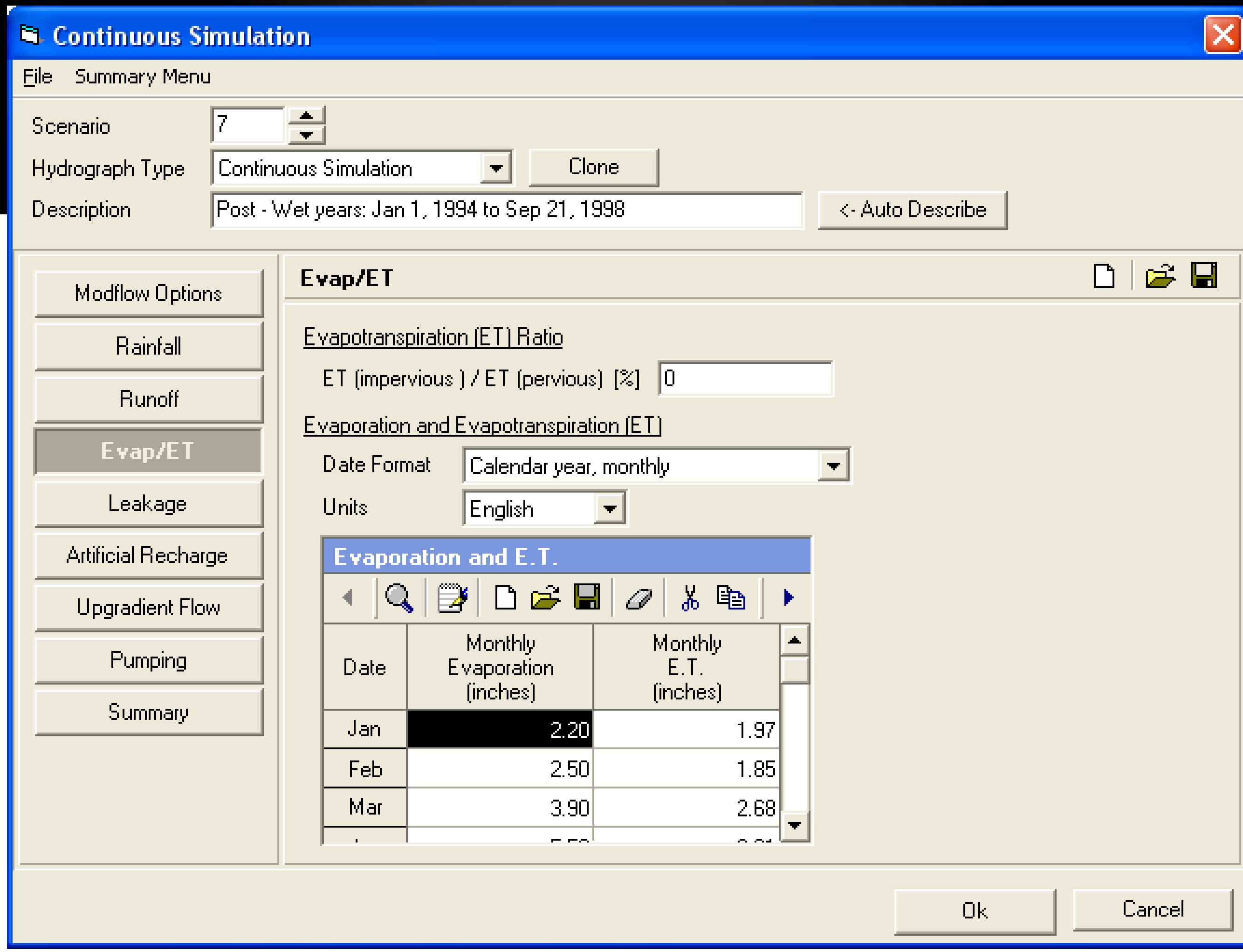
Continuous Simulation Hydrograph



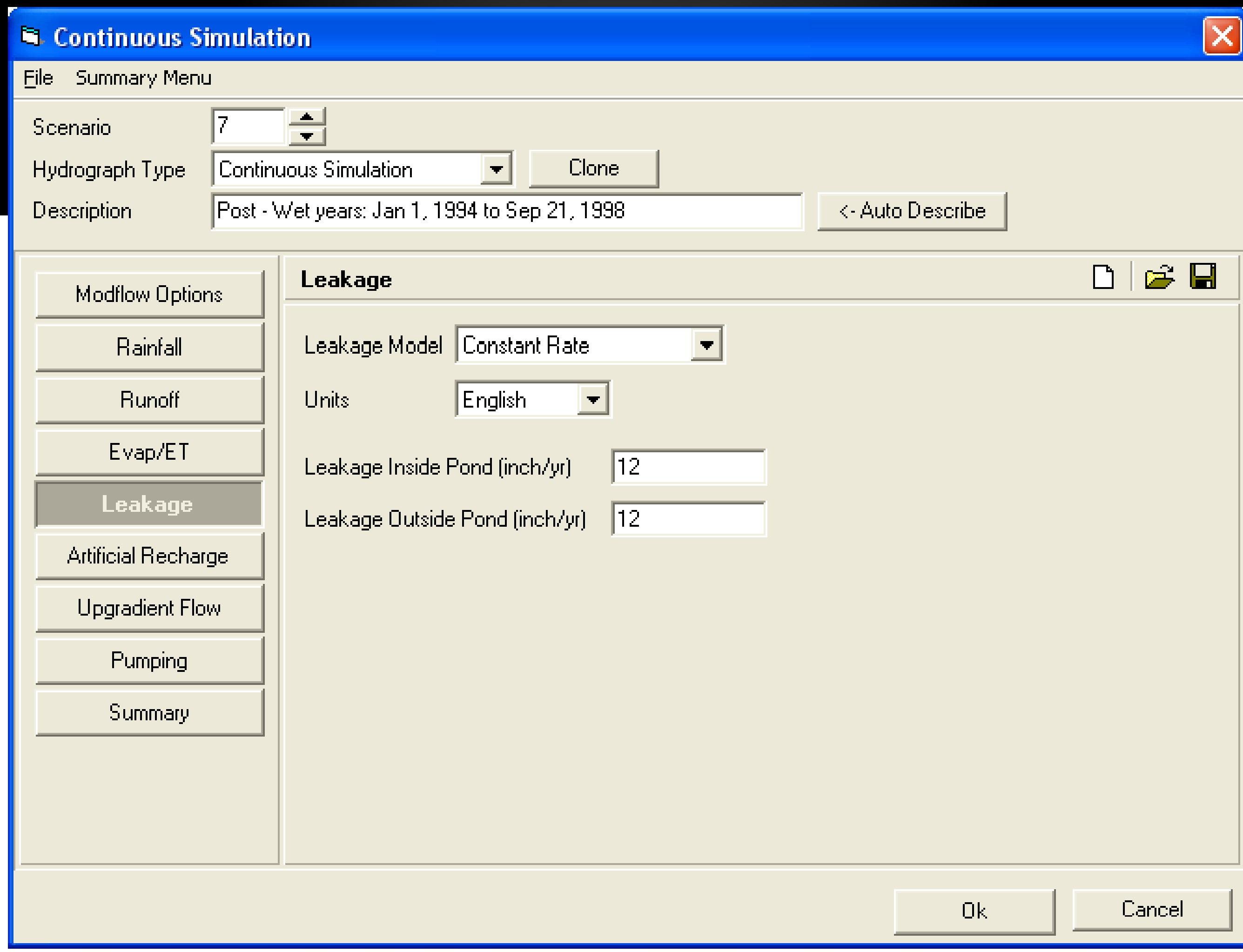
Continuous Simulation Hydrograph



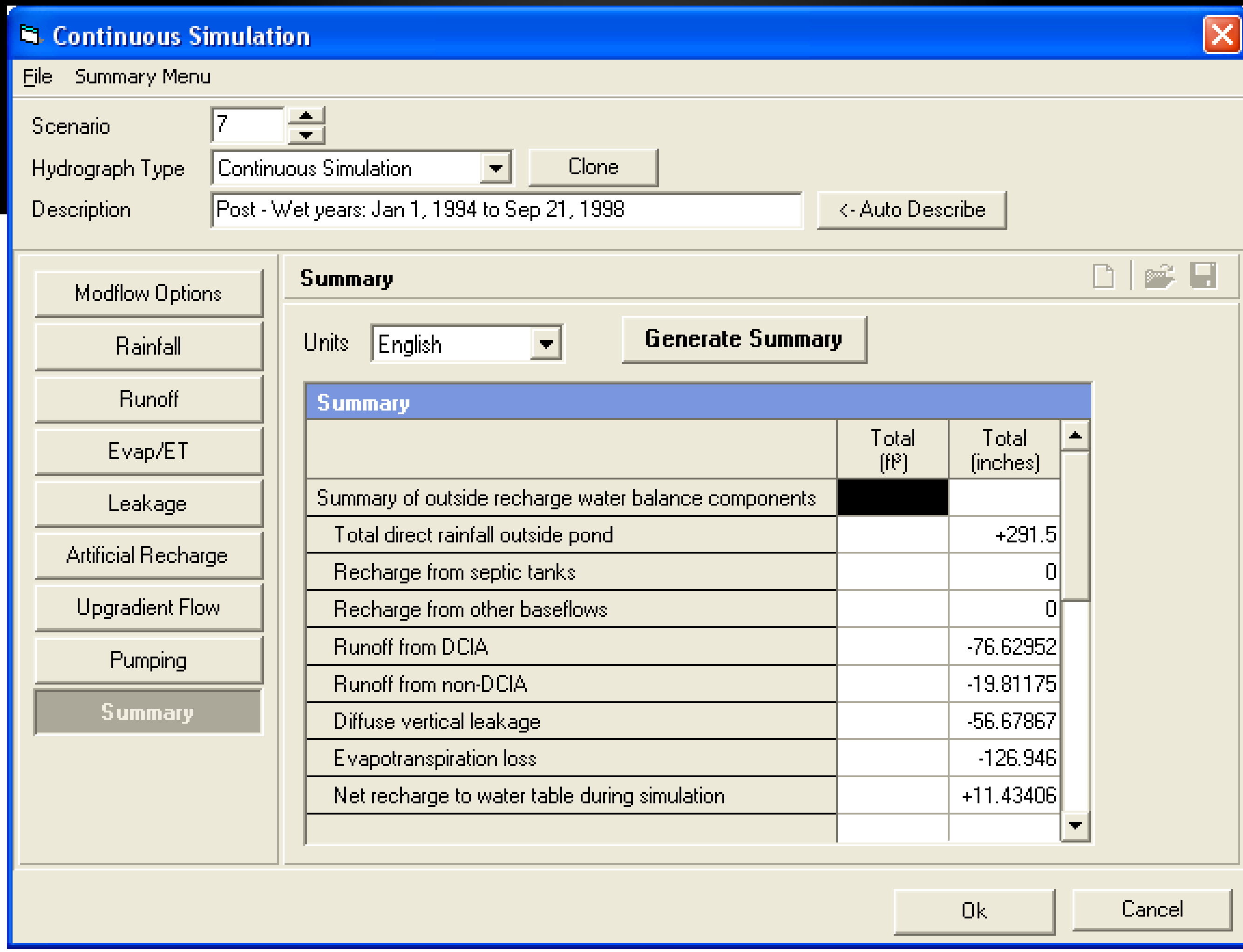
