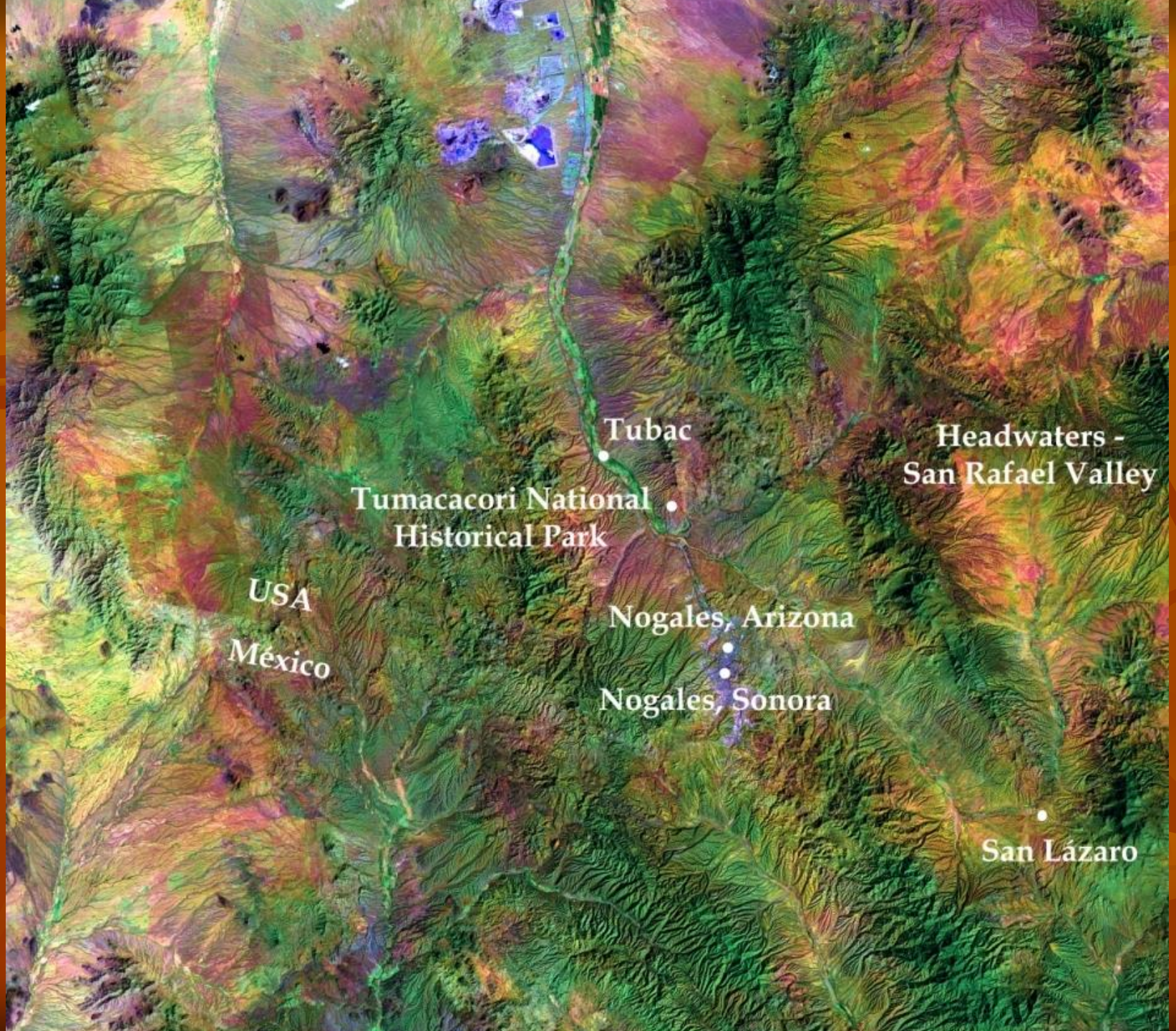
Santa Cruz AMA Hydrology & Groundwater Modeling

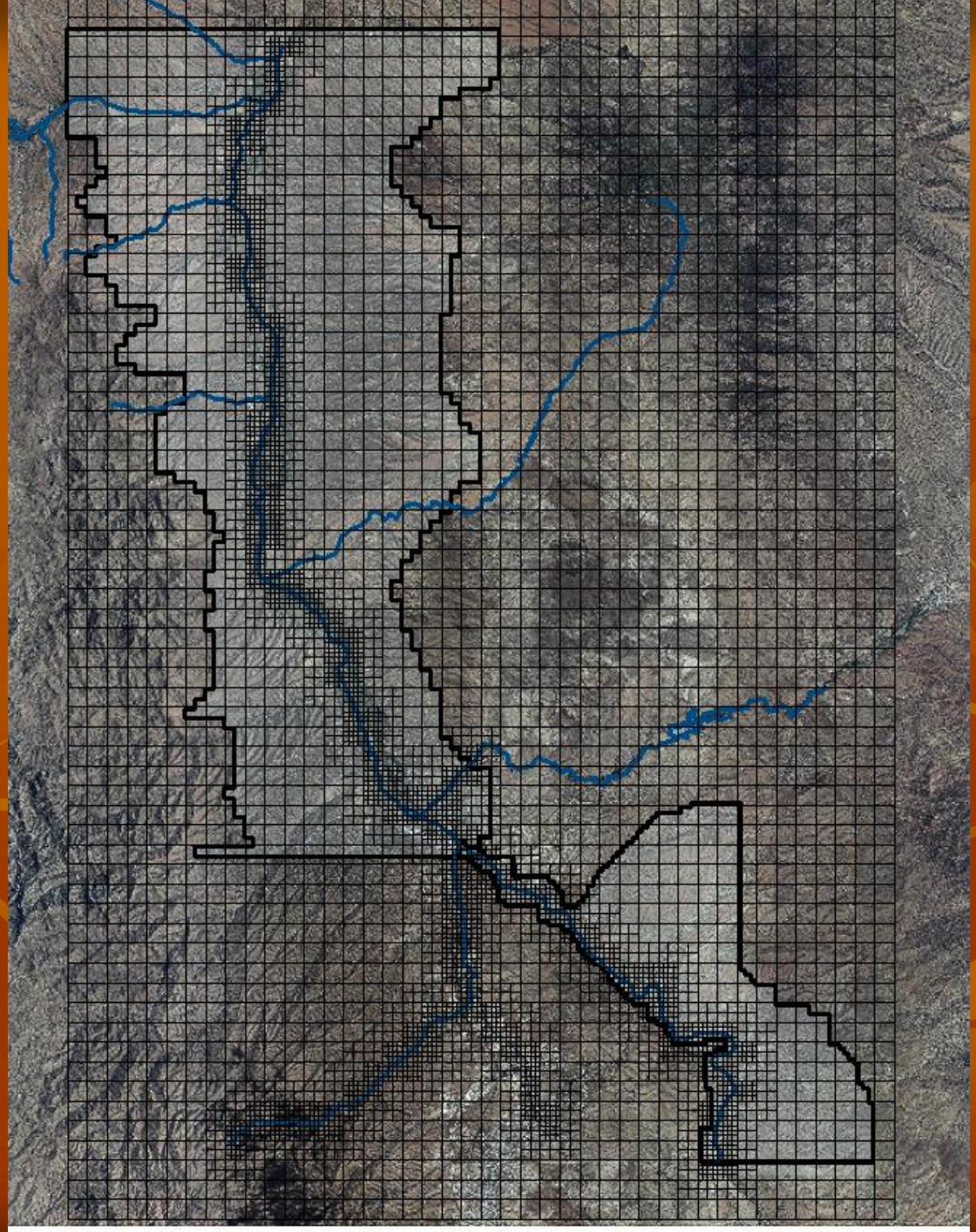
Keith Nelson ***kmnelson@azwater.gov***
Arizona Department of Water Resources

- Overview of Hydrology (Upper Santa Cruz)
- Hydrologic Models
- *1) Understand System; 2) Simulate Projections*
  - *Groundwater Flow Models*
  - *Stochastic Streamflow Model*
  - *Combining Streamflow and Groundwater Flow Models*
- Risk Analysis Examples

Santa Cruz AMA Goals § 45-562C:

1) *"Maintain Safe-Yield Conditions"*
2) *"Prevent local water tables from experiencing long-term declines"*


Tubac
Headwaters -
San Rafael Valley
Tumacacori National
Historical Park
USA
México
Nogales, Arizona
Nogales, Sonora
San Lázaro

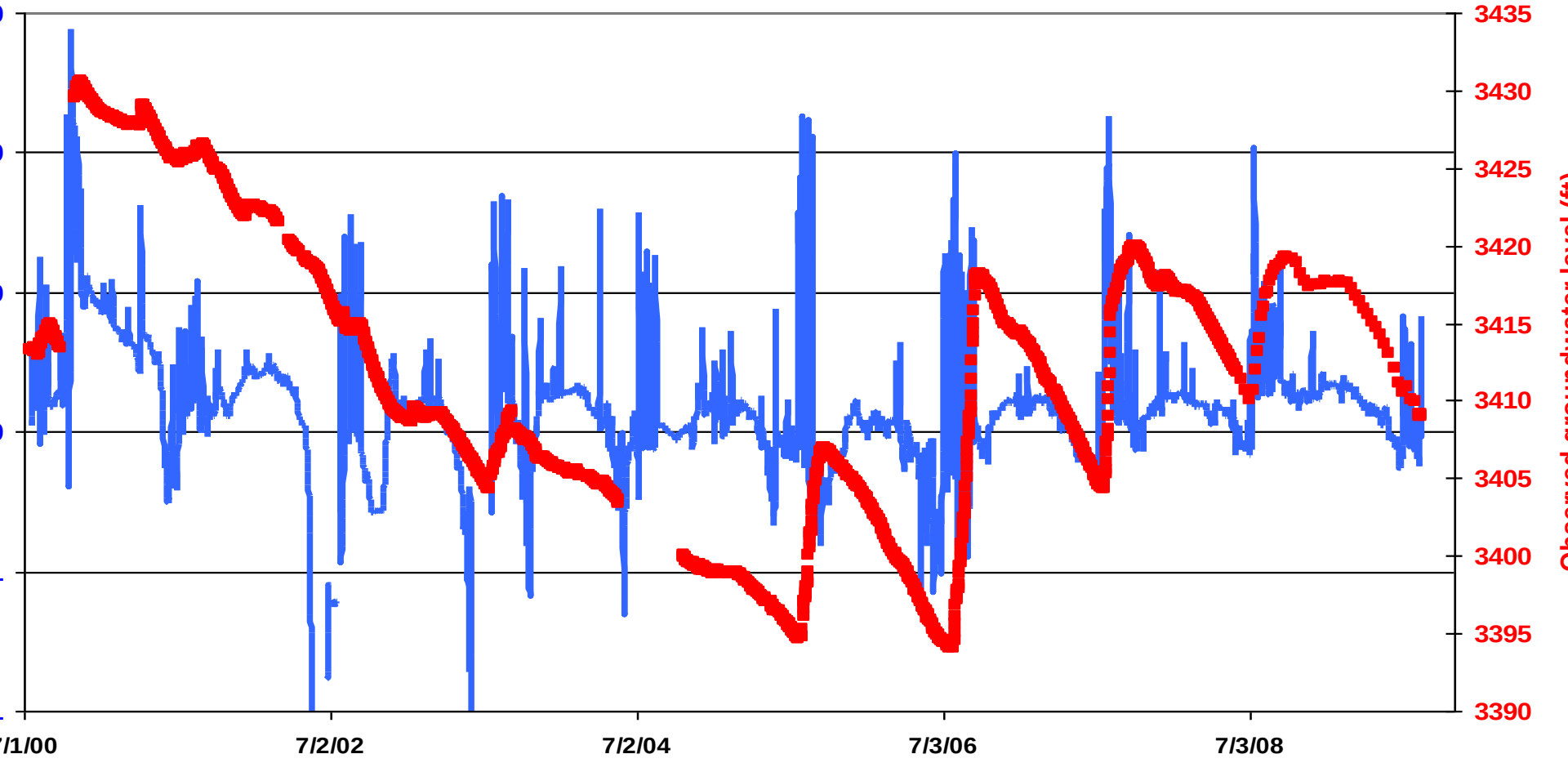


1. Flood Event Transmission Losses in Channel

2. Aquifer Recharge: Water Table Rise -> Baseflow?

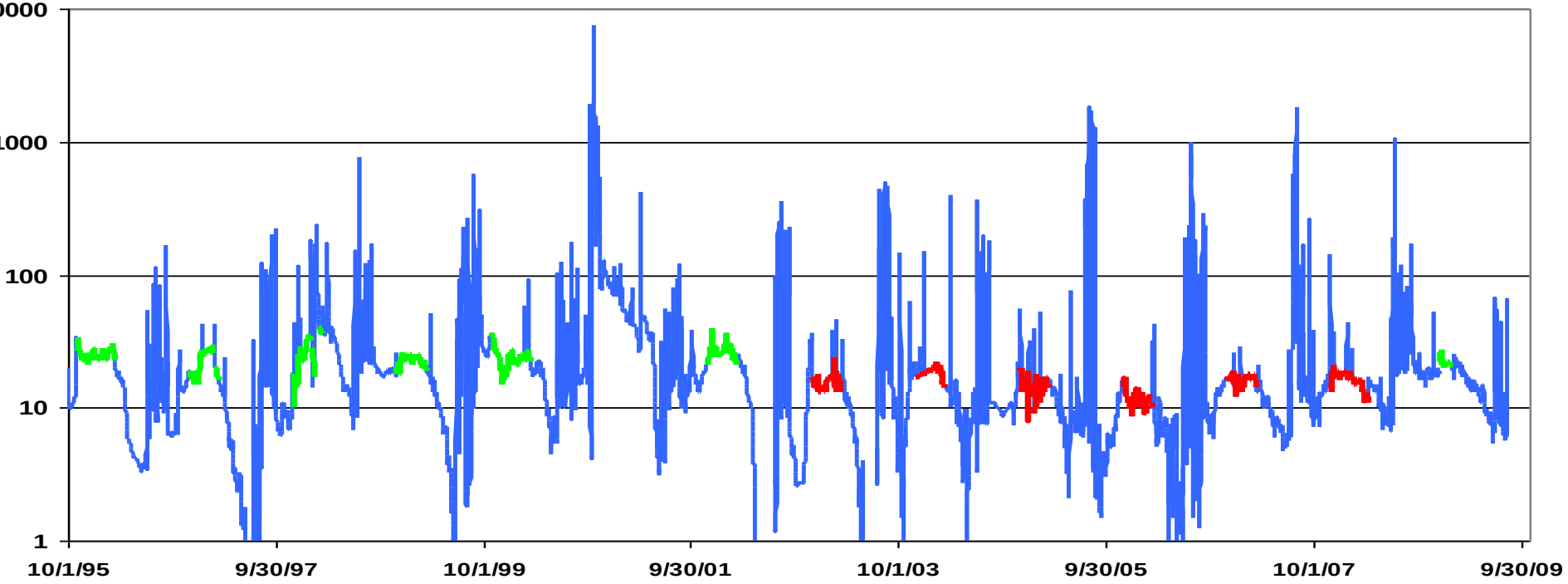
3. Periods of Low / No Recharge combined w/ Aquifer Stresses & Flux: GWL Decline

