Inyo/LA Cooperative Study

Deep Well Data Analysis

Summary Report

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LIST OF ACRONYMS AND ABBEVIATIONS

AF – acre-feet
DD - drawdown
fmsl – feet above mean sea level
ICWD – Inyo County Water Department
K_h – Horizontal hydraulic conductivity
K_v – Vertical hydraulic conductivity
LAA – Los Angeles Aqueduct
LADWP – Los Angeles Department of Water and Power
MWH – Montgomery Watson Harza
T - Transmissivity
T Well – Designation for a Test Well
S - Storativity
USGS – U.S. Geological Survey
V Well – Designation for a Monitoring Well (former production well)
W Well – Designation for a Production Well
Valley – Owens Valley

Deep Well Data Analysis Summary Report

INTRODUCTION

Under Amendment No. 1 to Agreement 47026 between the Los Angeles Department of Water and Power (LADWP) and MWH, MWH conducted Task A.7.1, entitled “Deep Well Operational Test Data Analysis.” The Inyo/LA Water Agreement (1991) recognizes the need for cooperative studies related to the effects of groundwater pumping on the environment of the Owens Valley. Accordingly, the deep well operational pump test and subsequent data analysis is a Cooperative Study between LADWP and the Inyo County Water Department (ICWD) with technical expertise provided by MWH.

This summary report summarizes the results of the operational test analysis, provides data interpretation, and proposes recommendations for improved management of deep aquifer pumping from wells W380 and W381, and suggestions for future deep well testing.

Deep well operational testing was conducted from August 18, 2003 until August 2, 2004 for two deep wells in the Owens Valley (W380 and W381) as shown on **Figure 1.** The test was conducted in accordance with the Deep Well Operational Testing Plan (MWH, 2003a). During this time, 2,220 acre-feet (AF) of water were pumped from well W380, and 2,189 AF were pumped from well W381. This testing was conducted in a controlled fashion in order to allow for quantification of the deep and shallow aquifer response to pumping from the deep aquifer. Characterization of the effects of pumping deep wells on the shallow water table is important for developing best management practices for pumping deep wells. Although water is pumped from deep zones, the effects on the shallow water table are of the most interest because of the presence of vegetation that is partially dependent on shallow groundwater. However, prediction of the shallow water table response to deep pumping is complicated by the fact that the aquifer is heterogeneous, and numerous surface water features and variable runoff may mask or exaggerate the potential effects in the shallow aquifer.

The purpose of the Deep Well Operational Test Data Analysis Cooperative Study was to compile, plot, and analyze the pumping and recovery test field data from both the shallow and deep zones. From this analysis, the Cooperative Study Team developed conclusions and recommendations that can be used to better operate deep wells W380 and W381.

PHYSICAL SETTING

Wells W380 and W381 are located in the Thibaut-Sawmill Wellfield approximately 8 miles north of the town of Independence, California and approximately 300 feet (100m) east of the Los Angeles Aqueduct. There are numerous other monitoring and production wells in this area, including pumping wells associated with the Blackrock Fish Hatchery and a variety of deep and shallow monitoring wells (**Figure 1**).

Figure 1
Deep Well Pump Test Vicinity Map

In a large portion of the central Owens Valley, a stratigraphic unit of low vertical hydraulic conductivity, called a “confining unit”, exists at depths of approximately 100 to 200 feet below ground surface. This confining unit has been referred to as Hydrogeologic Unit 2 by Hollett and others (1991). Hydrogeologic Unit 2 is a confining bed consisting of a series of lenticular clay beds that retard vertical flow of groundwater. In the vicinity of Wells W380 and W381, the cumulative thickness of low-permeability beds was found in previous cooperative studies to range from 100 to 300 feet (MWH, 2003b). The thickness, lateral continuity, vertical hydraulic conductivity, and hydraulic head differential across the confining unit control the quantity of groundwater that flows vertically through it. In the Owens Valley, a number of clay beds lying in close proximity to one another over a large area typify the configuration of this unit (Hollett et al, 1991). This unit occurs along the central portion of the Owens Valley and thins toward the bedrock margins of the White/Inyo and Sierra Nevada Mountains. In the vicinity of Wells W380 and W381, the confining layer is thicker south of the wells, and thin or absent north of the wells and on the margins of the Valley east and west of the pumping wells.

In recent years, LADWP has designed production wells such that the screened portion of the well is either mostly or entirely below this confining unit, in the deep confined aquifer. Wells at the lowest elevations in the Valley that are screened below this layer can experience artesian conditions during periods of low or no pumping.

There are no groundwater dependent seeps or springs in close proximity to the testing area, but there is extensive seepage from the Aqueduct and spreading from ditches for habitat enhancement. Vegetation parcels in the immediate vicinity of the production wells are Green Book Types C and D (Green Book, 1991).

In addition, there are many surface water flow gauging stations in the vicinity of Wells W380 and W381 which have historically been monitored by LADWP hydrographers, and were monitored during the pump test. **Figure 2** is a map showing water features and surface water measuring stations in the vicinity of the wells.

Ground surface elevations within a five mile radius of the pumping wells vary from 3,700 feet to well over 12,000 feet above mean sea level as shown on **Figure 3**.

Figure 2
Water Features and Surface Water Measuring Stations

Figure 3
Regional Elevation

APPROACH

The Cooperative Study Team's analysis of the pump test data consisted of the following sequential tasks:

- Data compilation and plotting,
- Trend analysis and correction,
- Drawdown analysis and map production, and
- Aquifer parameter calculations.

This approach to analyzing the pump test data was then used to develop conclusions and recommendations for:

- Updating the conceptual hydrogeologic model,
- Operating wells W380 and W381,
- Identifying a permanent monitoring site, and
- Implications for updating of numerical models in the area.

Data Compilation and Plotting

During the pump test, data was collected by LADWP hydrographers from various wells and surface water features within a two-mile radius of the wells W380 and W381. These data were compiled by MWH, combined with historical data collected up to ten years prior to the test, and plotted on hydrographs.

Flow measurements (in cubic feet per second, cfs) recorded for the major surface water features shown in **Figure 2** within a two-mile radius of the production wells was compiled and plotted for the period of 1999 to 2004 as shown in **Appendix A**. Detailed water level measurements for deep and shallow monitoring wells shown on **Figure 1** for the test pumping and recovery period (August 2003 – October 2004) were also compiled and graphed as shown in **Appendix B**.

In order to observe the long-term typical trends in groundwater elevations, longer-term hydrographs of monitoring wells in the vicinity of wells W380 and W381 were also compiled and plotted for the 10-yr period prior to the test, as shown in **Appendix C**.

Flow data from the two pumping wells (W380 and W381) during the test period is given in **Appendix D**. Data from six mountain stream flow gauges (Taboose Creek, Goodale Creek, Division Creek, Sawmill Creek, Thibaut Creek, and Oak Creek) were plotted for five years prior to the pumping test, as given in **Appendix E.** Precipitation data at the nearest precipitation station (LAA Intake) is also provided in **Appendix E.**

Trend Analysis and Drawdown Correction

Although changes in groundwater elevations at monitoring wells were well documented during the pump test, evaluation of the decline in the shallow water table *specifically* due to the pumping at wells W380 and W381 is complicated by a variety of factors. These factors include:

- Seasonal changes in evapotranspiration,
- Variable pumping at nearby wells,
- Changes in surface water flows,
- Boundary conditions which mask potential drawdown (such as leakage from the LAA), and
- Seasonal changes in runoff conditions, or multi-year changes in runoff.

These complicating factors create “noise” in the shallow groundwater response that needs to be corrected for (if possible) to isolate the specific impact of long-term pumping of wells W380 and W381. The Cooperative Study Team approached correction or “filtering” of the shallow drawdown data by careful observations of the patterns and trends in shallow hydrographs, and observations of surface flow data that might differentially affect shallow groundwater that was not associated with pumping from W380 and W381.

Several characteristic patterns of shallow groundwater fluctuation were observed based on the hydrographs compiled during this study (**Appendix C**). These patterns can be grouped as follows:

Wave-like, or sinusoidal: These hydrographs show a clear wave-like pattern of yearly fluctuations that are most probably the result of seasonal changes in runoff and/or evapotranspiration. If the frequency of water level measurements is less than four times per year, patterns can appear jagged like a saw blade. Examples include V006G, T804, T806, T507, and T603.

Flat or linear: These hydrographs do not show significant seasonal changes, but more gradual long-term changes most probably associated with longer-term changes in runoff or pumping. Examples include T660, T415, T416, T506, and T661.

Surface Water Dependent: These hydrographs appear clearly affected by changes in surface water flows, such that potential drawdown due to pumping of W380 and W381 is largely obscured. Examples include T458 and T674 (correlated to flows in Blackrock Ditch), T583 (probably affected by Sawmill Creek or the LAA), and T674 (probably affected by Thibaut Creek or the LAA).

Classic Confined or Leaky Aquifer Response: These hydrographs (typically deeper monitoring wells) display a typical drawdown response that would be expected with a confined or leaky aquifer. The drawdown and recovery response is typically relatively fast, with a magnitude much greater than that observed in shallow wells. Although these hydrographs are useful in evaluating aquifer parameters of the deeper zones, they less useful in evaluating effects on shallow groundwater because they are screened at deeper intervals. Examples include T631, T834, and V156.

In many cases, the hydrographs appeared to be a hybrid of the general types of patterns described above, reflecting multiple influences on groundwater elevations. Some hydrographs also seemed to reflect relatively heavy Valley floor rainfall occurring in February and March 2004. Examples include T458 and T674.

Various methods were used by the Cooperative Study Team in an attempt to filter out seasonal and other influences and to isolate those changes believed to be attributable only to the pumping of W380 and W381. These methods included projection of pre-test trends, fitting a trending sinusoidal curve on seasonal data, and visually judging the drawdown response. Examples of these methods are shown graphically in **Appendix F.** On January 13, 2005 the Cooperative Team divided the hydrographs into three groups for separate evaluation by LADWP, ICWD, and MWH hydrologists. The Cooperative team then met on February 10, 2005 to review initial findings of the other parties and to agree on estimation methods, and met again on April 14, 2005 to review preliminary drawdown maps and reach consensus on data errors and outliers.

Ultimately, the Cooperative Team found no purely objective or statistical means to filter the data, and the estimation of corrected drawdown was based on removing pre-test trends and using best judgment. Because judgment was used in many cases, the team attempted to quantify the uncertainty in the estimate by judging the maximum and minimum amount of drawdown that could be reasonably interpreted from the data, as well as a best estimate of the actual corrected drawdown. This resulted in a “bracket” of potential drawdown that could reasonably be interpreted from the data, and one value for corrected drawdown that was used in subsequent analysis described below. These drawdown values, along with the estimated uncertainty in the drawdown estimates are summarized in **Table 1**. For the estimates of drawdown occurring in the shallow aquifer, the uncertainty associated with using best judgment (difference between reasonable maximum and minimum estimates) averaged 0.4 feet, with a maximum uncertainty of 1.1 foot, and a minimum uncertainty close to zero.

In reviewing the data, it was noted that during the period of pumping of W380 and W381 in 2003 and 2004, groundwater levels in areas outside the potential influence of pumping were gradually declining due to conditions unrelated to the test pumping. For example, this was observed in wells T418, T419, T422, and T428 approximately three to five miles north of the pumping wells, and in wells T508, T464, and T465 located approximately five miles south of the pumping wells. This slight overall regional declining trend is most probably due to reduced runoff in the four years prior to the test, in which runoff was an average of 78% of normal (**Appendix E**). The effect of the low runoff conditions was difficult to objectively correct for in drawdown estimates, meaning that the estimates may be slightly over predicted (or conservative) estimates of drawdown occurring as a result of pumping W380 and W381.

Table 1
Drawdown Estimates at Selected Wells

Well	Best Estimate of Drawdown	Maximum Interpreted Drawdown	Minimum Interpreted Drawdown	Range of Max to Min (uncertainty)	Type
T629	53	53.5	49.5	4	Deep
T631	52	52	52	0	Deep
T834	1.9	2.3	1.85	0.45	Deep
V105	0.3	0.4	0	0.4	Deep
V156	4	4.7	3.3	1.4	Deep
V158	1.3	1.89	0.93	0.96	Deep
V339	0.9	0.9	0	0.9	Deep
V366	2.2	2.4	2	0.4	Deep
T583	--	--	--	--	Dry
T655	--	--	--	--	Dry
V049	--	--	--	--	Dry
F053	--	--	--	--	Flowing
F173	--	--	--	--	Flowing
T380	0.4	0.5	0	0.5	Shallow
T381	0.55	0.72	0.53	0.19	Shallow
T415	1	1.49	0.96	0.53	Shallow
T416	0	0.5	0	0.5	Shallow
T457	0.3	0.4	0.2	0.2	Shallow
T458	0.6	0.76	0.56	0.2	Shallow
T463	0.4	0.63	0.34	0.29	Shallow
T506	1.1	1.1	1	0.1	Shallow
T507	0.7	1.1	0	1.1	Shallow
T603	0.6	0.9	0	0.9	Shallow
T628	0.4	0.4	0	0.4	Shallow
T630	1	1.18	0.83	0.35	Shallow
T660	0	0.2	0	0.2	Shallow
T661	0.75	1.06	0.59	0.47	Shallow
T674	0	0	0	0	Shallow
T803	0	0.4	0	0.4	Shallow
T804	0.65	0.86	0.63	0.23	Shallow
T805	0.6	0.7	0.3	0.4	Shallow
T806	0.9	1	0.8	0.2	Shallow
T850	0.7	1.2	0.7	0.5	Shallow
V006G	1	1.4	0.95	0.45	Shallow

Shallow Aquifer Response to Pumping

As might be expected because of the presence of confining low-permeability layers, the estimated drawdown in the shallower portions of the aquifer were much more muted than those observed in deeper portions of the aquifer. **Figure 4** depicts contours of equal groundwater elevation in the shallow aquifer on August 8, 2003 prior to the beginning of the pump test.

Based on these data, shallow groundwater was flowing in an east and southeast direction, with some mounding of groundwater evident along Sawmill Creek, Thibaut Creek, Blackrock Ditch, and the LAA. **Figure 5** depicts contours of equal groundwater elevation approximately 6 months after the start of the pump test on January 9, 2004, while **Figure 6** depicts contours of equal groundwater elevation after approximately one year of pumping on July 23, 2004. While groundwater flow patterns are similar before and during the test, groundwater elevations are an average of roughly 0.5 feet lower in the shallow aquifer near the end of the test.

Estimated drawdown in the shallow aquifer varied from 0 to approximately 1.1 foot after approximately 1 year of pumping, as illustrated in **Figure 7,** and shown in tabular format in **Table 1**. The drawdown pattern is roughly elliptical, with the best estimate of maximum drawdown in the vicinity of the pumping wells observed in Well T415 of approximately 1 foot. Allowing for subjectivity in the drawdown estimates, the Cooperative Study Team estimated the maximum reasonable drawdown attributable to pumping of W380 and W381 to be approximately 1.5 foot, observed at well T415. The drawdown pattern was not circular as might be predicted with an infinite heterogeneous aquifer. The reason for this is believed to be the result of surface water influences such as the unlined LAA, which provides a buffering effect to groundwater elevations along its path, and the boundary effects of Eastern Sierra.

The true radius of influence of pumping W380 and W381 for one year in the shallow aquifer is difficult to determine based on the pump test data because low drawdowns at greater distance are obscured by “noise” in the system. However, it appears as though the radius of influence extends at least 3 miles south of the pumping wells, and 1.5 miles north of the wells. The radius of influence to the east and west of W380 and W381 is highly uncertain because of the lack of monitoring well data in these areas. The contours of equal drawdown in the shallow aquifer shown in **Figure 7** where monitoring data is not available may simply be an artifact of the kriging process used to create the contours.

Figure 4
Shallow Aquifer Pre-Test Groundwater Elevations

Figure 5
Shallow Aquifer Mid-Test Groundwater Elevations

Figure 6
Shallow Aquifer Post-Test Groundwater Elevations

Figure 7
Post-Test Drawdown in the Shallow Aquifer

Deep Aquifer Response to Pumping

Figure 8 depicts contours of equal groundwater elevation in the deep aquifer on August 8, 2003 prior to the beginning of the pump test. Based on these data, groundwater in the deeper aquifer was flowing in a generally northern direction, but with a much flatter gradient than observed in the shallow aquifer. **Figure 9** depicts contours of equal groundwater elevation in the deep aquifer approximately 6 months into the pump test on January 9, 2004, while **Figure 10** depicts contours of equal groundwater elevation in the deep aquifer after approximately one year of pumping on July 23, 2004. The drawdown effect in the deeper aquifer is much more pronounced than in the shallow aquifer, with maximum drawdown occurring in W380 of approximately 150 feet, and W381 of approximately 155 feet after one year of pumping.

Estimated drawdown in the deep aquifer is illustrated in **Figure 11,** and shown in tabular format in **Table 1**. The drawdown pattern is roughly circular, logarithmically increasing in the centroid of the two production wells as would be predicted by well hydraulics theory. The cone of depression appears to extend further north than south, however, this may simply be an artifact of the kriging method used to create the contours and the fact that there are less monitoring wells north of the tested wells.

The drawdown occurring in the deep zone is much more pronounced than the shallow zone. Contours of equal depth to water in the shallow zone are similar under pre- and post-test conditions, as shown in **Figure 12**.

Figure 8
Deep Aquifer Pre-Test Groundwater Elevations

Figure 9
Deep Aquifer Mid-Test Groundwater Elevations

Figure 10
Deep Aquifer Post-Test Groundwater Elevations

Figure 11
Post-Test Drawdown in the Deep Aquifer

Figure 12
Depth to Water in the Shallow Aquifer

Aquifer Parameter Calculations

The relatively long period in which pumping and monitoring was conducted at W380 and W381 provides a good opportunity to apply analytical techniques to quantify aquifer parameters using various analytical models. As part of this task, MWH utilized the method of Neuman and Witherspoon (1969) to estimate the aquifer properties of the deep and shallow aquifer zones. Originally, the project plan envisioned that the Neuman and Witherspoon method employed by MWH would be compared to the method of Denis and Motz (1998) applied by ICWD. However, due to other work commitments, ICWD was unable to apply the Denis and Motz method as of this writing.

Water level measurements from three wells (V156, W380, W381) were analyzed using the Neuman and Witherspoon (1969) method for leaky confined aquifers. Well V156 was selected as an observation well because it is screened at a similar depth as the production wells and did not appear to be significantly affected by other hydrologic influences. Because data is not available for the first 72 days of the pump test at V156, the pre-test water level at V156 was estimated from groundwater level contour maps to be 3810 feet above mean sea level (fmsl).

Drawdown data from the production wells shown in **Table 2** was used in the in the analysis, employing AQTESOLV software utilized in previous confining layer studies (MWH, 2003b). Measurements that appeared to be erroneous (significantly different from the preceding and following measurements) were omitted from the AQTESOLV analysis.

Table 2
Drawdown at Wells W380 and W381

W380		W381	
Elapsed Time (days)	**Drawdown (ft)**	**Elapsed Time (days)**	**Drawdown (ft)**
0.0000	5.72	0.0000	4.15
1.0090	5.14	0.1931	0
1.0097	84.22	0.2014	0
1.0104	96.09	1.0021	4.16
1.0118	101.45	1.0174	4.16
1.0146	105.35	1.0181	0
1.0194	108.5	1.0188	0
1.0299	111.85	1.0201	0
1.0507	115.33	1.0229	0
1.0924	118.82	1.0285	0
1.1757	122.63	1.0382	119.76
1.3424	126.38	1.0590	123.12
1.9500	131.38	1.1007	126.62
2.0701	131.82	1.1840	130.55
2.2056	132.36	1.3507	134.07
2.8958	134.21	1.9646	138.58
3.2076	134.72	2.0806	138.88
3.9674	135.82	2.2181	139.36

Table 2 (continued)
Drawdown at Wells W380 and W381

W380		W381	
Elapsed Time (days)	Drawdown (ft)	Elapsed Time (days)	Drawdown (ft)
4.8854	136.61	2.9069	141.03
5.9167	137.32	3.2174	141.49
7.1083	137.95	3.9792	142.41
7.9882	14.15	4.9014	143.35
8.0049	0	5.9292	144.14
8.2347	131.99	7.1118	144.51
9.0486	133.52	8.0042	11.76
9.1840	133.96	8.0174	0
9.9944	135.36	8.2340	139.51
14.9806	137.89	9.0611	140.94
16.0438	0	9.1972	141.4
16.3035	129.45	10.0118	142.72
17.2514	0	14.9965	144.84
18.0181	136.13	16.0556	0
45.2618	140.1	16.3160	137.85
70.9111	0	17.2618	0
80.2354	141.56	18.0292	143.71
87.9569	0	45.2750	146.96
97.9819	143.2	70.9201	0
108.2576	143.87	80.2708	148.16
130.0472	145.91	87.9674	0
136.9917	0	97.9965	149.15
143.2194	143.55	108.2708	149.53
155.9681	145.51	133.2299	150.98
170.9486	146.79	143.2299	151.74
172.0097	146.84	156.0674	151.06
185.0215	147.77	170.9625	152.12
190.0222	0	171.9854	152.2
190.0632	0	185.0340	152.92
198.9535	147.1	190.0069	0
214.0479	148.63	190.0167	0
226.9736	149.76	198.9563	152.5
230.9882	0	214.0611	153.51
231.0104	0	226.9840	153.96
242.0174	147.53	242.0160	153.05
256.0333	149.02	256.0479	154.15
262.1014	0	262.1118	0
270.0083	150.1	270.0285	154.8
283.9931	147.11	283.9882	153.45
289.9514	146.04	289.9653	152.97
297.9389	147.95	297.9528	154.18

Table 2 (continued)
Drawdown at Wells W380 and W381

W380		W381	
Elapsed Time (days)	Drawdown (ft)	Elapsed Time (days)	Drawdown (ft)
311.9778	149.37	311.9882	154.71
317.9813	149.98	317.9917	155.2
325.9694	150.73	325.9840	155.41
339.9854	149.76	339.9847	154.61
347.9535	0	347.9674	0
348.1063	0	348.1201	0
350.2590	0	350.2729	0

Schematic drawings of the W380 and W381 well logs, along the with aquifer conceptualization based on those well logs, are shown in **Figure 13**. The aquifer conceptualization is based on the well logs for W380 and W381, consistent with the approach used in the Confining Layer Characteristics Study (MWH, 2003b). This conceptualization of the aquifer was applied identically to the time-drawdown analysis for each observation well. In all analyses, the confining unit was 80 feet thick and the anisotropy ratio (K_h:K_v) was 1:1. The latter assumption was made in order to be consistent with previous confining layer ATESOLV analyses, although it may not be representative of actual aquifer conditions in which K_h:K_v is believed to be higher than 1. The saturated thickness of the confined aquifer was assumed to be the distance from the bottom of the confining unit to the bottom of the screened interval of the pumped well.

AQTESOLV allows multiple pumping wells at multiple locations, so pumping wells W380 and W381 were implemented in the solution with their actual pumping rates and actual spatial locations. The pumping well and observation well input parameters for AQTESOLV are shown in **Table 3** and **Table 4.**

Figure 13
Schematic Representation of Wells W380 and W381

Table 3
Pumping Well Inputs for AQTESOLV

AQTESOLV Inputs	W380	W381
Fully vs. Partially Penetrating Well	Partially	Partially
Distance from Base of Confining Unit to Top of Perforated Interval	100 feet	100 feet
Distance from Base of Confining Unit to Bottom of Perforated Interval	540 feet	540 feet
Pumping Rate	1409 gpm	1343 gpm

Table 4
Observation Well Inputs for AQTESOLV

AQTESOLV Inputs		V156	W380	W381
Location	UTM Easting (feet)	1282199	1282199	1282674.4
	UTM Northing (feet)	13404856.68	13409010	13408092
	Distance from Pumping Centroid	8,303 feet	517 feet	517 feet
Fully vs. Partially Penetrating Well		Fully	Partially	Partially
Distance from Base of Confining Unit to Top of Perforated Interval		0 feet	100 feet	100 feet
Distance from Base of Confining Unit to Bottom of Perforated Interval		57 feet	540 feet	540 feet
Time Period Analyzed		10/30/03 – 8/2/04	8/18/03 – 8/2/04	8/1/03 – 8/2/04

Time-drawdown plots, overlaid by the Neuman and Witherspoon method (1969) fits to the observed drawdown data, are shown in **Figures 14, 15,** and **16**. Late-time data was fit preferentially over early-time data, because these data are more representative of long-term pumping conditions.

Figure 14
Observations at V156

Figure 15
Observations at W380

Figure 16
Observations at W381

Similar to the findings of the earlier Confining Layer Study, the solution is relatively insensitive to T' and S' (transmissivity and storativity of the upper, unconfined aquifer), so the solutions shown for T' and S' should be utilized with caution. A significant difference between this test and those used in the previous Confining Layer Study is that in previous studies, pump tests were conducted over a period of approximately one day, whereas this test lasted nearly a year.

Results from the AQTESOLV analysis, as well as the calculated parameter, K' (vertical hydraulic conductivity of the confining layer), are shown in **Table 5**.

Table 5
Summary of Aquifer Test Analysis Results

Analysis Results	**Observation Well**		
	V156	**W380**	**W381**
Residual Statistics from AQTESOLV			
Mean	0.03039	-0.1531	-0.6014
Variance	0.1402	190.8	356.6
Standard Error	0.3744	13.81	18.88
Parameter Solutions from AQTESOLV			
T [ft^2/d]	11,000	3900	3900
S [unitless]	1.0×10^{-10}	0.00012	7.0×10^{-5}
r/B [unitless]	1.0×10^{-5}	2.8×10^{-5}	0.055
β [unitless]	3.2×10^{-5}	1×10^{-5}	2.0×10^{-5}
T^U [ft^2/d]	6.1×10^{-5}	2080	1.0×10^{-5}
S^U [unitless]	1.1×10^{-8}	0.0060	0.0025
Parameters Calculated from AQTESOLV Solutions			
K' [ft/d]	1.3×10^{-12}	9.1×10^{-10}	0.0035

RECOMMENDATIONS

The long-term pump test at W380 and W381 was a very successful means to determine the drawdown impact of pumping these wells for one year. This data is invaluable and is generally much more reliable than modeling data because it is based on actual field testing. The following sections detail recommendations based on the information developed during this test.

Update of Conceptual Model

The long-term testing of W380 and W381 confirmed the existence of strata that retards vertical flow of groundwater and retards or mutes shallow drawdown due to pumping. Based on lithologic data solely from the pumping wells, this unit is most prevalent at a depth of 70 to 120 feet. However, the confining unit is not a not an areally-continuous, discrete layer of clay or silt, but rather a lenticular series of strata of low permeability which results in strong vertical/horizontal anisotropy (high K_h:K_v ratio). The more-or-less continuous difference in vertical head with depth suggests that confinement is caused by a single aquifer with a high K_h:K_v ratio, rather than discreet shallow and deep aquifers separated by a single confining bed.

The retardation of vertical flow tends to mute the magnitude of drawdown in the shallow zone, but it is spread over a large area.

The testing also suggested that the vertical retardation of flow is not consistent from point to point, and is stronger in some areas than others. For example, the highest drawdowns observed in the shallow aquifer (where the most leakage occurred) were located adjacent to the Blackrock volcanics. This might be expected because the lack of clay or silt lenses, and existence of vertical factures would enable vertical flow of groundwater.

The testing at W380 and W381 also highlighted the importance of the effects of surface water features in modifying or buffering drawdown in the shallow zone. For example, it appears clear that leakage of water from the LAA resulted in less drawdown than might be expected in the vicinity of the pumping wells, and potential drawdown in shallow wells in the vicinity of Blackrock Ditch was in some cases entirely obscured by changes in surface flow.

The testing also showed that in the deep zone, drawdown reached a quasi equilibrium after a period of approximately three months, although drawdown in the shallow zone continued longer, and was slower to recover after pumping stopped (see hydrographs in **Appendix B and C**, and drawdown estimates in **Appendix F**). This effect noted in field results should be confirmed from a theoretical standpoint using the method of Denis and Motz (1998) when time allows.

Updates to the Numerical Model

The relatively large volume of water extracted from W380 and W381 and the long duration of the test means that the groundwater system significantly altered, or stressed relative to pre-test conditions. This, combined with the detailed monitoring conducted during the test, provides an ideal opportunity to use this data in transient calibration of the numerical model for the combined Taboose-Aberdeen and Thibaut-Sawmill Wellfield Model called the Taboose-Thibaut Model (MWH, 2006). The aquifer parameters estimated in this report can be used as guidelines for review of the parameters currently used in the numerical model.

During this calibration effort, particular attention should be paid to the elevation of model layers in comparison to the elevation of the screened intervals of W380 and W381, and the elevation of the monitoring wells with respect to the model layer elevations. If the elevations are significantly different, it would be expected that the model would not replicate the results of the test exactly. This is because the retardation of vertical flow is believed to be more of a continuum, rather than being the result of one discreet confining layer separating two homogenous shallow and deep aquifers.

From the perspective of managing vegetation, the response of shallowest layer of the numerical model to simulated pumping at W380 and W381 is of most importance. This is the most critical layer in which the numerical model should replicate observed conditions during the testing of W380 and W381. The model should be calibrated such that it replicates an elliptical cone of depression in the shallow zone with a maximum drawdown of 1.1 to 1.5 feet in the vicinity of W380 and W381. It would not be expected that pattern drawdown simulated in the numerical model would match those observed during the test exactly because of uncertainty in the drawdown correction and the local effects of surface water which are difficult to simulate with a wellfield-scale model. However, in order to have confidence in the numerical model, the general shape and magnitude of the drawdown cone in the shallow zone should be replicated.

The conceptual model of a anisotropic aquifer (high K_h:K_v ratio) as opposed to the conceptual model of two aquifers separated by a discreet confining layer suggests that a numerical model with more layers would provide a more realistic simulation of actual conditions. In this fashion, the more continuous change in vertical head conditions can be more accurately simulated.

Operation of Wells W380 and W381

Current work regarding refinement of ON/OFF guidelines for the Green Book involves the development of two algorithms used in combination that are relatively easy to apply. One algorithm would be used to estimate the drawdown at a specific location due to the pumping at one or more wells after a period of one year, and the second algorithm would be used to estimate the effect on vegetation at specific locations.

The results of this testing at W380 and W381 can be utilized to eliminate the need for the first algorithm for simultaneous pumping of W380 and W381, in that the cone of depression in the shallow aquifer has been documented by actual field testing for a period of one year. Although the actual drawdown experienced in a specific year might differ due to surface water management conditions during that year, this would need to be accounted for anyway using an algorithm based on regression. The data developed during this test can also be used to estimate expected drawdown that would occur in periods of less than one year.

The data developed during this testing also has an advantage over regression-based methods in that it can be applied over a continuous area of an approximately three-mile radius, rather than at discreet points where regression data is available.

Potential Permanent Monitoring Site

Documentation of the cone of depression in the shallow water table due to pumping of W380 and W381 is a major milestone in development of optimal locations for monitoring of potential changes in vegetation attributable to extraction of groundwater at these wells. In a meeting on April 14, 2005 the Cooperative Study Team decided that the first step in evaluating the need for new permanent monitoring sites would be to provide a map showing vegetation parcels and types overlain by the estimated drawdown in the shallow zone developed during this study. Other criteria that might be employed in selection of alternate permanent monitoring sites include:

- Sites where the principal vegetation have rooting zones may be affected by pumping
- Sites where interference from surface water does not obscure the observation of drawdown attributable to pumping of W380 and W381
- Sites where an existing monitoring well is located with an adequate history of water level measurement

Figure 17 provides a map combining vegetation and drawdown information in which three potential monitoring sites are located, based on the existence of monitoring wells with adequate data. One site, located near well T507 is located in the center of the BLK086 parcel. A second site is located near well V006G near the boundaries of parcels BLK052 and BLK055. A third site is located near well T583 on the boundaries of parcels BLK047 and BLK 084. These sites are located based on the existence of historic groundwater level monitoring information, but need to be reviewed by LADWP and ICWD vegetation specialists to ensure that they are appropriate in consideration of access, vegetation type, and historical observation of changes in vegetation, and other logistical or technical considerations.

Future Deep Well Testing at Other Locations

Although testing at W380 and W381 was very successful in characterizing the aquifer conditions at that site, the results are expected to be highly site-specific because of variable boundary conditions and aquifer parameters. Therefore, these types of tests should be performed at other locations as an aid to understanding the relationship between deep and shallow zones. The following criteria are recommended to selection of a potential site for deep well testing:

- A site that has high-capacity production wells that are screened below a confining unit as indicated by lithologic or geophysical logs.

- A site that has been subject to disagreement in the effects of pumping, or that has vegetation in the vicinity that is (under Green Book criteria) considered to be groundwater dependent.

- A site that has a significant number (at least five) of shallow monitoring wells or springs with at least a three-year baseline history of data to use in drawdown calculations.

- A site that has sufficient subsurface data (geophysical data, lithologic logs, and well construction details) such that a conceptual model of the deeper zones could be compiled.

- A site that would complement existing or previous studies, such as wellfield or geochemical studies.

- If practical, a site in which the idea of the interaction of groundwater and surface water could be tested and quantified. This type of site would require adjacent surface water bodies that have relatively accurate methods to quantify flow.

Although there are other sites that could be measured against the criteria above, during the Deep Well data analysis, the following sites were identified by the Cooperative Study Team:

Big Pine Wellfield, wells **W374 and W375**. Also, a triplet of wells (**W378, W379, and W389**) may also be good locations for deep testing.

Laws Wellfield, wells **W245, W387, W388** (associated with permanent monitoring site Laws 5). ICWD has expressed interest in testing these wells for the purpose of locating a monitoring site for these wells.

Thibaut-Sawmill Wellfield, well **W382**.

Taboose Aberdeen Wellfield, replacement for well **W349**. This well is currently screened from 30 to 300 feet.

Lone Pine Wellfield, well **W416.**

In the Confining Layer Study (MWH, 2003b), the project team selected eight additional locations:

- Laws Wellfield - well W388 EM
- Big Pine Wellfield - well W389 EM
- Big Pine Wellfield - well W374 AQ
- Thibaut-Sawmill Wellfield - well W382 EM
- Independence-Oak Wellfield - well W391 AQ
- Symmes-Shepherd Wellfield - well W395 AQ
- Bairs-Georges Wellfield - well W403 AQ
- Lone Pine Wellfield - well W390 EM

Any of these potential locations might serve as an appropriate location for future deep well testing.

The success in testing wells W380 and W381 was due in large part to a thorough planning process, which was detailed in the Deep Well Operational Testing Plan (MWH, 2003a). The plan included the following:

- Listing of pertinent surface water features that affect groundwater levels
- Listing of wells to be monitored in both the deep and shallow zones
- Description of recommended monitoring facilities for sensitive areas
- Recommendations for installation of monitoring points
- Monitoring schedules
- Equipment lists for monitoring facilities
- Pumping and recovery schedules
- Suggested criteria for ending the test
- Proposed analysis methods for the data resulting from the tests

Although many of the general methods (and equipment) used at W380 and W381 are directly transferable to another site, there is a significant amount of the testing plan that is site-specific, and would need to be tailored to incorporate details and available data at a new site. This effort has proved worthwhile.

The experience at W380 and W381 highlighted several factors that led to the success of the test, and several factors that could be improved. We recommend that these factors be considered in future testing, as summarized in **Table 6**.

Table 6
Success Factors and Areas of Improvement for Deep Well Testing

Success Factors in Testing of W380 and W381	Areas of Improvement for Future Testing
• Detailed planning focuses monitoring where most needed • Clear, detailed direction to hydrographers ensures correct data collected • Agreement with the ICWD on criteria for ending test. Criteria to end the deep well pump testing of W380 and W381 was conservative, yielded good results, and allowed the test to be stopped if concerns arose • Ending test as agreed upon • Cooperative nature of test reduced controversy and improved analysis through introduction of new ideas • Clear definition of responsibilities (MWH, LADWP, ICWD)	• Monitoring frequency could be reduced in some instances to reduce cost • Static water level data at pumping wells should have been collected • Clear, detailed direction to hydrographers for electronic data records. File naming conventions for wells, canal, creeks and rivers, will minimize post–processing analysis time.

Figure 17
Proposed Vegetation Monitoring Sites

REFERENCES

Denis, R.E. and L.H. Motz, 1998. Drawdowns in Coupled Aquifers with Confining Unit Storage and ET Reduction, Journal of Groundwater, Vol. 6, No. 2, pp. 201 – 207.

Green Book, 1991. Long-Term Groundwater Management Plan for the Owens Valley and Inyo County, 176 pages.

Hollett, K. J., W. R. Danskin, W. F. McCaffrey, and C. L. Walti, 1991. Geology and Water Resources of Owens Valley, California. U.S. Geological Survey Water-Supply Paper 2370-B. U.S. Geological Survey, Denver, Colorado, 77 p.

Inyo/LA Water Agreement, 1991. Agreement Between the County of Inyo and the City of Los Angeles and its Department of Water and Power on a Long Term Groundwater Management Plan for Owens Valley and Inyo County, 35 pages.

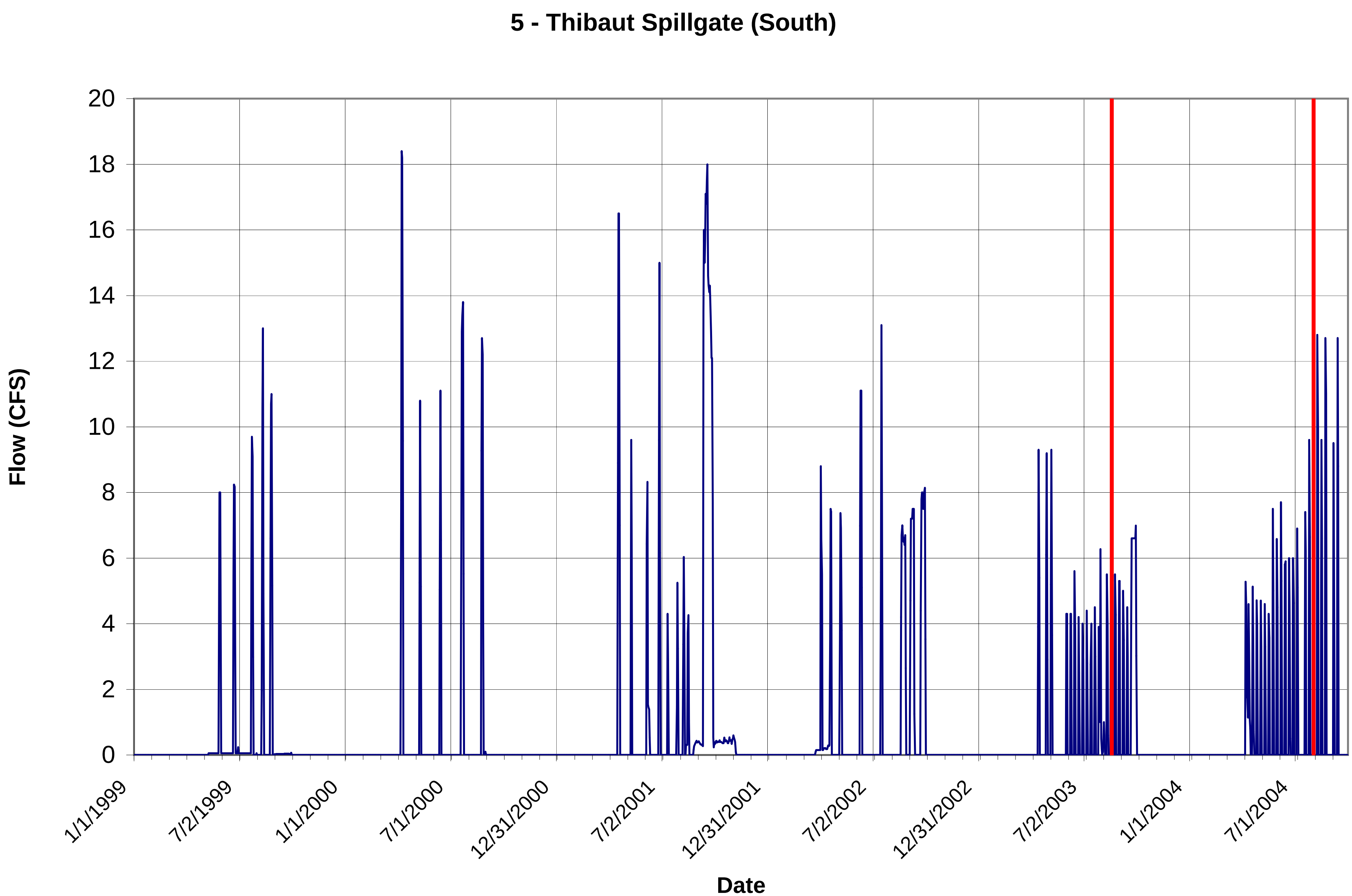
MWH, 2003a (October). Deep Well Operational Testing Plan.

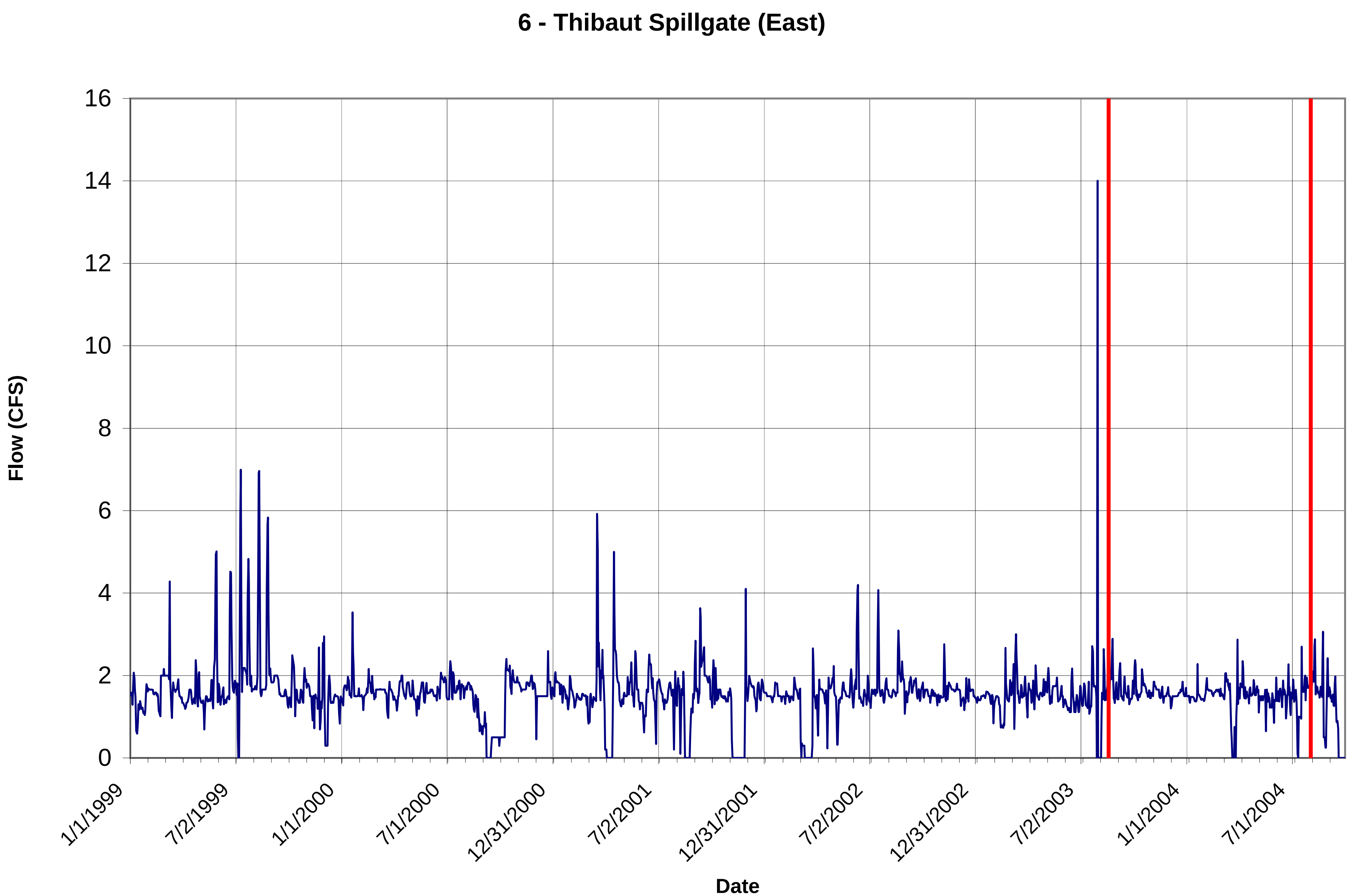
MWH, 2003b (April). Confining Layer Characteristics Cooperative Study Final Report, Inyo/LA Cooperative Study.