Continuous Simulation Hydrograph



Continuous Simulation Hydrograph



Continuous Simulation Hydrograph



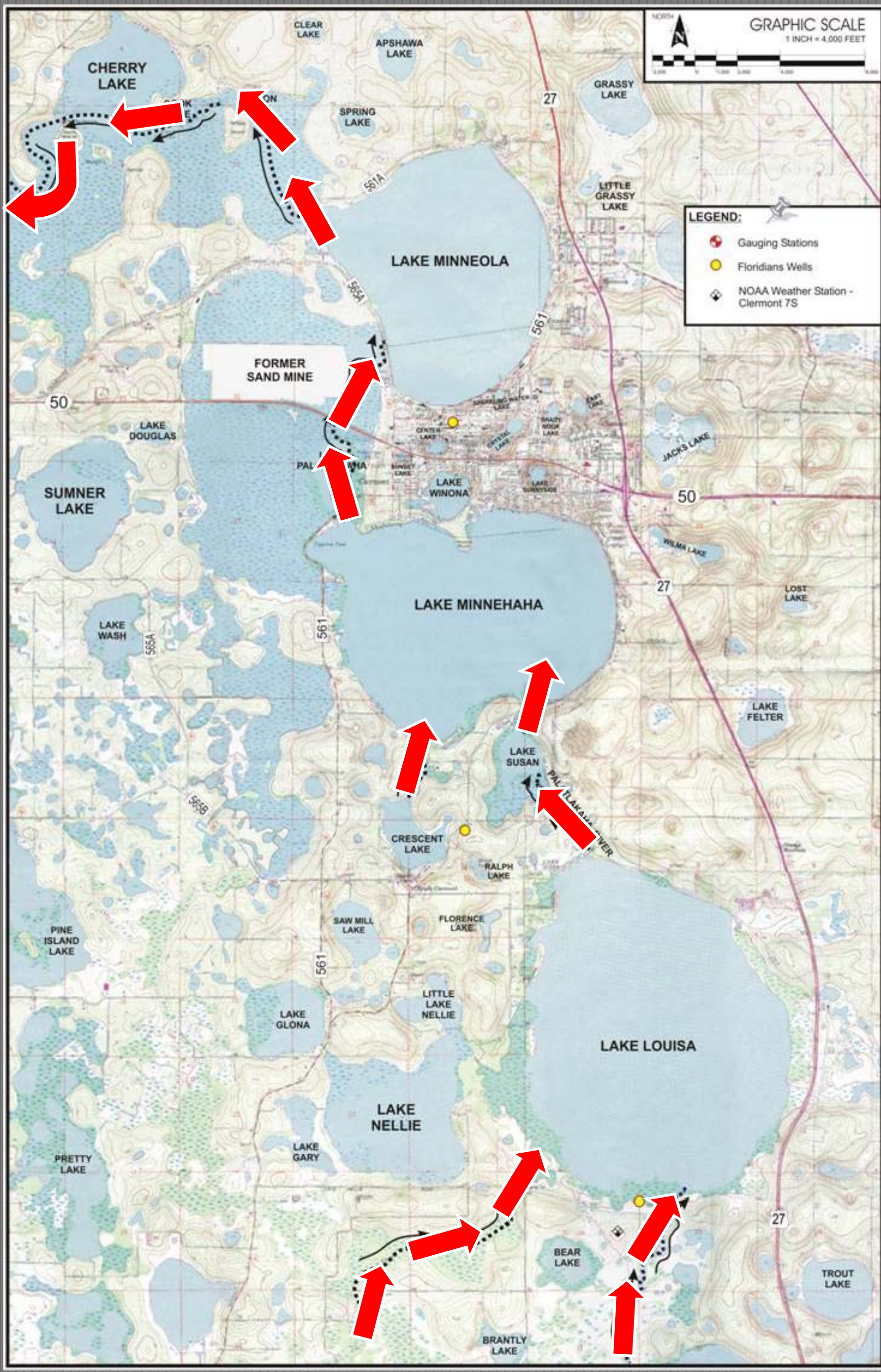
CONTINUOUS SIMULATION MODELING: