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

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%

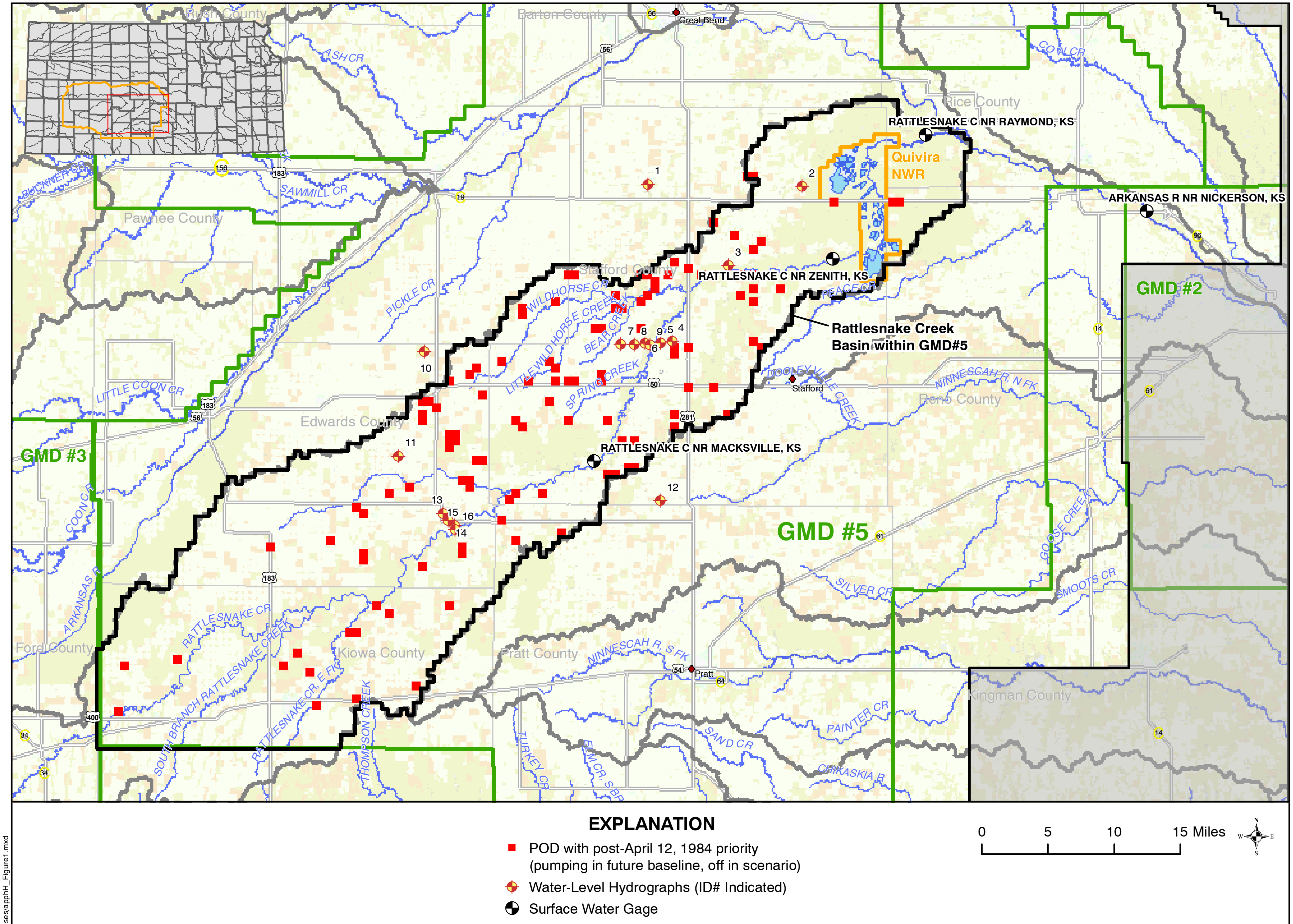

FIGURE 1. Location of Baseline PODs with Post-1984 Priorities

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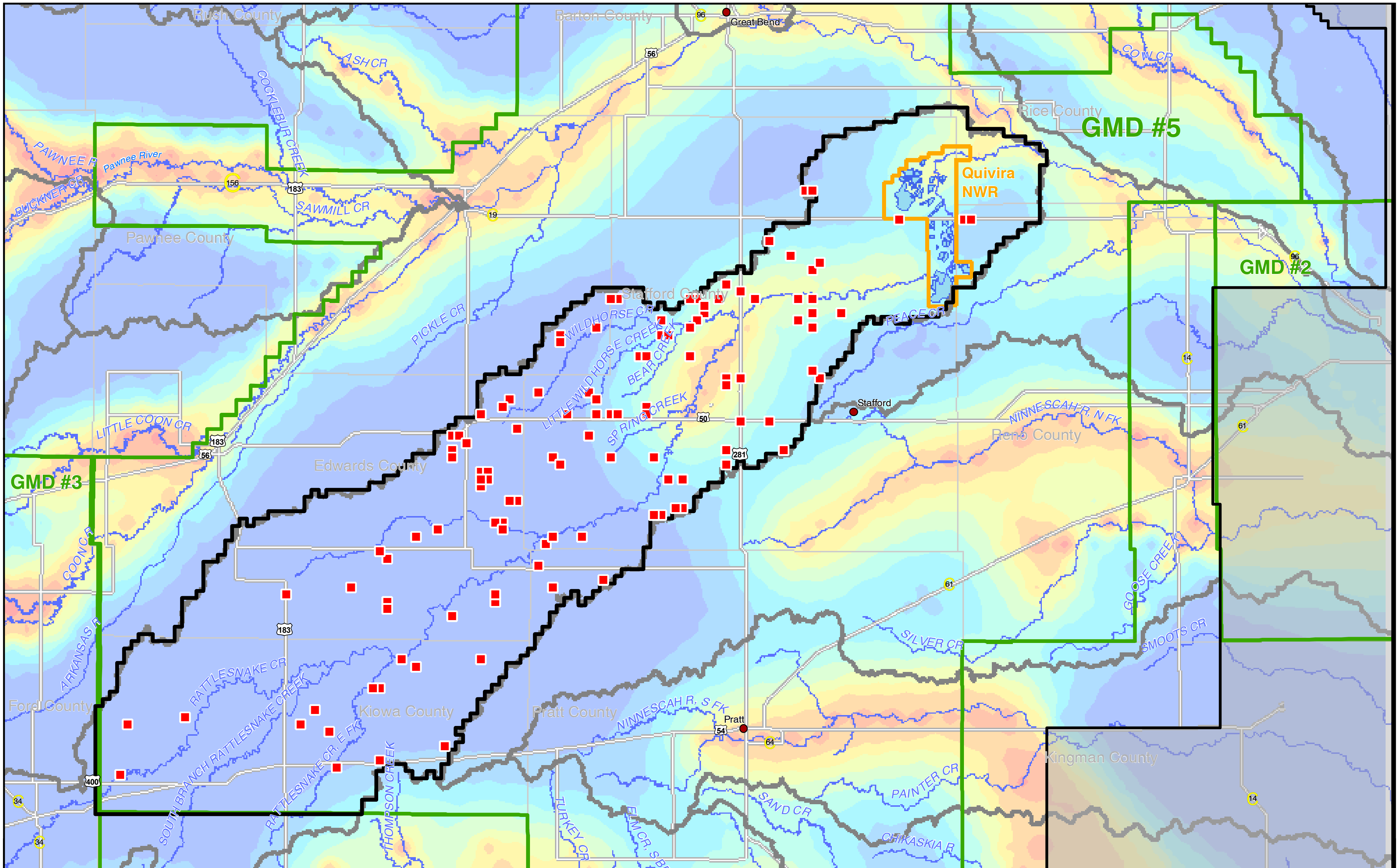


EXPLANATION

10-Year Stream-Depletion Fraction of Pumping

0.0 - 0.1, 0.1 - 0.2, 0.2 - 0.3, 0.3 - 0.4, 0.4 - 0.5, 0.5 - 0.6, 0.6 - 0.7, 0.7 - 0.8, 0.8 - 0.9, 0.9 - 1

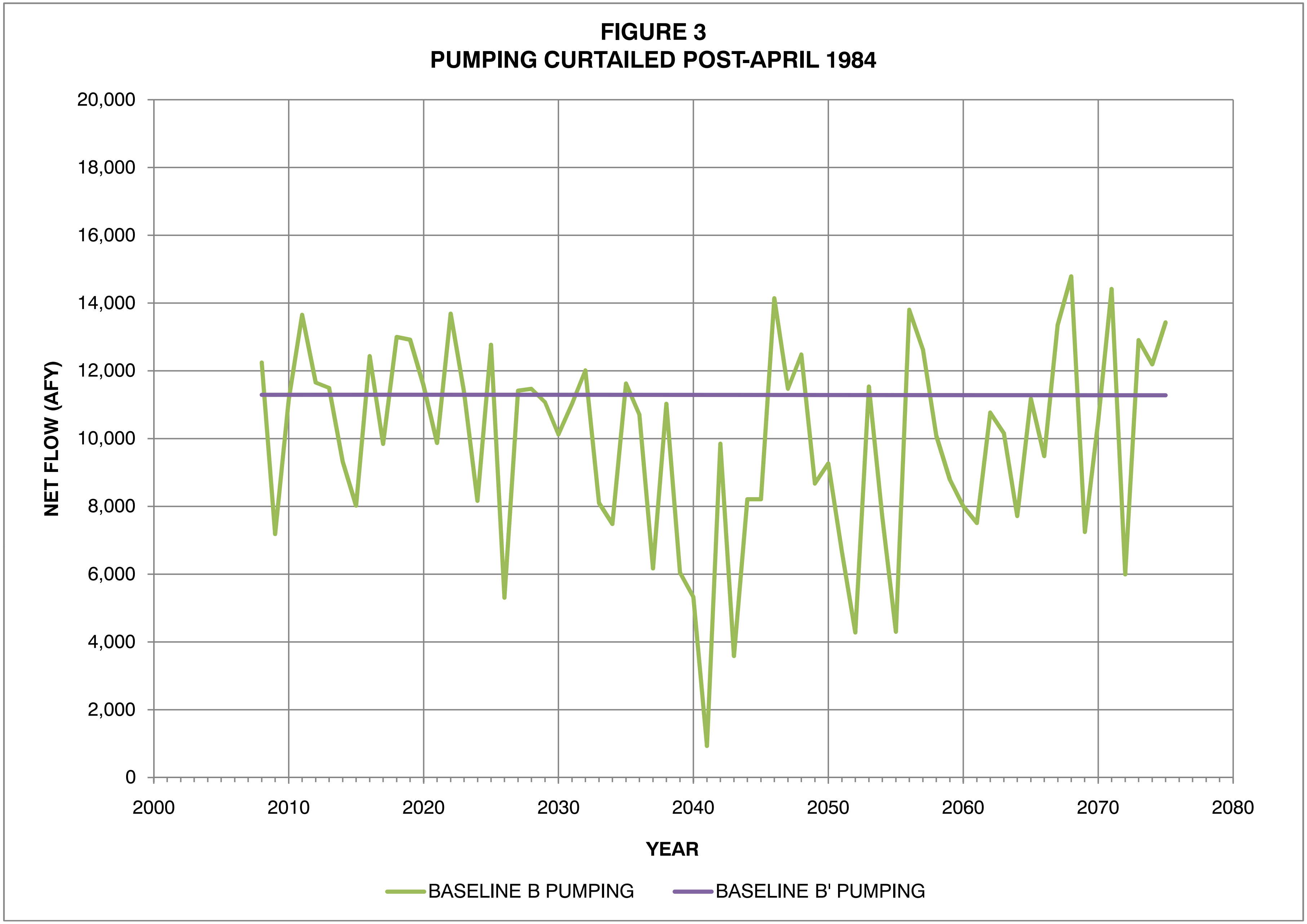
■ POD with post-April 12, 1984 priority (pumping in future baseline, off in scenario)

0 5 10 15 Miles

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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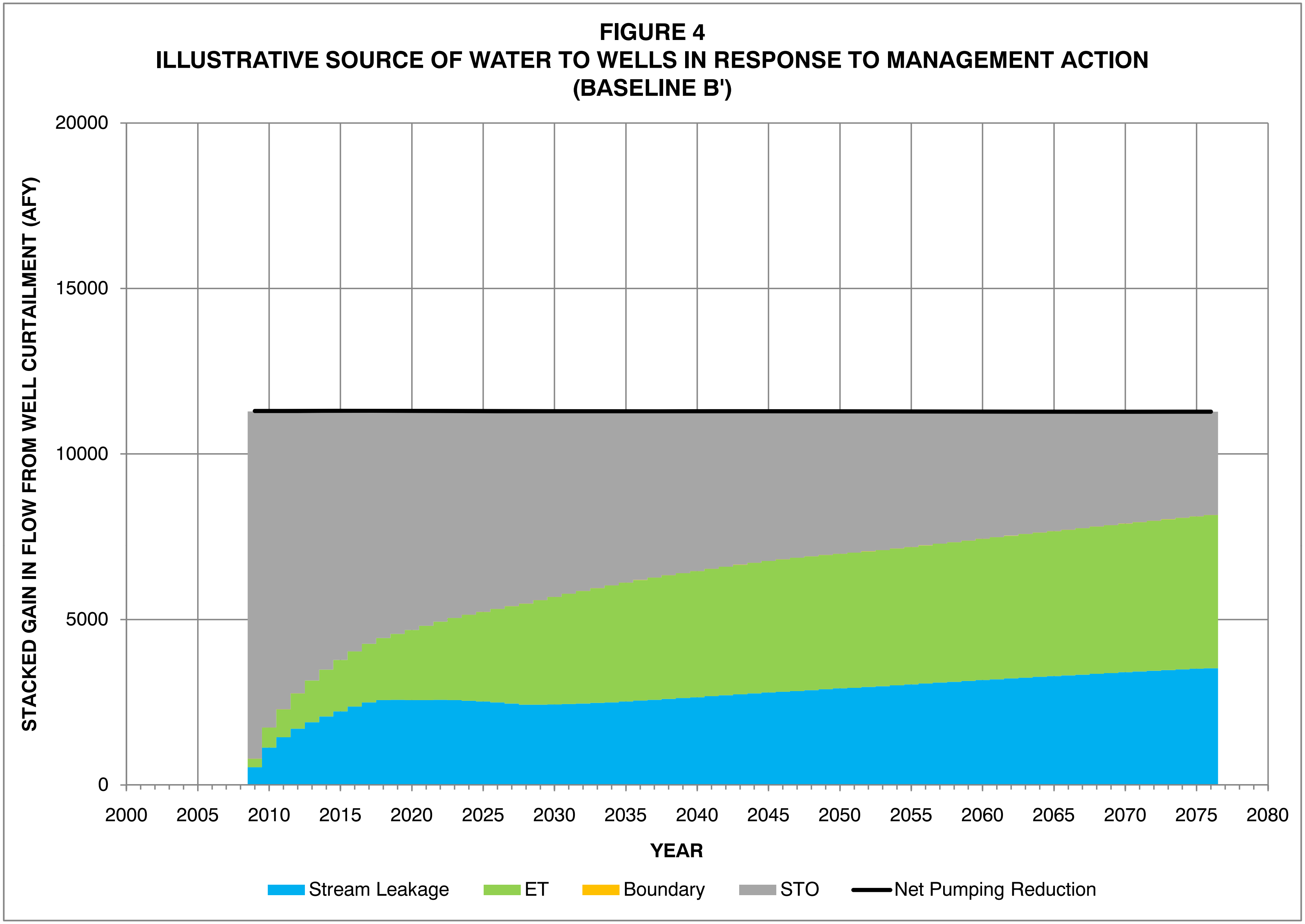
MODEL