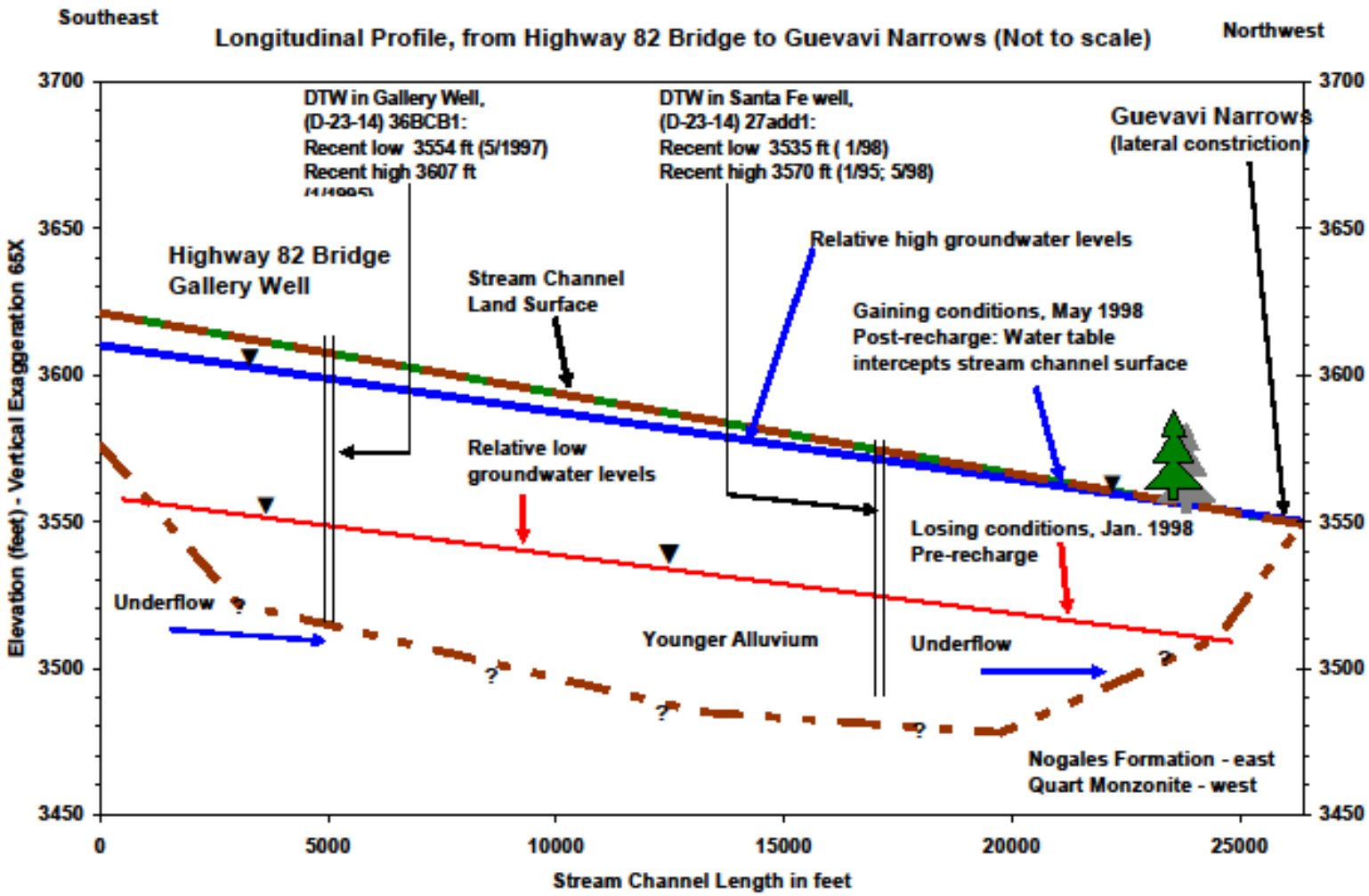
Relation between Surface water flow and Groundwater Levels

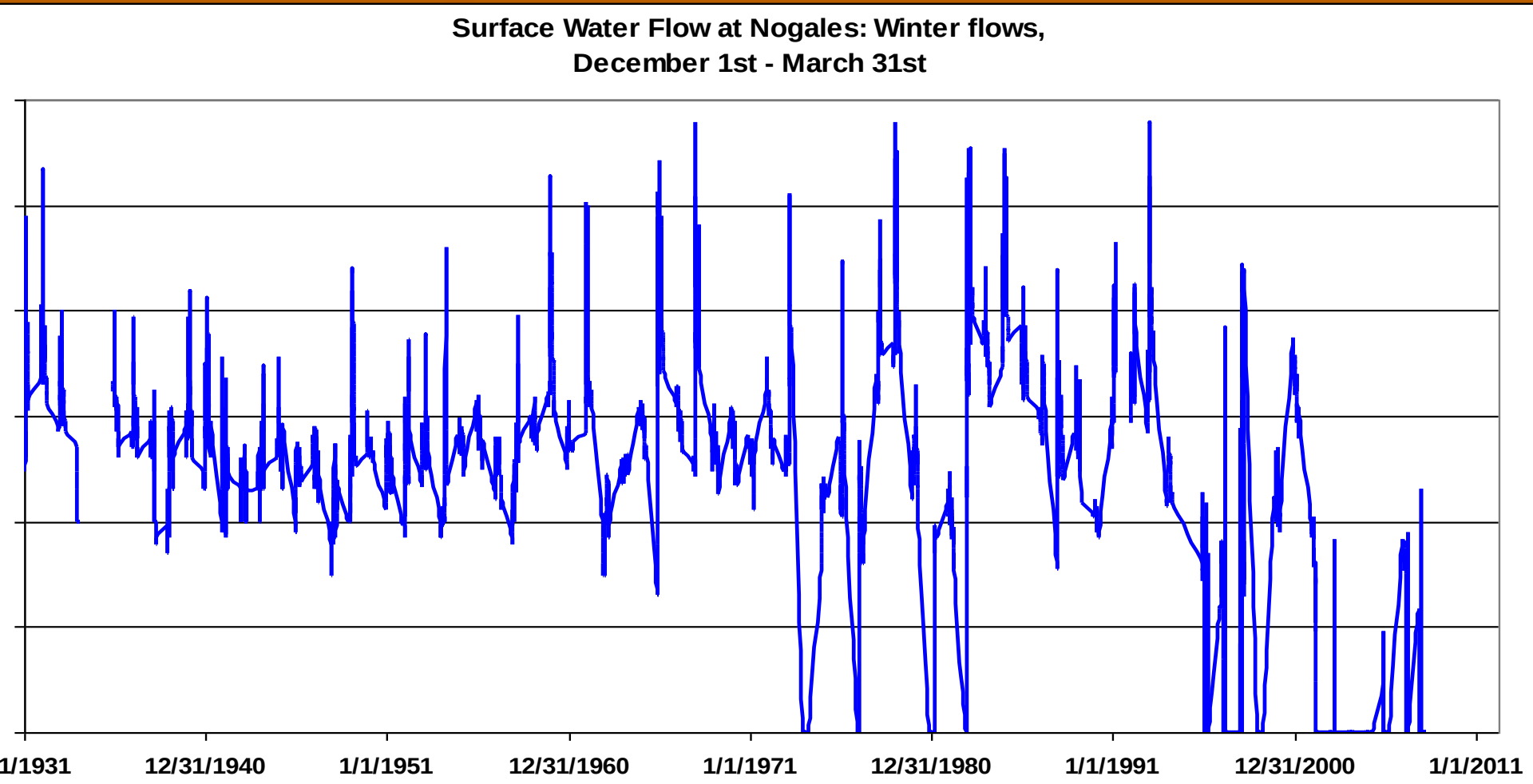


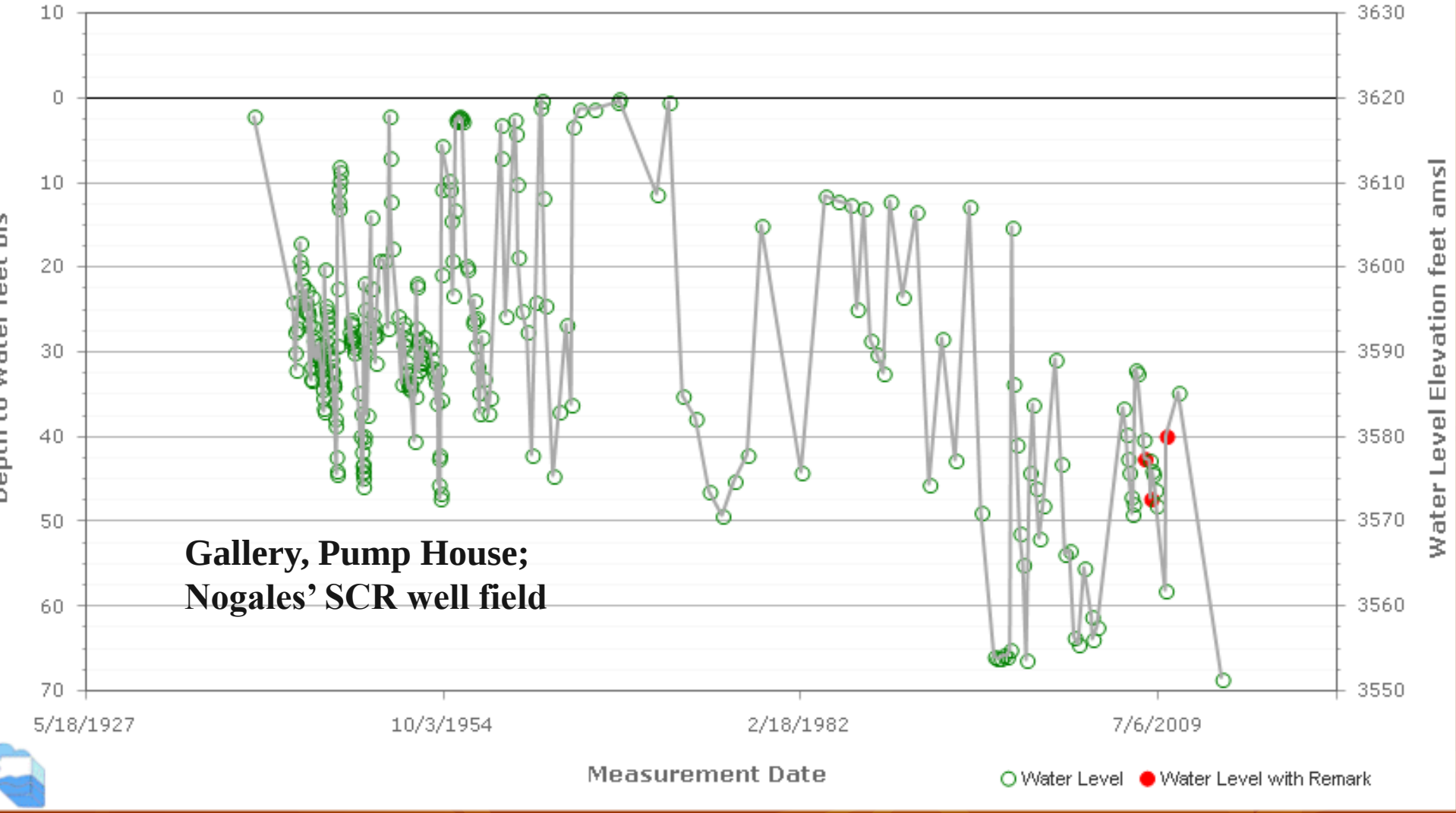
Stream Flow - Santa Cruz River: Baseflow Gaining (green); losing (red)

