Prepared for:
BIG BEND GMD NO. 5
125 S. Main Street
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HYDROLOGIC MODEL OF BIG BEND GROUNDWATER MANAGEMENT DISTRICT NO. 5

APPENDICES

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BALLEAU GROUNDWATER, INC.
901 Rio Grande Blvd. NW, Suite F-242
Albuquerque, New Mexico 87104
(505) 247-2000

APPENDIX A

JIAN, X., 1998

SIMULATION OF CANAL AND CONTROL-POND OPERATION AT THE QUIVIRA NATIONAL WILDLIFE REFUGE, SOUTH-CENTRAL KANSAS: U.S. GEOLOGICAL SURVEY WATER-RESOURCES INVESTIGATIONS REPORT 97-4289

Simulation of Canal and Control-Pond Operation at the Quivira National Wildlife Refuge, South-Central Kansas

By XIAODONG JIAN

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 97–4289

Prepared in cooperation with the
KANSAS GEOLOGICAL SURVEY

Lawrence, Kansas
1998

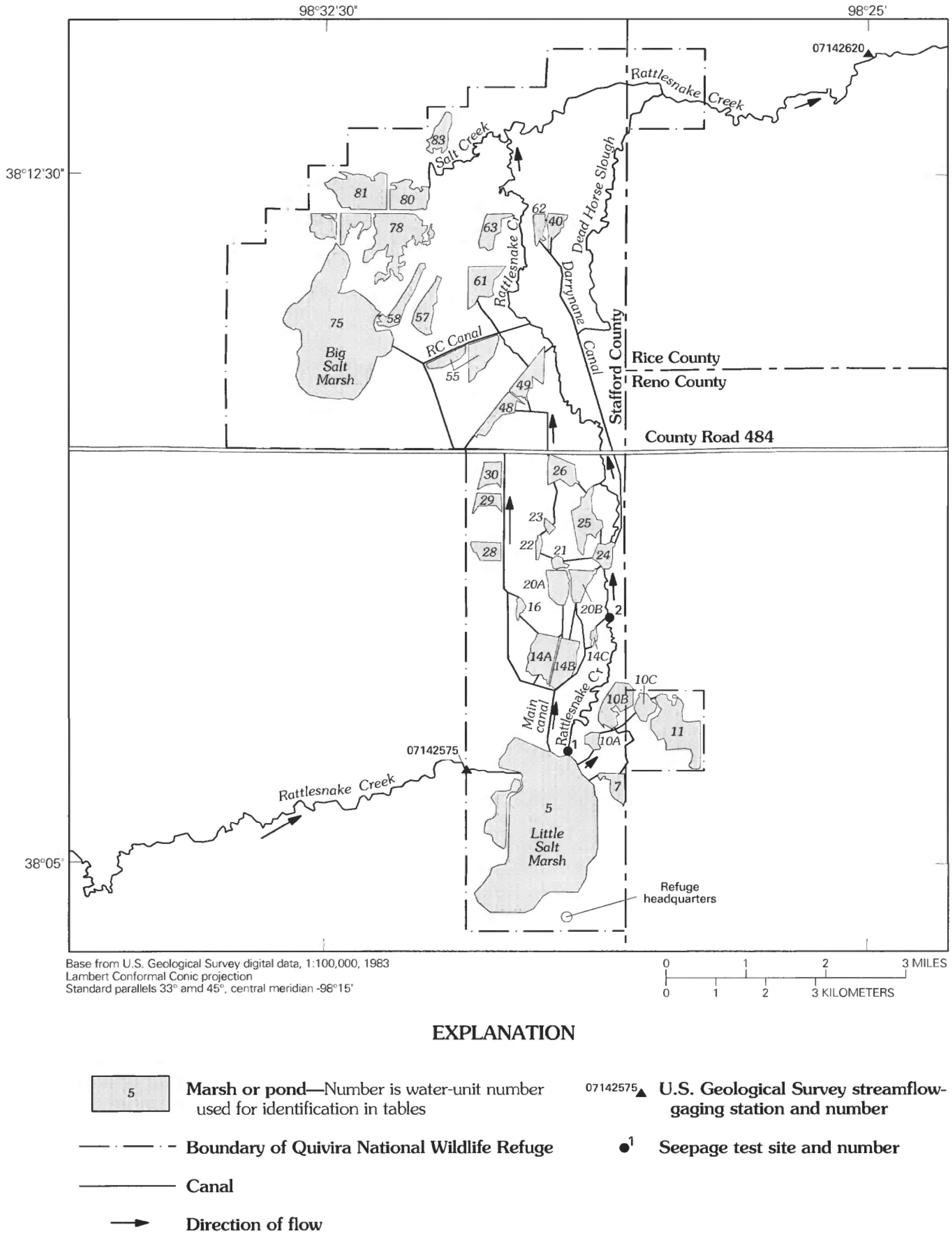


Figure 2. Ponds and canals at Quivira National Wildlife Refuge.

est, and highest annual mean discharges for the same period were 48.4, 2.77, and 190 ft^3/s, respectively (Putnam and others, 1996).

In addition to the water supplied by Rattlesnake Creek, surface runoff to ponds generated by precipitation also plays an important role. The delineated drainage areas of the ponds are listed in table 1 (Marios Sophocleous, Kansas Geological Survey, written commun., 1997). These drainage areas were used for the calculation of overland surface runoff to the ponds. Surface runoff was estimated using the SCS curve-number method (Soil Conservation Service, 1985). SCS curve numbers for control ponds at Quivira National Wildlife Refuge also are listed in table 1. A description of the SCS curve-number method is found in the section "Estimation of Direct Overland Surface Runoff."

The refuge currently diverts water from the Little Salt Marsh (water unit 5), which is supplied by Rattlesnake Creek, into the main canal and into water units 7, 10A, 10B, 10C, and 11 (fig. 2). Water also flows from the Little Salt Marsh back into Rattlesnake Creek. Water in the creek flows north to water unit 24, where part of the water is diverted into the Darrynane Canal and into units 21 and 25. Some water flows into Rattlesnake Creek north of unit 24 and is transported to the west and north into the units north of County Road 484.

Ground Water

The ponds in the north part of the refuge are within a ground-water discharge area. Table 2 shows the estimated monthly ground-water discharge from shallow aquifers to ponds for 1994 (Marios Sophocleous, Kansas Geological Survey, written commun., 1997). These values were estimated using a previous ground-water simulation done by Sophocleous and Perkins (1992) and the delineated drainage area of the ponds (table 1). The total ground-water discharge to ponds for 1994 was about 6,200 acre-ft.

Physical Features of Control Ponds

Bottom elevations and full-pond capacities of control ponds are listed in table 3 (Megan Estep-Johnston, U.S. Fish and Wildlife, written commun., 1995). To express mathematically the elevation-volume-area relation of a pond, the pond storage was first divided into several water-depth zones. The number of zones

Table 1. Drainage area and SCS curve number for control ponds at Quivira National Wildlife Refuge, south-central Kansas

[SCS, U.S. Soil Conservation Service. Drainage areas and SCS curve numbers are from the Kansas Geological Survey (Marios Sophocleous, written commun., 1997)]

Water-unit number (fig. 2)	Drainage area (acres)	SCS curve number
5	1,890.7	74.020
7	140.8	42.680
10A	84.9	48.397
10B	201.4	47.575
10C	84.5	47.575
11	341.4	47.575
14A	149.9	71.217
14B	124.9	71.693
14C	59.5	33.552
16	180.0	40.753
20A	179.4	58.461
20B	116.4	73.101
21	60.0	76.469
22	82.5	45.543
23	43.8	46.615
24	259.9	51.636
25	226.7	55.711
26	194.7	67.952
28	228.4	38.659
29	78.9	60.995
30	69.0	61.968
40	207.2	42.018
48	305.6	73.499
49	137.4	71.000
55	582.8	72.250
57	257.5	69.910
58	186.7	62.831
61	258.8	71.481
62	90.4	52.546
63	201.4	71.000
75	5,621.7	69.583
78	635.9	70.544
80	187.1	70.544
81	620.9	70.544
83	149.4	70.544
Total	**14,240.5**	

Table 3. Full-pond elevations, water-surface areas, and capacities for selected control ponds at Quivira National Wildlife Refuge

[Data from U.S. Fish and Wildlife Service (Megan Estep-Johnston, written commun., 1995). BM, bench mark; ft, feet]

Water-unit number (fig. 2)	Bottom elevation (feet above sea level)	Full-pond elevation, in feet above sea level (datum location)		Full-pond surface area (acres)	Full-pond capacity (acre-feet)
5	1,780	1,783	(SPILLWAY)	864	1,866
7	1,774	1,778	(TOP OF STOPLOG SLOT)	26	40
10A&10B	1,774	1,779	(TOP OF STOPLOG SLOT)	64	145
10C	1,772	1,774.4	(TOP OF GAGE)	11	13
11	1,754	1,774.9	(SPILLWAY)	90	338
14A	1,772	1,778	(SPILLWAY)	87	196
14B	1,772	1,776.7	(SPILLWAY)	65	96
14C	1,774	1,777	(14C[1] BM–0.67 ft)	7	16
16	1,768	1,775	(TOP OF STOPLOG SLOT)	31	80
20A	1,767	1,770.7	(SPILLWAY)	138	195
20B	1,767	1,770.7	(SPILLWAY)	138	195
21	1,764	1,770	(TOP OF STOPLOG SLOT)	30	81
22	1,764	1,766	(22A[1] BM–0.6 ft)	10	13
23	1,762	1,764.3	(TOP OF GAGE)	9	15
24	1,765	1,769.4	(SPILLWAY)	31	35
25	1,762	1,768.4	(TOP OF GAGE)	94	296
26	1,758	1,762	(SPILLWAY)	59	111
28	1,762	1,768	(28A[1] BM–0.86 ft)	85	153
29	1,757	1,762	(29C[1] BM–0.58 ft)	61	91
30	1,756	1,759	high water	78	119
40	1,736	1,742.5	(40B[1] BM–0.65 ft)	32	66
48	1,750	1,754.4	(SPILLWAY)	89	113
49	1,750	1,754.2	(SPILLWAY)	95	159
57	1,740	1,743.5	(57A[1] BM–0.6 ft)	127	212
58	1,736	1,742	(58B[1] BM–0.5 ft)	99	251
61	1,740	1,745.5	(62B[1] BM–0.58 ft)	218	498
62	1,735	1,744	(TOP OF STOPLOG SLOT)	47	120
63	1,736	1,741.2	(TOP OF GAGE)	154	339
75	1,736	1,740.8	(SPILLWAY)	1,768	2,446
			Total	**4,607**	**8,298**

[1]Letters indicate structure names where water levels are measured.

were different for different ponds. For example, the number of zones for water unit 5 and water unit 24 were two and five, respectively (table 4). The bottom elevation (above sea level) of each zone was called the zonal elevation base (Z_b) for the corresponding zone. The elevation-volume-area relation of a pond was rep-

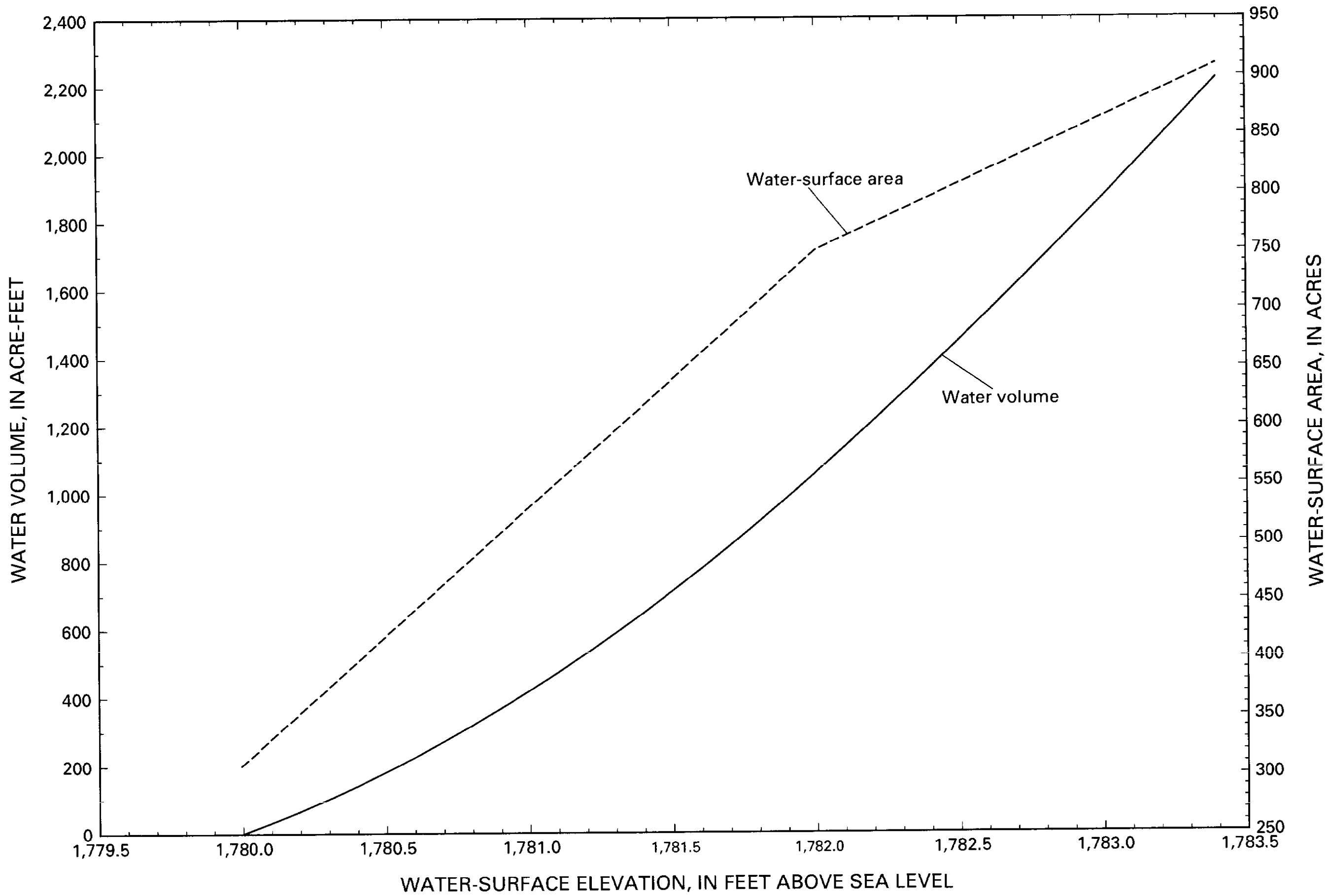


Figure 3. Relations of water-surface elevation, water volume, and water-surface area for Little Salt Marsh (water unit 5, fig. 2).

Because flows in canals at the refuge are not regulated, one flow zone (normal) was used in the flow model development. In model simulations, canal flows were maintained in the normal flow zone as long as possible.

Operating Policy

Under ideal inflow conditions, all pond levels would be maintained at the target water levels (rule curves), and all canal flows would be maintained in the normal flow ranges in addition to satisfying water-management requirements such as minimum desirable streamflow (Kansas Water Office, written commun., 1996). In reality, ideal inflow conditions rarely occur. If a pond water level was higher or lower than its rule curve, a "cost" or "penalty" was assessed to the water storage or depletion deviation from the rule curve. The penalty depended on the amount of water deviation from the target level and the penalty coefficient (cost per unit water deviation from the target level). A penalty was also assessed to canal flows. In other words, penalty coefficients were assigned to each storage zone of a pond and each flow zone in a canal to assess penalty.

Different penalty coefficients were assigned according to management priorities related to each storage zone of a pond. Penalty coefficients for canal flows were specified in a similar way. Higher penalty coefficients were assigned to the extended upper zone and inactive zone, and smaller penalty coefficients were assigned to the conservation zone (the lower zone and the upper zone) because water levels needed to be maintained in the conservation zone for normal use. The penalty coefficient in the normal-flow zone in a canal was generally zero or less than the penalty coefficient of the pond conservation zone. A higher penalty coefficient was assigned for violation of normal flow range; that is, the higher values of penalty coefficients were assigned to the upper and lower flow zones.

To optimally operate the canal and pond system at the refuge, it was necessary for some interpond rela-

Table 6. Results of seepage tests along Rattlesnake Creek, 1996, at Quivira National Wildlife Refuge

[Data from U.S. Fish and Wildlife Service (Megan Estep-Johnston, written commun., 1996). ft^3/s, cubic feet per second]

Date (month/day/year)	Discharge (ft^3/s) Upstream test site 1 (fig. 2)	Downstream test site 2 (fig. 2)
06/26/96	6.93	6.15
07/17/96	8.98	7.46
07/24/96	3.13	2.92
09/09/96	5.52	5.12

Geological Survey, written commun., 1997) for 1994 were used (table 2).

Pond Water-Surface Elevations

Water-surface elevations for selected control ponds were measured during the simulation period. Table 7 lists the ponds with measured water-surface elevations, the number of measurements, and the minimum and maximum water-surface elevations for the ponds. Because the water levels may be at the bottom of ponds or above the staff gage at ponds, the number of observations of water-surface elevations listed in table 7 may be different than the number of measurements listed. The difference between the number of observations and the number of measured elevations is the number of records without measurements. Those water-surface elevations observed outside the range of measurement on pond staff gages were treated accordingly as the pond-bottom elevation or the full-pond elevation in this simulation.

Pond Zoning and Operating Policy

Each control pond was divided into four storage zones—inactive zone, lower zone, upper zone, and extended upper zone as shown in figure 5. Target water levels (rule curves) were set at the top of the lower zone. For ponds with measured water-surface elevations (table 7), the measured water elevations were used as their rule curves, which indicates that the rule curves changed during the simulation period and so did the storage capacity of lower and upper zones. For those ponds without measured water levels, the rule curves were set at 95 percent of their corresponding full-pond storage capacities. The capacity of the inactive zone of a pond was set at 20 percent of full-pond storage capacity (selected in consultation with the U.S. Fish and Wildlife Service). Some of the rule curves for some ponds with measured water levels were located in the inactive zone during the simulation. In this case, the top boundary of the inactive zone capacity was set at the rule curve, and the capacity of the lower zone was set to zero. The top boundary of the upper zone was set at the full-pond elevation. The top boundary of the extended upper zone was set 0.5 ft higher than its full-pond elevation. For ponds whose maximum measured water levels were higher than the full-pond elevation plus 0.5 ft, the top boundaries of the extended upper zone were set at the maximum measured water level. Pond zoning expressed as pond storage is summarized in table 8.

To operate the system of canals and control ponds on the refuge, it was necessary to establish the priority of the ponds. Because Little Salt Marsh (water unit 5), which is supplied by Rattlesnake Creek, serves as the principal water-storage unit for the entire refuge, the highest operational priorities were given to its storages zones. Water units (75, 78, 80, 81, and 83, see fig. 2) in the north part of the refuge were given the lowest operational priorities because these ponds are at the downstream end of the refuge and control less drainage area. The remaining ponds were given priorities in between the highest and the lowest priorities. Under this operating policy, water to satisfy the downstream water requirements was released first (1) from the lowest priority ponds when water levels at the highest priority ponds were below the rule curve so that high-priority pond water levels were as close as possible to their rule curves, or (2) from the highest priority ponds when their water levels were higher than the rule curves so that the water levels would decrease to as close to their rule curves as possible. To represent priorities of ponds, different penalty coefficients were assigned to each of the storage zones of the ponds. The higher the priority, the higher the penalty coefficient assigned. It should be noted that the relative magnitudes, not the absolute values, of the penalty coefficients determined the optimal operation of the system. Different combinations of assigned values of penalty coefficients were tested for the control ponds on the refuge. Typical values of penalty coefficients used in this simulation are summarized in table 8.

Because there are no flow requirements such as minimum-required flow for canals on the refuge, there

Table 7. Summary of water-surface elevations for selected ponds at Quivira National Wildlife Refuge, June 11 through December 11, 1996

[Data from U.S. Fish Wildlife Service, written commun., 1997]

Water-unit number (fig. 2)	Number of observations	Number of measurements	Maximum measured elevation (feet above sea level)	Minimum measured elevation (feet above sea level)
5	30	30	1,783.30	1,782.62
7	30	23	1,778.96	1,777.33
10A	30	16	1,778.67	1,777.03
10B	30	29	1,778.89	1,777.32
10C	32	32	1,774.86	1,773.22
11	32	14	1,773.91	1,771.95
14A	30	30	1,777.92	1,776.30
14B	30	30	1,777.36	1,774.90
16	30	28	1,774.46	1,772.72
20A	29	29	1,770.84	1,769.56
21	29	17	1,769.09	1,767.00
22	29	29	1,767.17	1,764.91
23	29	27	1,764.78	1,763.02
24	30	30	1,770.46	1,769.61
25	33	20	1,766.92	1,763.16
26	28	28	1,762.06	1,760.14
28	30	17	1,767.81	1,764.10
29	30	26	1,761.83	1,757.20
30	30	17	1,760.01	1,756.48
40	29	22	1,742.59	1,738.58
48	29	25	1,754.28	1,750.88
49	29	29	1,754.13	1,750.25
58	30	30	1,740.90	1,739.59
61	29	29	1,743.89	1,742.54
62	29	29	1,742.64	1,739.55
63	29	29	1,740.73	1,739.17
75	29	7	1,740.17	1,739.55

Table 8. Initial storage, zoning, and penalty coefficients assigned to control ponds at Quivira National Wildlife Refuge, June 11 through December 11, 1996

Water-unit number (fig. 2)	Initial storage (acre-feet)	Upper boundary of extended upper zone (acre-feet)	Penalty coefficient for extended upper zone	Upper boundary of upper zone (acre-feet)	Penalty coefficient for upper zone	Lower boundary of lower zone (acre-feet)	Penalty coefficient for lower zone	Lower boundary of inactive zone (acre-feet)	Penalty coefficient for inactive zone
5	1,988.26	2,312.18	2,000	1,866.00	1,500	373.20	1,500	1.00	5,000
7	39.72	72.90	2,000	40.00	1,500	8.00	1,000	1.00	2,000
10A	145.48	180.30	2,000	145.00	1,500	29.00	1,000	1.00	2,000
10B	145.48	180.30	2,000	145.00	1,500	29.00	1,000	1.00	2,000
10C	19.54	21.81	2,000	13.00	1,500	2.60	1,000	1.00	2,000
11	388.37	440.07	2,000	338.00	1,500	67.60	1,000	1.00	2,000
14A	161.70	242.20	2,000	196.00	1,500	39.20	1,000	1.00	2,000
14B	93.40	185.74	2,000	96.00	1,500	19.20	1,000	1.00	2,000
14C	15.51	19.07	2,000	16.00	500	3.20	500	1.00	2,000
16	62.67	96.07	2,000	80.00	1,500	16.00	1,000	1.00	2,000
20A	163.88	268.01	2,000	195.00	1,500	39.00	1,000	1.00	2,000
20B	163.88	268.01	2,000	195.00	1,500	39.00	1,000	1.00	2,000
21	34.34	96.62	2,000	81.00	1,500	16.20	1,000	1.00	2,000
22	2.30	18.81	2,000	13.00	1,500	2.60	1,000	1.00	2,000
23	15.41	19.66	2,000	15.00	1,500	3.00	1,000	1.00	2,000
24	132.55	139.01	2,000	35.00	1,500	7.00	1,000	1.00	2,000
25	18.00	344.05	2,000	296.00	1,500	59.20	1,000	1.00	2,000
26	91.48	142.39	2,000	111.00	1,500	22.20	1,000	1.00	2,000
28	6.11	198.82	2,000	153.00	1,500	30.60	1,000	1.00	2,000
29	0.20	124.51	2,000	91.00	1,500	18.20	1,000	1.00	2,000
30	2.82	161.64	2,000	119.00	1,500	23.80	1,000	1.00	2,000
40	55.91	83.19	2,000	66.00	1,500	13.20	1,000	1.00	2,000
48	3.94	161.19	2,000	113.00	1,500	22.60	1,000	1.00	2,000
49	51.63	209.05	2,000	159.00	1,500	31.80	1,000	1.00	2,000
57	212.22	280.74	2,000	212.00	1,500	42.40	1,000	1.00	2,000

Table 8. Initial storage, zoning, and penalty coefficients assigned to control ponds at Quivira National Wildlife Refuge, June 11 through December 11, 1996—Continued

Water-unit number (fig. 2)	Initial storage (acre-feet)	Upper boundary of extended upper zone (acre-feet)	Penalty coefficient for extended upper zone	Upper boundary of upper zone (acre-feet)	Penalty coefficient for upper zone	Lower boundary of lower zone (acre-feet)	Penalty coefficient for lower zone	Lower boundary of inactive zone (acre-feet)	Penalty coefficient for inactive zone
58	146.39	302.82	2,000	251.00	1,500	50.20	1,000	1.00	2,000
61	212.80	613.17	2,000	498.00	1,500	99.60	1,000	1.00	2,000
62	48.58	145.00	2,000	120.00	1,500	24.00	1,000	1.00	2,000
63	268.98	419.01	2,000	339.00	1,500	67.80	1,000	1.00	2,000
75	2,445.85	3,490.32	1,000	2,446.00	500	489.20	500	1.00	2,000
78	5,270.43	6,091.37	1,000	5,270.00	500	1,054.00	500	1.00	2,000
80	355.20	474.34	1,000	355.00	500	71.00	500	1.00	2,000
81	25.31	60.68	1,000	25.00	500	5.00	500	1.00	2,000
83	314.34	419.31	1,000	314.00	750	62.80	750	1.00	2,000

was only one flow zone for canals designated in this simulation. It was assumed that flow through a canal reach ranged in magnitude from zero to the full capacity of the canal. Because of the complexity of the canal flow network on the refuge, flows could reach the same location through different routes of canals. Different penalty coefficients were assigned to the flow zones of canals so that the most efficient route could be determined by minimizing the total penalty applied to canal flows. However, costs of transporting water through canals were not available. Because Rattlesnake Creek is used as the major route to distribute water to the refuge and because other canals are used only when necessary, flows through Rattlesnake Creek and canals downstream from control ponds were assigned penalty coefficients of zero, and the remaining canals were assigned nonzero penalty coefficients as shown in table 9 (see figures 2 and 4 for nodal names, location, and flow network).

Results

The simulation of canal and control-pond operation at the Quivira National Wildlife Refuge for June 11 through December 11, 1996, was conducted using the following specifications for pond zoning, operating policy, and canal outflow from the refuge: (1) four storage zones for each pond, with the inactive storage of 20 percent of full-pond storage capacity; (2) rule curves set at the measured water levels for ponds with measurements, otherwise at 95 percent of full-pond storage capacity; (3) initial storage in ponds interpreted from the water levels measured on June 10, 1996, for ponds with measurements, otherwise set at 95 percent of full-pond storage capacity; and (4) outflows from the refuge through Rattlesnake Creek near the USGS streamflow-gaging station near Raymond equal to the observed discharges at the streamflow-gaging station (fig. 11*C*).

Figures 12*A-D* show the water-budget components simulated for the operation of water unit 5. Similar figures also can be generated for other control ponds. Inflows shown in figure 12*A* are upstream inflows from Rattlesnake Creek, which are equal to the discharges observed at the USGS streamflow-gaging station near Zenith. Total downstream releases shown in figure 12*C* are the summations of releases to all downstream nodes (water units 7 and 10A, and nodes C–2 and JE–1, see figure 4). Ground-water seepage during the simulation period shown in figure 12*B* is almost the same for the whole simulation period (the values were estimated for 1994, see table 2). Figure 12*E* shows the simulated and measured water stages and depths. From July 9 to August 8, even though there were no releases from the pond, the simulated water stages were lower than the

Table 10. Water budgets simulated for selected control ponds at Quivira National Wildlife Refuge, June 11 through December 11, 1996

[All values are in acre-feet; --, not applicable]

Water-unit number (fig. 2)	Initial storage	+ Total upstream inflow	+ Total surface runoff	- Water-surface evaporation	- Ground-water seepage	- Total downstream release	= Final storage
5	1,988.26	17,782.22	1,117.84	1,795.73	286.00	16,844.87	1,961.72
7	39.72	486.93	31.98	57.25	0	431.67	69.71
10A	145.48	169.66	57.79	109.78	0	117.67	145.48
10B	145.48	531.21	55.60	98.40	34.04	467.15	132.70
10C	19.54	459.95	9.25	20.34	0	449.93	18.47
11	388.37	448.42	54.08	101.65	0	400.85	388.37
14A	161.70	214.52	96.82	152.05	0	152.25	168.74
14B	93.40	197.43	150.80	120.57	-9.20	179.99	150.27
14C	15.51	102.95	6.88	12.81	18.09	91.24	3.20
16	62.67	114.02	29.02	51.88	0	92.57	61.26
20A	163.88	493.65	142.78	250.73	0	353.34	196.24
20B	163.88	433.68	141.17	249.69	7.36	285.45	196.23
21	34.34	531.79	31.32	48.36	0	494.16	54.93
22	2.30	489.96	13.63	22.24	0	460.62	23.03
23	15.41	458.46	10.26	17.77	0	448.68	17.68
24	132.55	12,741.83	63.05	93.63	103.47	12,666.91	73.42
25	18.00	676.23	55.85	72.37	40.89	494.09	142.73
26	91.48	862.43	63.69	93.92	7.25	829.71	86.72
28	6.11	635.03	44.60	69.63	0	497.53	118.58
29	.20	482.72	38.38	53.35	0	404.38	63.57
30	2.82	396.78	62.17	97.04	0	196.68	168.05
40	55.91	77.90	14.03	34.19	-36.27	83.58	66.34
48	3.94	316.42	73.47	72.85	0	245.36	75.62
49	51.63	567.52	64.72	102.76	11.87	437.18	132.06
57	212.22	1,193.02	156.57	257.91	0	1,102.51	201.39
58	146.39	1,388.52	83.47	135.49	-86.07	1,429.80	139.16
61	212.80	340.11	123.31	209.47	-50.68	380.83	136.60
62	48.58	59.57	17.64	33.97	-31.89	57.62	66.09
63	268.98	132.23	129.33	232.08	-76.44	243.73	131.17
75	2,445.85	1,177.96	1,445.34	2,043.86	-2,484.88	4,004.79	1,505.38
78	5,270.43	5,359.15	1,728.99	3,161.14	-291.63	7,252.18	2,236.88
80	355.20	7,542.65	155.93	363.20	-85.77	7,705.34	71.01
81	25.31	7,252.18	41.67	94.73	-323.22	7,542.65	5.00
83	314.34	0	188.34	352.91	-68.48	14.14	204.11
Total	**13,102.68**	--	**6,499.77**	**10,683.75**	**-3,035.56**	--	**9,211.91**

Table 11. Water budget simulated for entire canal and control-pond system at Quivira National Wildlife Refuge, June 11 through December 11, 1996

[All values are in acre-feet; --, not applicable]

Water-budget component	Storage	Inflow	Outflow
Initial storage	13,102.68	--	--
Stream inflow	--	17,782.21	--
Surface runoff	--	6,559.04	--
Water-surface evaporation	--	--	10,683.74
Net ground-water seepage	--	3,035.56	--
Canal-flow transmission loss	--	--	2,761.79
Outflow from Raymond node	--	--	17,822.07
Final storage	**9,211.88**	--	--

Data Preparation

In this section, data needed for the simulation are discussed. Measurement data were used if available. If some data were not available, reasonable values were interpreted on the basis of other related data.

Precipitation

One of the major factors affecting the generation of direct overland surface runoff to ponds is the amount of precipitation. Figure 13*A* shows the daily precipitation measured at the Sandyland Experiment Station and at the USGS streamflow-gaging station near Zenith (fig. 1). Precipitation data from October 1, 1990, through May 20, 1991, were measured at the Sandyland Experiment Station. Precipitation data from May 21 through September 30, 1991, were measured at the USGS streamflow-gaging station near Zenith. The total amount of precipitation during the 1991 water year was 13.43 in.

Water-Surface Evaporation

The daily potential evapotranspiration (PET) estimated with the Penman method using the climatic data collected at the Sandyland Experiment Station (Marios Sophocleous, Kansas Geological Survey, written commun., 1996) is shown in figure 13*B*. The total amount of PET was 61.23 in. for the 1991 water year. For the 1991 water year simulation, it was assumed that the daily water-surface evaporation rate for ponds on the refuge was equal to the corresponding daily potential evapotranspiration at the Sandyland Experimental Station.

Canal Discharge

Discharges for Rattlesnake Creek measured at the USGS streamflow-gaging stations near Zenith and Raymond (fig. 1) from October 1, 1990, through September 30, 1991, are shown in figure 13*C* (Geiger and others, 1992). The mean daily discharges for the Zenith and Raymond stations during the 1991 water year were 6.59 and 2.77 ft^3/s, respectively, which are much smaller than the long-term means of 50.6 ft^3/s (1973–95 water years) and 48.8 ft^3/s (1960–95 water years), respectively. As shown in the figure 13*C*, there was almost no flow during late September 1991.

For this simulation, the daily mean discharge observed at the USGS streamflow-gaging station near Zenith station was used as daily inflows to Little Salt Marsh from Rattlesnake Creek. The daily mean discharge observed at the USGS streamflow-gaging station near Raymond was used as the streamflow requirement for Rattlesnake Creek near Raymond.

Canal-Flow Transmission Losses

Canal-flow transmission loss was difficult to estimate. Because there were no data available to estimate the canal-flow transmission loss coefficient for the canals on the refuge during the simulation period, the estimated transmission loss coefficient (k in equation 42) of 9.16×10^{-6} ft^{-1} for the 1996 simulation period was used for this simulation. Similar to 1996, canal-flow transmission losses occurred only in canals south of the RC Canal.

Ground-Water Discharge to Ponds

No monthly data for ground-water discharge to ponds were available for the simulation period. The study conducted using MODFLOW by Marios Sophocleous (Kansas Geological Survey, written commun., 1996) shows that the amount of annual ground-water discharge to ponds on the refuge was almost the same from 1975 through 1990. Consequently, the monthly ground-water-discharge data obtained from Marios Sophocleous (Kansas Geological Survey, written commun., 1997) for 1994 were used (see table 2).

Table 13. Water budgets simulated for control ponds at Quivira National Wildlife Refuge with rule curve at 90 percent of full-pond capacity, 1991 water year

[All values are in acre-feet; --, not applicable]

Water-unit number (fig. 2)	Initial storage at 80 percent of full-pond capacity +	Total upstream inflow +	Total surface runoff -	Water-surface evaporation -	Ground-water seepage[1] -	Total downstream release =	Final storage
5	1,492.80	4,772.63	900.16	3,970.32	545.66	2,312.24	337.37
7	32.00	27.62	17.03	60.87	0	15.78	0
10A	116.00	81.59	48.37	196.59	0	41.33	8.04
10B	116.00	56.16	31.97	132.51	64.84	6.78	0
10C	10.40	6.68	5.53	22.61	0	0	0
11	270.40	0	41.11	175.91	0	0	135.60
14A	156.80	117.93	67.12	252.34	0	80.85	8.66
14B	76.80	64.16	44.27	171.41	-18.25	27.51	4.56
14C	12.80	56.63	5.13	17.70	24.97	31.89	0
16	64.00	48.64	19.21	72.22	0	54.60	5.03
20A	156.00	100.37	78.10	303.93	0	29.97	.57
20B	156.00	196.85	96.66	380.01	13.88	55.62	0
21	64.80	51.83	22.11	85.13	0	50.50	3.11
22	10.40	50.07	6.45	23.09	0	43.83	0
23	12.00	43.62	6.40	23.31	0	38.71	0
24	28.00	1,541.96	17.28	62.83	149.33	1,375.08	0
25	236.80	94.39	73.72	268.01	75.04	61.85	.01
26	88.80	99.09	30.52	121.74	13.50	83.17	0
28	122.40	61.71	44.38	172.26	0	53.03	3.20
29	72.80	51.45	31.35	123.71	0	30.83	1.06
30	95.20	30.25	42.70	167.16	0	.99	0
40	52.80	0	30.79	134.70	-86.83	8.19	27.53
48	90.40	35.50	43.20	167.99	0	.12	.99
49	127.20	45.13	52.38	205.68	19.03	0	0
57	169.60	343.12	114.11	485.65	0	102.75	38.43
58	200.80	362.88	92.46	394.82	-173.34	390.50	44.16
61	398.40	565.28	208.54	902.49	-109.08	283.94	94.87
62	96.00	0	40.37	173.96	-70.19	3.15	29.45
63	271.20	189.92	150.50	650.00	-161.39	59.07	63.94
75	1,956.80	254.24	1,478.91	6,103.74	-5,002.59	1,642.84	945.96
78	4,216.00	1,881.86	1,262.39	5,406.83	-587.57	1,486.99	1,054.00
80	284.00	2,028.75	147.51	646.47	-172.74	1,915.53	71.00
81	20.00	1,486.99	37.92	162.60	-651.44	2,028.75	5.00
83	251.20	0	133.69	522.11	-137.75	0	.53
Total	**11,525.60**	--	**5,422.34**	**22,760.70**	**-6,264.92**	--	**2,883.07**

[1]The positive values of ground-water seepage indicate that ponds lost water to the aquifer. The negative values of ground-water seepage indicate that ponds gained water from the aquifer.

Table 14. Water budget simulated for entire canal and control-pond system at Quivira National Wildlife Refuge with rule curve at 90 percent of full-pond capacity, 1991 water year

[All values are in acre-feet; --, not applicable]

Water-budget component	Storage	Inflow	Outflow
Initial storage	11,525.60	--	--
Stream inflow	--	4,772.63	--
Surface runoff	--	5,422.34	--
Water-surface evaporation	--	--	22,760.70
Net ground-water seepage	--	6,264.92	--
Canal-flow transmission loss	--	--	336.51
Outflow from Raymond node	--	--	2,005.24
Final storage	**2,883.07**	**--**	**--**

To examine the water budget for the whole flow system at the refuge, table 14 summarizes the overall water budget for the entire canal and control-pond system with the rule curve set at 90 percent of full-pond capacity. It can be seen from this table that although there were total inflows of 16,459.89 acre-ft, of which 4,772.63 acre-ft were from Rattlesnake Creek at Zenith node, 5,422.34 acre-ft from direct surface runoff, and 6,264.92 acre-ft from the ground-water seepage to ponds, the final water storage in the system was substantially reduced from the initial storage of 11,525.60 acre-ft, which was set at 80 percent of full-pond capacity, to 2,883.07 acre-ft due to the outflows from the Raymond node, water-surface evaporation, and canal-flow transmission loss. Total water out of the system (outflow, evaporation, and canal-flow transmission loss) from the system was 25,102.45 acre-ft, of which 22,760.70 acre-ft (or 91 percent of water outflow from the system) was due to water-surface evaporation. At the end of simulation period, 30 out of 34 ponds, including water unit 5, had water stored only in the inactive zone or were dry due to the large amount of water-surface evaporation.

To compare the operation of canal and control ponds with the rule curve at 90 percent of full-pond capacity, simulations were also conducted with the rule curves at 80, 70, and 60 percent of full-pond capacity. All of simulations were conducted with the same model specification except for the rule curves.

Figure 15 shows the change in water storage for water units 5 and 78, respectively, with different rule curves. As the rule curve was reduced from 90 to 60 percent of full-pond capacity, water storage in water unit 5 during the simulation period decreased, and the final pond storage was also reduced from 337 to 48 acre-ft (fig. 15*A*). Because water unit 5 had the highest priority and because the initial storage was higher than the rule curve, water was released immediately downstream as shown in figure 15*A*. On the other hand, water storage in water unit 78 increased during the simulation period (fig. 15*B*). Because water unit 78 had the lowest priority and because water storage in the upstream higher priority ponds was in the upper zone, water was released from these higher priority ponds to maintain their rule curves, and water released from the upstream pond was stored in the unit 78, which caused the water storage to reach full-pond capacity (fig. 15*B*). After mid-June 1991, there were not enough inflow (upstream inflow plus surface runoff) to water unit 5 to maintain water levels at the rule curve, and water levels decreased due to water-surface evaporation. At the end of simulation, the water level in water unit 5 was located in the inactive zone (figs. 14 and 15*A*). Similar changes in water storages were also observed for other control ponds.

The simulated water budget for the entire canal and control-pond system for the 1991 water year with different rule curves is summarized in table 15. As the rule curves were reduced from 90 to 60 percent of full-pond capacity, surface runoff, water-surface evaporation, and ground-water seepage from ponds were reduced, and stream outflow and final storage increased (see table 15). The reduction of the rule curve of a pond generally caused a lower pond water level to be maintained for the higher priority ponds. In other words, the total water-surface evaporation and rainfall onto the water-surface area of a pond were reduced for the same evaporation rate and precipitation depth. When initial pond storage was higher than the rule curve (initial storage was set at 80 percent of full-pond capacity), water was released from the ponds with higher priority to meet the rule-curve water level, which caused more canal-flow transmission losses along the canals in the south part of the refuge and increased outflows from water unit 11. The final pond water storage also increased due to storage increases in water unit 78 (fig.15*B*) and other ponds in the north part of the refuge.

Table 15. Water budgets simulated for entire canal and control-pond system at Quivira National Wildlife Refuge using different rule curves, 1991 water year

[all values are in acre-feet]

Water-budget component	Rule curve set at 90 percent of full-pond capacity	Rule curve set at 80 percent of full-pond capacity	Rule curve set at 70 percent of full-pond capacity	Rule curve set at 60 percent of full-pond capacity
Initial pond storage	11,525.60	11,525.60	11,525.60	11,525.60
Inflow:				
Stream inflow from Rattlesnake Creek	4,772.63	4,772.63	4,772.63	4,772.63
Surface runoff	5,422.34	5,393.31	5,260.83	4,981.23
Net ground-water seepage, including canal-flow transmission loss	-5,928.41	-5,900.37	-5,854.23	-5,854.04
Outflow:				
Water-surface evaporation	22,760.70	22,694.41	22,238.25	21,299.74
Total outflow	2,005.24	2,005.28	2,073.30	2,547.26
Final pond storage	**2,883.07**	**2,892.22**	**3,101.74**	**3,286.50**

Simulation results for the 1991 water year indicate that water-surface evaporation was the major factor in lowering water storage in ponds. Storing more water in the ponds in the north part of the refuge by reducing the rule curve for higher priority ponds may reduce the overall water-surface evaporation. However, this will also cause water unit 5 to dry out quickly if there is not enough upstream inflow as was the case during the 1991 water year. Maintaining high water levels in water unit 5 depends upon the rule curve in water unit 5 being set at a high level. The simulation results discussed for the 1991 water year were obtained based on a number of assumptions, such as the initial storage in ponds. If the specifications for the simulation model change, the results may be much different.

SUMMARY

In 1995, a 3-year study was undertaken to develop a water budget and flow-routing model to assist the U.S. Fish and Wildlife Service in determining the outcome of possible water-management options at the Quivira National Wildlife Refuge, south-central Kansas. The study was done by the U.S. Geological Survey in cooperation with the Kansas Geological Survey. A computer program OPONDS, written in FORTRAN, was developed using network flow analysis to determine the optimal operation of a system of canals and control ponds. Applications of the model are presented that investigate the daily operation of canals and control ponds on the refuge using historical discharge and pond water levels.

The daily operation of a system of canals and control ponds at the refuge in the Rattlesnake Creek Basin was simulated for June 11 through December 11, 1996, using a linear-network flow model. In this simulation, some management requirements included the measured water levels of control ponds as the target management pond levels and the observed stream discharges in Rattlesnake Creek near Raymond as the outflow requirement from the refuge. Measured precipitation and calculated potential evapotranspiration were used to compute the surface runoff to ponds and water-surface evaporation, respectively. The operating policy was determined by using selected storage zones within a pond and prioritization of the ponds by using the relative magnitude of penalty coefficients within the computer model to adjust pond storages and canal flows. Results of the 1996 simulation indicate that the current specification for pond zoning and rule curves, with water unit 5 given the highest priority and ponds in the north part of the refuge given the lowest priori-

APPENDIX B

KOELLIKER, J.K.
EFFECTS OF AGRICULTURE ON WATER YIELD IN KANSAS;
CHAPTER 7, *IN* SOPHOCLEOUS, M., ED., 1998,
PERSPECTIVES ON SUSTAINABLE DEVELOPMENT OF WATER RESOURCES
IN KANSAS: KANSAS GEOLOGICAL SURVEY BULLETIN 239

CHAPTER 7

Effects of Agriculture on Water Yield in Kansas,

James K Koelliker
Kansas State University, Manhattan, Kansas

Most of the land area of Kansas (over 90%) is used for agricultural purposes. Nearly all of the potential water supply for Kansas (98%) comes from precipitation onto the land surface.. The amount of precipitation averages about 28 inches (70 cm) per year over the state. The primary source of water resources available over the long term for other users in the state is runoff and percolation from the precipitation that falls on agricultural land within the state. Therefore, the activities of agriculture to use and manage the land play a role in affecting the amount and quality of water available for water-resource purposes. Effects of agriculture on water yield are of particular interest because the prior appropriation doctrine is used to allocate water rights. Therefore, understanding how agricultural activities influence the quantity of water lost from agricultural lands is crucial to account for the effects of more efficient use of water from precipitation as well as to decide how much water is potentially available for appropriation by other users.

Effects of agriculture on water yield have been of interest for many years. In much of the state, natural ecosystems, particularly prairies, have been converted to agricultural production Of cultivated crops. Two important changes occur. First, surface runoff is increased because the potential for loss by runoff is increased from soil that is bare or partially bare during the cropping cycle. Bare soil has a lower rate of infiltration than the same soil covered with growing plants or crop residue. Second, actual evapotranspiration is decreased because annual crops are actively growing for a shorter period of the year than perennial plants. This increases the potential for percolation and subsequent recharge. The exact effects of these changes depend upon the interactions of the climate, soil, and agricultural-management practices including those of soil and water conservation at a particular location.

In most of the state, water supply is limited because precipitation usually is less than potential evapotranspiration for much of the growing season. The success of dryland agricultural technology hinges on its ability to use precipitation as effectively as possible by a combination reducing runoff and increasing the amount of water used as evapotranspiration through useful crops. Additionally, where ground water is available, making use of it is usually very desirable.

The necessity to control wind and water erosion and improve water management was soon recognized in Kansas agriculture. Conservation techniques began to emerge in the 1930’s following the disastrous drought. National programs to reduce erosion soon were developed. Kansas has been a leader in the adoption of soil- and water-conserving techniques including terracing, conservation tillage, farm ponds, and watershed dams. A terrace is a broad channel, bench, or embankment constructed across the slope to intercept runoff and to detain the water or to channel the excess water to protected outlets for disposal from the field. Conservation tillage is a practice that uses mechanical or chemical means to control weeds and/or plant crops such that plant residues cover at least 30% of the soil surface to promote wind- and water-erosion control and moisture conservation.

To quantify the effects of agriculture, several factors that, interact must be considered—climate, soil, and agricultural-management practices which include type of land use, production practices, and conservation practices. Ideally, there would have been field experiments conducted to determine these effects. However, few have been done, and the length of time the experiments were operated were often insufficient to understand the interactions of all of the factors. Thus, simulation-modeling techniques have been required to obtain estimates of effects and to explain the effects on the availability of water resources in the state. The remainder of this chapter focuses on the development of a model, the results from a specific study, and a broader interpretation of those results for the entire state.

Background for Computer-simulation Modeling

In the 1960’s, the U.S. Department of Agriculture Soil Conservation Service (SCS), now known as the Natural Resources Conservation Service (NRCS), and Agricultural Research Service (ARS) used a joint task force to develop procedures to assess the effects of land and watershed treatment on streamfiow. Land and watershed treatment include change in land use from cropland to permanent cover crops such as native or tame grasses, structural measures such as terraces, tillage and surface-residue management, irrigation, farm ponds and watershed darns. The result was a rational approach based upon annual amounts of precipitation, a climatic variable, extent of land-use changes and conservation practices and other factors. At the time this work was done, however, the effectiveness of residue management was uncertain and the extent of future use of land treatment and other conservation practices was not well known. The procedure, however, has been used by the NRCS, and it did serve as a good basis for future work on the effects of land treatment on water yield. One major limitation of the procedure, however, was that the effects of land treatment and conservation practices on a continuous basis on water yield could not be determined easily. In particular, the variability from year to year in climate could not be accounted for very well with the rational technique.

Continuous computer-simulation modeling allows questions about effects of changes in land use, crops, and management practices to be assessed at various locations over a simulation period of many years. While direct comparison with measured results from field experiments are not possible because such measurements have not been made on whole watersheds, results can be compared with measured streamfiow if conditions in a drainage area are simulated for a period of time. In the late 1960's, water yield into several flood-control and irrigation-supply western Kansas reservoirs that had been built in the 1950's was much less than expected. When well-above-average amounts of precipitation that occurred in the early 1970's did not result in expected inflows to these reservoirs, the Bureau of Reclamation began a study of the Solomon River basin in Kansas to identify what was happening to the water supply. Speculation implicated changes in land use and soil-and water-conservation practices, changes in the precipita tion regime, and increased use of ground water from alluvial aquifers were involved. Work began at Kansas State University to develop a method to assess the effects of land use and soil- and water-conservation practices on water yield on a watershed basis.

Potential Yield Model

When a method was needed to assess the effects of land use and conservation practices on large watersheds for the Bureau of Reclamation, a continuous computer simulation model, called the Potential Yield (POTYLD) (Koelliker et al., 1981, Koelliker et al., 1982), was developed for this purpose. POTYLD simulates the daily change in the water budget for different climatic and landuse conditions to estimate the dispensation of precipitation as interception, runoff, actual evapotranspiration, percola tion, and change in water content in the soil. The model utilizes values of runoff curve numbers (RCN) to predict the split between runoff and infiltration for land uses from daily amounts of rainfall and snowmelt (See chapter 1 for more information on RCN values). Individual land uses and conservation-practice conditions can be described by a RCN, and the RCN technique is used widely to predict runoff from design storms. It follows that the RCN method can predict runoff over a period of time provided the antecedent moisture condition (AMC), how wet the soil was at the time of each storm, can be determined. This technique to assess runoff through a computer- simulation model is now used widely in watershed-simulation models. Recently, POTYLD has been modified to include additional refinements and to include irrigation; consequently, the name was changed to Potential Yield Revised (POTYLDR) (Koelliker, 1994a, 1994b). This model simulates the water budget on a daily basis for different land uses and estimates the water yield on a monthly or annual basis for a drainage area. A more comprehensive description of **POTYLDR** can be found in Appendix 7.A of this chapter.

The POTYLDR model is useful to estimate effects of land-use changes and agricultural soil-water conservation practices on surface-water yield and on percolation. Exact comparisons with data from the field are difficult because such data are very limited. The following section does provide the results of a comprehensive study to combine all impacts on water yield into Webster Reservoir along with estimates of the effects across the state. Extended use of the POTYLDR model for other studies, too, provides evidence that it reasonably documents real effects that have been and are being experienced in Kansas.

Results of Modeling Water-yield Changes

Several studies have been done with POTYLD. The most extensive was for the South Fork of the Solomon River basin above Webster Reservoir in northwest Kansas (Koelliker et al., 1981). Webster Reservoir, located on the South Fork of the Solomon River in Rooks County, has a watershed of 1,150 mi2 (2,980 kin2; fig. 7.1). It was completed in 1956, primarily to serve as a water supply for an 8,400-acre (3,400-ha) irrigation district and to control flooding and to provide recreation. After about 1975, however, the irrigation district seldom received a full delivery of water, and in several years no water was delivered. At streamflow-gaging stations in the region with 30 or more years of records, average streamflow during the 1970's was less than 25% of the long-term average. A report by the Bureau of Reclamation (1984) concluded that phreatophytes, water-loving plants, and changes in the nature of precipitation events were not important contributors to the declining streamflow. That same report did, however, conclude that withdrawal of ground water from the alluvial aquifer was an important contributor. The largest effect by far upon declining streamflow was that of soil- and water-conservation practices, a finding substantiated by POTYL

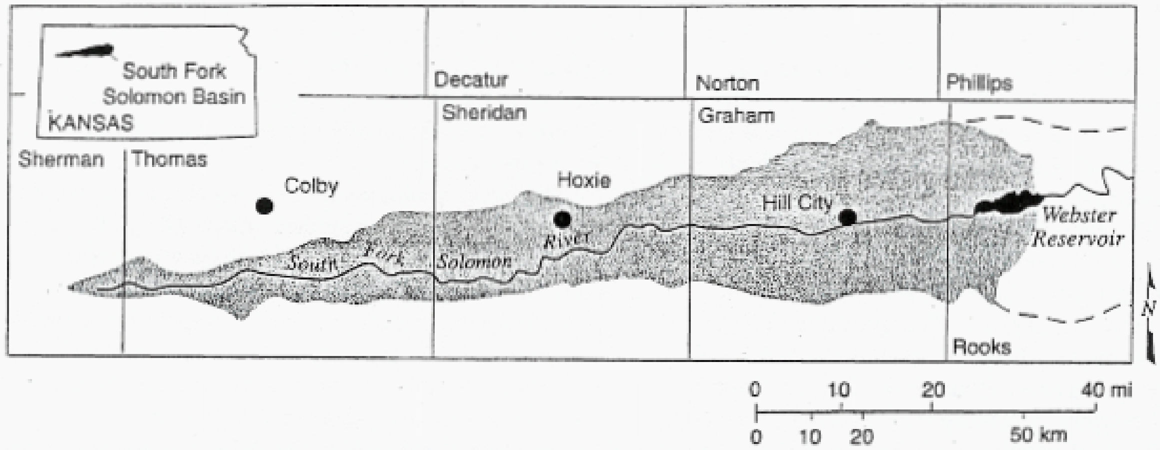


FIGURE 7.1—MAP OF THE SOUTH FORK SOLOMON RIVER BASIN (Koelliker et al., 1981).

Figure 7.2 shows streamflow for two conditions along with measured streamflow into Webster Reservoir for a period when both daily precipitation and streamflow were available for the study. The curve labeled "1950" represents the expected streamflow into Webster Reservoir if conditions above the reservoir had remained unchanged after 1950 Until the end of the simulation period in 1978. The curve labeled "changing" accounted for changes in land use, conservation practices, and ground-water withdrawals during the period simulated. A 3-year moving average is used because of limited availability of continuous weather records to represent the area. Rainfall is spatially quite variable because of the continental-type climate in the area. Because long-term changes were of interest, averaging shows the trend more clearly.

The results of the study showed that by 1980, the expected water yield into Webster Reservoir was predicted to be less than half the historic inflow (1920—1955) of 50,900 acre-feet/year (62.8x106 m3/yr). The Bureau of Reclamation reported the inflow to Webster Reservoir for the period, 1979—1988, averaged 13,300 acre-feet/year (16.4x106 m3/yr; Kutz, 1990), which further substantiated the results obtained by the use of POTYLD.

Fluctuations in all three curves in fig. 7.2 are caused by temporal changes in amounts of precipitation and the ability of that precipitation to produce runoff. Amounts of individual rainfall events and their timing and aerial distribution are critical tO the production of runoff. Continuous simulation is very helpful to evaluate fluctuations in streamflow because it can account for conditions in the watershed when precipitation occurs. By aggregating results from several sub-basins for a stream, the aerial distribution also can be accounted for partially. This is very helpful to describe the impact of precipitation on yield. A study of the Upper Republican River basin of northeastern Colorado, southern Nebraska, and northwest ern Kansas was done using POTYLD as a major component of the work (Koelliker et al., 1983). While changes in precipitation regime appear to be occurring in the Great Plains, the length of record (1920—1978) available for that study did not show it. When POTYLD was used with 1950 basin conditions held constant, essentially no

decrease in water yield with time was expected. A more recent study to estimate the future water supply for the Cheyenne Bottoms Wildlife Refuge, which comes from streamflow originating in west-central Kansas, showed a difference attributable to precipitation. For the period 1973—1988, the ability of precipitation to produce streamflow from this drainage basin was about 27% below that for the earlier period 1948—1972 (Koelliker, 1991).

An historical view of land use and development of agricultural technology on streamflow can be done by simulating for many years with conditions in the water shed fixed at given points in time. Then, the average of the results can be graphed against time to see if there are trends and effects. Such an analysis was done for the South Fork of the Solomon River above Webster Reser voir. In addition, the effects of changes in land use, conservation practices, and ground-water withdrawals during the period show the estimated impact of agriculture on water yield (fig. 7.3) (Koelliker, 1984). Initially, the watershed was all rangeland before 1850. Figure 7.4 shows the important changes with time that have occurred in the watershed. Agriculture was started around 1860 and by about 1930, 70% of the watershed was cropland. Drought and erosion has caused some cropland to be put

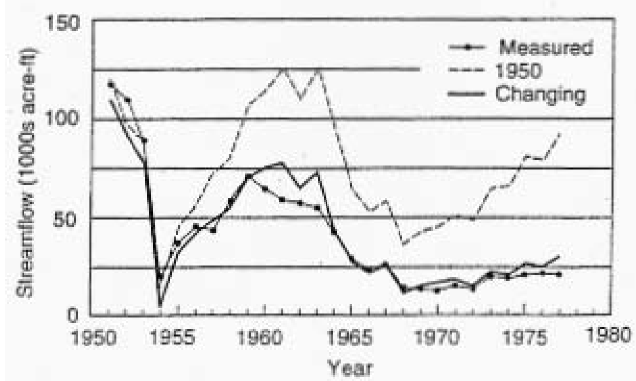


FIGURE 7.2—COMPARISON OF THE THREE-YEAR MOVING AVERAGE ACTUAL STREAMFLOW ABOVE WEBSTER RESERVOIR with streamflow predicted with changing conditions, and when 1950 conditions were held constant (adapted from Koelliker et al., 1981).

back to grass since 1930. Development and adoption of conservation practices have progressed since the 1930's. From the early 1950's, development of ground-water resources has reduced baseflow in the stream. In the future, amounts of surface-water yield will be less than the amount estimated for conditions before agricultural development began.

In fig. 7.3, the line labeled POTENTIAL YIELD represents an estimate of the total streamflow from the watershed jf agricultural land use and practices in the 1930's had remained in place. That period is chosen only because it was the set of conditions in the last 150 years that produced the greatest streamflow. Records from that period also probably influenced the design conditions that were used for the development of Webster Reservoir and its original operations plan. The line labeled ACTUAL YIELD represents the expected amount of streamflow into the reservoir as affected by the changing conditions in the watershed. This line does not imply that water yield does not fluctuate from year to year. It shows an expected average for a given date that would have resulted if the precipitation from 1920 to 1978 had occurred on the watershed when it was in a particular set of conditions that were in place on that date. The split of the actual yield into surface runoff and ground water is an estimate based upon the types of land use with time and the effects of withdrawals of ground water for irrigation.

The contributions of the various soil- and water-conservation practices are estimated with time on the graph. Dams are stockwatering and erosion control structures that create features commonly known as farm ponds. These farm ponds in aggregate collect runoff from over one-third of the watershed. Terraces have been installed on nearly one-half of the cropland in the water shed to reduce water erosion and to improve moisture conservation. Here, residue refers to a variety of agricultural-management practices to keep the soil surface partially or totally covered with plant residue to reduce potential for water and wind erosion. Conservation tillage of various kinds is the most widely used practice. Irrigation is used to describe the effects of withdrawals of ground water from the alluvial aquifer. Nearly all the water withdrawn is subsequently lost as evapotranspiration from the irrigated areas.

The latest conditions in the watershed above Webster Reservoir have not been studied with POTYLDR. Further evidence of the effects of agriculture on water yield appeared from the flood of 1993. This flood and the precipitation that caused it were remarkably similar to the flood year of 1951 (see chapter 1 comparison of 1951 and 1993 floods). Although the reservoir was not completed in 1951, the streamflow-gaging station just upstream was operational and estimates of the inflows to the reservoir had the lake existed have been made for that period by the Bureau of Reclamation. Figure 7.5 shows the precipitation and inflow to Webster Reservoir on a monthly basis for both floods. The amount of inflow in 1993 was essentially half the amount in 1951. This points out that even in years with high precipitation, the effects of agriculture on watersheds in the western half of Kansas can be and are substantial.

At the same time that runoff is reduced, more water is added to the soil to aid subsequent crop production and to add to percolation. At Webster Reservoir, the amount of baseflow into the reservoir appears to be higher than in 1951. Some of the water that did not leave as runoff is' slowly seeping from the watershed and reaching the reservoir. Much more of the seepage water may be being 'used to satisfy ground-water withdrawals in the alluvial aquifers that are above the reservoir.

The impact of agriculture on available water resources for other uses above Webster Reservoir has been substantial. At the same time, however, the water that was lost previously has been converted into more production on the land where it fell. This fact is based upon yield of wheat on dryland in the Northwest Crop Reporting District, which

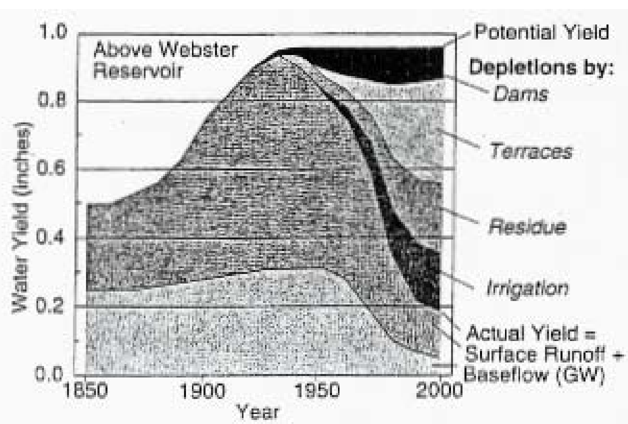


FIGURE 7.3—Historical perspective of the effect of agricultural technology on water yield above Webster Reservoir showing increases caused by conversion to cropland and depletions caused by various soil- and water-conservation practices and changes in agricultural technology (adapted from Koelliker, 1984).

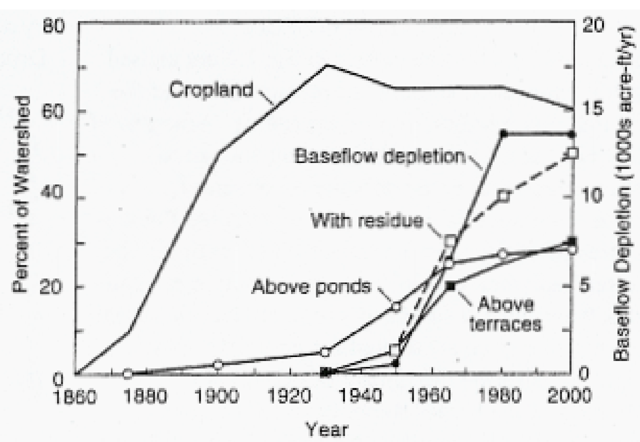


FIGURE 7.4—Historical amounts of cropland, conservation practices, and baseflow depletions in the South Fork Solomon Basin above Webster Reservoir (adapted from Koelliker, 1984).

includes the watershed above Webster Reservoir (fig. 7.6) (State Board of Agriculture, 1989, and previous). Wheat yields have increased steadily since the 1930's. This is the result of better agricultural technology, which includes better varieties, fertilizer and herbicides, and management practices. All of these factors, however, are benefited by more available water. In this area, the USDA ARS estimates that about 40% of the total increase in agricultural production can be attributed to-better water conservation.

There is a tradeoff here between more agricultural production on dryland and water resources available for users downstream. This work points out that the availability of water resources may not be constant over time. It will be necessary to make adjustments in water use-so that the demand is more in line with the supply. As Robert Ingersoll, a 19th century orator from Kansas, stated, "In nature there are no rewards or punishments—there are consequences."

General Procedure to Estimate the Magnitude of Land-use Changes on Water Yield

Agriculture and agricultural land-use changes are affected by location in the state. The POTYLDR model has been used for several studies in Kansas, and from those general results, inferences can be drawn about the effects of agriculture on water resources in the state. One of the most important aspects that influences the magnitude of land-use changes is that the climate at a particular location can be described by the moisture deficit (MD). The MD is defined as the difference between the average annual lake evaporation and the average annual precipita tion at a location. Figure 7.7 shows a map of the average in each county (DWIR, 1994). There is a substantial difference in MD across the state (see also fig. 1.12 of Chapter 1). MD is greatest in the southwest corner of the state where lake evaporation is greatest and precipitation is near the lowest in the state. The MD is smallest along the eastern border of the state where lake evaporation is lowest and precipitation is more abundant. This variable is one that correlates well with many of the important effects that climate plays on agriculture. The greater the MD the more arid the climate while the lower the MD the more humid is the climate.

The greater the MD the greater the potential to reduce total runoff if the soil can hold the extra water that infiltrates it so that it will be lost later by evapotranspiration. As MD decreases, the potential of percolation increases because the soil cannot hold all of the water that infiltrates during extended wet periods. Soil type is important, particularly the soil's ability to store water that is available for later use by plants. Deep, silt-loam-type soils are best, whereas shallow, sandy-type soils are poorest for storing water. Crops, too, have an effect. Perennial crops and grass use the most water because they are actively growing during a longer portion of the year. Annual or summer crops use less because they are growing for a shorter period of the year. Fallowed soils do not use water, although water is lost from fallowed soil by evaporation. The least water loss is from fallow land with good crop-residue cover, provided no plants are allowed to grow.- Protecting the soil surface on fallowed land with residue decreases runoff, decreases evaporation, and may increase the potential for percolation during wetter years.

Further, experience with the results from the POTYLD model for many locations in Kansas shows that its results are in general agreement with what is observed. The depth of the amount of reduction in surface runoff increases with decreasing MD where conservation practices are added. The effect, however, as a percentage

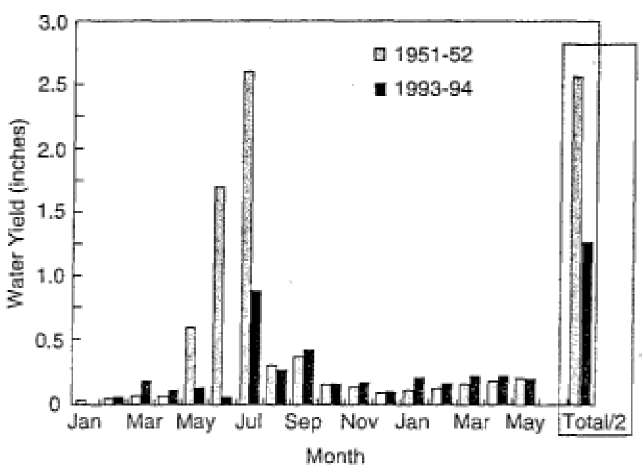


FIGURE 7.5—Comparison of monthly inflow to Webster Reservoir for the floods of 1951 and 1993.

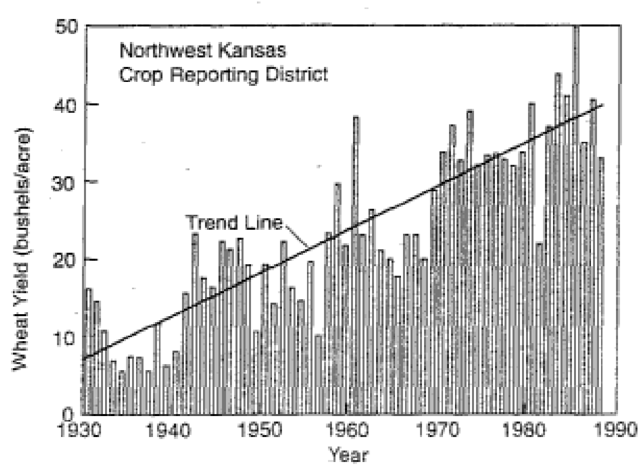


FIGURE 7.6—Dryland wheat yields in the Northwest Kansas Crop Reporting District (data from Kansas State Board of Agriculture).

of total yield decreases as the MD decreases. With decreasing MD, more percolation results from conservation practices. Finally, the effect of conservation practices on total water yield is greatest in areas where the MD is moderate. To illustrate the effect of MD on water yield across Kansas, results of simulating a change in continuous wheat production caused by changing from a condition of little conservation practices to good conservation practices are discussed in Appendix 7.A. The change is expressed primarily in a decrease in the RCN by five and a slight increase in the residue factor that reduces the rate of surface evaporation. Figure 7.8 shows how the general amount of total water yield (surface runoff + percolation), decrease in surface-runoff, increase in percolation, and the total de crease in water yield are affected by the MD. The reader is cautioned to notice that the “average annual” is a log scale in fig. 7.8. In areas where the MD is high, most of the surface runoff prevented by better conservation practices because of more infiltration is stored as soil moisture which is subsequently lost as evapotranspiration because the climatic demand for water is large. With moderate amounts of MD; a larger amount of water yield occurs because there is more potential surface runoff to affect. Some increase in percolation results because not all of the extra water can be stored in the soil during wetter periods. In areas where the MD is low, runoff is still reduced, but nearly all of the extra water that enters the soil becomes percolation. Here, the ability of the atmosphere to increase evapotranspiration during wet periods is insufficient to cause much of the additional water that does not become surface runoff to become evaporation. Also, practices that are effective at reducing runoff require residue cover on the surface. The residue cover also decreases evaporation from the soil. Thus, the total amount of water yield is affected very little in areas where the MD is low. In some cases, water yield may actually be increased in eastern Kansas, particularly during wet periods because evaporation is decreased. In eastern Kansas, if water is not lost by evapotranspiration, it will eventually become streamflow. There is just not enough storage in the soil to hold all of it for later use.

When the maximum potential for agricultural soil- and water-conservation practices to reduce surface runoff are added together they can have a substantial effect. Figure 7.9 shows a generalized map of these aggregate effects to reduce runoff from the amounts of strearnflow that were reported for conditions around 1930. By the late 1990’s, a substantial amount of these effects of agriculture are occurring. The numbers on fig. 7.9 show the percent reductions that were experienced during the 1980’s for various locations in western Kansas.

The above information is for one set of conditions described previously. Results for a wide variety of land uses and conservation practices found across Kansas have been produced with POTYLDR by making simulations at five locations (Koelliker, 1994a). Predicted average annual depth of runoff and percolation are included in table 7.1 from the representative RCN value for a Soil Conservation Service Group B/C soil (silt loam soil). For all locations, the same planting and harvest date for row crops (grain sorghum, May 10 and October 15) and small grain (winter wheat, October 10 and June 25) were used. The fallow shown is for a combination of wheat-fallow rotation with the wheat having an RCN equivalent to the small grain practice shown earlier in the table. Pasture/ range growing season was March 15 through October 31. These results can be generalized to other locations by relating the values to the MD at a particular location. The MD for three of the locations (Horton, Great Bend, and Garden City) were adjusted somewhat because the stations have more or less annual precipitation than is typical for the MD each one was most representative of across the state. Figure 7.10 shows there is a general relationship

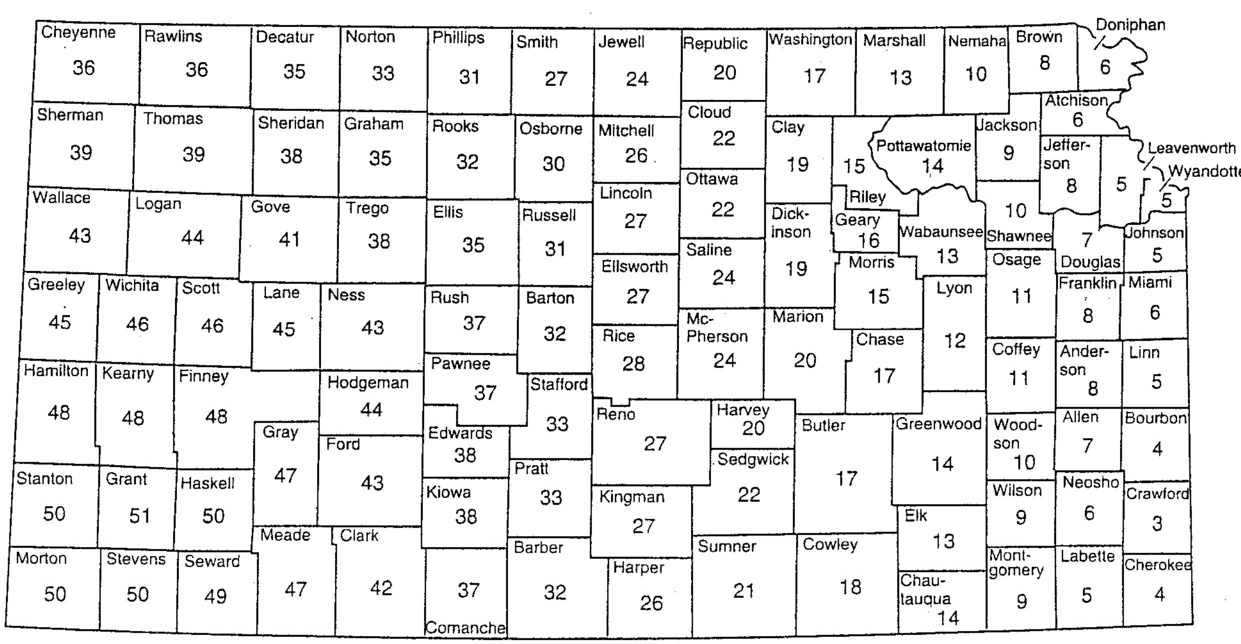


FIGURE 7.7—POTENTIAL NET Evaporation For KANSAS counties (Division of Water Resources, 1994).

between runoff and percolation and the adjusted MD across the range of conditions simulated. The transmission loss factor *(TLF)* is the ratio of runoff estimated upstream to the amount of runoff actually measured at a gaging station downstream. If the value of the *TLF* at each location as shown for each station in table 7.1 is used along with the amount of runoff shown in table 7.1, then the estimated effect of an agricultural practice change on surface streamflow can be calculated by dividing the runoff by the *TLF*.

With the values in table 7.1, it is possible to compare the effect of a change in land use and/or conservation practice from one condition to another condition and to estimate the effect on long-term average amount of runoff and percolation. Consider the effects of changing from an initial land use of annual cropping with row crops with straight row conservation practice (line 1 in table 7.1) to a second condition of pasture/range (line 29) that might result if highly erodible cropland were placed into the Conservation Reserve Program at Great Bend. Predicted

$$Y = (I - F) \cdot P / (TLF \cdot 100) \qquad \text{(eq. 7.1)}$$

average annual runoff for initial conditions, *I*, is 3.19 inches (81 mm) and for final conditions, *F*, is 1.52 inches (39 mm). Essentially no change in percolation is expected. The *TLF* is 1.15 for Great Bend. Further, consider if 4.0% *(P)* of the watershed were to be changed. To estimate the decrease in average annual water yield (Y) use,
The result is, *Y*= 0.06 inches (1.5 mm). At Great Bend, water yield averages about 1.5 inches/year (38 mm/year). So, total water yield. would be reduced by about 4%.

As agriculture developed, much pasture/range was converted to cropland and later conservation practices were added to cropland to reduce erosion and/or to improve moisture conservation. The impact of these changes depends upon the amount of the watershed affected and the magnitude of the change in runoff. Figure 7.11 shows a comparison of surface-water yield from
small grain production with various conservation practices to the surface-water yield from pasture/range across the amounts of MD found in Kansas. Straight row was the earliest agricultural practice. Later, contouring and conservation tillage or residue management were added. along with terraces as conservation practices. The line "Best Management Practice" includes the applicable type of terrace, conservation tillage, and contouring at each of the five locations simulated. The graph shows that the amount of surface runoff from small grain production can be reduced to that expected from pasture/range across Kansas with good management.

The effect of conservation practices on reducing runoff as a percent of the total water yield increases with increasing MD. When MD = 15 inches (38 cm) as found in eastern Kansas, the reduction from straight row to best management practice is about 30%. With MD = 40 inches (100 cm) as is the case in most of the western half of Kansas, the reduction in water yield is about 60%, similar to the results shown in fig. 7.9.

In summary, this section shows that effects of conser vation practices and land-use changes in Kansas on water yield can be Substantial, particularly in areas where the MD is large. Conservation practices have the ability to hold much of the potential runoff, which is then lost as evapotranspiration. These practices are most effective during drier years when streamflow is limited, which further aggravates the problem of allocating limited water resources to other users. The simulation method described in this chapter provides a way to determine the magnitude of these effects on a continuous basis so that effects with time on water yield and water availability can be evalu ated. Other measures such as watershed projects and irrigation withdrawals from alluvial aquifers along streams add further to potential depletions of streanflow. The impact on ground-water recharge is positive in the central portion of the state where several good aquifers store and transmit the additional water to potential ground-water users. In eastern Kansas where the potential to increase percolation is even better, there is limited opportunity to

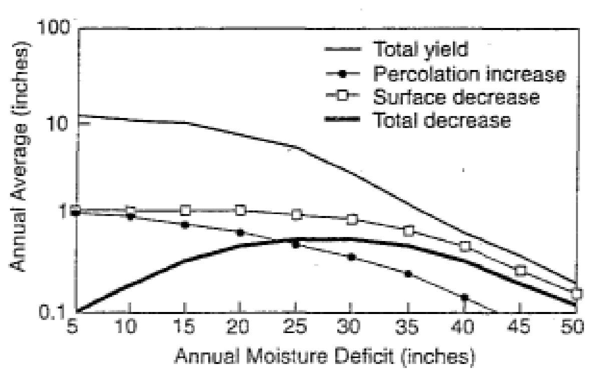


FIGURE 7.8—Simulated effects on aspects of the water budget when the RCN value for continuous wheat is reduced from 75 to 70 on a silt loam soil as related to the MD across Kansas.

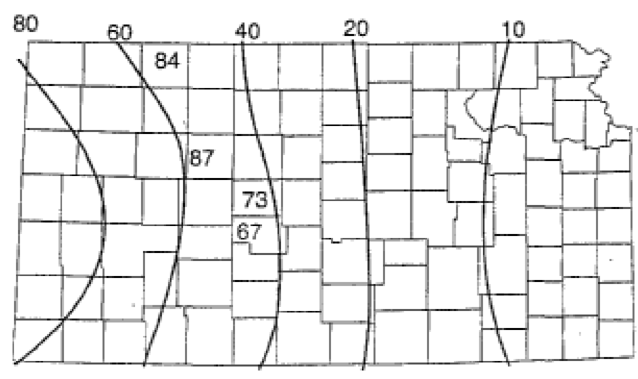


FIGURE 7.9—Generalized potential of soil and water conservation practices and agricultural technology to reduce streamflow below the amount measured in the 1930–1950 period, by percent.

TABLE 7.1—Simulated results from POTYLDR for average annual runoff and percolation, in inches, for various land uses and conservation practices (Koelliker, 1994b).

LOCATION	HORTON	MANHATTAN	GREAT BEND	COLBY	GARDEN CITY
Period of record simulated	1935–1975	1958–1986	1948–1988	1940–1980	1948–1988
Lake evaporation inches	48.90	51.13	61.47	55.65	64.03
Precipitation, inches	35.60	32.89	25.54	19.31	17.97
Moisture deficit, inches	13.30	18.24	35.93	36.34	46.06
Adjusted moisture deficit, inches	15.30	18.24	28.93	36.84	42.86
Transmission-loss factor	1.02	1.03	1.15	1.25	1.43

No. Land use	Conservation practice	RCN AMC II	Runoff	Perc.	Runoff	Perc.	Runoff	Perc.	Runoff	Perc.	Runoff	Perc.
1. row crops	straight row	81	7.61	2.39	6.37	1.17	3.19	0.07	1.92	0.02	1.27	0.00
2. row crops	contoured	78	6.24	3.73	5.19	2.20	2.54	0.28	1.55	0.07	0.99	0.03
3. row crops	level terrace	74	n/a	n/a	n/a	n/a	1.97	0.55	1.20	0.14	0.74	0.05
4. row crops	lev. terr., cl.-end	64	n/a	n/a	n/a	n/a	n/a	n/a	0.57	0.42	0.30	0.14
5. row crops	conserv. tillage	77	5.81	4.63	4.86	2.90	2.39	0.52	1.45	0.11	0.95	0.04
6. 2	graded terrace	75	5.19	4.97	4.30	3.19	2.04	0.58	1.27	0.14	0.79	0.05
7. 2 + 3		72	n/a	n/a	n/a	3.88	1.61	0.82	1.01	0.23	0.60	0.07
8. 2 + 4		62	n/a	n/a	n/a	n/a	n/a	n/a	0.46	0.50	0.23	0.18
9. 2 + 5		75	5.24	5.19	4.38	3.36	2.11	0.67	1.28	0.15	0.82	0.05
10. 2 + 3 + 5		70	n/a	n/a	n/a	n/a	1.46	1.05	0.90	0.29	0.54	0.09
11. 2 + 4 + 5		61	n/a	n/a	n/a	n/a	n/a	n/a	0.43	0.55	0.21	0.22
12. 6 + 5		74	5.16	5.28	4.29	3.43	2.04	0.71	1.24	0.16	0.80	0.05
13. 1 +	irrigated	81	9/05	4.58	8.09	3.26	4.78	0.86	3.15	0.41	2.50	0.09
14. 1 + 5 +	irrigated	77	6.78	6.93	6.14	5.23	3.56	1.65	2.31	0.80	1.81	0.35
15. small grain	straight row	78	6.08	3.80	4.87	2.34	2.33	0.18	1.36	0.03	0.90	0.02
16. small grain	contoured	75	5.03	5.01	4.00	3.31	1.88	0.44	1.10	0.14	0.71	0.04
17. small grain	level terrace	71	n/a	n/a	n/a	n/a	1.44	0.74	0.85	0.29	0.51	0.06
18. small grain	lev. terr., cl. end	63	n/a	n/a	n/a	n/a	n/a	n/a	0.45	0.56	0.23	0.17
19. small grain	conserv. tillage	74	5.03	5.55	3.99	3.74	1.90	0.60	1.15	0.24	0.72	0.04
20. 16	graded terrace	74	4.98	5.39	3.92	3.61	1.84	0.56	1.09	0.22	0.68	0.04
21. 16 + 17		70	n/a	n/a	n/a	n/a	1.32	0.90	0.78	0.39	0.46	0.08
22. 16 + 18		60	n/a	n/a	n/a	n/a	n/a	n/a	0.39	0.65	0.19	0.18
23. 16 + 19		74	5.04	5.60	4.08	3.78	1.91	0.62	1.15	0.25	0.72	0.04
24. 16 + 17 + 19		68	n/a	n/a	n/a	n/a	1.19	1.08	0.73	0.50	0.42	0.12
25. 16 + 18 + 19		59	n/a	n/a	n/a	n/a	n/a	n/a	0.36	0.78	0.17	0.23
26. 20 + 19		71	4.16	6.46	3.26	4.47	1.52	0.86	0.92	0.39	0.55	0.08
27. 15 +	irrigated	78	6.84	6.02	5.77	4.49	3.25	1.79	2.06	1.17	1.57	0.54
28. 15 + 19 +	irrigated	74	5.54	7.43	4.69	5.70	2.56	2.33	1.65	1.54	1.21	0.83
29. pasture/range		75	4.53	2.57	3.51	1.07	1.52	0.06	0.81	0.00	0.46	0.00
30. 29	improved	70	3.38	3.78	2.54	1.93	1.07	0.18	0.56	0.01	0.30	0.00
31. hay (alfalfa)		76	4.61	1.74	3.54	0.56	1.53	0.02	0.80	0.00	0.48	0.00
32. 31 + irrigated		76	6.58	4.76	5.52	3.31	3.42	0.98	1.94	0.73	1.76	0.21
33. fallow-wheat	straight row	86	n/a	n/a	n/a	n/a	3.69	0.72	2.37	0.25	1.70	0.04
34. fallow-wheat	contoured	83	n/a	n/a	n/a	n/a	3.01	1.26	1.92	0.52	1.35	0.13
35. fallow-wheat	level terrace	79	n/a	n/a	n/a	n/a	2.28	1.92	1.46	0.90	0.96	0.29
36. fall.-wheat	lev. terr., cl. end	68	n/a	n/a	n/a	n/a	n/a	n/a	0.71	1.54	0.38	0.72
37. fall.-wheat	conserv. tillage	81	n/a	n/a	n/a	n/a	2.94	1.74	1.87	0.81	1.29	0.24
38. 34	graded terrace	80	n/a	n/a	n/a	n/a	2.59	1.71	1.65	0.79	1.10	0.22
39. 34 + 35		77	n/a	n/a	n/a	n/a	1.94	2.25	1.27	1.10	0.81	0.43
40. 34 + 36		67	n/a	n/a	n/a	n/a	n/a	n/a	0.63	1.64	0.33	0.78
41. 34 + 37		79	n/a	n/a	n/a	n/a	2.72	1.94	1.73	0.93	1.18	0.31
42. 34 + 35 + 37		75	n/a	n/a	n/a	n/a	1.85	2.76	1.19	1.37	0.75	0.61
43. 34 + 36 + 37		66	n/a	n/a	n/a	n/a	n/a	n/a	0.61	1.89	0.31	0.96
44. 38 + 37		79	n/a	n/a	n/a	n/a	2.47	2.17	1.59	1.06	1.06	0.40

Notes: Soil is silt loam which fits SCS hydrologic group B/C and SCS Irrigation Class 3; unless noted otherwise, good hydrologic condition assumed.

make the additional percolation become usable ground water. It may seep out gradually to enhance the dry weather flow for a few weeks following wet periods.

The procedure described to estimate change in the surface runoff portion of water yield has been studied more intensely than that for percolation and the potential for ground-water recharge from such percolation. The operation of POTYLD, however, also estimates the amount of percolation as shown in fig. 7.7. An aspect of recharge that is important to understand when considering sustainable yield is that for many locations, particularly in drier areas, recharge occurs infrequently. The section following in the inset Boxed section 7.1 illustrates this phenomenon.

Conclusion

Agriculture has made substantial changes to the land charge. In the western half of the state, in particular, use in Kansas for more than 150 years. Sustainable crop streamflow has been reduced from the amounts measured production by agriculture without irrigation, in large part, before about 1950 by a combination of agricultural has been a matter of developing management practices that practices including withdrawal of ground water for increase the effectiveness of use of the limited water irrigation along streams. Reductions of streamflow by as supply and that protect the soil resource from excessive much as 50% or more have been experienced. In the erosion. Adoption of conservation practices that decrease eastern half of the state, the effect has been limited runoff

and reduce evaporation losses have been important. because of the difference in climatic conditions. As ways In much of the state, the effectiveness of these practices to use water more efficiently are developed and adopted has resulted in more efficient use of water for grain and for Kansas conditions, this means less for nonagricultural• forage production. Since water use by agriculture is a uses, particularly in the drier regions of the state. In the consumptive use that results in evaporation of water from future these effects will probably result in a further the land surface, more effective use means that less water decrease in the amount of water available for appropriation is left to become runoff or potential ground-water re- by other users.

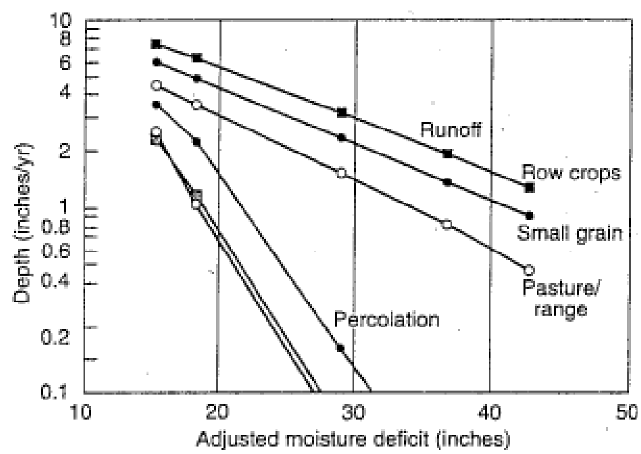


FIGURE 7.10—Simulated average annual depth of runoff and percolation from row crops and small-grain production with straight-row conservation practice compared with pasture/range as affected by moisture deficit (Koelliker, 1994b).

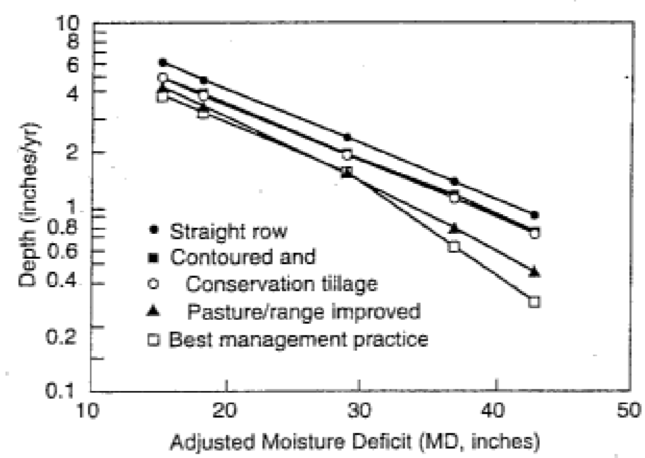


FIGURE 7.11—Comparison of simulated average annual runoff from small-grain production with various conservation practices to pasture/range as affected by moisture deficit (Koelliker, 1994b).

Under average conditions, evapotranspiration demand for water exceeds that supplied by precipitation. So, on average the soil should not become so saturated with water that percolation occurs. Average conditions, however, seldom occur in the continental climate that prevails in Kansas (see also Chapter 1). There are periodic episodes when drought and wet periods occur. Much of the percolation that results in ground-water recharge occurs in extended wet periods.

To illustrate this point, a 44-year simulation for Great Bend was made with POTYLDR. Great Bend (MD 35 inches [89 cm]) is representative of that part of the state where agricultural practices have important effects on water yield, and aquifers benefit from increase in percolation. Representa tive RCN values for a Soil Conservation Service Group B/C soil (silt loam soil) for Great Bend are shown in table B7.1.l. The planting and harvest date for grain sorghum were May 10 and October 15, respectively, and for winter wheat they were October 10 and June 25, respectively. The results of the conditions simulated for Great Bend produced average amounts of runoff and percolation as shown in table B7. 1.1. Percolation or recharge is least from pasture/range which has a long growing season and is greatest from irrigated crops.

TABLE B7.1.1 SIMULATED RESULTS FROM POTYLDR FOR AVERAGE ANNUAL RUNOFF AND PERCOLATION, IN INCHES, FOR VARIOUS LAND USES AT GREAT BEND ON A SILT LOAM SOIL

	Predicted annual average, inches	
Land use	Runoff	Percolation
pasture/range, good condition	1.1	0.2
pasture/range, fair condition	1.5	0.1
continuous wheat	1.8	1.2
wheat-fallow	2.5	2.6
irrigated wheat	2.5	3.6
grain sorghum, conventional	2.3	0.4
grain sorghum, conservation tillage	2.1	0.7
irrigated grain sorghum	3.2	2.2

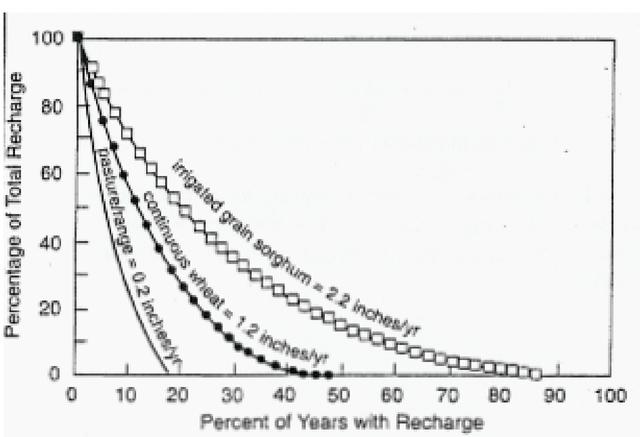


FIGURE B7.1.1—SUMMARY OF SIMULATED PERCENT OF ACCUMULATED PERCOLATION FROM THREE LAND USES AT GREAT BEND ON A SILT LOAM SOIL VERSUS THE PERCENT OF YEARS WITH PERCOLATION.

Here, the average amount of net irrigation water applied to the soil in 2.0-inch (5-cm) increments when the available soil moisture decreased to 50% was 9.0 inches (23 cm) and 13.0 inches (33 cm) for wheat and grain sorghum, respectively.

Figure B7. 1.1 was prepared from the annual results from three of the simulations to show the distribution of percent of years with percolation within the simulation period for three of the land uses. For pasture/range in good condition, recharge was estimated to occur in less than 20% of the years and half of the recharge occurred in less than 5% of the years. For continuous wheat, recharge was predicted to occur in less than half of the years and half of the total occurred in about one year in eight on average. Irrigated grain sorghum showed some recharge in about seven out of eight years; however, half of the total recharge occurred in about one year out of five. The example above is for one location only. Where recharge is most needed in western Kansas, the climate has a greater moisture deficit. There, recharge is even less than for the example above, and more of the recharge occurs in a lower percentage of the years. While runoff events are rather widely spaced in time, recharge events are even more widely spaced in time. Providing a sustainable yield from an aquifer that must be periodically replenished, the event nature of recharge must be taken into account. The time between years with recharge for the Great Bend example for pasture/range is illustrated in fig. B7. 1.2. Here, three periods with lengths of eight years or longer between recharge events were predicted in the 44-year simulation for the range/pasture land use.

Sustainable yield from ground water must include estimates of total recharge as an upper limit as well as the distribution of recharge in time and space over the aquifer. Using average annual values is risky, especially if the storage capacity of the aquifer is limited.

References

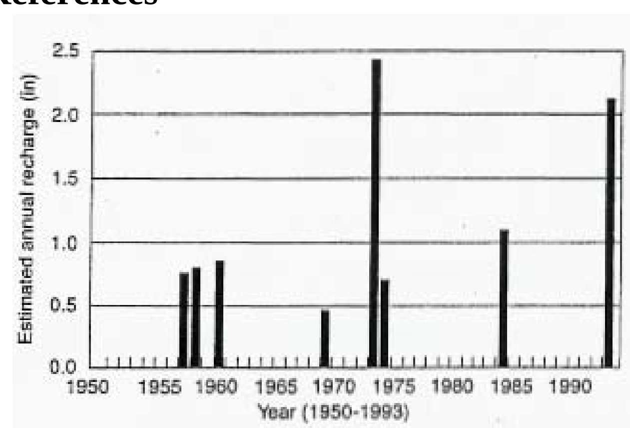


FIGURE B7.1.2—SUMMARY OF PREDICTED ANNUAL AMOUNT OF RECHARGE (PERCOLATION) FROM RANGE/PASTURE AT GREAT BEND ON A SILT LOAM SOIL.

Blaney, H. F., and Criddle, W. D., 1962, Determining consump tive use and irrigation water requirements: U.S. Department of Agriculture, Technical Bulletin 1275

Brunt, D., 1944, Physical and dynamical meteorology: Cam bridge, Cambridge University Press

Bureau of Reclamation, 1984, Solomon River Basin Study: U.S. Department of Agriculture, Lower Missouri Basin Division, Denver, CO

Division of Water Resources (DWR), 1994, Potential net evaporation map for Kansas counties: Prepared by the Division of Water Resources, Kansas Department of Agriculture

Fenster, C. R., Owens, H. I., and Follett, R.H., 1977, Conserva tion tillage for wheat in the Great Plains: U.S. Department of Agriculture, Extension Pamphlet 1190

Gray, D. M., ed., 1973, Principles of hydrology: Huntington, New York, Water Information Center, Inc.

Kansas State Board of Agriculture, 1989 and previous, 71st Annual Report and Farm Facts: Topeka, Kansas, Kansas Crop and Livestock Reporting Service

Koelliker, J. K., Zovne, J. J., Steichen, J. M., and Berry, M. W., 1981, Study to assess water yield changes in the Solomon basin, Kansas; Part I—Final report: Manhattan, Kansas, Kansas Water Resources Research Institute, 123 p.

_____ 1982, Study to assess water yield changes in the Solomon basin, Kansas; Part 11—User's manual: Manhat tan, Kansas, Kansas Water Resources Research Institute

Koelliker, J.K., Brown, M. J., and Zovne, J. J., 1983, Assessment of changes in the precipitation regime of the Republican River basin: Working paper for the Bureau of Reclamation, Denver, Colorado; Civil Engineering Department, Kansas State University, Manhattan

Koelliker, J. K., 1984, An historical perspective on soil and water conservation—Its effect on surface-water supplies: Soil and Water Conservation Society of America, Oklahoma City, Oklahoma, August 139th Annual Meeting; Civil Engineer ing Department, Kansas State University, Manhattan

____ 1991, Future water supply for Cheyenne Bottoms Wildlife Refuge, Kansas; Final report to Howard Needles, Tammen and Bergendoff: Kansas State University, Manhat tan, Civil Engineering Department

____ l994a, User's manual for POTential YieLD Model Revised: Kansas State University, Manhattan, Civil Engineering Department

• , 1994b, Effects of agricultural development on surface water yield in the Central Great Plains; in, Effects ofthe mid-1970's. Zovne et al. (1977) devel oped a continuous water-budget simulation model that worked on daily time steps for use in assessing the performance of open feedlots to control runoff from feedlots. The model predicted runoff from 'the feedlot

Human-induced Changes on Hydrologic Systems: Ameri can Water Resources Association, Bethesda, Maryland, p. 745—754

Koelliker, J. K., Govindaraju, R. S., and Lewis, S. L., 1995, Evaluation of Marion and Council Grove Lakes water supply capabilities—Final report to Kansas Water Office: Kansas State University, Manhattan, Civil Engineering Department, 110 p.

Kutz, R., 1990, Bureau of Reclamation reservoirs in Kansas: Presented to the Kansas Academy of Science, March 1990; Bureau of Reclamation, McCook, Nebraska

Rawls, W. J., Onstad, C. A., and Richardson, H. H., 1980, Residue and tillage effects on SCS runoff curve numbers: Transactions of the ASAE, v. 23, p. 357—36 1

Ritchie, J. T., 1972, Model for predicting evaporation from a row crop with incomplete cover: U.S. Department of Agricul ture, Soil & Water Conservation Research Division, Blackland Conservation Research Center, Temple, Texas, p. 1,204—1,213

Sauer, S. P., and Masch, F. D., 1969, Effects of small structures on water yield in Texas; ***in***, Effects of Watershed Changes on Streamflow, W. L. Moore and C. W. Morgan, eds.: University of Texas Press, Austin, p. 118—135 Sharp, A. L., Gibbs,'A. E., and Owens, W. J., 1966, Development of a procedure for estimating the effects of land and watershed treatment on streamfiow: U.S. Department of Agriculture, Technical Bulletin 1352

Steichen, J. M., 1983, Field verification of runoff curve numbers for fallow rotations: Journal of Soil and Water Conserva tion, v. 38, p. 496—499

U.S. Department of Agriculture, Soil Conservation Service, 1972, Hydrology: National Engineering Handbook, section 4. Washington, D.C.

____ *1975*, Kansas Irrigation Guide: U.S. Department of Agriculture, Soil Conservation Service, Salina, Kansas

Water Information Center, Inc., 1974, Climates of the states, volume 2: Port Washington, New York

Zovne, J. J., Bean, T. A., Koelliker, I. K., and Anschutz, J. A., 1977, Model to evaluate feedlot runoff control systems: Journal of the Irrigation and Drainage Division, ASCE, v. 103, p. 79—92

Zovne, J. J,. and Koelliker, J. K., 1979, Application of continuous watershed modeling to feedlot runoff management and control: National Technical Information Service, Spring field, Virginia, Report No. EPA—600/2—79—065

Appendix 7.A
POTYLD MODEL DESCRIPTION

Continuous watershed-simulation modeling was budgets for various land areas where the runoff was common by the mid-1970's. Zovne et al. (1977) devel- applied according to some management scheme. The oped a continuous water-budget simulation model that model utilized runoff curve nufnbers (RCN) values to worked on daily time steps for use in assessing the predict the split between runoff and infiltration for the performance of open feedlots to control runoff from feedlot and areas where runoff was applied to daily feedlots. The model predicted runoff from 'the feedlot amounts of rainfall and snowrnelt (See Chapter 1 for more drainage area, operation of a storage pond, and water information on RCN values). The model named

FROMKSU was designed to be physically based, to use readily available information to describe conditions in an area of interest, and to be capable of being applied anywhere in the continental US. Its detailed description is contained in Zovne and Koelliker (1979).

The Potential Yield (POTYLD) model simulates a continuous water budget for land uses with different conditions in a watershed on a daily basis (see fig. 7.A1). Up to 18 different land-use combinations can be simulated in one run of the model. Estimates of the upstream runoff and percolation that would result from various land uses and conservation practices are provided. A RCN value for antecedent moisture condition (AMC) II is needed for each land use and conservation practice based upon soil characteristics, land cover, conservation practice, and management practice. Soil characteristics are assumed to fall into one of 12 irrigation group classifications for Kansas (USDA—SCS, *1975)*, which define the water-holding characteristics of the soil layers and soil-water evaporation characteristics. A continuous water-budget simulation produces estimates of water content in the soil. AMC values are adjusted based upon available soil moisture (ASM) in the upper 1.0 ft (30 cm). AMC I holds below 50% ASM, AMC III holds above 90% ASM, and AMC II holds in the intermediate range of ASM.

The water budget is driven by daily precipitation and minimum and maximum temperature for a single station representative of the area under study. Large areas are divided into sub-areas which are modeled separately, then combined for better representation of the entire watershed. Long-term monthly average values of percent sunshine, relative humidity, solar radiation, windrun, and average temperature are used to estimate potential evapotranspira tion (PET) by the Penman combination equation after Gray (1973). Long-term monthly values are obtained by triangulation from published values for first-order weather stations (Water Information Center, 1974). Geographical coefficients, Brunt a and b (Brunt, 1944) are used to

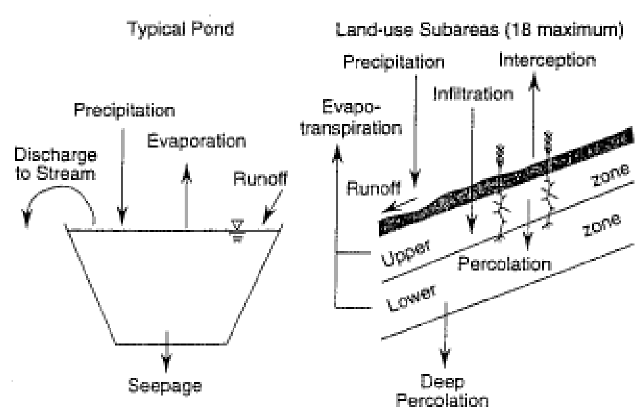


FIGURE 7.A1—Schematic of POTYLD water-budget model (adapted from Zovne and Koelliker, 1979).

calibrate Penman's PET such that predicted average annual lake evaporation at a location agrees with published values (Zovne and Koelliker, 1979). Actual water use by crops is simulated by multiplying daily PET by a monthly Blaney—Criddle crop coefficient (Blaney and Criddle, 1962) and a coefficient based upon ASM.

The crop coefficients are calculated by pre-programmed equations in the program which require the user to provide planting and harvest dates. The soil-moisture coefficient is 1.0 forASM greater than 30%; below 30% it decreases linearly to zero when ASM is zero. When crops

•are not growing, bare soil and fallow water loss is simu lated by a decay-rate equation (Ritchie, 1972) and adjusted for assumed amount of surface residue. Water loss by percolation from the rooting zone is assumed to cascade from the lower layer whenever the ASM in the lower zone exceeds 90%. POTYLD simulates the complete daily water budget for a "typical" pond. The pond is defined by assigning a stage-storage and stage-surface area relation ship along with a seepage loss rate. The model treats the pond as an inverted frustum of a pyramid which can match most actual relationships fairly well. Runoff into the typical pond is determined by routing runoff from speci fied areas of the various land-use subareas which would be typical of the drainage area for a pond in the particular study area. Modeled results of predicted depletions of surface water caused by ponds have compared closely with depletion effects described by Sauer and Masch (1969) for watershed flood-control dams in Texas. Figure 7.A2 shows the general relationship from Sauer and Masch and the average results found for typical ponds above Webster Reservoir (Koelliker et al., 1981).

Substantial revisions have been made to the model and the name changed to POTYLD (Revised) (Koelliker, 1994a, 1994b). Enhancements to the PET routine to reflect greater daily and annual variation based upon daily minimum and maximum temperature and a function to simulate annual variation in heat storage and dissipation at the surface have been made. Also, RCN between AMC I and AMC III is varied linearly with ASM between 50 and 90%. AMC II holds when ASM is 70%.

COMPARING MODEL RESULTS WITH ACTUAL STREAMFLOW

Results from POTYLD must be adjusted by estimates of transmission losses and the effects of depletion from or additions to strearnflow in order to compare with actual streamfiow records. In addition, because agricultural effects on upstream yield are changing with time, changes must be accounted for in output from POTYLD by making successive runs with the inputs that represent conditions applicable over the period of the streamflow record. Once all of these changes are accounted for, then modeled results can be compared directly with reported streamflow records.

Transmission loss refers to the ratio of annual volume of upstream runoff to downstream streamflow. It accounts for natural losses caused by infiltration, evaporation, and detention storage. The value of the transmission loss factor *(TLfl* was originally predicted by a technique developed by Sharp et al. (1966). This loss is related to the ratio of PET (Thornthwaite's values) to annual amount of precipitation. Our work shows that annual moisture deficit (MD), defined as lake evaporation minus precipitation, is an effective characteristic of the climate that can be used estimate the *TLF* (Koelliker et al., *1995).* In dry years when runoff is low and MD is higher, the *TLF* is larger and in wet years when MD is lower *TLF* approaches 1.0 as shown in Figure 7.A3.

Finally, estimates of depletions or additions to streamflow from ground-water use, importation, exportation, return flows, etc. must be accounted for to compare POTYLD modified results with reported streamflow records.

Average MD for each county (DWR, 1994) is shown in fig. 77. There is a substantial difference in MD across the state. MD is greatest in the southwest corner of the state where lake evaporation is greatest and precipitation is near the lowest in the state. MD is lowest in the far eastern part of the state where lake evaporation is lowest and precipitation is more abundant. This variable is one that correlates well with many of the important effects that climate plays on agriculture. The greater the MD the more arid the climate while the lower the MD the more humid is the climate. In Kansas this helps explain why northeast Kansas is in the western end of the Corn Belt even though it receives less precipitation than southeastern Kansas which has a larger MD than the northeast. Predicted effects of land use and conservation practices on water yield based upon MD are shown in table 7.1.

Results from POTYLD for an entire watershed provide evidence that various practices and land use effects when aggregated together are useful to assess or estimate combined effects of individual practices. When the model, FROMKSU, was used to study feedlots in different parts of the United States, it was noted that the water yield from the runoff disposal areas using published RCN values (USDA, SCS, 1972) generally agreed reasonably well with values reported for streamflow. In more arid areas, however, water yield was overestimated as expected because transmission losses and effects of ground-water withdrawals have important effects on streamflow. This provided reasonable confidence it the applicability of RCN values to larger watersheds. When POTYLD was developed, however, RCN values were not available to account for levels of residue management, particularly on wheat-fallow. Work reported by Rawls et al. (1980) on effects of residue and tillage on RCN values was influential for predicting how much RCN values for important practices in the area could be reduced when residue management was used. Field simulations in the area were run by Steichen (1983) and those results substantially agreed with predicted amounts that RCN values could be reduced as predicted by Rawis et al. (1980). Finally, field data for runoff from bare fallow and stubble mulch were available for Alliance, Nebraska (Fenster et al., 1977). Those results were simulated with POTYLD and showed the RCN value for stubble mulch with good residue management was six less (73 vs. 79) than for bare fallow on the same soil (Koelliker et al. 1981).

The reference list at the end of Chapter 7 contains several references to work where POTYLD has been used. Also, a copy of the user's manual, computer code, and diskettes are available from the author.

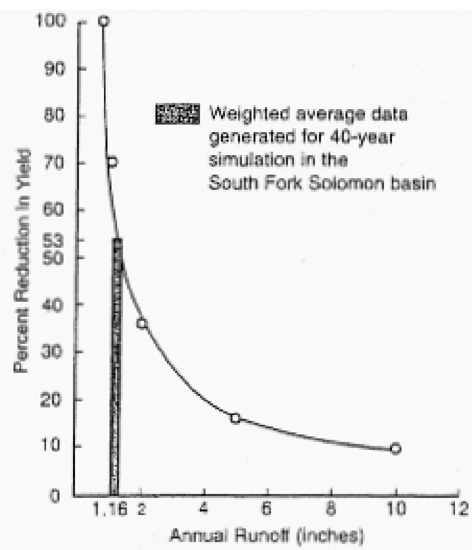


FIGURE 7.A2—Function of percent reduction in watershed yield due to ponds as a function of annual runoff in the watershed.

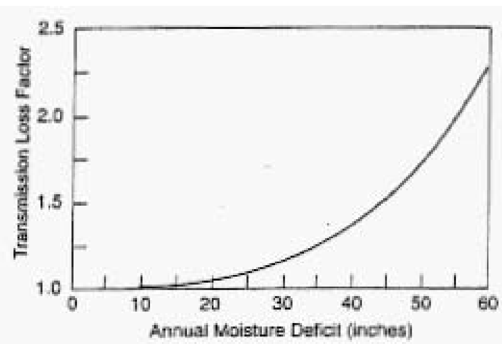


FIGURE 7.A3—Transmission loss factor for reducing upstream runoff to compare with measured runoff at a downstream streamflow gaging station [adapted by Koelliker et al. (1995) from Sharp et al. (1966)].

APPENDIX C

ZELLER, D.E., 1968

THE STRATIGRAPHIC SUCCESSION IN KANSAS:

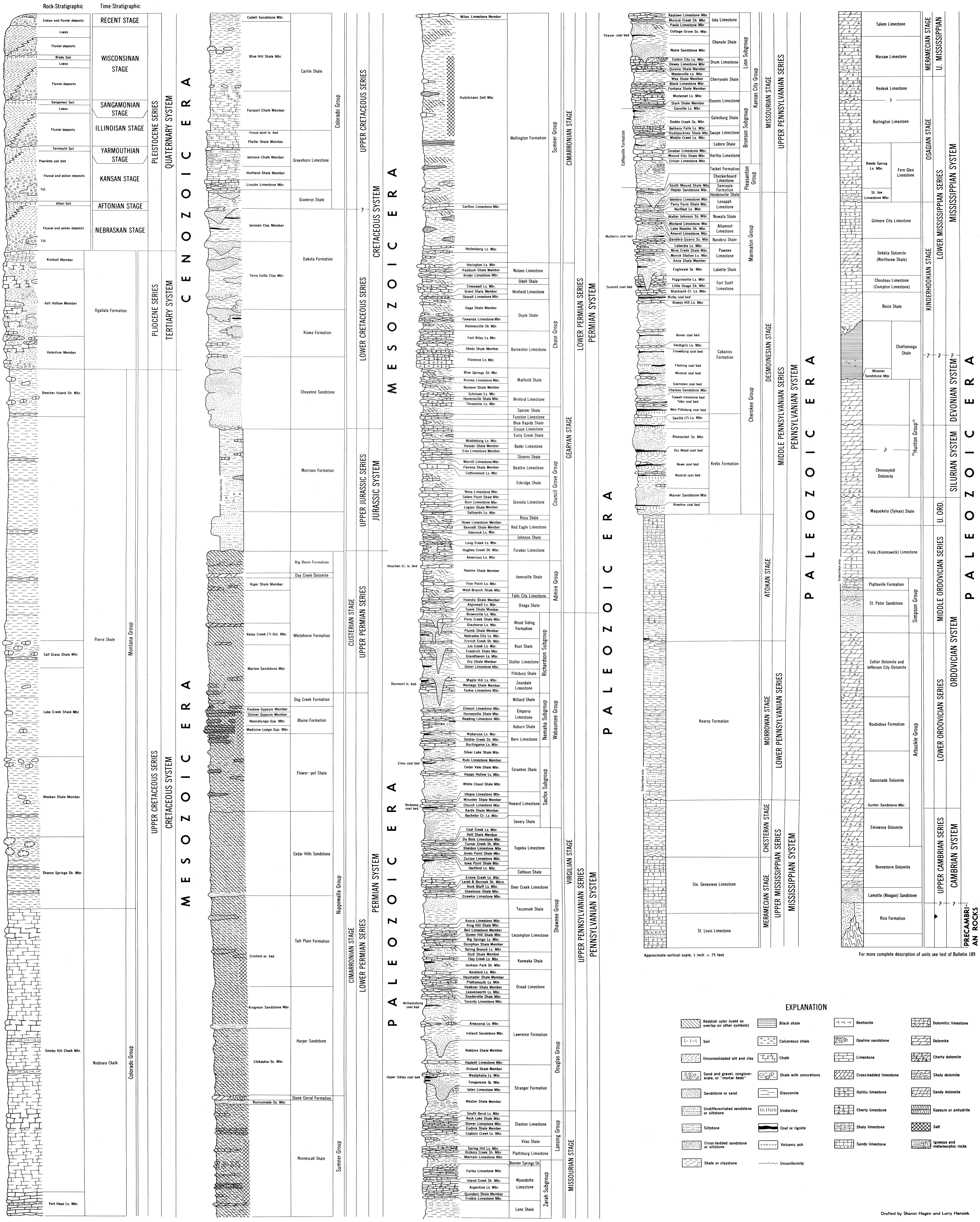
KANSAS GEOLOGICAL SURVEY, BULLETIN 189, PLATE 1

CLASSIFICATION OF ROCKS IN KANSAS

1968

State Geological Survey of Kansas

Bulletin 189
Plate 1



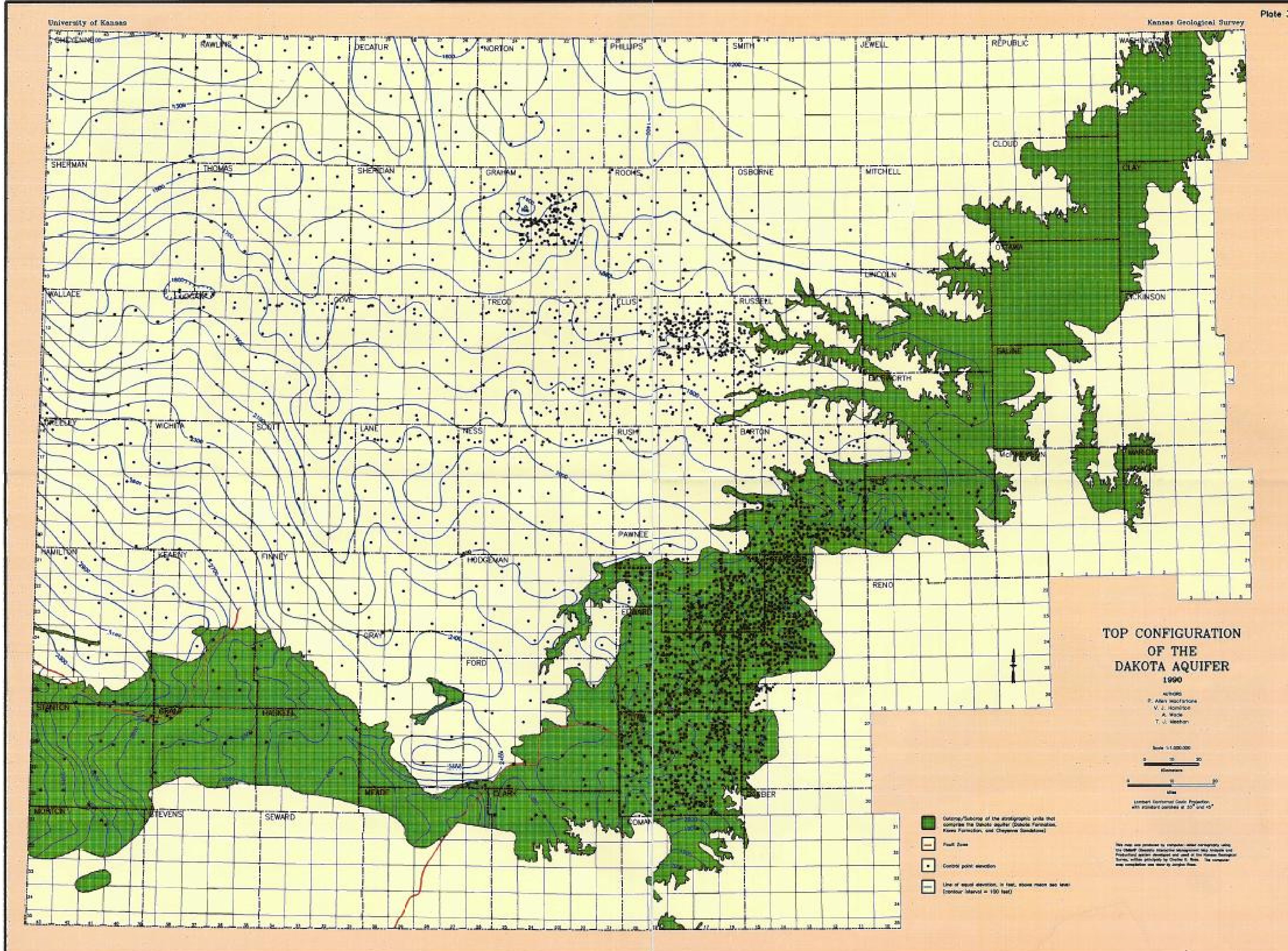
Approximate vertical scale, 1 inch = 75 feet

For more complete description of units see text of Bulletin 189

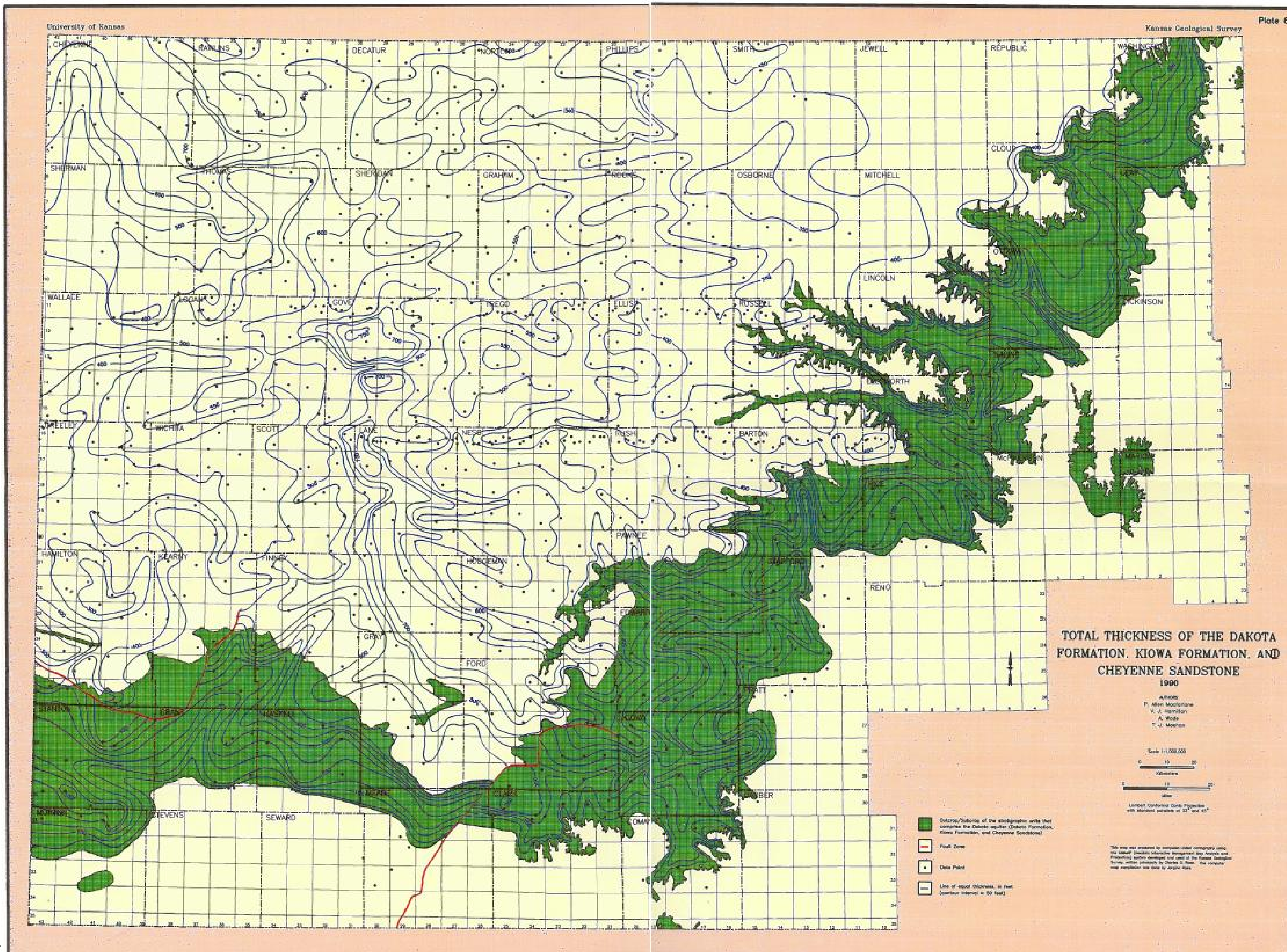
Drafted by Sharon Hagen and Larry Hensiek

APPENDIX D

MACFARLANE, P.A., WHITTEMORE, D.O., TOWNSEND, M.A., DOVETON, J.H., HAMILTON, V.J., COYLE III, W.G. AND WADE, A., 1990, THE DAKOTA AQUIFER PROGRAM: ANNUAL REPORT, Y89: KANSAS GEOLOGICAL SURVEY OPEN-FILE REPORT 90-27



University of Kansas
Kansas Geological Survey
Plate 3
TOP CONFIGURATION
OF THE
DAKOTA AQUIFER
1990
AUTHORS
P. Allen Macfarlane
V. J. Hamilton
A. Wade
T. J. Meehan
CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
CLOUD
CLAY
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
OTTAWA
LINCOLN
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
DICKINSON
SALINE
ELLSWORTH
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
McPHERSON
MARION
RICE
PAWNEE
HAMILTON
KEARNY
FINNEY
HODGEMAN
RENO
EDWARDS
GRAY
FORD
STANTON
GRANT
HASKELL
MEADE
CLARK
KIOWA
BARBER
MORTON
STEVENS
SEWARD
COMANCHE
Outcrop/Subcrop of the stratigraphic units that comprise the Dakota aquifer (Dakota Formation, Kiowa Formation, and Cheyenne Sandstone)
Fault Zone
Control point elevation
Line of equal elevation, in feet, above mean sea level (contour interval = 100 feet)
Kilometers
Miles


University of Kansas
Kansas Geological Survey
Plate 6
CHEYENNE
RAWLINS
DECATUR
NORTON
PHILLIPS
SMITH
JEWELL
REPUBLIC
WASHINGTON
CLOUD
SHERMAN
THOMAS
SHERIDAN
GRAHAM
ROOKS
OSBORNE
MITCHELL
LINCOLN
WALLACE
LOGAN
GOVE
TREGO
ELLIS
RUSSELL
DICKINSON
GREELEY
WICHITA
SCOTT
LANE
NESS
RUSH
BARTON
McPHERSON
PAWNEE
HAMILTON
KEARNY
FINNEY
HODGEMAN
RENO
GRAY
FORD
PRATT
STEVENS
SEWARD
BARBER
TOTAL THICKNESS OF THE DAKOTA FORMATION, KIOWA FORMATION, AND CHEYENNE SANDSTONE
1990
Authors
P. Allen Macfarlane
Scale 1:1,000,000
Kilometers
Miles
Fault Zone
Data Point

APPENDIX E

BALLEAU GROUNDWATER, INC., JANUARY 6, 2010
TECHNICAL MEMORANDUM:
EVAPOTRANSPIRATION IN BIG BEND GMD NO. 5

TECHNICAL MEMORANDUM

To File GMD#5/MODEL January 6, 2010

From W. Peter Balleau, CPG

Subject EVAPOTRANSPIRATION IN BIG BEND GMD NO. 5

Some material that Balleau Groundwater, Inc. (BGW) has used for reference on crop and water table interactions is attached alongside some web-page references. These help to guide the model factors (maximum ET rate, ET extinction depth, coverage) that may be adjusted in calibration, and which factors are reasonable as initially specified in the model.

The Natural Resources Conservation Service (NRCS) handbook (NRCS, 2007) has a guideline for a water table in the 1 to 6½-foot range of loamy soils that provides 10 percent to 100 percent of the crop irrigation requirement (attached 4 pp). They use a non-linear relationship with upward flow disproportionately greater at shallow depths. The root zone bottom is considered to be the surface boundary condition in the DRAINMOD (Wetland Science Institute, 1980) calculation used by NRCS to develop these curves for sub-irrigation design. The relationship is for soil depth below the root zone, rather than below the land surface. The NRCS curves address upward capillary rise in soil to the reachable root zone, they do not address the root-zone moisture depletion. The root zone moisture depletion in a uniformly moist profile after irrigation is weighted toward the shallow zones as in the attached Figure 3.2 of the NRCS handbook. The water table contribution, however, is taken from the bottom of the root zone upwards.

Some background distinctions are needed for this model concept, such as laid out in Lubczynski (2009). ET is a lumped term covering both evaporation (E) from soil moisture reaching the land surface and transpiration (T) taking moisture from the plant root to the canopy system. T has more capacity to reach deep layers of the soil profile. T extracts more water that E does. T draws on fluctuating stored moisture in root zones above the water table or touching the top of capillary zone, combined with moisture from rain or irrigation before it reaches the water table. T removed from the canopy usually is greater than the smaller amount of water abstracted from the saturated capillary/water table at the bottom of the root zone. E also can be from both sources, but usually is from the saturated zone if the water table is within three to six feet in good agricultural soils, as NRCS recognizes in their guidance for sub-irrigation. Silty soil zones such as described in the Pawnee Basin and described by Butler and Others, (2004) for the O'Rourke Bridge Mid-Ark shallow soils can promote E from deeper than three to six feet. Pawnee corridor has tens of feet of such reworked fine-grained loess in the shallow soil profile. Thus, E can be strong in such a soil profile with a water table less than 10 feet depth.

The NRCS guidance gives root zone depths as five to nine feet for wheat, corn, and alfalfa. Annual weeds such as kochia roots can penetrate to ten feet. The capillary rise above the water table serves to feed those root zones, so a water-table below 10 feet in depth can feed annual and woody plants.

Our modeled ten-foot extinction depth for ET is intended to cover water table extraction from underlying capillary feed to generalized root zones, and to cover losses at the land surface where bare ground may be present. The ten-feet being simulated represents a six-foot root depth over a four-foot capillary rise, or a four-to-ten-foot capillary rise (depending on texture) in the lack of a vegetated cover. We are not breaking out riparian zone trees, which can reach deeper to 30 or more feet (Butler and Others, 2004).

Due to concern about the linear monotonically increasing, [from extinction depth (zero loss) to land surface (max rate loss)], standard EVT function in MODFLOW, the United States Geological Survey (USGS) (Schmid and Others, 2006); (Schmid and Hanson, 2009) (Baird and Others, 2005) have added the facility to reduce T or alternatively keep T operating, in waterlogged root zones, while increasing E as on overlapping function in the same waterlogged intervals. The effect of the new MODFLOW packages is to maintain the overall pattern of combined E and T similar to the original curve in EVT package, while isolating the two functions. We see no pressing need to alter the ET package to address those distinctions.

A few pertinent points on ET concepts from our reference shelf include:

a. Two bar charts are attached (last two pages) from Cleverly and Others (2008) showing that various unmanaged riparian zone vegetation types in New Mexico consume water roughly similarly (~ 3.5 feet/year) through the years 1998-2007 and by vegetation type of annuals and woody perennial plants. Kochia weeds as undergrowth add ten percent to ET. Burning and understory removal are relatively ineffective at reducing ET.
b. Evaporation (not ET) from bare soil with a water table at three to six feet is measured in New Mexico at up to 0.3 inch/day (Stormont and Coonrod, 2004). This is a high rate equivalent to full crop ET.

c. Removal of understory vegetation in the riparian zone of New Mexico causes 20 percent reduced fluctuation in water table (Martinet, 2005), but no rise in the water table. The water table depth is related to river flow more than to ET.

d. A paper by Papdopulos & Associates and NMISC (MacClune and Others, 2006) modeling the three to five mile wide Middle Rio Grande (MRG) ET with the new RIP-ET package concludes that *"…maximum evapotranspiration rates of 4 acre-feet per year were replaced with…3 acre feet per year…the river seepage loss was reduced by 0.1-0.2 cfs/mile, and water lost to ET was reduced by up to 25%.*" This result confirms the linearity of the RIP-ET model, where a given percent reduction in max ET rate translates to the same proportion reduction in simulated ET. The same relationship is expected in the MID-ARK model with the standard EVT package. ET is simulated throughout the river flood plain.

e. Saltcedar – cottonwood communities along the MRG in New Mexico have ET rates of 0.2 inch/day, and satellite imagery correlates at r = 0.76 (EVI) to 0.68 (NDVI) compared to on-site eddy covariance data (Nagler and Others, 2005). We have used NDVI for filtering irrigation from non-irrigating areas in the GMD#5 model.

f. A recent paper by the University of New Mexico group (Stormont and Others, 2009) uses data and models to report (p. 910) that "*…evaporation from bare soil in the presence of a shallow water table can be comparable to ET from riparian vegetation…suggesting that cleaning tracts of vegetation…would not generate significant water savings in the presence of a shallow water table.*"

g. Arizona studies of containerized trees report (Nagler and Others, 2003) that cottonwood, willow, and saltcedar all have similar ET rates under non-stressed conditions, but saltcedar persists better under stress.

h. An excellent review of various aspects of riparian consumptive use has been released by Nebraska DNR (2008). They cite Butler on the Larned Research site. The paper endorses satellite energy balance methods as good to ±15 percent of field methods, notes the failure of vegetation control measures to yield water at gages, emphasizes that gross ET does not indicate the groundwater component of ET, cites the RRCA using ten feet for extinction depth and COHYST using ten to three feet. They call out research needs for areas of improvement, mainly involving elevation data and measurement methods.

The potential ET in the GMD#5 is estimated to vary by month as Max ET = ETref – (Precipitation – Runoff). The potential for active ET is present in shallow water areas, including the two to three mile wide flood plain of the Arkansas River under 1940's conditions. For example, the flood plain from Kinsley to Great Bend is 65 miles long with about 100,000 acres quantifying for ET potential. The river stage drops six feet in history. The 40 wells with historical data in the alluvial reach show five to ten feet of drawdown in history to 2007. With an extinction depth of ten feet below land surface, many of the original 1940 ET areas are now inactive, and likely are controlled by the six-feet lower river stage to be inactive in the future also.

From field and air photo inspection, the Mid-Ark flood plain has about 19,000 acres of irrigated lands among over 100,000 acres of flood plain consisting of low density brush. Trees are dense only in the incised riverbed. Trees remain dense and vigorous in the narrow corridor below Larned, decline upstream to Garfield, where Coon Creek rewaters the riparian zone. Riparian density and vigor then decline upstream to Kinsley above where the channel is poorly vegetated due to the lower water table. Butler and Others (2004) quantifies the ET loss in the 500-foot wide incised valley below the flood plain as losing three feet of water in 2002, equivalent to a 600-gpm irrigation operation every three miles along the river, or 19,000 AFY in the 65-mile reach. The orthophoto quads around Pawnee Rock show that tree stands occupy many small areas of non-farm land in the flood plain, suggesting the potential for recovery of woody vegetation in the future where land-use management is altered.

Based on the references and local vegetative conditions, we conclude that the Big Bend GMD No. 5 model should follow these concepts:

1. Vegetation type is not a sensitive factor for the strength of evapotranspiration.
2. Bare soil does not necessarily indicate low evaporation where the water table is shallow.
3. Managing vegetation cover does not necessarily alter water-table depth, particularly where a river stage and flood water overrides the other factors.
4. The standard MODFLOW EVT package functions reasonably.
5. The evapotranspiration specifications in the GMD#5 model should call for climatic-driven rates, wide extent throughout areas of shallow water table, and a generalized 10-foot extinction depth of evapotranspiration.
6. Farm operations affect only a few percent of the Mid-Ark flood plain and are not a critical part of the ET balance.
7. The Larned Research site (O'Rourk Bridge) reports three feet of water use by riparian vegetation in the 500 foot wide incised river bed, equivalent to 19,000 acre feet per year in the 65 miles reach. This loss is from a much smaller area than the entire flood plain.

8. Trees are present in the flood plain, outside the incised bed, where lands are not managed for other purposes. Woody vegetation might be re-established in a larger area in the future, thus the ET function should be retained in the model even where temporarily extinguished.
9. The large areal extent of active ET from the water table appears to be removing water at low rates of a few inches per year, much less than the maximum potential rate, but nevertheless the low rates and large areas involved accumulate to a large volume of the overall water balance.

If further adjustment in Model ET proves necessary for calibration, then reasonable mechanisms would include:

1. Raise extinction depth to three to six feet for cleared areas after 1970's, from the initial ten feet. This would reduce the simulated ET from areas cleared for cultivation.
2. Delete ET function from farm places of use in history and in future. This would cut 10 to 15% of ET activity in the flood plain.