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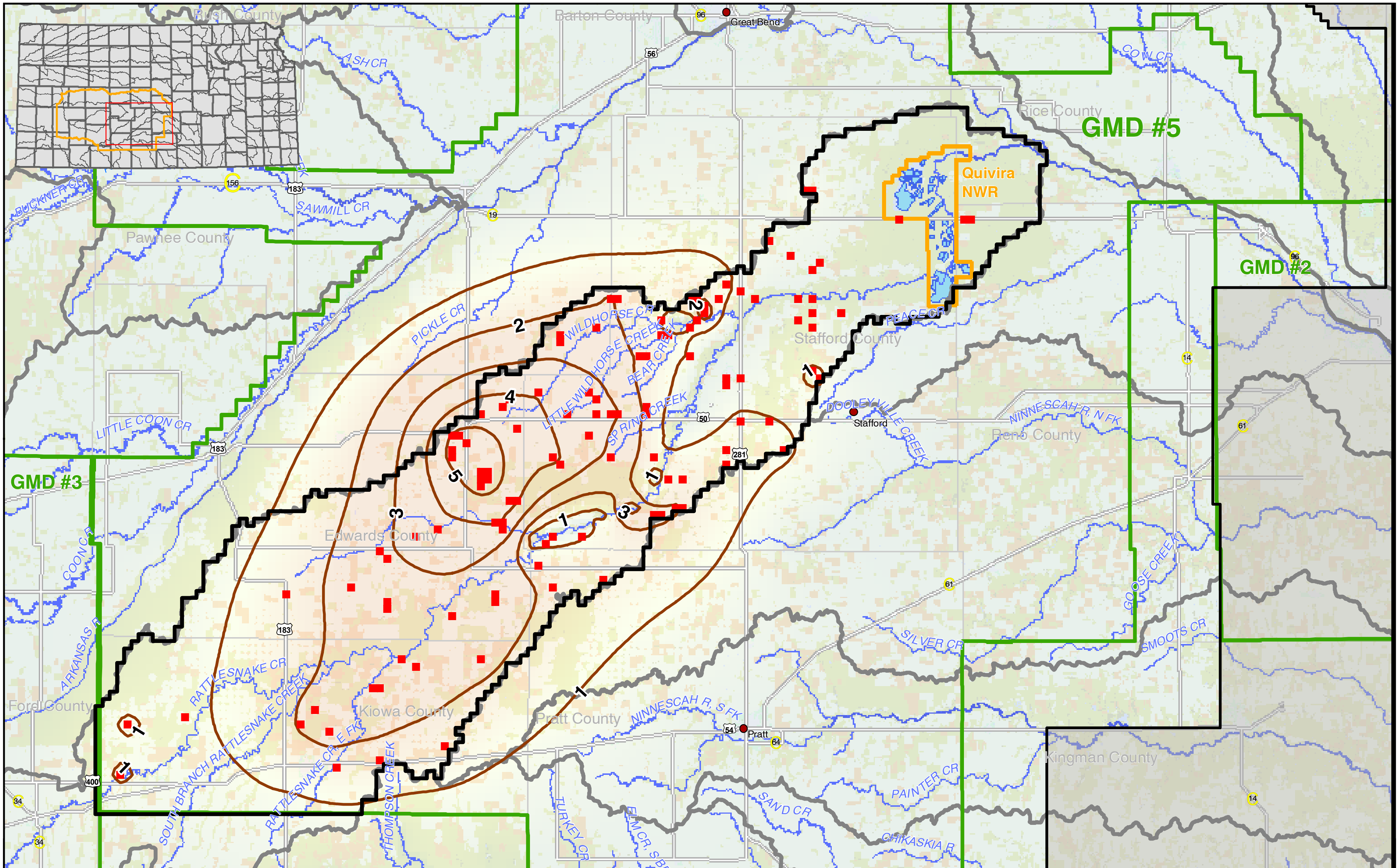


EXPLANATION

■ 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

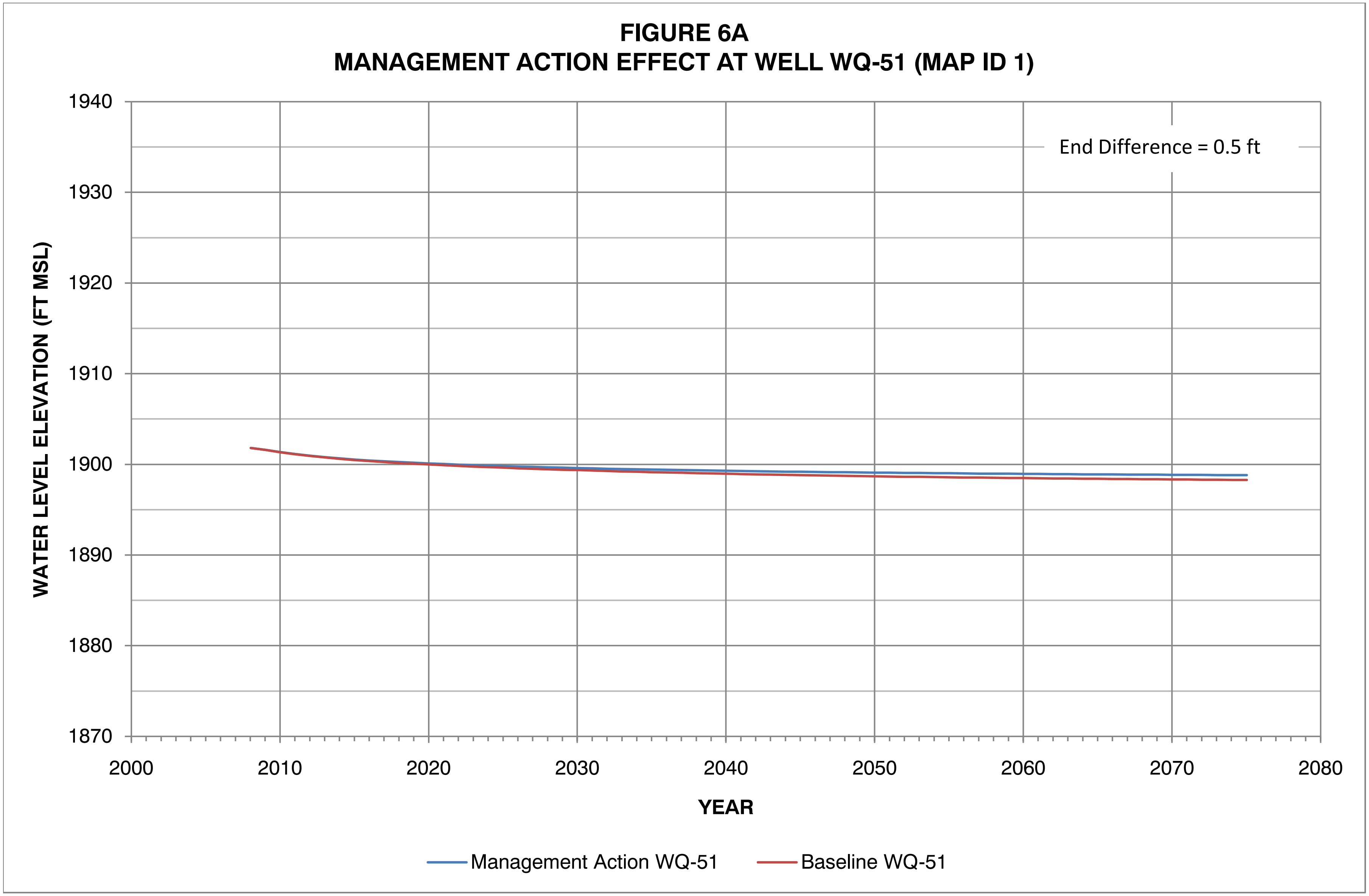


FIGURE 6A
MANAGEMENT ACTION EFFECT AT WELL WQ-51 (MAP ID 1)
End Difference = 0.5 ft
WATER LEVEL ELEVATION (FT MSL)
1940
1930
1920
1910
1900
1890
1880
1870
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action WQ-51
Baseline WQ-51

MODEL

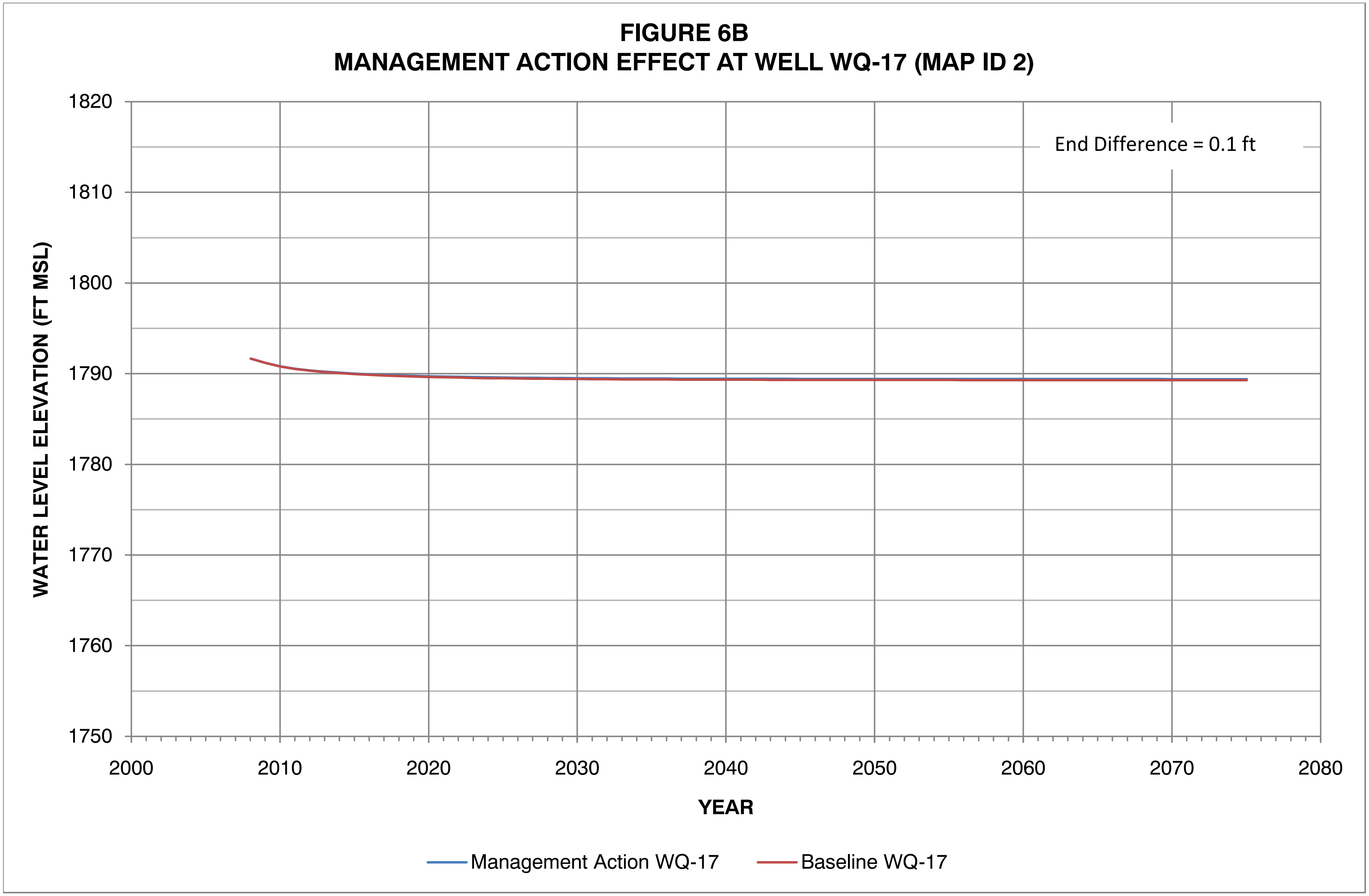


FIGURE 6B
MANAGEMENT ACTION EFFECT AT WELL WQ-17 (MAP ID 2)
End Difference = 0.1 ft
WATER LEVEL ELEVATION (FT MSL)
1820
1810
1800
1790
1780
1770
1760
1750
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action WQ-17
Baseline WQ-17