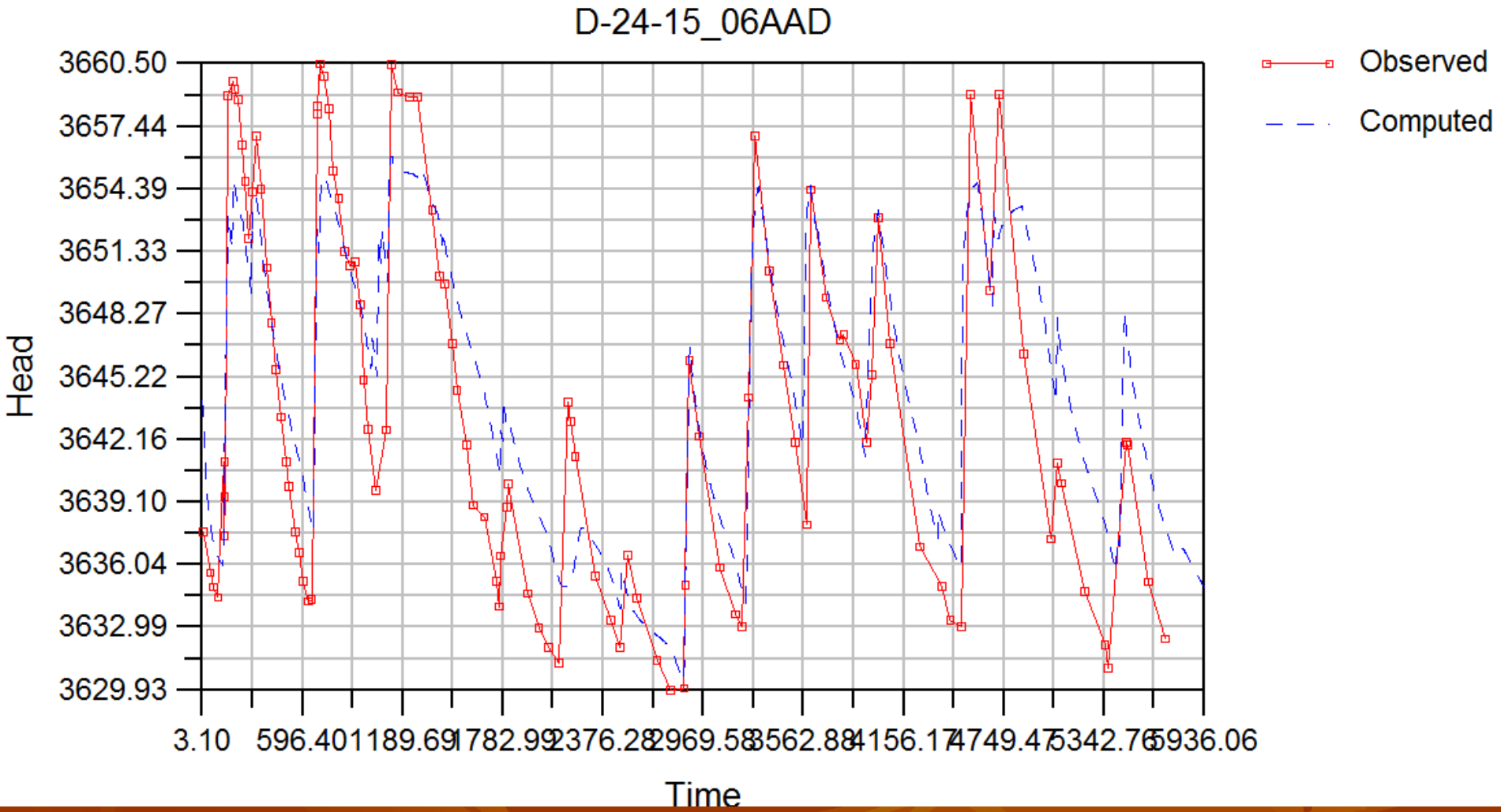
<---Intensive Drought---->

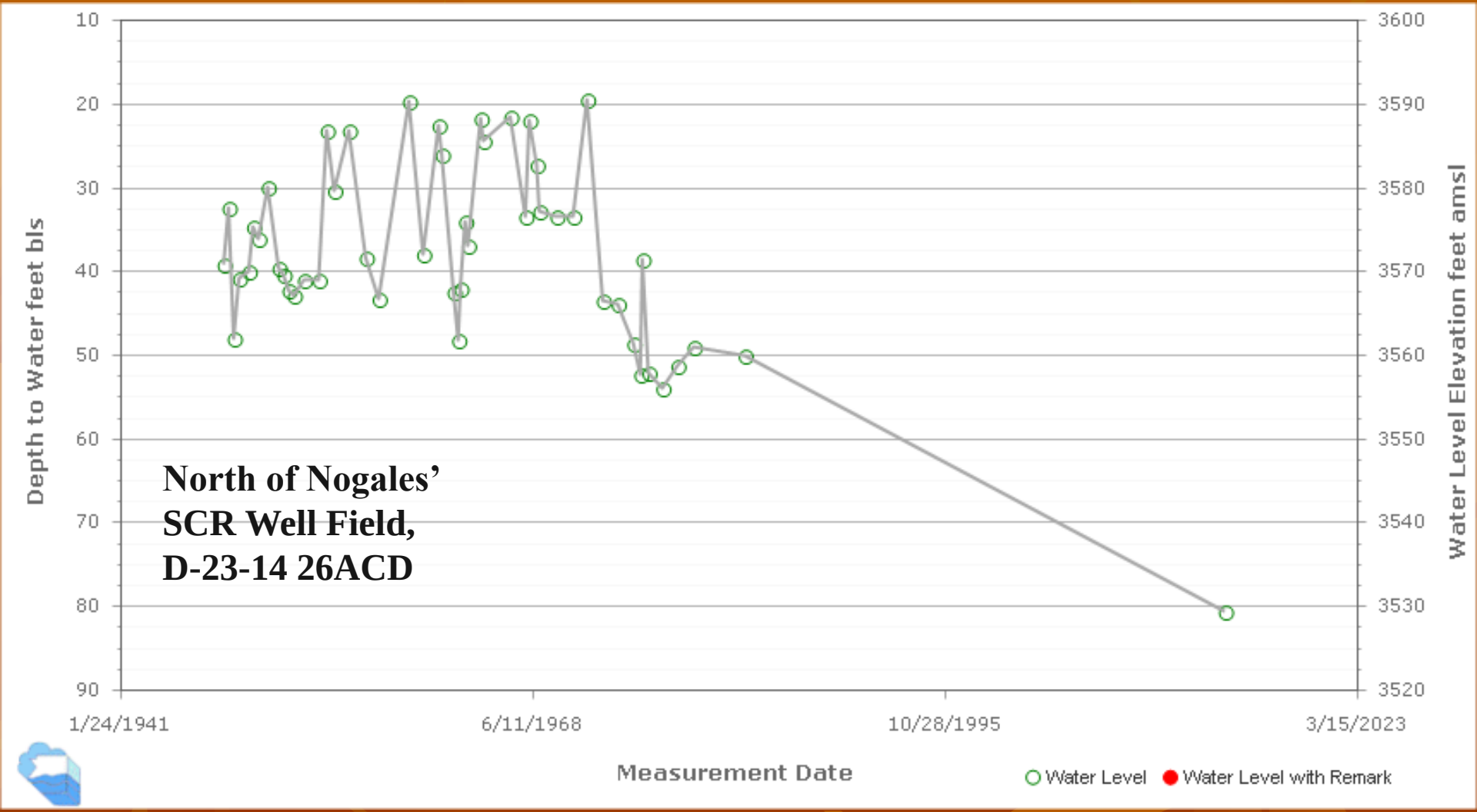



Southeast
Longitudinal Profile, from Highway 82 Bridge to Guevavi Narrows (Not to scale)
Northwest
DTW in Gallery Well,
(D-23-14) 36BCB1:
Recent low 3554 ft (5/1997)
Recent high 3607 ft
DTW in Santa Fe well,
(D-23-14) 27add1:
Recent low 3535 ft (1/98)
Recent high 3570 ft (1/95; 5/98)
Guevavi Narrows
(lateral constriction)
Highway 82 Bridge
Gallery Well
Stream Channel
Land Surface
Relative high groundwater levels
Gaining conditions, May 1998
Post-recharge: Water table
intercepts stream channel surface
Relative low
groundwater levels
Losing conditions, Jan. 1998
Pre-recharge
Underflow
Younger Alluvium
Underflow
Nogales Formation - east
Quart Monzonite - west
Elevation (feet) - Vertical Exaggeration 65X
3700
3650
3600
3550
3500
3450
0
5000
10000
15000
20000
25000
Stream Channel Length in feet

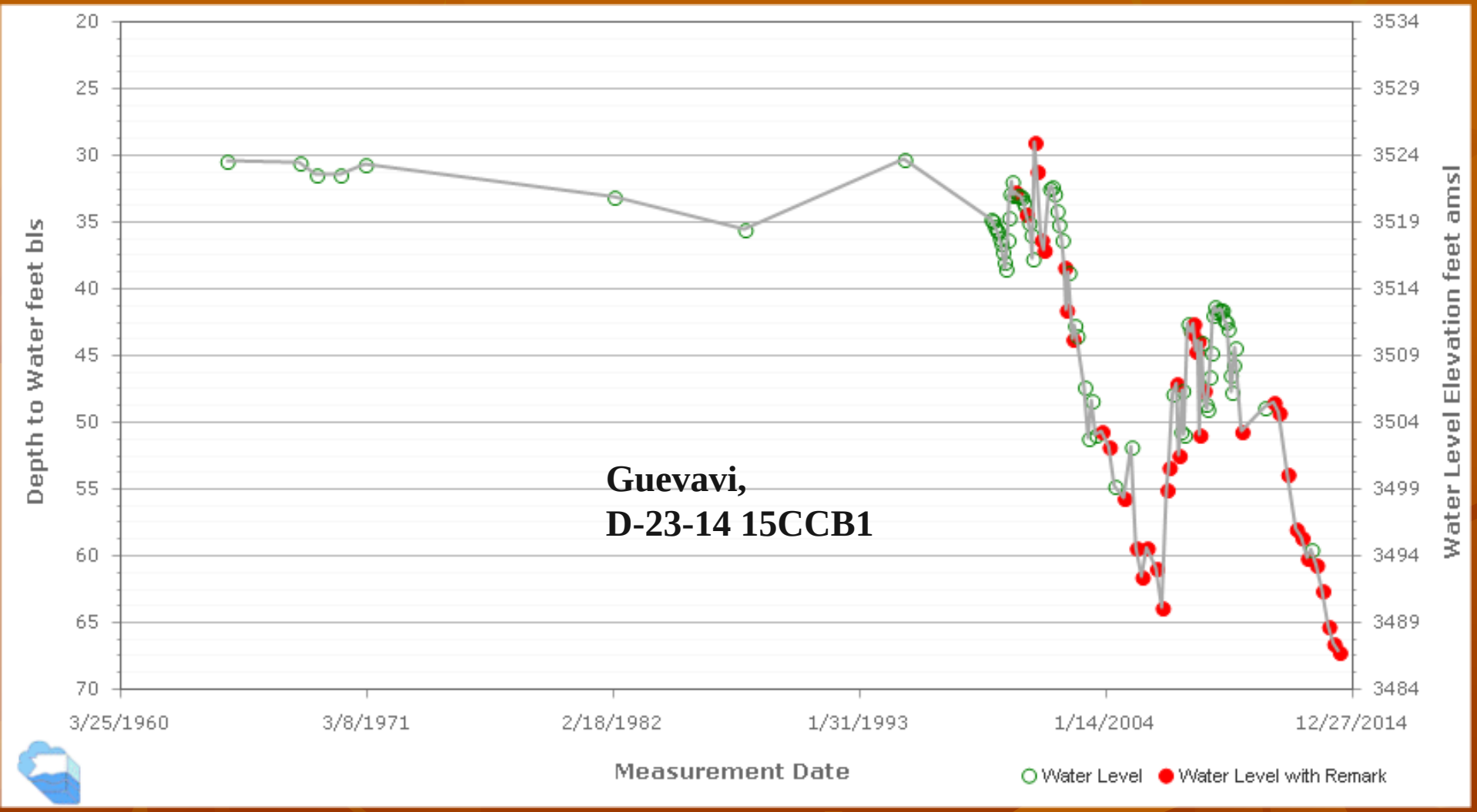

Surface Water Flow at Nogales: Winter flows,
December 1st - March 31st
1/1931
12/31/1940
1/1/1951
12/31/1960
1/1/1971
12/31/1980
1/1/1991
12/31/2000
1/1/2011

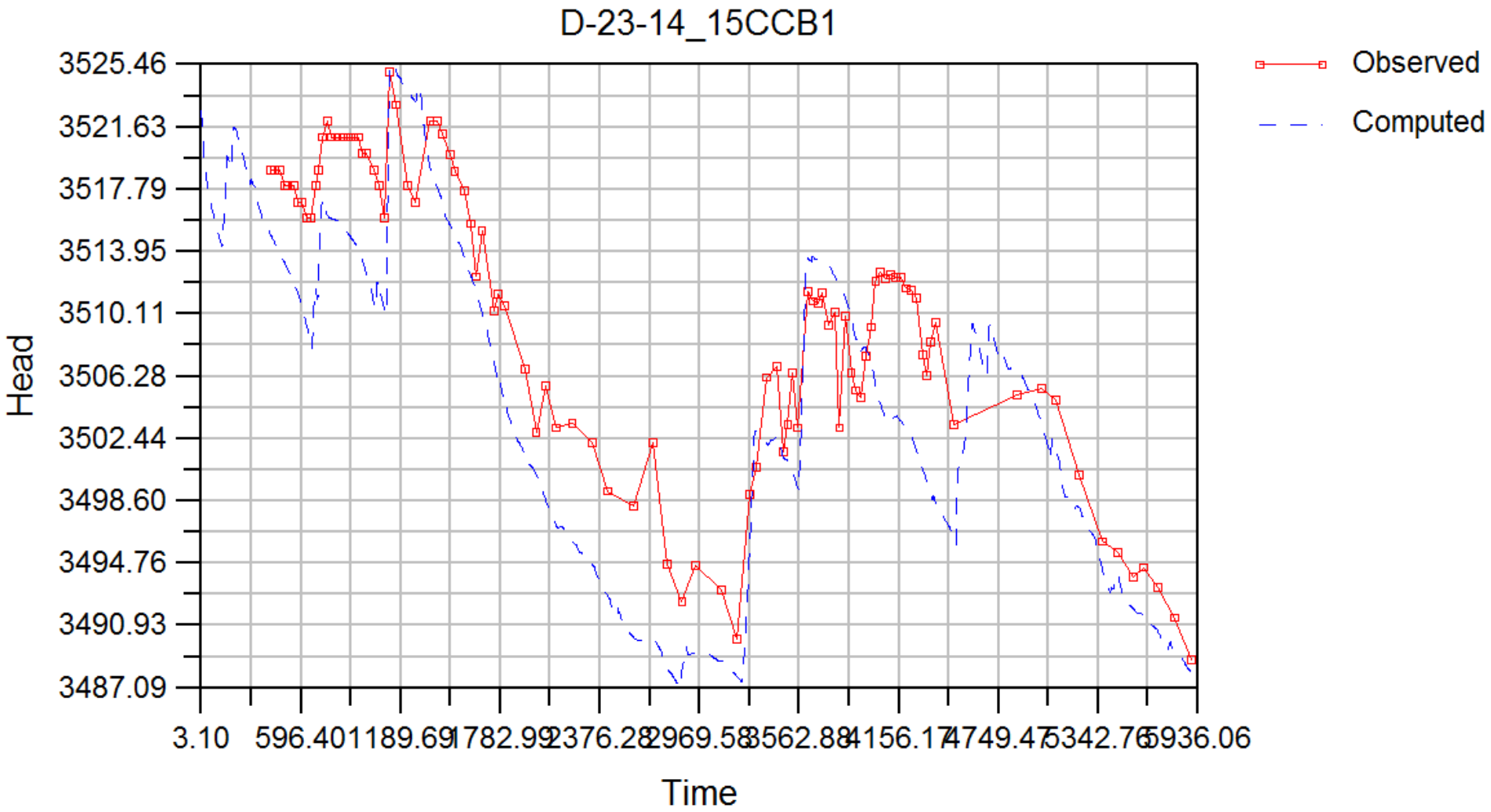

Gallery, Pump House;
Nogales' SCR well field
Depth to Water feet bls
Water Level Elevation feet amsl
10
0
10
20
30
40
50
60
70
3630
3620
3610
3600
3590
3580
3570
3560
3550
5/18/1927
10/3/1954
2/18/1982
7/6/2009
Measurement Date
Water Level
Water Level with Remark