Attachments: (6) sheets

References

Baird, K.J., Stromberg, J.C., Maddock III, T., 2005, Linking Riparian Dynamics and Groundwater: An Ecohydrologic Approach to Modeling Groundwater and Riparian Vegetation: Environmental Management Vol. 36, No. 4, pp. 551-564, http://www.springerlink.com/content/k041l1j676758462/fulltext.pdf.

Butler, J.J., Kluienberg, G.J., A Field Assessment of a Method for Estimation of Ground-water Consumption by Phreatophytes: United States Geological Survey, http://water.usgs.gov/wrri/AnnualReports/2004/FY2004_KS_Annual_Report.pdf.

Cleverly, J.R., Vanderbilt, K., Dahn, C., Thibault, J.R., Martinet, M.C., 2008, Evapotranspiration, Water Table Fluctuations, and Riparian Restoration: urban Flood Demonstration Program Annual Report 2007-2008, http://bosque.unm.edu/~cleverly/ET_Report_2007-2008-update_UFDP.pdf.

Dunnigan, B., Schneider, J., Hallum, D., Alexander, J., Ostdiek, A., Cartwright, T., Lear, J., Pun, M., Bradley, J., Josiah, S., Koester, P., Kloch, D., 2008, Assessment of Resources Available to Quantify Non-beneficial Consumptive Water Use by Riparian Vegetation in Nebraska: The Nebraska Department of Natural Resources, http://www.dnr.state.ne.us/Publications_Studies/RipET_FINAL_1208.pdf.

Lubczynski, M. W., 2009, The Hydrogeological Role of Trees in Water-Limited Environments: Hydrogeology Journal Volume 17, pp. 247-259.

Maclune, K.L., Barth, G., Shafike N., Hathaway, D., 2006, High-Resolution Groundwater Models for the Assessment of Riparian Restoration Options and River Conveyance Efficiency: S.S. Papadopulos & Associates, Inc., http://www.sspa.com/publications/MacClune%202006%20MODFLOW%20vol1.pdf.

Martinet, M.C., 2005, The Effects of Non-Native vegetation Removal on Rio Grande Shallow Alluvial Ground Water, Bosque Hydrology Group Meeting, http://www.fws.gov/southwest/bhg/Power%20Point/GW_SW/maceo.ppt.

Nagler P.L., Clerverly, J., Glenn, E., Lampkin, D., Huete, A., Wan, Z., 2005, Predicting Riparian Evapotranspiration from MODIS Vegetation Indices and Meteorological Data: Remote Sensing of Environment, http://www.icess.ucsb.edu/modis/papers/wan_p40.pdf.

Nagler, P.L., Glenn, E. P., Thompson T. L., 2003, Comparison of Transpiration Rates Among Saltcedar, Cottonwood and Willow Trees by Sap Flow and Canopy Temperature Methods: Agricultural and Forest Meteorology 116, pp. 73-89.

Natural Resource Conservation Service, 2007, National Engineering Handbook (NEH) Part 652 - Irrigation Guide: United States Department of Agriculture, http://www.ks.nrcs.usda.gov/technical/ks_supplements/neh652.html.

Schmid, W., Hanson, R.T., 2009, The Farm Process version 2(FMP1) for MODFLOW-2005-Modifications and Upgrades to FMP1: Unites States Geological Survey 6-A-32, http://pubs.usgs.gov/tm/tm6a32/pdf/tm6a32.pdf.

Schmid, W., Hanson, R. T., Maddock III, T., Leake, S.A., 2006, User Guide for the Farm Process (FMP1) for the U.S. Geological Survey's Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, MODFLOW-2000: United States Geological Survey 6-A17, http://pubs.usgs.gov/tm/2006/tm6A17/tm6A17.pdf.

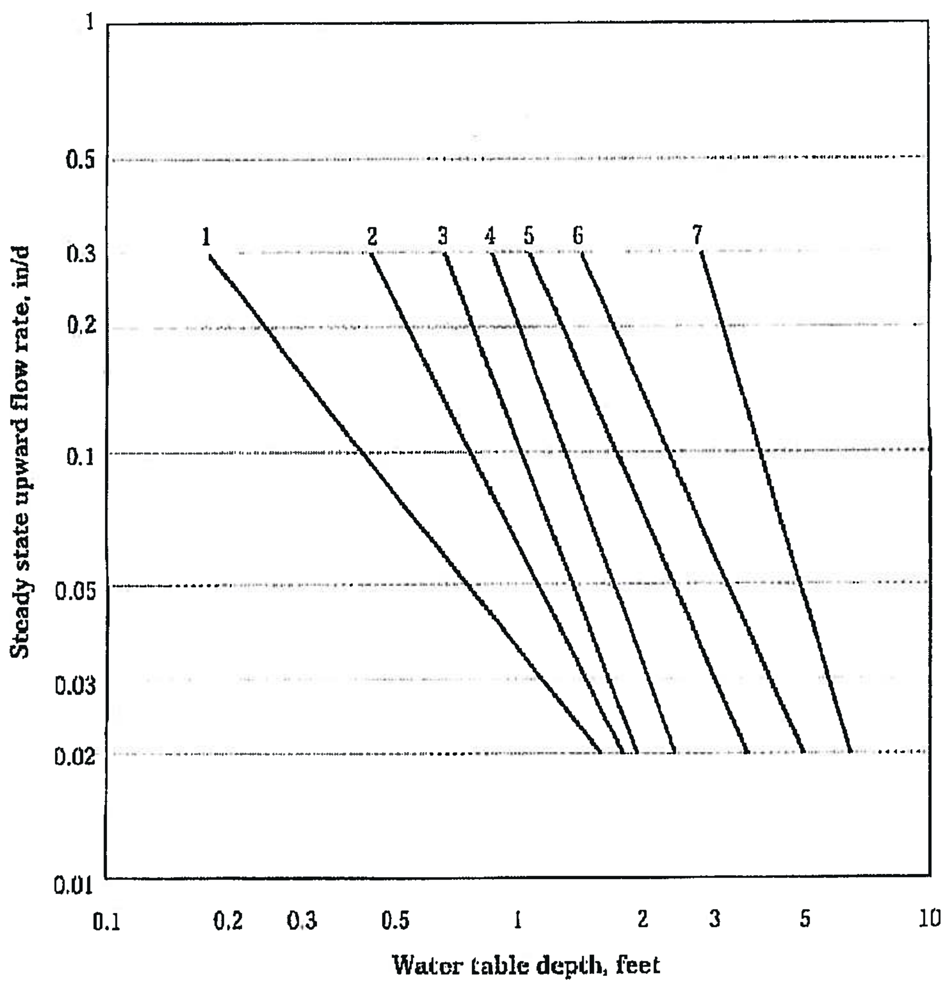
Stormont, J.C., Coonrod, J., 2004, Water Depletions from Soil Evaporation, http://www.unm.edu/~cstp/Reports/H2O_Session_2/2-5_Stormont.pdf.

Stormont, J.C., Farfan, E., Coonrod, J.E.A., 2009, Total Soil water Evaporation in a Riparian Environment: Model Development and Application: Journal of Hydrologic Engineering, pp. 904-912.

Wetland Science Institute, 1980, DRAINMOD Reference Report: Natural Resource Conservation Service, http://www.bae.ncsu.edu/soil_water/documents/drainmod/chapter5.pdf

Figure 6–25 Water table contribution to irrigation requirements as a function of water table depth and soil type

Soil type	Line number
Sticky clay	1
Loamy sand	2
Clay	3
Peat	4
Clay loam	5
Sandy loam	6
Fine sandy loam	7



652.0406 Water table contribution

Upward flow of water from a water table can be used to meet part of or all the seasonal crop water requirement. Reasonable estimates need to be made of the water supplied by a water table. See figure 2–6 in chapter 2 of this guide. Methods to predict upward soil-water flow rates (upflux) from a water table are given in NEH Part 623, Chapter 2, Irrigation Water Requirements, and in the water table management software program DRAINMOD. Soil parameters required for these procedures are quite variable and may require field data to evaluate specific sites.

652.0407 Water requirements for soil-water budget/balance analysis

The components of a soil-water budget/balance analysis must include all water going *in* and all water going *out* of an area for the period of consideration. The basic purpose for such an analysis is to determine the location of all water applied. Generally a soil-water budget analysis is determined for a period involving a month, an irrigation season, a year, or maybe even for an average over several years. Availability of climatic data may also dictate the time period for the analysis. For example, if long-term mean temperature is the only reliable data available, determining monthly and seasonal water requirements may be the most accurate analysis that can be done. This would dictate a reasonably accurate analysis period of a month or longer.

If complete and reliable daily climatic data (temperature, solar radiation, wind movement, and relative humidity) are available nearby, then a daily soil-water accounting or balance can be developed because accurate daily water requirements can be estimated. The soil-water budget/balance analysis process is a tool that can be used for determining gross water applied and contributions of irrigation water and precipitation to downstream surface water and ground water. The soil-water budget/balance can be displayed in equation form as follows (sum may be positive if soil water is stored in the plant root zone):

$$F_g = ET_c + A_w + D_P + RO + SDL - P - GW - \Delta SW$$

where:

F_g = Gross irrigation water applied during the period considered

ET_c = Crop evapotranspiration during the period considered

A_w = Water applied for auxiliary purposes during the period considered

D_p = Deep percolation below the root zone from irrigation and precipitation

RO = Surface runoff that leaves the site from irrigation and precipitation

SDL = Spray, drift losses, and canopy intercept evaporation from sprinkler irrigation system during the period considered
P = Total precipitation during the period considered
GW = Ground water contribution to the crop root zone during the period
ΔSW = Change in soil-water content within the crop root zone during the period

Note: Only those factors that apply to the site under consideration need to be used. Typically all factors would not be used for an analysis of one site.

Generally the soil-water budget analysis can be thought of as supporting a planning process where the soil-water balance analysis can be thought of as supporting an operational process. With appropriate soil-water content monitoring, accurate estimated daily crop ET and measurement of system inflow and surface outflow, a reliable daily soil-water balance can be developed. These daily values can be summarized for any desirable longer period that data are available.

The period of reliable climatic data is key to the soil-water budget/balance analysis. For development of a soil-water balance, only immediate past events are evaluated. It is not an irrigation scheduling tool. For example, a soil-water balance is an analysis process of what water went where for the last year, last month, last week, last event, or from some specific date up to the present time. Each rainfall and irrigation event versus daily crop ET and soil-water content change can be evaluated. It requires appropriate and current monitoring of soil-water content, irrigation water applied, onsite rainfall measurement, runoff, and full climatic data for daily crop ET determination.

For development of a soil-water budget, historic climate data along with estimated or measured soil-water content, irrigation flows, and losses would be used. The time period for an analysis for an average condition is whatever is necessary to provide reliable data. As an example, a site with fairly consistent climate from year to year, but with a rather short number of years record, might provide satisfactory results. Whereas a site with wide ranging climate from year to year might require a much longer period of record. An analysis showing the average for the last 5 years, or for a specific year of importance, could use climate data for that specific period only.

Table 4–2 displays a simple and basic soil-water budget using assumed and estimated values. The input data can be refined to whatever degree is necessary with field observations or measurements, or both. In this table, a water surplus of 1.7 inches for the season is indicated, and the water will go into deep percolation below the root zone.

A soil-water budget can be developed for planning purposes or as an evaluation tool. As the example shows, the consultant can use any level of accuracy desired or necessary.

(a) Example soil-water budget

A simplified soil-water budget would be displayed using the following assumptions:

- Crop is grain corn.
- Mature rooting depth = 48 inches.
- Total AWC = 8.0 inches.
- MAD = 50%.
- Soil profile is at field capacity at start of season.
- Sprinkler irrigation system with gross application for each irrigation = 6.0 inches.
- Application efficiency of 67% providing a net application = 4.0 inches.
- DU = 100% with no surface runoff.
- Precipitation infiltration for all season = 70% of total.
- No contribution from a shallow water table.

All crop ET, irrigation, and precipitation units are in inches.

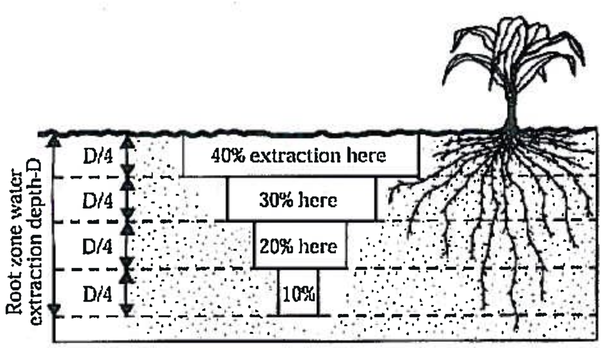
Additional and more detailed examples of a soil-water budget and a soil-water balance are in Chapter 8, Project and Farm Irrigation Water Requirements.

In uniform soils that are at field capacity, plants use water rapidly from the upper part of the root zone and more slowly from the lower parts. Figure 3–2 shows the typical water extraction pattern in a uniform soil. About 70 percent of available soil water comes from the upper half of a uniform soil profile. Any layer or area within the root zone that has a very low AWC or increased bulk density affects root development and may be the controlling factor for frequency of irrigations.

Figure 3–3 illustrates the effect on root development of some limitations in a soil profile. Variations and inclusions are in most soil map units, thus uniformity should not be assumed. Field investigation is required to confirm or determine onsite soil characteristics including surface texture, depth, slope, and potential and actual plant root zone depths.

Soil texture, structure, and condition help determine the available supply of water in the soil for plant use and root development. Unlike texture, structure and condition of the surface soil can be changed with management.

Figure 3–2 Typical water extraction pattern in uniform soil profile



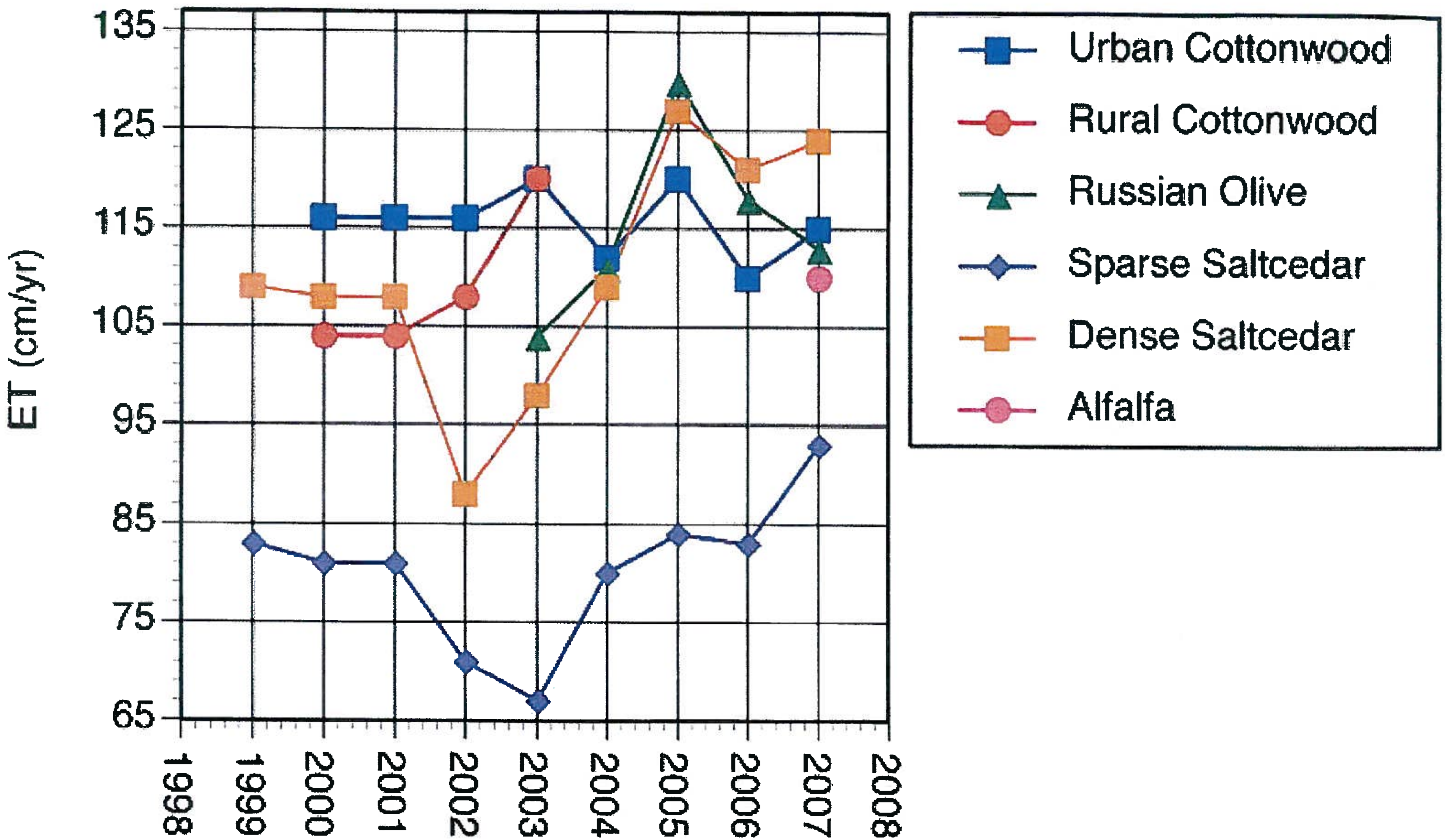
Note: Approximately 70 percent of water used by plants is removed from the upper half of the plant root zone. Optimum crop yields result when soil-water tensions in this area are kept below 5 atmospheres. Very thin tillage pans can restrict root development in an otherwise homogenous soil. **Never assume a plant root zone.** Observe root development of present or former crops.

Numerous soil factors may limit the plant's genetic capabilities for root development. The most important factors are:

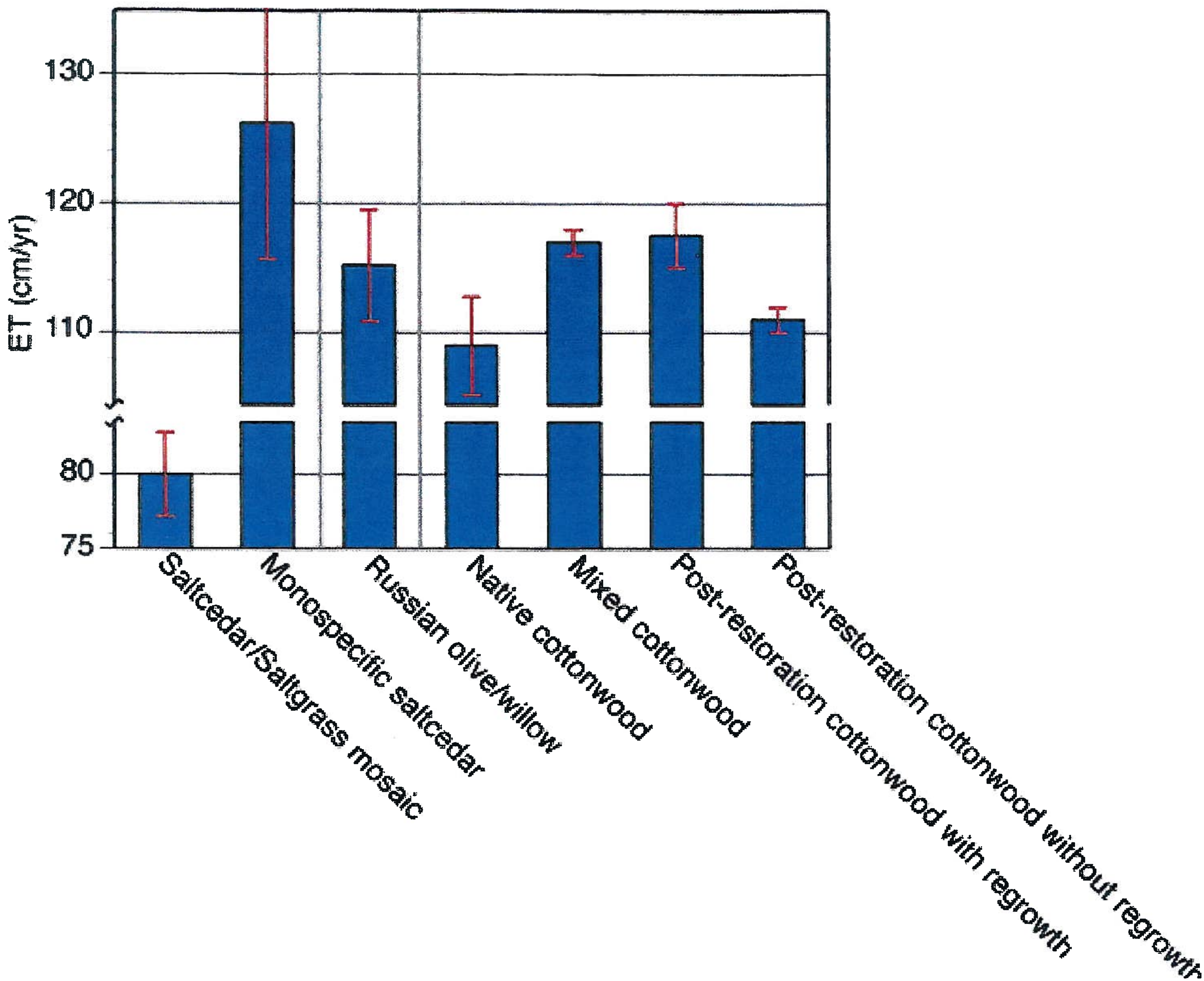
- soil density and pore size or configuration,
- depth to restrictive layers and tillage pans,
- soil-water status,
- soil condition,
- soil aeration,
- organic matter,
- nutrient availability,
- textural or structural stratification,
- water table,
- salt concentrations, and
- soil-borne organisms that damage or destroy plant roots.

Root penetration can be extremely limited into dry soil, a water table, bedrock, high salt concentration zones, equipment and tillage compaction layers, dense fine texture soils, and hardpans. When root development is restricted, it reduces plant available soil-water storage and greatly alters irrigation practices necessary for the desired crop production and water conservation.

Root penetration is seriously affected by high soil densities that can result from tillage and farm equipment. Severe compacted layers can result from heavy farm equipment, tillage during higher soil moisture level periods, and from the total number of operations during the crop growing season. In many medium to fine textured soils, a compacted layer at a uniform tillage depth causes roots to be confined to the upper 6 to 10 inches. Roots seek the path of least resistance, thus do not penetrate a compacted dense layer except through cracks. Every tillage operation causes some compaction. Even very thin tillage pans restrict root development and can confine roots to a shallow depth, thereby limiting the depth for water extraction. This is probably most common with row crops where many field operations occur and with hayland when soils are at high moisture levels during harvest.



ET (cm/yr)
135
125
115
105
95
85
75
65
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Urban Cottonwood
Rural Cottonwood
Russian Olive
Sparse Saltcedar
Dense Saltcedar
Alfalfa


ET (cm/yr)
130
120
110
80
75
Saltcedar/Saltgrass mosaic
Monospecific saltcedar
Russian olive/willow
Native cottonwood
Mixed cottonwood
Post-restoration cottonwood with regrowth
Post-restoration cottonwood without regrowth

APPENDIX F

BALLEAU GROUNDWATER, INC., AUGUST 28, 2008

TECHNICAL MEMORANDUM:

AQUIFER-TEST RESULTS AT SIX SITES IN BIG BEND GMD #5

TECHNICAL MEMORANDUM

To File GMD#5/MODEL August 28, 2008

From W. Peter Balleau, CPG

Subject AQUIFER-TEST RESULTS AT SIX SITES IN BIG BEND GMD#5

W. PETER BALLEAU LICENSED 686 KANSAS GEOLOGIST

Introduction

Big Bend Groundwater Management District #5 (GMD#5) delivered to Balleau Groundwater, Inc. (BGW) on June 27, 2008 a set of data files on four multi-well aquifer tests completed in the period 1995 to 1996, and two earlier, 1979, similar tests. Electronic data with background on the four tests had been received on June 10, 2008. The layout of the six tests is displayed on attached Figure 1.

The electronic data included earlier interpretations by GMD#5 of the mid-1990 tests concluding that the aquifer transmissivity among the four sites ranged from 1500 to 20,000 feet squared per day (ft^2/d) and hydraulic conductivity ranged from 12 to 370 feet per day (ft/d). Our re-examination of the data generally supports the earlier characterization with new weight given to the higher values.

Setting and Data

The aquifer test data is displayed for analysis of the six sites in attached Figures 2 through 4 (Bliss), Figures 5 through 7 (Bookstore), Figures 8 through 10 (Froetschner), Figures 11 through 15 (Heyen with streamflow data), Figures 16 through 18 (Ketterl) and Figures 19 through 21 (Smith). The data are input from GMD#5 field sheets or tables and are plotted as hydrographs, log-log plots of drawdown versus a lumped parameter (time over radial distance squared) for radial-flow analysis (Cooper and Jacob, 1946), and residual drawdown during the recovery phase plotted by the Theis-recovery method (Theis, 1935). The figures are for analysis of transmissivity, storage coefficient, leaky aquifer properties, and any evidence of positive or negative boundaries in the extended flow field. The test-well construction is summarized on Table 1.

Graphical logs were provided by GMD#5 for multiple wells at each of four sites (Bliss, Heyen, Ketterl, and Smith). The well-construction and graphic logs show that the tests differ in detail among the zones stressed in the “Great Bend Prairie” aquifer. The general geologic section was a surface silt, over a middle sand, above a medial clay or silt, over basal sand. Bliss, Froetschner and Smith sites used split screens across the medial clay to test both sands. Bookstore and Heyen sites used one screen in the middle sand, while Ketterl used one screen in the lower sand. Smith site was unique in being at a relatively-high topographic elevation where the depth to water and top of the water-table aquifer lies in the middle sand rather than in the upper silt. The Smith site screen-zone, therefore, was in good communication with the water-table sand, which accounts for the observed water-table response. The Ketterl and Heyen screen-zones were relatively isolated from the water table by intervening clay. The Bliss site water table was a few feet into the top silt. Bookstore and Froetschner sites had fewer details on strata in the file.

The pre-test water levels (Table 1) reflect the vertical head gradient at several nested wells. Bliss (#3 and #4) have an upward (0.005) gradient, while an adjacent nest (WQ 3-1 and WQ 3-2) a half-mile south had an unexplained strong (0.06) downward gradient. Ketterl sites (3 and 4) had (0.02) upward gradient, suggesting local discharge. The Smith site was distinctive in having three nests with downward gradient at each, reflecting recharge to the lower sand in this relatively high topography.

Site Response

The Bliss test demonstrates that the pumping well is hydraulically inefficient where formation drawdown at the well radius would be 40 percent of the observed drawdown. There is no boundary effect seen in the recovery data.

The Bookstore test has no pumping-well data, but observation-well drawdown and recovery are consistent and show no boundary effects.

The Froetschner test in the Pawnee Creek alluvial corridor has no pumping-well data, but the observation wells display the characteristics of a nearly-closed container (drawdown proportional to time) consistent with compartmentalized valley-terrace walls. Local transmissivity within the “container” is large, with less than two feet drawdown at the nearest observation well (87 ft distance) after three days pumping at 1000 gpm.

The Heyen test drawdown and recovery had the highest transmissivity and showed that high values are associated with the shallower upper-sand units. The pumping well is relatively inefficient. The alluvial sediment at the confluence of the Wild Horse and Rattlesnake Creeks may be related to the good hydraulic performance of the aquifer. The stream gaging during the Heyen two-cubic feet per second (cfs) test showed that flow was receding about one cfs per day from 12 to 9 cfs. The difference between upstream and downstream flow varied probably due to gaging accuracy, but displayed about 0.5 less flow downstream. However, it remains uncertain whether or not the Figure 15 data show a meaningful trend in terms of a response to the test. The Figure 15 data are compatible with the well recovery data which showed little or no appreciable local-induced stream recharge.

The Ketterl test drawdown and recovery are consistent without appreciable positive or negative boundary effects for the observation period. The pumping well is near 100 percent efficient.

The Smith site displayed relatively good transmissivity and was the only site where data trends deviated from radial flow expected from aquifer-storage depletion. The drawdown and recovery data display a positive (recharge) boundary interpreted to be water-table storage response across a five- to ten-foot leaky silt between the screen zone and the water-table sand. The vertical hydraulic conductivity corresponding (Hantush and Jacob, 1955) to the observed trend is 0.2 ft/d. The pumping well is efficient.

Aquifer Test Results

Table 2 provides a summary of aquifer properties derived from interpretation of the data plots. Radial-flow storage-depletion analysis (Theis, 1935 and Cooper-Jacob, 1946) for transmissivity and storage alongside equivalent leaky-aquifer (Hantush and Jacob, 1955) results for vertical properties are given. The transmissivity is converted to hydraulic conductivity assuming a characteristic test-zone thickness based on the graphic logs and screen geometry. The hydraulic conductivity values lie in the range of 40 ft/d (Ketterl) to 550 ft/d (Heyen), characteristic of clean sand and gravel of High Plains river alluvium.

The initial storage coefficient was in two groups 0.0003 to 0.0005 at deep-screen sites and 0.025 to 0.005 at the shallower sites. The smaller values are interpreted to be an elastic response, such as caused by a specific storage of 3×10^{-6} ft^{-1} in a 100-foot thick system. The larger values at shallow sites are interpreted to reflect a component of pore-water drainage at the water table.

Vertical hydraulic conductivity (K_z) is related to the cross-bed properties of the silt and clay layers. Leaky-bed thickness is assumed to be the clay or silt gap, commonly about 20 feet, between the screen interval (Table 1) and the full aquifer thickness (Table 2). The Smith site demonstrates that some thin and silty zones may be near 0.2 ft/d. The ratio to horizontal hydraulic conductivity at Smith site is 0.1/220, or 0.0005, which allowed an observable leaky recharge to be induced over the four-day observation period. Other sites had a generally less permeable value vertically, with threshold values less than the range of 0.001 to 0.3 ft/d, and anisotropy ratios less than 1×10^{-3} to 1×10^{-6}. The other sites indicate K_z less than the threshold values cited, otherwise leakage effects would have been observed during the test.

The relationship of transmissivity to screen-zone depth suggests, with exceptions, that the shallow sands have relatively high transmissivity (Heyen), and the deeper sands have relatively less transmissivity (Ketterl). There is no apparent spatial correlation among the test locations. The variation in properties may be associated with depth and geology more than with location.

Conclusions

1. The GMD#5 file data at five aquifer-test sites is amenable to analysis of characteristic aquifer properties in the “Great Bend Prairie”. One site in the Pawnee Creek alluvial corridor is less informative because of overriding barrier-boundary effects.

2. Hydraulic conductivity values near 220 feet squared per day are characteristic of the shallow sands. Values near one-third to one-quarter of that characterize the deeper sands.

3. Well-efficiency ranges from near 100 percent to near 40 percent and should be accounted for in projecting the yield and service lifetime of production wells.

4. Storage properties during test periods of a few days reflect a mix of elastic and pore-water release, but pore-water storage is expected to dominate long-term properties.

5. Induced recharge from adjacent streams was not apparent in the short-term data trend, but is expected to be seen in longer-term performance of the hydrologic system.

6. Anisotropy between horizontal and vertical hydraulic conductivity is significant and should be accounted for in characterizing the system. Anisotropy serves to delay stream interaction.

7. Both recharging and discharging vertical gradients are seen among the several sites, depending on topography.

8. The aquifer characteristics identified by GMD#5 aquifer tests are suitable for use in quantitative model accounting of the source of water to wells and the interaction with surface-water features.

References

Cooper, H.H. and Jacob, C.E., 1946, A Generalized Graphical Method for Evaluating Formation Constants and Summarizing Well-field History, Trans. Am. Geophys. Union, Vol. 27, No. 4, pp. 526-534.

Hantush, M.S. and Jacob, C.E., 1955, Non-steady Radial Flow In An Infinite Leaky Aquifer: Trans. Amer. Geophys. Union Vol. 36, pp. 95 – 100.

Theis C.V., 1935, The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage: American Geophysical Union, Volume 16, pp. 519-524.

Attachments: Table (2)
Figures (21)

MODEL

TABLE 1. TEST WELLS CONSTRUCTION SUMMARY

Well ID	Distance from Pumping Well (ft)	Total Depth (ft)	Screened Interval Depth (ft)	Screened Thickness (ft)	Static Water Level (ft)
BLISS SITE					
Pumping	0	80	32-52, 60-80	40	23.31
Test Hole	14	88	--	--	22.82
#1 East	261	74	54-74	20	16.76
#2 South	263	78	68-78	10	21.37
#3 South	637	115	110-115	5	19.94
#4 South	623	77	67-77	10	20.16
Abnd Irr	1081	78	--	--	23.07
N Irr	1371	95	54-95	41	15.26
WQ 3-1	2300	140	120-140	20	26.24
WQ 3-2	2300	75	65-75	10	22.68
SE Stock	3200	--	--	--	14.66
BOOKSTORE SITE					
Pumping	0	96	46-96	50	--
Obs1	75	71	7-71	64	27.16
Obs2	152	62	17-62	45	26.19
Obs3	226	76	21-76	55	27.82
FROETSCHNER SITE					
Pumping	0	106	29-44, 78-106	43	--
Obs1	87	--	--	--	37.76
Obs2	197	--	--	--	36.60
Obs3	272	--	--	--	34.23
HEYEN SITE					
Pumping	0	65	40-64	24	5.08
Obs1	300	--	--	--	4.88
Obs2	600	55	45-55	10	3.10
Obs3	300	54.5	44.5-54.5	10	3.63
Obs4	125	--	--	--	6.95
Obs5	360	54.5	44.5-54.5	10	0.75
Obs6	393	54.5	44.5-54.5	10	2.42
Obs7	435	49.5	39.5-49.5	10	1.37
Obs8	300	--	--	--	6.92
Obs9	600	--	--	--	4.64
KETTERL SITE					
Pumping (IW1)	0	136	99-135	36	18.82
SW2	25.5	--	--	--	18.17
OBDW3	327	120[1]	110-120[1]	10	19.49
OBSW4	327	50[1]	40-50[1]	10	20.88
OFSW5	954	120	100-120	20	19.02
OB6	327	120[1]	110-120[1]	10	19.99
SMITH SITE					
Pumping	0	148	73-93, 107-147	60	--
Pumping Obs	20	149	--	--	32.34
Obs1	300	90	80-90	10	34.53
Obs2	300	130	120-130	10	34.67
Obs3	900	95	85-95	10	45.28
Obs4	900	139	129-139	10	45.68
Obs6	300	94	84-94	10	38.82
Obs7	300	130	120-130	10	38.94
Obs8	2450	--	--	--	38.00
Obs9	2650	140	92-140	48	33.48
Obs10	3650	135	95-135	40	33.75
Obs11	4250	--	--	--	38.50

Source: Aquifer test materials provided by GMD#5.

[1] Well depth and screen interval from proposed construction plan.

MODEL

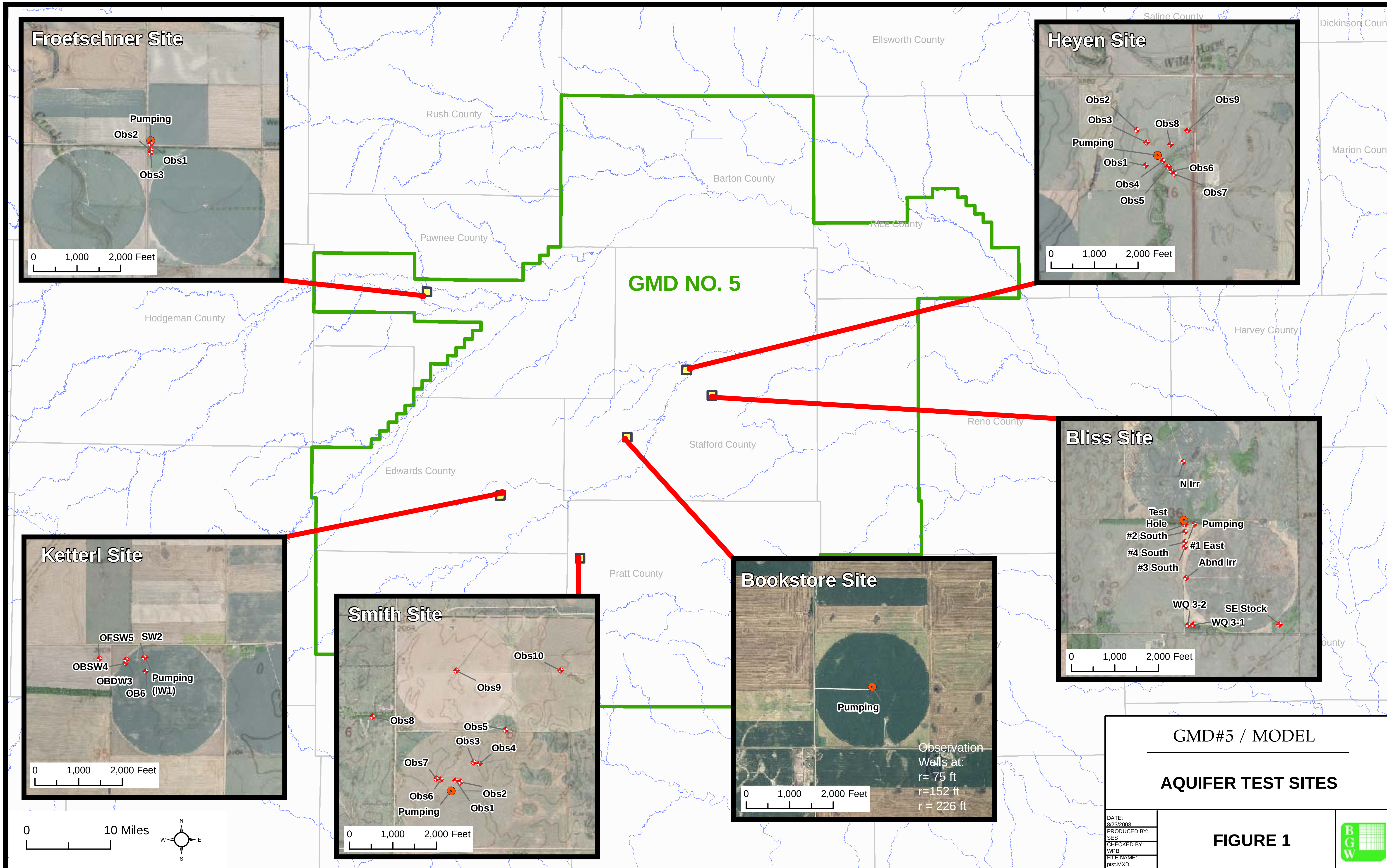
TABLE 2. PUMPING TEST ANALYTICAL SUMMARY

Test Site	Start Date	Discharge Rate (gpm)	Pumping Duration (days)	Recovery Duration (days)	Approximate Thickness of Aquifer (ft)	Analysis by Theis and Cooper-Jacob Methods[1]			Hantush-Jacob Method[1]
						T (ft^2/d)	S	K (ft/d)	K_z (ft/d)
Bliss	10/17/1995	574	2.2	2.1	60	13,500	0.005	225	0.01[2]
Bookstore	6/20/1979	715	0.25	0.11	70	9000	0.025	130	0.3[2]
Froetschner	6/18/1979	995	3.1	0	70	--[3]	--[3]	--[3]	--[3]
Heyen	5/21/1996	900	2.7	0.33	55	30,000	0.0005	550	0.001[2]
Ketterl	10/30/1995	990	1.9	1.6	115	5000	0.0003	43	0.003[2]
Smith	4/1/1996	1150	2.1	1.9	90	20,000	0.0005	220	0.2

[1] T = Transmissivity
S = Storage Coefficient
K = Horizontal Hydraulic Conductivity
K_z = Vertical Hydraulic Conductivity

[2] Value that K_z is <u>less</u> than, as indicated by threshold for observed duration of test response.

[3] Test response indicates pumping from bounded leaky "container" of low flow dimension, not radial flow.



GMD#5 / MODEL

AQUIFER TEST SITES

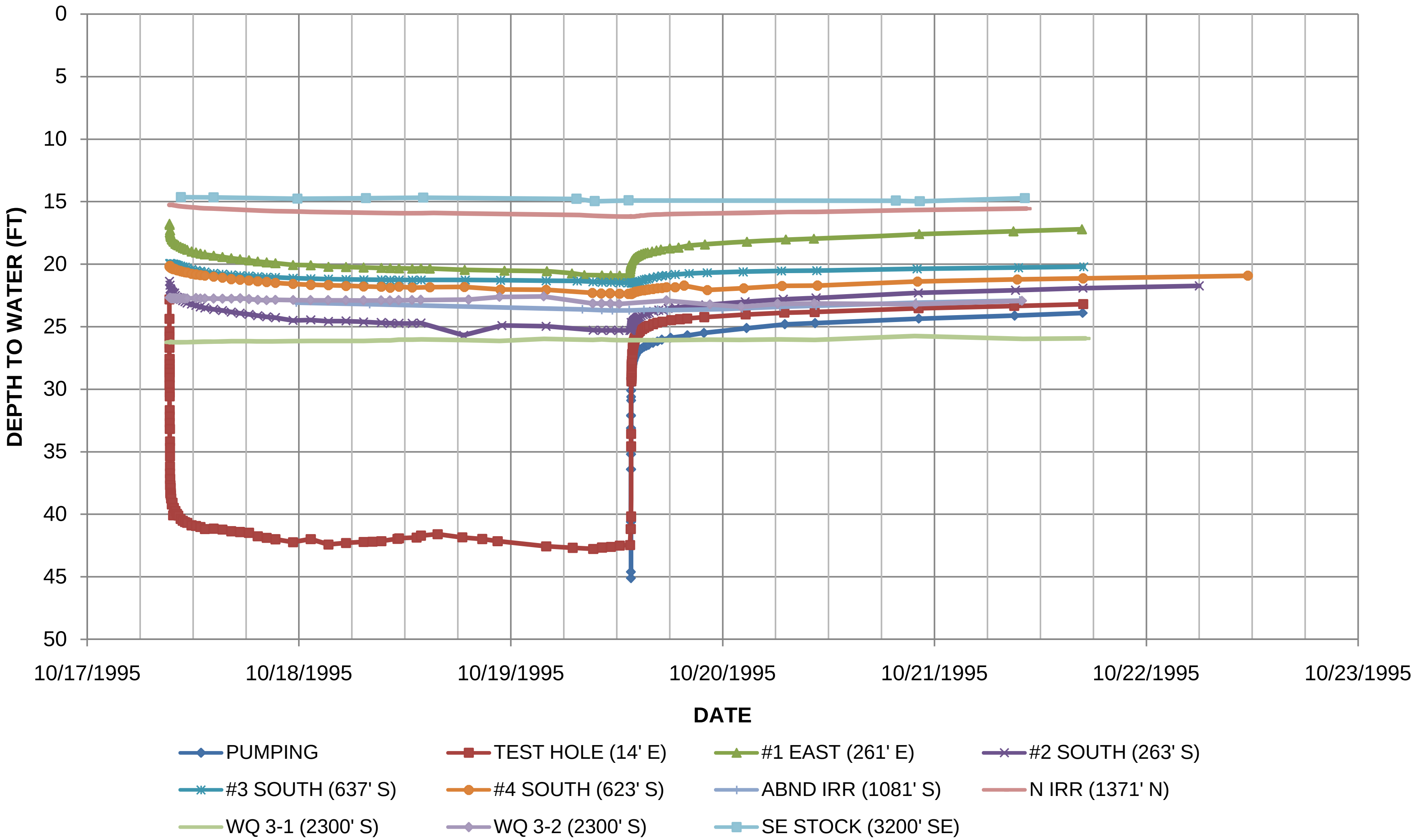
DATE: 8/23/2008
PRODUCED BY: SES
CHECKED BY: WPB
FILE NAME: ptst.MXD

FIGURE 1

BALLEAU GROUNDWATER, INC.

MODEL

FIGURE 2
BLISS SITE HYDROGRAPHS



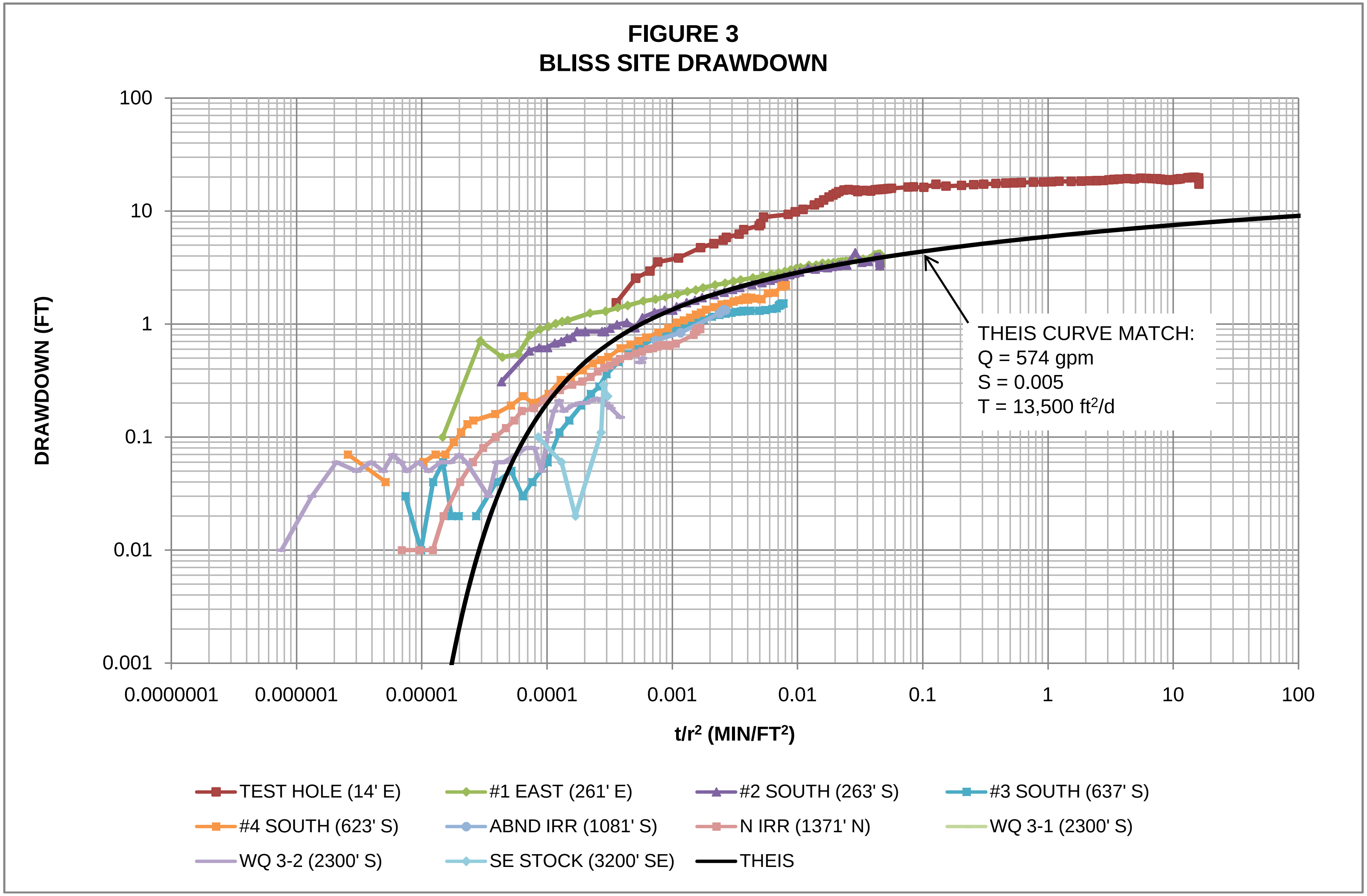
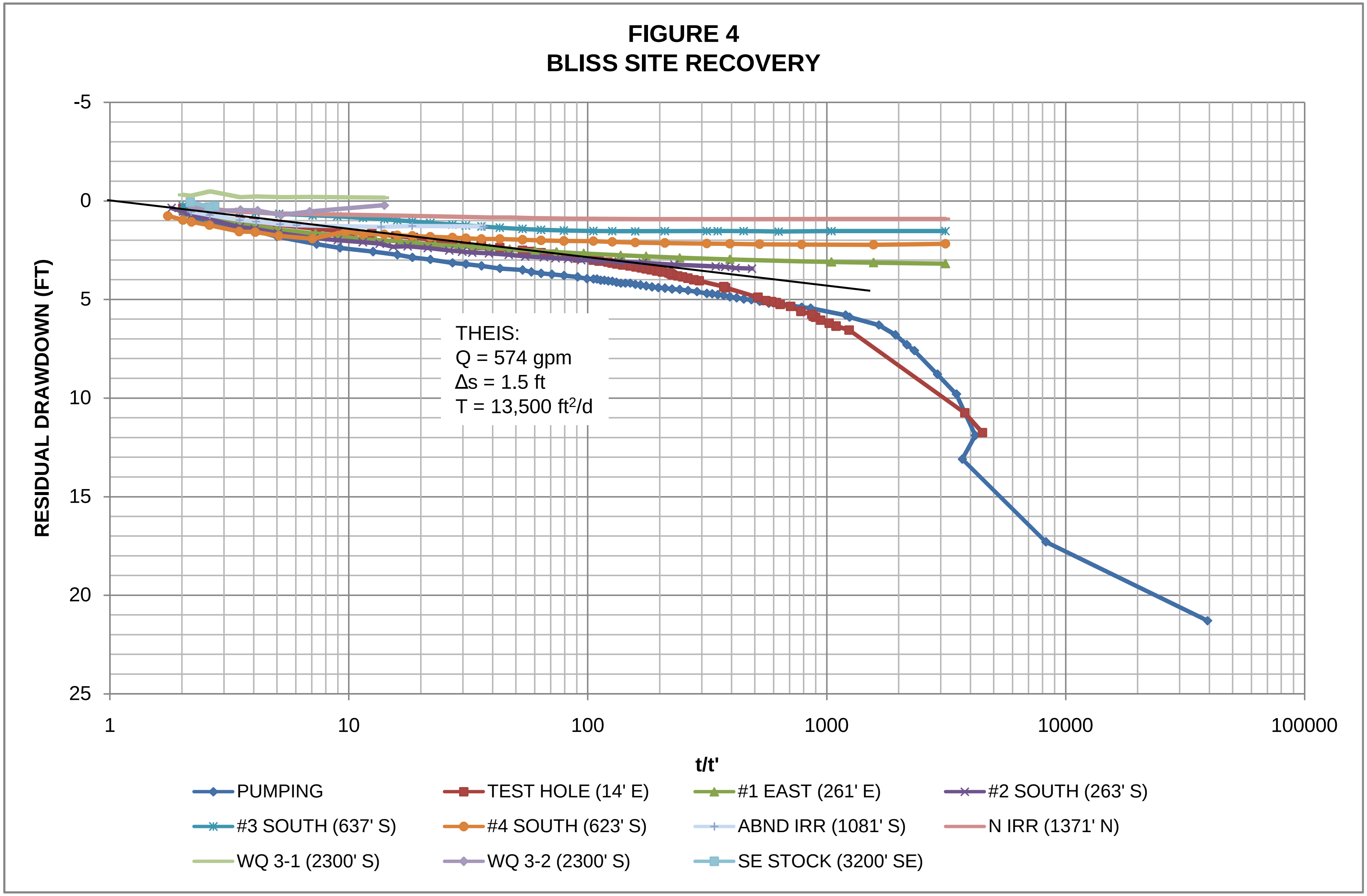


FIGURE 3
BLISS SITE DRAWDOWN
DRAWDOWN (FT)
100
10
1
0.1
0.01
0.001
0.0000001
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
10
100
t/r² (MIN/FT²)
THEIS CURVE MATCH:
Q = 574 gpm
S = 0.005
T = 13,500 ft²/d
TEST HOLE (14' E)
#1 EAST (261' E)
#2 SOUTH (263' S)
#3 SOUTH (637' S)
#4 SOUTH (623' S)
ABND IRR (1081' S)
N IRR (1371' N)
WQ 3-1 (2300' S)
WQ 3-2 (2300' S)
SE STOCK (3200' SE)
THEIS

MODEL



bliss_pumping.xls
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8/28/2008

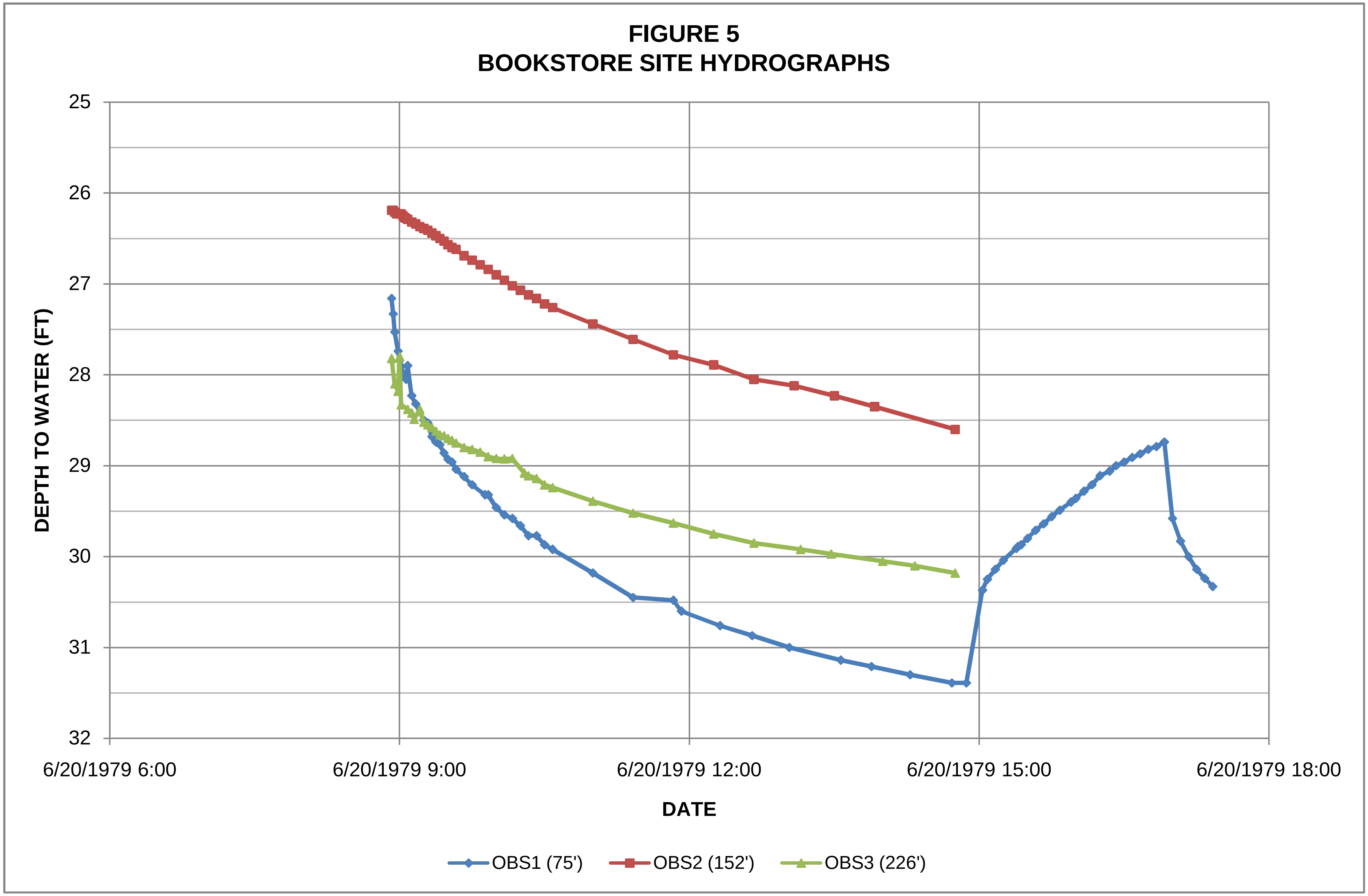


FIGURE 5
BOOKSTORE SITE HYDROGRAPHS
DEPTH TO WATER (FT)
25
26
27
28
29
30
31
32
6/20/1979 6:00
6/20/1979 9:00
6/20/1979 12:00
6/20/1979 15:00
6/20/1979 18:00
DATE
OBS1 (75')
OBS2 (152')
OBS3 (226')

MODEL

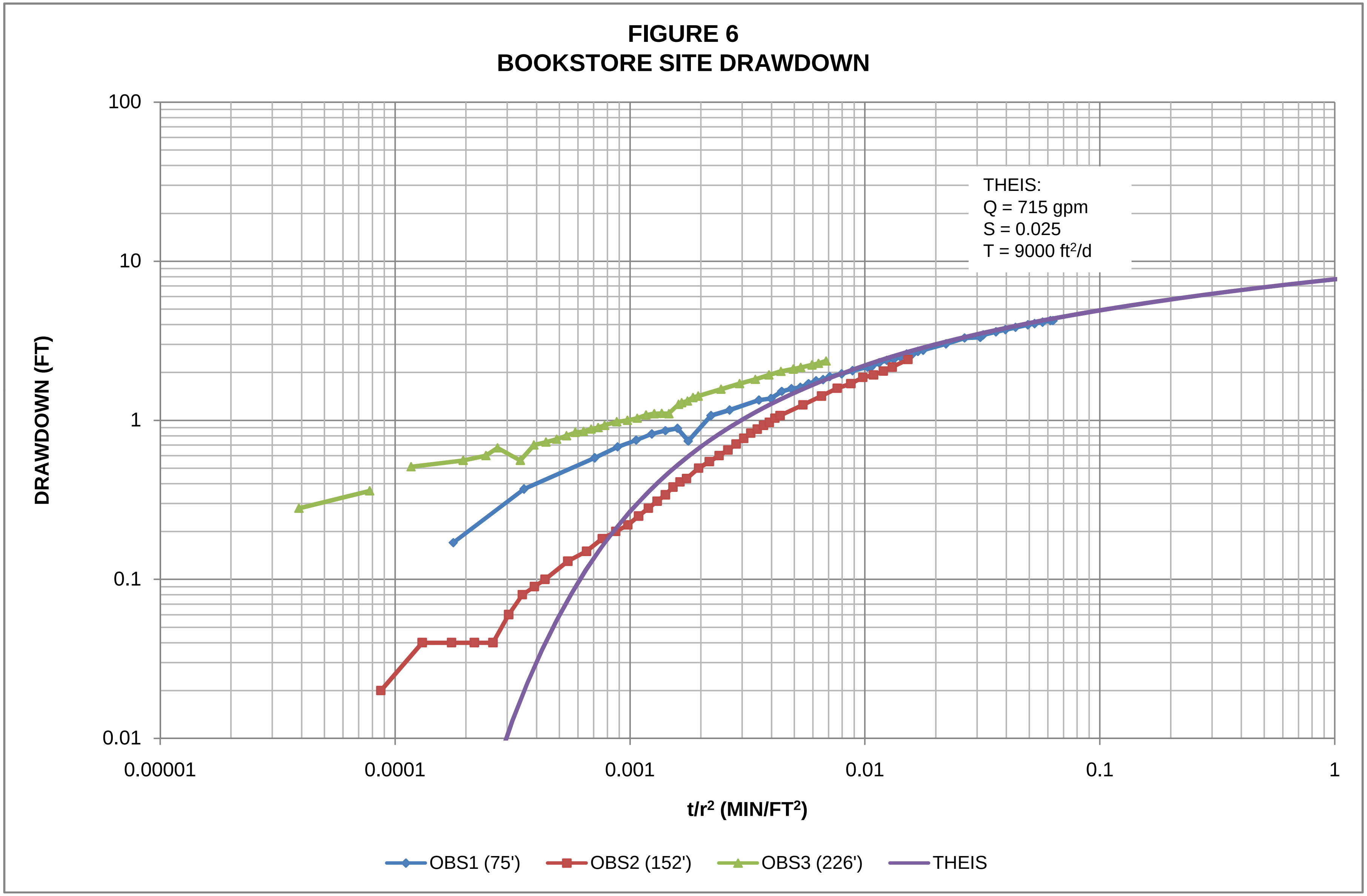


FIGURE 6
BOOKSTORE SITE DRAWDOWN
DRAWDOWN (FT)
100
10
1
0.1
0.01
0.00001
0.0001
0.001
0.01
0.1
1
t/r² (MIN/FT²)
THEIS:
Q = 715 gpm
S = 0.025
T = 9000 ft²/d
OBS1 (75')
OBS2 (152')
OBS3 (226')
THEIS

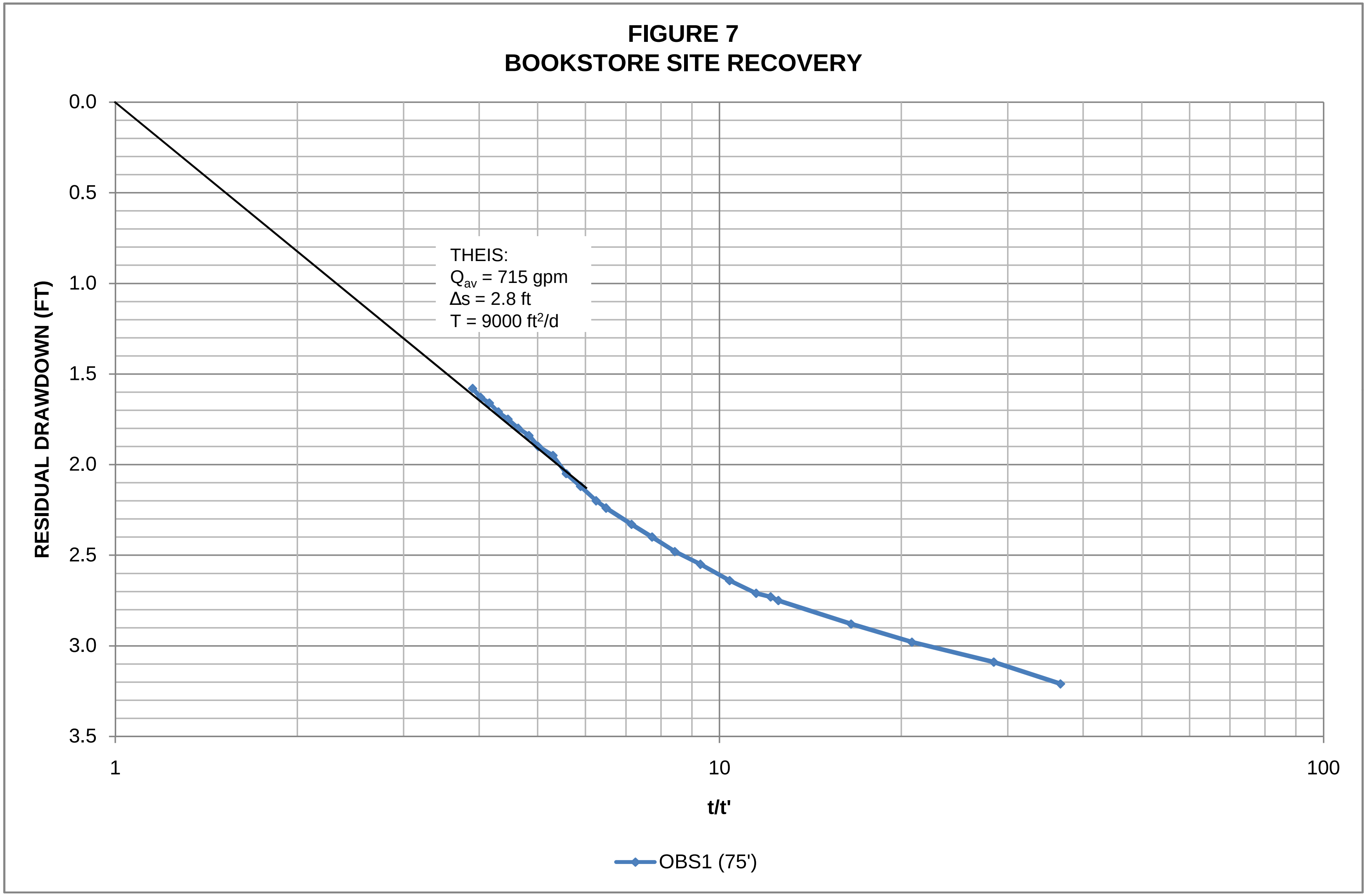


FIGURE 7
BOOKSTORE SITE RECOVERY
RESIDUAL DRAWDOWN (FT)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
1
10
100
t/t'
THEIS:
Q_{av} = 715 gpm
Δs = 2.8 ft
T = 9000 ft^2/d
OBS1 (75')

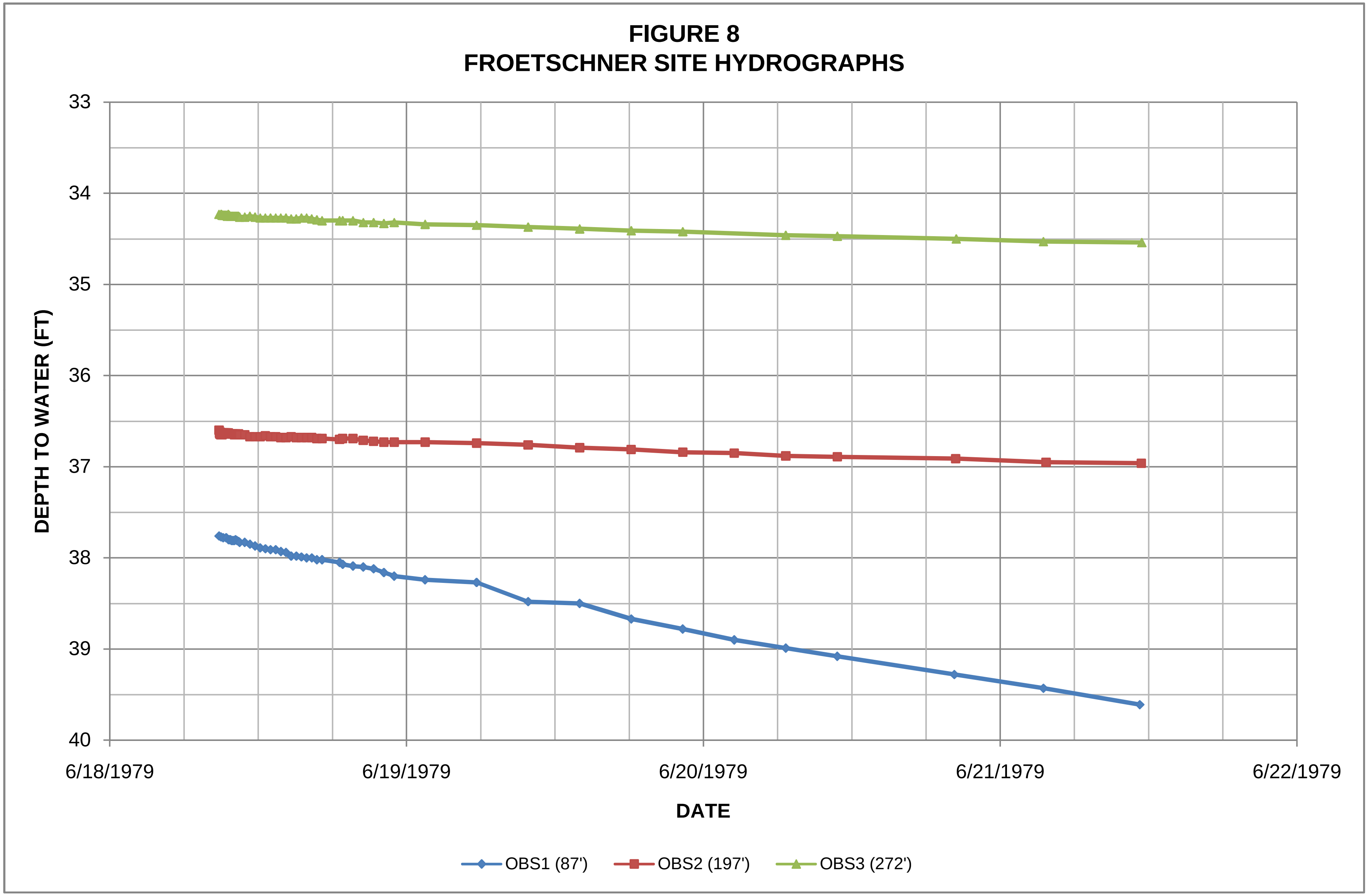


FIGURE 8
FROETSCHNER SITE HYDROGRAPHS
33
34
35
36
37
38
39
40
DEPTH TO WATER (FT)
6/18/1979
6/19/1979
6/20/1979
6/21/1979
6/22/1979
DATE
OBS1 (87')
OBS2 (197')
OBS3 (272')

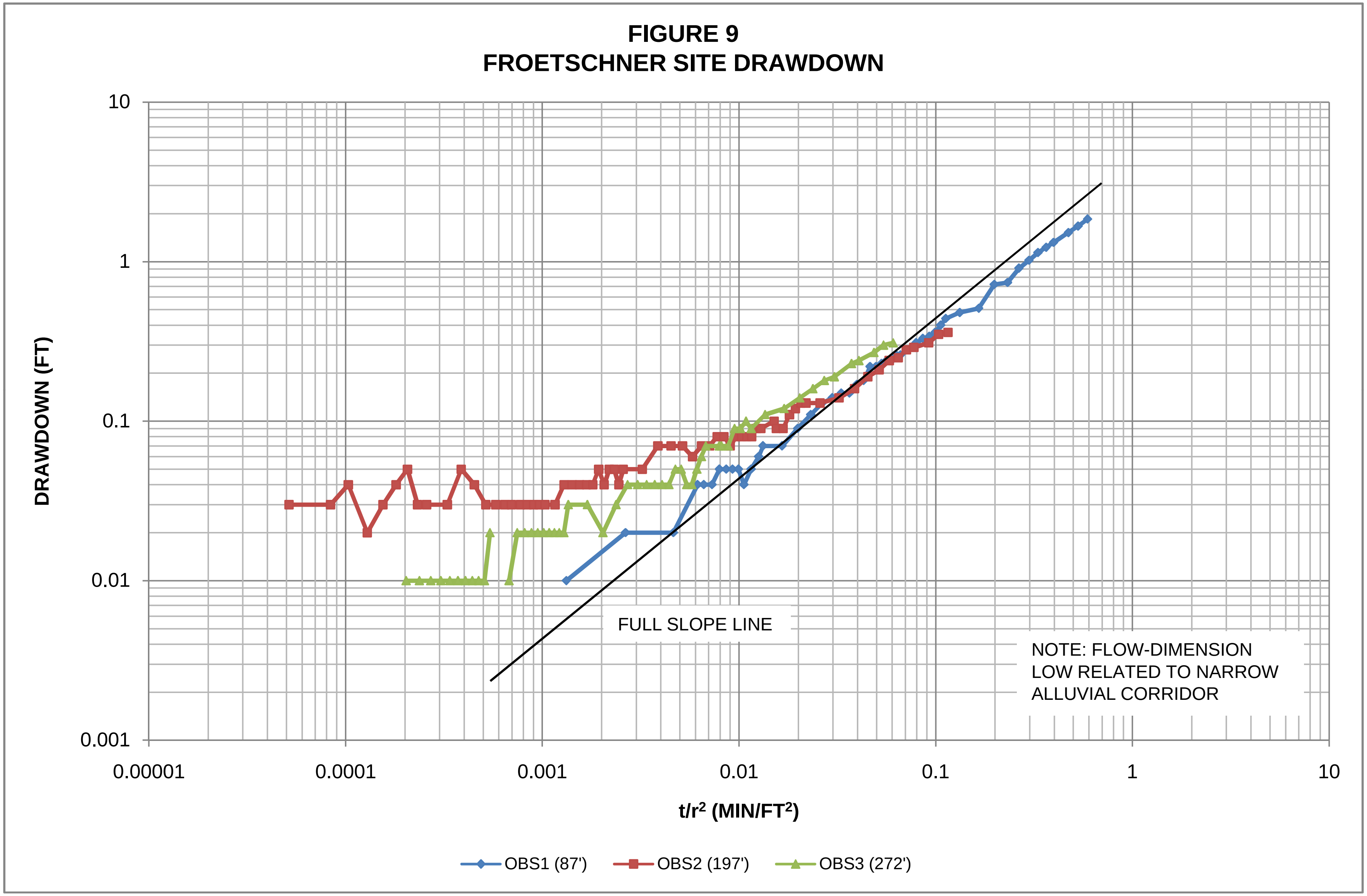
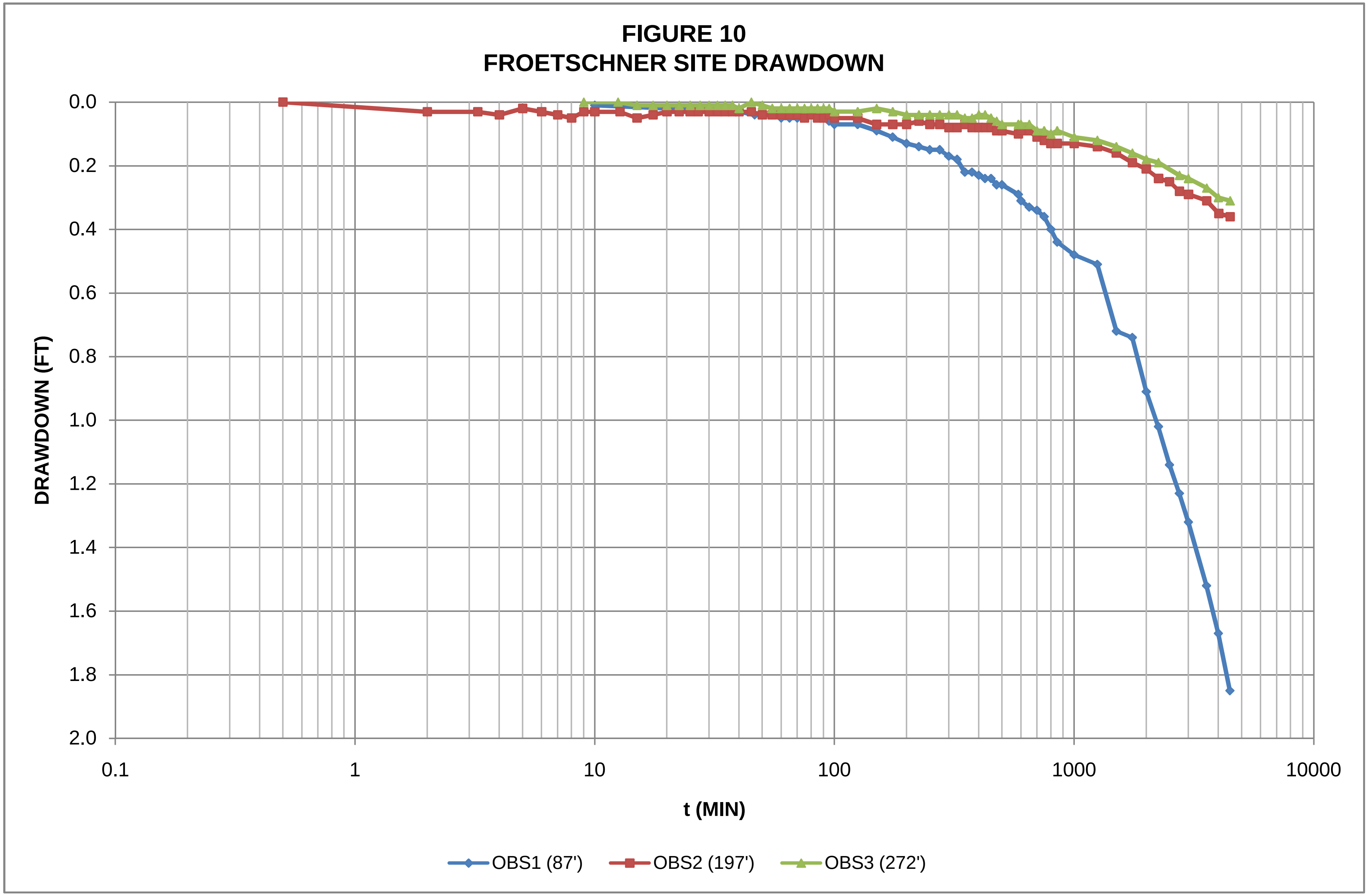


FIGURE 9
FROETSCHNER SITE DRAWDOWN
DRAWDOWN (FT)
10
1
0.1
0.01
0.001
0.00001
0.0001
0.001
0.01
0.1
1
10
t/r² (MIN/FT²)
FULL SLOPE LINE
NOTE: FLOW-DIMENSION
LOW RELATED TO NARROW
ALLUVIAL CORRIDOR
OBS1 (87')
OBS2 (197')
OBS3 (272')

MODEL



froet_obs1.xls
BY
8/28/2008

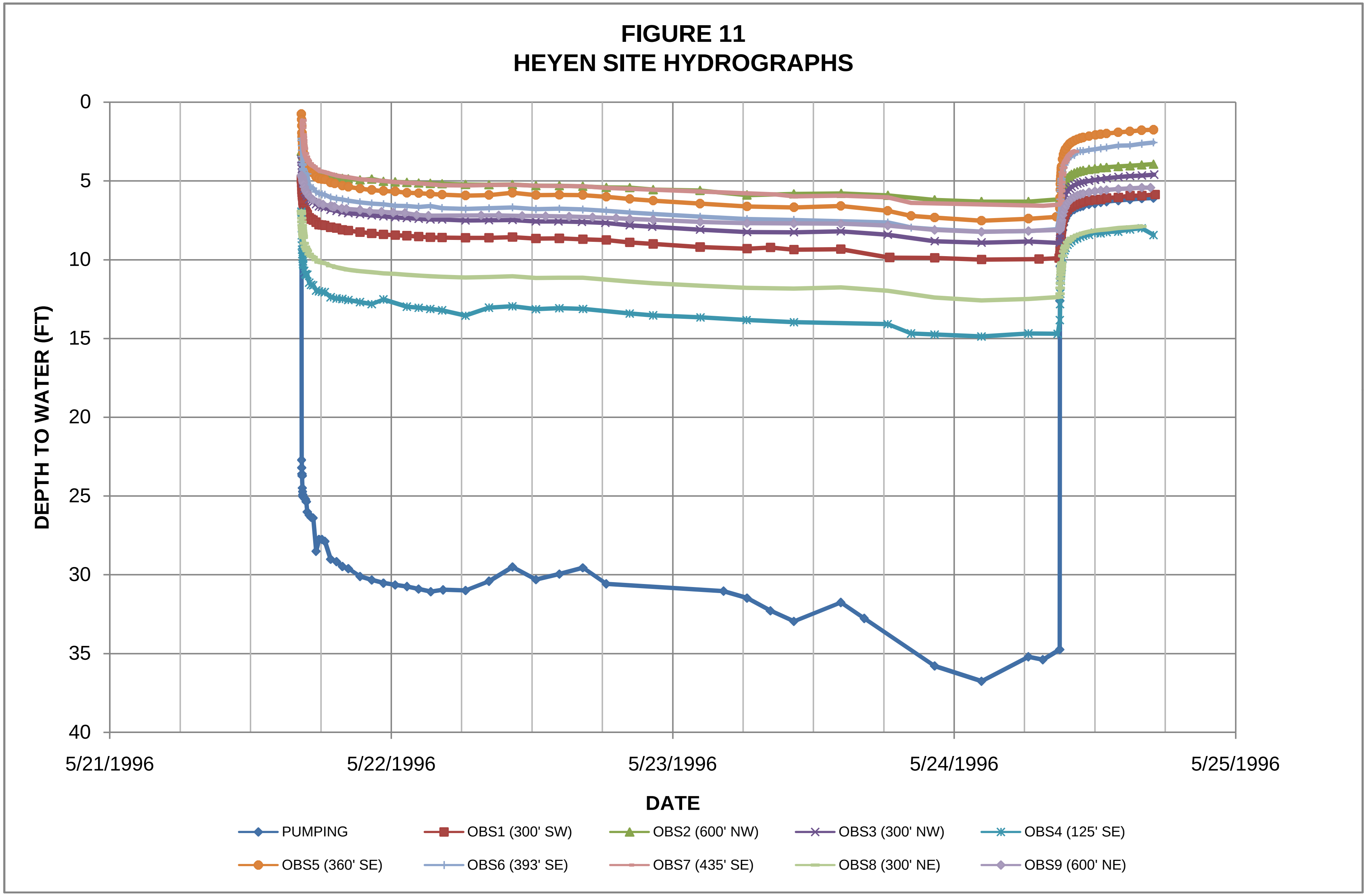


FIGURE 11
HEYEN SITE HYDROGRAPHS
DEPTH TO WATER (FT)
0
5
10
15
20
25
30
35
40
5/21/1996
5/22/1996
5/23/1996
5/24/1996
5/25/1996
DATE
PUMPING
OBS1 (300' SW)
OBS2 (600' NW)
OBS3 (300' NW)
OBS4 (125' SE)
OBS5 (360' SE)
OBS6 (393' SE)
OBS7 (435' SE)
OBS8 (300' NE)
OBS9 (600' NE)

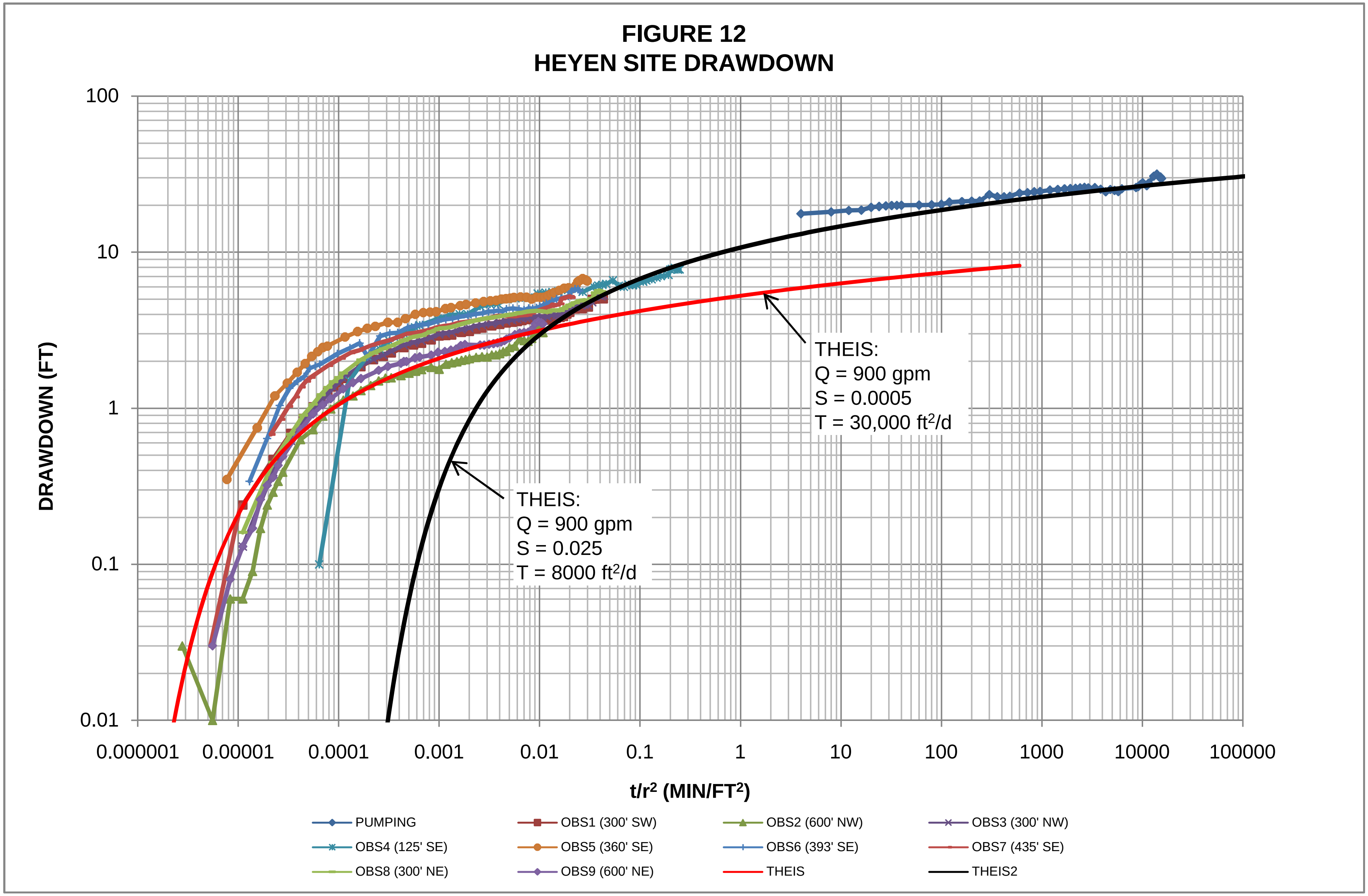


FIGURE 12
HEYEN SITE DRAWDOWN
DRAWDOWN (FT)
100
10
1
0.1
0.01
0.000001
0.00001
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
100000
t/r² (MIN/FT²)
THEIS:
Q = 900 gpm
S = 0.0005
T = 30,000 ft²/d
THEIS:
Q = 900 gpm
S = 0.025
T = 8000 ft²/d
PUMPING
OBS1 (300' SW)
OBS2 (600' NW)
OBS3 (300' NW)
OBS4 (125' SE)
OBS5 (360' SE)
OBS6 (393' SE)
OBS7 (435' SE)
OBS8 (300' NE)
OBS9 (600' NE)
THEIS
THEIS2

MODEL

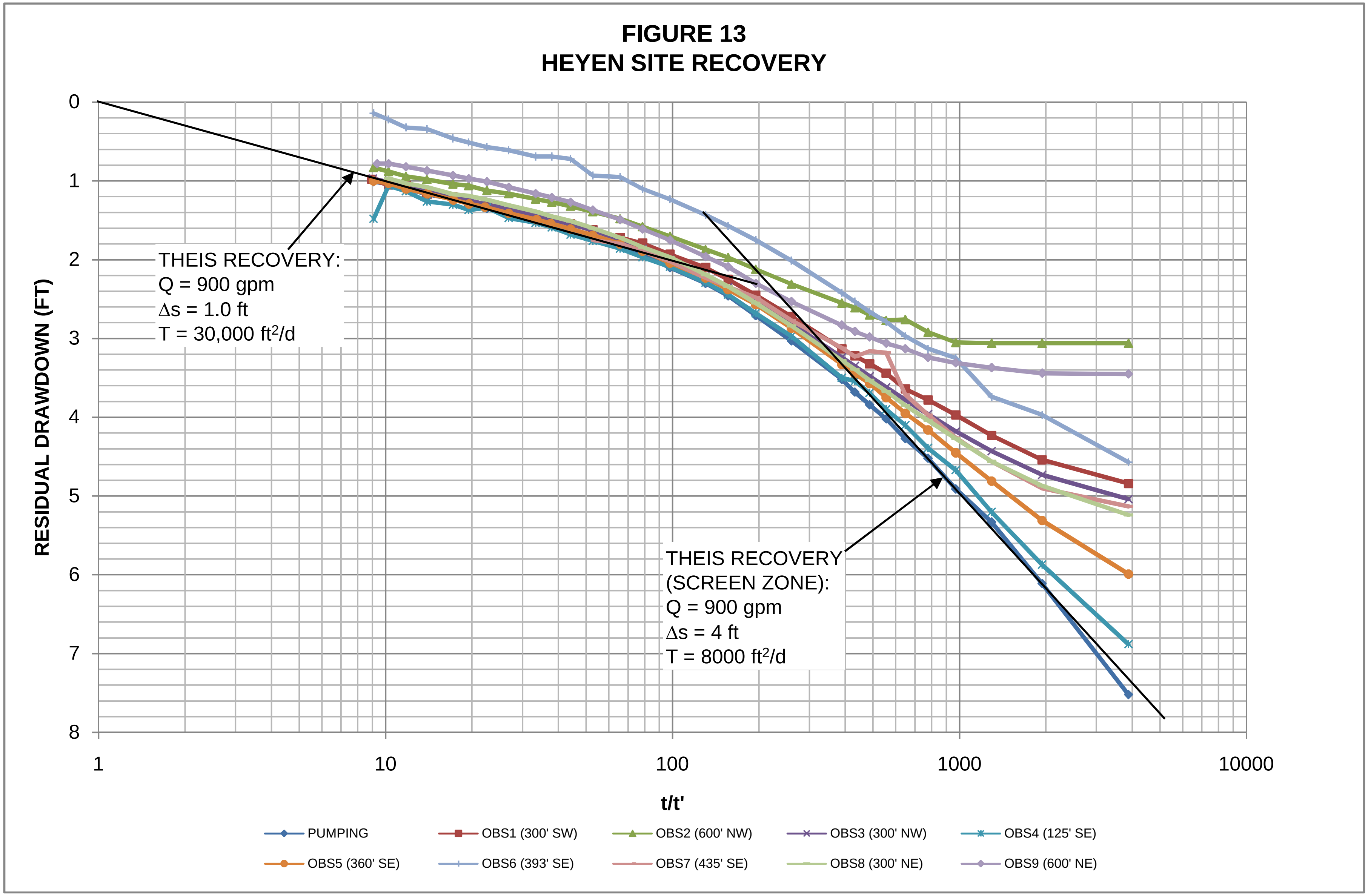


FIGURE 13
HEYEN SITE RECOVERY
RESIDUAL DRAWDOWN (FT)
0
1
2
3
4
5
6
7
8
1
10
100
1000
10000
t/t'
THEIS RECOVERY:
Q = 900 gpm
Δs = 1.0 ft
T = 30,000 ft²/d
THEIS RECOVERY
(SCREEN ZONE):
Q = 900 gpm
Δs = 4 ft
T = 8000 ft²/d
PUMPING
OBS1 (300' SW)
OBS2 (600' NW)
OBS3 (300' NW)
OBS4 (125' SE)
OBS5 (360' SE)
OBS6 (393' SE)
OBS7 (435' SE)
OBS8 (300' NE)
OBS9 (600' NE)

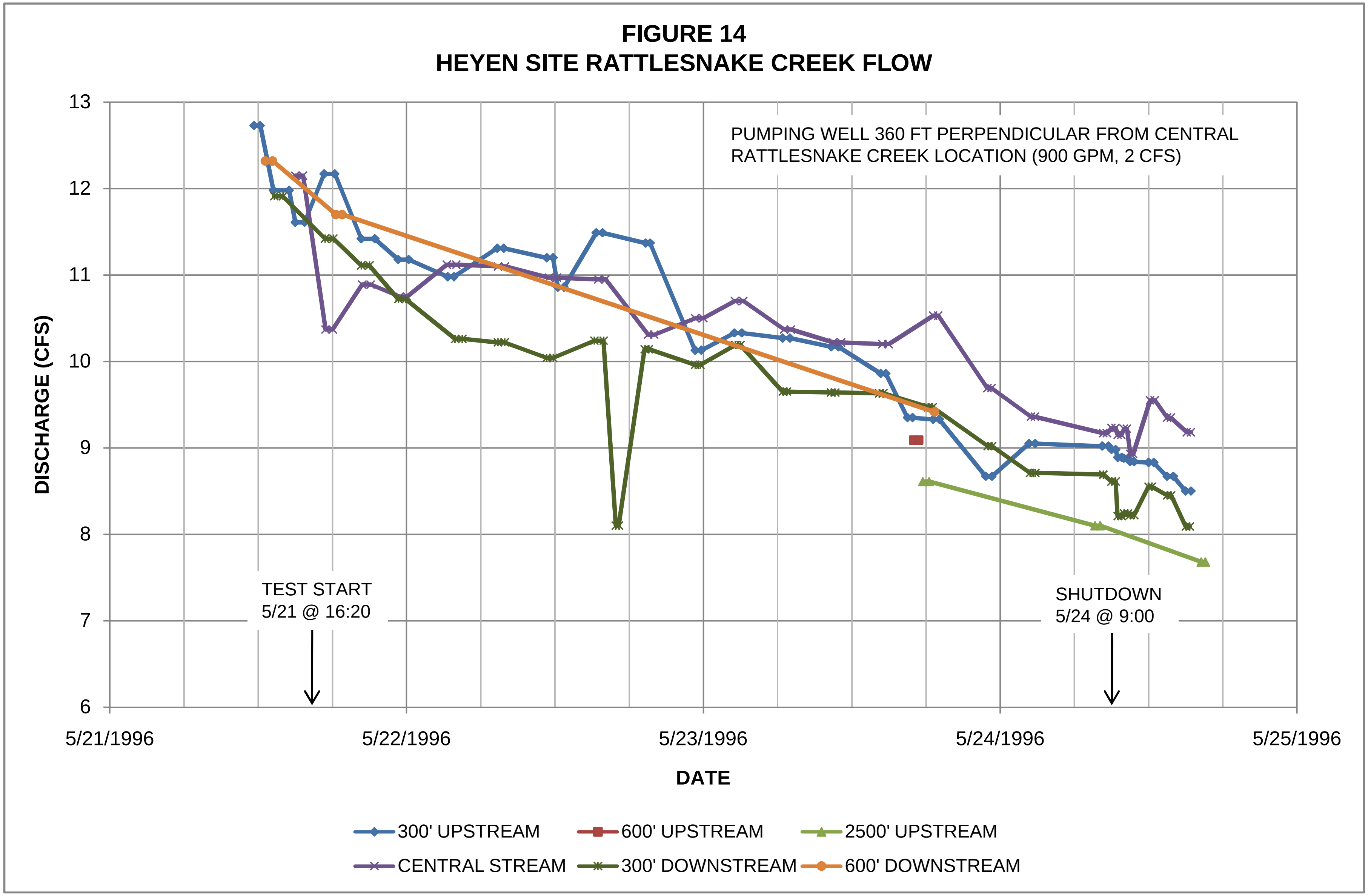


FIGURE 14
HEYEN SITE RATTLESNAKE CREEK FLOW
PUMPING WELL 360 FT PERPENDICULAR FROM CENTRAL RATTLESNAKE CREEK LOCATION (900 GPM, 2 CFS)
13
12
11
10
9
8
7
6
DISCHARGE (CFS)
TEST START
5/21 @ 16:20
SHUTDOWN
5/24 @ 9:00
5/21/1996
5/22/1996
5/23/1996
5/24/1996
5/25/1996
DATE
300' UPSTREAM
600' UPSTREAM
2500' UPSTREAM
CENTRAL STREAM
300' DOWNSTREAM
600' DOWNSTREAM

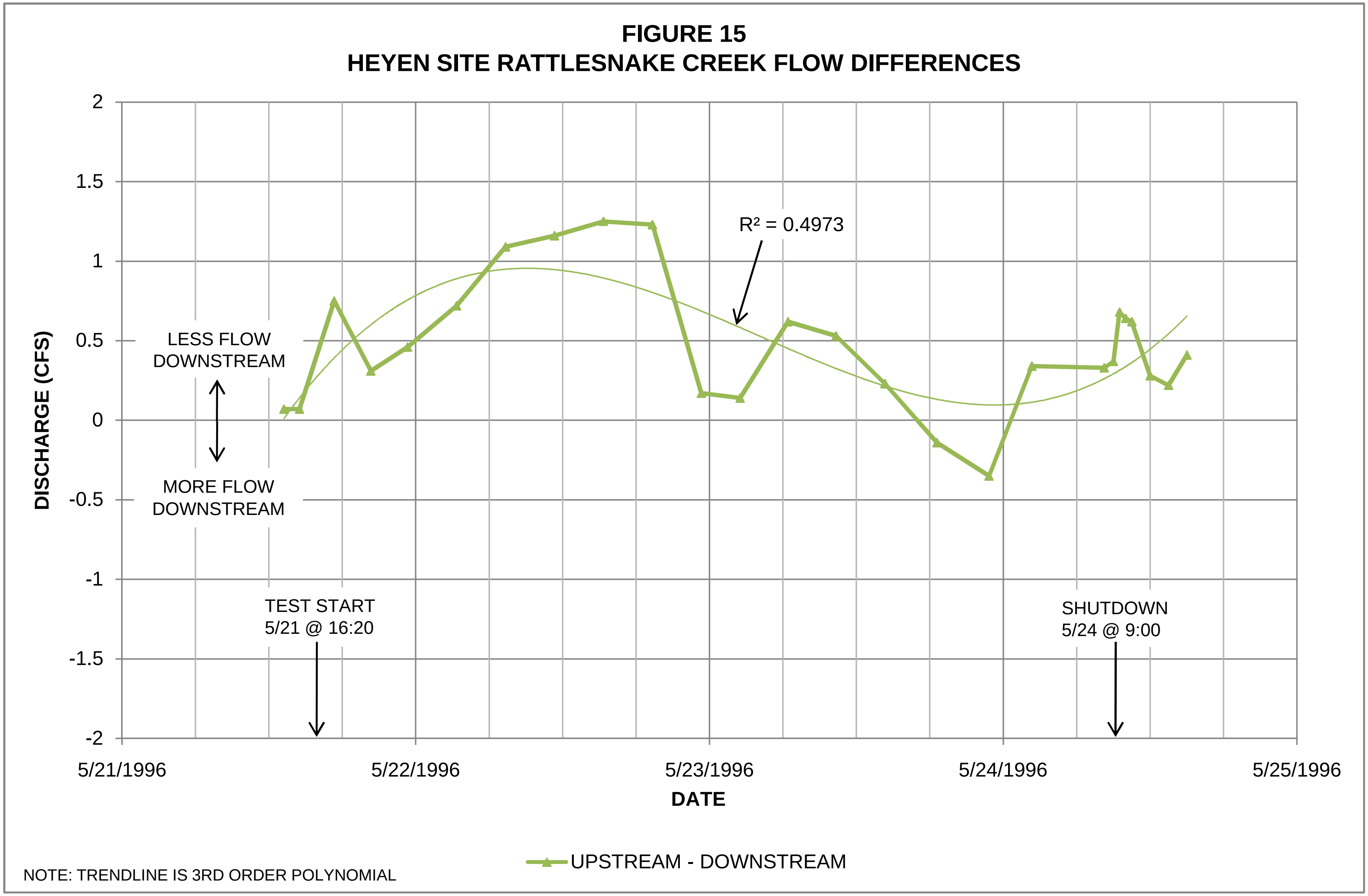
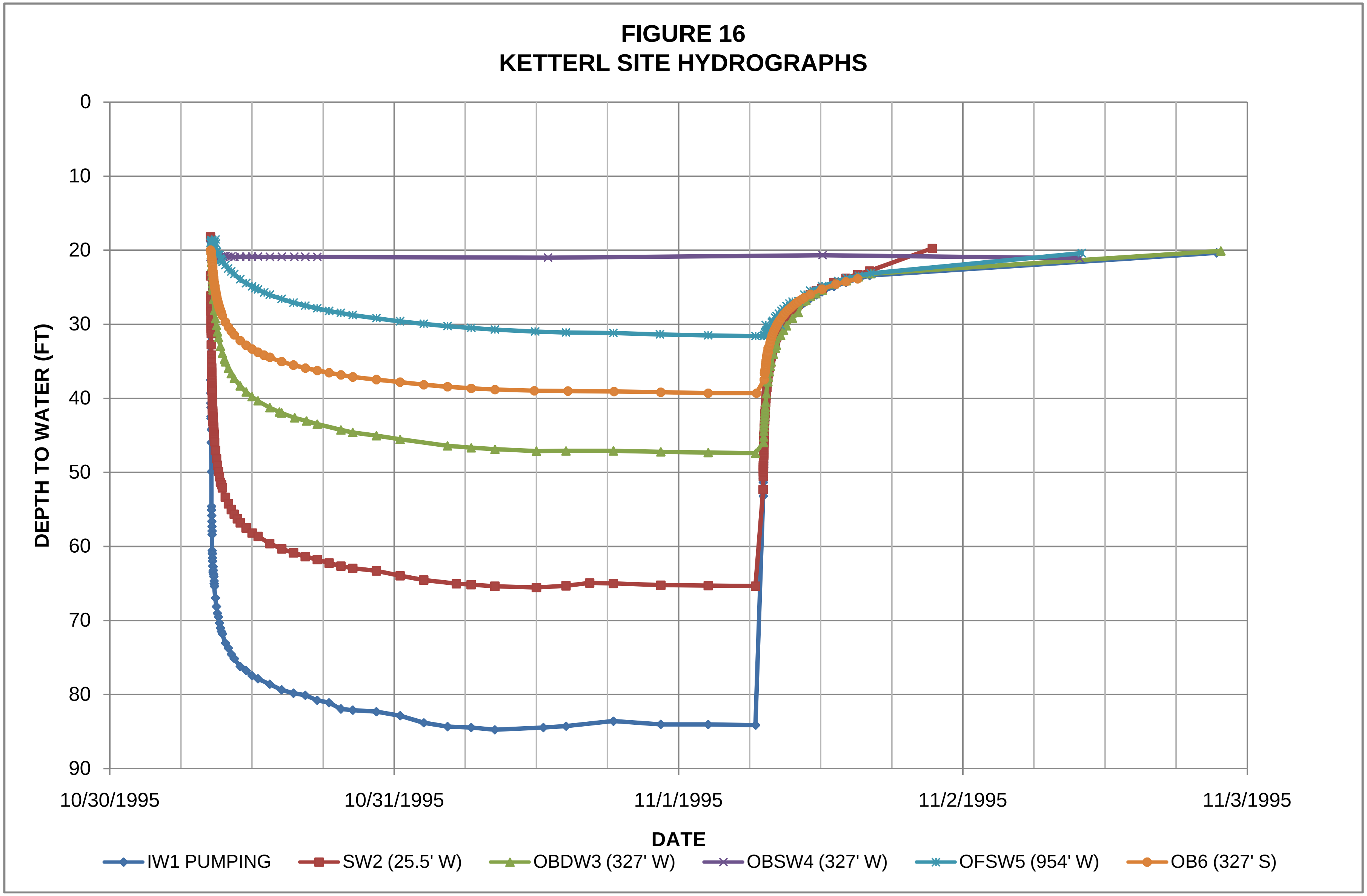


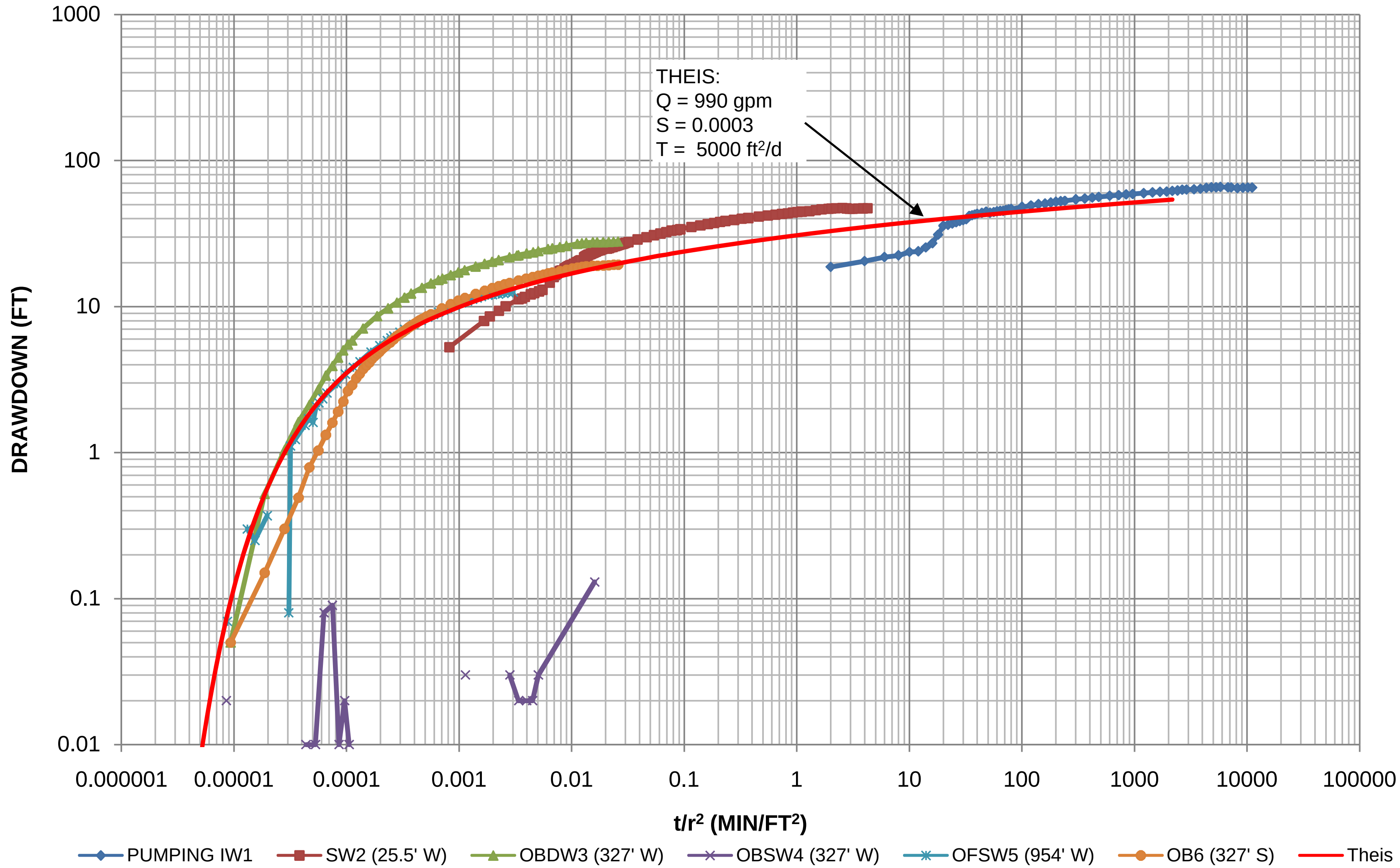
FIGURE 15
HEYEN SITE RATTLESNAKE CREEK FLOW DIFFERENCES
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
DISCHARGE (CFS)
R² = 0.4973
LESS FLOW
DOWNSTREAM
MORE FLOW
DOWNSTREAM
TEST START
5/21 @ 16:20
SHUTDOWN
5/24 @ 9:00
5/21/1996
5/22/1996
5/23/1996
5/24/1996
5/25/1996
DATE
UPSTREAM - DOWNSTREAM
NOTE: TRENDLINE IS 3RD ORDER POLYNOMIAL

MODEL



ketiw1_qtest.xls
BY
8/28/2008

FIGURE 17
KETTERL SITE DRAWDOWN



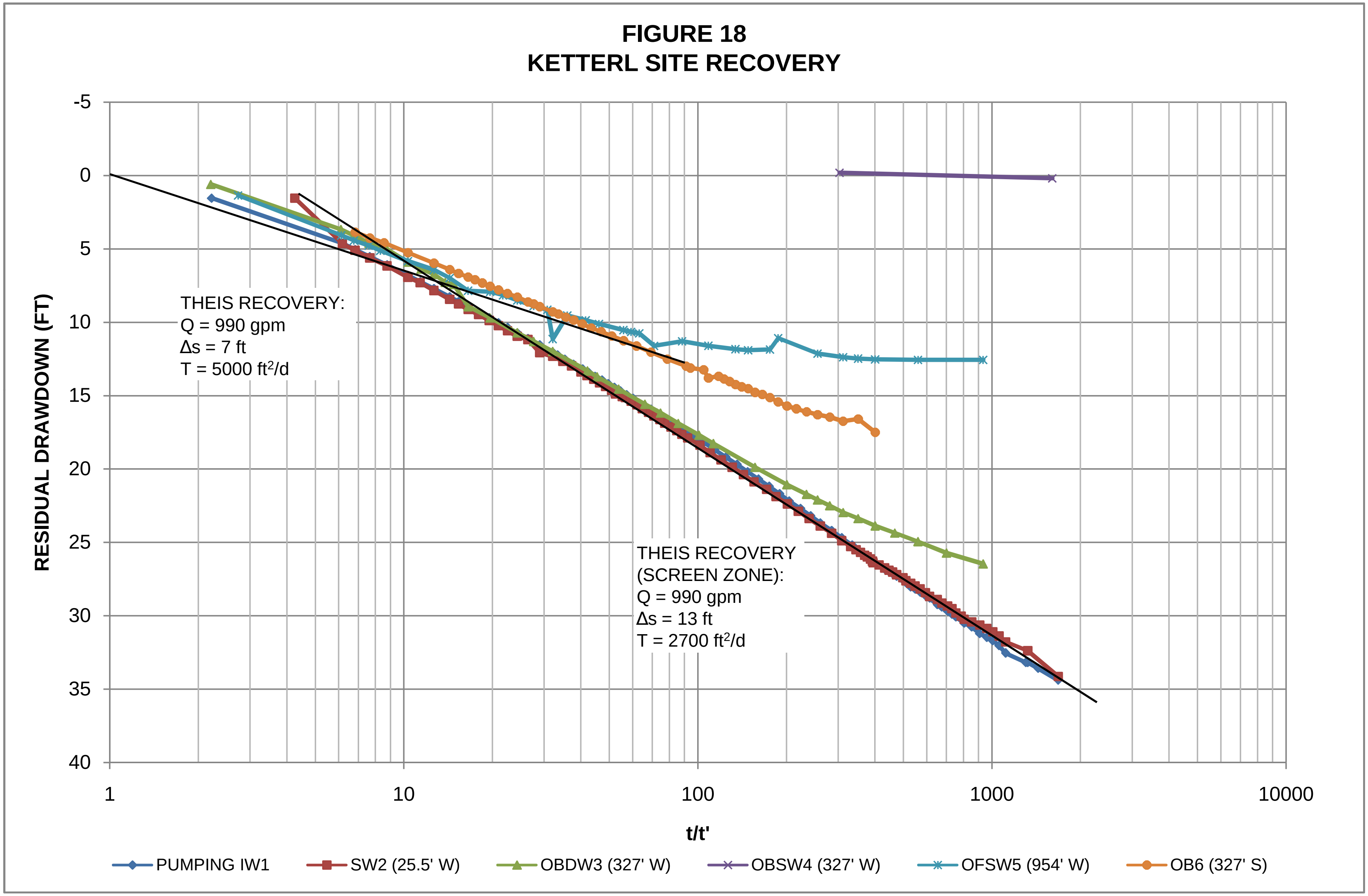


FIGURE 18
KETTERL SITE RECOVERY
RESIDUAL DRAWDOWN (FT)
-5
0
5
10
15
20
25
30
35
40
1
10
100
1000
10000
t/t'
THEIS RECOVERY:
Q = 990 gpm
Δs = 7 ft
T = 5000 ft²/d
THEIS RECOVERY
(SCREEN ZONE):
Q = 990 gpm
Δs = 13 ft
T = 2700 ft²/d
PUMPING IW1
SW2 (25.5' W)
OBDW3 (327' W)
OBSW4 (327' W)
OFSW5 (954' W)
OB6 (327' S)

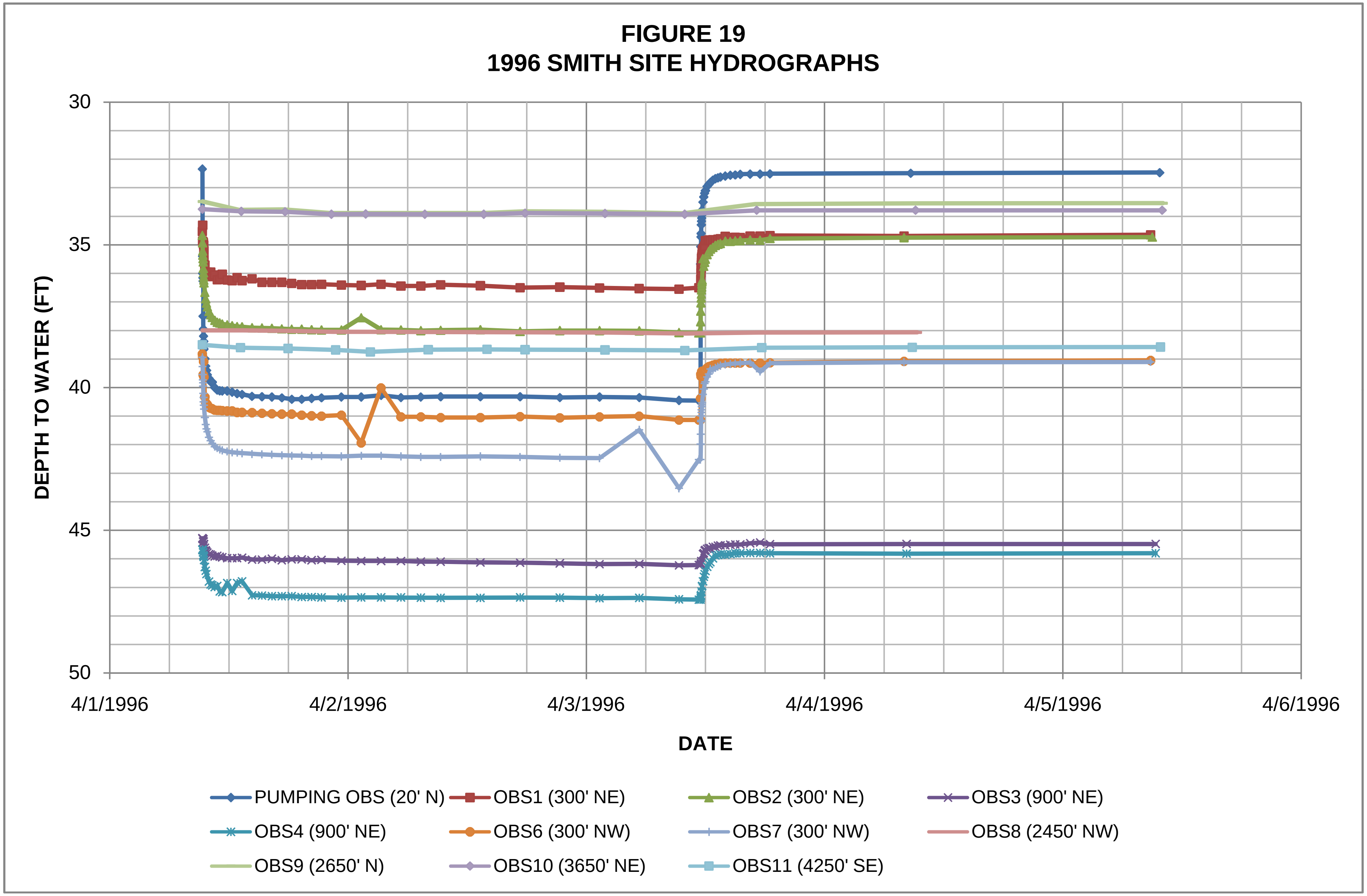
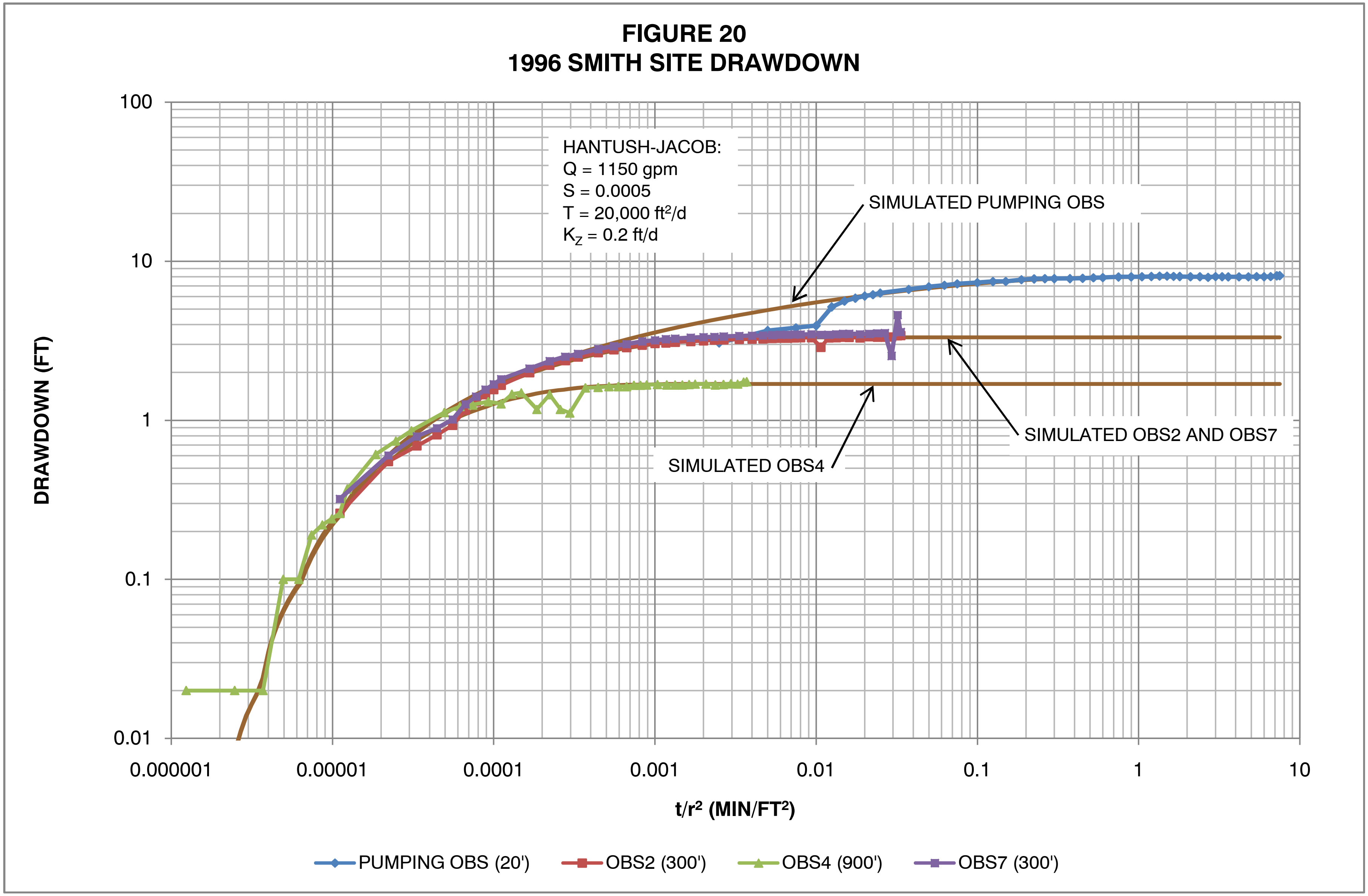


FIGURE 19
1996 SMITH SITE HYDROGRAPHS
DEPTH TO WATER (FT)
30
35
40
45
50
4/1/1996
4/2/1996
4/3/1996
4/4/1996
4/5/1996
4/6/1996
DATE
PUMPING OBS (20' N)
OBS1 (300' NE)
OBS2 (300' NE)
OBS3 (900' NE)
OBS4 (900' NE)
OBS6 (300' NW)
OBS7 (300' NW)
OBS8 (2450' NW)
OBS9 (2650' N)
OBS10 (3650' NE)
OBS11 (4250' SE)



smith96_Pumping_Hantush-Jacob_LeakyAquifer2.xls
BY
10/28/2008

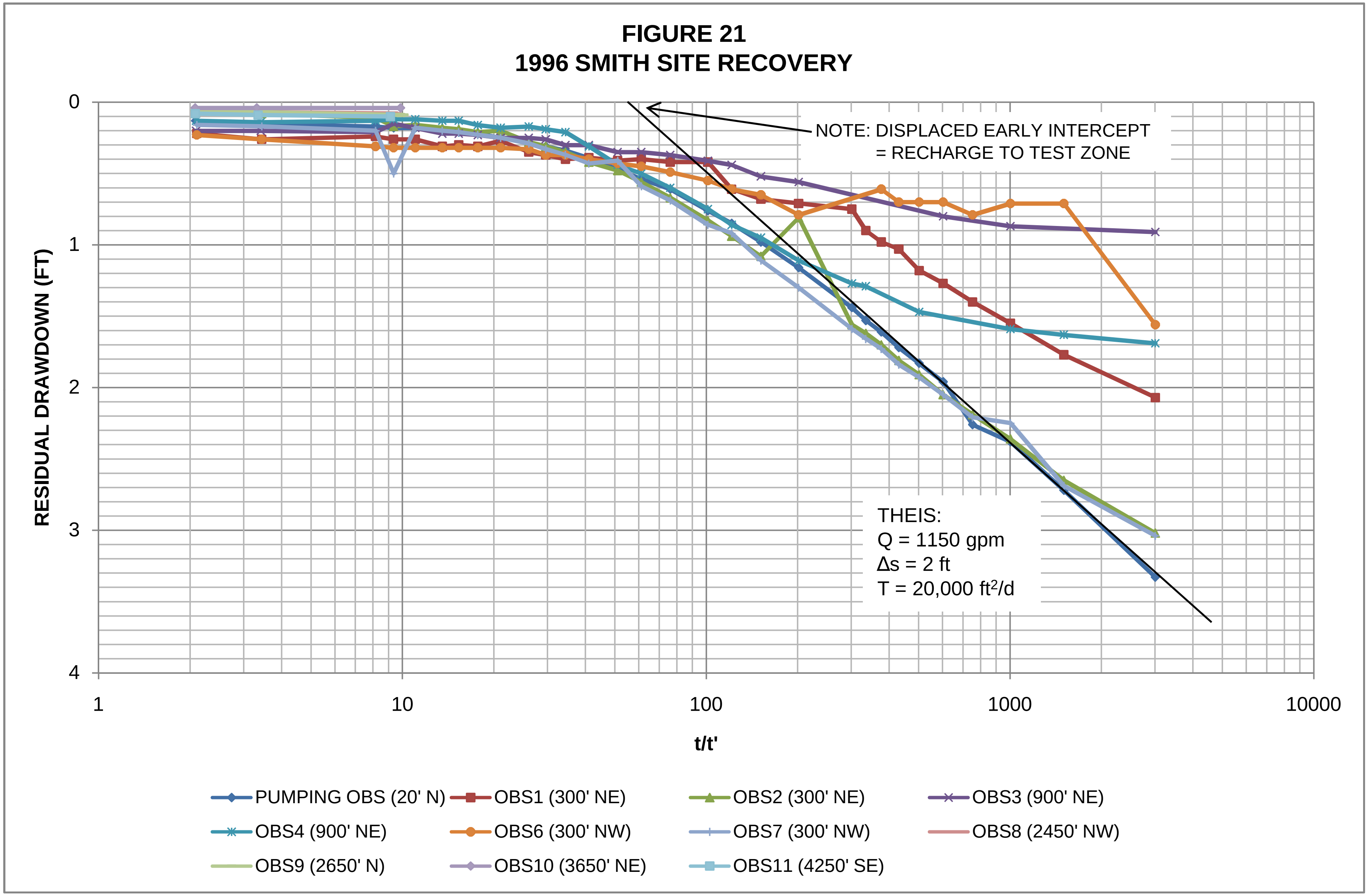


FIGURE 21
1996 SMITH SITE RECOVERY
RESIDUAL DRAWDOWN (FT)
0
1
2
3
4
1
10
100
1000
10000
t/t'
NOTE: DISPLACED EARLY INTERCEPT
= RECHARGE TO TEST ZONE
THEIS:
Q = 1150 gpm
Δs = 2 ft
T = 20,000 ft²/d
PUMPING OBS (20' N)
OBS1 (300' NE)
OBS2 (300' NE)
OBS3 (900' NE)
OBS4 (900' NE)
OBS6 (300' NW)
OBS7 (300' NW)
OBS8 (2450' NW)
OBS9 (2650' N)
OBS10 (3650' NE)
OBS11 (4250' SE)

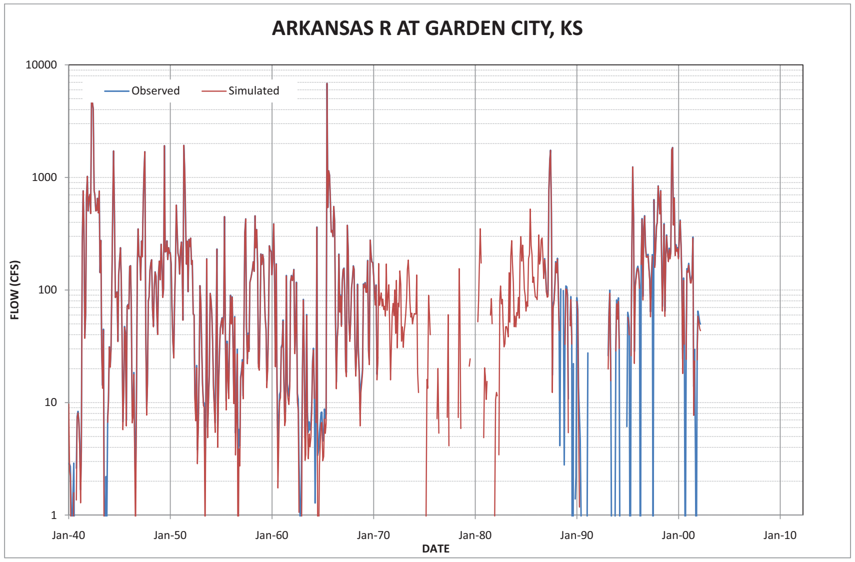
APPENDIX G

HYDROGRAPHS

SW Hydrograph and Transect Station Locations

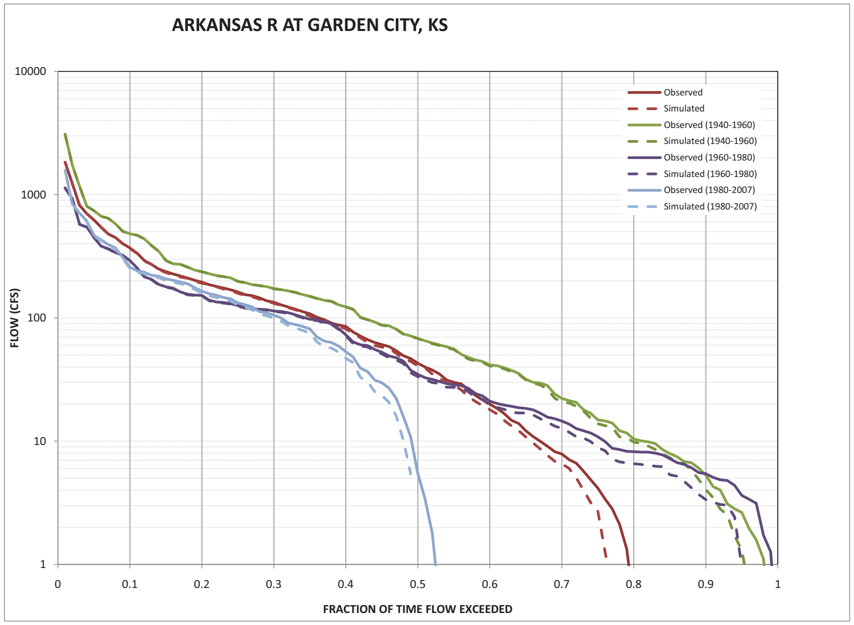
GMD #5

MODEL



nTCStrmLake.xlsb
SES
6/18/2010

BALLEAU GROUNDWATER, INC.



GMD #5

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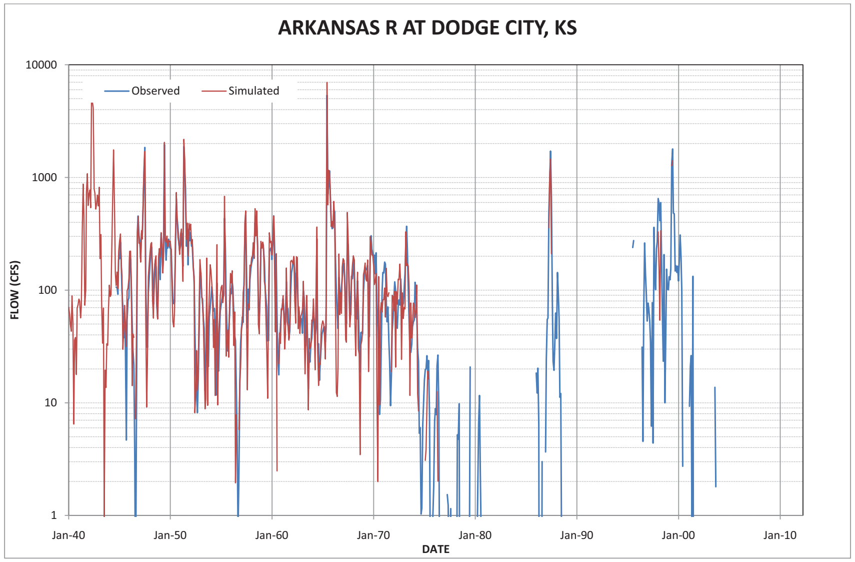

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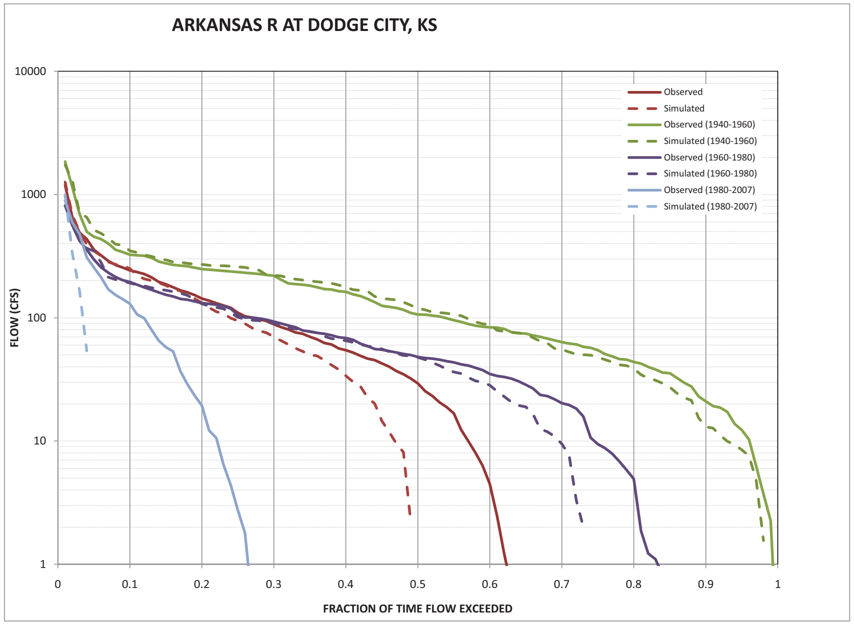
BALLEAU GROUNDWATER, INC.