MODEL

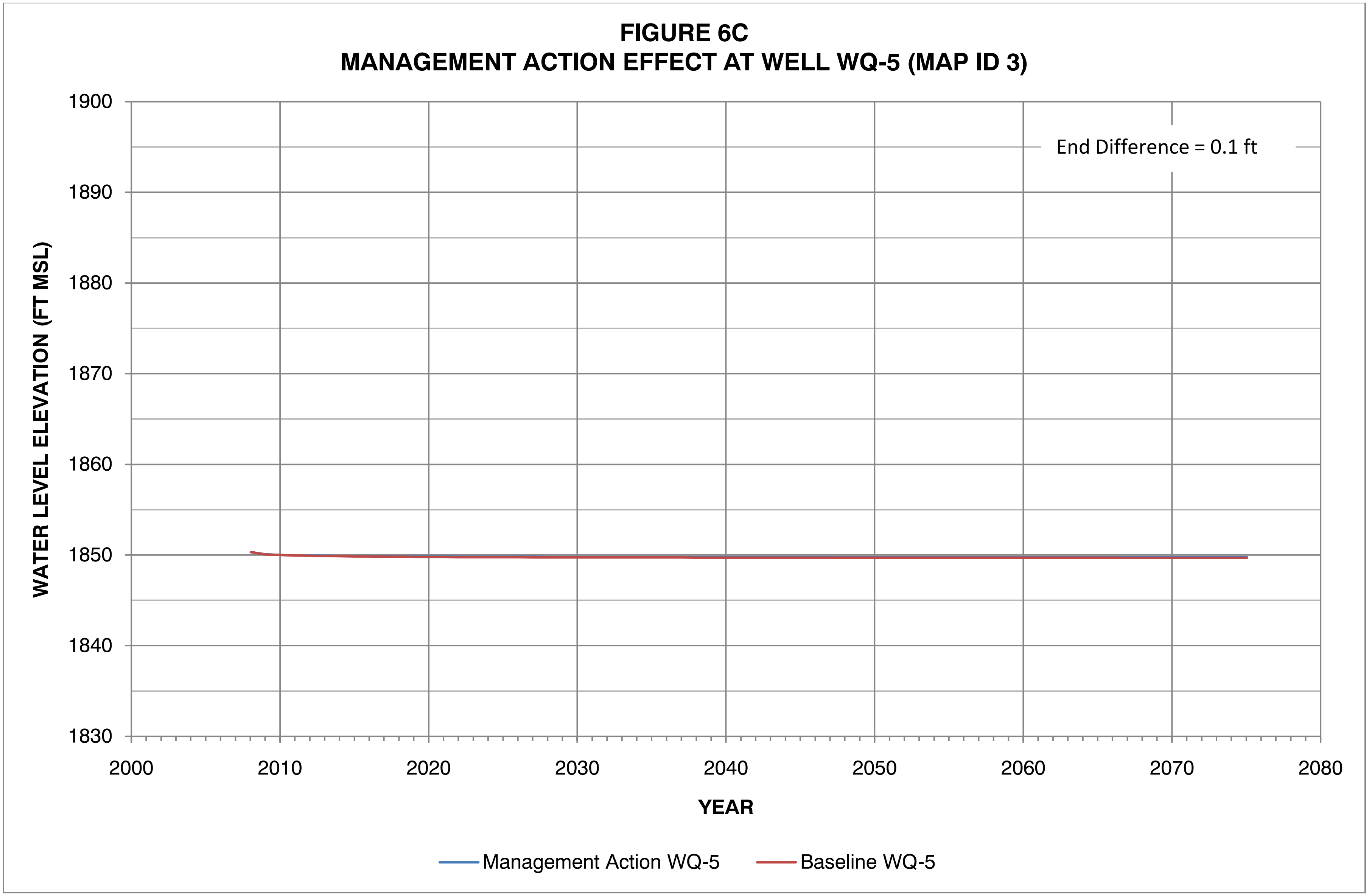


FIGURE 6C
MANAGEMENT ACTION EFFECT AT WELL WQ-5 (MAP ID 3)
End Difference = 0.1 ft
WATER LEVEL ELEVATION (FT MSL)
1900
1890
1880
1870
1860
1850
1840
1830
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action WQ-5
Baseline WQ-5

MODEL

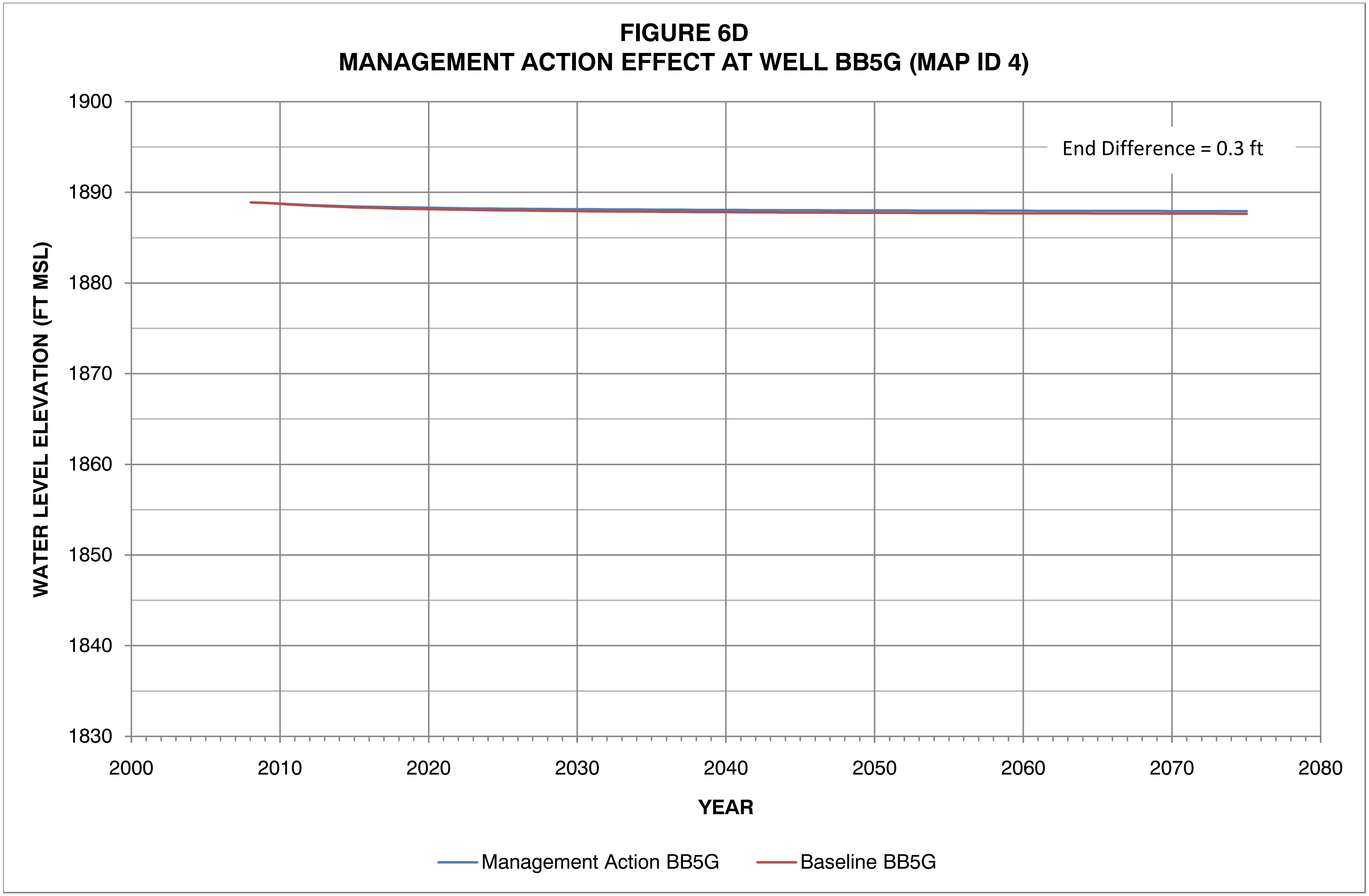


FIGURE 6D
MANAGEMENT ACTION EFFECT AT WELL BB5G (MAP ID 4)
End Difference = 0.3 ft
WATER LEVEL ELEVATION (FT MSL)
1900
1890
1880
1870
1860
1850
1840
1830
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB5G
Baseline BB5G

MODEL

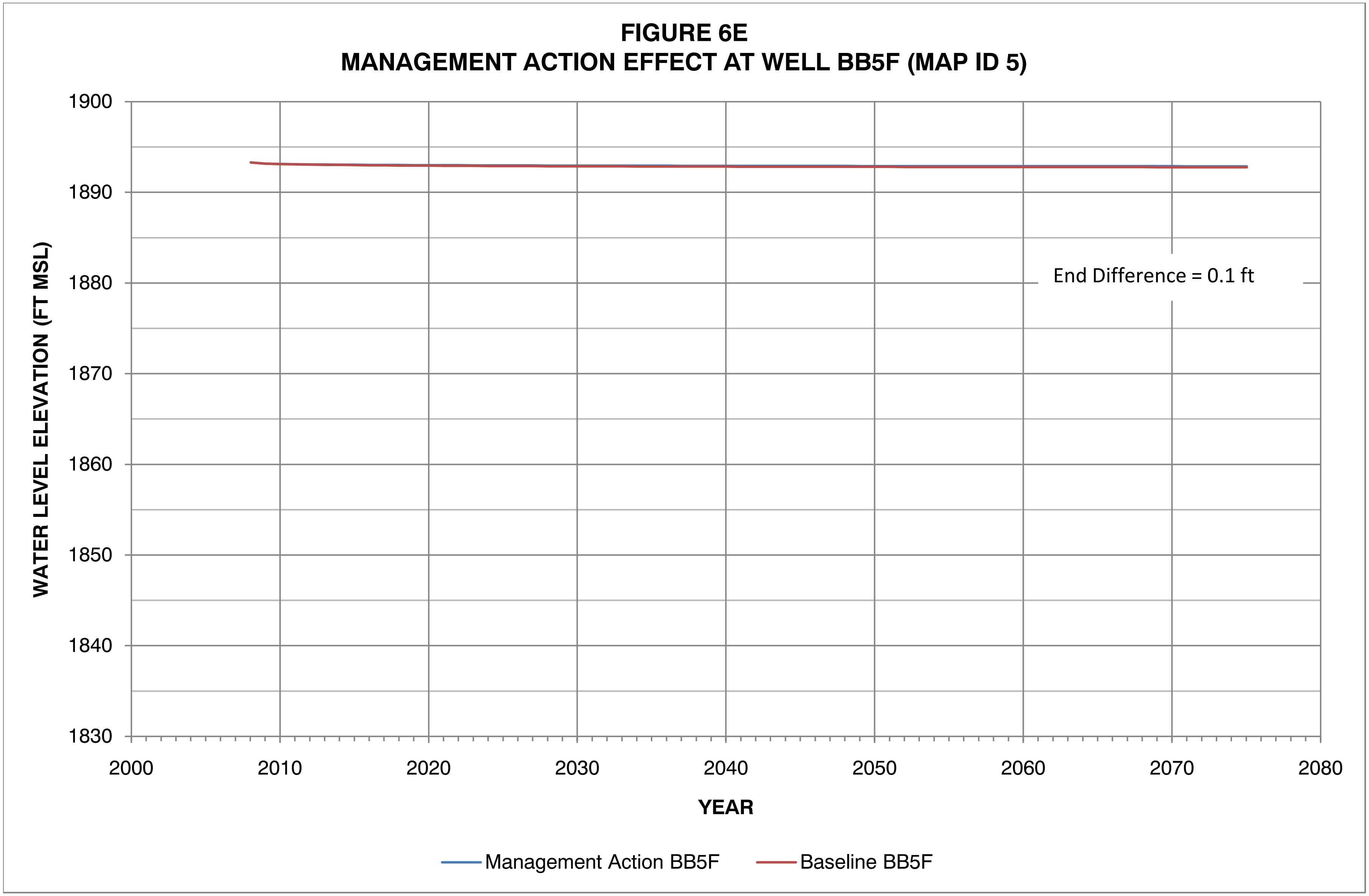
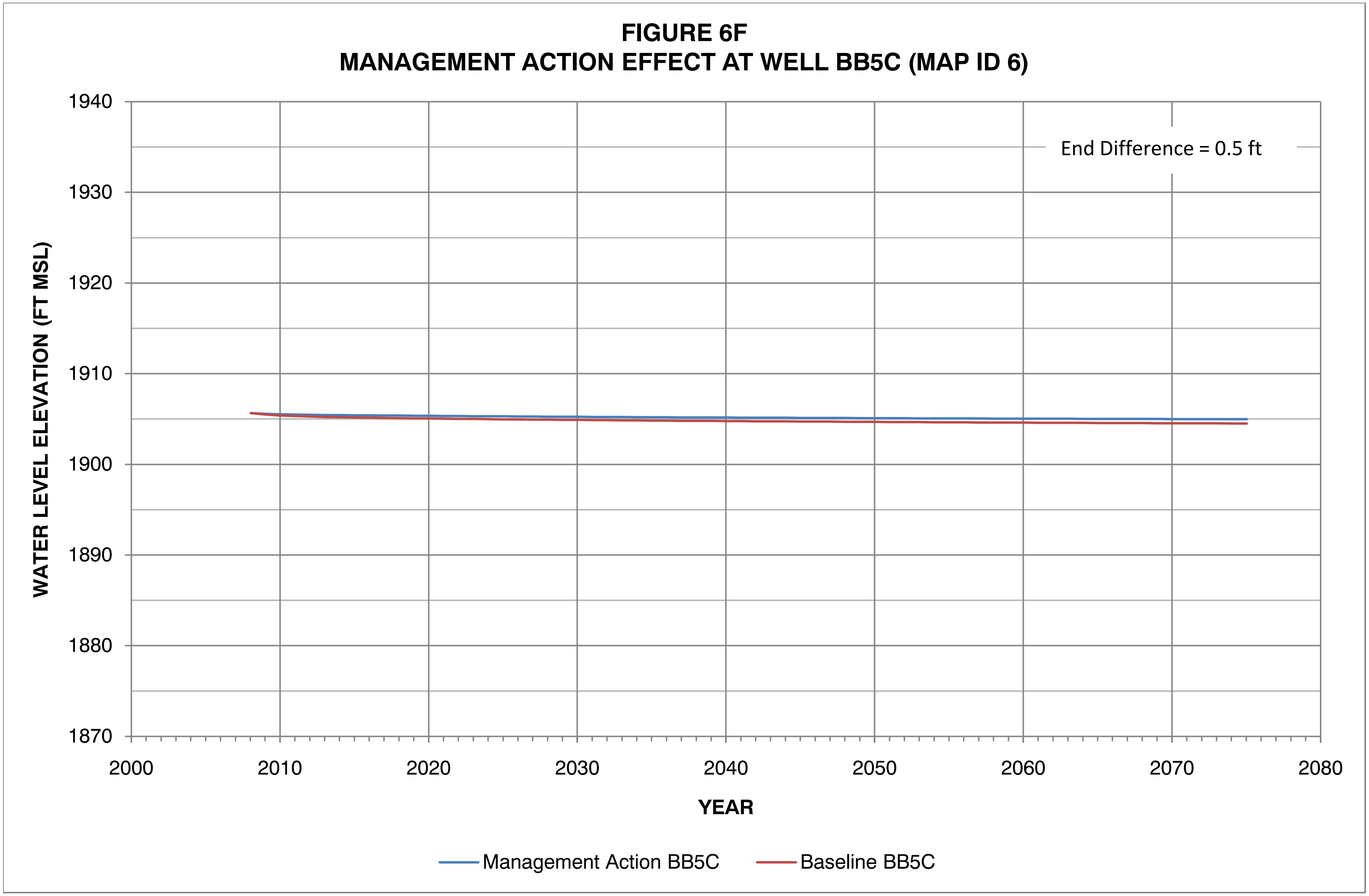