DOES IT WORK?, HAS IT BEEN TESTED?

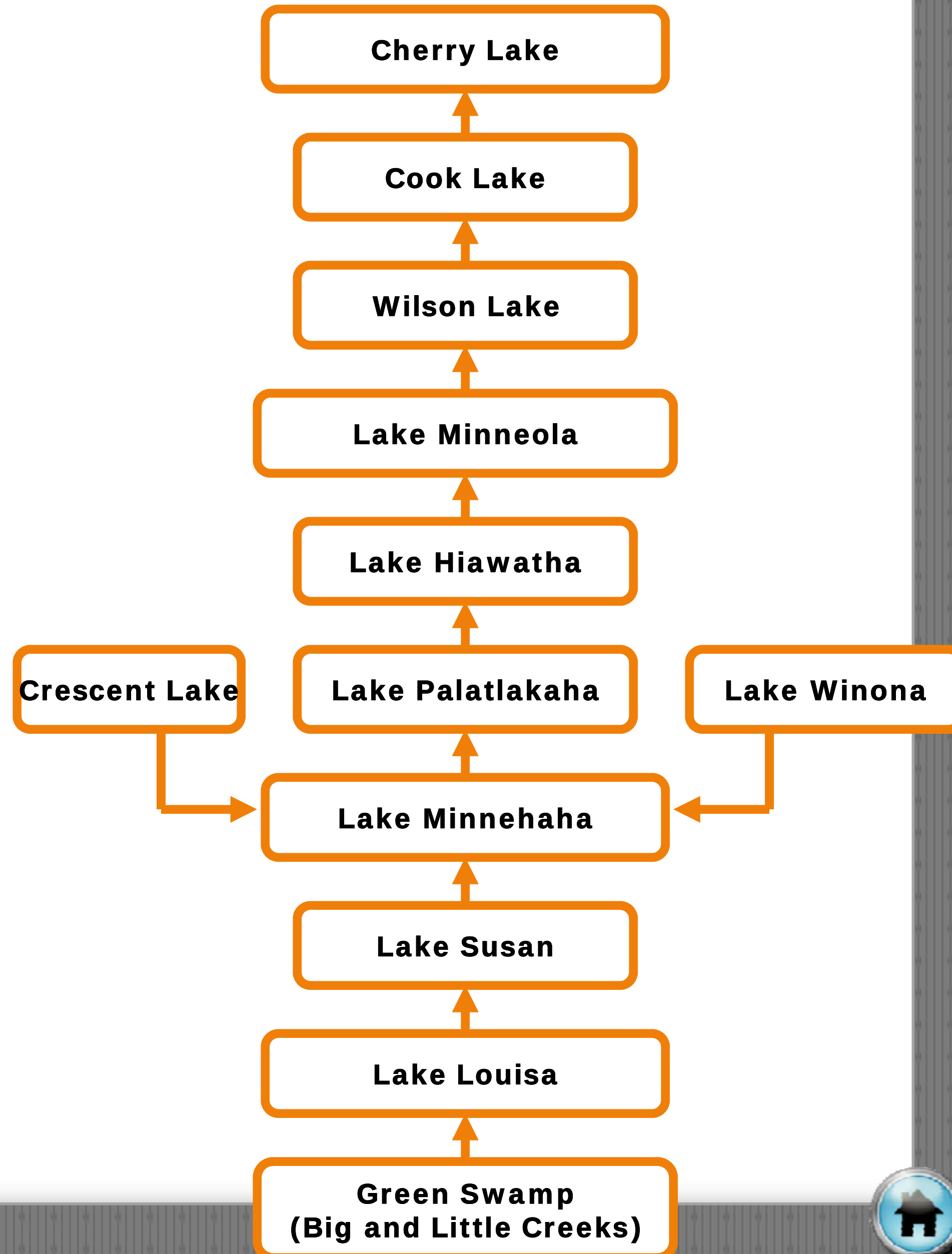
LET US LOOK AT SOME EXAMPLES OF ACTUAL MODELING PROJECTS AND COMPARISONS BETWEEN MEASURED AND PREDICTED LEVELS