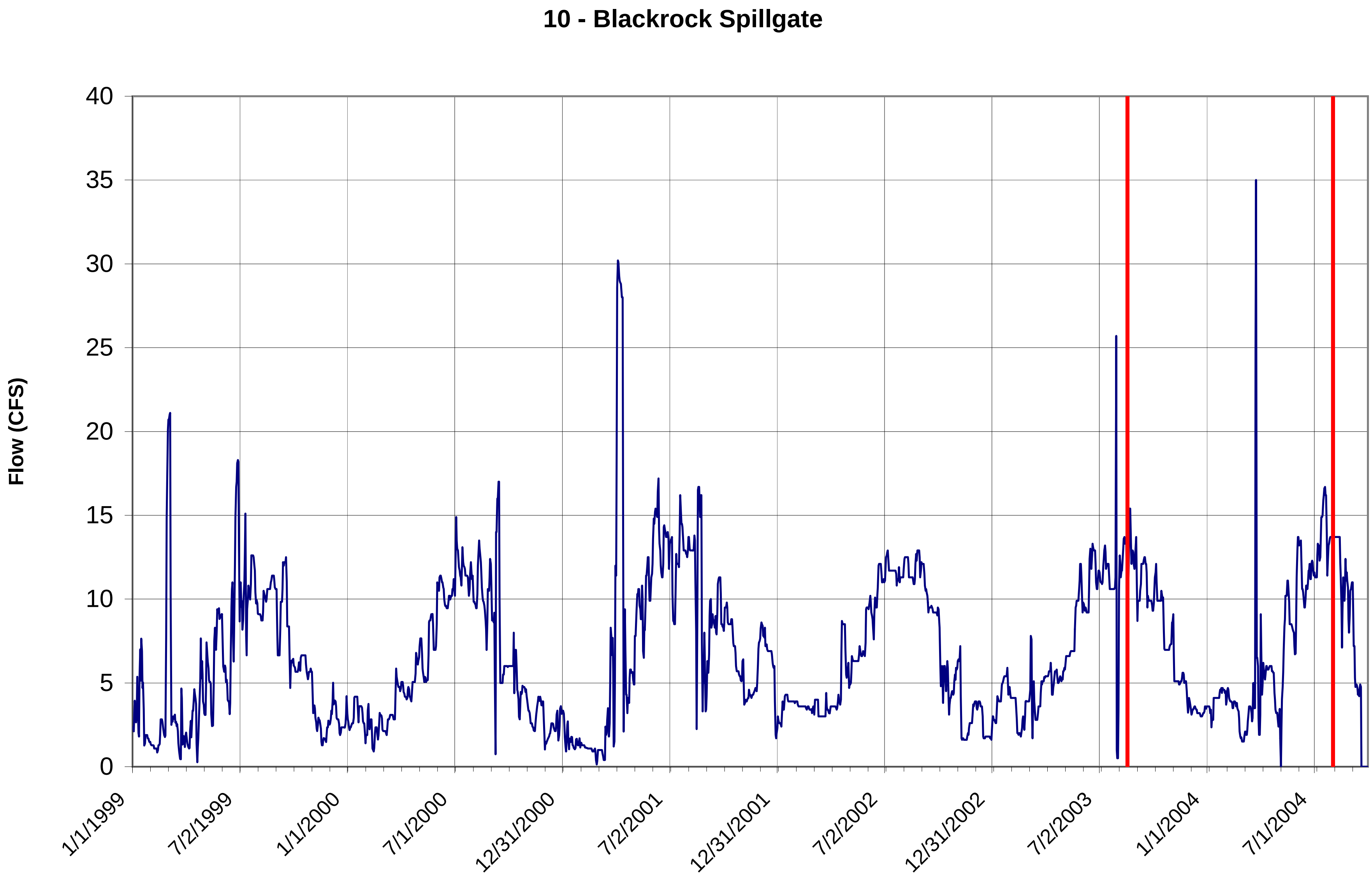
MWH, June 2006, Taboose-Thibaut Model Documentation Memorandum. Memo from MWH to Saeed Jorat of LADWP, 83 pages.

Neuman S.P. and P.A. Witherspoon,1969. Theory of Flow in a Confined Two Aquifer System, Water Resources Research,, Vol. 5, No. 4, pp. 803 – 816.

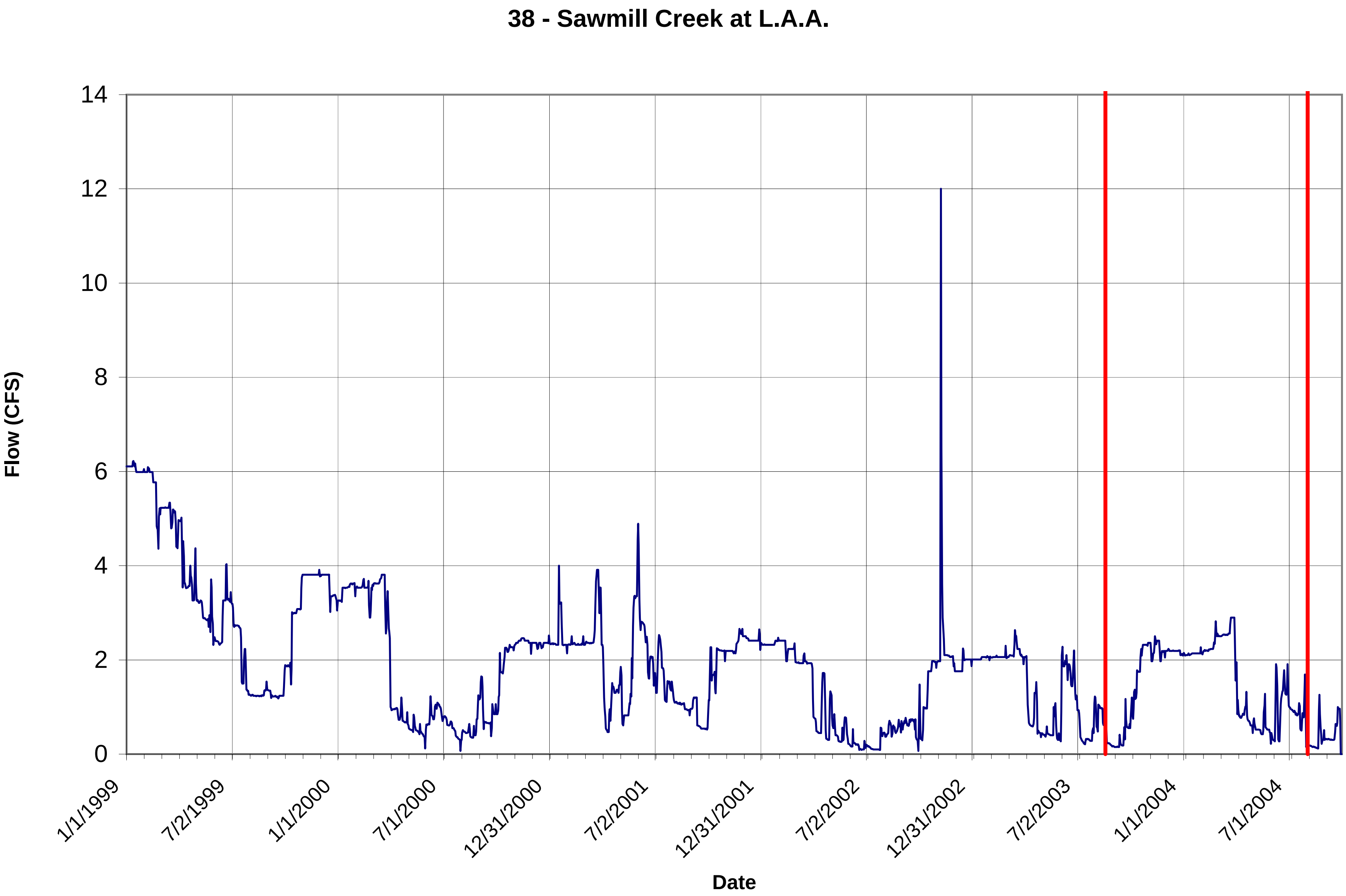
APPENDIX A
Flow at Surface Water Features (1999 – 2004)

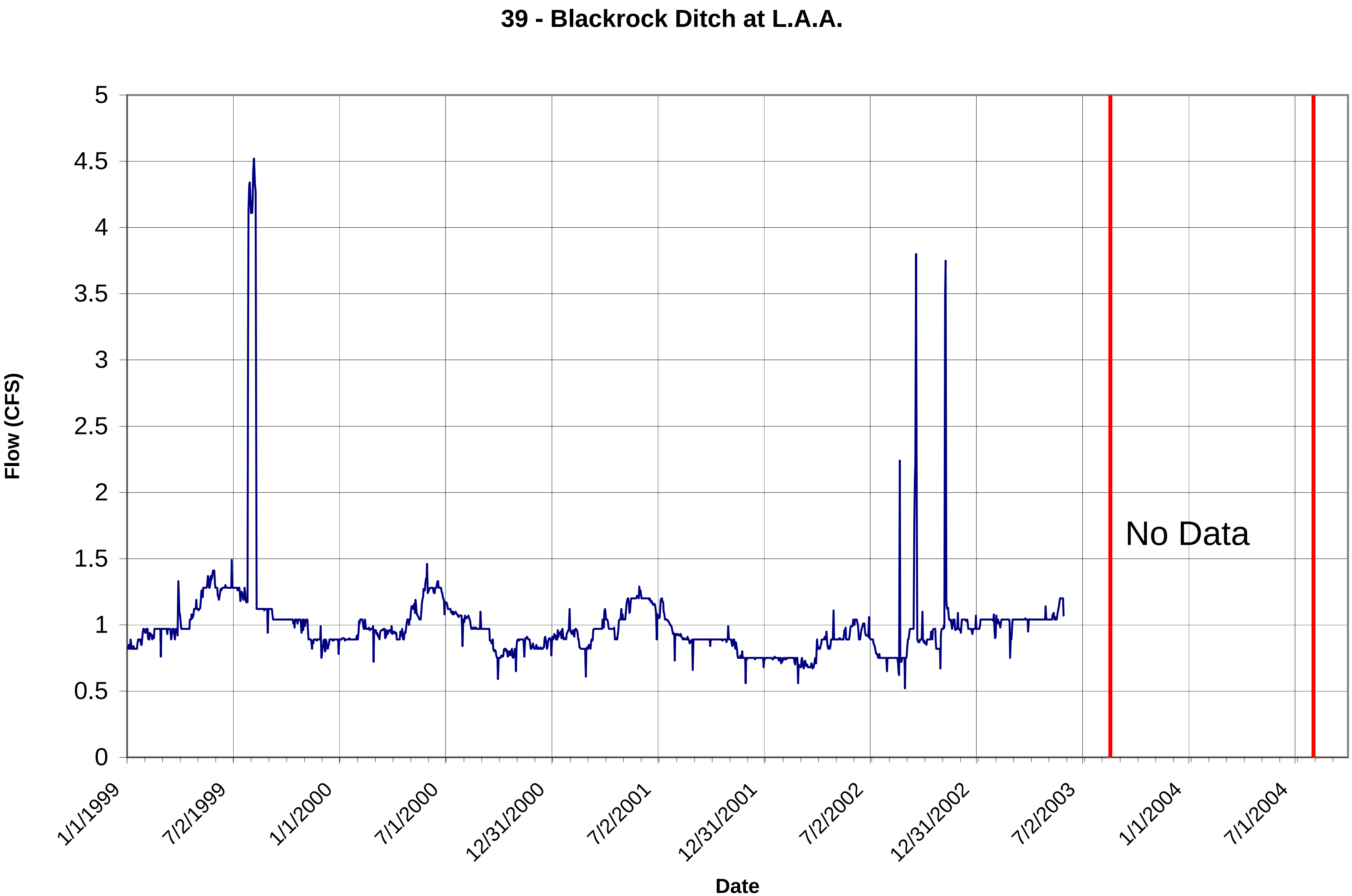

5 - Thibaut Spillgate (South)
Flow (CFS)
20
18
16
14
12
10
8
6
4
2
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


6 - Thibaut Spillgate (East)
Flow (CFS)
16
14
12
10
8
6
4
2
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



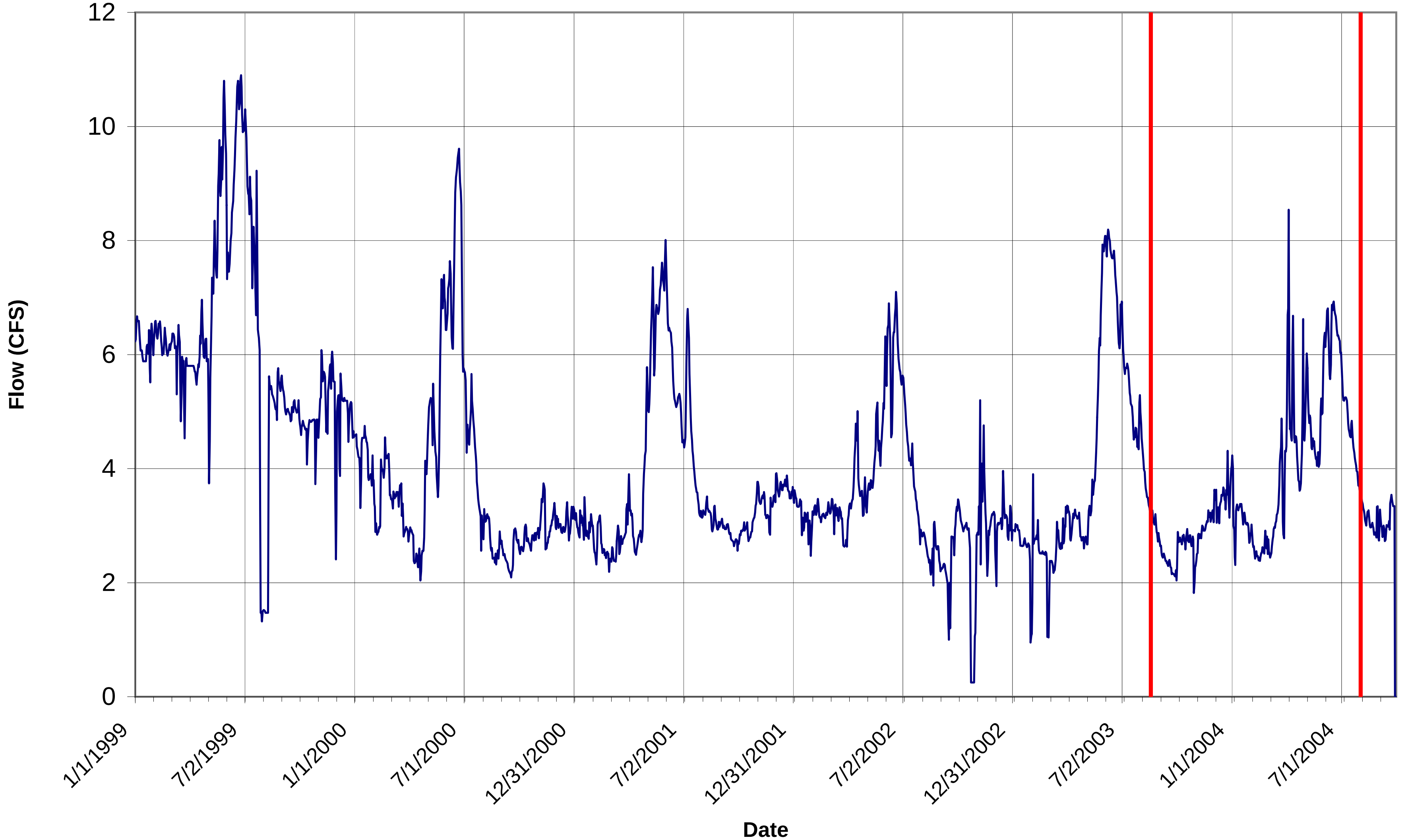
10 - Blackrock Spillgate
Flow (CFS)
40
35
30
25
20
15
10
5
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

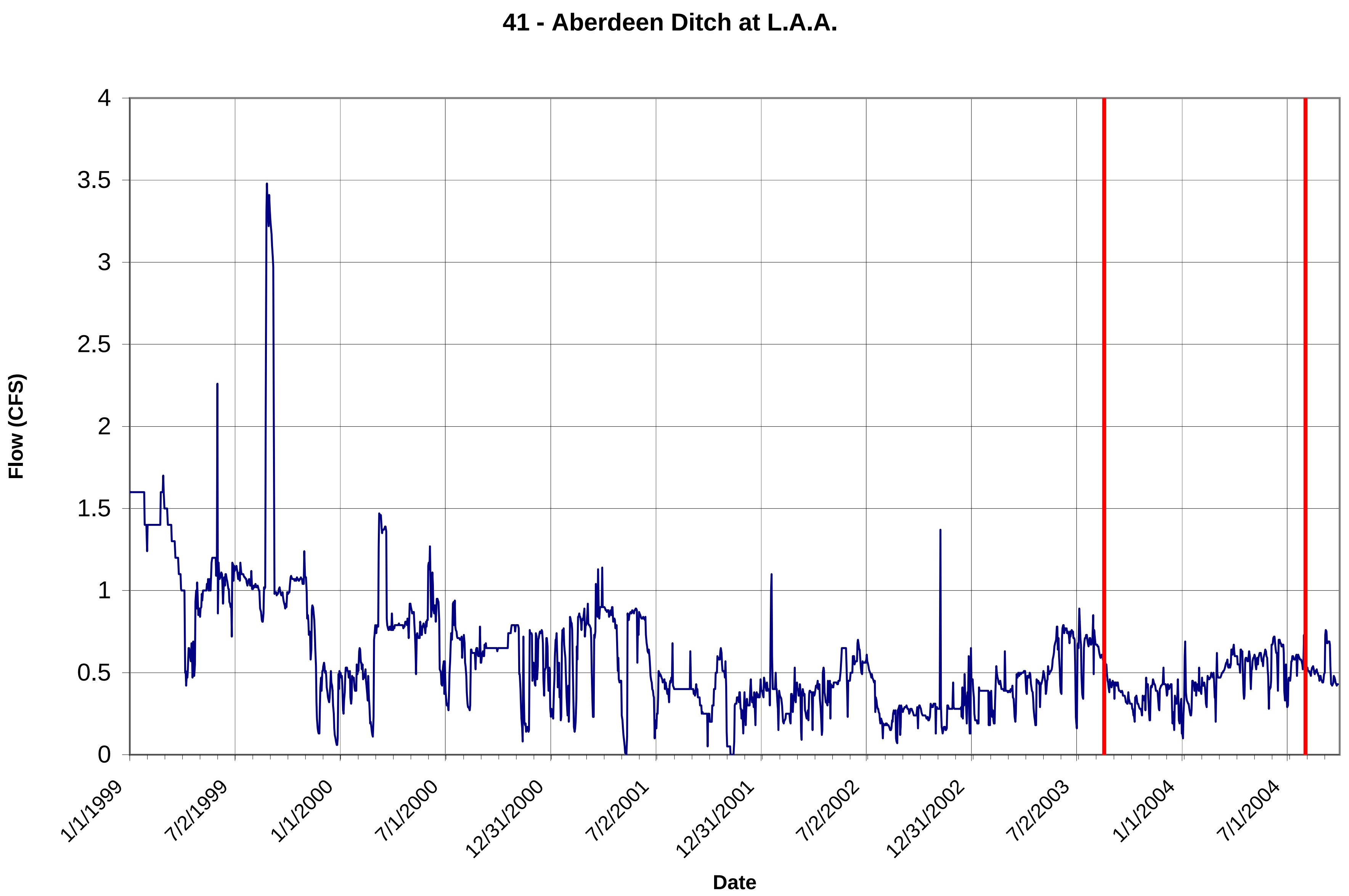

38 - Sawmill Creek at L.A.A.
Flow (CFS)
0
2
4
6
8
10
12
14
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

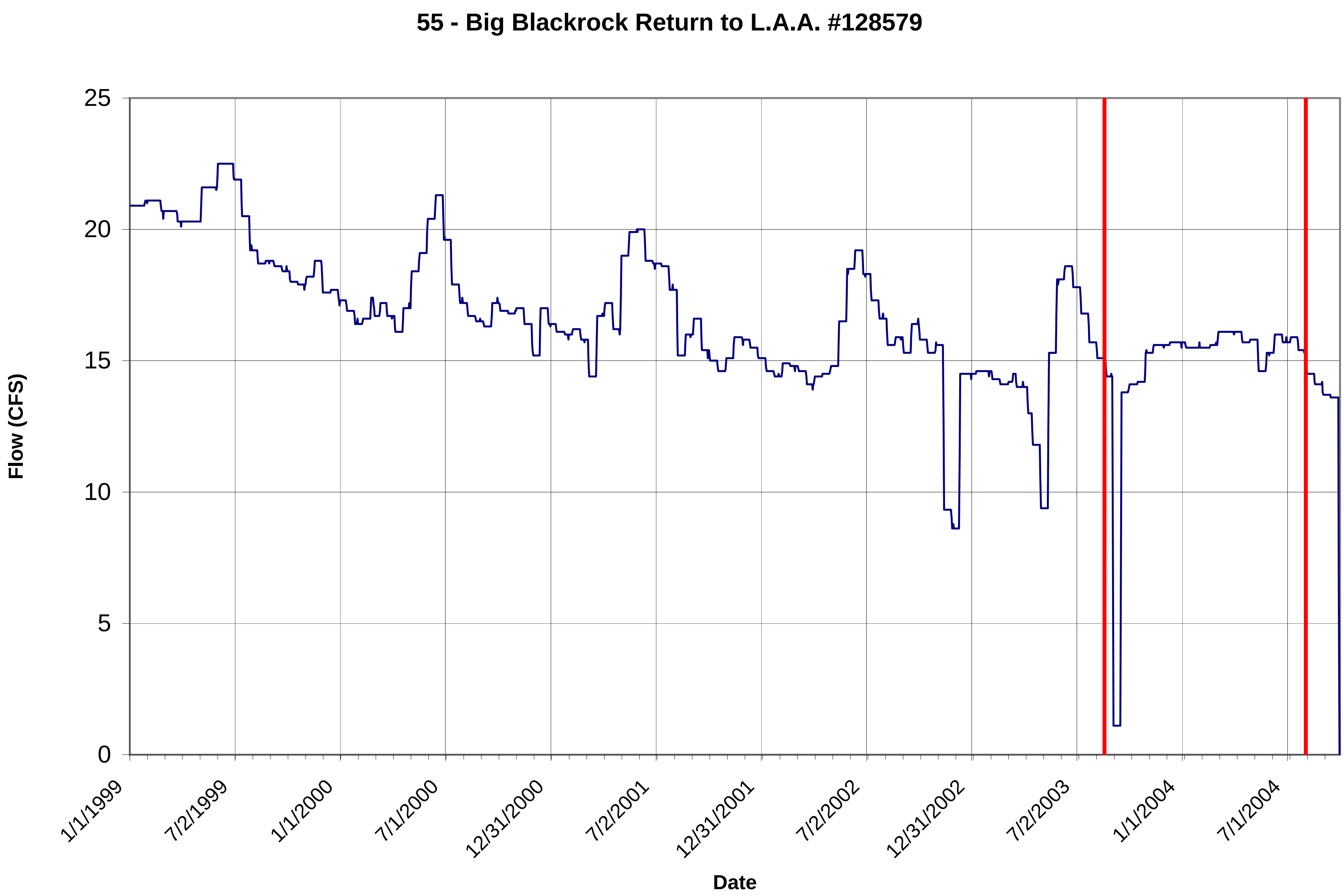


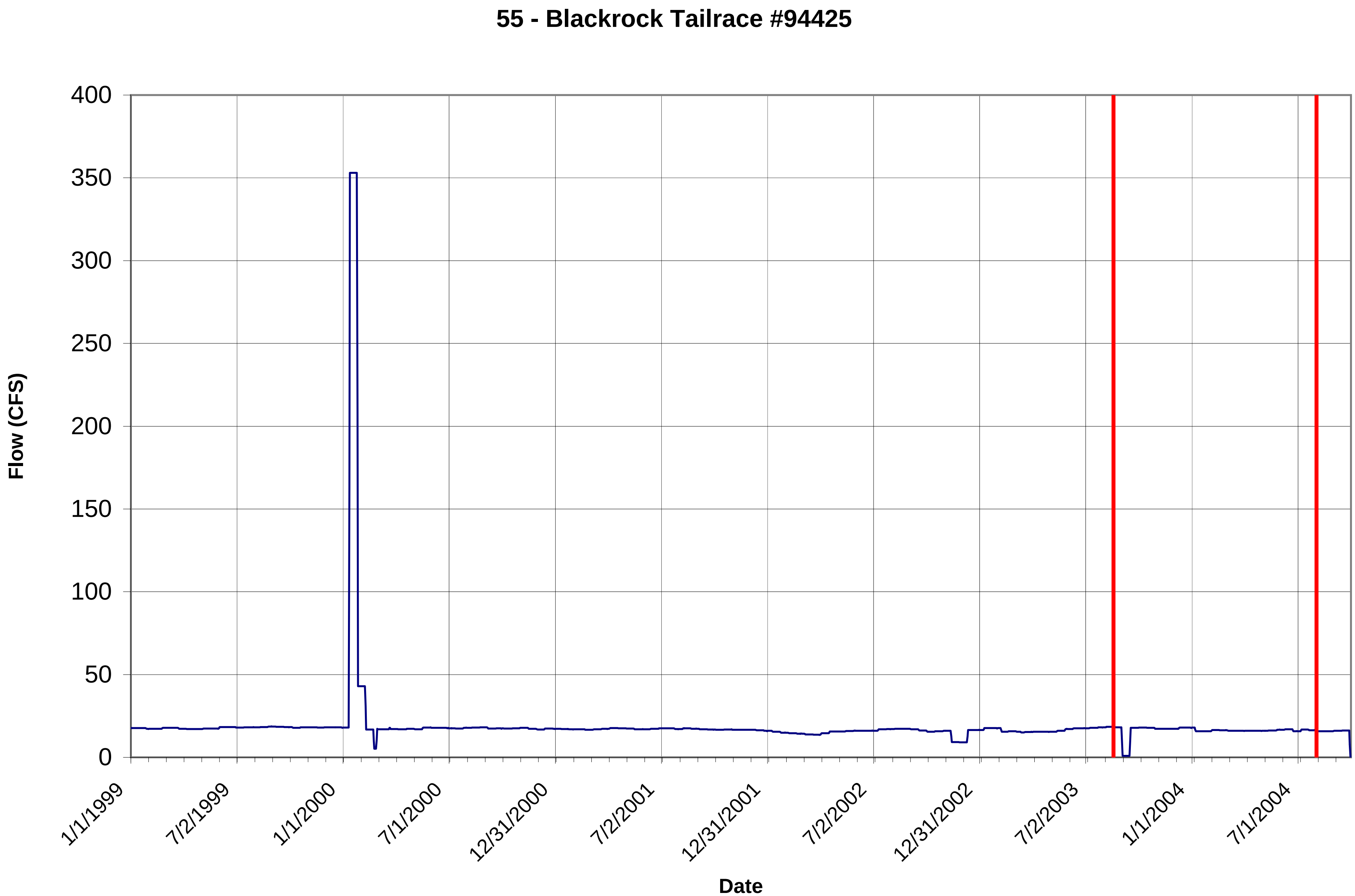
39 - Blackrock Ditch at L.A.A.
Flow (CFS)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
No Data
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

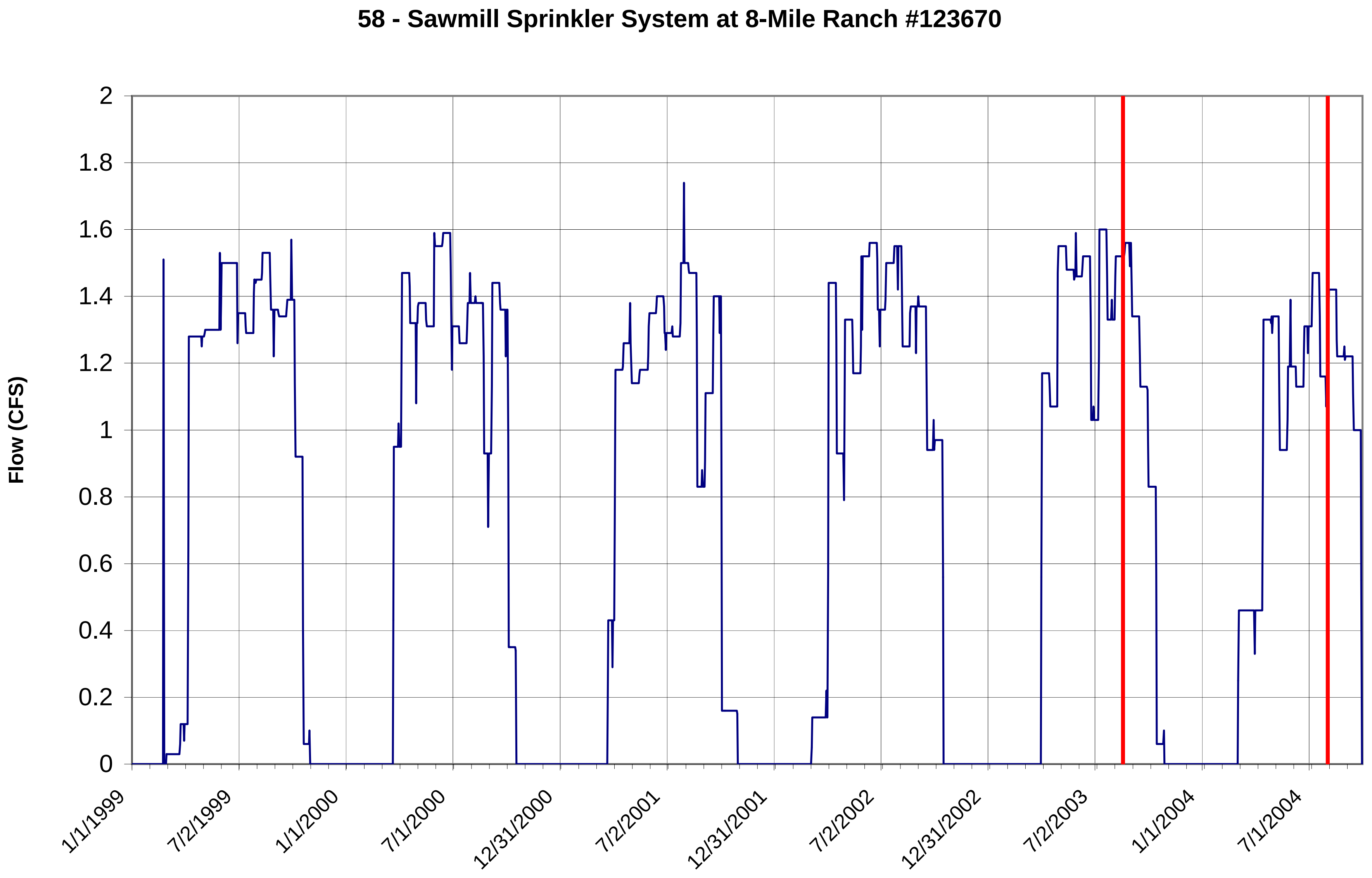
40 - Blackrock Ditch Diversion Above Flume

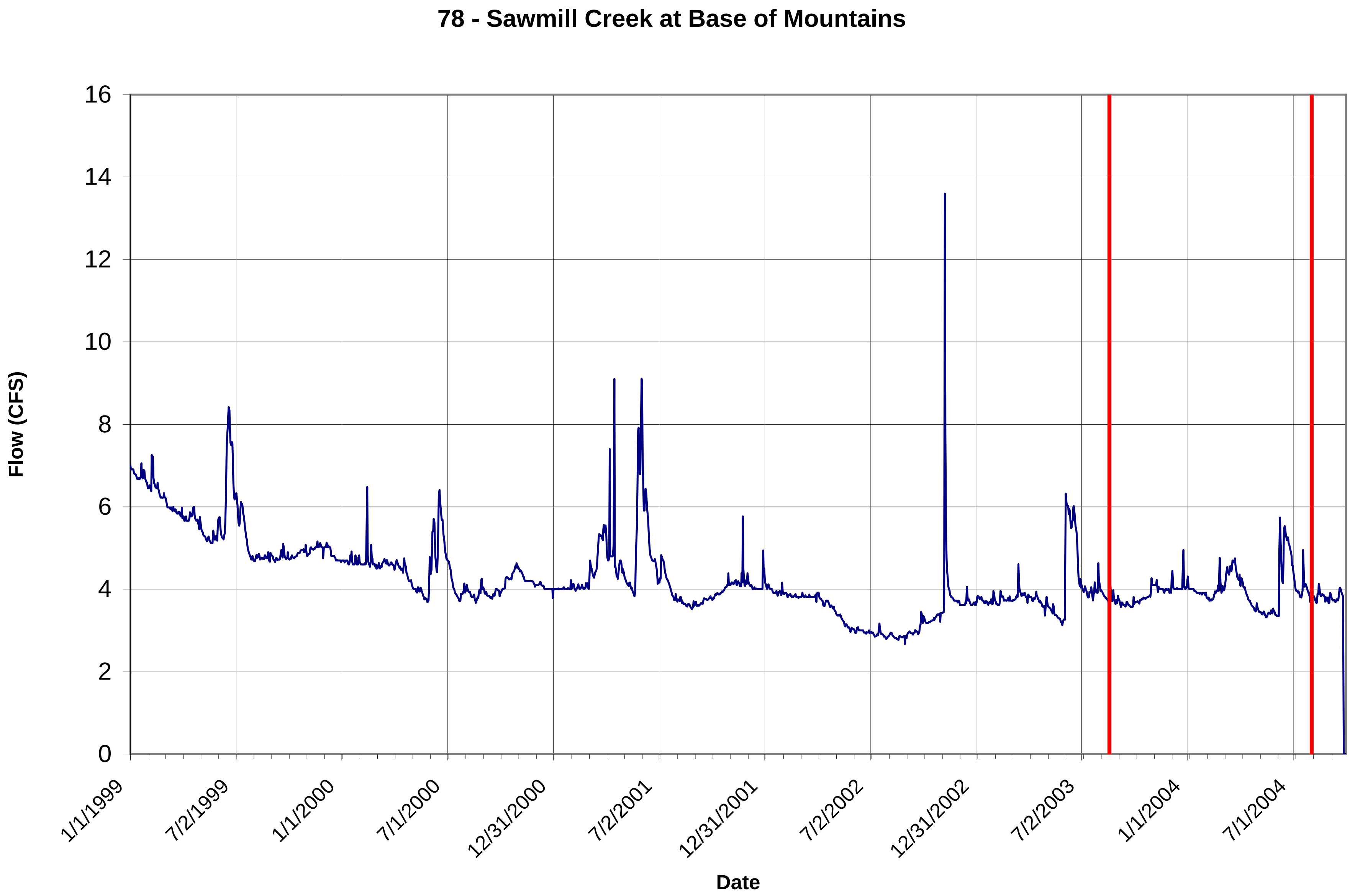



41 - Aberdeen Ditch at L.A.A.
Flow (CFS)
4
3.5
3
2.5
2
1.5
1
0.5
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

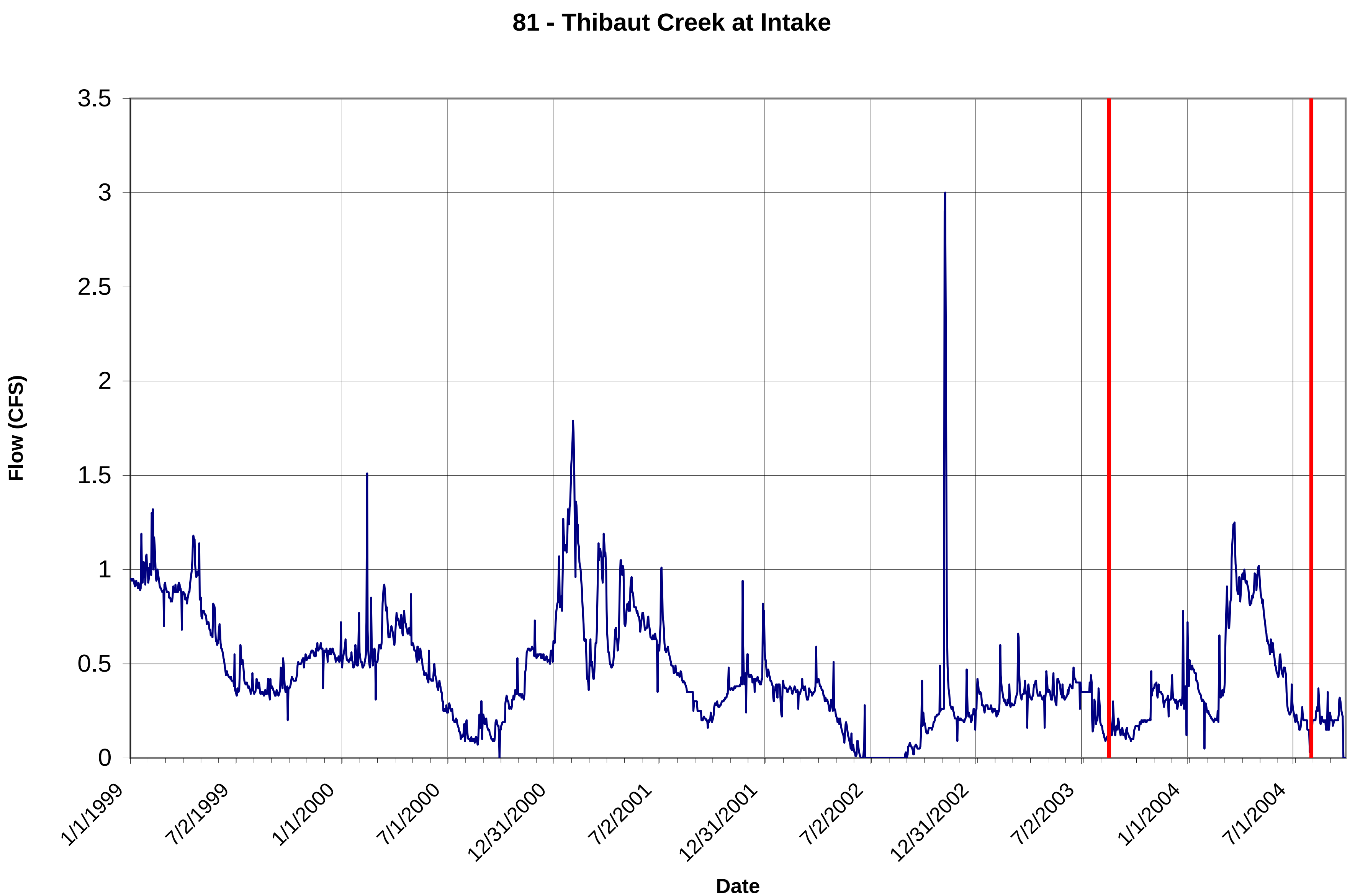

55 - Big Blackrock Return to L.A.A. #128579
Flow (CFS)
0
5
10
15
20
25
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

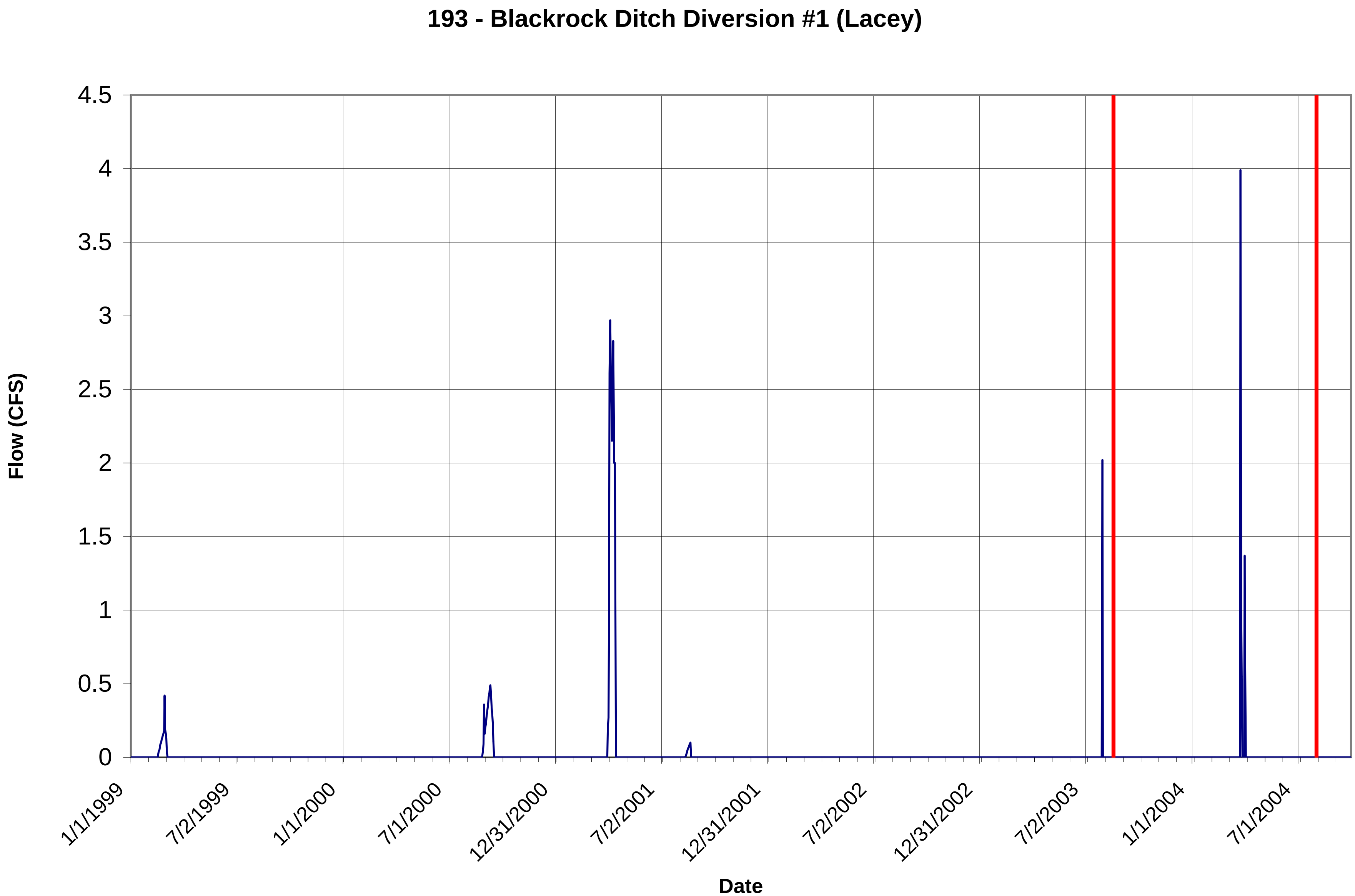

55 - Blackrock Tailrace #94425
Flow (CFS)
400
350
300
250
200
150
100
50
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


58 - Sawmill Sprinkler System at 8-Mile Ranch #123670
Flow (CFS)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