FIGURE 6E
MANAGEMENT ACTION EFFECT AT WELL BB5F (MAP ID 5)
1900
1890
1880
1870
1860
1850
1840
1830
WATER LEVEL ELEVATION (FT MSL)
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
End Difference = 0.1 ft
Management Action BB5F
Baseline BB5F

MODEL



ScenarioPlotsBprime.xlsb
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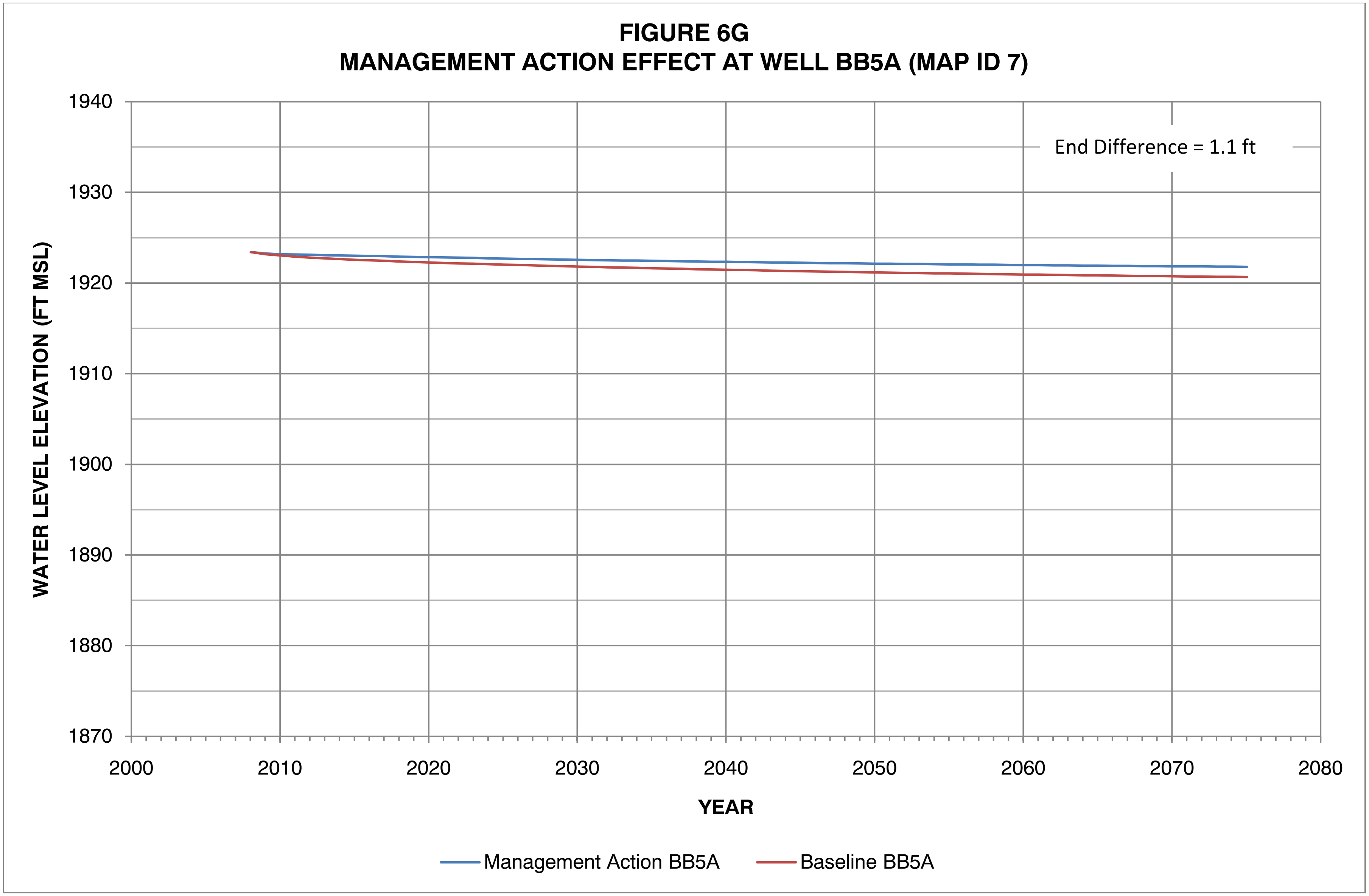
MODEL



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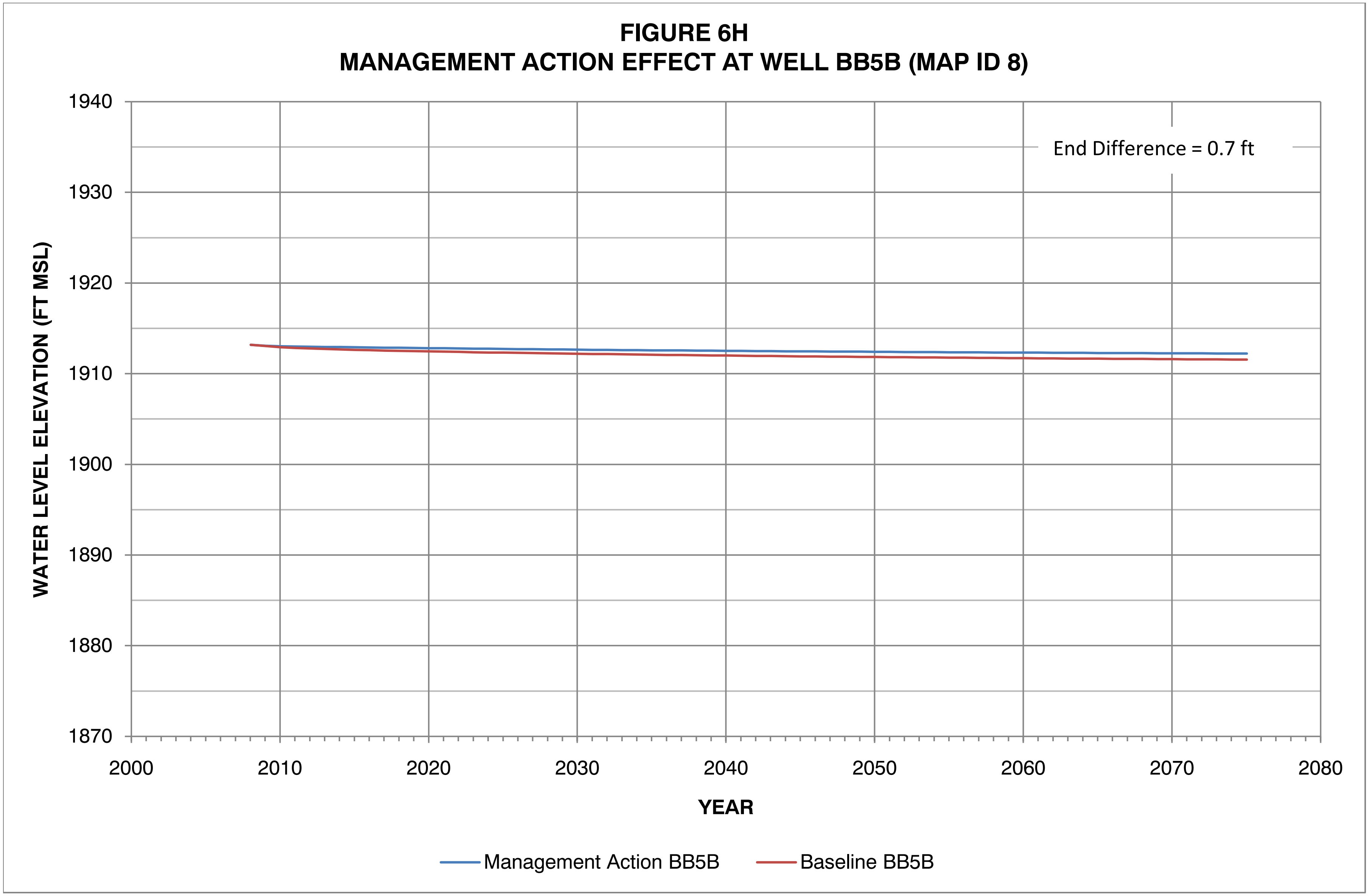
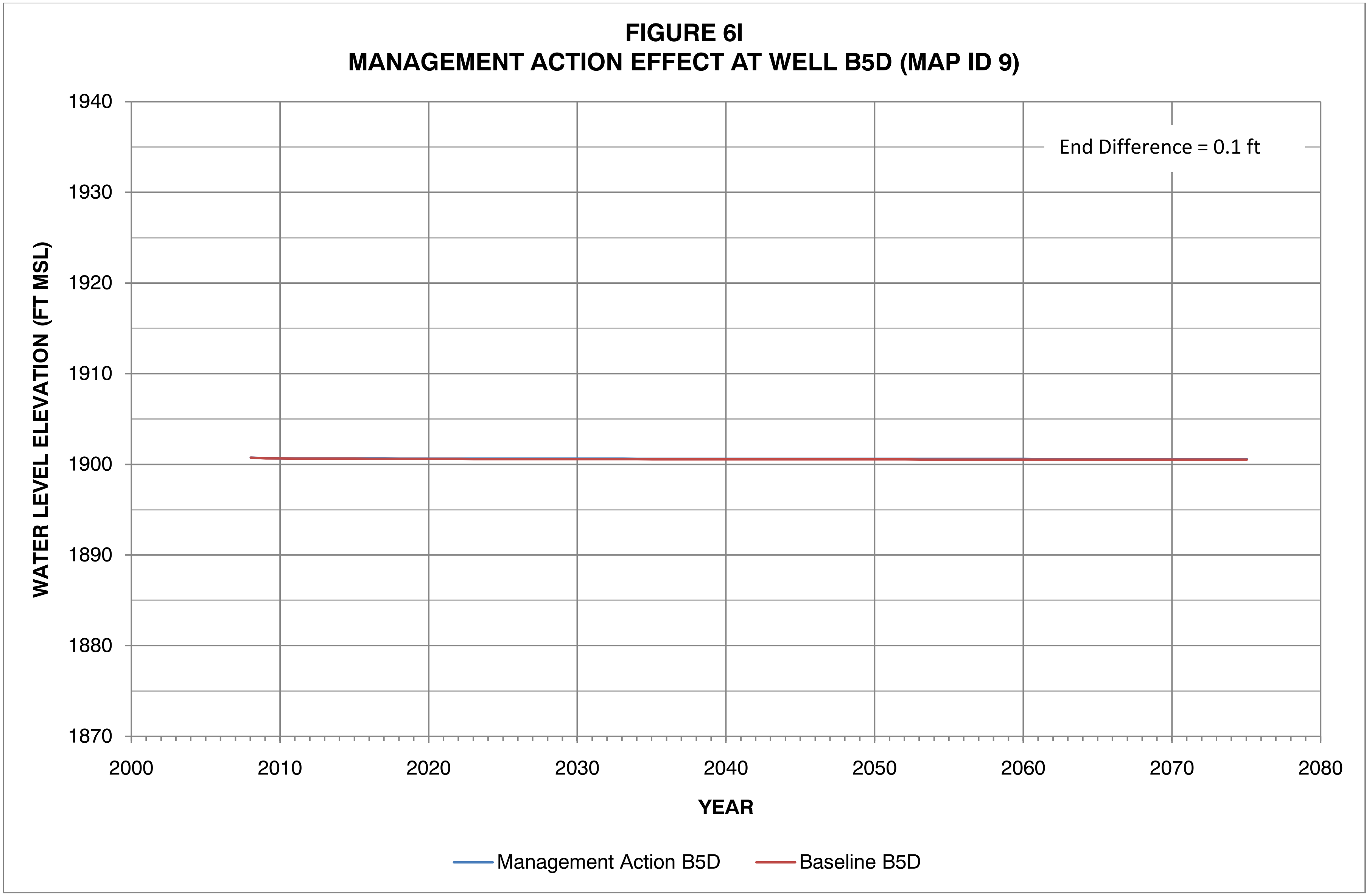


FIGURE 6H
MANAGEMENT ACTION EFFECT AT WELL BB5B (MAP ID 8)
End Difference = 0.7 ft
WATER LEVEL ELEVATION (FT MSL)
1940
1930
1920
1910
1900
1890
1880
1870
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB5B
Baseline BB5B

MODEL



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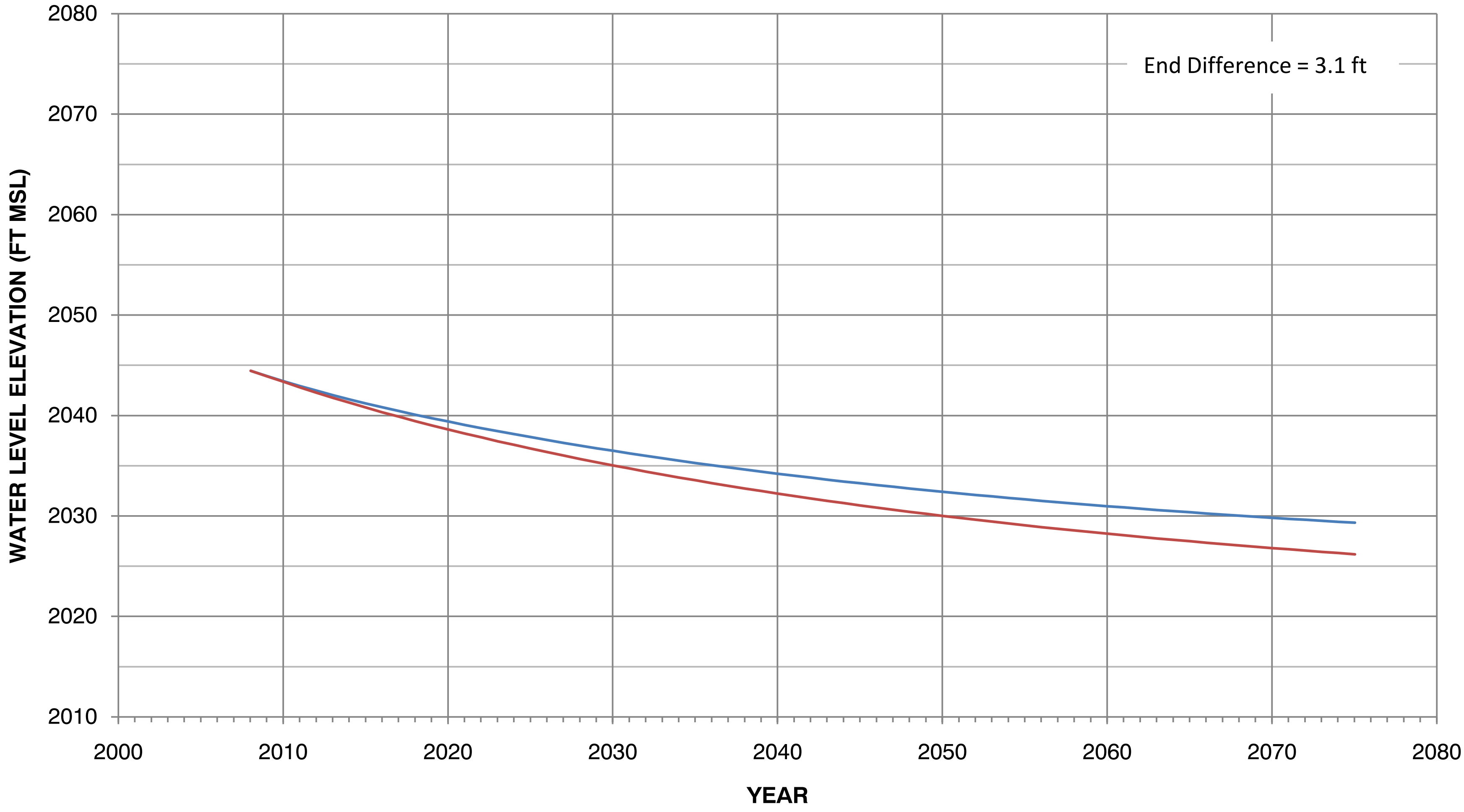
MODEL