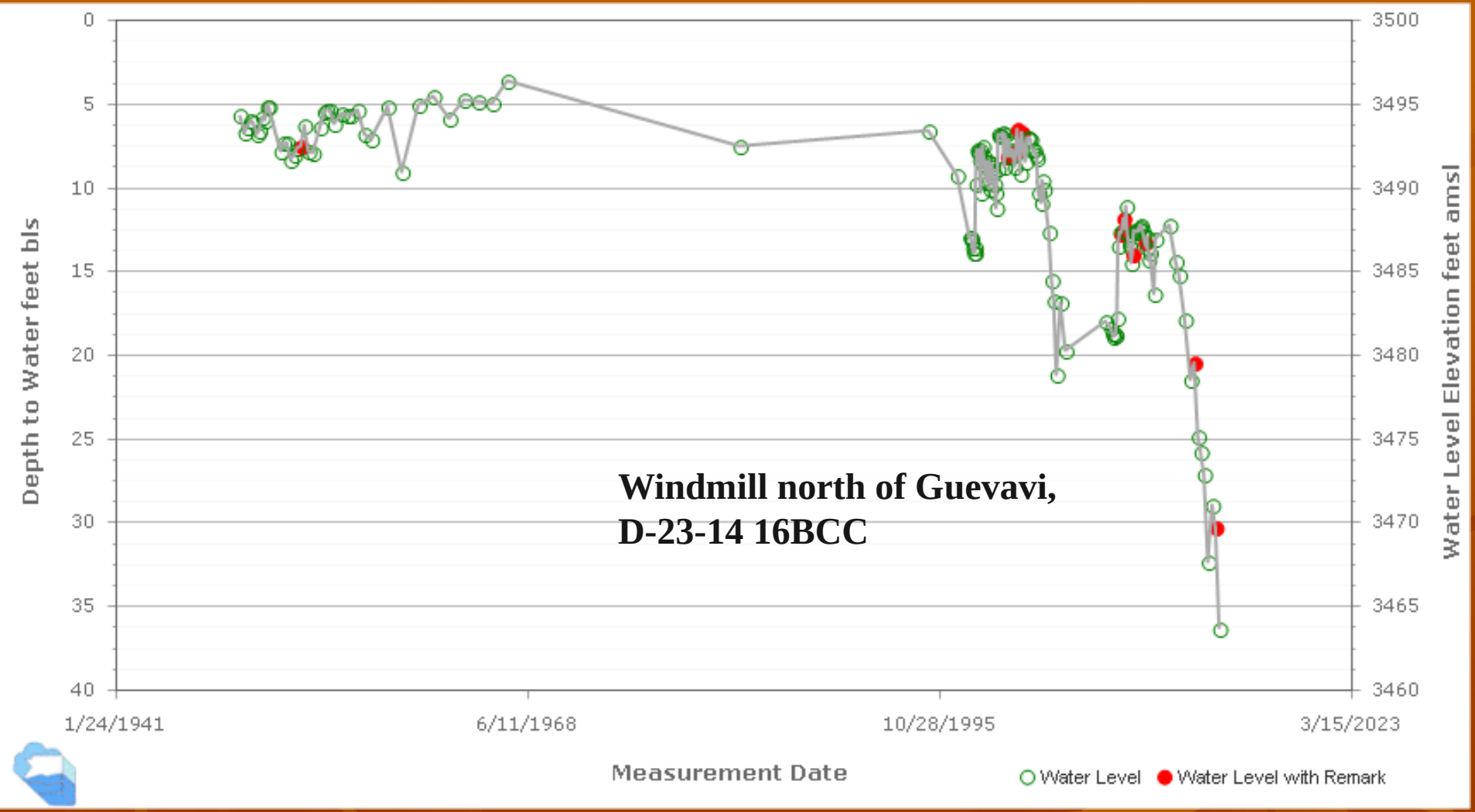

D-24-15_06AAD
Observed
Computed
Head
3660.50
3657.44
3654.39
3651.33
3648.27
3645.22
3642.16
3639.10
3636.04
3632.99
3629.93
3.10
596.40
1189.69
1782.99
2376.28
2969.58
3562.88
4156.17
4749.47
5342.76
5936.06
Time

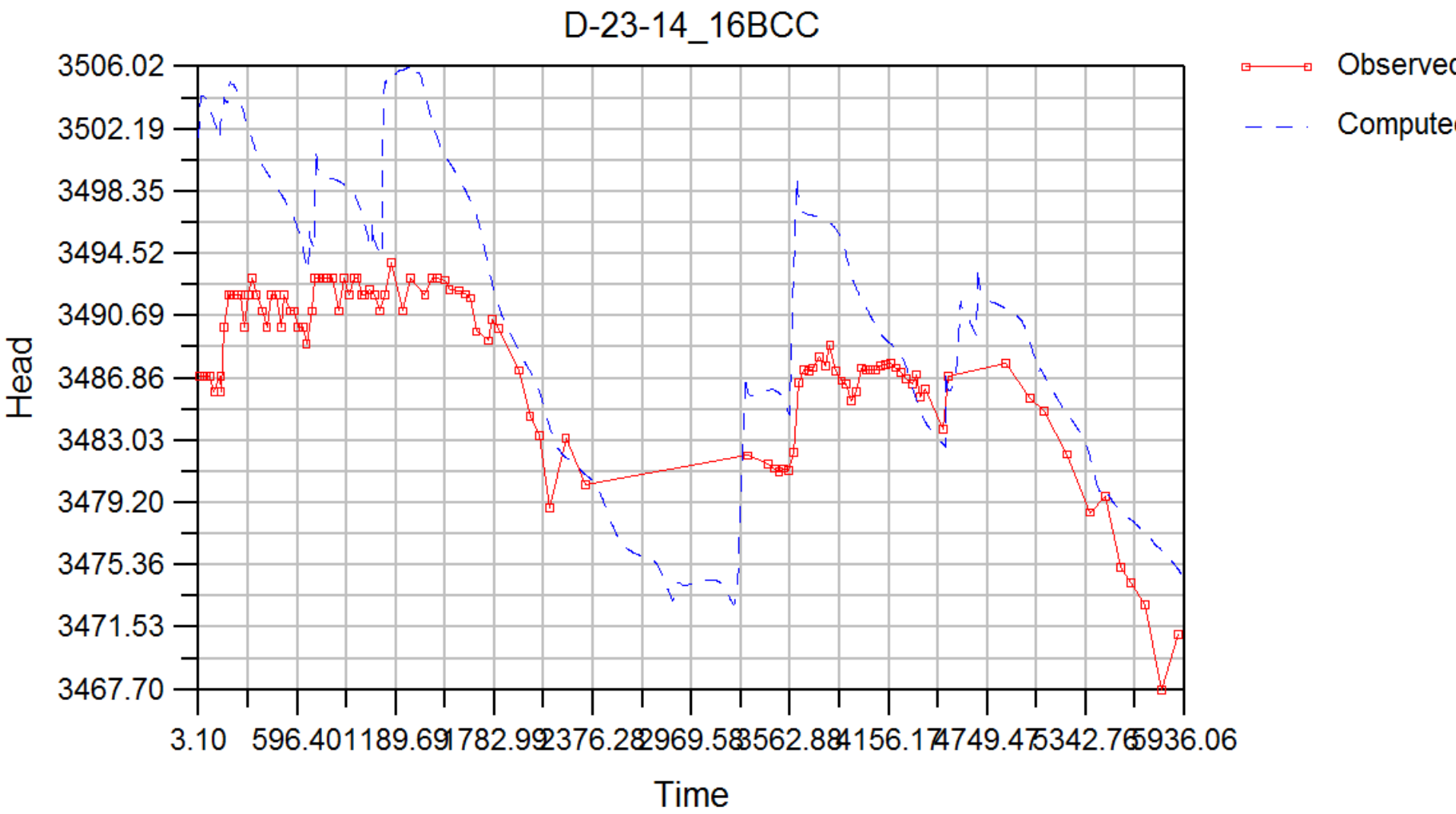

North of Nogales'
SCR Well Field,
D-23-14 26ACD
Depth to Water feet bls
Water Level Elevation feet amsl
10
20
30
40
50
60
70
80
90
3600
3590
3580
3570
3560
3550
3540
3530
3520
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark

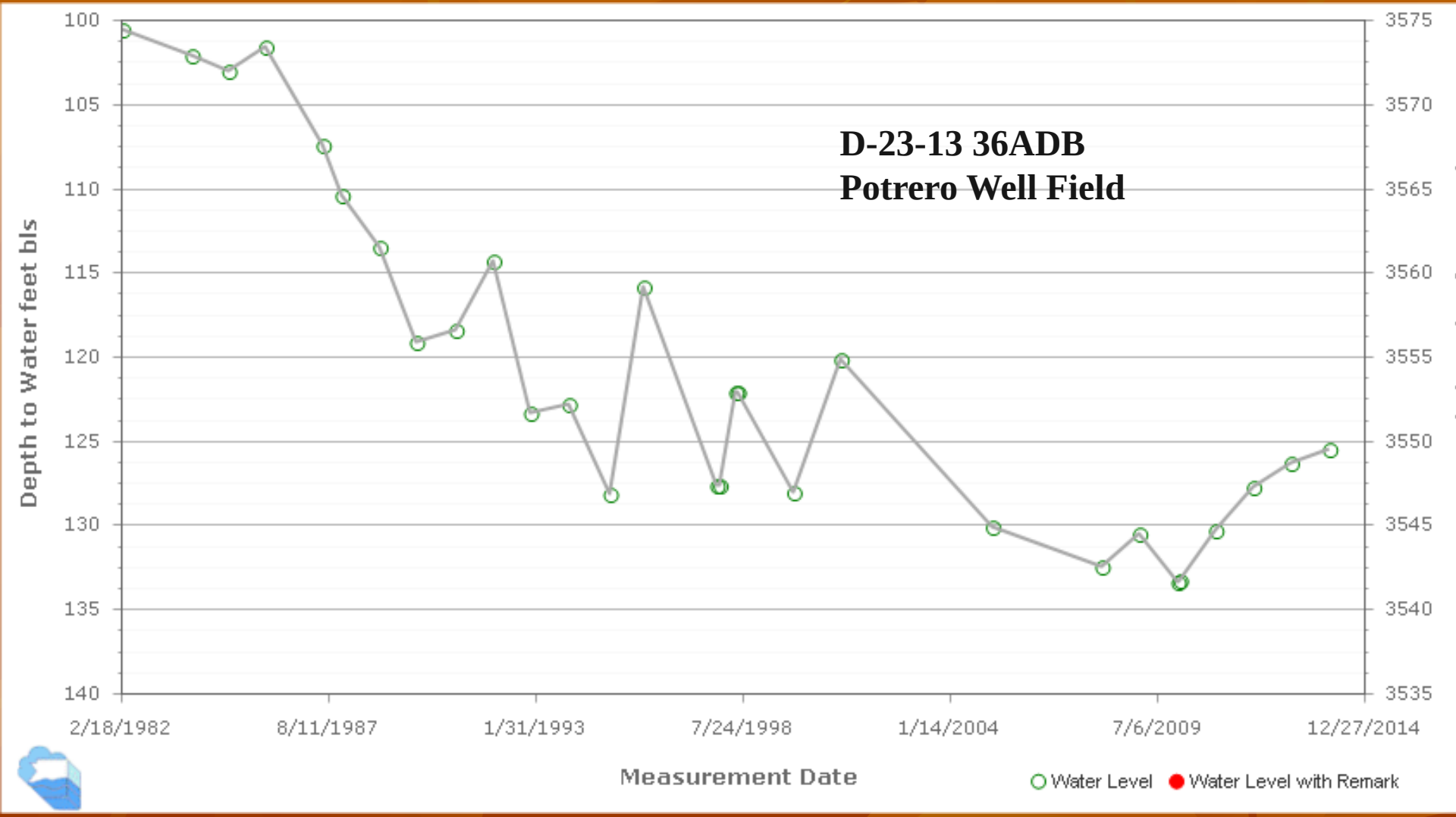
Guevavi Narrows,
D-23-14 22CDD2
Depth to Water feet bls
10
15
20
25
30
35
40
45
50
3565
3560
3555
3550
3545
3540
3535
3530
3525
10/10/2006
7/6/2009
4/1/2012
12/27/2014
Measurement Date
Water Level
Water Level with Remark

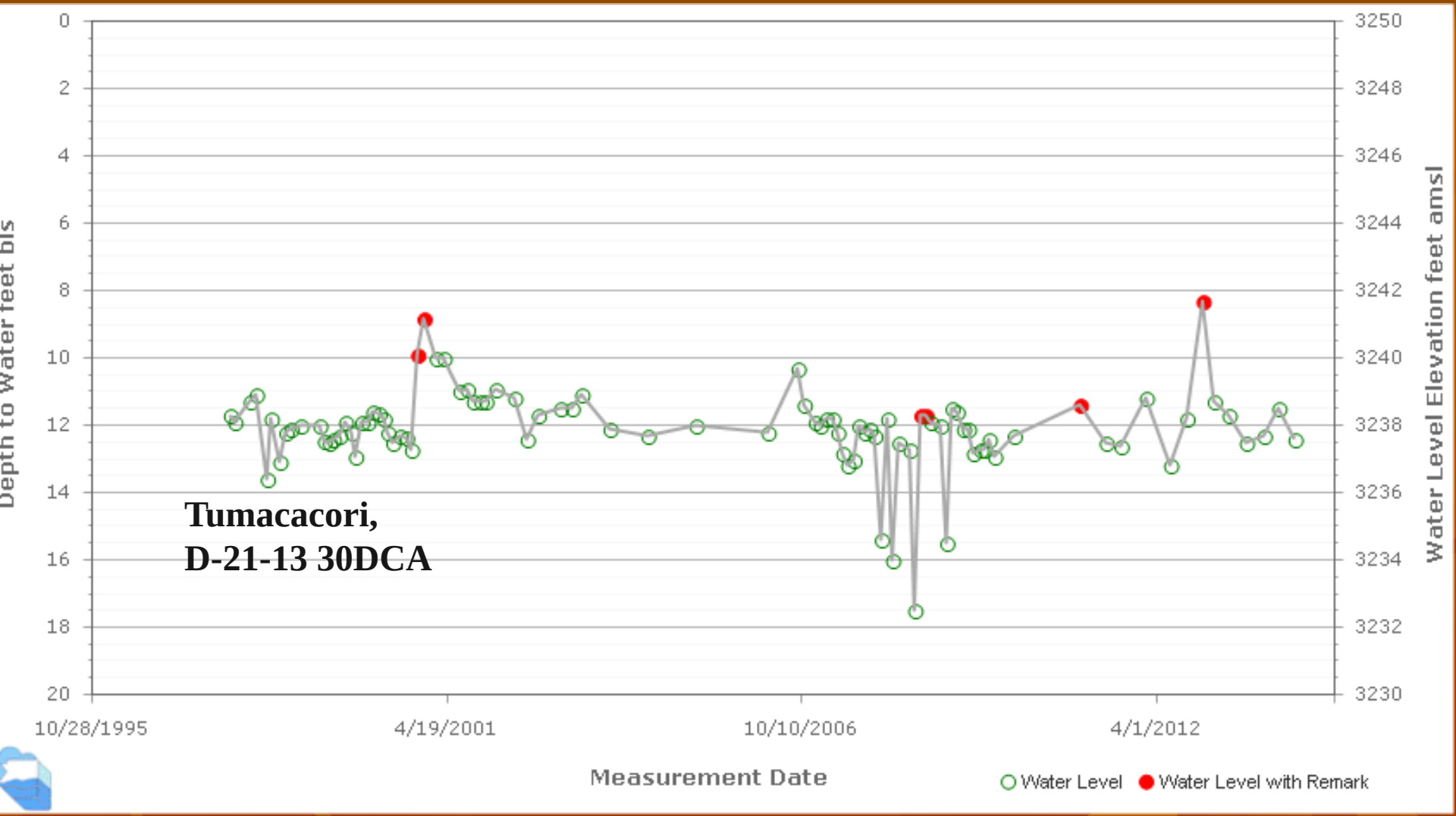

Guevavi,
D-23-14 15CCB1
Depth to Water feet bls
Water Level Elevation feet amsl
Measurement Date
20
25
30
35
40
45
50
55
60
65
70
3534
3529
3524
3519
3514
3509
3504
3499
3494
3489
3484
3/25/1960
3/8/1971
2/18/1982
1/31/1993
1/14/2004
12/27/2014
Water Level
Water Level with Remark