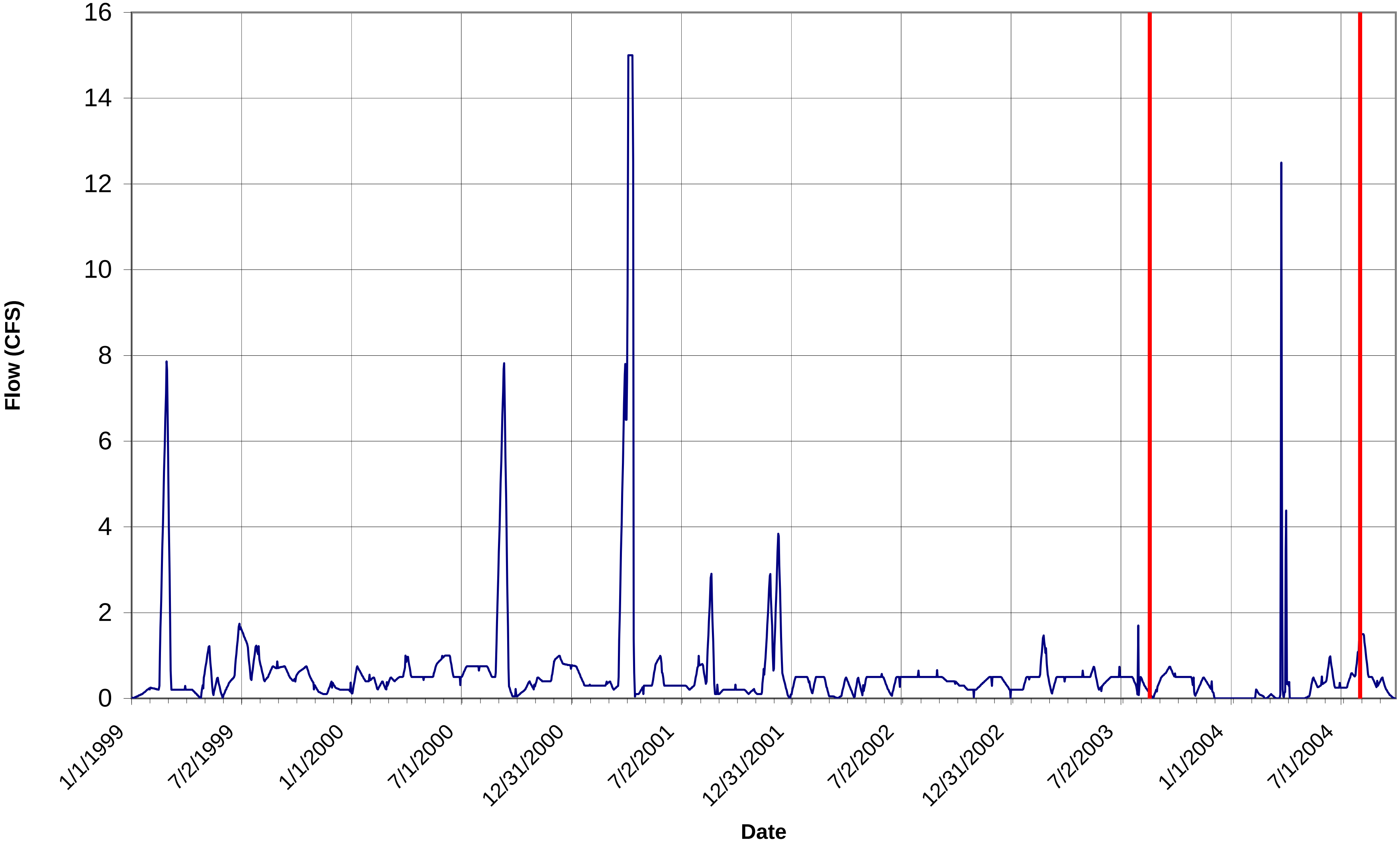


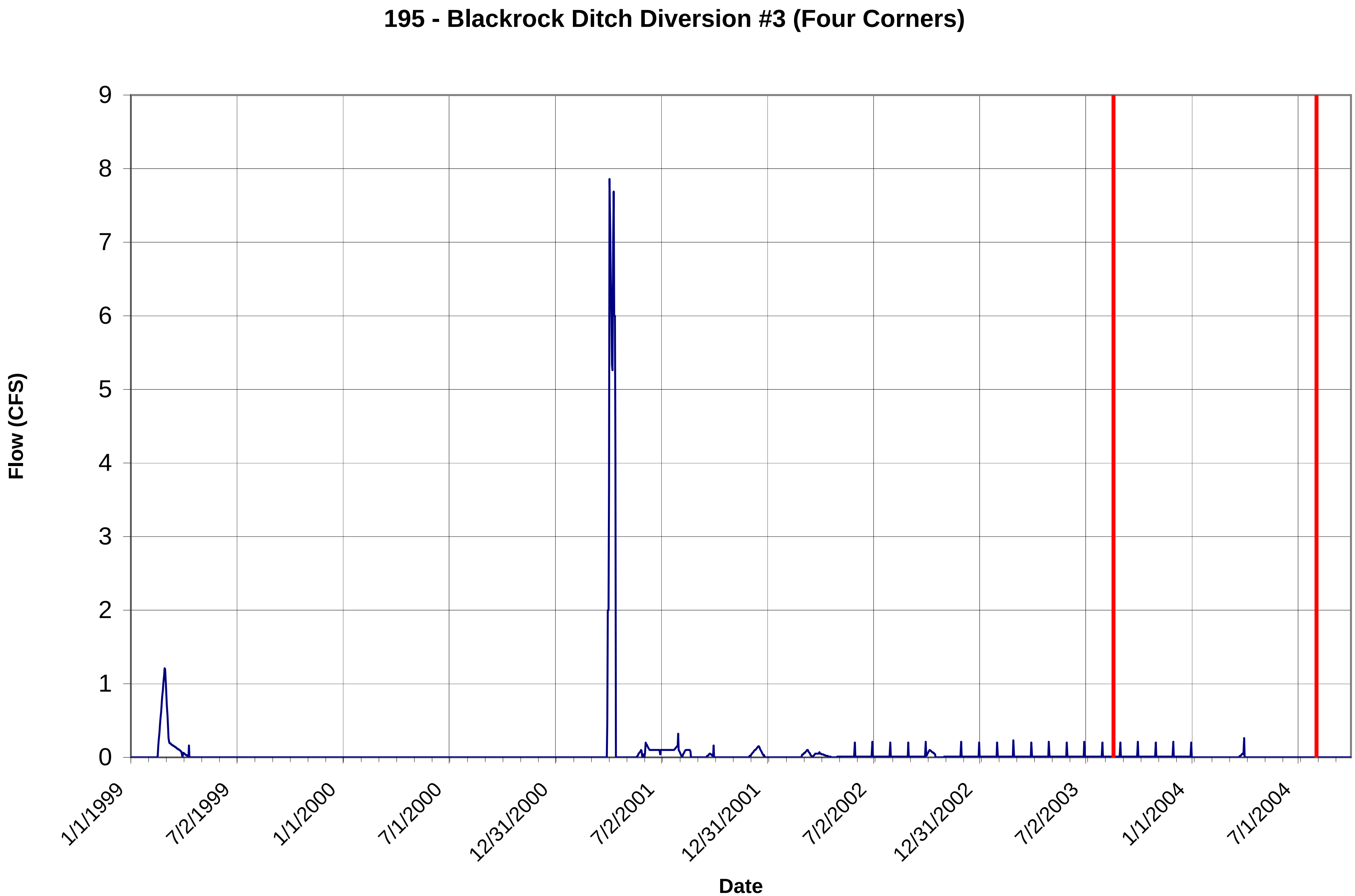
78 - Sawmill Creek at Base of Mountains
Flow (CFS)
16
14
12
10
8
6
4
2
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

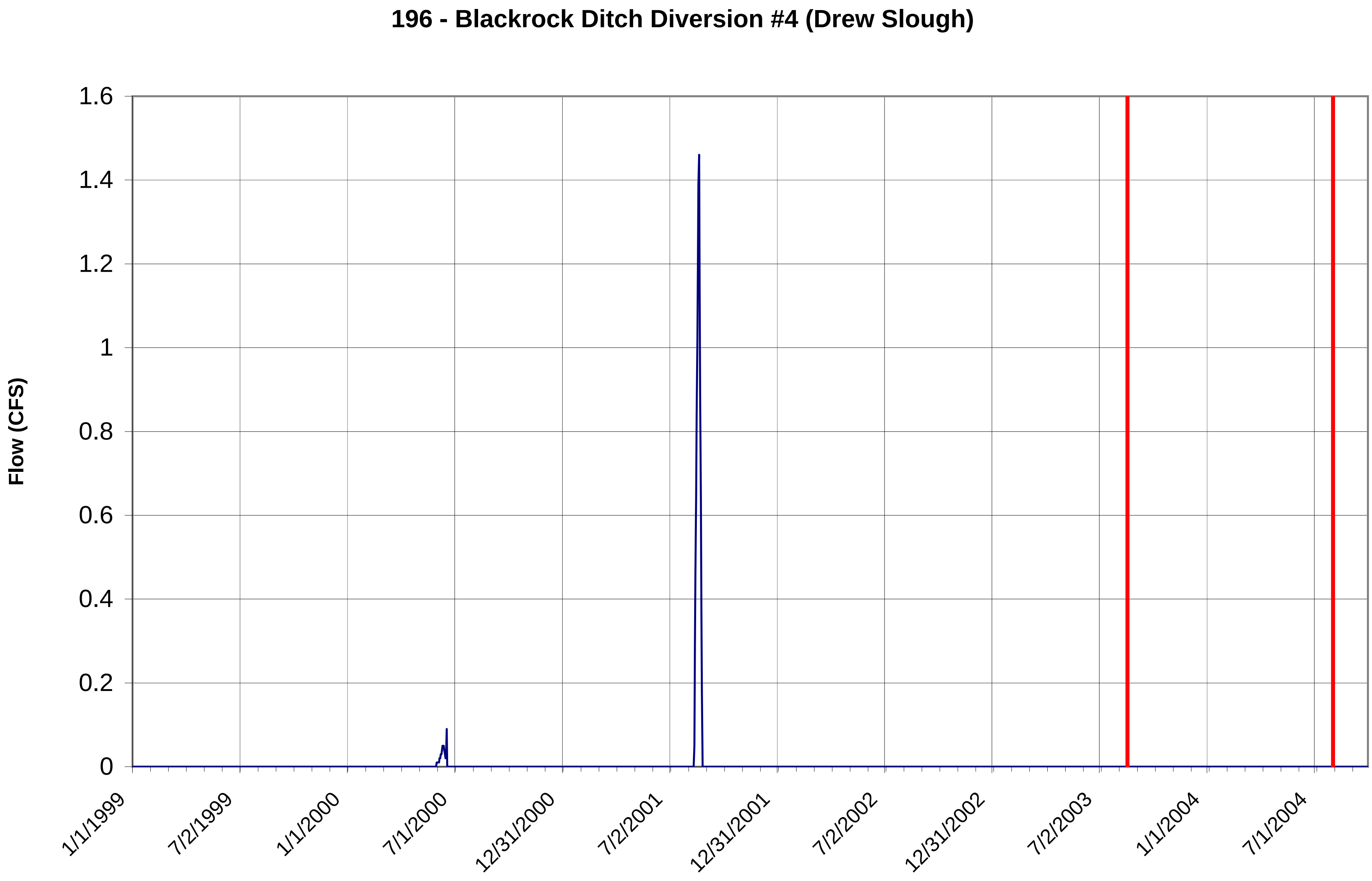

81 - Thibaut Creek at Intake
Flow (CFS)
3.5
3
2.5
2
1.5
1
0.5
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

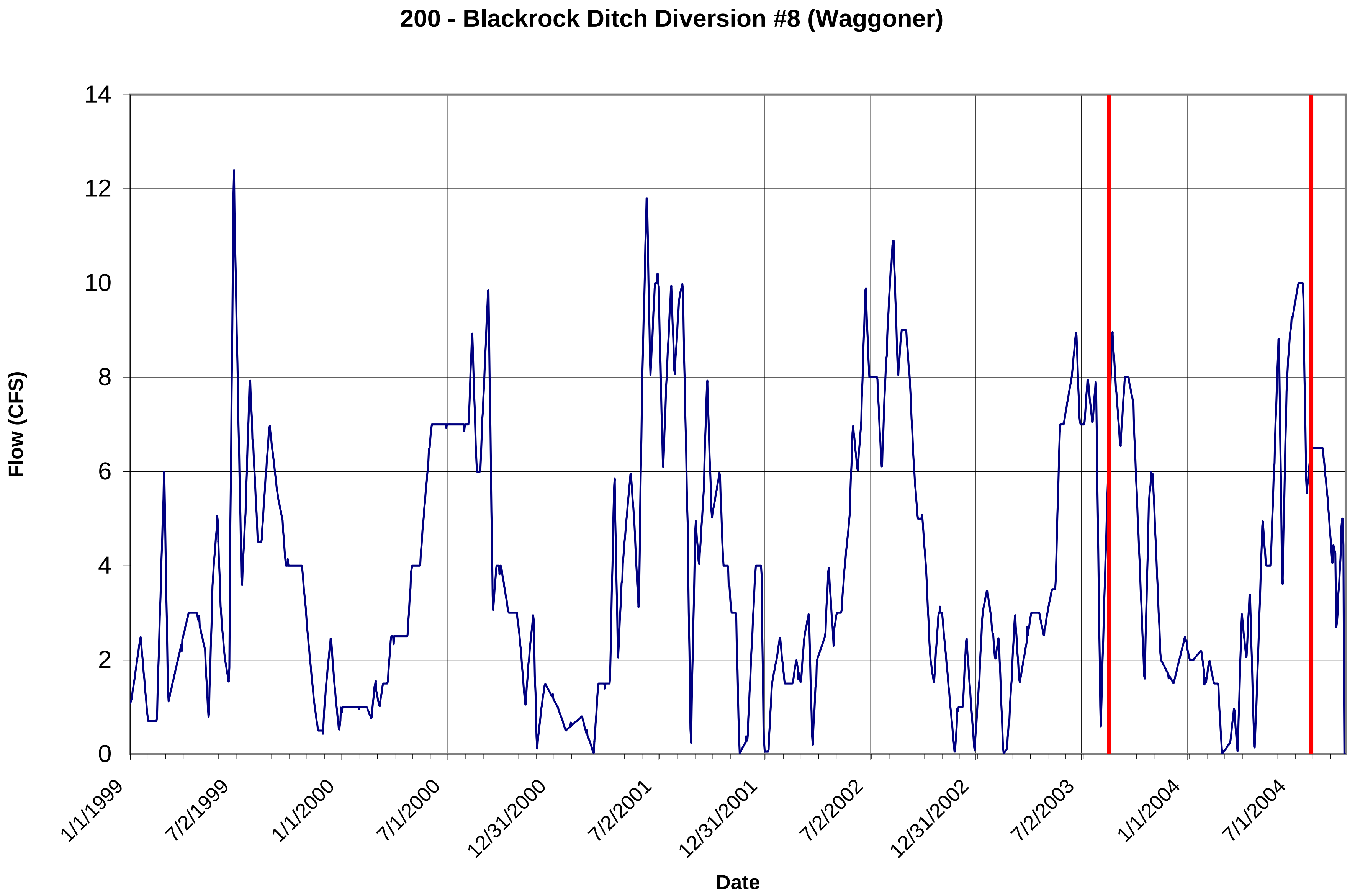

193 - Blackrock Ditch Diversion #1 (Lacey)
Flow (CFS)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

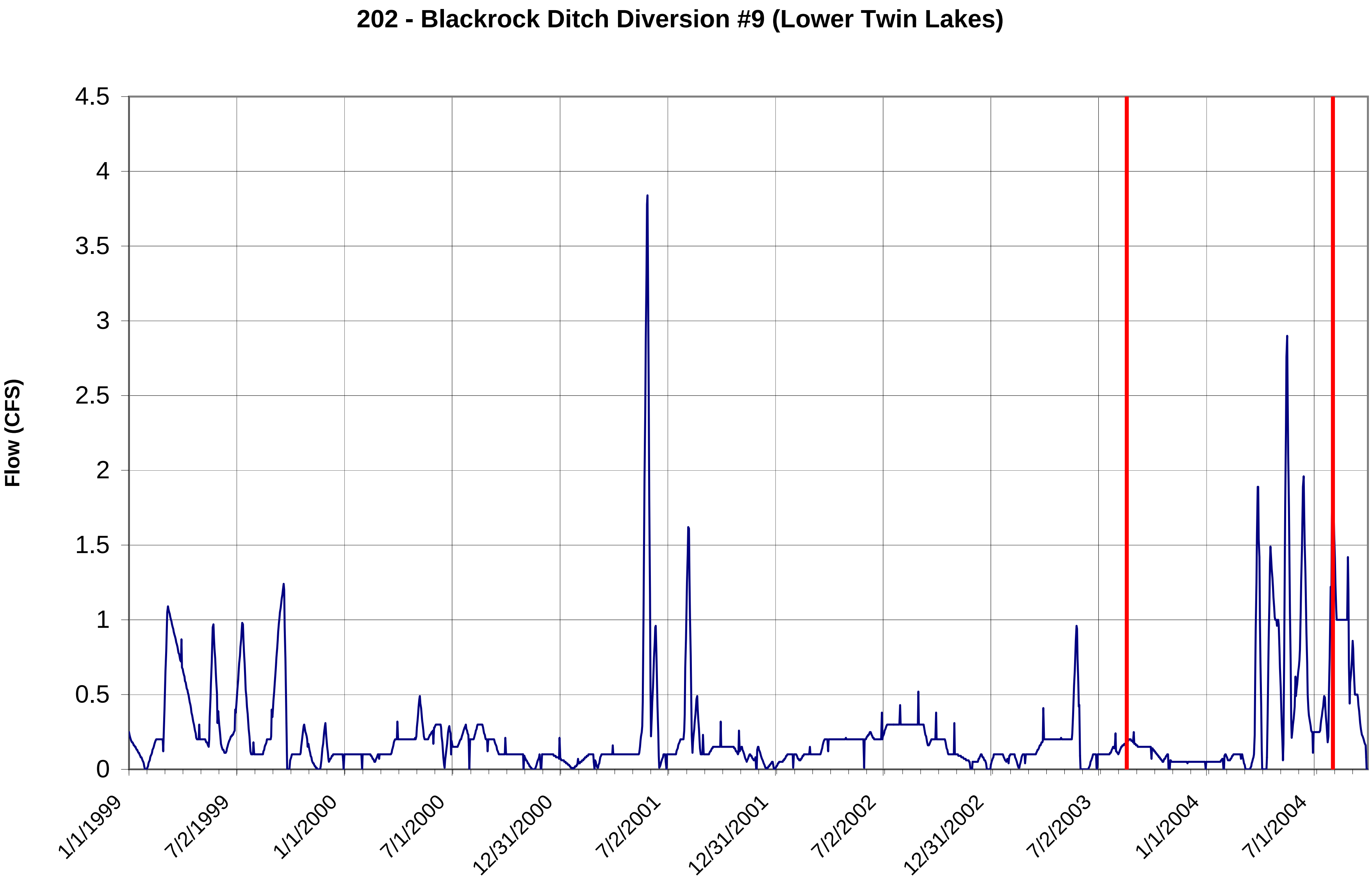
194 - Blackrock Ditch Diversion #2 (Winterton)

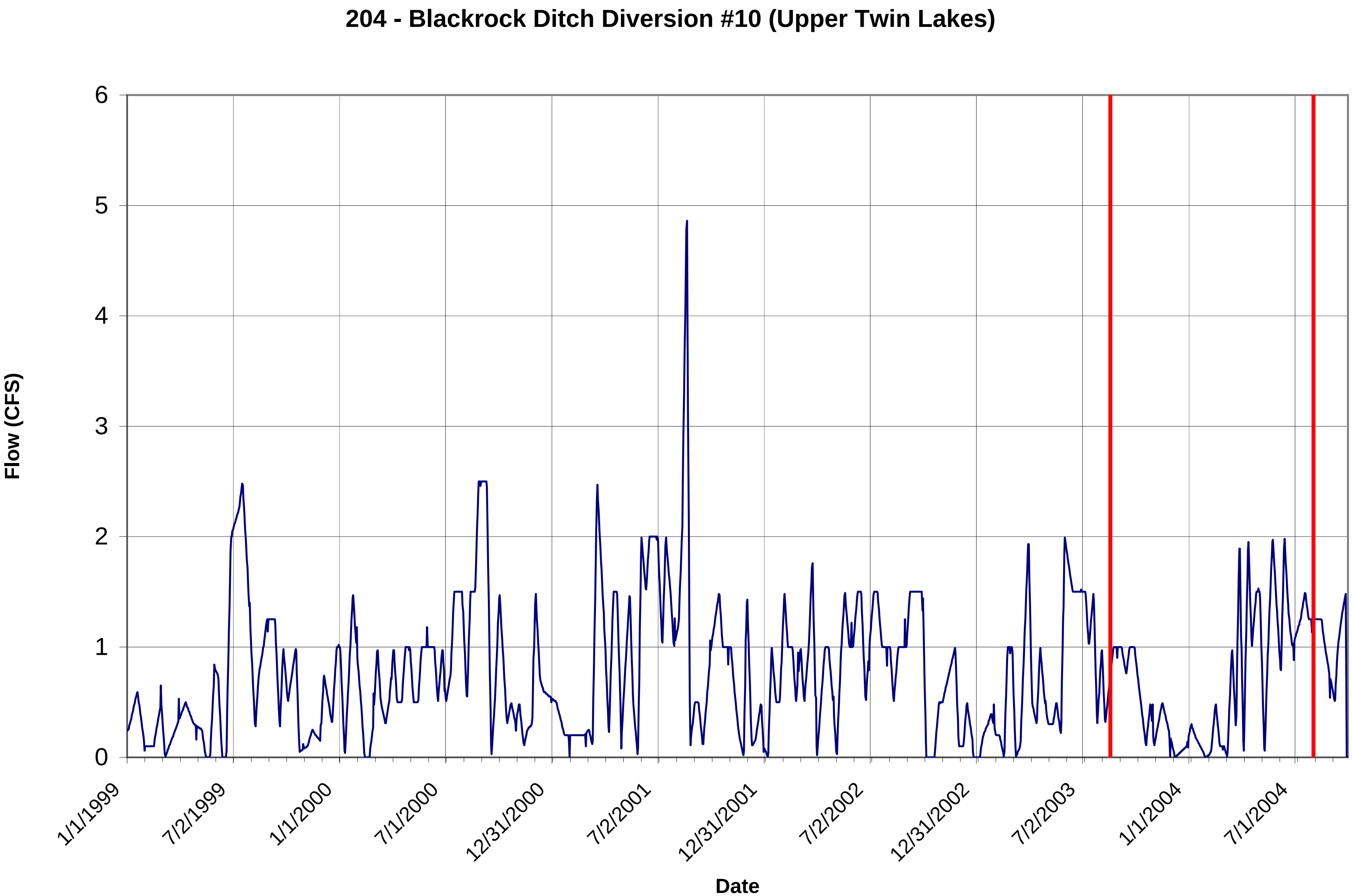


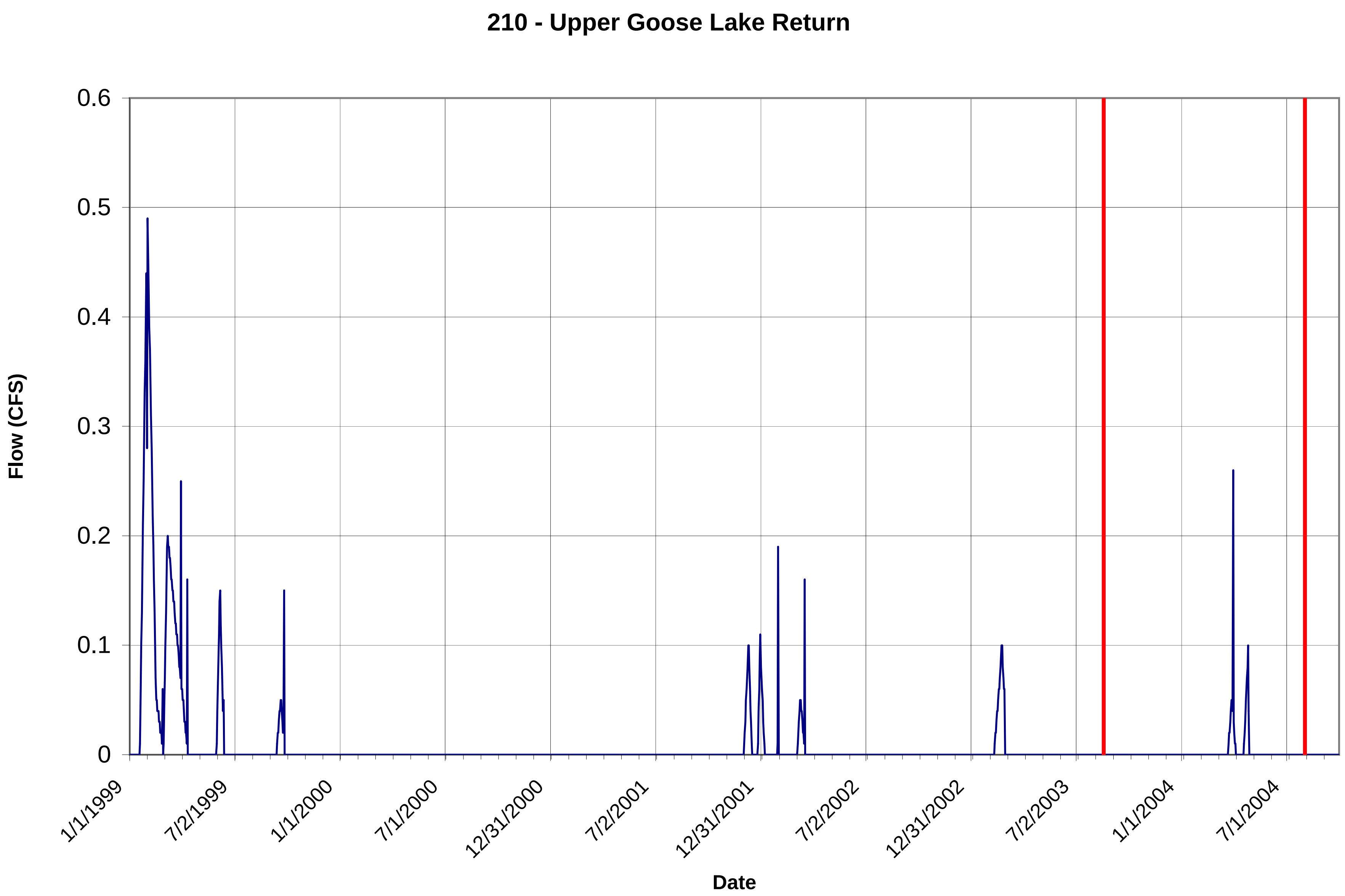

195 - Blackrock Ditch Diversion #3 (Four Corners)
Flow (CFS)
9
8
7
6
5
4
3
2
1
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


196 - Blackrock Ditch Diversion #4 (Drew Slough)
Flow (CFS)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


200 - Blackrock Ditch Diversion #8 (Waggoner)
Flow (CFS)
0
2
4
6
8
10
12
14
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

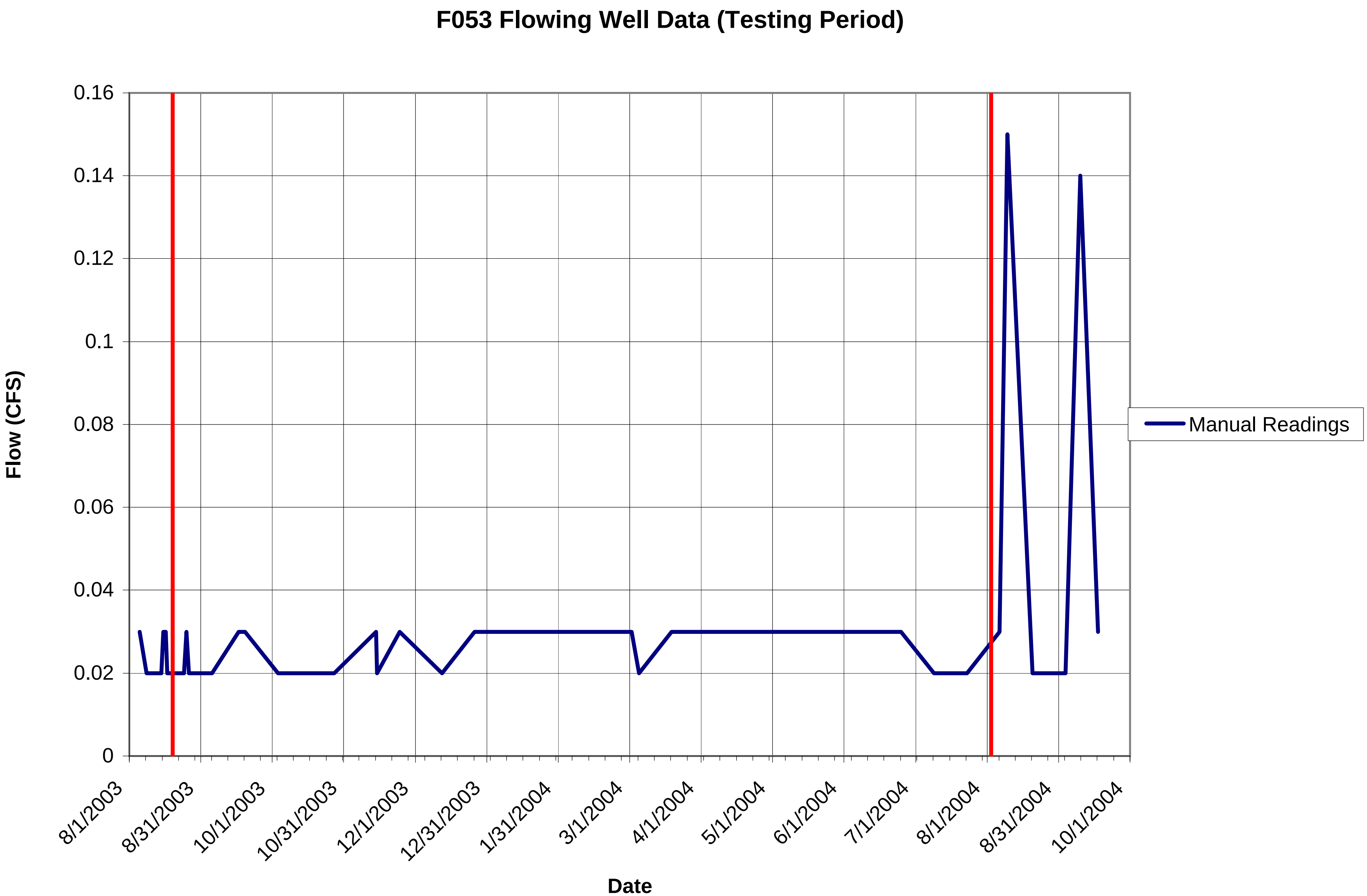

202 - Blackrock Ditch Diversion #9 (Lower Twin Lakes)
Flow (CFS)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

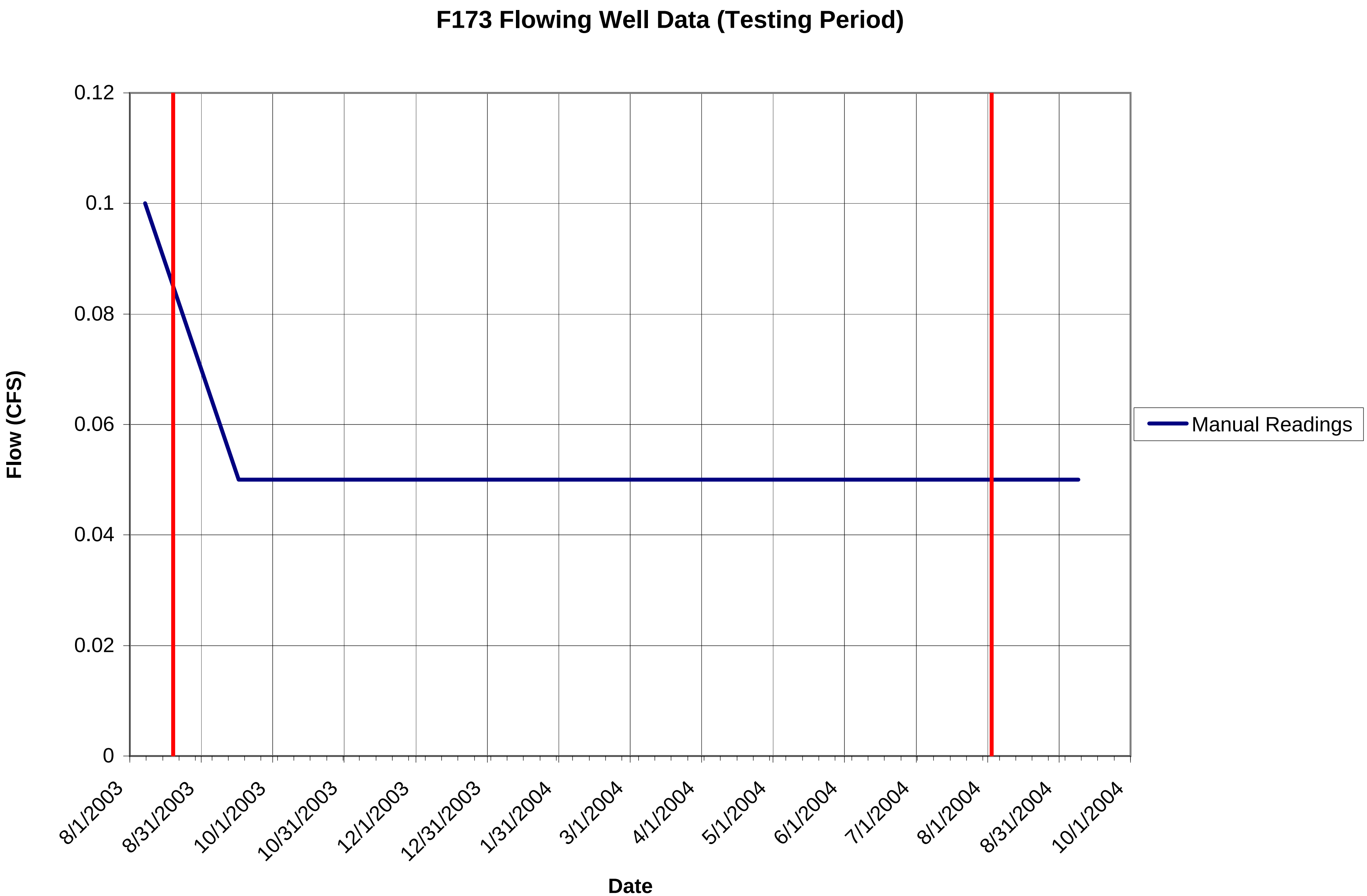

204 - Blackrock Ditch Diversion #10 (Upper Twin Lakes)
Flow (CFS)
0
1
2
3
4
5
6
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



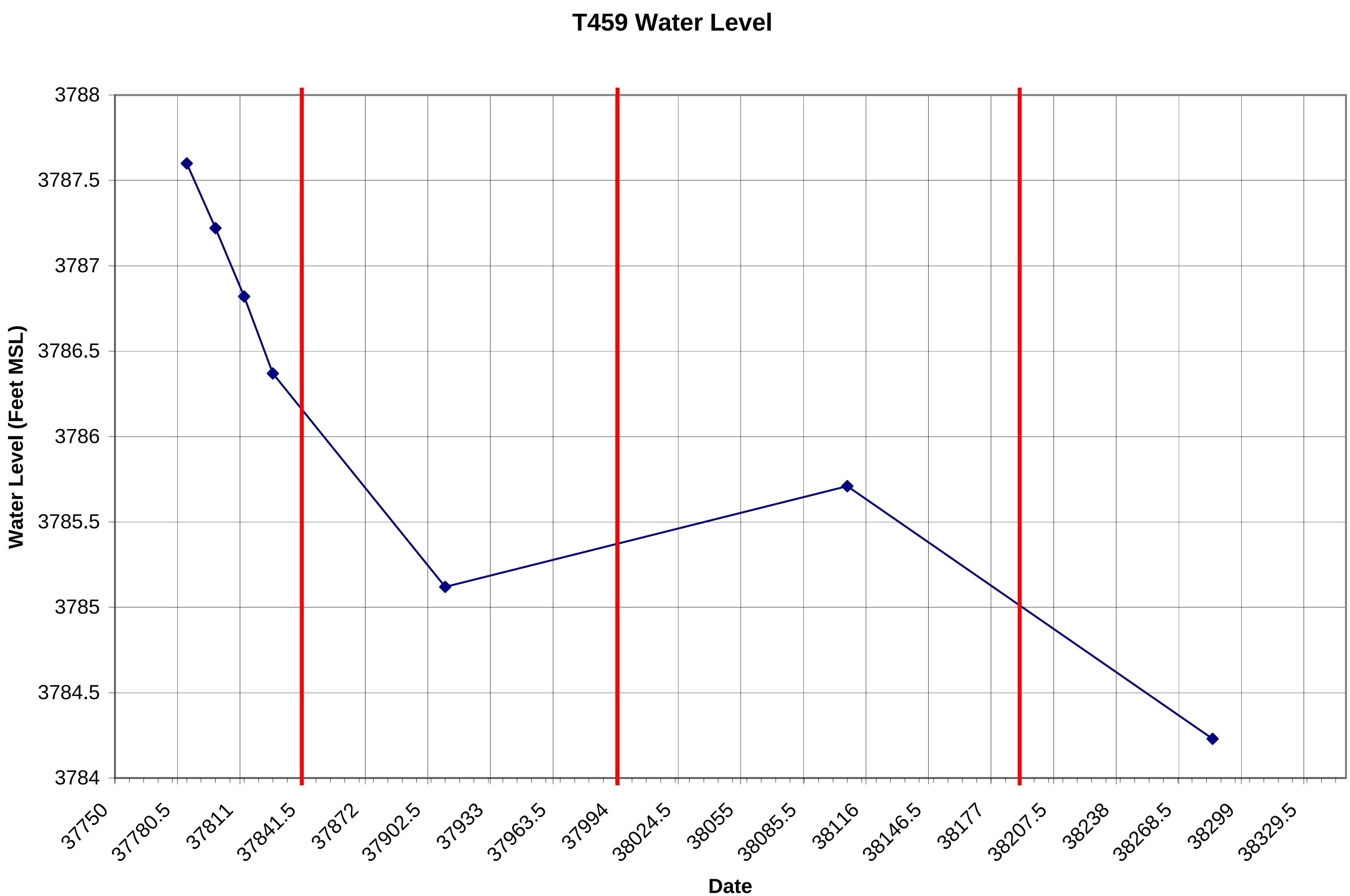
210 - Upper Goose Lake Return
Flow (CFS)
0.6
0.5
0.4
0.3
0.2
0.1
0
1/1/1999
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

APPENDIX B
Detailed, Short-Term Hydrographs (August 2003 – October 2004)

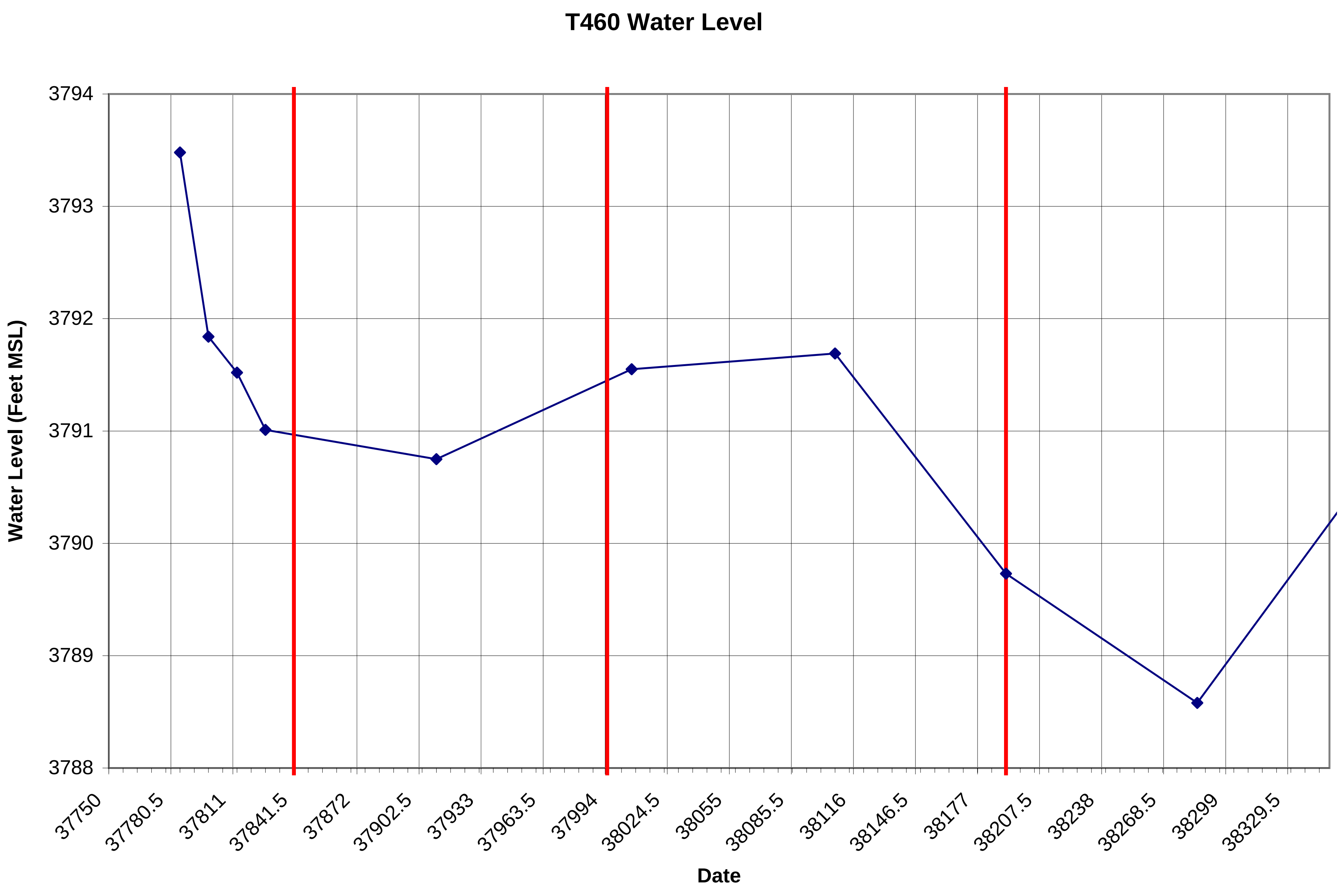

F053 Flowing Well Data (Testing Period)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Flow (CFS)
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Manual Readings

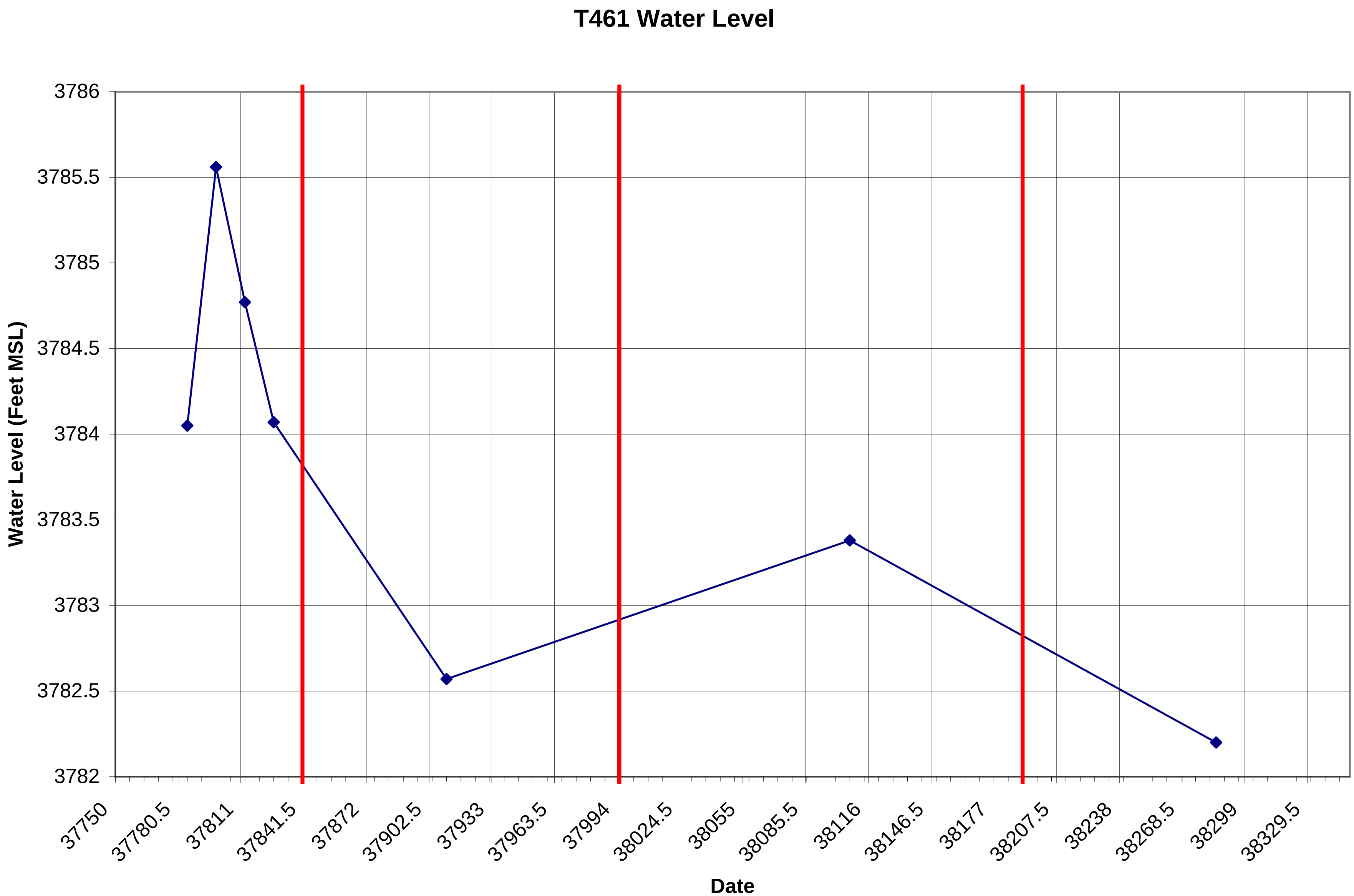


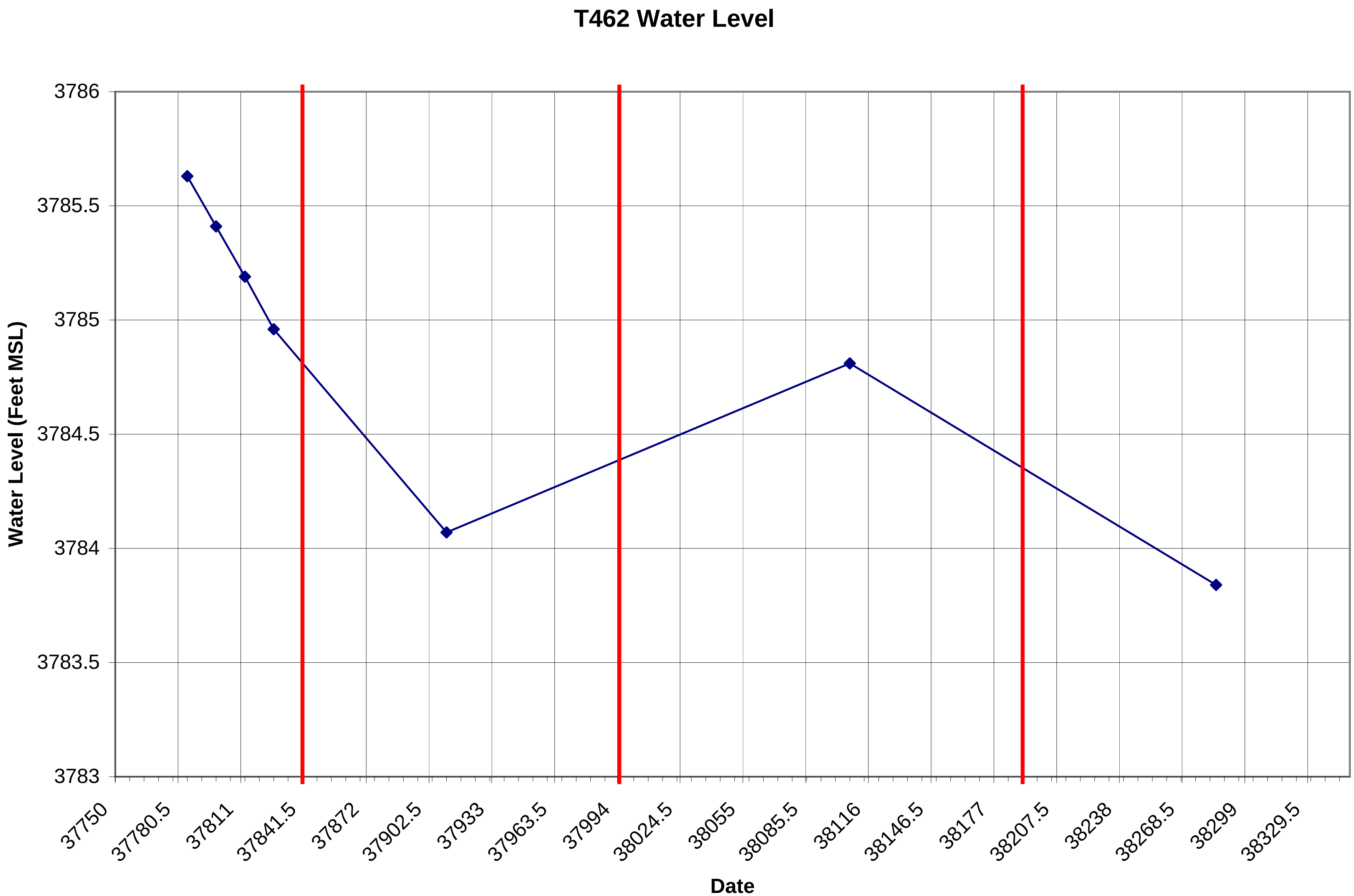
F173 Flowing Well Data (Testing Period)
Flow (CFS)
0.12
0.1
0.08
0.06
0.04
0.02
0
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Manual Readings