GMD #5

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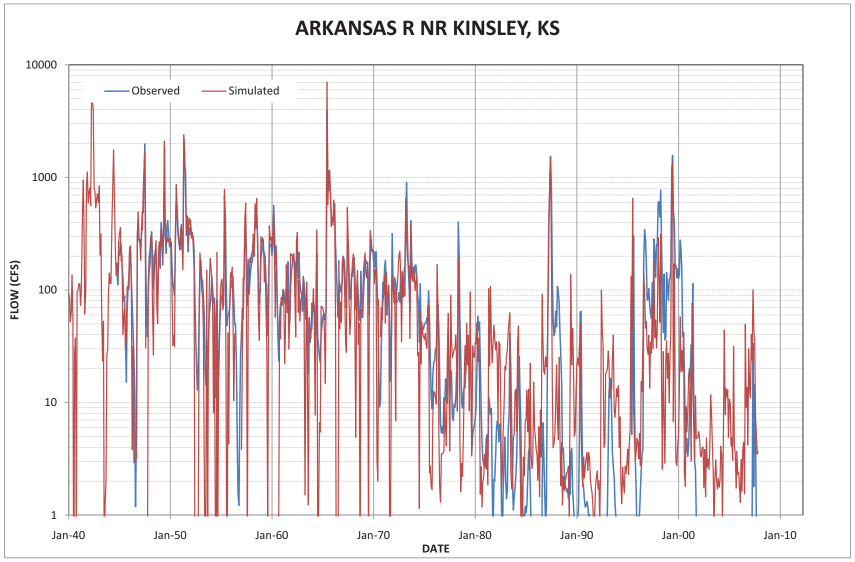

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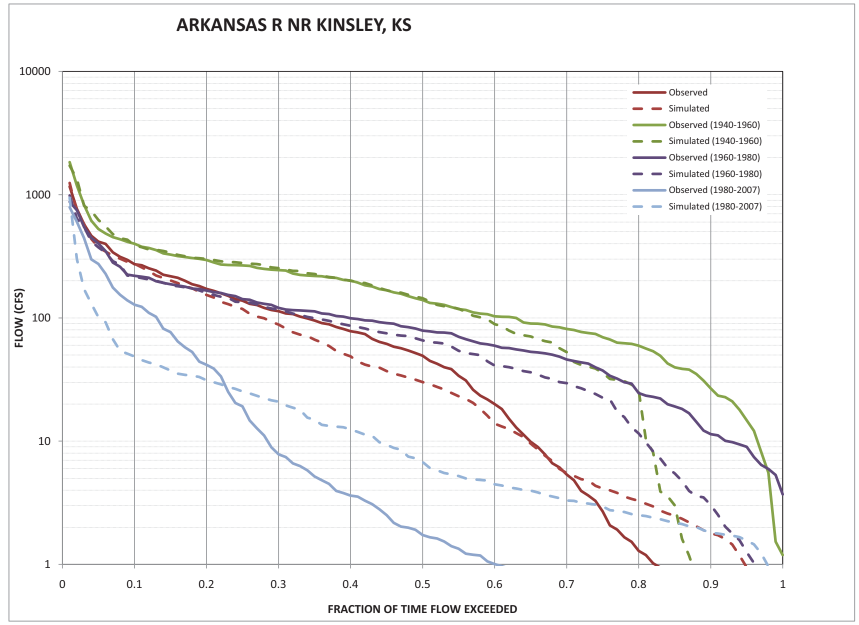

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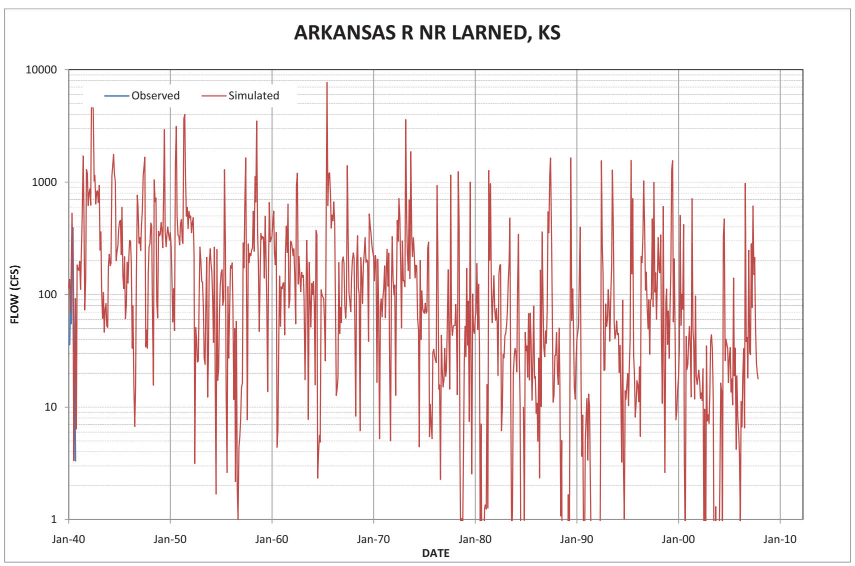

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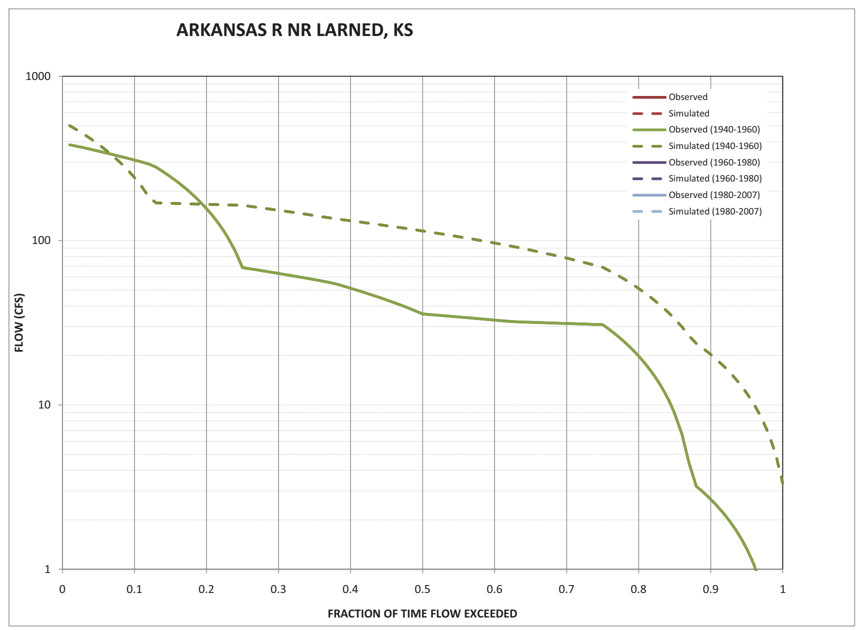

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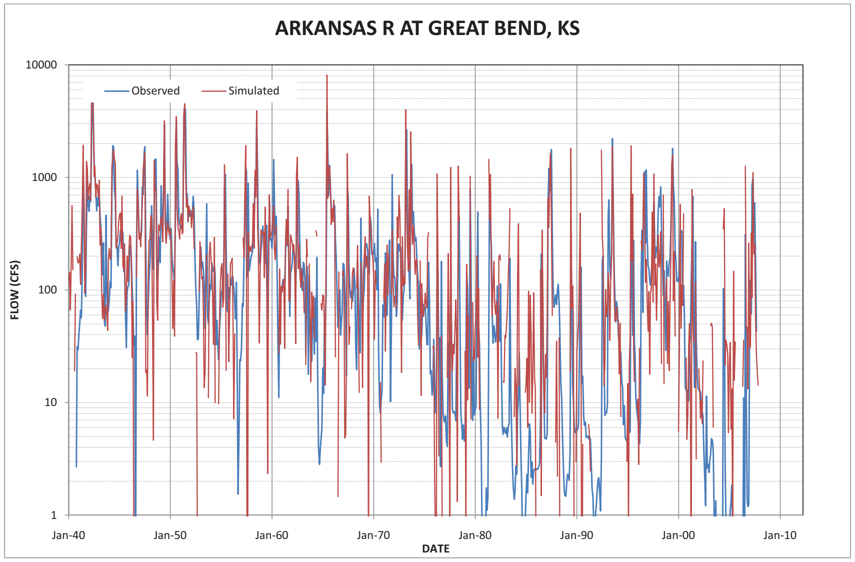

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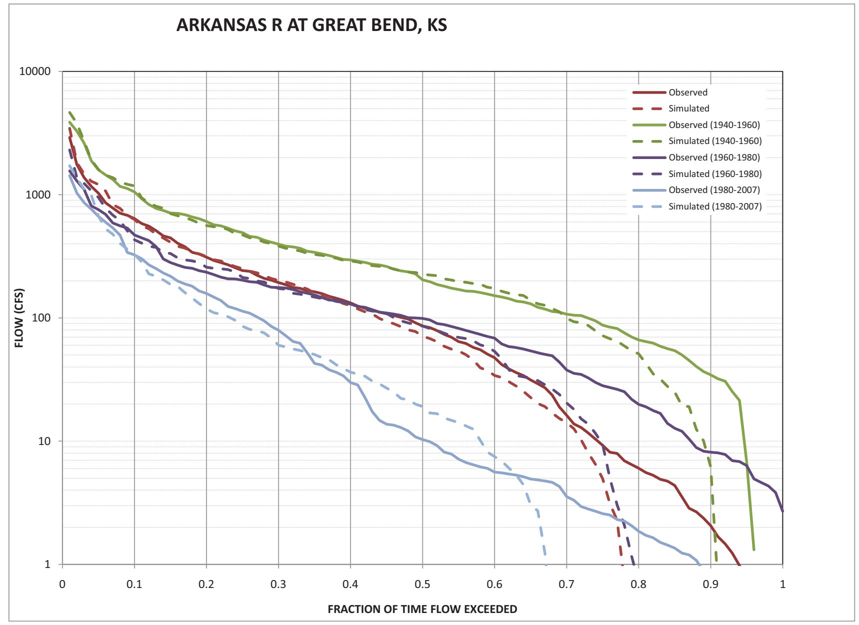

GMD #5

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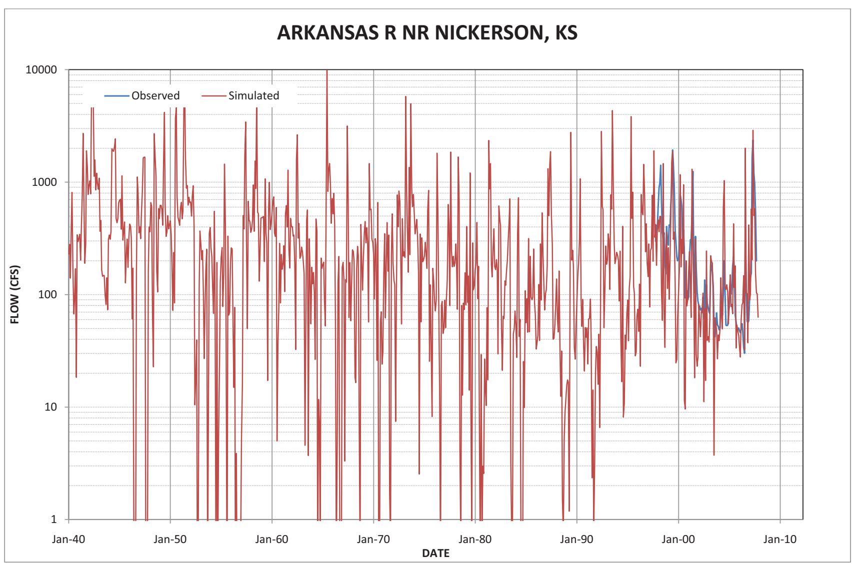

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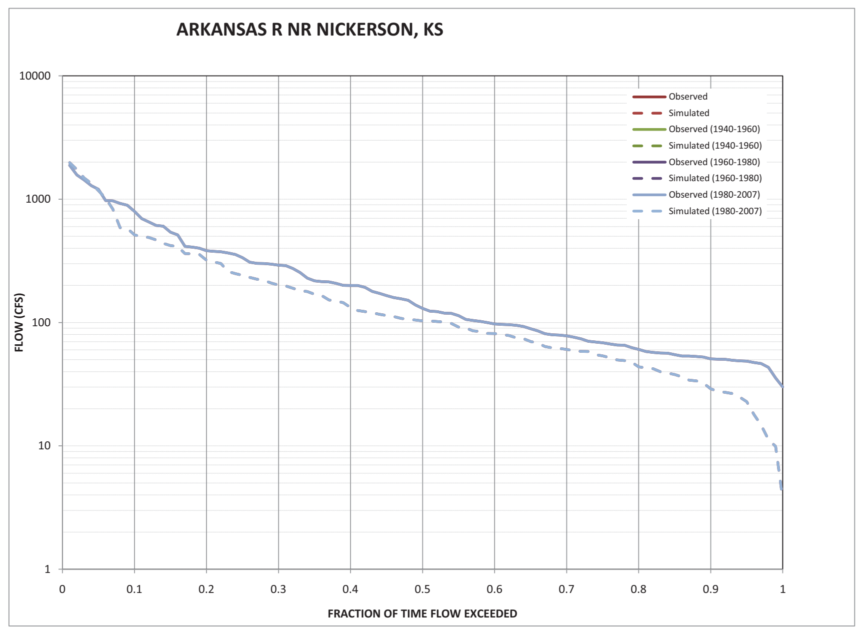

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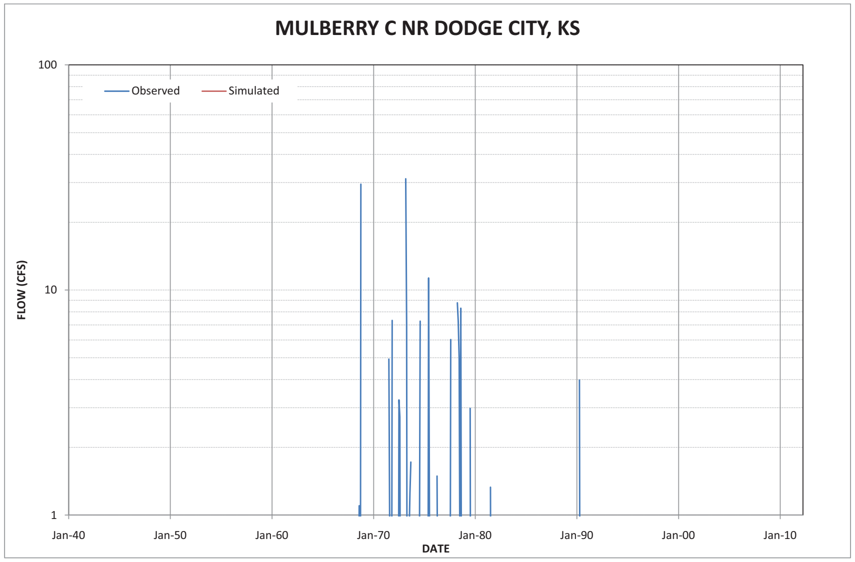

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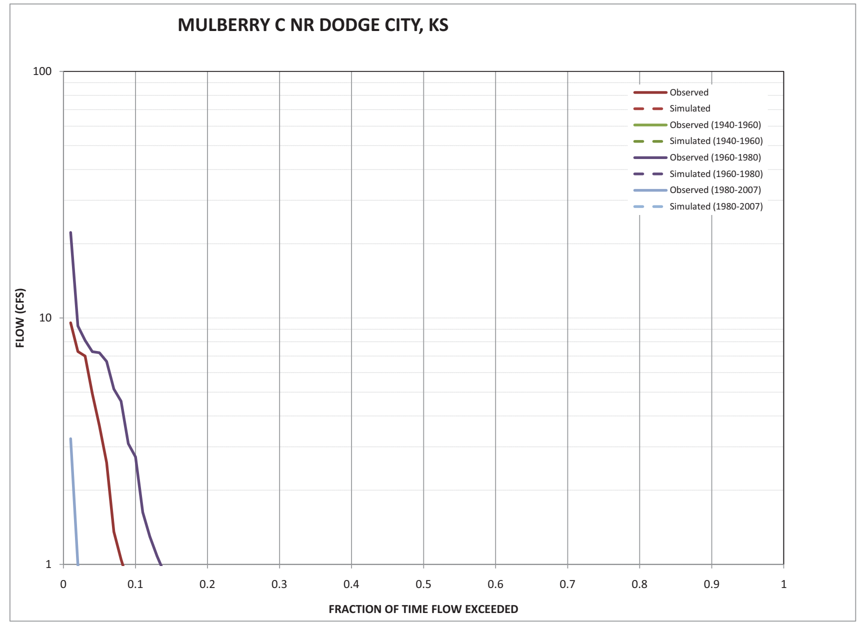

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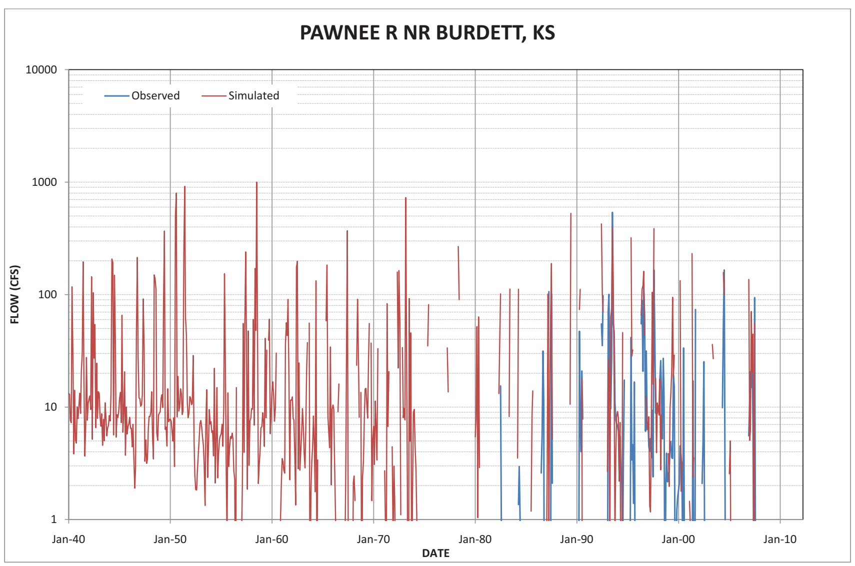

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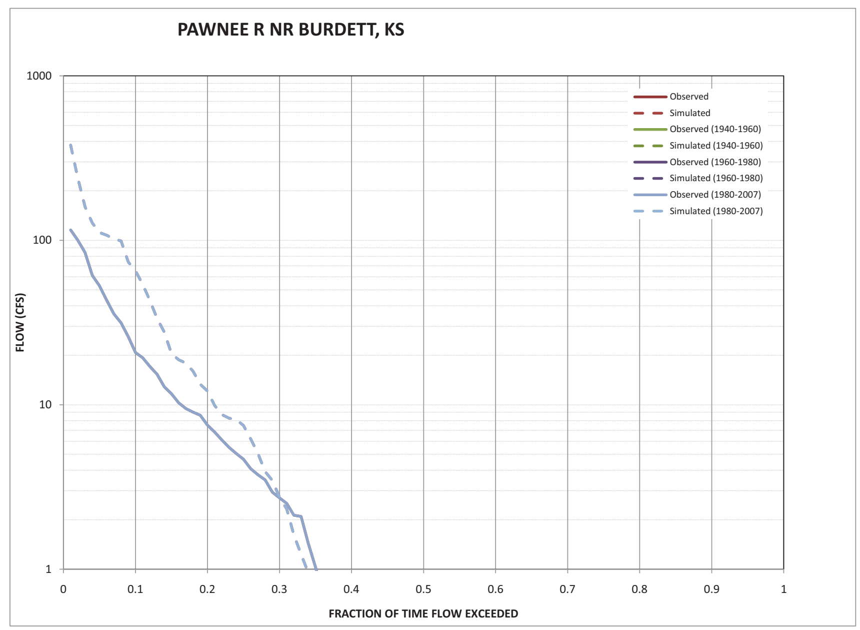

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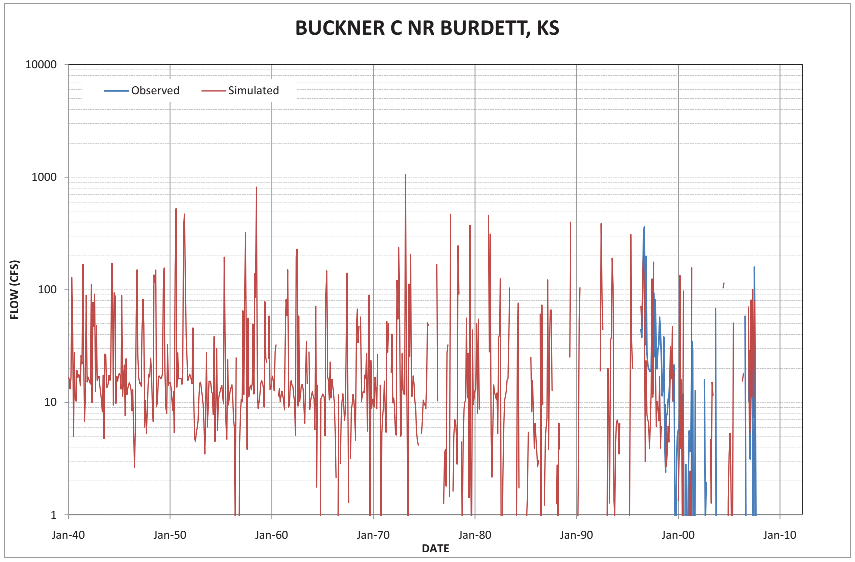

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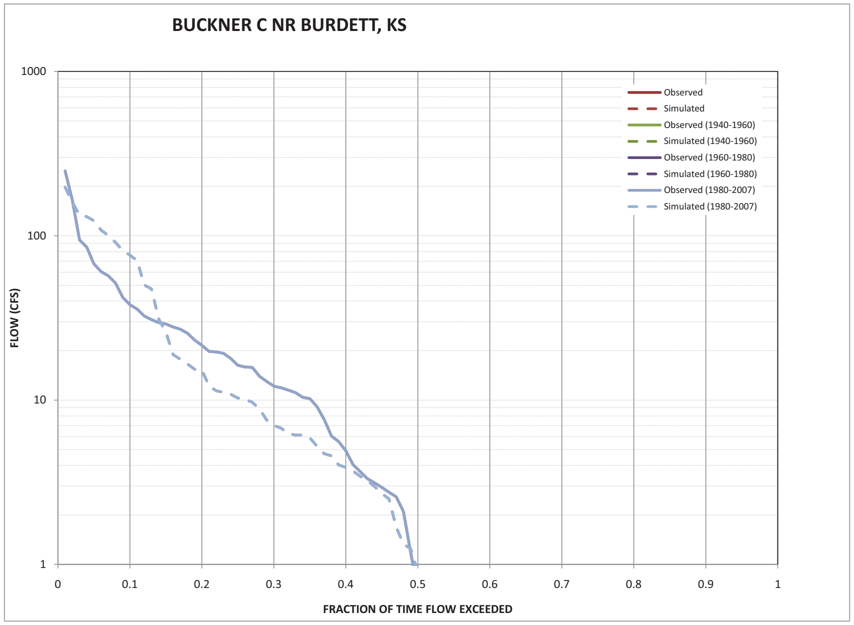

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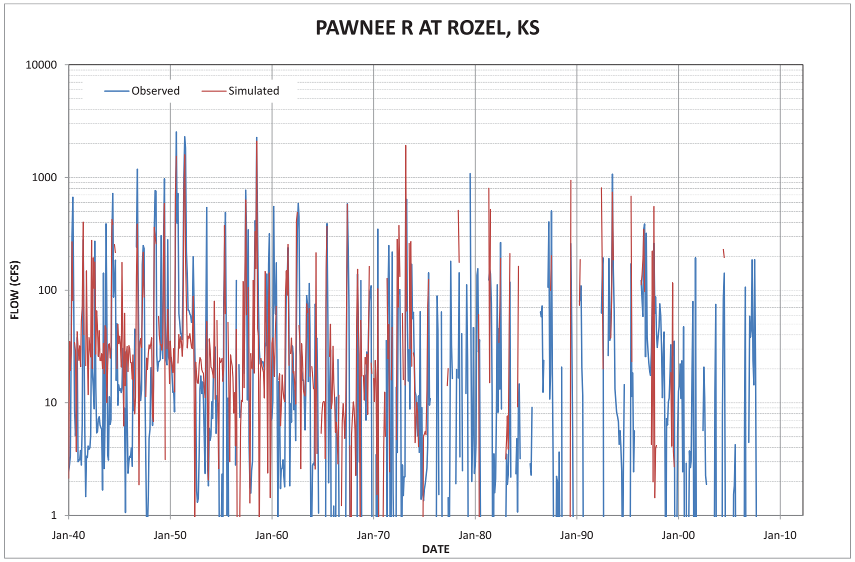

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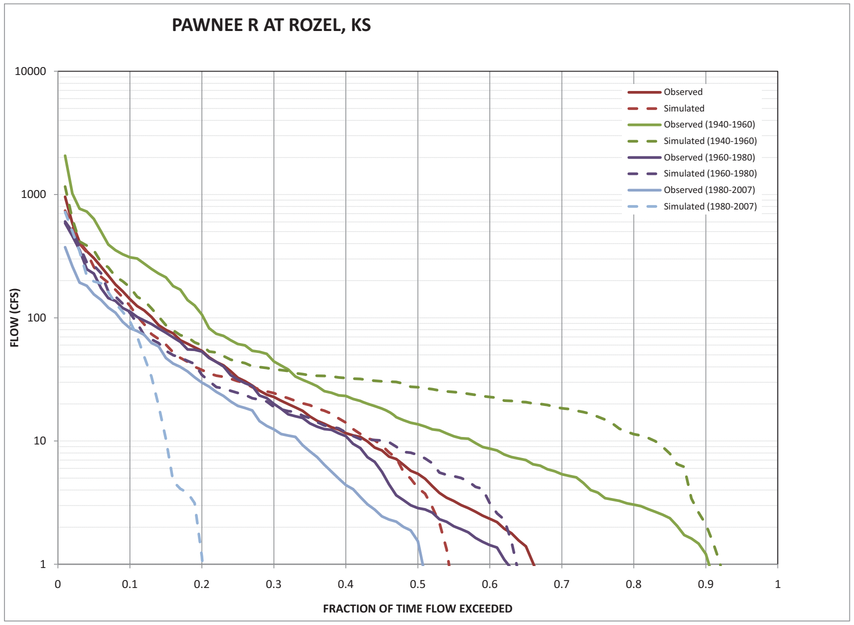

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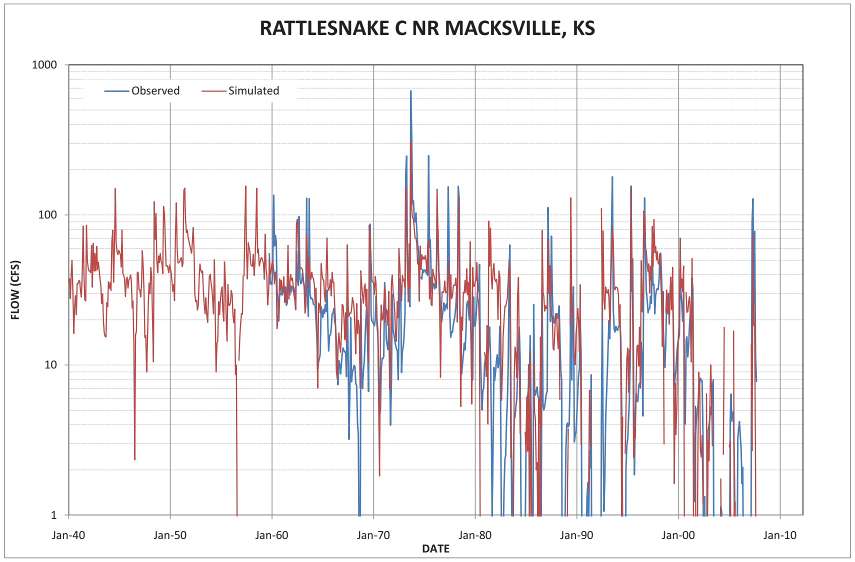

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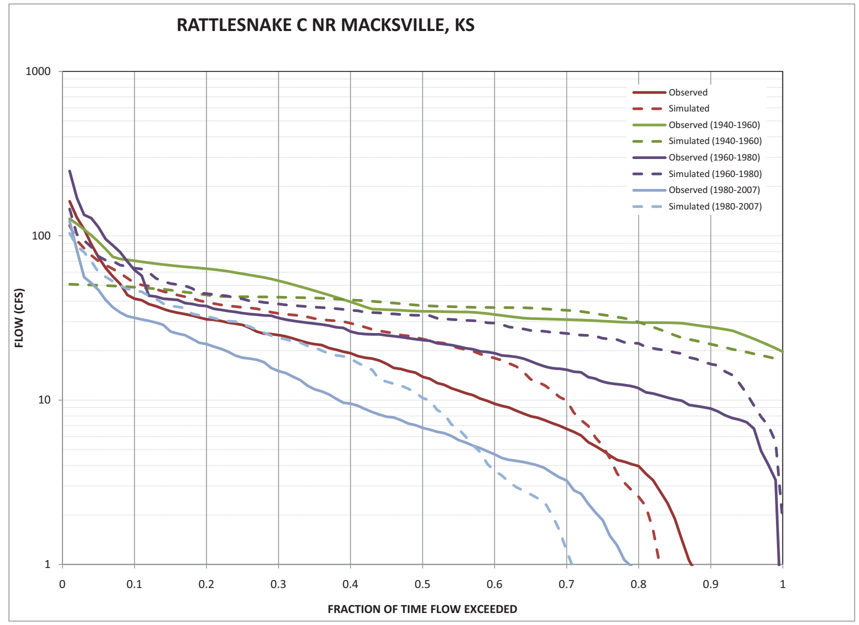
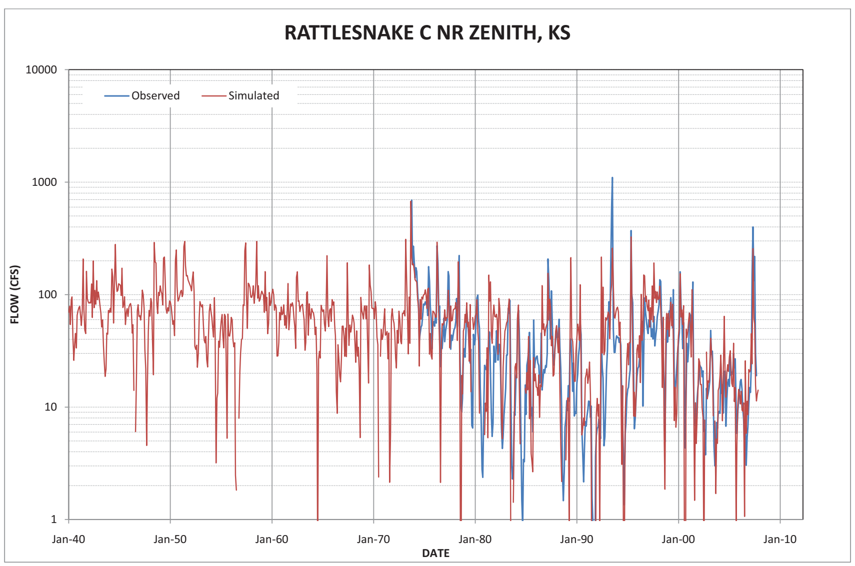


GMD #5

MODEL



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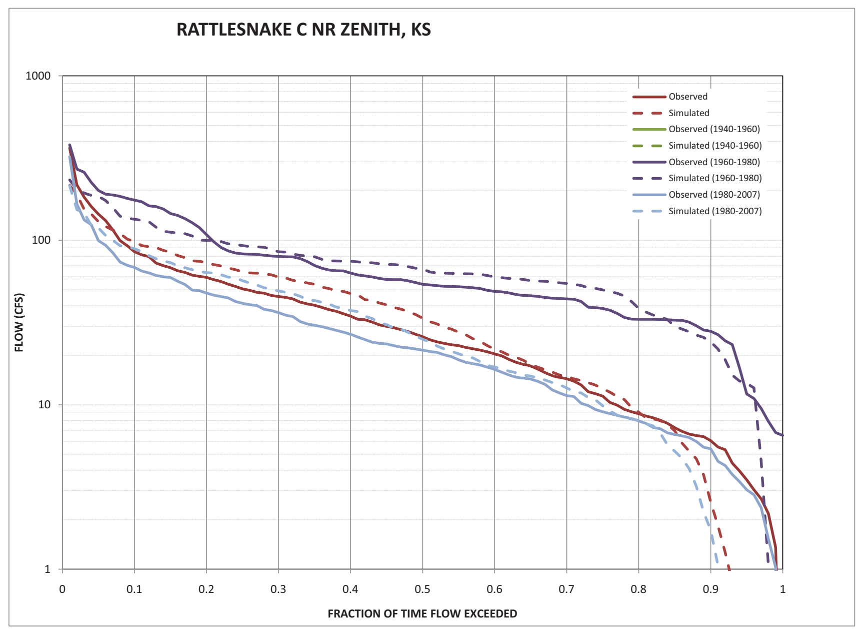

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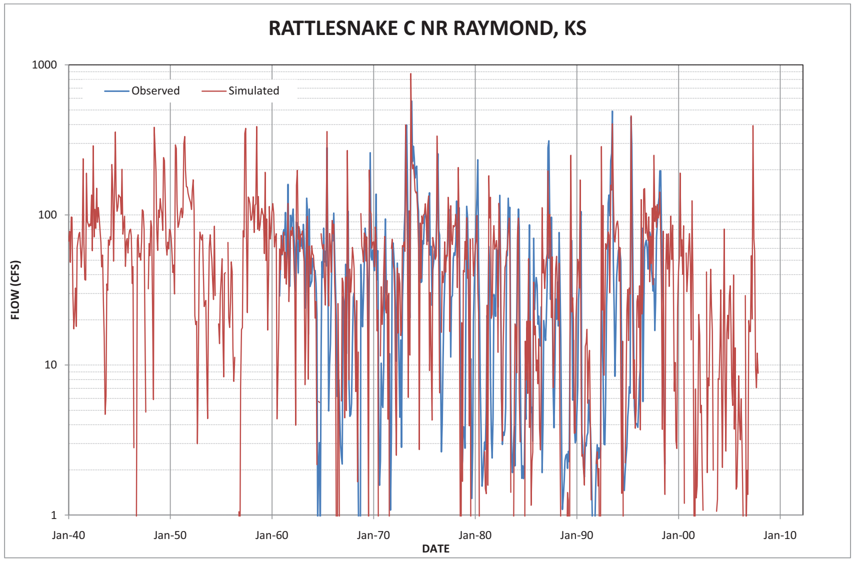
MODEL



nTCStrmLake.xlsb
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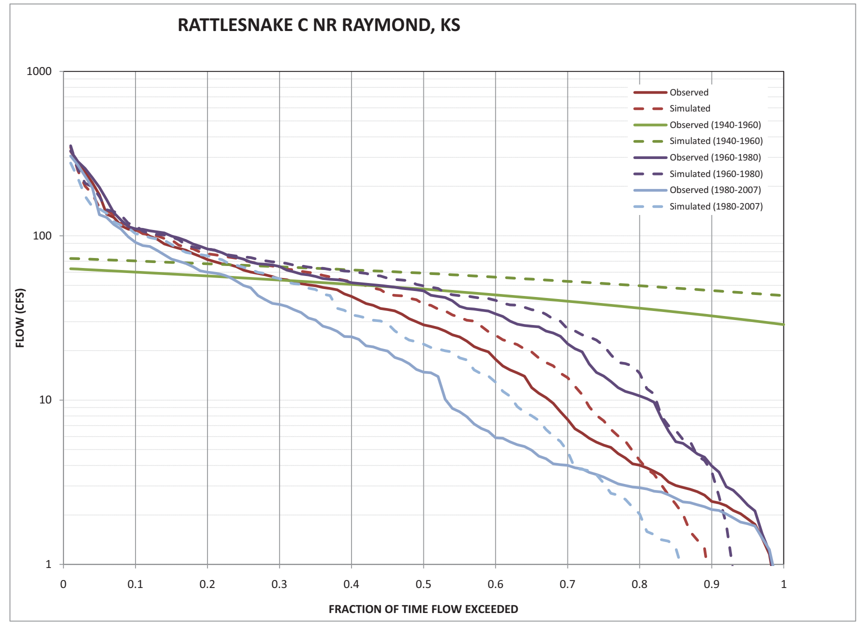
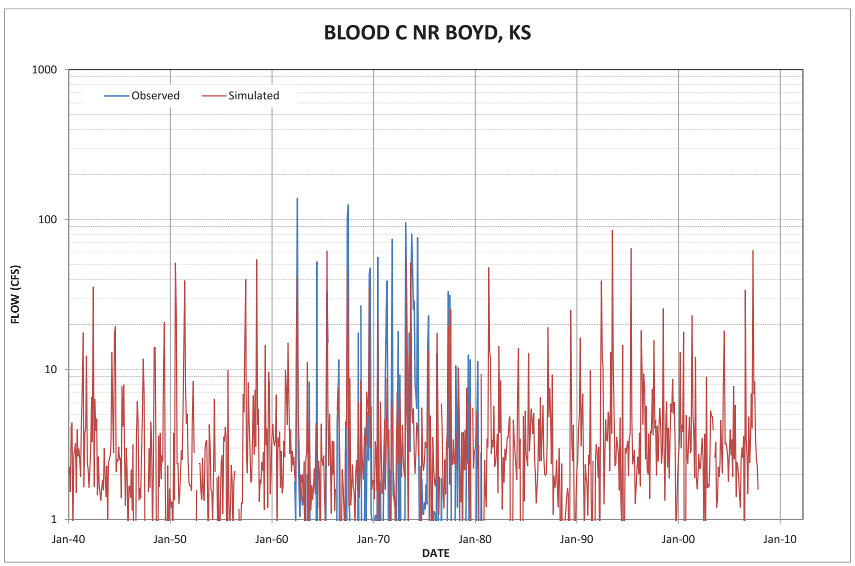
6/18/2010

BALLEAU GROUNDWATER, INC.



GMD #5

MODEL



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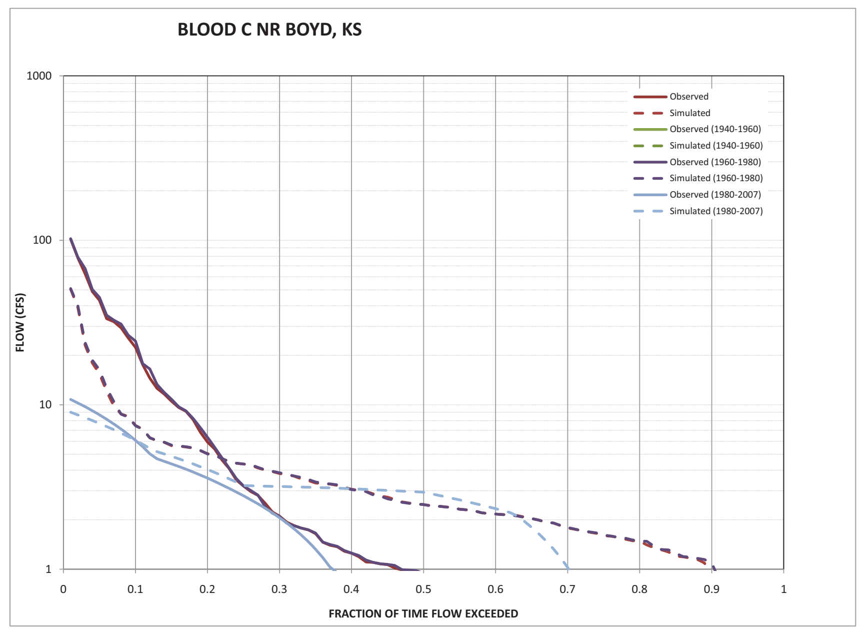
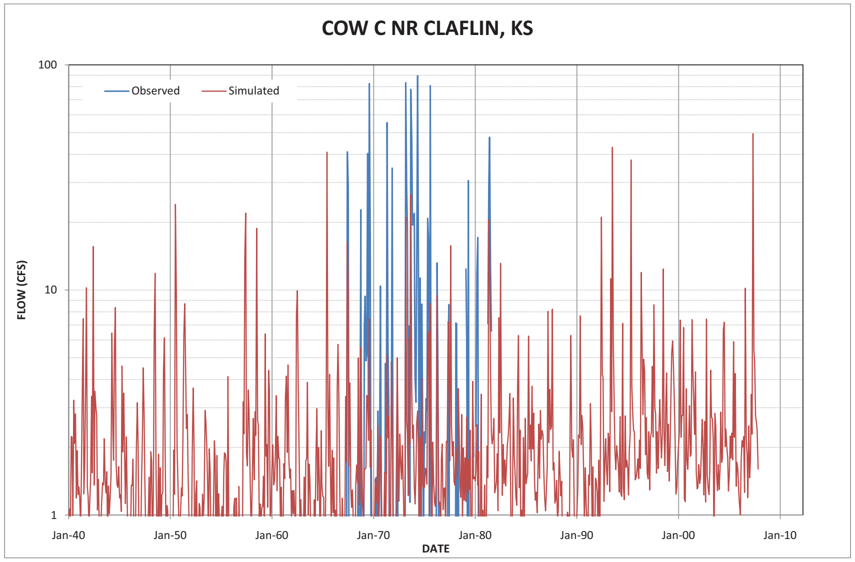
6/18/2010

BALLEAU GROUNDWATER, INC.



GMD #5

MODEL



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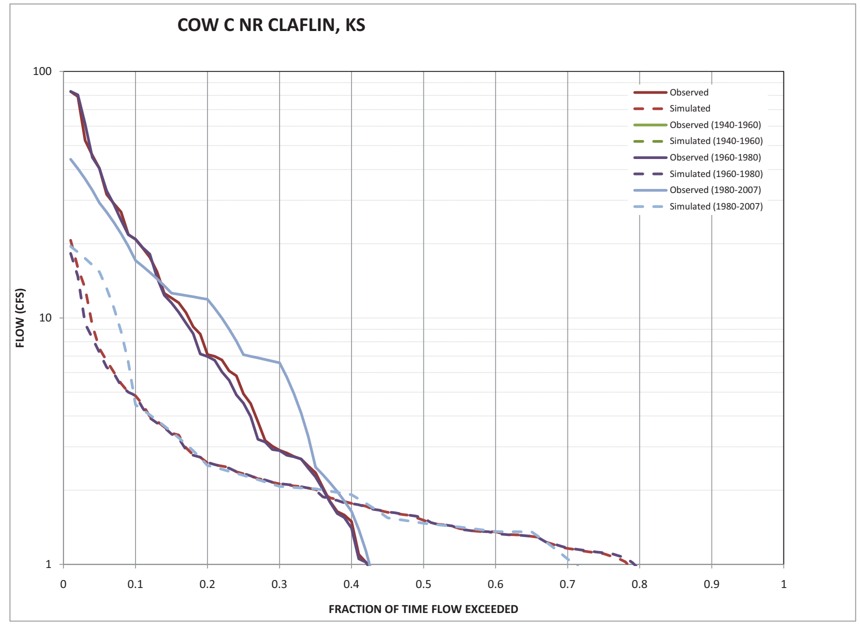
6/18/2010

BALLEAU GROUNDWATER, INC.



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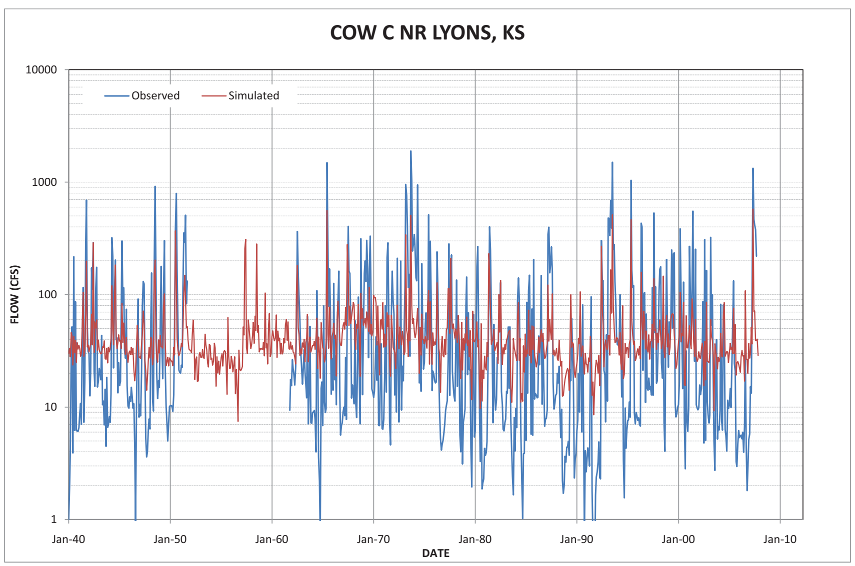

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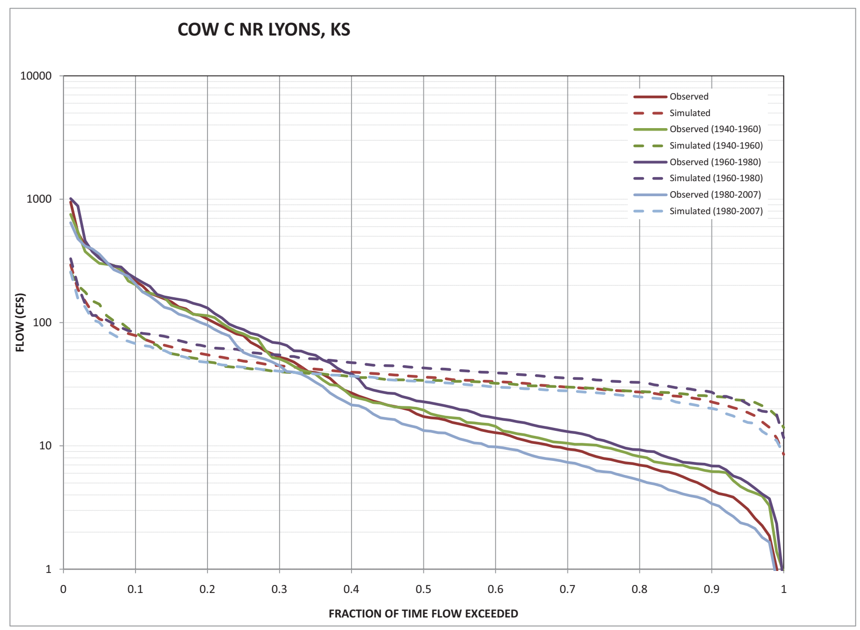

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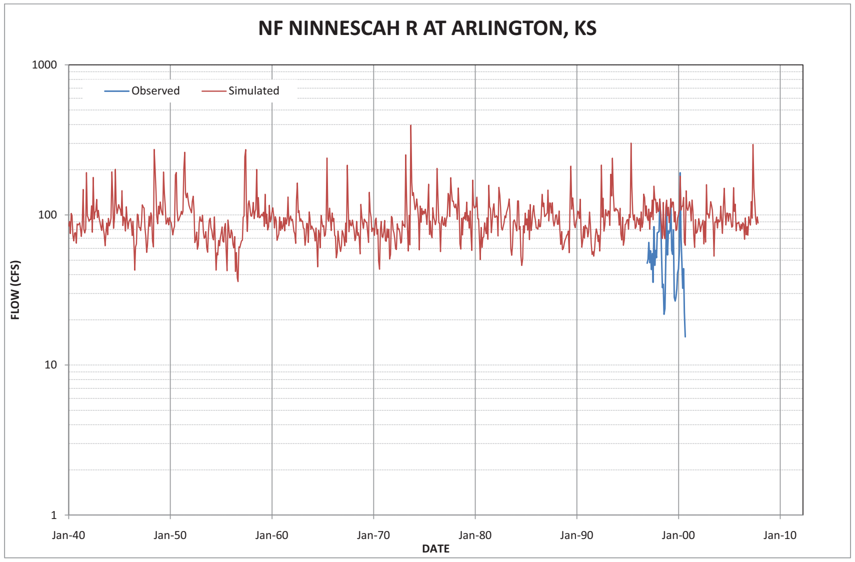

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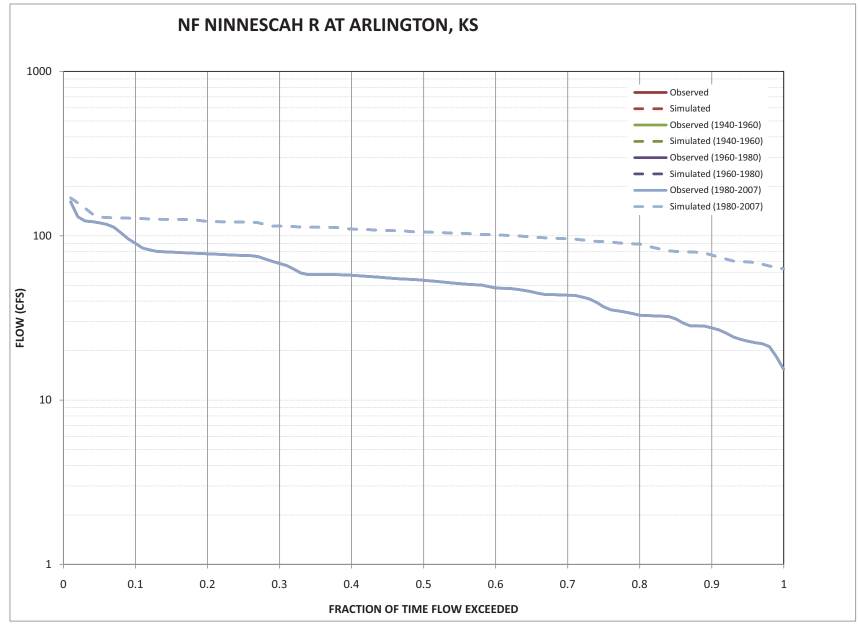

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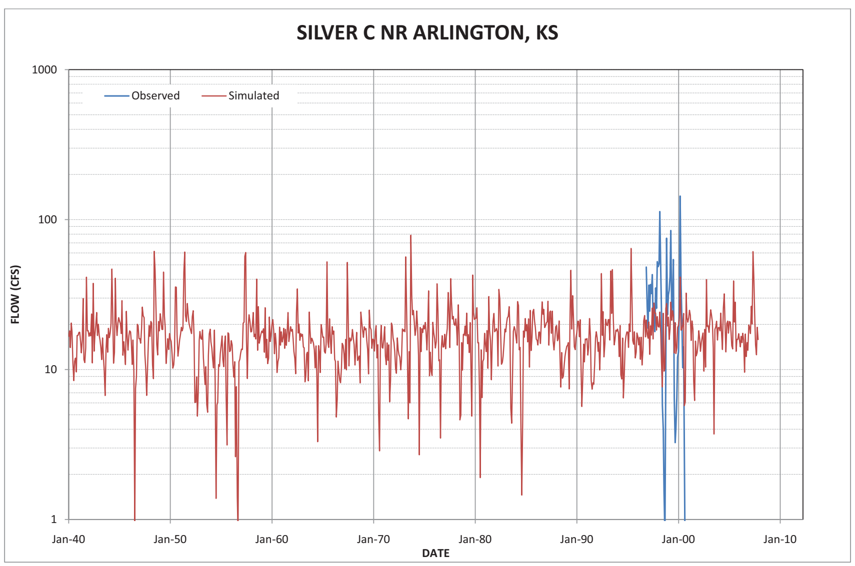

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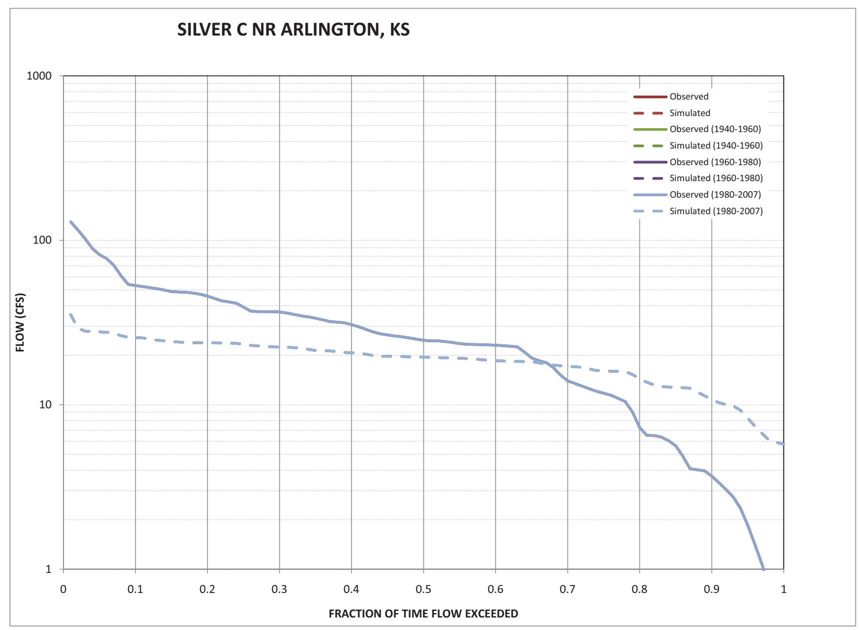

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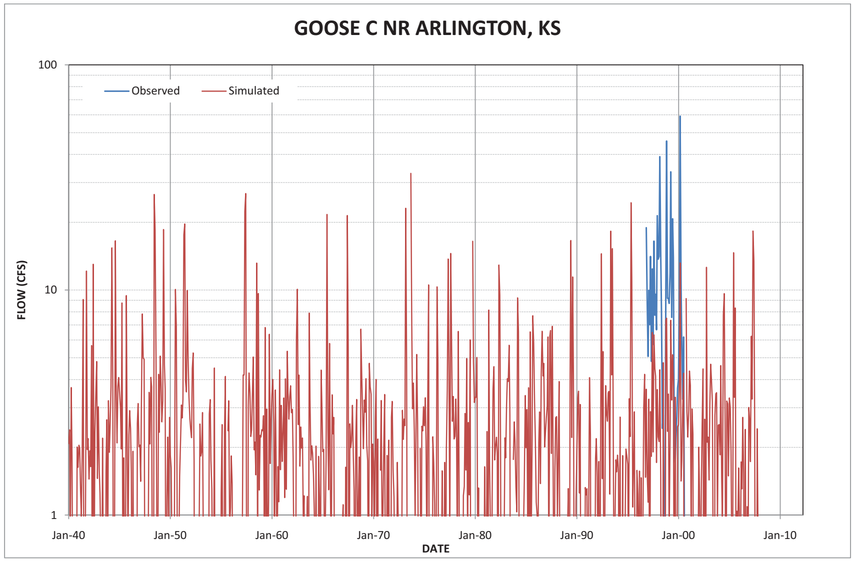

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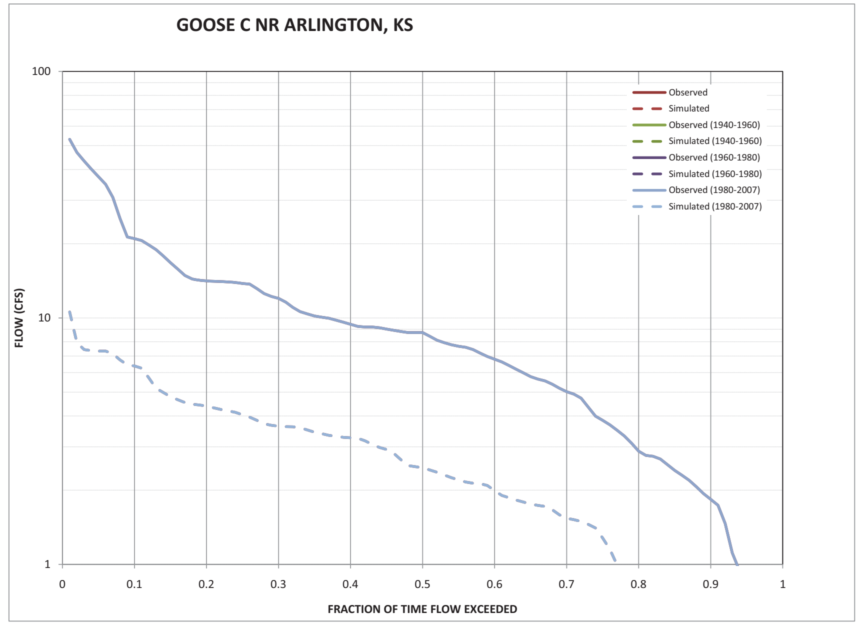

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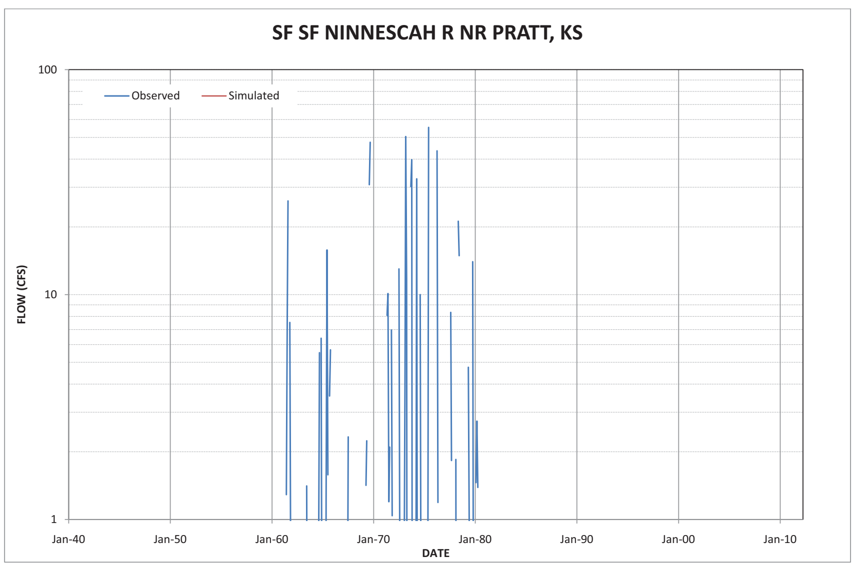

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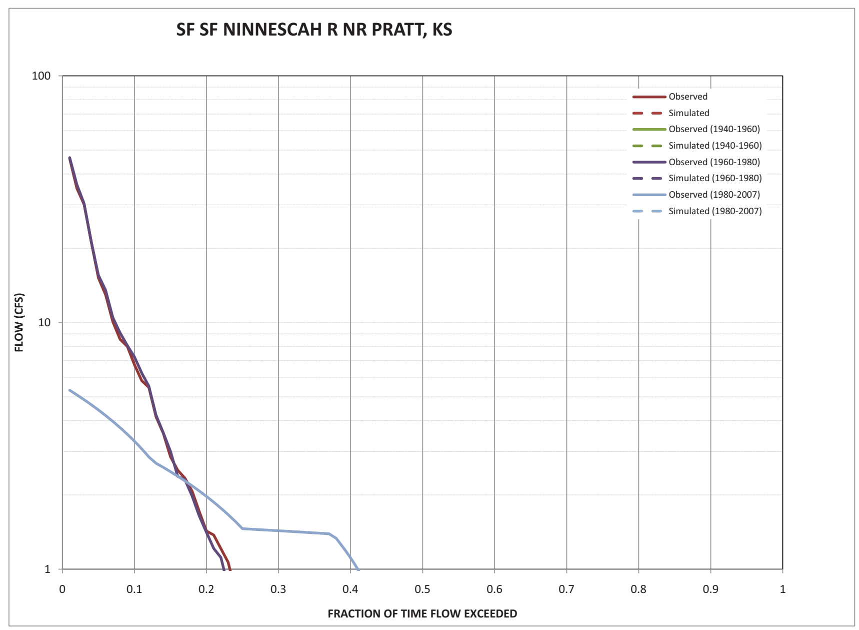

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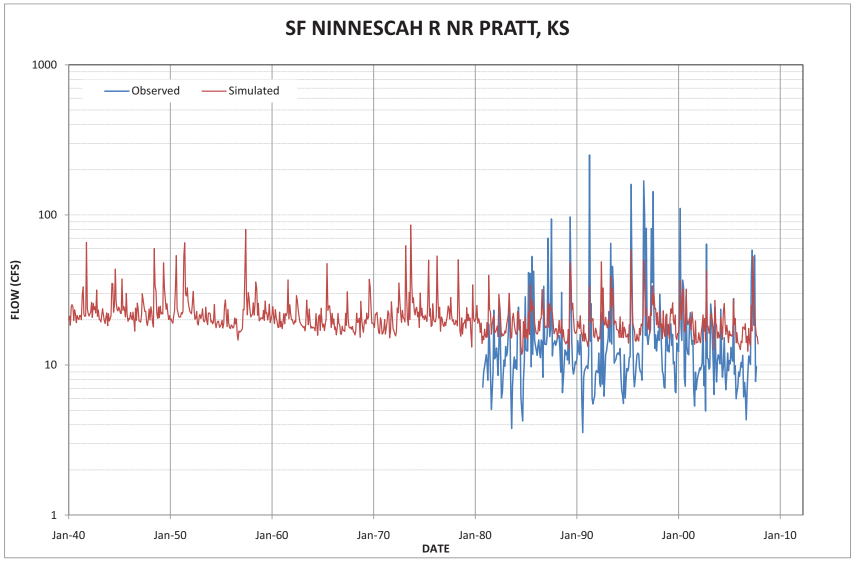

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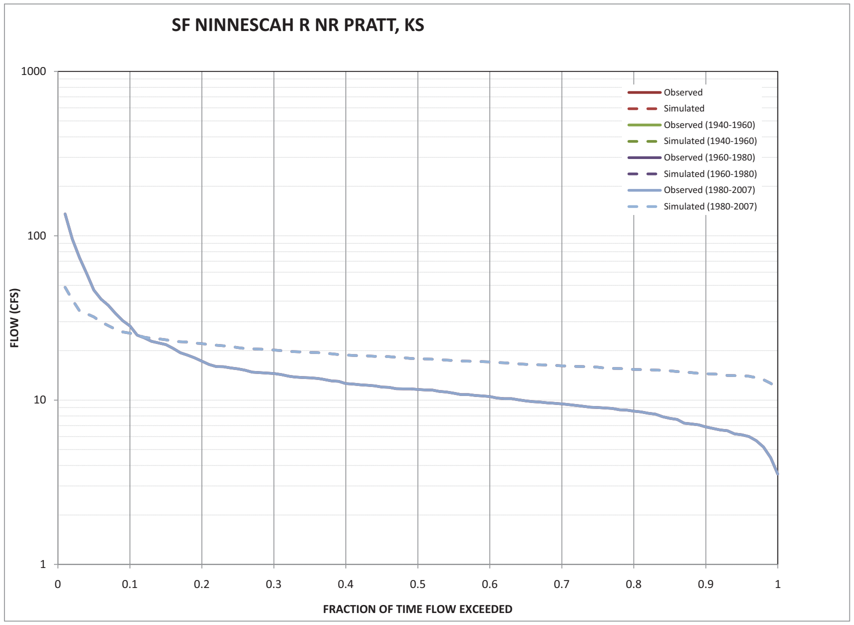

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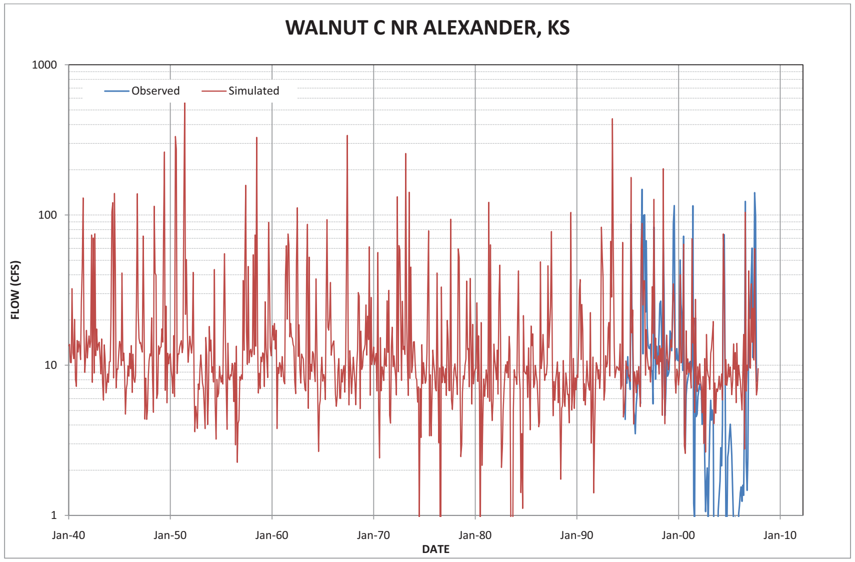

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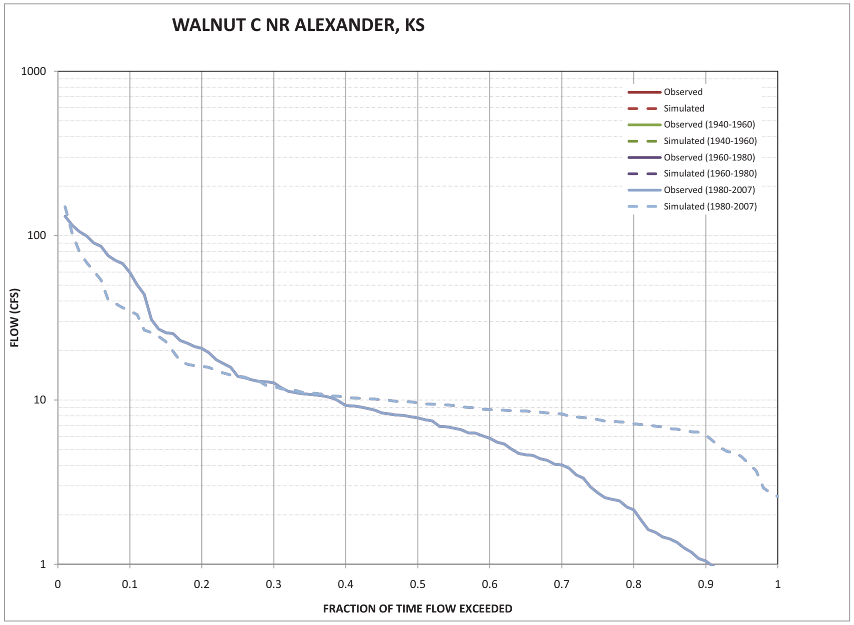

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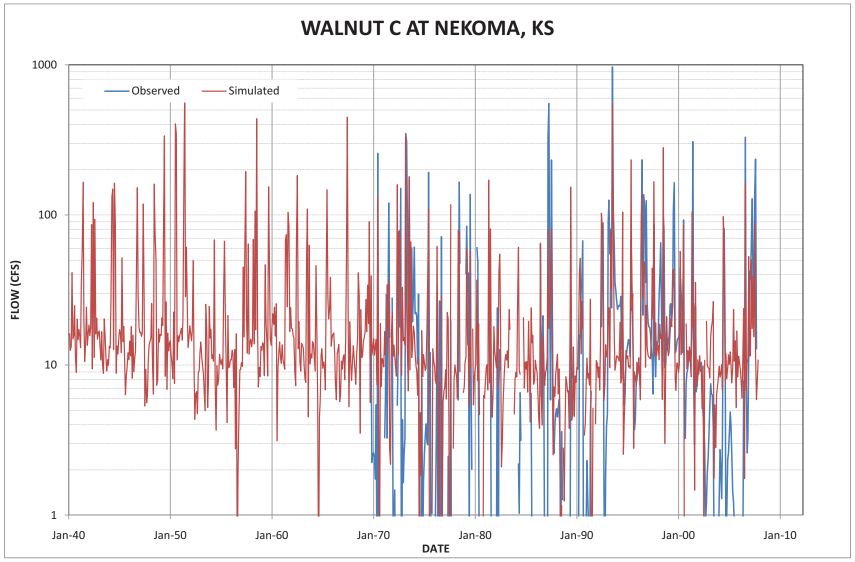

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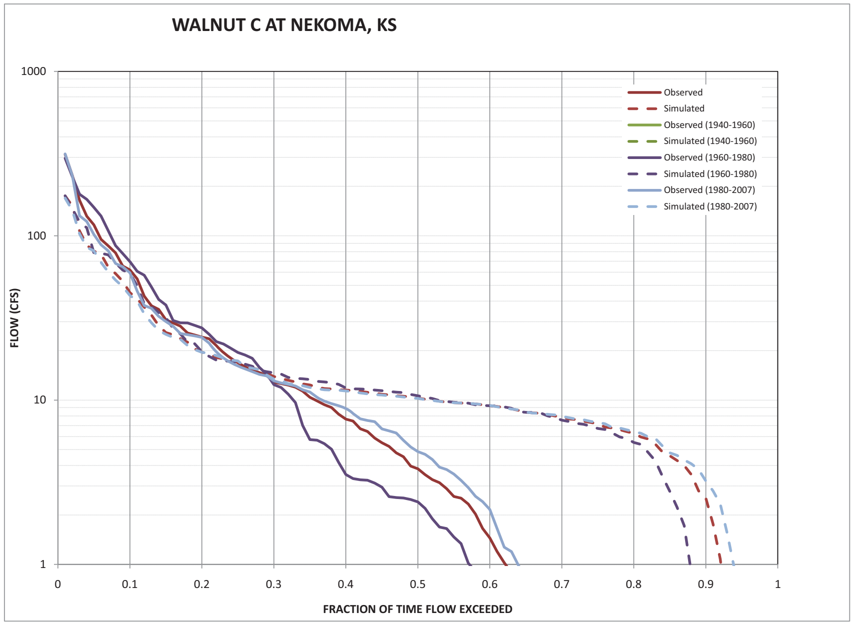

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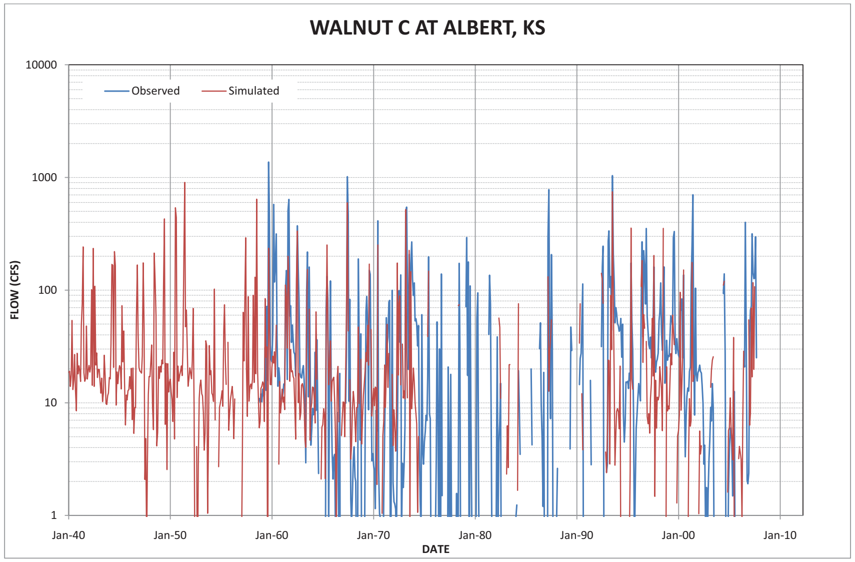

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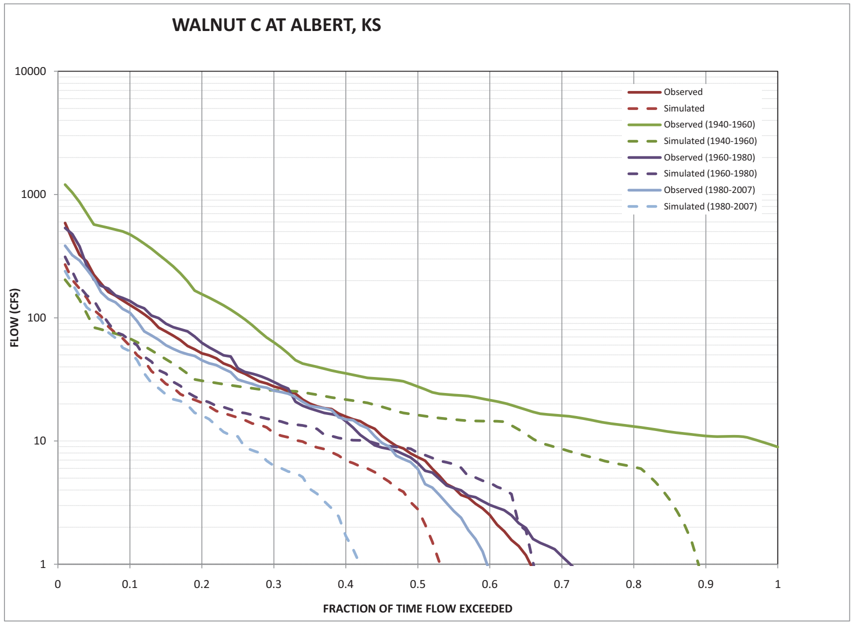

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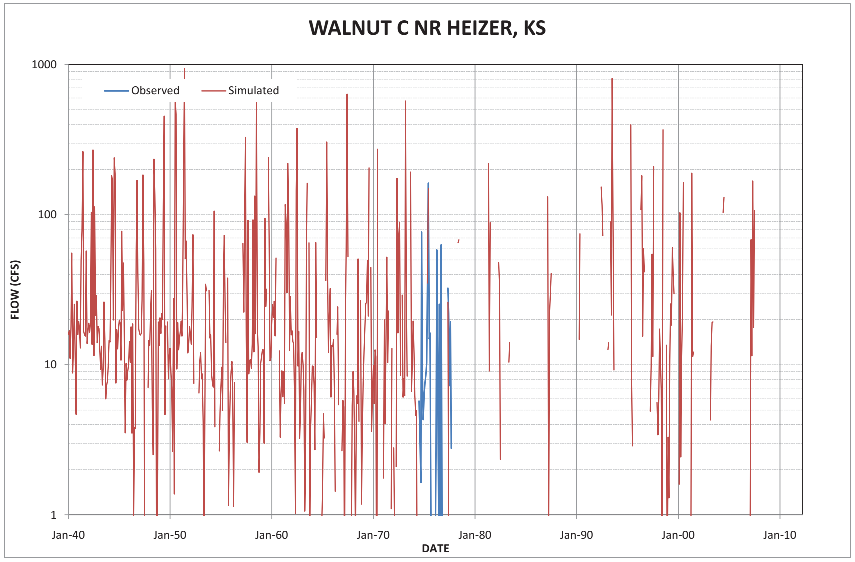

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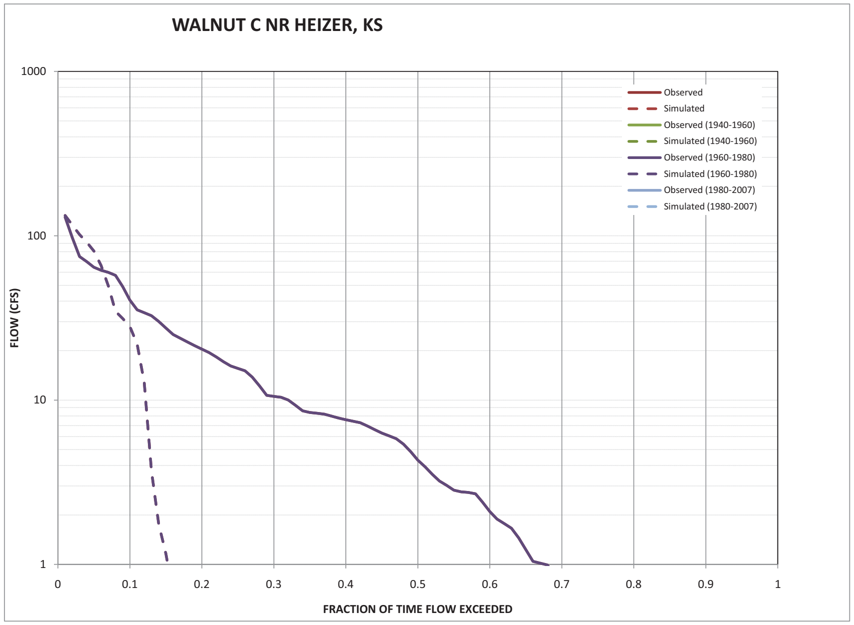

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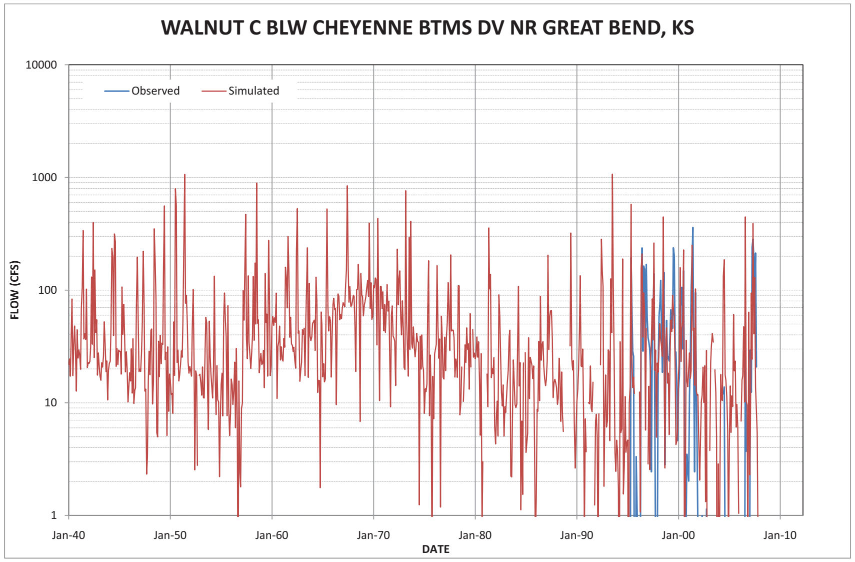

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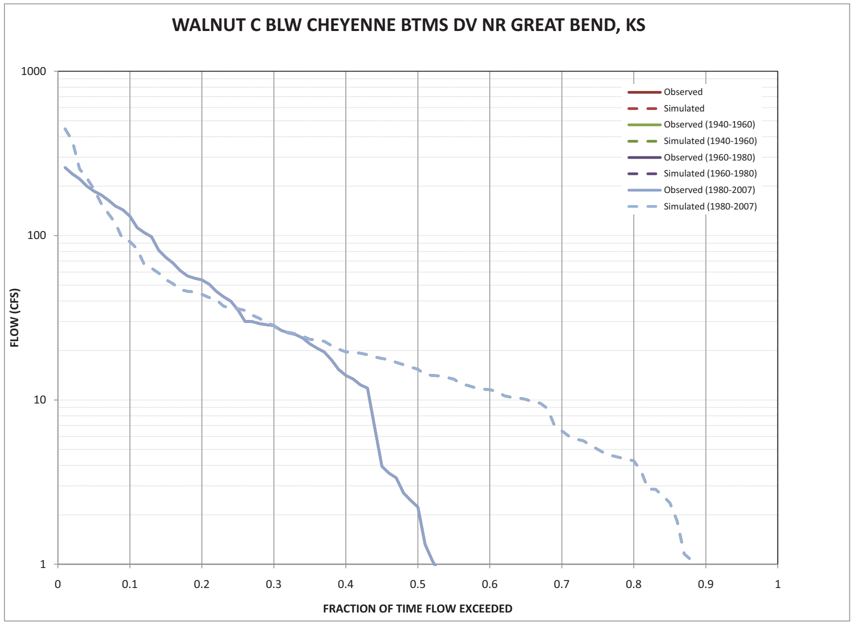
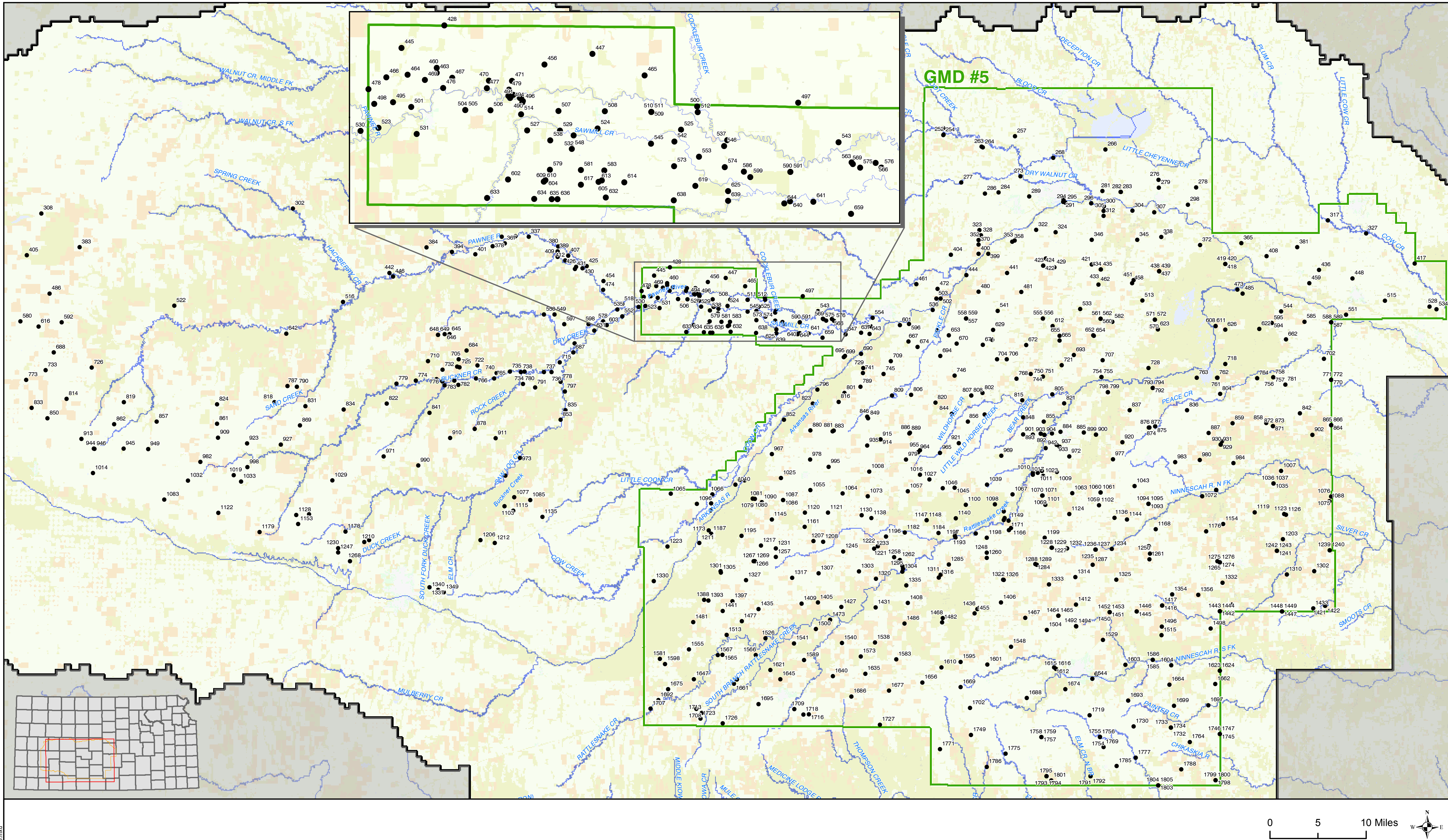




5/18/2010 ses\WPB Figure45.mxd

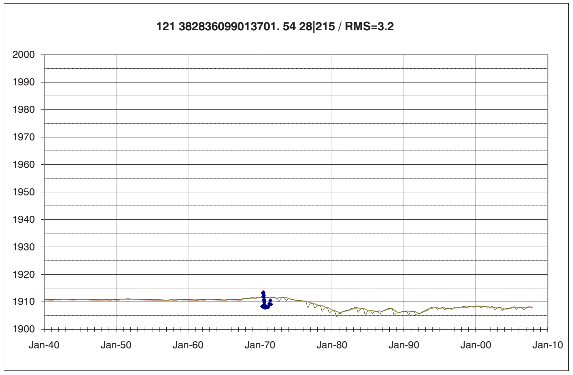
Groundwater Hydrograph Locations

GMD #5 / MODEL

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

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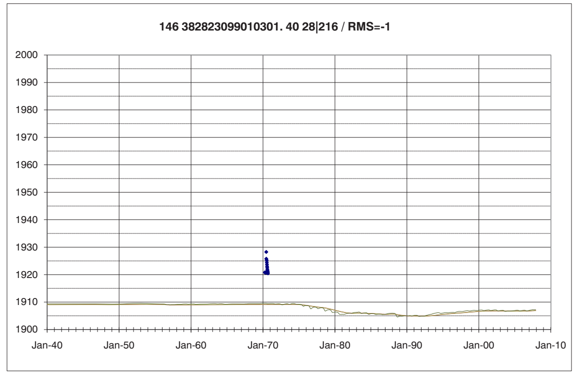

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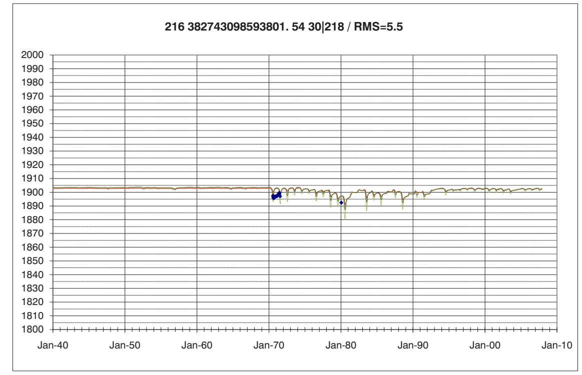

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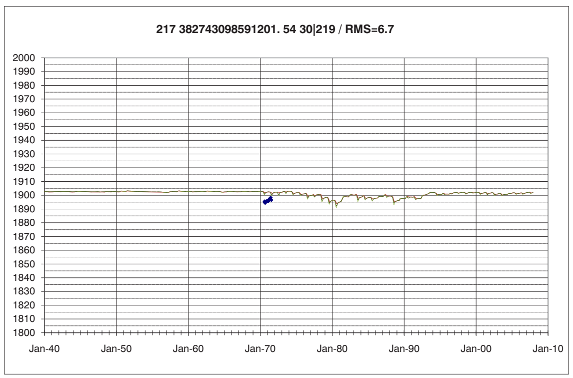

BALLEAU GROUNDWATER, INC.

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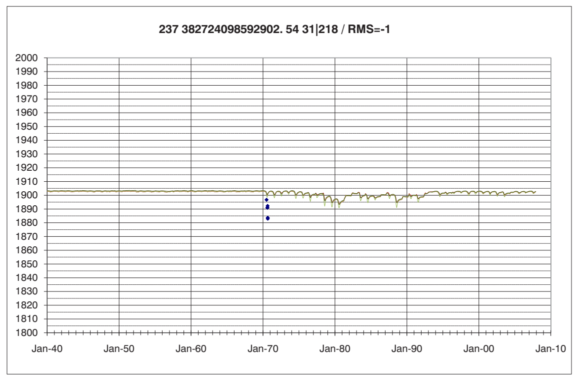

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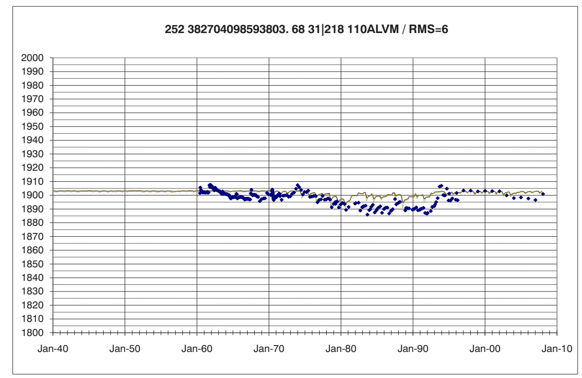

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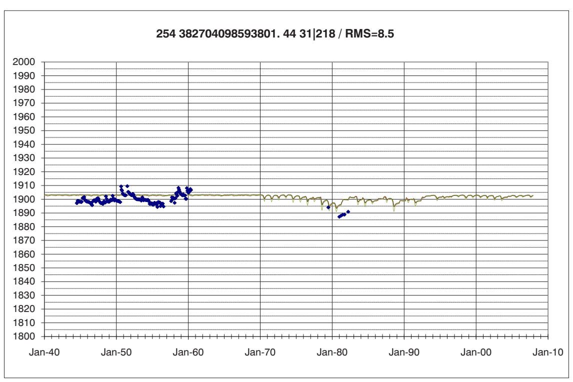

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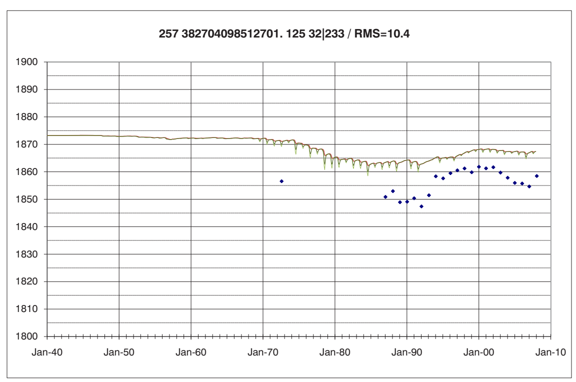

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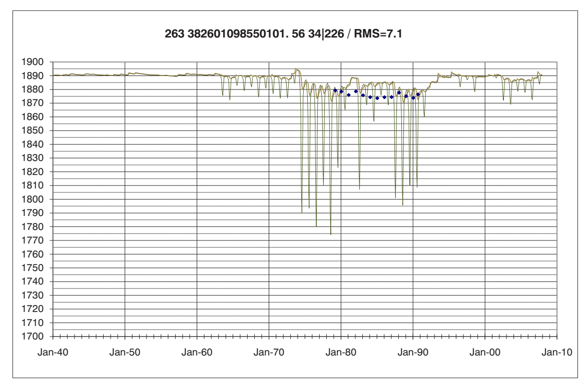

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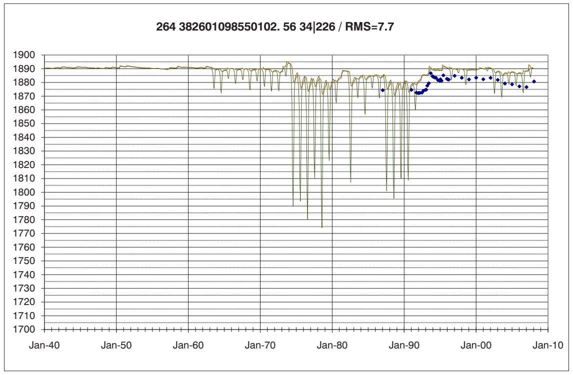

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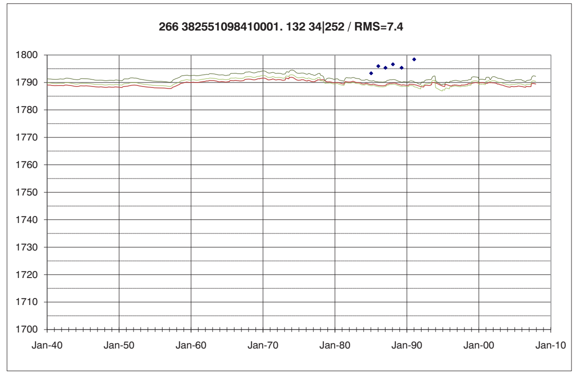

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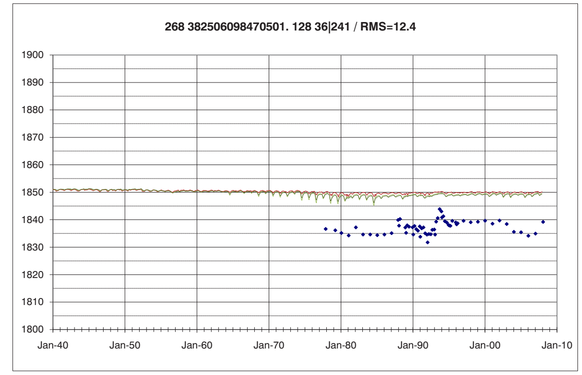

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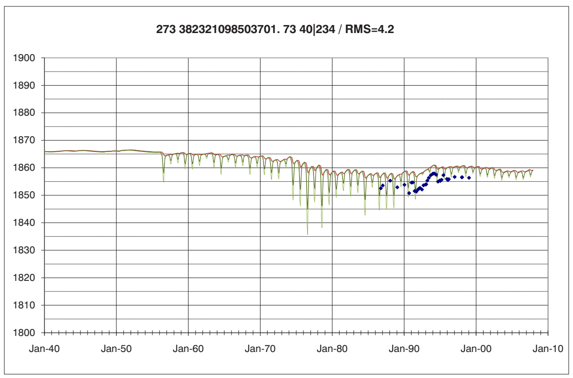

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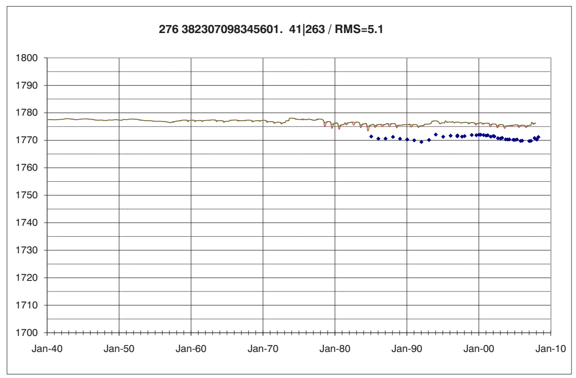

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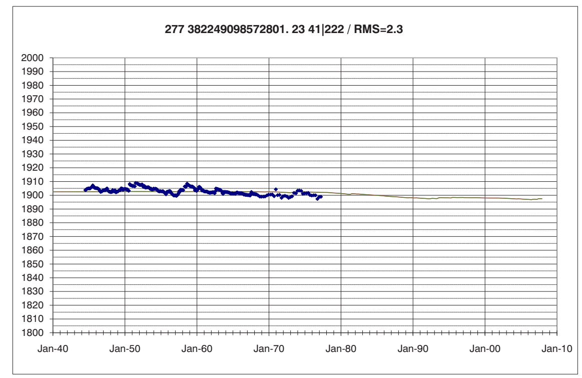

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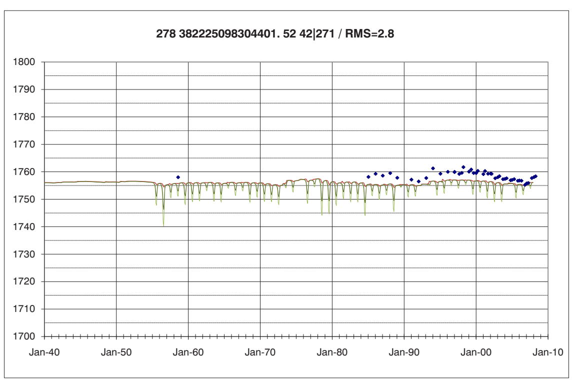

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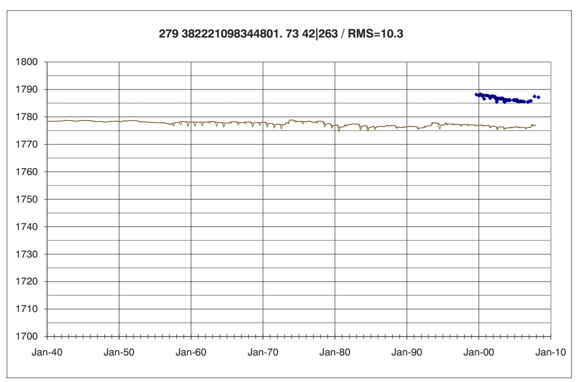

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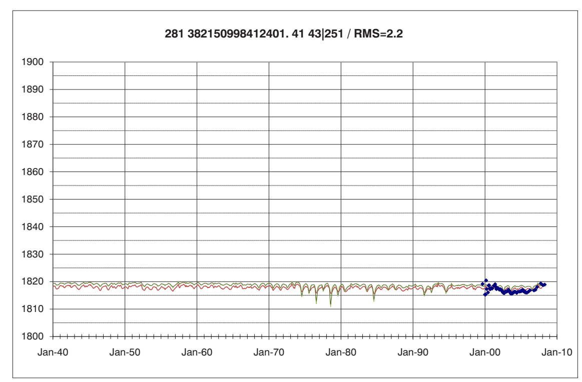

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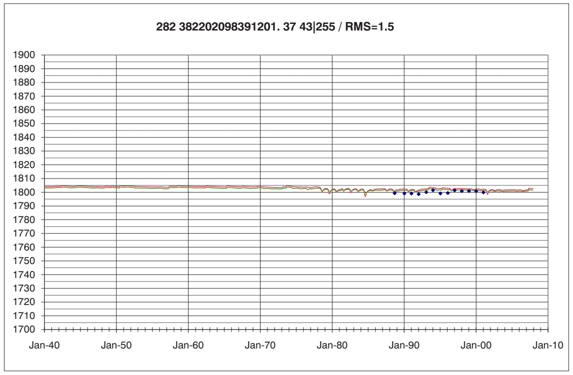

Fig46ProcWL.xlsb
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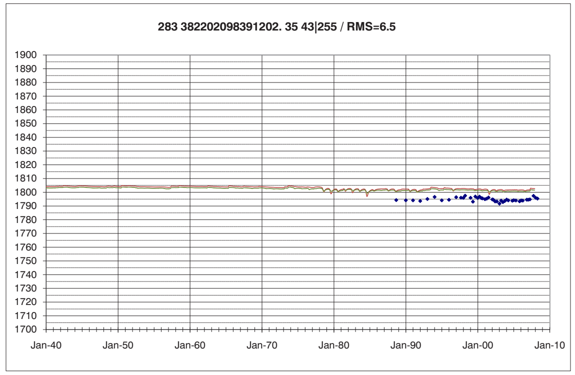

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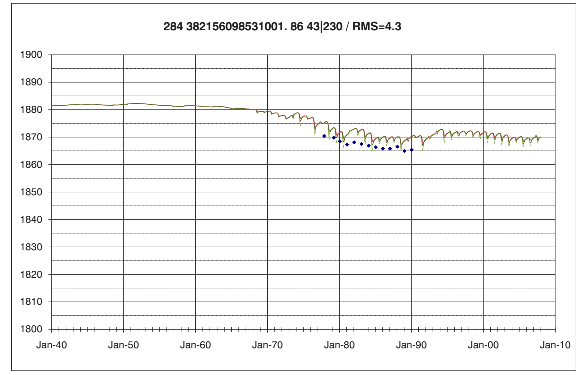

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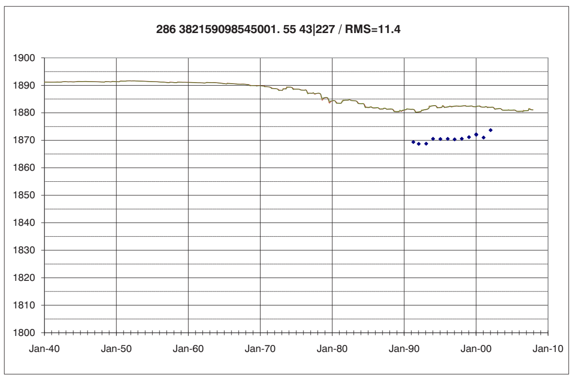

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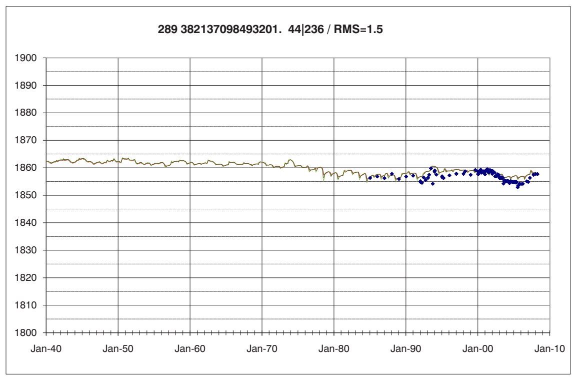

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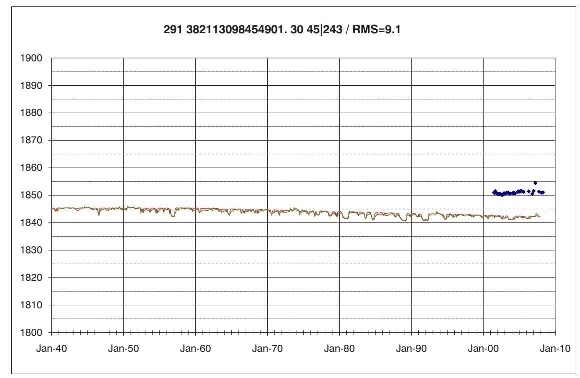

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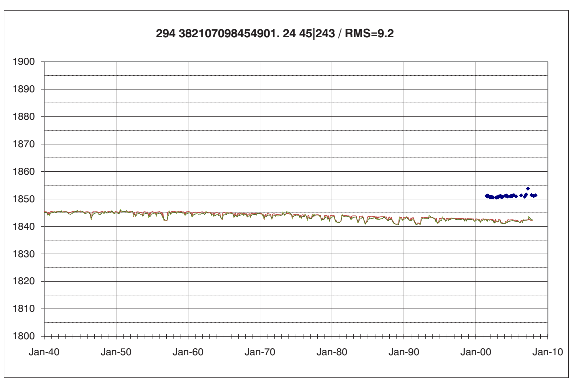

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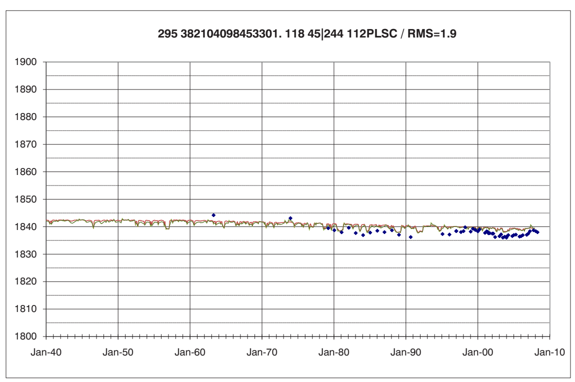

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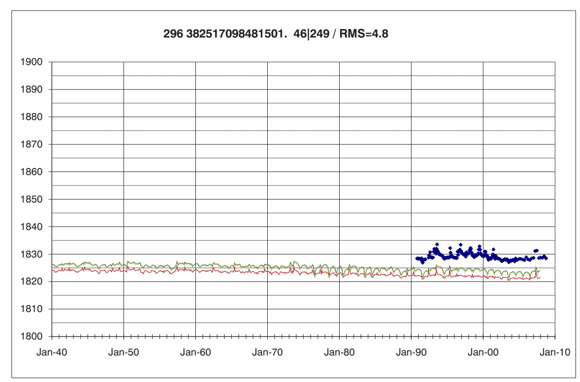

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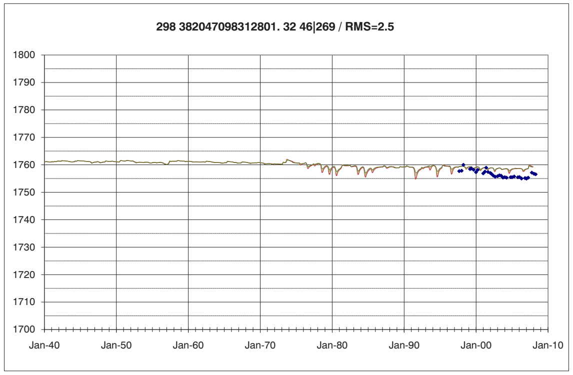

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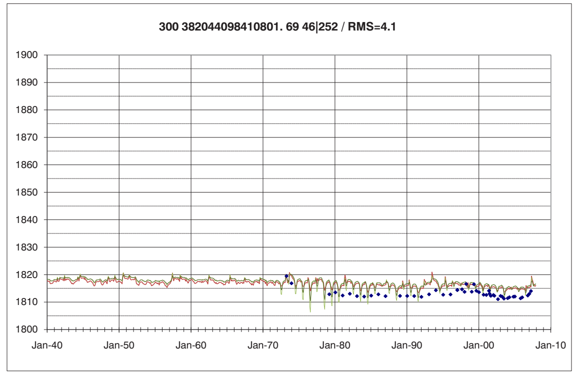

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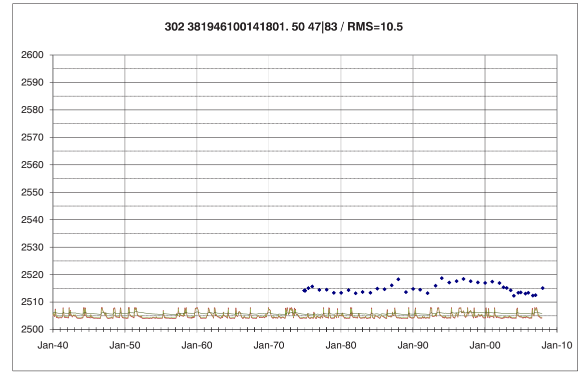

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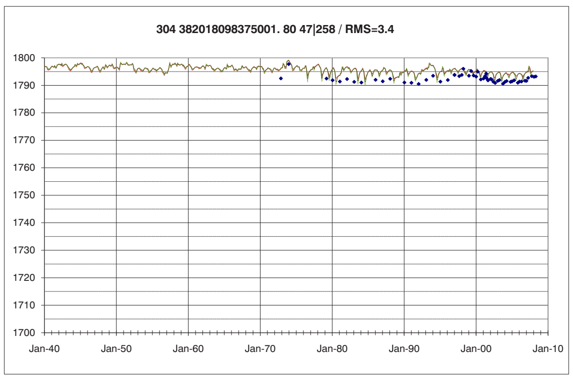

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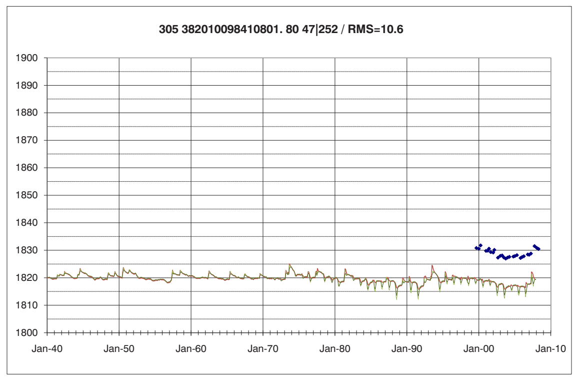

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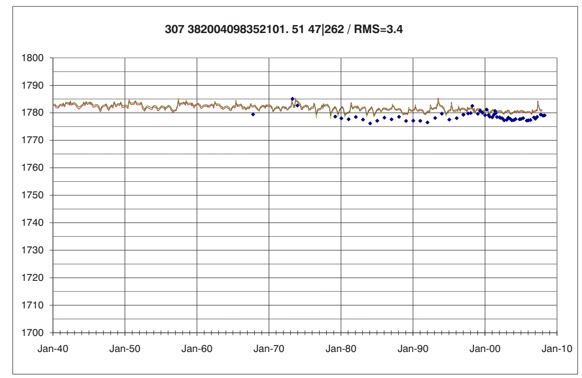

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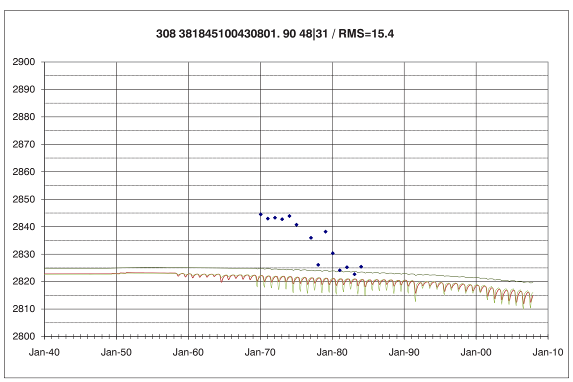

BALLEAU GROUNDWATER, INC.

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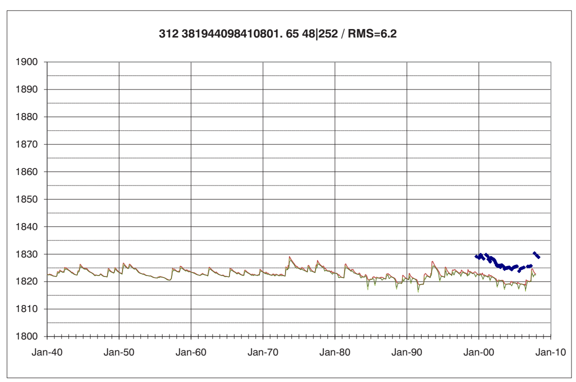

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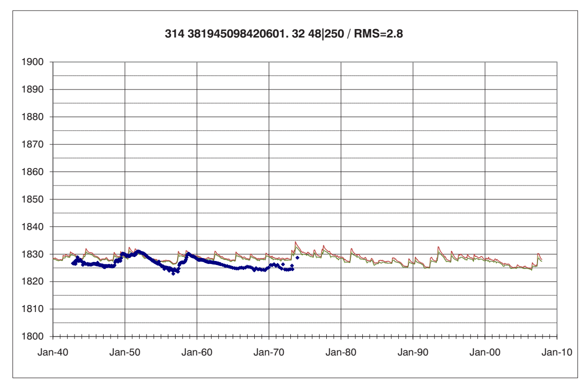

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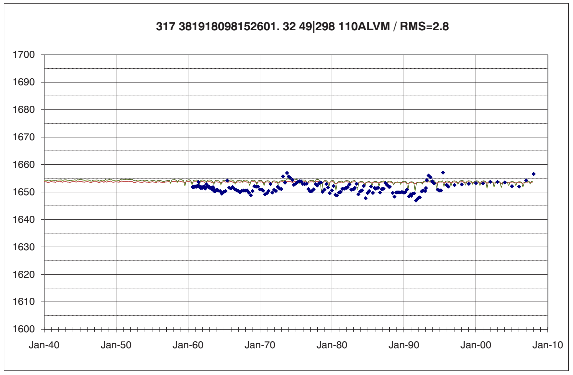

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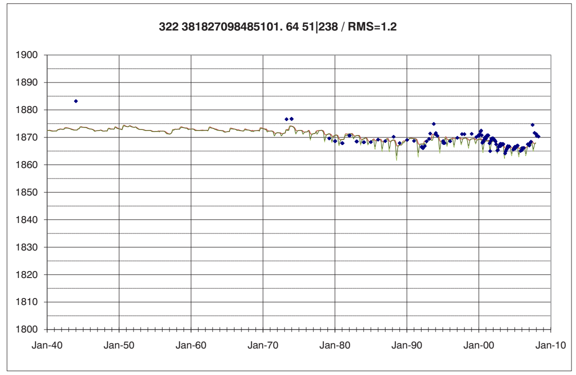

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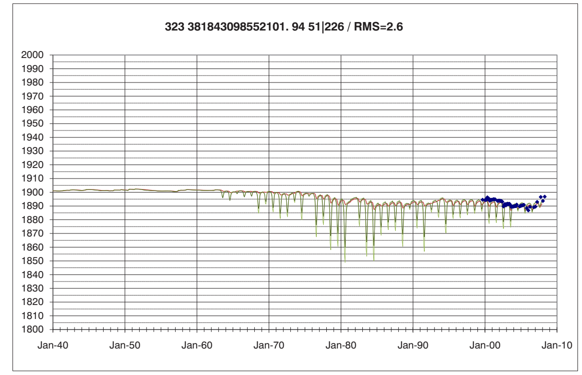

BALLEAU GROUNDWATER, INC.

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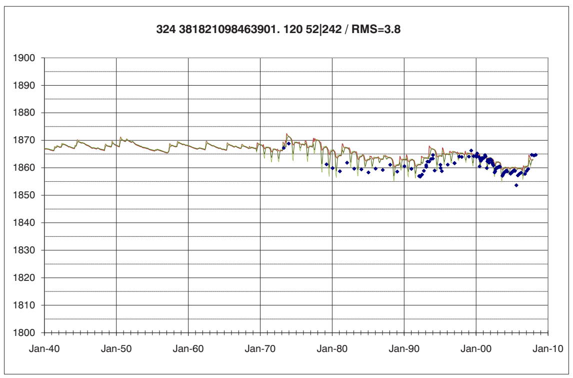

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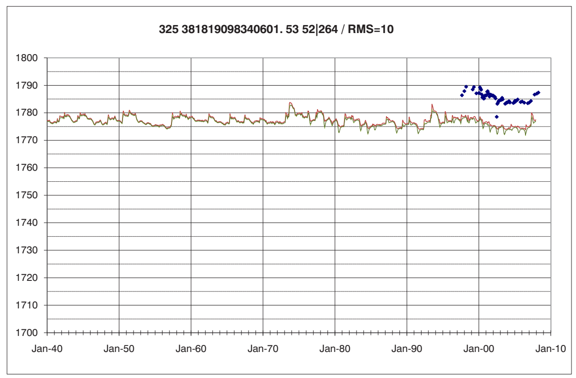

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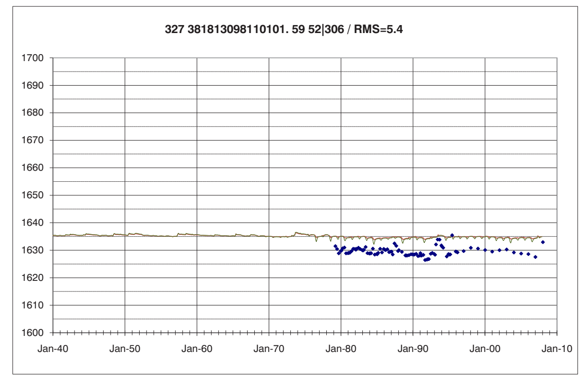

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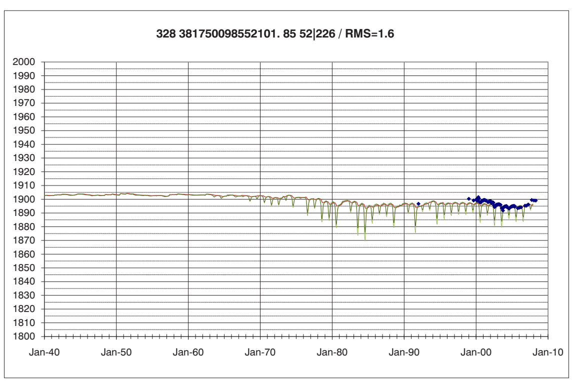

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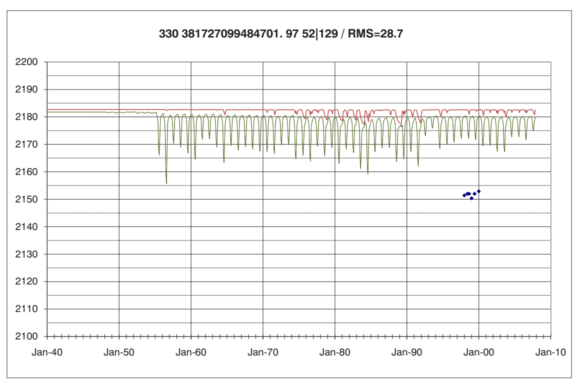

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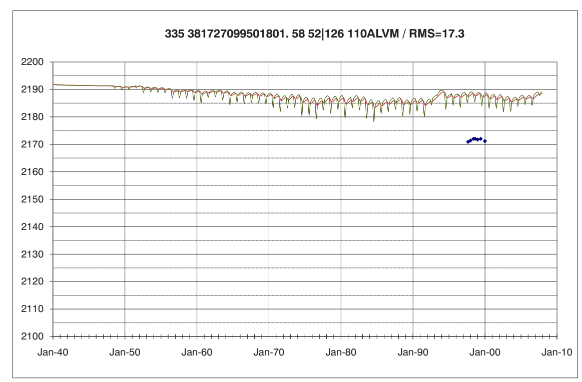

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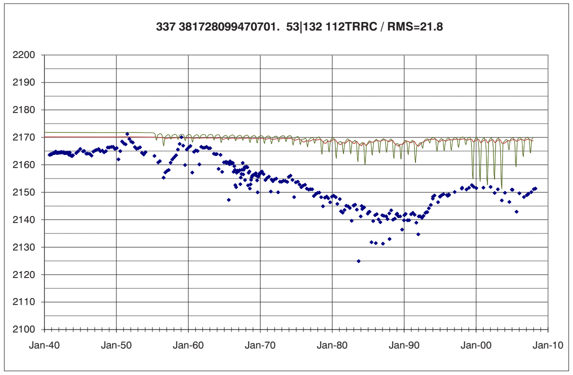

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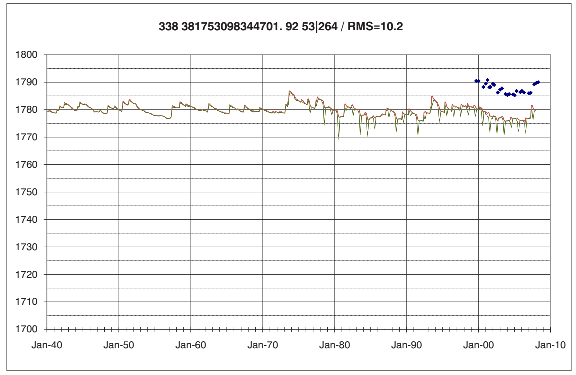

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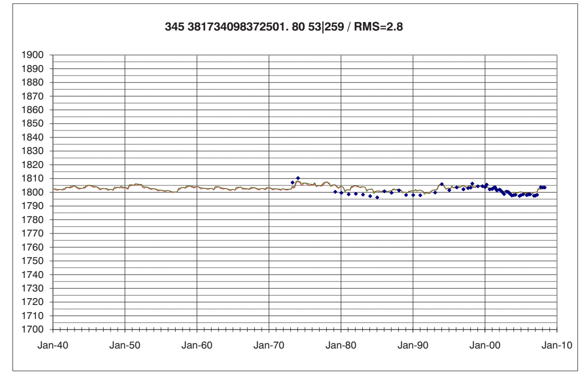

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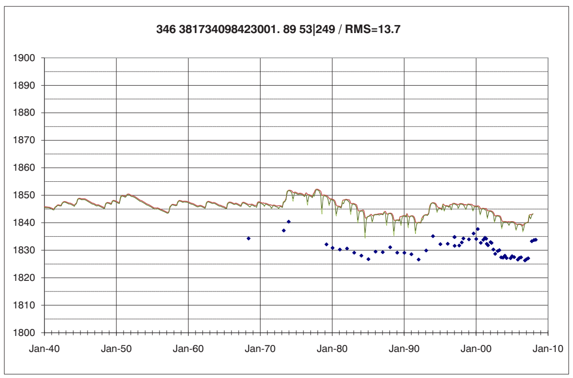

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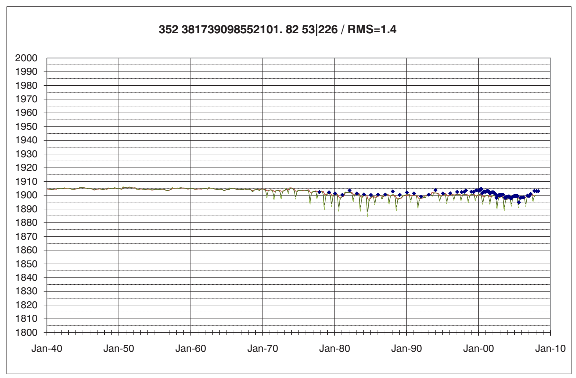

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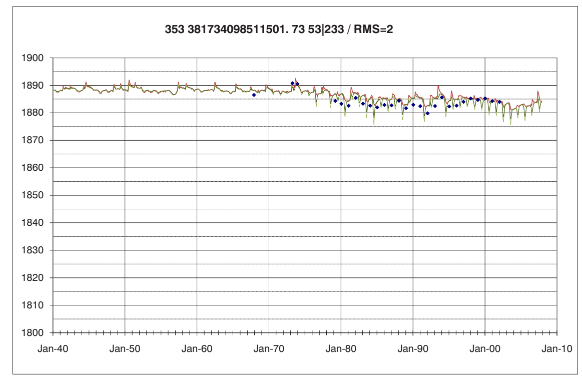

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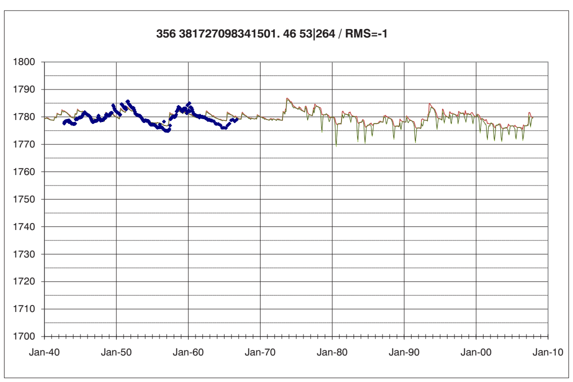

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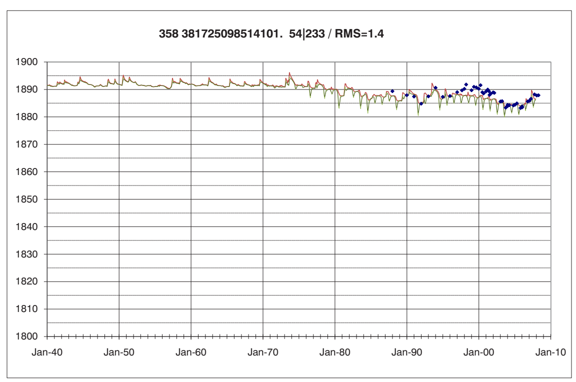

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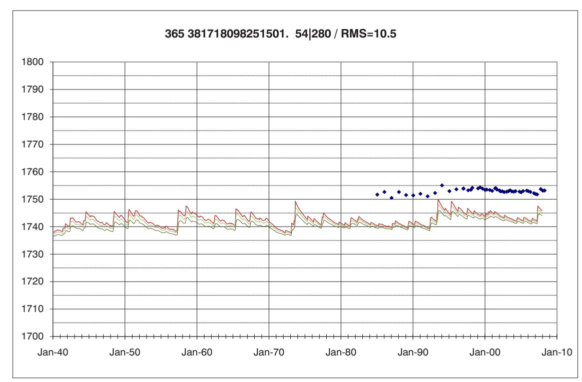

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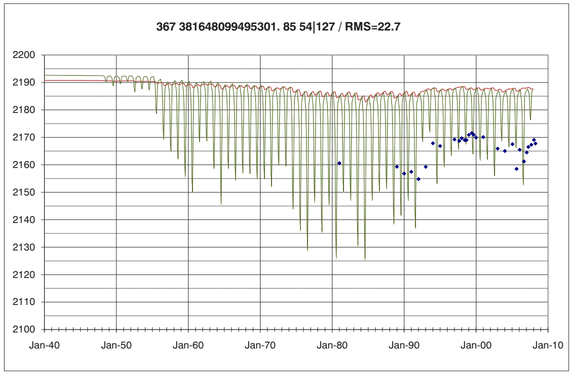

Fig46ProcWL.xlsb
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BALLEAU GROUNDWATER, INC.

GMD #5

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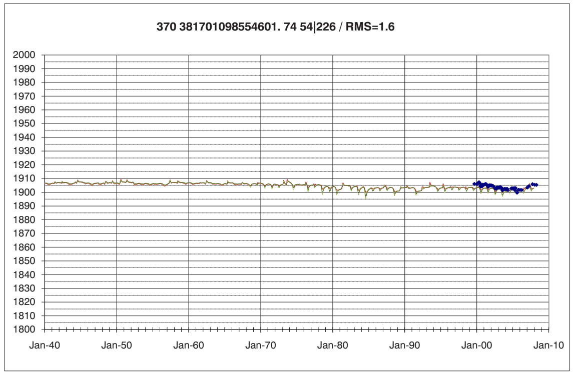

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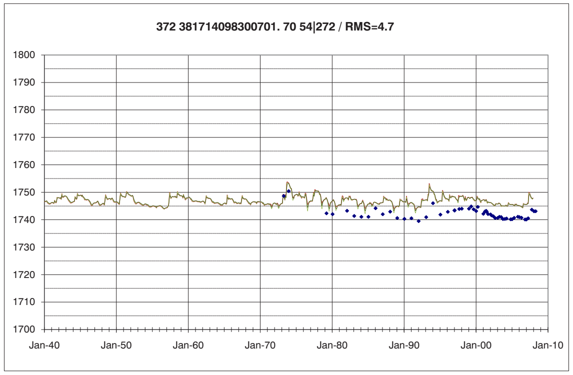

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BALLEAU GROUNDWATER, INC.

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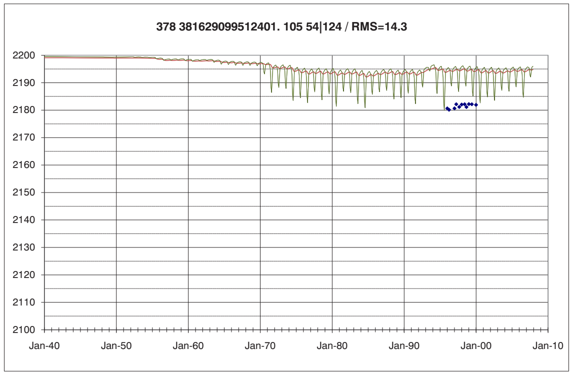

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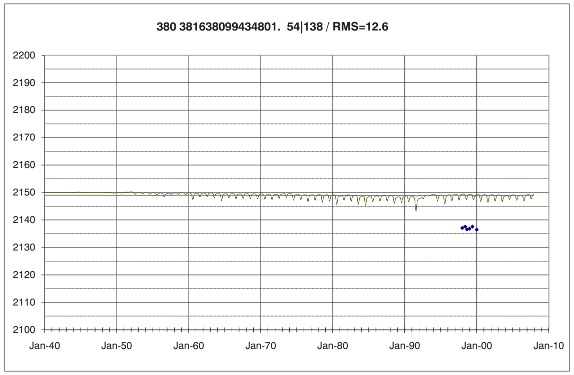

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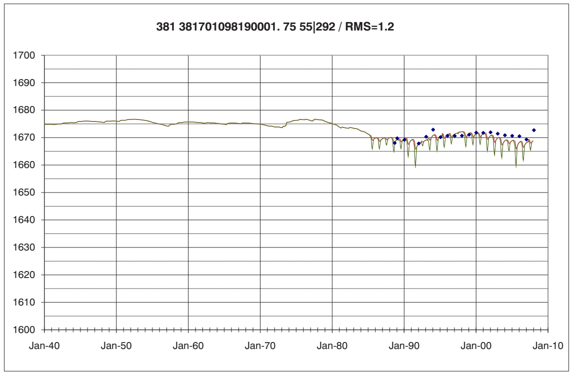

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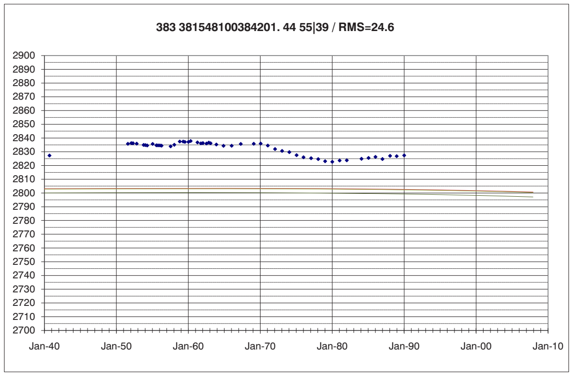

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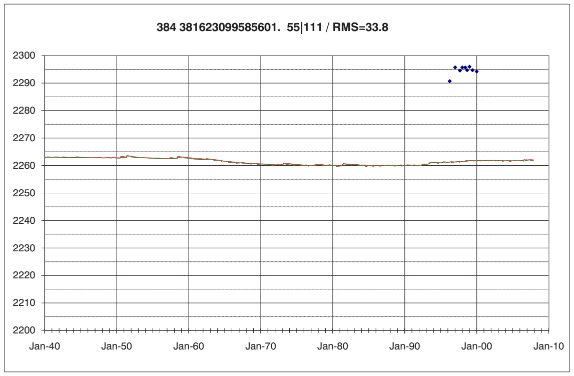

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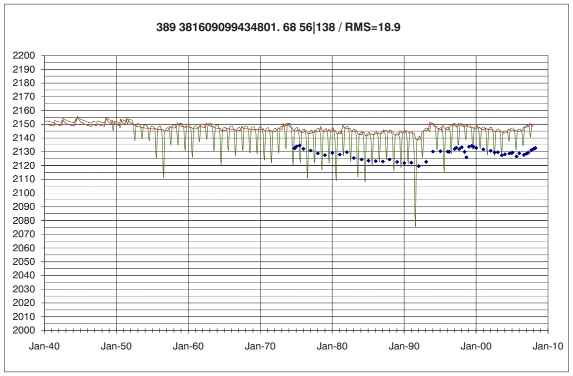

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GMD #5

MODEL

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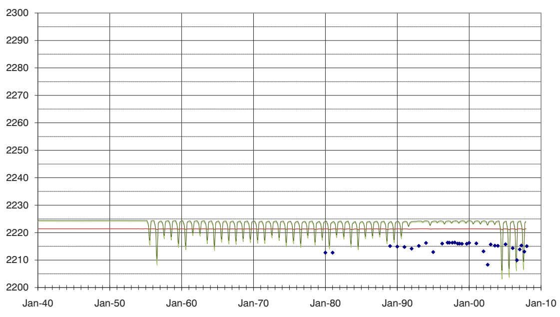

BALLEAU GROUNDWATER, INC.

GMD #5

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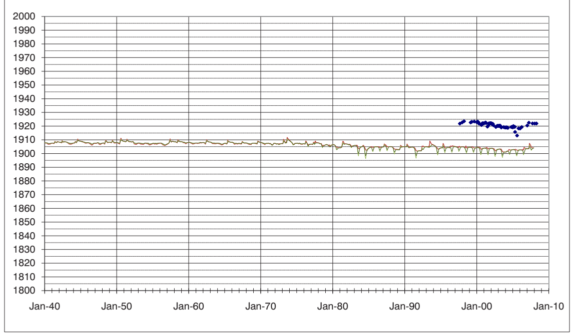

BALLEAU GROUNDWATER, INC.

GMD #5

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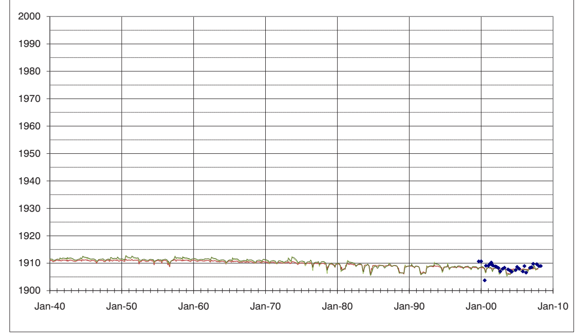

BALLEAU GROUNDWATER, INC.

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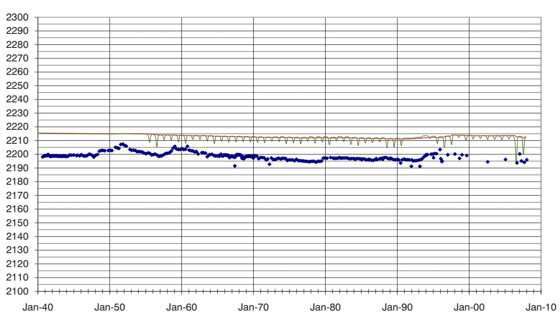

BALLEAU GROUNDWATER, INC.

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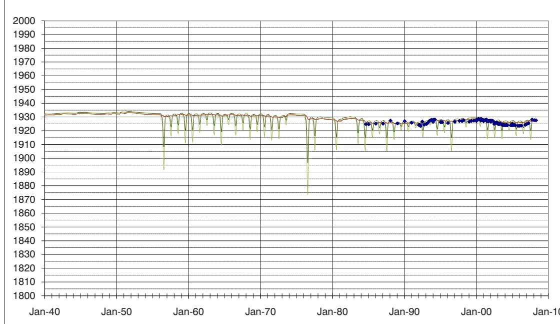

BALLEAU GROUNDWATER, INC.

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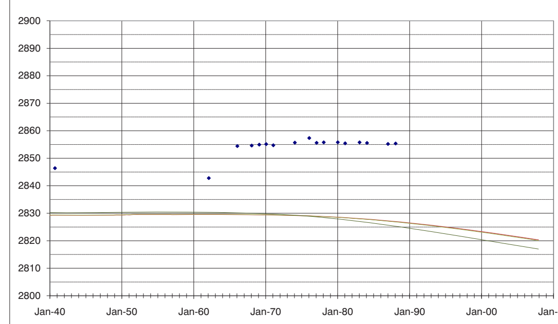

BALLEAU GROUNDWATER, INC.

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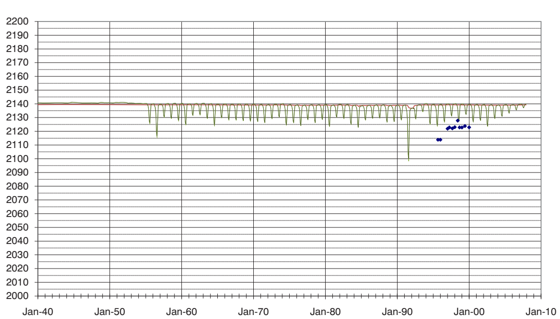

BALLEAU GROUNDWATER, INC.

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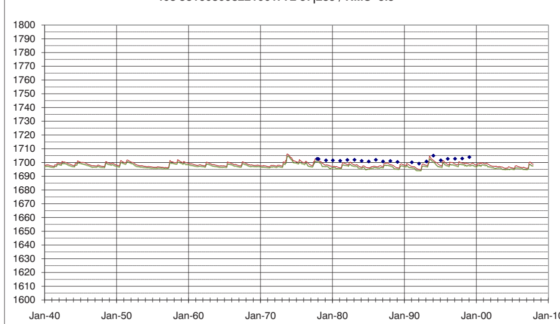

BALLEAU GROUNDWATER, INC.

GMD #5

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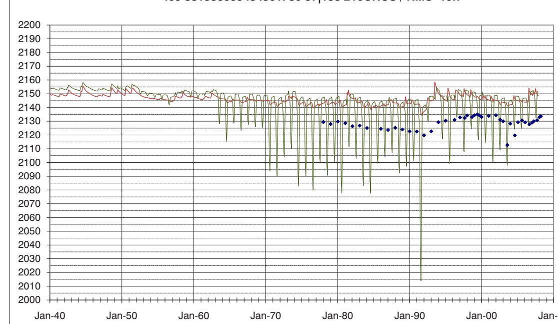

BALLEAU GROUNDWATER, INC.

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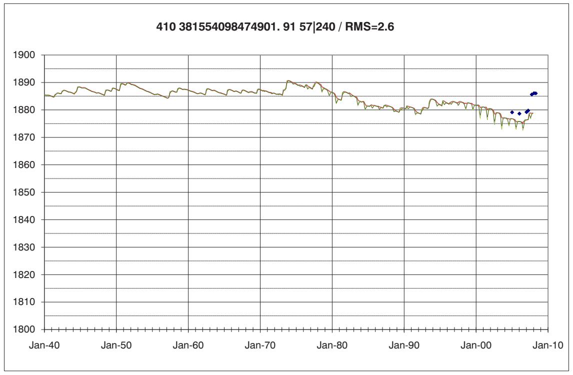

Fig46ProcWL.xlsb
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BALLEAU GROUNDWATER, INC.