Example: Clermont Chain of Lakes

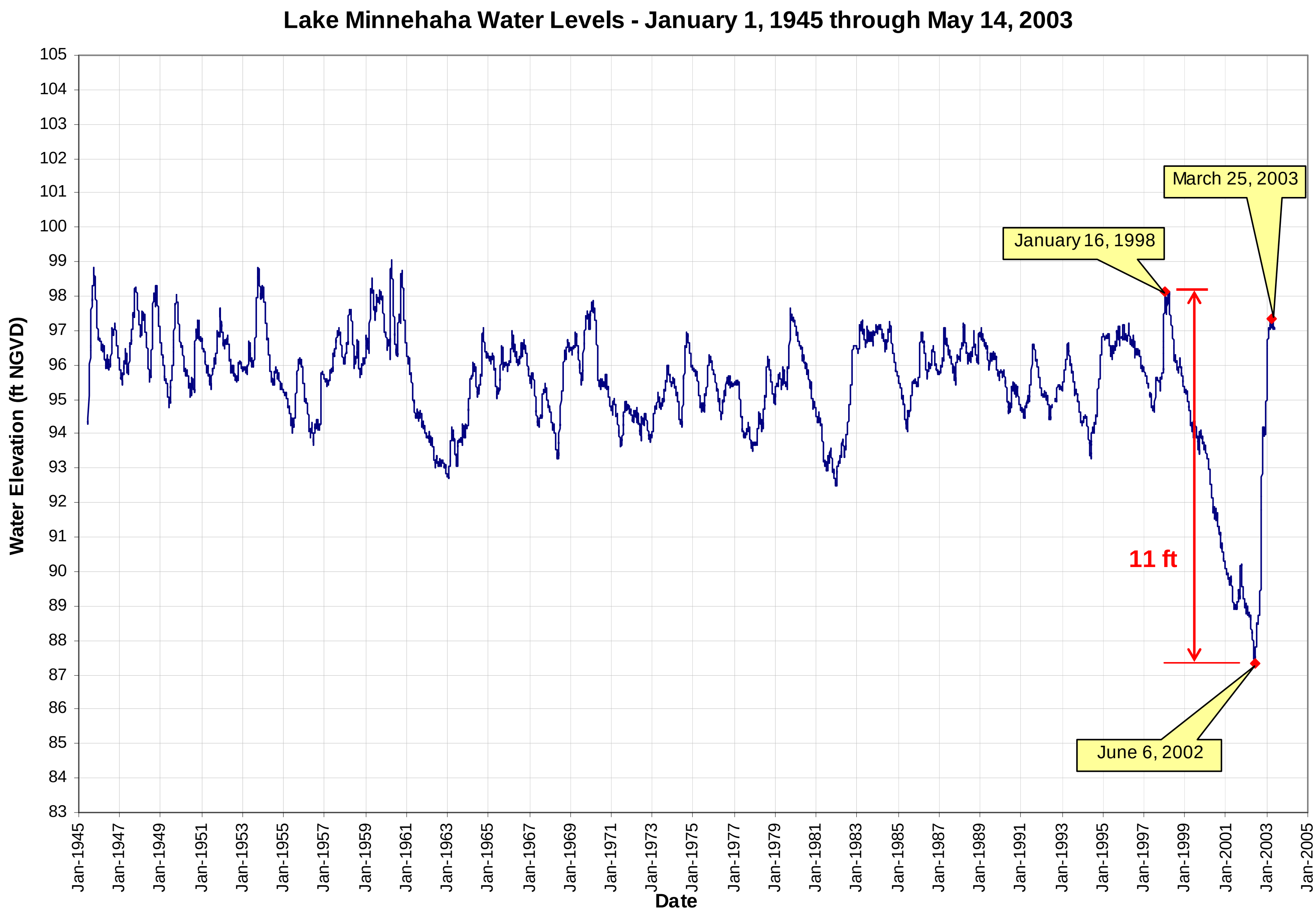
Lake Minneola, 6/10/2002

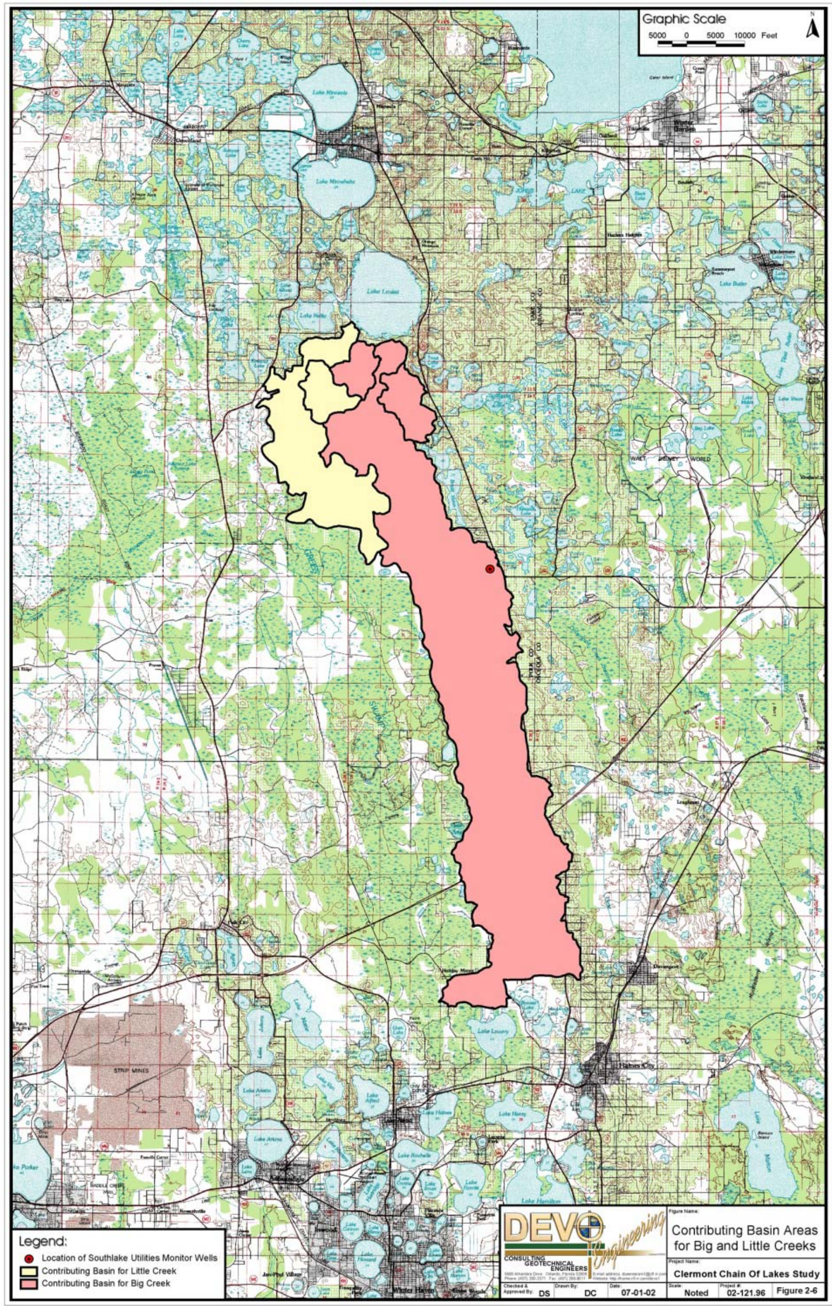
Clermont Chain of Lakes





Lake Minnehaha Water Levels