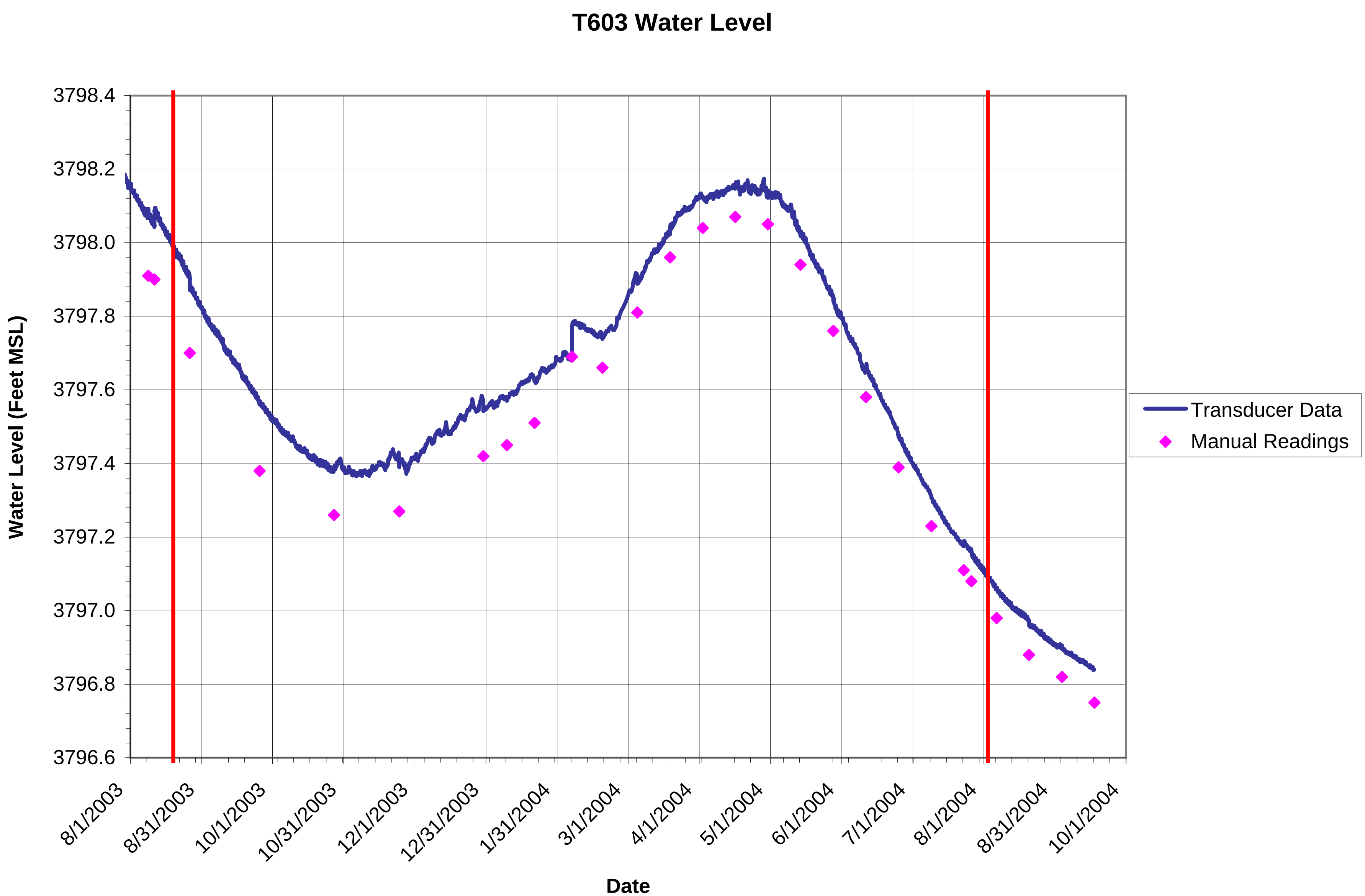
T459 Water Level
Water Level (Feet MSL)
3788
3787.5
3787
3786.5
3786
3785.5
3785
3784.5
3784
37750
37780.5
37811
37841.5
37872
37902.5
37933
37963.5
37994
38024.5
38055
38085.5
38116
38146.5
38177
38207.5
38238
38268.5
38299
38329.5
Date


T460 Water Level
Water Level (Feet MSL)
3794
3793
3792
3791
3790
3789
3788
37750
37780.5
37811
37841.5
37872
37902.5
37933
37963.5
37994
38024.5
38055
38085.5
38116
38146.5
38177
38207.5
38238
38268.5
38299
38329.5
Date

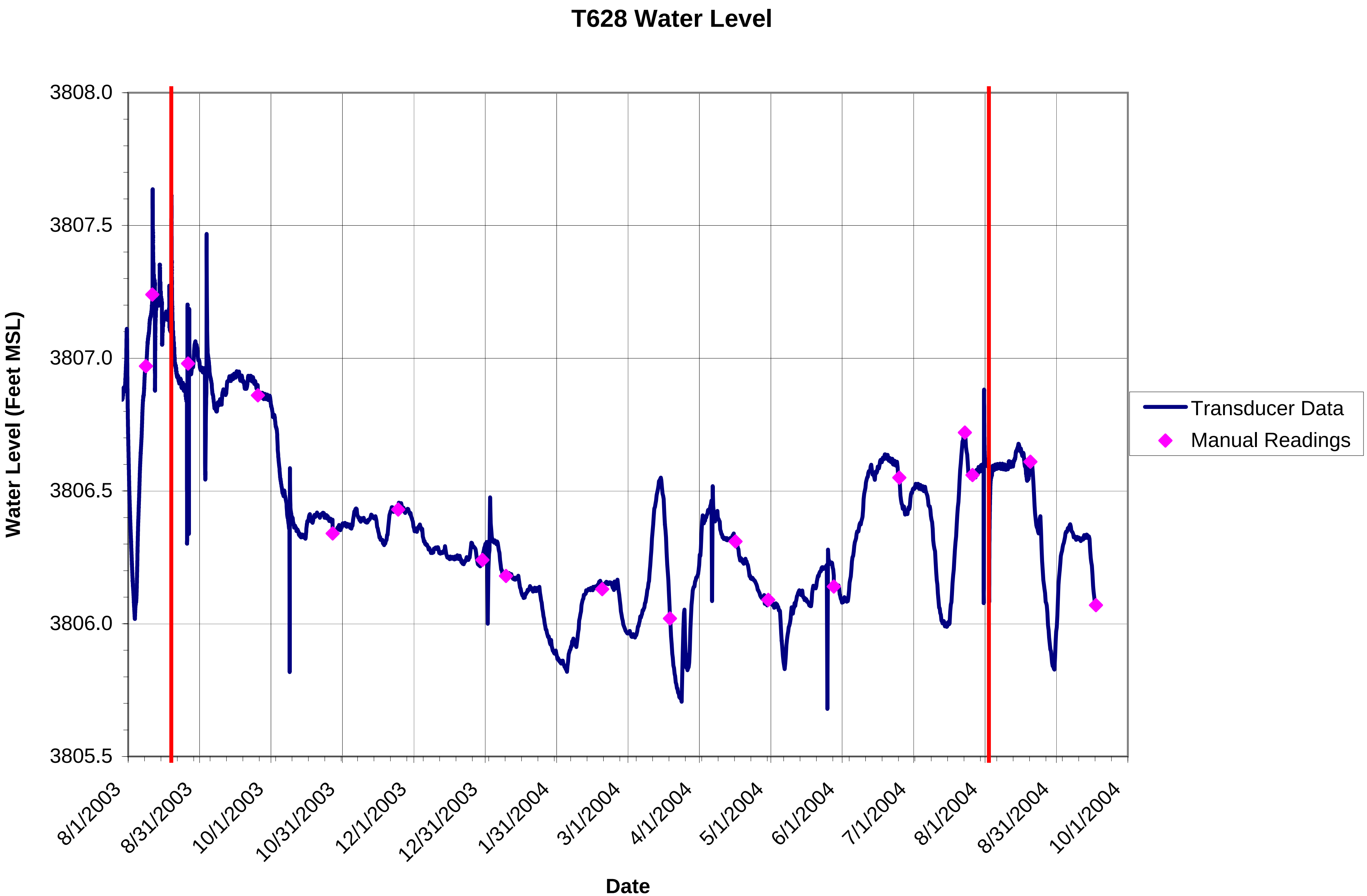

T461 Water Level
Water Level (Feet MSL)
3786
3785.5
3785
3784.5
3784
3783.5
3783
3782.5
3782
37750
37780.5
37811
37841.5
37872
37902.5
37933
37963.5
37994
38024.5
38055
38085.5
38116
38146.5
38177
38207.5
38238
38268.5
38299
38329.5
Date



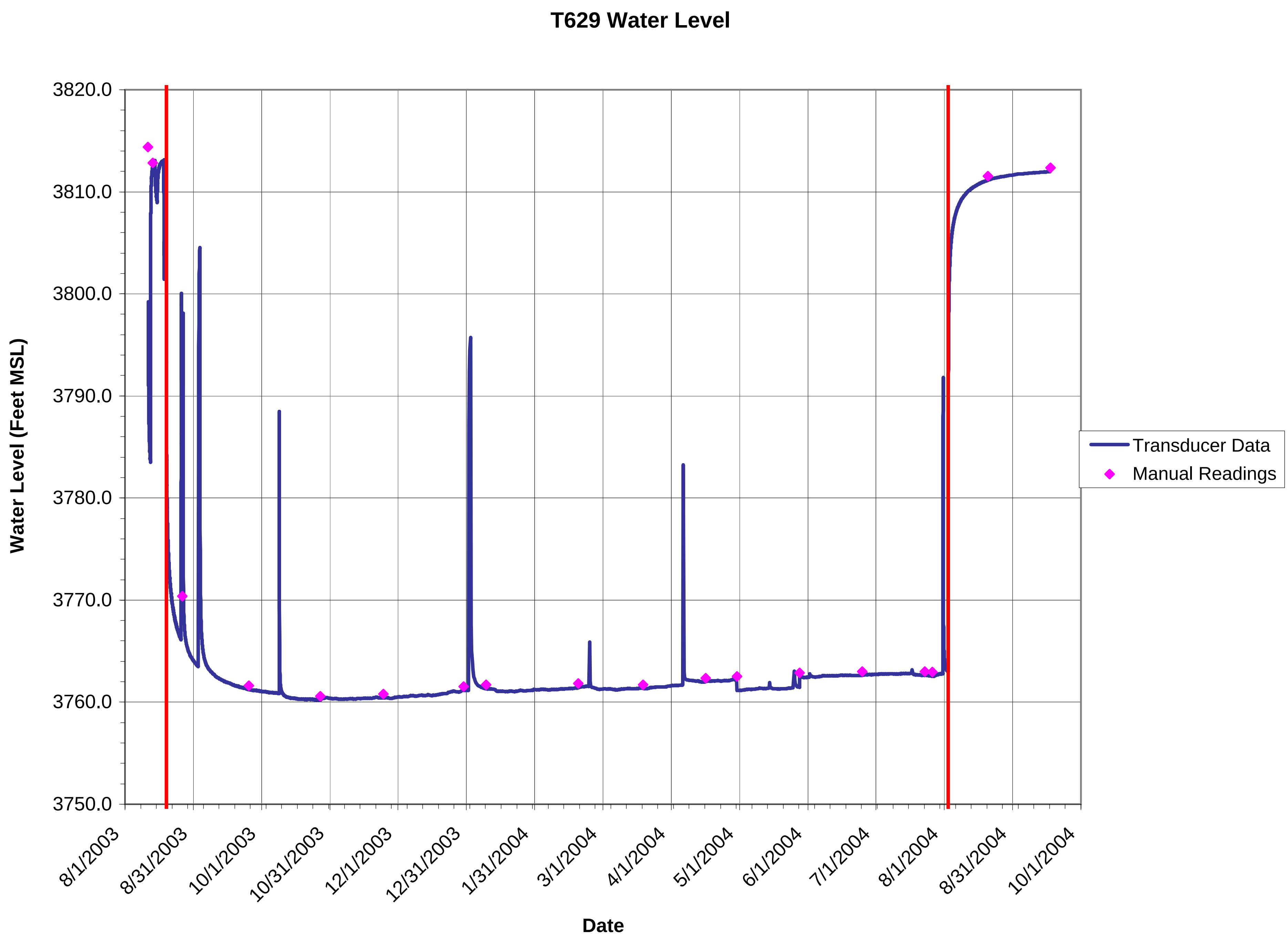
T462 Water Level
Water Level (Feet MSL)
3786
3785.5
3785
3784.5
3784
3783.5
3783
37750
37780.5
37811
37841.5
37872
37902.5
37933
37963.5
37994
38024.5
38055
38085.5
38116
38146.5
38177
38207.5
38238
38268.5
38299
38329.5
Date



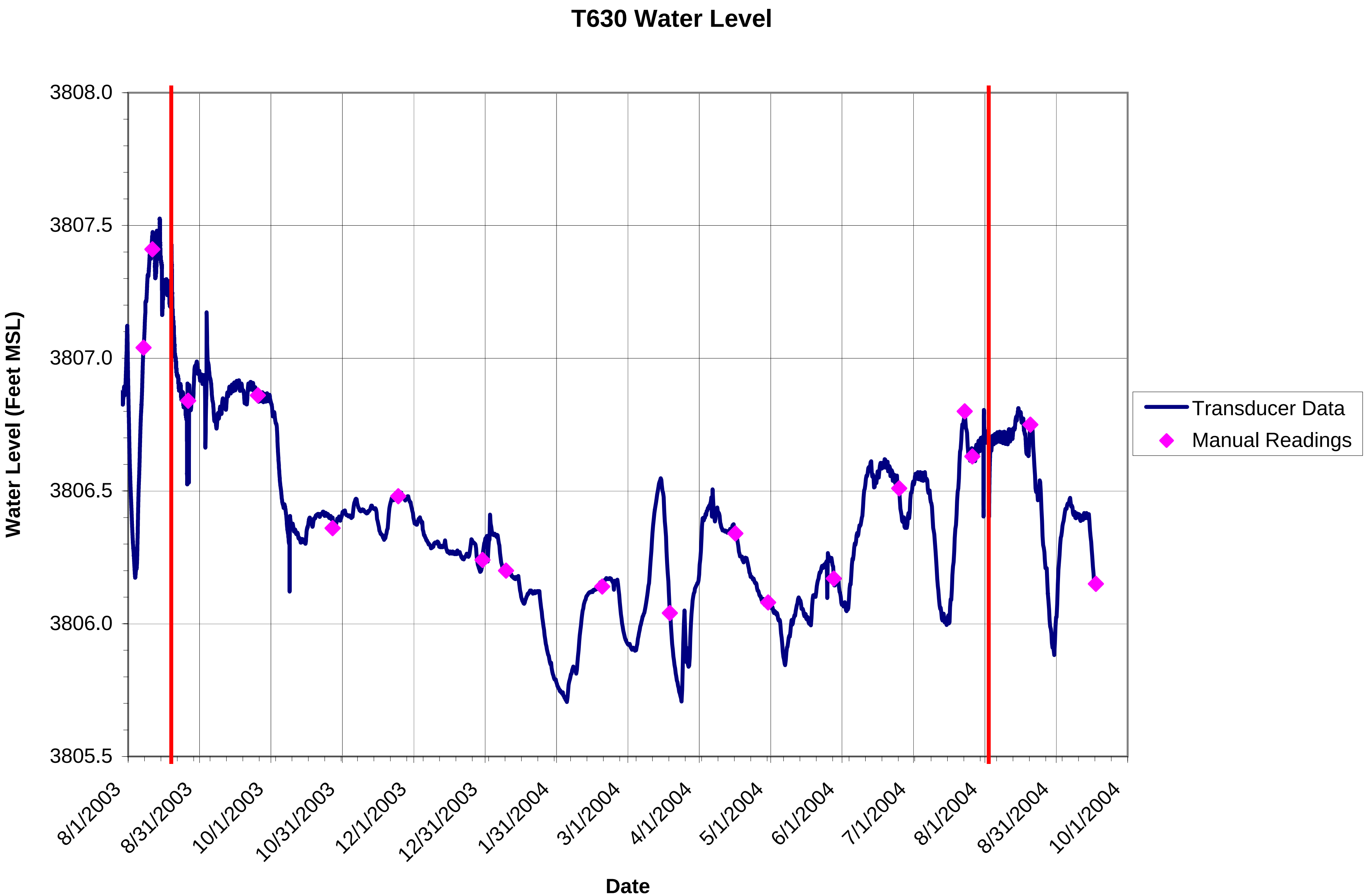
T603 Water Level
3798.4
3798.2
3798.0
3797.8
3797.6
3797.4
3797.2
3797.0
3796.8
3796.6
Water Level (Feet MSL)
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

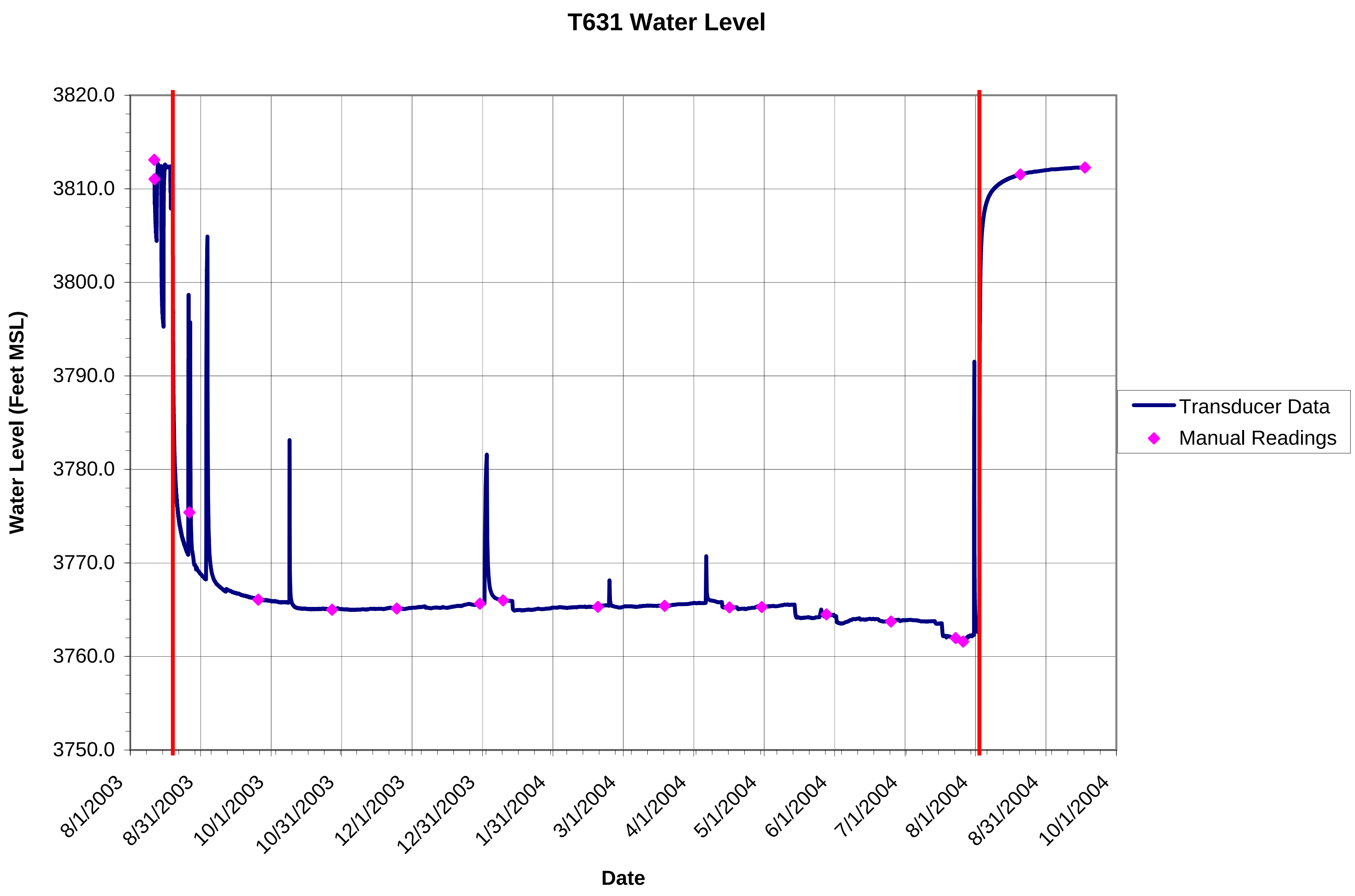


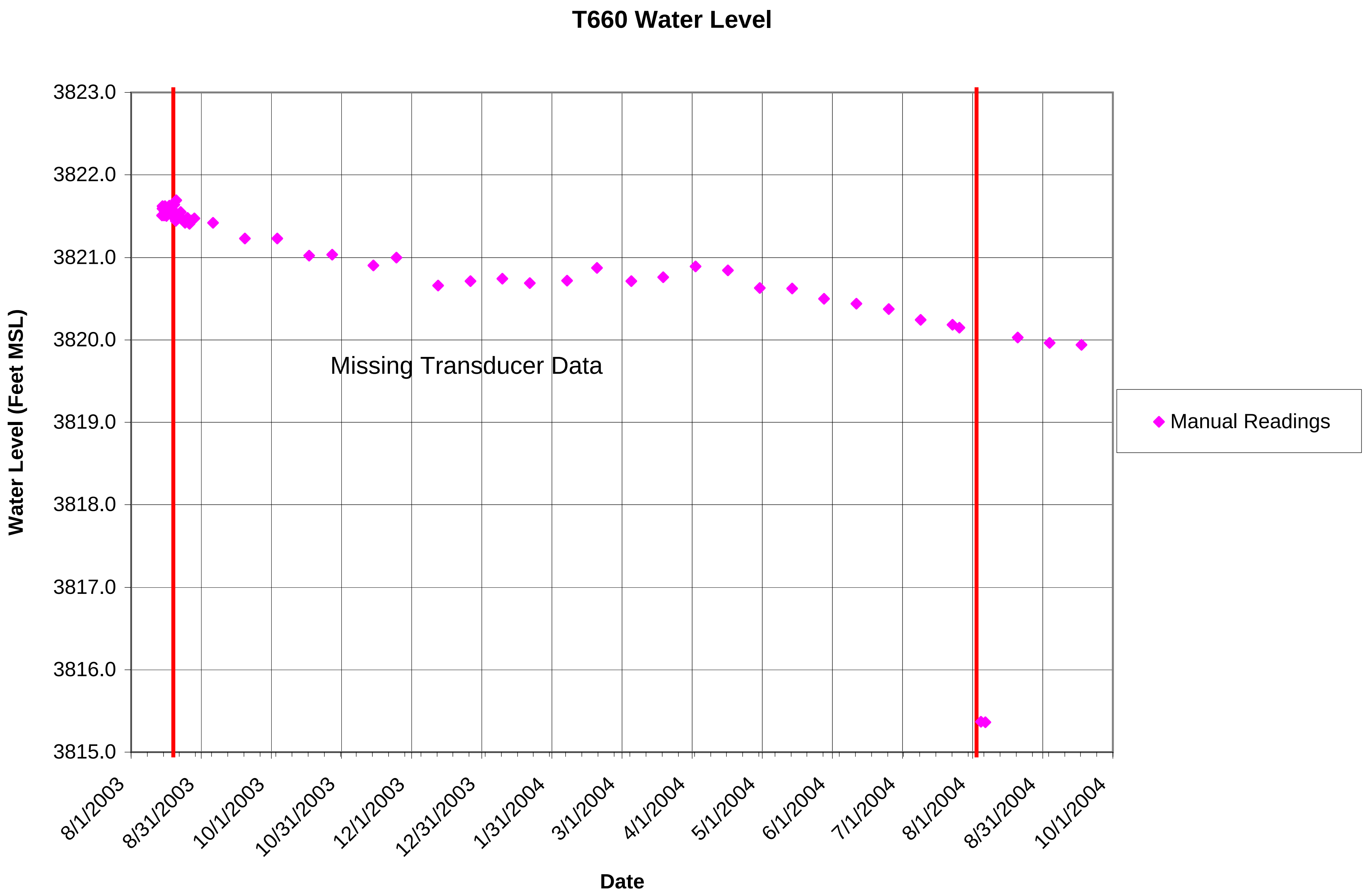
T628 Water Level
Water Level (Feet MSL)
3808.0
3807.5
3807.0
3806.5
3806.0
3805.5
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings



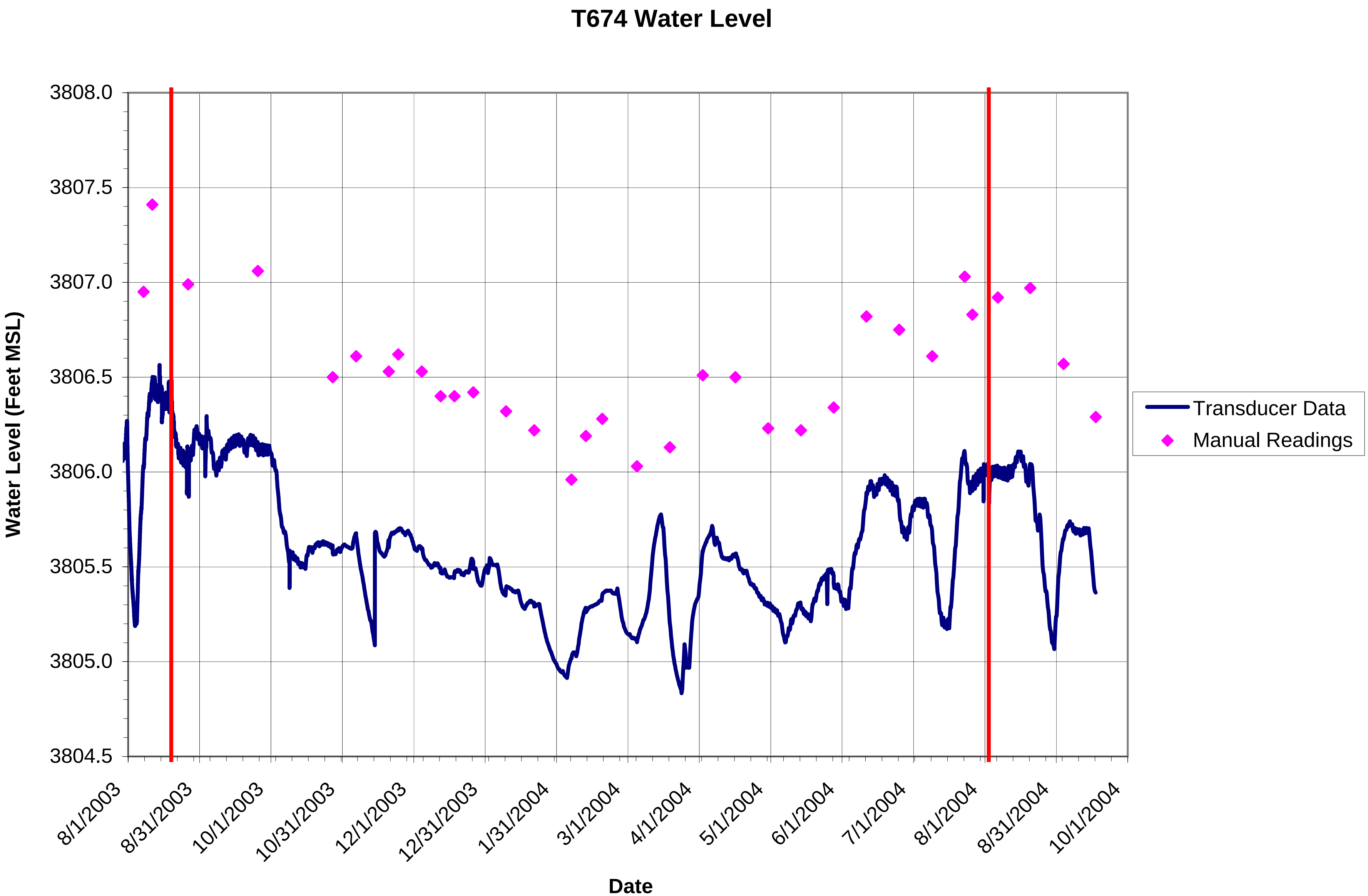
T629 Water Level
Water Level (Feet MSL)
3820.0
3810.0
3800.0
3790.0
3780.0
3770.0
3760.0
3750.0
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings


T630 Water Level
Water Level (Feet MSL)
3808.0
3807.5
3807.0
3806.5
3806.0
3805.5
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

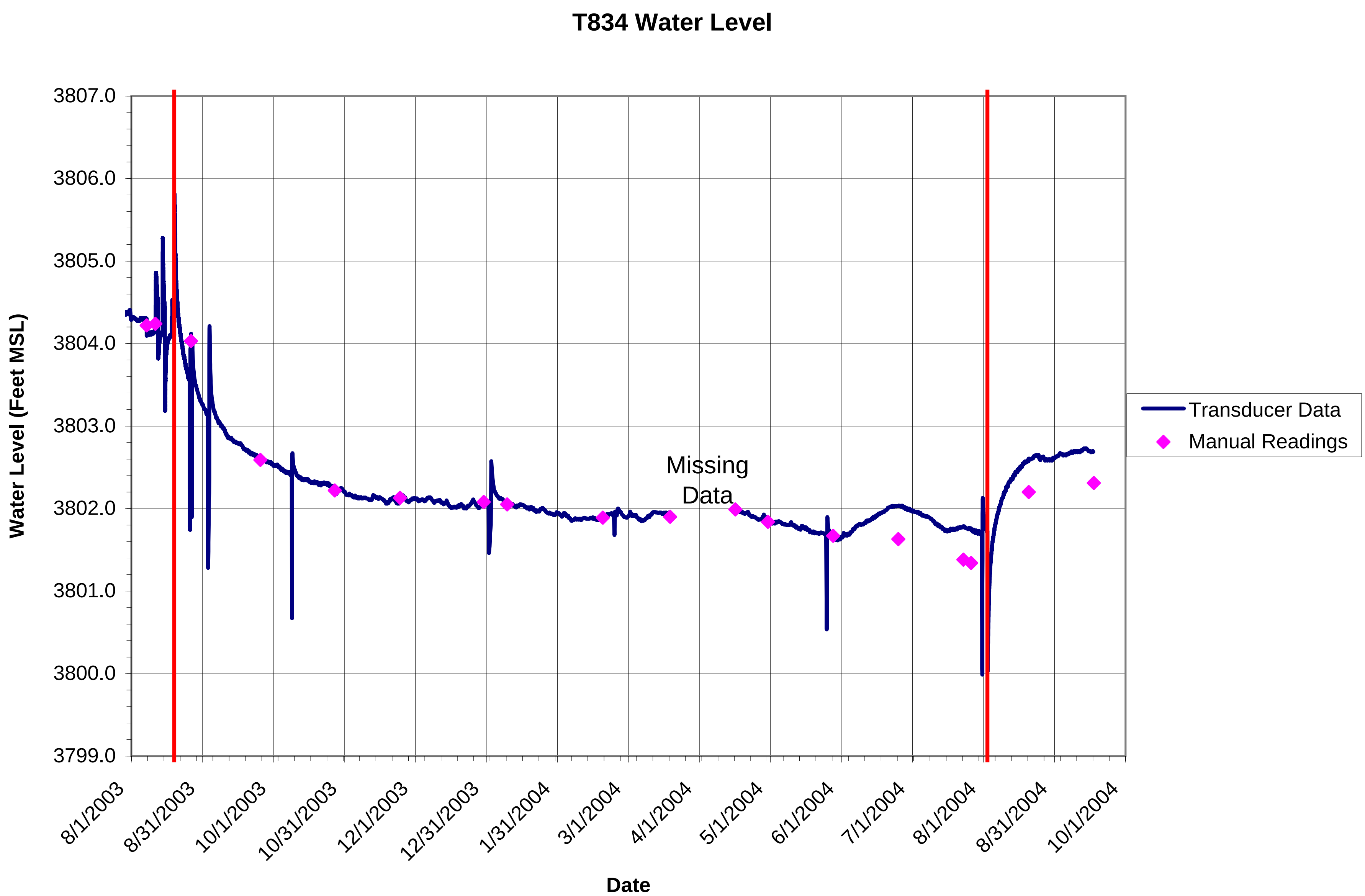

T631 Water Level
Water Level (Feet MSL)
3820.0
3810.0
3800.0
3790.0
3780.0
3770.0
3760.0
3750.0
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

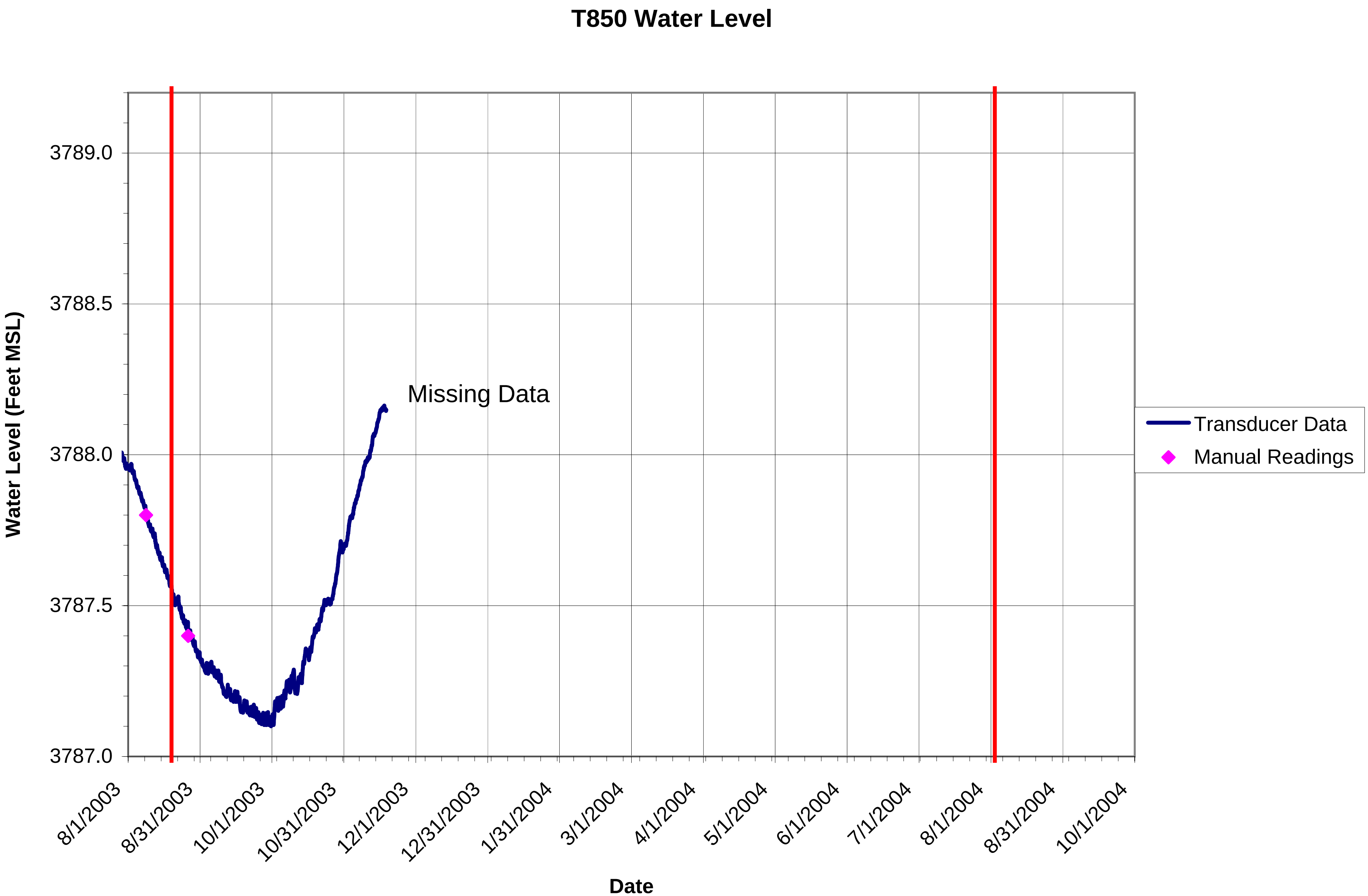


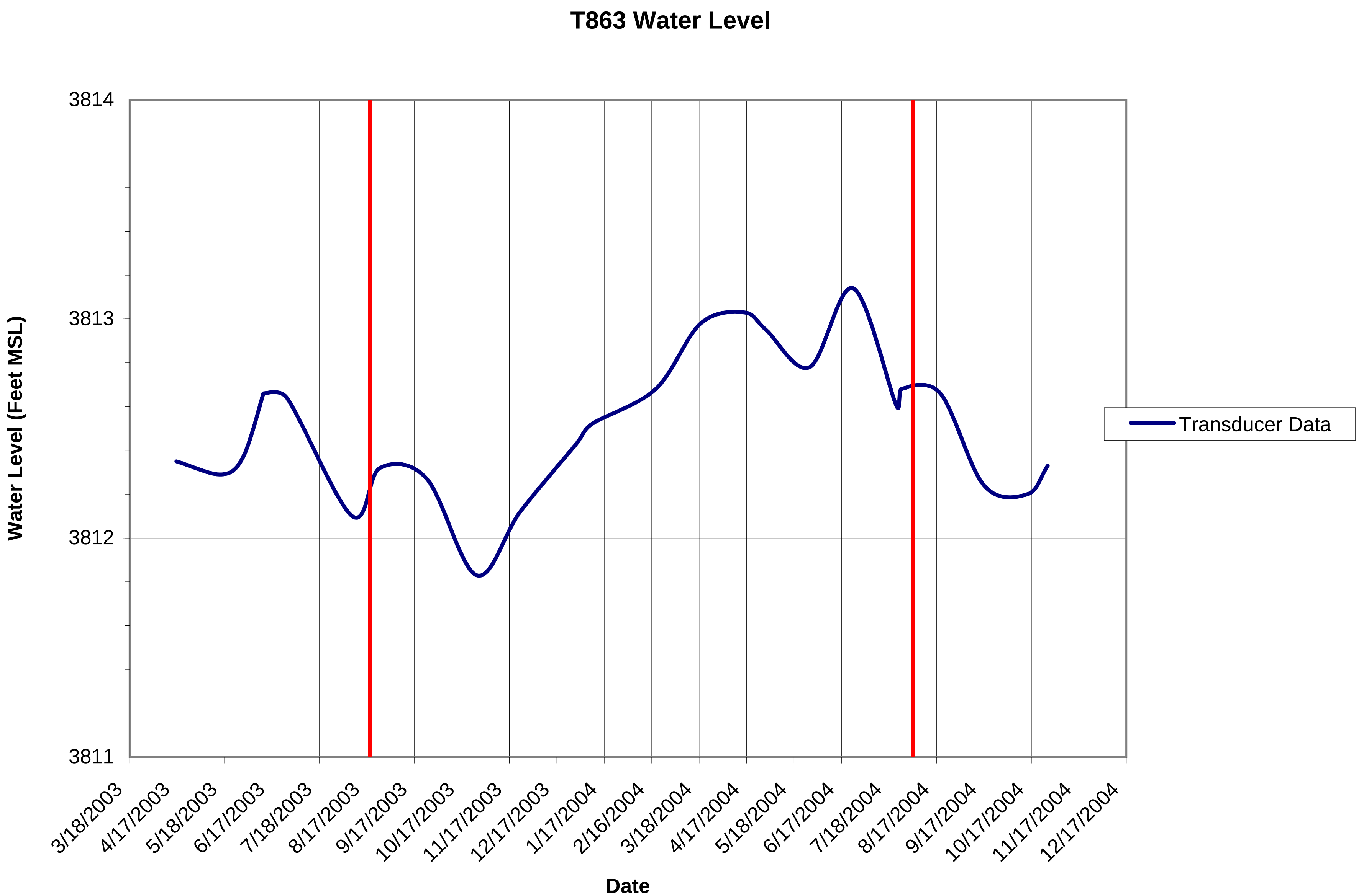
T660 Water Level
Water Level (Feet MSL)
3823.0
3822.0
3821.0
3820.0
3819.0
3818.0
3817.0
3816.0
3815.0
Missing Transducer Data
Manual Readings
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date



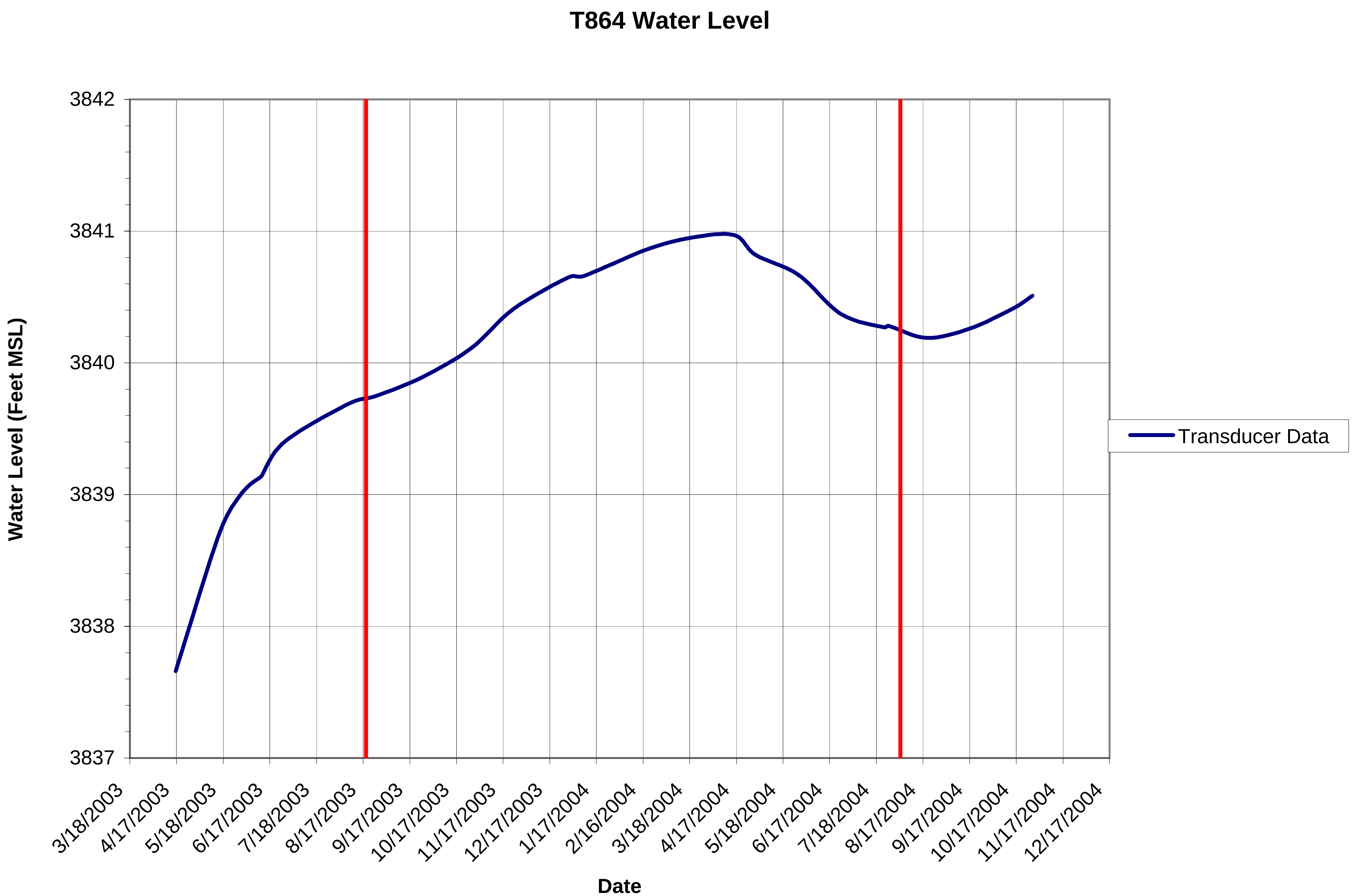
T674 Water Level
Water Level (Feet MSL)
3808.0
3807.5
3807.0
3806.5
3806.0
3805.5
3805.0
3804.5
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