FIGURE 6J
MANAGEMENT ACTION EFFECT AT WELL BB18-A (MAP ID 10)



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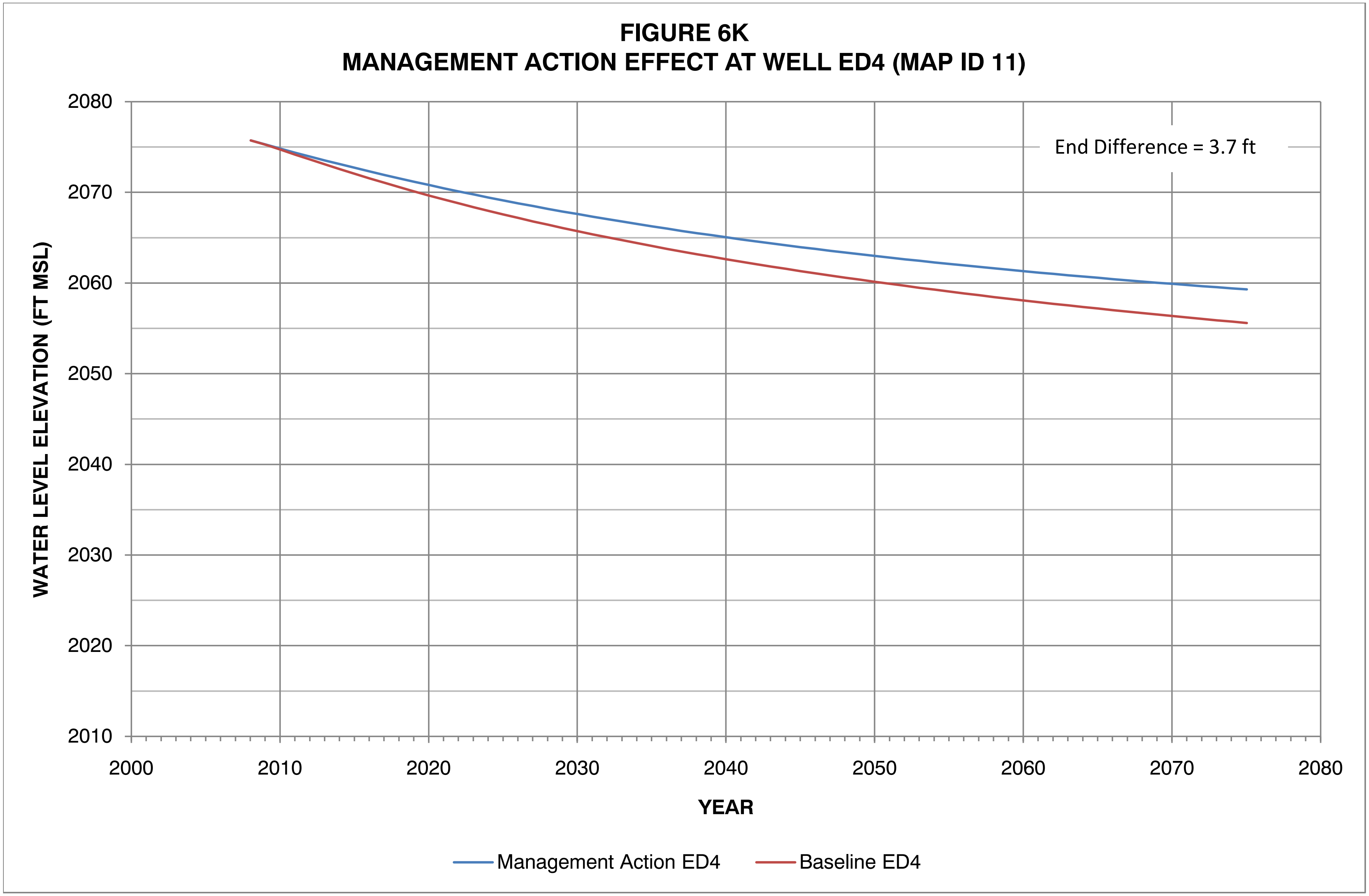
MODEL



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MODEL

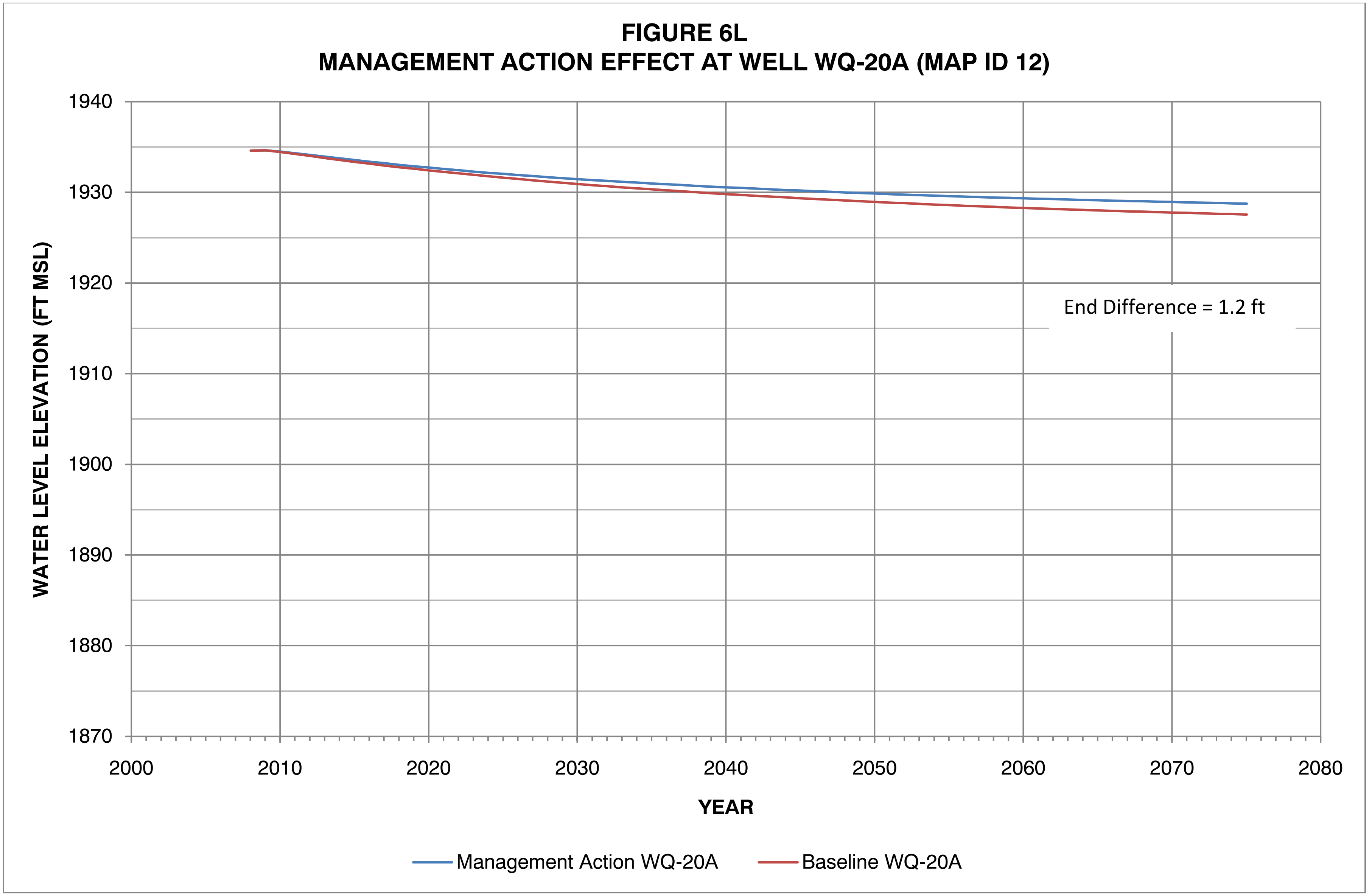
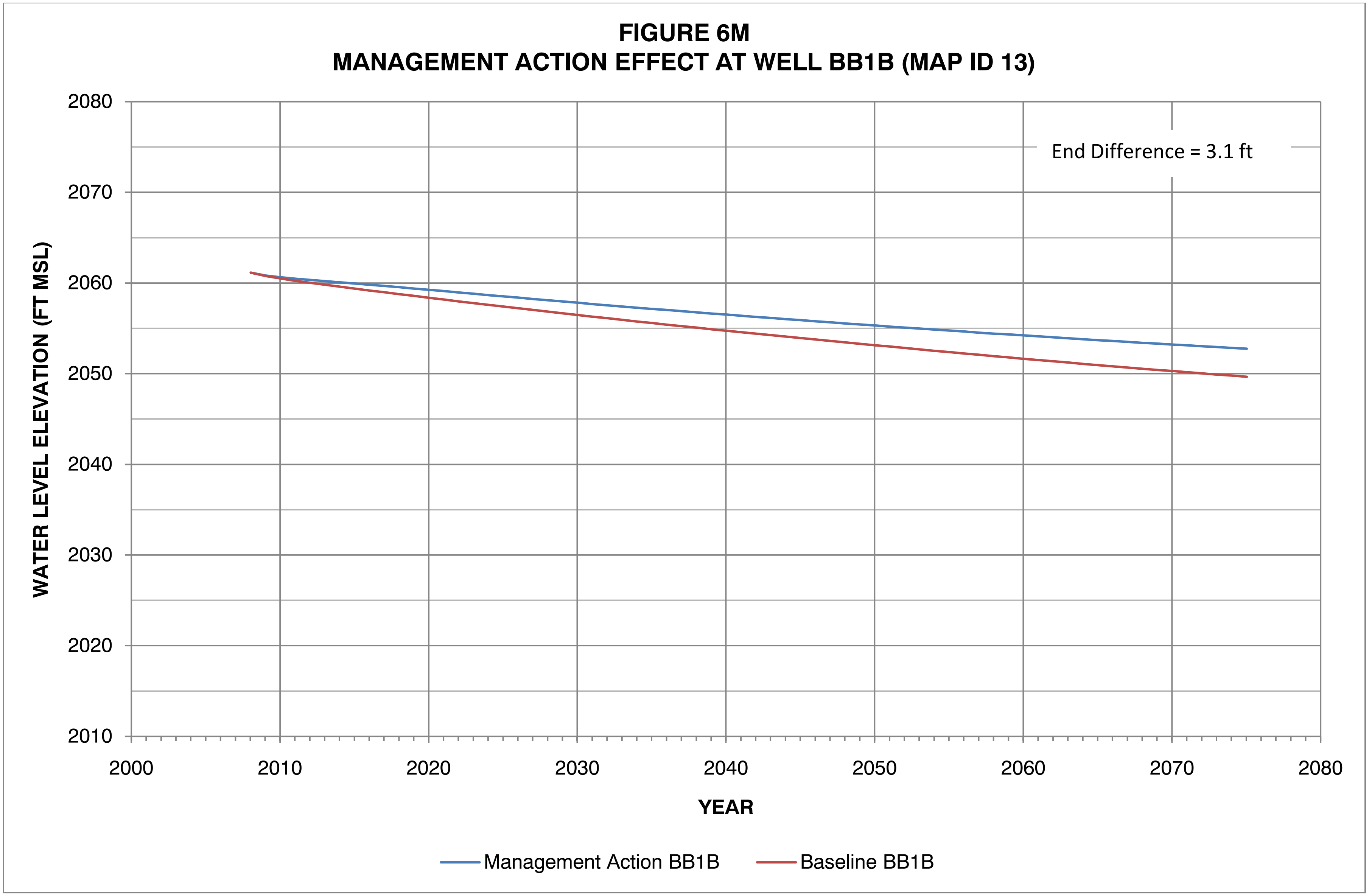


FIGURE 6L
MANAGEMENT ACTION EFFECT AT WELL WQ-20A (MAP ID 12)
1940
1930
1920
1910
1900
1890
1880
1870
WATER LEVEL ELEVATION (FT MSL)
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
End Difference = 1.2 ft
Management Action WQ-20A
Baseline WQ-20A

