Appendix 2

Effect of Increased Flow in the San Joaquin River on Stage, Velocity, and Water Fate, Water Years 1964 and 1988

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FSI 048007.2
November 24, 2008

INTRODUCTION

Various Delta stakeholders have discussed requiring measures that would increase flows in the lower portion of the San Joaquin River. The San Joaquin River Group Authority (SJRGA) is interested in how such increased flows would affect stage and velocity in the river, as well as the ultimate fate of San Joaquin River water (e.g., how much water is exported from the basin, how much leaves the Delta at its downstream boundary). SJRGA retained Flow Science Incorporated (Flow Science) to analyze these effects for potential future increases in San Joaquin River flow. This technical memorandum summarizes the results of Flow Science's analysis.

Flow Science's approach was to use the Fischer Delta Model (FDM) to simulate both a historical dry water year (1964) and a historical critically dry water year (1988), when impacts of increased flows on a change in salinity standards would be expected to be most significant. The model yielded water stage and velocity information at key locations in the Delta and tracked the ultimate fate of San Joaquin River water entering the Delta between April 15 and May 15.

MODEL OVERVIEW

Flow Science utilized the Fischer Delta Model (FDM)[1] to simulate hydrodynamics and the fate of an added tracer within the Delta for this project. The Fischer Delta Model (FDM) consists of two linked models: a hydrodynamic model and a water quality model. The hydrodynamic model (DELFLO) utilizes the fixed grid method of characteristics to simulate the hydrodynamics of the Delta. The water quality model (DELSAL) uses the Lagrangian method, in which the motions of parcels of water are followed through the Delta. The Lagrangian method uses no grid points, but the computational effort required is equivalent to the use of approximately 2,500 grid points in a finite element numerical model.

The FDM extends from a downstream boundary at the Carquinez Strait, upstream to Sacramento on the Sacramento River, and to Vernalis on the San Joaquin River. It also includes all tidally-influenced sloughs and accounts for inflows from all major tributaries, state and federal project exports, riparian diversions, channel depletion, and agricultural returns.

These models describe hydrodynamics and changes in water quality in the Delta as affected by changes in channel geometry, hydrology, and Delta operations. Changes in hydrology include changes in river flows and diversions and exports within and to the south of the Delta. The models are also designed to allow prediction of the effect of levee breaks, channel gate operations, changes in agricultural discharges, and changes in municipal discharges and withdrawals. The model is capable of simulating a partial year, a full year, or multiple years of hydrology.

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1 The model is operated by Flow Science Incorporated for the Hugo B. Fischer Estate.

DELFLO was initially calibrated by comparing model output at 40 stations to observations in the field and to the physical hydraulic model operated by the U. S. Army Corps of Engineers at Sausalito, California. Two conditions were studied: the tide of August 27-28, 1968, with a net Delta outflow of 2,500 cfs, and the tide of September 14-15, 1968, with a net Delta outflow of 17,200 cfs. The values of Manning's "n" for each channel were varied until a satisfactory agreement was obtained between the numerical model and physical model water surface elevations. In most cases, the field and physical model elevations agreed within 0.2-feet water surface elevation. DELFLO has also been recalibrated and verified using both extensive flow and stage measurements made by the USGS within the Delta in 1988 and in 1995.

DELSAL, the water quality model, has been calibrated by comparing model output for salinity to field data and verified using measured elemental tracer concentrations in the Delta. The Lagrangian method adopted in the model eliminates numerical dispersion, which is inherent in finite difference and finite element models and is difficult to reconcile with actual dispersion processes in the Delta. The model was designed to simulate salinity changes in the Delta, as affected by physical and hydrologic changes in the Delta, but it can also be used to determine the movement and dispersion of pollutants (or any mass-conserving, neutrally-buoyant particles) released from point sources. The FDM has also been verified by comparing FDM-computed "source fractions" (computations of the quantity of water located at specific interior Delta locations that originated from specific water sources) to measured source fractions. Measured source fractions were determined using elemental concentrations measured at specific points in the Delta over a one-year period beginning in March 1996.