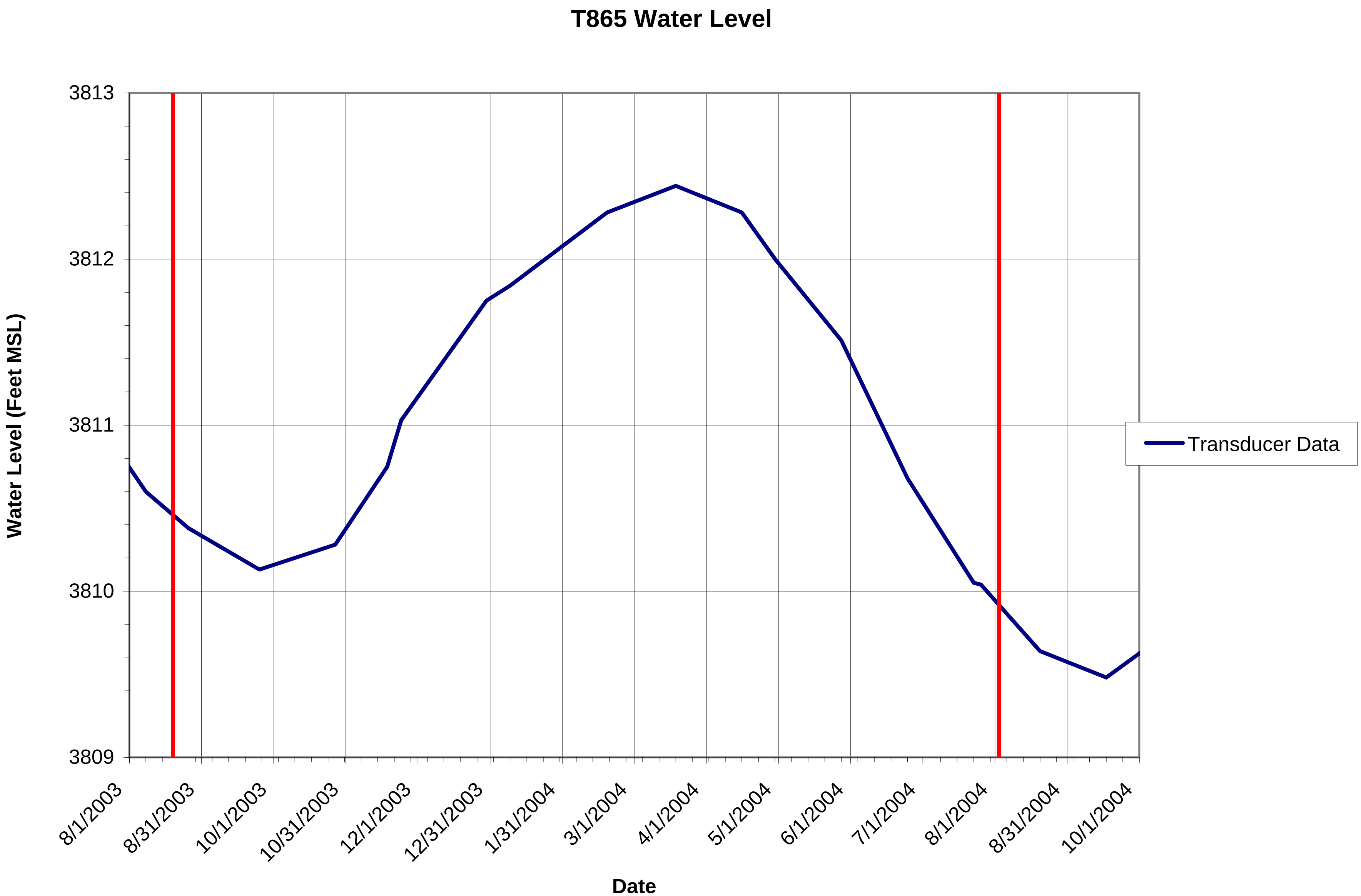

T834 Water Level
Water Level (Feet MSL)
3807.0
3806.0
3805.0
3804.0
3803.0
3802.0
3801.0
3800.0
3799.0
Missing
Data
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

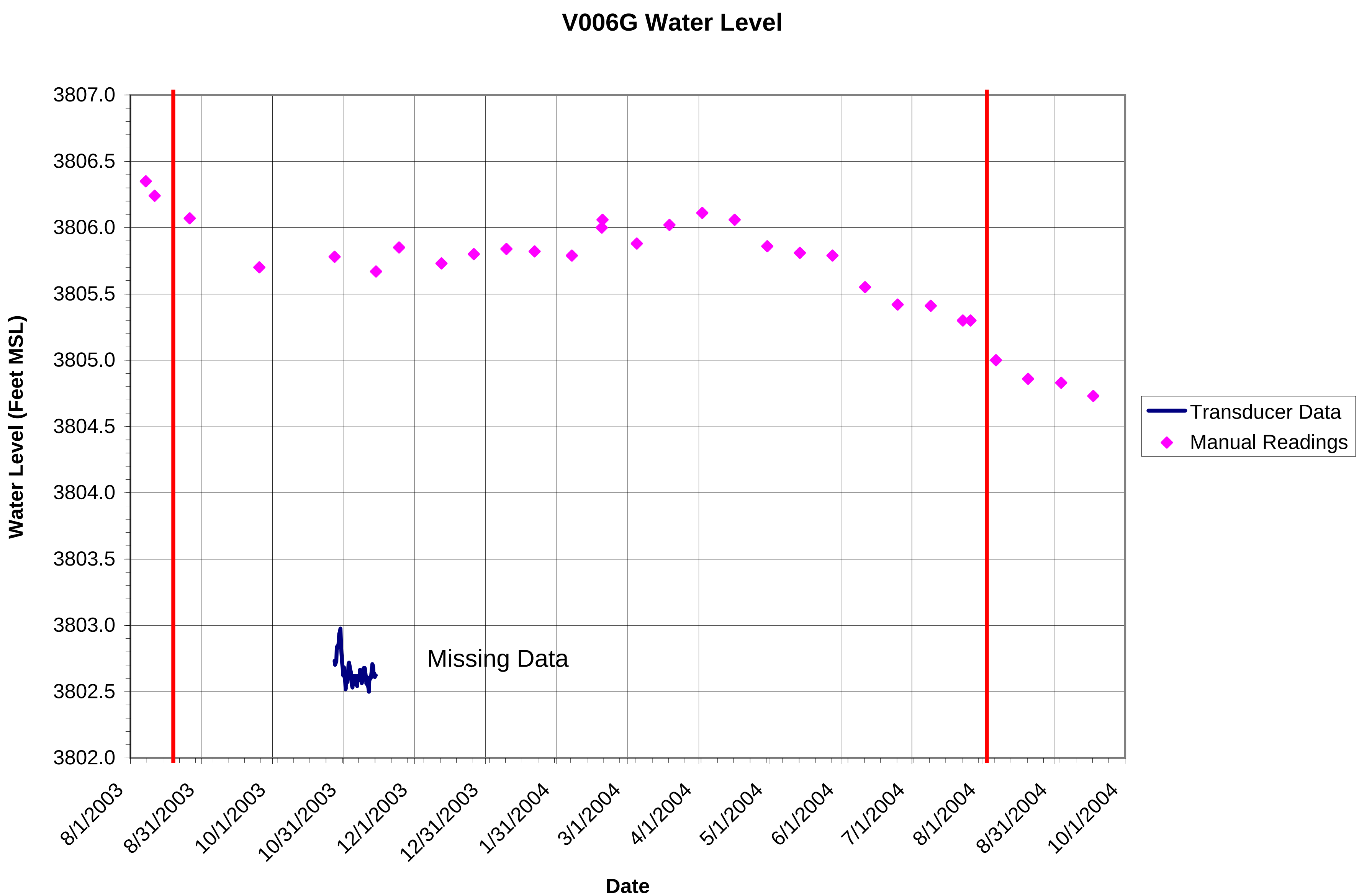

T850 Water Level
Water Level (Feet MSL)
3789.0
3788.5
3788.0
3787.5
3787.0
Missing Data
Transducer Data
Manual Readings
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date



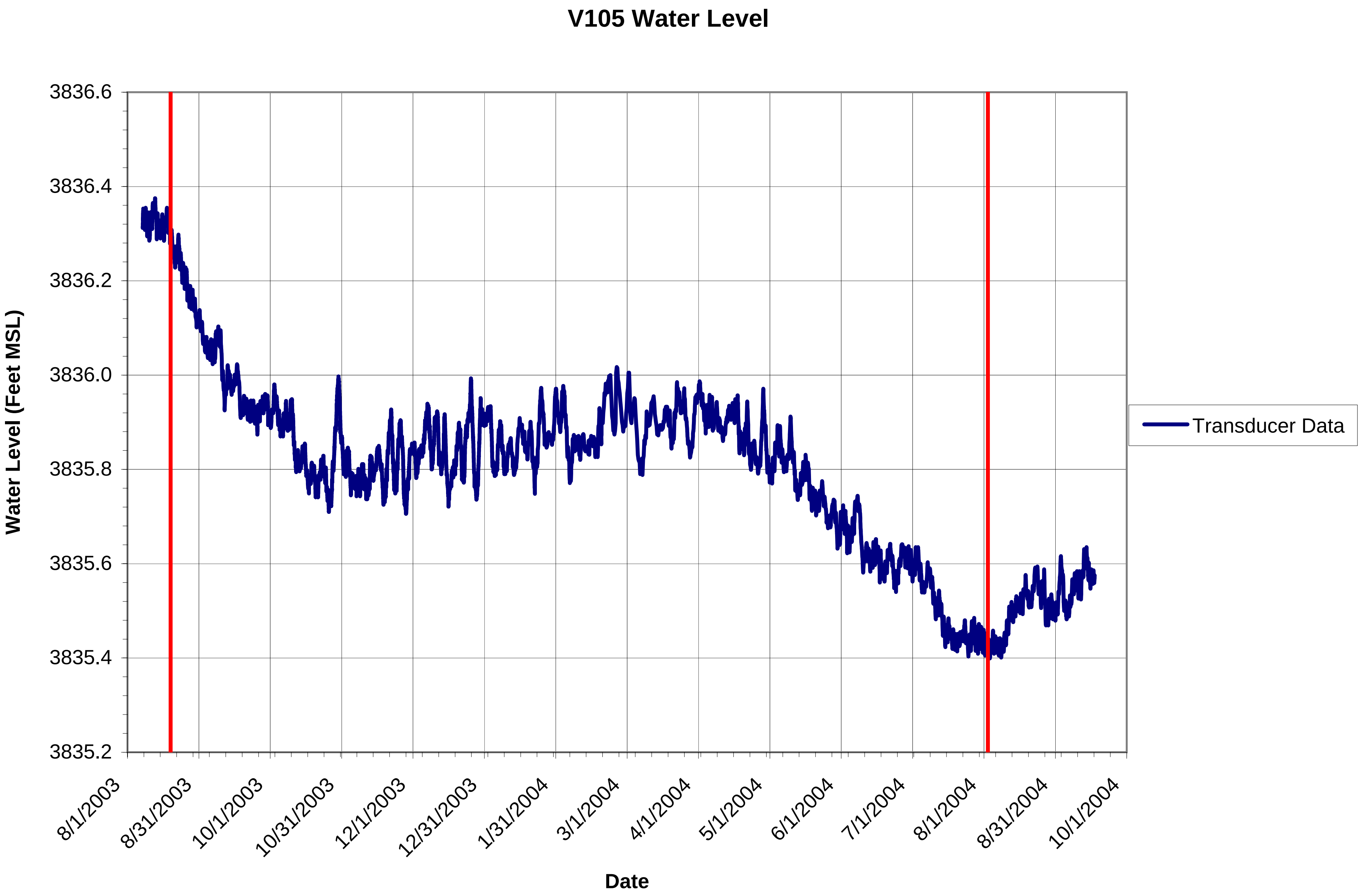
T863 Water Level
Water Level (Feet MSL)
3814
3813
3812
3811
3/18/2003
4/17/2003
5/18/2003
6/17/2003
7/18/2003
8/17/2003
9/17/2003
10/17/2003
11/17/2003
12/17/2003
1/17/2004
2/16/2004
3/18/2004
4/17/2004
5/18/2004
6/17/2004
7/18/2004
8/17/2004
9/17/2004
10/17/2004
11/17/2004
12/17/2004
Date
Transducer Data


T864 Water Level
Water Level (Feet MSL)
3842
3841
3840
3839
3838
3837
3/18/2003
4/17/2003
5/18/2003
6/17/2003
7/18/2003
8/17/2003
9/17/2003
10/17/2003
11/17/2003
12/17/2003
1/17/2004
2/16/2004
3/18/2004
4/17/2004
5/18/2004
6/17/2004
7/18/2004
8/17/2004
9/17/2004
10/17/2004
11/17/2004
12/17/2004
Date
Transducer Data

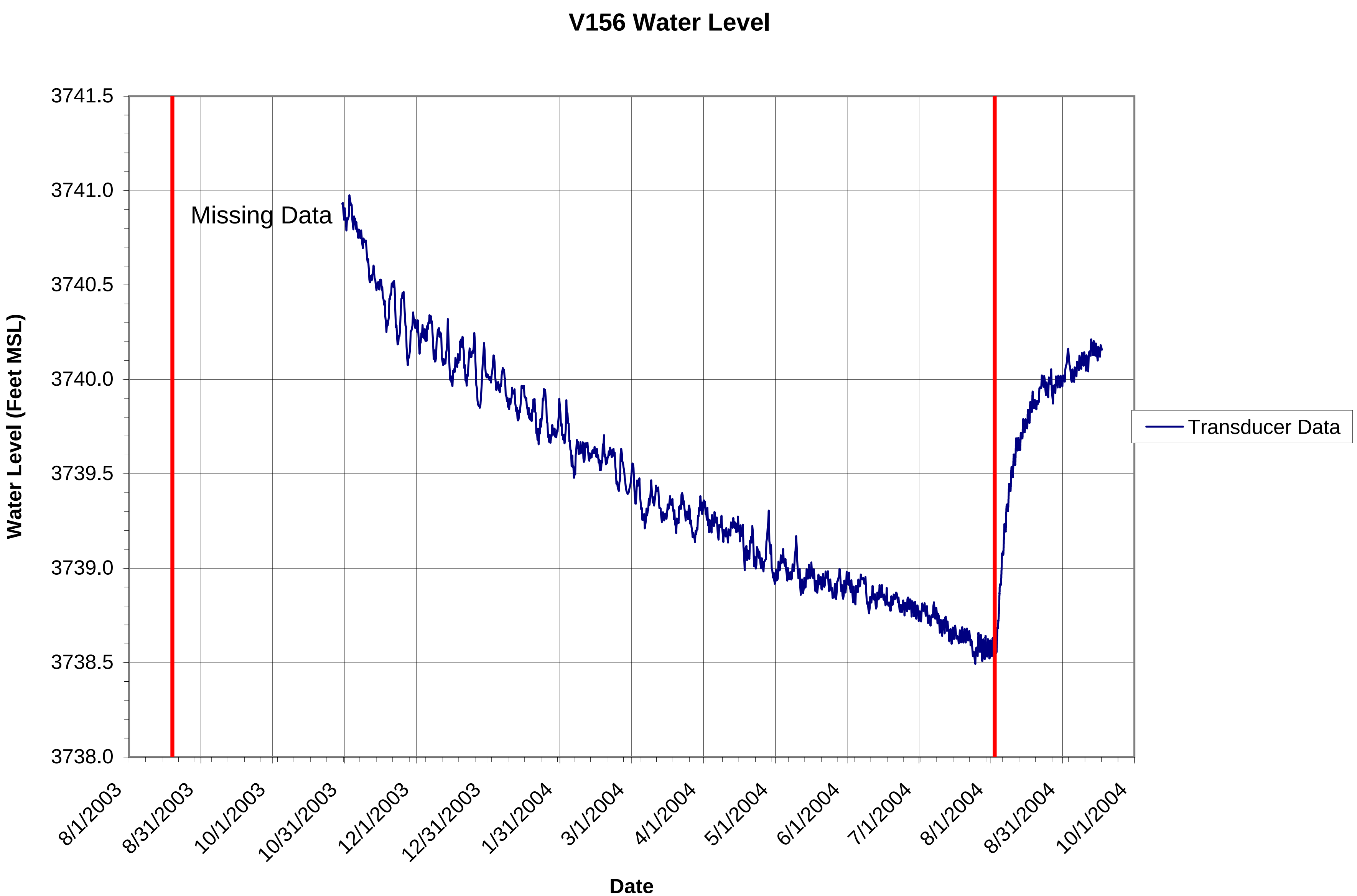

T865 Water Level
Water Level (Feet MSL)
3813
3812
3811
3810
3809
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data

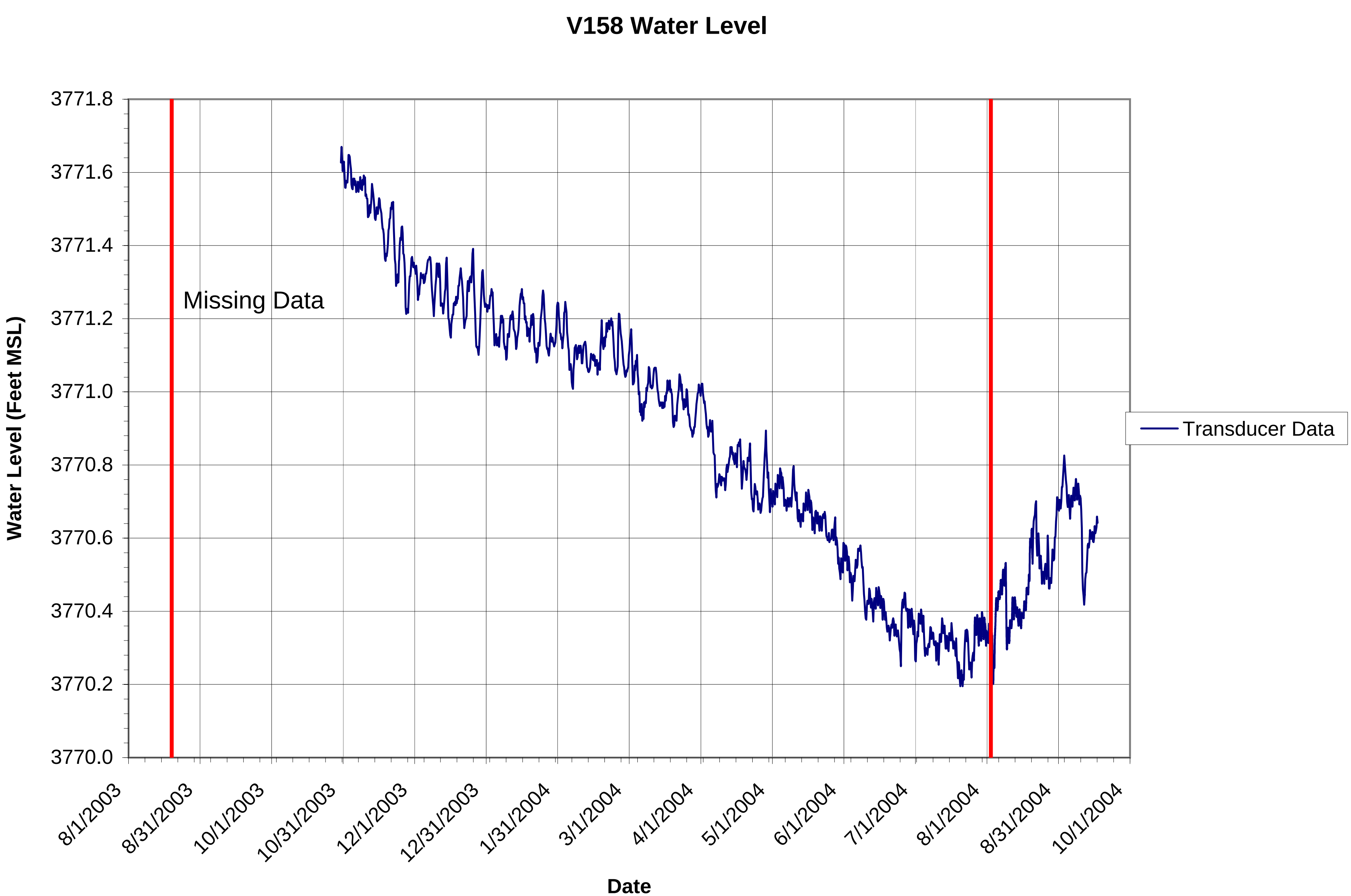


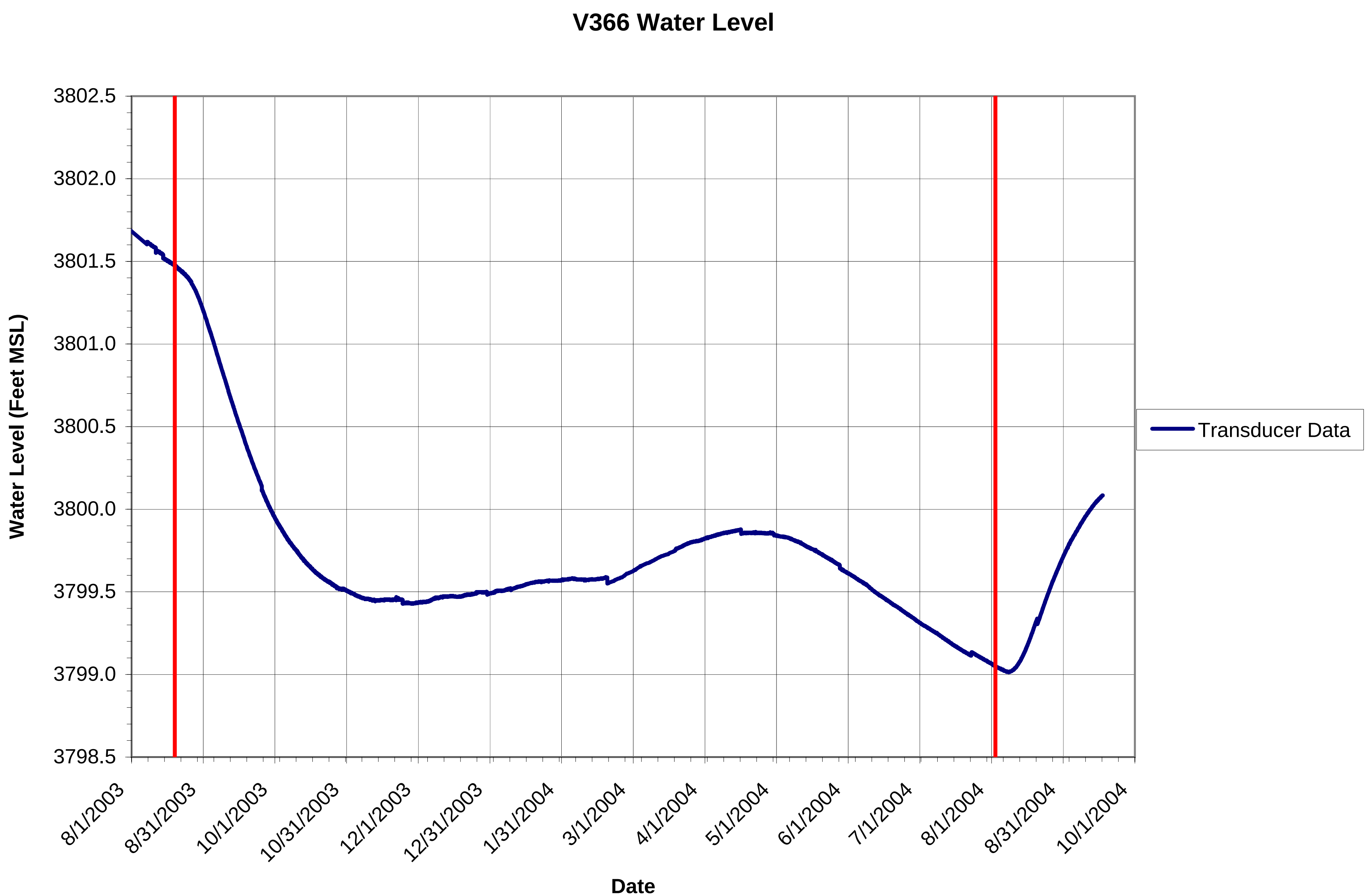
V006G Water Level
Water Level (Feet MSL)
3807.0
3806.5
3806.0
3805.5
3805.0
3804.5
3804.0
3803.5
3803.0
3802.5
3802.0
Missing Data
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data
Manual Readings

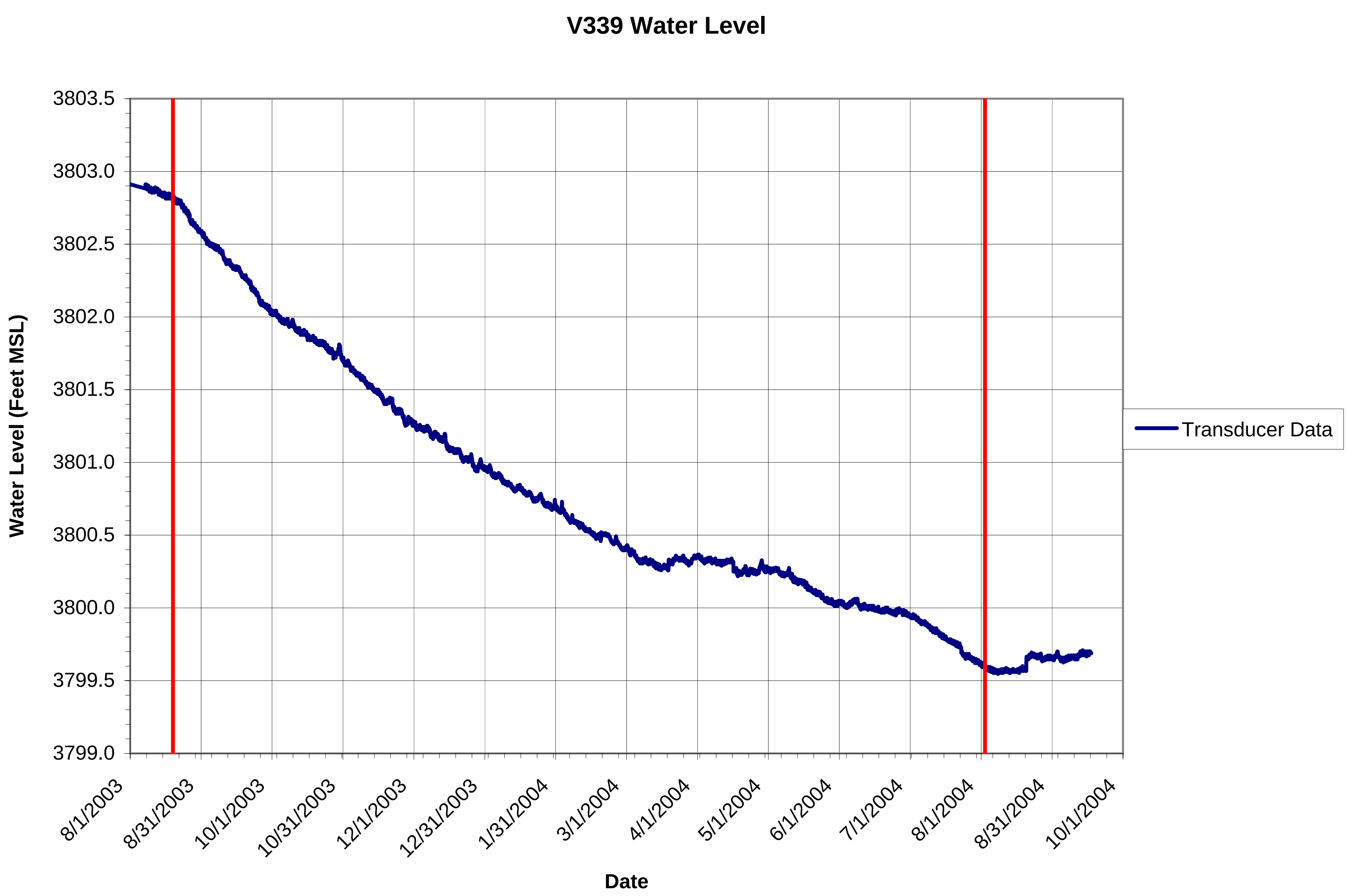


V105 Water Level
Water Level (Feet MSL)
3836.6
3836.4
3836.2
3836.0
3835.8
3835.6
3835.4
3835.2
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data

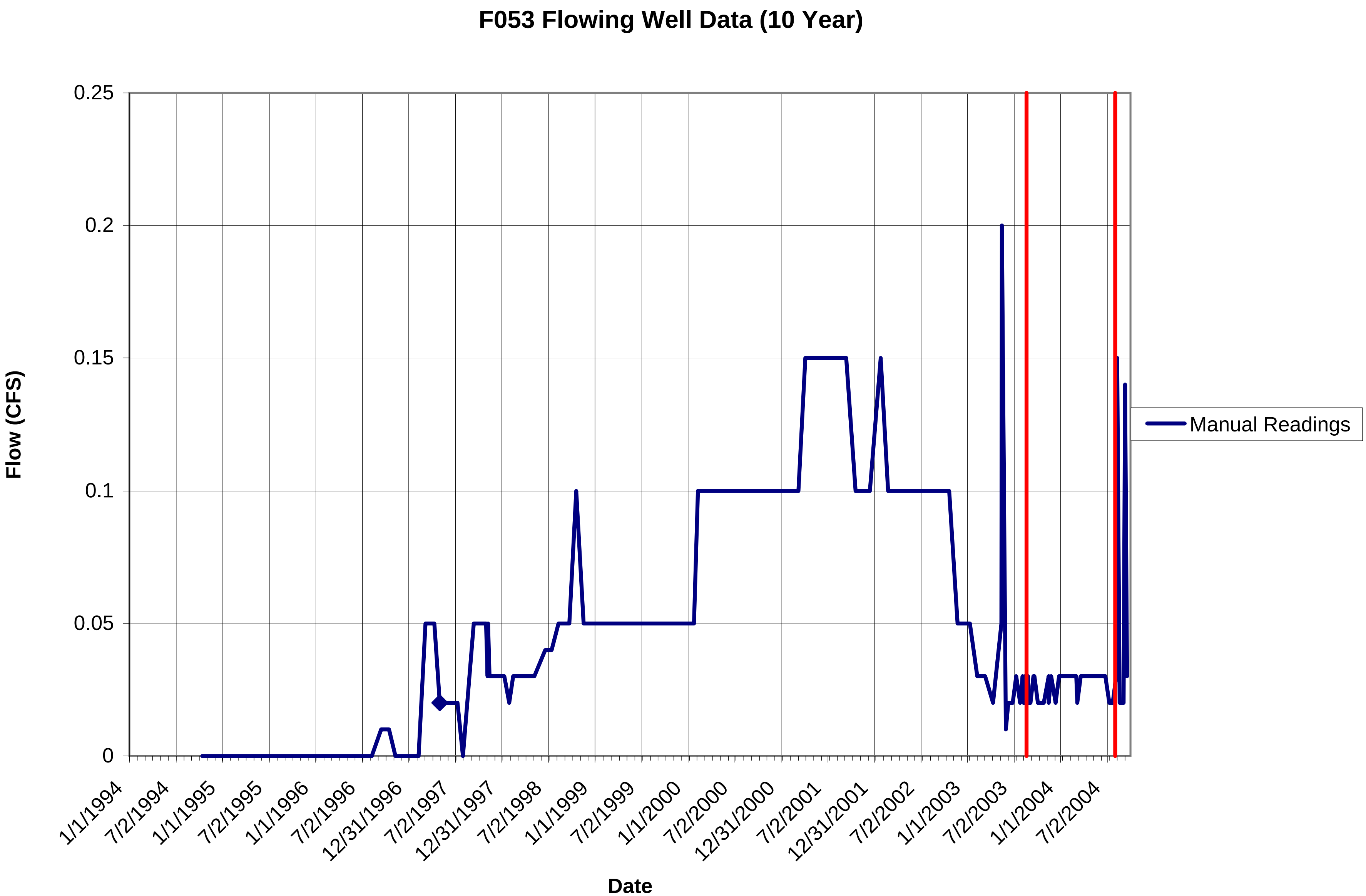

V156 Water Level
3741.5
3741.0
3740.5
3740.0
3739.5
3739.0
3738.5
3738.0
Water Level (Feet MSL)
Missing Data
Transducer Data
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date

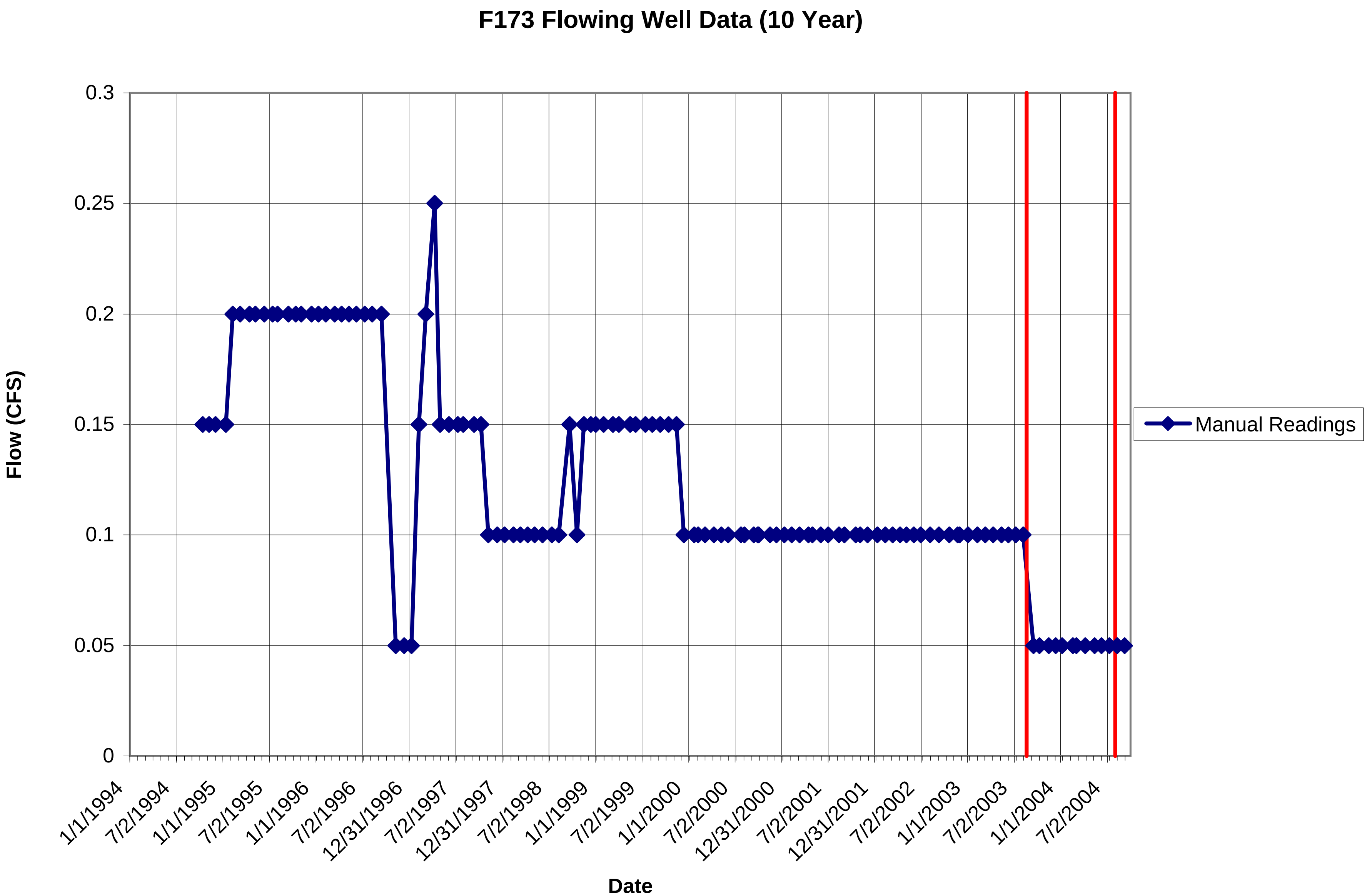

V158 Water Level
3771.8
3771.6
3771.4
3771.2
3771.0
3770.8
3770.6
3770.4
3770.2
3770.0
Water Level (Feet MSL)
Missing Data
Transducer Data
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date

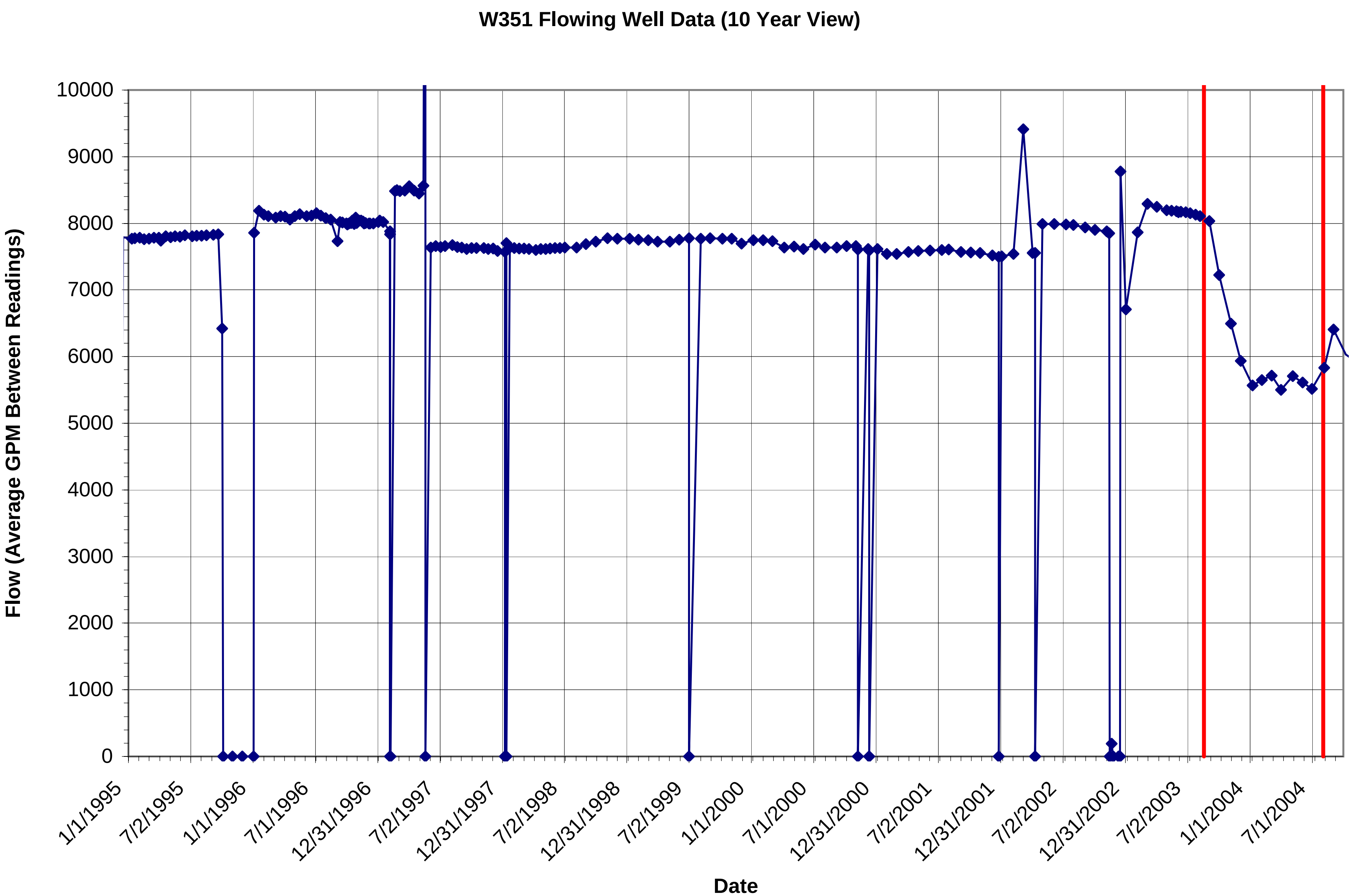

V366 Water Level
Water Level (Feet MSL)
3802.5
3802.0
3801.5
3801.0
3800.5
3800.0
3799.5
3799.0
3798.5
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data

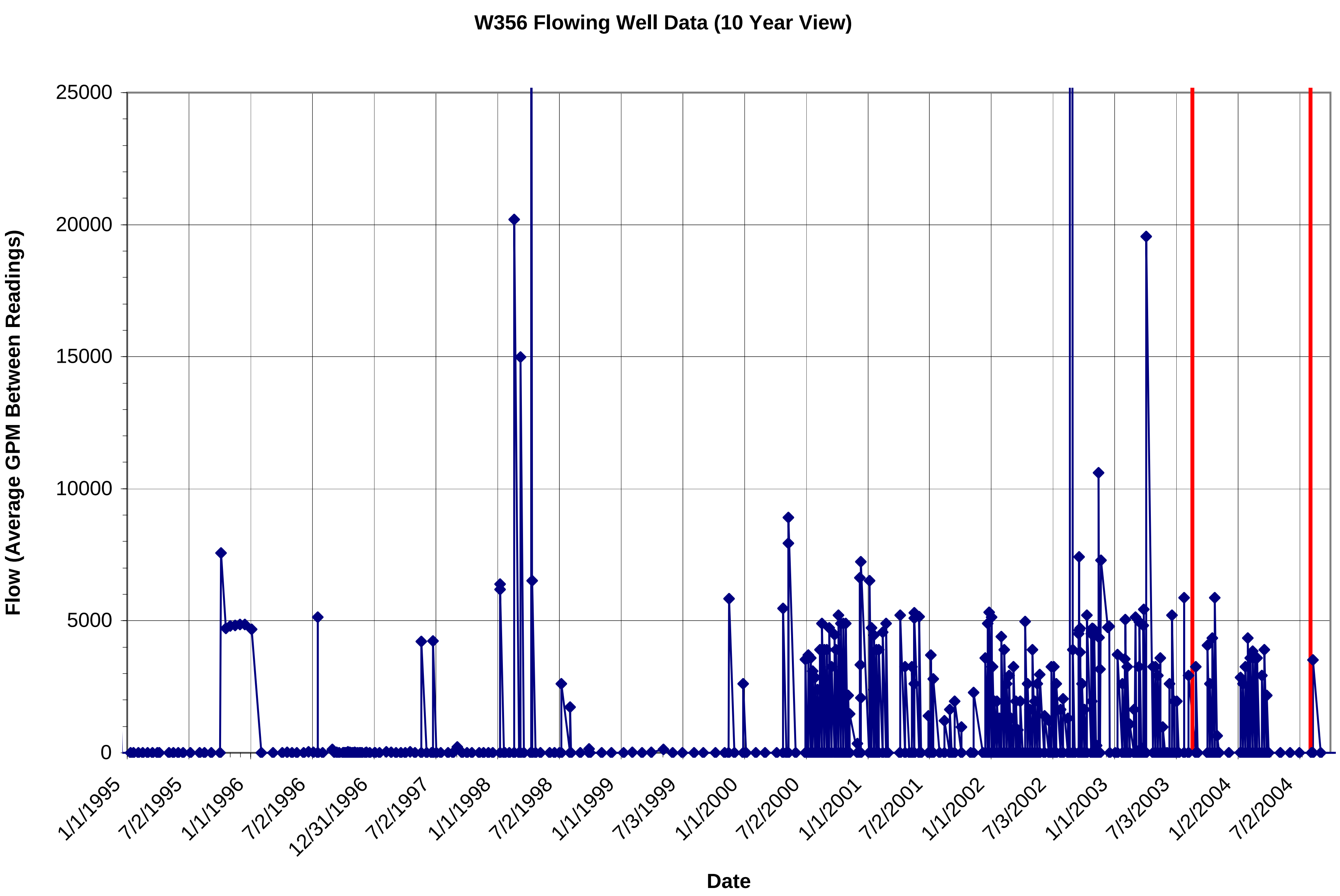

V339 Water Level
Water Level (Feet MSL)
3803.5
3803.0
3802.5
3802.0
3801.5
3801.0
3800.5
3800.0
3799.5
3799.0
8/1/2003
8/31/2003
10/1/2003
10/31/2003
12/1/2003
12/31/2003
1/31/2004
3/1/2004
4/1/2004
5/1/2004
6/1/2004
7/1/2004
8/1/2004
8/31/2004
10/1/2004
Date
Transducer Data