GMD #5

MODEL



ScenarioPlotsBprime.xlsb
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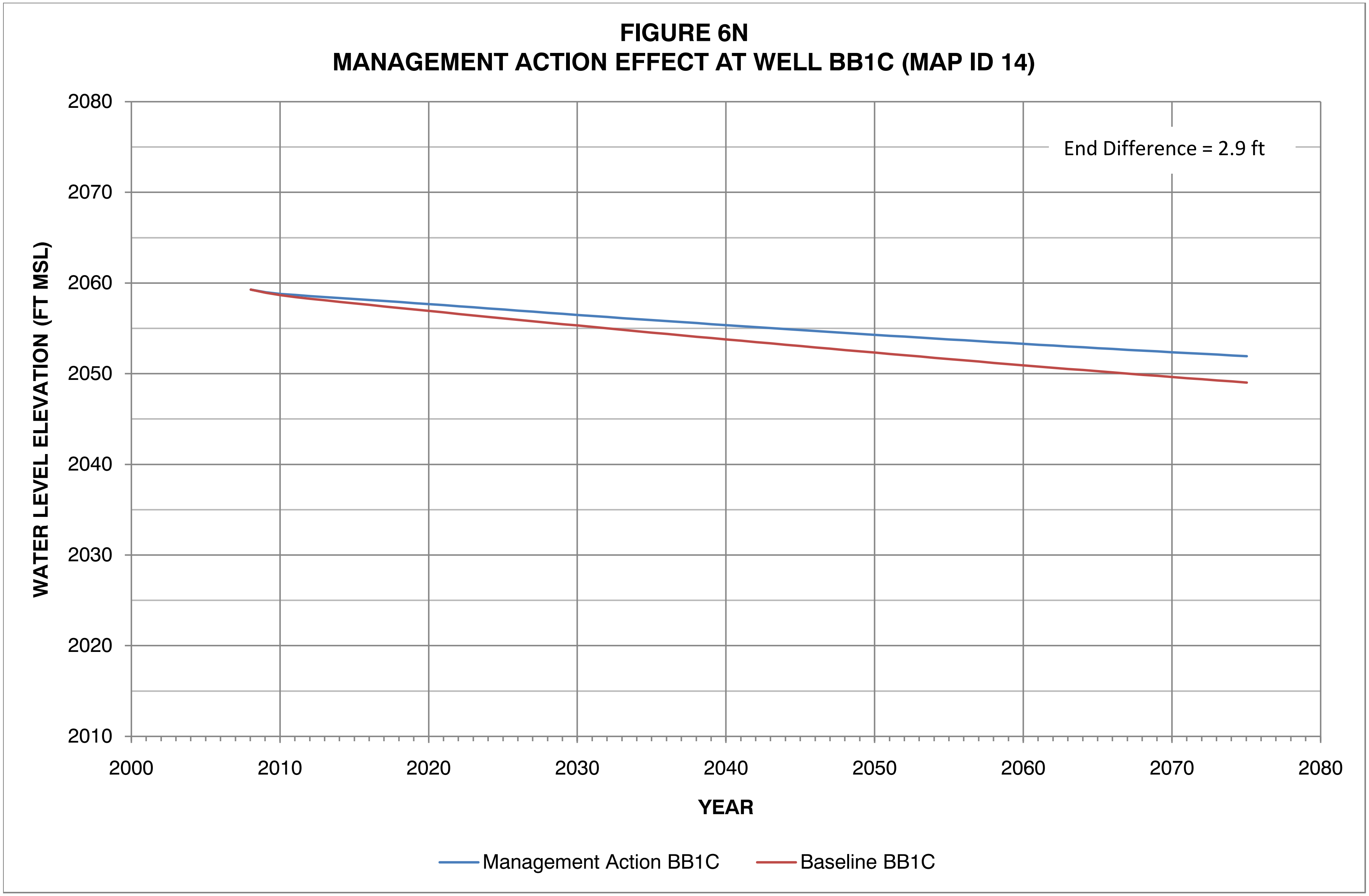


FIGURE 6N
MANAGEMENT ACTION EFFECT AT WELL BB1C (MAP ID 14)
End Difference = 2.9 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB1C
Baseline BB1C

MODEL

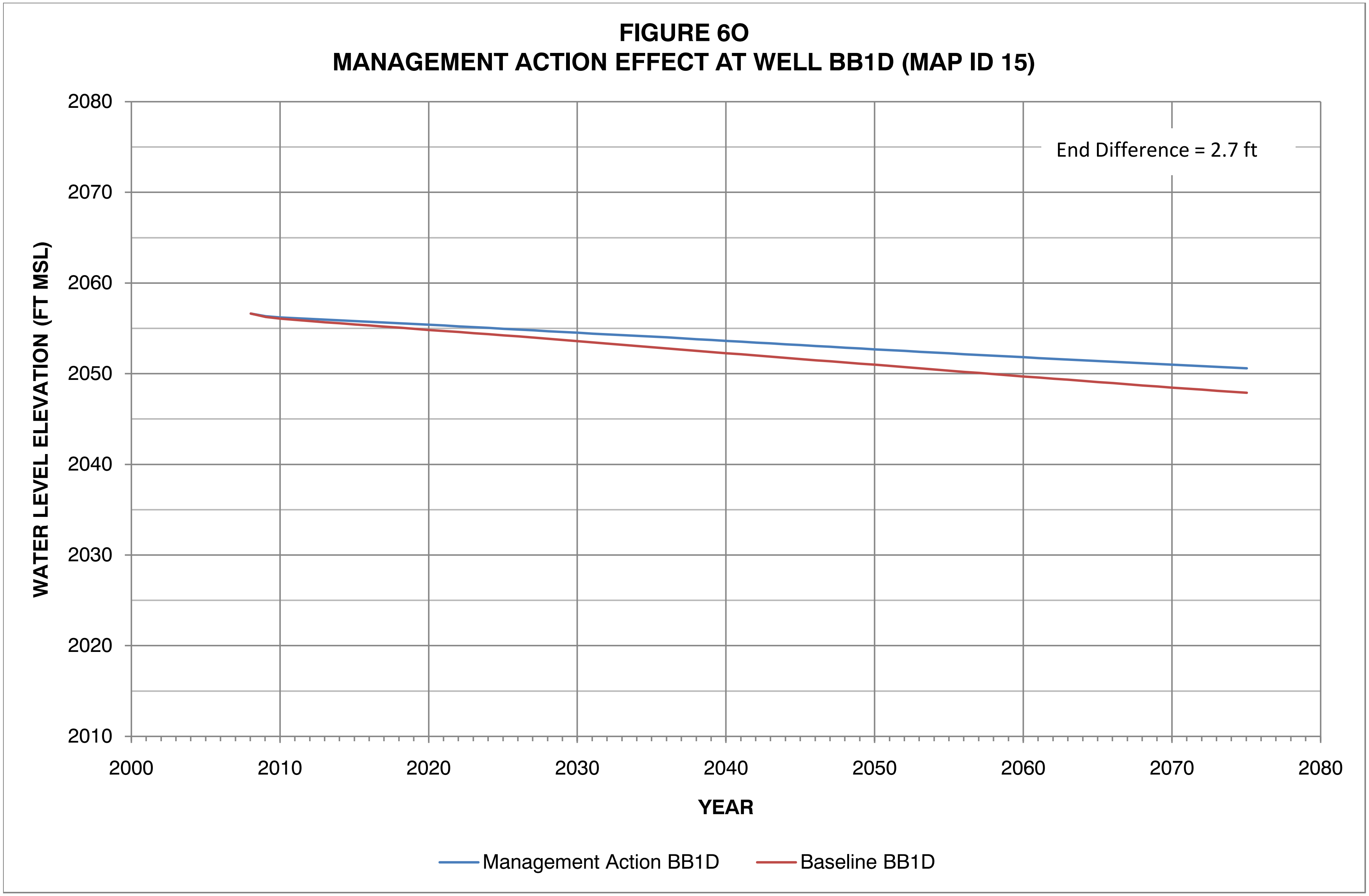


FIGURE 6O
MANAGEMENT ACTION EFFECT AT WELL BB1D (MAP ID 15)
End Difference = 2.7 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB1D
Baseline BB1D

MODEL

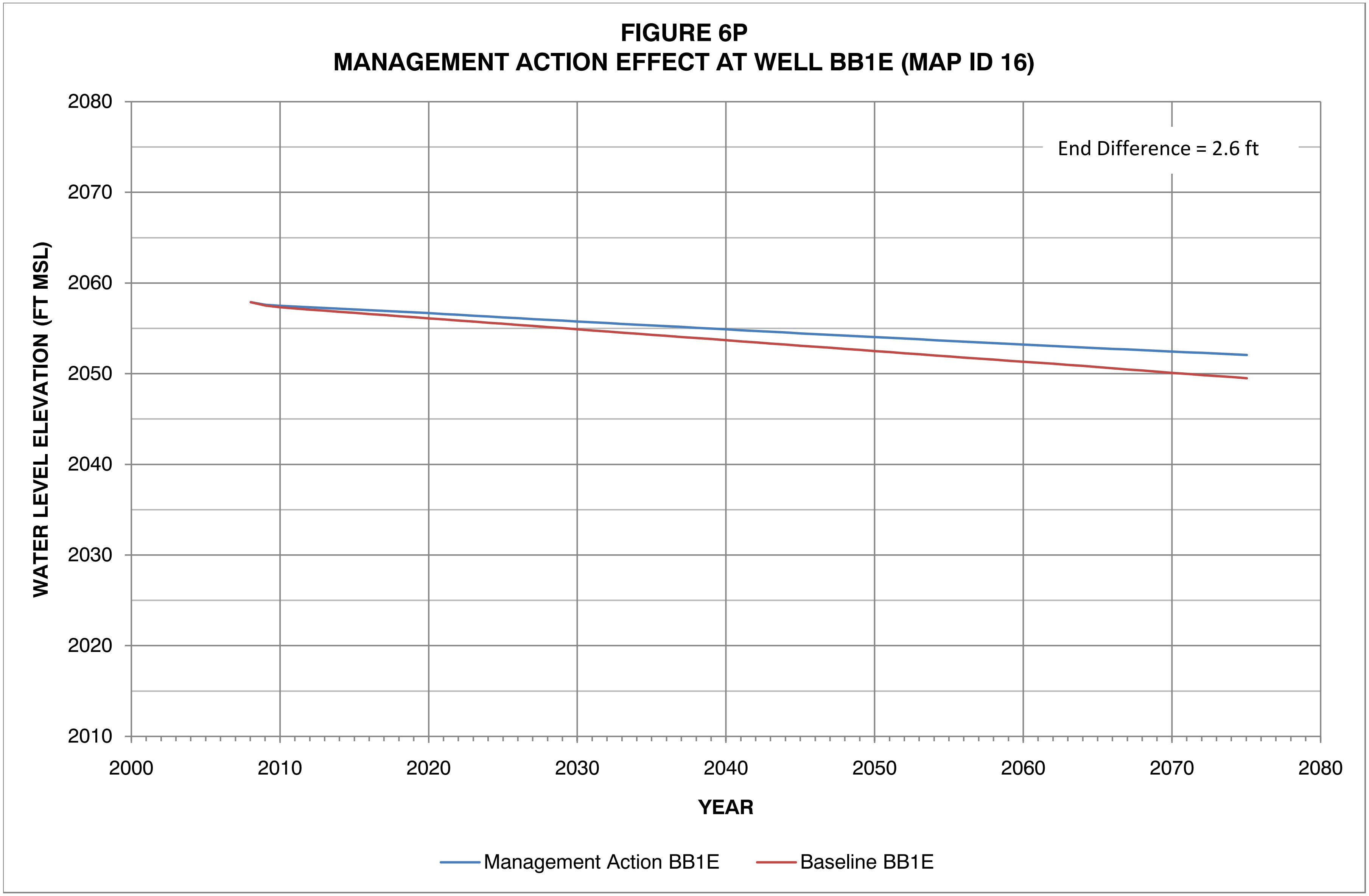


FIGURE 6P
MANAGEMENT ACTION EFFECT AT WELL BB1E (MAP ID 16)
End Difference = 2.6 ft
WATER LEVEL ELEVATION (FT MSL)
2080
2070
2060
2050
2040
2030
2020
2010
2000
2010
2020
2030
2040
2050
2060
2070
2080
YEAR
Management Action BB1E
Baseline BB1E

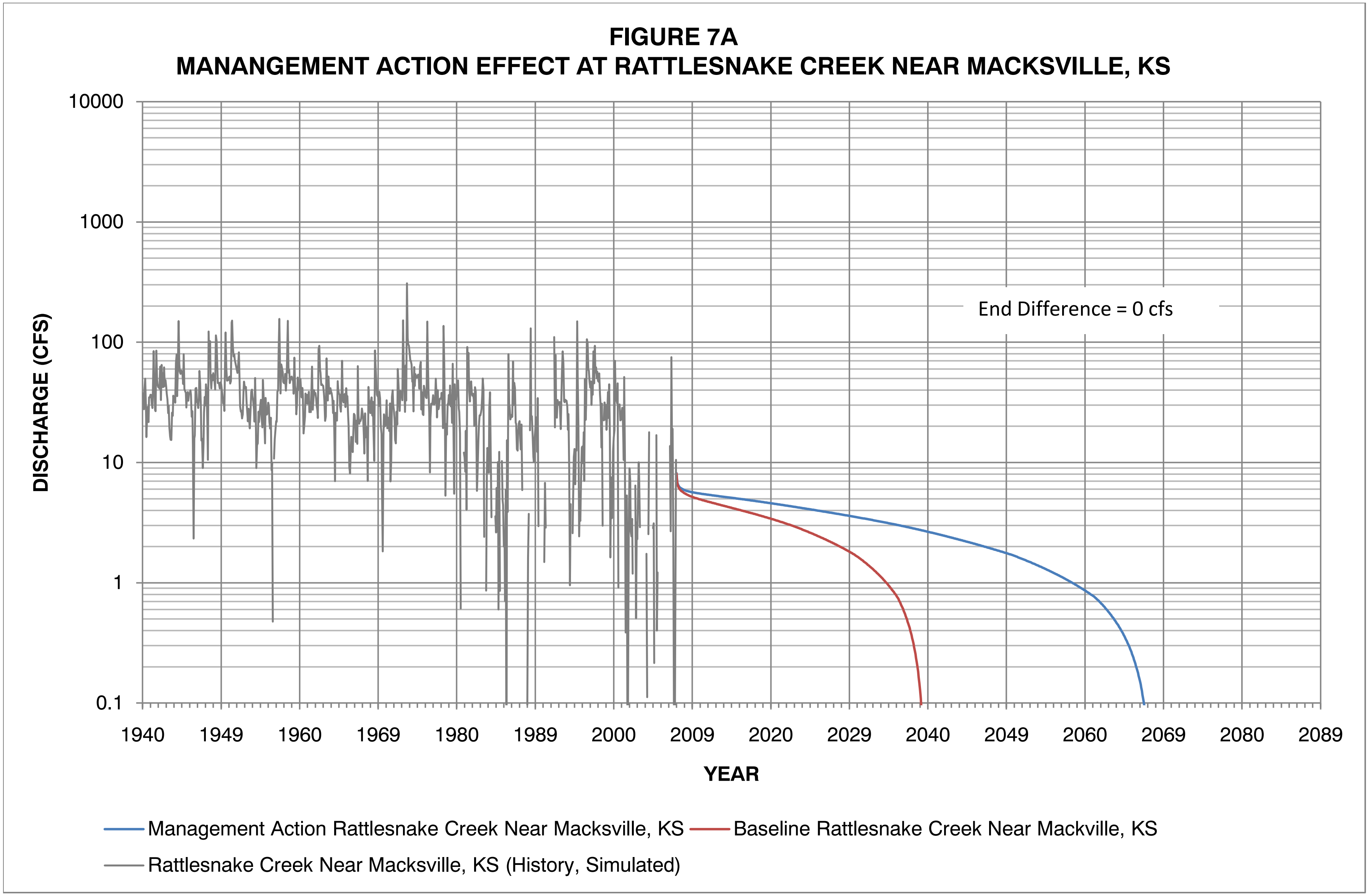


FIGURE 7A
MANANGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR MACKSVILLE, KS
DISCHARGE (CFS)
10000
1000
100
10
1
0.1
End Difference = 0 cfs
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
Management Action Rattlesnake Creek Near Macksville, KS
Baseline Rattlesnake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