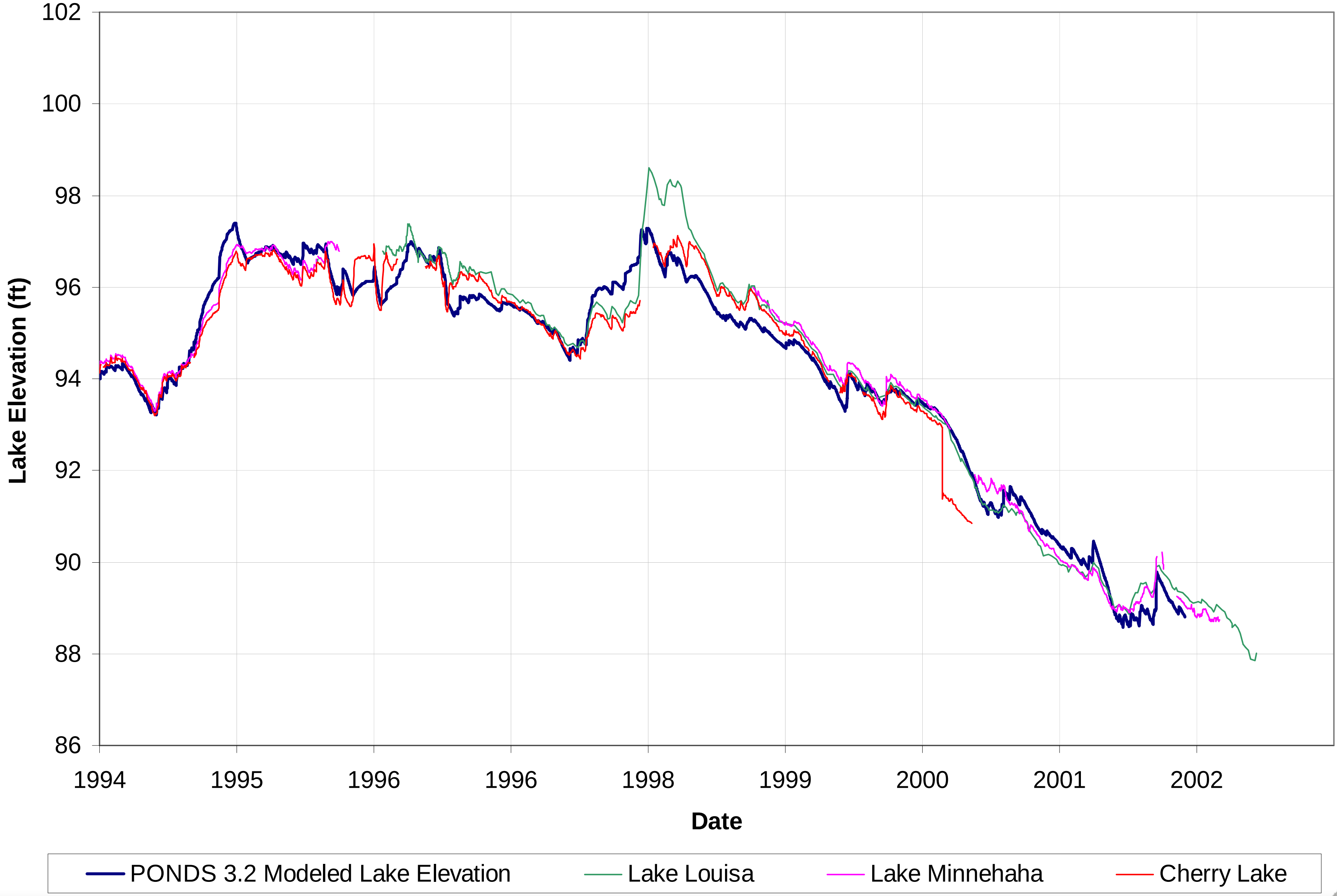




Location of Big Creek Recharge Basins

- Approximately 39,000 acres
- Running parallel to Lake Wales Ridge

Measured and Predicted Lake Levels – Clermont Chain