APPENDIX C
Long-Term (10-Year) Hydrographs

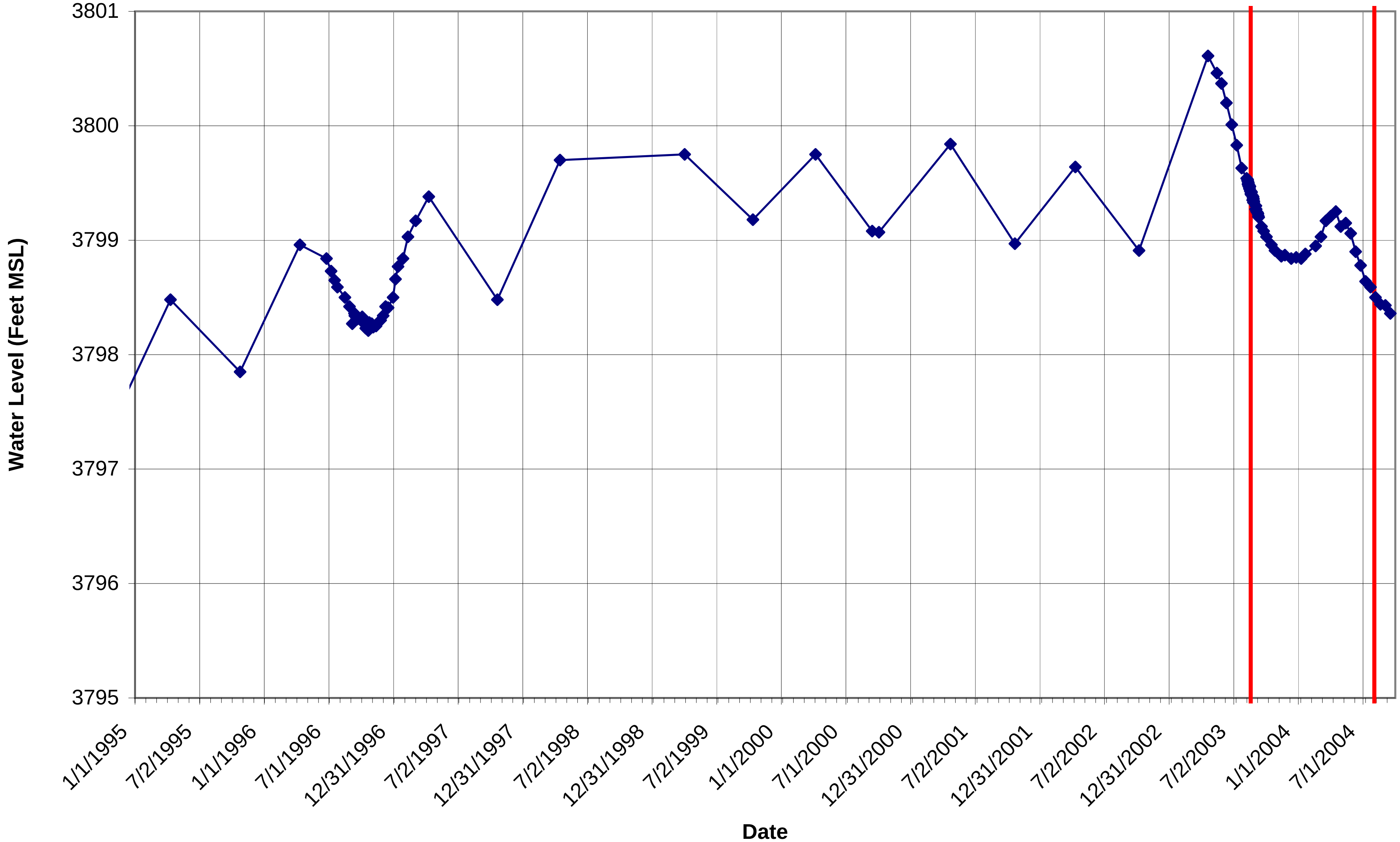

F053 Flowing Well Data (10 Year)
Flow (CFS)
0.25
0.2
0.15
0.1
0.05
0
Manual Readings
1/1/1994
7/2/1994
1/1/1995
7/2/1995
1/1/1996
7/2/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
1/1/1999
7/2/1999
1/1/2000
7/2/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
1/1/2003
7/2/2003
1/1/2004
7/2/2004
Date

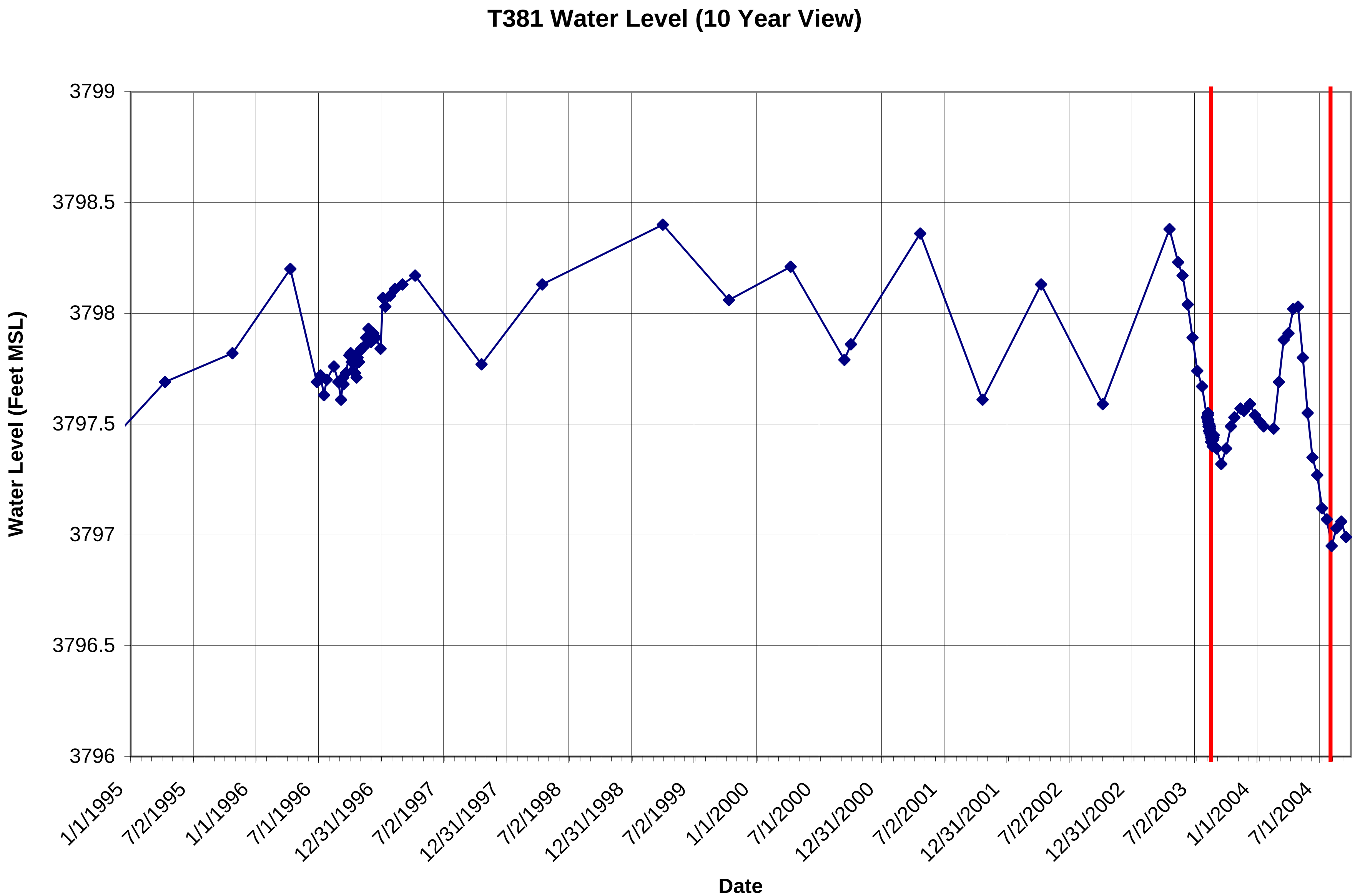

F173 Flowing Well Data (10 Year)
Flow (CFS)
0.3
0.25
0.2
0.15
0.1
0.05
0
1/1/1994
7/2/1994
1/1/1995
7/2/1995
1/1/1996
7/2/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
1/1/1999
7/2/1999
1/1/2000
7/2/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
1/1/2003
7/2/2003
1/1/2004
7/2/2004
Date
Manual Readings


W351 Flowing Well Data (10 Year View)
Flow (Average GPM Between Readings)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

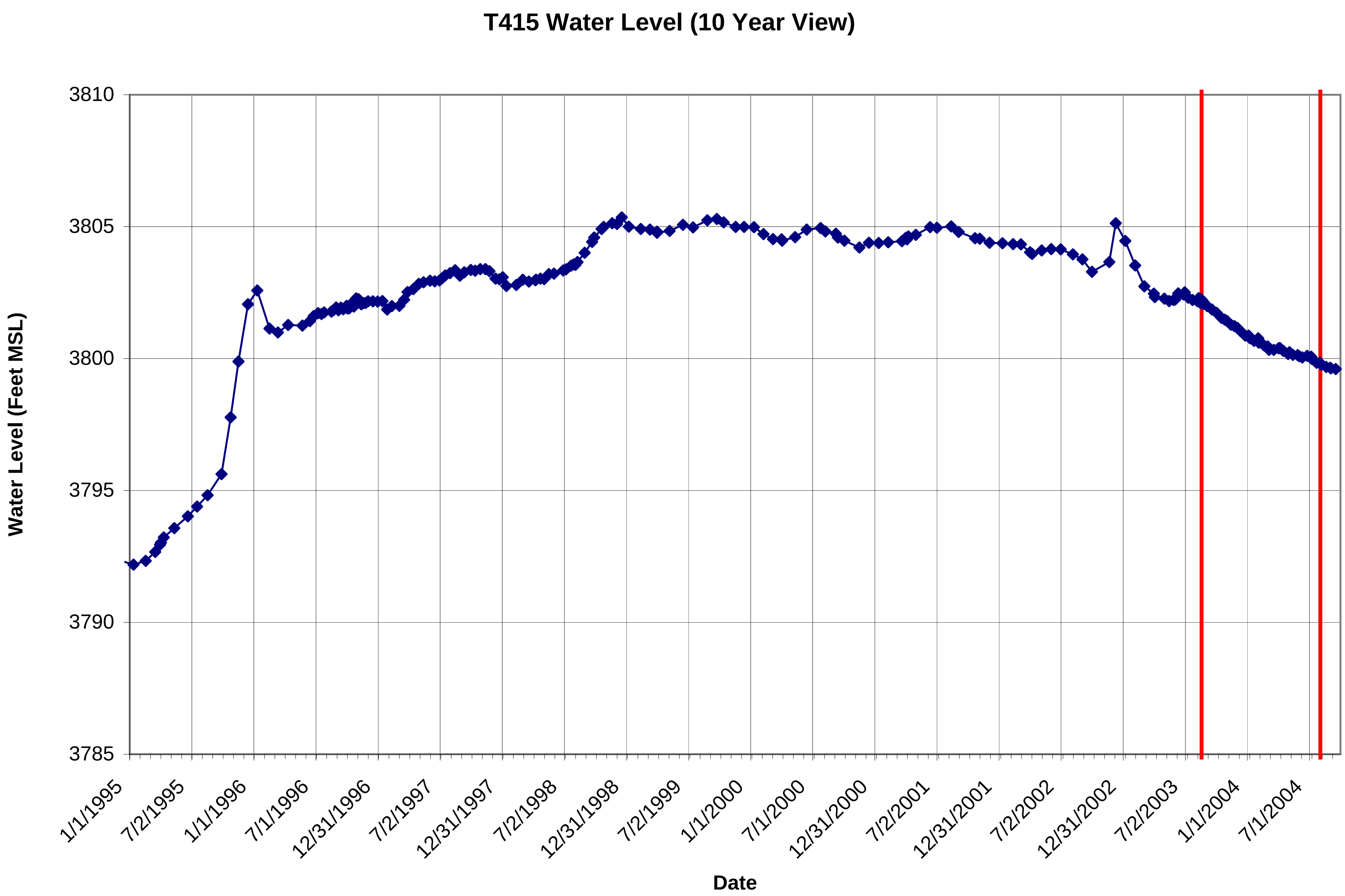

W356 Flowing Well Data (10 Year View)
Flow (Average GPM Between Readings)
25000
20000
15000
10000
5000
0
1/1/1995
7/2/1995
1/1/1996
7/2/1996
12/31/1996
7/2/1997
1/1/1998
7/2/1998
1/1/1999
7/3/1999
1/1/2000
7/2/2000
1/1/2001
7/2/2001
1/1/2002
7/3/2002
1/1/2003
7/3/2003
1/2/2004
7/2/2004
Date

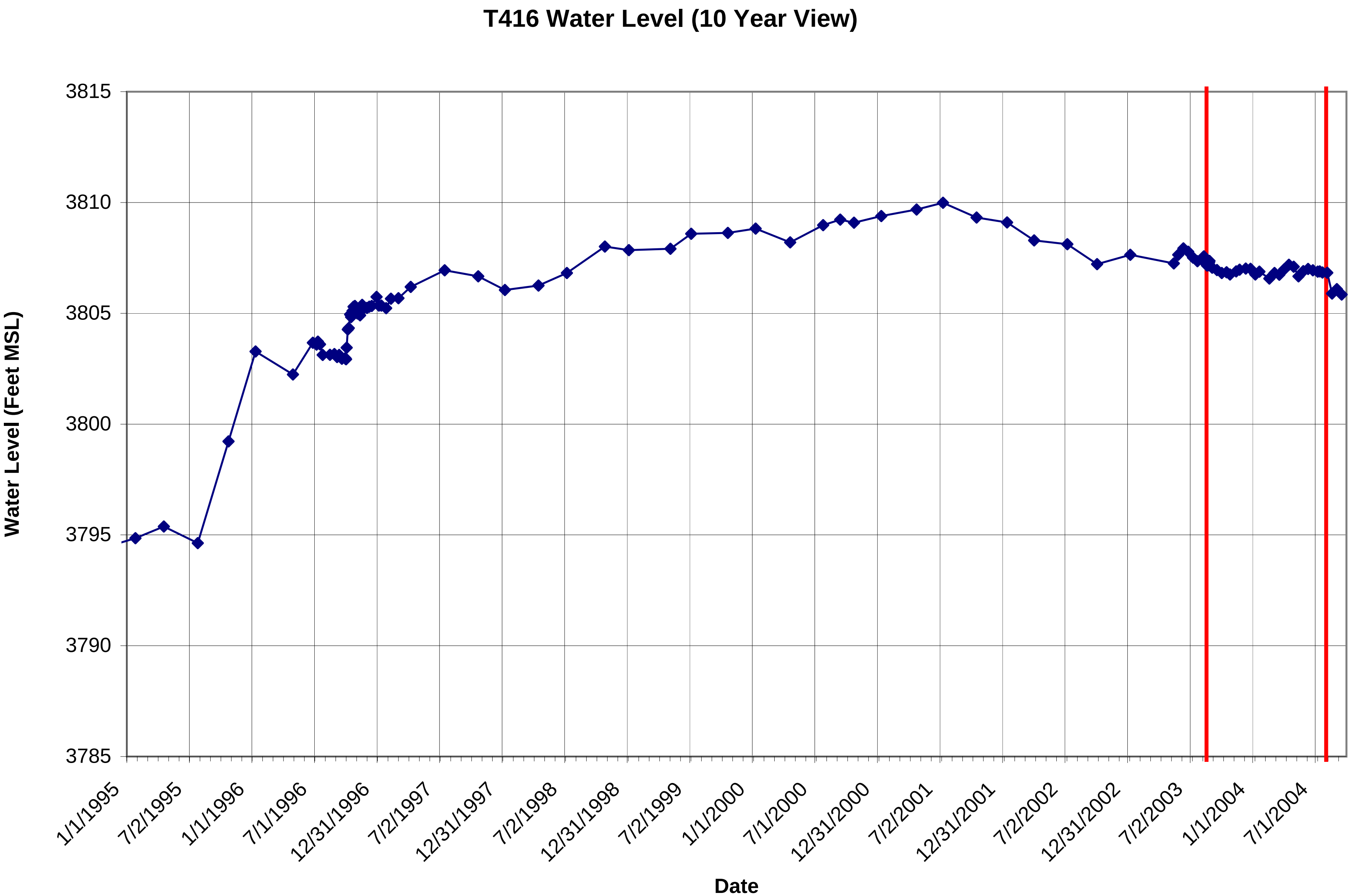
T380 Water Level (10 Year View)





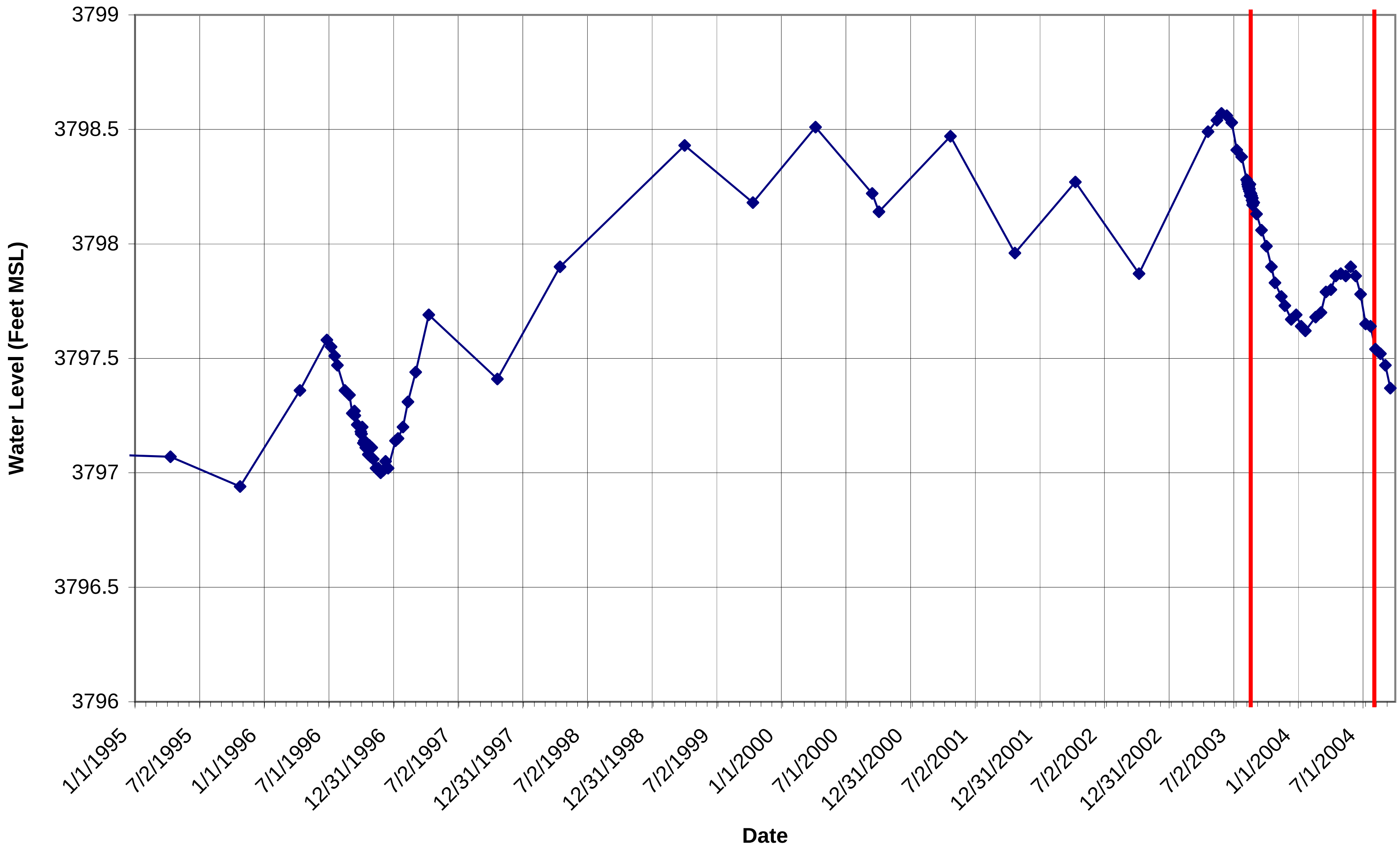
T381 Water Level (10 Year View)
Water Level (Feet MSL)
3799
3798.5
3798
3797.5
3797
3796.5
3796
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


T415 Water Level (10 Year View)
Water Level (Feet MSL)
3810
3805
3800
3795
3790
3785
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

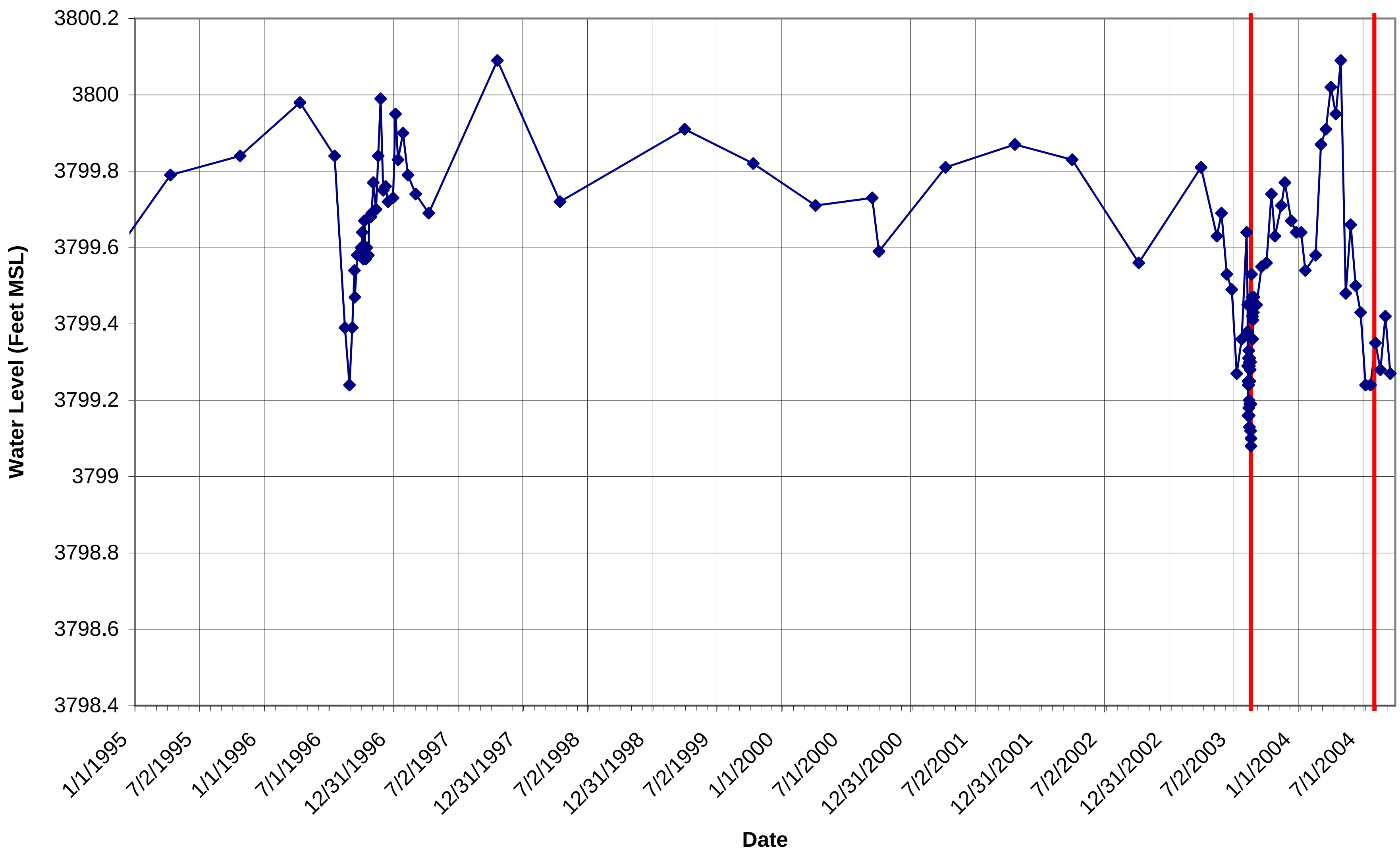


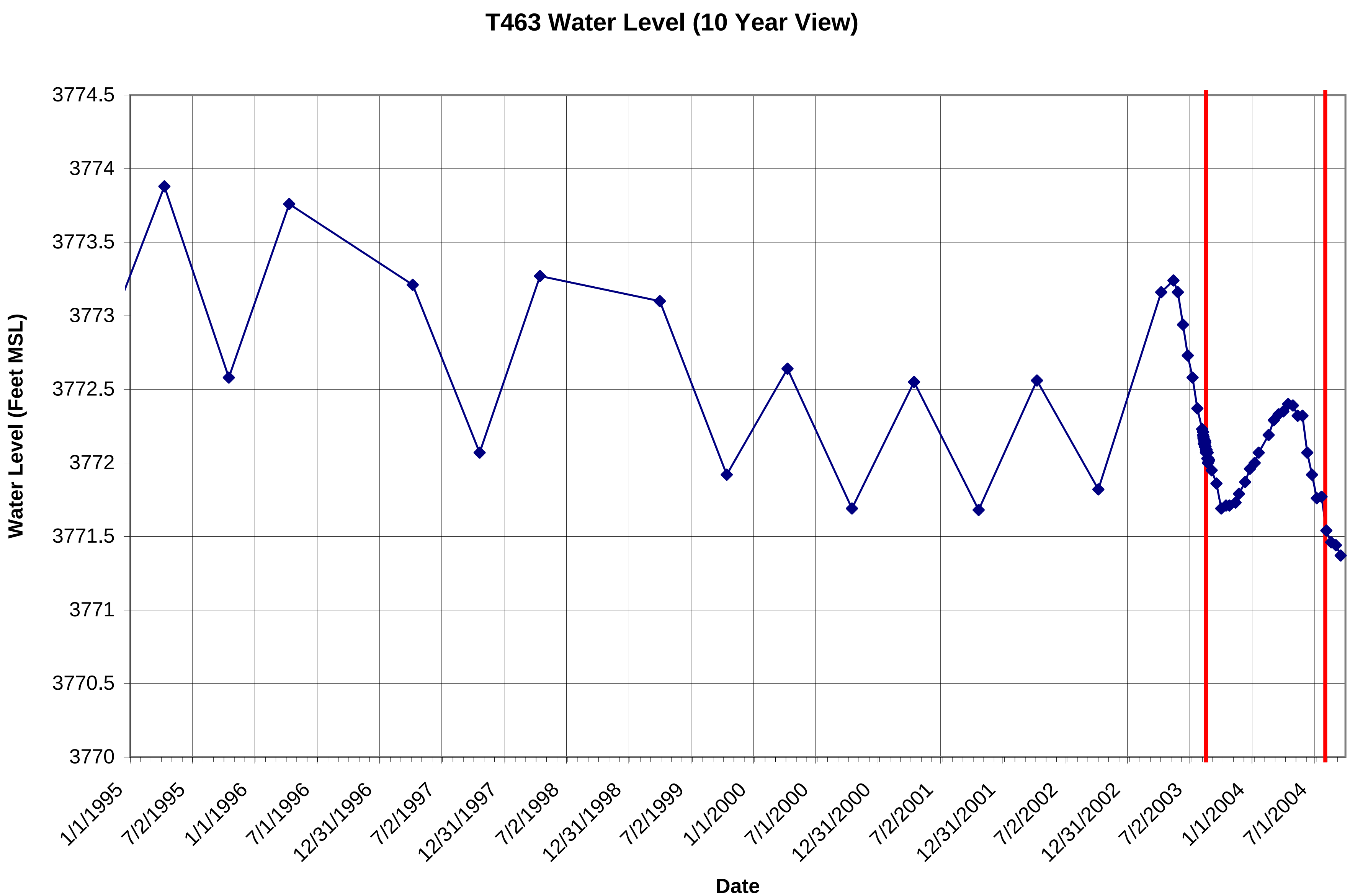
T416 Water Level (10 Year View)
Water Level (Feet MSL)
3815
3810
3805
3800
3795
3790
3785
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

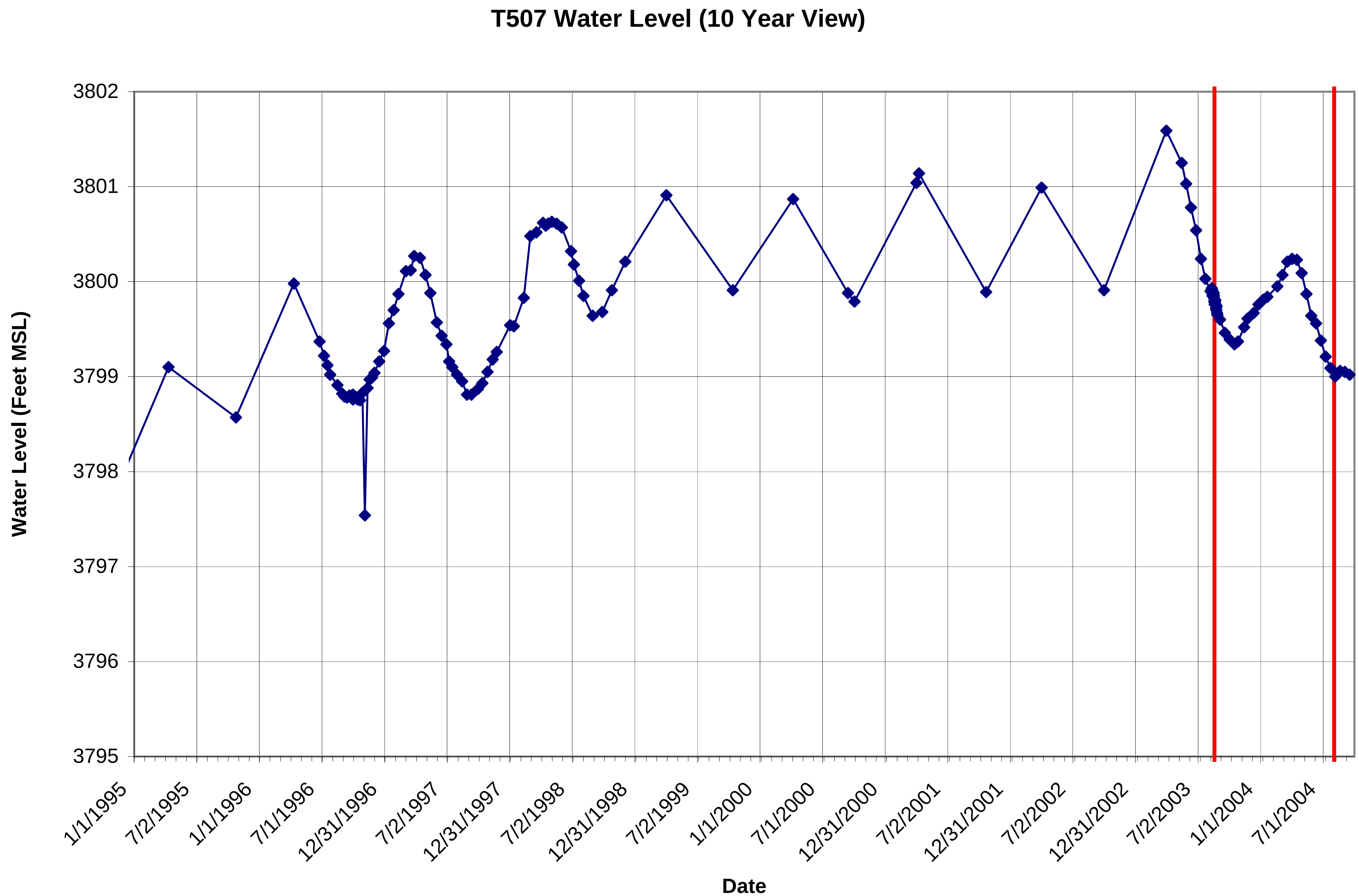
T457 Water Level (10 Year View)

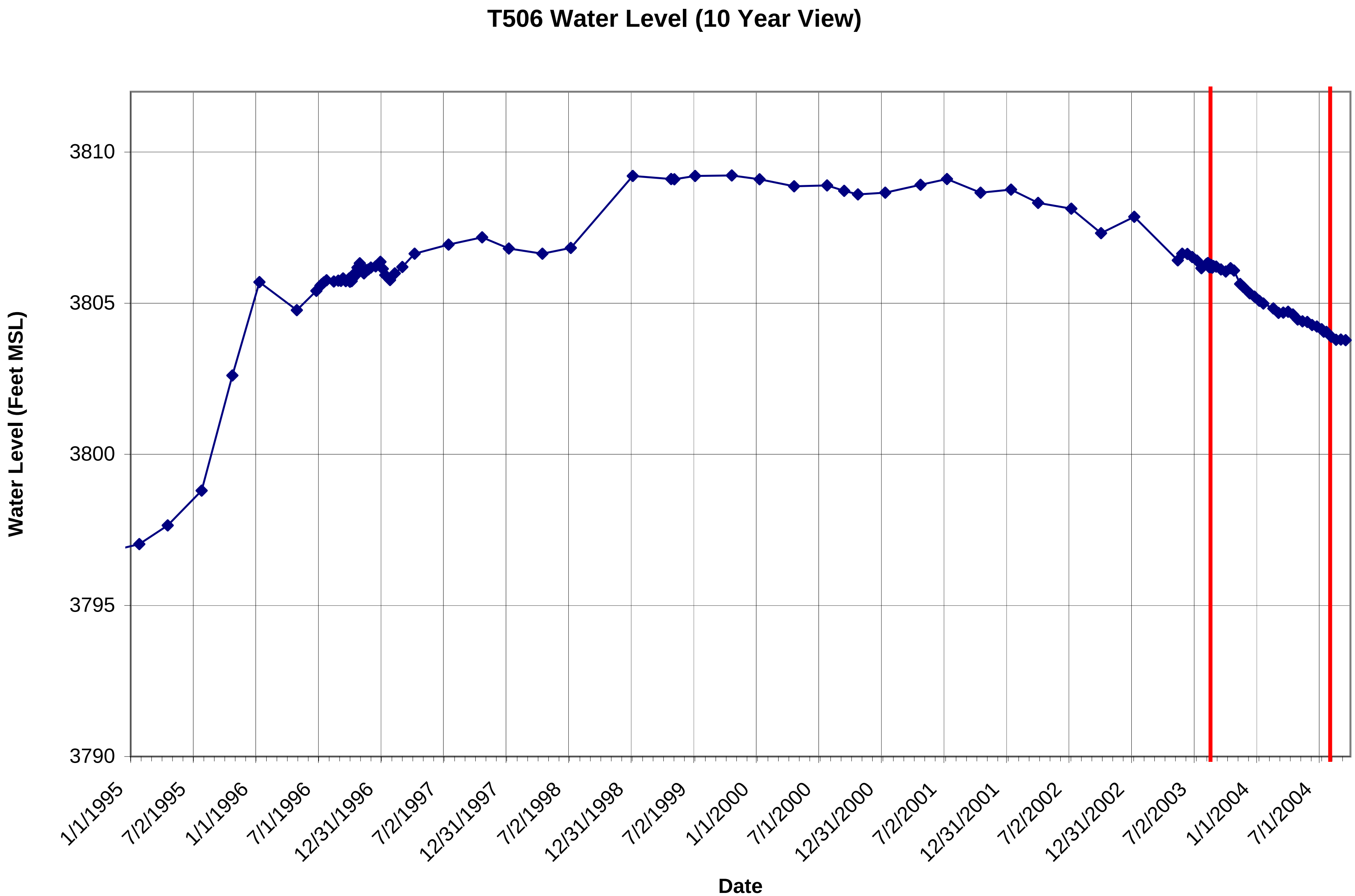


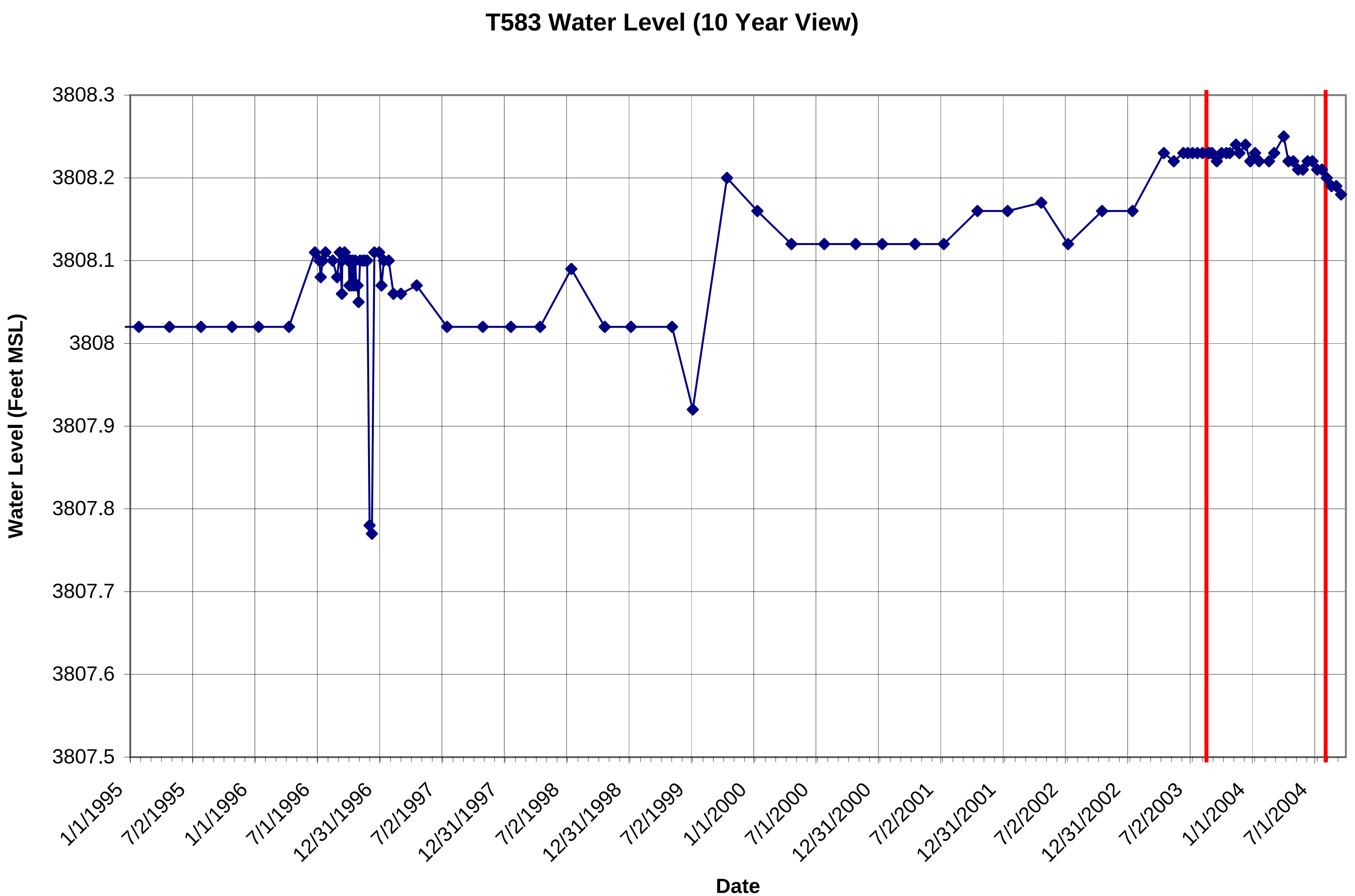
T458 Water Level (10 Year View)

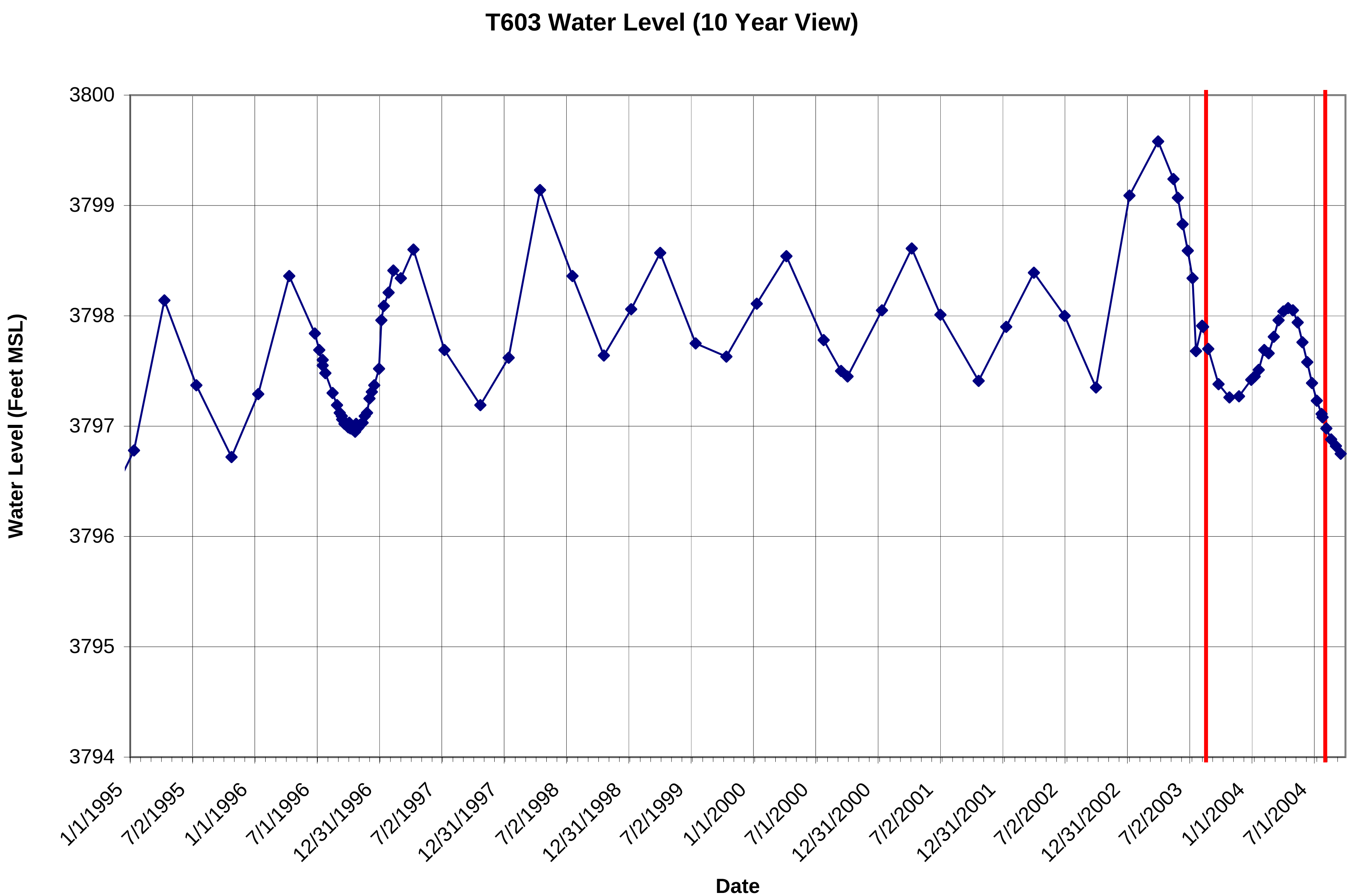


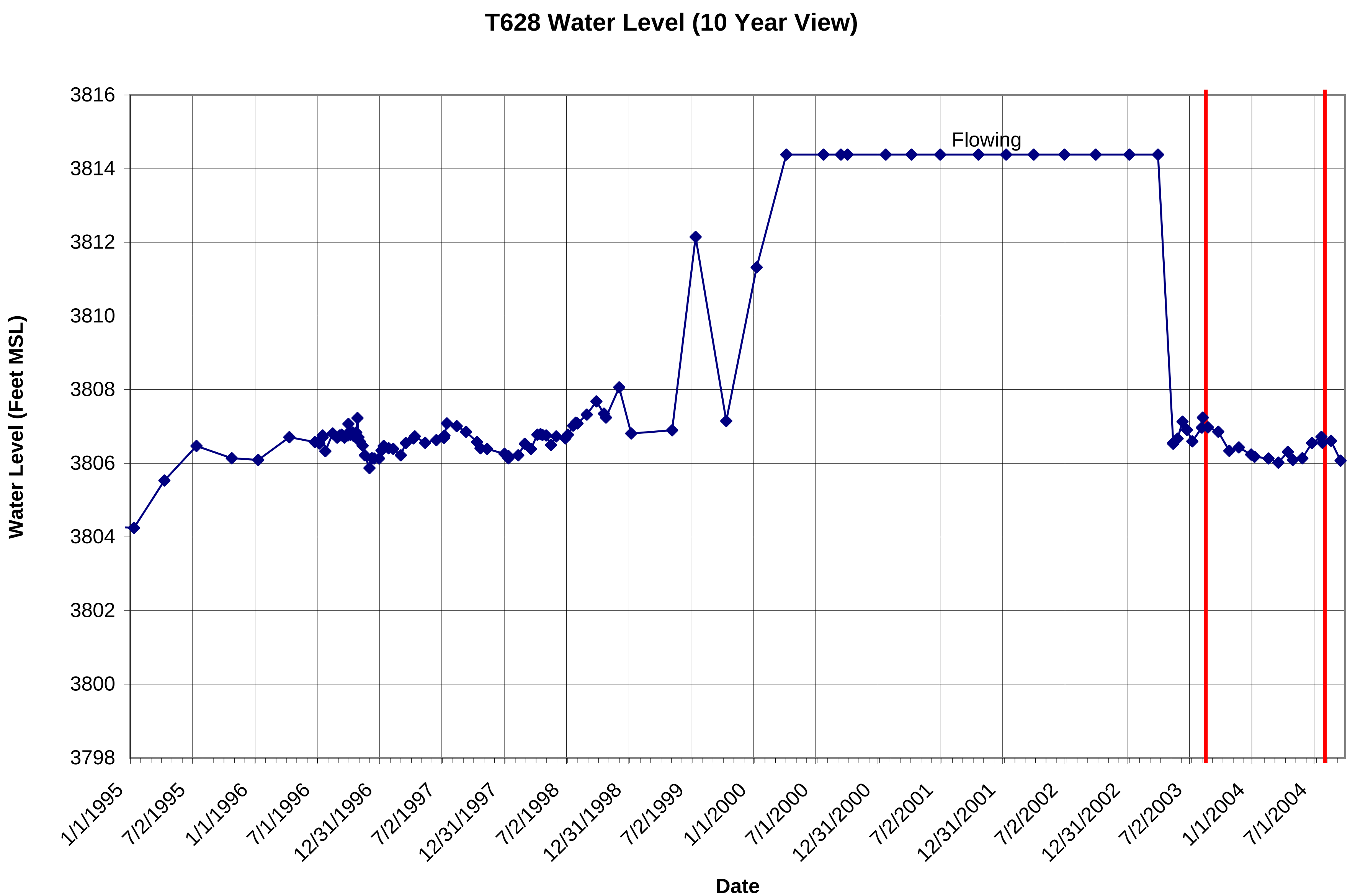

T463 Water Level (10 Year View)
Water Level (Feet MSL)
3774.5
3774
3773.5
3773
3772.5
3772
3771.5
3771
3770.5
3770
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