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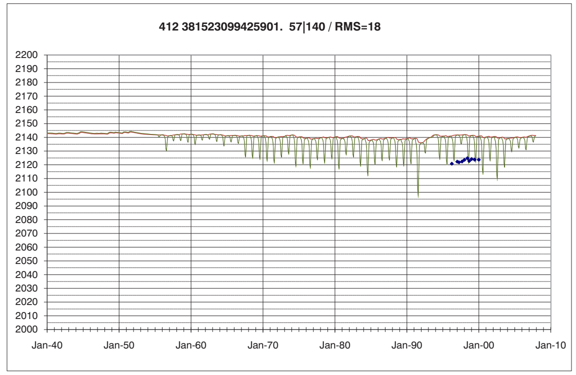

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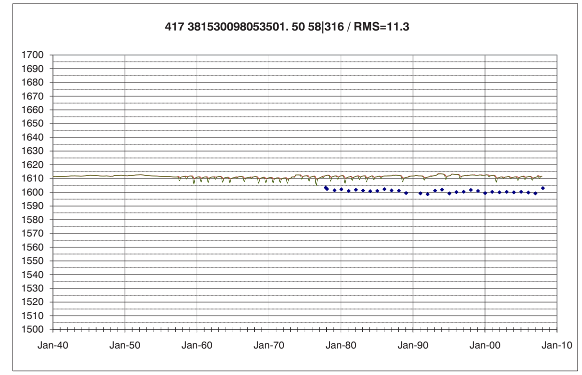

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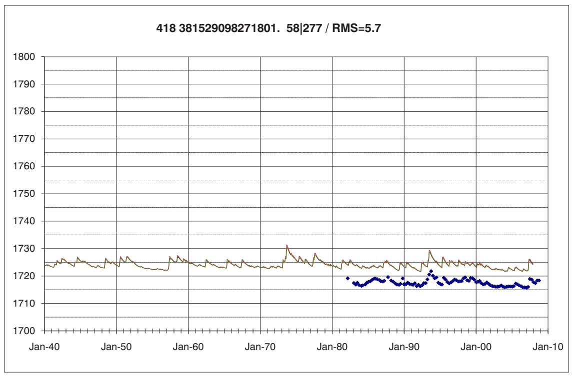

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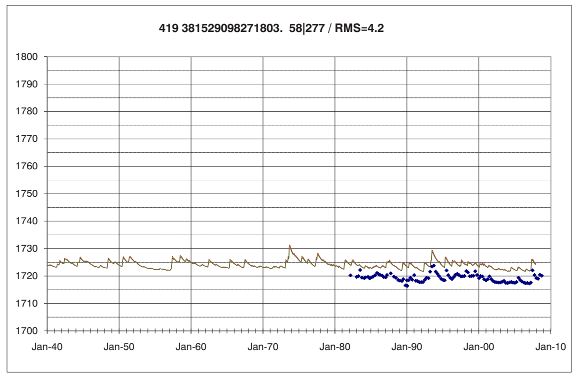

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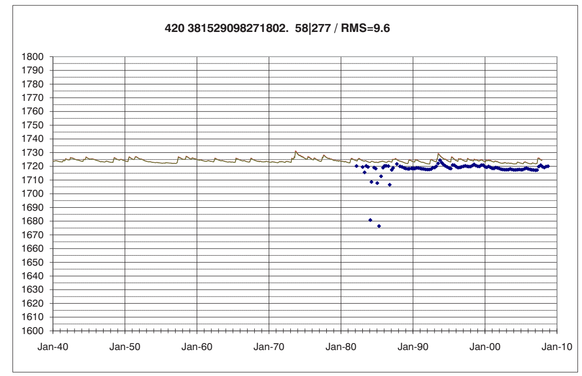

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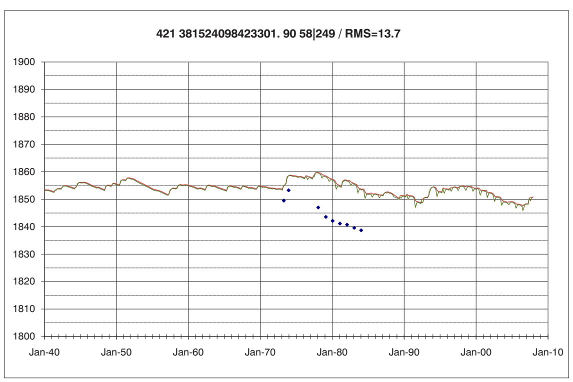

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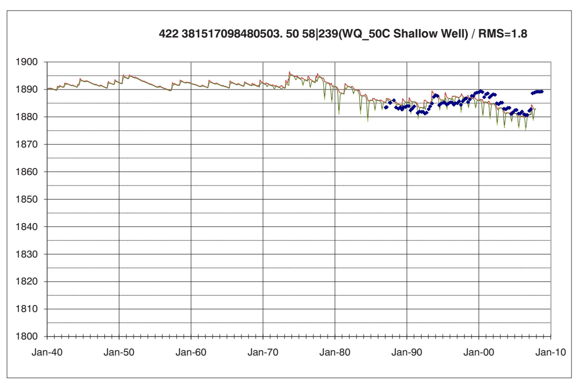

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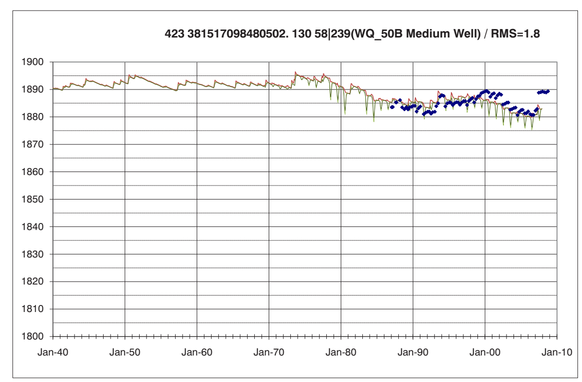

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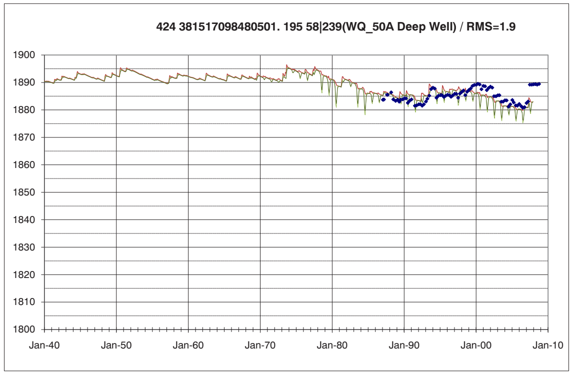

BALLEAU GROUNDWATER, INC.

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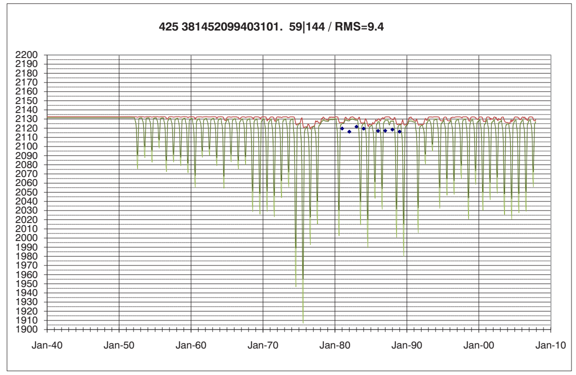

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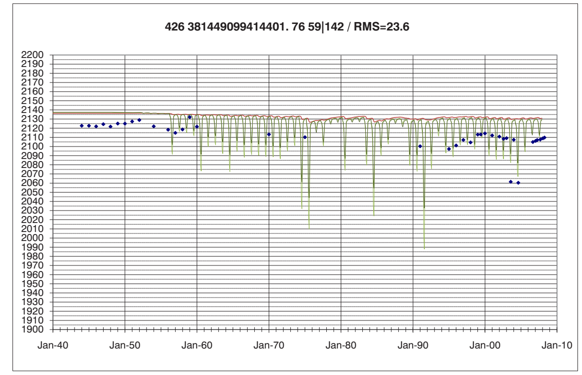

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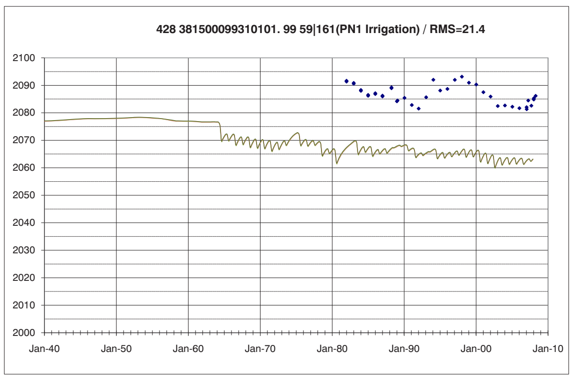

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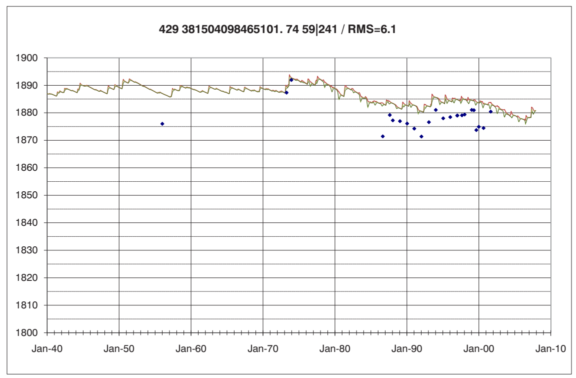

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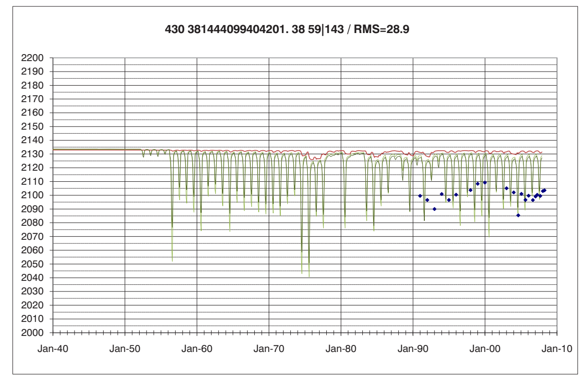

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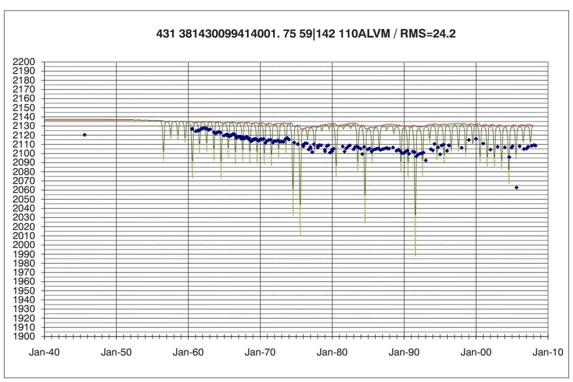

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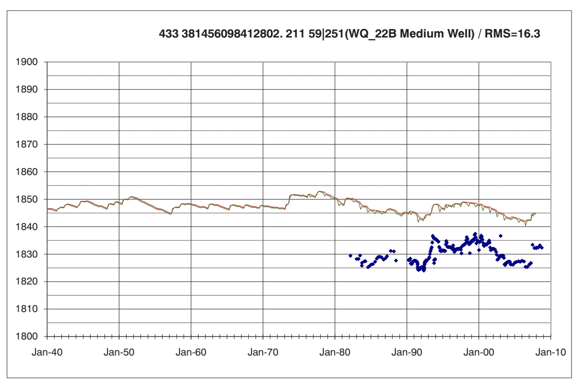

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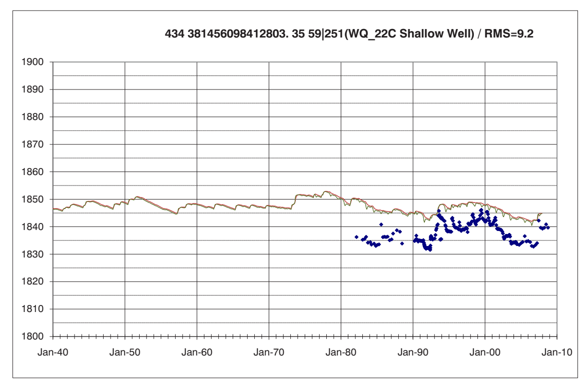

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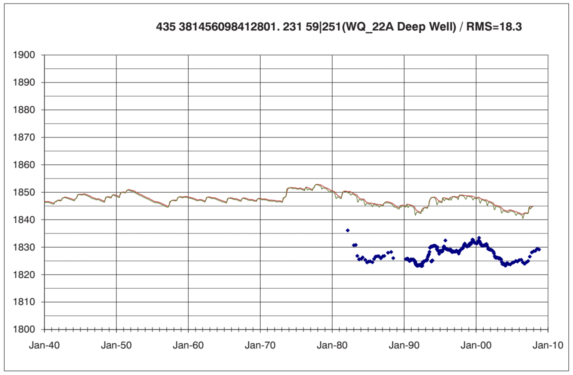

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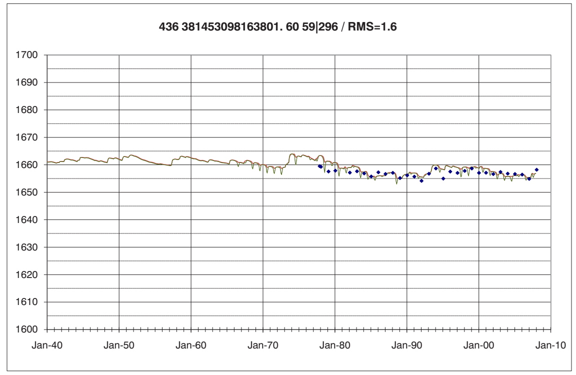

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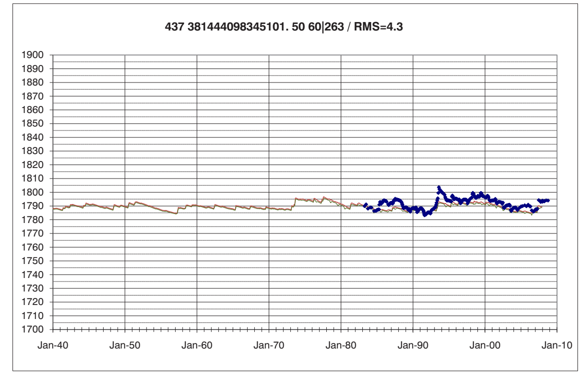

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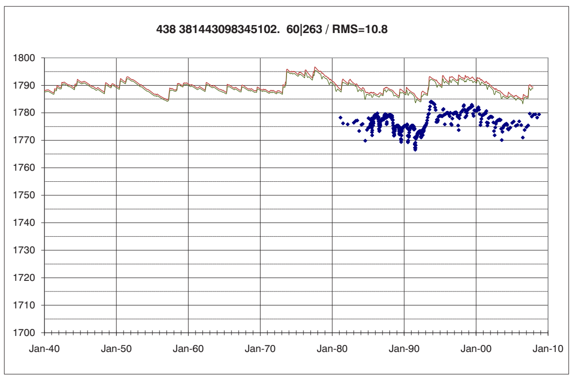

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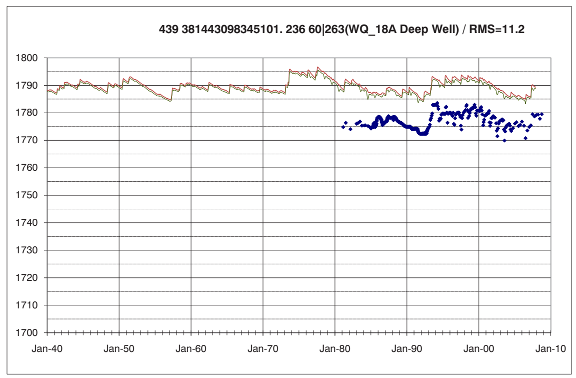

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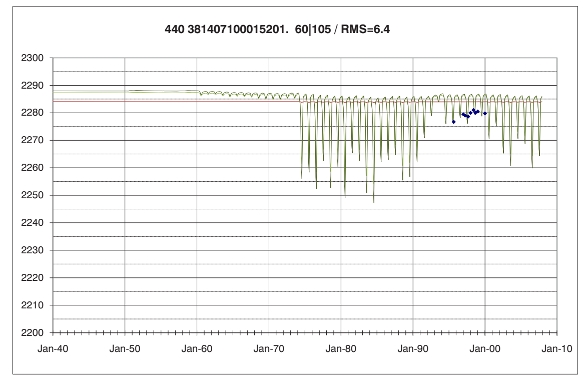

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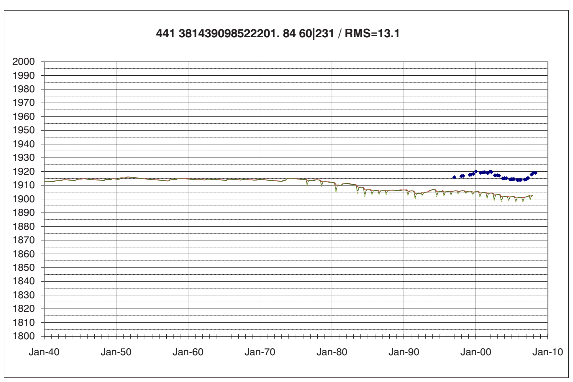

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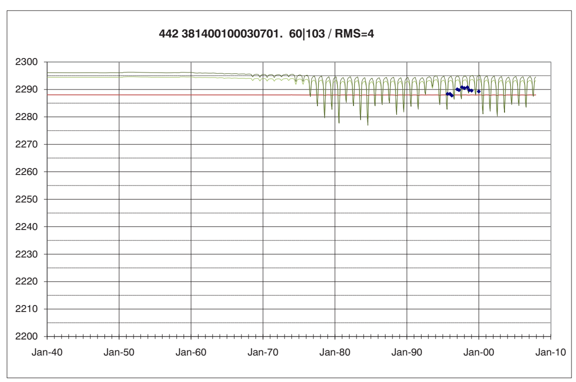

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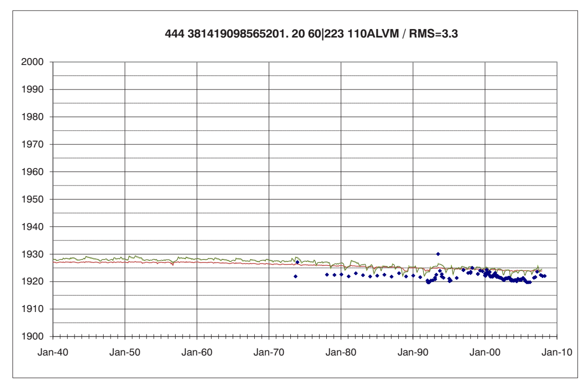

BALLEAU GROUNDWATER, INC.

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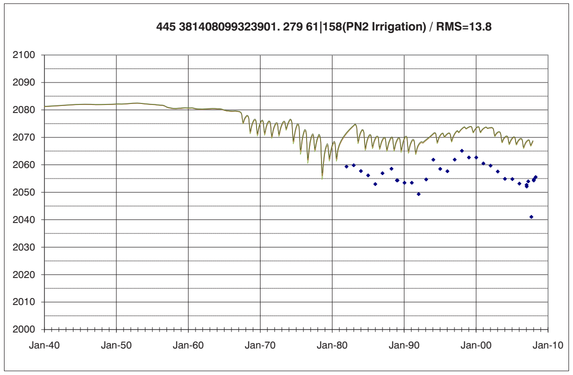

BALLEAU GROUNDWATER, INC.

GMD #5

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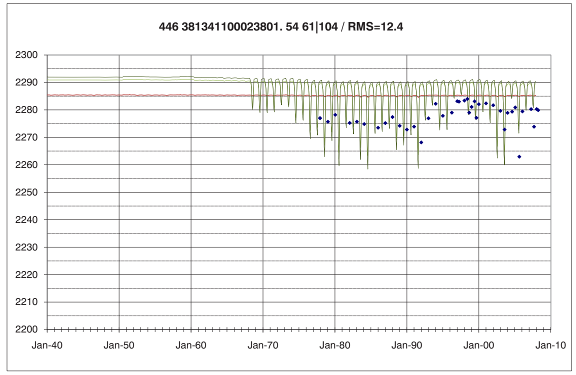

BALLEAU GROUNDWATER, INC.

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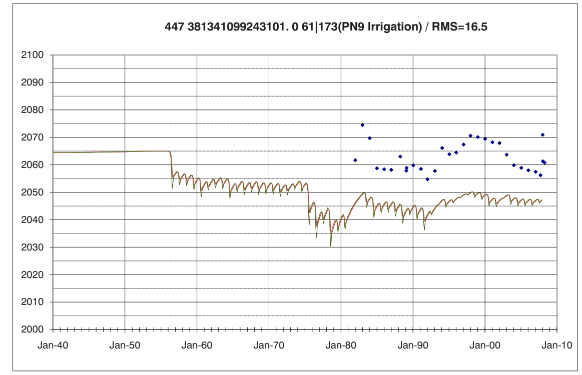

BALLEAU GROUNDWATER, INC.

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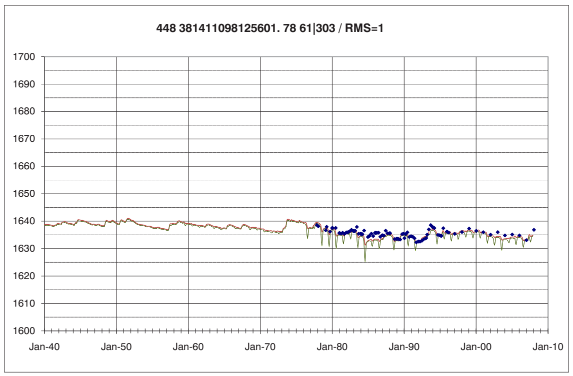

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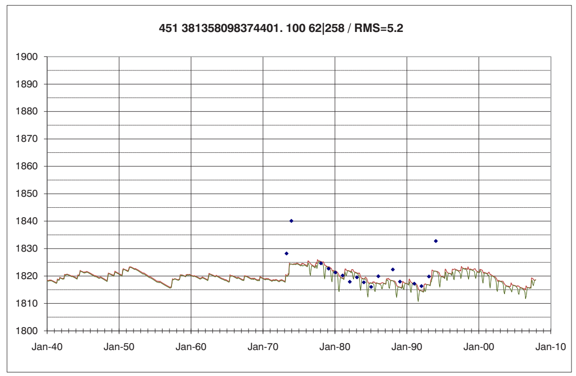

BALLEAU GROUNDWATER, INC.

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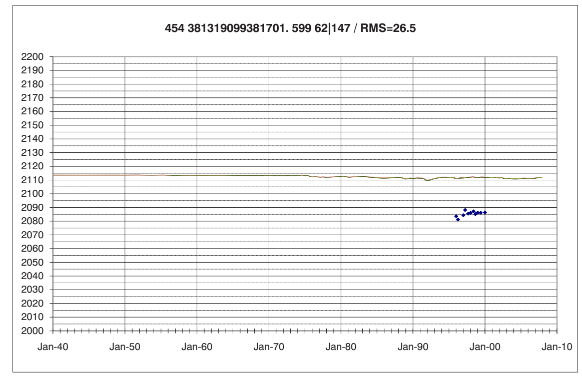

BALLEAU GROUNDWATER, INC.

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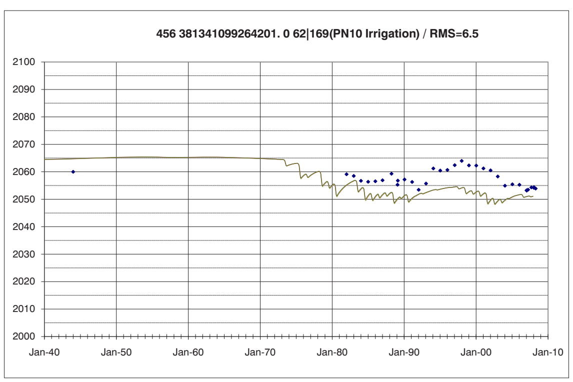

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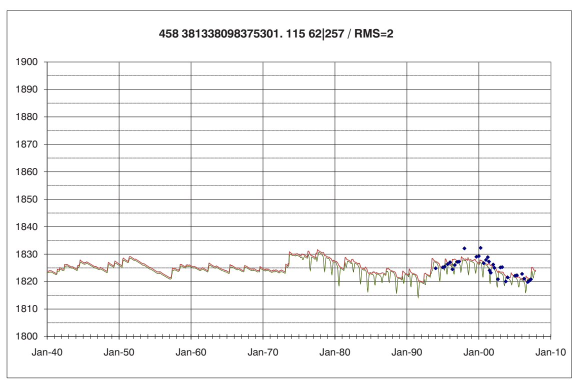

BALLEAU GROUNDWATER, INC.

GMD #5

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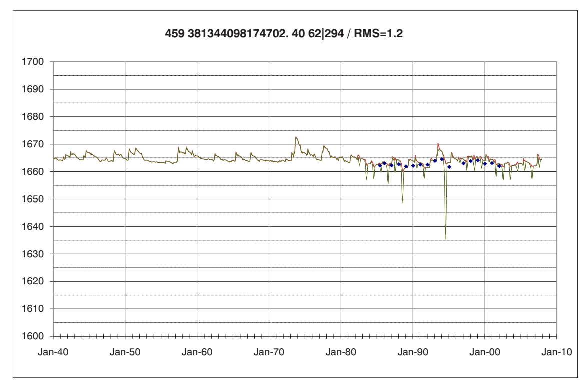

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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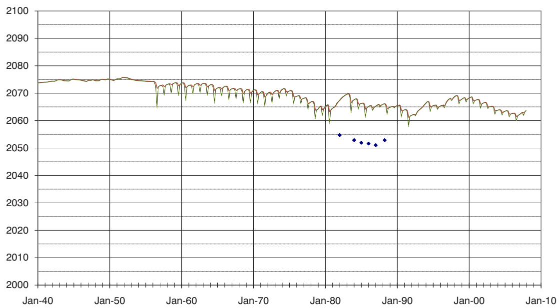

BALLEAU GROUNDWATER, INC.

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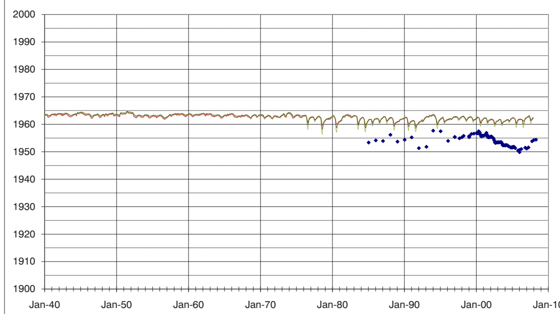

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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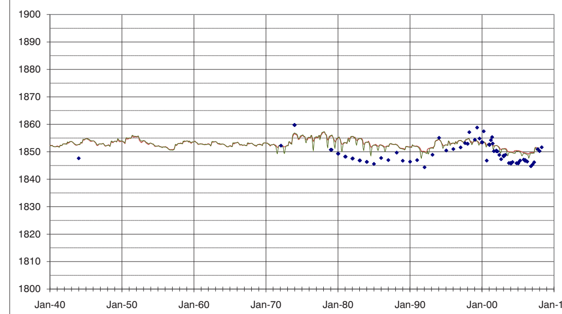

BALLEAU GROUNDWATER, INC.

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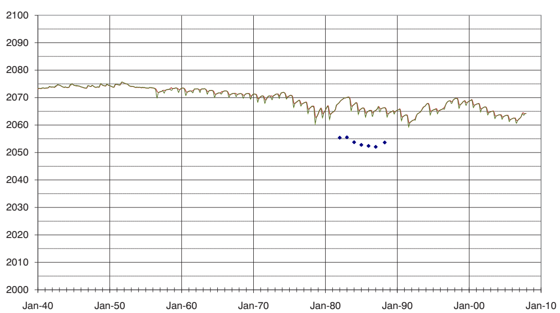

BALLEAU GROUNDWATER, INC.

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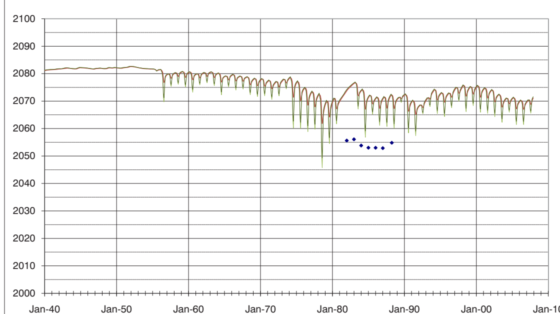

BALLEAU GROUNDWATER, INC.

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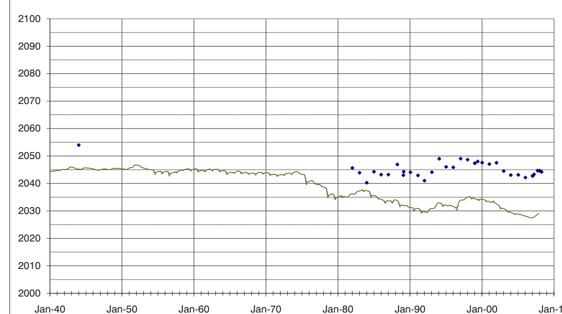

BALLEAU GROUNDWATER, INC.

GMD #5

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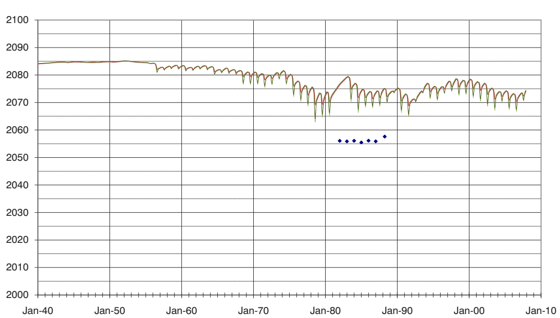

BALLEAU GROUNDWATER, INC.

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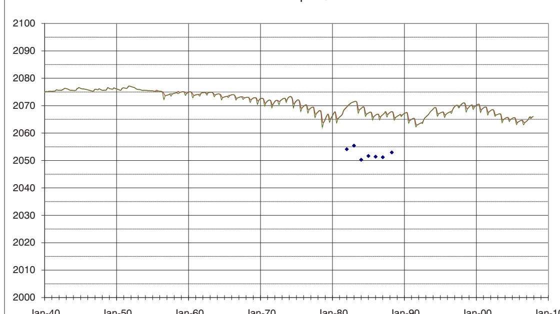

BALLEAU GROUNDWATER, INC.

GMD #5

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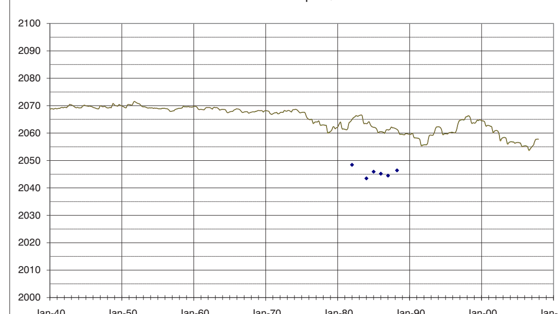

BALLEAU GROUNDWATER, INC.

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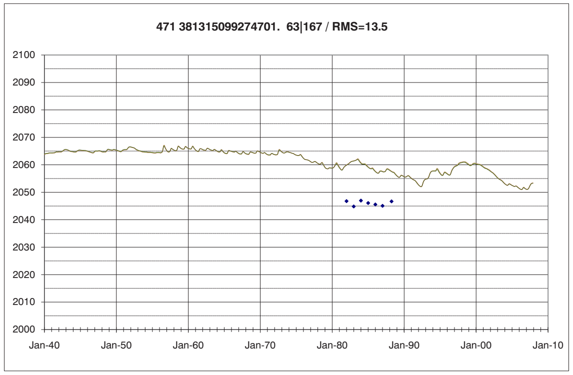

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6/18/2010

BALLEAU GROUNDWATER, INC.

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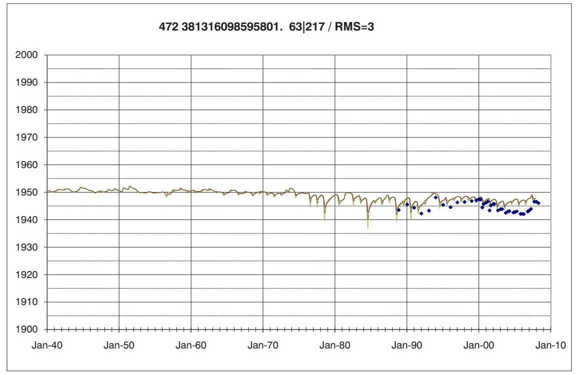

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BALLEAU GROUNDWATER, INC.

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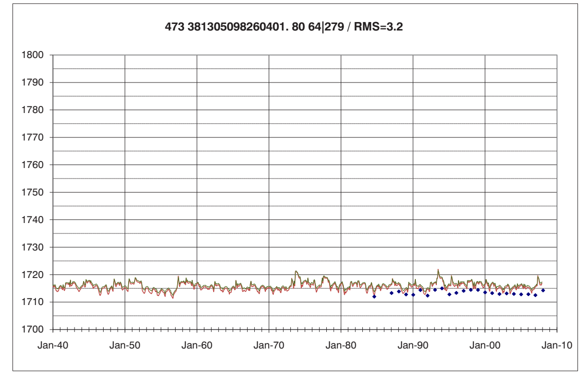

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BALLEAU GROUNDWATER, INC.

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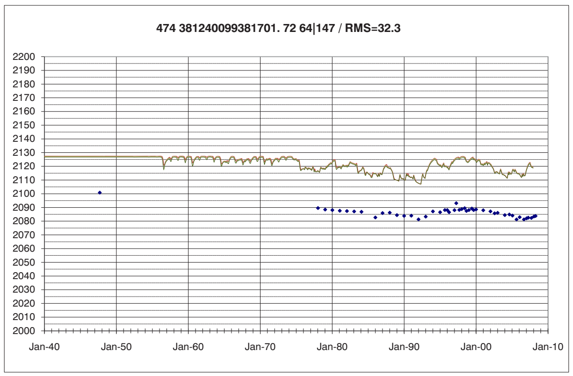

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BALLEAU GROUNDWATER, INC.

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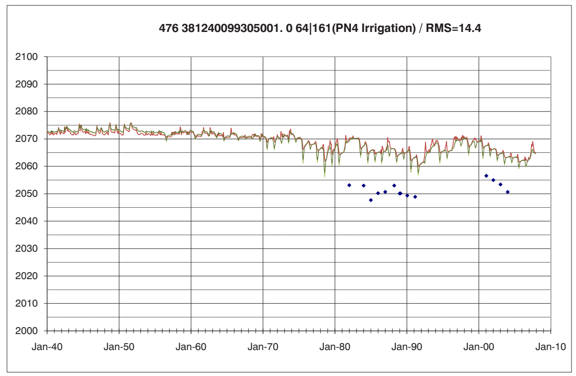

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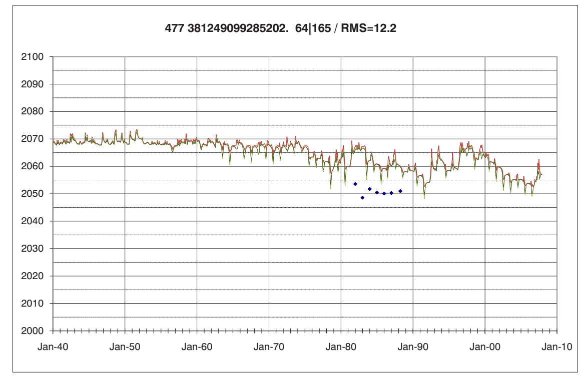

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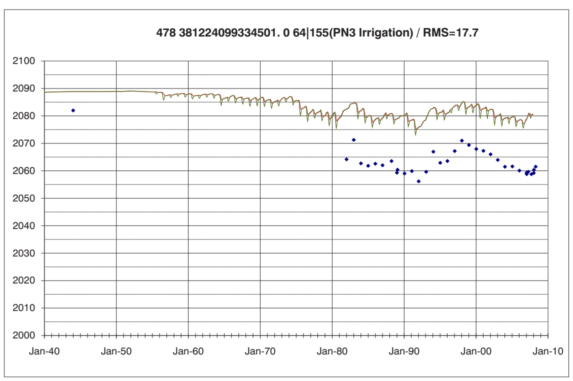

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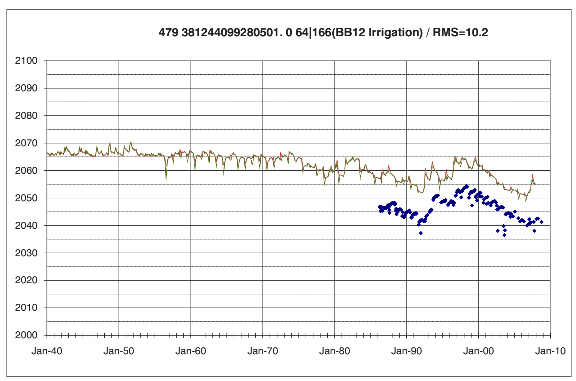

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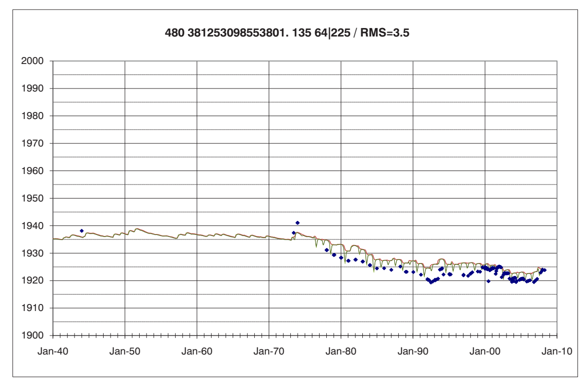

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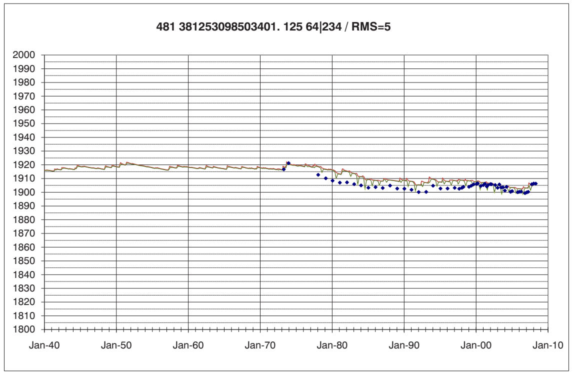

BALLEAU GROUNDWATER, INC.

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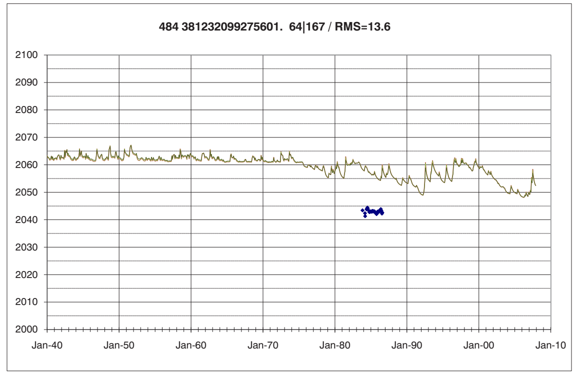

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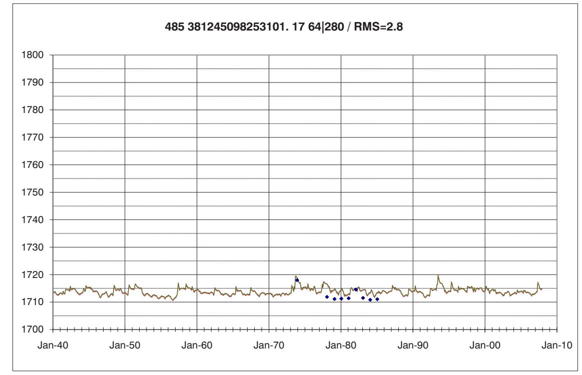

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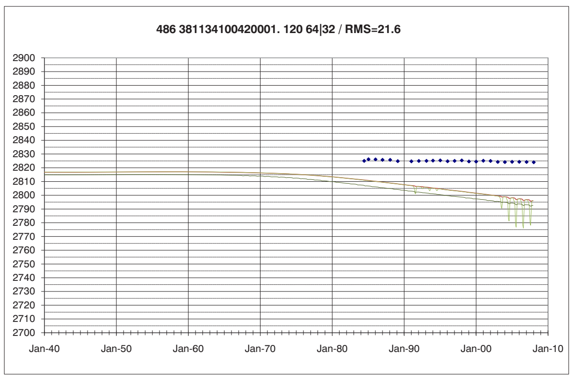

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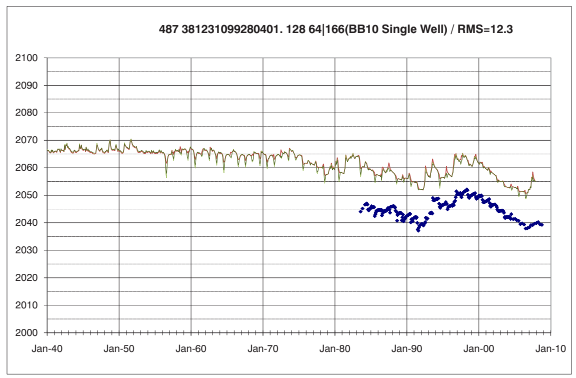

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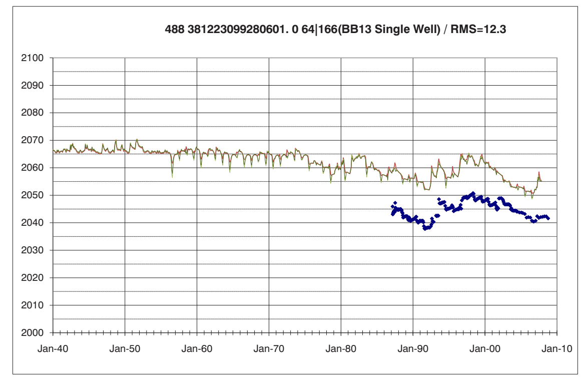

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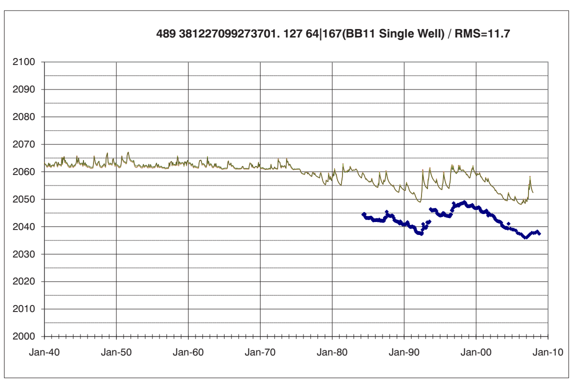

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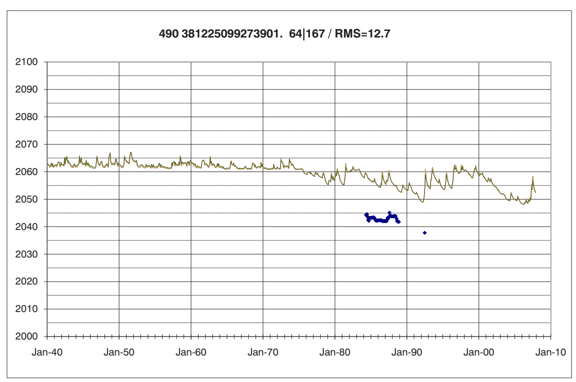

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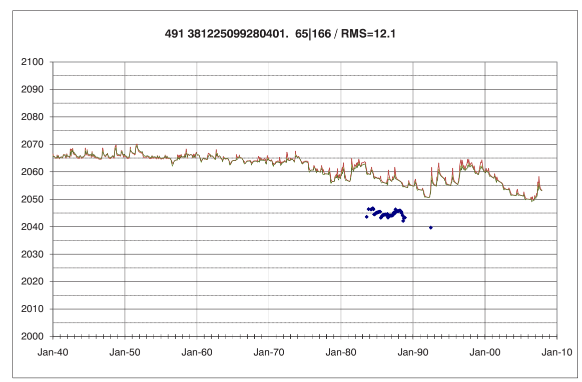

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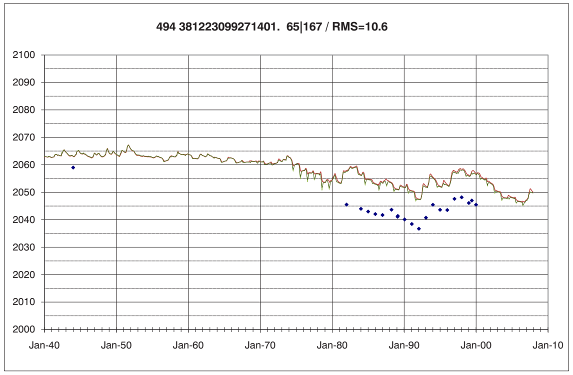

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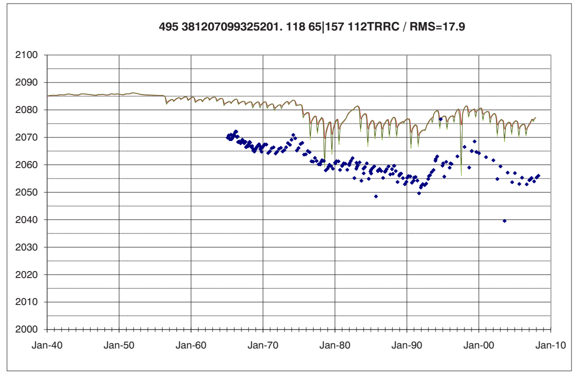

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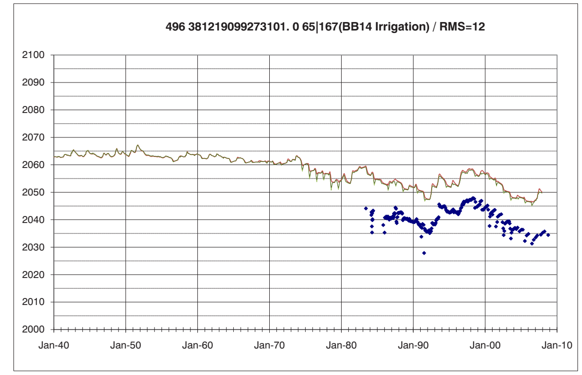

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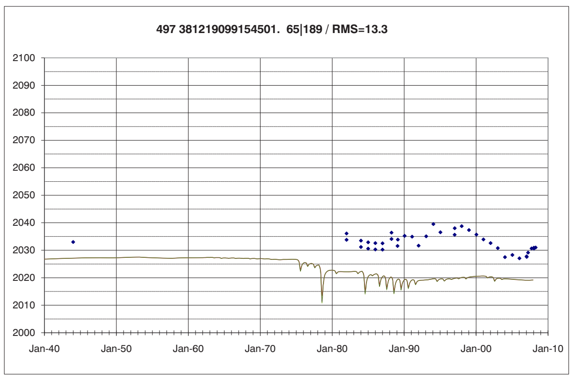

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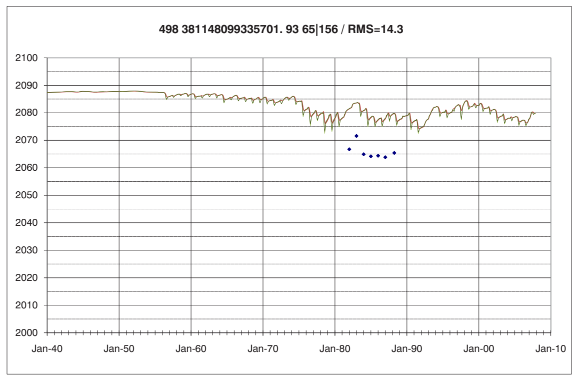

BALLEAU GROUNDWATER, INC.

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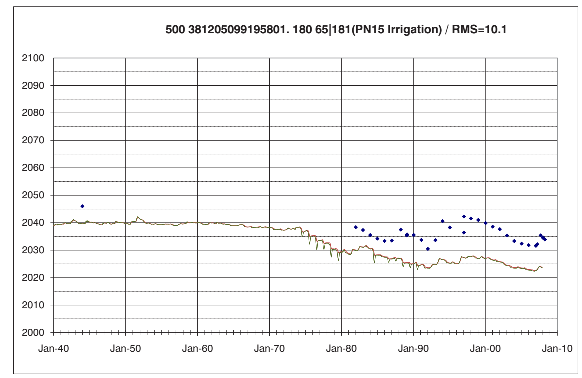

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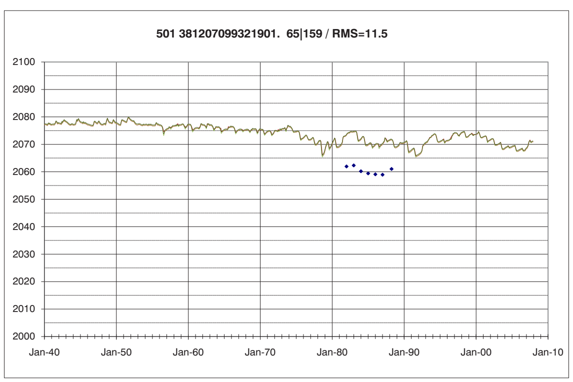

BALLEAU GROUNDWATER, INC.

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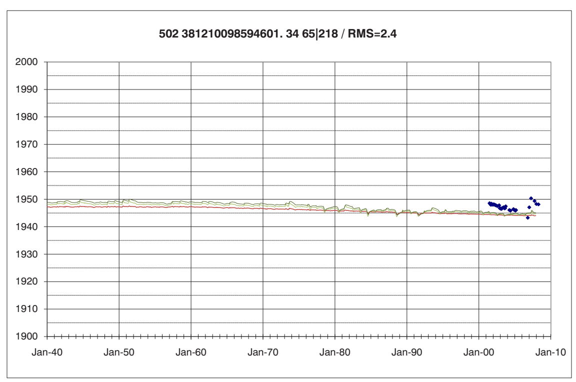

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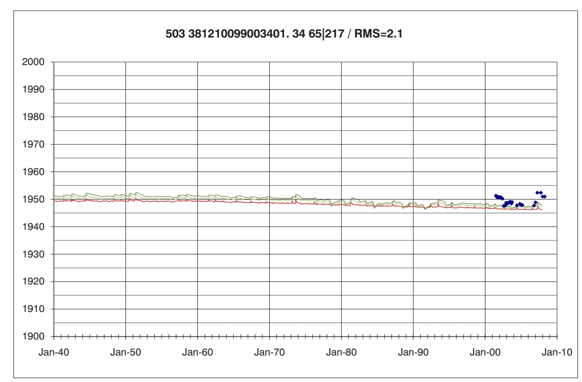

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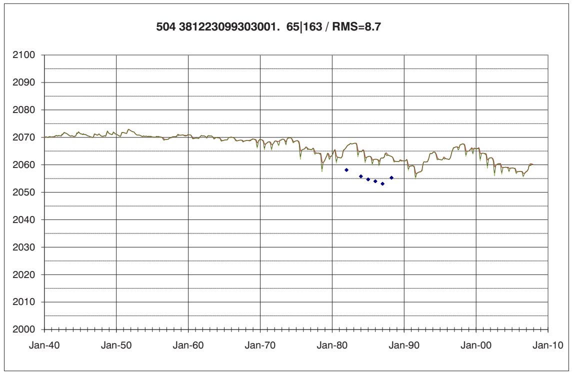

BALLEAU GROUNDWATER, INC.

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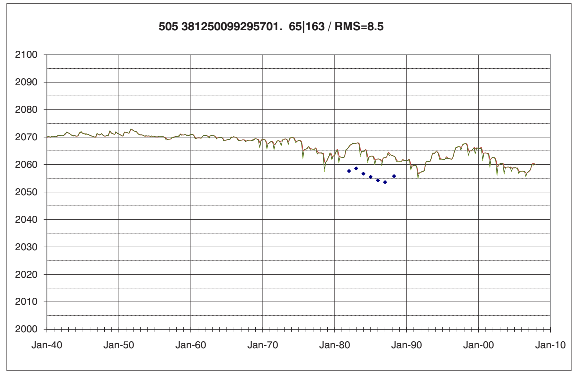

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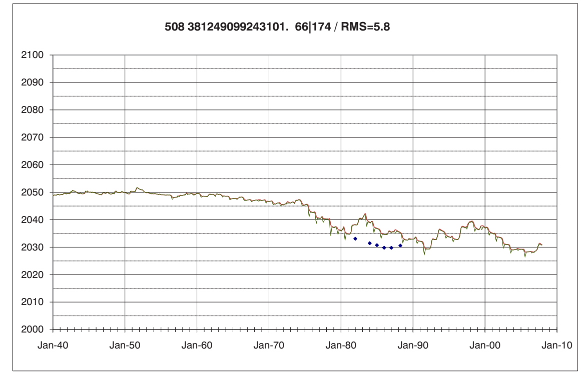

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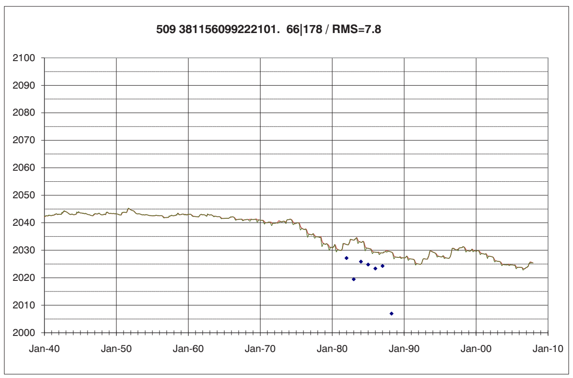

BALLEAU GROUNDWATER, INC.

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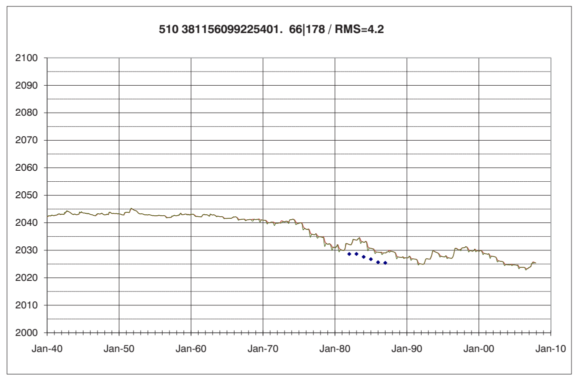

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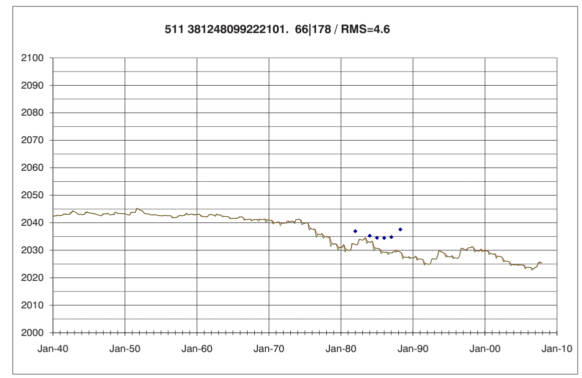

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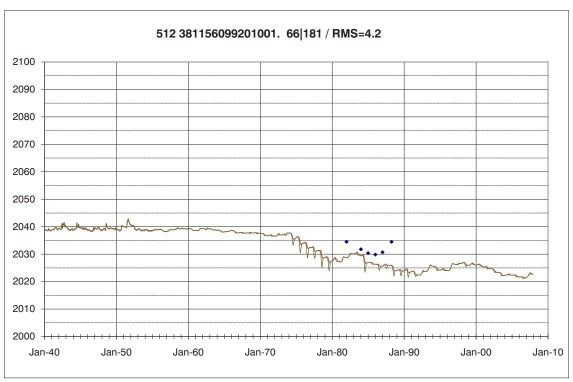

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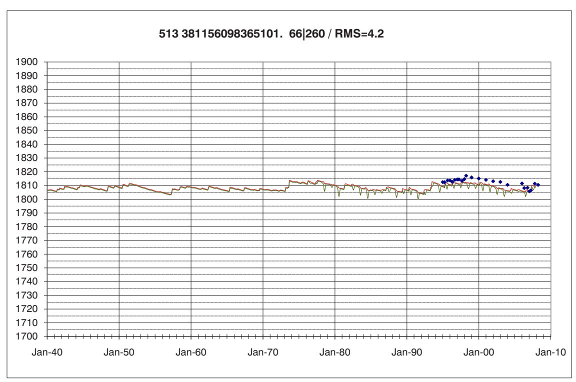

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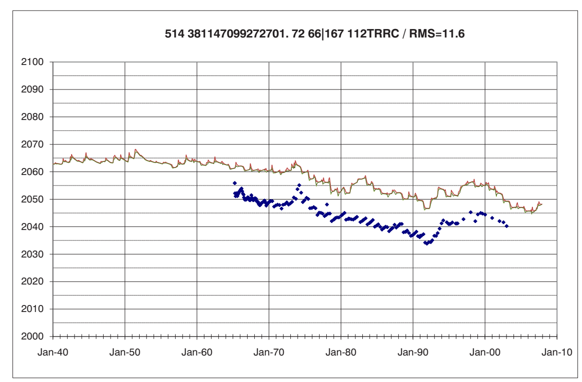

BALLEAU GROUNDWATER, INC.

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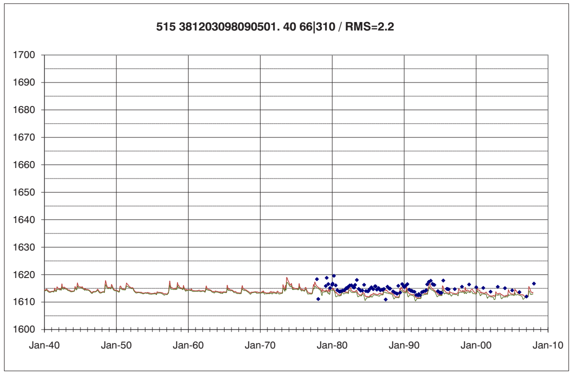

BALLEAU GROUNDWATER, INC.

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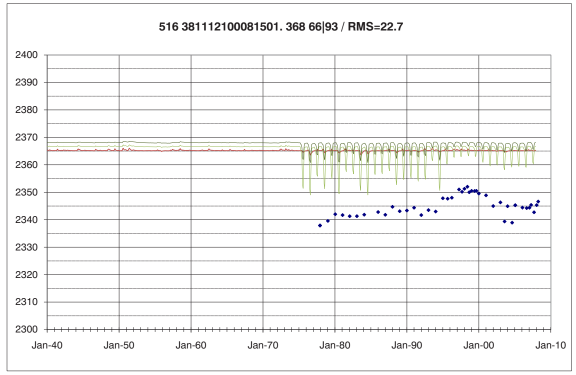

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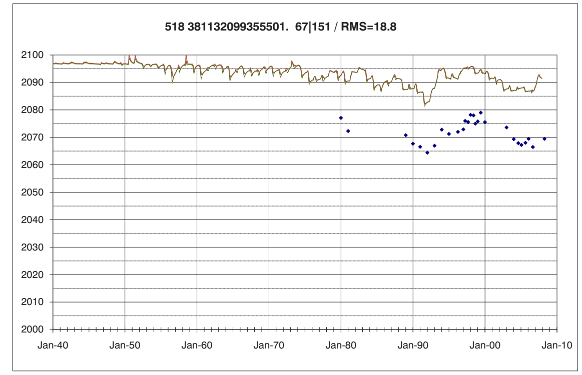

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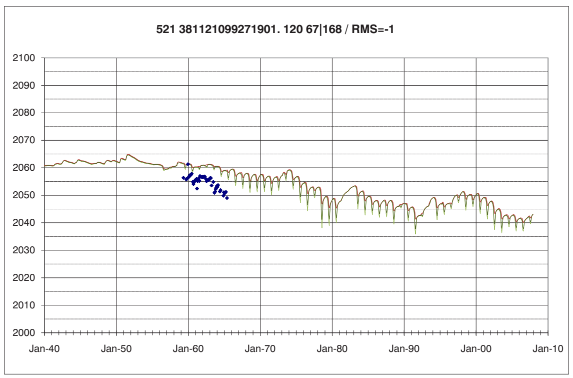

BALLEAU GROUNDWATER, INC.

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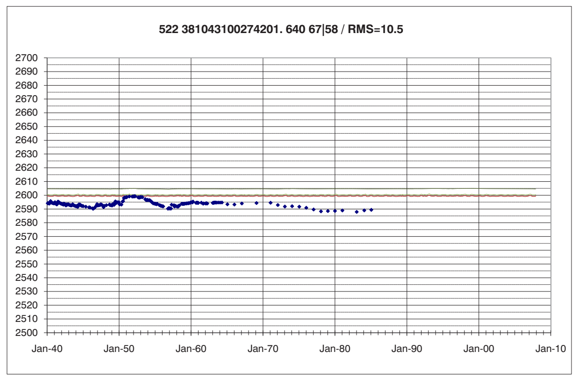

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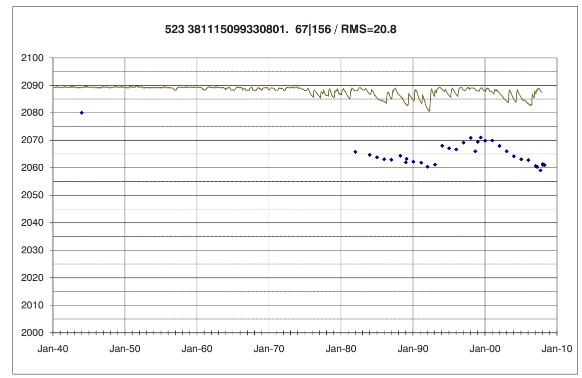

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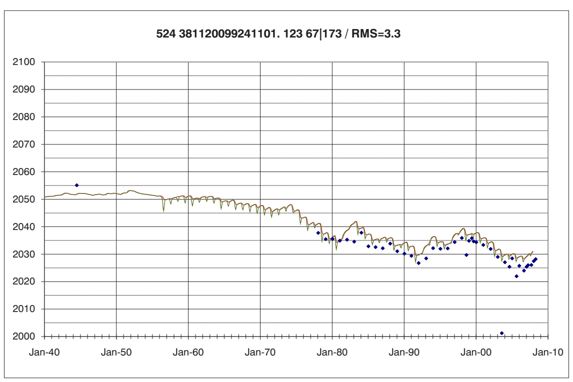

BALLEAU GROUNDWATER, INC.

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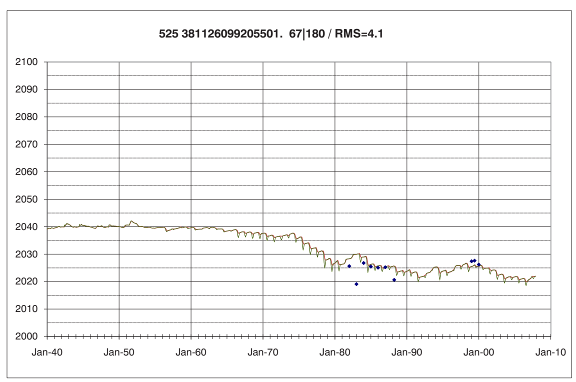

BALLEAU GROUNDWATER, INC.

GMD #5

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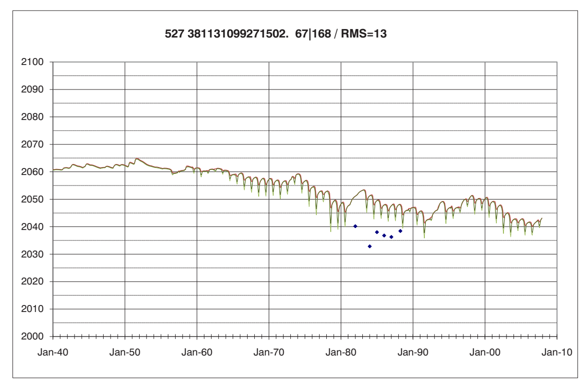

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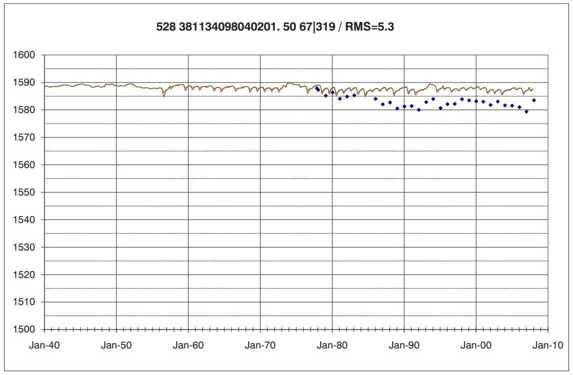

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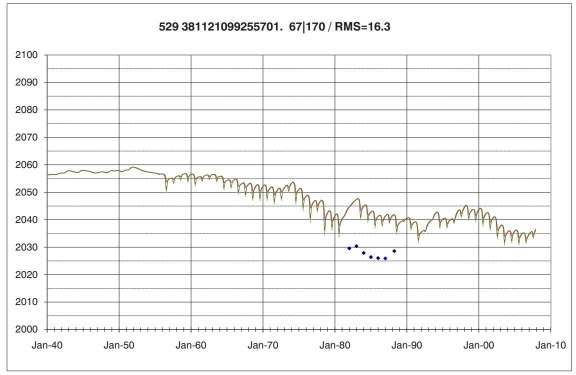

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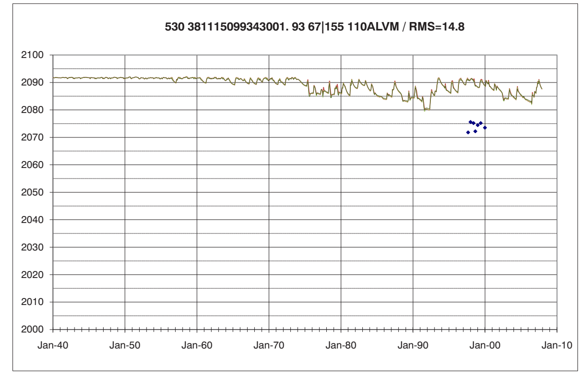

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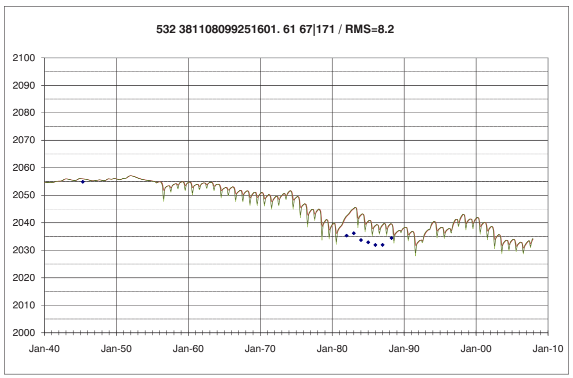

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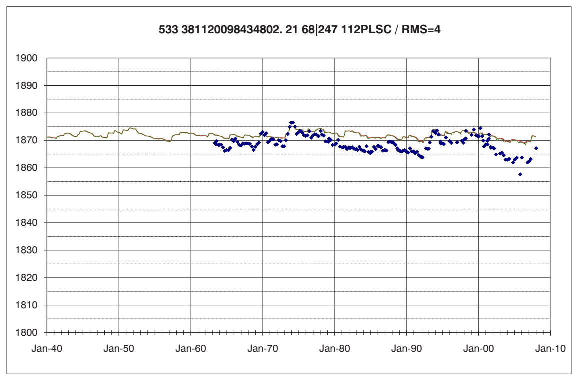

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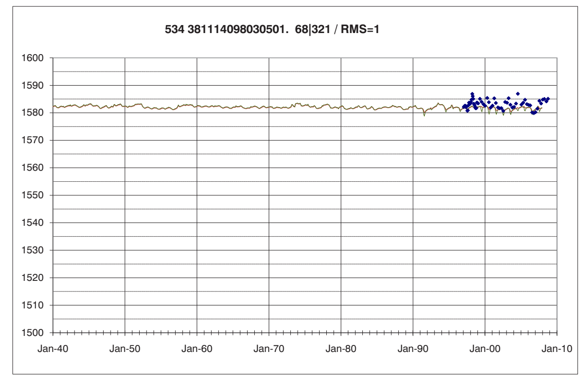

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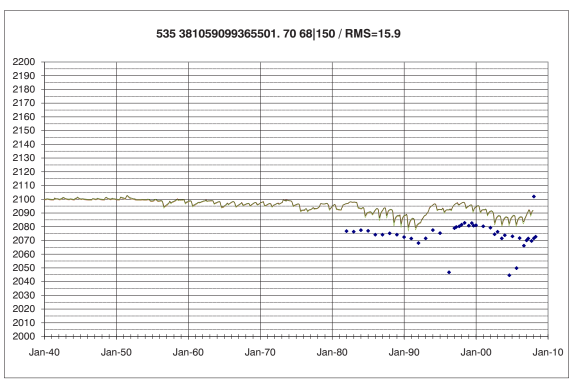

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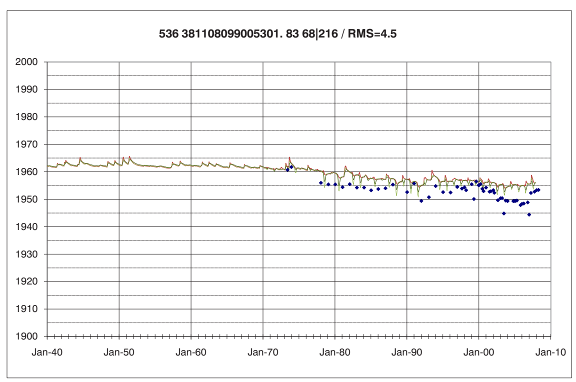

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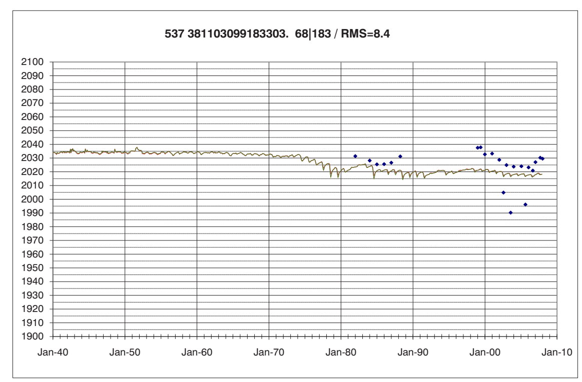

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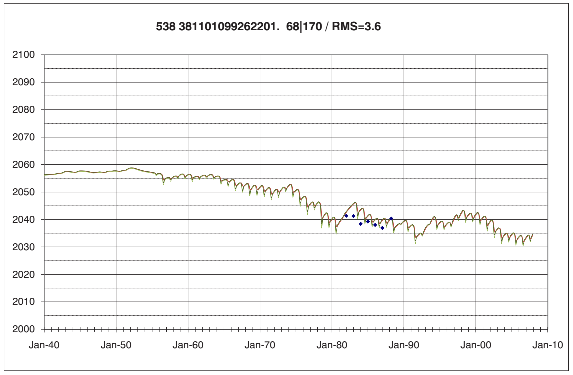

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BALLEAU GROUNDWATER, INC.

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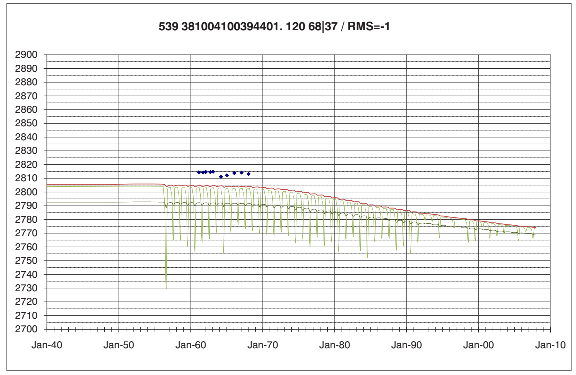

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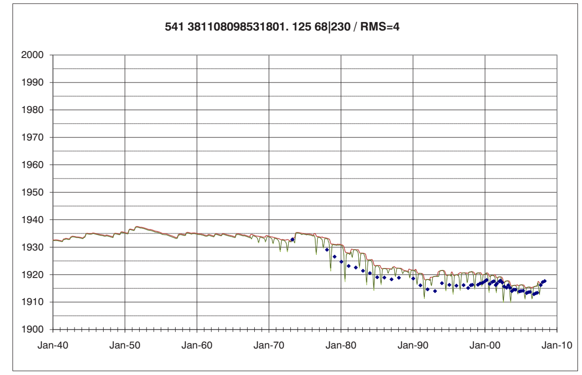

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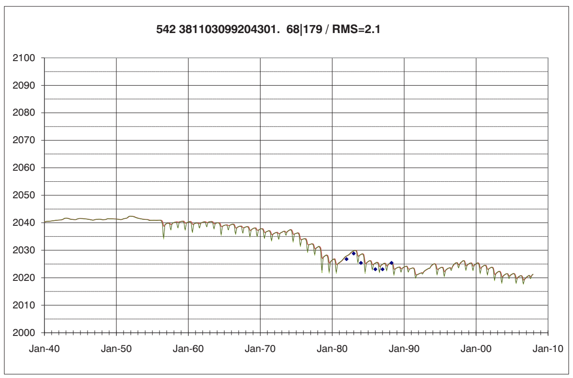

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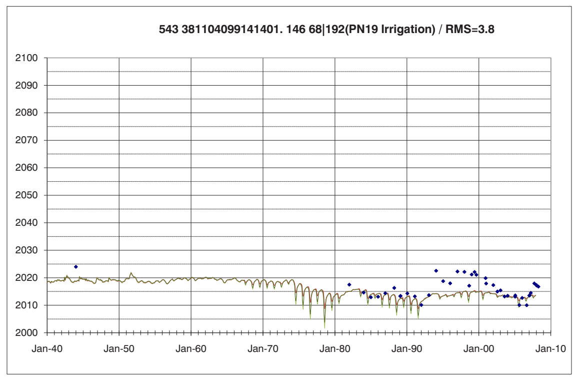

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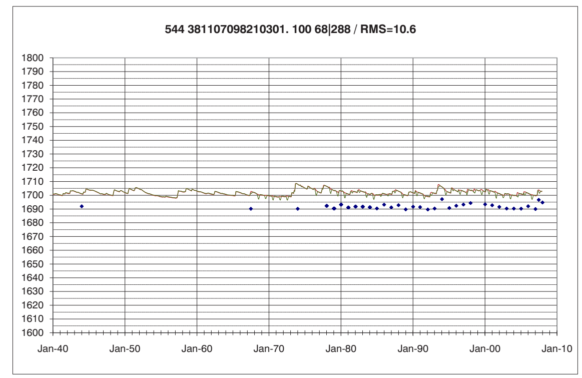

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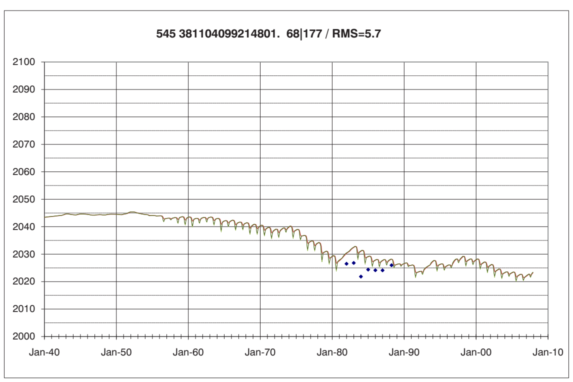

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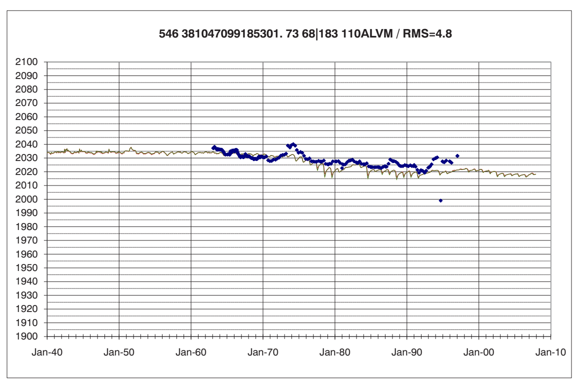

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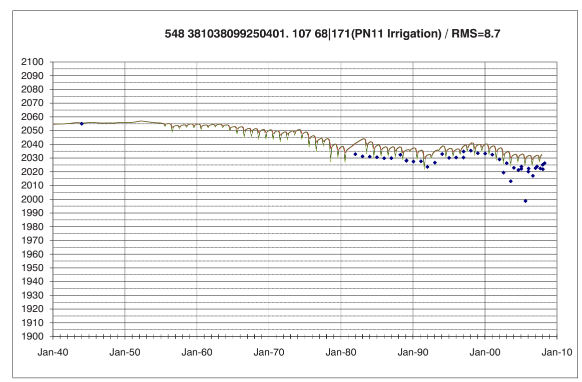

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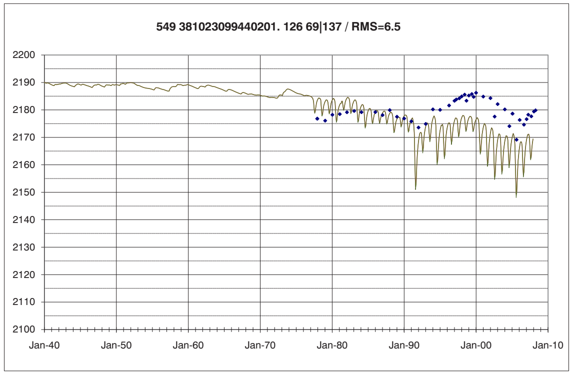

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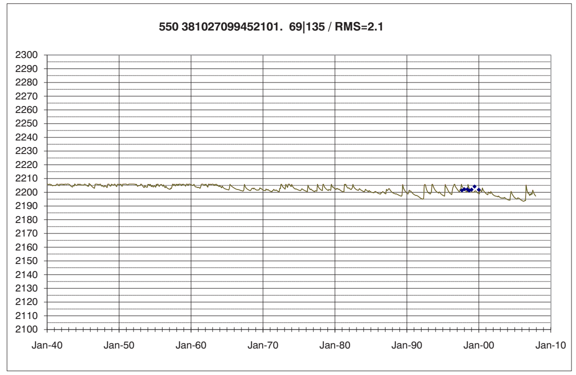

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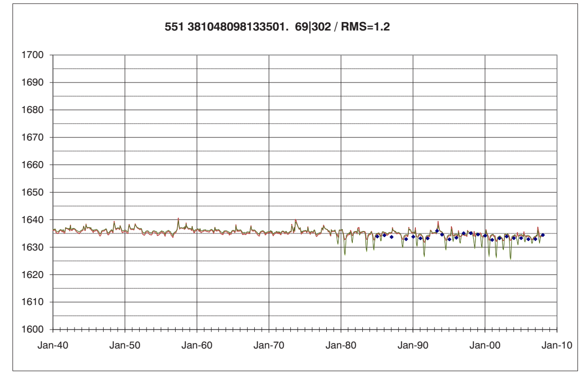

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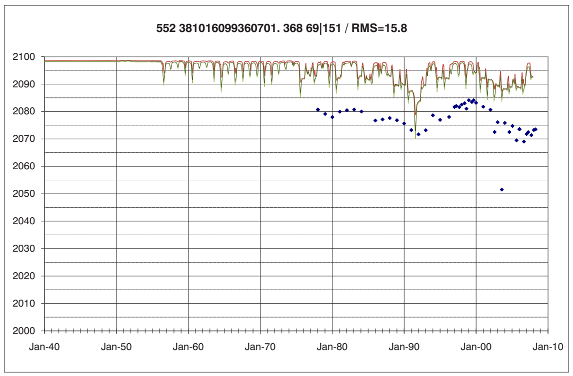

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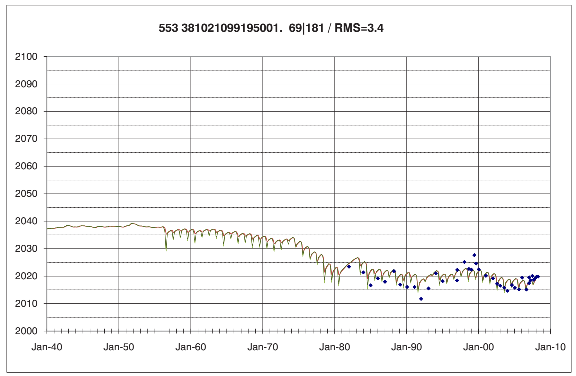

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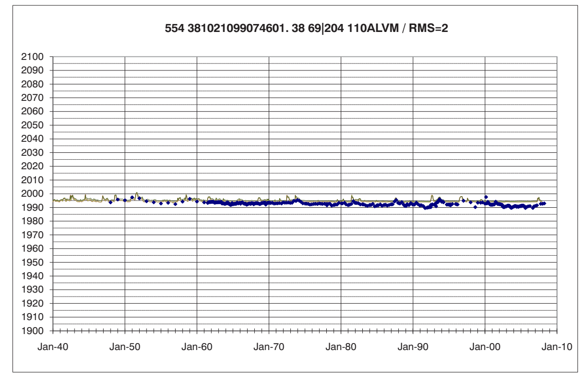

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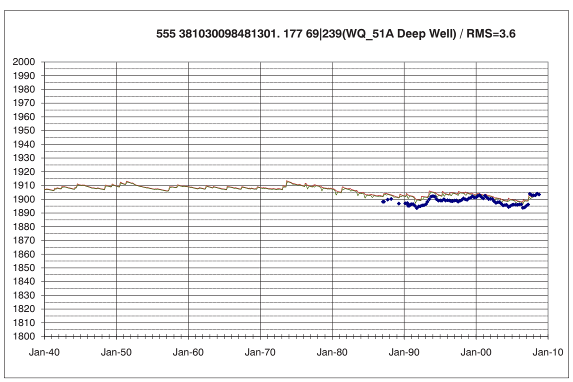

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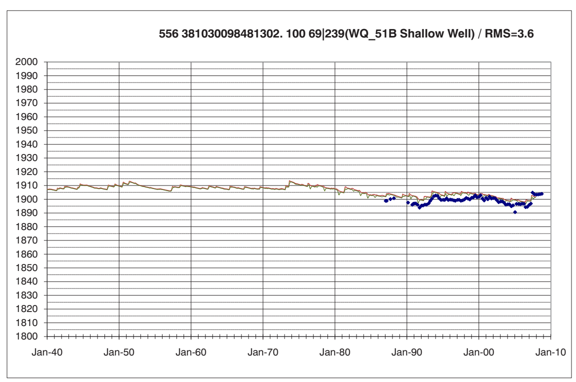

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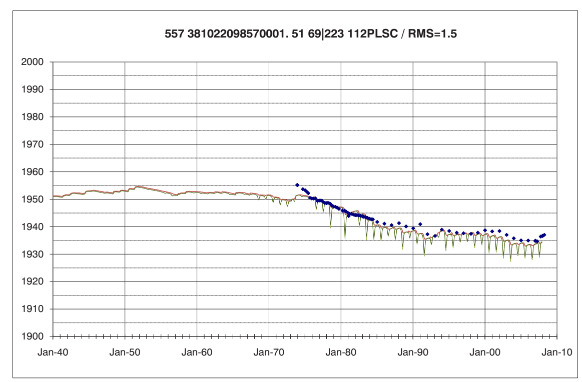

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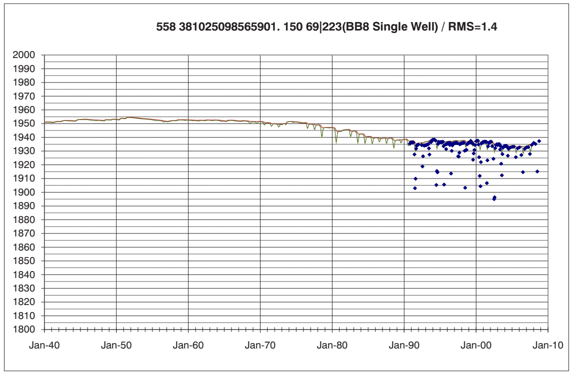

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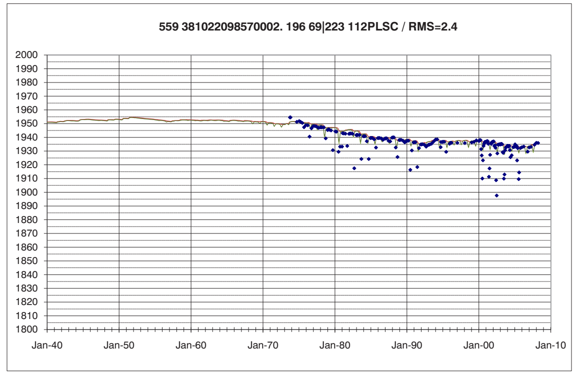

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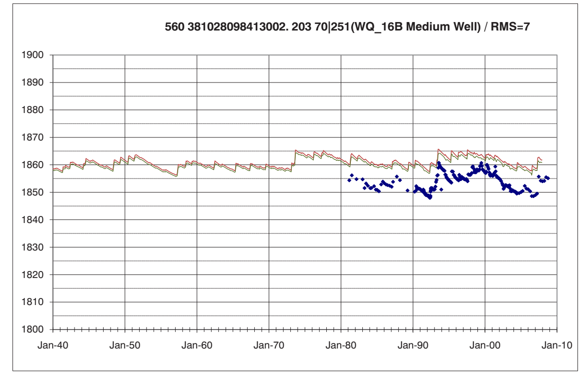

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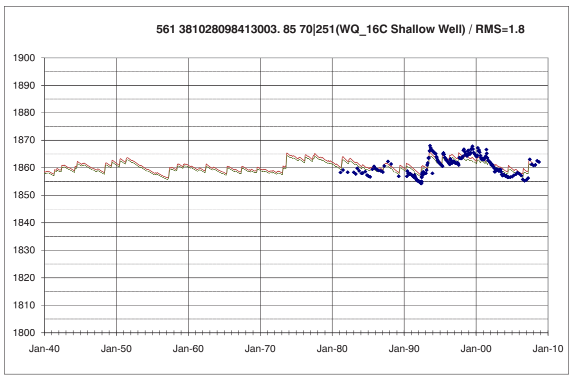

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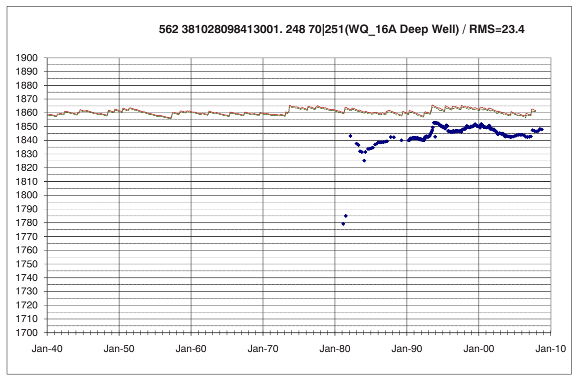

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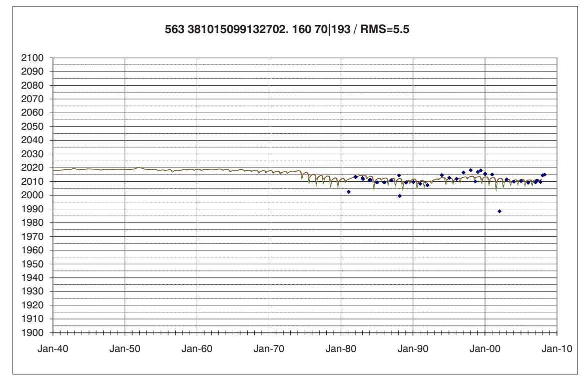

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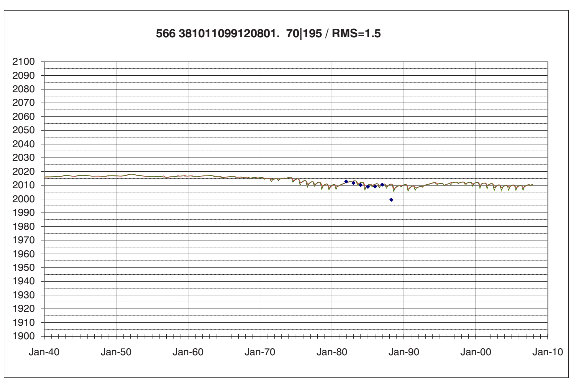

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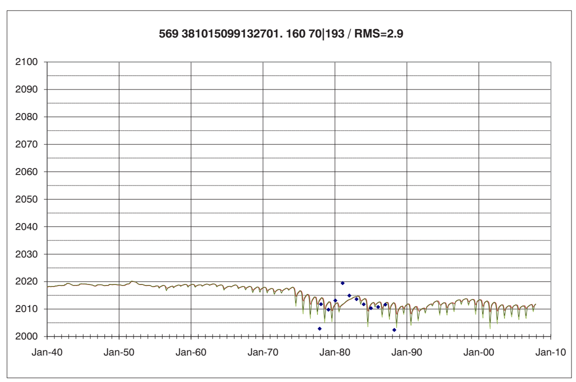

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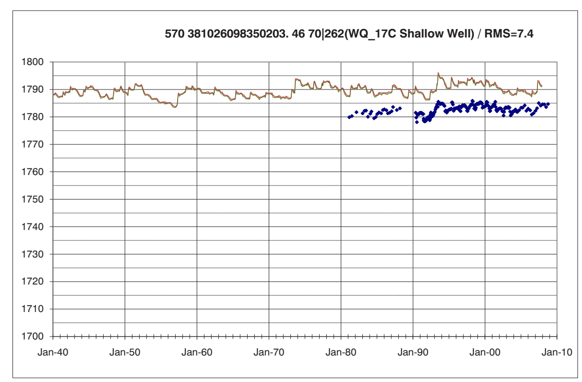

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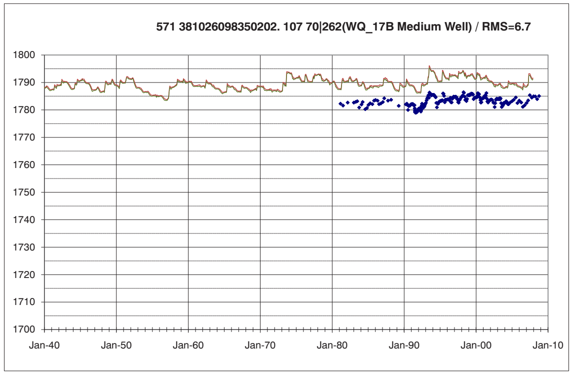

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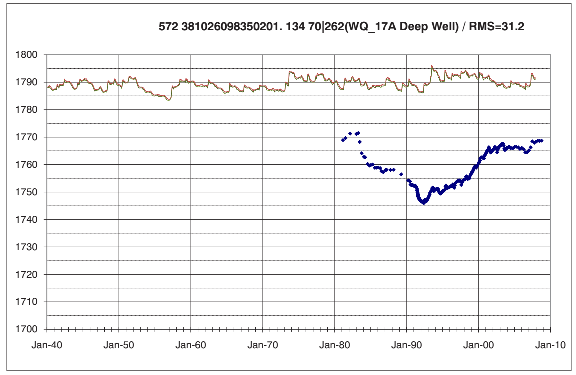

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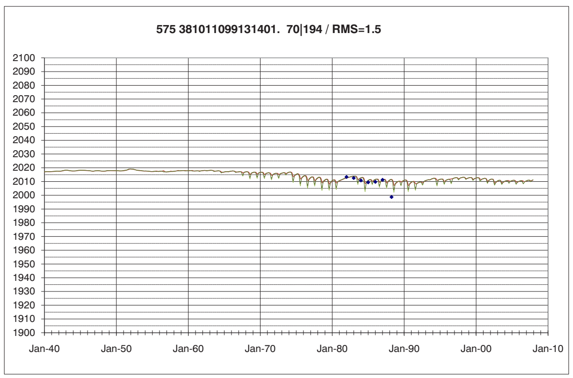

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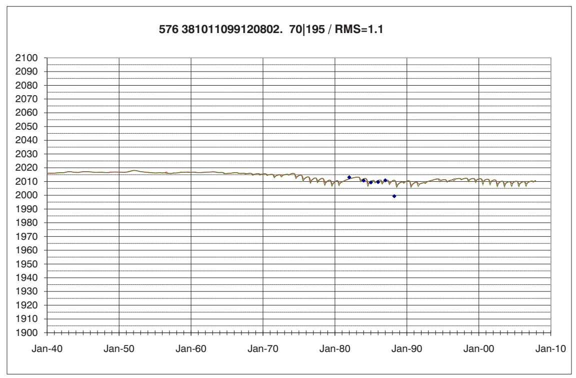

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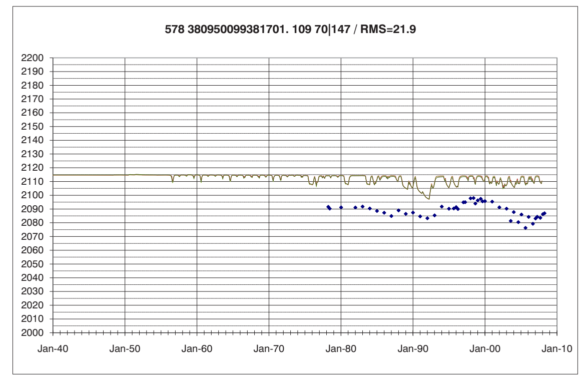

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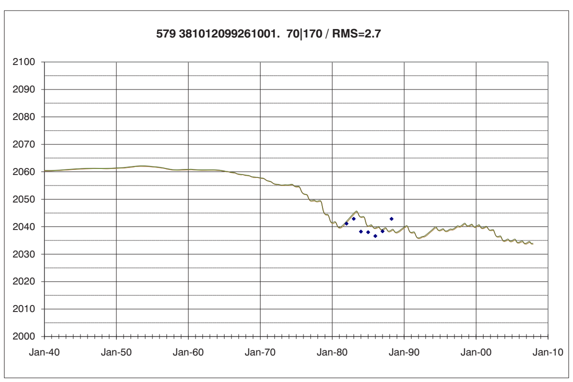

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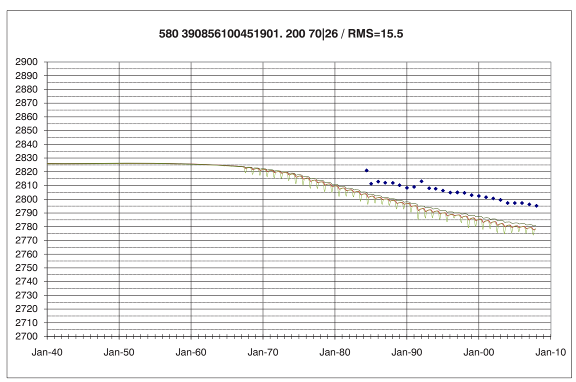

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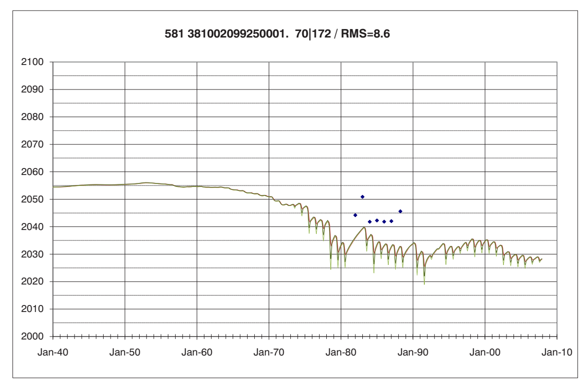

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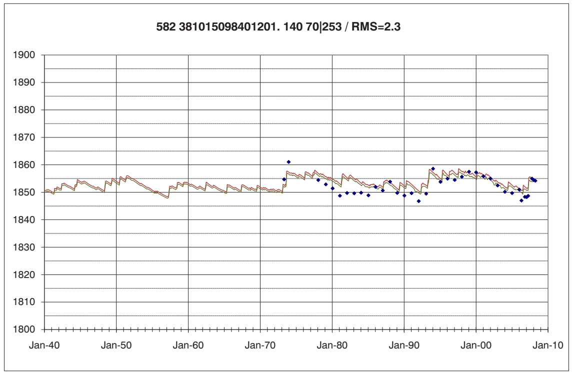

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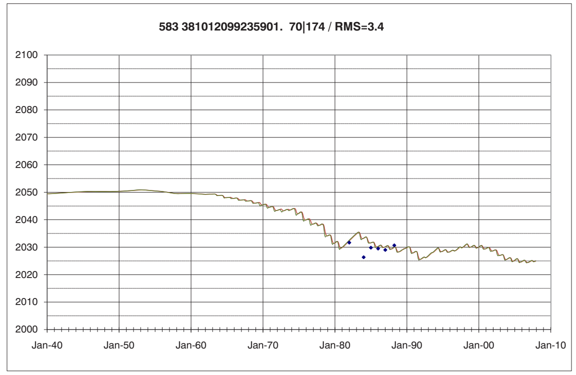

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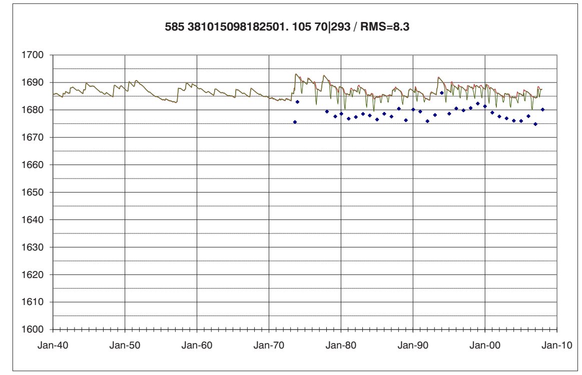

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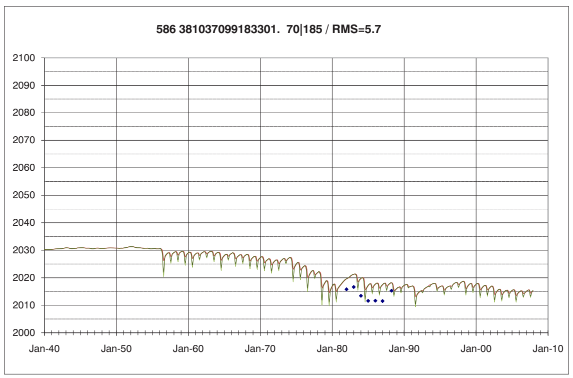

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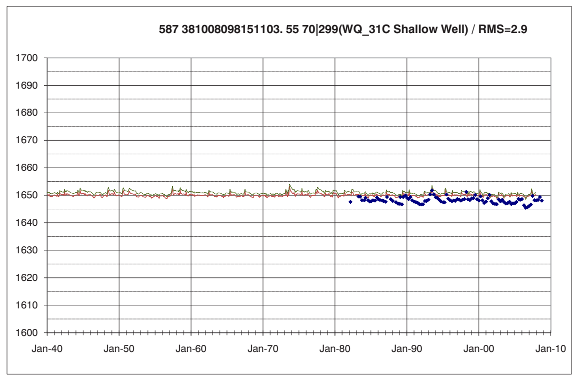

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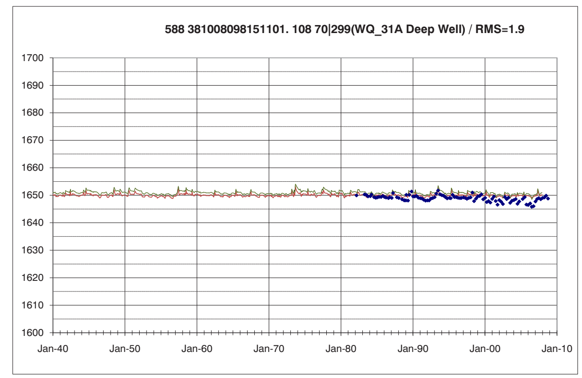

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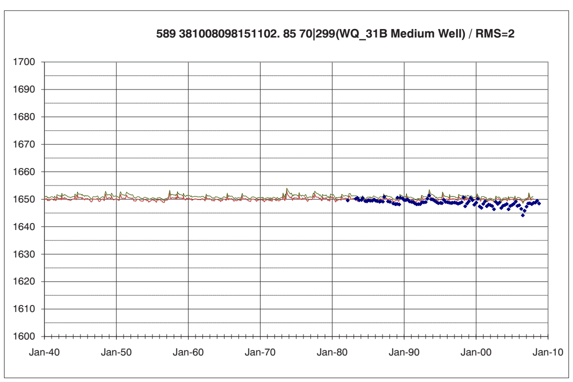

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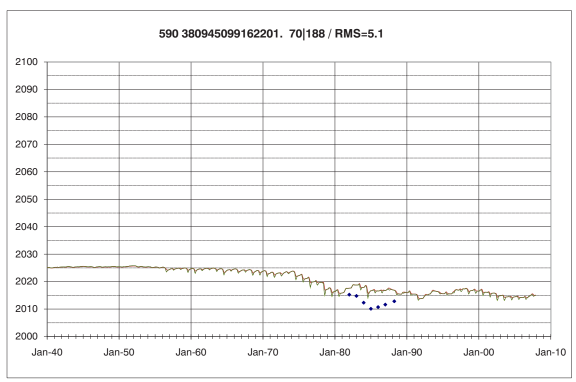

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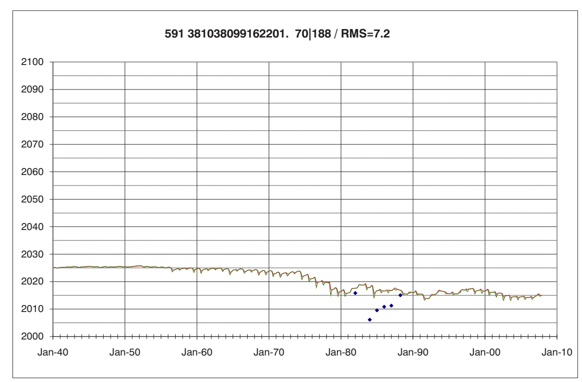

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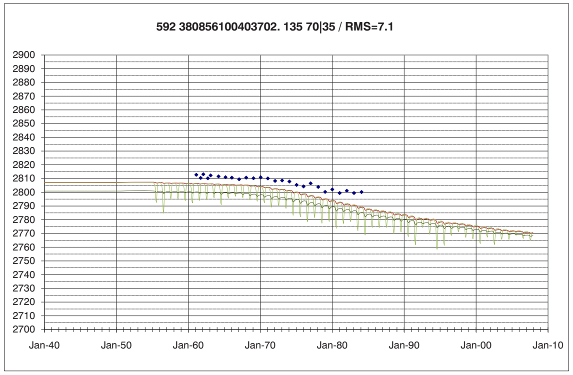

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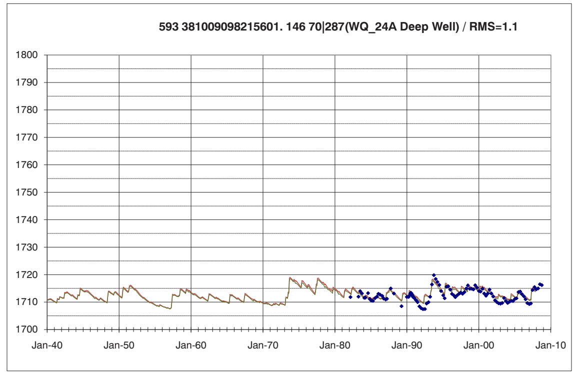

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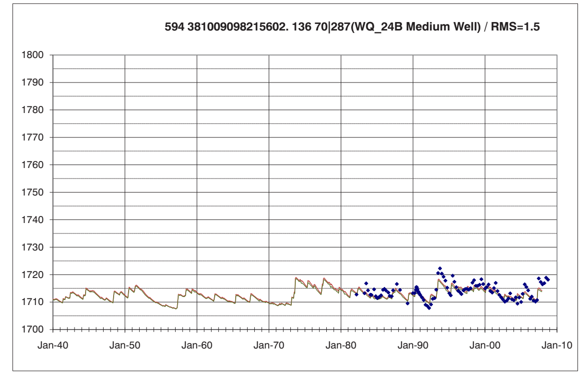

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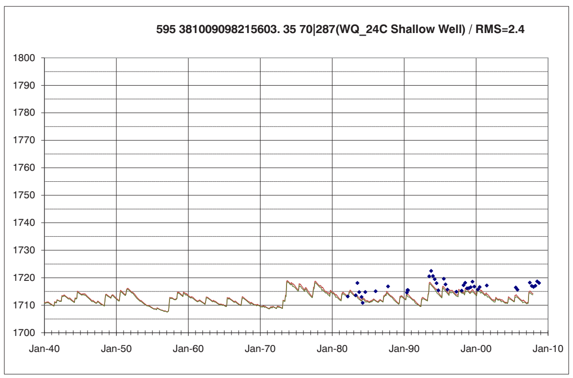

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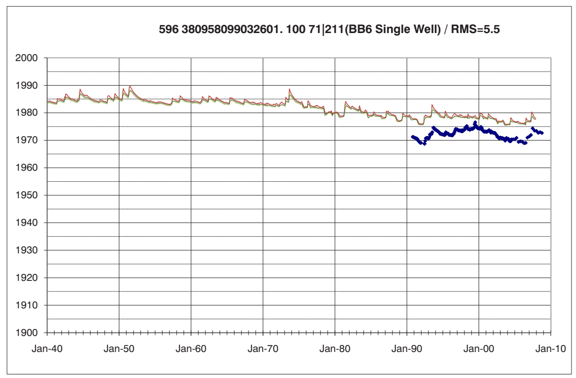

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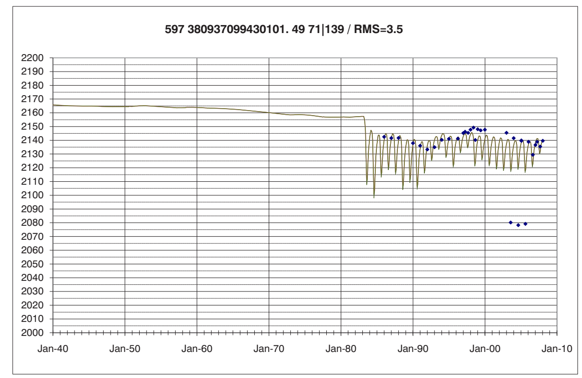

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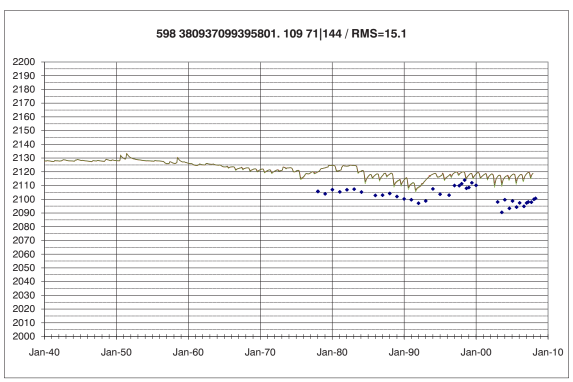

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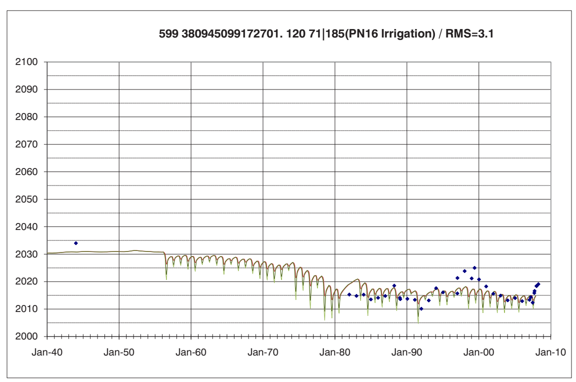

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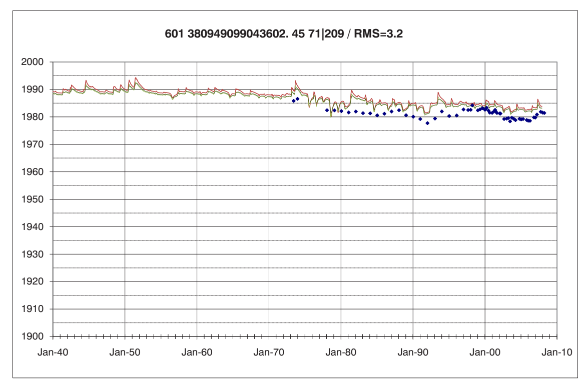
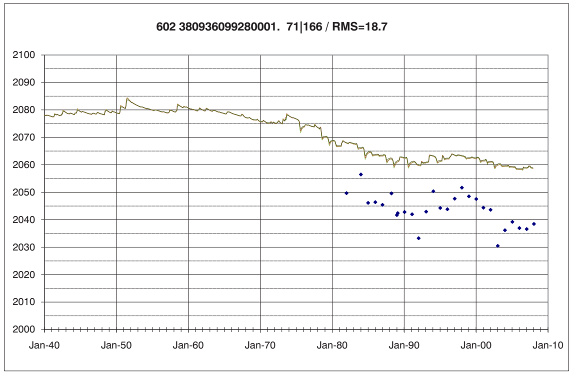


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



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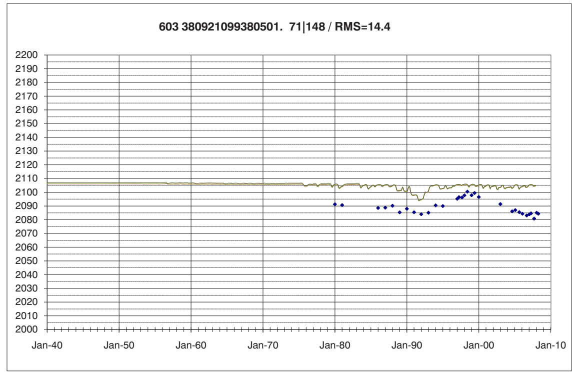

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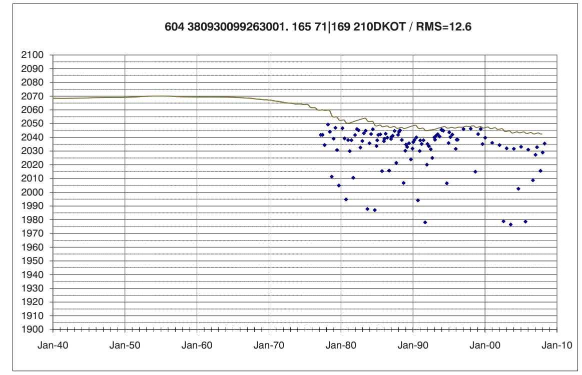

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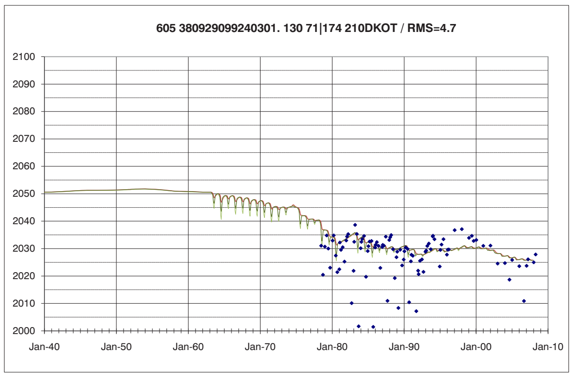

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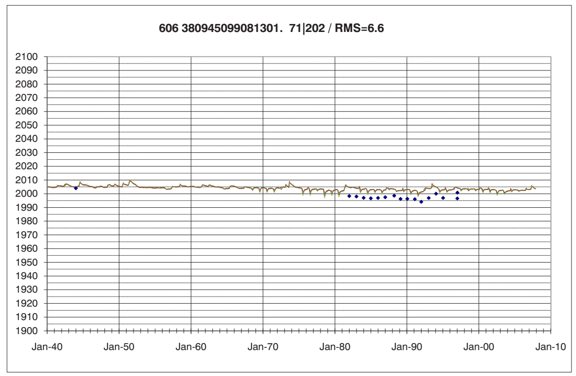

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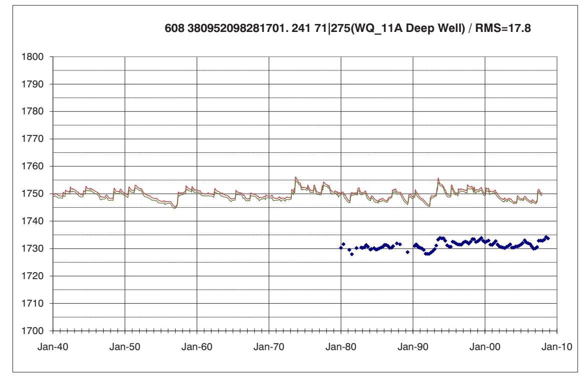

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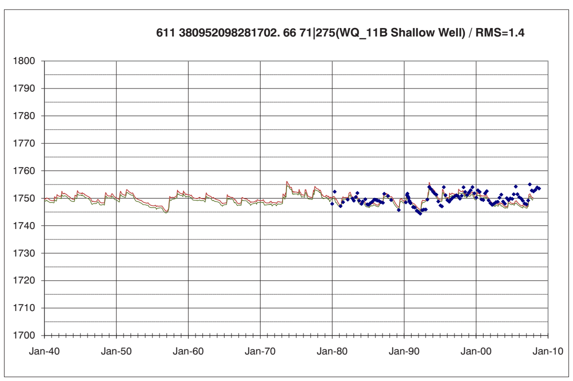

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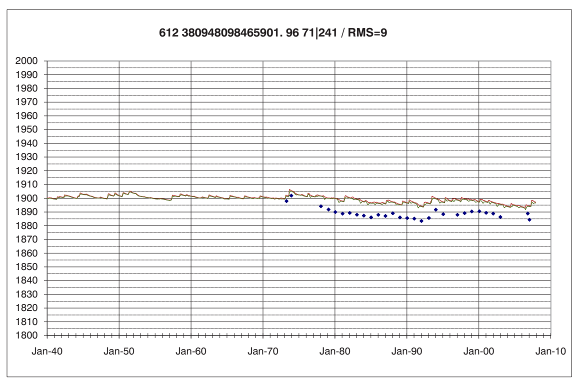

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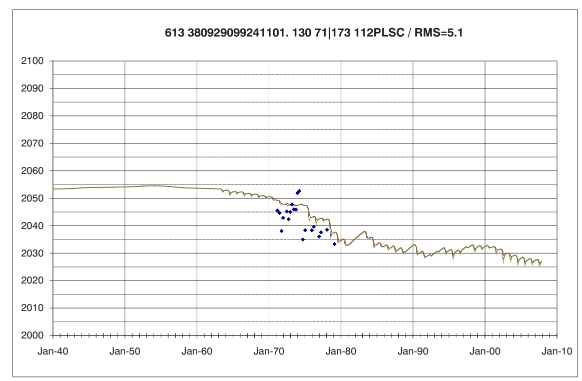

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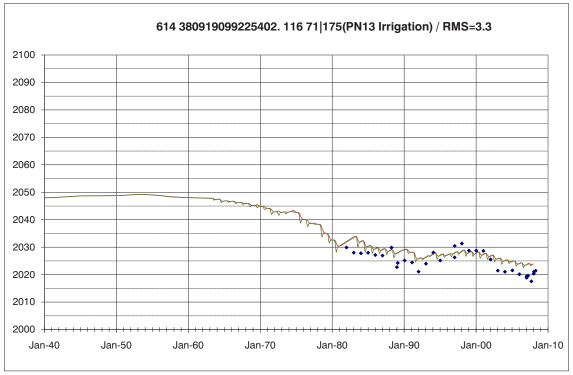

BALLEAU GROUNDWATER, INC.

GMD #5

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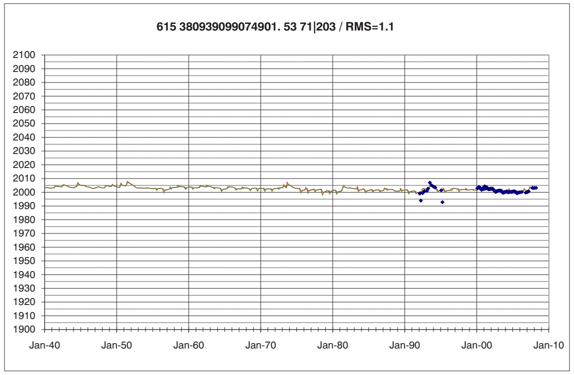

BALLEAU GROUNDWATER, INC.

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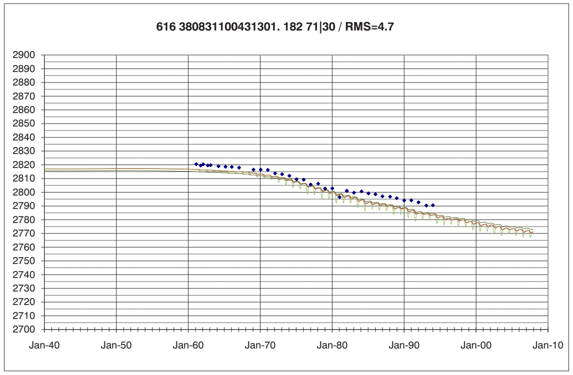

BALLEAU GROUNDWATER, INC.

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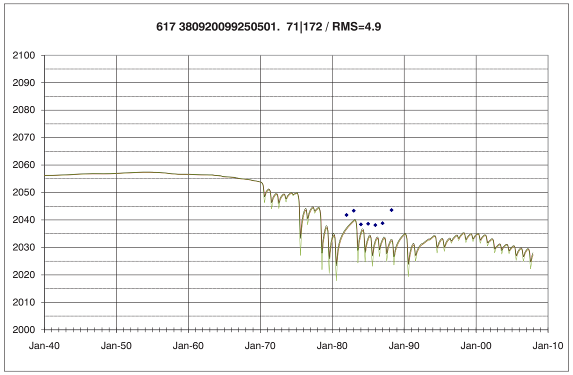

BALLEAU GROUNDWATER, INC.

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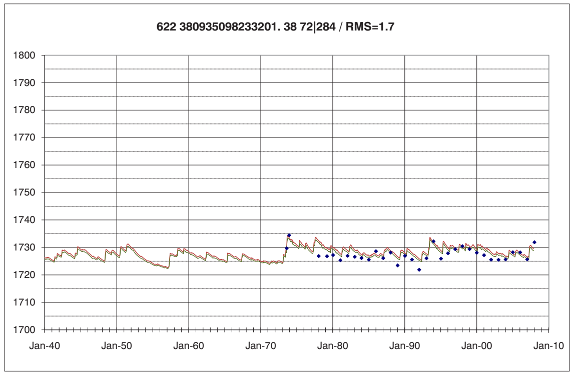

BALLEAU GROUNDWATER, INC.

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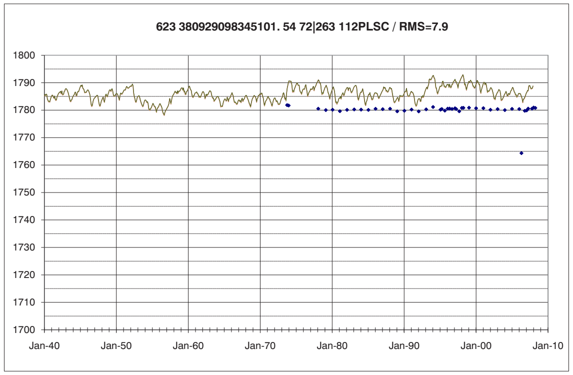

BALLEAU GROUNDWATER, INC.

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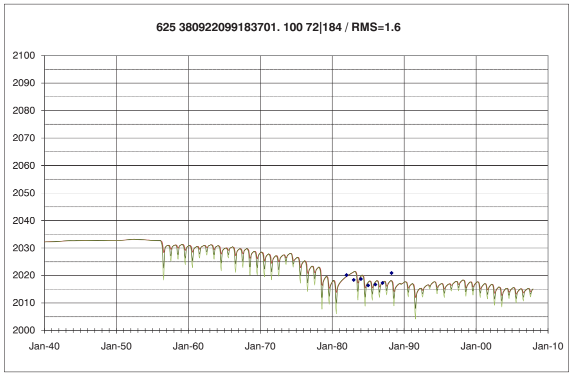

BALLEAU GROUNDWATER, INC.

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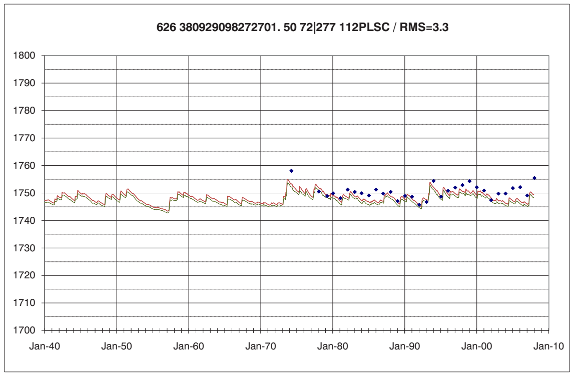

BALLEAU GROUNDWATER, INC.

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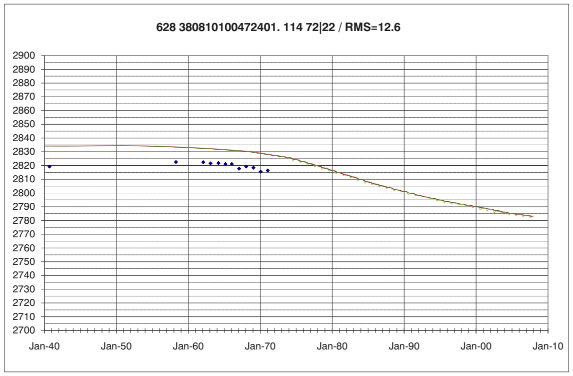

BALLEAU GROUNDWATER, INC.

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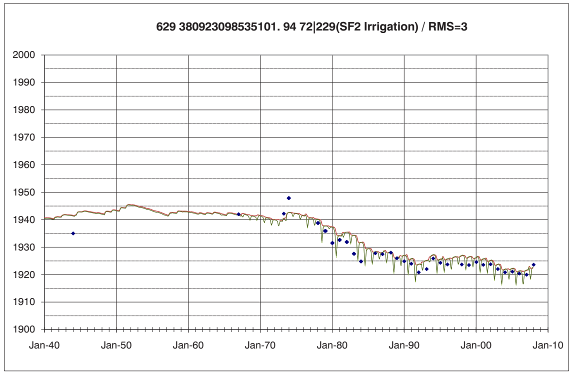

BALLEAU GROUNDWATER, INC.

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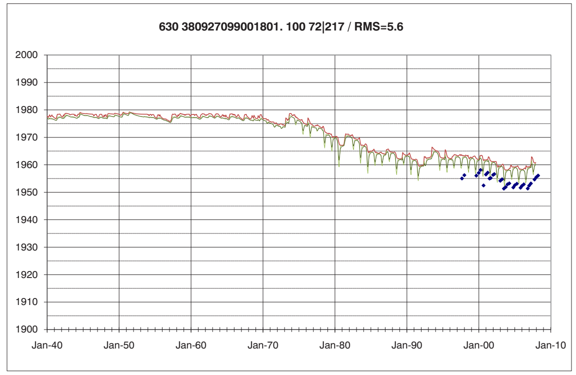

BALLEAU GROUNDWATER, INC.

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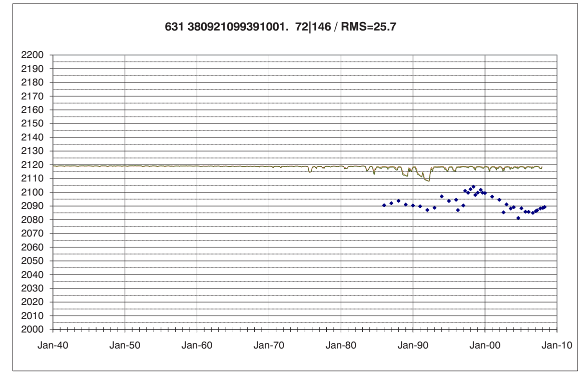

BALLEAU GROUNDWATER, INC.

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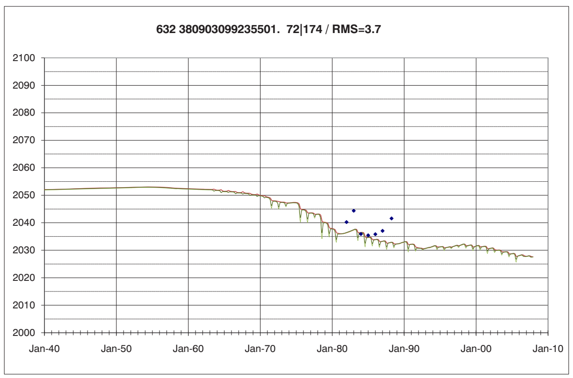

BALLEAU GROUNDWATER, INC.

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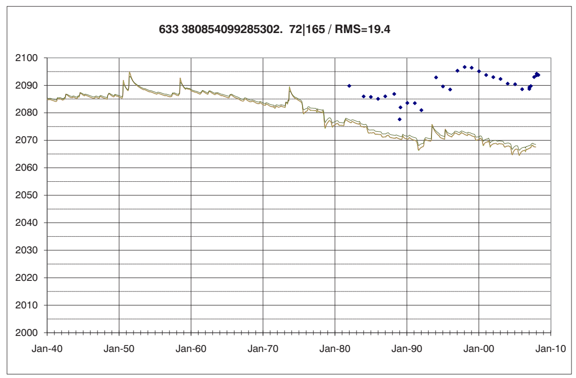

BALLEAU GROUNDWATER, INC.

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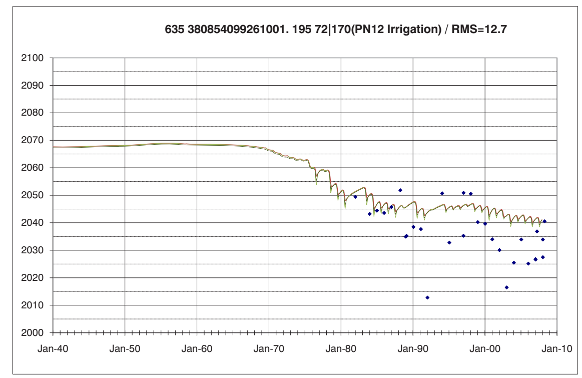

BALLEAU GROUNDWATER, INC.

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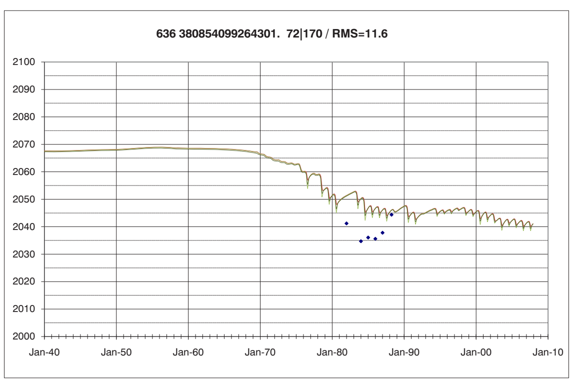

BALLEAU GROUNDWATER, INC.

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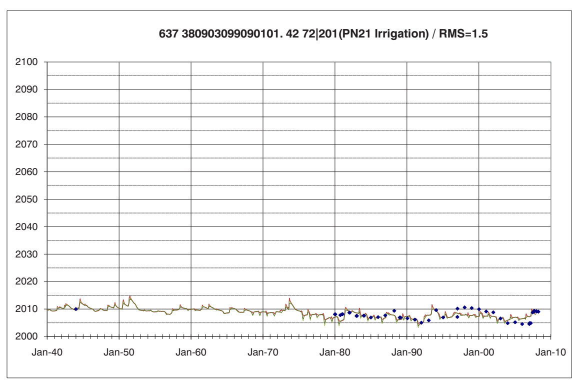

BALLEAU GROUNDWATER, INC.

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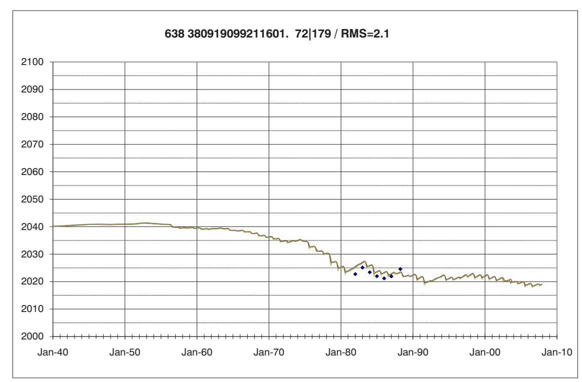

BALLEAU GROUNDWATER, INC.