The FDM has been successfully applied to the transport of total dissolved solids (TDS) and other neutral buoyant tracers in the Sacramento-San Joaquin Delta for over twenty years. The model has undergone continuous improvement over the years.

MODELING METHODOLOGY

Water years 1964 and 1988 were modeled in this study. Water year 1964 was a dry year in both the Sacramento and San Joaquin River basins, while 1988 was a critically dry year in both basins[2]. These years were selected as representative of hydrologic conditions in which the proposed SJR salinity changes are likely to have the largest effect.

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2 A dry water year is defined as having a water year index below 6.5 million acre-feet (Sacramento Valley) or below 2.5 million acre-feet (San Joaquin Valley). A critically dry water year is defined as having a water year index below 5.4 million acre-feet (Sacramento Valley) or below 2.1 million acre-feet (San Joaquin Valley) according to California Department of Water Resources criteria. 1964 was a dry year in both basins, while 1988 was a critically dry water year in both basins. See DWR's Chronological Reconstructed Sacramento and San Joaquin Valley Water year Hydrologic Classification Indices, available at http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

A total of twelve scenarios were modeled for this study. These scenarios were divided into four groups. The modeled scenarios are listed in Table 1.

Table 1. Modeled Scenarios

Group	Scenario Name	Description
1964 with HORB[1]	S64	Water Year 1964 base scenario
	S64+3k	Water Year 1964 base scenario plus 3,000 cfs added SJR inflow[2].
	S64+6k	Water Year 1964 base scenario plus 6,000 cfs added SJR inflow.
1988 with HORB	S88	Water Year 1988 base scenario
	S88+3k	Water Year 1988 base scenario plus 3,000 cfs added SJR inflow
	S88+6k	Water Year 1988 base scenario plus 6,000 cfs added SJR inflow
1964 without HORB	S64HORB0	Water Year 1964 base scenario, no HORB
	S64HORB0+3k	Water Year 1964 base scenario, no HORB, plus 3,000 cfs added SJR inflow
	S64HORB0+6k	Water Year 1964 base scenario, no HORB, plus 6,000 cfs added SJR inflow
1988 without HORB	S88HORB0	Water Year 1988 base scenario, no HORB
	S88HORB0+3k	Water Year 1988 base scenario, no HORB, plus 3,000 cfs added SJR inflow
	S88HORB0+6k	Water Year 1988 base scenario, no HORB, plus 6,000 cfs added SJR inflow

[1] "HORB": Head of Old River Barrier.
2 "SJR inflow": Inflow to the San Joaquin River at Vernalis.

The basic river and export flow rate data—based on CALSIM II simulations of Water Year 1964 (WY64) and WY88—were provided by Dan Steiner and have been used in previous modeling for the SJRGA. The simulated tracer concentrations in all rivers were set to zero, except that San Joaquin River flows entering the Delta from April 16 to May15 (inclusive) were simulated as carrying a tracer. The "fate" of the simulated tracer (i.e., the point at which that tracer is removed from or leaves the Delta) was recorded for each simulation, and results are presented as a fraction or percentage of the tracer added to the model domain. Gates and barriers were modeled according to current barrier operations based on information obtained from DWR[3]. Table 2 below summarizes the barrier operation schedules for both 1964 and 1988 for the HORB, the Old River Barrier at Tracy (ORB), the Middle River Barrier (MRB), and the Grant Line Canal Barrier (GLCB). The table shows the dates that the barriers were in place. Note that all of the simulations "1964 without HORB" and "1988 without HORB" assumed that the HORB was not installed during the simulation time period.

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3 E-mails from Andy Chu, Senior Water Resources Engineer, California Department of Water Resources, 1/13/05; Mark Holderman, Chief-Temporary Barriers Project, California Department of Water Resources, 1/27/05.

Table 2. Barrier Operations for Modeled Scenarios, Water Years 1964 and 1988

All scenarios	
HORB[a]	Apr. 16-May 15, Sep. 16-Sep. 30
ORB[b]	Apr. 16-Sep. 30
MRB[c]	Same as ORB
GLCB[d]	Same as ORB

a. HORB was simulated as spanning the full channel width at elevation 10 feet (all elevations reference NGVD29). The HORB was not simulated in the "without HORB" model runs.
b. ORB was simulated as spanning the full channel width at elevation 4 feet.
c. MRB was simulated as spanning the full channel width at elevation 3 feet.
d. GLCB was simulated as spanning the full channel width at elevation 3.5 feet.