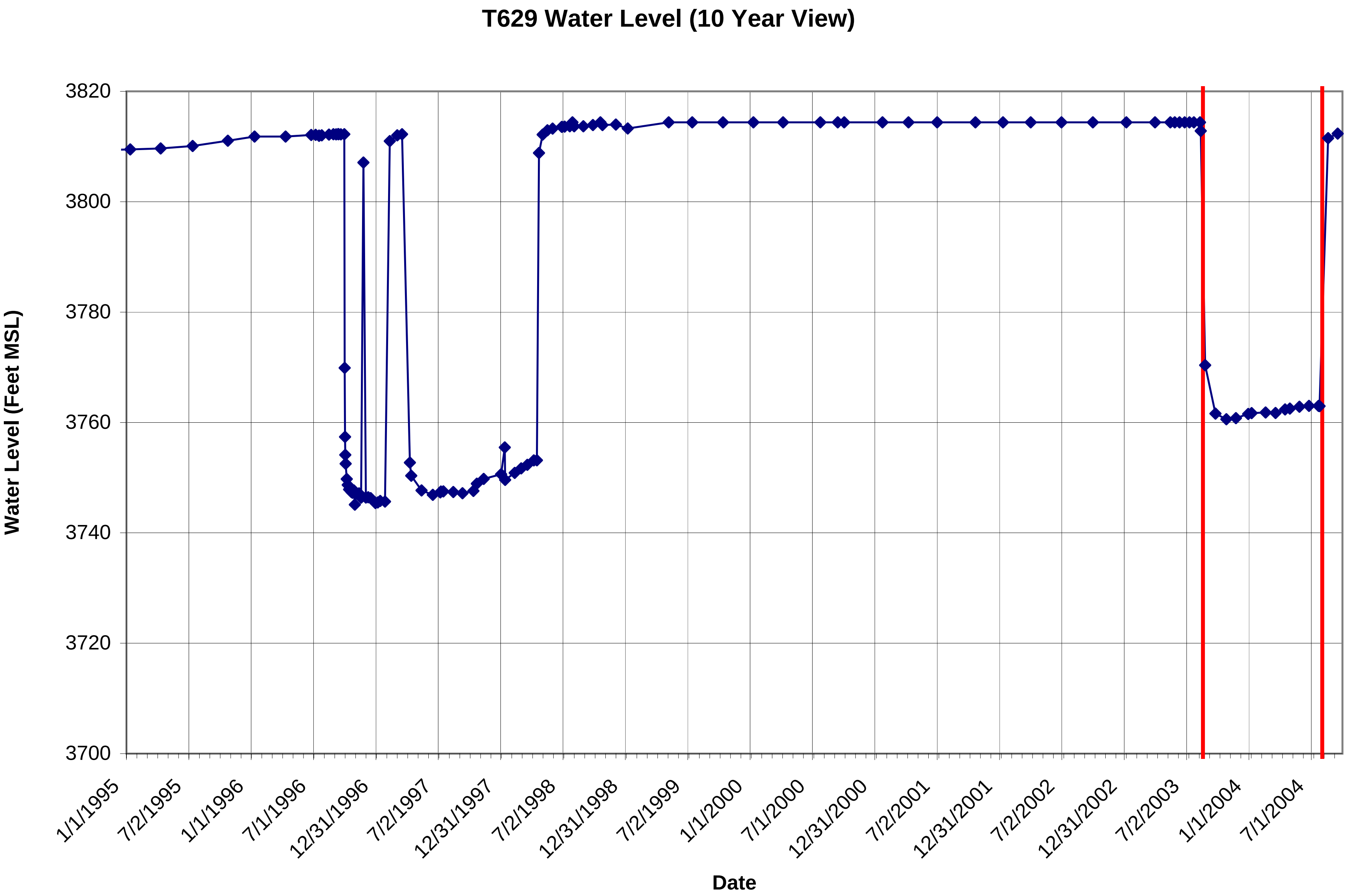

T507 Water Level (10 Year View)
Water Level (Feet MSL)
3802
3801
3800
3799
3798
3797
3796
3795
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

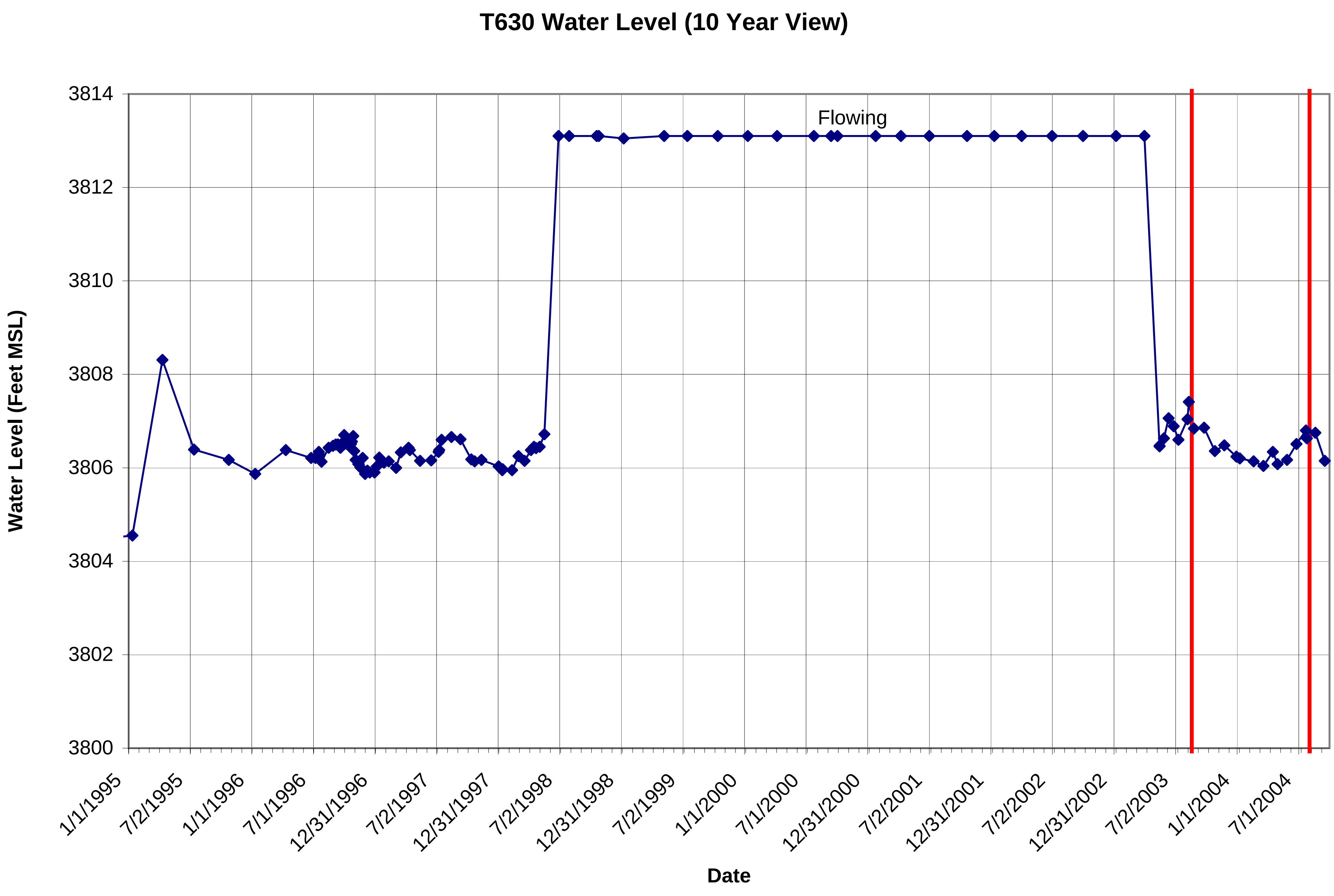

T506 Water Level (10 Year View)
Water Level (Feet MSL)
3810
3805
3800
3795
3790
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


T583 Water Level (10 Year View)
Water Level (Feet MSL)
3808.3
3808.2
3808.1
3808
3807.9
3807.8
3807.7
3807.6
3807.5
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

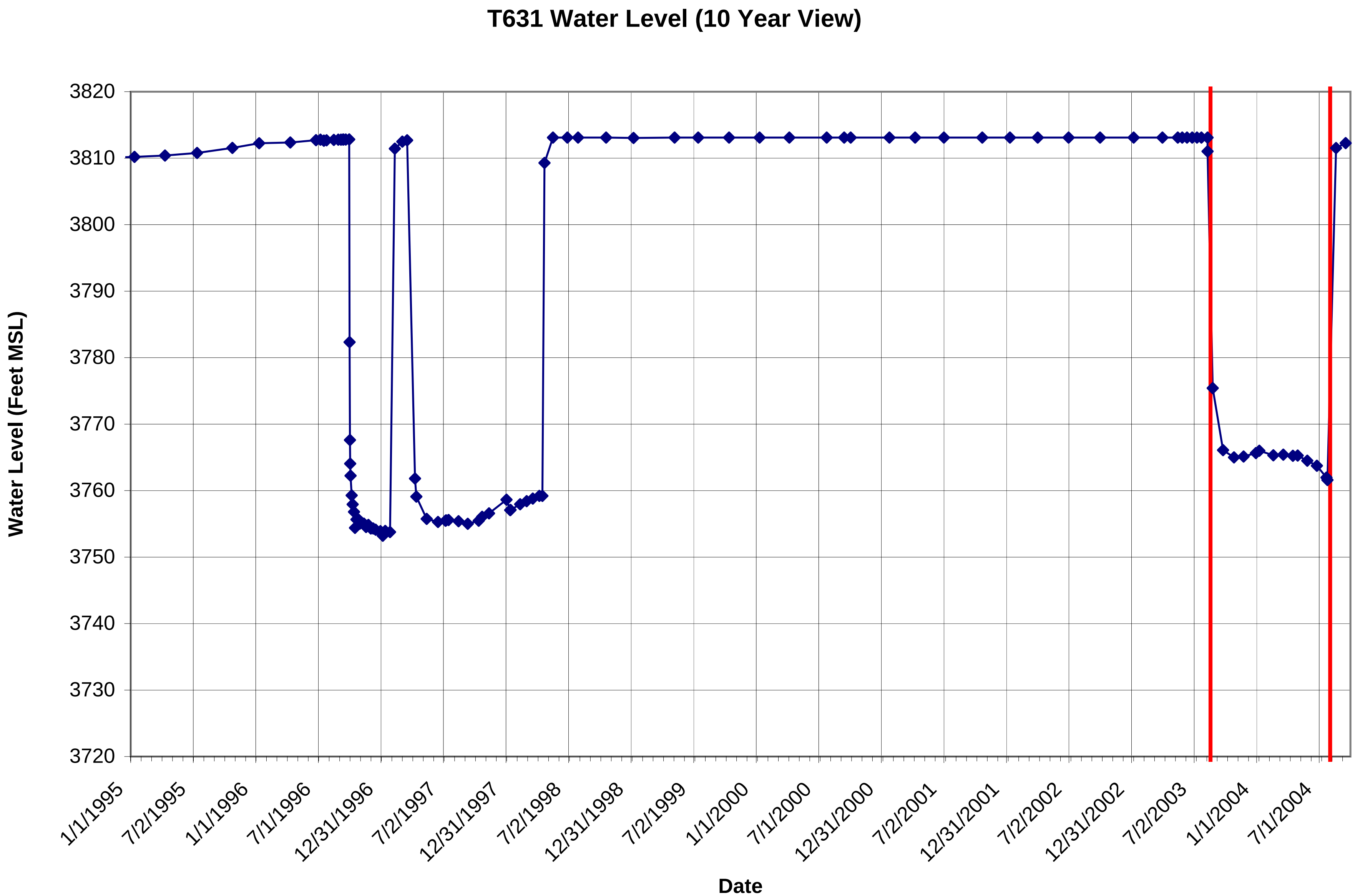

T603 Water Level (10 Year View)
Water Level (Feet MSL)
3800
3799
3798
3797
3796
3795
3794
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


T628 Water Level (10 Year View)
Water Level (Feet MSL)
3816
3814
3812
3810
3808
3806
3804
3802
3800
3798
Flowing
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

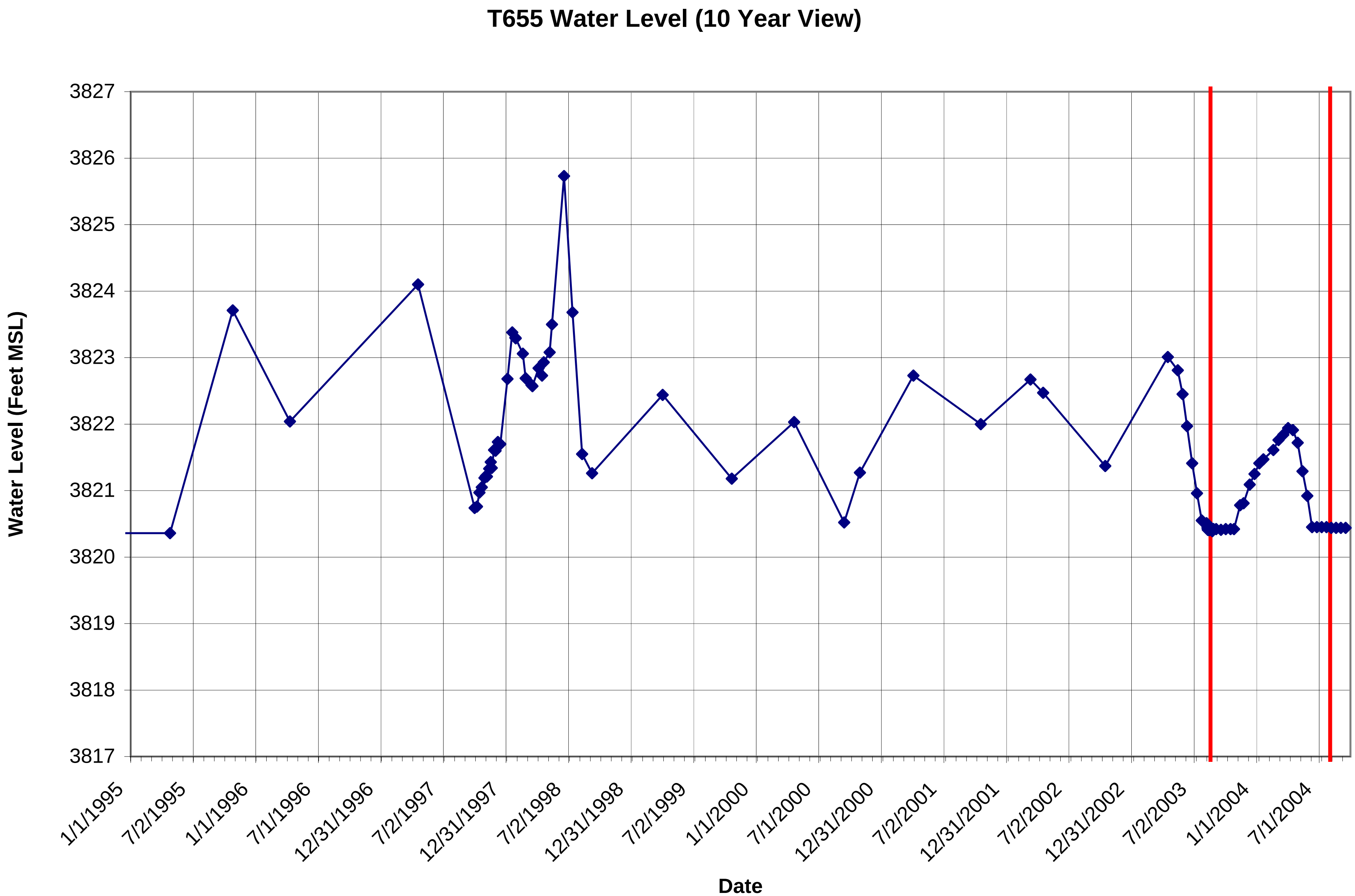

T629 Water Level (10 Year View)
Water Level (Feet MSL)
3820
3800
3780
3760
3740
3720
3700
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



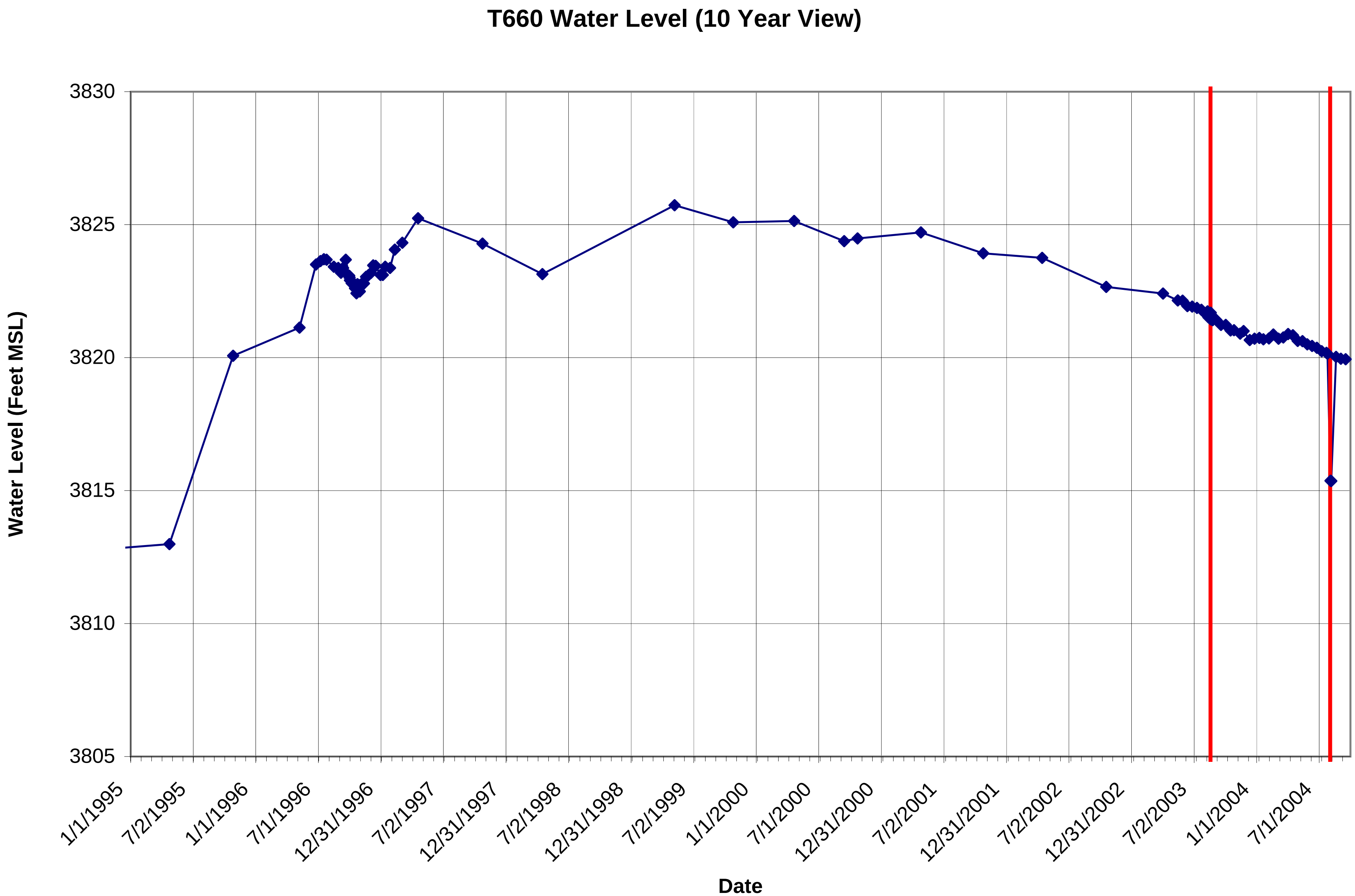
T630 Water Level (10 Year View)
Water Level (Feet MSL)
3814
3812
3810
3808
3806
3804
3802
3800
Flowing
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

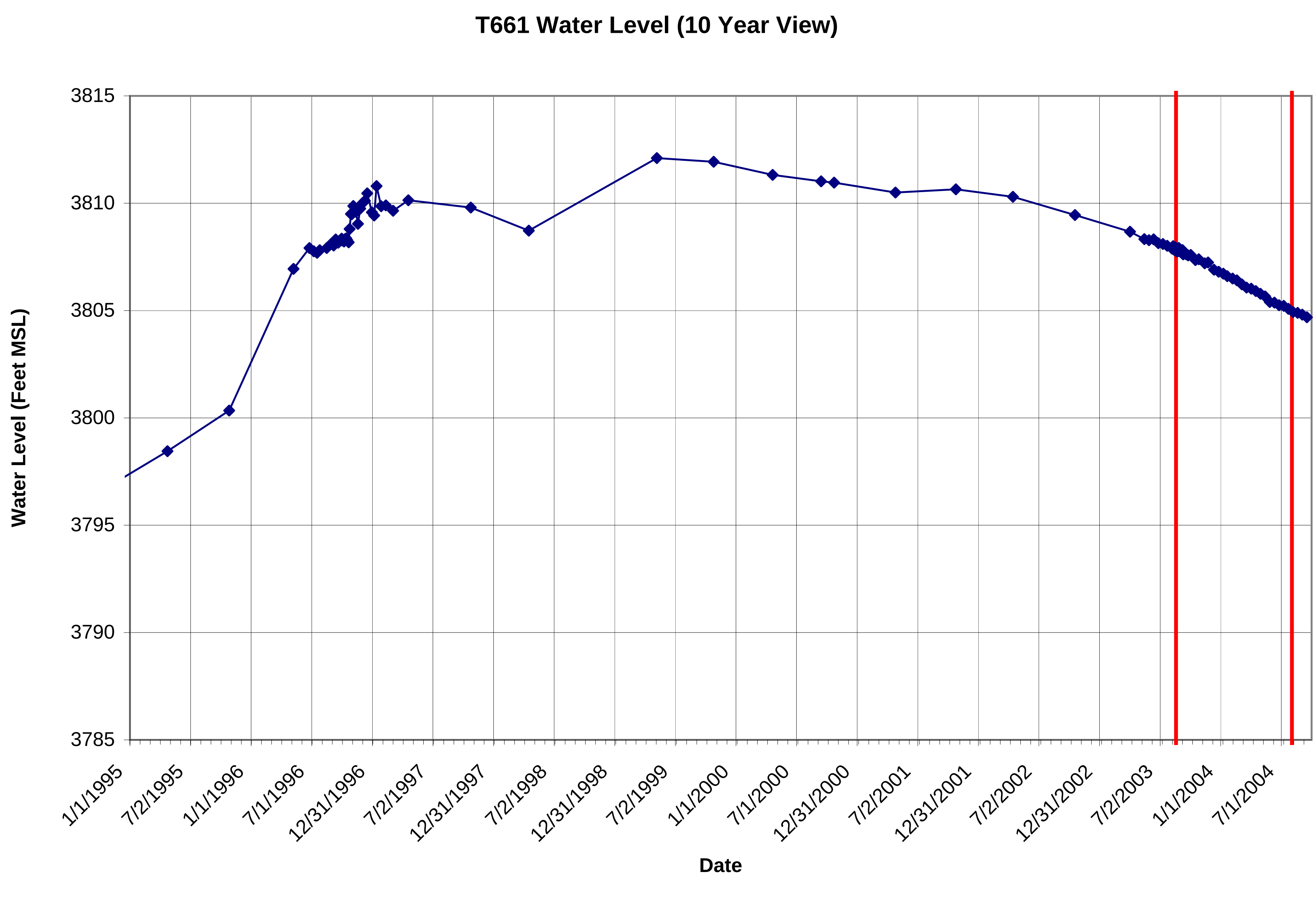


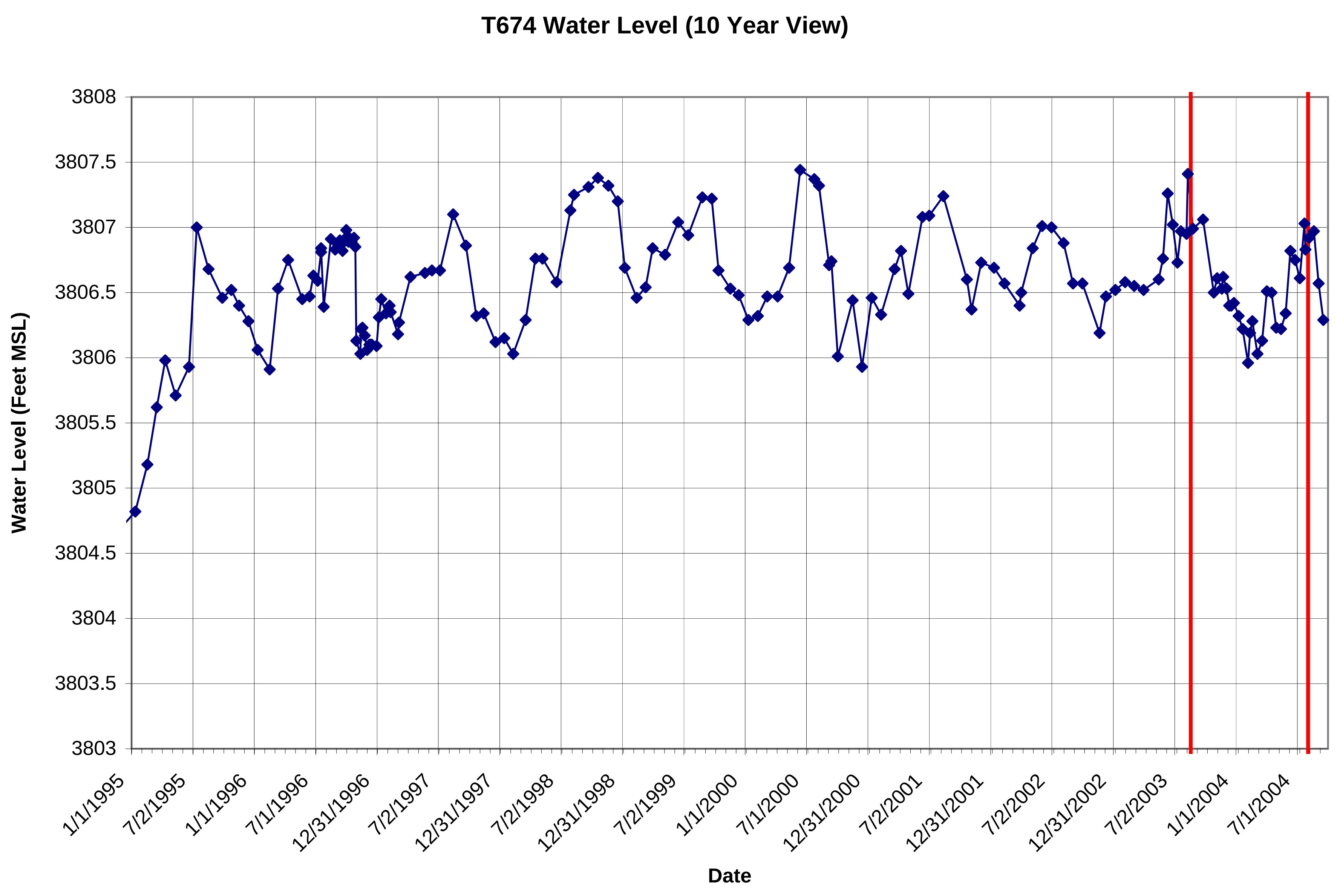
T631 Water Level (10 Year View)
Water Level (Feet MSL)
3820
3810
3800
3790
3780
3770
3760
3750
3740
3730
3720
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



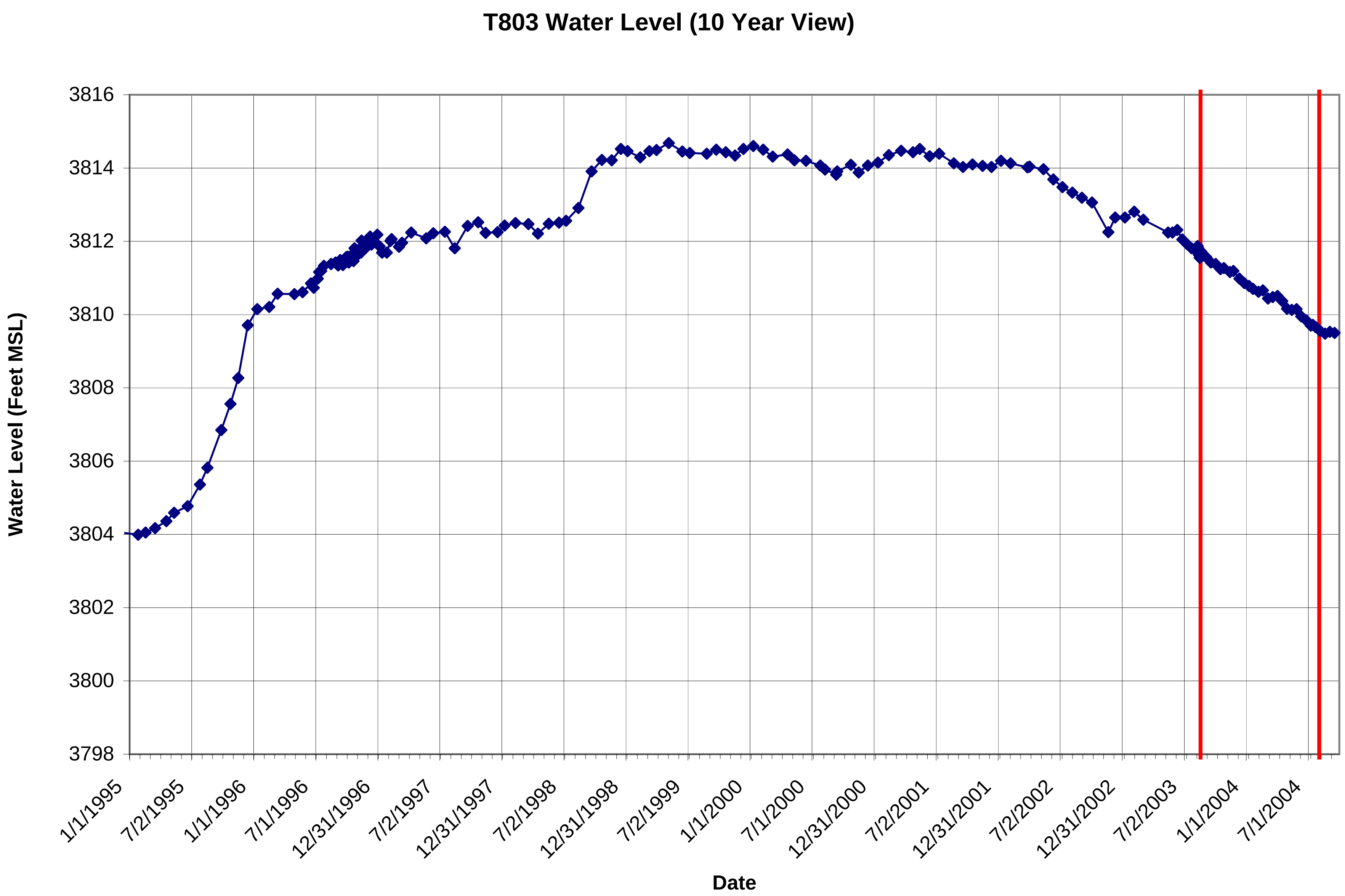
T655 Water Level (10 Year View)
Water Level (Feet MSL)
3827
3826
3825
3824
3823
3822
3821
3820
3819
3818
3817
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date


T660 Water Level (10 Year View)
Water Level (Feet MSL)
3830
3825
3820
3815
3810
3805
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

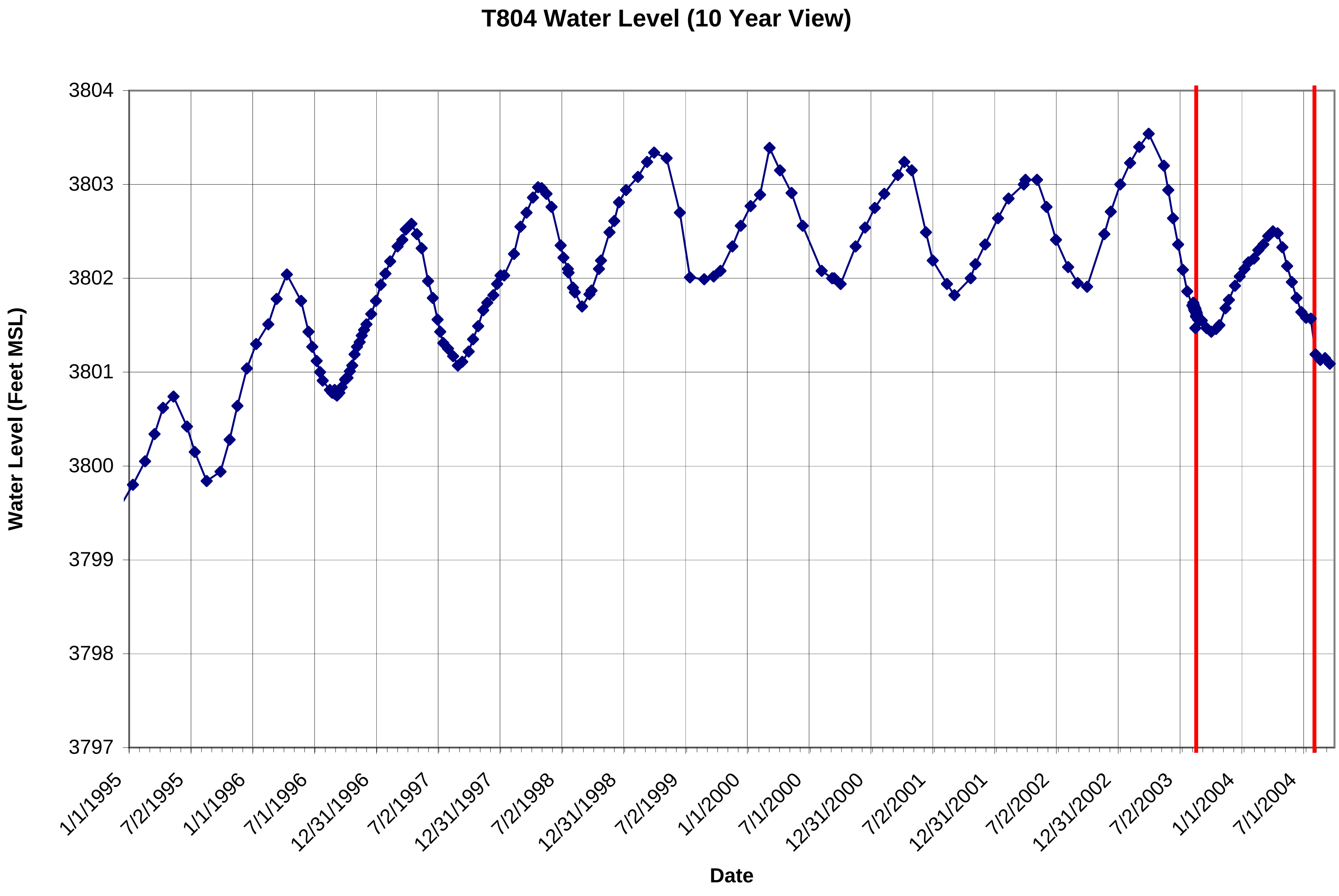

T661 Water Level (10 Year View)
Water Level (Feet MSL)
3815
3810
3805
3800
3795
3790
3785
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

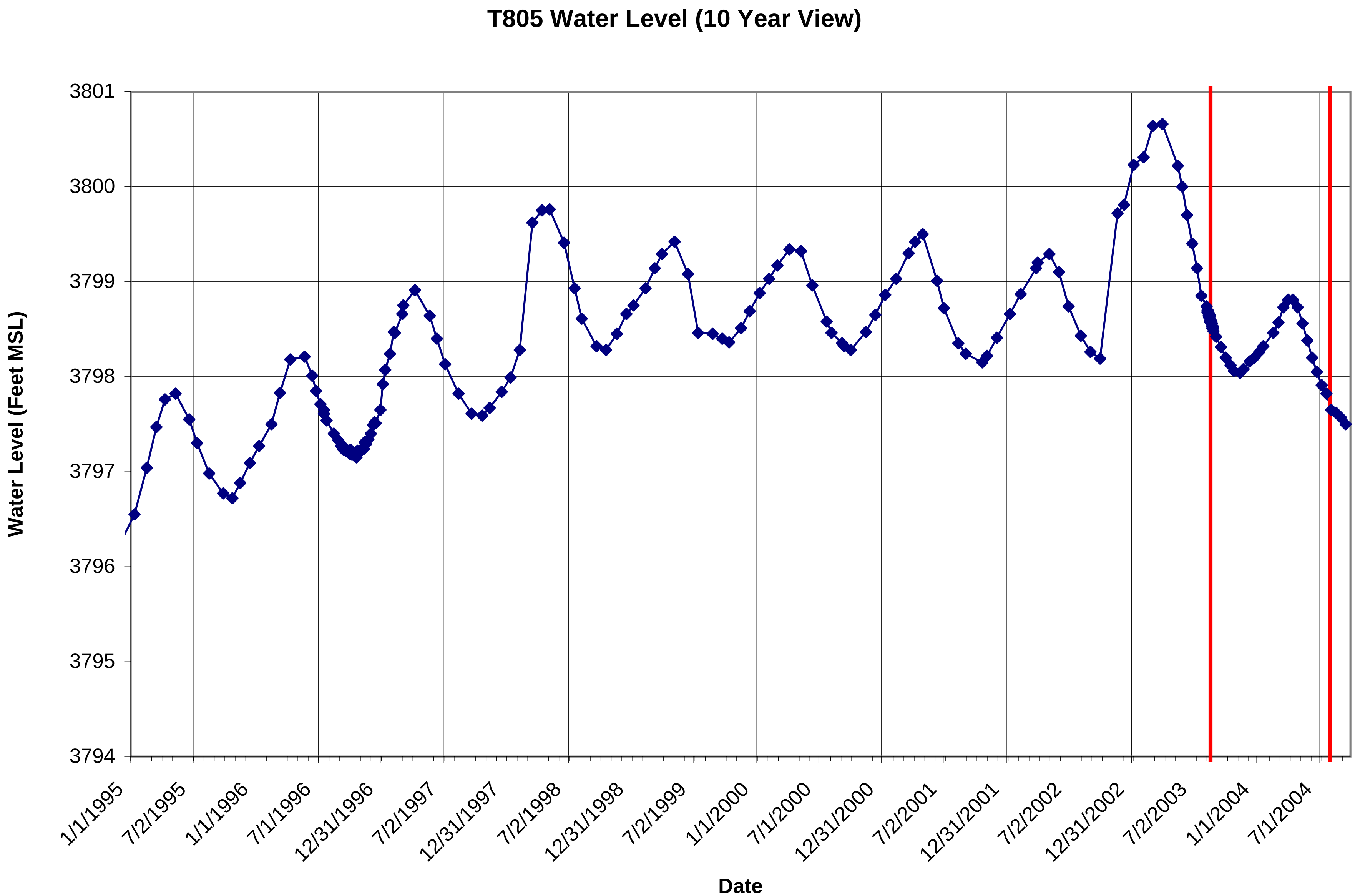


T674 Water Level (10 Year View)
Water Level (Feet MSL)
3808
3807.5
3807
3806.5
3806
3805.5
3805
3804.5
3804
3803.5
3803
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

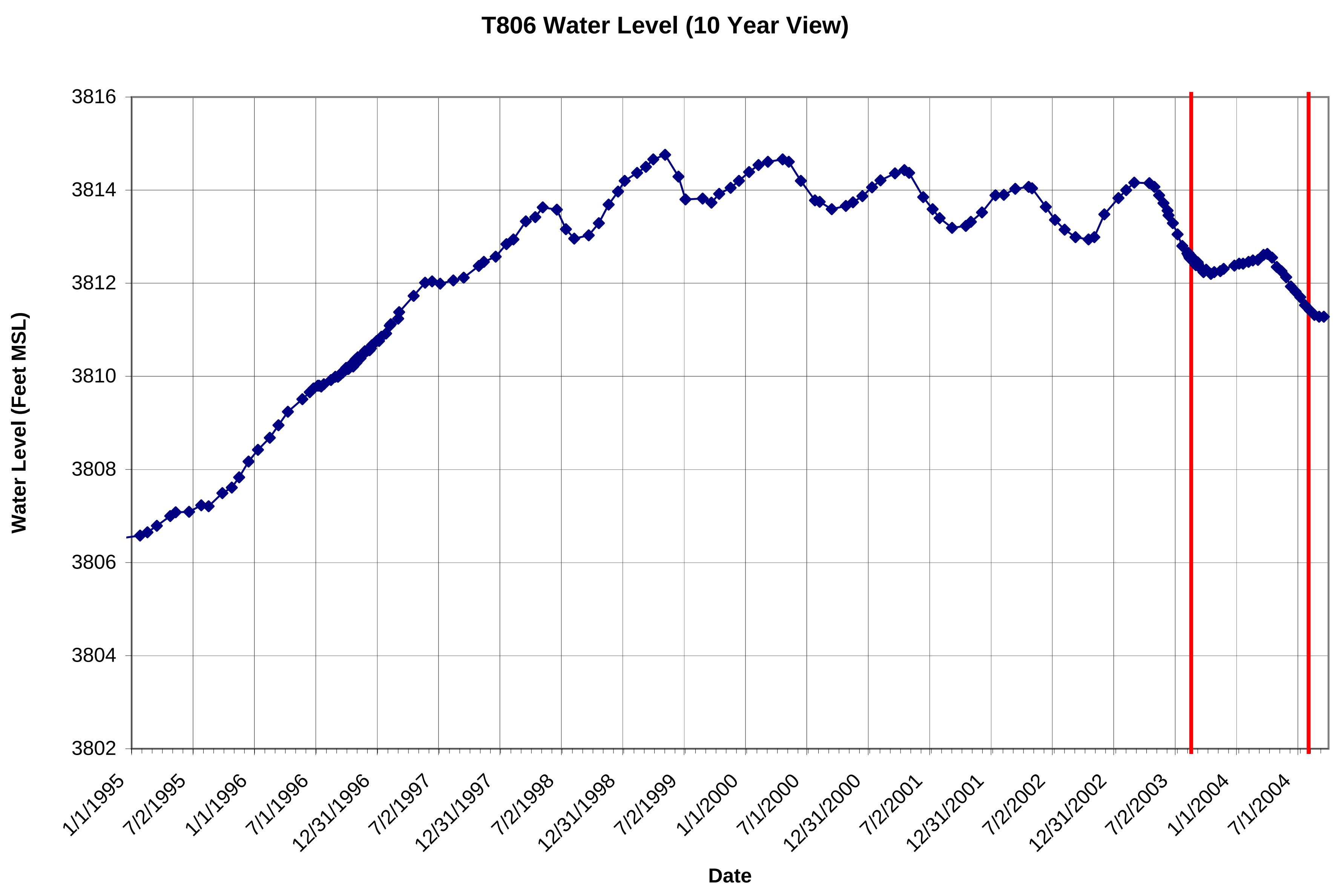


T803 Water Level (10 Year View)
Water Level (Feet MSL)
3816
3814
3812
3810
3808
3806
3804
3802
3800
3798
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