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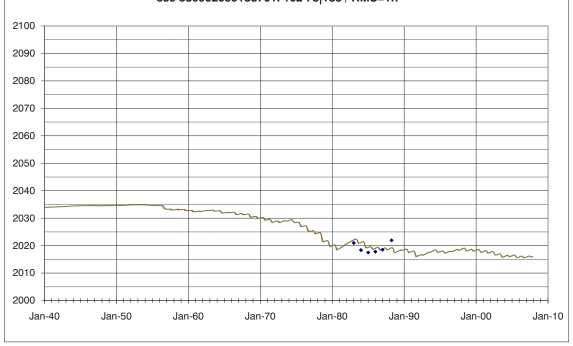
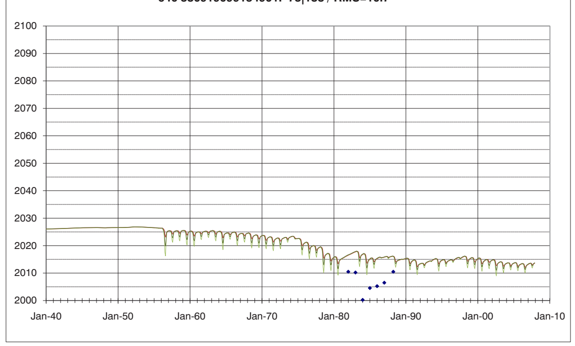


639 380902099183701. 102 73|183 / RMS=1.7

GMD #5

MODEL



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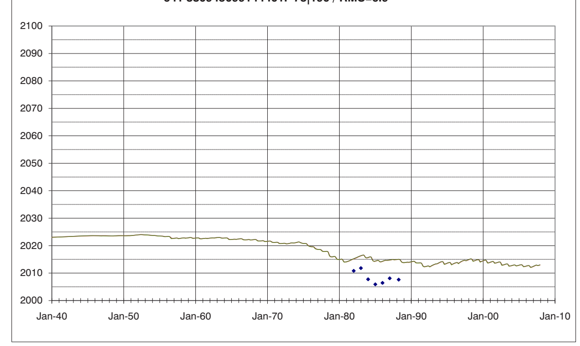

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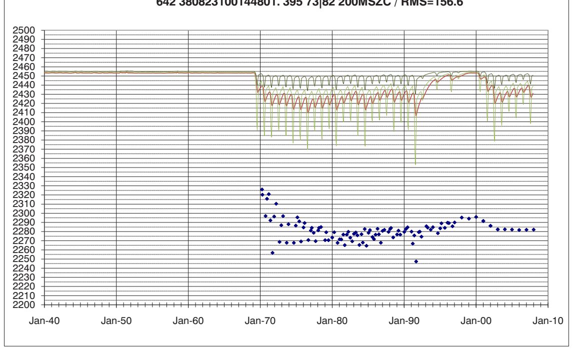
GMD #5

MODEL



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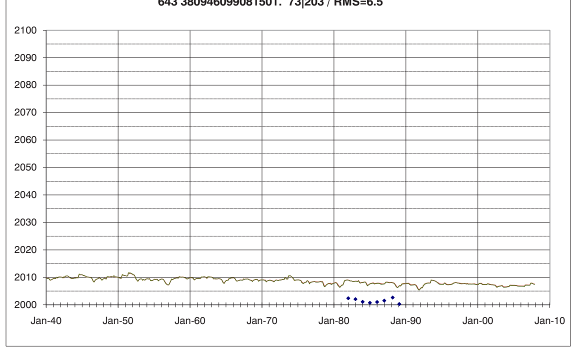
GMD #5

MODEL



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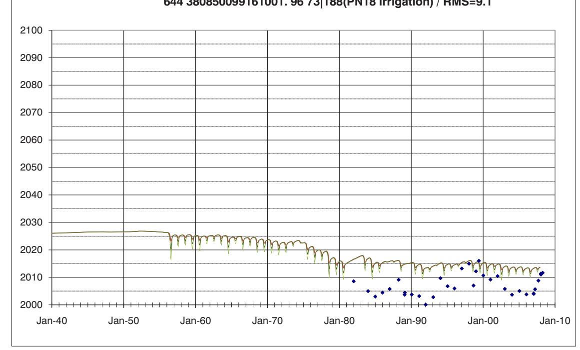
GMD #5

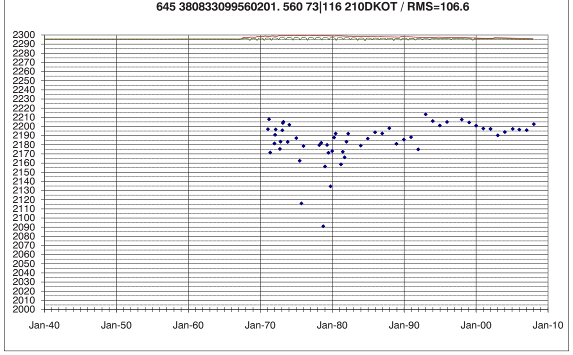
MODEL



644 380850099161001. 96 73|188(PN18 Irrigation) / RMS=9.1

GMD #5

MODEL



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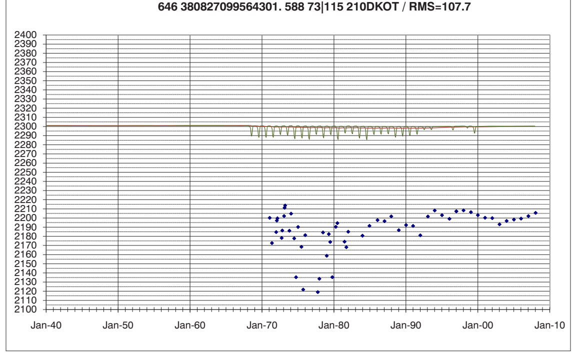
GMD #5

MODEL



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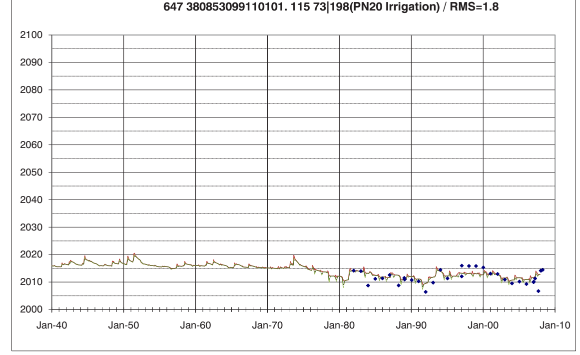
GMD #5

MODEL



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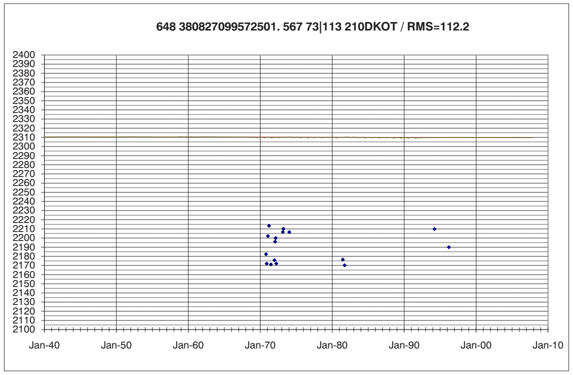
GMD #5

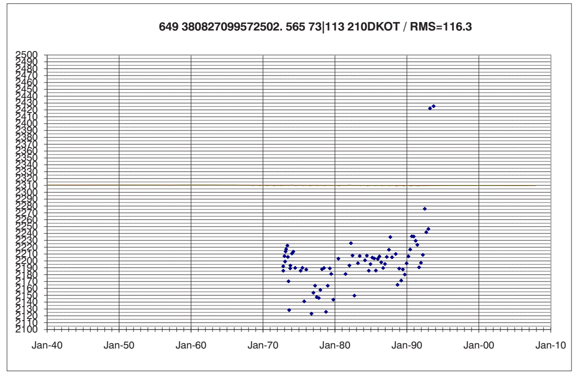
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

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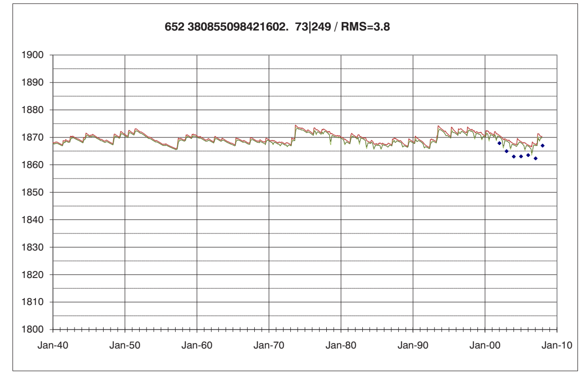

BALLEAU GROUNDWATER, INC.

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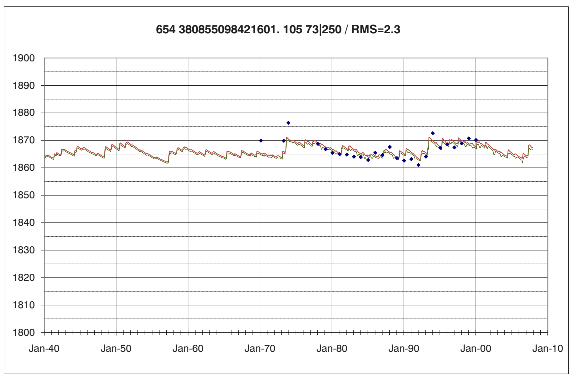

BALLEAU GROUNDWATER, INC.

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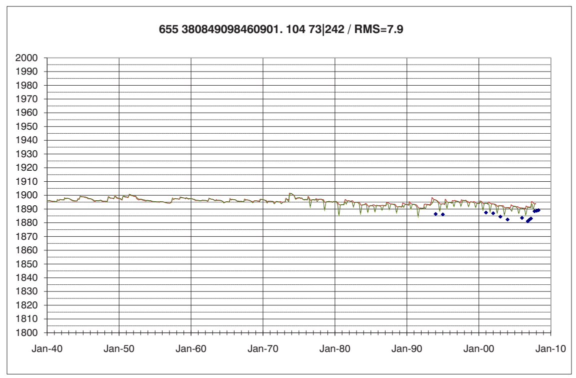

BALLEAU GROUNDWATER, INC.

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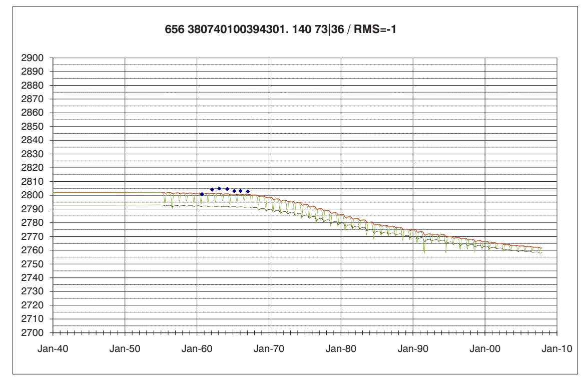

BALLEAU GROUNDWATER, INC.

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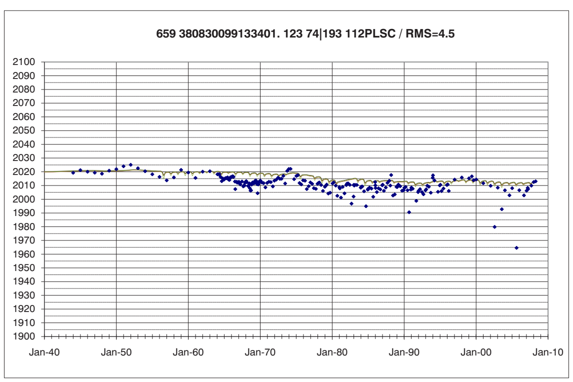

BALLEAU GROUNDWATER, INC.

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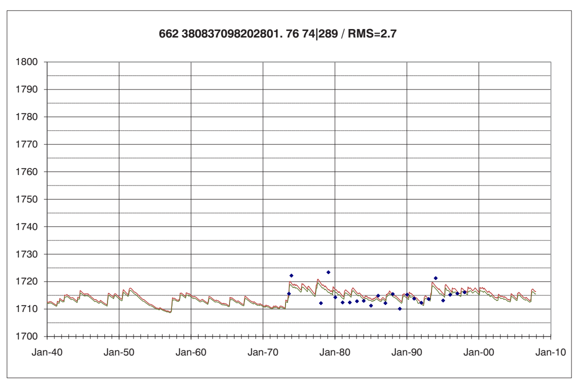

BALLEAU GROUNDWATER, INC.

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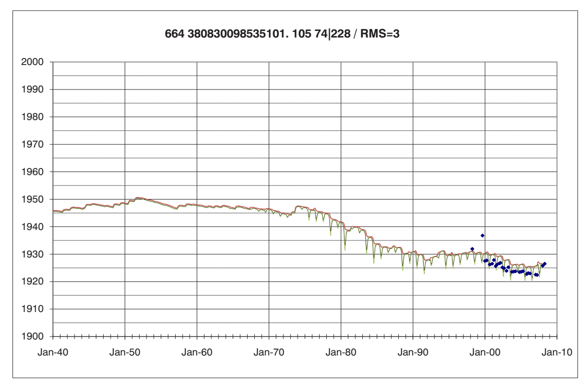

BALLEAU GROUNDWATER, INC.

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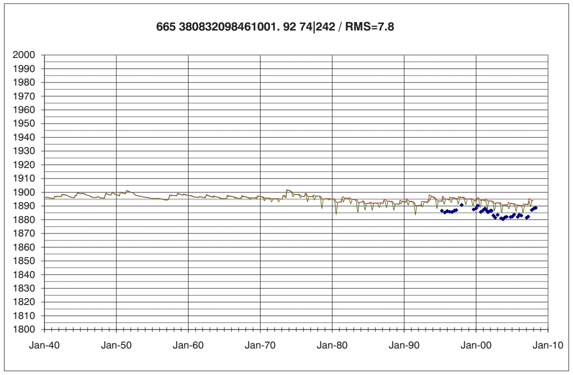

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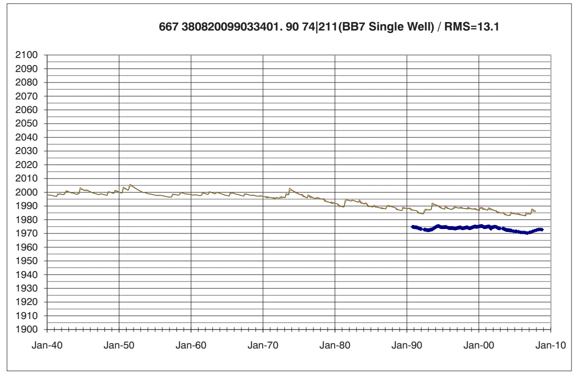

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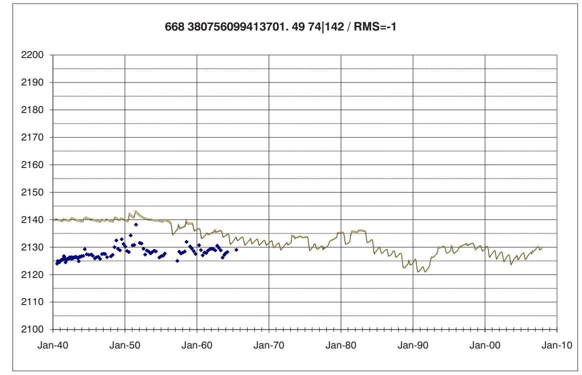

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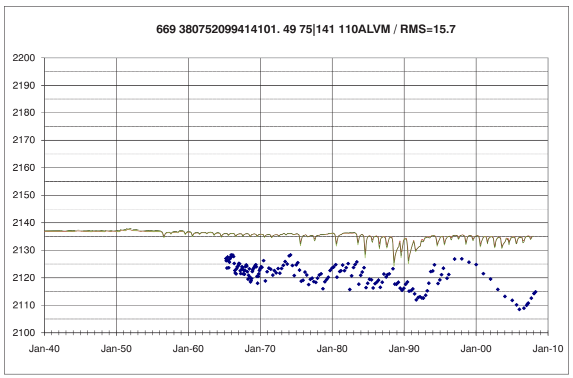

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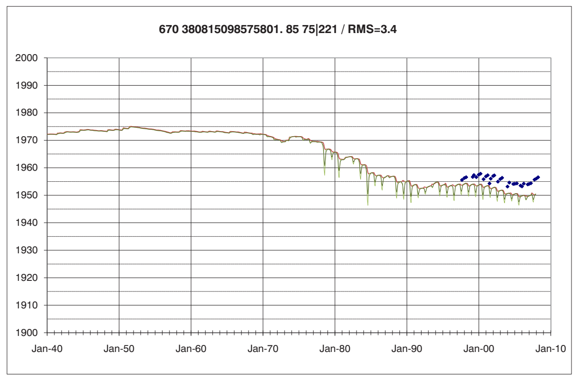

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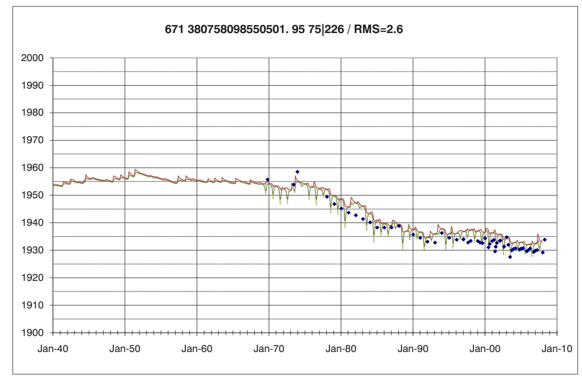

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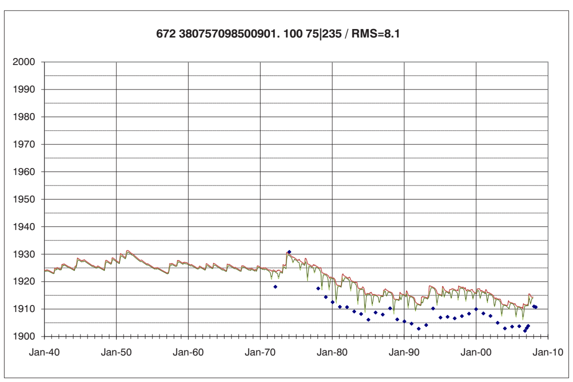

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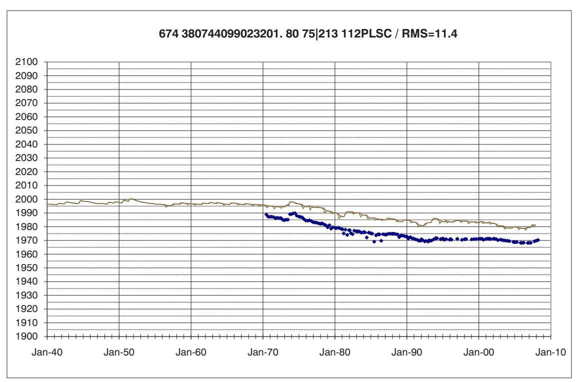

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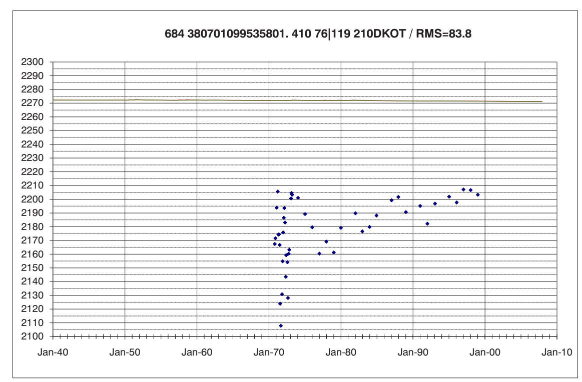

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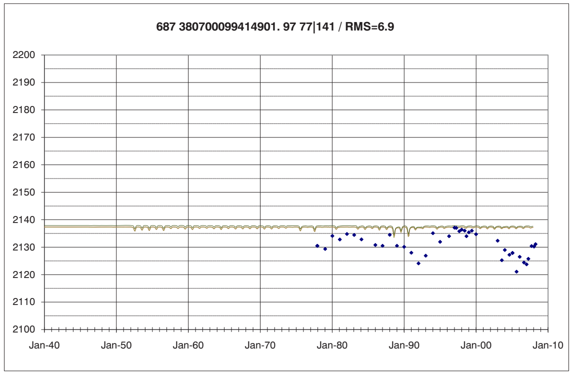
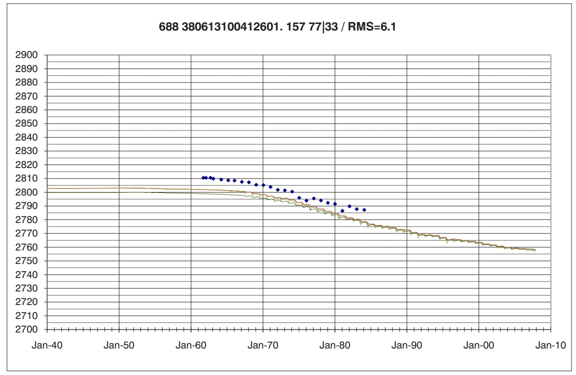


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

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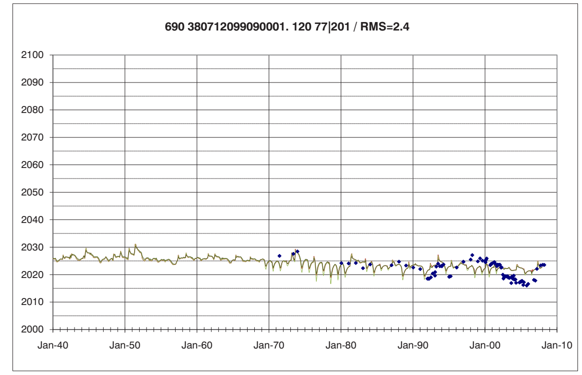

BALLEAU GROUNDWATER, INC.

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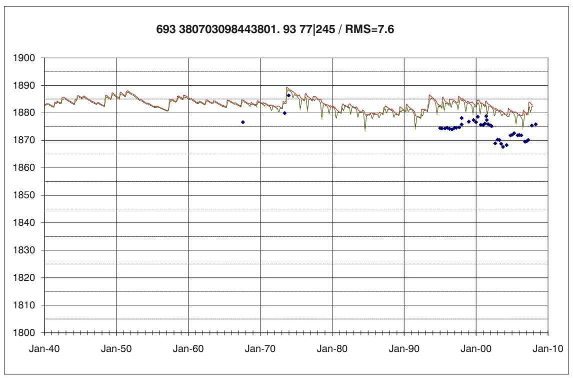

BALLEAU GROUNDWATER, INC.

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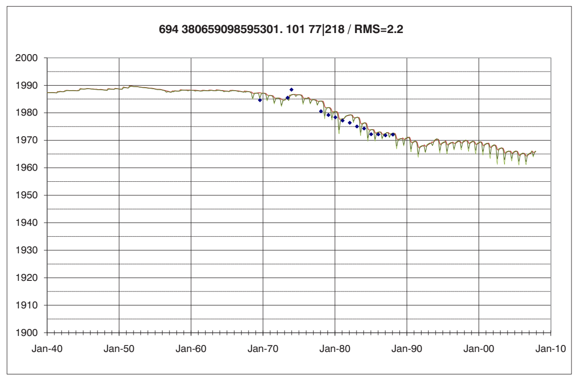

BALLEAU GROUNDWATER, INC.

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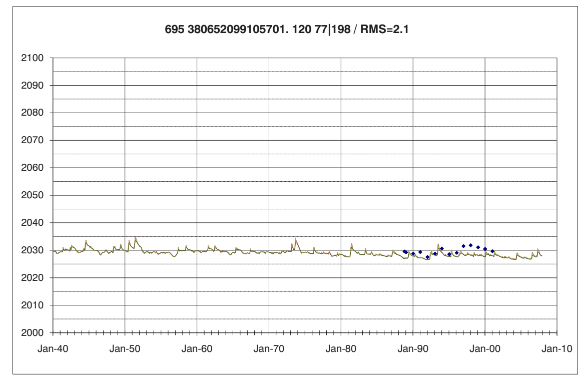

BALLEAU GROUNDWATER, INC.

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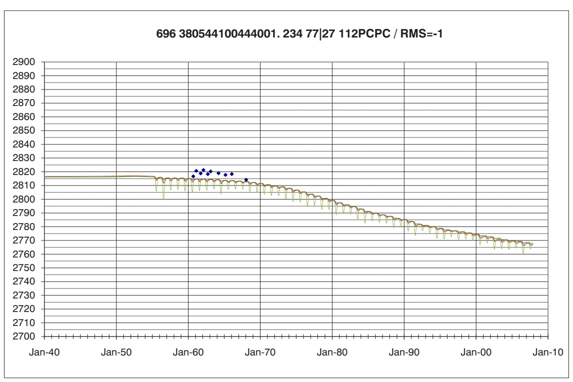

BALLEAU GROUNDWATER, INC.

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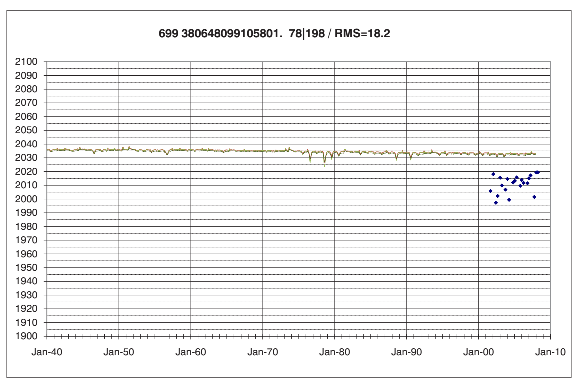

BALLEAU GROUNDWATER, INC.

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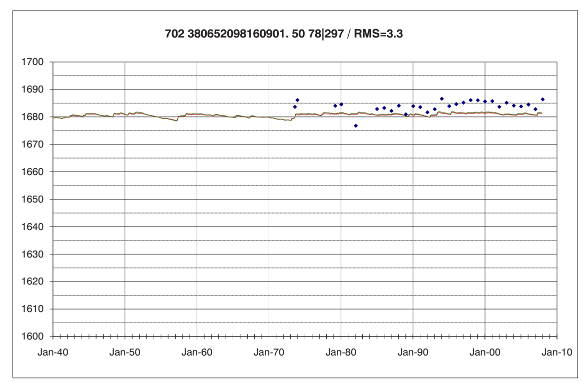

BALLEAU GROUNDWATER, INC.

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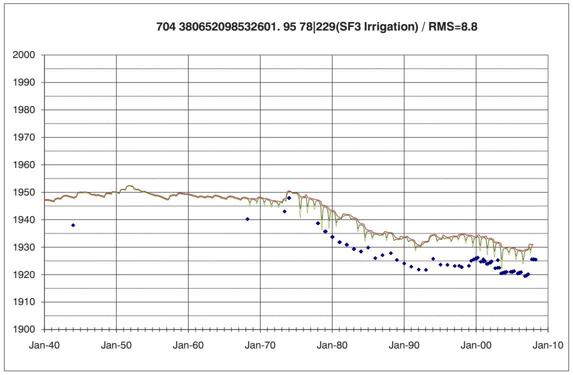

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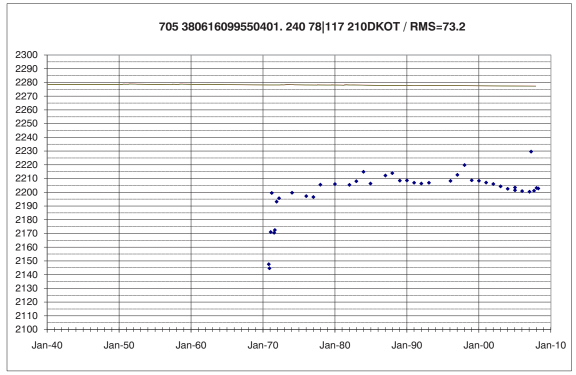
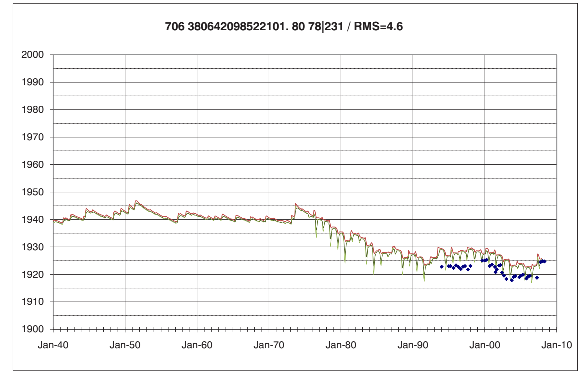


GMD #5

MODEL



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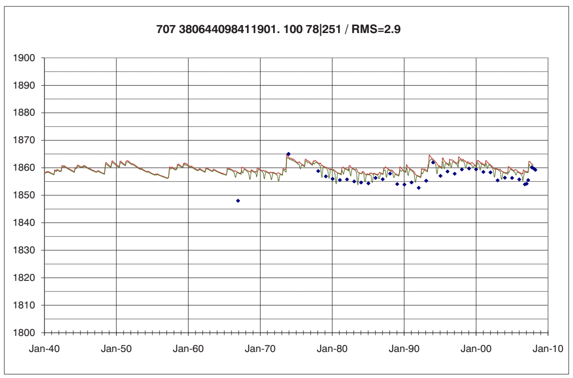
MODEL



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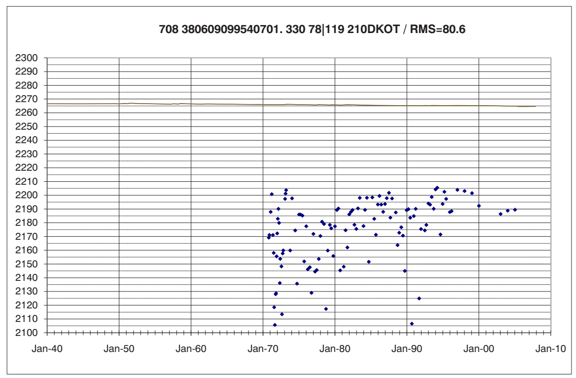

GMD #5

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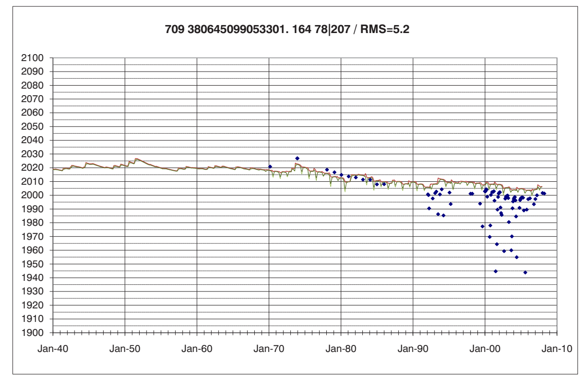

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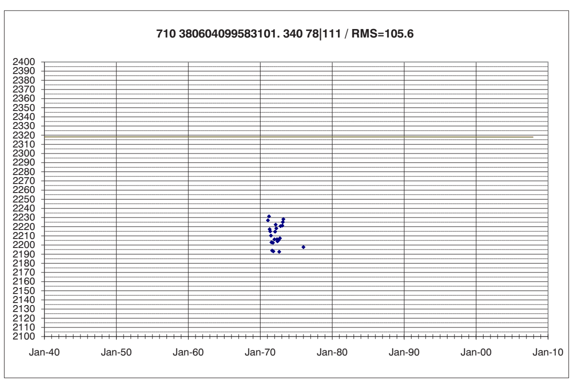

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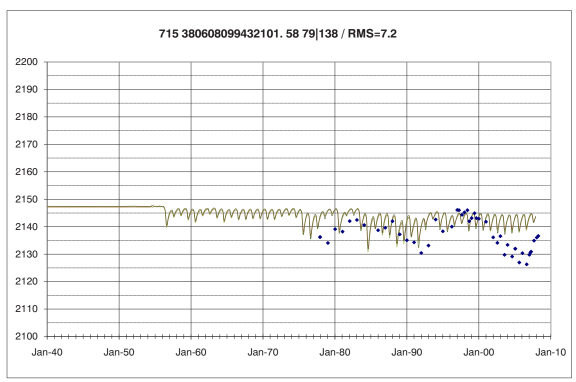

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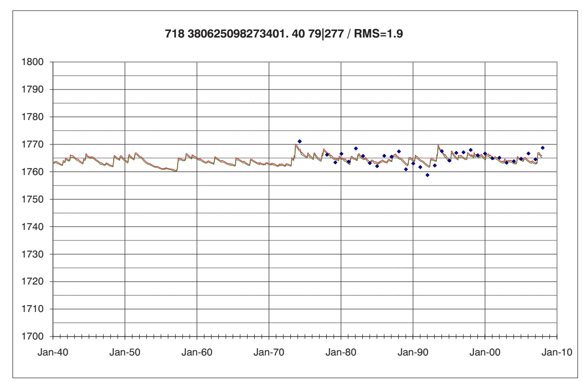

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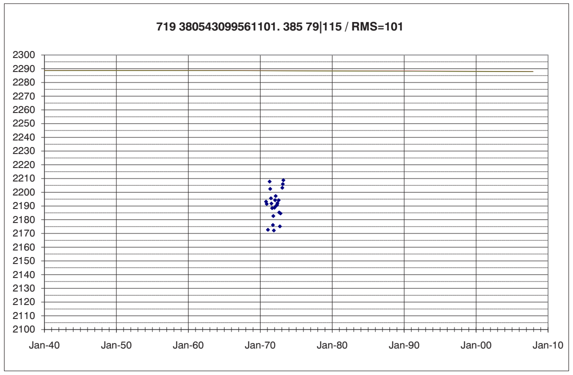

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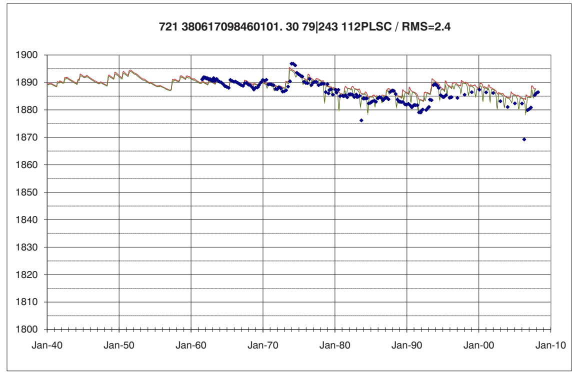

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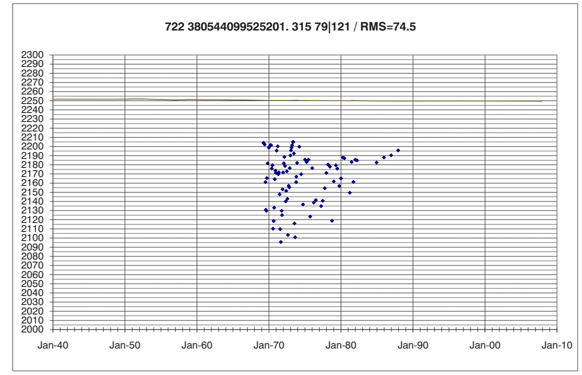

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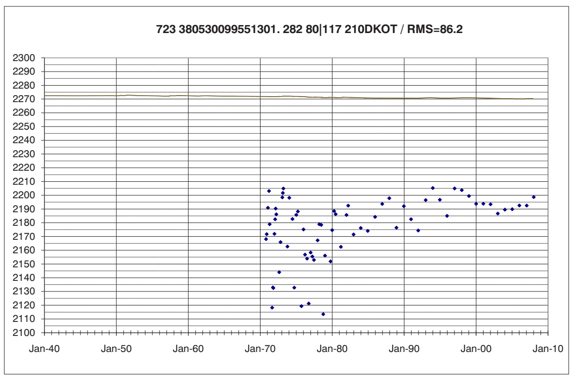

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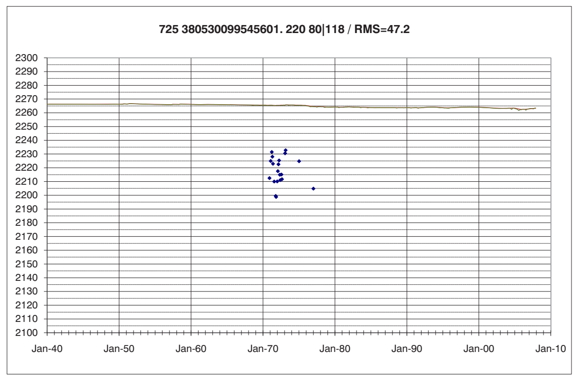

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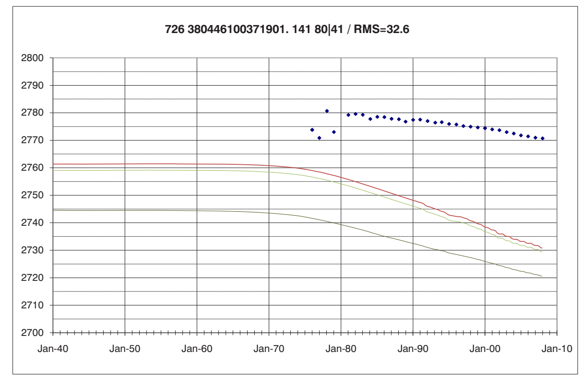

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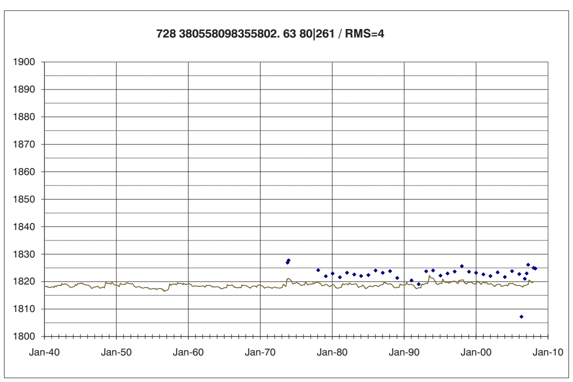

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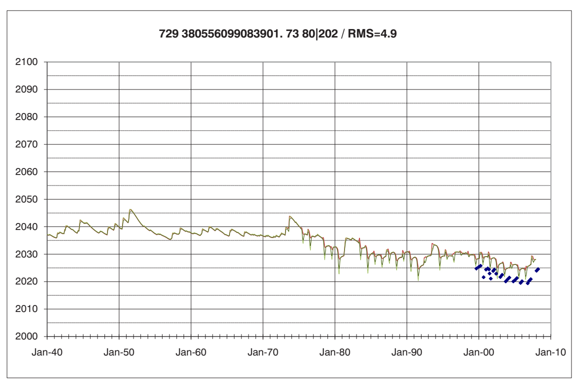

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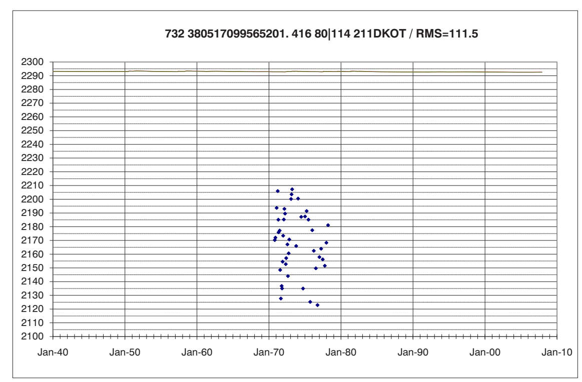

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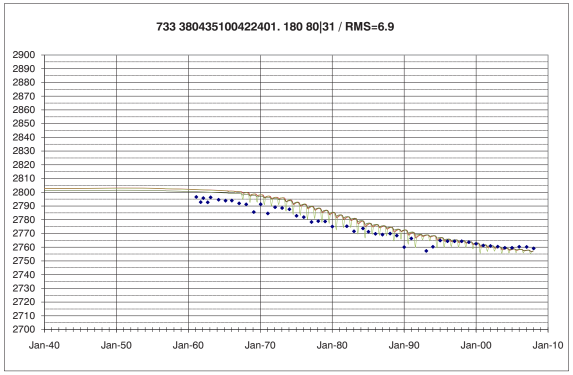
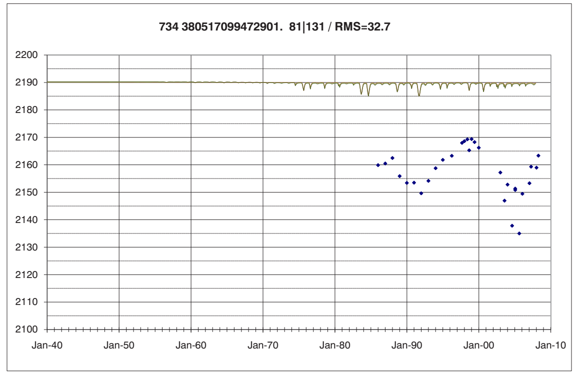


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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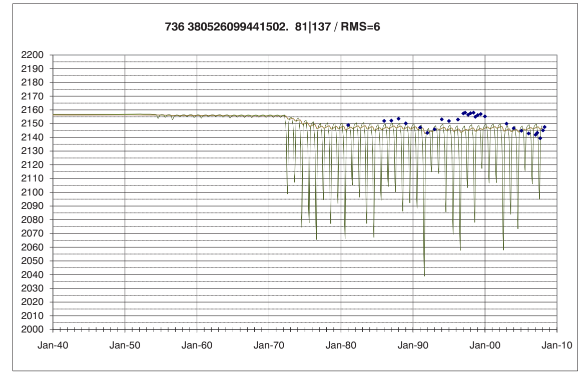

BALLEAU GROUNDWATER, INC.

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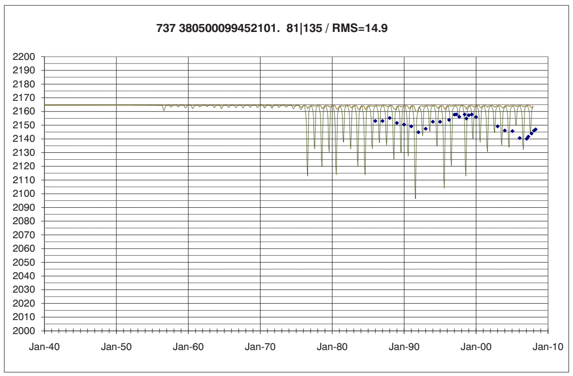

BALLEAU GROUNDWATER, INC.

GMD #5

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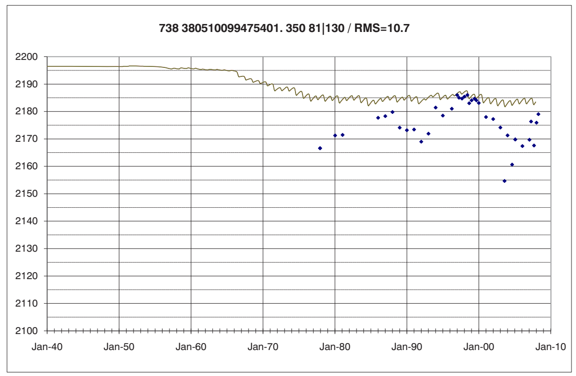

BALLEAU GROUNDWATER, INC.

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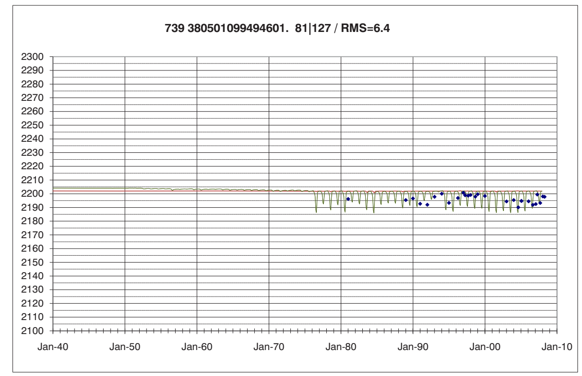

BALLEAU GROUNDWATER, INC.

GMD #5

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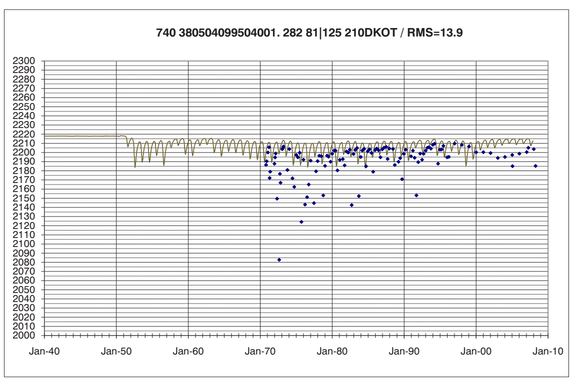


BALLEAU GROUNDWATER, INC.

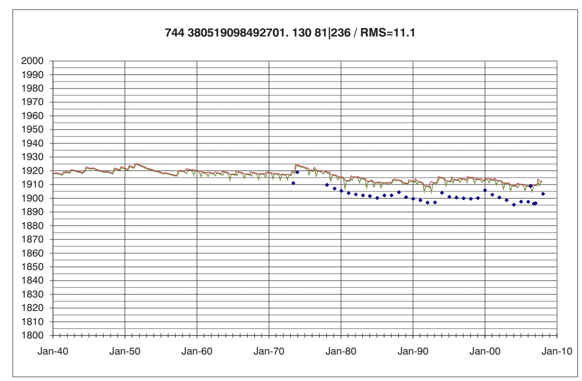
GMD #5

MODEL

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

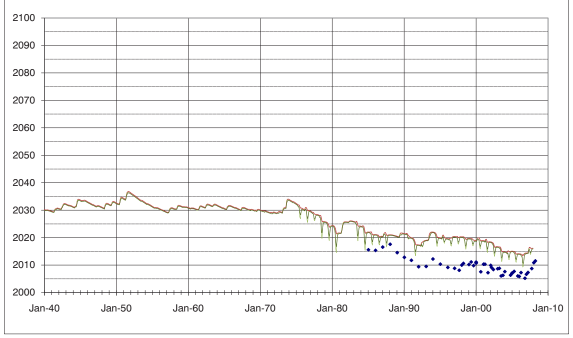


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

745 380513099062201. 81|206 / RMS=8



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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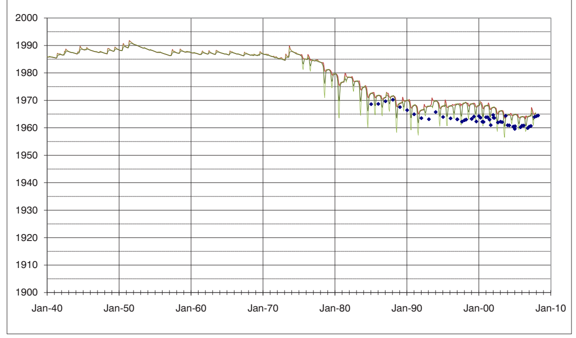
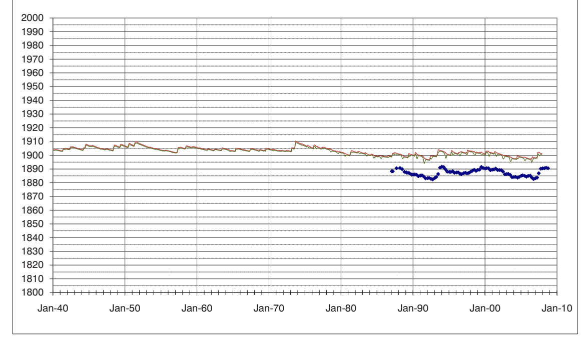


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

750 380509098480402. 102 82|239(WQ_52B Shallow Well) / RMS=12.6



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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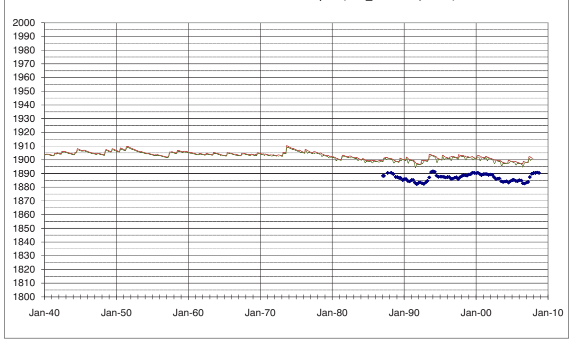

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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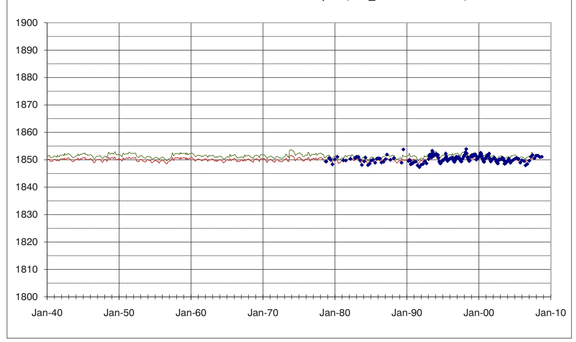
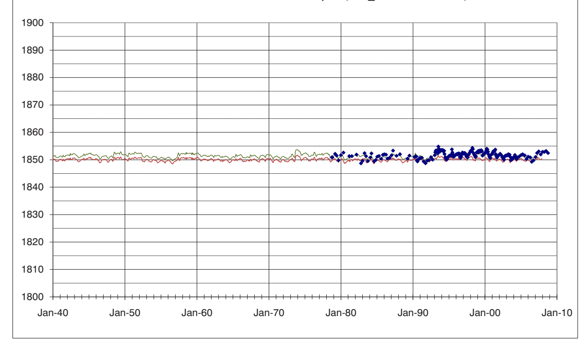


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

754 380508098412703. 50 82|251(WQ_5C Shallow Well) / RMS=0.6



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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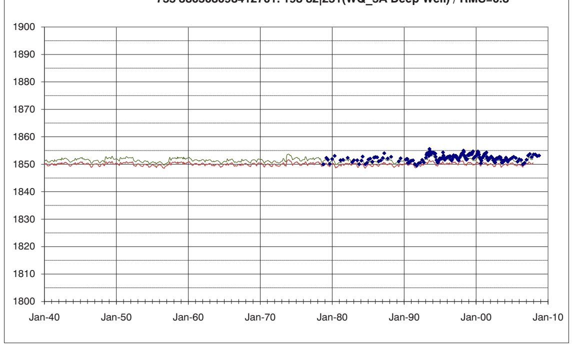

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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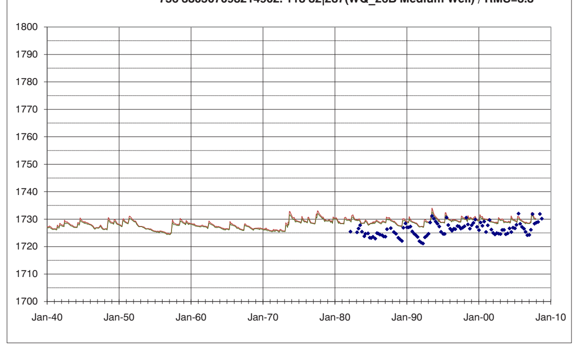

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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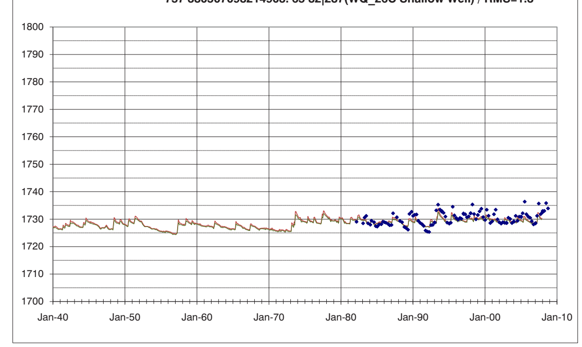

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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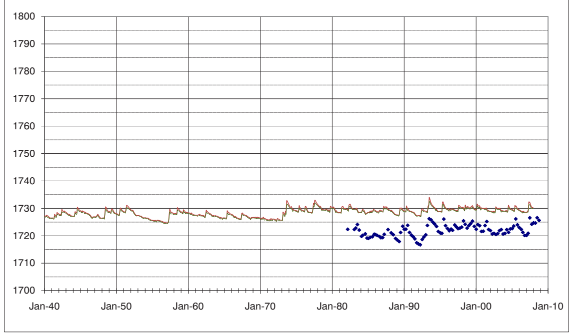
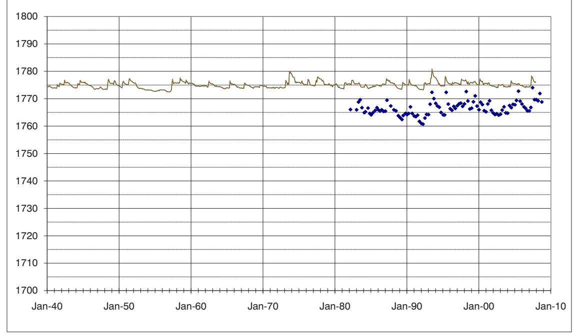


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

760 380505098280801. 120 82|275(WQ_25A Deep Well) / RMS=9.7



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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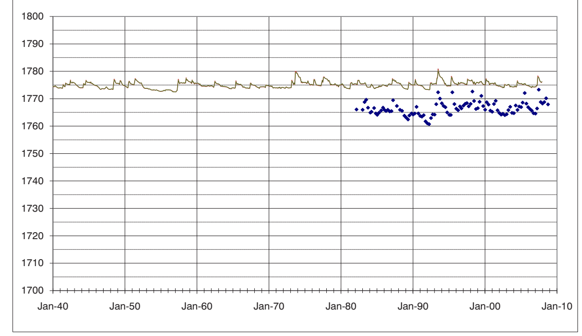

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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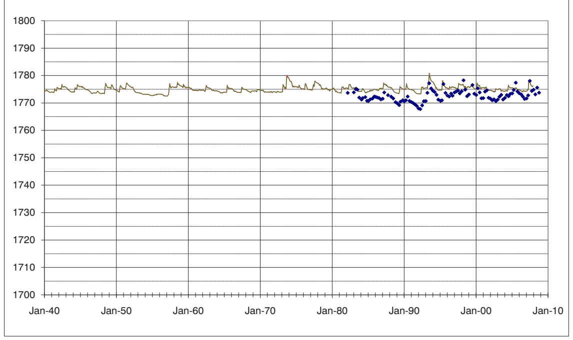
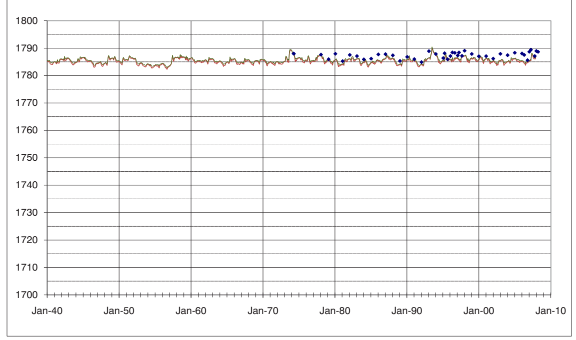


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

763 380506098302901. 30 82|271 112PLSC / RMS=1.5



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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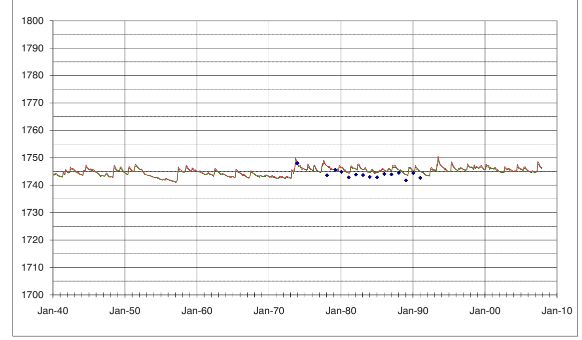

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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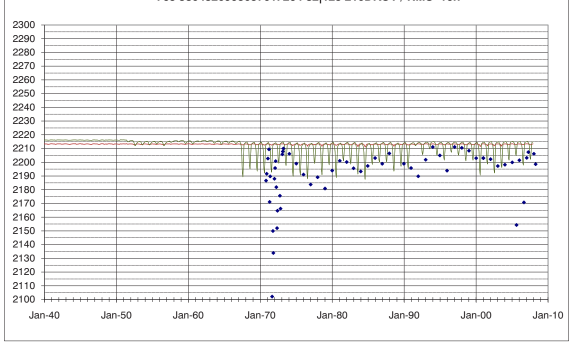

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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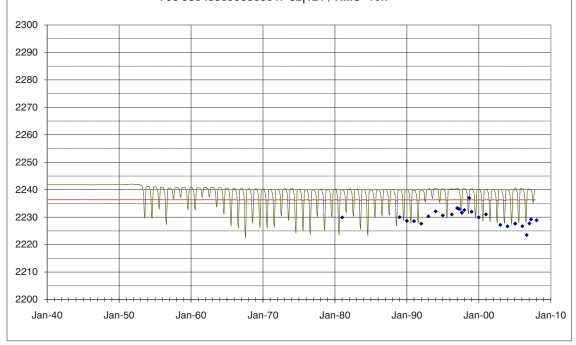

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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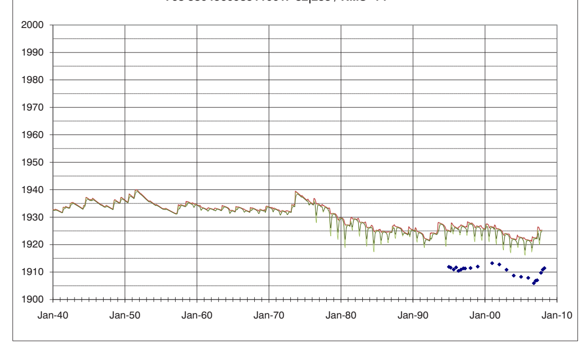
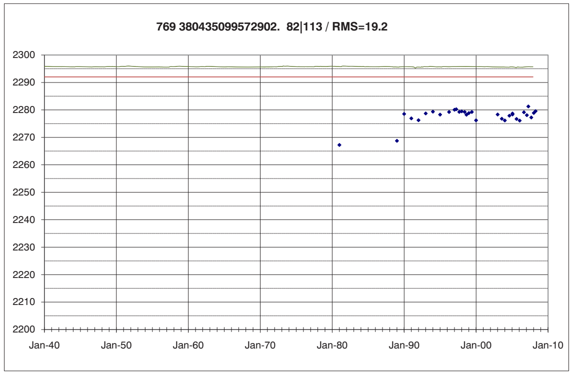


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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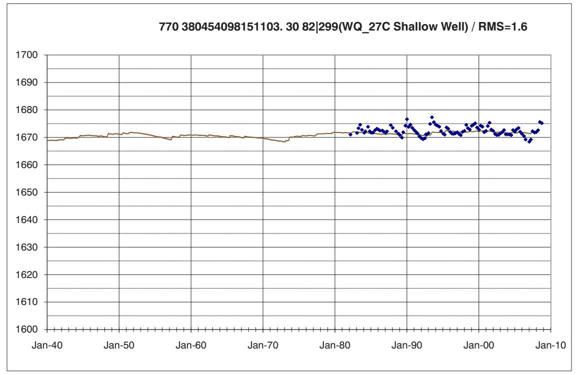

BALLEAU GROUNDWATER, INC.

GMD #5

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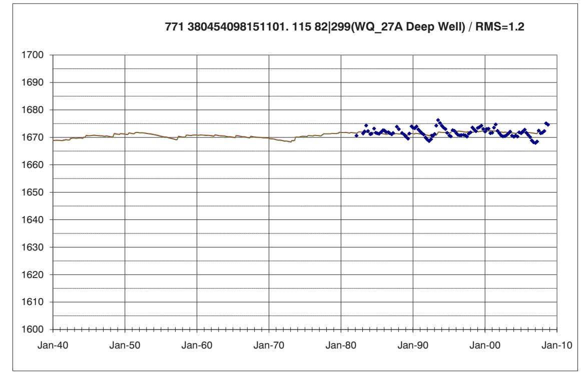
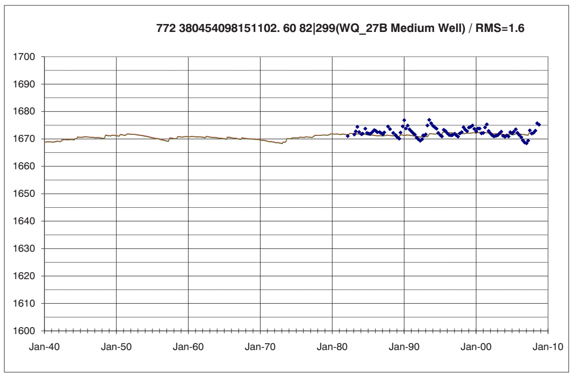


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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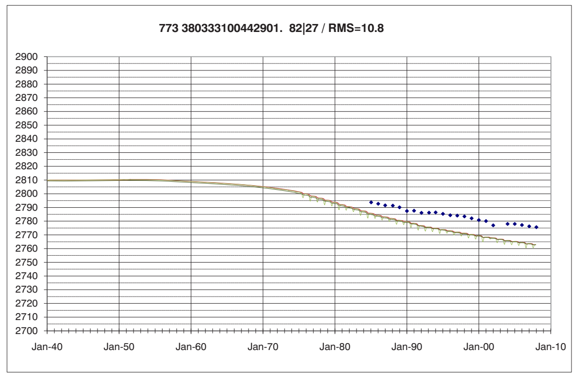

BALLEAU GROUNDWATER, INC.

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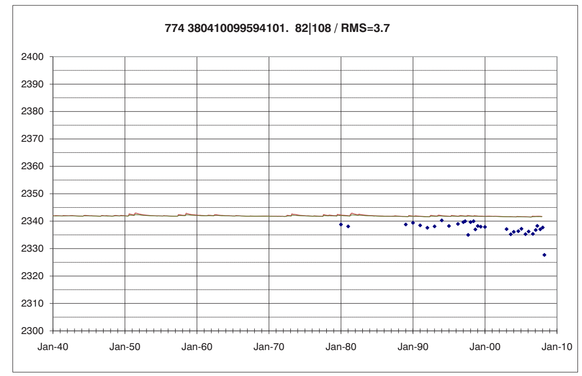
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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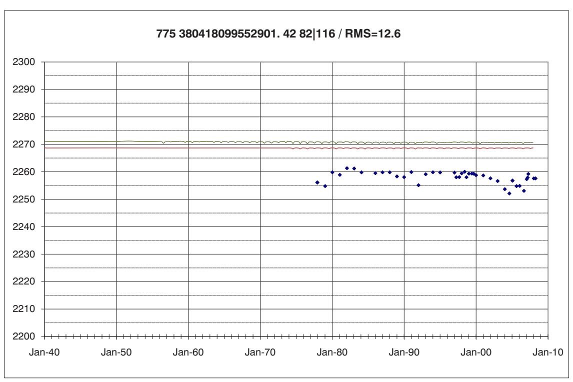
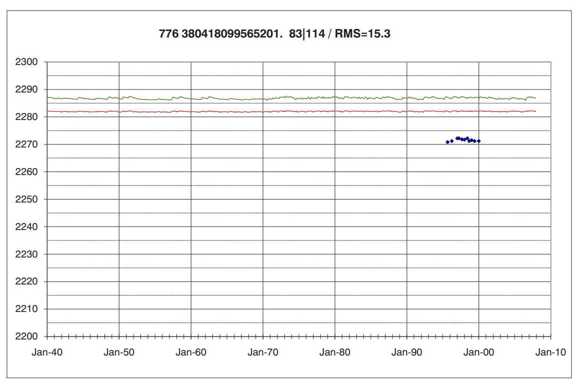


BALLEAU GROUNDWATER, INC.

GMD #5

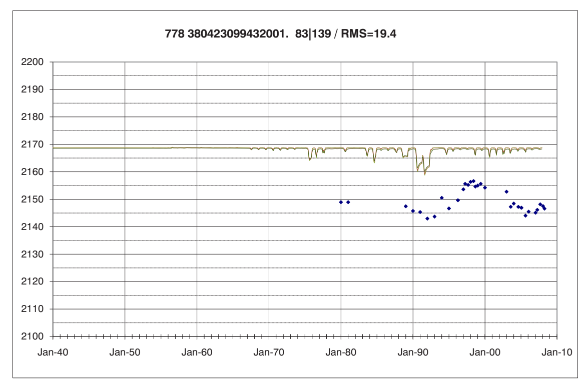
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

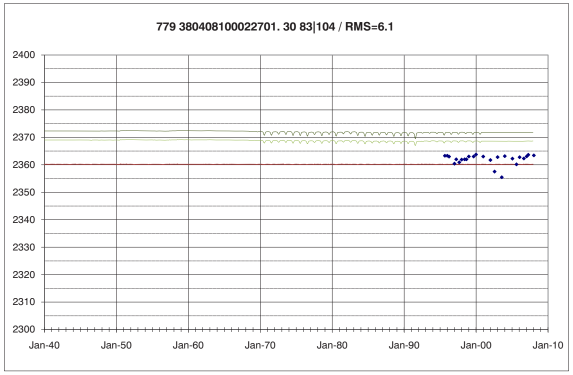
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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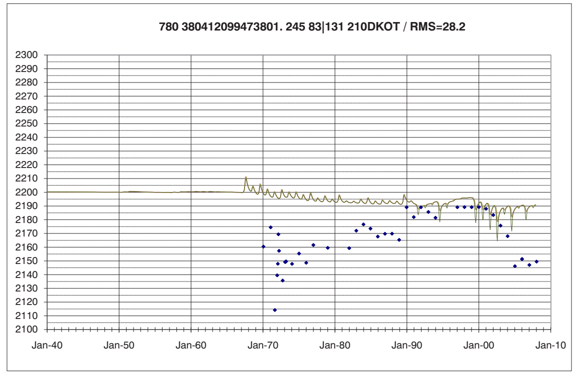

BALLEAU GROUNDWATER, INC.

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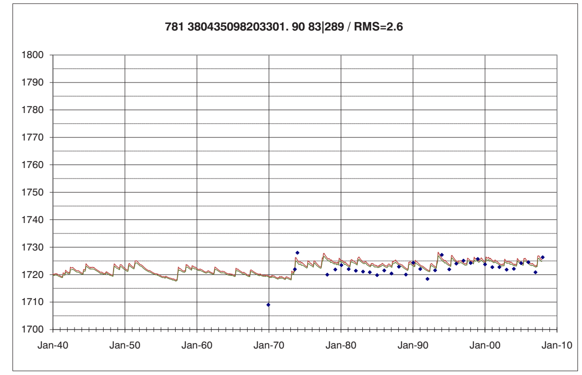

BALLEAU GROUNDWATER, INC.

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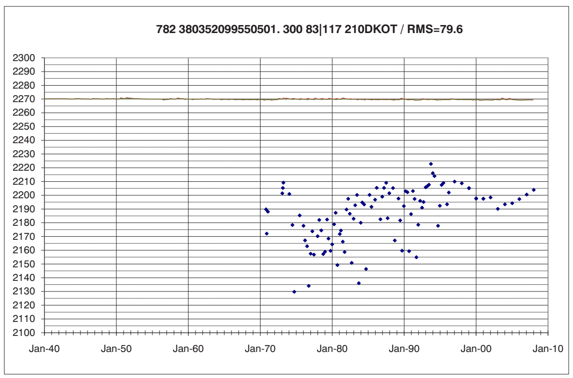

BALLEAU GROUNDWATER, INC.

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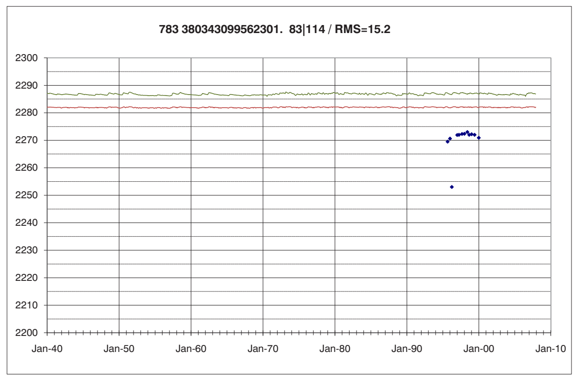

BALLEAU GROUNDWATER, INC.

GMD #5

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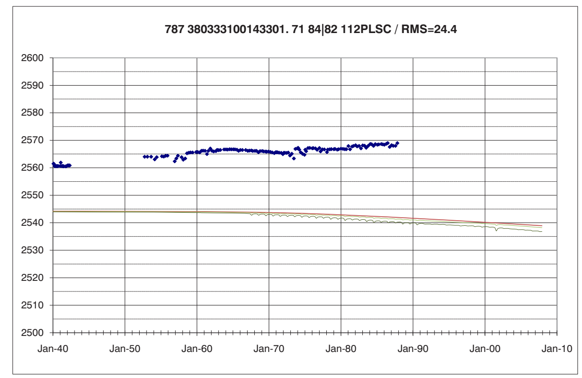

BALLEAU GROUNDWATER, INC.

GMD #5

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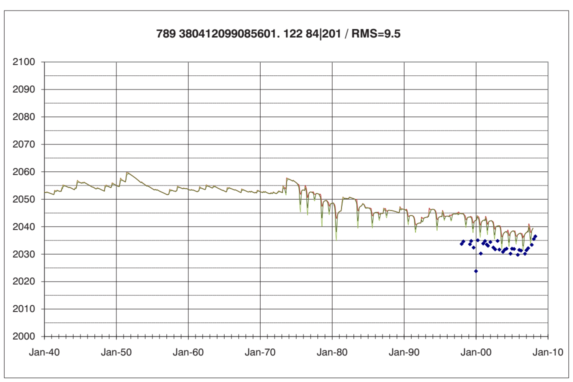

BALLEAU GROUNDWATER, INC.

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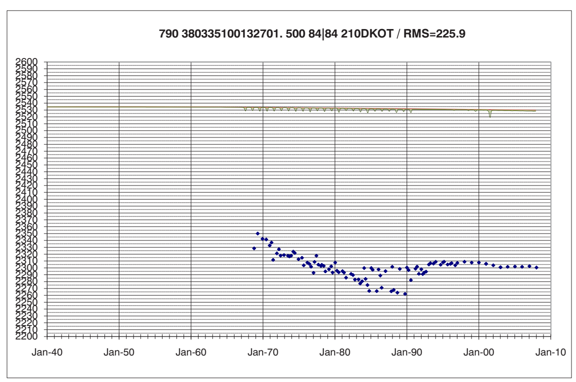
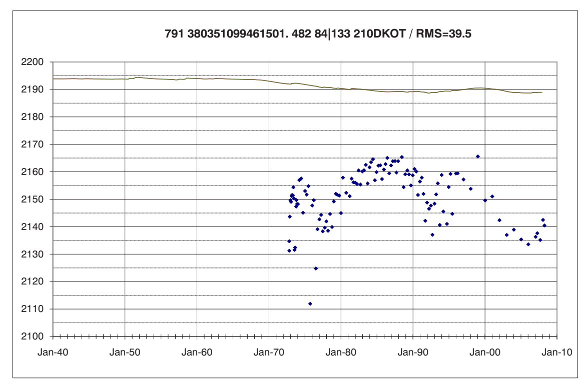


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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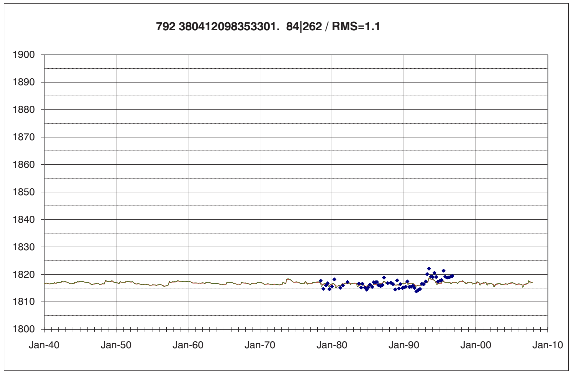

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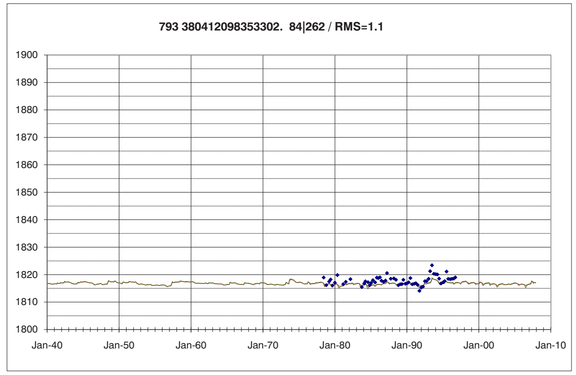
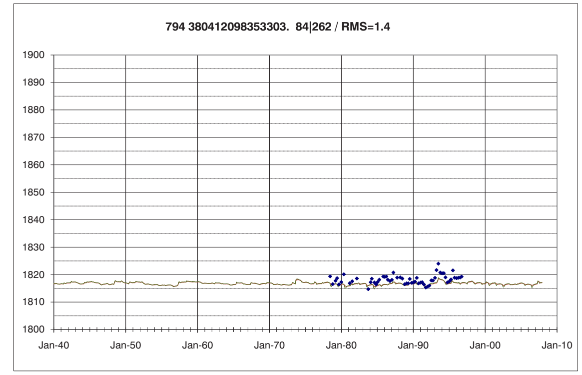


GMD #5

MODEL



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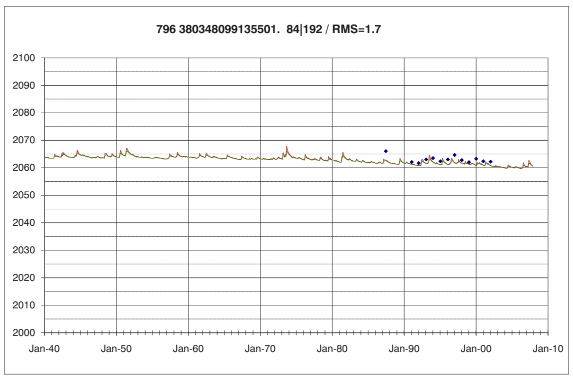

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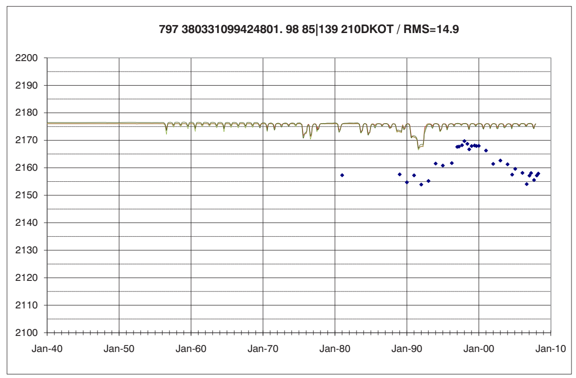

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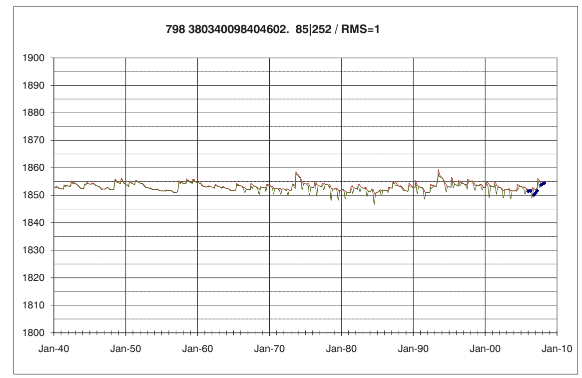

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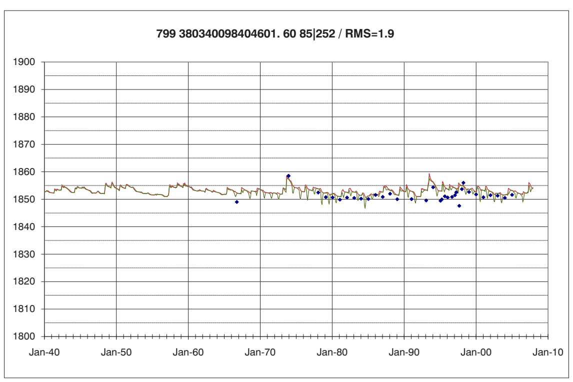

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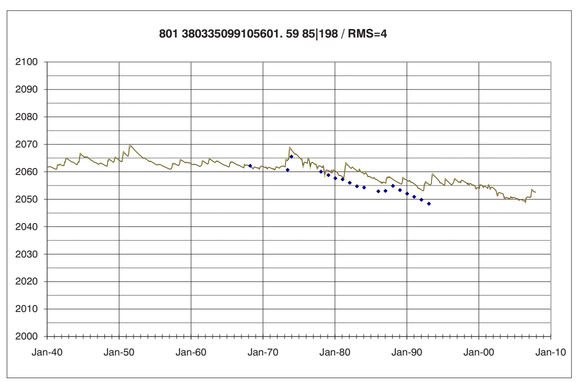

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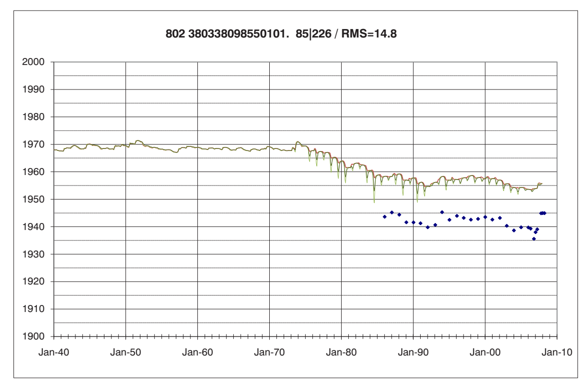

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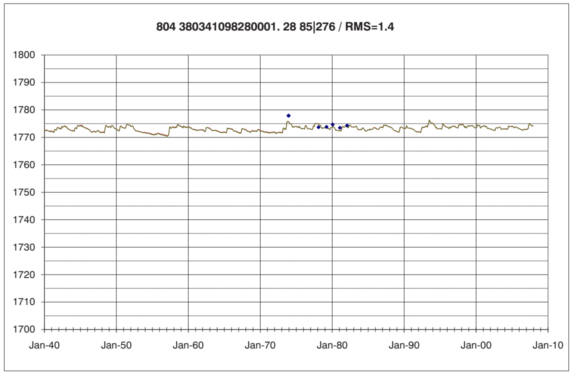

BALLEAU GROUNDWATER, INC.

GMD #5

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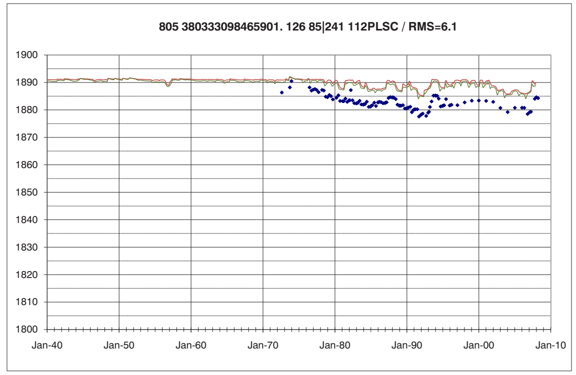

BALLEAU GROUNDWATER, INC.

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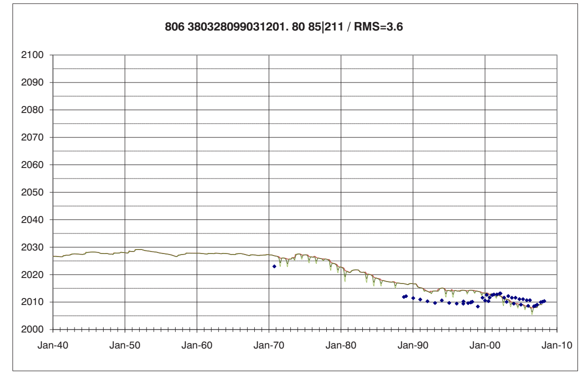

BALLEAU GROUNDWATER, INC.

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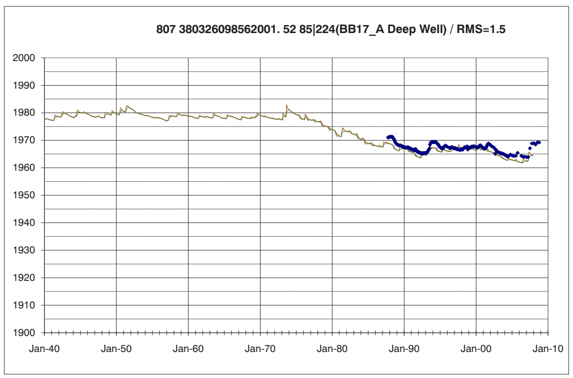

BALLEAU GROUNDWATER, INC.

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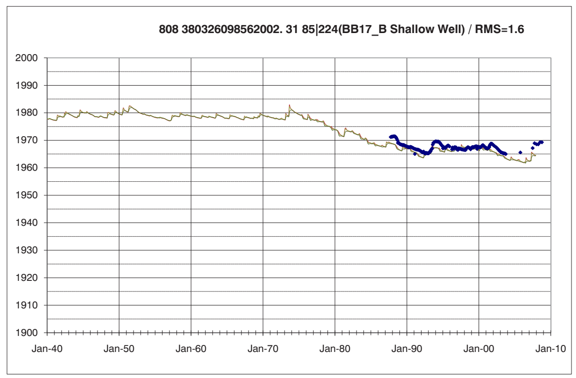

BALLEAU GROUNDWATER, INC.

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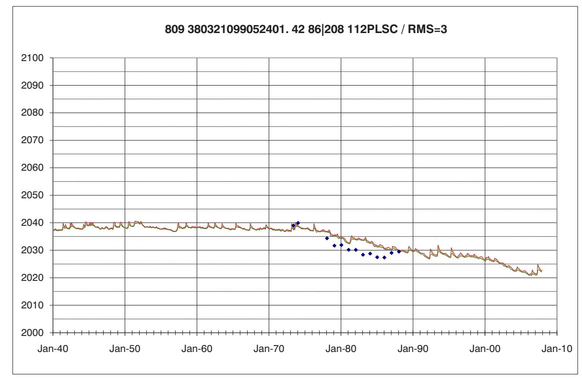

BALLEAU GROUNDWATER, INC.

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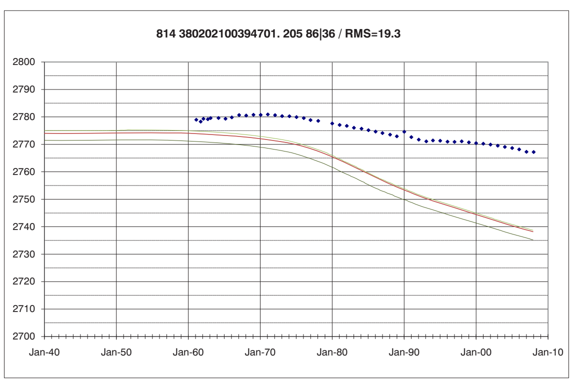

BALLEAU GROUNDWATER, INC.

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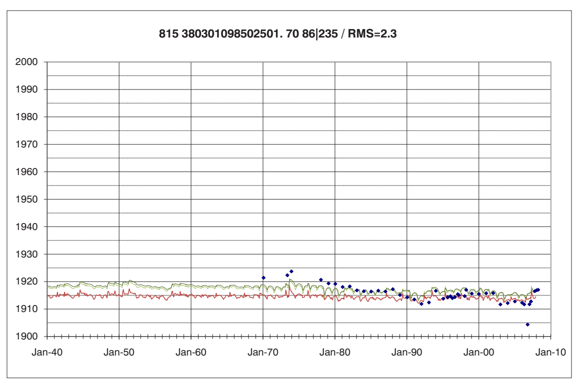

BALLEAU GROUNDWATER, INC.

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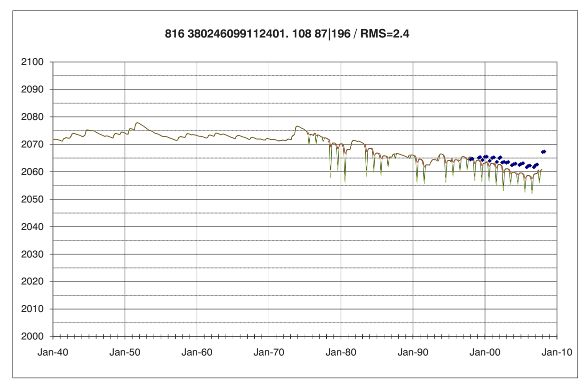

BALLEAU GROUNDWATER, INC.

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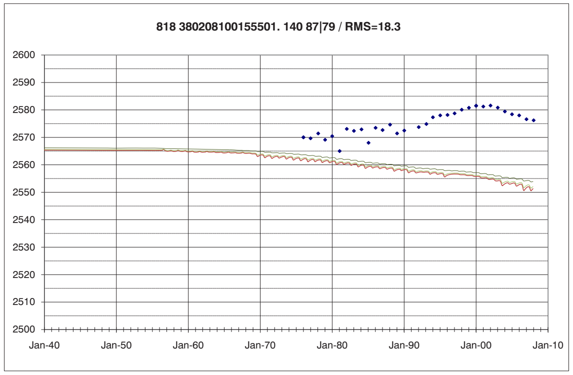

BALLEAU GROUNDWATER, INC.

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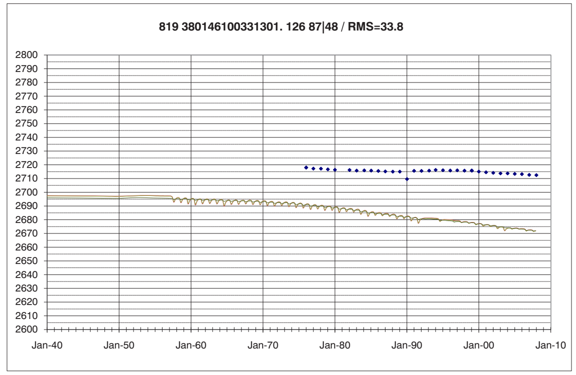

BALLEAU GROUNDWATER, INC.

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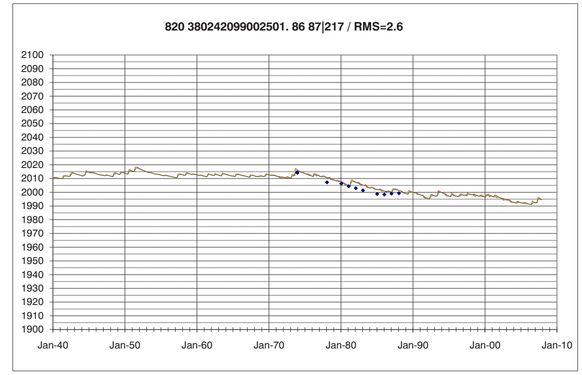

BALLEAU GROUNDWATER, INC.

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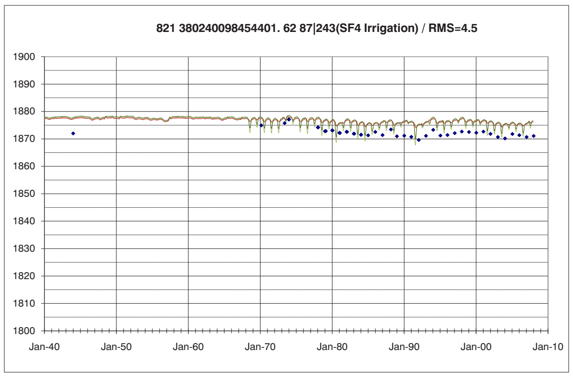

BALLEAU GROUNDWATER, INC.

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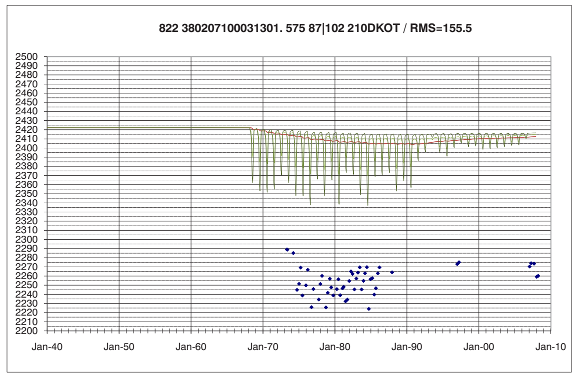

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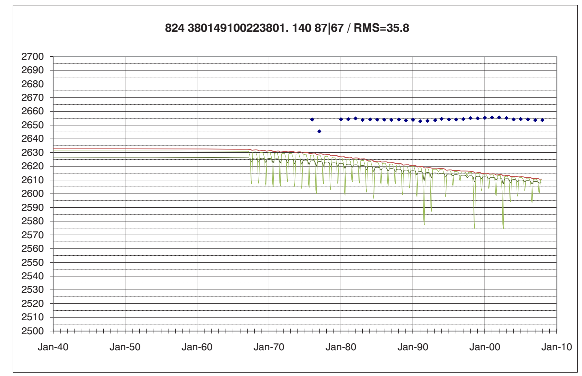

BALLEAU GROUNDWATER, INC.

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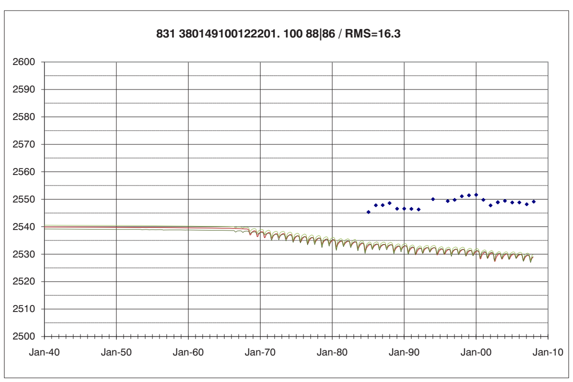

BALLEAU GROUNDWATER, INC.

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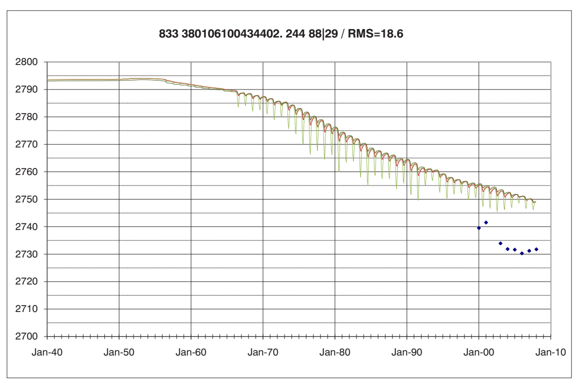

BALLEAU GROUNDWATER, INC.

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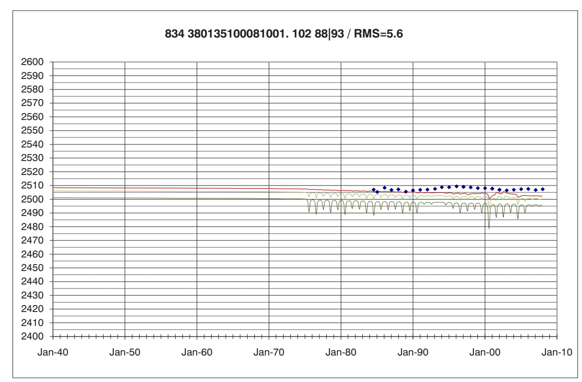

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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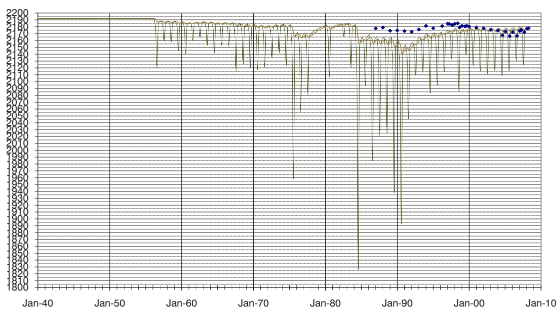

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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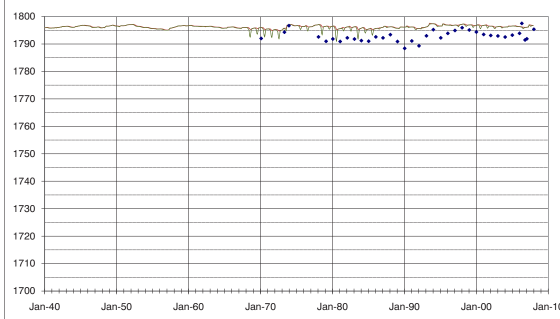

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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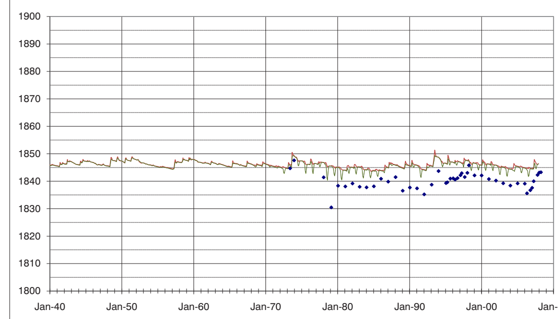

BALLEAU GROUNDWATER, INC.

GMD #5

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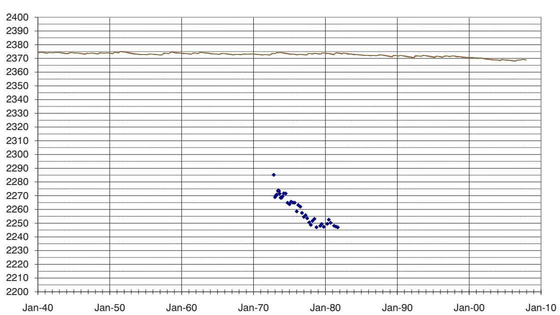

BALLEAU GROUNDWATER, INC.

GMD #5

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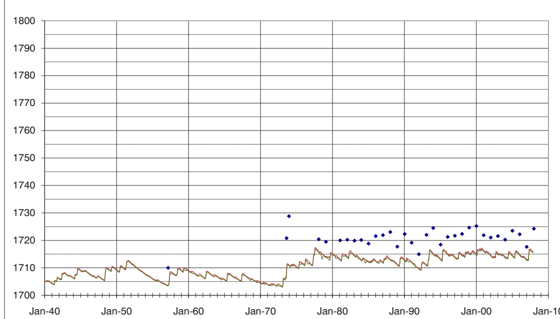

BALLEAU GROUNDWATER, INC.

GMD #5

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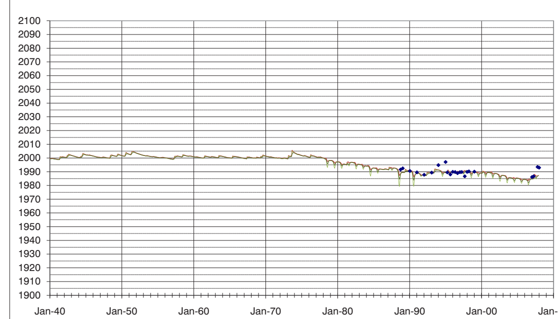

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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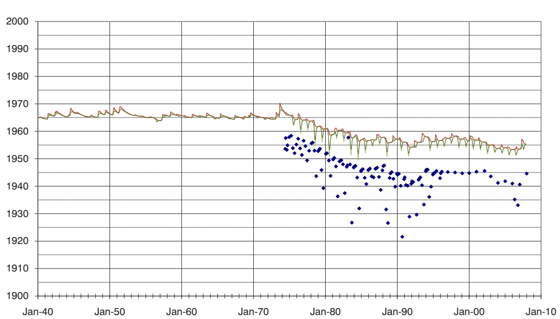

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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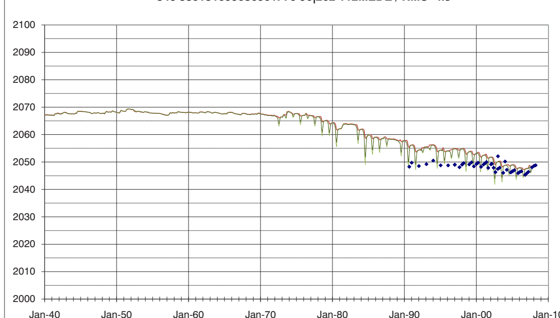

BALLEAU GROUNDWATER, INC.

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MODEL

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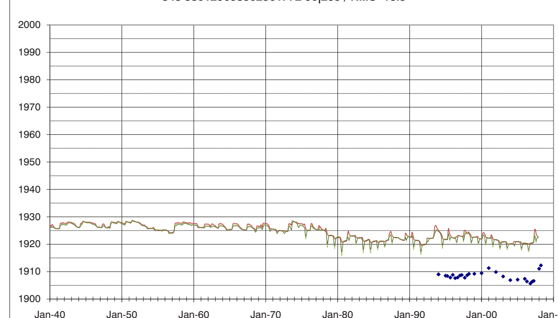

BALLEAU GROUNDWATER, INC.

GMD #5

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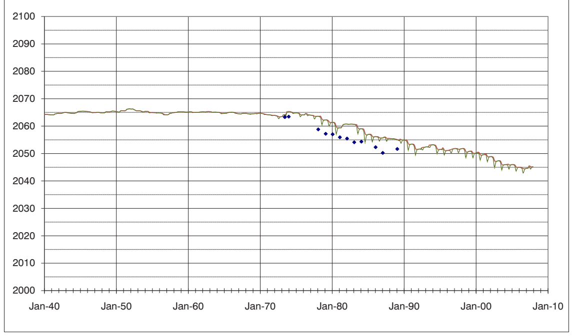

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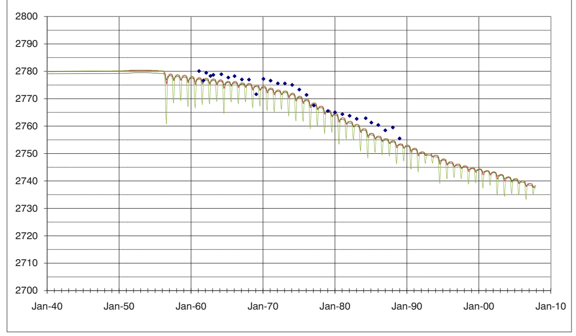

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MODEL

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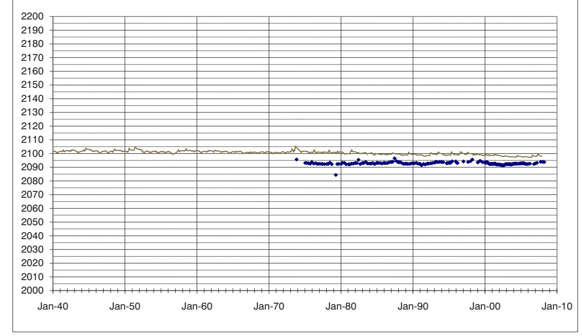

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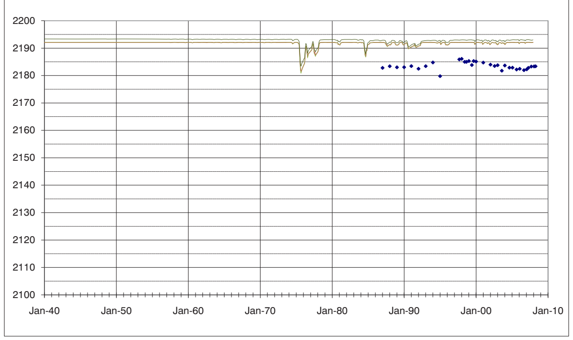

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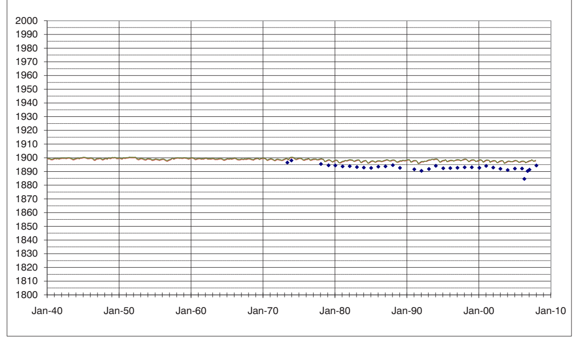

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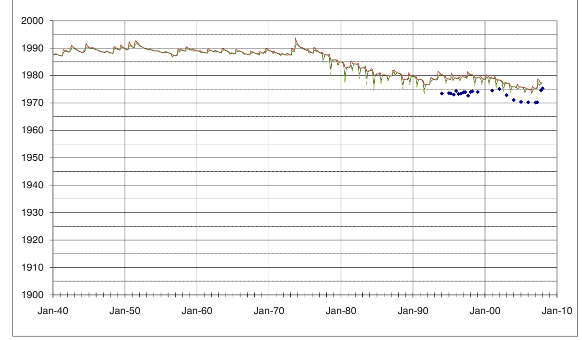

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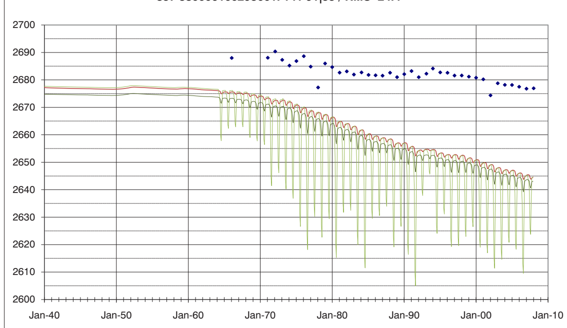

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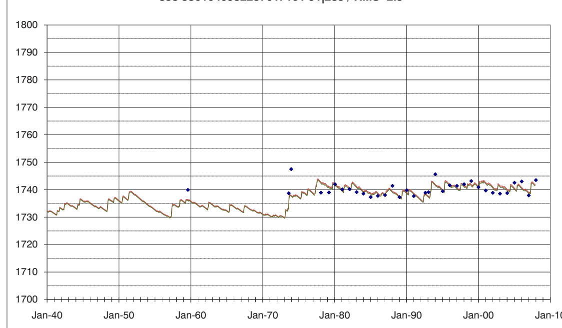

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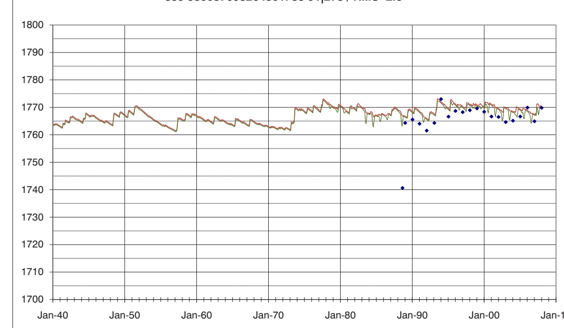

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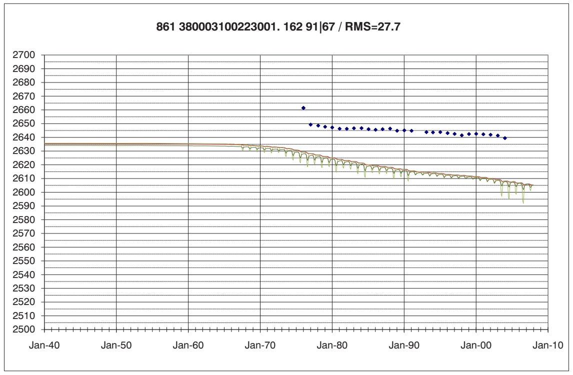

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SES
6/18/2010

BALLEAU GROUNDWATER, INC.

GMD #5

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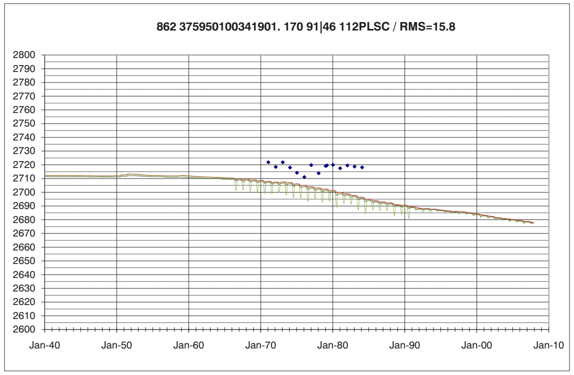

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BALLEAU GROUNDWATER, INC.

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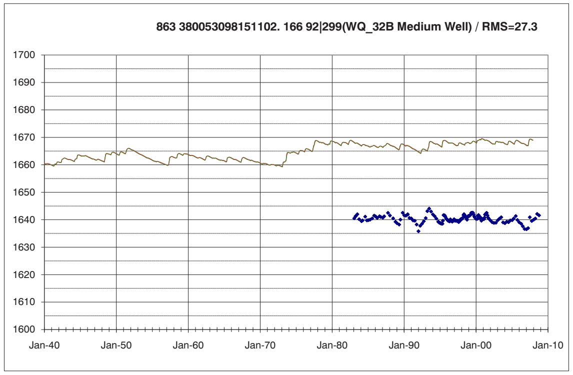

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BALLEAU GROUNDWATER, INC.

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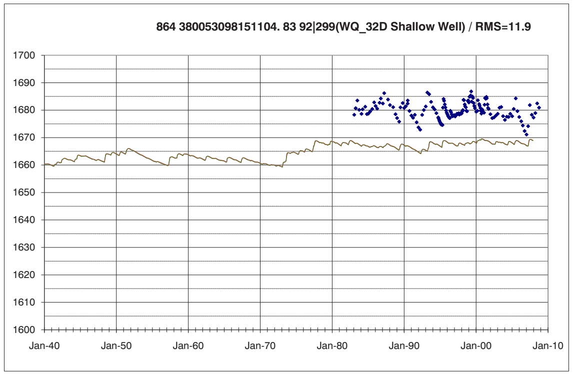

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BALLEAU GROUNDWATER, INC.

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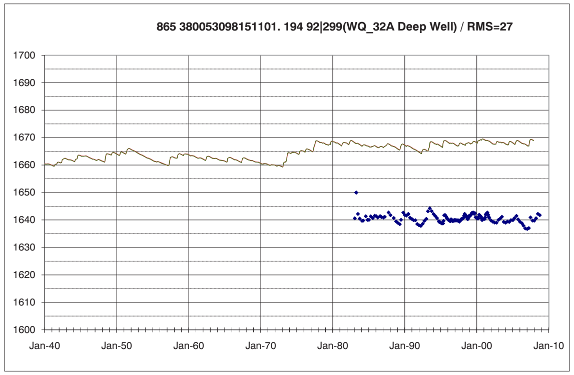

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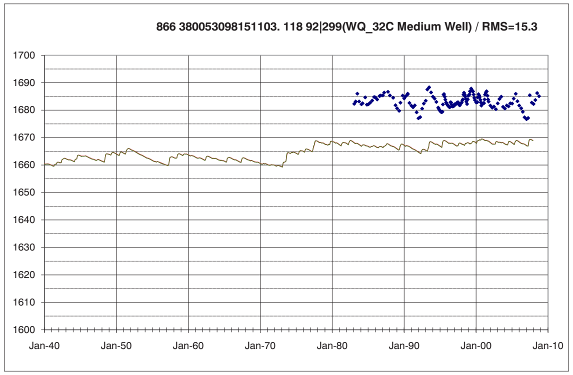

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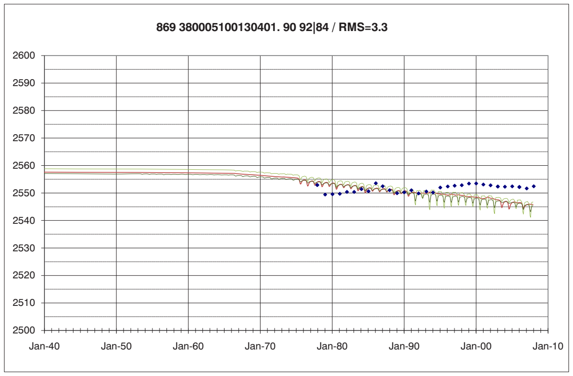

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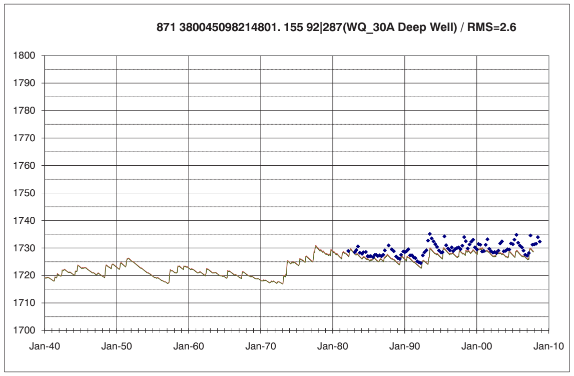

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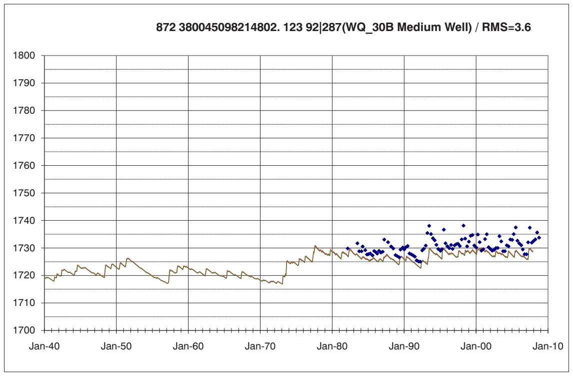

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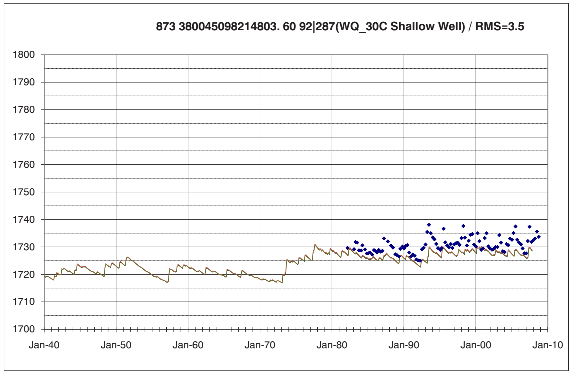

BALLEAU GROUNDWATER, INC.

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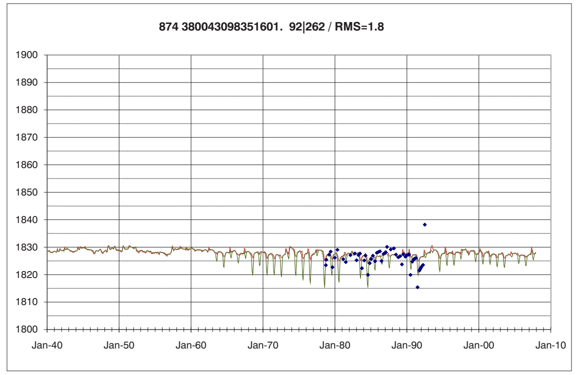

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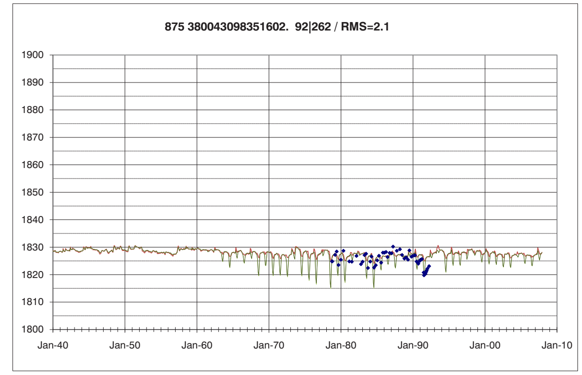

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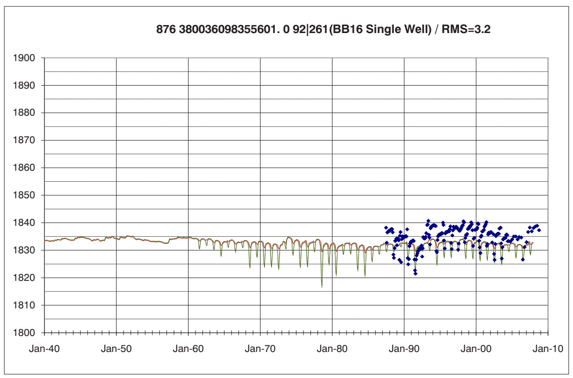

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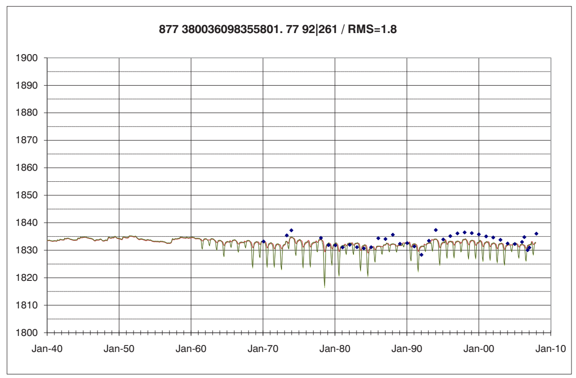

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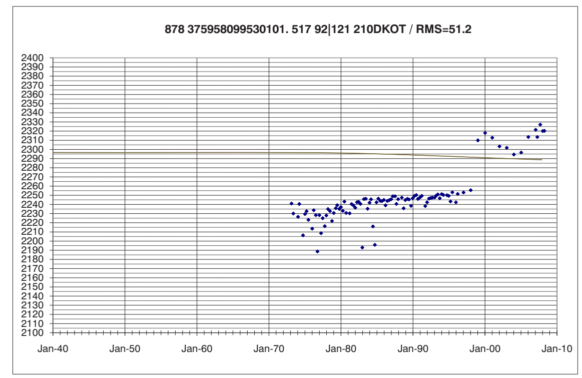

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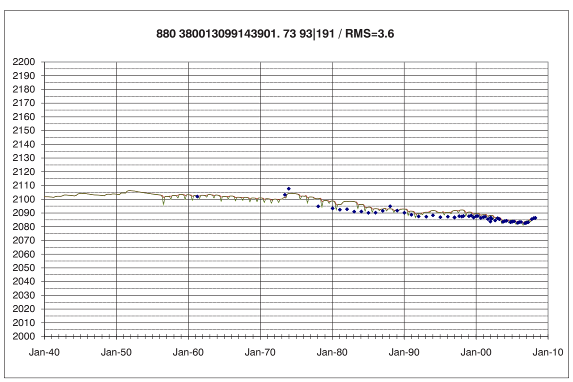

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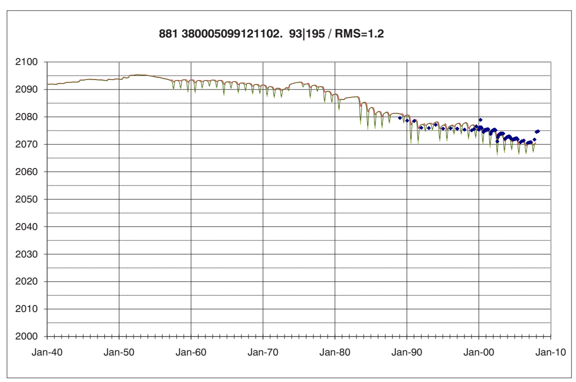

BALLEAU GROUNDWATER, INC.

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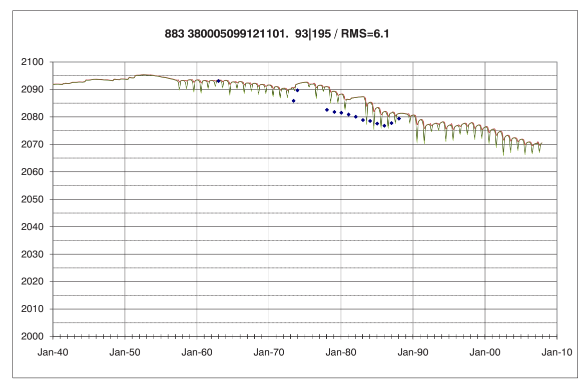

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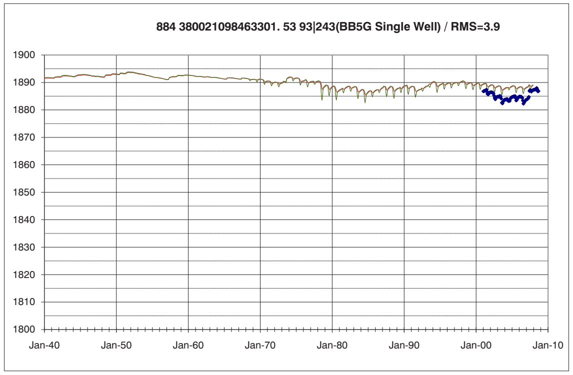

BALLEAU GROUNDWATER, INC.

GMD #5

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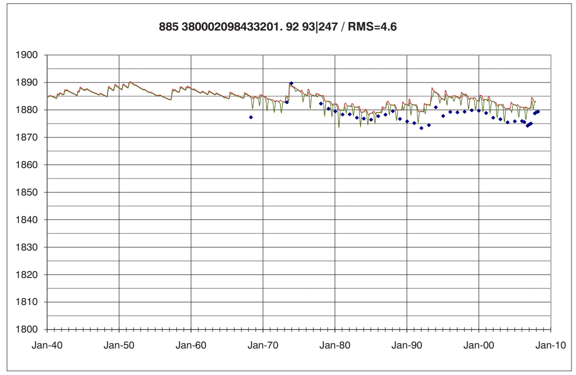

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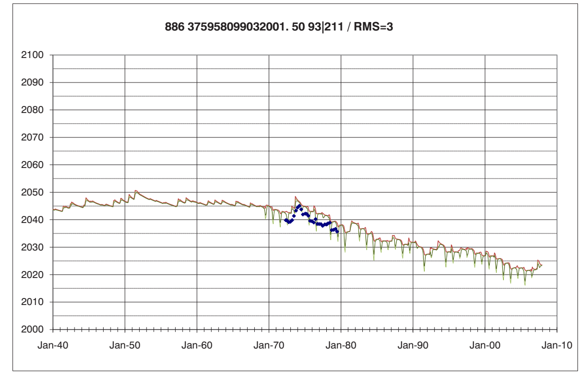

BALLEAU GROUNDWATER, INC.

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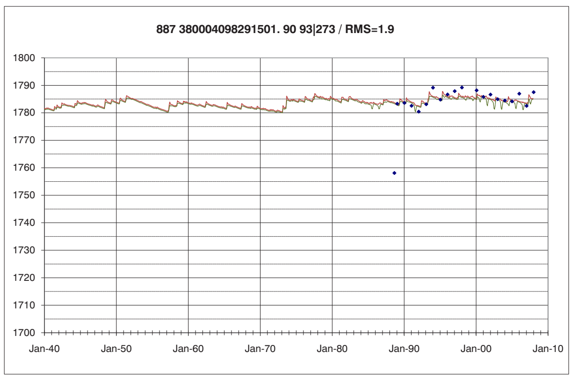

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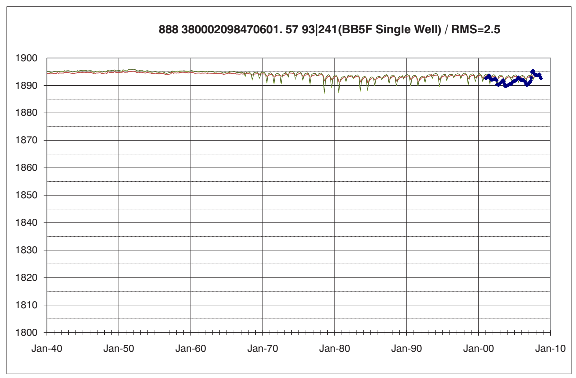

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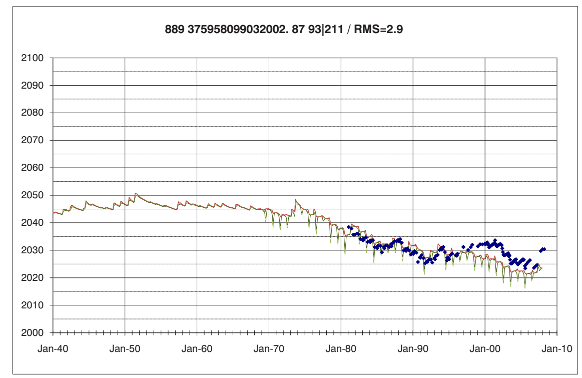

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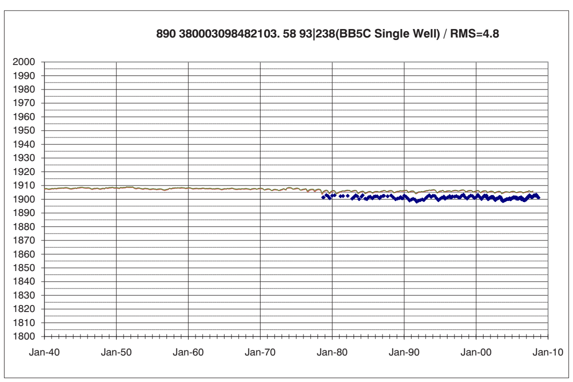

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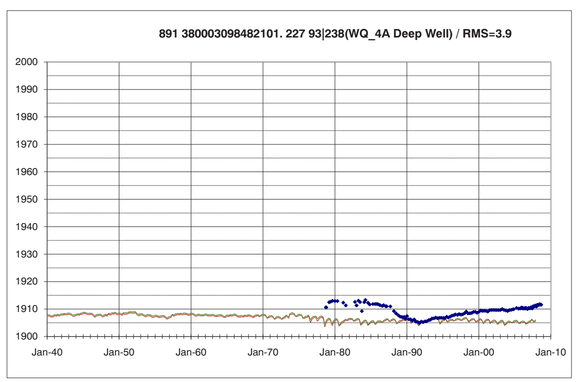

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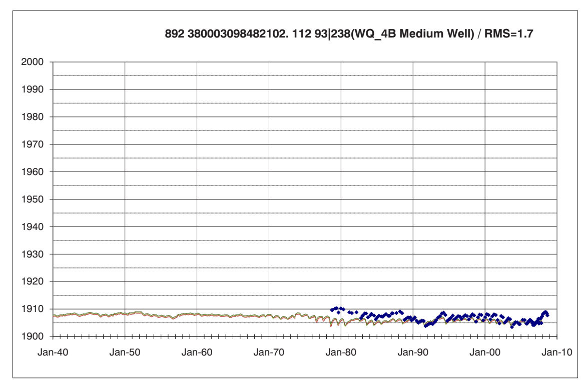

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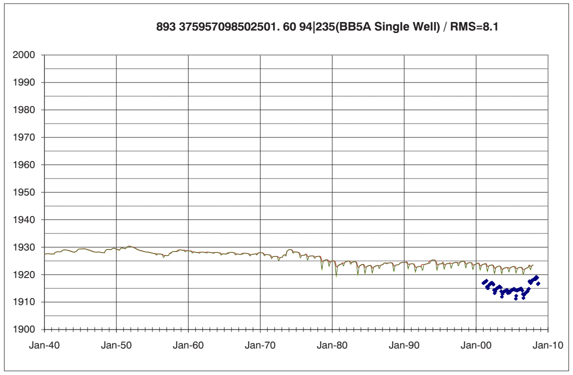

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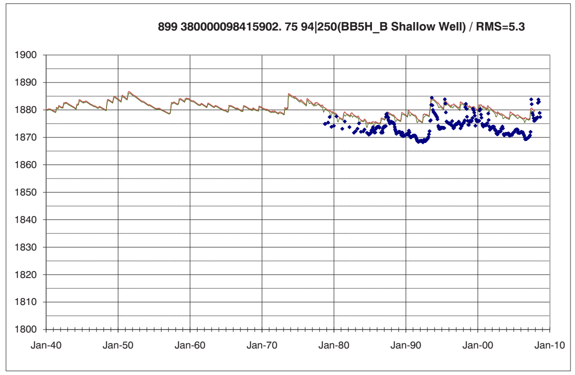

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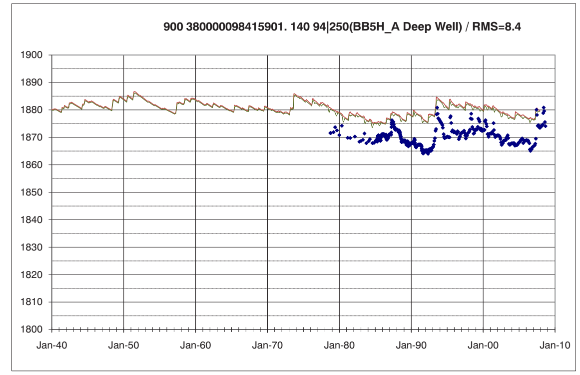

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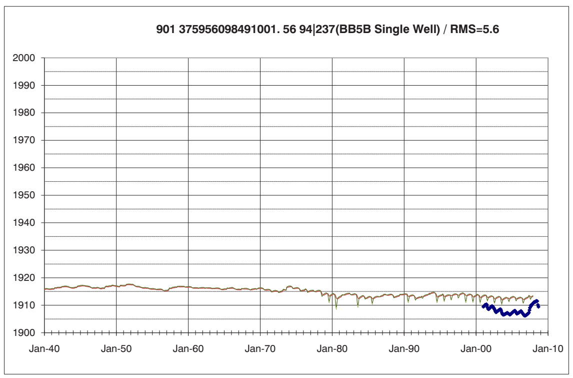

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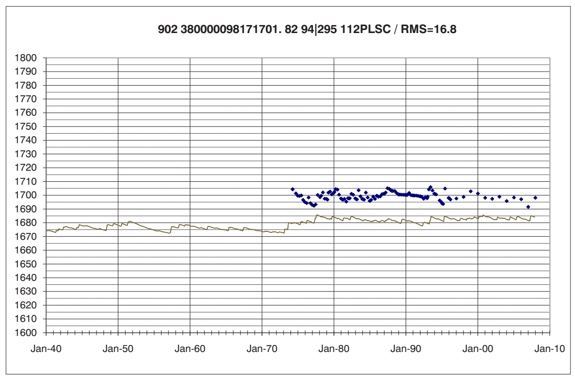

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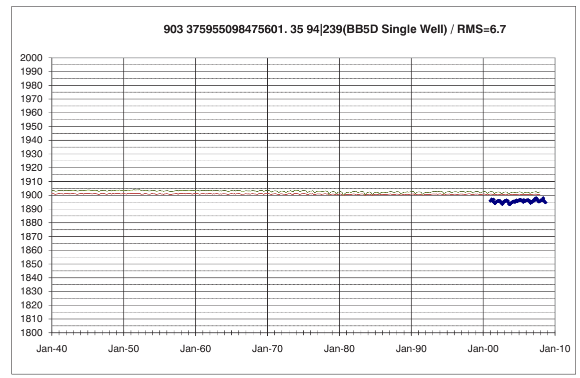

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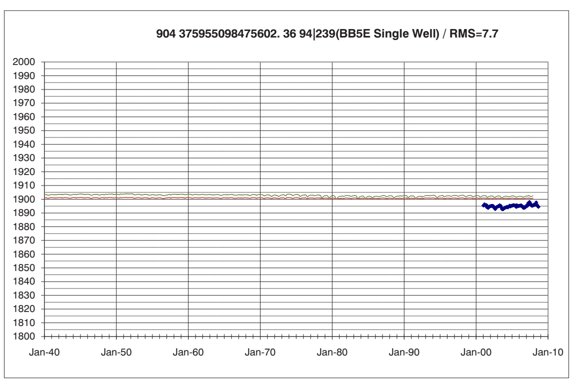

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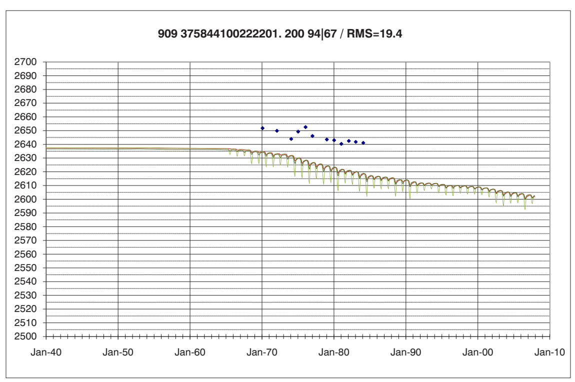

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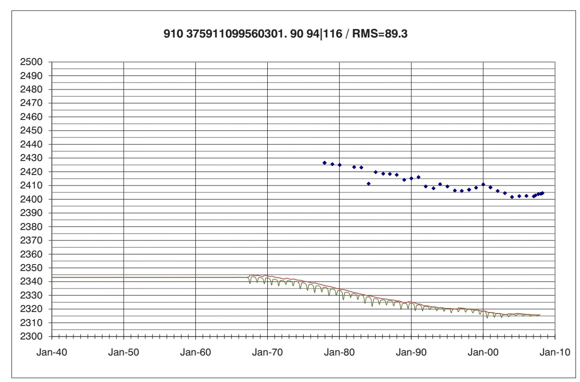

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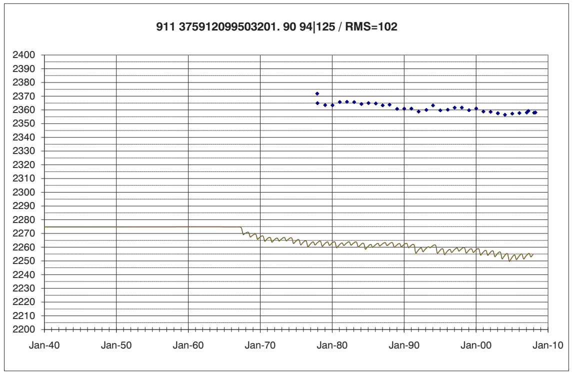

BALLEAU GROUNDWATER, INC.