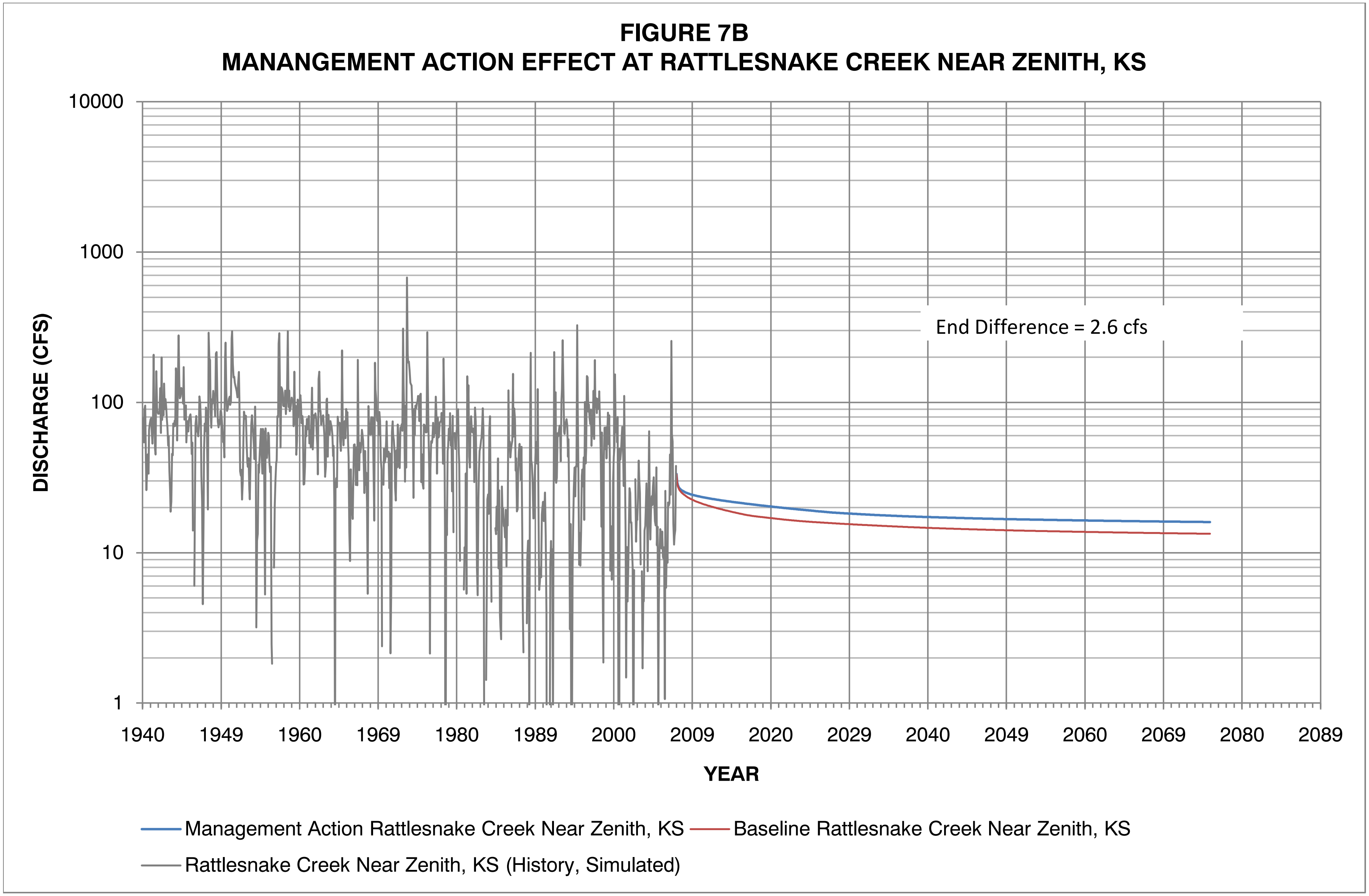
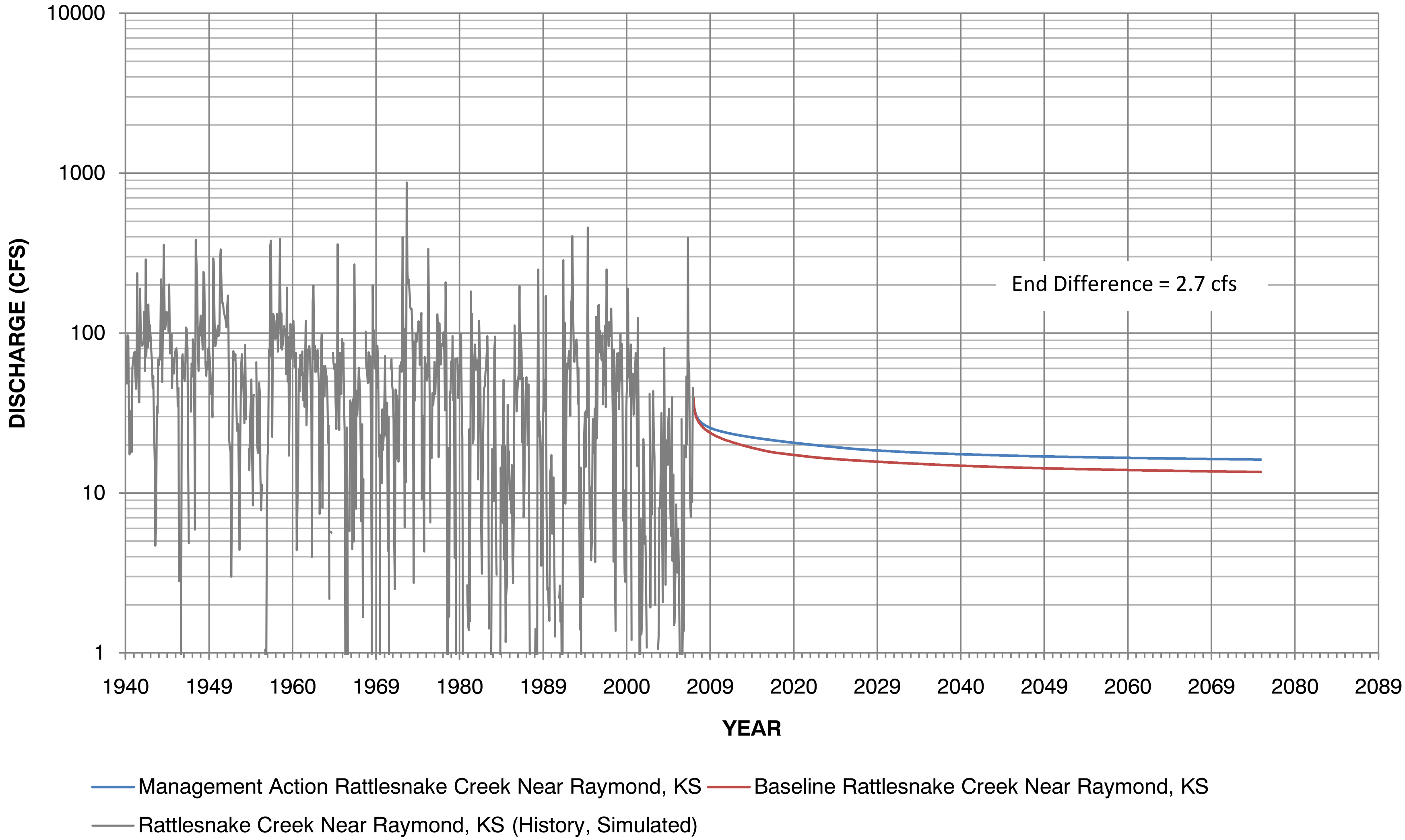


FIGURE 7B
MANANGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR ZENITH, KS
10000
1000
100
10
1
DISCHARGE (CFS)
End Difference = 2.6 cfs
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
Management Action Rattlesnake Creek Near Zenith, KS
Baseline Rattlesnake Creek Near Zenith, KS
Rattlesnake Creek Near Zenith, KS (History, Simulated)

MODEL

FIGURE 7C
MANANGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR RAYMOND, KS



MODEL

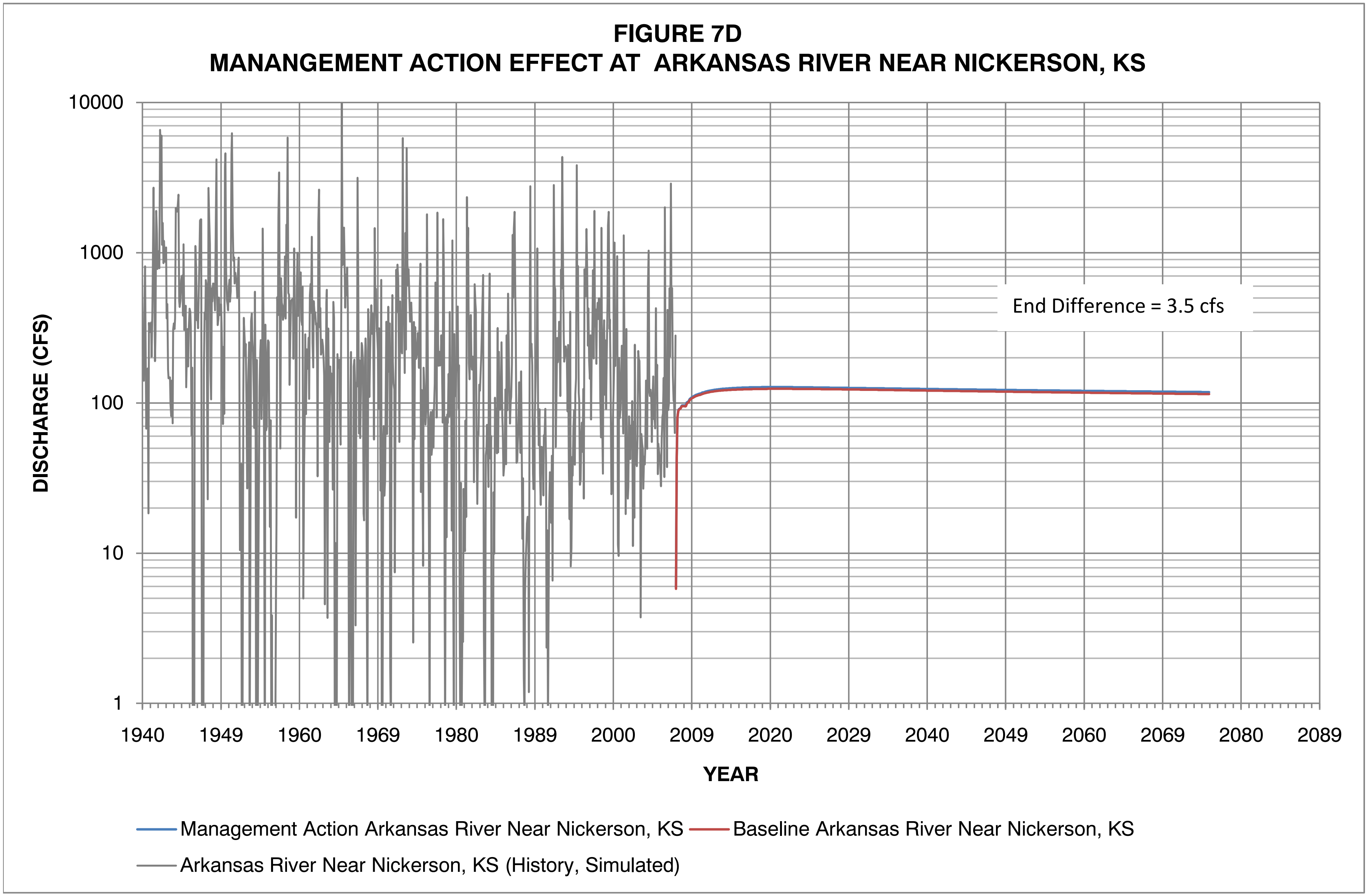
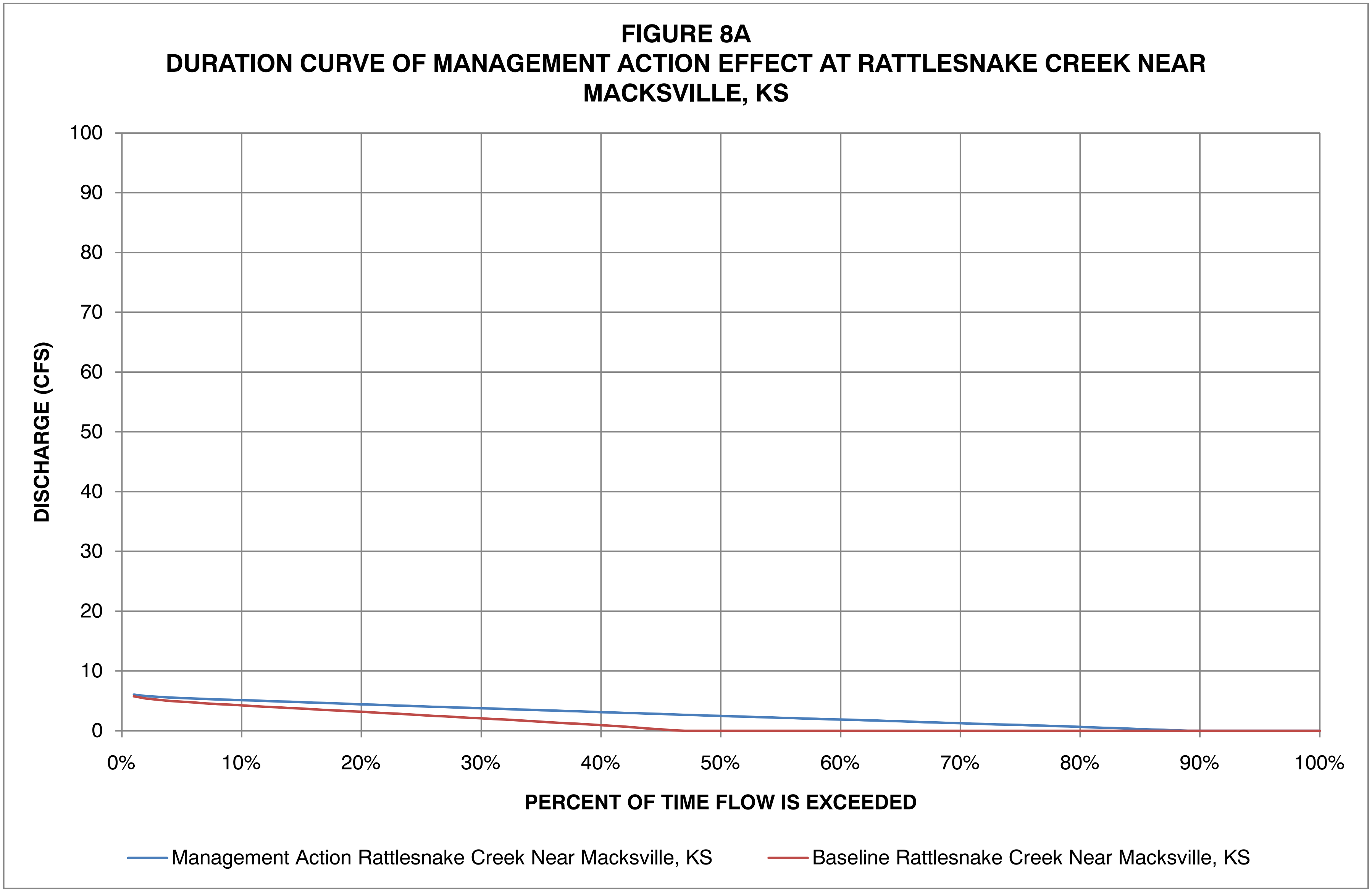