Several additional assumptions were made, as follows:

- No culverts or notches were placed in the barriers (HORB, ORB, MRB, and GLCB).
- Clifton Court Forebay gates were assumed to be open all of WY64 and WY88.
- The Delta Cross Channel (DXC) gates were simulated as open from the first of each month until the month's "open days" quota was spent, where the number of open days were specified by the CALSIM II modeling. This is in accordance with DWR's modeling practices[4].
- All CCWD diversions are assumed to be through Rock Slough Pumping Plant #1 (i.e., no Old River diversions).
- Monthly data from CALSIM II were transformed to daily data by assigning each day its corresponding month's average value (i.e., flow was a constant value for each day in a given month).
- Diversions, exports, and river flow rates used as model input are not actual WY64 and WY88 historical flows, but those specified in CALSIM II runs provided by Dan Steiner.

Flow velocity and water surface elevation (i.e., stage) model results were stored at the following five monitoring stations (see Figure 1) every 15 minutes: 117 (at the middle of Victoria Canal, 15,300 ft west of the Middle River barrier), 130 (Old River at Highway 4), 136 (in the Grant Line Canal, 16,200 ft west of the Grant Line Canal barrier), 137 (in Old River near Tracy, 24,100 ft east of the barrier in the Old River near Tracy), and 141 (in Old River, 12,100 ft west of the Head of Old River).

4 Telephone conversation with Andy Chu, Senior Water Resources Engineer, California Department of Water Resources, 1/18/05.

RESULTS

Flow Velocity

Flow velocity results at the five monitoring stations for all twelve scenarios for the months of April and May (April 1 through May 30, inclusive) were used to compute cumulative probability diagrams showing both the 25-hour average flow velocity[5] and the 15-minute flow velocity. Cumulative probability diagrams of the daily average flow velocity for each group of scenarios are shown in Tables 3 and 4 and Figures 2 through 6, while cumulative probability diagrams of 15-minute flow velocities are shown in Tables 5 and 6 and Figures 7 through 11. Time series plots of flow velocity for the five monitoring stations for each of the twelve scenarios are shown in Figures A-1 through A-60 of Appendix A. The data summarized in Tables 3 through 6 and Figures 2 through 11 were derived from the flow velocity data shown in Figures A-1 through A-60.

For example, Figure 2 shows the cumulative probability statistics for the mean (25-hour averaged) flow velocity in Victoria Canal for all scenarios modeled for the period of April and May in each modeled year. (Note that the time series of flow velocity for Victoria Canal for Scenario S64 is shown in Figure A-1.) The tidally-averaged flow in Victoria Canal is always negative, i.e., toward the pumps in the south Delta. Flows in 1964 are more strongly toward the pumps (i.e., exhibit higher net velocities) than flows in 1988. The three bars on the left-most side of Figure 2 illustrate the effect of adding additional San Joaquin River flows to the Delta; the 25-hour averaged flow velocity becomes larger as San Joaquin River flows increase and as more water is transported through Victoria Canal. As shown by the next set of bars for 1964, the removal of the HORB has little effect on flow velocities in Victoria Canal. Similar flow velocities are predicted for April and May 1988, and again the removal of the HORB has little effect on velocities in Victoria Canal.

Results for Grant Line Canal (Figure 3) are similar; net flow velocities are always westward, and velocities increase as additional San Joaquin River flow is added to the Delta. The effect of the barrier in Grant Line Canal is clear, as flows are near zero for approximately half the time period of April-May. As shown in Figure A-3 of Appendix A, the installation of the barrier on April 15 has the effect of reducing the amplitude of flows in the channel, and while water rises and falls with the tides, there is little net water movement. Modeled flow velocities in Old River near Tracy and at the Head of Old River are similar to those in Grant Line Canal, and are strongly influenced by the construction of the interior Delta barriers. Average flows in Old River at Highway 4 (Figure 6) resemble those in Victoria Canal, with 25-hour averaged flows always to the north, and with flow velocities increasing as additional San Joaquin River flows are added to the Delta. Because San Joaquin River flows were added to the Delta, but exports and diversions were unchanged, more water passes these stations in the added-flow scenarios as the added San Joaquin River water flows

[5] A 25-hour average approximates a tidal average. A true tidal average would have a period of 24 hours and 52 minutes but cannot be computed using 15-minute model output.

through the Delta and toward the Bay. Note that in each of these figures, flow rates for the lowest 50th percentile flows remain largely unchanged.