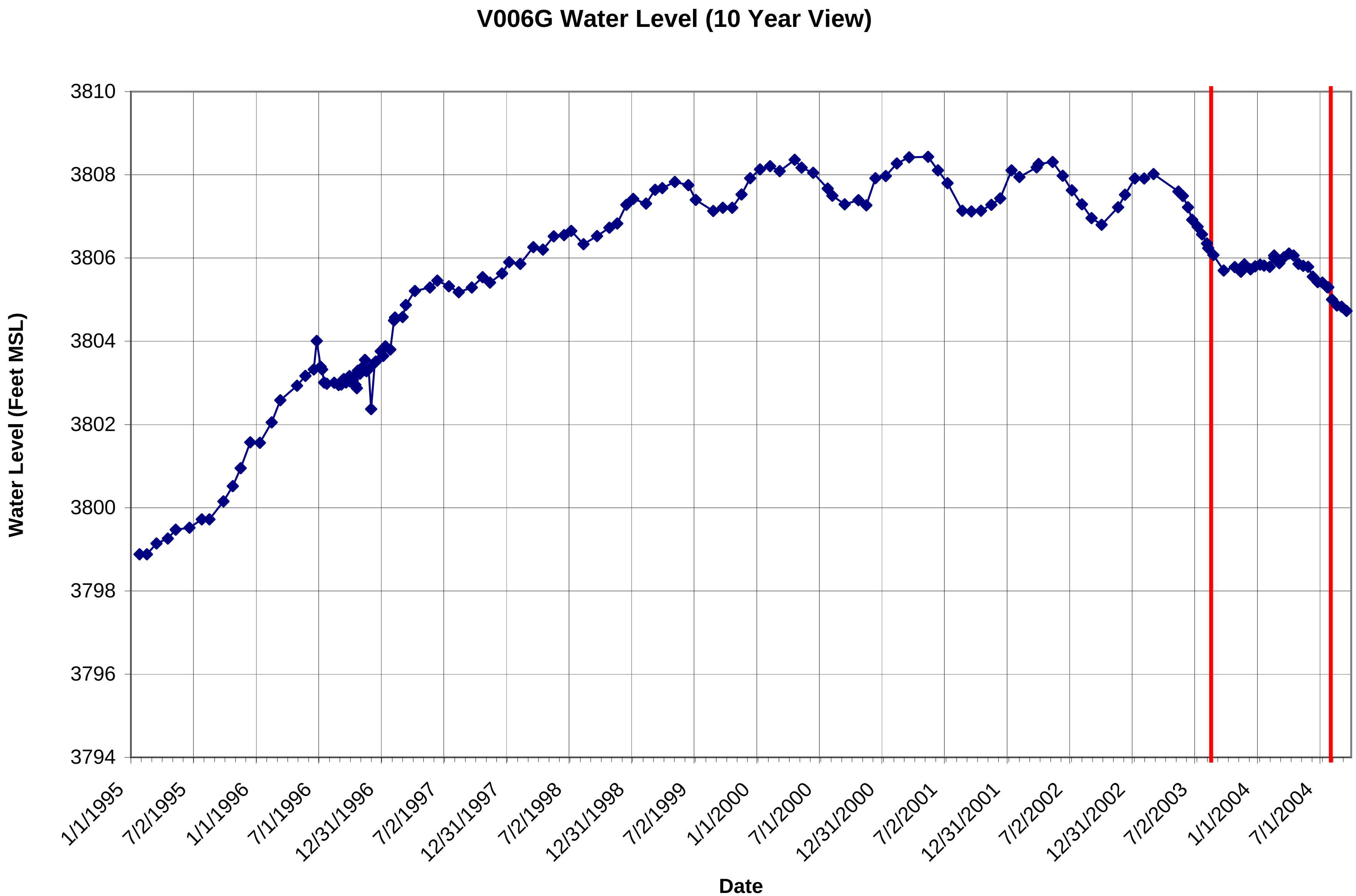

T804 Water Level (10 Year View)
Water Level (Feet MSL)
3804
3803
3802
3801
3800
3799
3798
3797
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



T805 Water Level (10 Year View)
Water Level (Feet MSL)
3801
3800
3799
3798
3797
3796
3795
3794
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

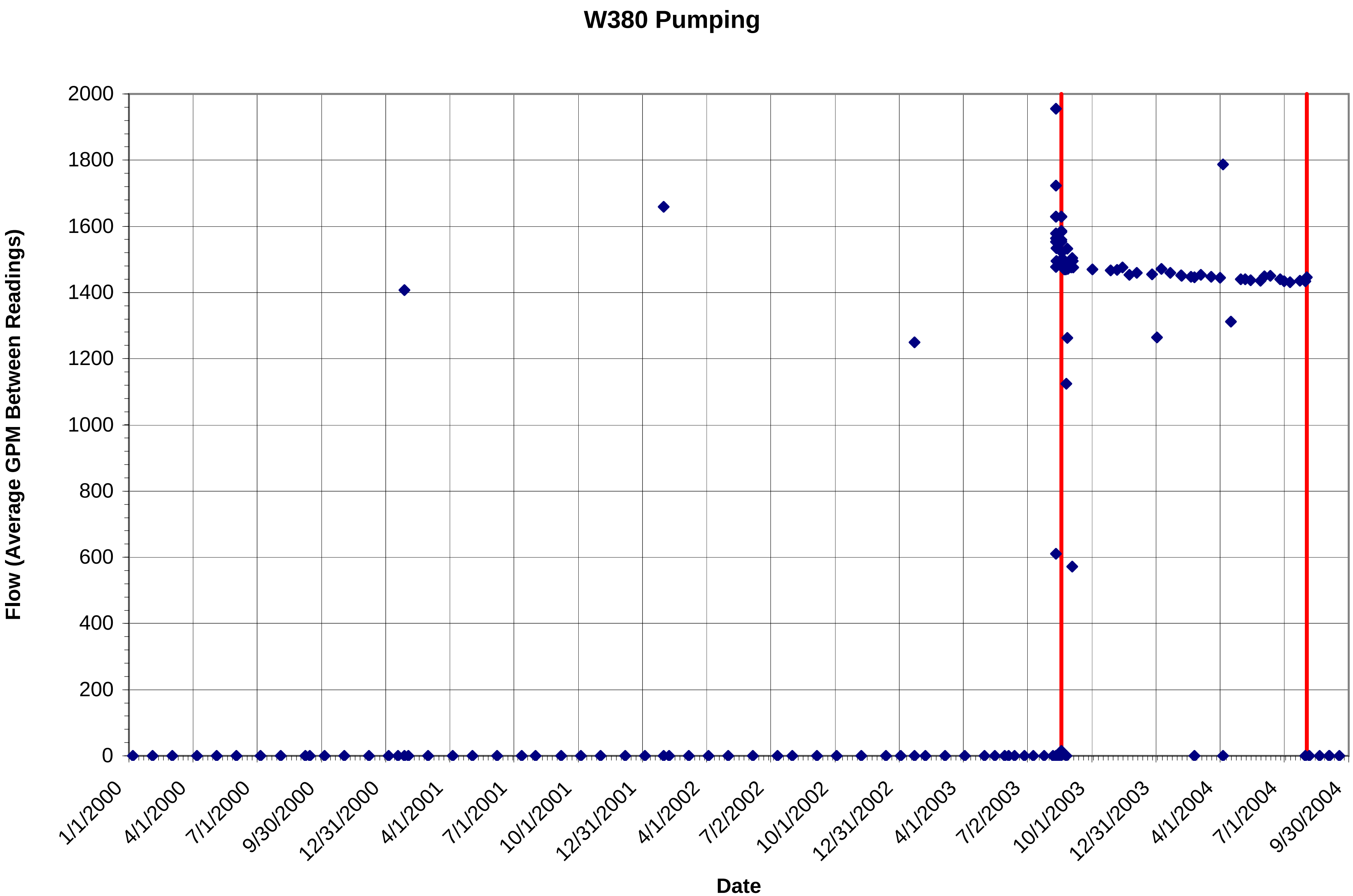


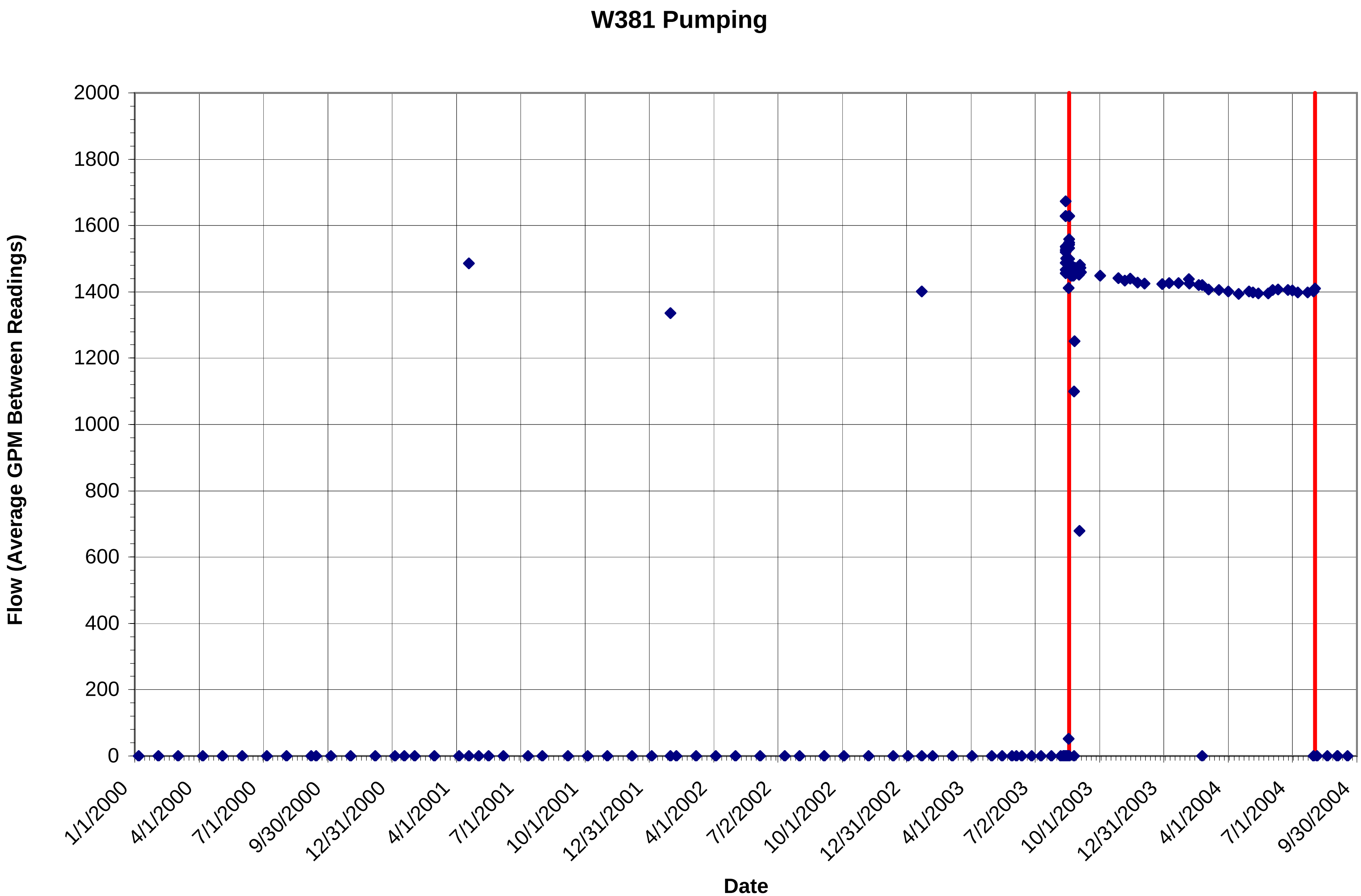
T806 Water Level (10 Year View)
Water Level (Feet MSL)
3816
3814
3812
3810
3808
3806
3804
3802
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date



V006G Water Level (10 Year View)
Water Level (Feet MSL)
3810
3808
3806
3804
3802
3800
3798
3796
3794
1/1/1995
7/2/1995
1/1/1996
7/1/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
12/31/1998
7/2/1999
1/1/2000
7/1/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
12/31/2002
7/2/2003
1/1/2004
7/1/2004
Date

APPENDIX D
Well W380 and W381 Flow Data

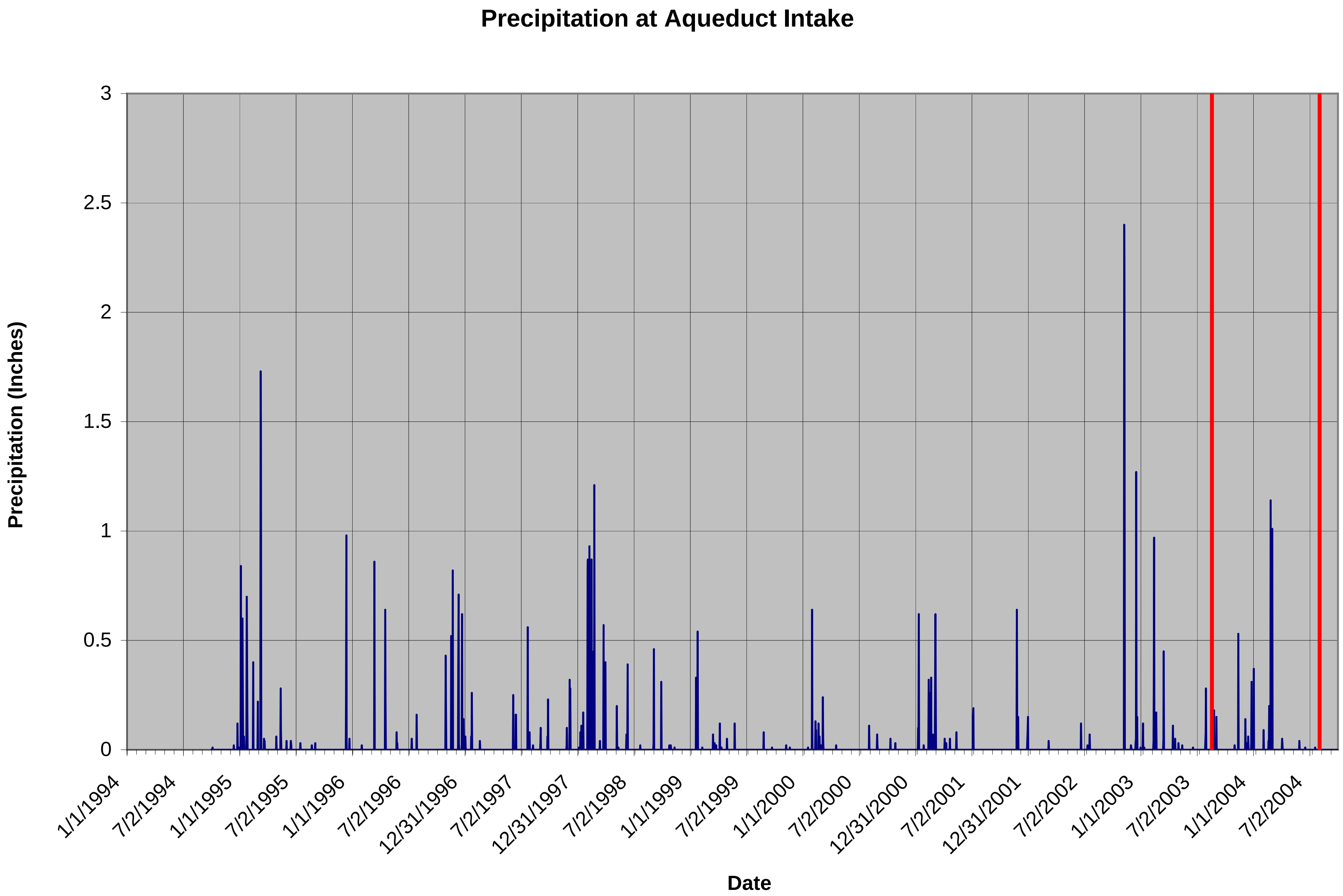

W380 Pumping
Flow (Average GPM Between Readings)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/1/2000
4/1/2000
7/1/2000
9/30/2000
12/31/2000
4/1/2001
7/1/2001
10/1/2001
12/31/2001
4/1/2002
7/2/2002
10/1/2002
12/31/2002
4/1/2003
7/2/2003
10/1/2003
12/31/2003
4/1/2004
7/1/2004
9/30/2004
Date

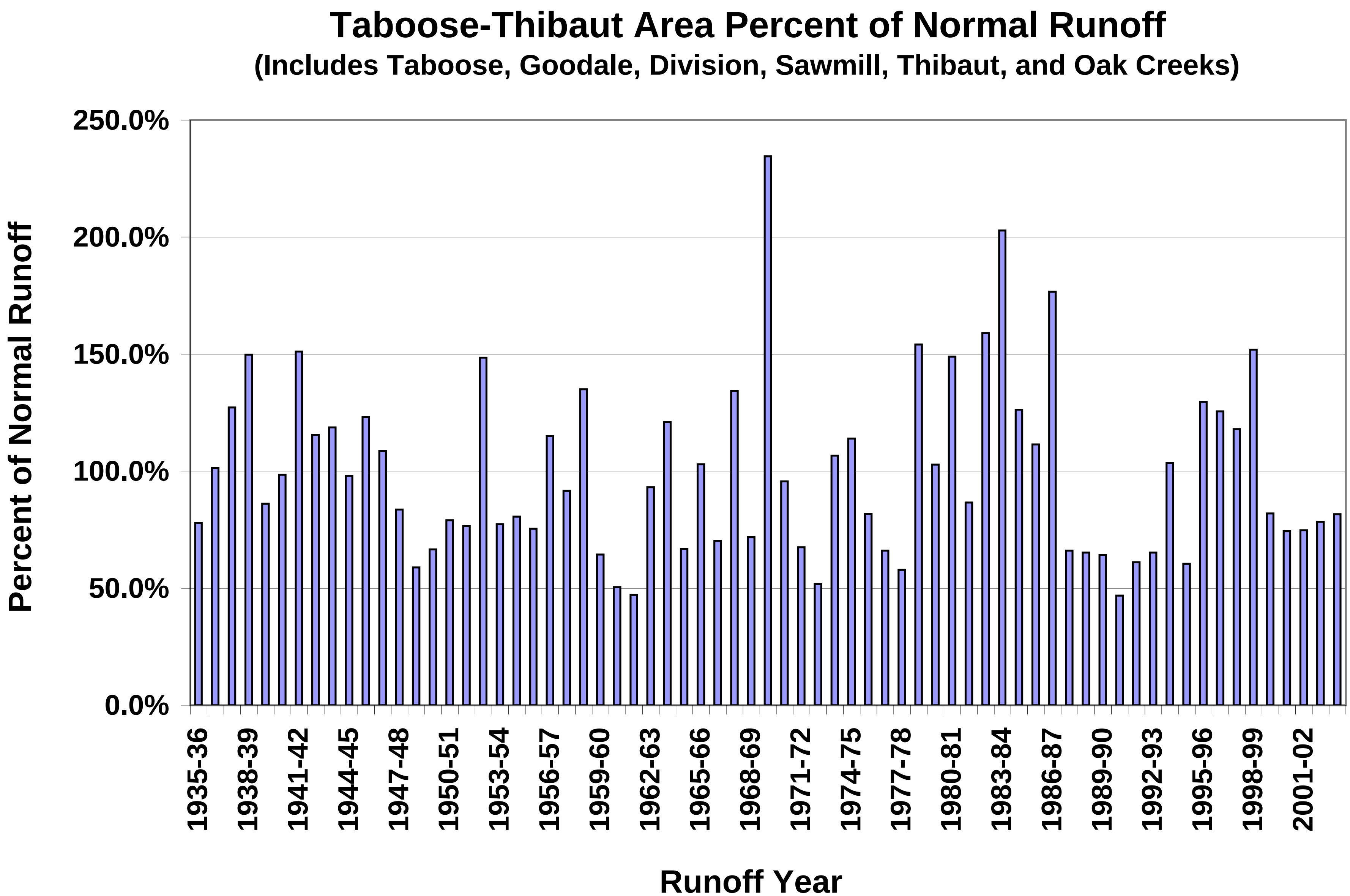


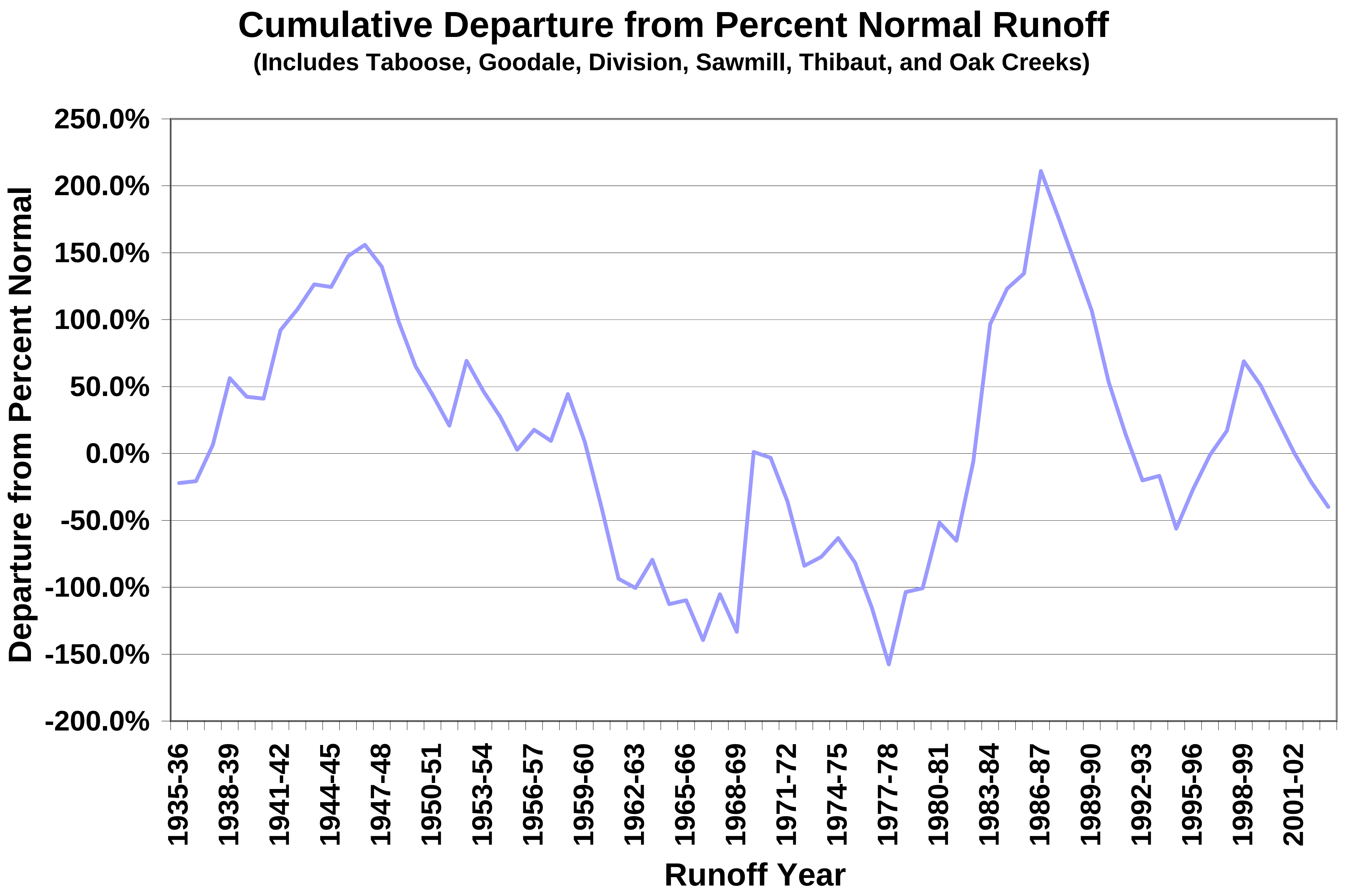
W381 Pumping
Flow (Average GPM Between Readings)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1/1/2000
4/1/2000
7/1/2000
9/30/2000
12/31/2000
4/1/2001
7/1/2001
10/1/2001
12/31/2001
4/1/2002
7/2/2002
10/1/2002
12/31/2002
4/1/2003
7/2/2003
10/1/2003
12/31/2003
4/1/2004
7/1/2004
9/30/2004
Date

APPENDIX E

Runoff and Precipitation Data for Taboose-Thibaut Area

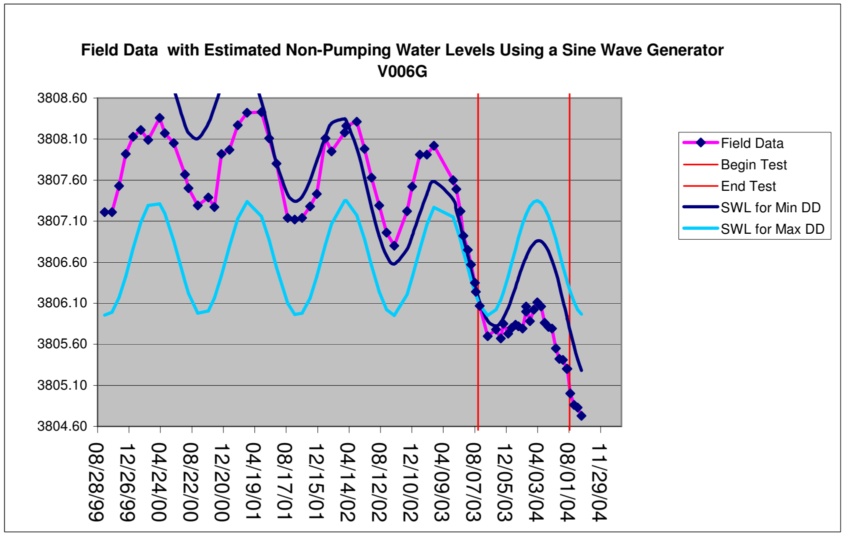

Precipitation at Aqueduct Intake
Precipitation (Inches)
3
2.5
2
1.5
1
0.5
0
1/1/1994
7/2/1994
1/1/1995
7/2/1995
1/1/1996
7/2/1996
12/31/1996
7/2/1997
12/31/1997
7/2/1998
1/1/1999
7/2/1999
1/1/2000
7/2/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
1/1/2003
7/2/2003
1/1/2004
7/2/2004
Date

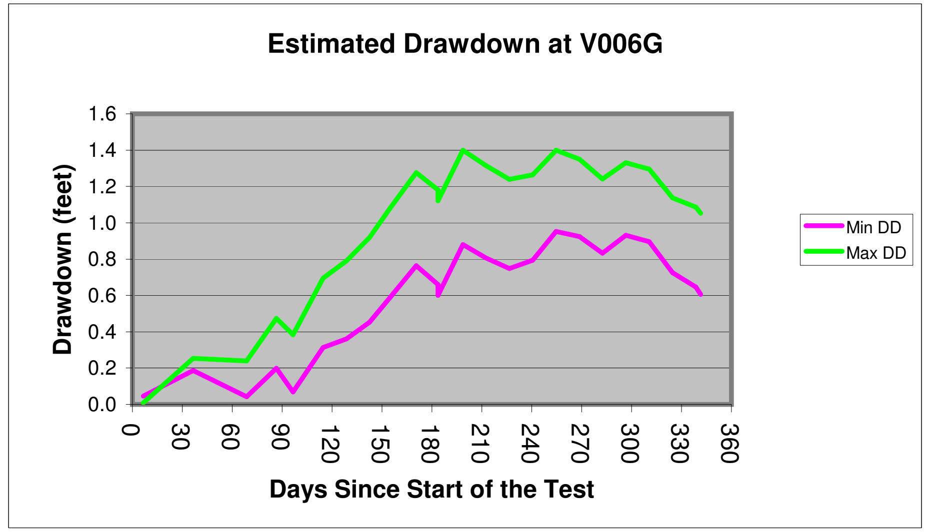

Taboose-Thibaut Area Percent of Normal Runoff
(Includes Taboose, Goodale, Division, Sawmill, Thibaut, and Oak Creeks)
Percent of Normal Runoff
250.0%
200.0%
150.0%
100.0%
50.0%
0.0%
1935-36
1938-39
1941-42
1944-45
1947-48
1950-51
1953-54
1956-57
1959-60
1962-63
1965-66
1968-69
1971-72
1974-75
1977-78
1980-81
1983-84
1986-87
1989-90
1992-93
1995-96
1998-99
2001-02
Runoff Year


Cumulative Departure from Percent Normal Runoff
(Includes Taboose, Goodale, Division, Sawmill, Thibaut, and Oak Creeks)
Departure from Percent Normal
250.0%
200.0%
150.0%
100.0%
50.0%
0.0%
-50.0%
-100.0%
-150.0%
-200.0%
1935-36
1938-39
1941-42
1944-45
1947-48
1950-51
1953-54
1956-57
1959-60
1962-63
1965-66
1968-69
1971-72
1974-75
1977-78
1980-81
1983-84
1986-87
1989-90
1992-93
1995-96
1998-99
2001-02
Runoff Year

APPENDIX F
Examples of Graphic Methods of Drawdown Correction

Appendix F - Example Methods of Drawdown Correction

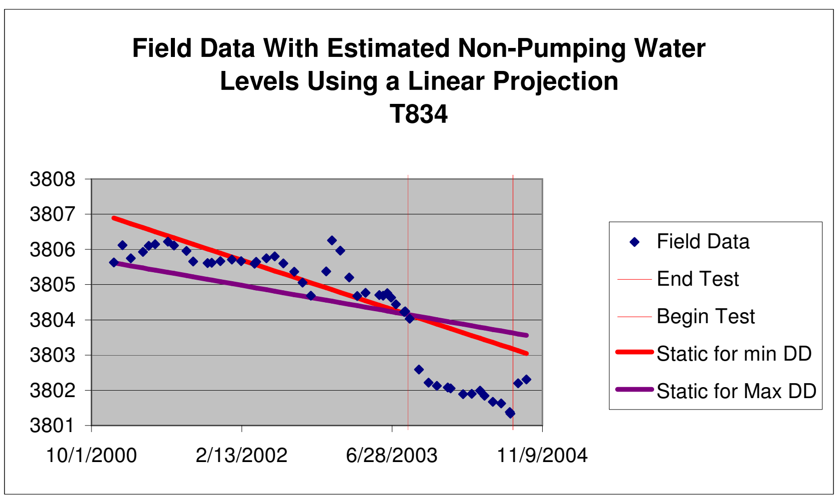


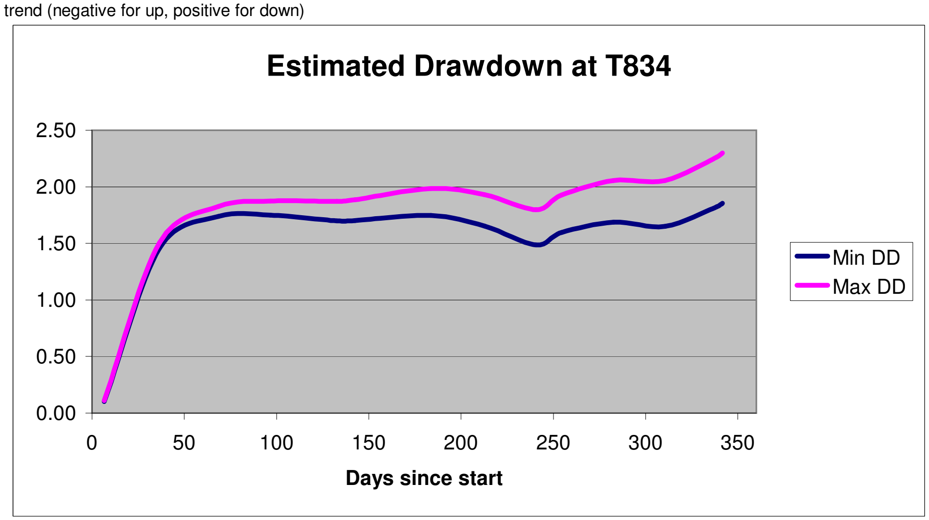


Sine Wave Generator:

$$y=(A\sin[\omega(x-\alpha)]+C)-x\delta$$

A =	0.7	0.7	**A** is the amplitude (the height of each peak above the baseline)
P =	380.0	365.0	**P** is the period or wavelength (the length of each cycle, generally 1 year)
α =	37620	37621	**α** is the phase shift (horizontal offset)
C =	3807.1	3806.65	**C** is the vertical offset (vertical offset)
ω =	0.016535	0.017214	**ω** is the angular frequency, given by $\omega = 2\pi/P$ (calculated value)
δ =	0.002	0	**δ** is the linear trend superimposed on the sine trend (negative for up, positive for down)





APPENDIX G
Meeting Notes and Correspondence

M E M O R A N D U M

MWH
MONTGOMERY WATSON HARZA

To:	Deep Well Operational Test Cooperative Study Team	**Date:**	2-December 2004
From:	MWH	**Reference:**	1342202.070101
Subject:	Deep Well Operational Test		

The Deep Well Operational Testing of wells W380 and W381 was conducted from August 19, 2003 to August 2, 2004. During this period, the wells were pumped continuously (except for brief shutdowns), while groundwater elevations and surface flows were monitored in a variety of locations.

The data collected during the test has been organized, reduced, and plotted on Excel spreadsheets for analysis by the Cooperative Study team. The next step in the analysis is to "filter" the data to estimate what the drawdown due to pumping (only) was. The purpose of this memo and accompanying spreadsheet is to provide an initial evaluation of the data, and to provide some suggested methods of filtering the data as a basis for our next group discussion. The raw data and hydrographs produced from this data are being transmitted to the Study Team on CD via Federal Express.

General Observations

For each well, hydrographs have been produced for a 10-year period prior to the test, and a more detailed 1-year period during the test. For many of the hydrographs, an upward trend in groundwater elevations is observed from 1995 to 2000, while a stable or slightly downward trend is observed since approximately 2000. For this reason, the pre-2000 data appears to be of little value in estimating what the trend would have been had the wells not been pumping.

Transmitted with this memorandum is a spreadsheet entitled "Deep Well – Test Filtering.xls". The first worksheet of the spreadsheet entitled "Summary Table" provides a summary of the hydrographs that have been plotted.

As an initial data reduction method, each of the hydrographs were classified as to their apparent response to the year-long pumping of wells W380/381. Three basic classifications were identified, which where named "Trendline", "Peak Comparison", and "Surface Water (SW) Features". The names assigned to these hydrographs suggest potential methods to filter out the effects of pumping (vs. other effects on groundwater levels), as noted below.

In general, **"trendline"** hydrographs appear to differentiate themselves in that the non-test trend (or estimated water level if W380 and W381 had not been pumped) appears to be a more-or-less linear projection of conditions prior to the test. Two subsets of this type of hydrograph are noted: those that occur in flowing wells, and those that appear to occur under apparently confined conditions. The "trendline/confined" wells show a clear, classic, confined aquifer response to pumping. The trendline hydrographs are generally the most straightforward in terms of filtering out the effects of pumping (only).

The hydrographs labled "**peak comparison**" differentiate themselves by displaying a sinusoidal pattern of seasonal fluctuation, sometimes overlain on a downward trend observed since about 2000. All of these wells are in the shallow zone. In many cases, the relatively regular sinusoidal pattern shows higher amplitude in the spring of 2003 prior to initiation of the test. This higher amplitude appears to be the result of high total rainfall in the fall of 2002, and in particular, a relatively intense rainfall event on November 8 and 9, 2002.

The "**SW features**" hydrographs are characterized by irregular changes of groundwater levels that suggest significant influences by adjacent surface water or other external factors.

The categorizations described above are necessarily general and somewhat arbitrary, and in many cases, hybrids of the different generalizations are observed. In fact, each hydrograph is unique, and will require significant subjective judgement to estimate what effects are due to pumping of W380/381, and what effects are due to other factors.

Potential Filtering Methods

The attached spreadsheet entitled "Deep Well – Test Filtering.xls" has worksheets showing examples of potential methods to filter the data. The examples given are for wells V066, T661, and T631. Well V066 is an example of a "peak comparison" type well. The method used to estimate drawdown displayed in this hydrograph is as follows:

- Construct two parallel lines representing the trend of the peaks and troughs of the preceding seasons
- Align the peak and trough of the estimated non-pumping hydrograph with the observed peak and trough during testing, and the projected peaks from previous seasons.
- Complete the estimated "non-pumping" hydrograph by using rising and falling slopes similar to what was seen in preceding seasons.
- Subtract the estimated non-pumping hydrograph from the actual field data to estimate drawdown.

The other two examples are examples of trendline-type hydrographs, and are therefore more straightforward. The most challenging type of filtering occurs in "SW features"-type hydrographs, where a relationship between groundwater elevations and causal factors is complex. In our initial review, we found no universally applicable, statistical method for filtering of the data. The hydrographs should be completed on a case-by-case basis, using professional judgement.

Recommended Next Steps

The CD being transmitted to you has all of the hydrographs and other surface flow data collected during the test. Prior to investing further in potential filtering methods, it is probably worthwhile for the team to meet and discuss the hydrographs. The recommended next steps are for the Cooperative Team members to:

- Review the data on the CD and the suggested filtering methods
- Meet to discuss ideas on improvements of methods to filter the data
- Assign filtering of various wells to team members (MWH, ICWD, LADWP)
- Compile the filtered data and produce maps of areal patterns of drawdown

It will important for the team to produce an estimate of drawdown at *all* of the points where data is available, and fill in column J of the attached summary worksheet. This is because it will be required to produce a map of drawdown, and will help calibrate estimations at adjacent points. Although estimating drawdown is subjective and can be frustrating, it is unlikely that better data will become available in the near future. The map of estimated drawdown after one year will be very important for producing an accurate conceptual model of aquifer behavior during deep pumping, and, as always, the more data points we have, the better.

While DWP and ICWD is reviewing the hydrographs and other data, MWH will proceed with production of maps of the potentiometric surface of non-filtered data, and preparations for aquifer parameter calculations using the methods of Neuman and Witherspoon (1969).

M E M O R A N D U M

MWH
MONTGOMERY WATSON HARZA

To: Robert Harrington, ICWD
Victor Harris, MWH
Saeed Jorat, LADWP
Tom McCarthy, MWH

Date: Feb 14, 2005

From: Jae Hill, Pacifica Services

Reference: 1342202

Subject: Notes from Deep Well Pump Test Cooperative Study Meeting, Feb 10 2005

These notes briefly outline the key points of a meeting held on February 10th. In attendance were: Robert Harrington of ICWD, Saeed Jorat of LADWP, Thomas McCarthy of MWH, and Jae Hill of Pacifica Services. Attending via teleconference was Victor Harris of MWH. The meeting took place between the hours of 1pm and 3:30pm, at the LADWP Bishop Admin Office. The main purpose of the meeting was to discuss the results of the hydrographic evaluation and to prepare for future drawdown mapping. The key points are listed below.

MAPS

- A drawdown map will likely need to be made to identify outliers.
- Drawdown maps will need to produced using recommended "best guess" data between the max-max and min-max estimates.
- Cross sections will be created based on the drawdown maps.
- Bob Harrington initially suggested plotting one map for max-max drawdown, and one for min-max. Later, the group consensus was the "best professional judgement" or "best guess" method.

DATA

- Methods used – sinusoidal, trough-to-trough, peak-to-peak, linear through zero.
- Wells had often dropped off of the trend prior to the start of the test.
- There is a general declining trend dating back further than the start of the tests.
- ICWD's wells outside of the study zone indicated a general declining trend as well. (eg 418, 419.) This must be documented in the study report.
- The terminology concerning the "best guess estimates" needs to be carefully chosen and refined. "Max DD" or "Min DD" are confusing and misleading.
- "Recommended drawdown estimates" seemed to be the best working title for the drawdown values that will be plotted.
- T631 and T629 appear to be deep wells, and should be swapped with T628 and T630 which are listed as deep. This could eliminate the variance from the expected data.

DATES

- Respective parties should have their summarized data and recommended drawdown figures to Jae by the 22nd of February for compilation into a master table, which will then be circulated for review.
- One week will be allotted for comments. After the review is complete, the data should be returned to Jae, comments will be summarily incorporated, and the mapping process will commence.

FUTURE WORK

- Bob will discuss wells associated with the monitoring site “Laws 5” (W387, W388, W245,?) with ICWD. There are currently no monitoring wells associated with “Laws 5”.
- Saeed offered to have wells T628 through T631 sounded by a hydrographer to give certain results on depth and screening.
- Bob will check the hydrographer’s notes for the flowing wells to determine if the high values are legitimate.

Bob Harrington <bharrington@inyowater.org>

02/17/2005 10:14 AM

To Victor E Harris <Victor.E.Harris@us.mwhglobal.com>

cc "Hill, Jae" <Jae.Hill@WATER.LADWP.com>, saeed.jorat@water.ladwp.com, Thomas D McCarthy <Thomas.D.McCarthy@us.mwhglobal.com>

Subject Re: Deep well

Hi all-------

Attached is a table, similar to what Victor circulated, that summarizes what I think we are after. As Victor says, it's hard to quantitatively factor in the observation that there may be a regional decline from 2002 to 2003 that deviates from the linear trend of the previous couple of years. I made note of it in the comments, and put the lower limit of estimated maximum drawdown at zero for wells where it seemed that the regional decline might be possible for the observed decline.

Regarding the nomenclature, the headers I used were 'range of maximum drawdown' and 'best estimate of maximum drawdown.' The term 'Recommended drawdown' might be misconstrued as a statement about what drawdown thresholds we think should be used for groundwater management -- we aren't recommending these drawdowns for any particular purpose; they are our best assessment of what amount of our observed drawdown was due to pumping.

Bob

--
Bob Harrington, Hydrologist
Inyo County Water Department
163 May St.
Bishop, CA 93514
(760) 872-1168
bharrington@inyowater.org

Table XXX. Drawdown at monitoring wells attributable to operation of W380 and W381.

Well	Range in est. maximum drawdown (ft)	Best estimate of maximum drawdown (ft)	Comments
Shallow wells			
T660	0.0 - <0.2	0.0	No apparent effect.
T416	0.0 - <0.5	0.0	Irregular hydrograph; steep decline following end of test (LAA-mediated?).
T803	0.0 - 0.4	0.0	Linear decline; background trend poorly defined.
T583	---	---	Dry.
T380	0.0 - 0.5	0.4	Declined from background trend during test, decline possibly regional.
T507	0.0 - 1.1	0.7	Declined from background trend during test, possibly regional; decline prior to test occurs earlier in season than in previous years.
T805	0.3 - 0.7	0.6	Declined from background trend during test; some part of decline maybe regional.
T850	0.0 - 0.6	0.4	Declined from background trend during test, decline possibly regional.
Deep wells			
T629	49.5 - 53.5	53.0	Rapid decline to over 50 feet, gradual recovery to 49.5; rapid recovery at end of test (decline in pumping well efficiency/rate with drawdown?).
V105	0.0 - 0.4	0.3	Possible drawdown during first few months of test, but recovers during test. Post-test recovery similar to initial drawdown.
V366	2.0 - 2.4	2.2	Rapid drawdown followed by irregular increasing trend.
V049	---	--	No data.
Flowing well			
F053	---	--	Flow data only.

M E M O R A N D U M

Pacifica Services Inc.

To:	Robert Harrington, ICWD Victor Harris, MWH Saeed Jorat, LADWP Tom McCarthy, MWH	**Date:**	April 14, 2005
From:	Jae Hill, Pacifica Services	**Reference:**	1342202

Subject: Notes from Deep Well Pump Test Cooperative Study Meeting, April 14th 2005

These notes briefly outline the key points of a meeting held on April 14th. The meeting took place between the hours of 3pm and 4:30pm, at the LADWP Bishop Admin Office. In attendance were: Robert Harrington of the Inyo County Water Department, Saeed Jorat of the Los Angeles Department of Water and Power, Thomas McCarthy and Victor Harris of MWH, and Jae Hill of Pacifica Services. The main purpose of the meeting was to review the preliminary mapping effort, and discuss the results of the drawdown estimations. The key points are listed below.

REVIEWING INTERPRETED DRAWDOWN

- The idea was brought forward to put in zeroes at the Aqueduct locations to show the buffering effects of the LAA. This idea was later dismissed.
- Due to an error in the original XYZ locations provided for the wells, T416 and T457 were mapped in the incorrect locations, adding confusion to the drawdown map.
- A discussion on the unconstrained boundaries should be included in the text.
- Cut off contours to delimit area of greatest confidence.
- Determine the limits of influence

REVIEW OF REPORT OUTLINE

- Review will take place outside of the meeting.
- Requests and changes should be submitted to the group as soon as possible.

CONSENSUS ON NEXT TESTING LOCATION

- Recommended to superimpose the veg map over the drawdown map to evaluate effects.
- Next site could be “Laws 5”, if Sally and Paula can agree.
- A new scope of work is required for the project.
- Intensive monitoring at the start was likely overkill, according to Bob.
- If canal operations change in Laws, this may affect data.
- The test should start in the fall.
- Seasonal effects will be present no matter when the tests are started.

SCHEDULE

- Revised maps – week of April 18th
- Draft report – in two to three weeks