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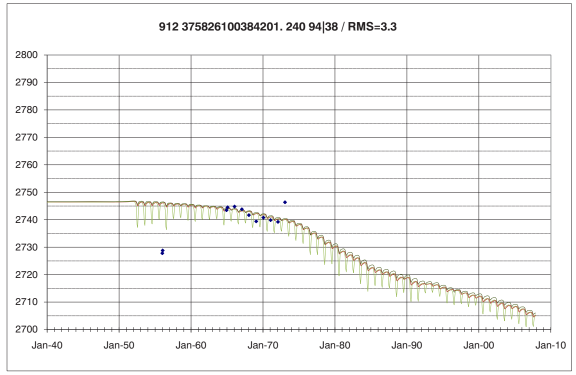

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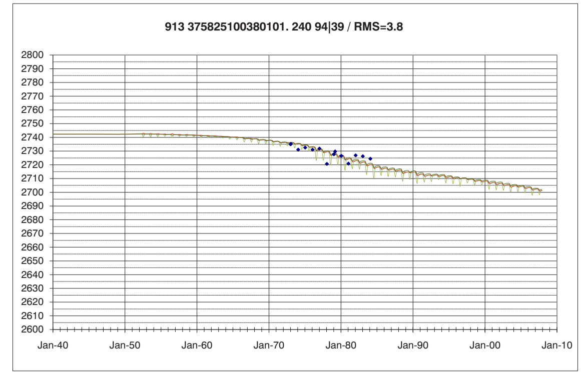

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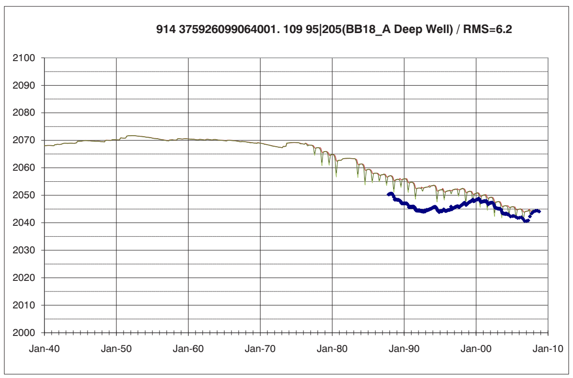

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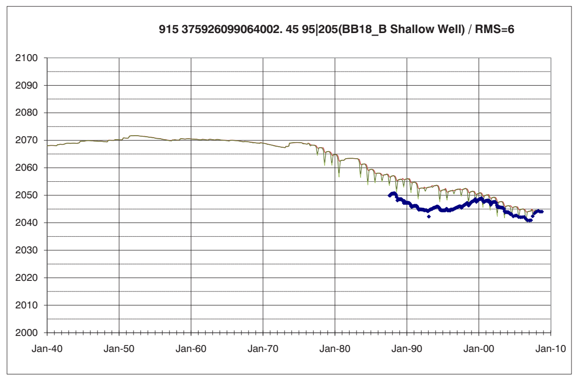

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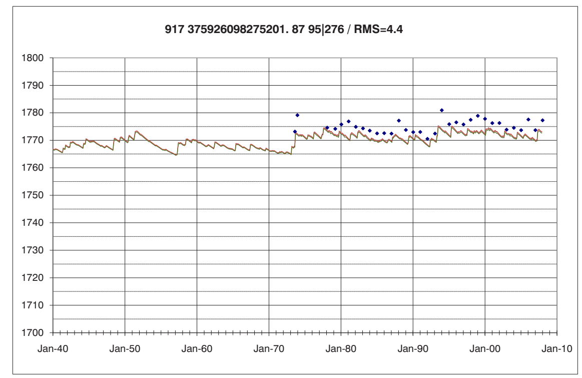

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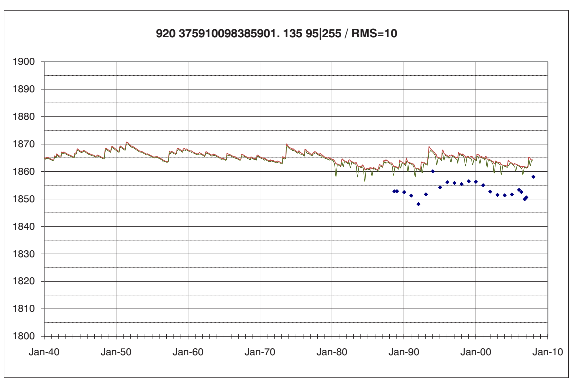

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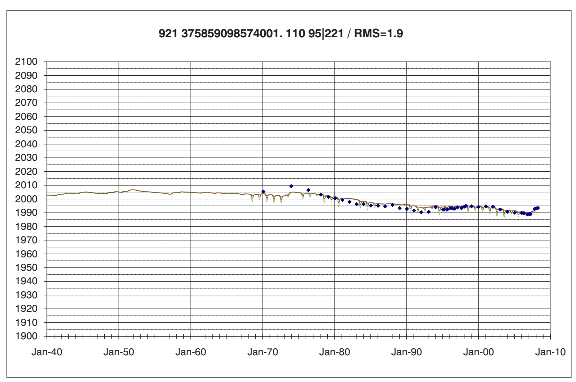

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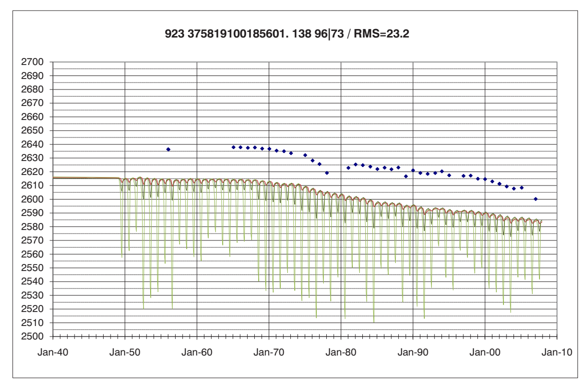

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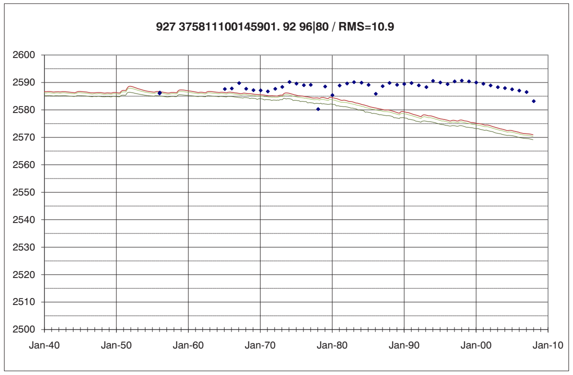

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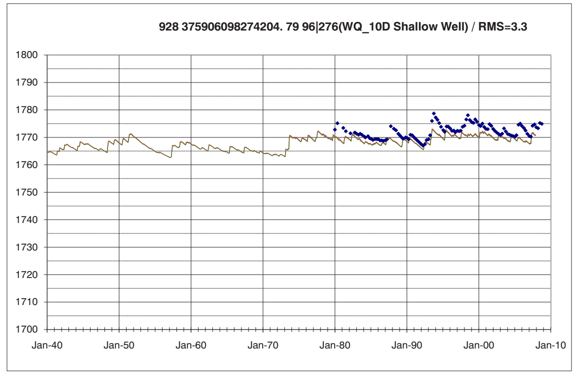

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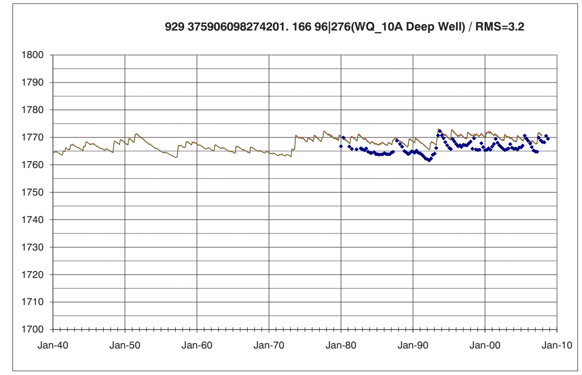

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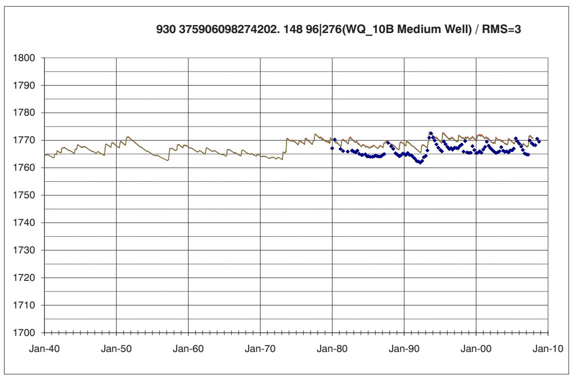

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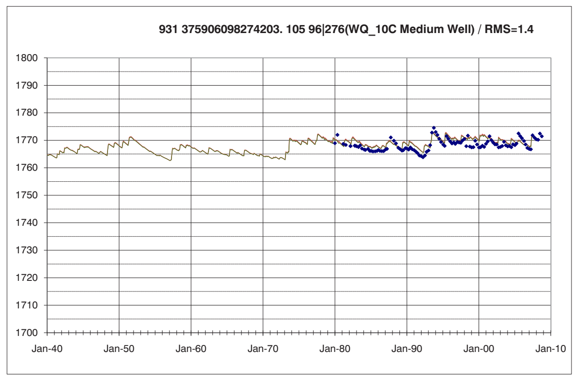

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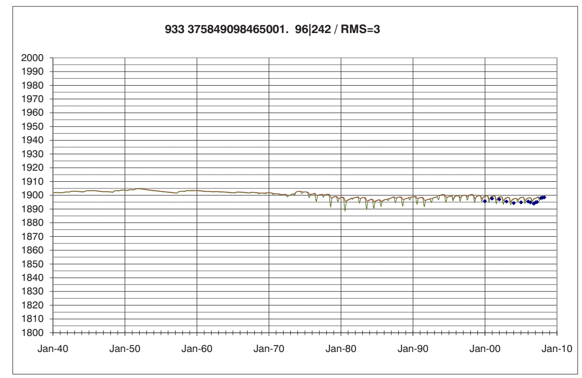

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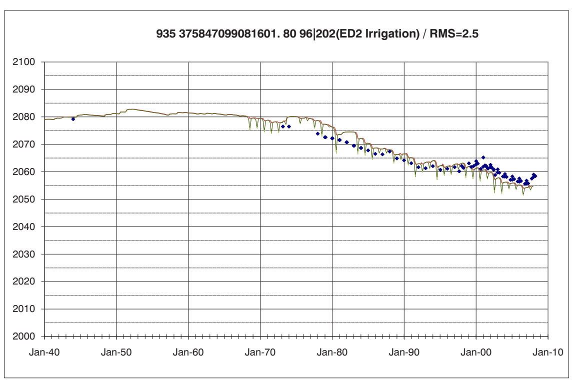

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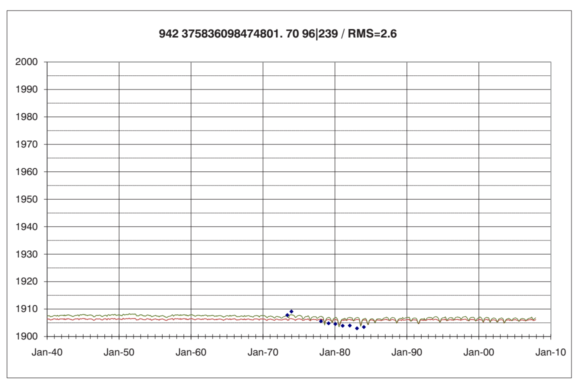

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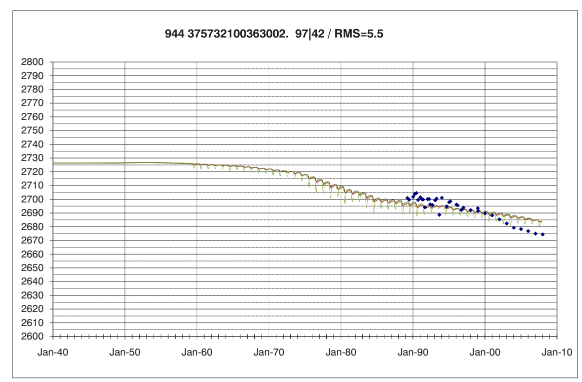

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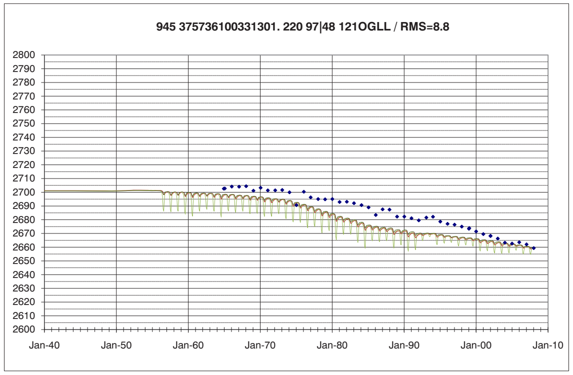

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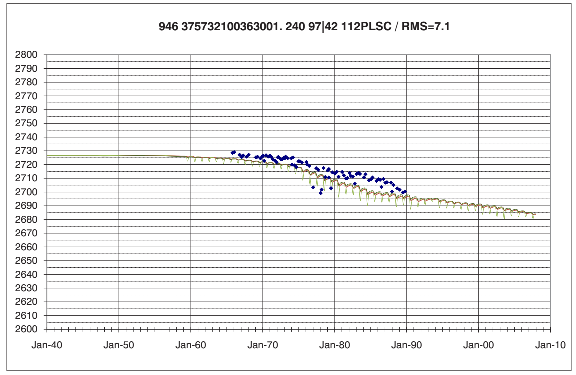

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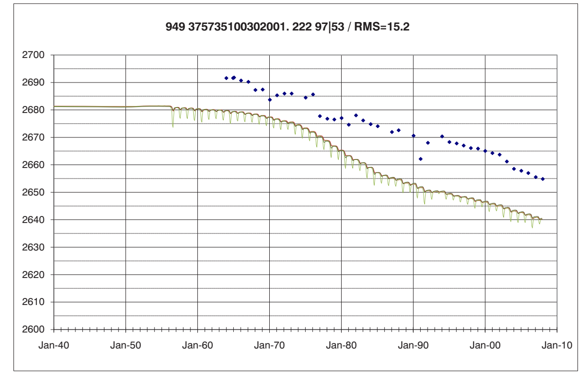

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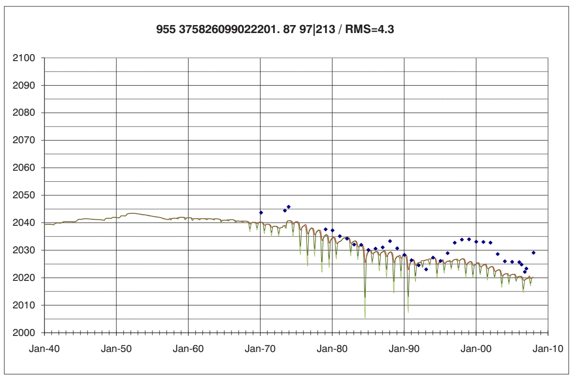

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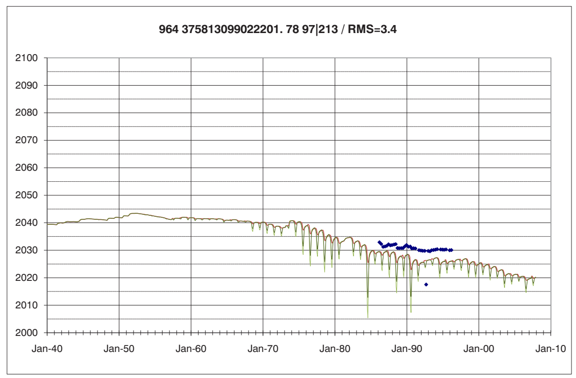

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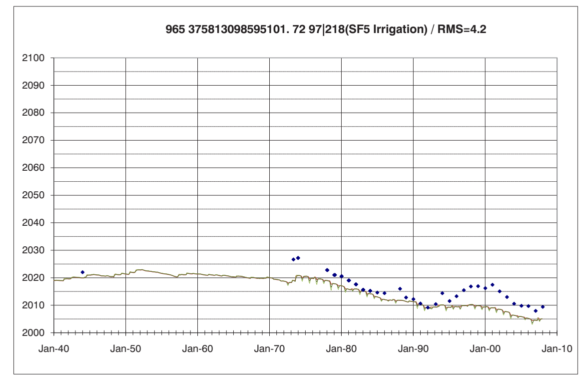

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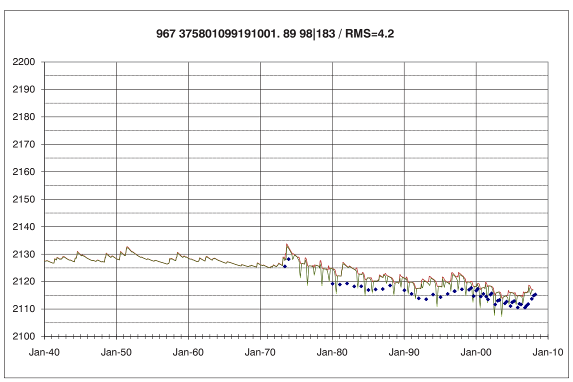

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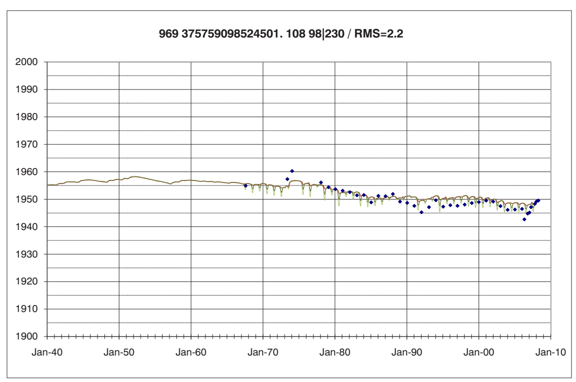

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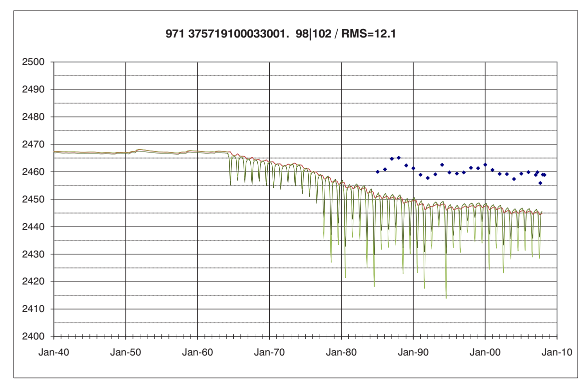

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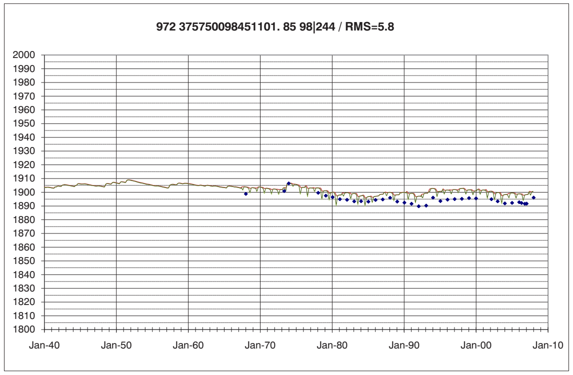

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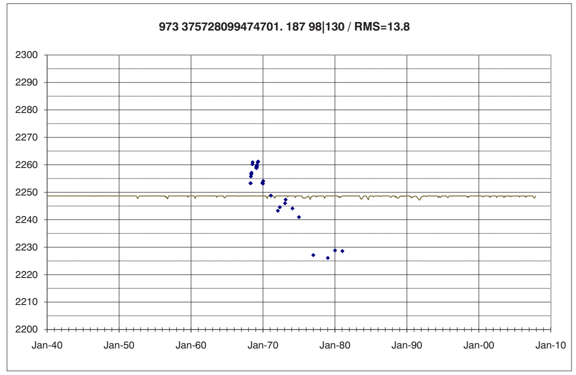

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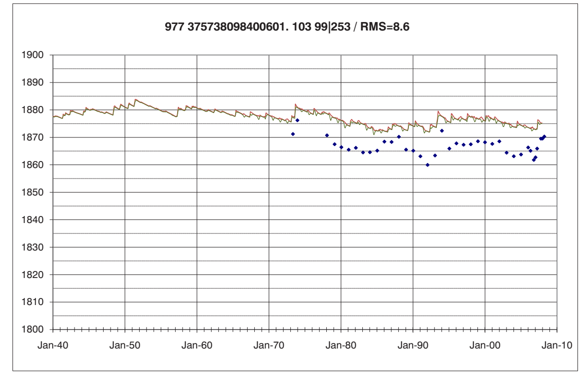

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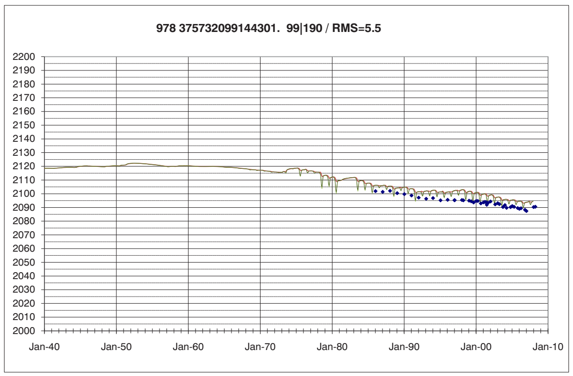

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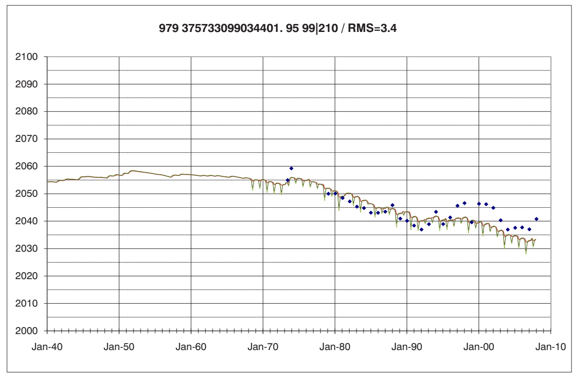

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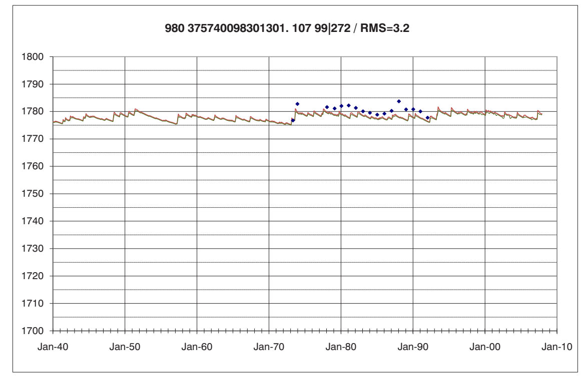

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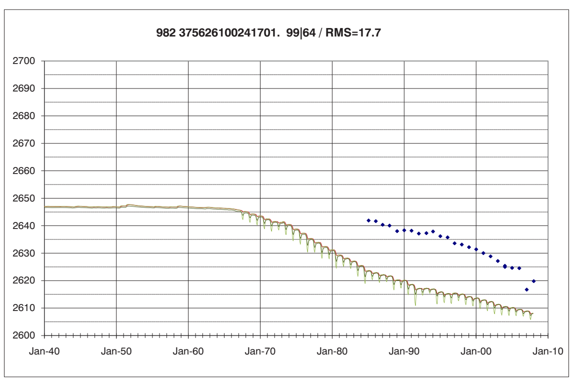

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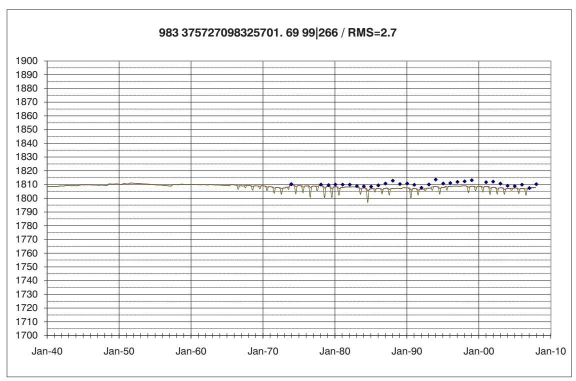

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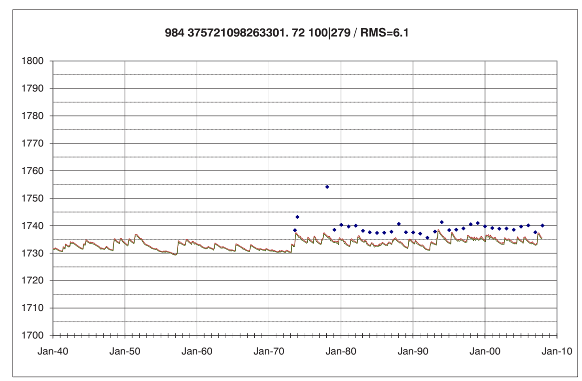

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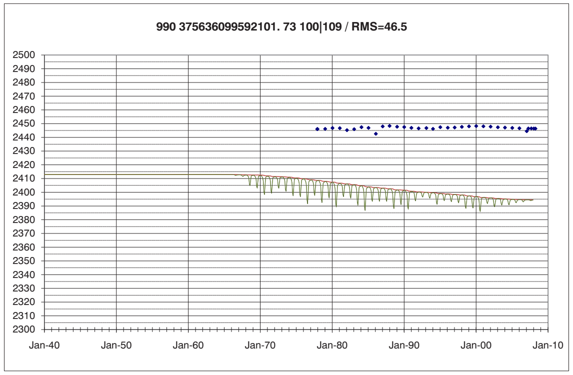

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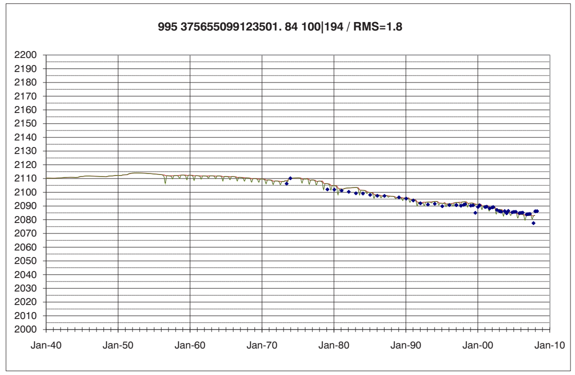

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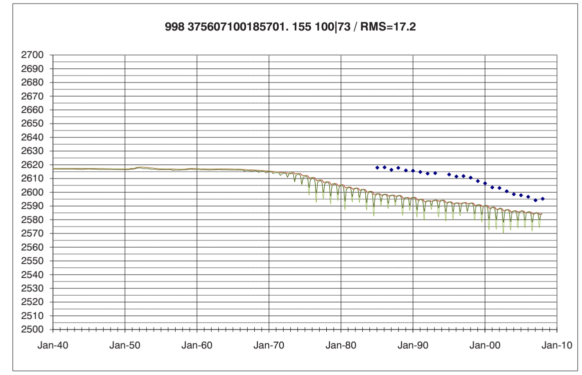

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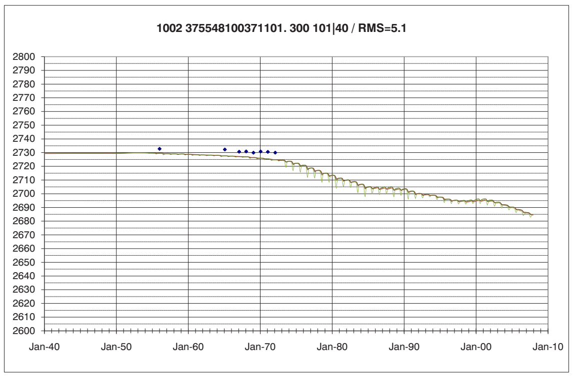

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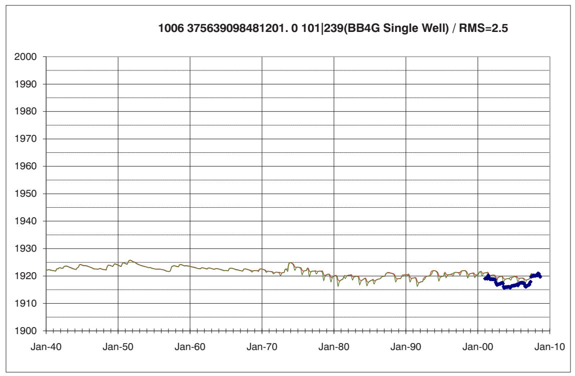

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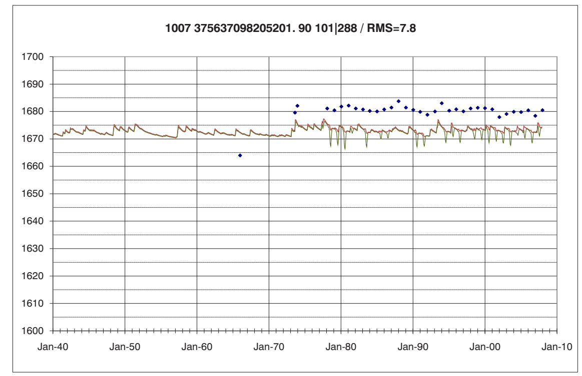

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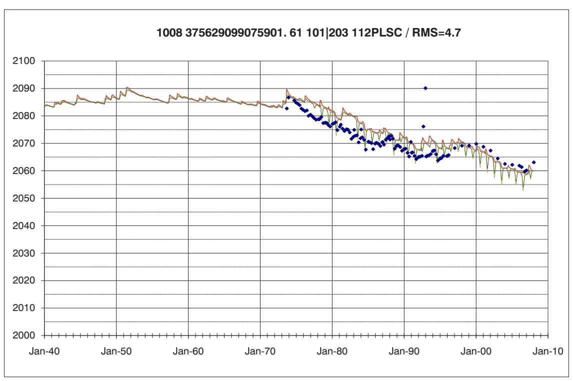

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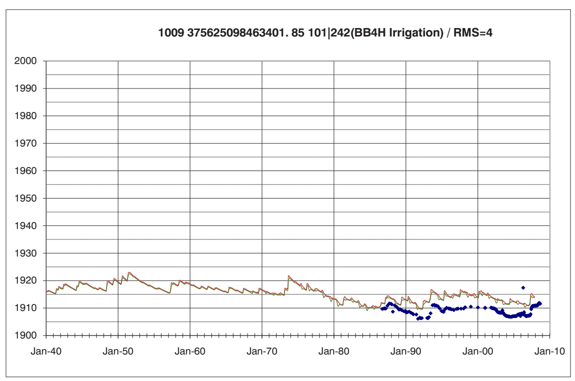

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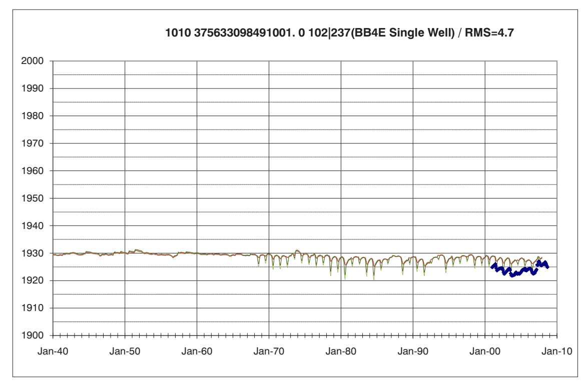

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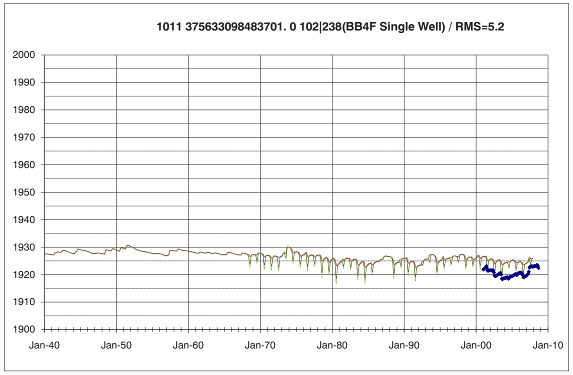

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BALLEAU GROUNDWATER, INC.

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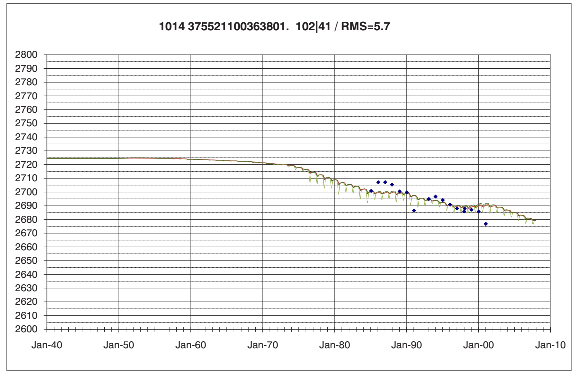

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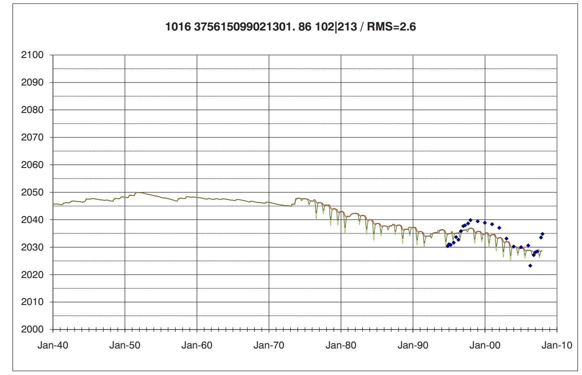

Fig46ProcWL.xlsb
SES
6/18/2010

BALLEAU GROUNDWATER, INC.

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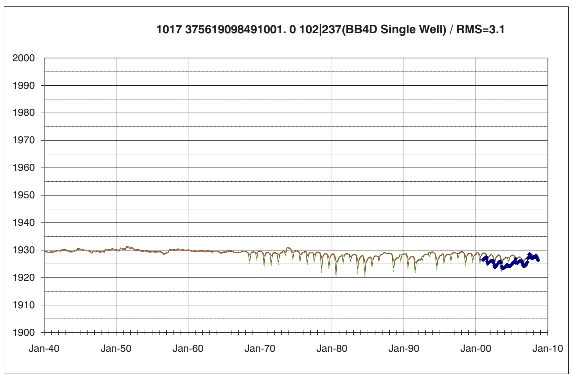

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BALLEAU GROUNDWATER, INC.

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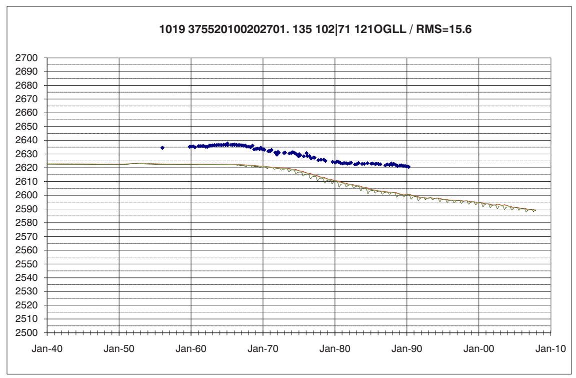

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BALLEAU GROUNDWATER, INC.

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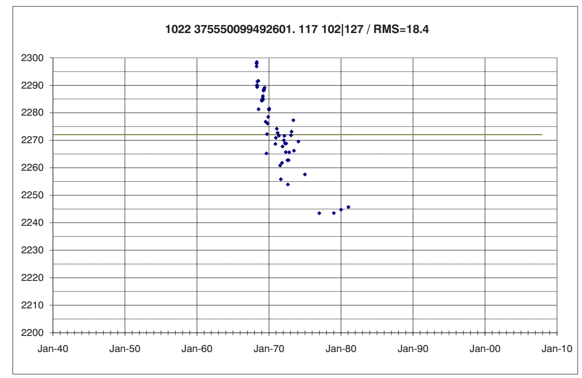

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BALLEAU GROUNDWATER, INC.

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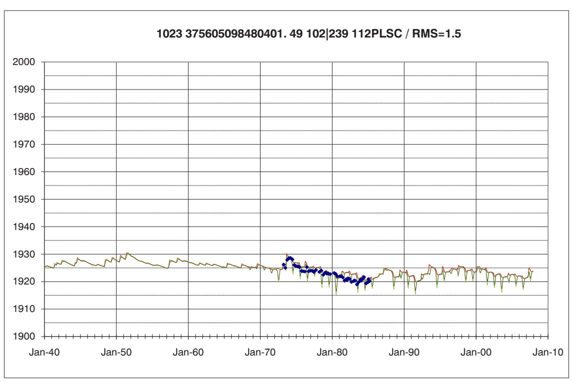

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BALLEAU GROUNDWATER, INC.

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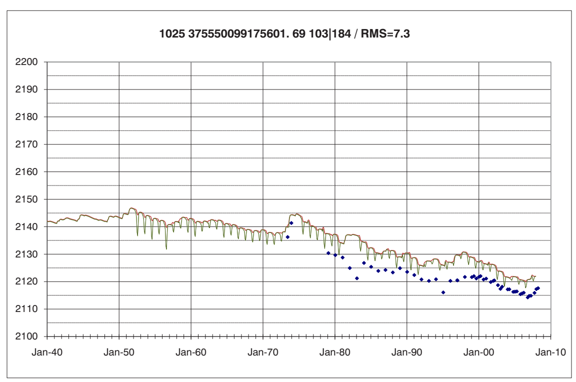

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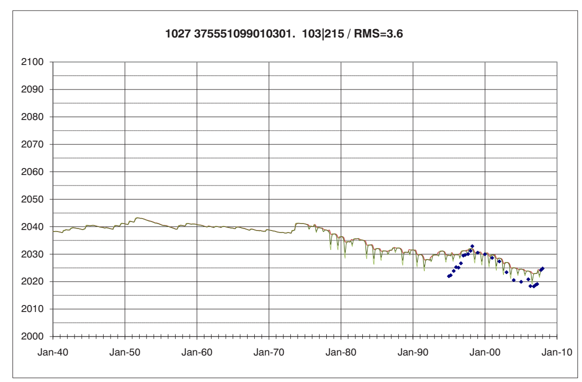

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BALLEAU GROUNDWATER, INC.

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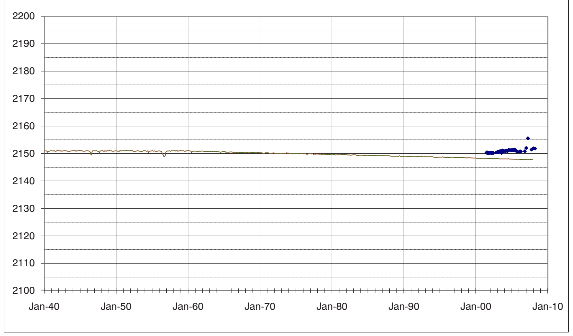

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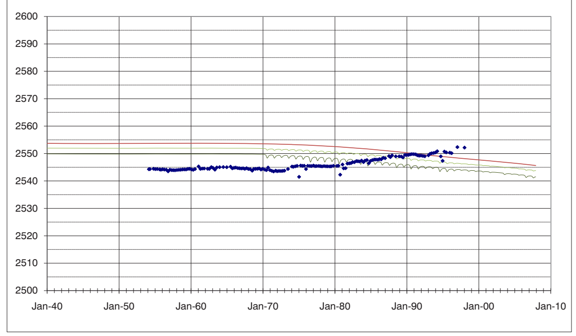

BALLEAU GROUNDWATER, INC.

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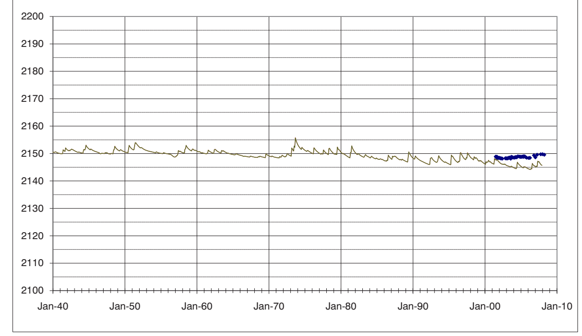

BALLEAU GROUNDWATER, INC.

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MODEL

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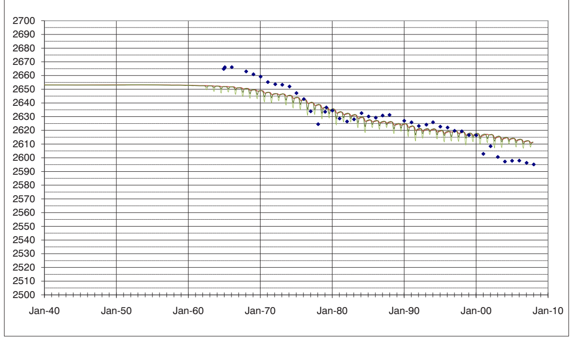

BALLEAU GROUNDWATER, INC.

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MODEL

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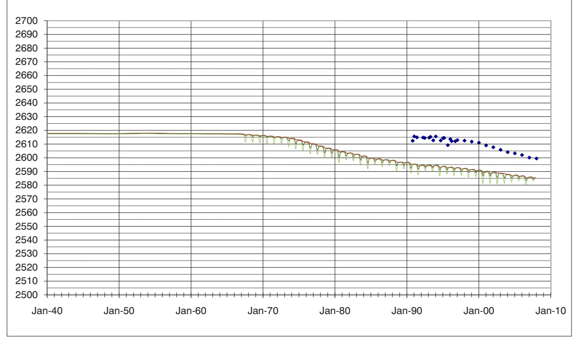

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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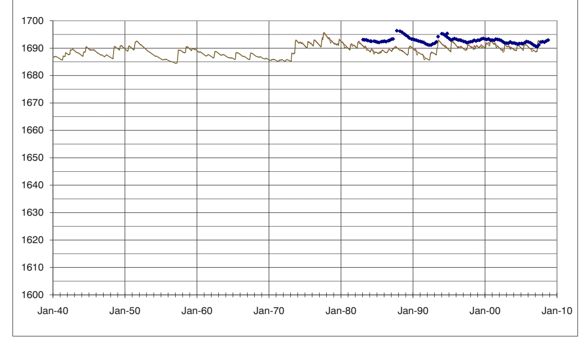

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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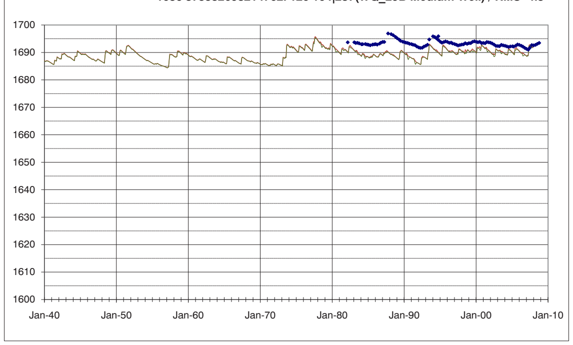

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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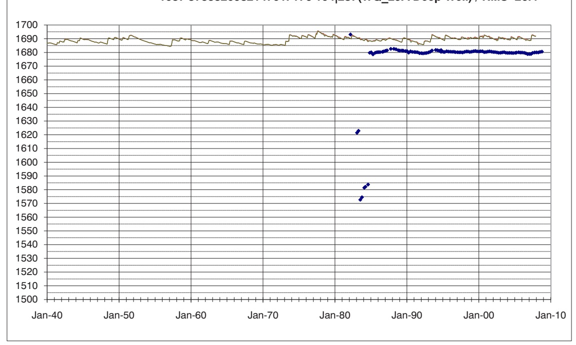

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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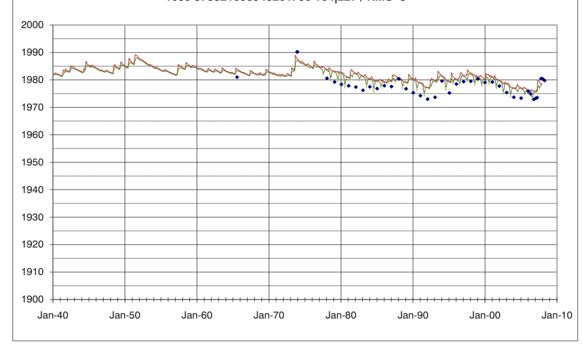

BALLEAU GROUNDWATER, INC.

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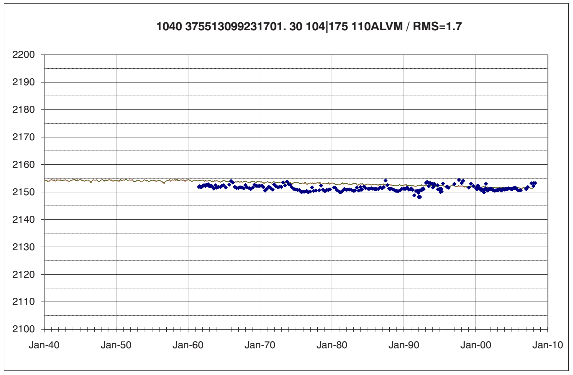
MODEL



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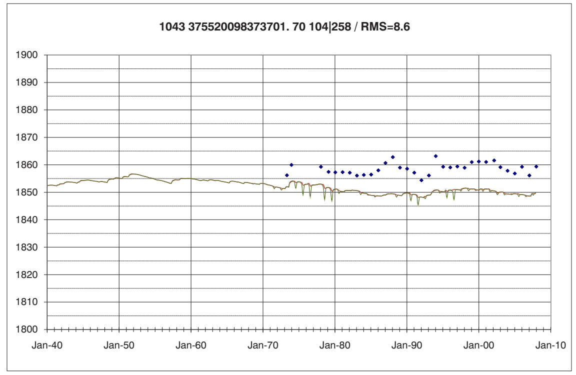

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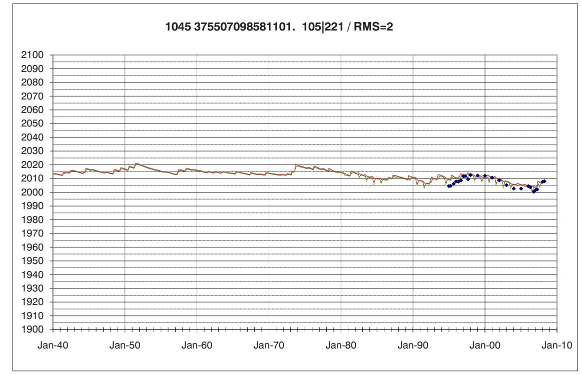

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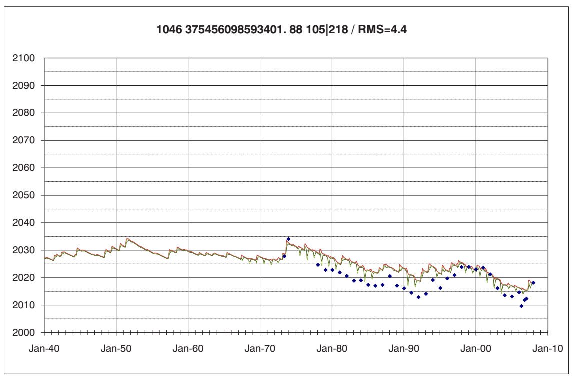

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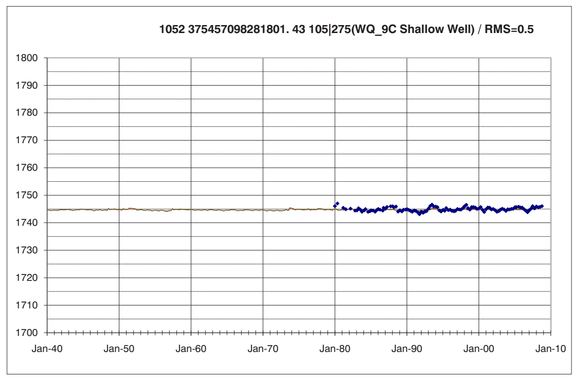

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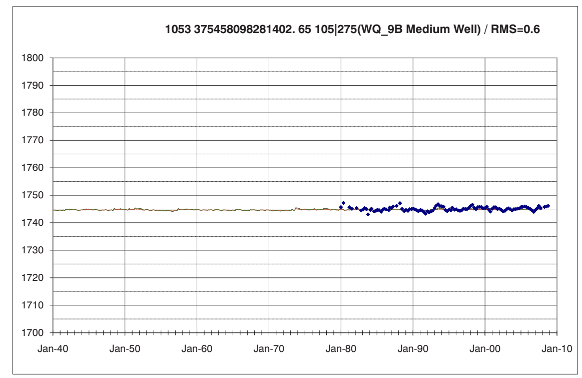

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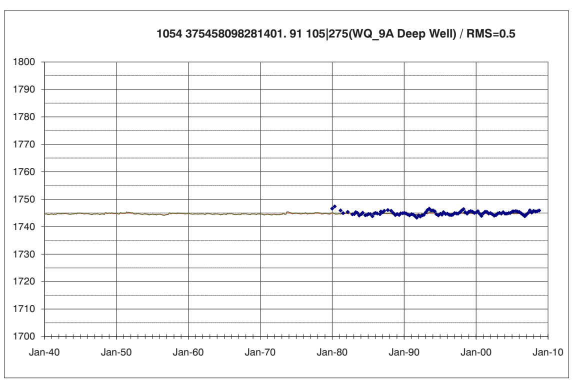

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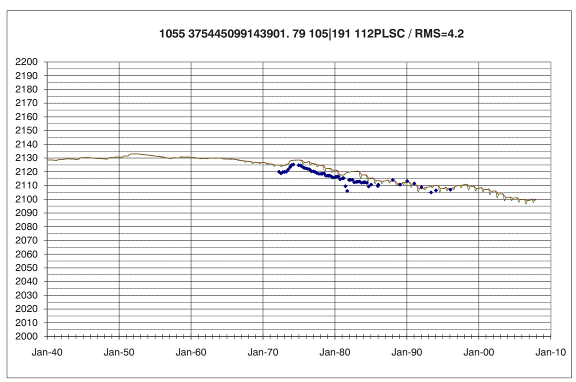

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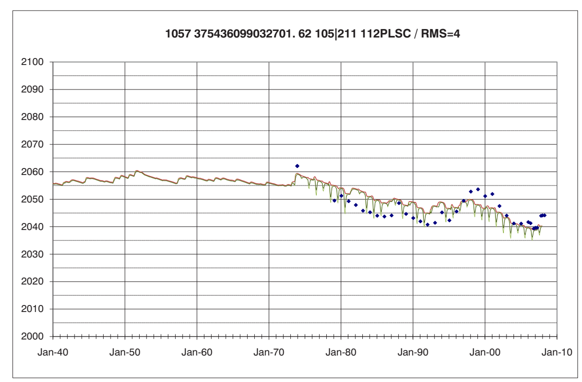

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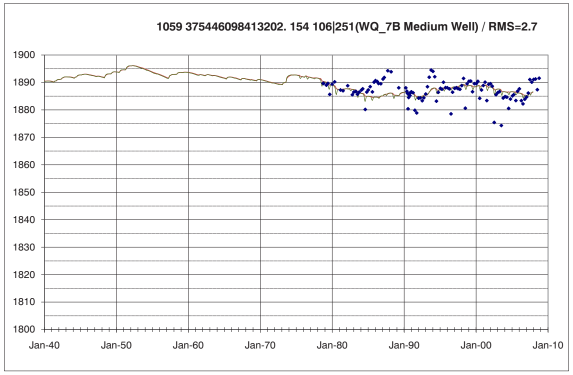

Fig46ProcWL.xlsb
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BALLEAU GROUNDWATER, INC.

GMD #5

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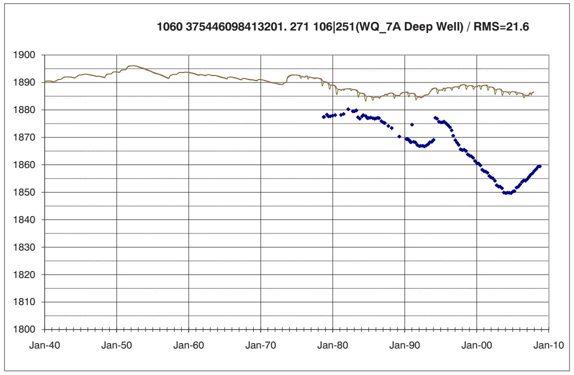

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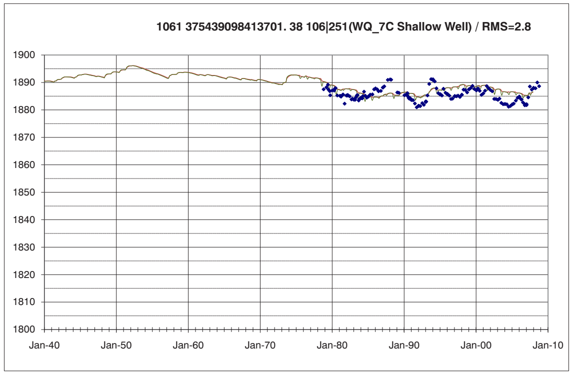

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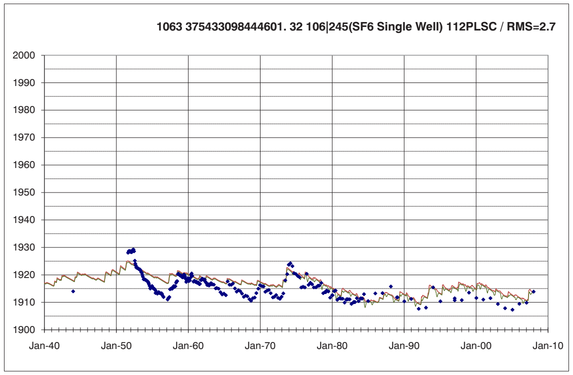

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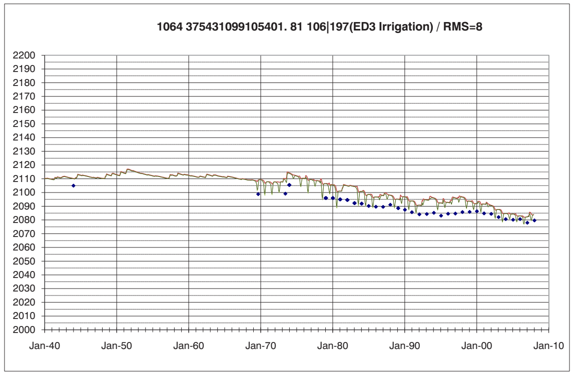

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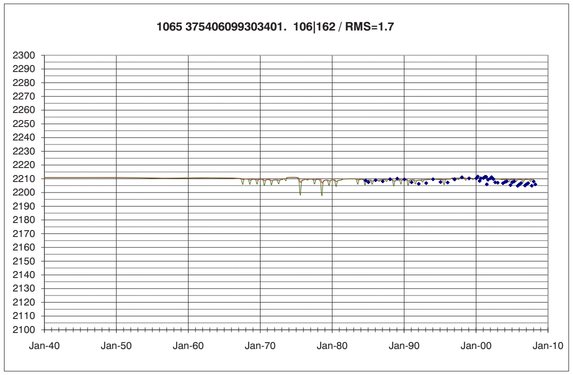

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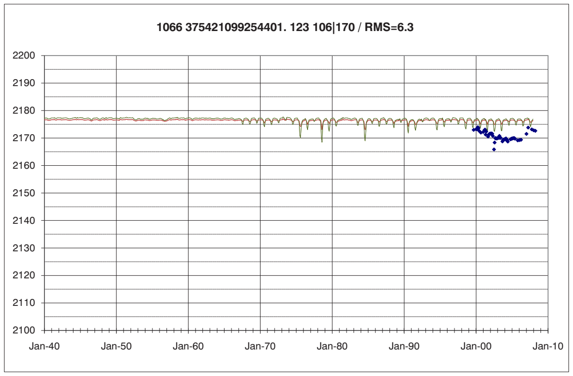

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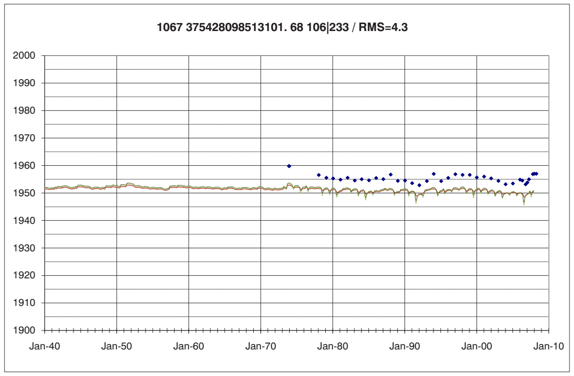

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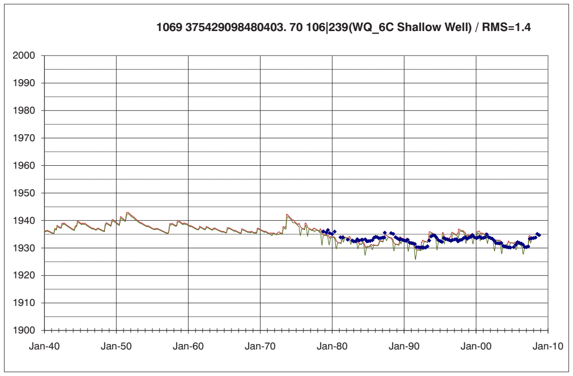

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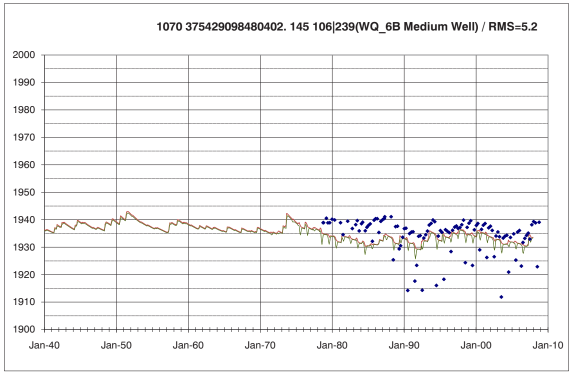

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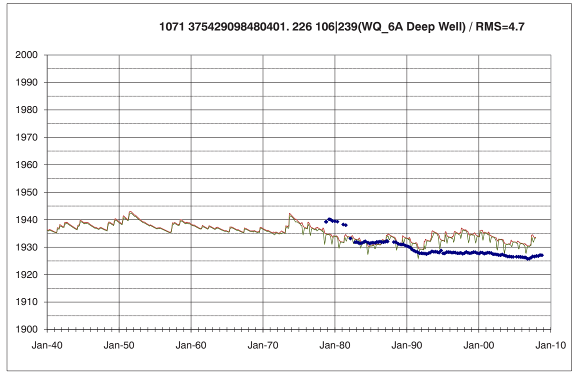

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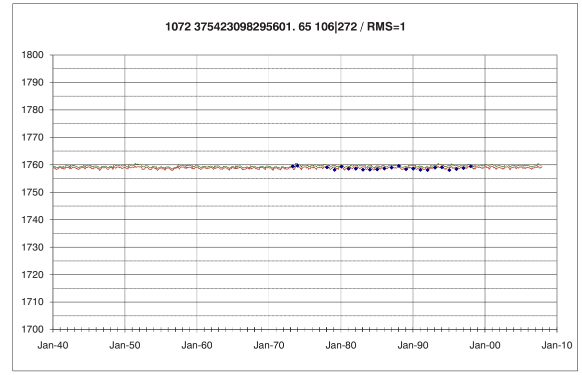

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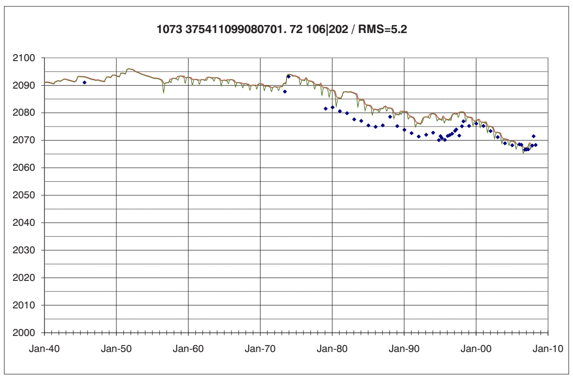

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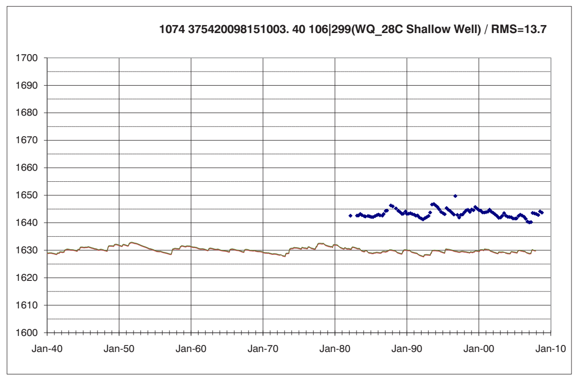

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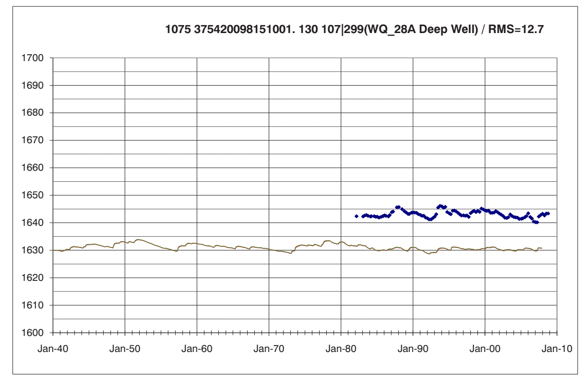

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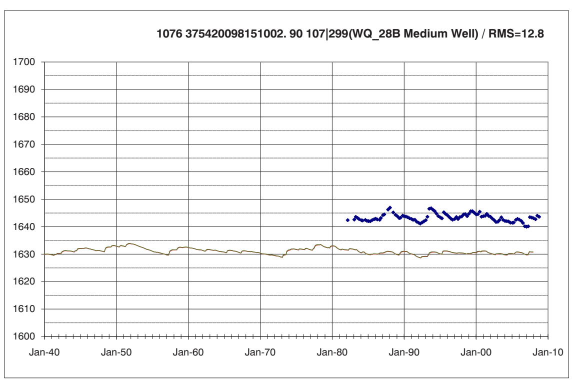

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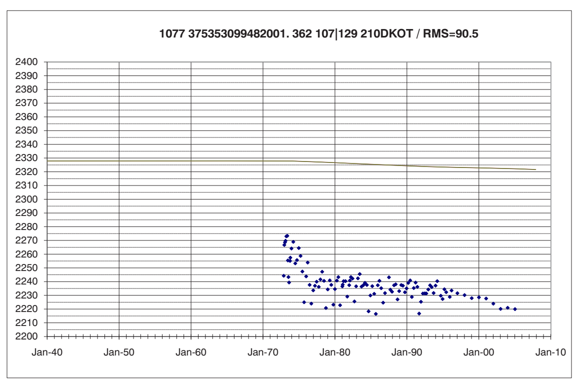

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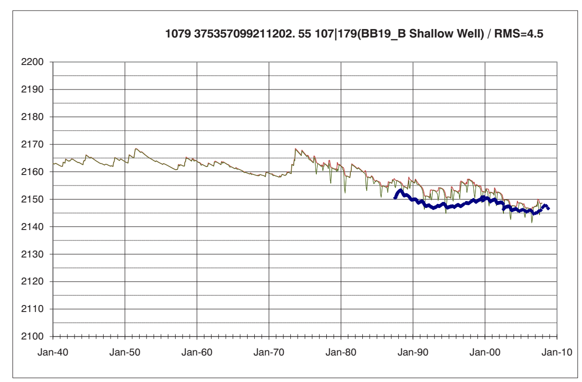

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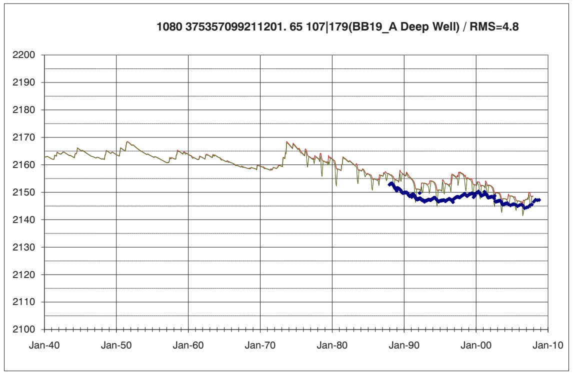

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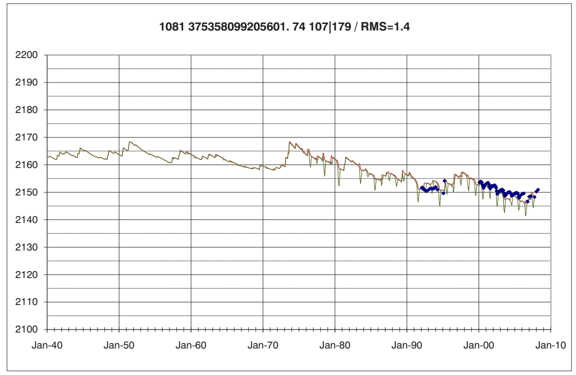

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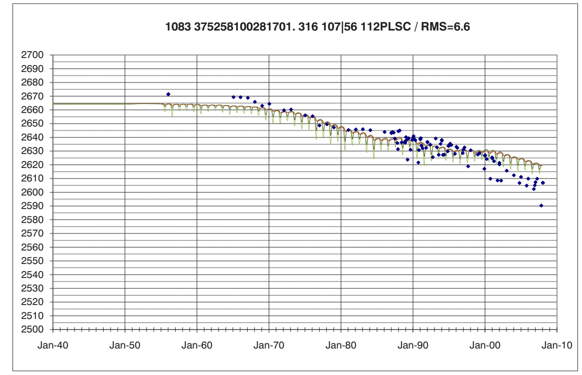

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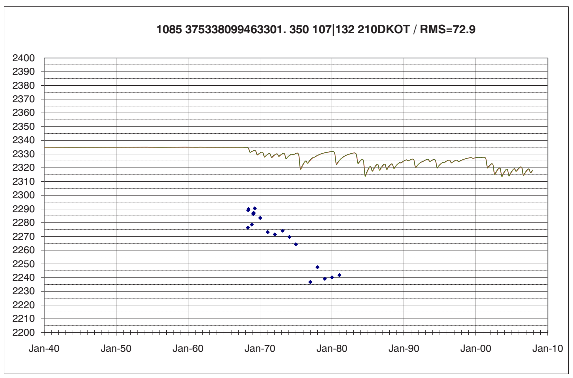

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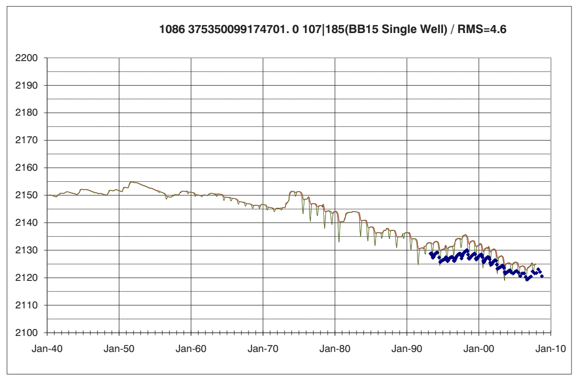

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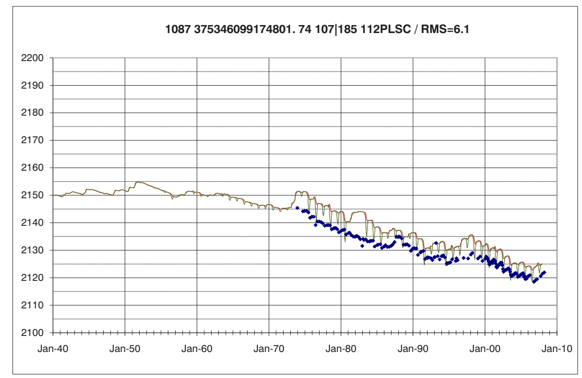

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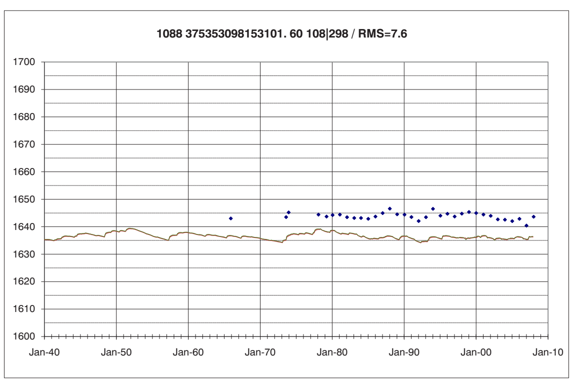

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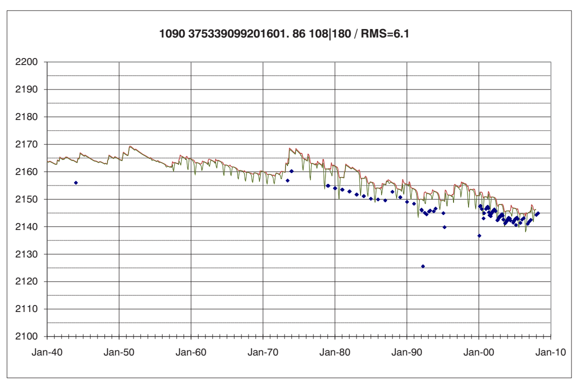

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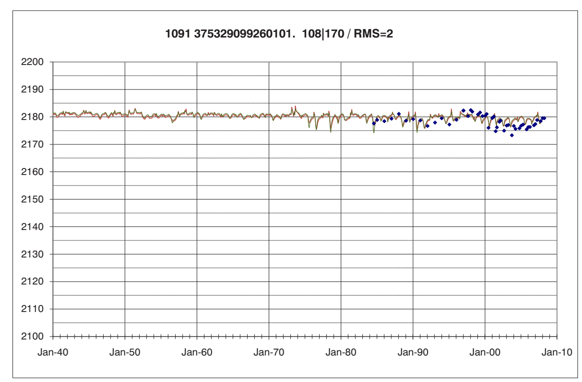

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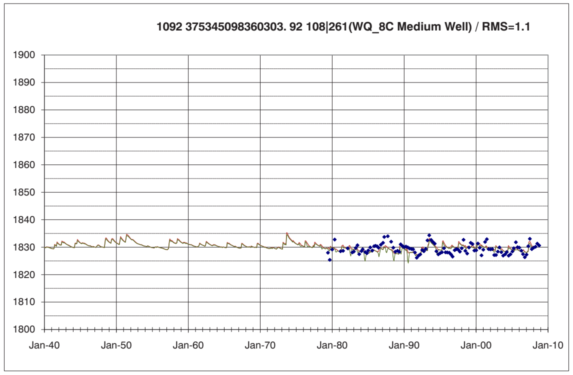

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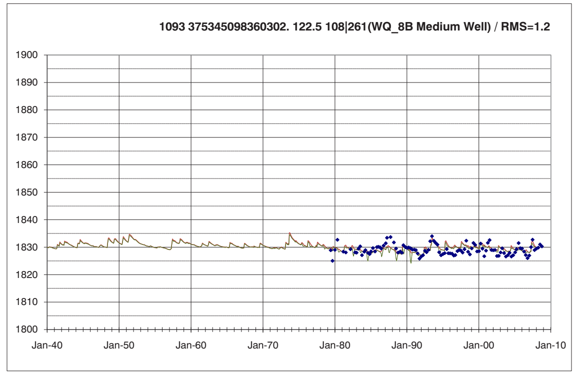

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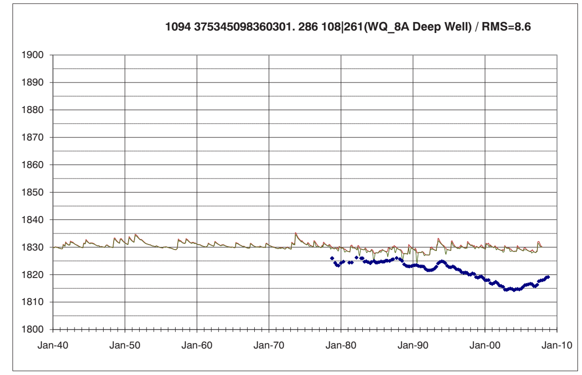

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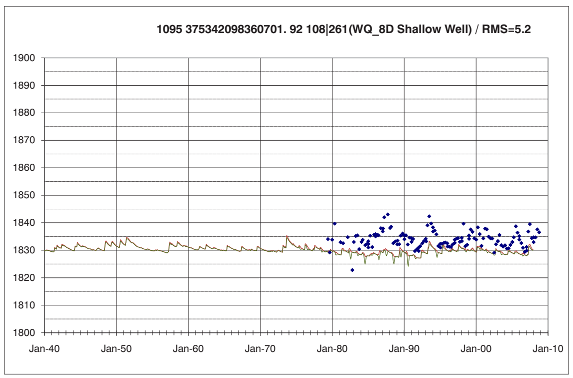

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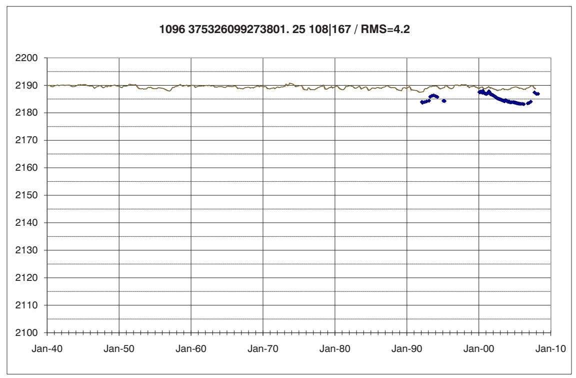

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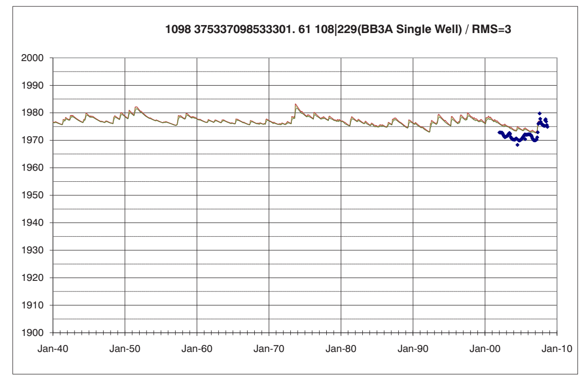

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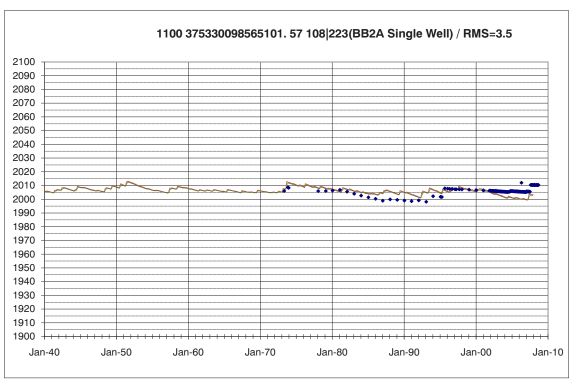

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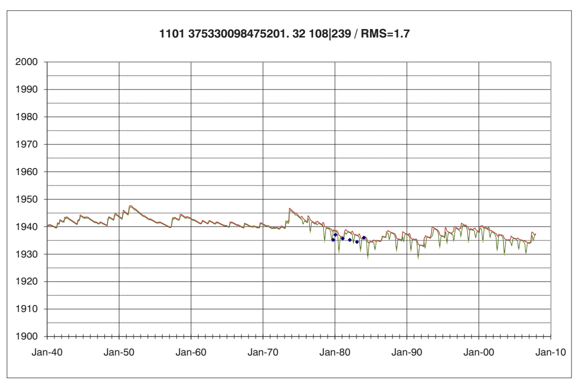

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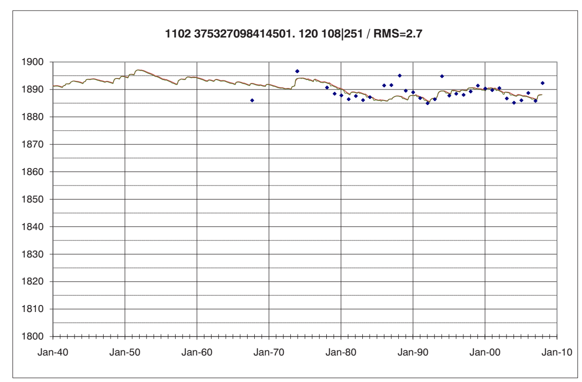

BALLEAU GROUNDWATER, INC.

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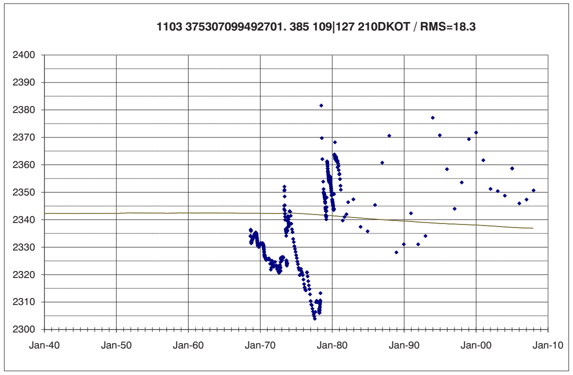

BALLEAU GROUNDWATER, INC.

GMD #5

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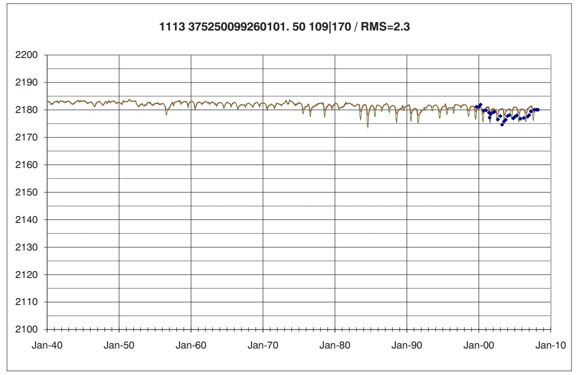

BALLEAU GROUNDWATER, INC.

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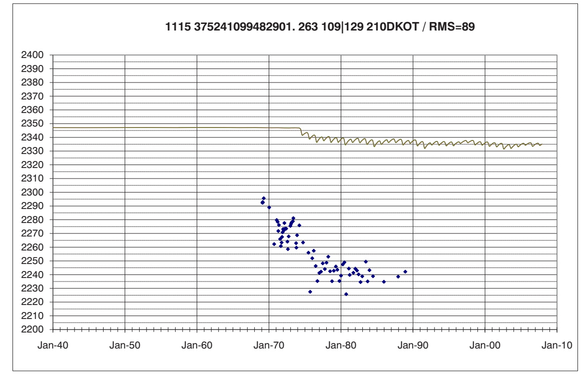

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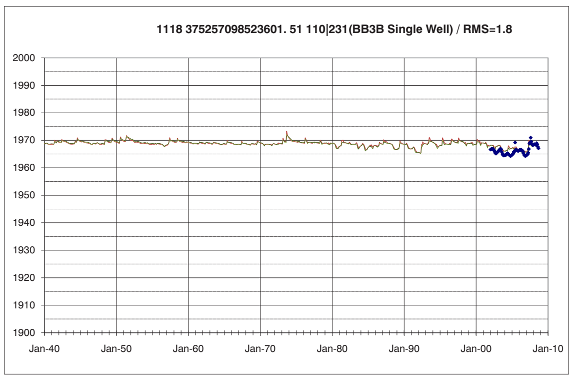

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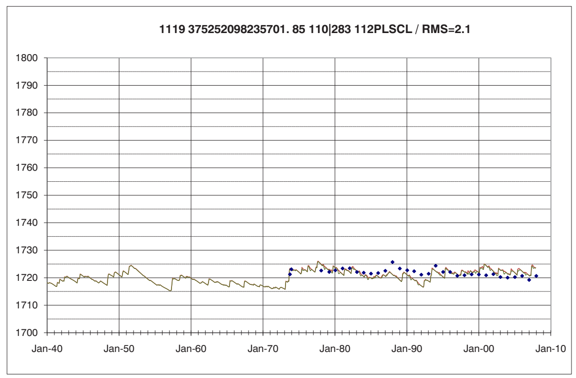

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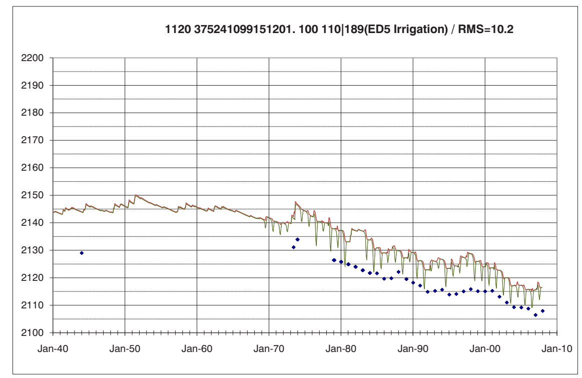

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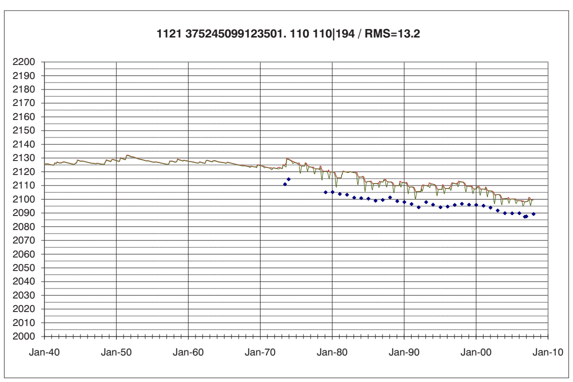

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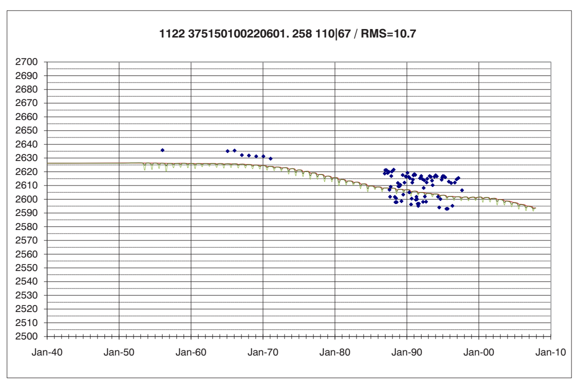

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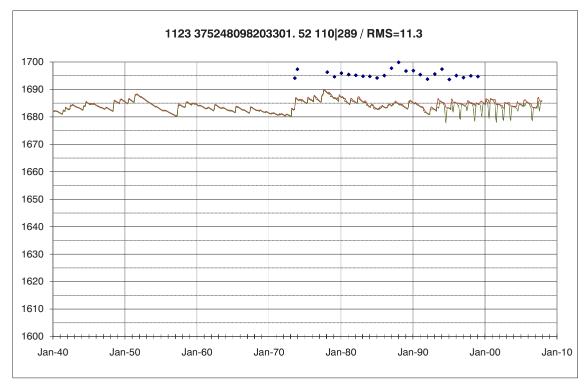

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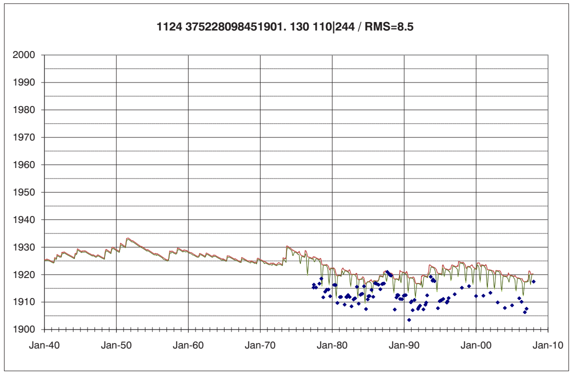

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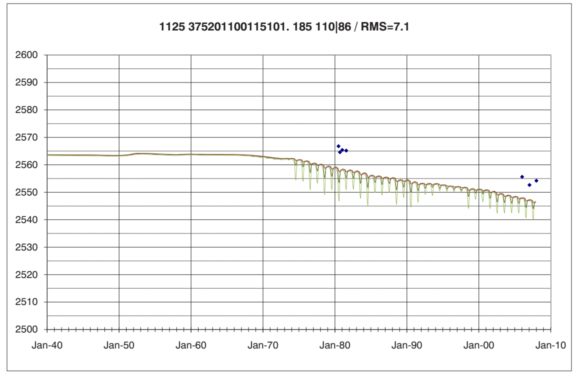

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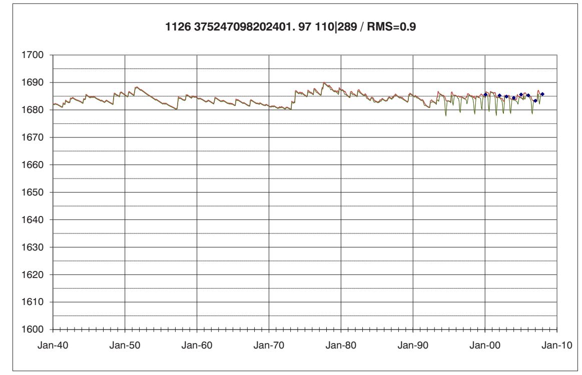

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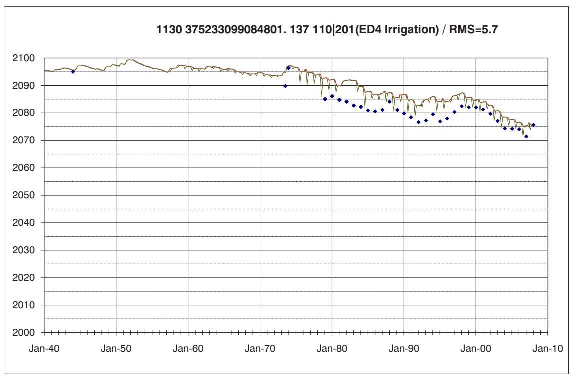

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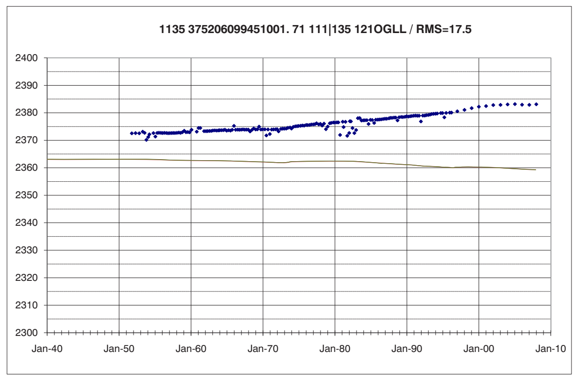

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GMD #5

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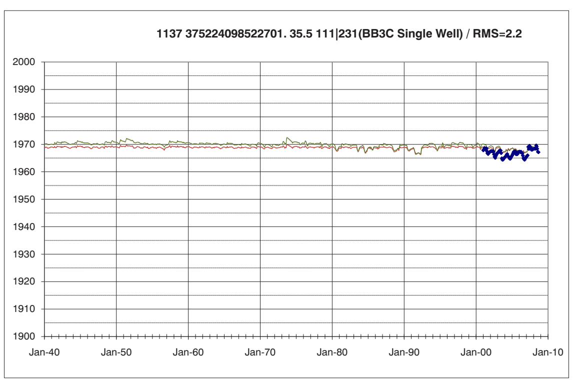

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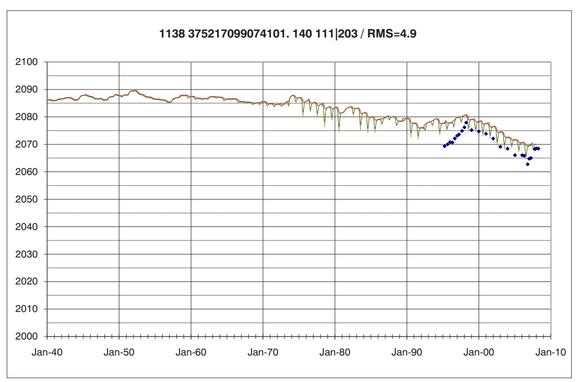

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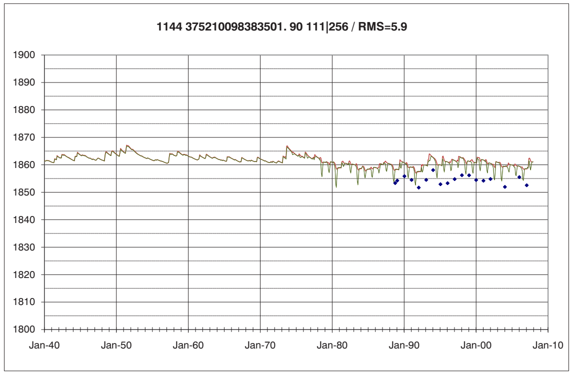

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BALLEAU GROUNDWATER, INC.

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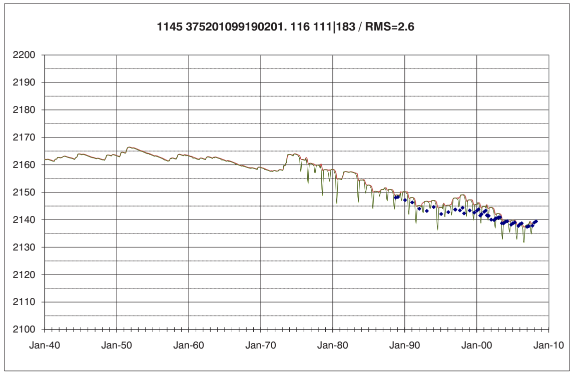

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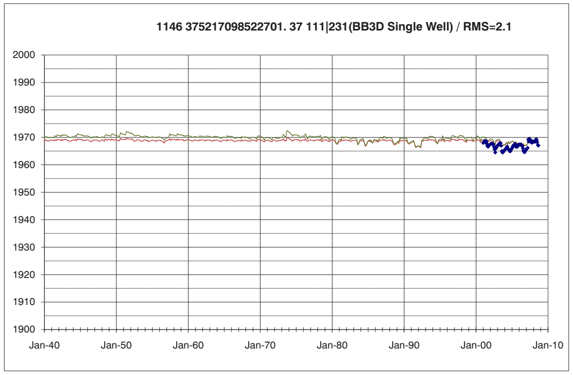

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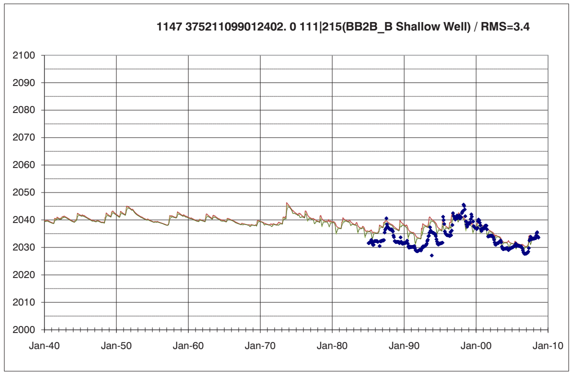

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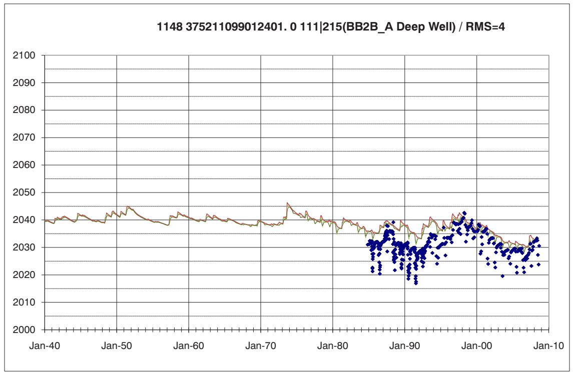

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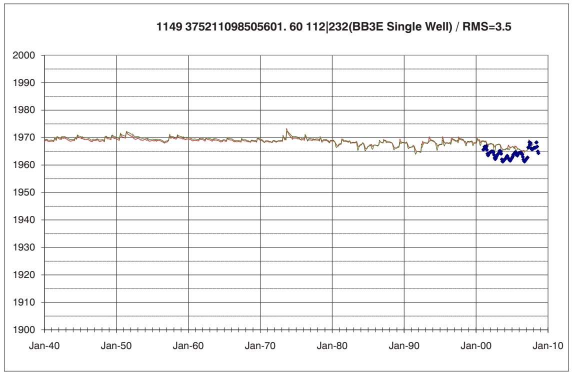

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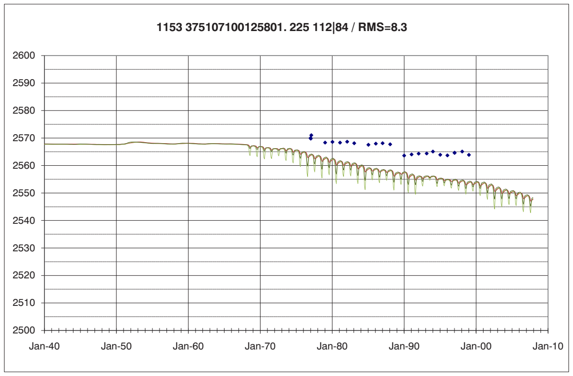

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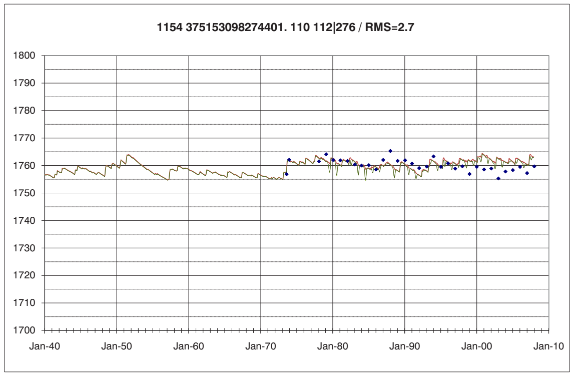

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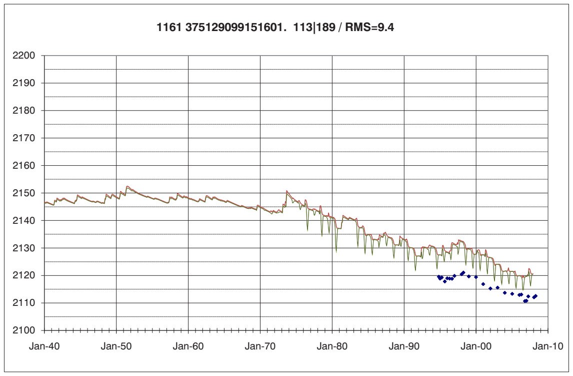

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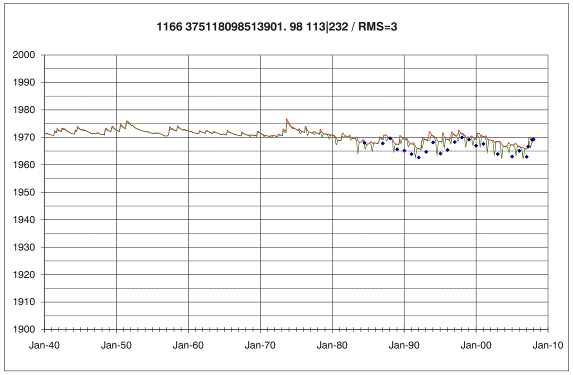

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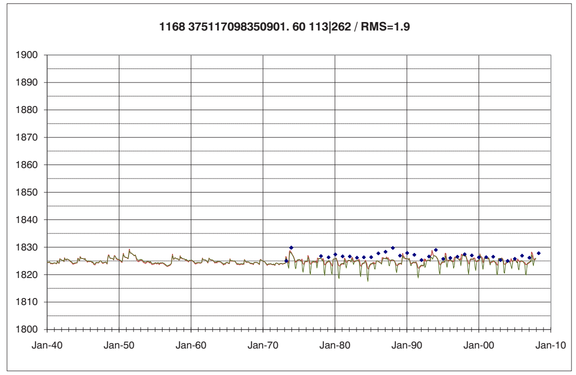

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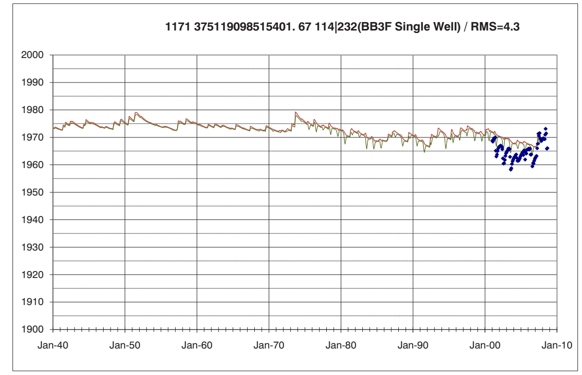

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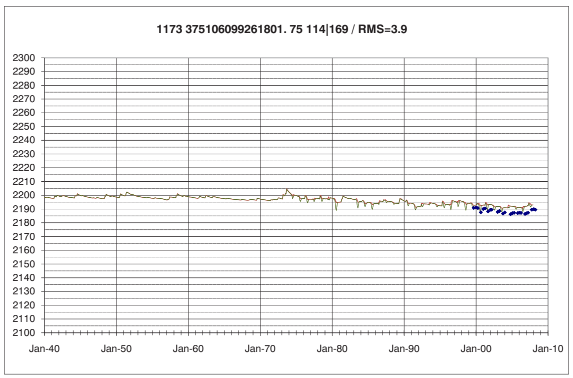

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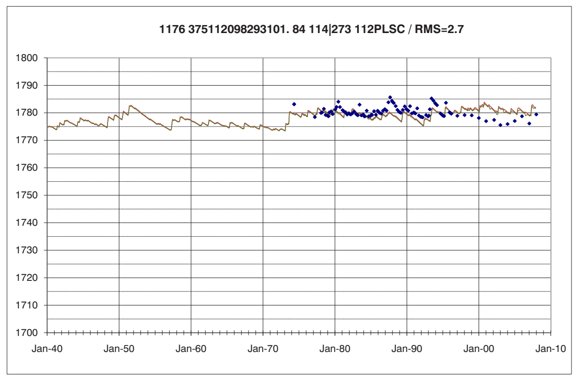

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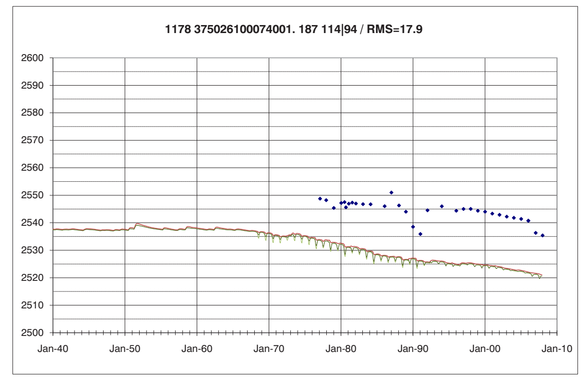

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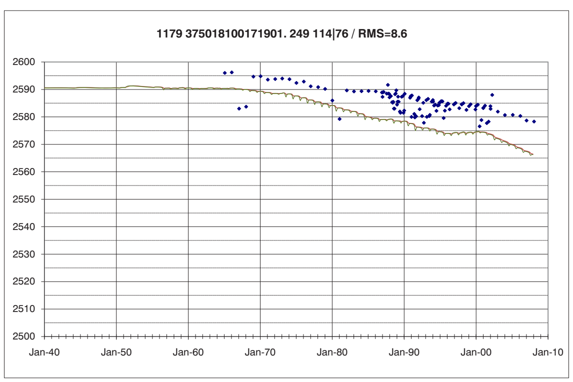

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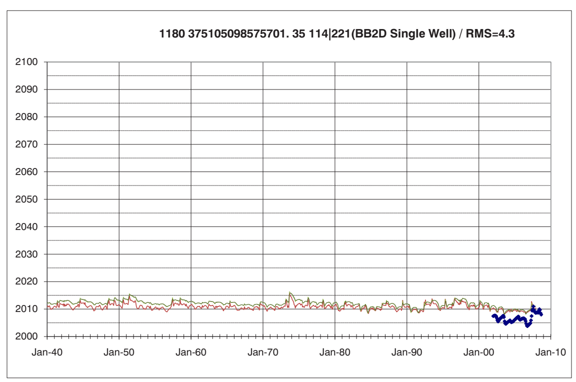

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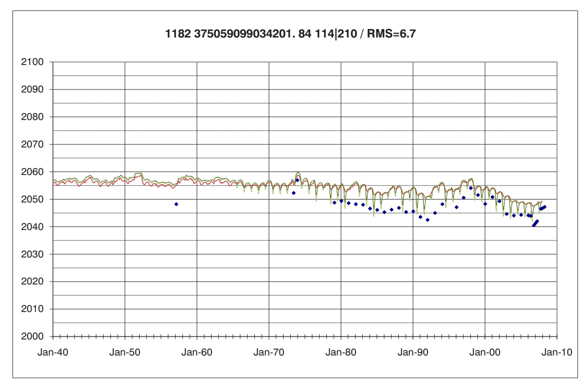

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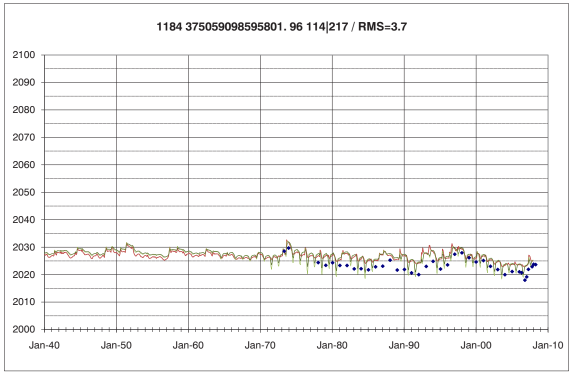

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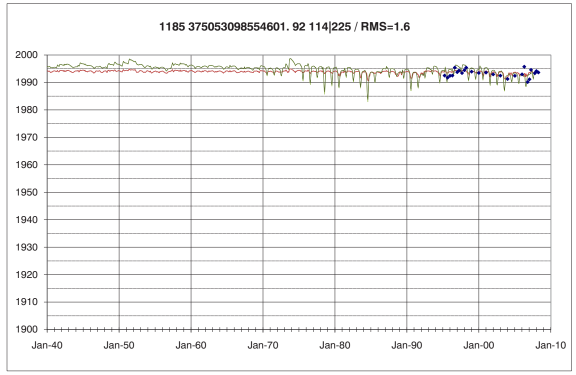

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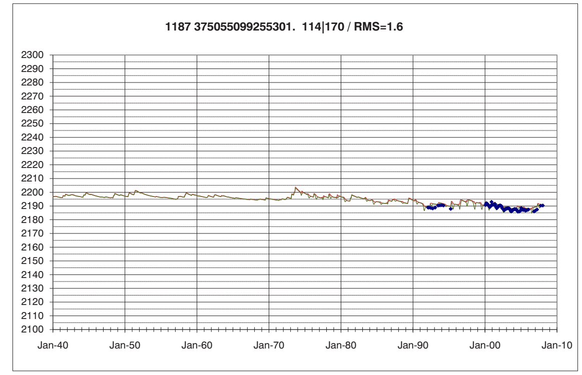

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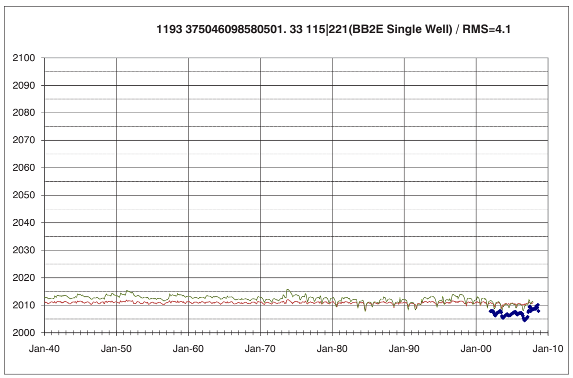

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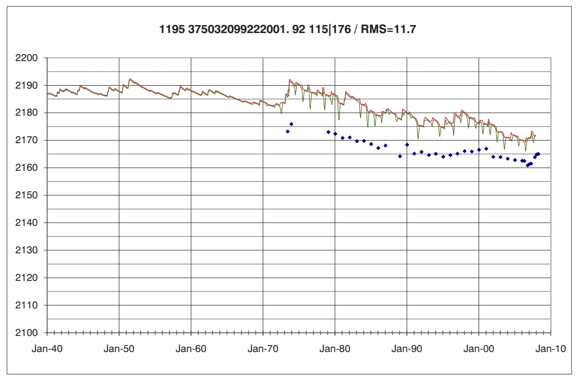

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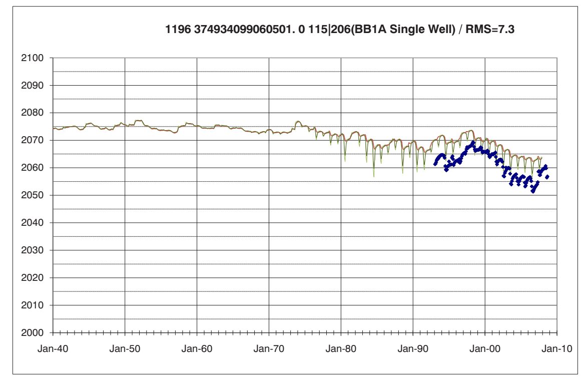

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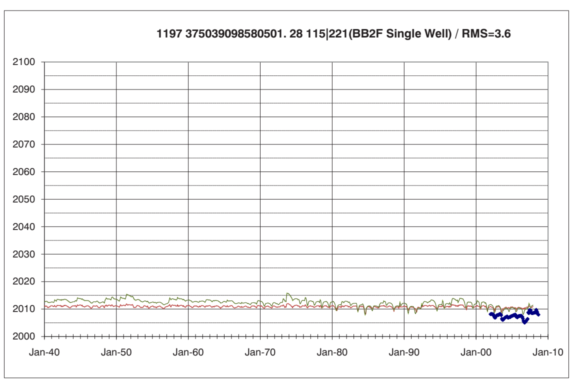

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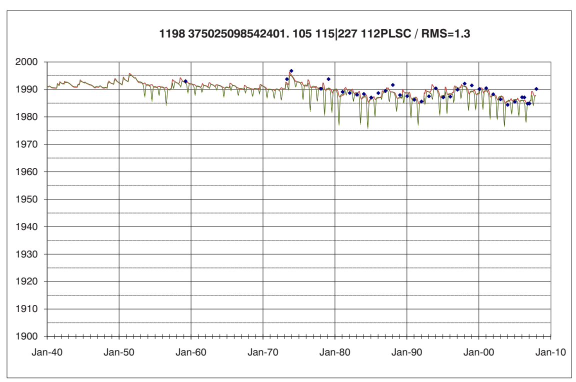

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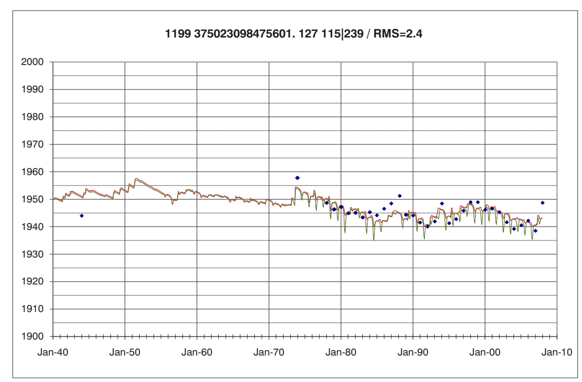

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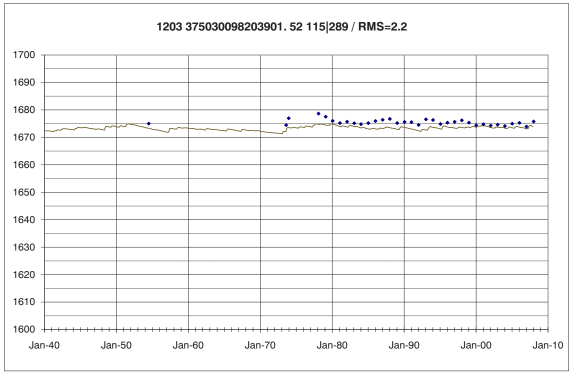

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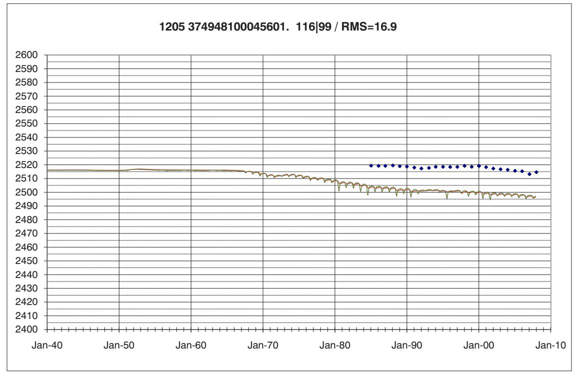

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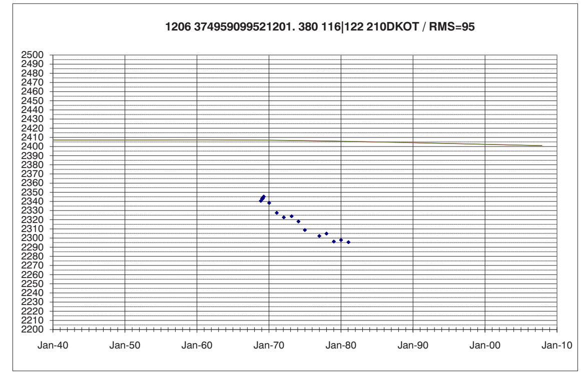

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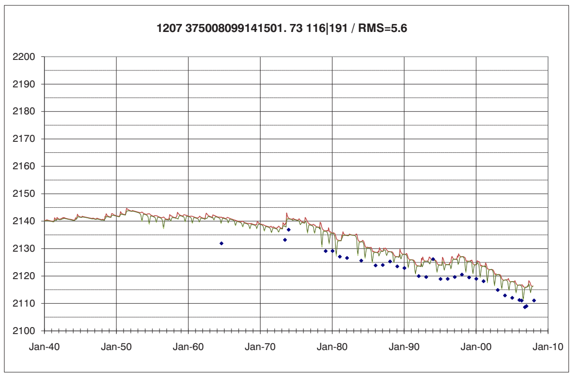

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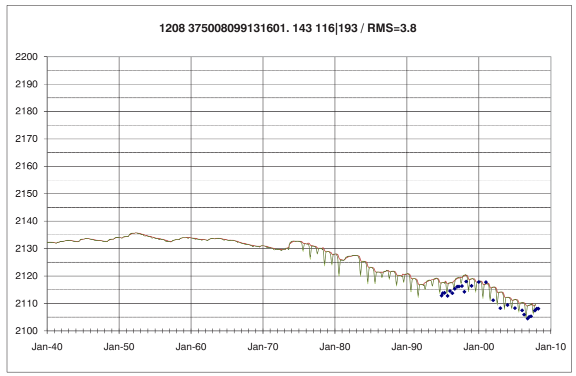

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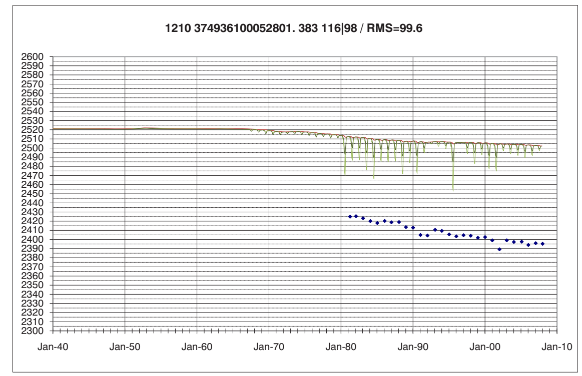

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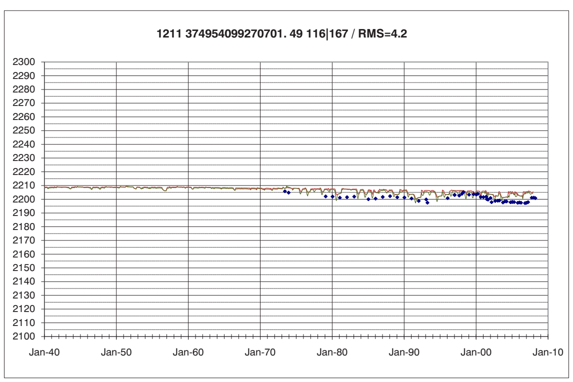

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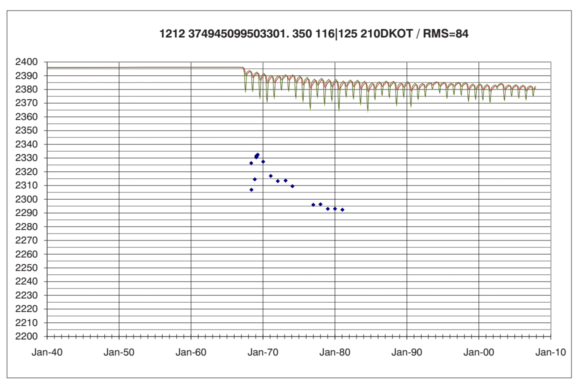

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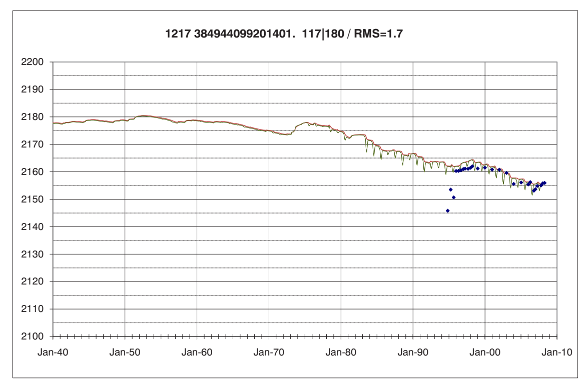

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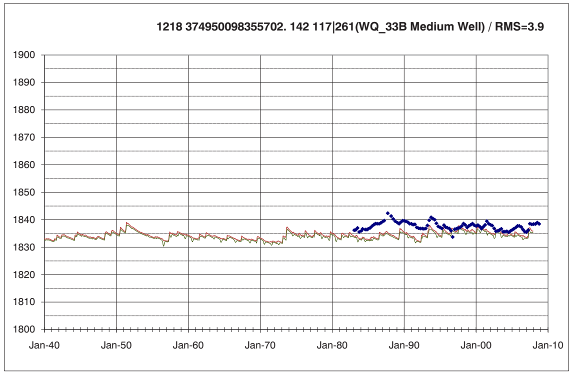

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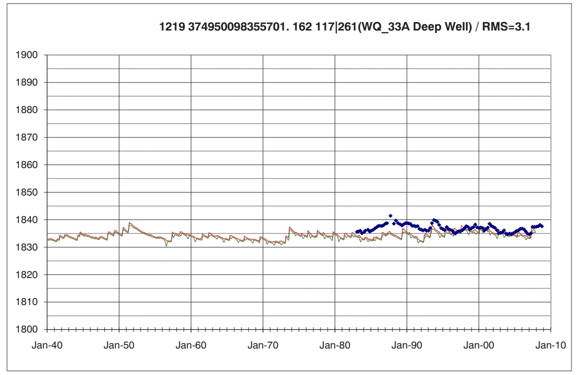

BALLEAU GROUNDWATER, INC.

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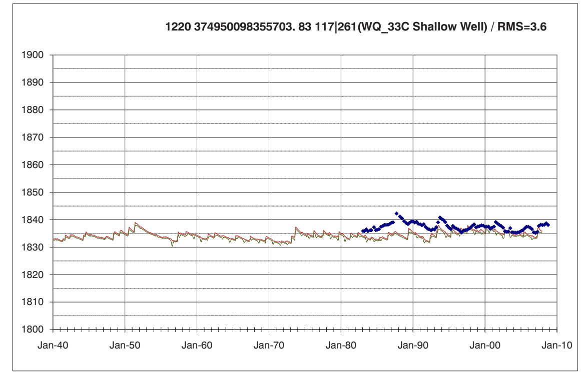

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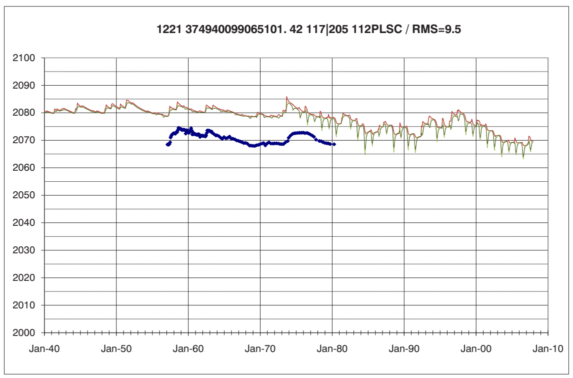

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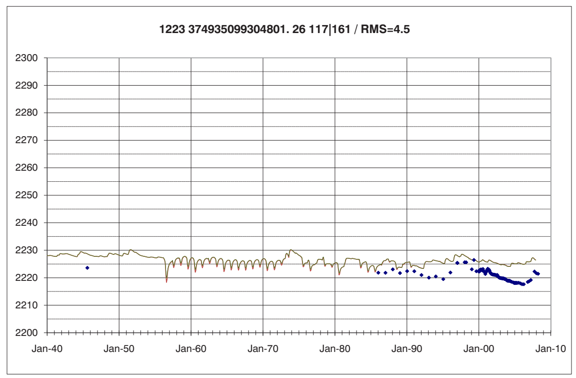

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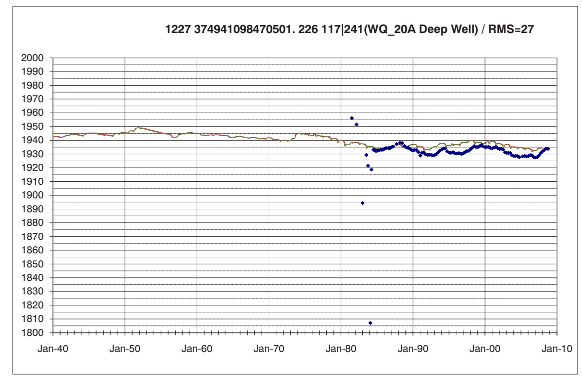

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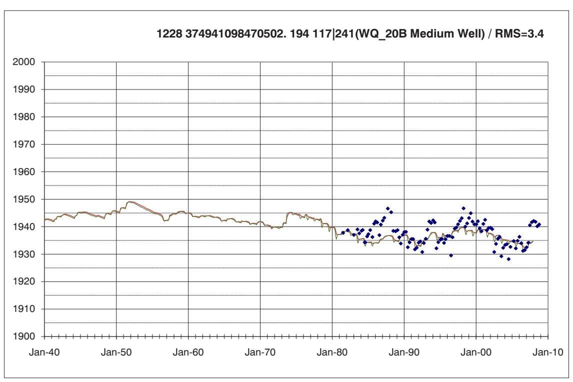

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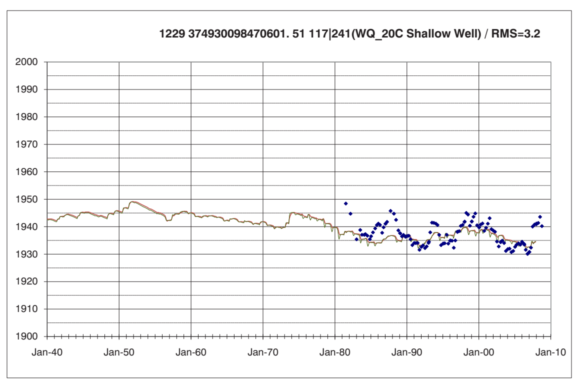

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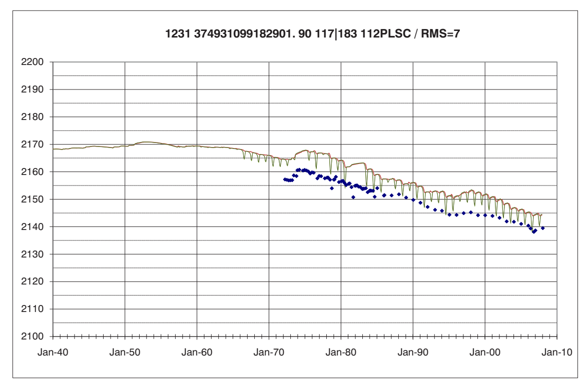

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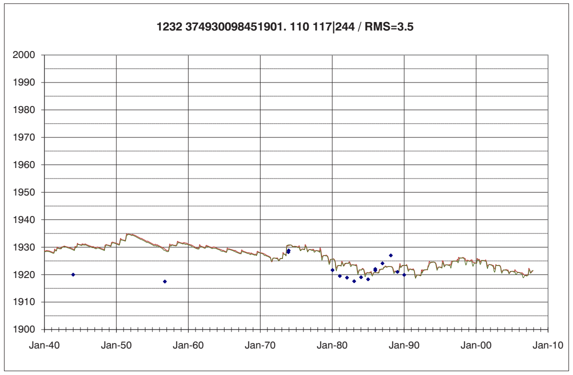

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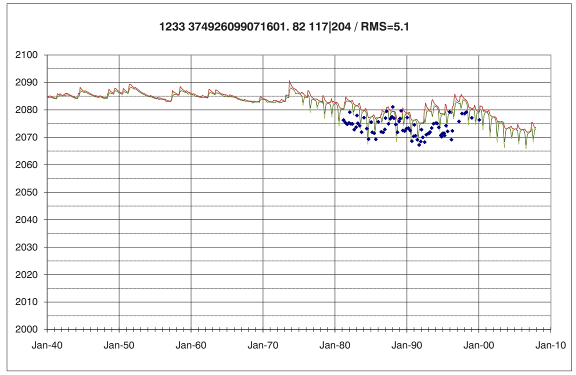

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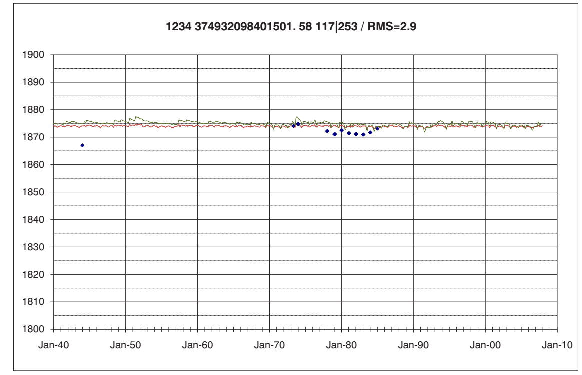

BALLEAU GROUNDWATER, INC.

GMD #5

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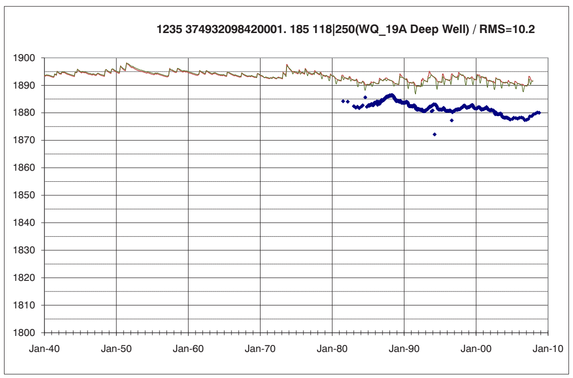

BALLEAU GROUNDWATER, INC.

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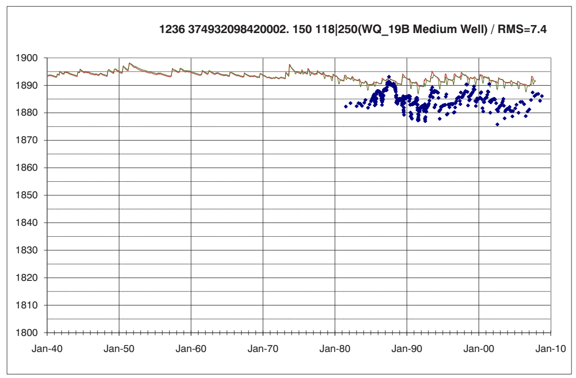

BALLEAU GROUNDWATER, INC.

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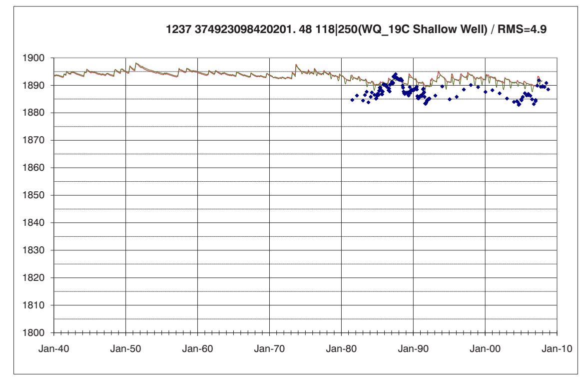

BALLEAU GROUNDWATER, INC.

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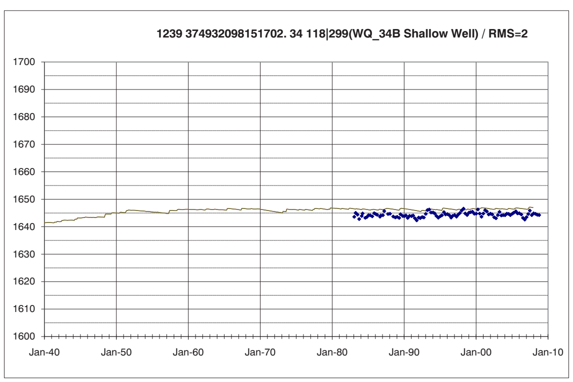

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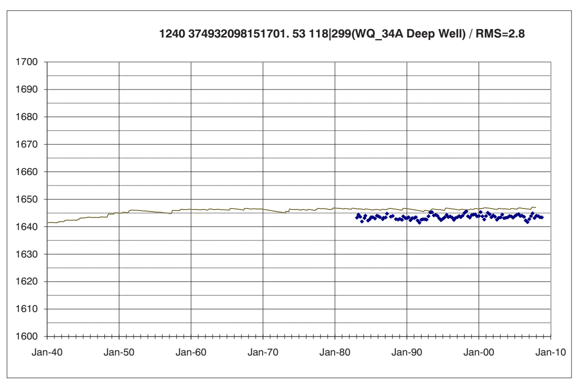

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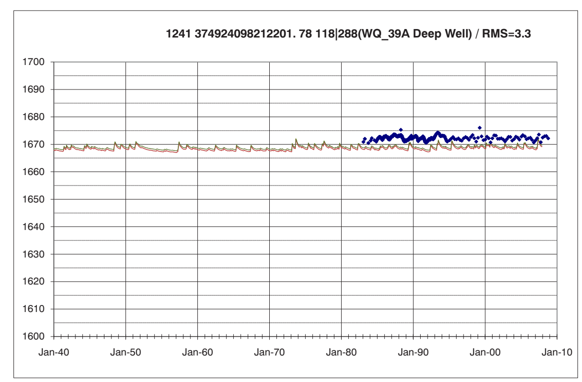

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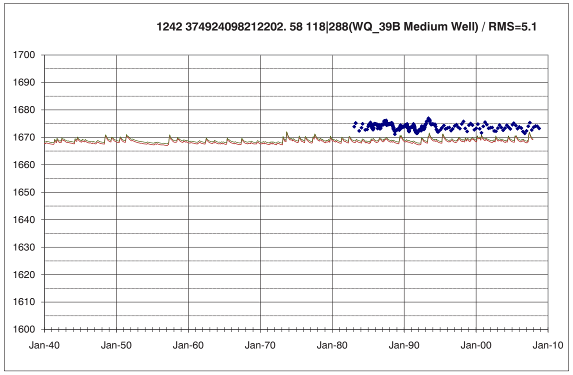

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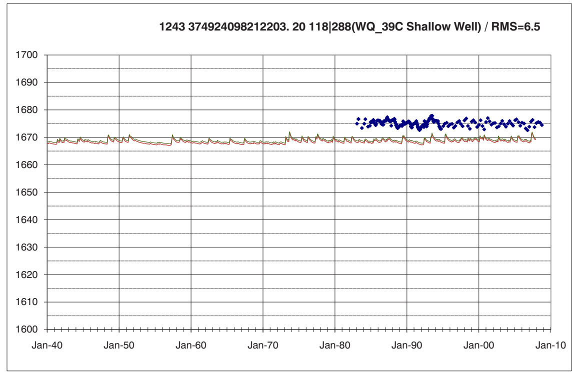

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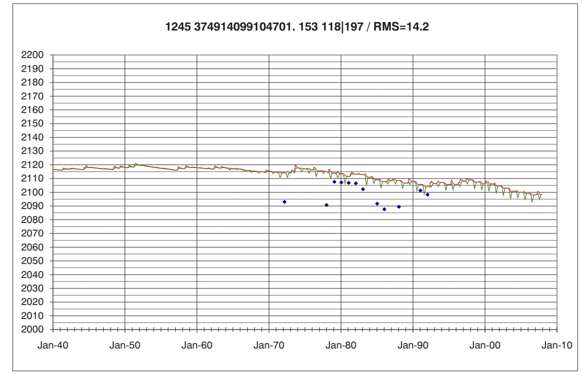

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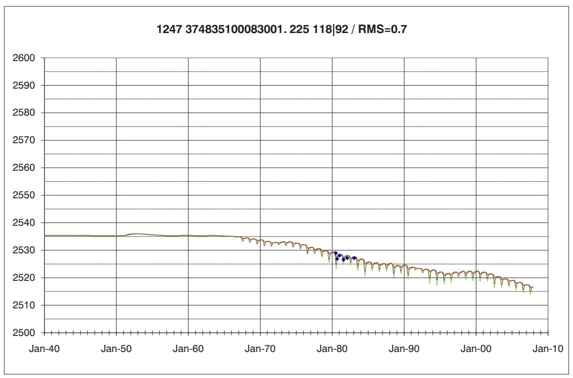

BALLEAU GROUNDWATER, INC.

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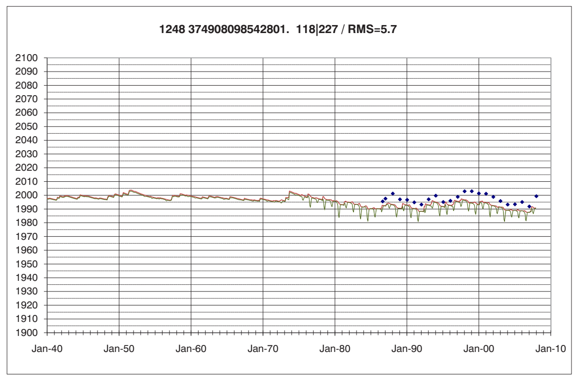

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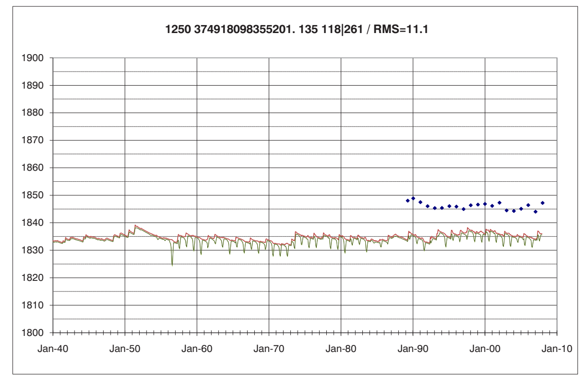

BALLEAU GROUNDWATER, INC.

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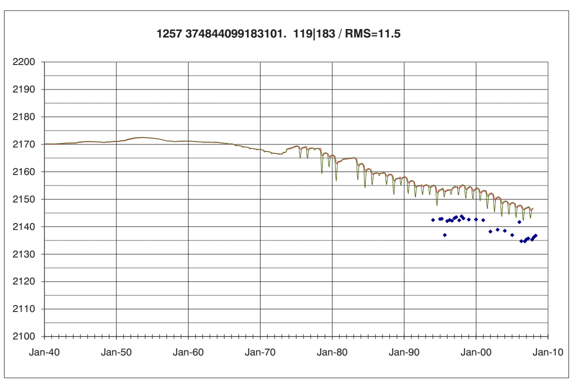

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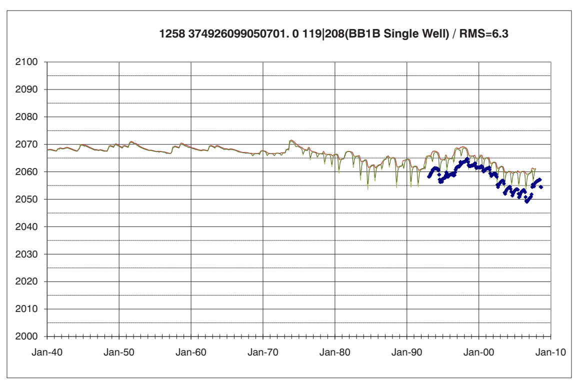

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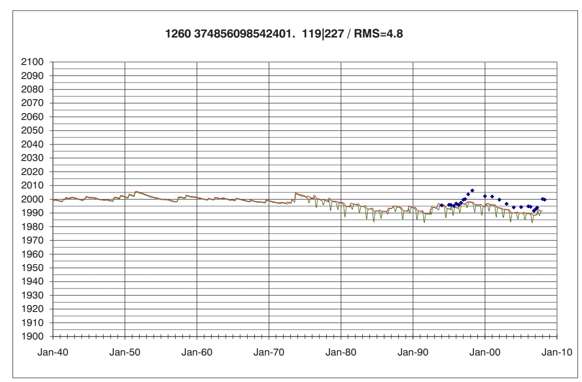

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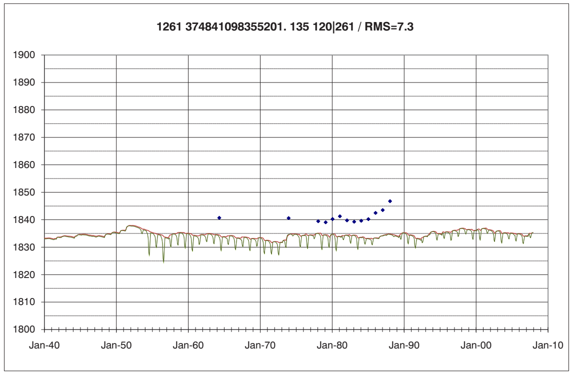

BALLEAU GROUNDWATER, INC.

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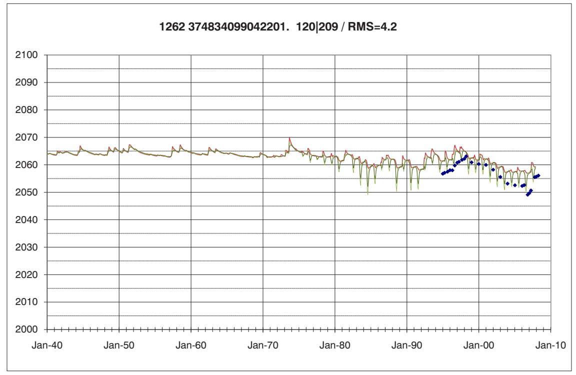

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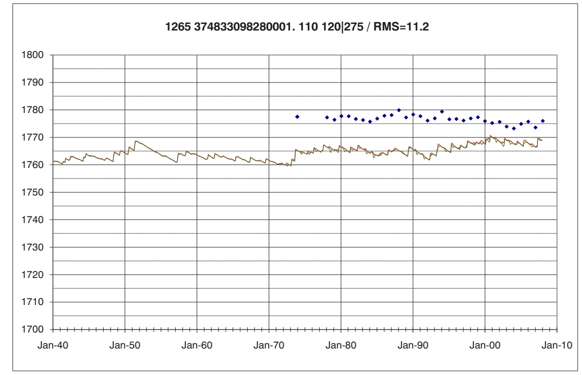

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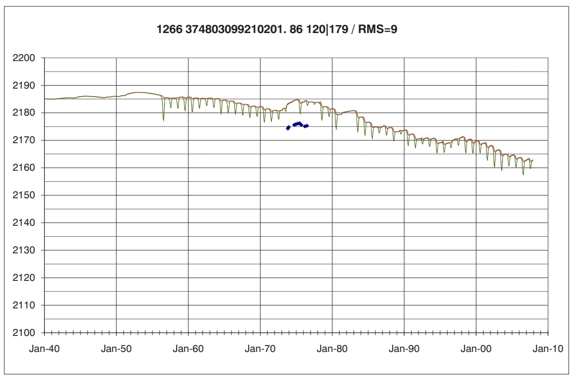

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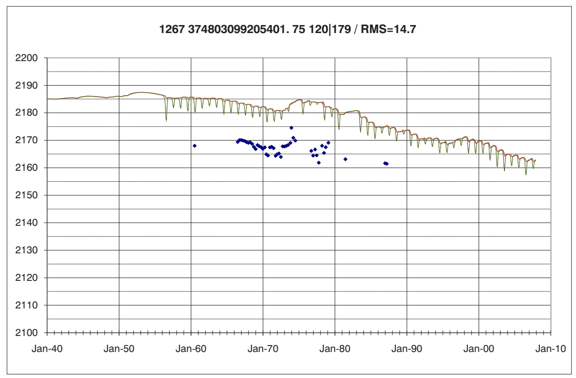

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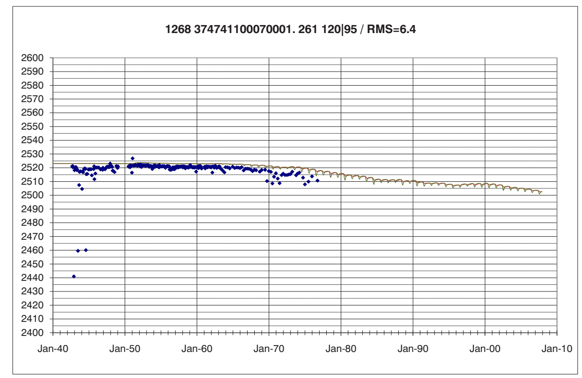

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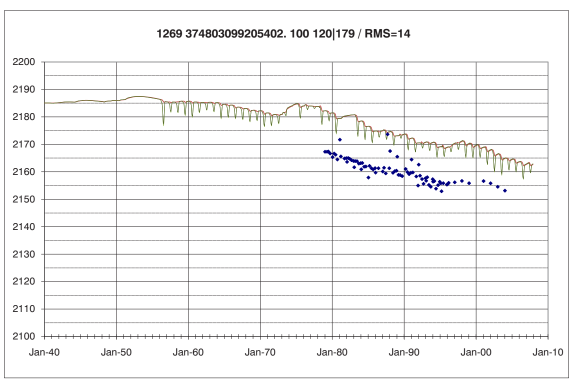

BALLEAU GROUNDWATER, INC.