The amplitude of the tidal flows is shown in the cumulative probability diagrams that portray the 15-minute flow rates. For example, in Figure 7 flow velocities in Victoria Canal are between -0.7 and +0.4 feet per second (fps) during the 1964 simulations, where a negative flow velocity indicates flow toward the southwest (i.e., toward the pumps). The cumulative probability diagrams for the 15-minute flow velocities in Victoria Canal do not change as additional San Joaquin River flow is added to the Delta. Cumulative probability diagrams of flow velocity in Grant Line Canal, in Old River near Tracy, and at the head of Old River (Figures 8, 9, and 10) show that the flow velocities increase as more San Joaquin River flow is added to the Delta, consistent with the tidally-averaged flows shown in Figures 3, 4, and 5. As shown in Figure 11, the tidal amplitude in Old River at Highway 4 is largely unchanged, even though net flows increase, as shown in Figure 6, or whether the HORB is in place or not.

Table 3. Cumulative probability for 25-hr running average flow velocity data during April and May, 1964

Cumulative probability	Scenarios						Exceedance probability
	S64	S64 +3000	S64 +6000	S64HORB0	S64HORB0 +3000	S64HORB0 +6000	
	Stn. 117 (Victoria Canal, positive northeastward)						
1%	-0.167	-0.177	-0.190	-0.168	-0.179	-0.193	99%
5%	-0.158	-0.168	-0.181	-0.159	-0.170	-0.184	95%
25%	-0.147	-0.155	-0.162	-0.147	-0.156	-0.163	75%
50%	-0.140	-0.142	-0.143	-0.140	-0.142	-0.143	50%
75%	-0.133	-0.135	-0.137	-0.133	-0.135	-0.137	25%
95%	-0.123	-0.125	-0.126	-0.123	-0.125	-0.127	5%
99%	-0.119	-0.120	-0.122	-0.119	-0.120	-0.121	1%
	Stn. 136 (Grant Line Canal, positive westward)						
1%	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	99%
5%	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	95%
25%	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	75%
50%	0.002	0.002	0.002	0.002	0.002	0.002	50%
75%	0.038	0.051	0.067	0.057	0.092	0.131	25%
95%	0.161	0.294	0.402	0.167	0.316	0.435	5%
99%	0.174	0.298	0.408	0.185	0.321	0.440	1%
	Stn. 137 (Old R near Tracy, positive westward)						
1%	-0.006	-0.003	-0.002	-0.016	-0.016	-0.013	99%

5%	-0.003	-0.002	-0.002	-0.006	-0.004	-0.003	95%
25%	-0.001	-0.001	-0.001	-0.001	0.000	0.000	75%
50%	-0.001	-0.001	0.000	0.001	0.001	0.000	50%
75%	0.043	0.061	0.080	0.065	0.123	0.170	25%
95%	0.132	0.247	0.332	0.136	0.266	0.355	5%
99%	0.147	0.251	0.334	0.163	0.273	0.361	1%
	Stn. 141 (Head of Old R, positive westward)						
1%	-0.050	-0.018	-0.018	-0.144	-0.145	-0.120	99%
5%	-0.016	-0.001	-0.013	-0.042	-0.028	-0.016	95%
25%	0.000	0.000	0.000	0.000	0.006	0.006	75%
50%	0.001	0.001	0.001	0.021	0.016	0.012	50%
75%	0.400	0.569	0.742	0.446	0.829	1.174	25%
95%	0.587	1.258	1.768	0.615	1.371	1.906	5%
99%	0.725	1.316	1.801	0.837	1.476	1.996	1%
	Stn. 130 (Old R @ Hwy 4, positive northward)						
1%	-0.464	-0.461	-0.459	-0.464	-0.461	-0.459	99%
5%	-0.448	-0.445	-0.443	-0.448	-0.445	-0.443	95%
25%	-0.420	-0.417	-0.415	-0.420	-0.417	-0.415	75%
50%	-0.399	-0.395	-0.393	-0.398	-0.395	-0.393	50%
75%	-0.363	-0.355	-0.345	-0.361	-0.337	-0.292	25%
95%	-0.268	-0.149	-0.048	-0.264	-0.129	-0.020	5%
99%	-0.247	-0.137	-0.034	-0.241	-0.116	-0.007	1%