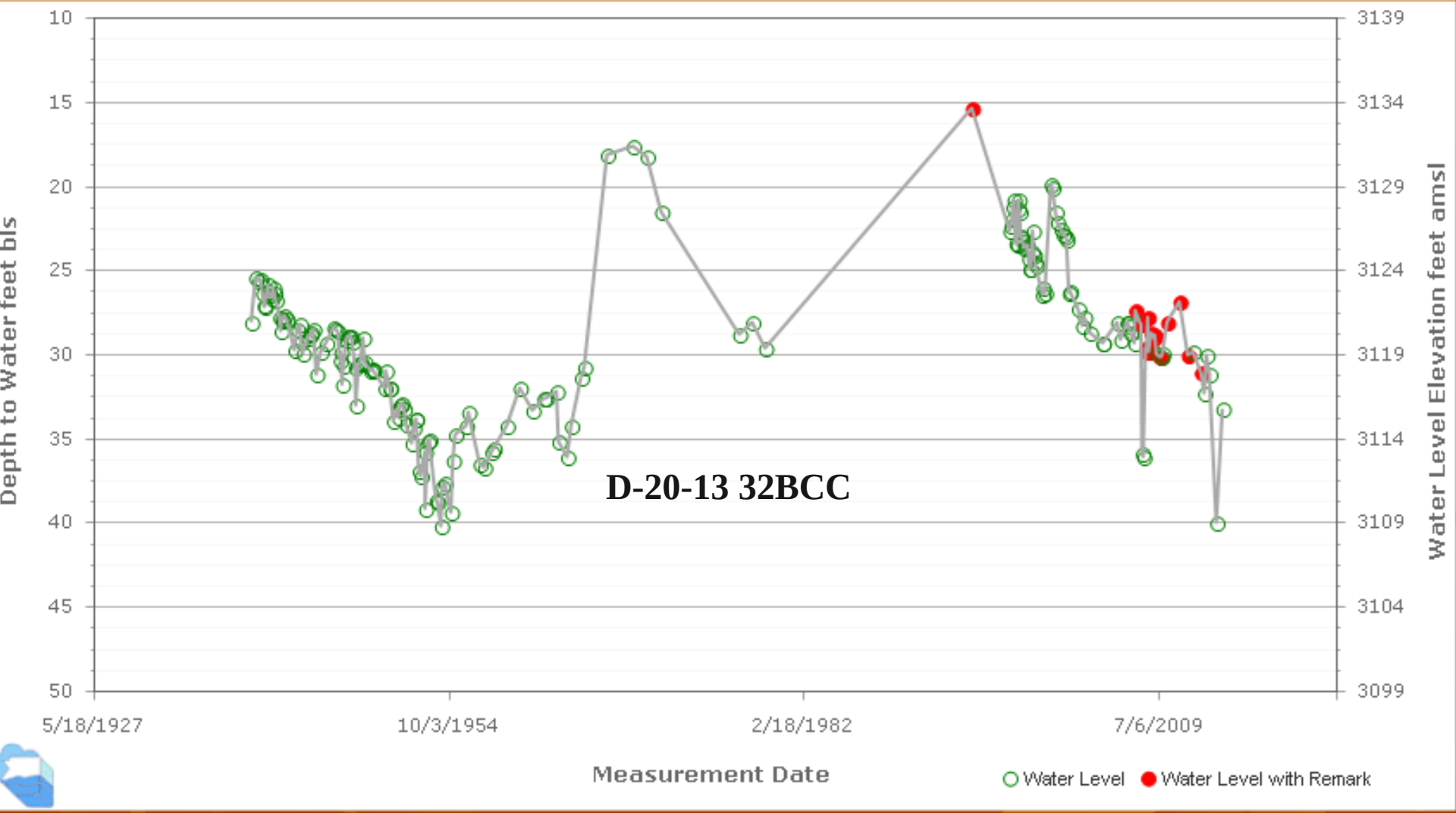

D-23-14_15CCB1
Observed
Computed
Head
3525.46
3521.63
3517.79
3513.95
3510.11
3506.28
3502.44
3498.60
3494.76
3490.93
3487.09
3.10
596.40
1189.69
1782.99
2376.28
2969.58
3562.88
4156.17
4749.47
5342.76
5936.06
Time

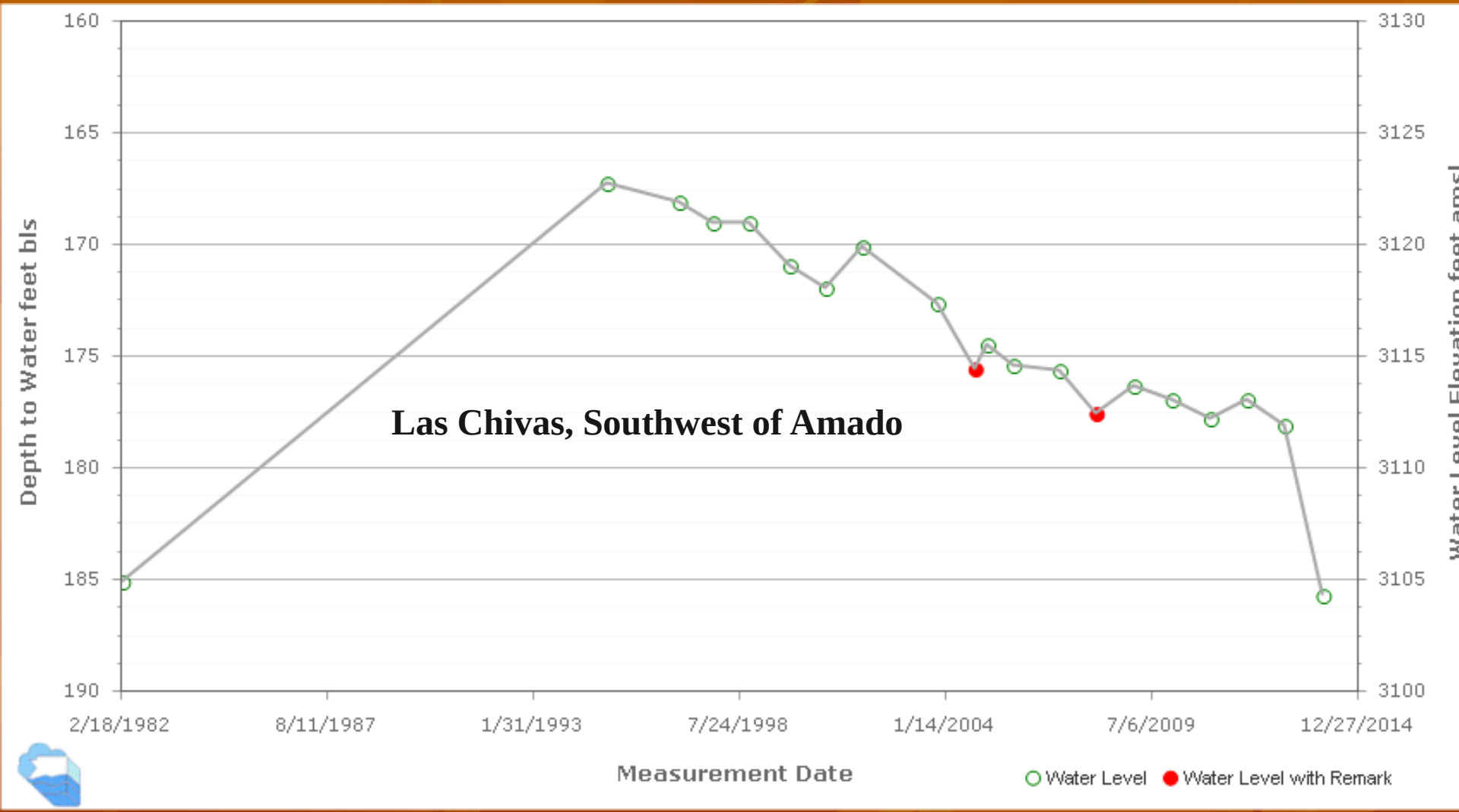

Windmill north of Guevavi,
D-23-14 16BCC
Depth to Water feet bls
Water Level Elevation feet amsl
0
5
10
15
20
25
30
35
40
3500
3495
3490
3485
3480
3475
3470
3465
3460
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark

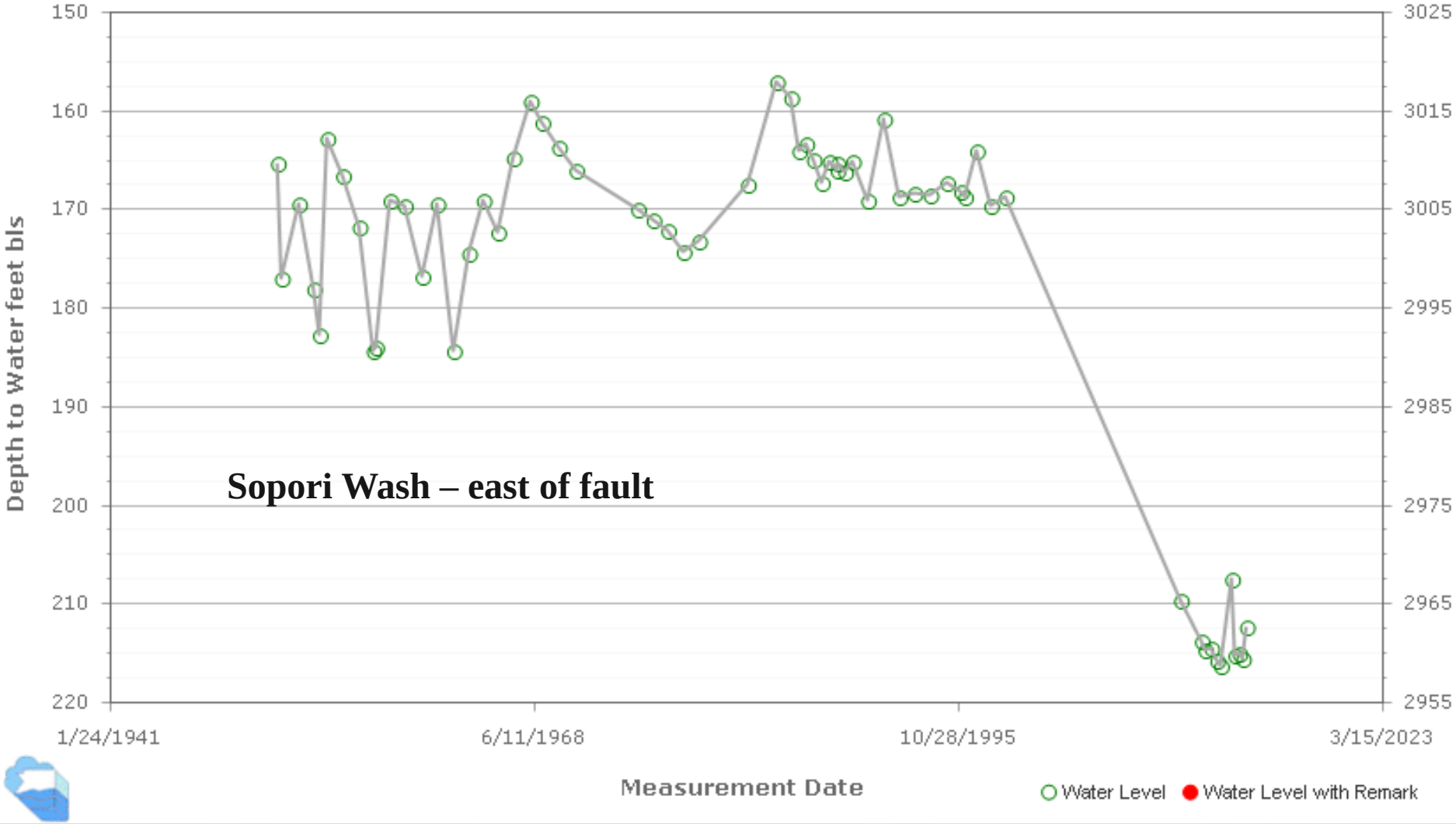

D-23-14_16BCC
Observed
Computed
Head
3506.02
3502.19
3498.35
3494.52
3490.69
3486.86
3483.03
3479.20
3475.36
3471.53
3467.70
3.10
596.40
1189.69
1782.99
2376.28
2969.58
3562.88
4156.17
4749.47
5342.76
5936.06
Time