Example: Lake Sherwood Closed Basin Lake with Drainage Well

Date: Sept. 2004

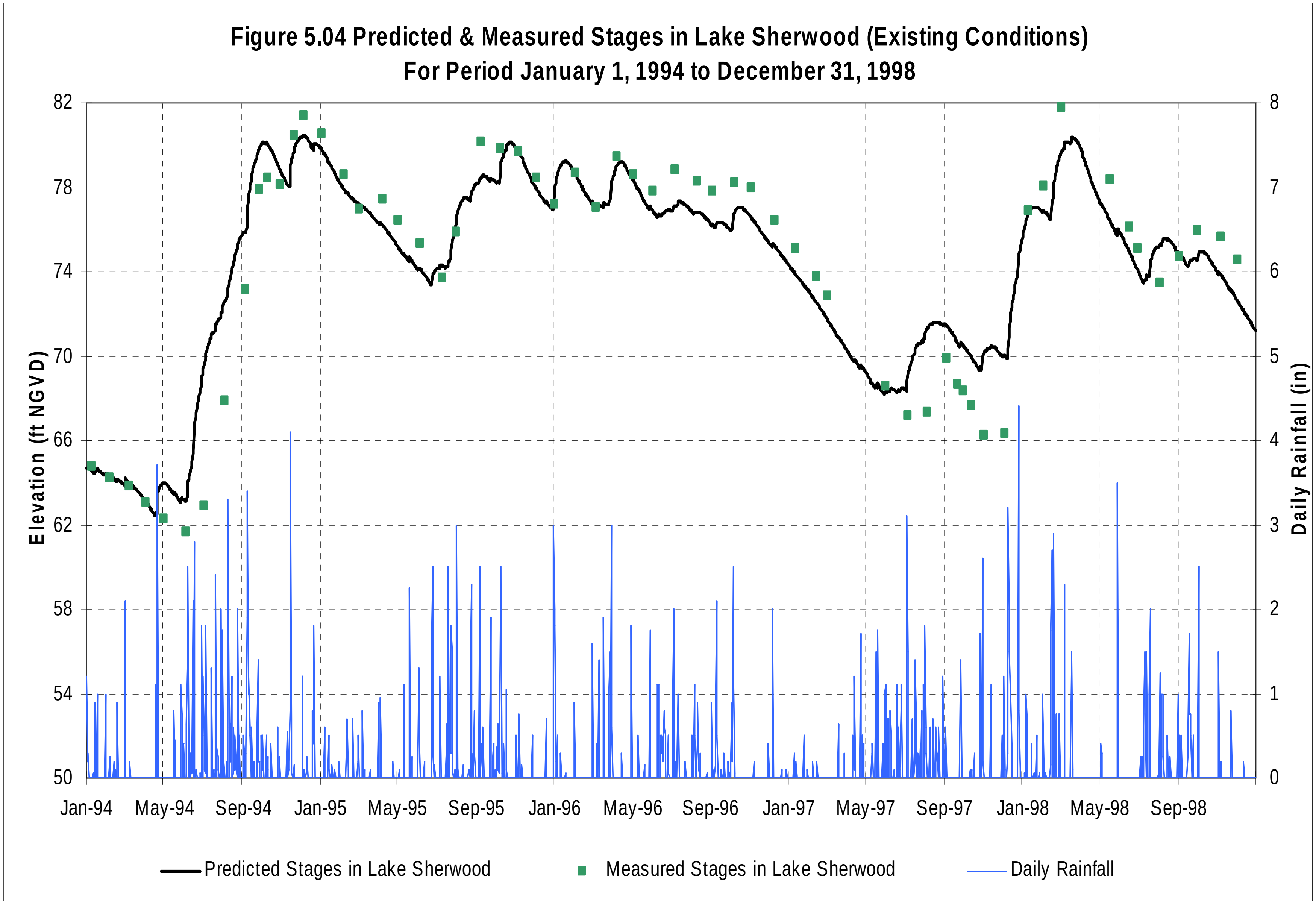
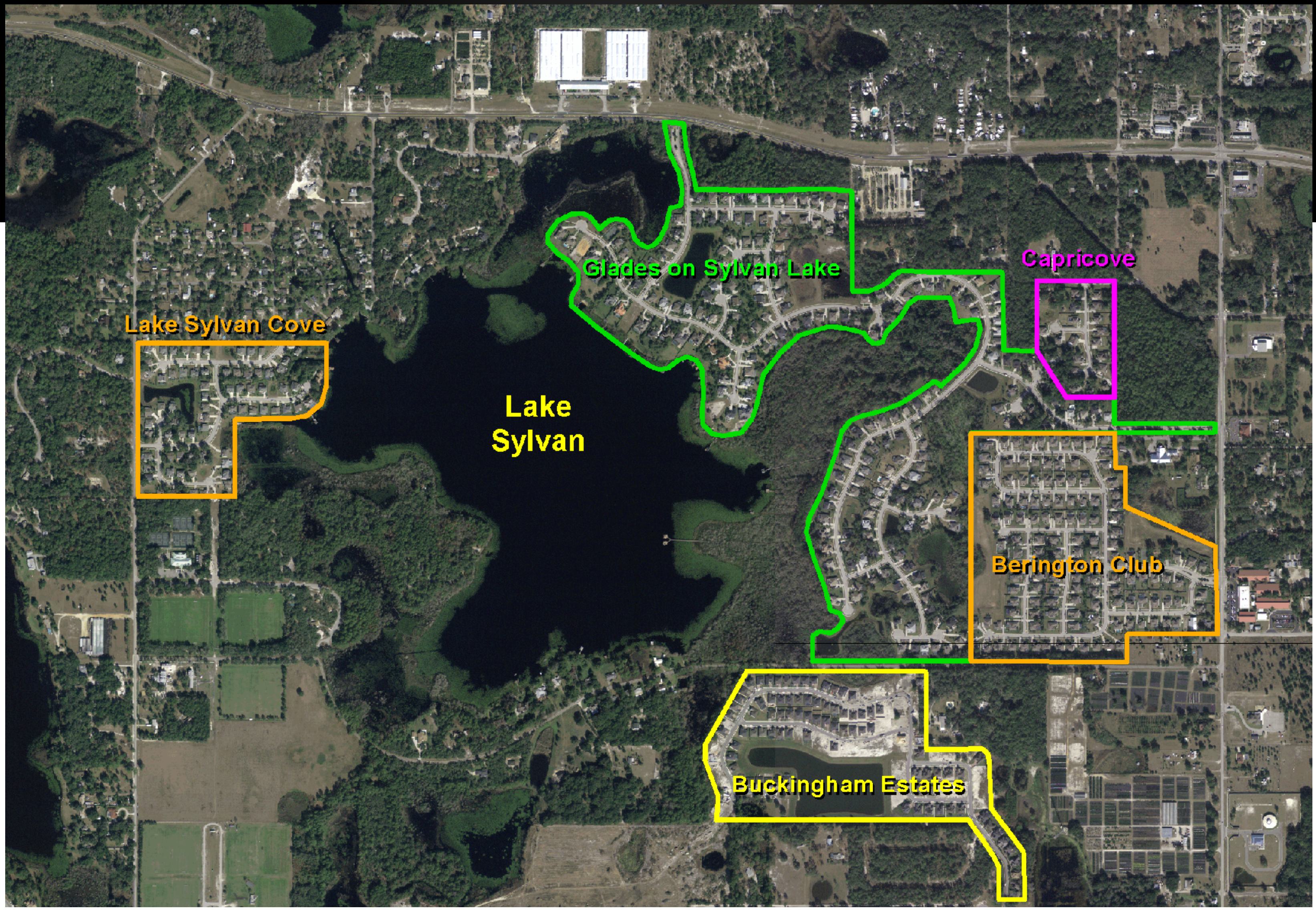