Table 4. Cumulative probability for 25-hour running average flow velocity data during April and May, 1988

Cumulative probability	Scenarios						Exceedance probability
	S88	S88 +3000	S88 +6000	S88HORB0	S88HORB0 +3000	S88HORB0 +6000	
	Stn. 117 (Victoria Canal, positive northeastward)						
1%	-0.157	-0.169	-0.183	-0.157	-0.172	-0.186	99%
5%	-0.148	-0.159	-0.172	-0.148	-0.161	-0.175	95%
25%	-0.132	-0.140	-0.149	-0.132	-0.141	-0.151	75%
50%	-0.115	-0.118	-0.120	-0.115	-0.118	-0.120	50%
75%	-0.098	-0.100	-0.102	-0.098	-0.100	-0.102	25%
95%	-0.075	-0.078	-0.080	-0.075	-0.078	-0.080	5%
99%	-0.070	-0.072	-0.075	-0.070	-0.072	-0.074	1%
	Stn. 136 (Grant Line Canal, positive westward)						
1%	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	99%

5%	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	95%
25%	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	75%
50%	0.002	0.002	0.002	0.002	0.002	0.002	50%
75%	0.032	0.046	0.066	0.057	0.101	0.136	25%
95%	0.168	0.296	0.409	0.174	0.319	0.442	5%
99%	0.190	0.314	0.424	0.196	0.338	0.457	1%
	Stn. 137 (Old R near Tracy, positive westward)						
1%	-0.011	-0.011	-0.010	-0.014	-0.016	-0.014	99%
5%	-0.009	-0.008	-0.008	-0.007	-0.004	-0.002	95%
25%	-0.004	-0.003	-0.002	-0.002	-0.001	-0.001	75%
50%	-0.001	-0.001	-0.001	0.002	0.001	0.000	50%
75%	0.072	0.095	0.117	0.072	0.129	0.175	25%
95%	0.136	0.246	0.336	0.141	0.265	0.359	5%
99%	0.147	0.256	0.342	0.164	0.275	0.366	1%
	Stn. 141 (Head of Old R, positive westward)						
1%	-0.068	-0.032	0.000	-0.127	-0.148	-0.134	99%
5%	-0.024	-0.014	0.000	-0.048	-0.024	-0.009	95%
25%	0.001	0.001	0.001	0.013	0.012	0.011	75%
50%	0.003	0.003	0.018	0.038	0.027	0.020	50%
75%	0.552	0.785	0.976	0.499	0.907	1.242	25%
95%	0.618	1.260	1.796	0.647	1.380	1.934	5%
99%	0.767	1.334	1.834	0.862	1.493	2.014	1%
	Stn. 130 (Old R @ Hwy 4, positive northward)						
1%	-0.420	-0.417	-0.415	-0.419	-0.417	-0.414	99%
5%	-0.394	-0.389	-0.386	-0.392	-0.388	-0.386	95%
25%	-0.340	-0.337	-0.335	-0.340	-0.336	-0.333	75%
50%	-0.291	-0.283	-0.279	-0.290	-0.282	-0.279	50%
75%	-0.249	-0.213	-0.209	-0.246	-0.211	-0.202	25%
95%	-0.209	-0.095	0.010	-0.204	-0.073	0.038	5%
99%	-0.170	-0.061	0.041	-0.165	-0.039	0.069	1%

Table 5. Cumulative probability for 15-min flow velocity data during April and May, 1964