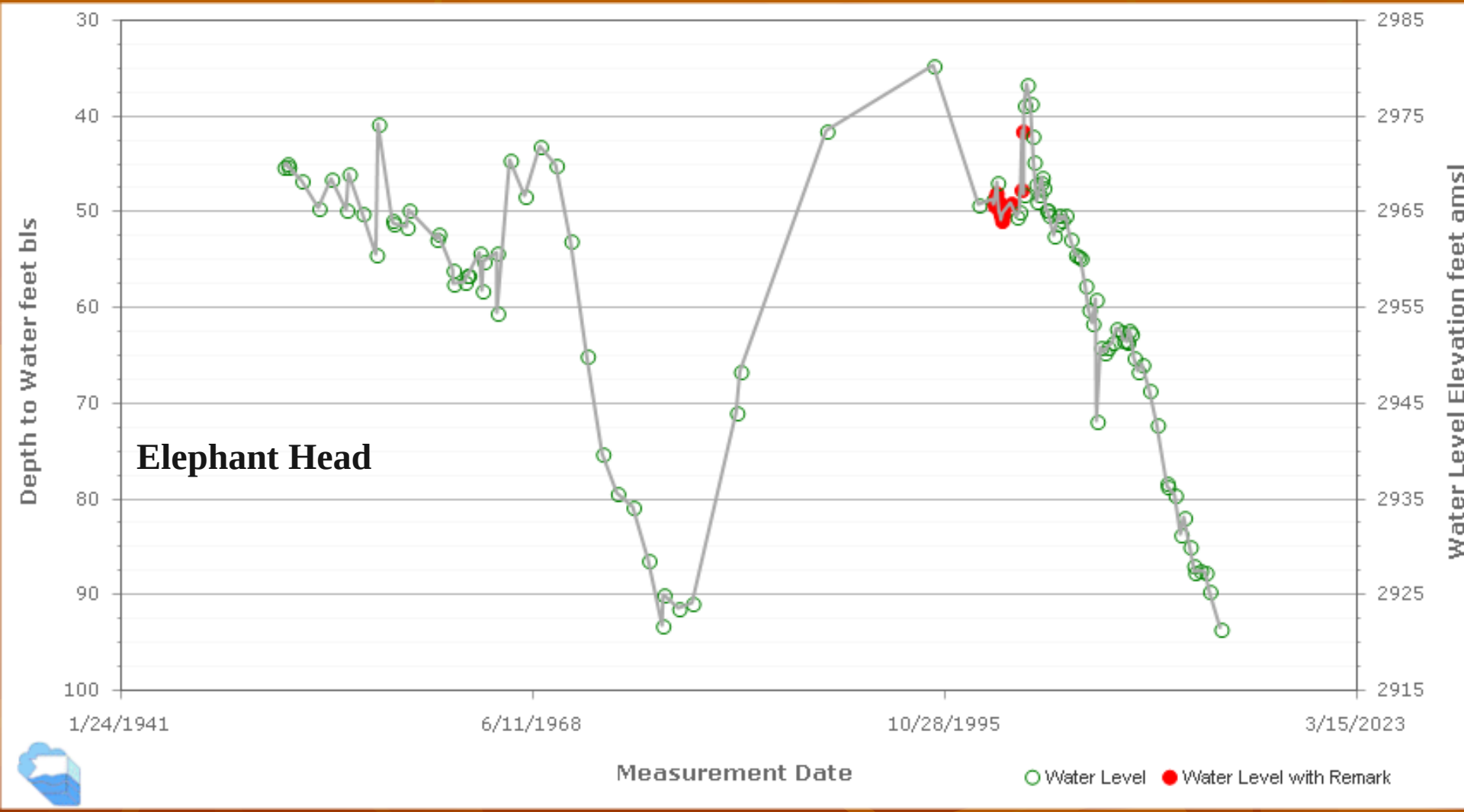

D-23-13 36ADB
Potrero Well Field
Depth to Water feet bls
100
105
110
115
120
125
130
135
140
3575
3570
3565
3560
3555
3550
3545
3540
3535
2/18/1982
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
Measurement Date
Water Level
Water Level with Remark


Depth to Water feet bls
0
2
4
6
8
10
12
14
16
18
20
Water Level Elevation feet amsl
3250
3248
3246
3244
3242
3240
3238
3236
3234
3232
3230
10/28/1995
4/19/2001
10/10/2006
4/1/2012
Measurement Date
Water Level
Water Level with Remark
Tumacacori,
D-21-13 30DCA


D-20-13 32BCC
Depth to Water feet bls
Water Level Elevation feet amsl
10
15
20
25
30
35
40
45
50
3139
3134
3129
3124
3119
3114
3109
3104
3099
5/18/1927
10/3/1954
2/18/1982
7/6/2009
Measurement Date
Water Level
Water Level with Remark


Las Chivas, Southwest of Amado
Depth to Water feet bls
160
165
170
175
180
185
190
3130
3125
3120
3115
3110
3105
3100
2/18/1982
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
Measurement Date
Water Level
Water Level with Remark


Sopori Wash – east of fault
Depth to Water feet bls
150
160
170
180
190
200
210
220
3025
3015
3005
2995
2985
2975
2965
2955
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark


Elephant Head
Depth to Water feet bls
Water Level Elevation feet amsl
30
40
50
60
70
80
90
100
2985
2975
2965
2955
2945
2935
2925
2915
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark

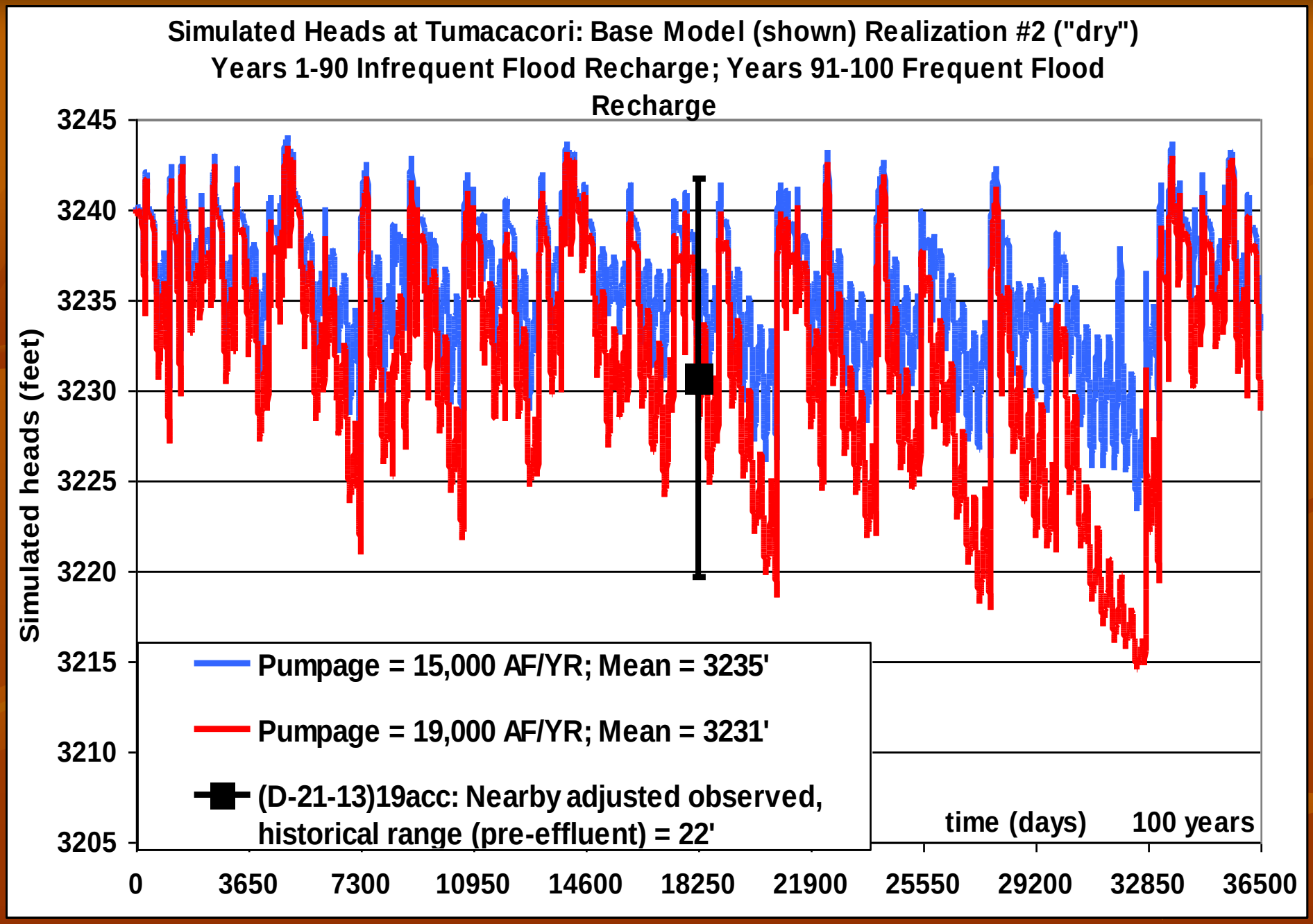
Hydrologic Model

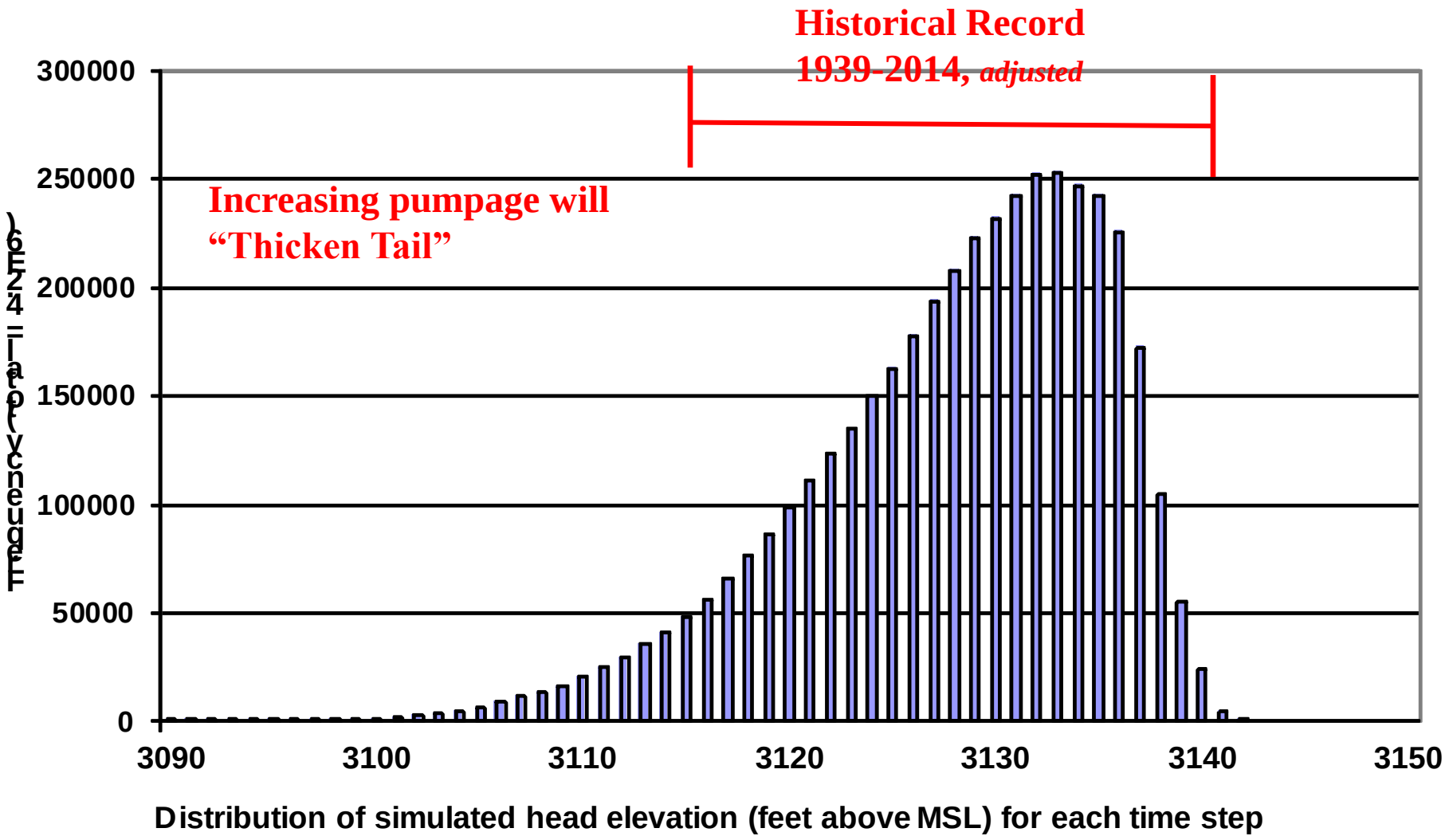
DOS Batch Program
inter-changing modules
~8 hrs on a 2X2.66GHZ; 3G RAM

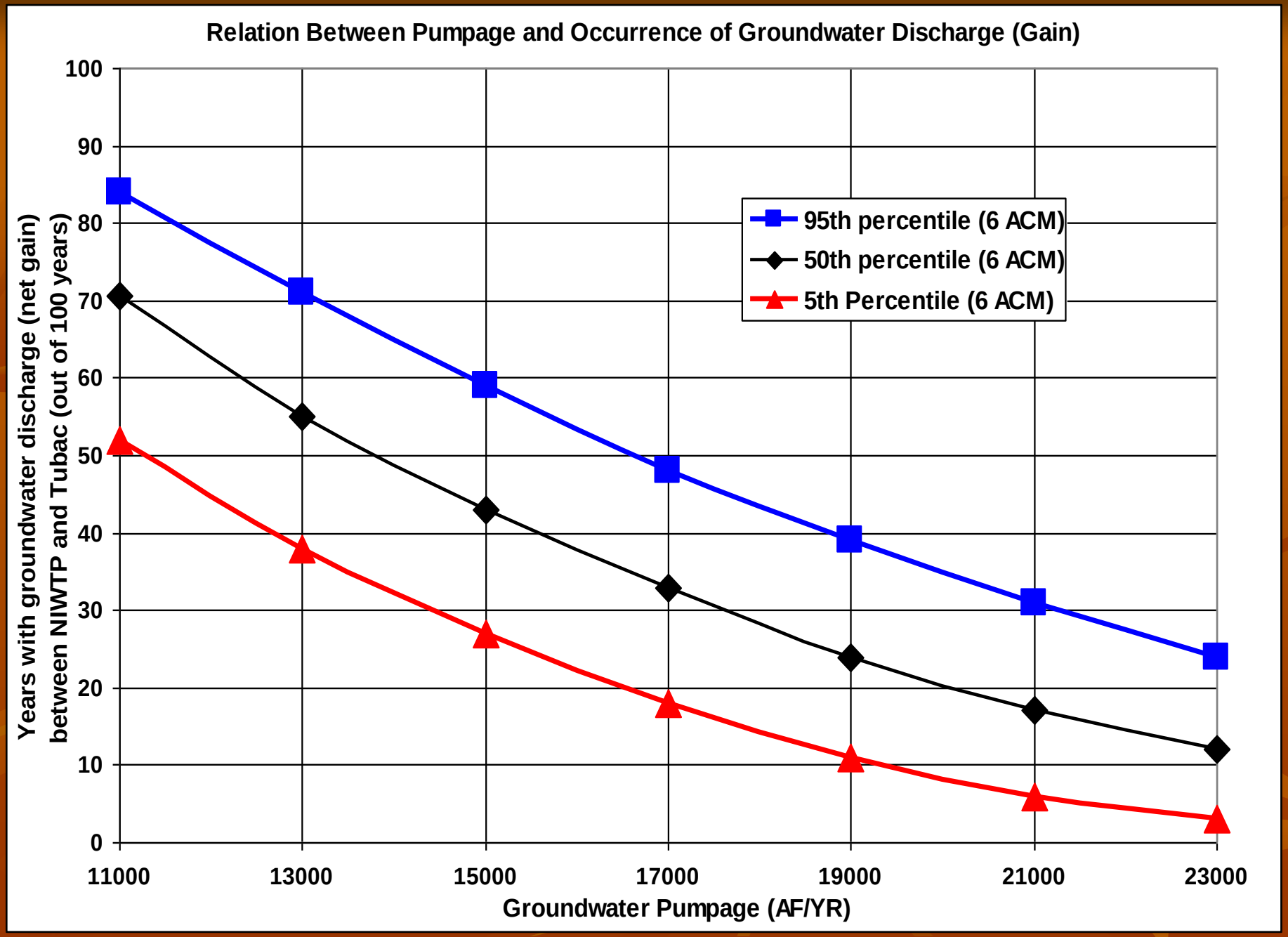
Stochastic
Stream Model >
Convert to
Stream-aquifer BC's