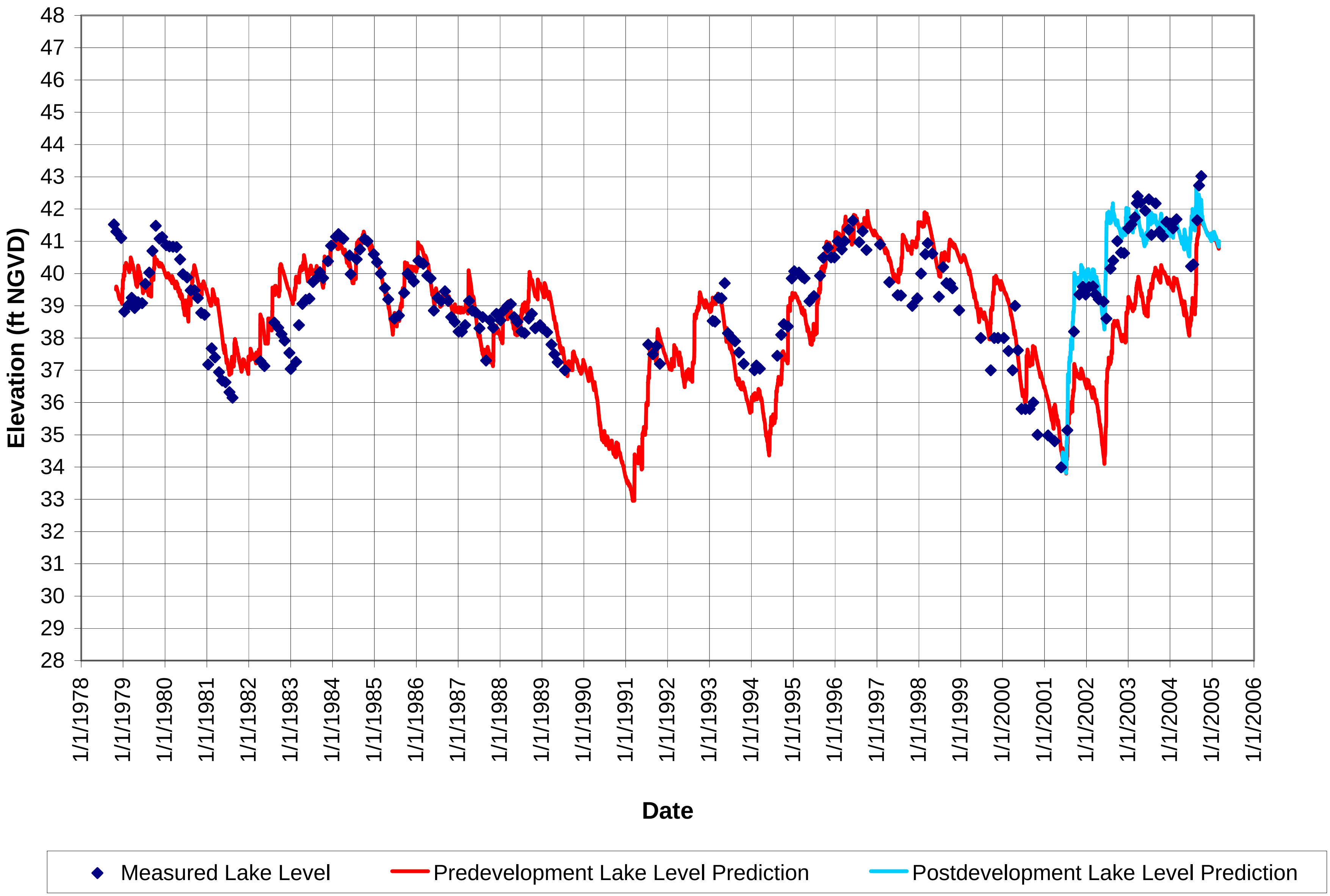
Figure 5.04 Predicted & Measured Stages in Lake Sherwood (Existing Conditions)
For Period January 1, 1994 to December 31, 1998
Elevation (ft NGVD)
Daily Rainfall (in)
82
78
74
70
66
62
58
54
50
8
7
6
5
4
3
2
1
0
Jan-94
May-94
Sep-94
Jan-95
May-95
Sep-95
Jan-96
May-96
Sep-96
Jan-97
May-97
Sep-97
Jan-98
May-98
Sep-98
Predicted Stages in Lake Sherwood
Measured Stages in Lake Sherwood
Daily Rainfall