FIGURE 7D
MANANGEMENT ACTION EFFECT AT ARKANSAS RIVER NEAR NICKERSON, KS
10000
1000
100
10
1
DISCHARGE (CFS)
End Difference = 3.5 cfs
1940
1949
1960
1969
1980
1989
2000
2009
2020
2029
2040
2049
2060
2069
2080
2089
YEAR
Management Action Arkansas River Near Nickerson, KS
Baseline Arkansas River Near Nickerson,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

MODEL



ScenarioPlotsBprime.xlsb
BY
6/14/2010

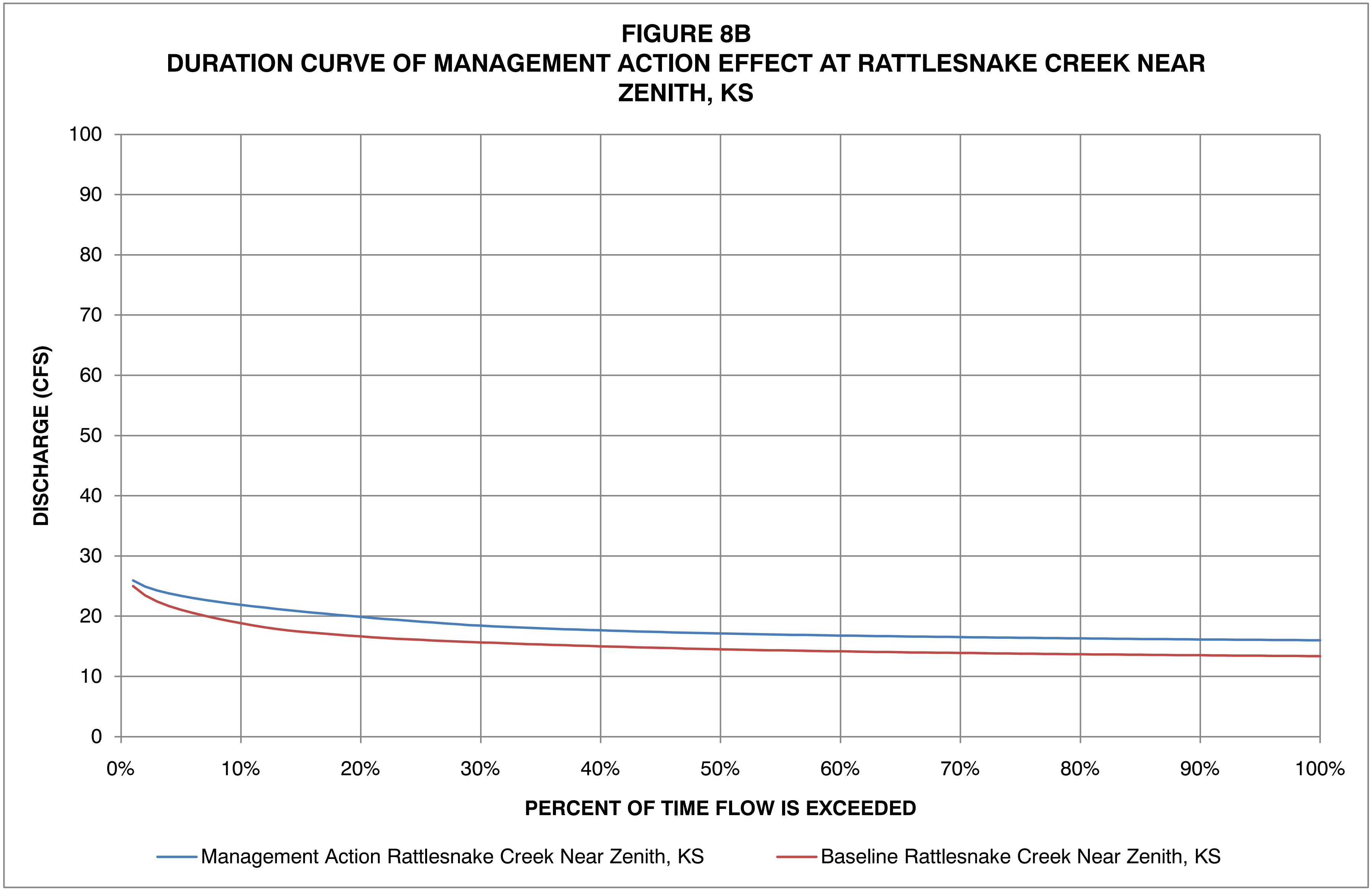
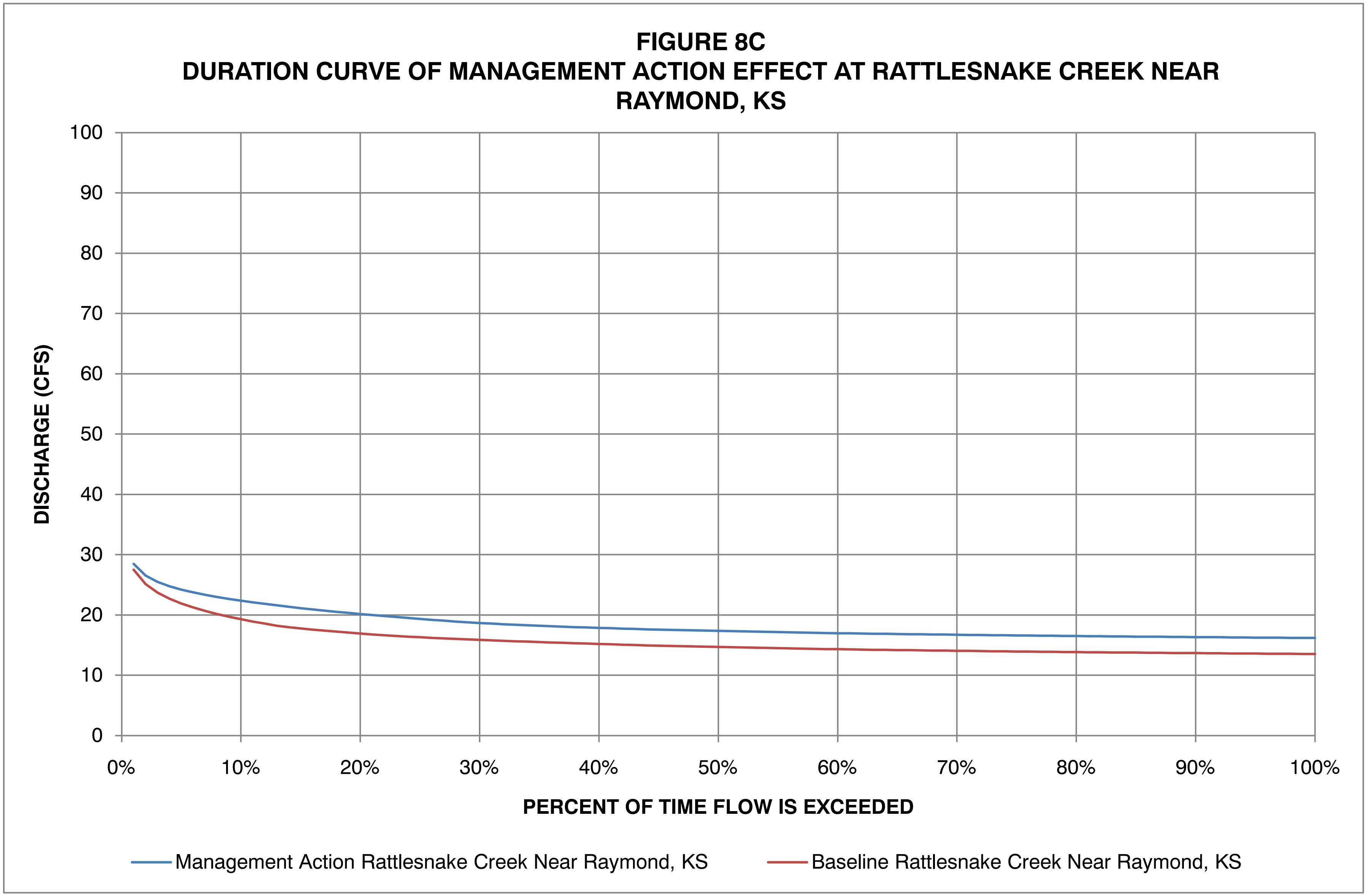


FIGURE 8B
DURATION CURVE OF MANAGEMENT ACTION EFFECT AT RATTLESNAKE CREEK NEAR ZENITH, KS
100
90
80
70
60
50
40
30
20
10
0
DISCHARGE (CFS)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT OF TIME FLOW IS EXCEEDED
Management Action Rattlesnake Creek Near Zenith, KS
Baseline Rattlesnake Creek Near Zenith,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

MODEL



ScenarioPlotsBprime.xlsb
BY
6/14/2010

MODEL

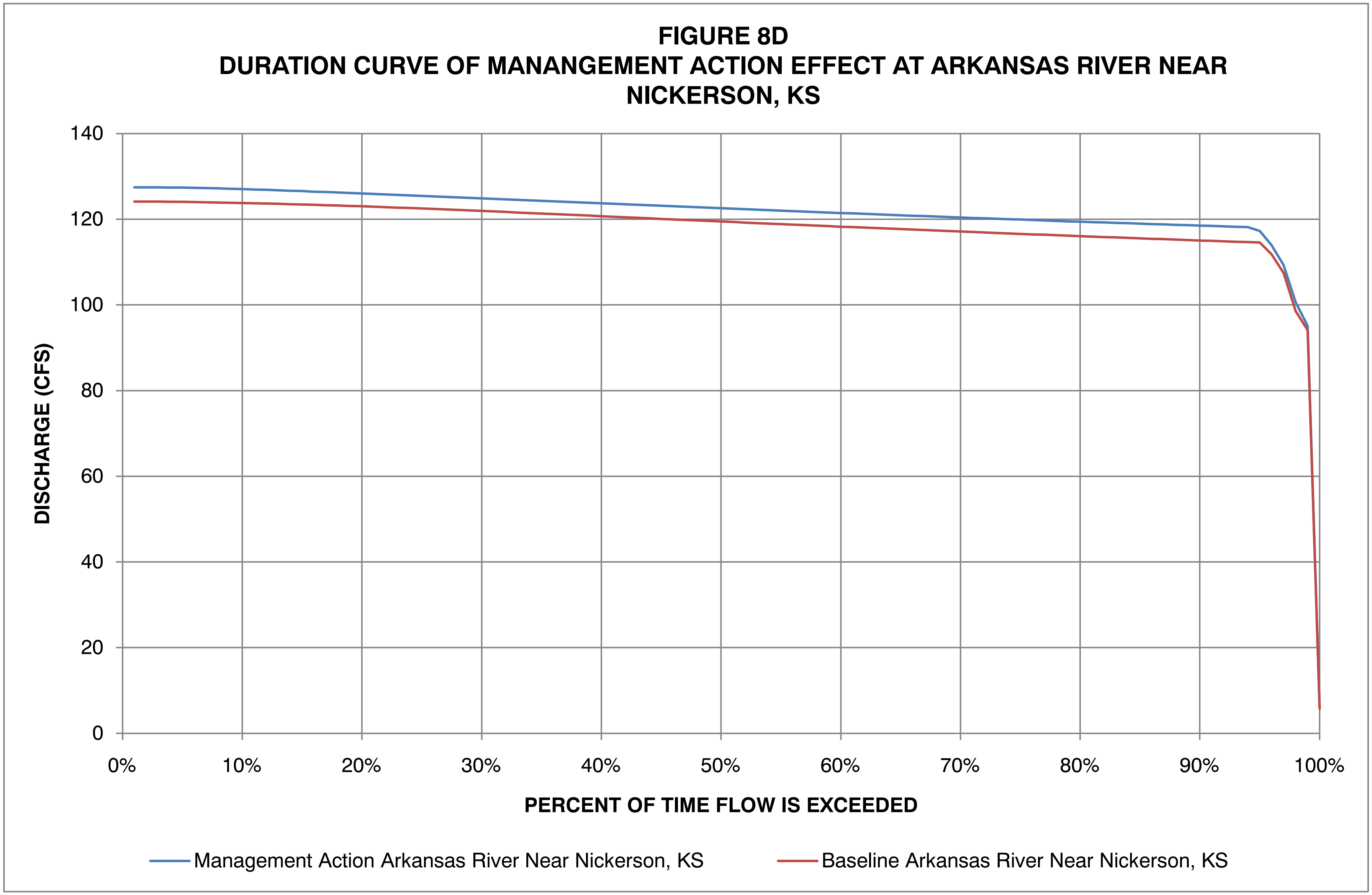


FIGURE 8D
DURATION CURVE OF MANANGEMENT ACTION EFFECT AT ARKANSAS RIVER NEAR NICKERSON, KS
DISCHARGE (CFS)
0
20
40
60
80
100
120
140
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
PERCENT OF TIME FLOW IS EXCEEDED
Management Action Arkansas River Near Nickerson, KS
Baseline Arkansas River Near Nickerson,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