Translate
Stream BC +
Demand >
through 6 ACM's:

Analysis of Simulated
Heads and Flows:
trends; patterns
Inter-arrival stats
(MATLAB; FOXPRO)


Simulated Heads at Tumacacori: Base Model (shown) Realization #2 ("dry")
Years 1-90 Infrequent Flood Recharge; Years 91-100 Frequent Flood Recharge
Simulated heads (feet)
3245
3240
3235
3230
3225
3220
3215
3210
3205
0
3650
7300
10950
14600
18250
21900
25550
29200
32850
36500
time (days)
100 years
Pumpage = 15,000 AF/YR; Mean = 3235'
Pumpage = 19,000 AF/YR; Mean = 3231'
(D-21-13)19acc: Nearby adjusted observed, historical range (pre-effluent) = 22'


Distribution of Simulated Heads at Chavez Siding, 100X6 ACM
Assigned Pumpage 15K
Historical Record
1939-2014, adjusted
Increasing pumpage will
"Thicken Tail"
300000
250000
200000
150000
100000
50000
0
3090
3100
3110
3120
3130
3140
3150
Distribution of simulated head elevation (feet above MSL) for each time step

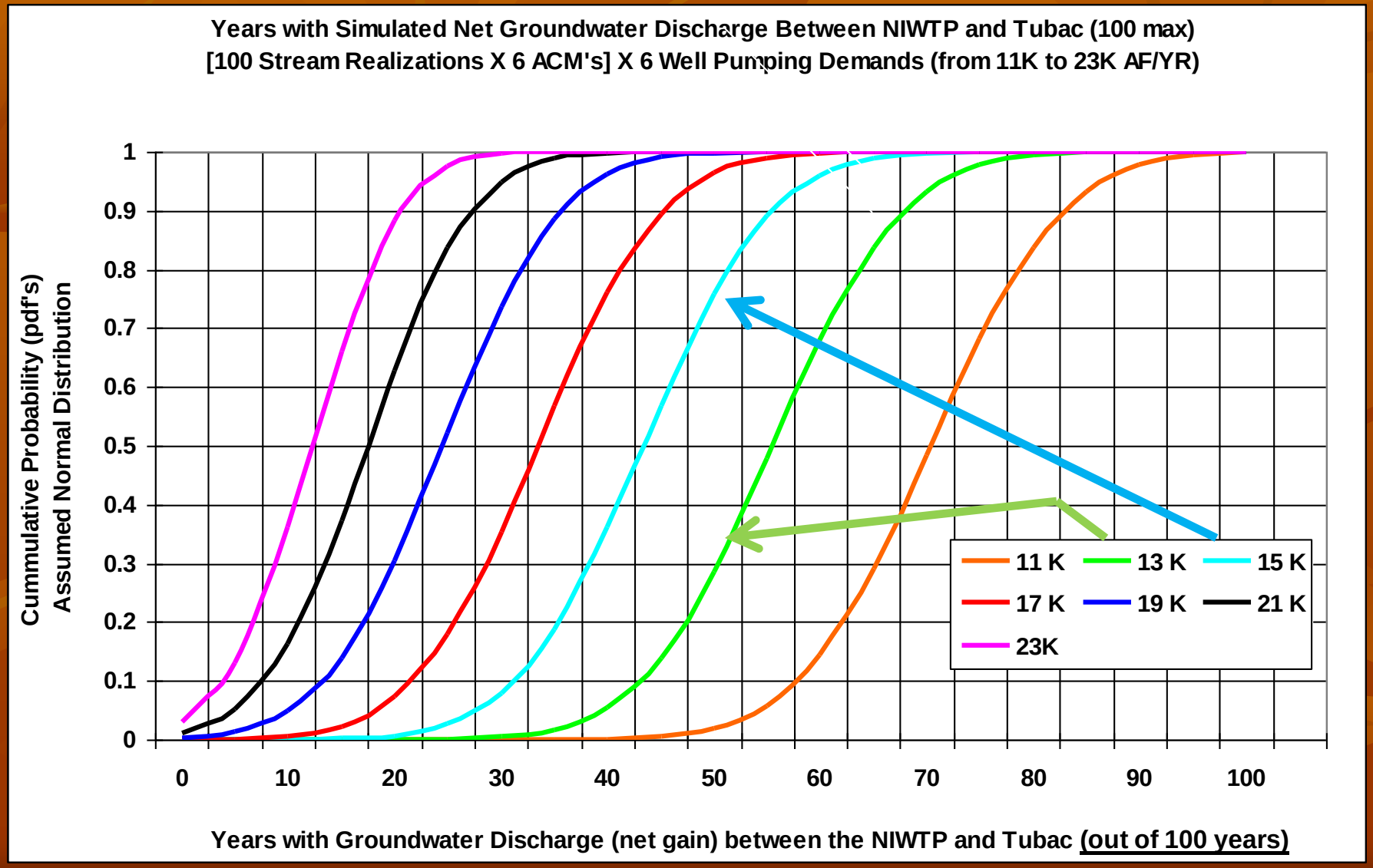

Relation Between Pumpage and Occurrence of Groundwater Discharge (Gain)
Years with groundwater discharge (net gain) between NIWTP and Tubac (out of 100 years)
100
90
80
70
60
50
40
30
20
10
0
11000
13000
15000
17000
19000
21000
23000
Groundwater Pumpage (AF/YR)
95th percentile (6 ACM)
50th percentile (6 ACM)
5th Percentile (6 ACM)

Pumping 15K: 75% chance gaining conditions will occur less than half of the time

" 25% chance that gaining conditions will occur more than half the time

Pumping 13K: 30% chance gaining conditions will occur less than half of the time

" 70% chance that gaining conditions will occur more than half the time



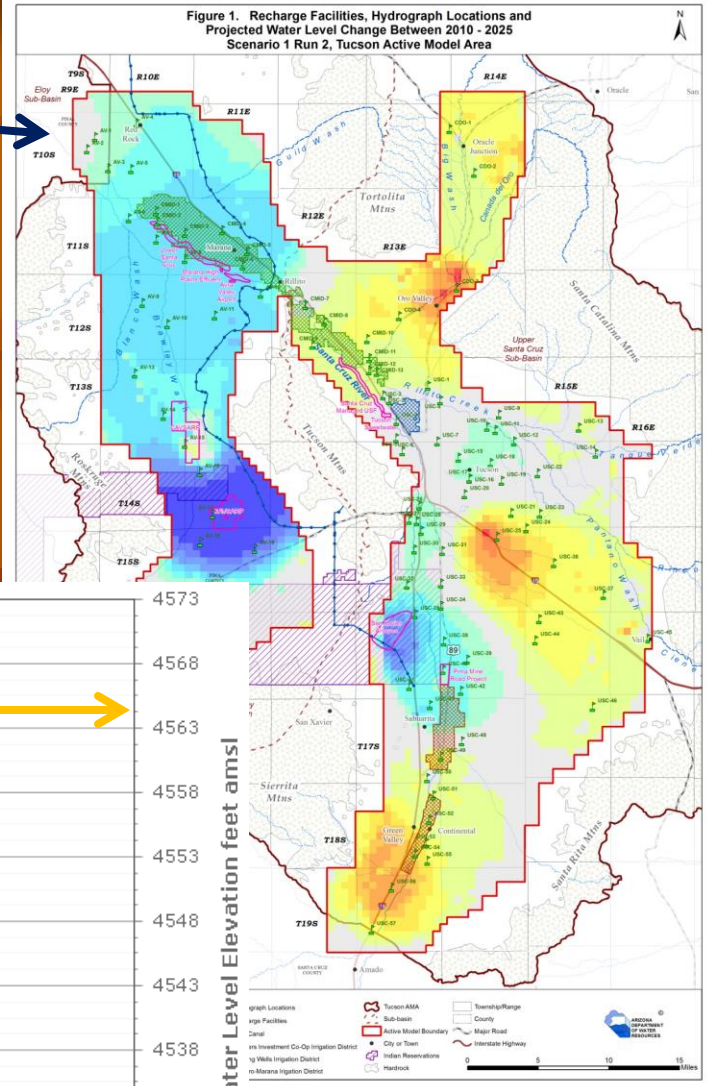
Findings

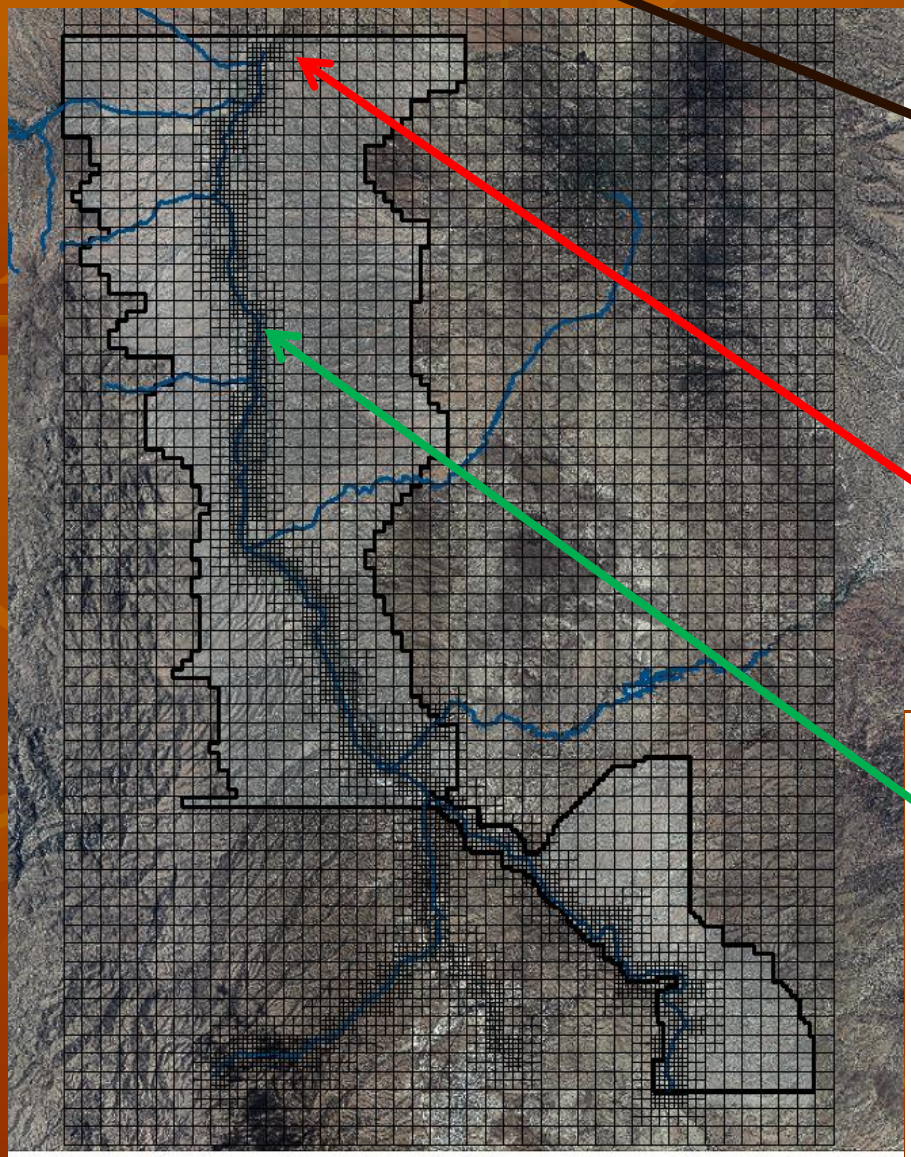
- Model Errors are OK; Adverse Model Bias is not OK
- Understand Distribution;
- Attempt to Quantify Uncertainty
- Simulate many *plausible* realizations
  - Ensemble distribution: system central tendencies; outliers
  - Reduce risk of ‘model’ bias impacting projection
- Sensitive to Flood Recharge *Inter-arrival Periods* and Duration periods (trends)
  - Inner Valleys Require Simulation at Seasonal Stress Periods
    - Broader extents and aquifers buffered by aquitards or distance may be simulated at annualized stress periods (or longer) along losing reaches
- *Sensitive to ACM and boundary conditions*

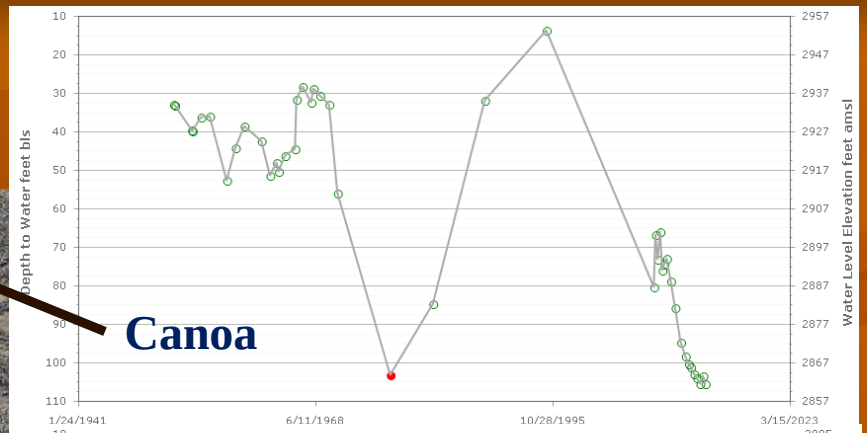
Tucson AMA Model (DRAFT Projection)

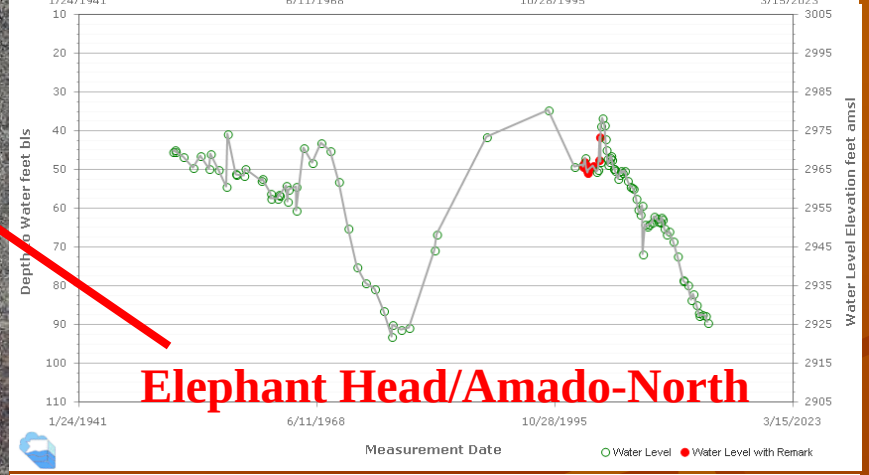
1940-65: 33,750 AF/yr (28%)
1966-95: 52,780 AF/yr(51%)
1996-2010: 43,950 AF/yr (21%)