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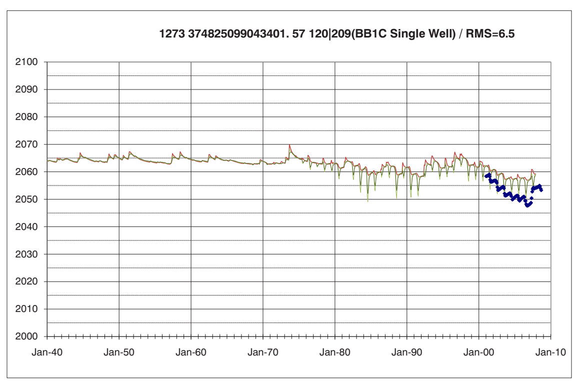

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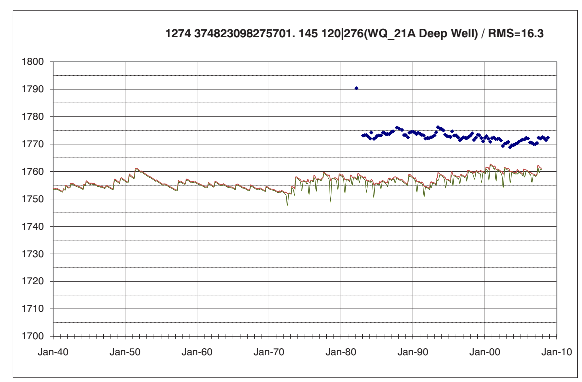

BALLEAU GROUNDWATER, INC.

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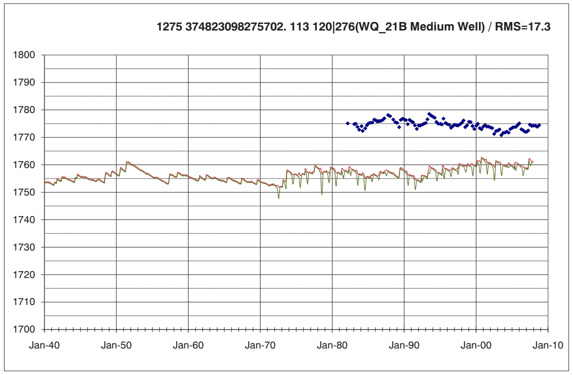

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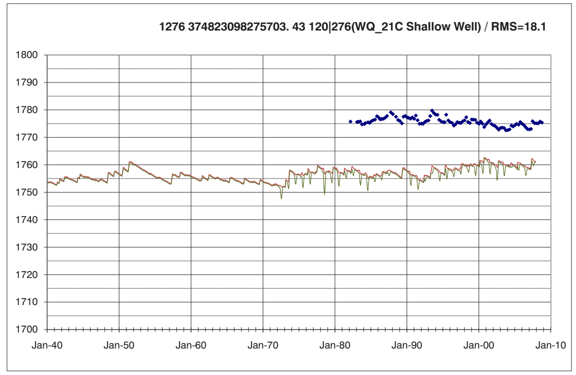

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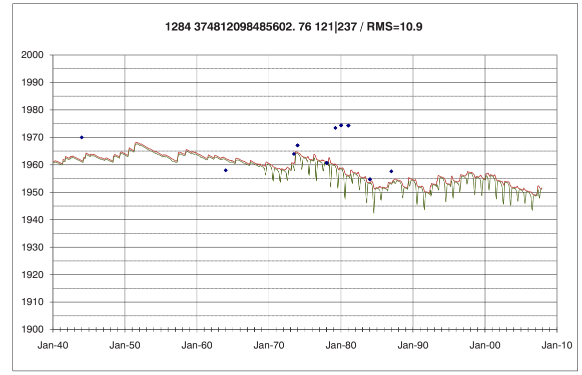

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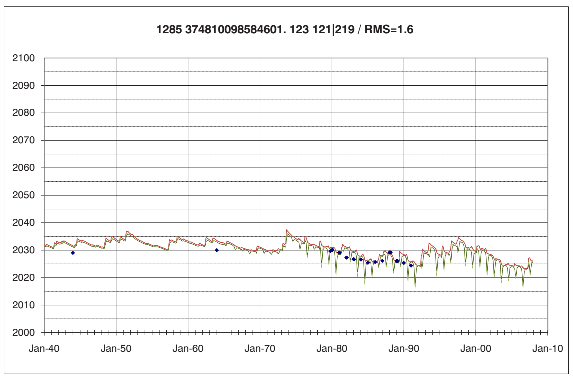

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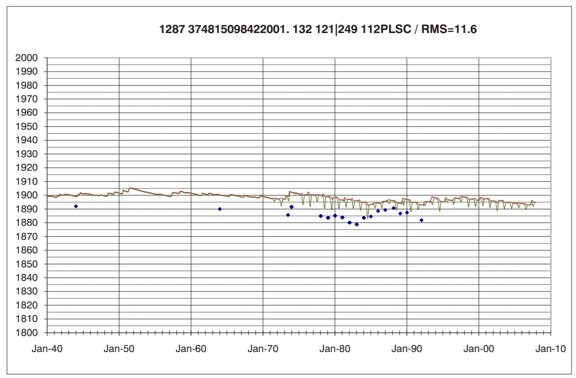

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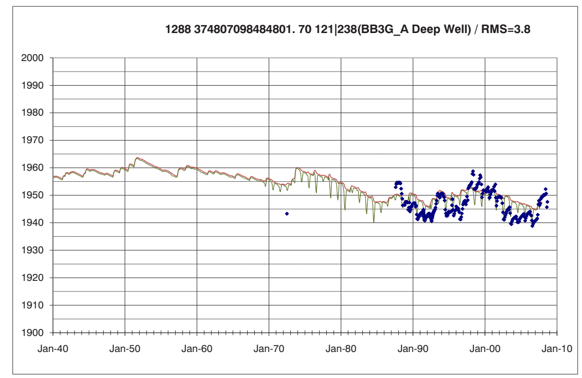

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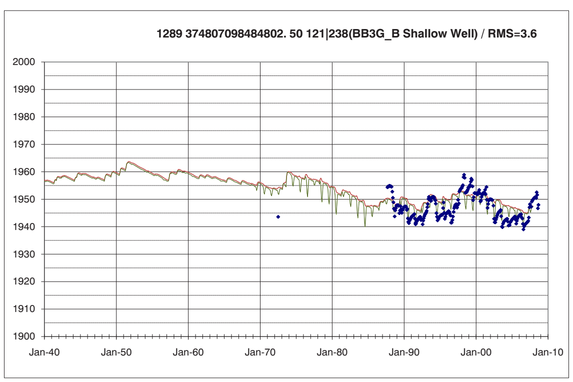

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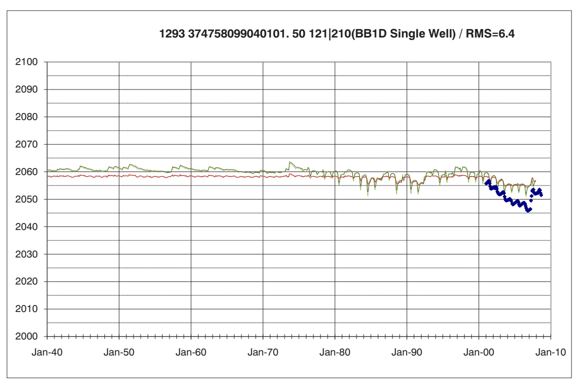

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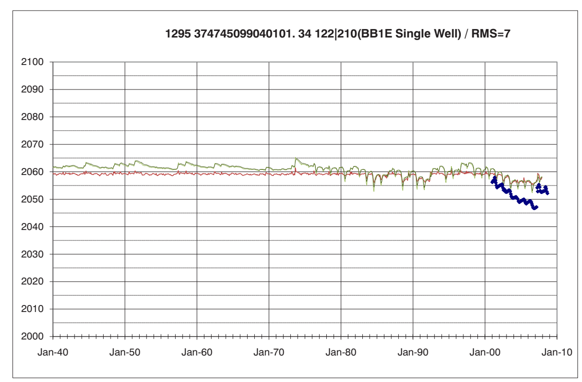

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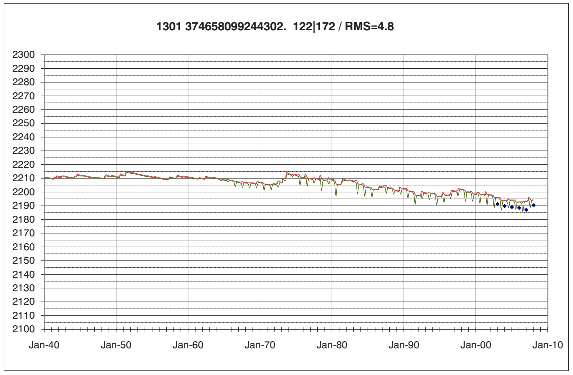

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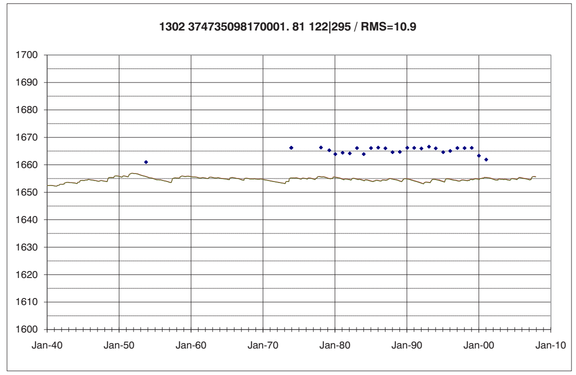

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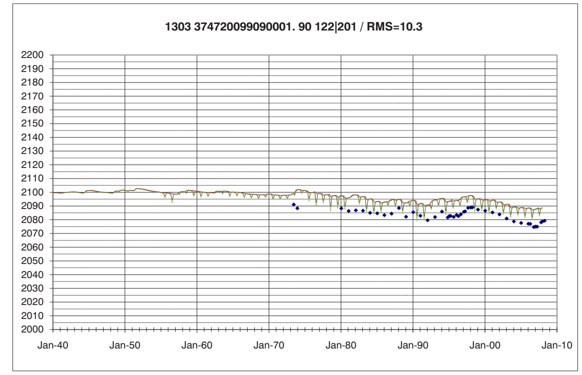

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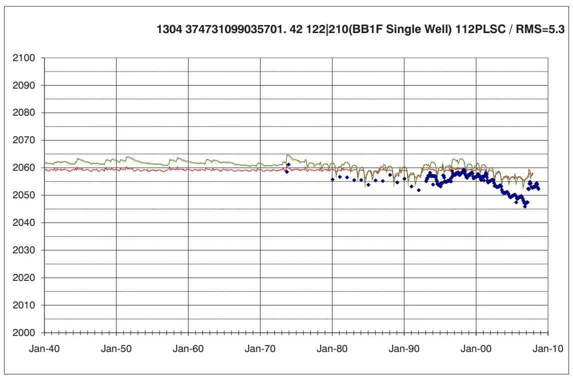

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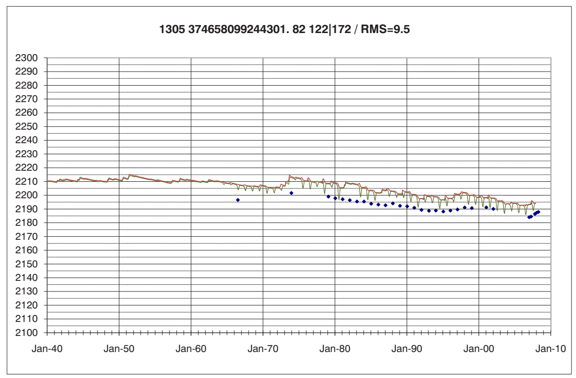

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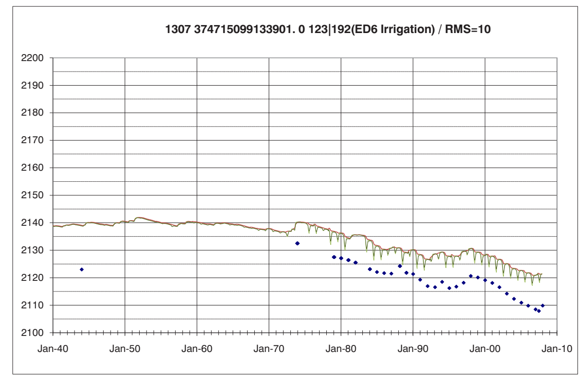

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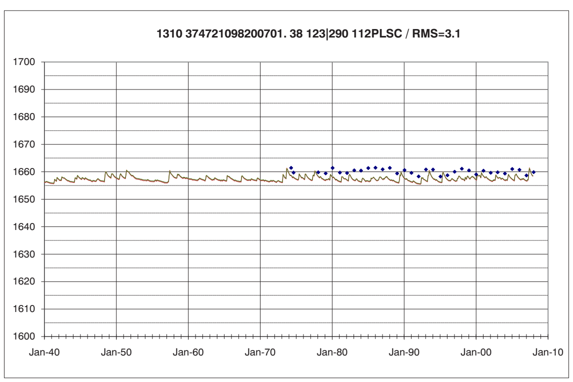

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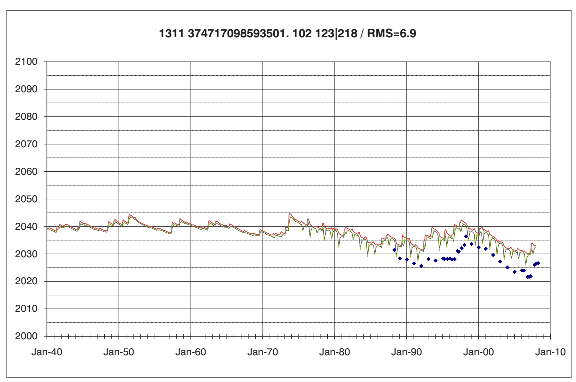

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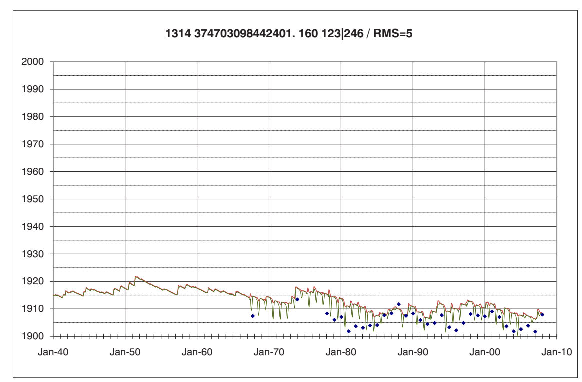

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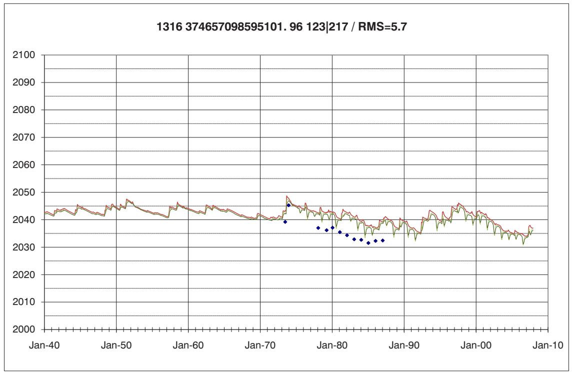

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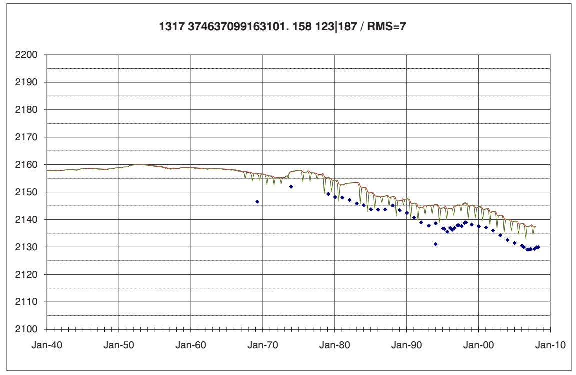

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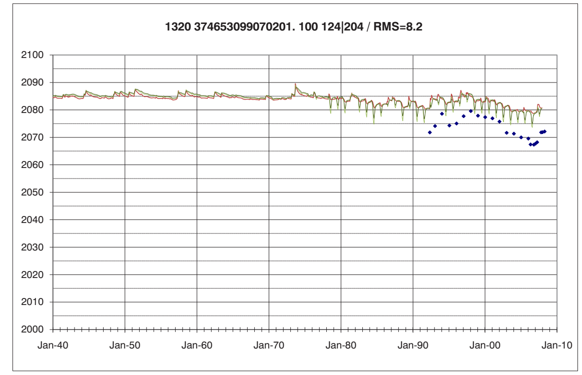

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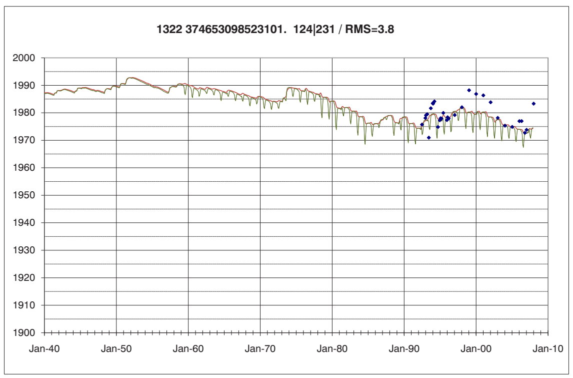

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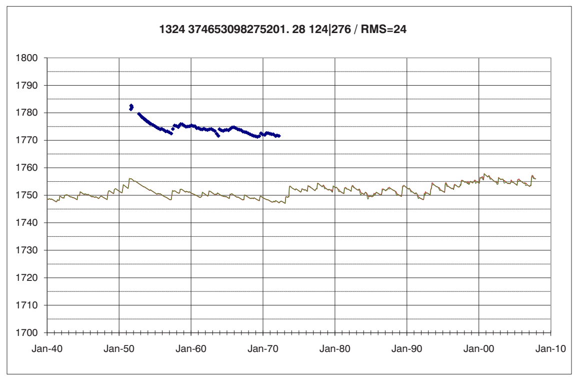

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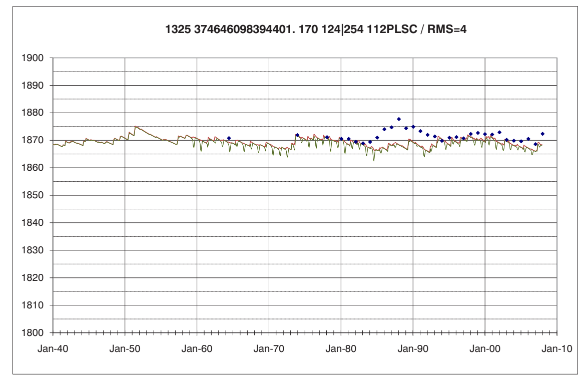

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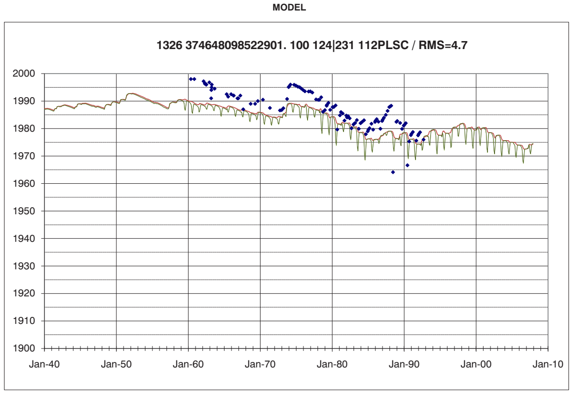

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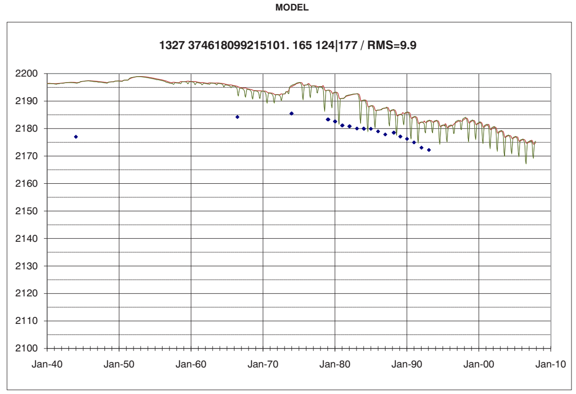

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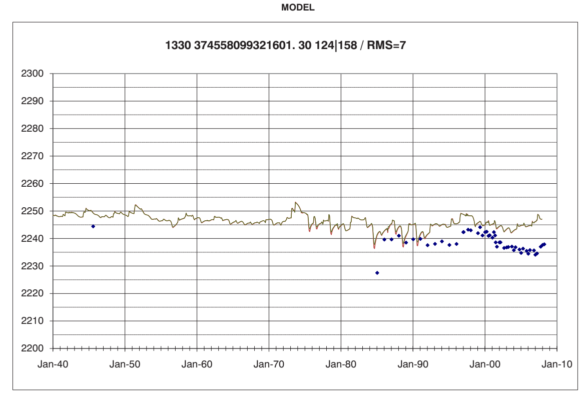

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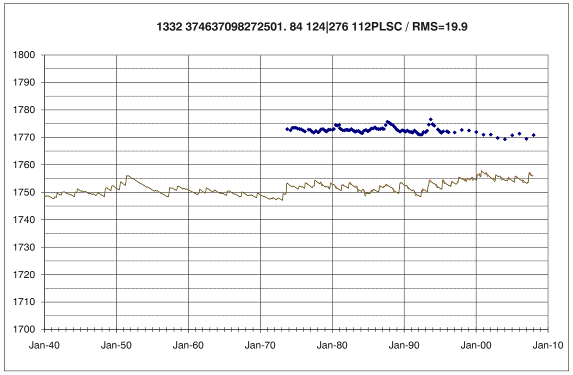

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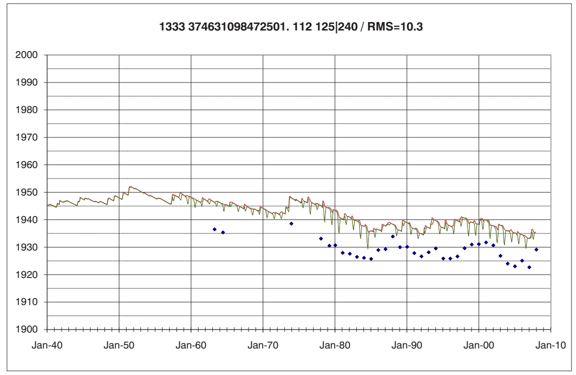

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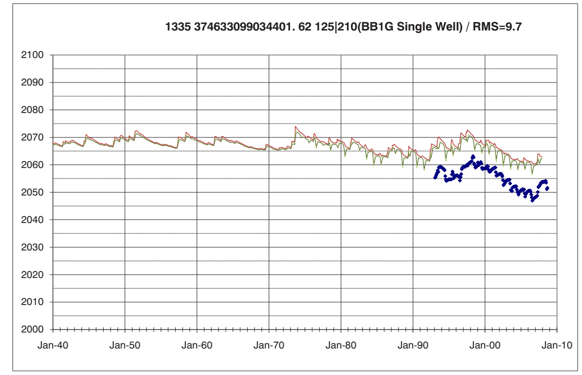

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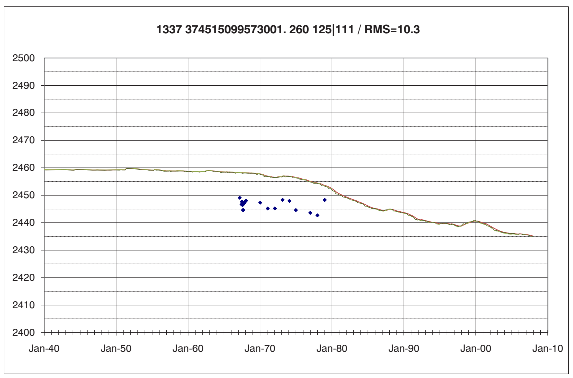

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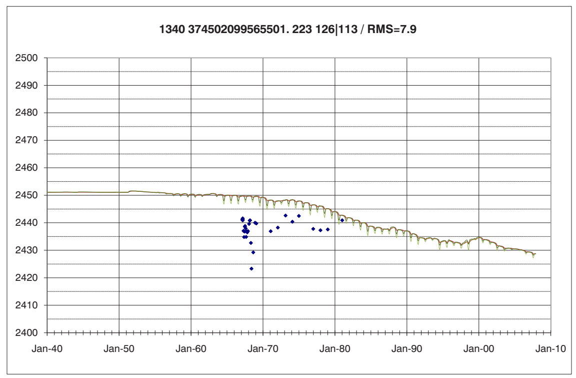

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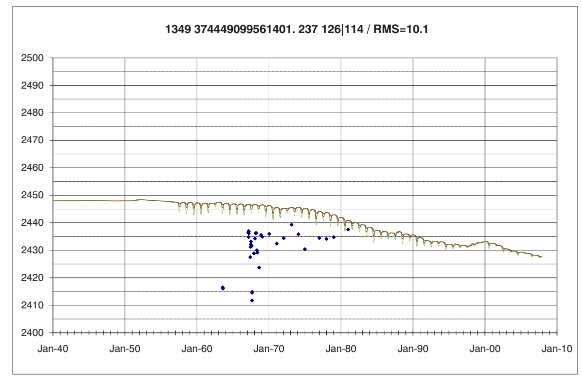

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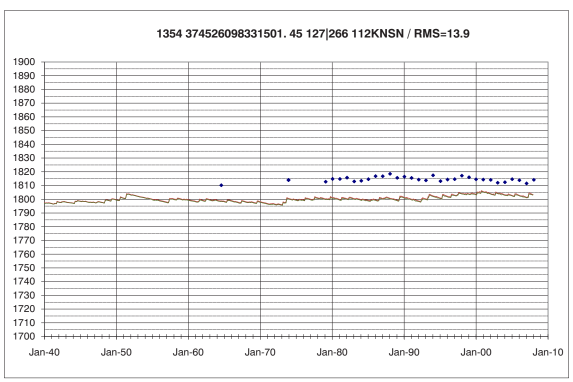

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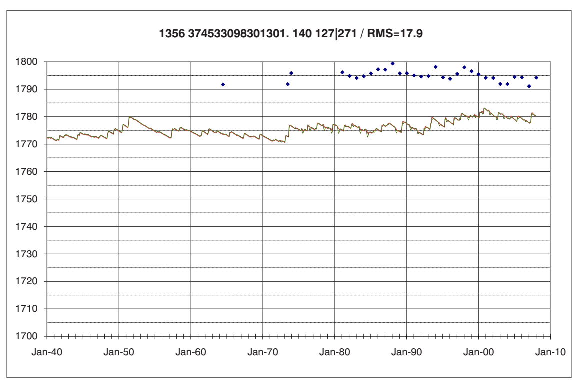

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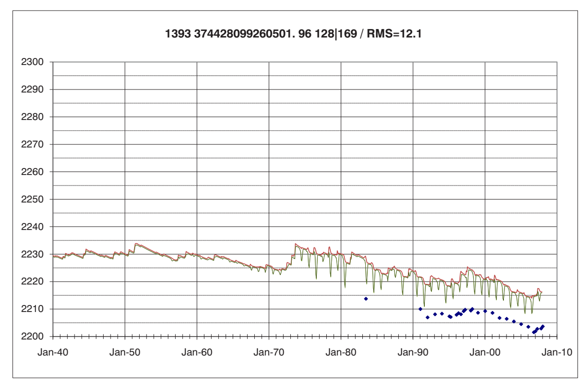

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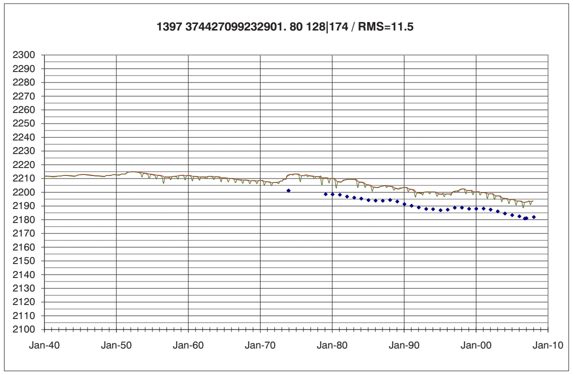

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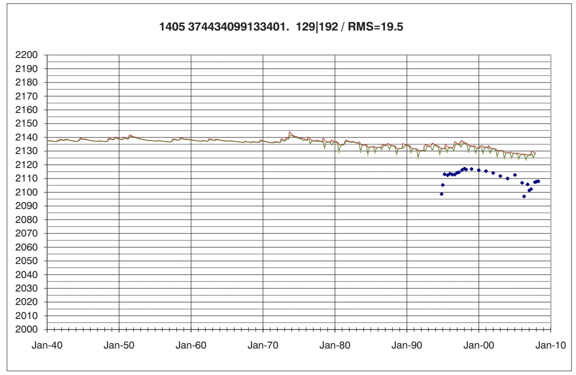

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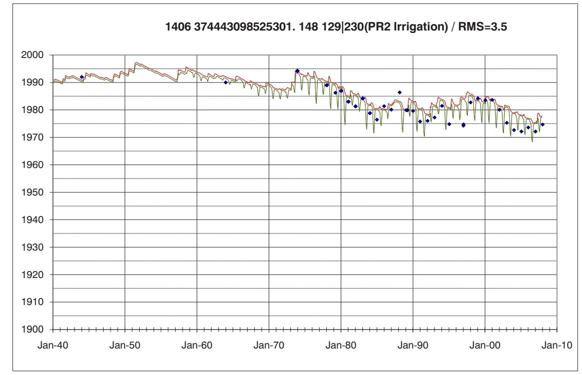

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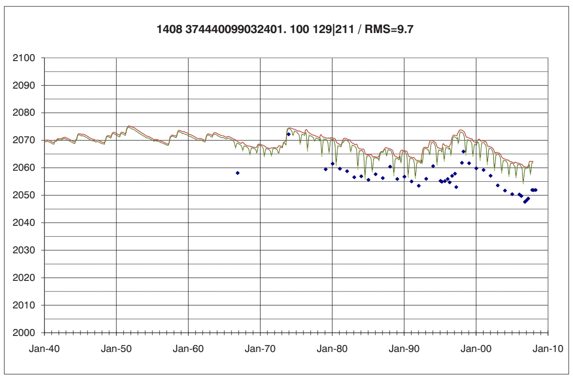

BALLEAU GROUNDWATER, INC.

GMD #5

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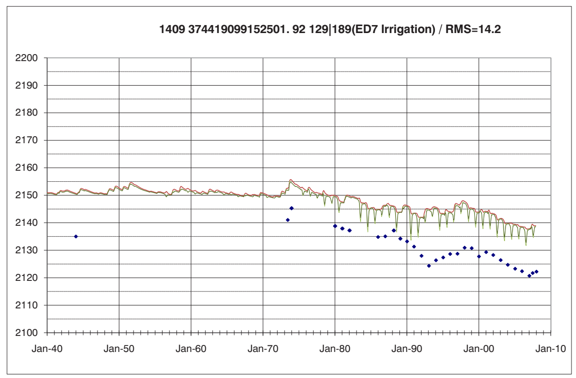

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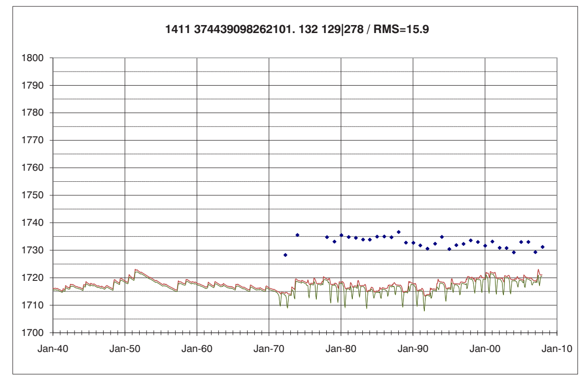

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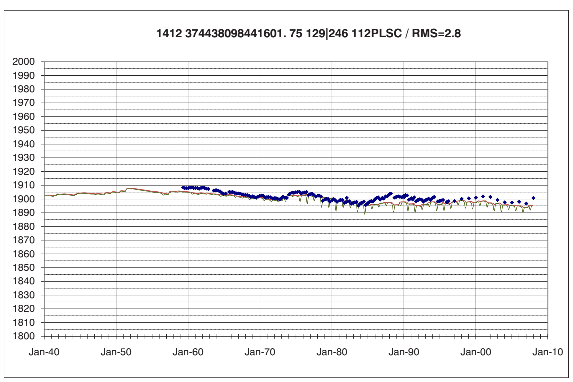

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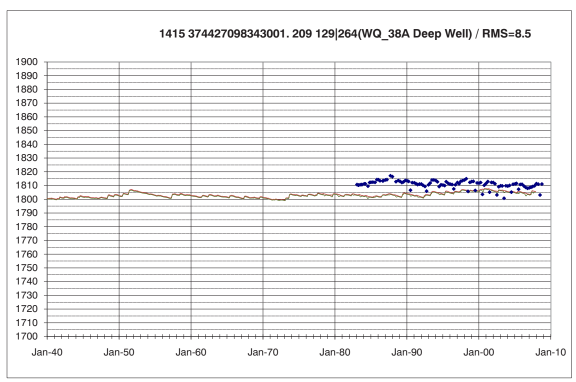

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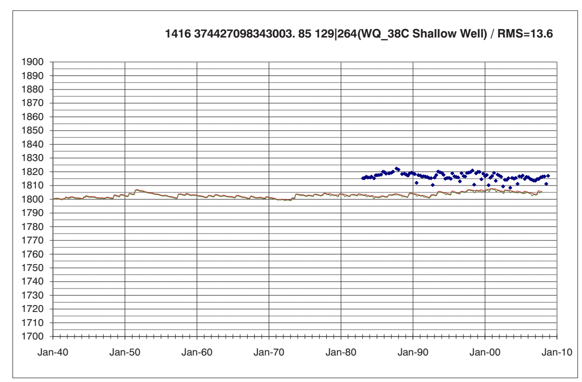

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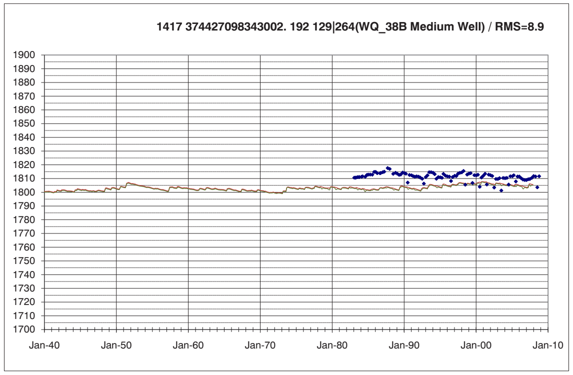

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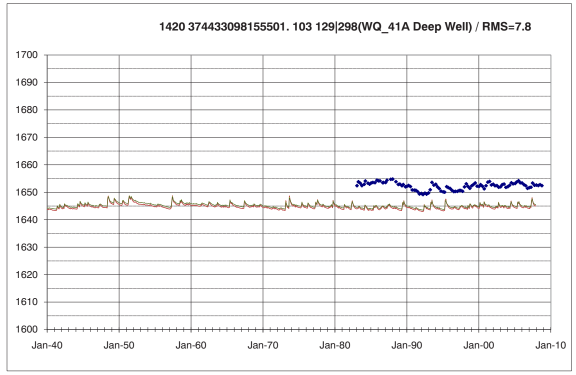

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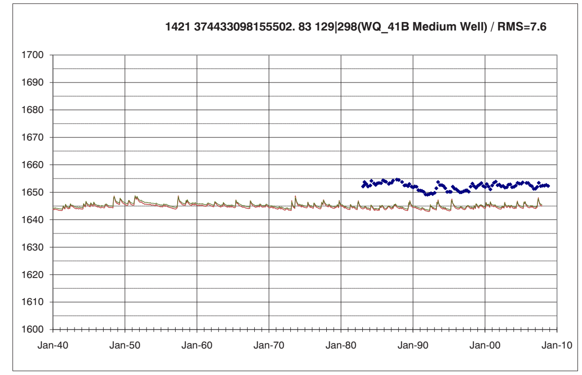

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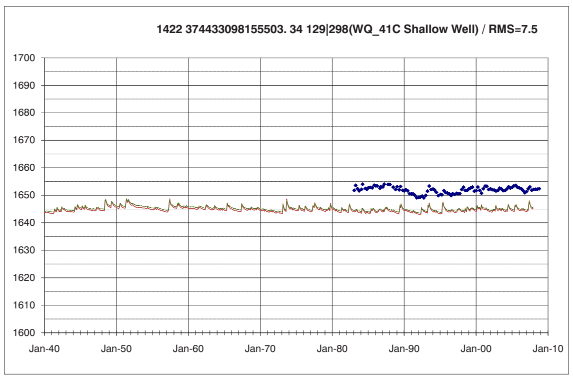

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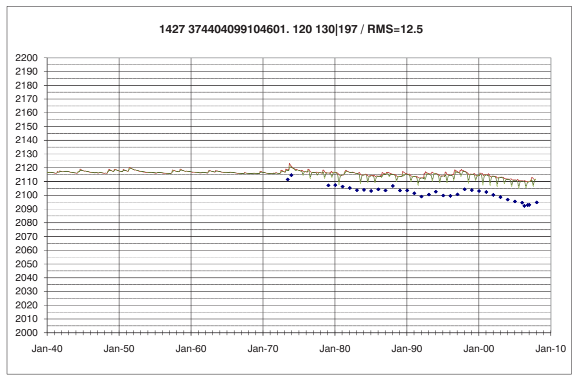

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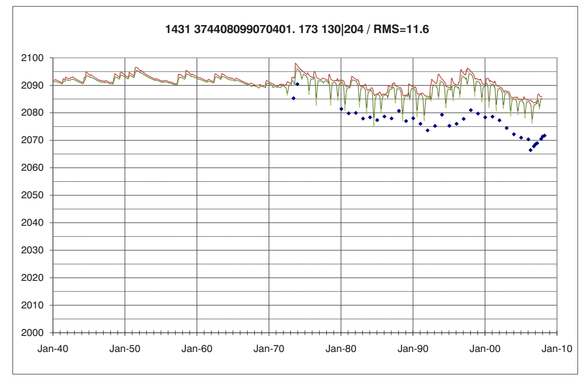

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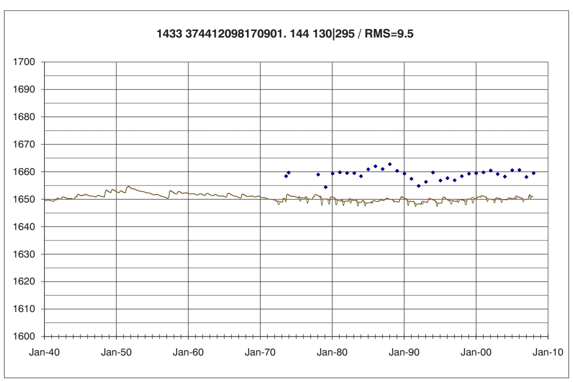

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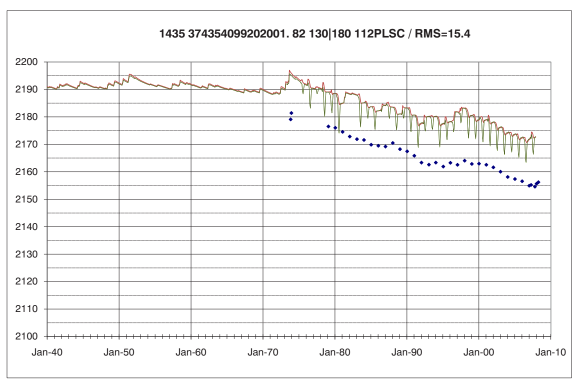

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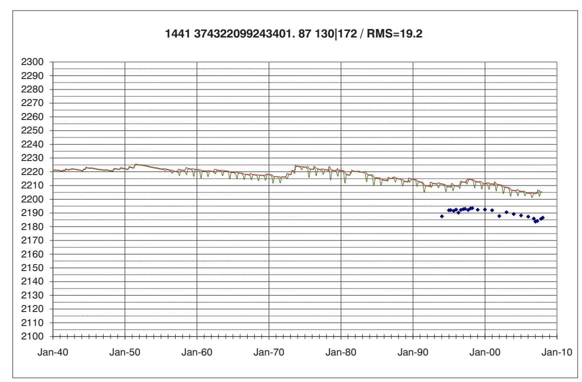

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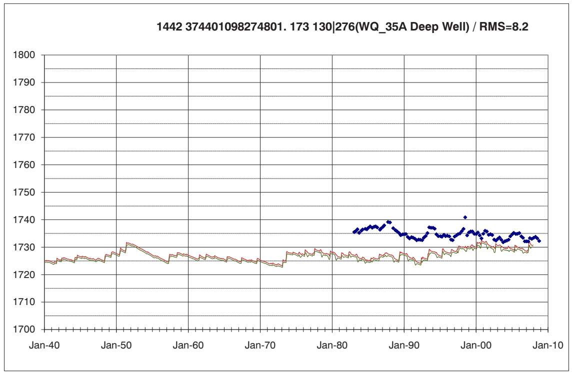

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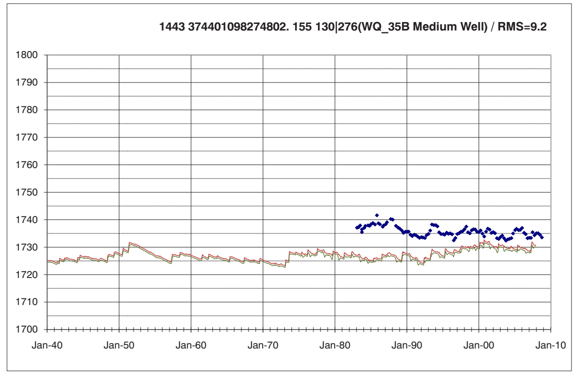

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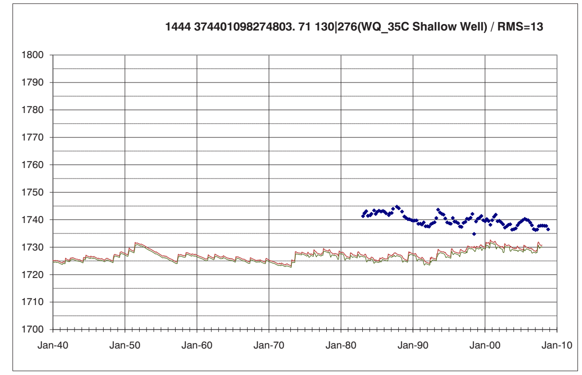

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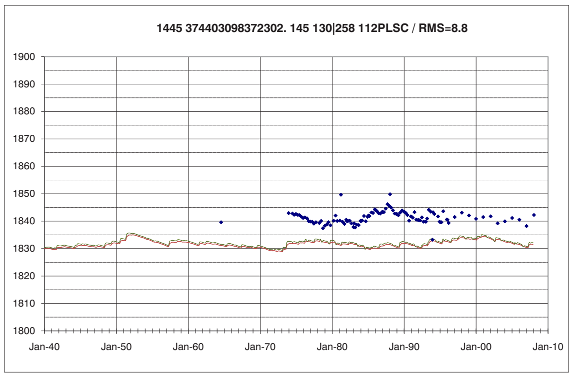

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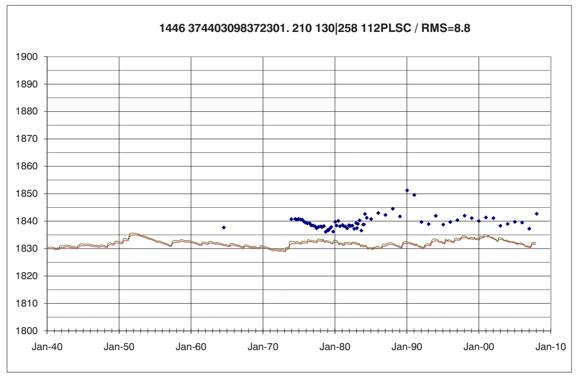

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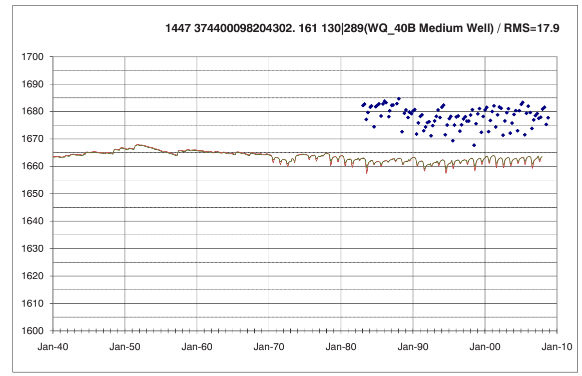

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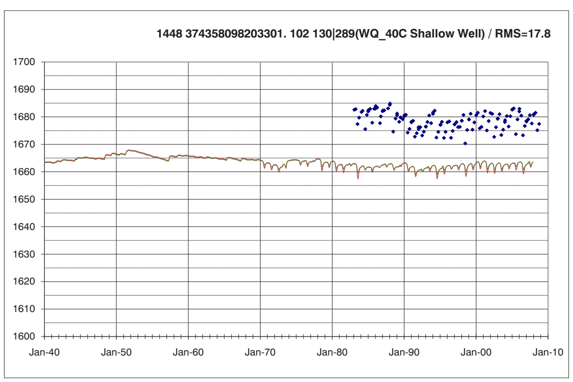

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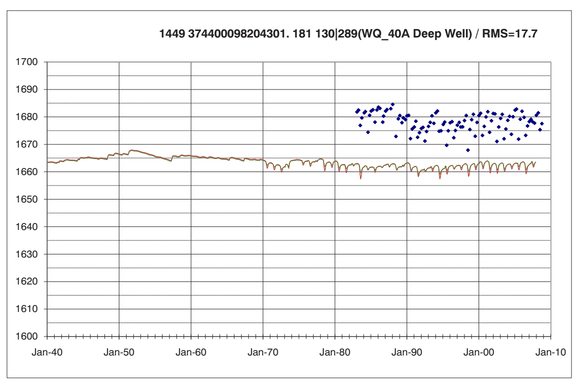

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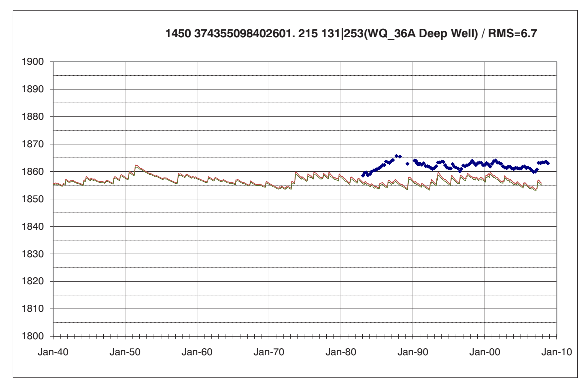

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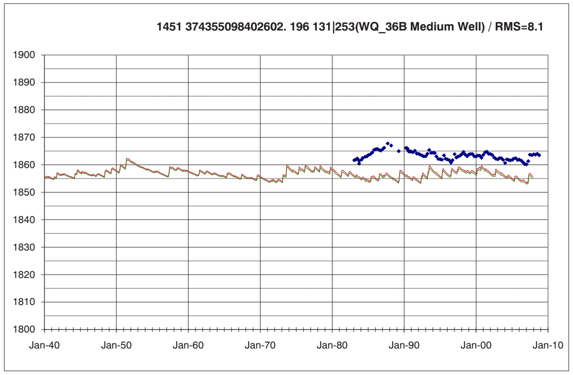

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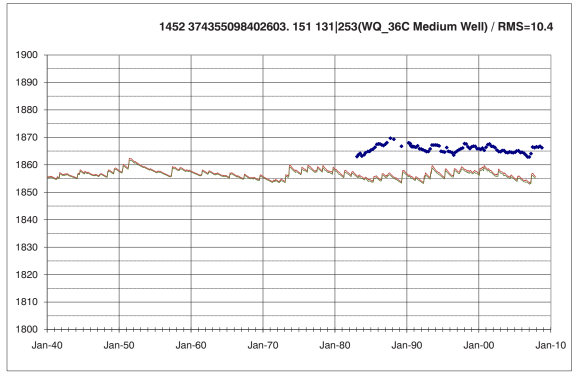

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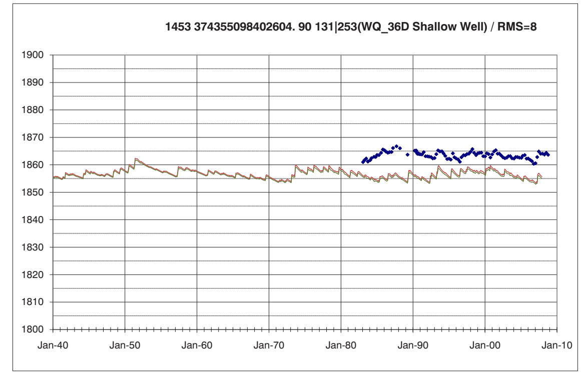

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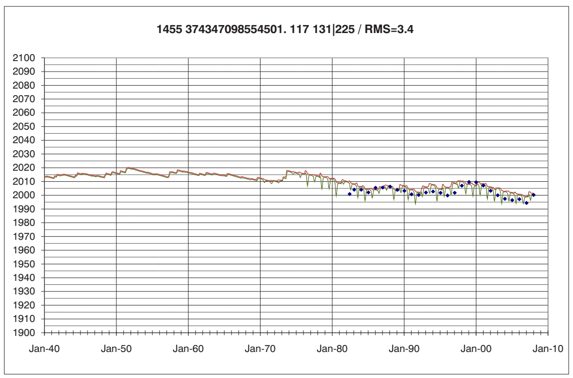

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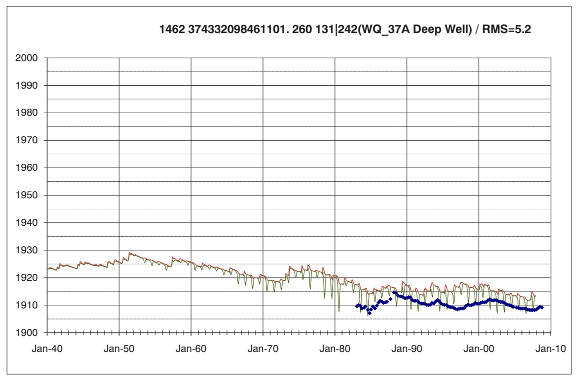

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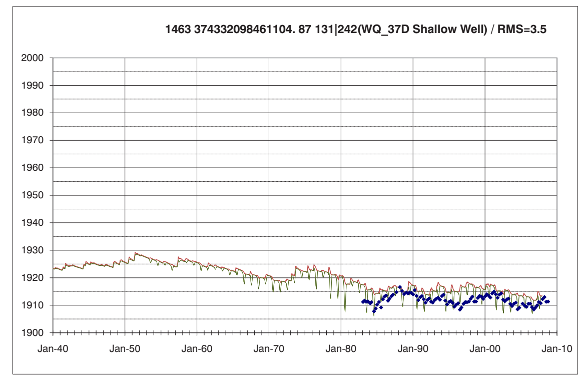

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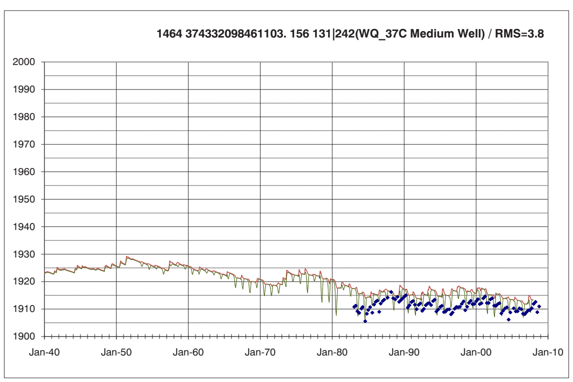

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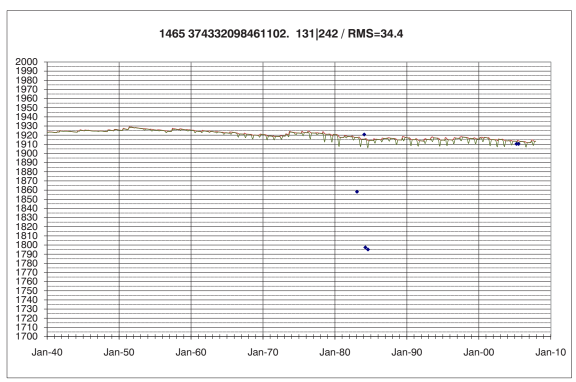

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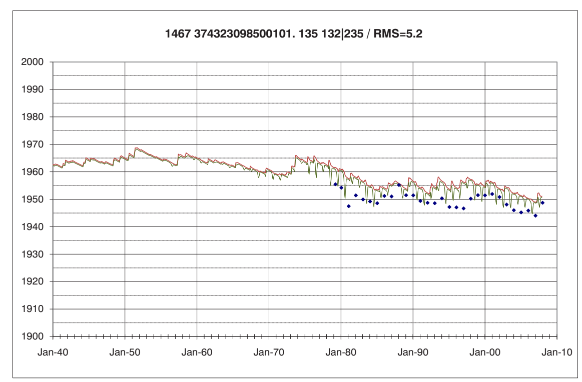

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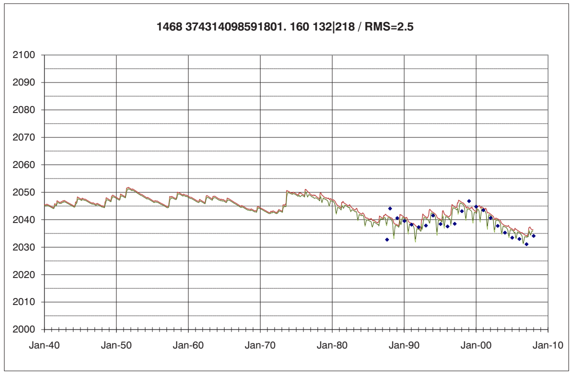

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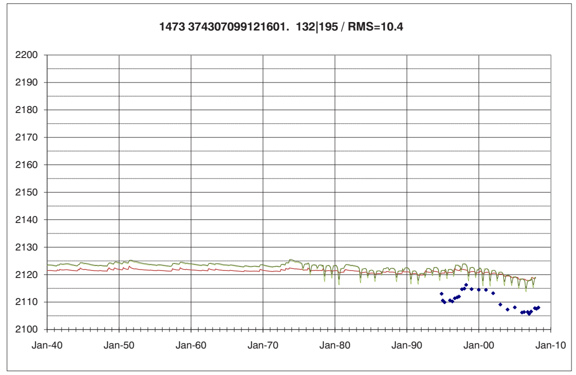

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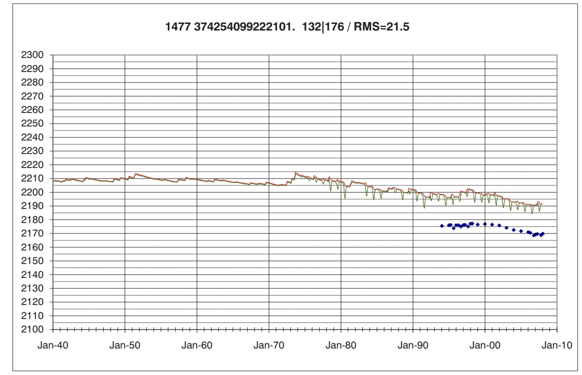

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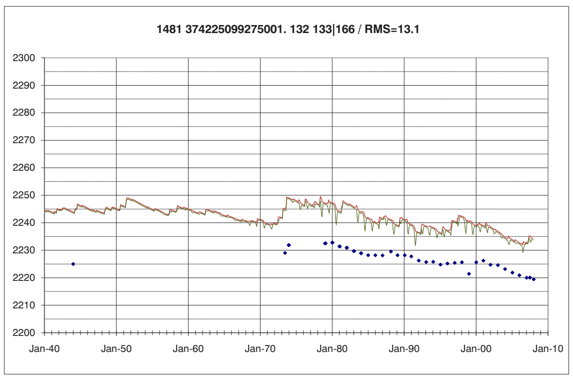

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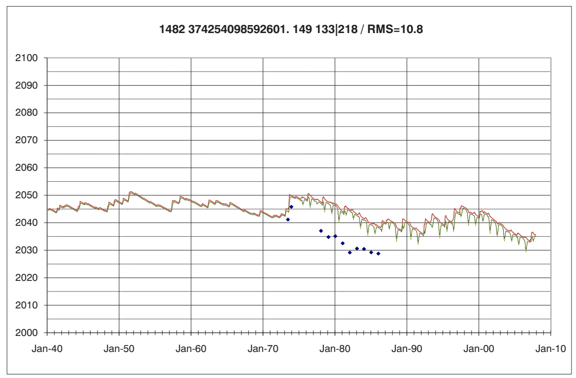

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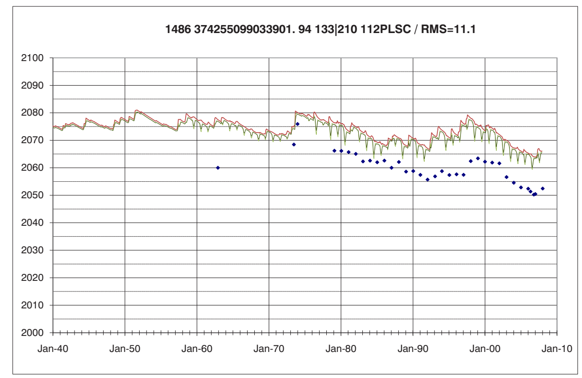

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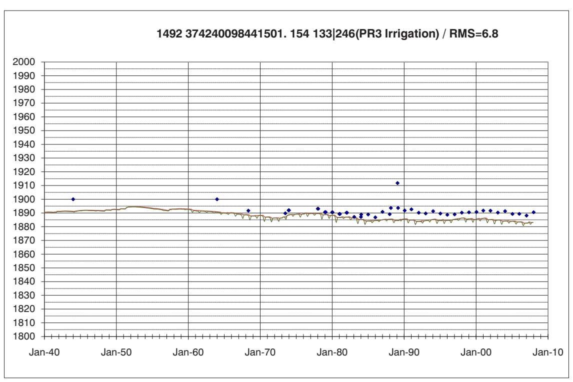

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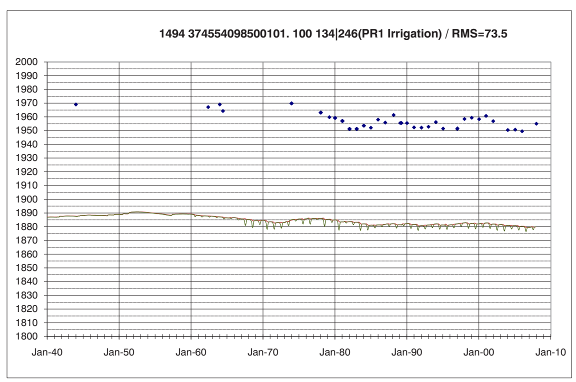

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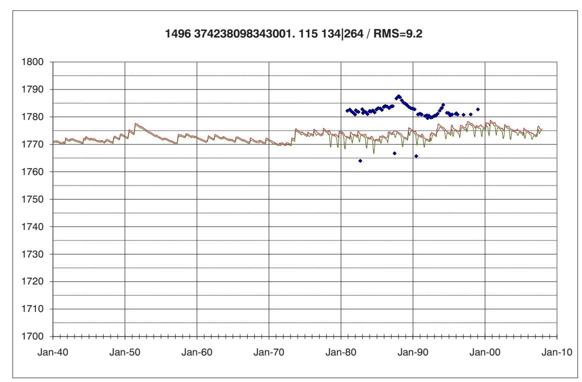

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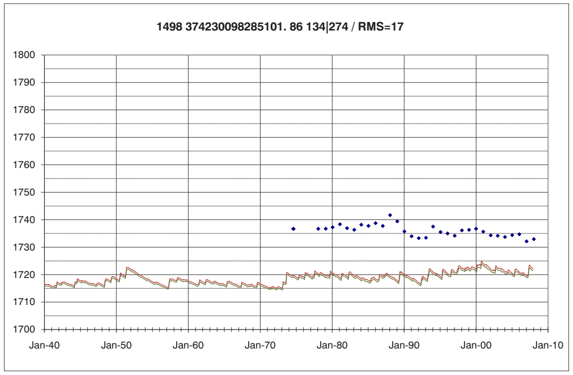

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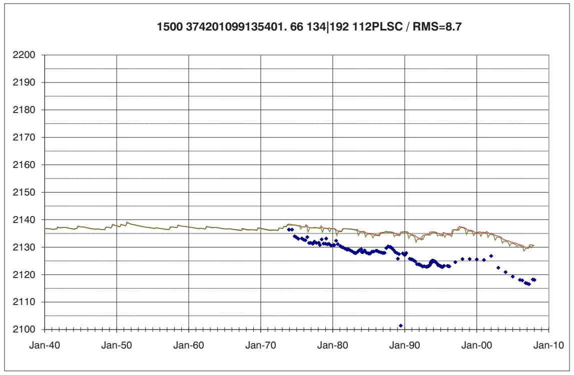

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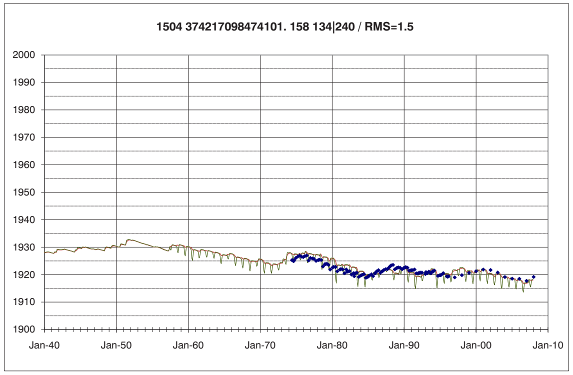

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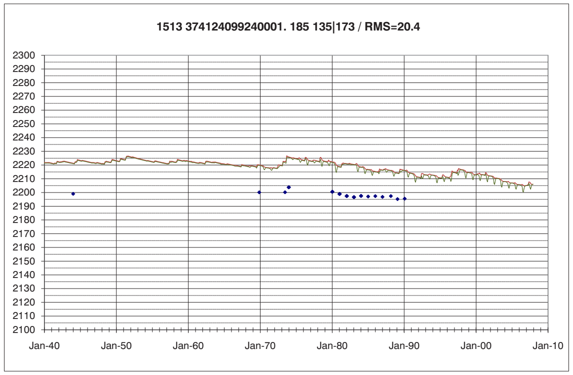

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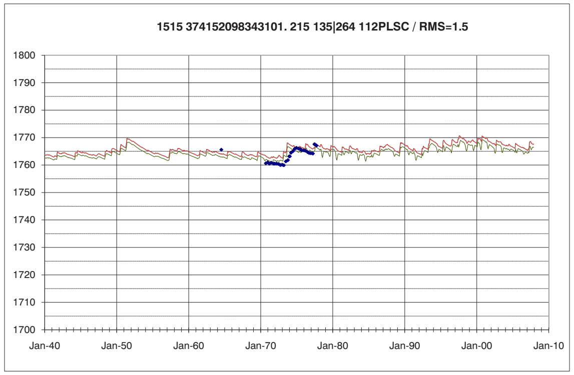

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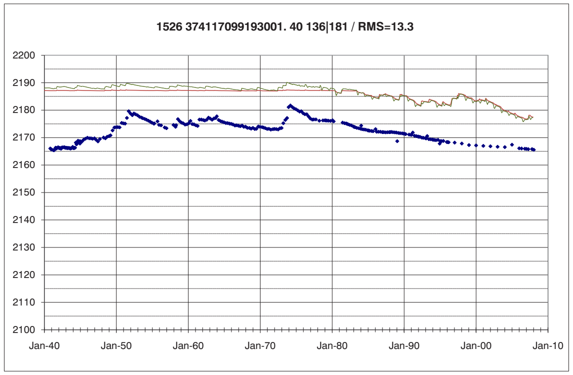

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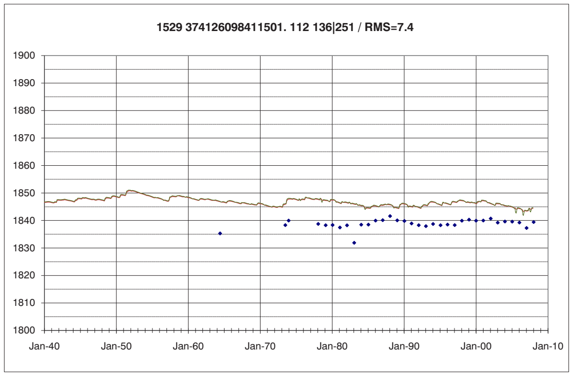

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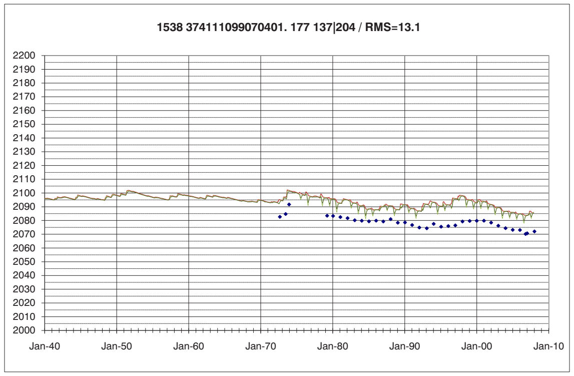

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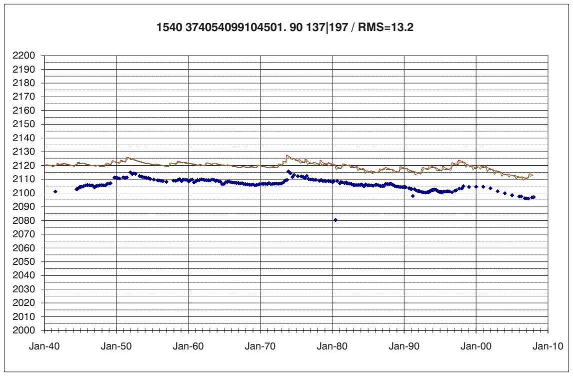

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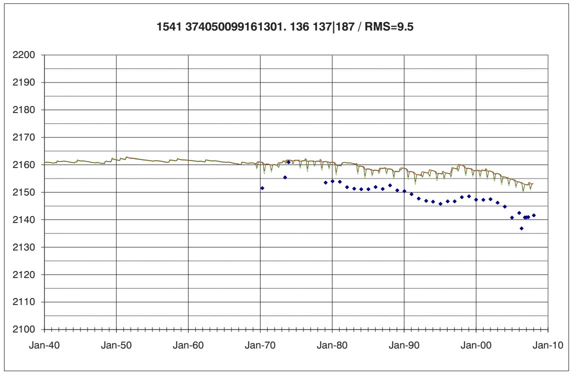

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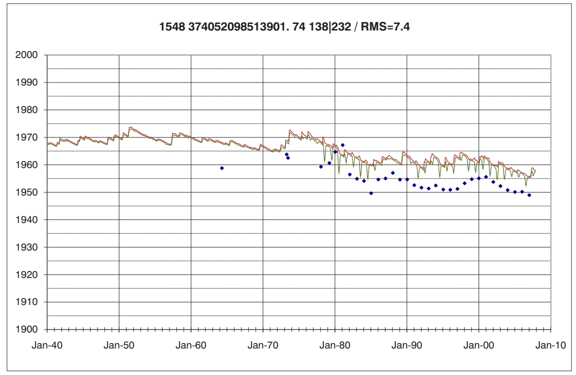

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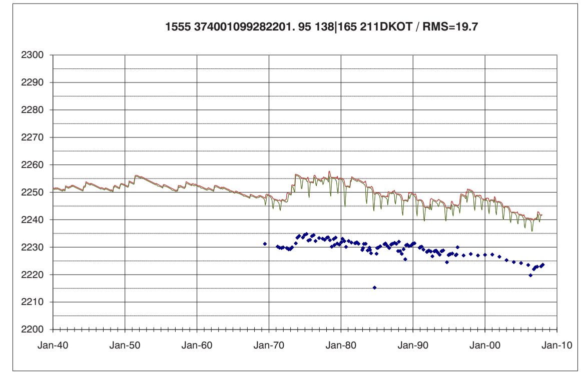

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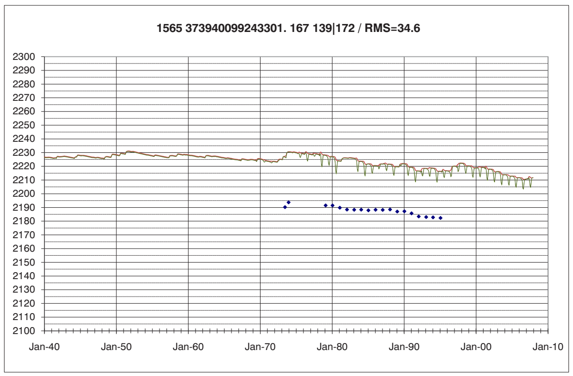

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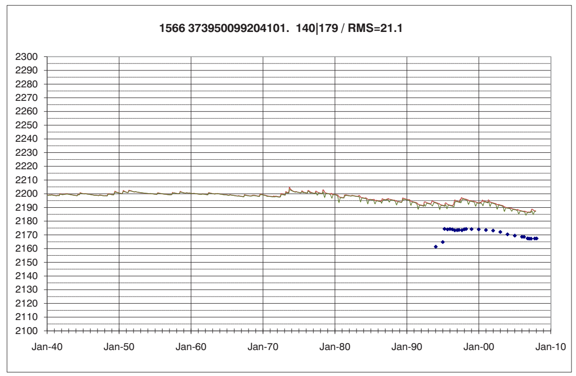

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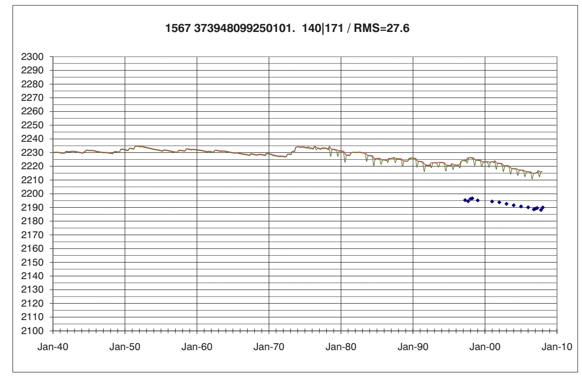

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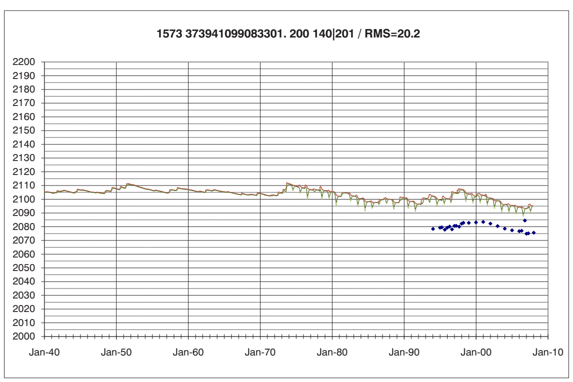

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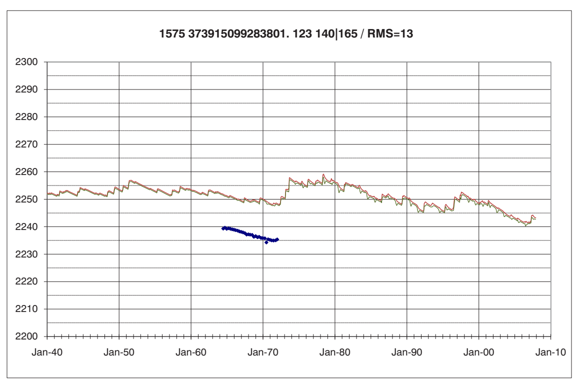

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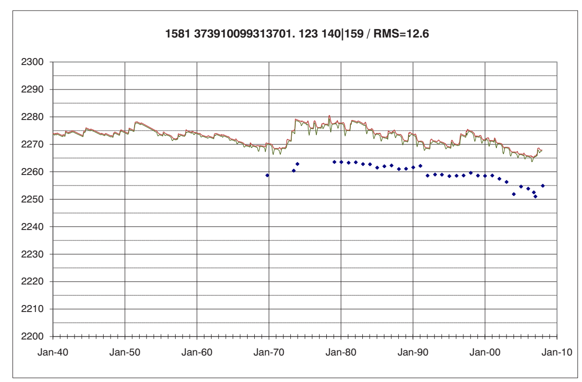

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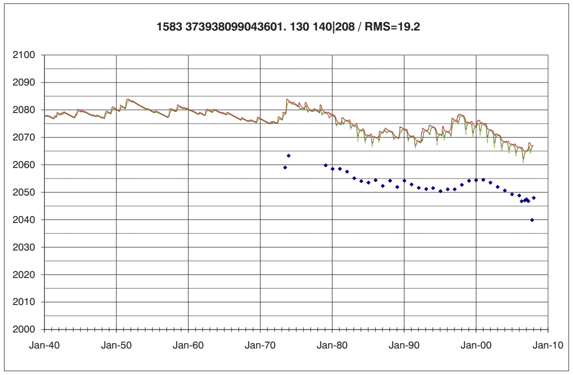

BALLEAU GROUNDWATER, INC.

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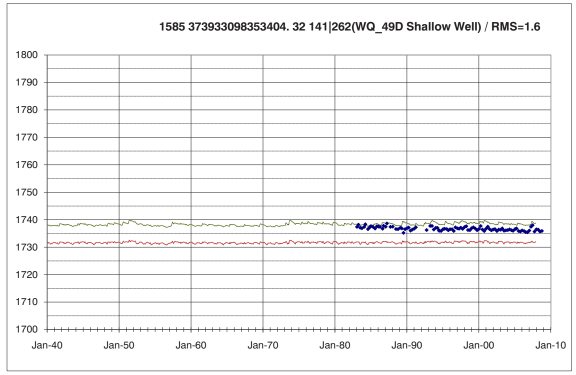

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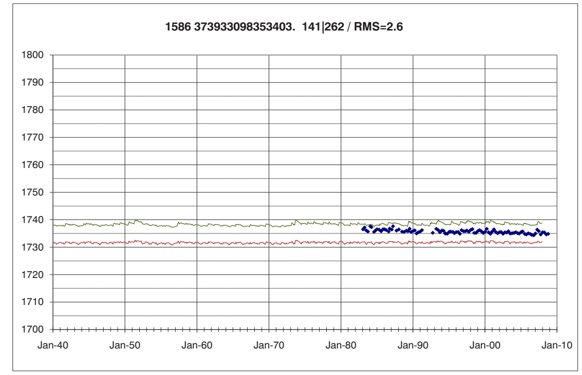

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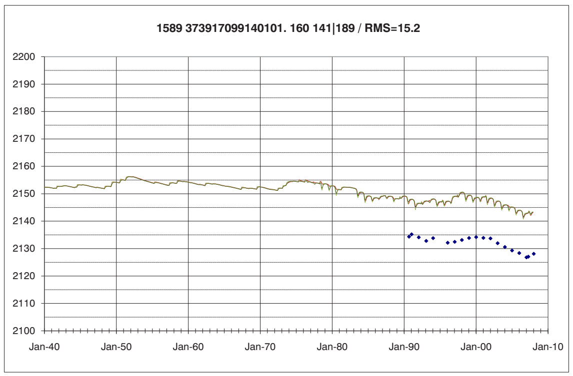

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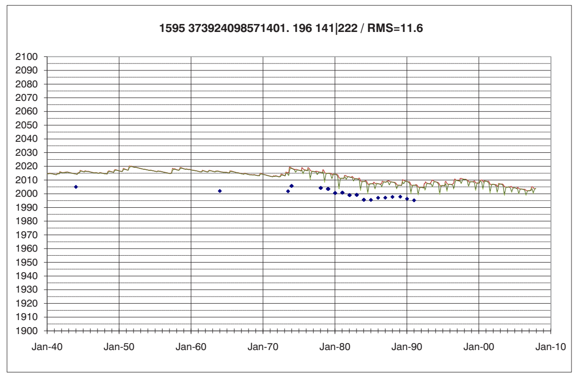

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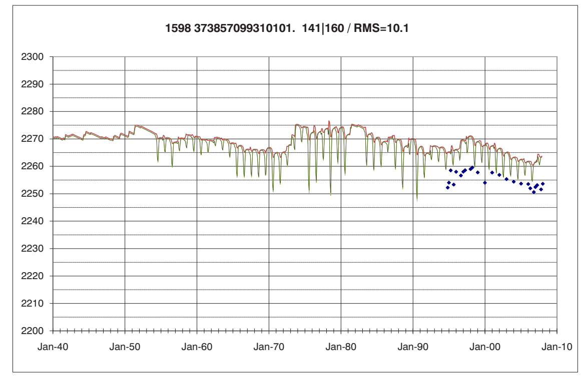
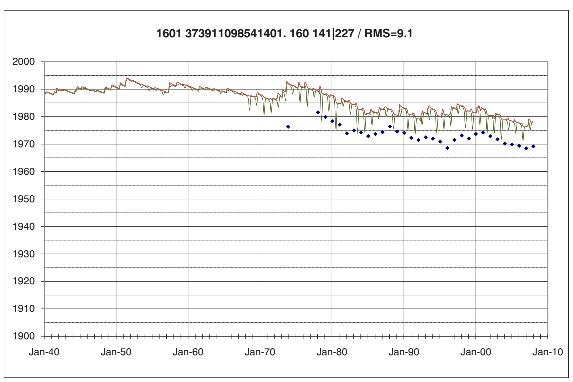


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

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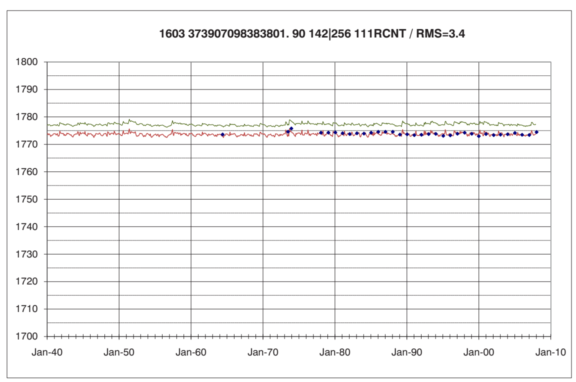

BALLEAU GROUNDWATER, INC.

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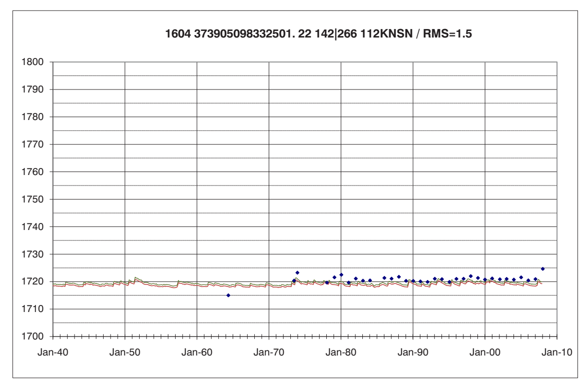

BALLEAU GROUNDWATER, INC.

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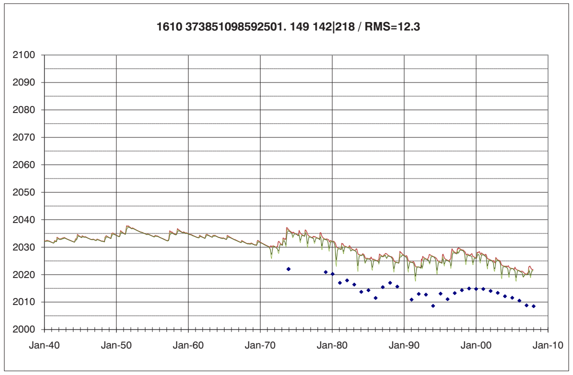

BALLEAU GROUNDWATER, INC.

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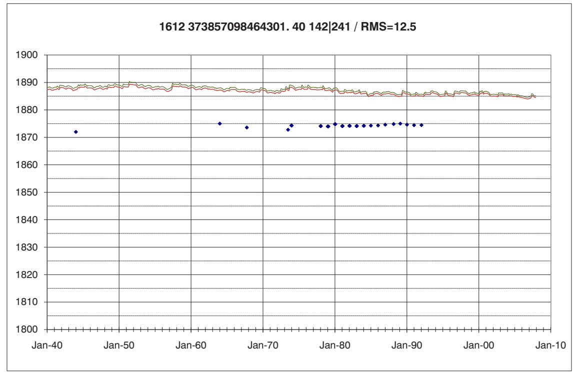

BALLEAU GROUNDWATER, INC.

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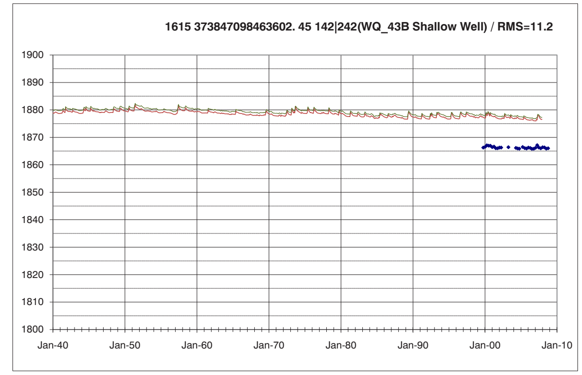

BALLEAU GROUNDWATER, INC.

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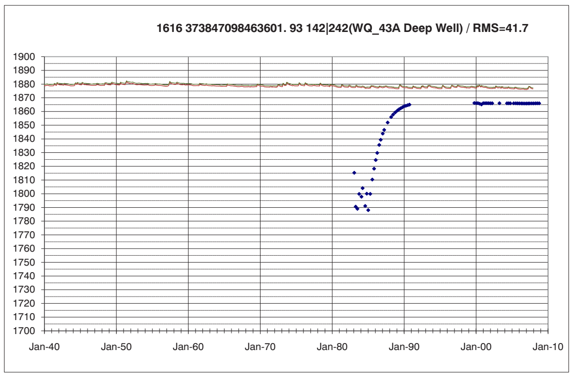

BALLEAU GROUNDWATER, INC.

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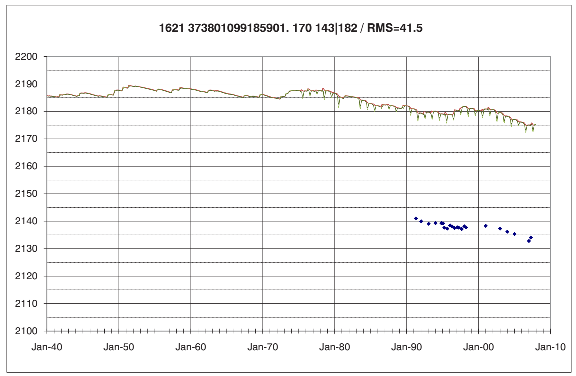

BALLEAU GROUNDWATER, INC.

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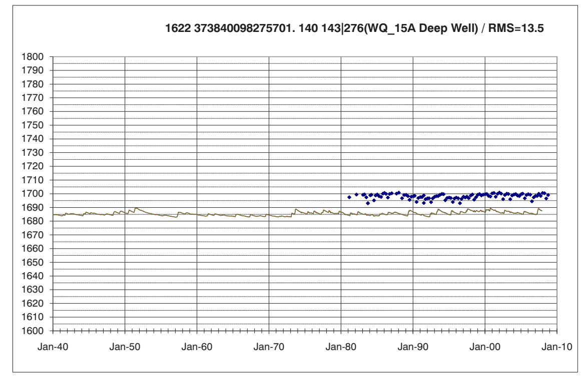

BALLEAU GROUNDWATER, INC.

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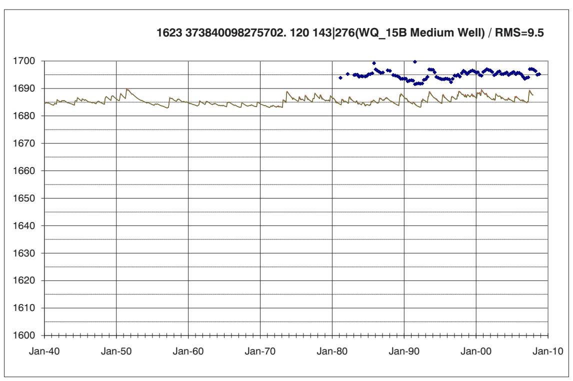

BALLEAU GROUNDWATER, INC.

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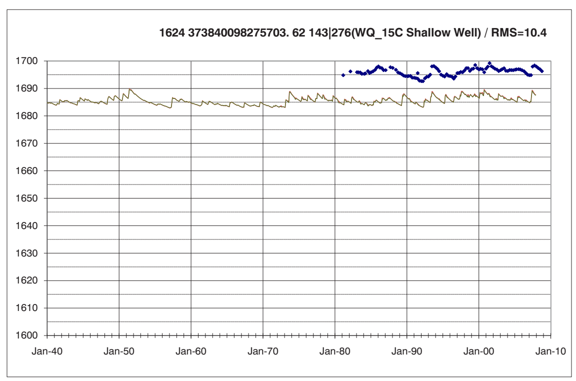

BALLEAU GROUNDWATER, INC.

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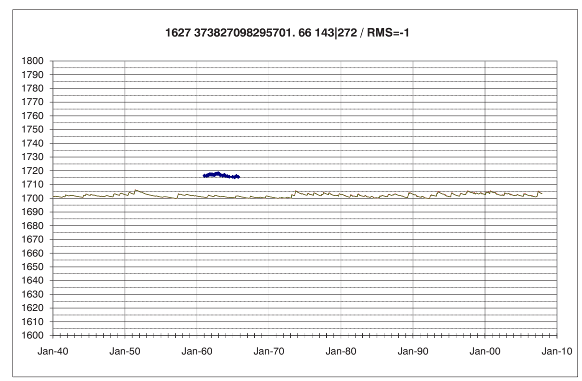

BALLEAU GROUNDWATER, INC.

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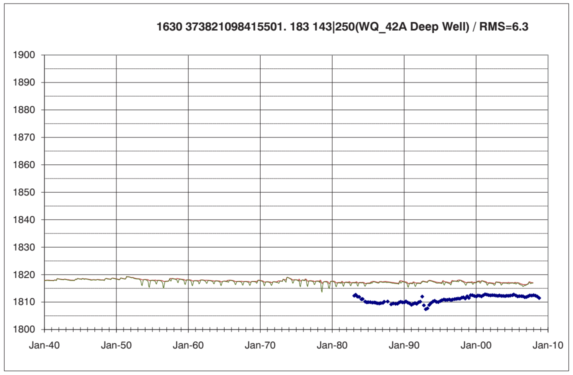

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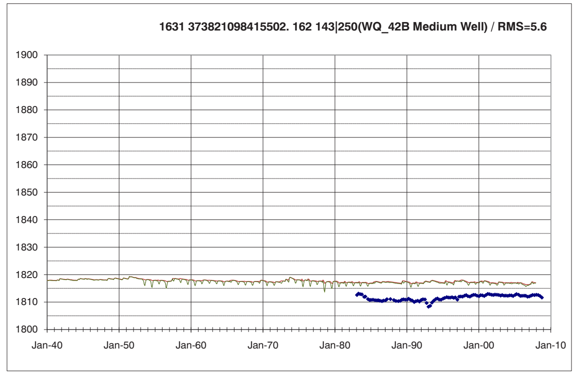

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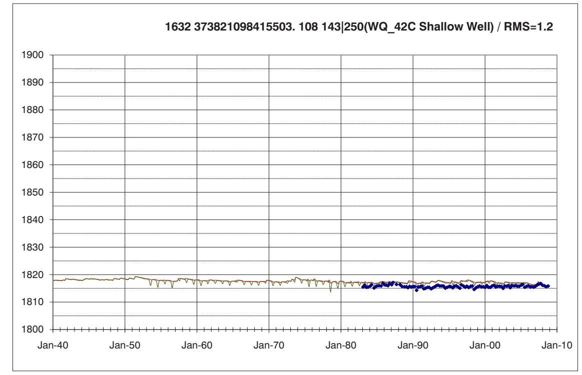

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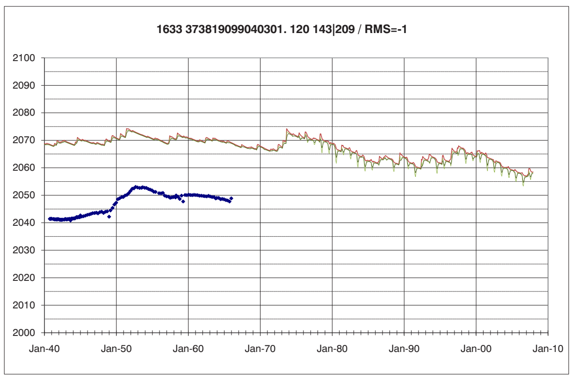

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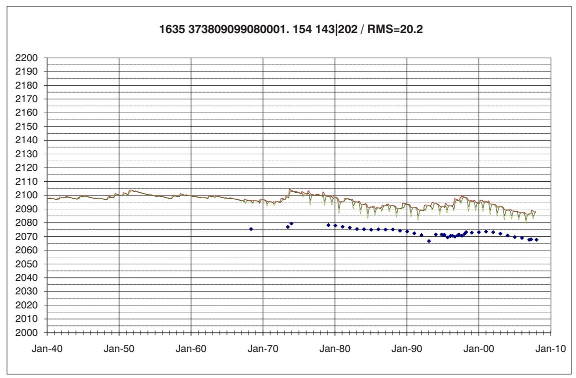

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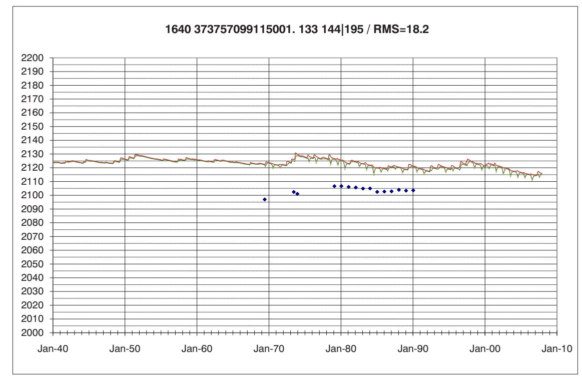

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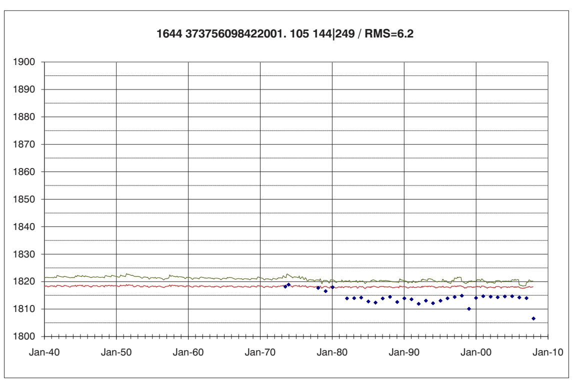

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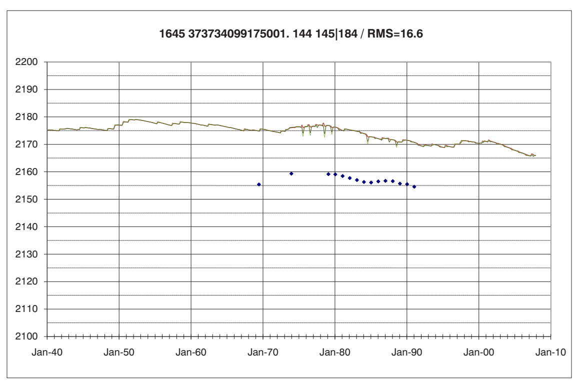

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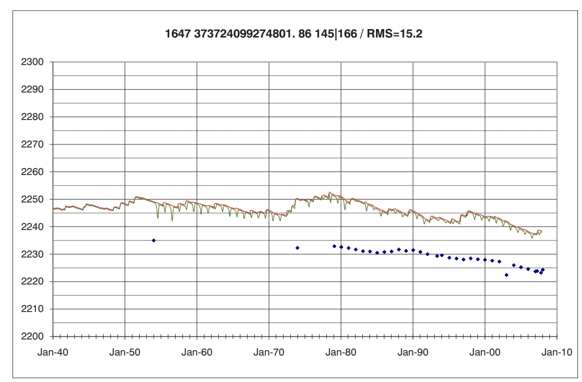

GMD #5

MODEL

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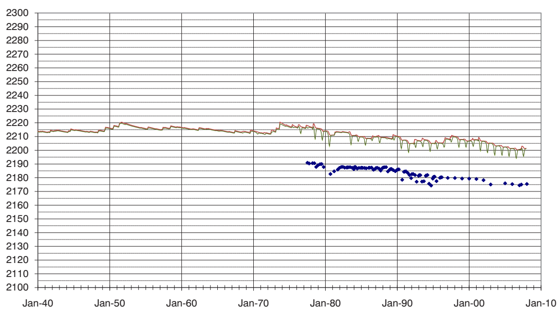

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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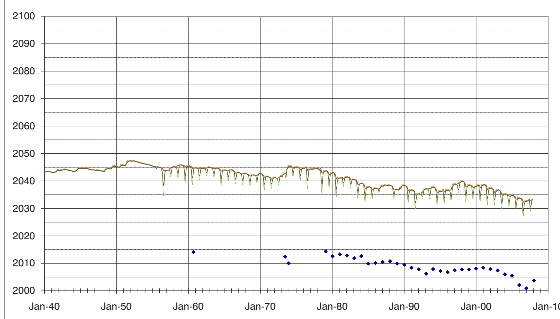

BALLEAU GROUNDWATER, INC.

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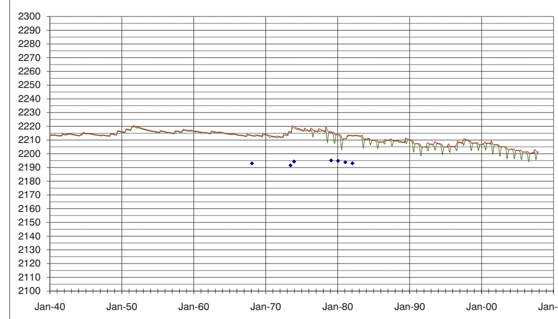

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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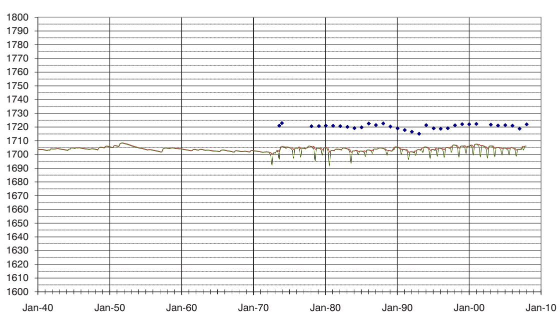

BALLEAU GROUNDWATER, INC.

GMD #5

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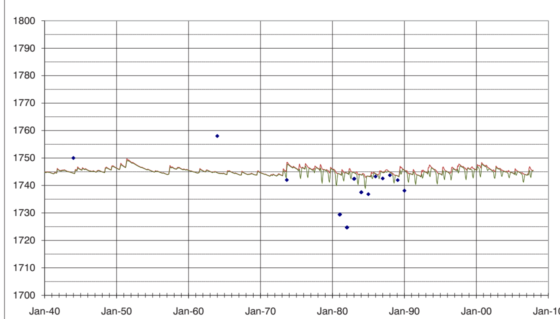

BALLEAU GROUNDWATER, INC.

GMD #5

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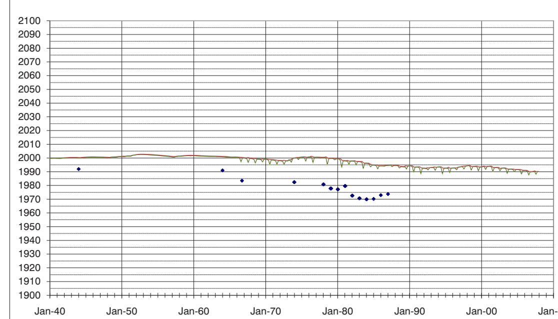

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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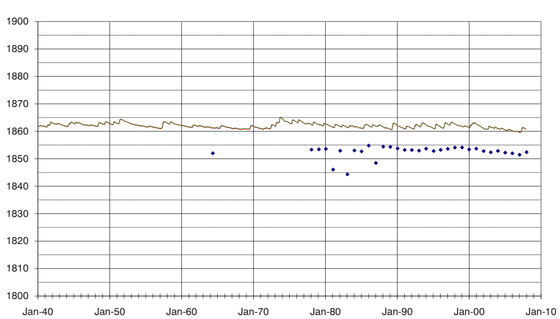

BALLEAU GROUNDWATER, INC.

GMD #5

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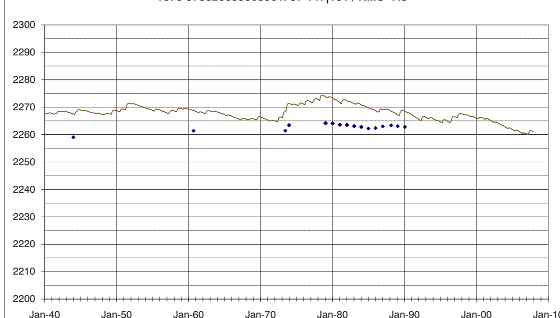

BALLEAU GROUNDWATER, INC.

GMD #5

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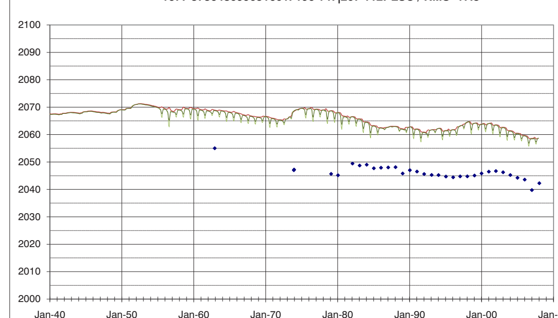

BALLEAU GROUNDWATER, INC.

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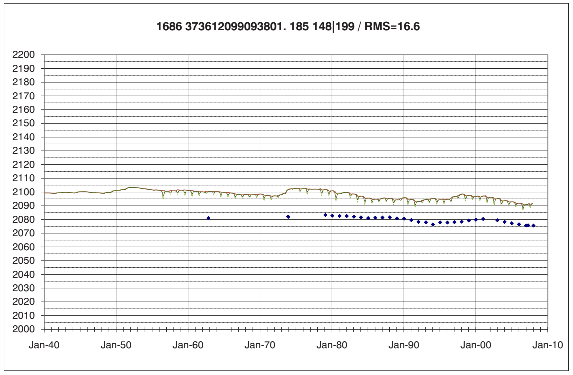

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6/18/2010

BALLEAU GROUNDWATER, INC.

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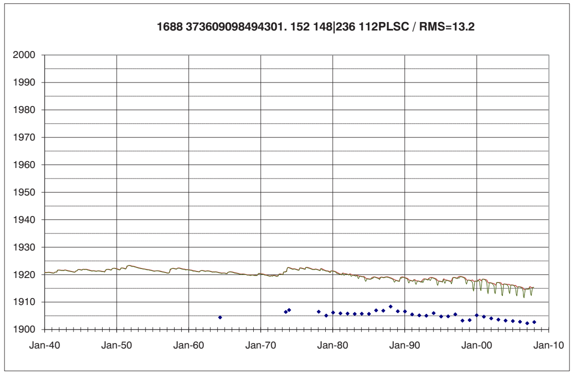

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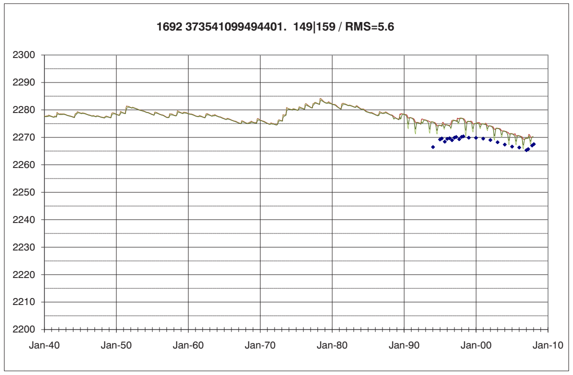

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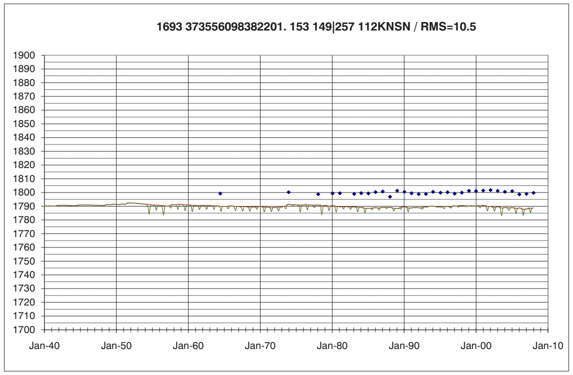

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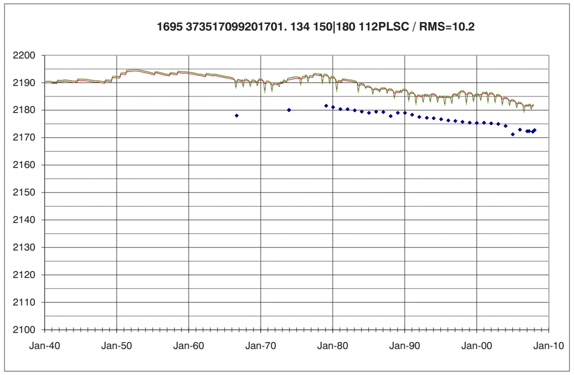

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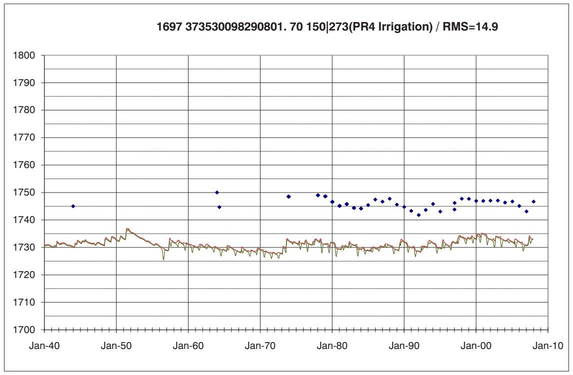

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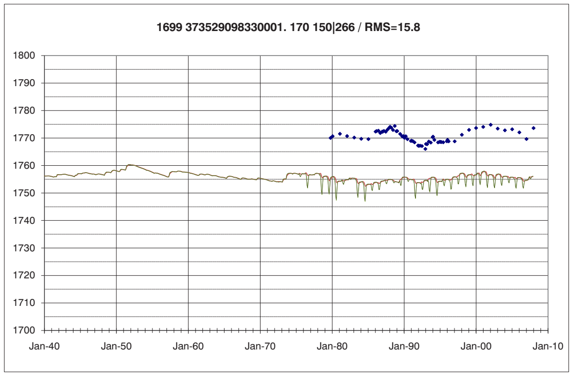

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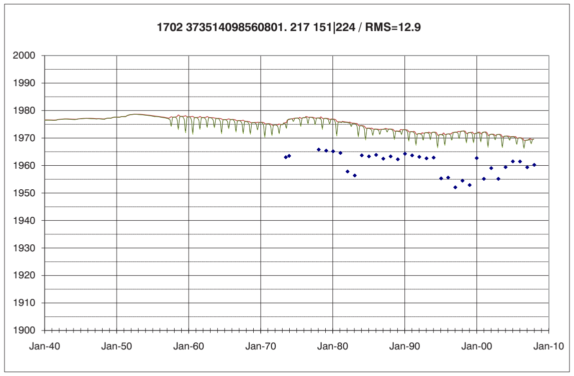

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BALLEAU GROUNDWATER, INC.

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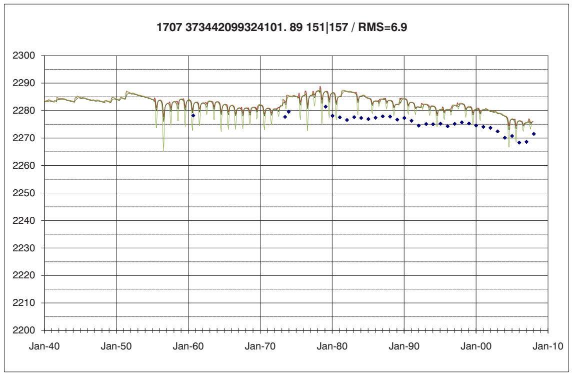

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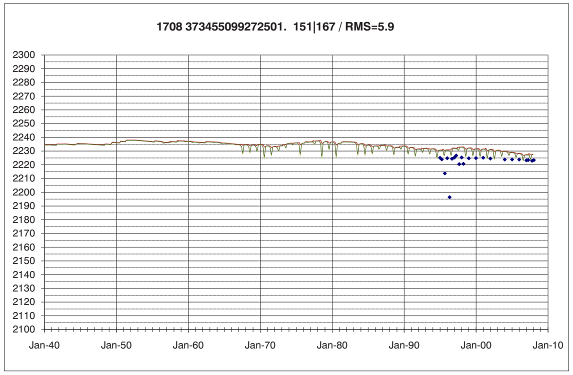

BALLEAU GROUNDWATER, INC.

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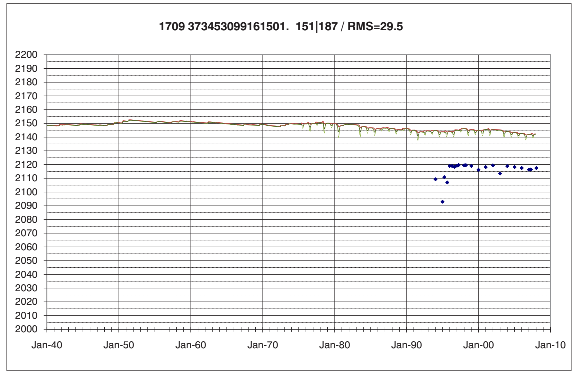

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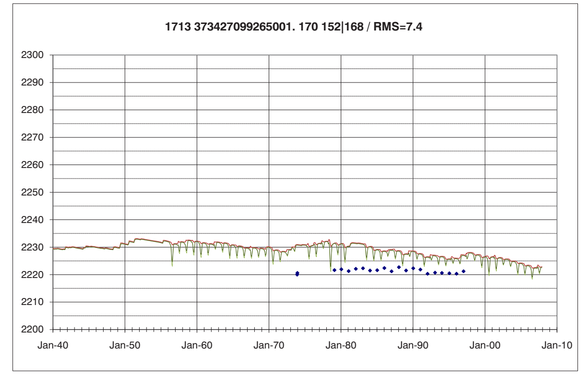

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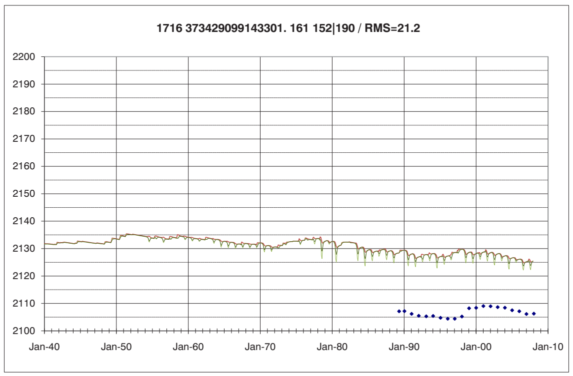

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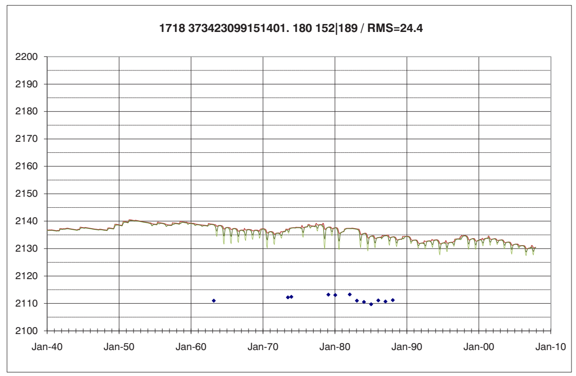

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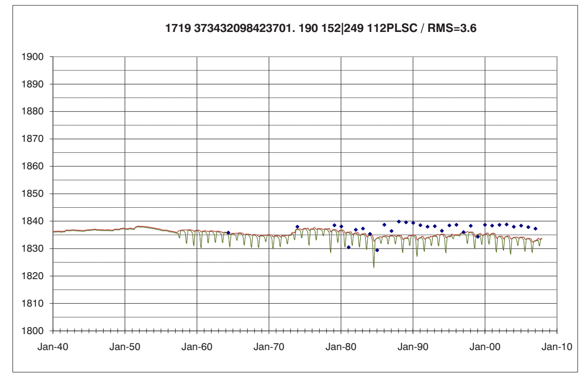

BALLEAU GROUNDWATER, INC.

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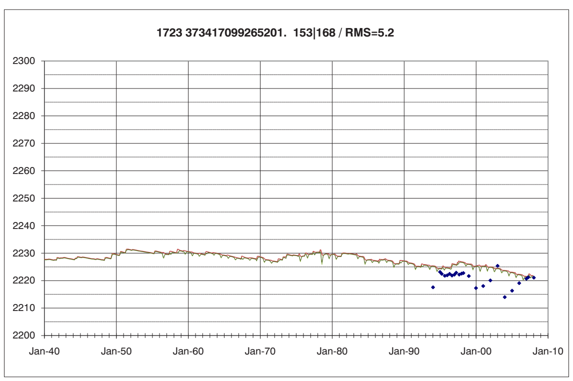

BALLEAU GROUNDWATER, INC.

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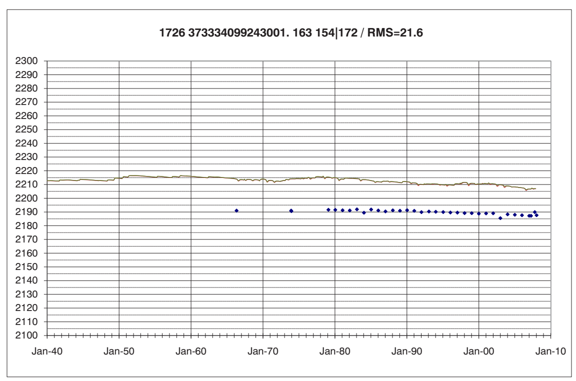

BALLEAU GROUNDWATER, INC.

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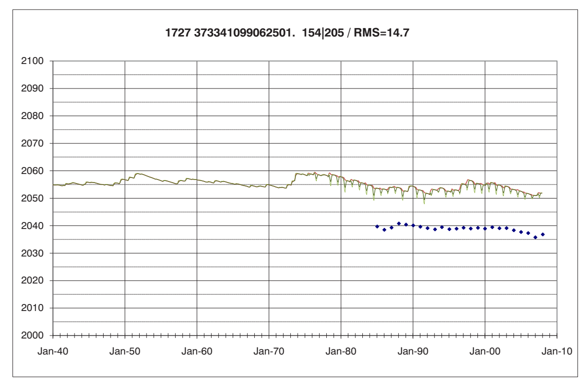

BALLEAU GROUNDWATER, INC.

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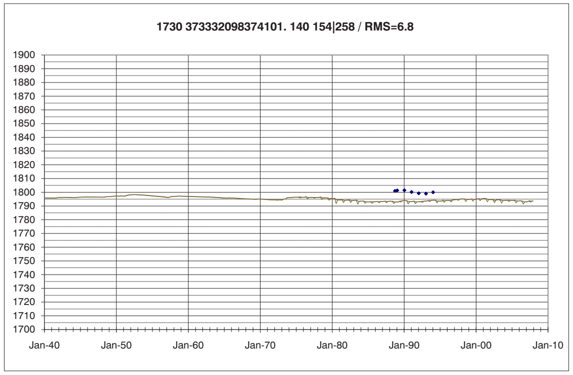

BALLEAU GROUNDWATER, INC.

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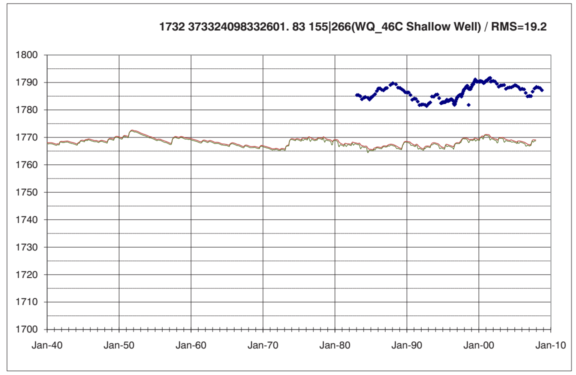

BALLEAU GROUNDWATER, INC.

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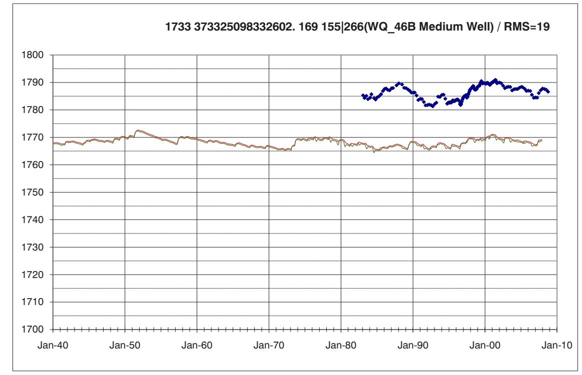

BALLEAU GROUNDWATER, INC.

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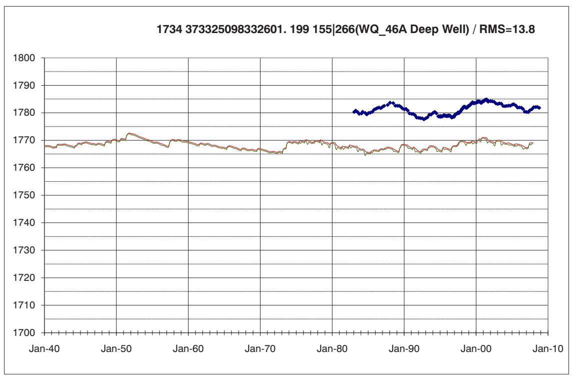

BALLEAU GROUNDWATER, INC.

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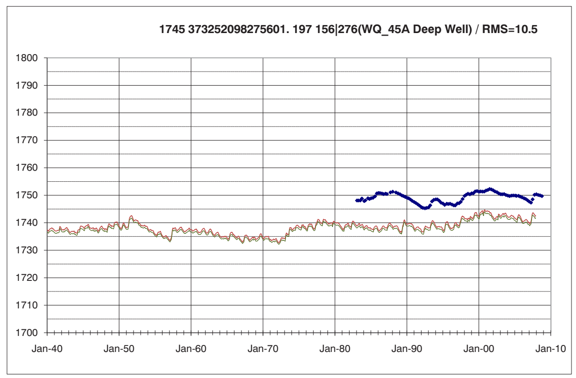

BALLEAU GROUNDWATER, INC.

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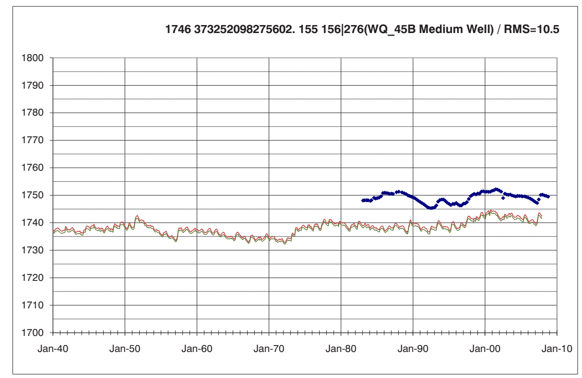

BALLEAU GROUNDWATER, INC.

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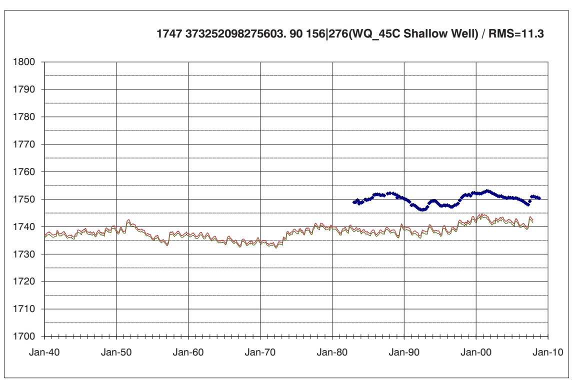

BALLEAU GROUNDWATER, INC.

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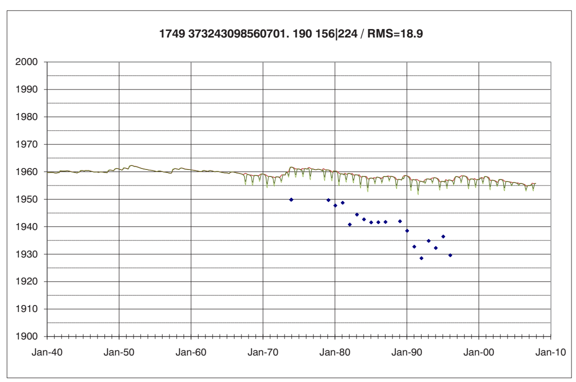

BALLEAU GROUNDWATER, INC.

GMD #5

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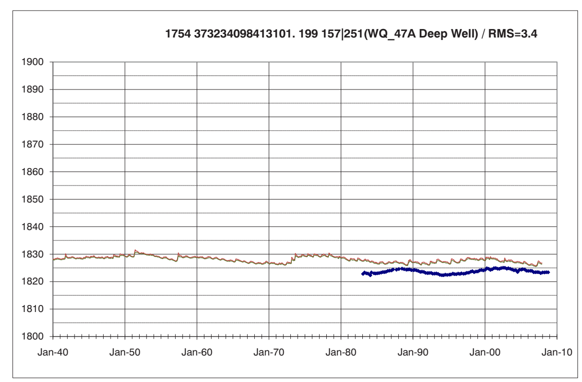

BALLEAU GROUNDWATER, INC.

GMD #5

MODEL

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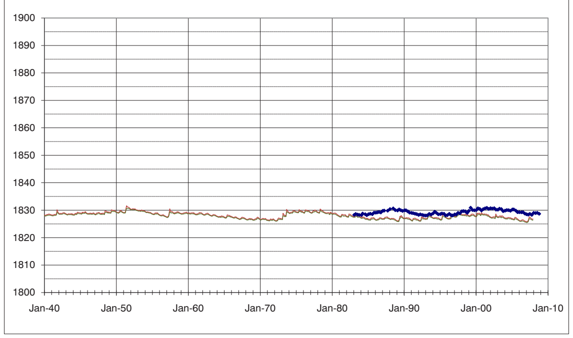

GMD #5

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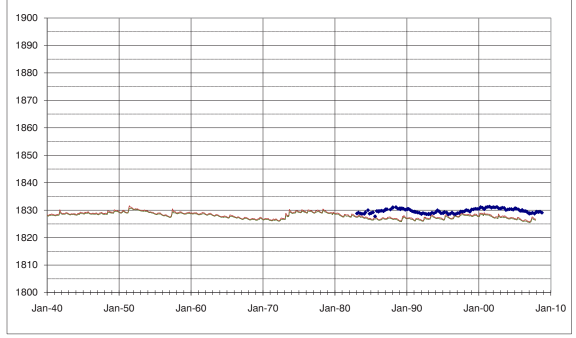

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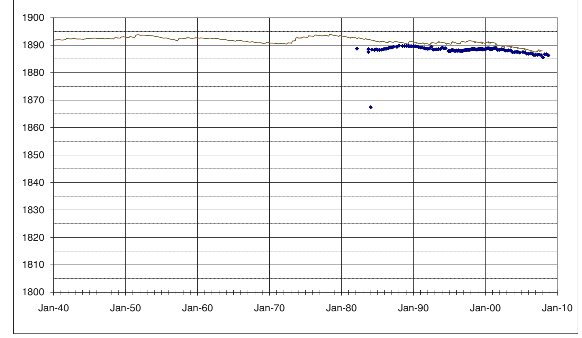

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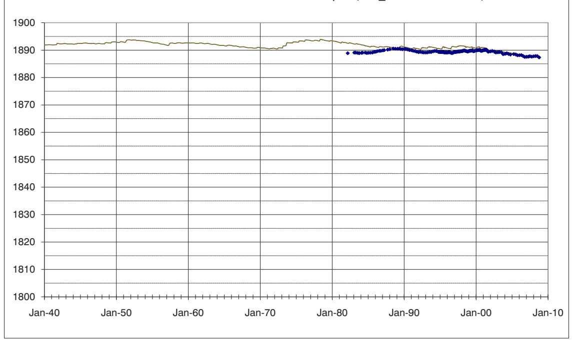

GMD #5

MODEL

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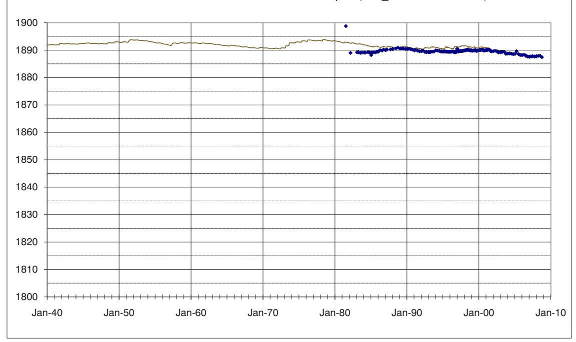

GMD #5

MODEL

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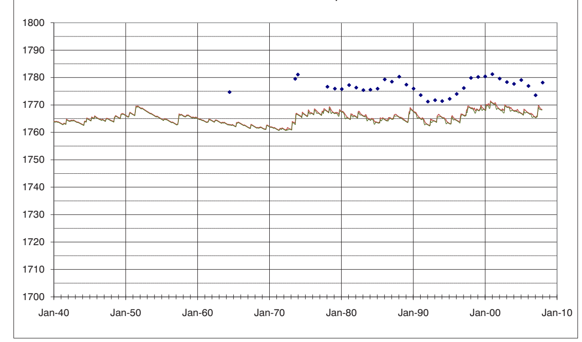

GMD #5

MODEL

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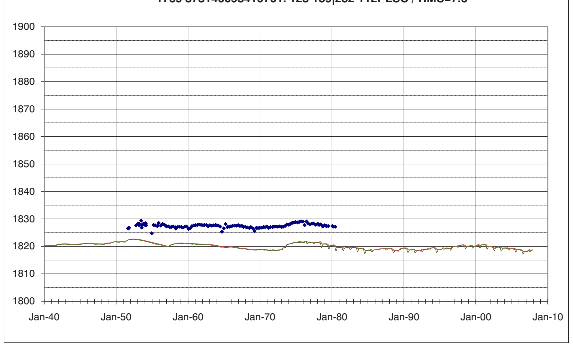

GMD #5

MODEL

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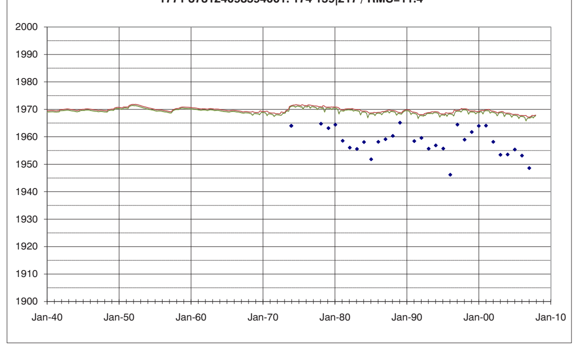

GMD #5

MODEL

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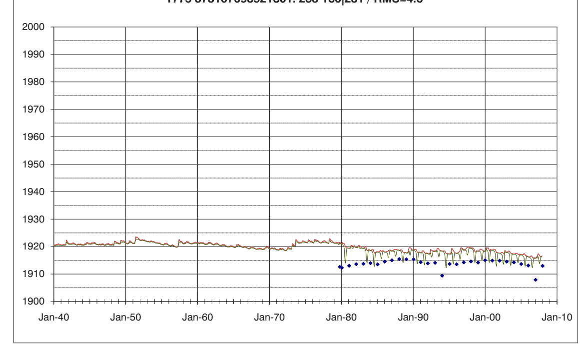
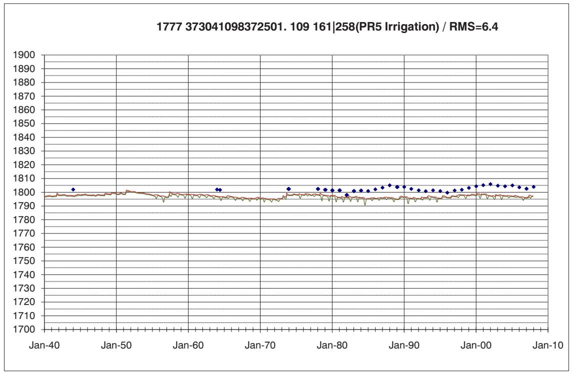


GMD #5

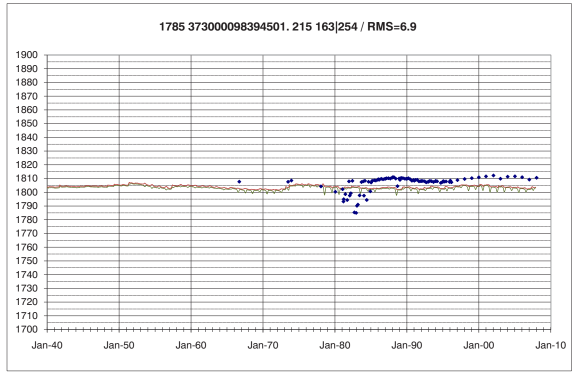
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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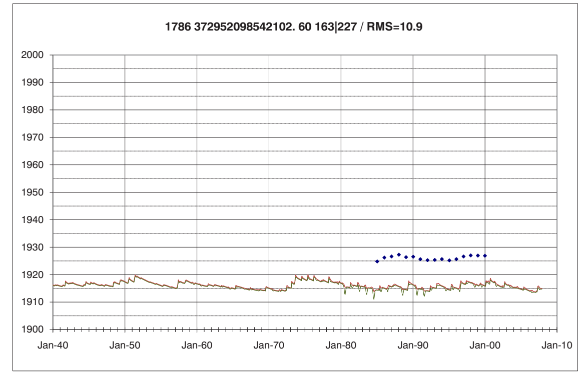
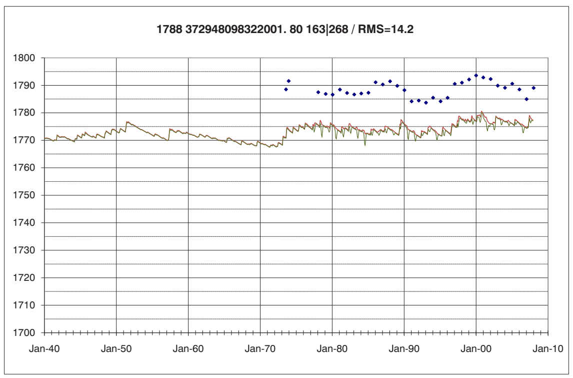


BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

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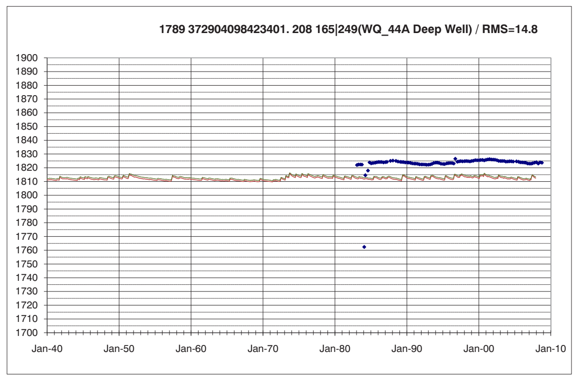

BALLEAU GROUNDWATER, INC.

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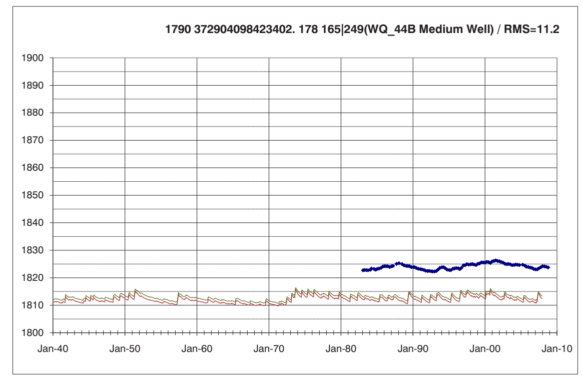

BALLEAU GROUNDWATER, INC.

GMD #5

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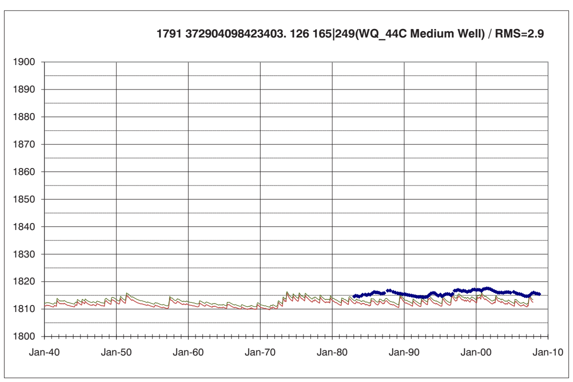

BALLEAU GROUNDWATER, INC.

GMD #5

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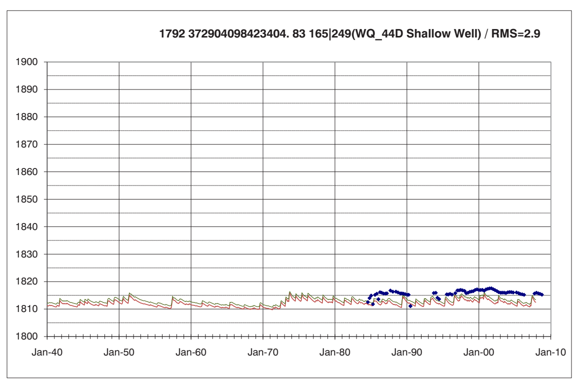

BALLEAU GROUNDWATER, INC.

GMD #5

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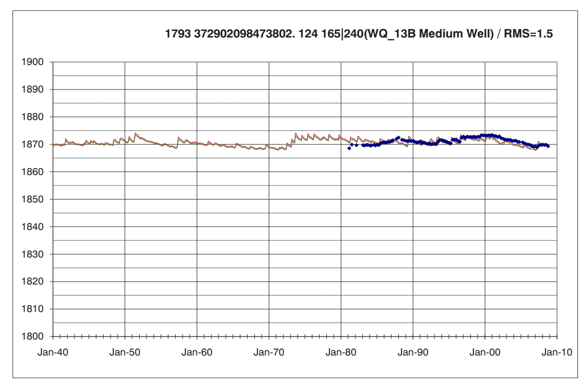

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GMD #5

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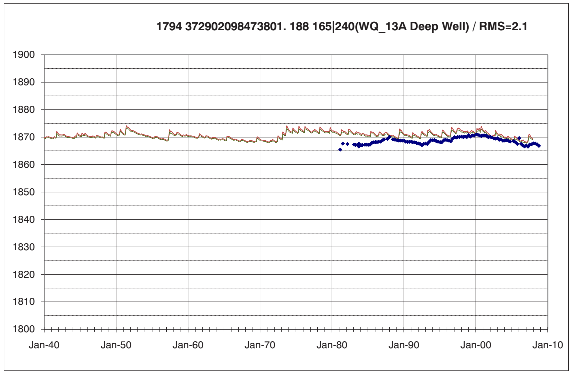

BALLEAU GROUNDWATER, INC.

GMD #5

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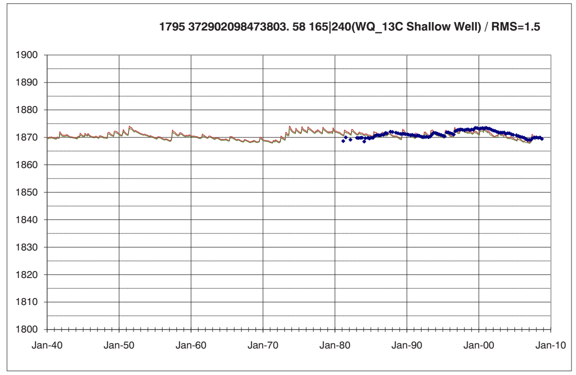
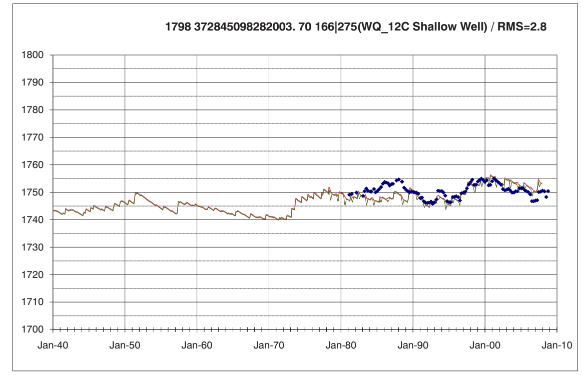


BALLEAU GROUNDWATER, INC.