Lake Sylvan - Predevelopment

Lake Sylvan - Postdevelopment



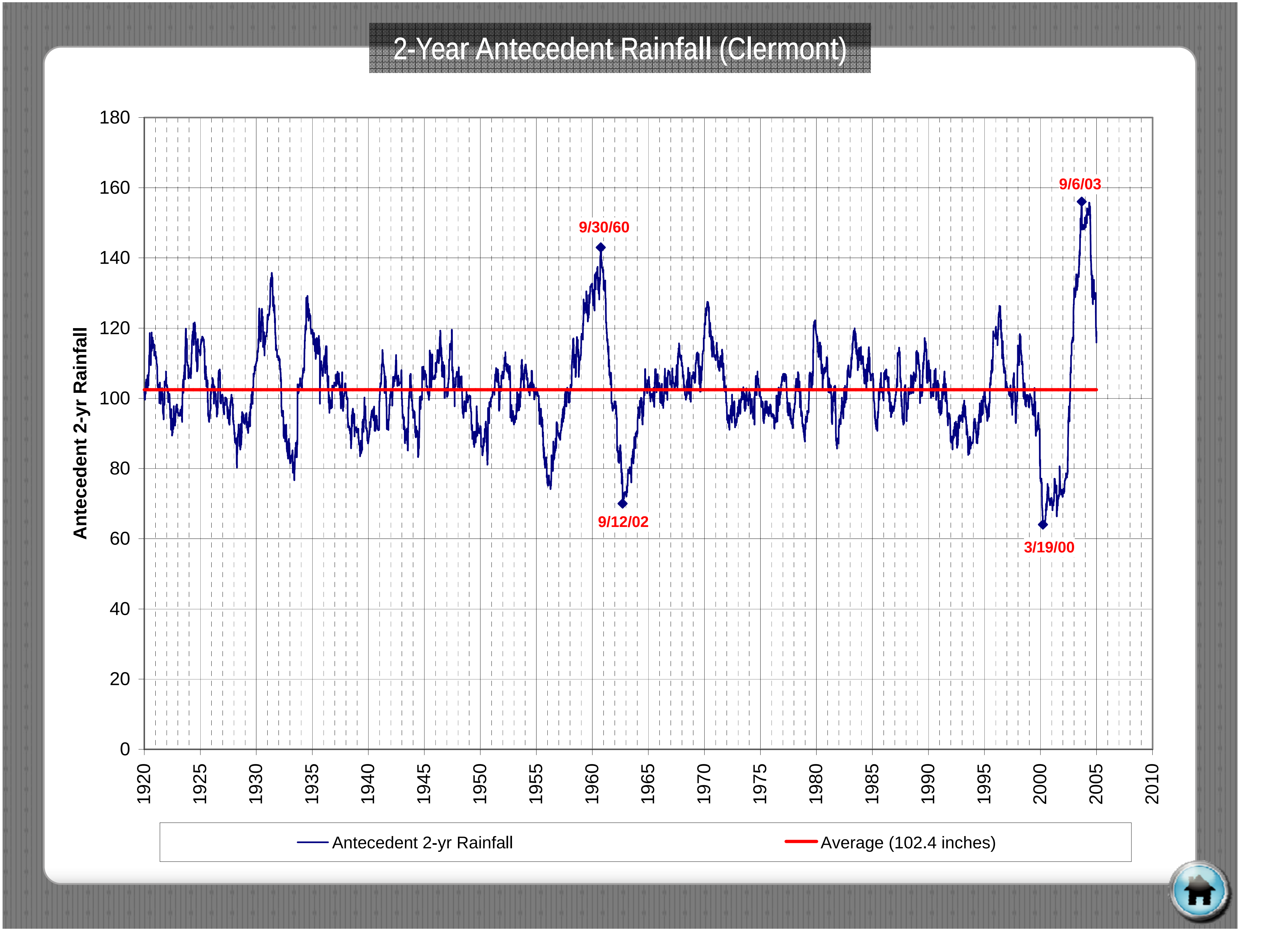
Measured and Predicted Lake Levels – Lake Sylvan



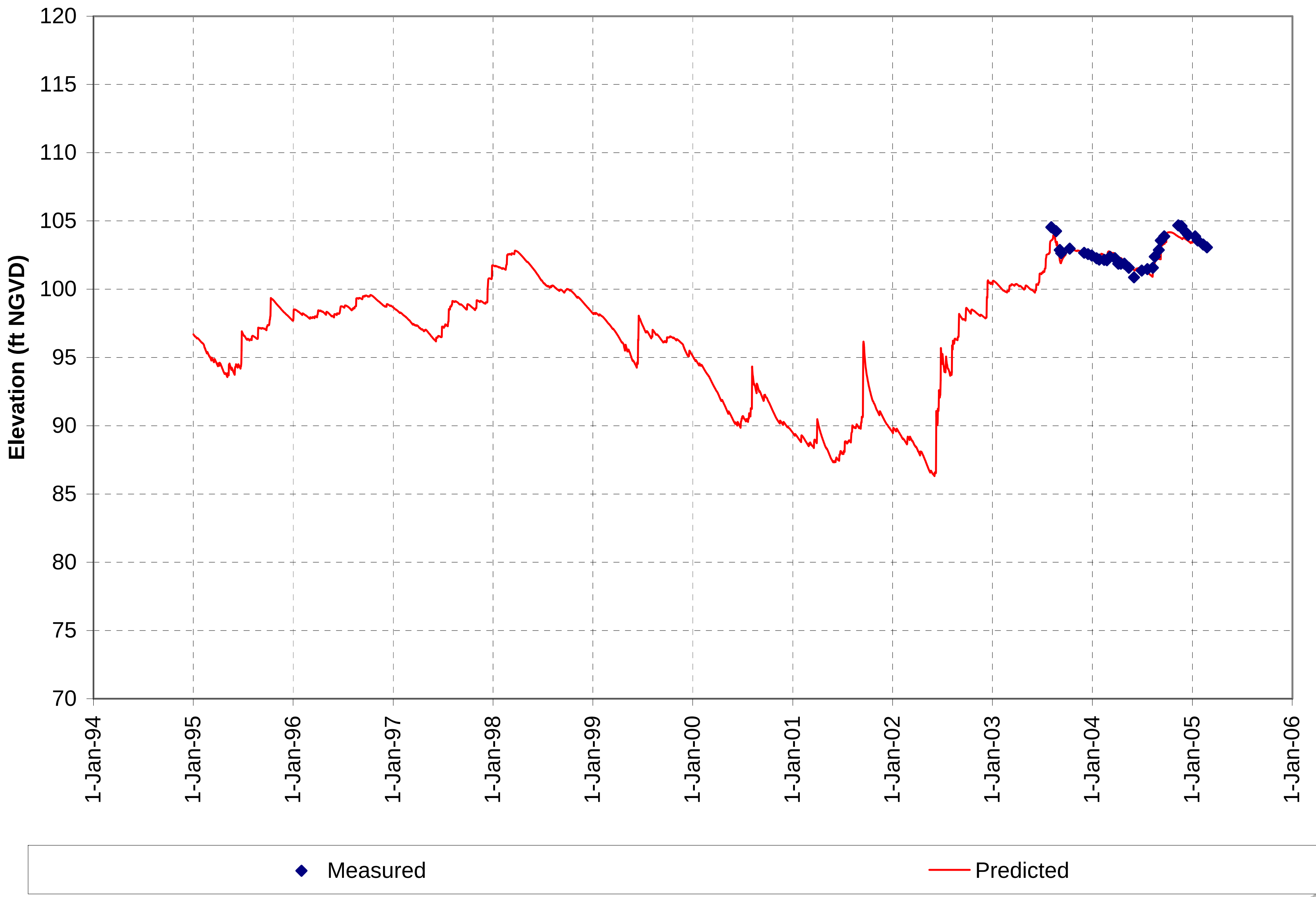
Example:

Lake Katherine / Lake Clair

Closed basin flooding with emergency pumping in July/August 2003


2-Year Antecedent Rainfall (Clermont)
Antecedent 2-yr Rainfall
180
160
140
120
100
80
60
40
20
0
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
9/30/60
9/12/02
3/19/00
9/6/03
Antecedent 2-yr Rainfall
Average (102.4 inches)

Model Results for Lake Katherine



Model Results for Lake Clair