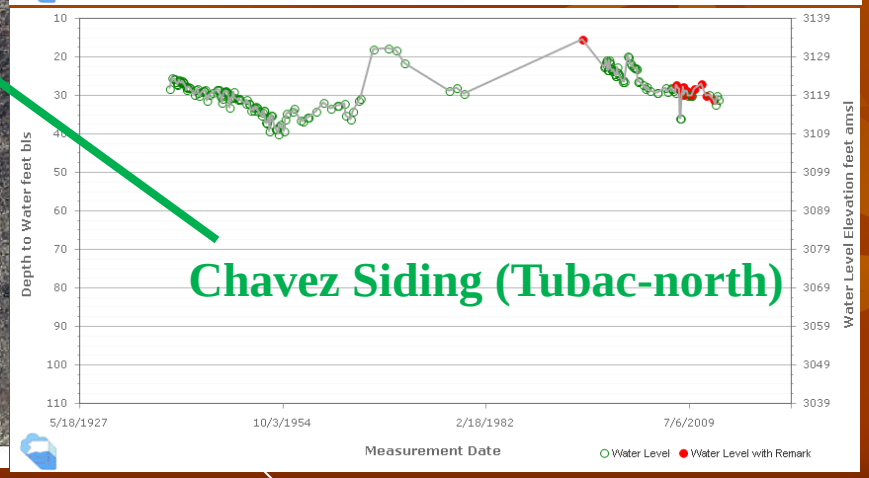
Typical Prescott AMA Hydrograph (Below)

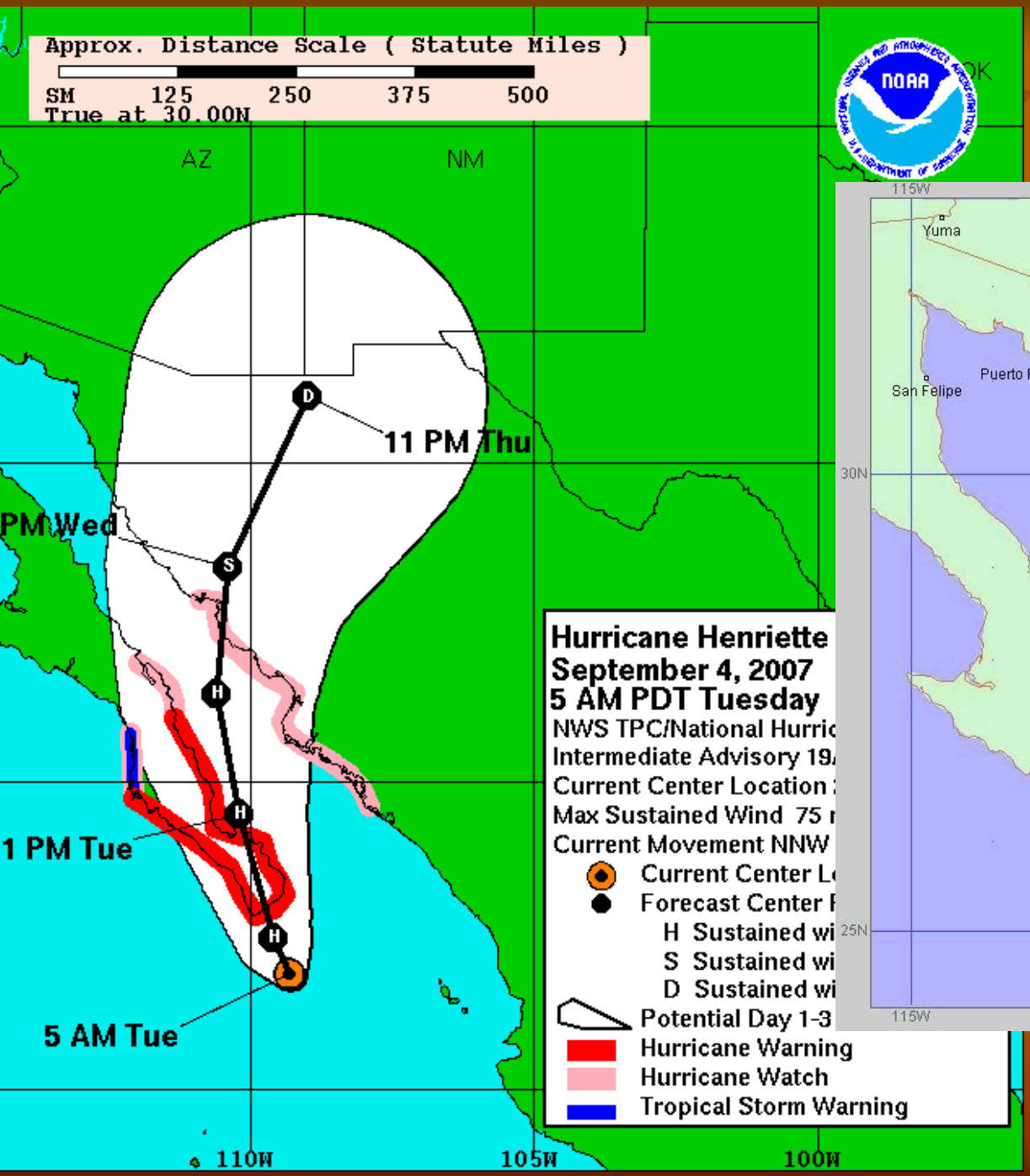





Canoa
Depth to Water feet bls
Water Level Elevation feet amsl
1/24/1941
6/11/1968
10/28/1995
3/15/2023


Elephant Head/Amado-North
Depth to Water feet bls
Water Level Elevation feet amsl
1/24/1941
6/11/1968
10/28/1995
3/15/2023
Measurement Date
Water Level
Water Level with Remark


Chavez Siding (Tubac-north)
Depth to Water feet bls
Water Level Elevation feet amsl
5/18/1927
10/3/1954
2/18/1982
7/6/2009
Measurement Date
Water Level
Water Level with Remark


Approx. Distance Scale (Statute Miles)
SM 125 250 375 500
True at 30.00N
AZ
NM
11 PM Thu
PM Wed
1 PM Tue
5 AM Tue
110W
105W
100W
Hurricane Henriette
September 4, 2007
5 AM PDT Tuesday
NWS TPC/National Hurric
Intermediate Advisory 19
Current Center Location
Max Sustained Wind 75
Current Movement NNW
Current Center L
Forecast Center
H Sustained wi
S Sustained wi
D Sustained wi
Potential Day 1-3
Hurricane Warning
Hurricane Watch
Tropical Storm Warning

115W
110W
Gila Bend
Yuma
Safford
Ajo
Tucson
Deming
Las Cruces
Ciudad Ju
Sierra Vista
Nogales
Douglas
Puerto Penasco
San Felipe
30N
5, 11pm
Hermosillo
Bahia Kino
5, 5pm
Guaymas
Cuidad Obregon
Santa Rosalia
Navojoa
Mulege
5, 5am
Los Mochis
25N
Bahia Magdalena
Culiacan
Hurricane Henriet
2007

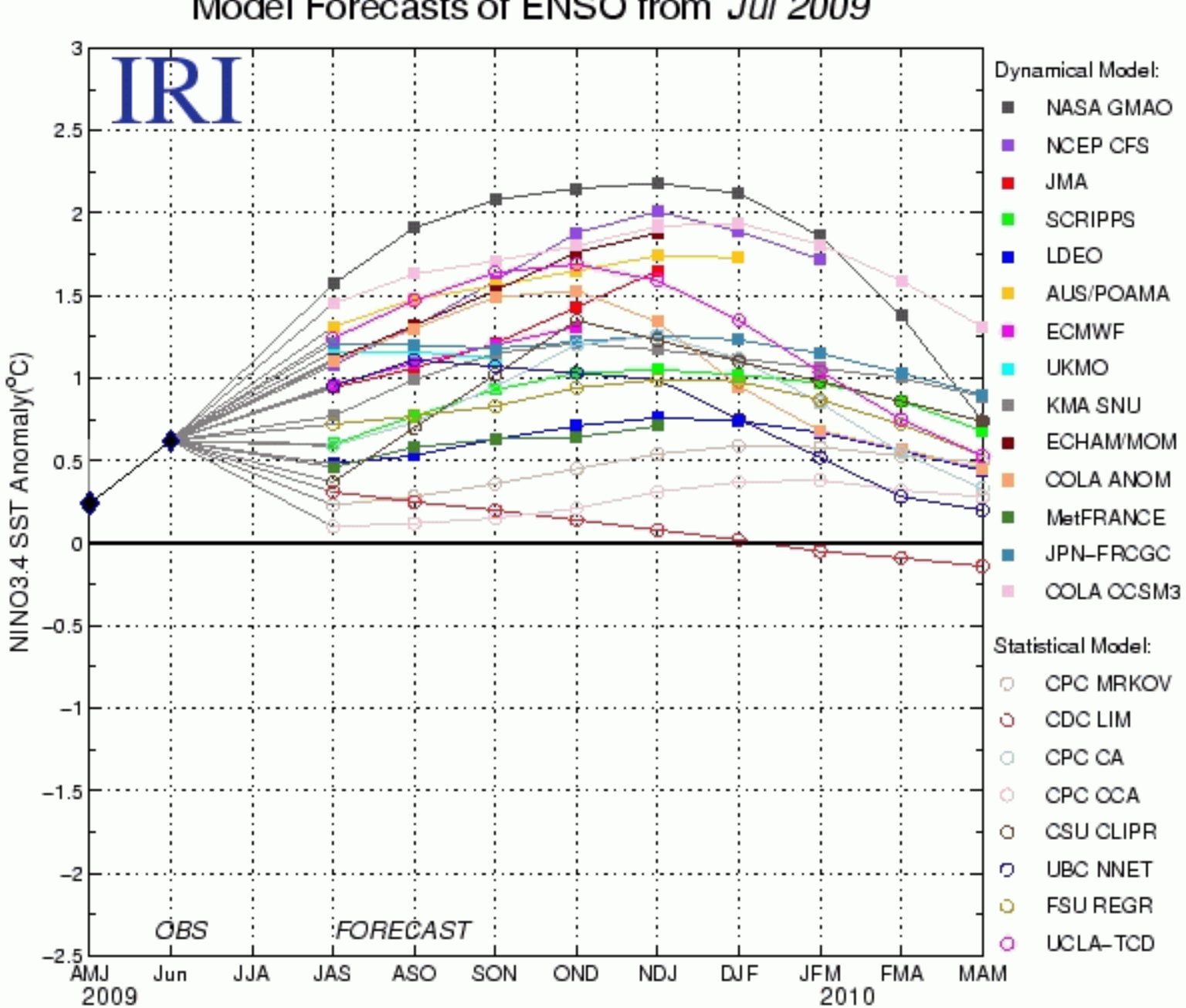
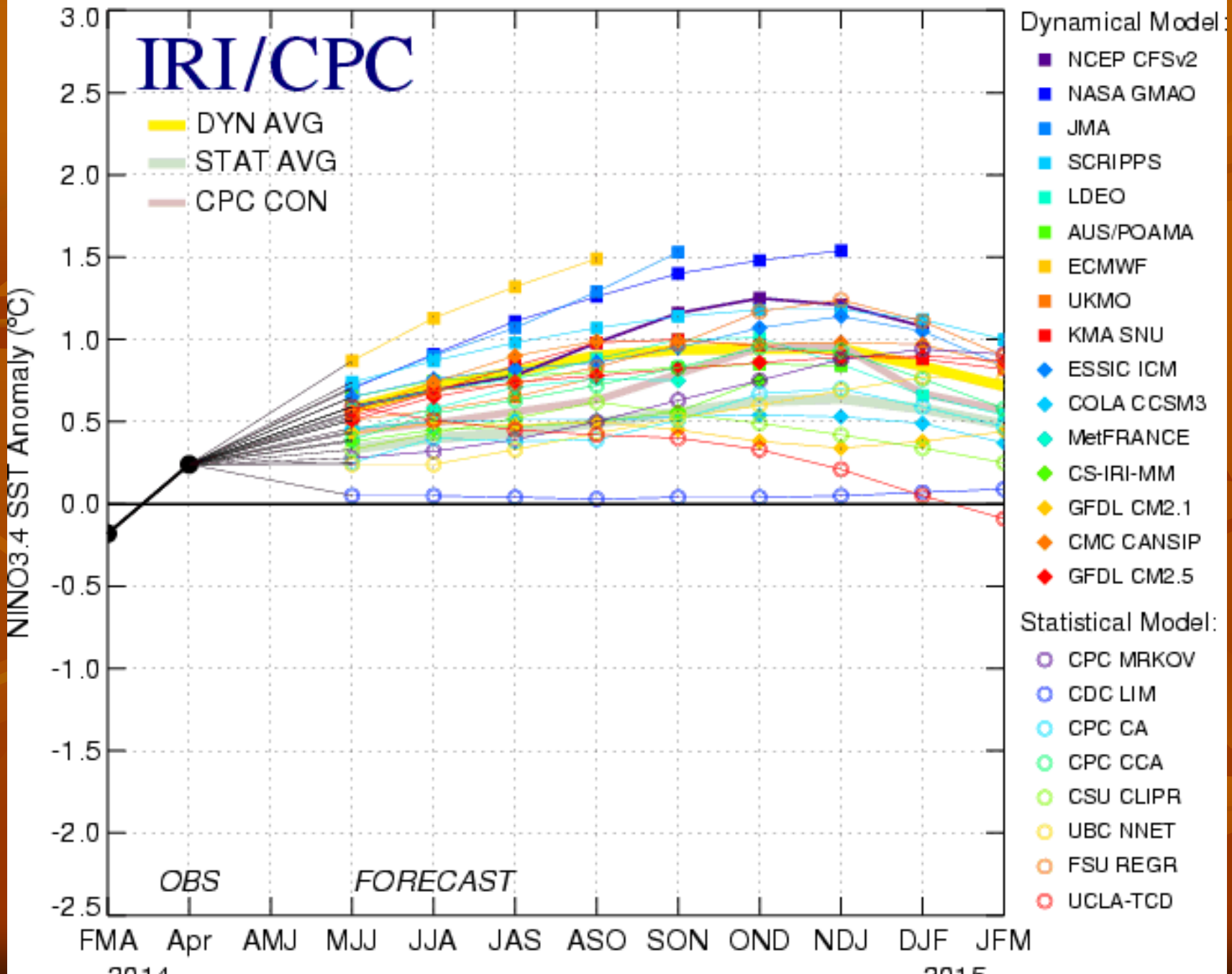


Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-

Mid-May 2014 Plume of Model ENSO Predictions



Questions?

- Thanks to ADWR Basic Data & Survey Units; Hydrologic Research Center (San Diego); USGS (Tucson); U of A; Santa Cruz AMA GUAC and staff; IBWC; FOSCR; AZ State Parks