GMD #5

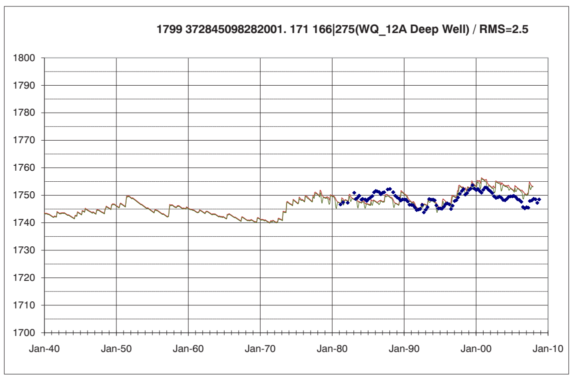
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

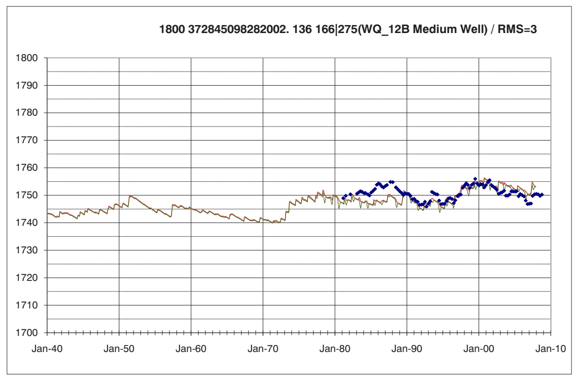
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

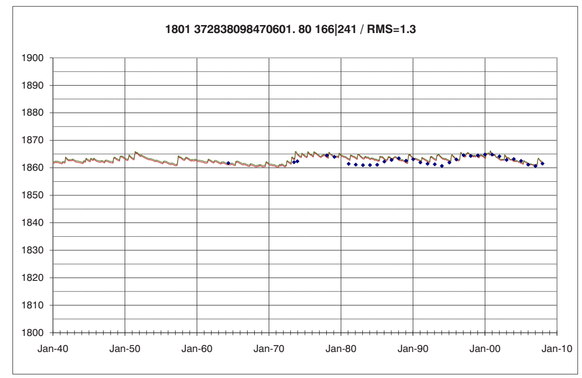
MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

MODEL



BALLEAU GROUNDWATER, INC.

GMD #5

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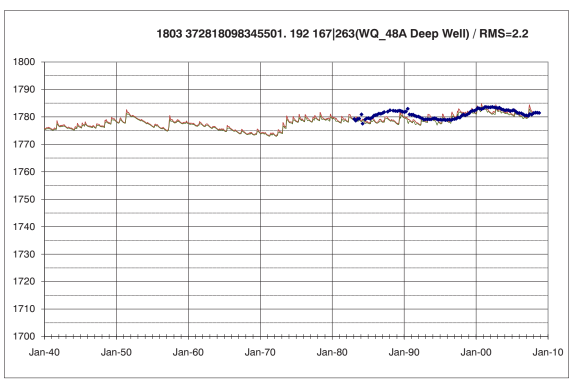

BALLEAU GROUNDWATER, INC.

GMD #5

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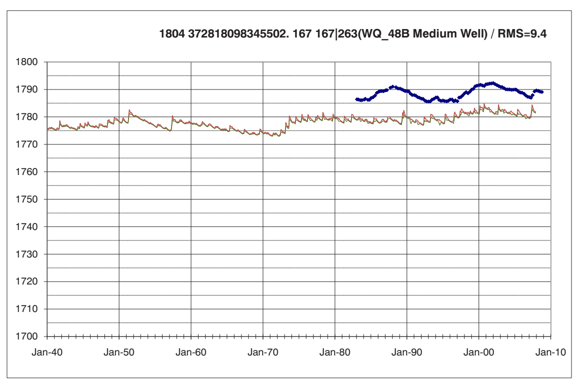

BALLEAU GROUNDWATER, INC.

GMD #5

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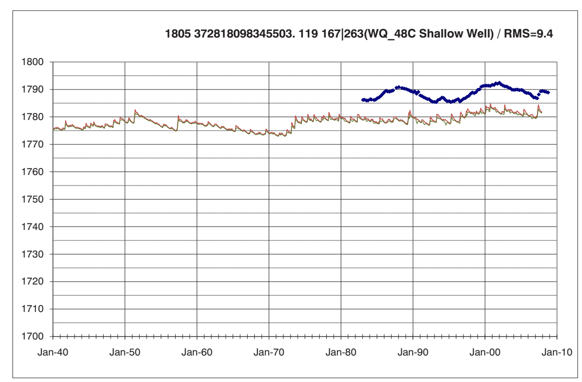


BALLEAU GROUNDWATER, INC.

APPENDIX H

BALLEAU GROUNDWATER, INC., JUNE 10, 2010,

TECHNICAL MEMORANDUM:

ILLUSTRATIVE RESPONSE TO MANAGEMENT ACTION

TECHNICAL MEMORANDUM

To File BIG BEND GMD NO. 5/PLANNING June 10, 2010

From W. Peter Balleau, CPG

Subject ILLUSTRATIVE RESPONSE TO MANAGEMENT ACTION

Scenario

A model calculation of an illustrative response to management action is presented to demonstrate how the Big Bend GMD No. 5 model may be used in addressing such questions. The purpose of the run is to display the type of information to be gained from the model. An illustrative case is simulated of constraining future exercise of permitted water use in the Rattlesnake Basin area of Big Bend GMD No. 5 to those permits with a priority through April 12, 1984, the date at which subsequent permits were conditioned to protect minimum desirable streamflows (MDS). The locations of post-April 1984 wells are shown in Figure 1. The effect of such an action can be interpreted roughly from review of unit-response information such as displayed on Figure 2. The specific result is found by making two runs of the model and examining the difference between them. The smoothed-average future baseline B' (run 1) is subtracted from an alternative future with post-1984 permitted use curtailed in the model (run 2). The difference in drawdown and in water balance at each feature of interest is reported by examining the difference in the two runs. This method of model analysis demonstrates the usual protocol for informing proposed management actions. The formats of the attached tables and figures are amenable to presentation of the results of any such management scenarios. The management effect is reported as a change relative to the smoothed B' baseline. The effect of management action also is superimposed on the unsmoothed baseline B to examine the impact on the range of variable conditions projected for the future. A set of figures and tables is presented herein to show how model results may be understood.

It is emphasized that the specific action of curtailing post-1984 uses has not been proposed by Big Bend GMD No. 5, but is used here for illustration only.

Orientation

The location of post-April 1984 wells is shown in Figure 1, along with the well and stream locations where hydrograph results are displayed. The magnitude of curtailment of net pumping (Figure 3) is 11,297 acre feet per year (AFY) on average (purple line), varying about 500 to 15,000 AFY from year to year in the unsmoothed baseline (green line). The river gains 1,000 to 2,500 AFY (1.4 to 3.5 cubic feet per second (cfs)) through the early decades of response to curtailment (Figure 4). The monotonic trends on Figure 4 are a result of smoothing of average stress in Baseline B'. That scale of response can be foreseen from the unit-response pattern on Figure 2. Storage and evapotranspiration (ET) absorb the remainder of the nearly 11,300 AFY average curtailed use. Both pumping and associated return flow at curtailed sites are turned off in the illustrative run. MDS requirements at the Zenith gage range from three cfs in summer to 15 cfs in winter. Those flow thresholds are the target of the April 1984 permit conditions on wells. The MDS requirements are satisfied by monthly flow conditions which are better examined in the unsmoothed baseline B projection.

Water Budget

Table 1 shows the water budget components throughout the responsive model area. The table values apply to the water account for the model area influenced by curtailment, which is a greater area than the Rattlesnake drainage basin. The smoothed effect on the hydrologic system is to reduce water use by 11,290 AFY[1] below the baseline, while altering aquifer storage 5,125 AFY and adding 2,741 AFY to all affected streams. Enhanced ET due to the rising water level takes 3,423 AFY.

Table 1 illustrates the smoothed-average year-by-year response to action over the 68 years to year 2075. Of 11,297 AFY net pumping curtailed, some goes to support recovery in areas and in streams outside Rattlesnake Basin. The table shows that an average 24 percent of the roughly 10,000 AFY goes to support all benefitted surface streams, including Arkansas and Ninnescah Rivers system wide, that 45 percent of the response is in raising water levels and that 30 percent goes to increasing ET in shallow water areas. Streamflow impacts are the smallest of the three water accounts in Table 1 aided by the curtailment (storage, ET and streams).

---

[1] Net reduction in pumping specified in the WEL package (return flow) and solved for by MNW package (well pumping). The specified average reduction in net pumping is 11,297 AFY before MNW solves for pumping water level.

Water Levels

Figure 5 illustrates the area of buildup of water levels over 68 years to year 2075. Selected wells at 16 sites are displayed in Figures 6A-P as smoothed water-level hydrographs for 68 years with (blue line) and without (red line) the action. Well locations by map identification numbers are shown on Figure 1. It takes several decades for the water-level rise to be effective. The long-term difference in water levels ranges from a tenth of a foot to 3.7 feet among the 16 sites.

The variability to be expected from climate and well-stress conditions is absent from the smooth trends of Figure 4. Climate and well-stress fluctuation should be provided for as discussed below. Figure 5 illustrates that the pattern of aquifer water-level benefit includes significant areas outside Rattlesnake Basin.

Surface Flow

Surface gage hydrographs in Figures 7A-D are projected from the smoothed baseline B' for three stations on the Rattlesnake Creek and one on the Arkansas River. Duration curves in Figures 8A-D are given for the same four stations. The effect of simulated drought and wet decades is absent, but should be allowed for in planning. The difference in gage flow at the end of 68 years, posted on Figures 8 A-D, is 0 to 3.5 cfs among the four stations.

At the Rattlesnake near Zenith gage (Figure 7B) a 2.6-cfs increase in median monthly flow at end of simulation is projected. The average increase is 1,948 AFY. However, the climate variation should be planned with an allowance for months that do not satisfy MDS in the unsmoothed baseline. The history of flow on Figure 7B shows that climate variation is the dominant aspect of MDS satisfaction.

MDS

One consideration is the effectiveness of a proposed action in terms of the magnitude of water operations relative to desired impacts. The benefit of the illustrative policy in terms of total flow is to produce about 17 percent (1,948 AFY change at Zenith out of 11,290 AFY curtailment) of the change in managed water use as a gain to streams in the same basin. Thus, about six acre feet (AF) would be left unused in agriculture to yield one AF in flow at Zenith. Total flow, however, is not entirely effective in altering MDS status because in many baseline months MDS is satisfied (or not) regardless of the management action.

Table 2 counts the action to be effective only in those months where MDS would be changed from unsatisfied to satisfied status. The monthly benefit of action in the smoothed baseline B' is superimposed on the variable monthly flow conditions of baseline B. The well curtailment action would not avoid climatic variation that sometimes causes MDS to be unsatisfied. Curtailing 11,290 AFY under the MDS condition remains relatively ineffective regarding MDS, insofar as it provides about 229 AFY (about two percent of the amount curtailed) to improve MDS status. The 229 AFY is 12 percent of 1,948 AFY, based on a 12 percent increase in the number of months MDS is effective with curtailment. Thus, 49 AF of well use would be curtailed for every one AF produced toward effective satisfaction of MDS at Zenith gage.

Conclusion

The management operation examined in the illustrative scenario is to turn off wells from year 2007 in the Big Bend GMD No. 5 part of Rattlesnake Basin where the wells are permitted with the MDS condition. An average amount of 11,297 AFY is curtailed in the basin. The effects are not immediate, but take several decades to become fully effective on streams and water levels. Up to five feet of water-level rise is seen in 68 years. Significant aquifer recovery up to four feet is expected in areas outside Rattlesnake Basin. The effect on the Zenith gage is to recover 2.7 cfs at the end of the simulation period. The MDS flow would be satisfied in about 12 percent more of the future baseline months with climate variation. Zenith gage receives 1,948 AFY benefit. Twelve percent of that volume is effective at satisfying MDS, while in 88 percent of the future months, the MDS status at Zenith gage is unaltered by the action.

Attachments: Tables (2)
Figures (29)

MODEL

TABLE 1. NET BUDGET COMPONENT DIFFERENCE WITH POST APRIL 12, 1984 WELLS CURTAILED IN RATTLESNAKE CREEK BASIN (BASELINE B') (AFY)

Year	Stream Leakage	ET	Model Boundary	Aquifer Storage	Recharge	Well Pumping[1]
2008	533	264	0	10,490	0	-11,296
2009	1,129	603	0	9,620	0	-11,302
2010	1,439	849	0	9,006	0	-11,300
2011	1,696	1,071	0	8,532	0	-11,301
2012	1,898	1,256	0	8,148	0	-11,301
2013	2,069	1,417	0	7,820	0	-11,304
2014	2,225	1,553	0	7,524	0	-11,302
2015	2,366	1,668	0	7,269	0	-11,302
2016	2,491	1,772	0	7,039	0	-11,302
2017	2,566	1,873	0	6,860	0	-11,302
2018	2,571	1,993	0	6,732	0	-11,302
2019	2,564	2,123	0	6,609	0	-11,302
2020	2,562	2,246	0	6,485	0	-11,302
2021	2,568	2,364	0	6,361	0	-11,302
2022	2,562	2,482	0	6,249	0	-11,302
2023	2,547	2,597	0	6,142	0	-11,294
2024	2,520	2,711	0	6,053	0	-11,293
2025	2,491	2,826	0	5,966	0	-11,293
2026	2,458	2,940	0	5,885	0	-11,293
2027	2,427	3,054	0	5,803	0	-11,293
2028	2,426	3,156	0	5,704	0	-11,293
2029	2,431	3,247	0	5,610	0	-11,293
2030	2,447	3,328	0	5,513	0	-11,293
2031	2,463	3,398	0	5,426	0	-11,292
2032	2,477	3,469	0	5,341	0	-11,292
2033	2,494	3,534	0	5,260	0	-11,292
2034	2,524	3,590	0	5,175	0	-11,292
2035	2,550	3,642	0	5,097	0	-11,292
2036	2,573	3,694	0	5,022	0	-11,292
2037	2,598	3,738	0	4,954	0	-11,292
2038	2,624	3,777	0	4,889	0	-11,292
2039	2,650	3,813	0	4,827	0	-11,292
2040	2,682	3,848	0	4,762	0	-11,293
2041	2,711	3,884	0	4,696	0	-11,292
2042	2,739	3,913	0	4,638	0	-11,291
2043	2,766	3,947	0	4,577	0	-11,291
2044	2,791	3,978	0	4,522	0	-11,291
2045	2,815	4,004	1	4,472	0	-11,291
2046	2,839	4,024	1	4,428	0	-11,291
2047	2,866	4,040	1	4,385	0	-11,291

AppH_Fig3Table1.xlsb
SES
6/22/2010

MODEL

TABLE 1. NET BUDGET COMPONENT DIFFERENCE WITH POST APRIL 12, 1984 WELLS CURTAILED IN RATTLESNAKE CREEK BASIN (BASELINE B') (AFY)

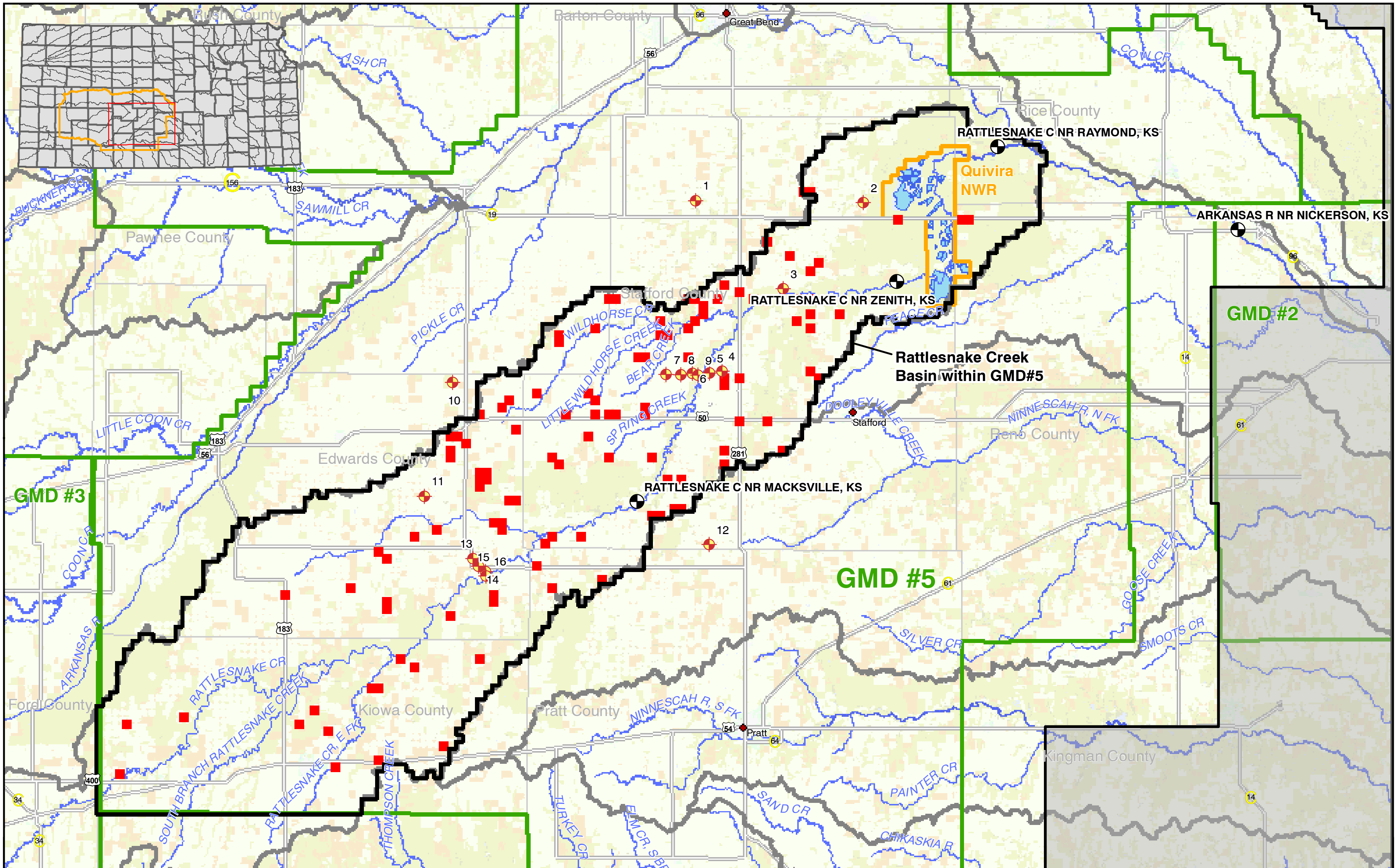
Year	Stream Leakage	ET	Model Boundary	Aquifer Storage	Recharge	Well Pumping[1]
2048	2,895	4,055	1	4,342	0	-11,291
2049	2,917	4,067	1	4,299	0	-11,284
2050	2,937	4,080	1	4,273	0	-11,291
2051	2,961	4,095	1	4,230	0	-11,286
2052	2,985	4,112	1	4,189	0	-11,286
2053	3,011	4,130	1	4,144	0	-11,286
2054	3,039	4,149	1	4,097	0	-11,286
2055	3,066	4,172	1	4,048	0	-11,286
2056	3,092	4,195	1	3,998	0	-11,286
2057	3,118	4,216	1	3,948	0	-11,282
2058	3,144	4,239	1	3,898	0	-11,281
2059	3,170	4,264	1	3,847	0	-11,281
2060	3,195	4,288	1	3,798	0	-11,281
2061	3,220	4,311	1	3,749	0	-11,281
2062	3,244	4,337	1	3,699	0	-11,281
2063	3,266	4,360	1	3,654	0	-11,281
2064	3,288	4,381	2	3,609	0	-11,281
2065	3,311	4,397	2	3,570	0	-11,281
2066	3,334	4,422	2	3,523	0	-11,281
2067	3,359	4,444	2	3,476	0	-11,281
2068	3,383	4,467	2	3,430	0	-11,281
2069	3,406	4,487	2	3,386	0	-11,281
2070	3,429	4,508	2	3,342	0	-11,281
2071	3,451	4,529	2	3,299	0	-11,281
2072	3,473	4,552	2	3,253	0	-11,281
2073	3,493	4,577	2	3,208	0	-11,281
2074	3,510	4,602	2	3,167	0	-11,281
2075	3,526	4,625	2	3,127	0	-11,281
Average (2008 to 2075)	2,741	3,423	1	5,125	0	-11,290
Average Percent of Pumping (2008 to 2075)	24.3%	30.3%	0%	45.4%	0%	--

[1]Net reduction in pumping specified in the WEL package (return flow) and solved for by MNW package (well pumping). The specified average reduction in net pumping is 11,297 AFY before MNW solves for pumping water level.

MODEL

TABLE 2. EFFECTIVENESS OF MDS AT MACKSVILLE AND ZENITH

Run	Number and Percent of Months in 68 Years MDS Is Satisfied			
	Macksville Gage		Zenith Gage	
(B)	197	24.1%	471	57.7%
(B + B' Curtailment)	307	37.6%	567	69.5%
Change Due to Curtailment	110	13.5%	96	11.8%



EXPLANATION

- POD with post-April 12, 1984 priority (pumping in future baseline, off in scenario)
- Water-Level Hydrographs (ID# Indicated)
- Surface Water Gage

0 5 10 15 Miles

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FIGURE 1. Location of Baseline PODs with Post-1984 Priorities

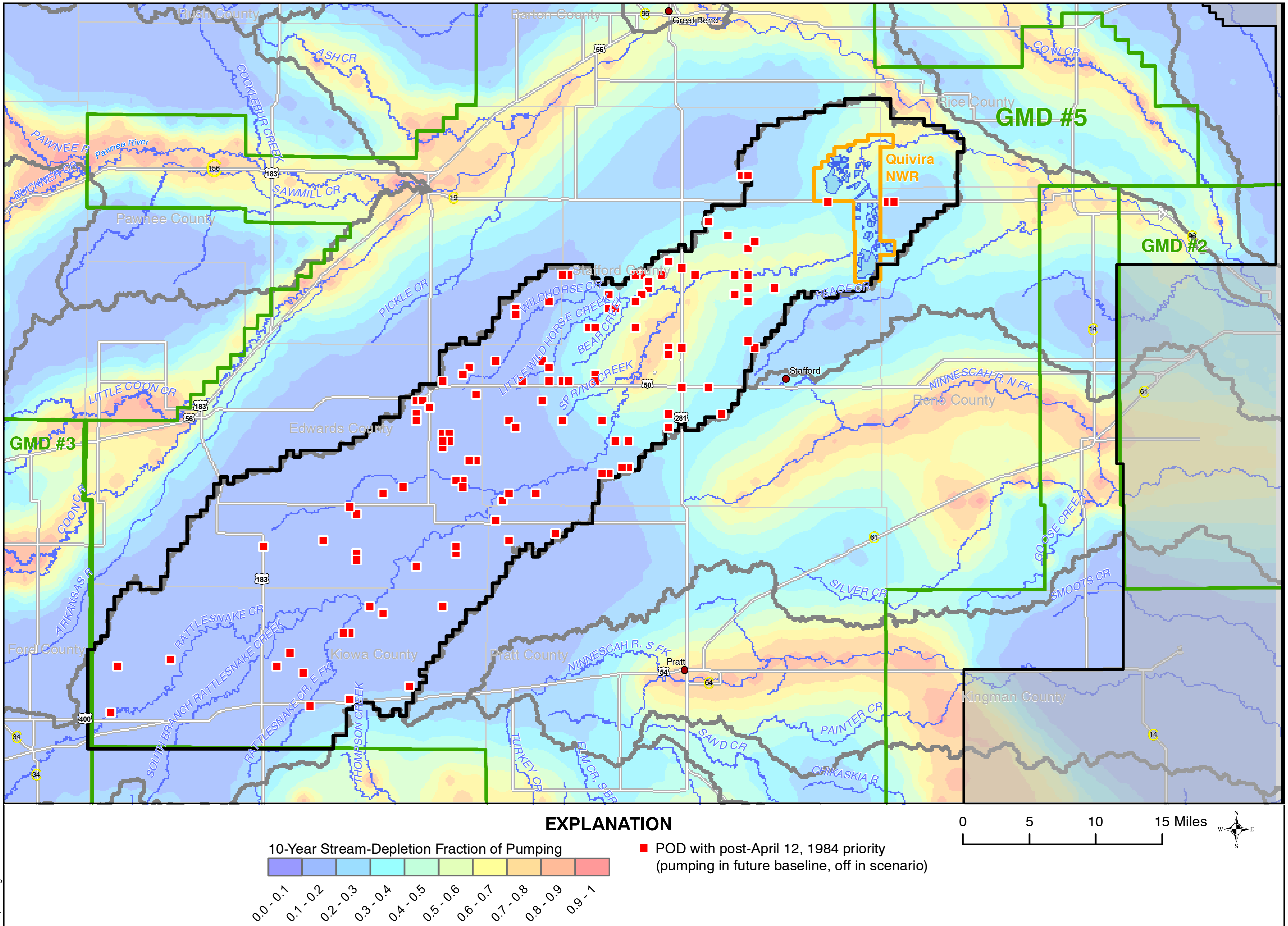
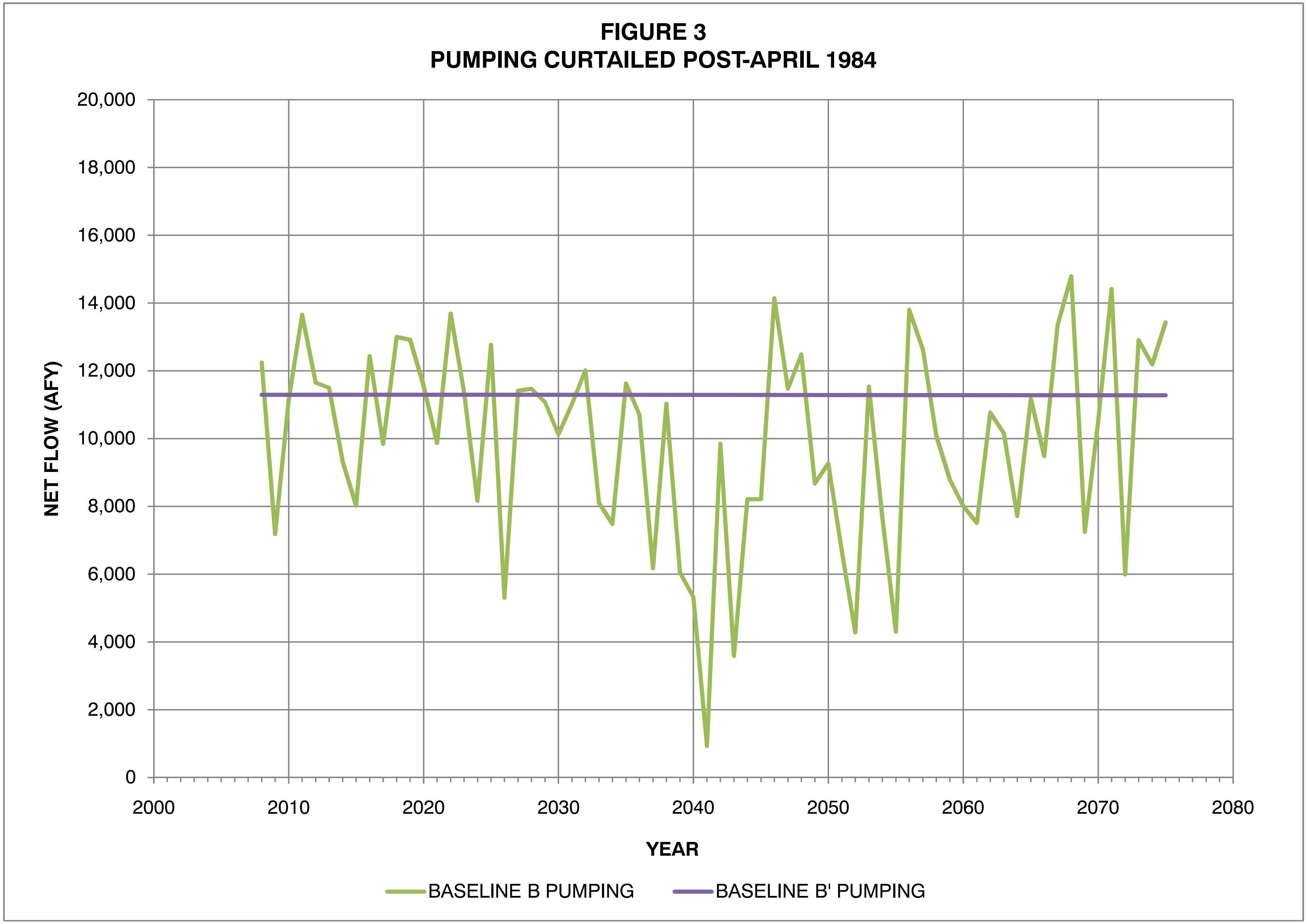


FIGURE 2. Ten-Year Stream-Depletion Fraction of Pumping (From Year 2020 Condition to Year 2030)

6/11/2010 ses/WPB Figure51.mxd

MODEL



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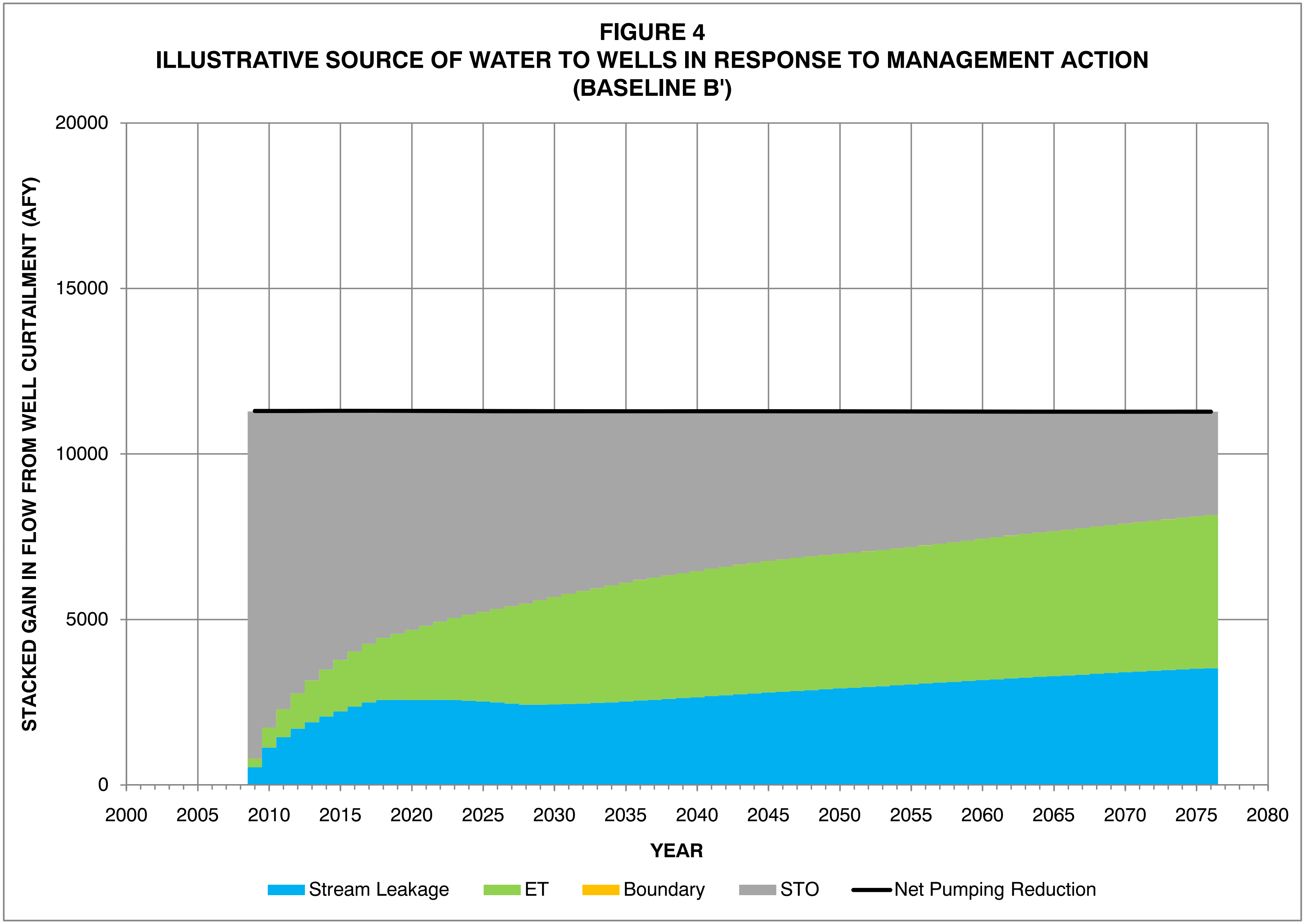
6/22/2010

MODEL



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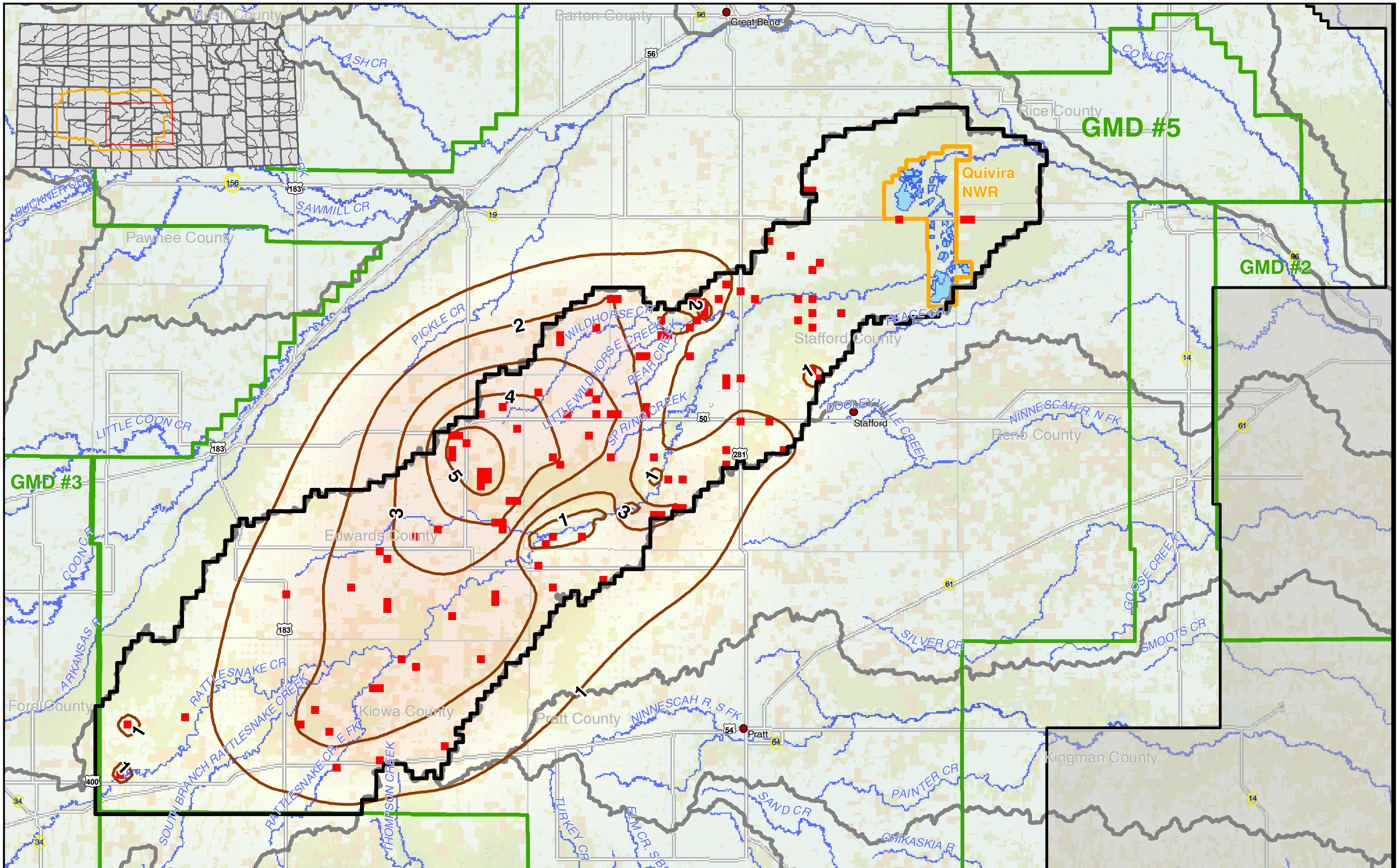


EXPLANATION

■ POD with post-April 12, 1984 priority (pumping in future baseline, off in scenario)

Buildup contour due to scenario (ft)

0 5 10 15 Miles

6/11/2010 ses/WPB Figure64.mxd

FIGURE 5. Water-Table Buildup at Year 2075 Due to Priority Curtailment

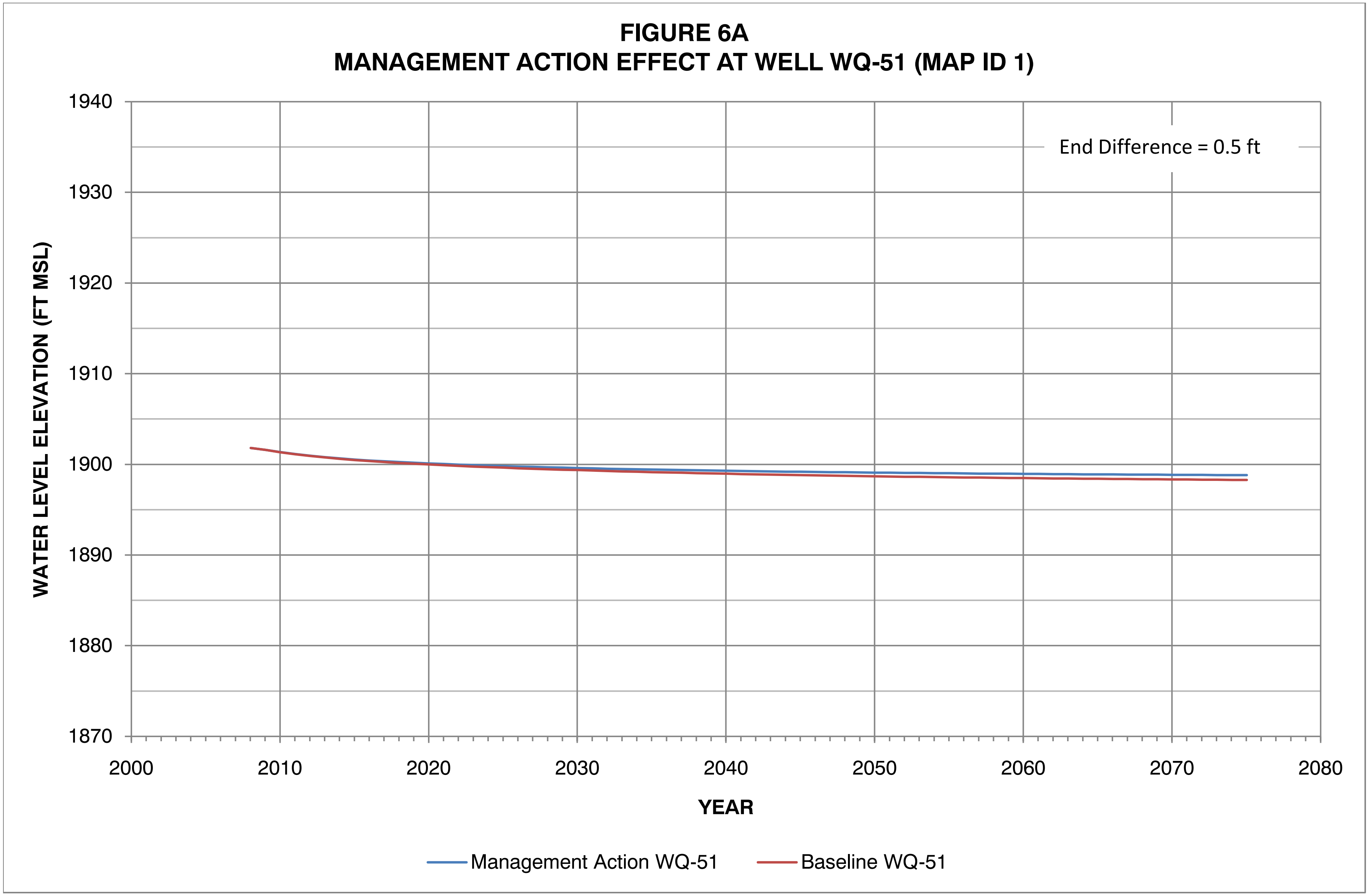
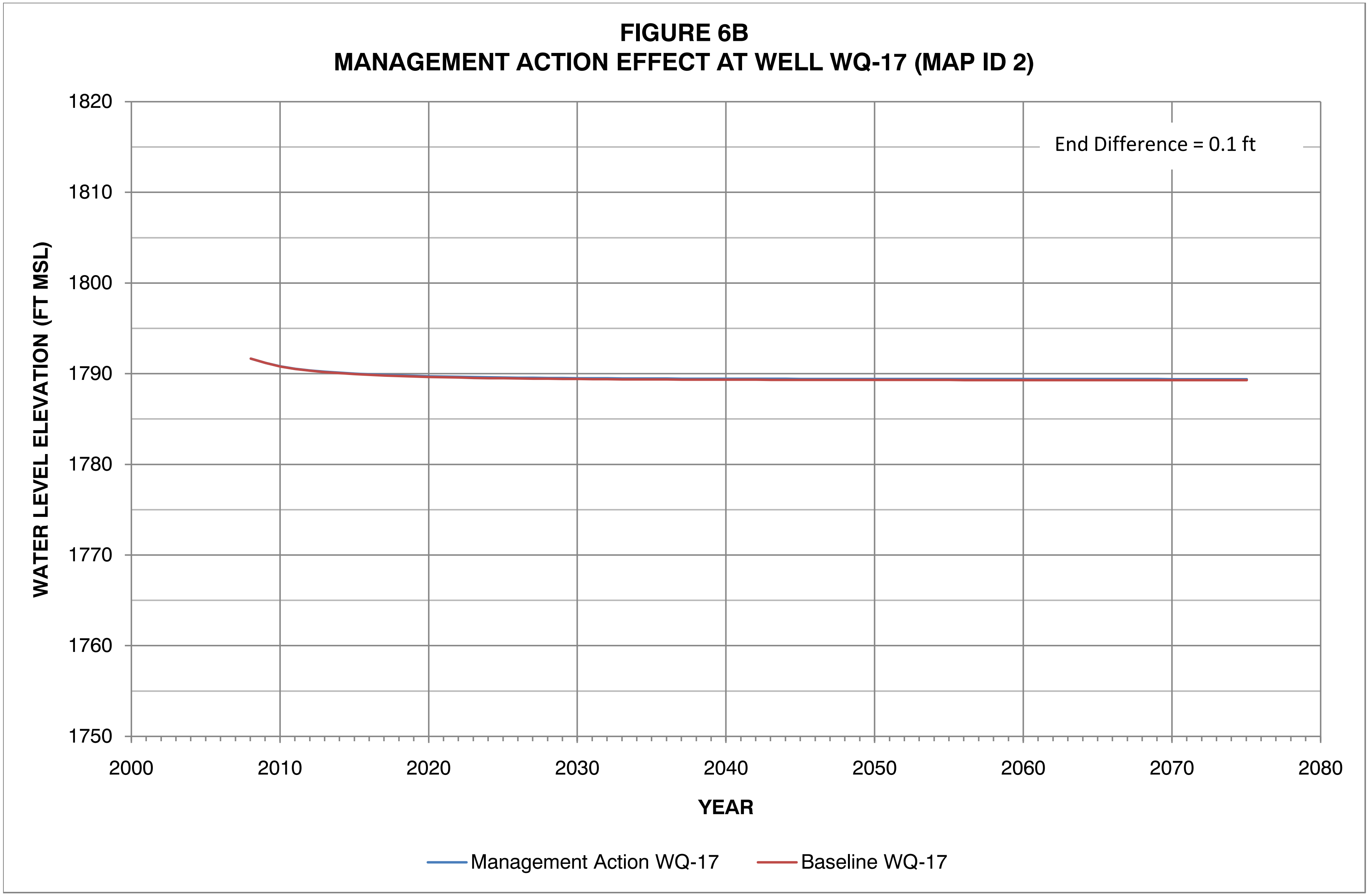


FIGURE 6A
MANAGEMENT ACTION EFFECT AT WELL WQ-51 (MAP ID 1)
End Difference = 0.5 ft
WATER LEVEL ELEVATION (FT MSL)
1940
1930
1920
1910
1900
1890
1880
1870
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action WQ-51
Baseline WQ-51

MODEL



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BALLEAU GROUNDWATER, INC.

MODEL

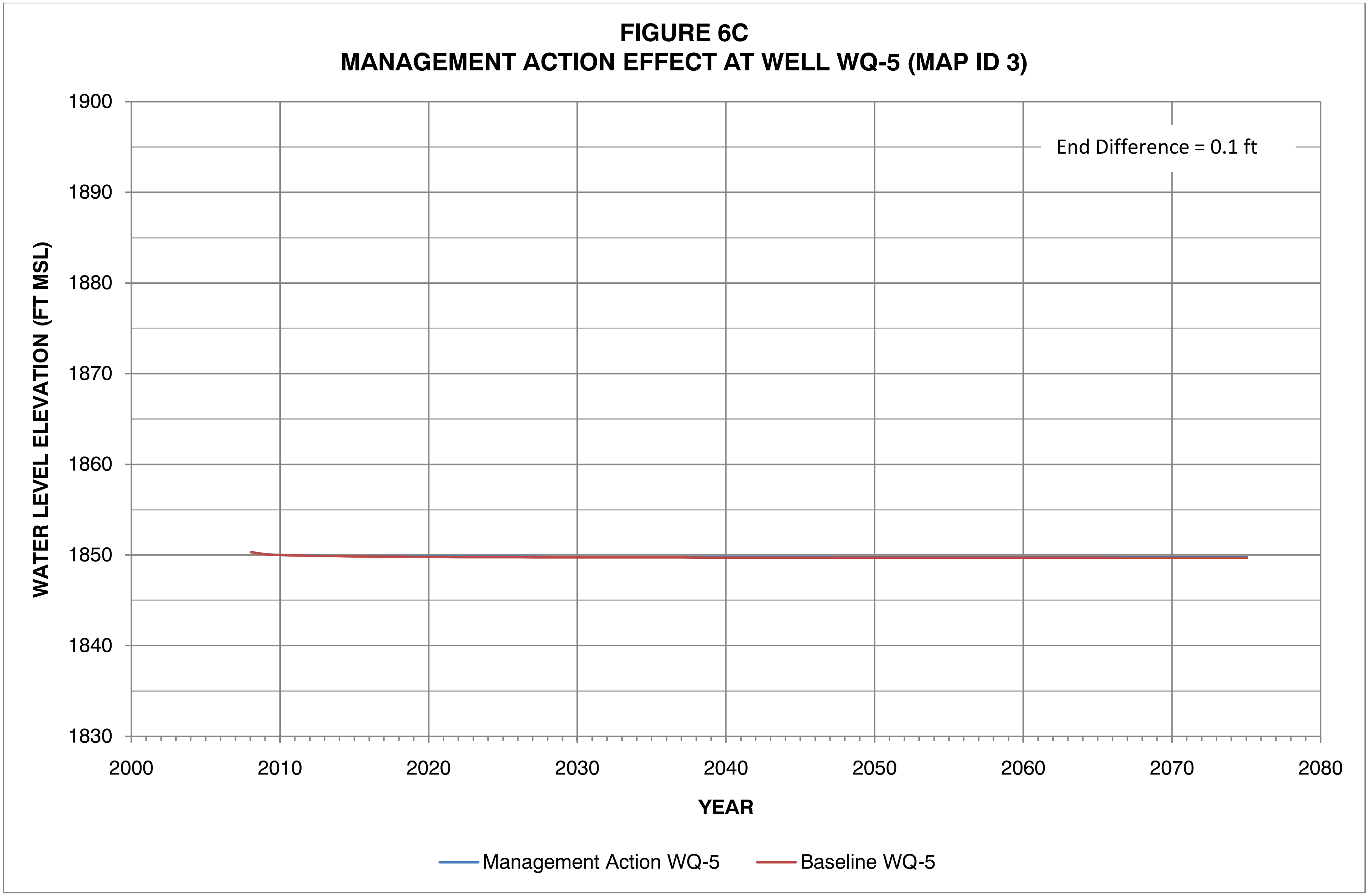
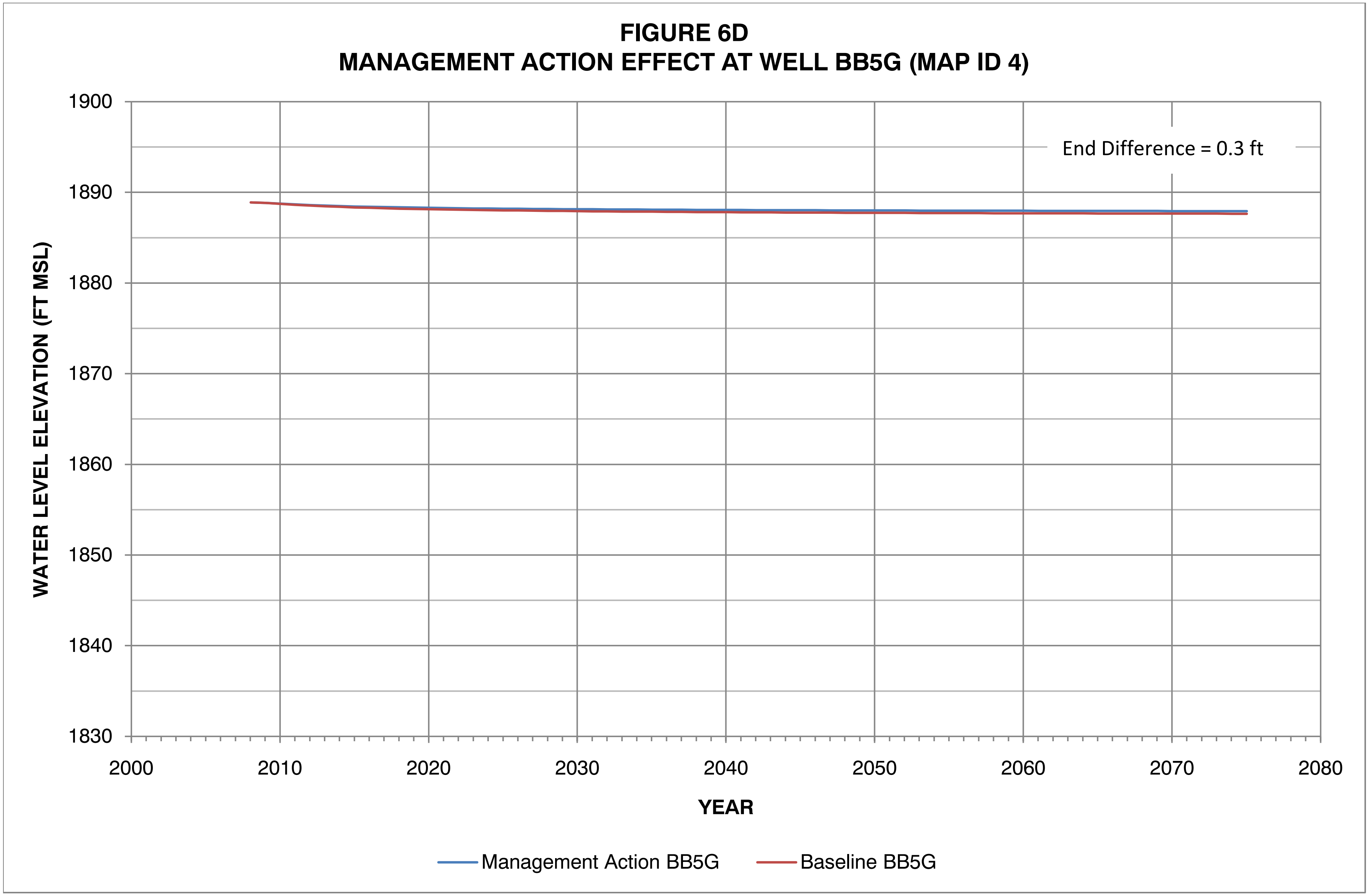


FIGURE 6C
MANAGEMENT ACTION EFFECT AT WELL WQ-5 (MAP ID 3)
End Difference = 0.1 ft
WATER LEVEL ELEVATION (FT MSL)
1900
1890
1880
1870
1860
1850
1840
1830
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action WQ-5
Baseline WQ-5

MODEL



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MODEL

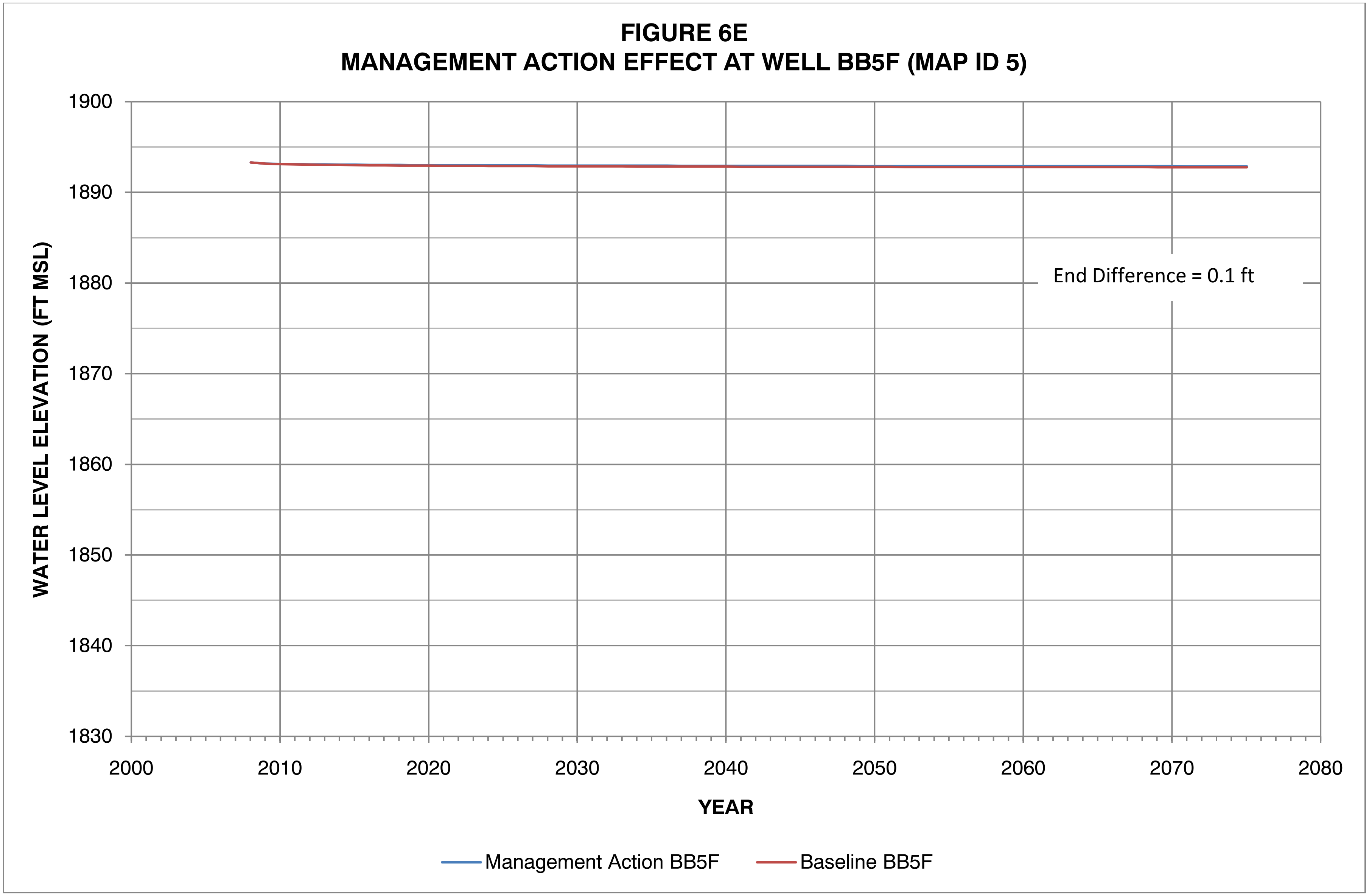

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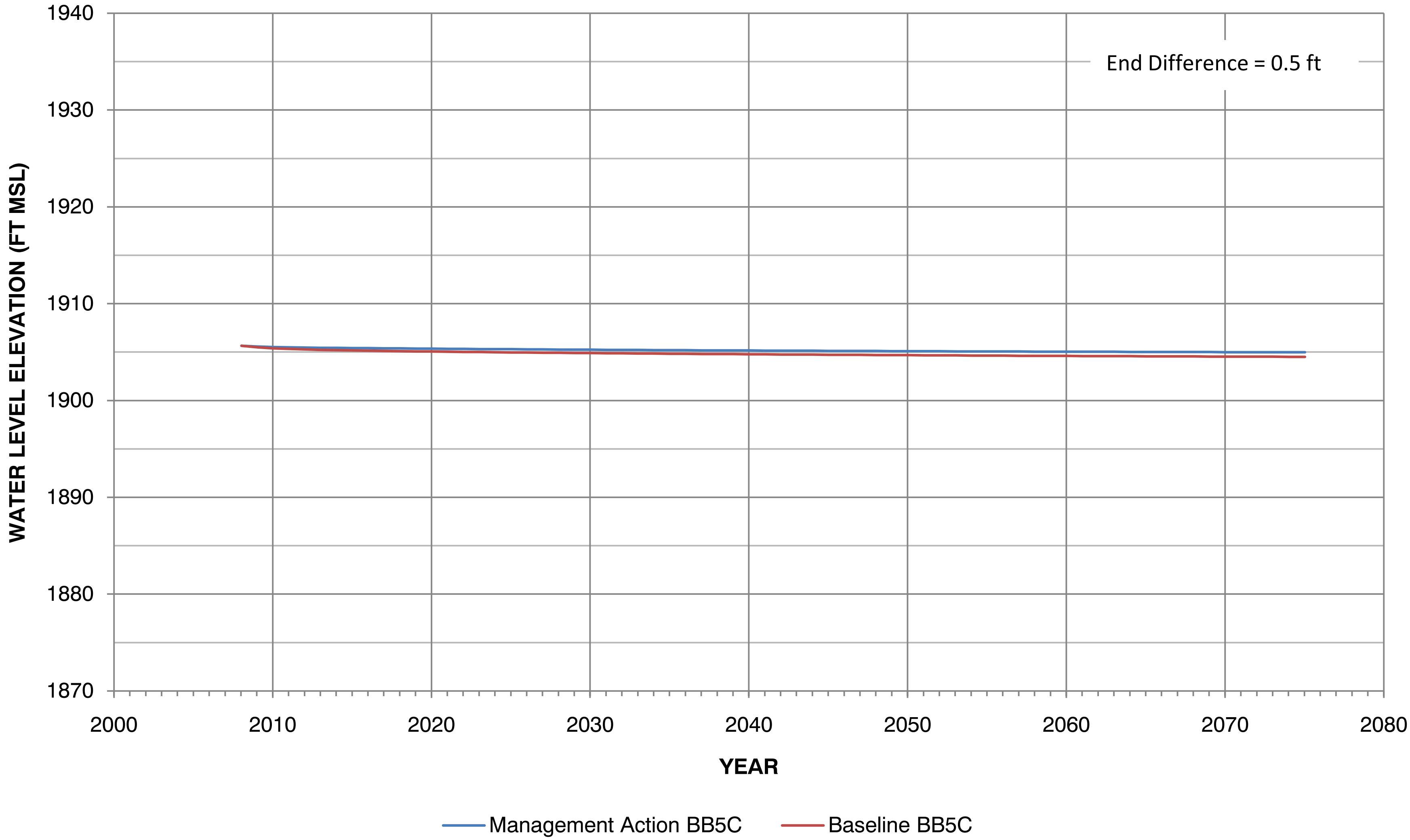
FIGURE 6F
MANAGEMENT ACTION EFFECT AT WELL BB5C (MAP ID 6)



MODEL

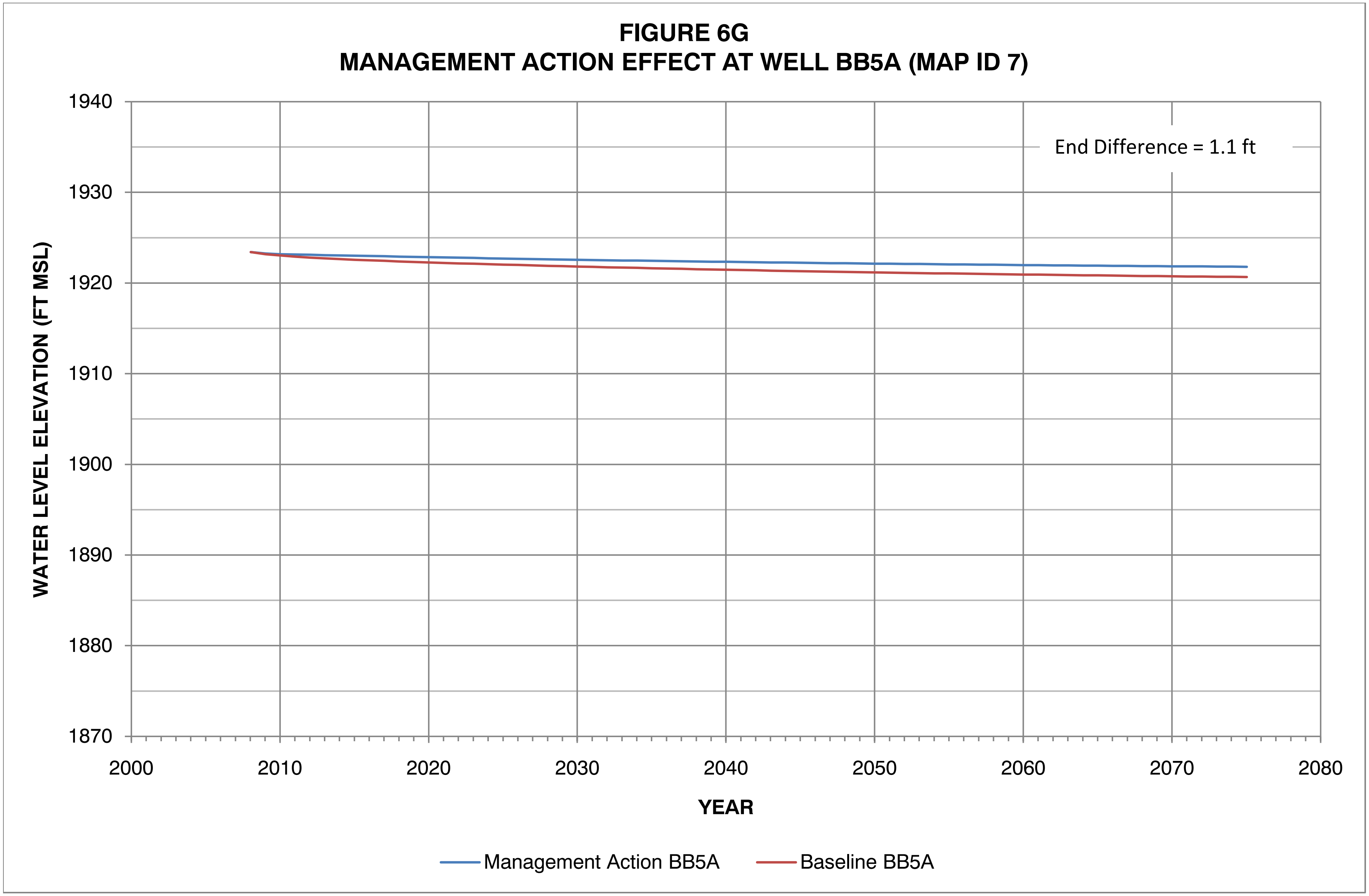
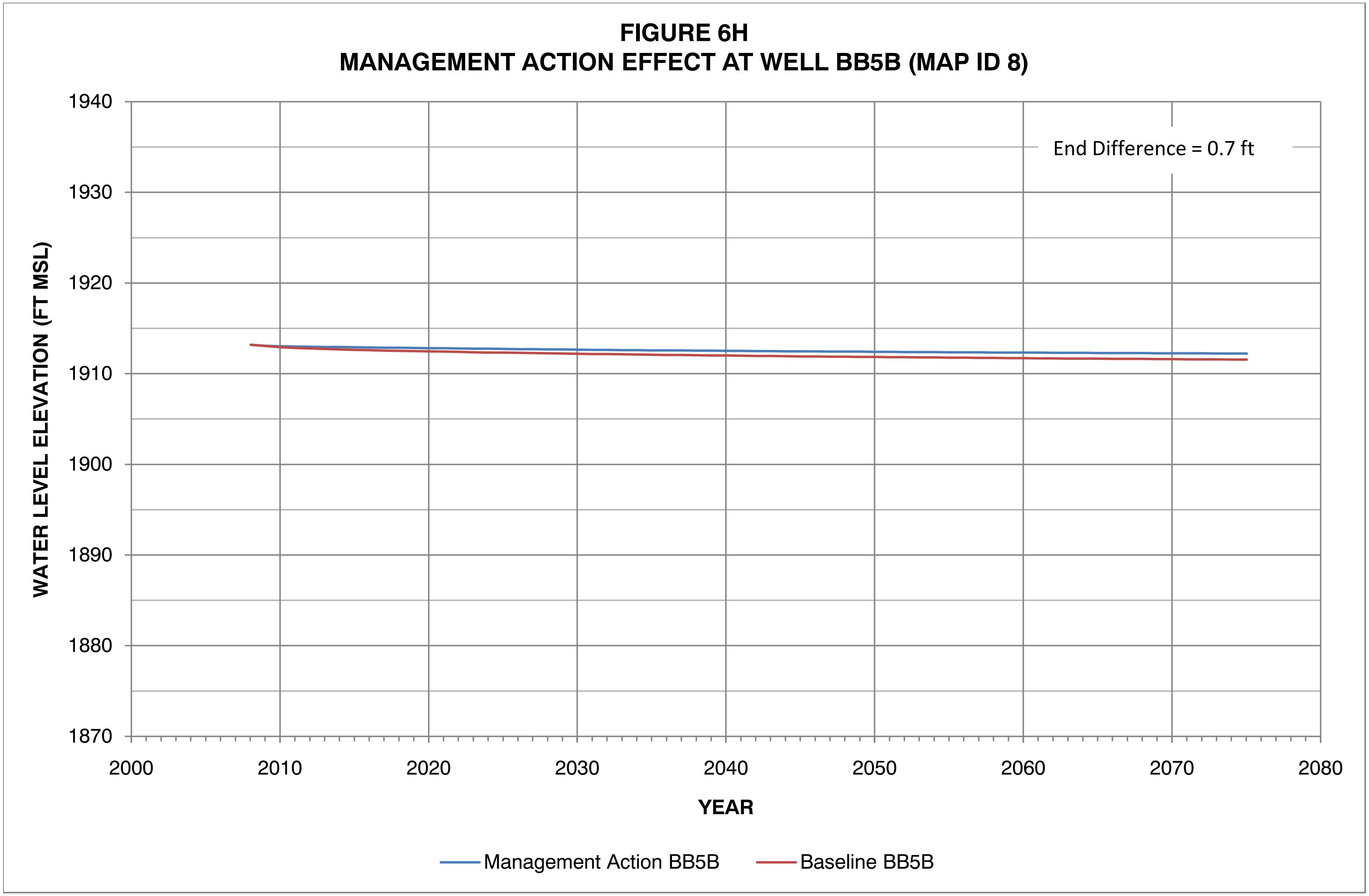


FIGURE 6G
MANAGEMENT ACTION EFFECT AT WELL BB5A (MAP ID 7)
End Difference = 1.1 ft
WATER LEVEL ELEVATION (FT MSL)
1940
1930
1920
1910
1900
1890
1880
1870
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB5A
Baseline BB5A

MODEL



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MODEL

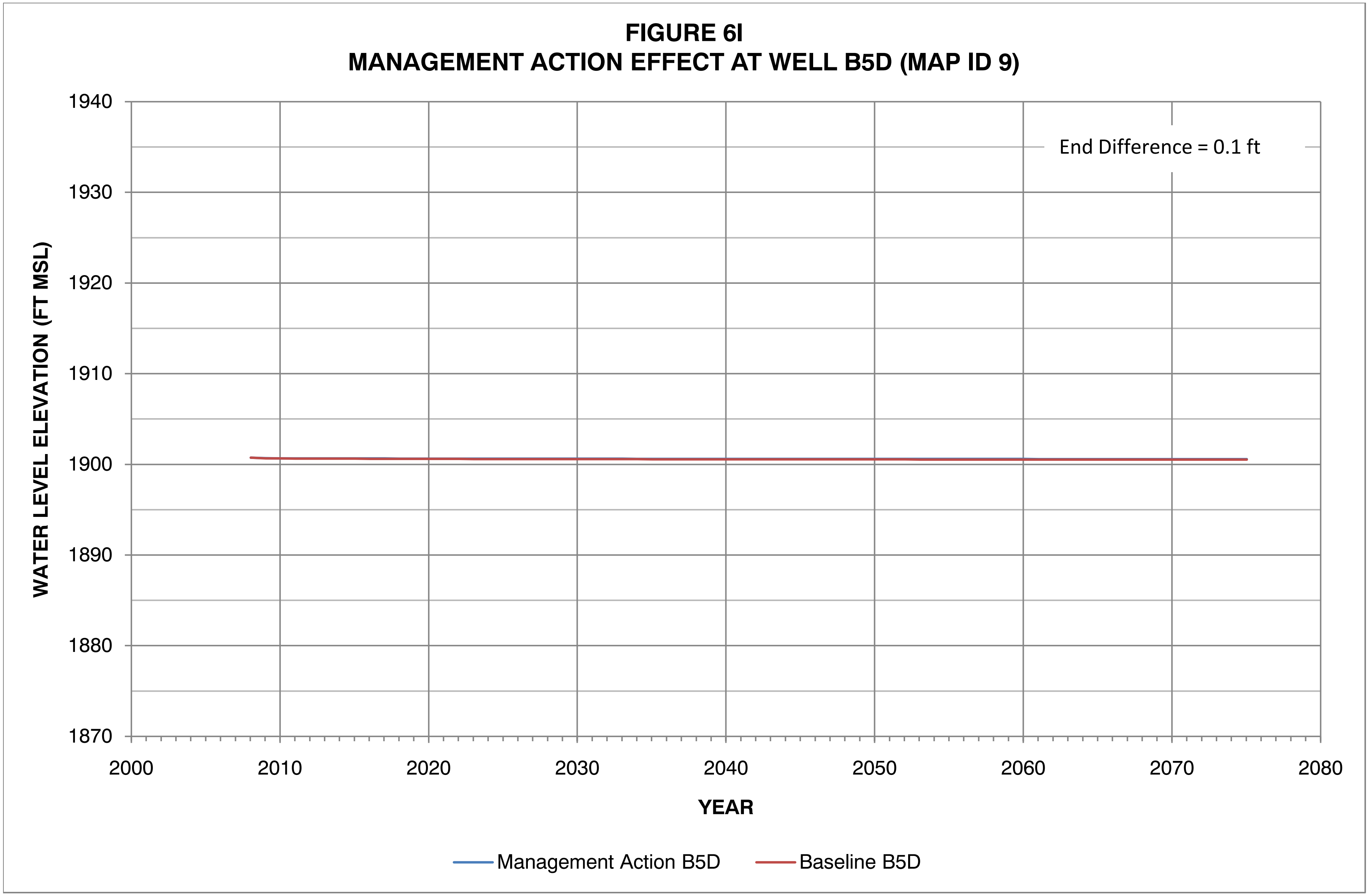
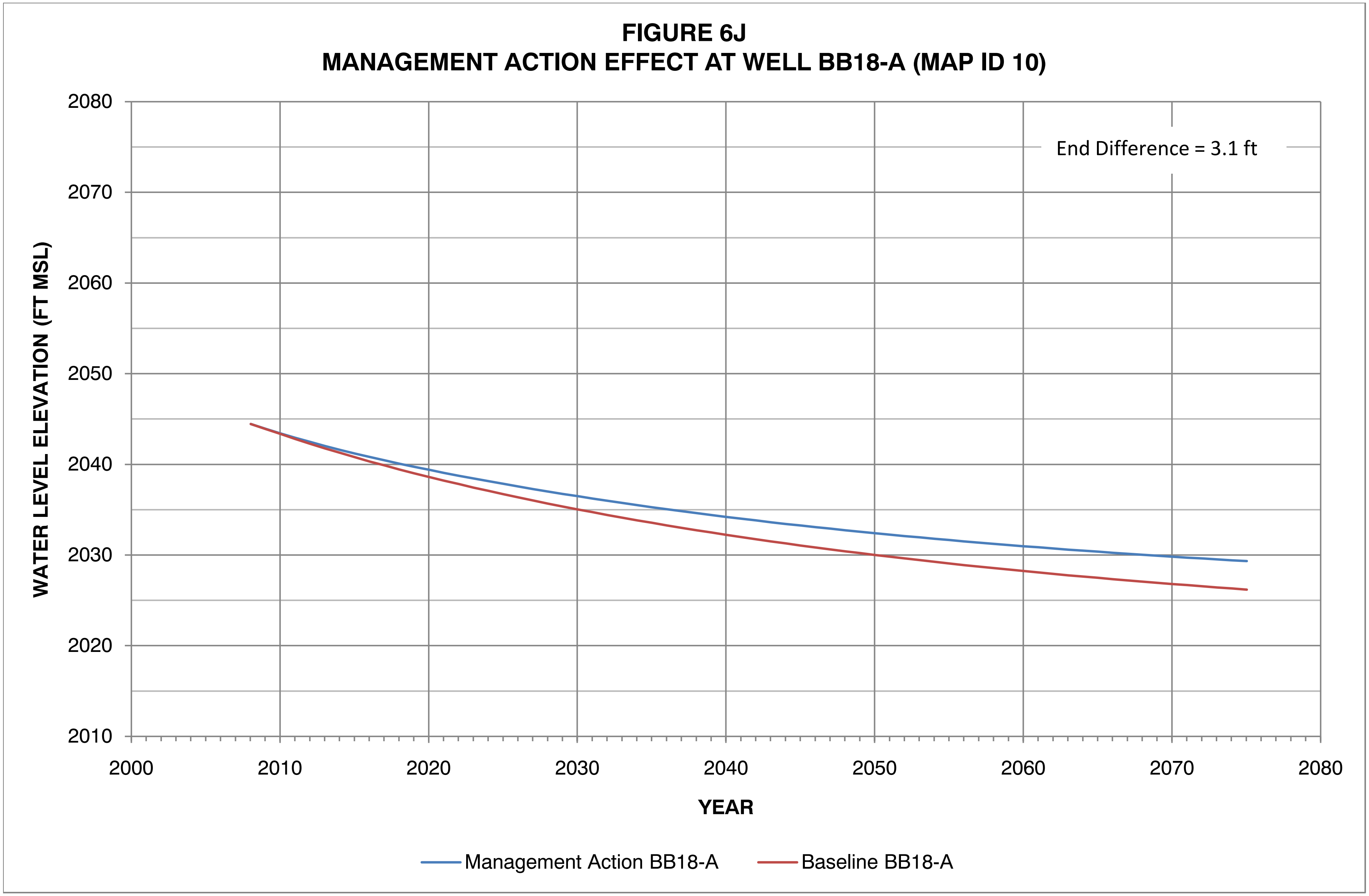


FIGURE 6I
MANAGEMENT ACTION EFFECT AT WELL B5D (MAP ID 9)
End Difference = 0.1 ft
WATER LEVEL ELEVATION (FT MSL)
1940
1930
1920
1910
1900
1890
1880
1870
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action B5D
Baseline B5D

MODEL



ScenarioPlotsBprime.xlsb
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MODEL

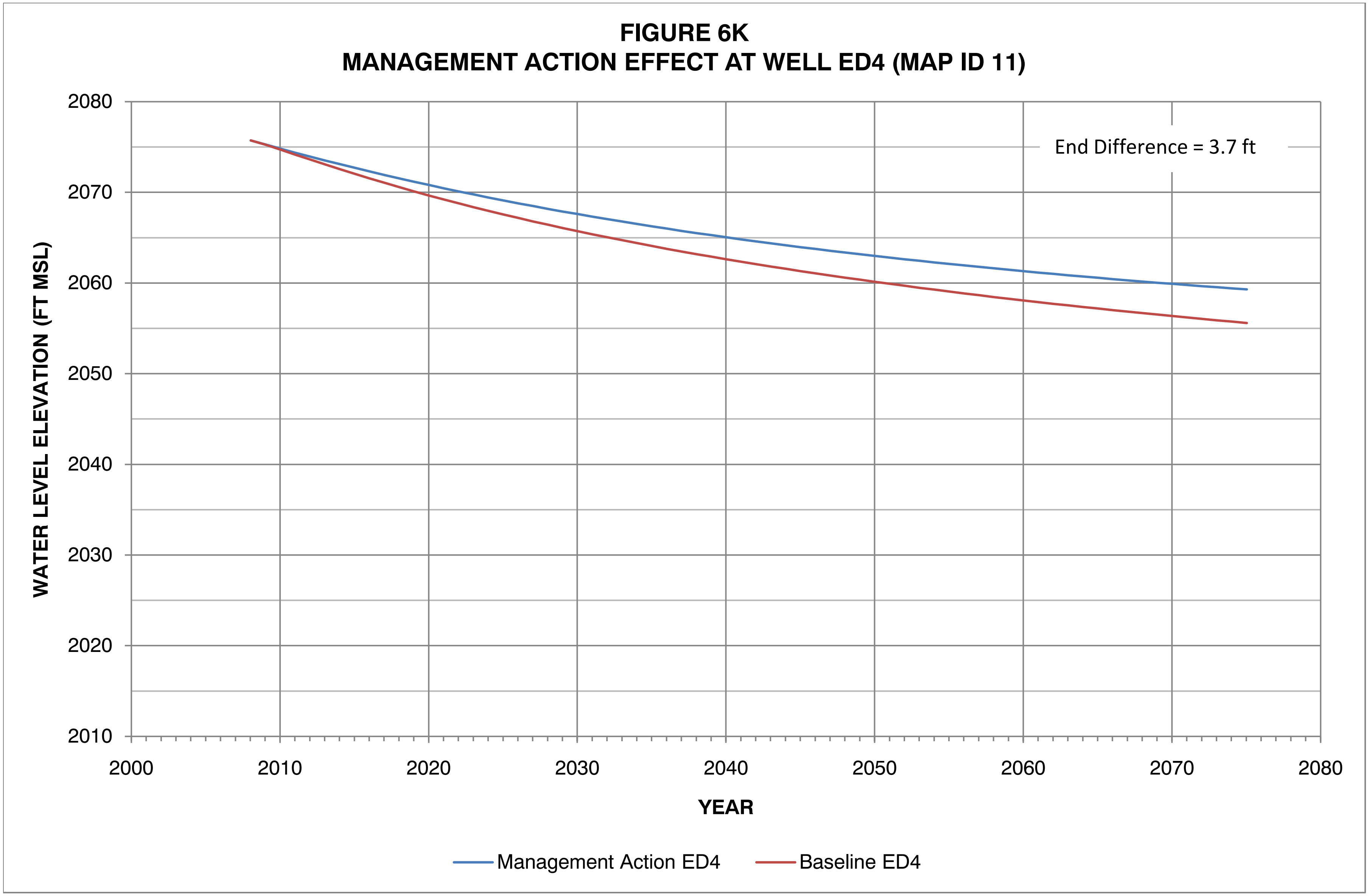


FIGURE 6K
MANAGEMENT ACTION EFFECT AT WELL ED4 (MAP ID 11)
End Difference = 3.7 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action ED4
Baseline ED4

MODEL

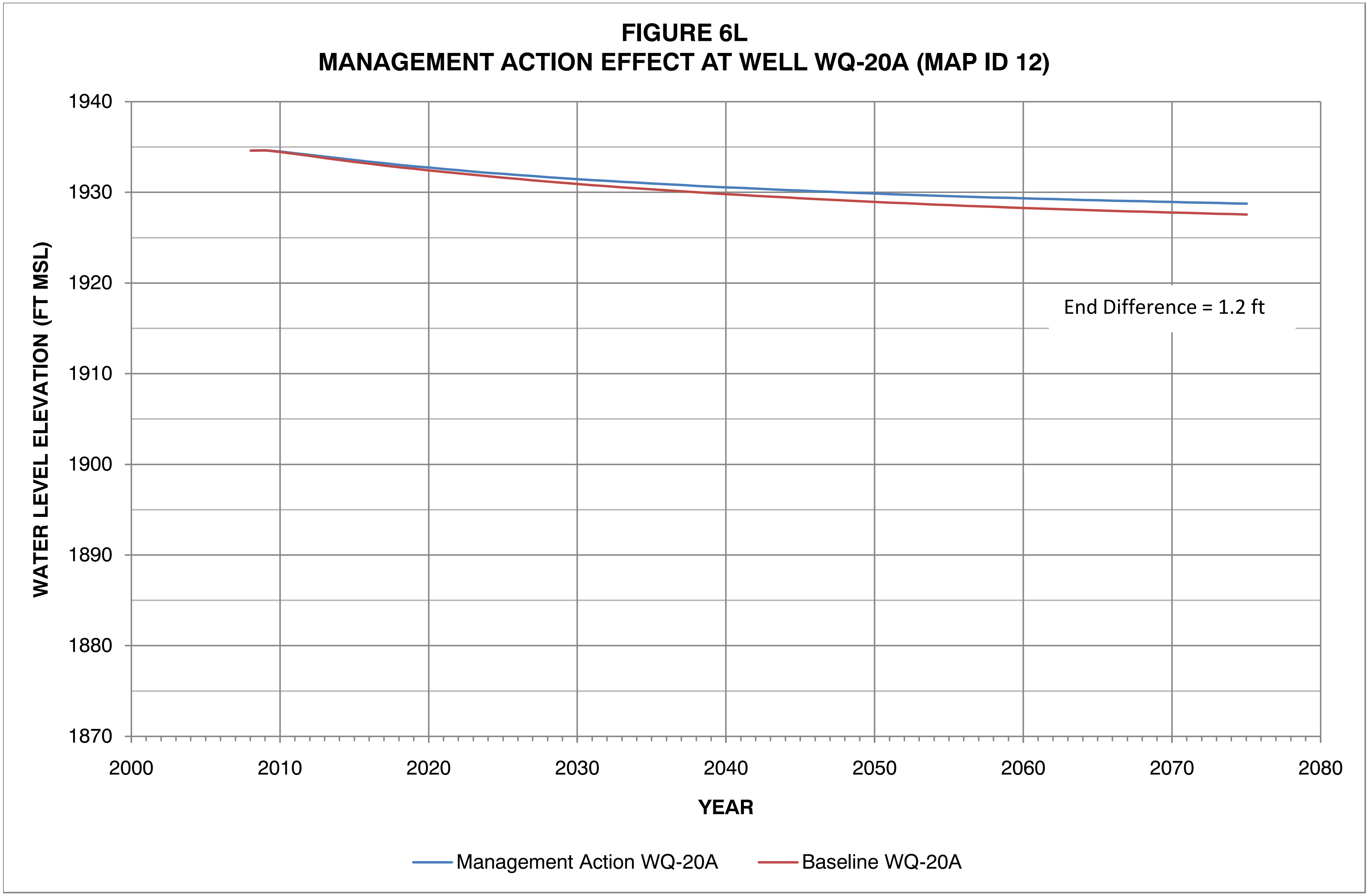


FIGURE 6L
MANAGEMENT ACTION EFFECT AT WELL WQ-20A (MAP ID 12)
1940
1930
1920
1910
1900
1890
1880
1870
WATER LEVEL ELEVATION (FT MSL)
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
End Difference = 1.2 ft
Management Action WQ-20A
Baseline WQ-20A

MODEL

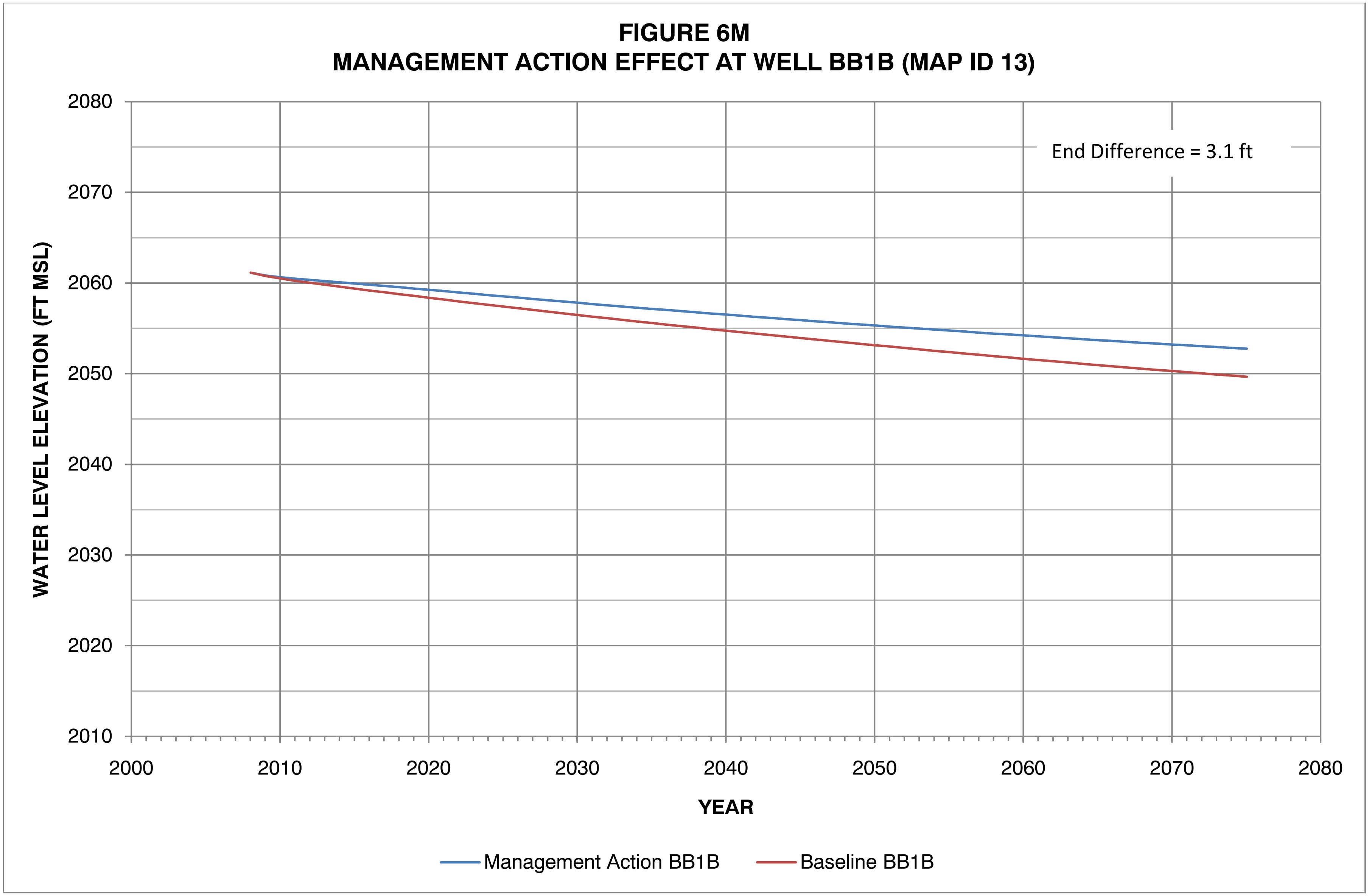


FIGURE 6M
MANAGEMENT ACTION EFFECT AT WELL BB1B (MAP ID 13)
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
End Difference = 3.1 ft
Management Action BB1B
Baseline BB1B

MODEL

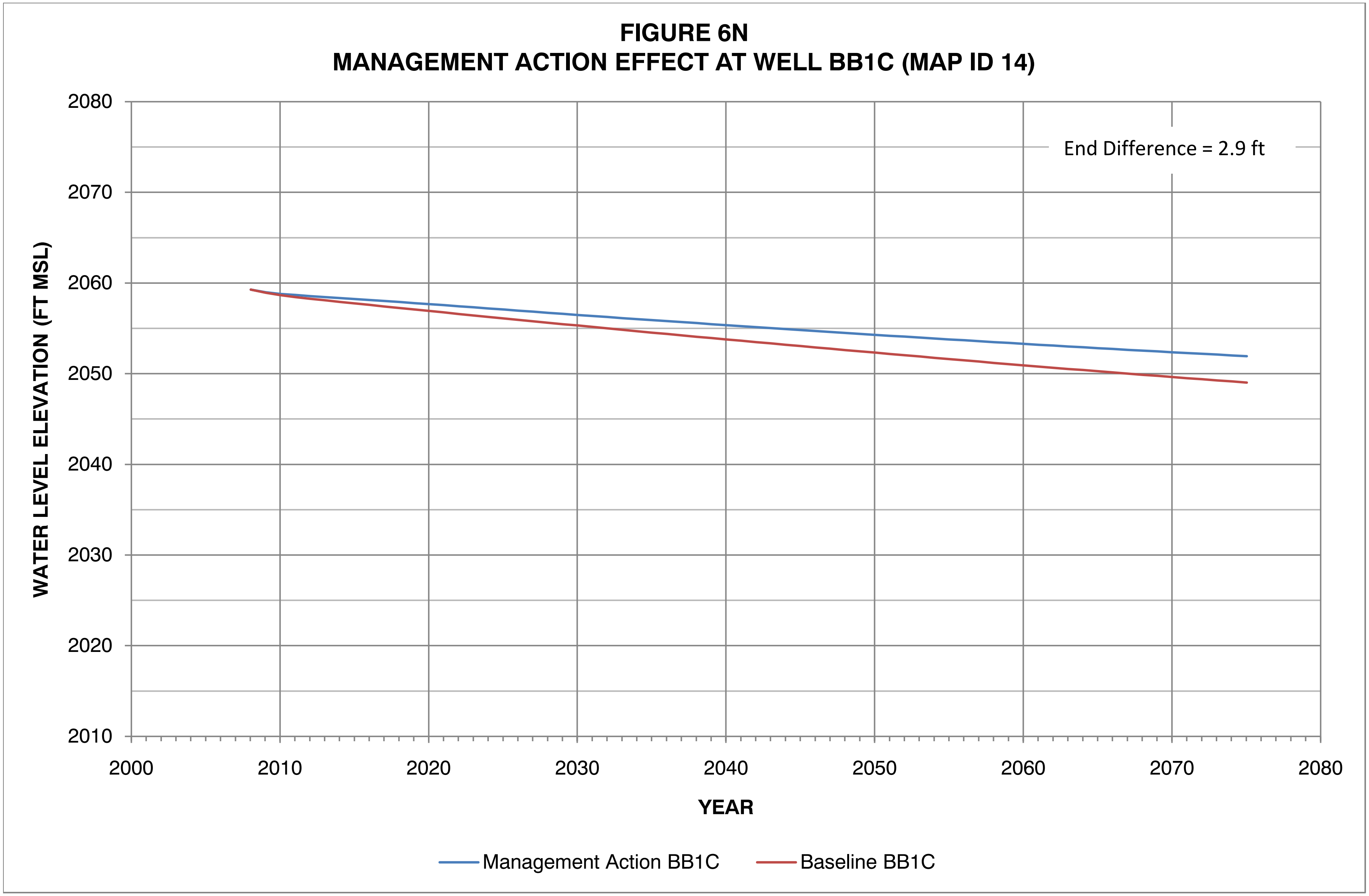


FIGURE 6N
MANAGEMENT ACTION EFFECT AT WELL BB1C (MAP ID 14)
End Difference = 2.9 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB1C
Baseline BB1C

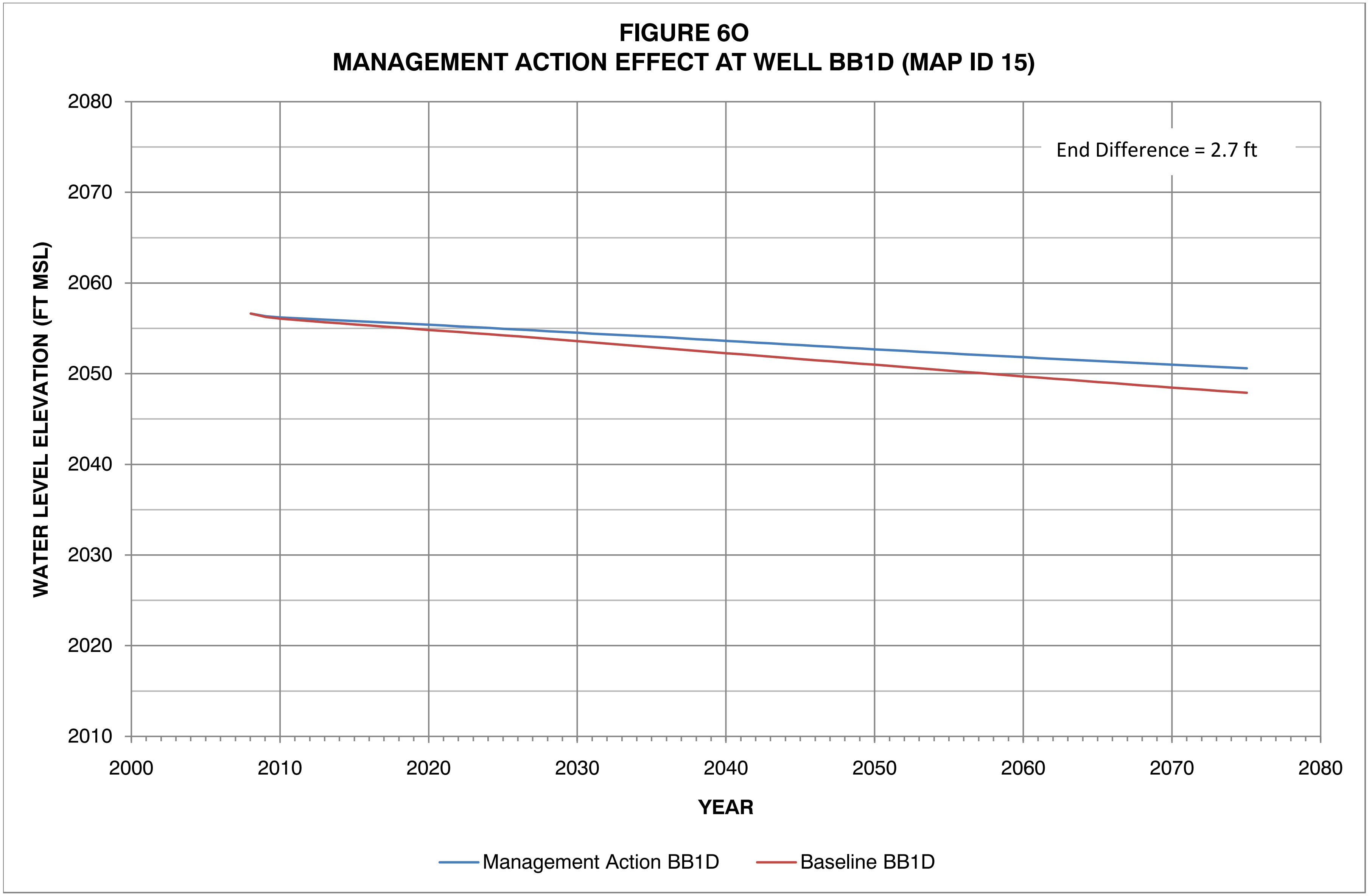
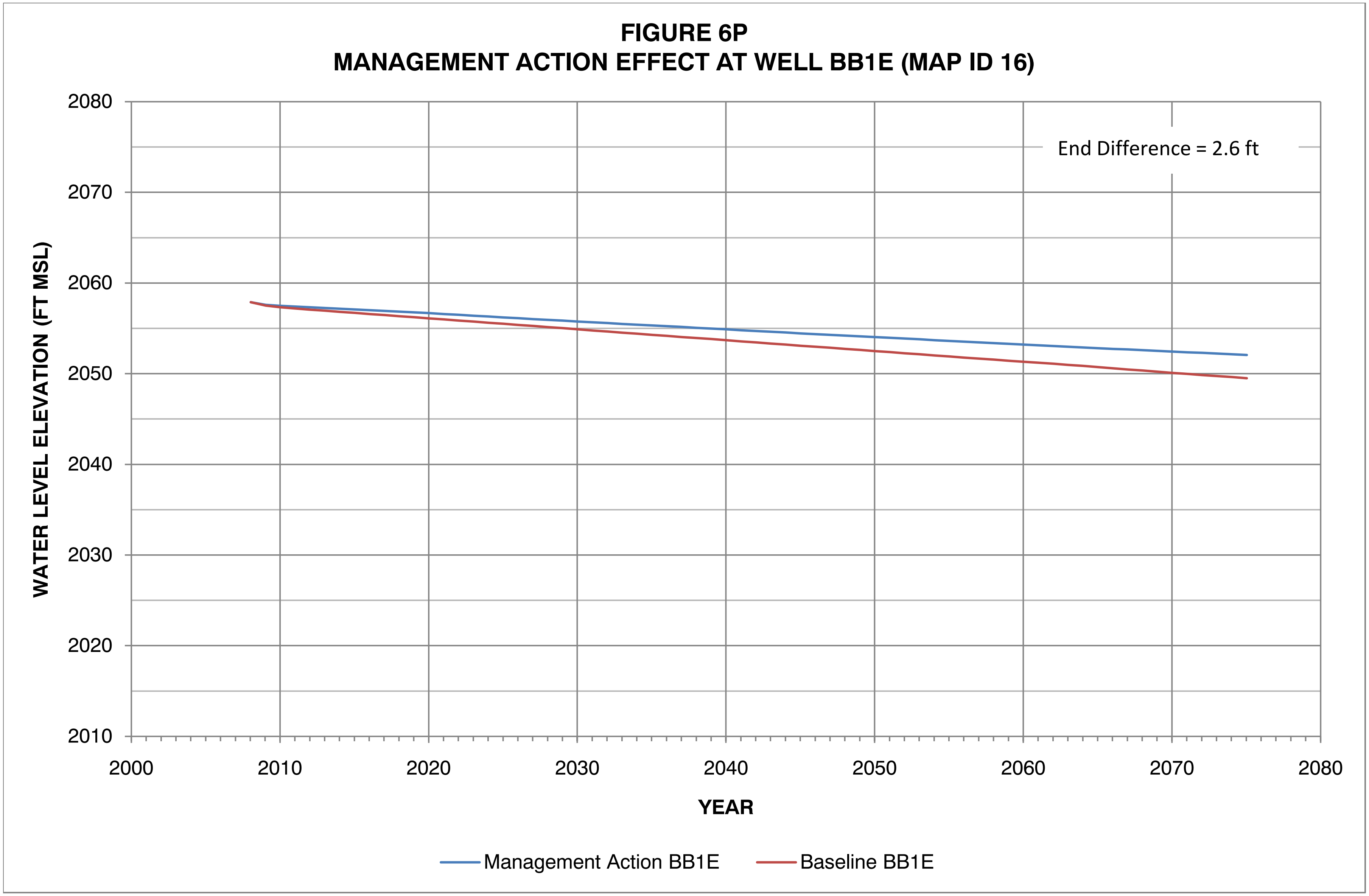


FIGURE 6O
MANAGEMENT ACTION EFFECT AT WELL BB1D (MAP ID 15)
End Difference = 2.7 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB1D
Baseline BB1D

MODEL



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MODEL

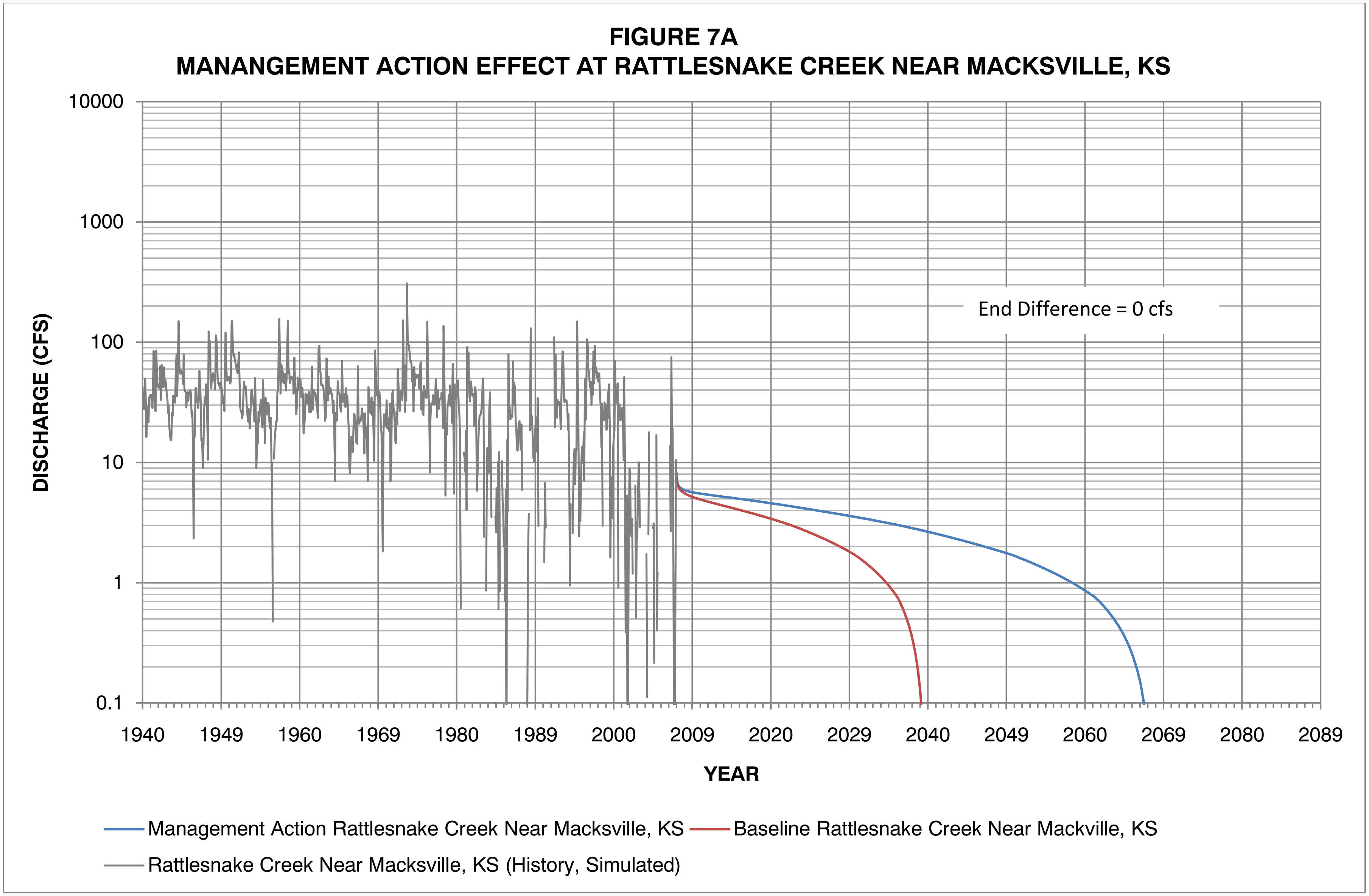
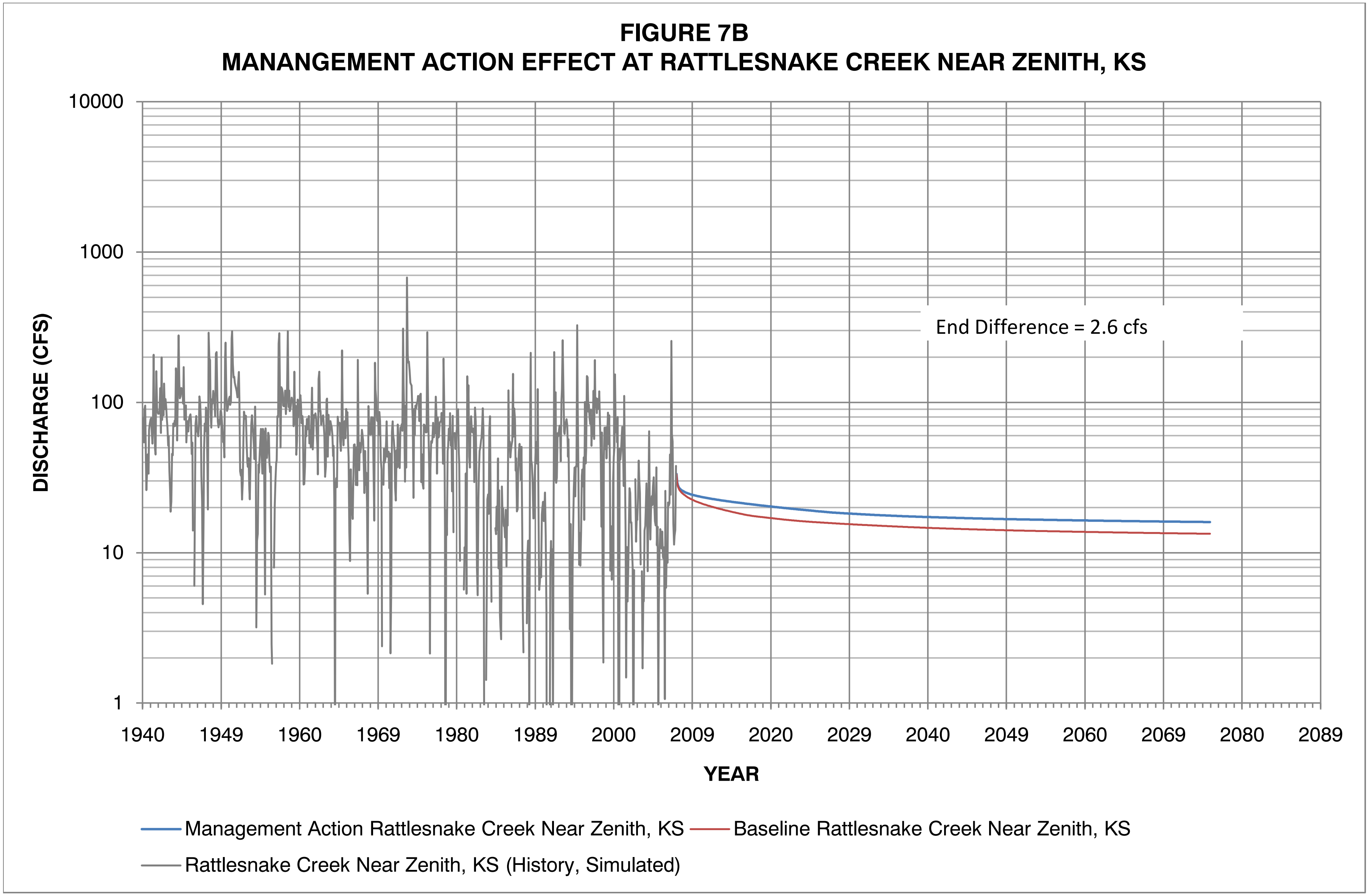


FIGURE 7A
MANANGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR MACKSVILLE, KS
10000
1000
100
10
1
0.1
DISCHARGE (CFS)
End Difference = 0 cfs
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
Management Action Rattlesnake Creek Near Macksville, KS
Baseline Rattlesnake Creek Near Mackville, KS
Rattlesnake Creek Near Macksville, KS (History, Simulated)

MODEL



ScenarioPlotsBprime.xlsb
BY
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MODEL

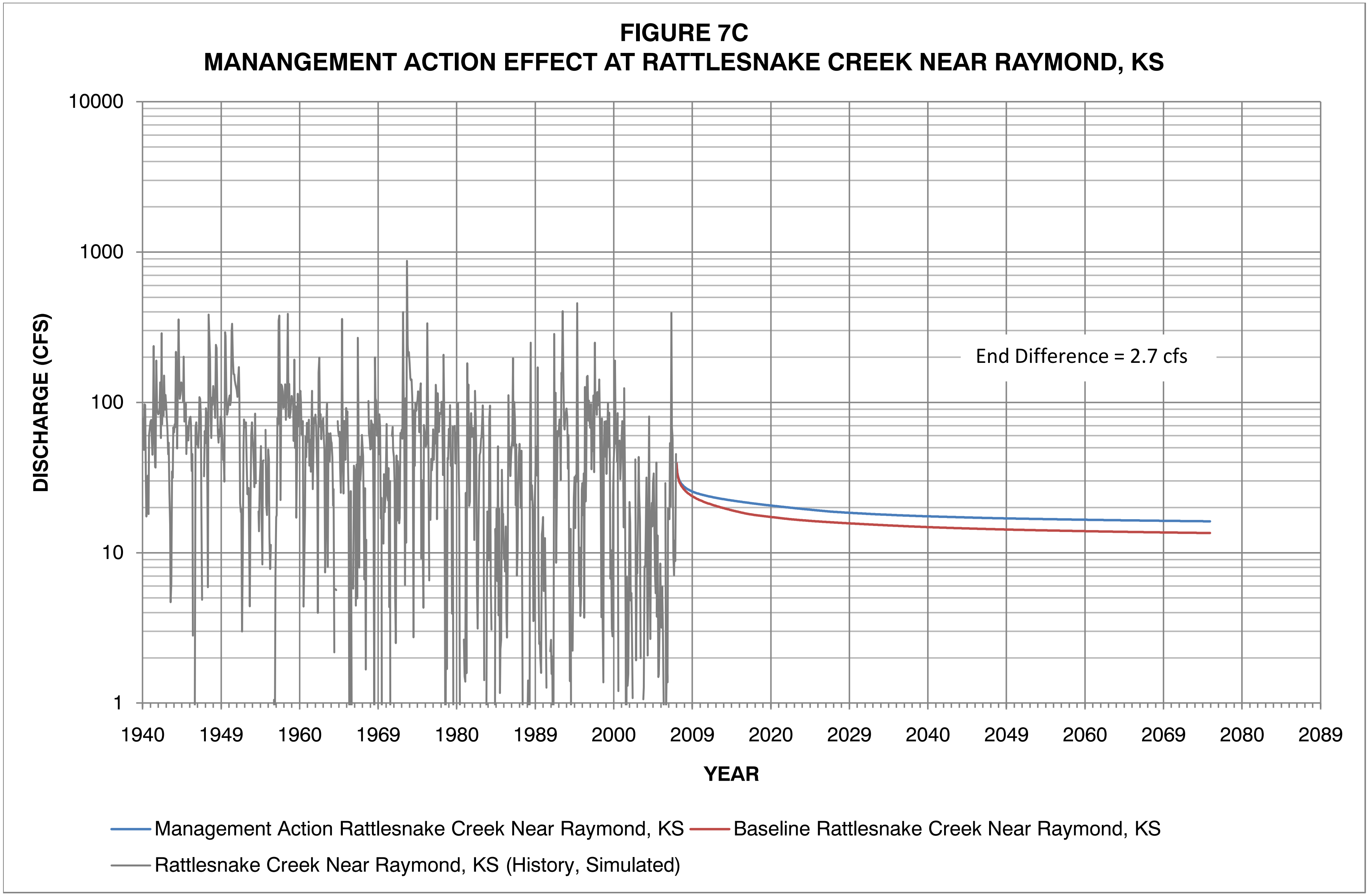


FIGURE 7C
MANANGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR RAYMOND, KS
DISCHARGE (CFS)
10000
1000
100
10
1
End Difference = 2.7 cfs
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
Management Action Rattlesnake Creek Near Raymond, KS
Baseline Rattlesnake Creek Near Raymond, KS
Rattlesnake Creek Near Raymond, KS (History, Simulated)

MODEL

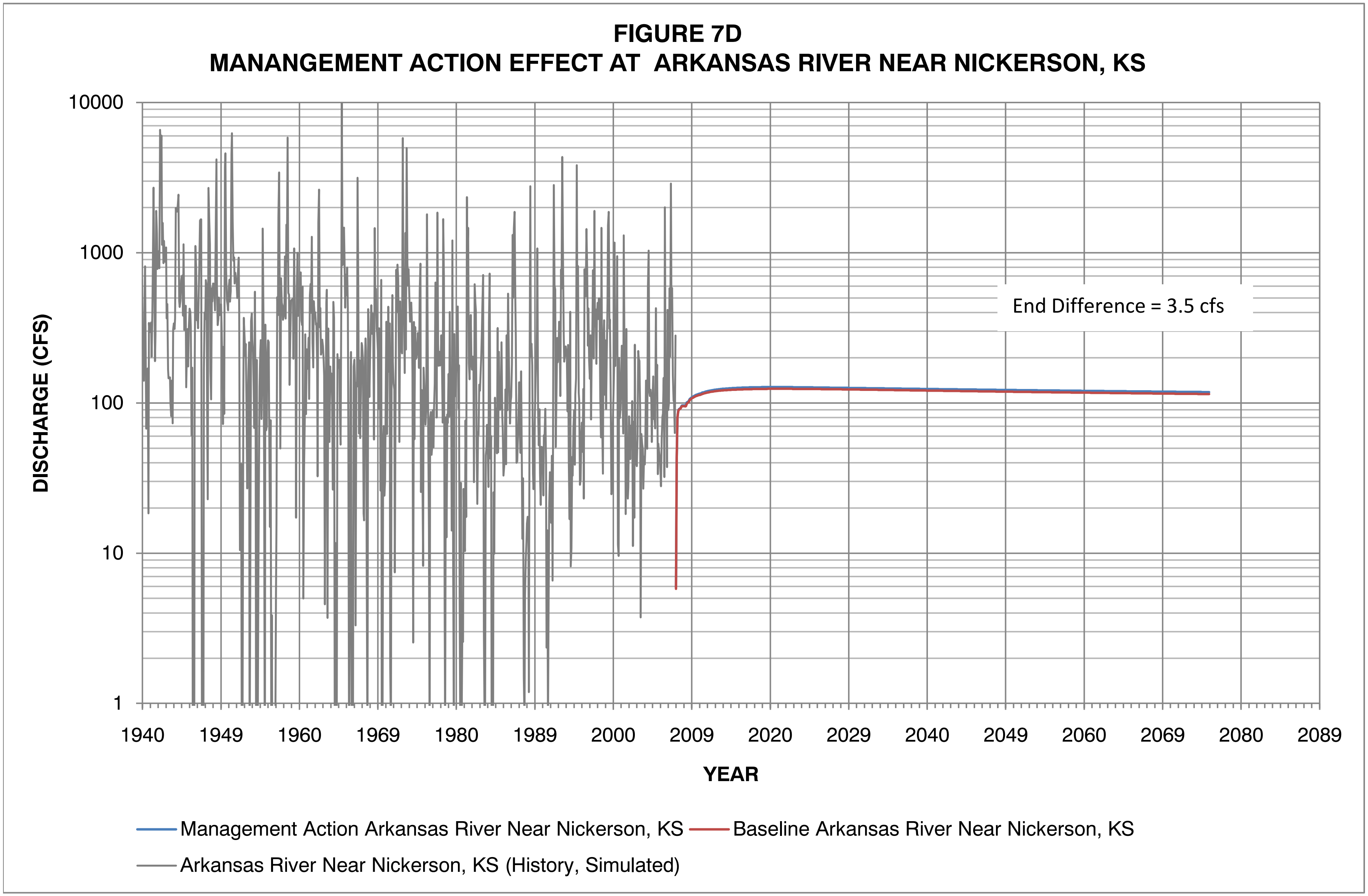
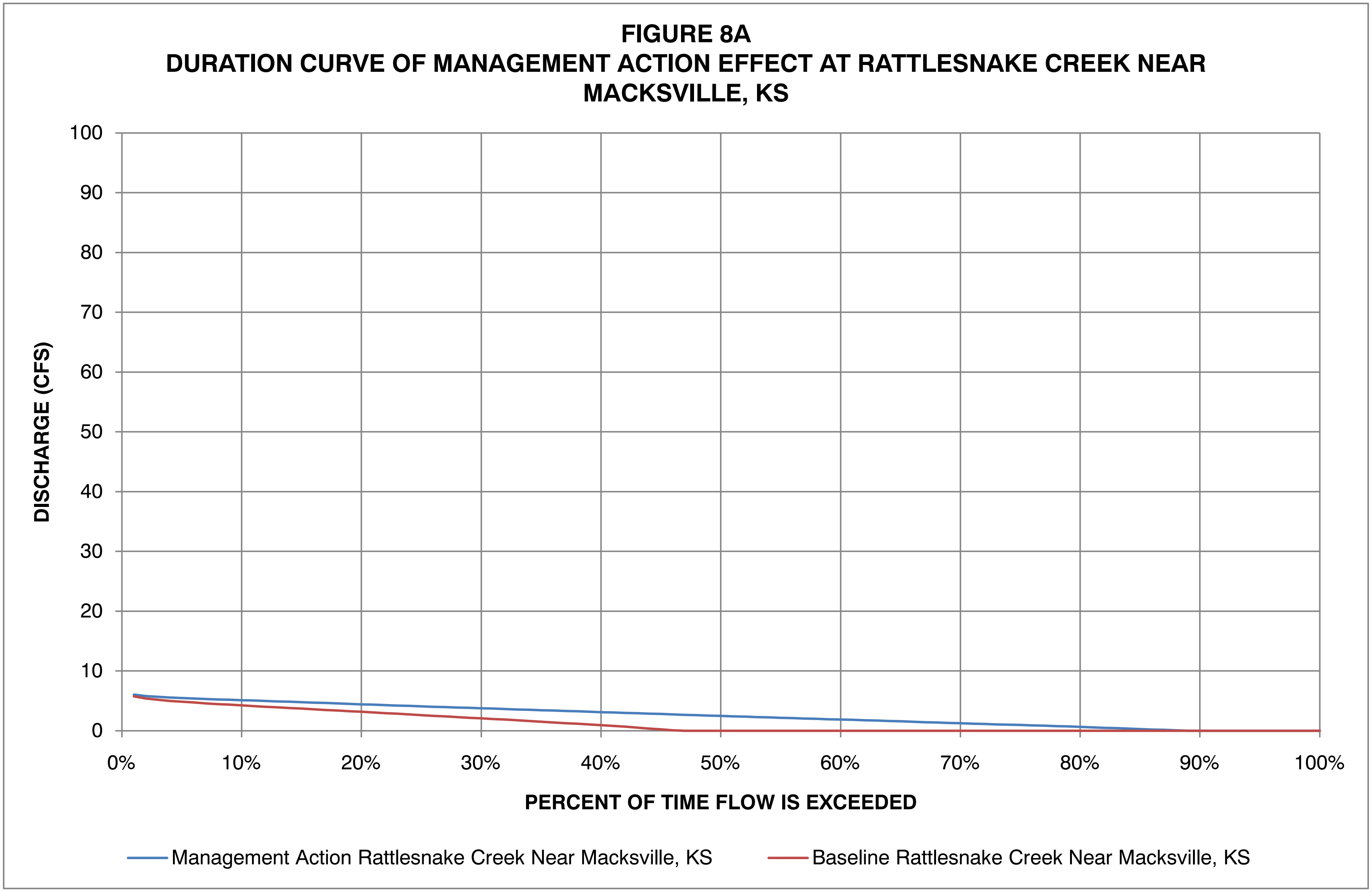


FIGURE 7D
MANANGEMENT ACTION EFFECT AT ARKANSAS RIVER NEAR NICKERSON, KS
DISCHARGE (CFS)
10000
1000
100
10
1
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
End Difference = 3.5 cfs
Management Action Arkansas River Near Nickerson, KS
Baseline Arkansas River Near Nickerson, KS
Arkansas River Near Nickerson, KS (History, Simulated)

MODEL



ScenarioPlotsBprime.xlsb
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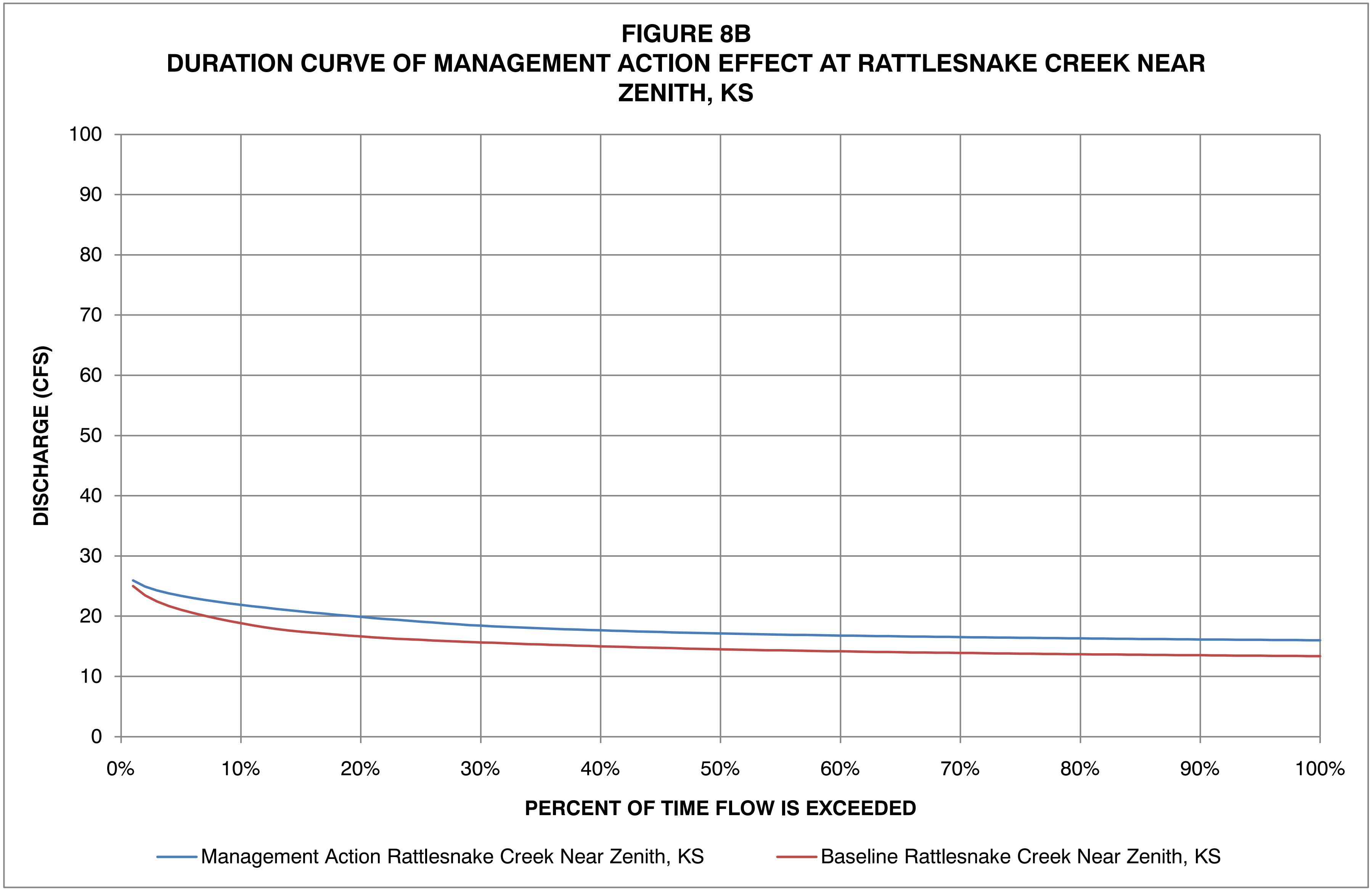
FIGURE 8B
DURATION CURVE OF MANAGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR ZENITH, KS
100
90
80
70
60
50
40
30
20
10
0
DISCHARGE (CFS)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT OF TIME FLOW IS EXCEEDED
Management Action Rattlesnake Creek Near Zenith, KS
Baseline Rattlesnake Creek Near Zenith, KS

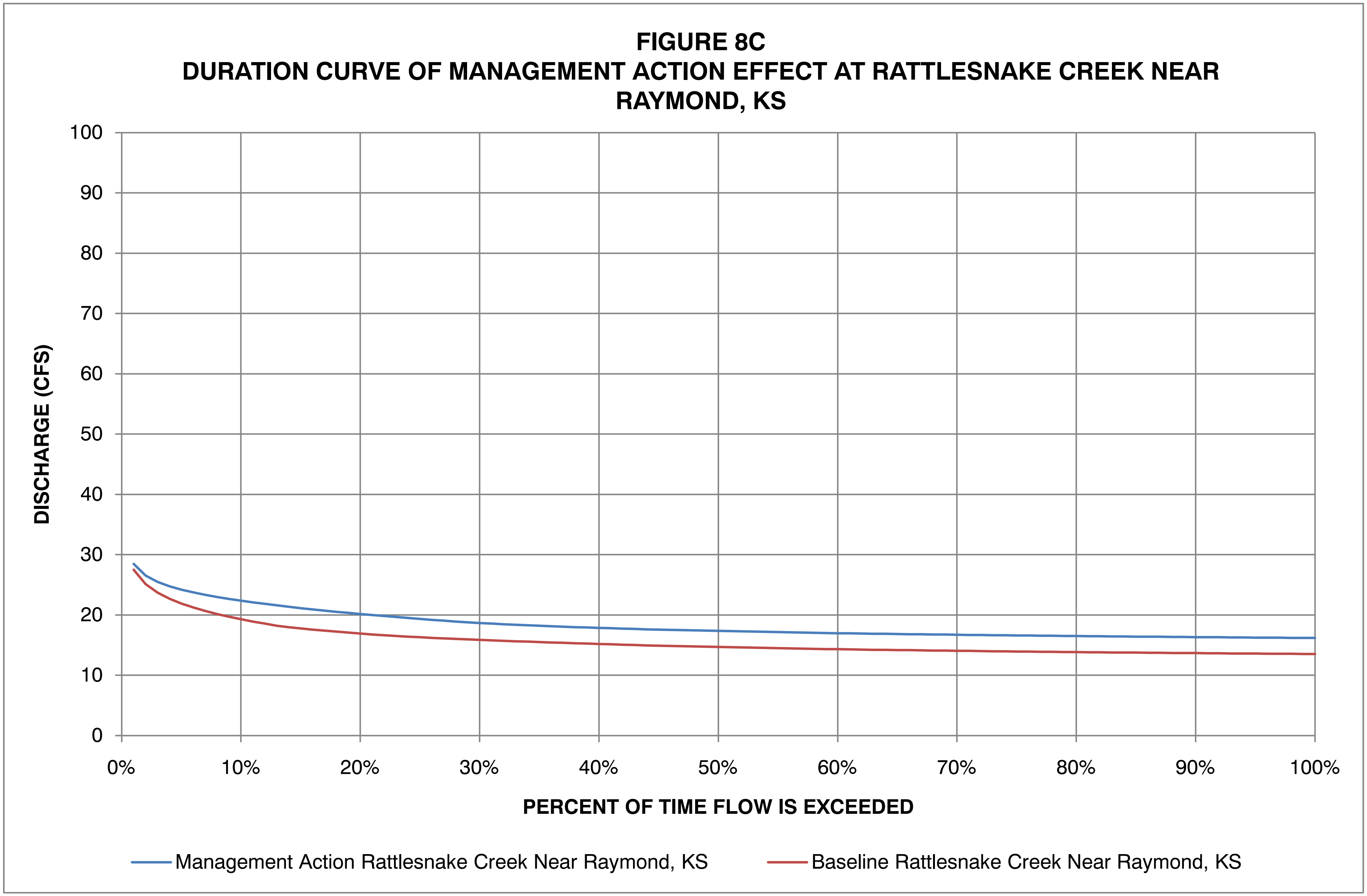
FIGURE 8C
DURATION CURVE OF MANAGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR RAYMOND, KS
100
90
80
70
60
50
40
30
20
10
0
DISCHARGE (CFS)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT OF TIME FLOW IS EXCEEDED
Management Action Rattlesnake Creek Near Raymond, KS
Baseline Rattlesnake Creek Near Raymond, KS

MODEL

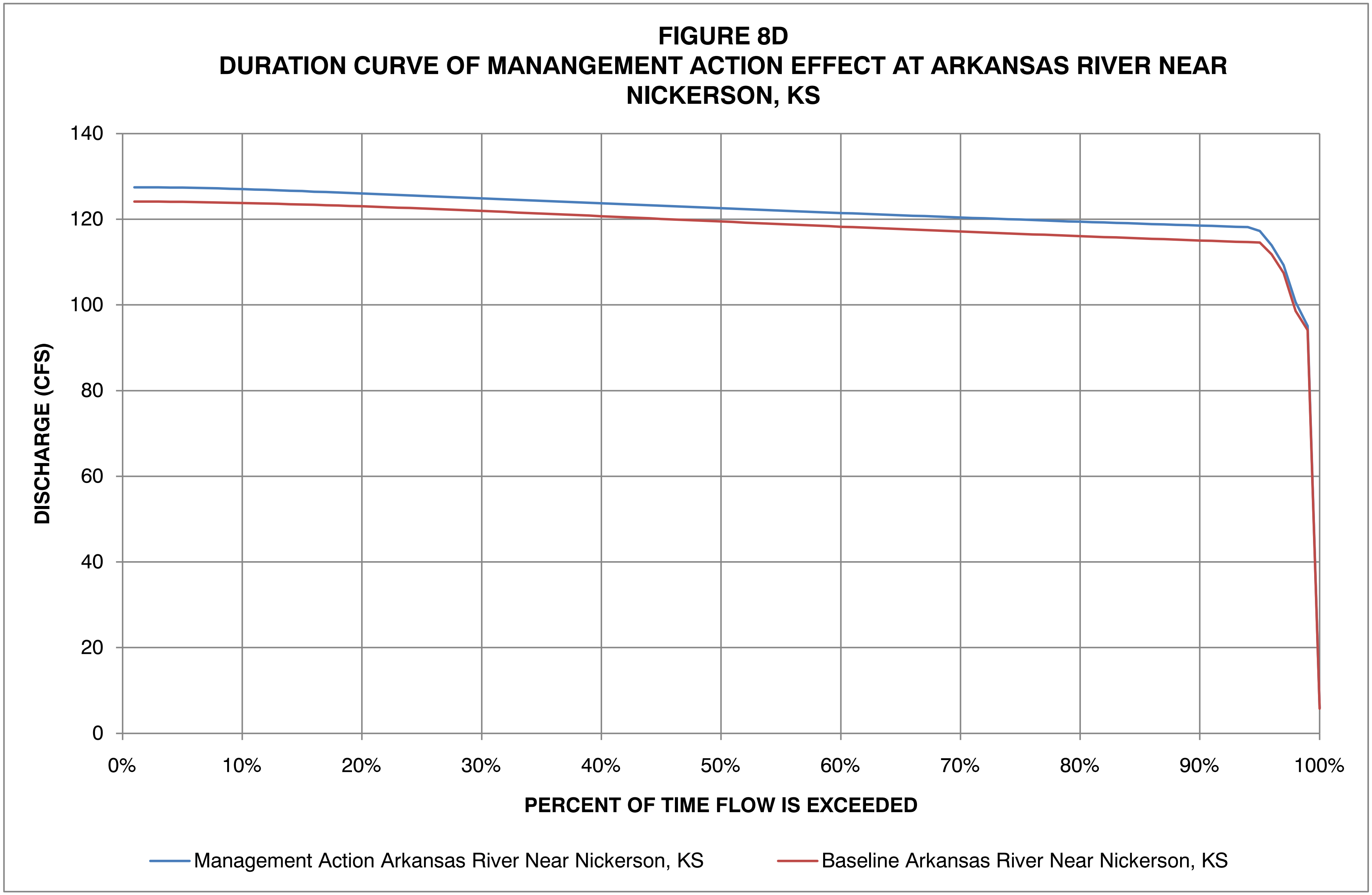
FIGURE 8D
DURATION CURVE OF MANANGEMENT ACTION EFFECT AT ARKANSAS RIVER NEAR NICKERSON, KS
140
120
100
80
60
40
20
0
DISCHARGE (CFS)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT OF TIME FLOW IS EXCEEDED
Management Action Arkansas River Near Nickerson, KS
Baseline Arkansas River Near Nickerson, KS