Cumulative probability							Excedance Probability
	Scenarios						
	S64	S64 +3000	S64 +6000	S64HORB0	S64HORB0 +3000	S64HORB0 +6000	
	Stn. 117 (Victoria Canal, positive northeastward)						
1%	-0.726	-0.731	-0.733	-0.726	-0.731	-0.732	99%

5%	-0.622	-0.628	-0.633	-0.623	-0.631	-0.633	95%
25%	-0.467	-0.473	-0.478	-0.467	-0.474	-0.479	75%
50%	-0.195	-0.185	-0.169	-0.193	-0.184	-0.166	50%
75%	0.200	0.194	0.187	0.200	0.194	0.187	25%
95%	0.368	0.358	0.356	0.368	0.357	0.356	5%
99%	0.432	0.429	0.425	0.433	0.429	0.425	1%
	Stn. 136 (Grant Line Canal, positive westward)						
1%	-0.546	-0.447	-0.366	-0.535	-0.421	-0.360	99%
5%	-0.407	-0.348	-0.305	-0.403	-0.337	-0.295	95%
25%	-0.169	-0.146	-0.121	-0.167	-0.138	-0.113	75%
50%	0.043	0.064	0.081	0.043	0.068	0.087	50%
75%	0.176	0.182	0.191	0.176	0.185	0.195	25%
95%	0.716	0.799	0.867	0.720	0.812	0.885	5%
99%	0.774	0.861	0.933	0.780	0.877	0.954	1%
	Stn. 137 (Old R near Tracy, positive westward)						
1%	-0.138	-0.035	-0.015	-0.140	-0.035	-0.019	99%
5%	-0.090	-0.024	-0.010	-0.092	-0.026	-0.014	95%
25%	-0.003	-0.002	-0.001	-0.040	-0.014	-0.007	75%
50%	-0.001	-0.001	-0.001	-0.006	0.008	0.006	50%
75%	0.032	0.033	0.063	0.062	0.040	0.084	25%
95%	0.338	0.418	0.493	0.347	0.435	0.513	5%
99%	0.369	0.450	0.527	0.378	0.468	0.550	1%
	Stn. 141 (Head of Old R, positive westward)						
1%	-0.598	-0.247	-0.144	-0.678	-0.292	-0.173	99%
5%	-0.536	-0.195	-0.105	-0.572	-0.230	-0.119	95%
25%	0.000	0.000	0.000	-0.301	-0.115	-0.060	75%
50%	0.001	0.001	0.001	0.105	0.107	0.065	50%
75%	0.377	0.580	0.716	0.582	0.908	1.373	25%
95%	0.979	1.490	1.984	1.074	1.607	2.130	5%
99%	1.048	1.586	2.077	1.174	1.709	2.225	1%
	Stn. 130 (Old R @ Hwy 4, positive northward)						
1%	-1.795	-1.775	-1.753	-1.791	-1.768	-1.745	99%
5%	-1.559	-1.532	-1.509	-1.556	-1.525	-1.496	95%
25%	-1.104	-1.088	-1.070	-1.103	-1.084	-1.066	75%
50%	-0.494	-0.437	-0.381	-0.493	-0.424	-0.365	50%
75%	0.424	0.435	0.440	0.424	0.437	0.442	25%
95%	0.845	0.932	1.000	0.849	0.947	1.017	5%
99%	0.959	1.036	1.086	0.959	1.047	1.105	1%

Table 6. Cumulative probability for 15-min flow velocity data during April and May, 1988

Cumulative probability	Scenarios						Exceedance probability
	S88	S88 +3000	S88 +6000	S88HORB0	S88HORB0 +3000	S88HORB0 +6000	
	Stn. 117 (Victoria Canal, positive northeastward)						
1%	-0.624	-0.627	-0.629	-0.624	-0.626	-0.629	99%
5%	-0.526	-0.534	-0.541	-0.527	-0.534	-0.542	95%
25%	-0.424	-0.430	-0.437	-0.425	-0.431	-0.437	75%
50%	-0.119	-0.121	-0.117	-0.120	-0.121	-0.117	50%
75%	0.175	0.168	0.162	0.175	0.168	0.161	25%
95%	0.365	0.354	0.348	0.365	0.353	0.347	5%
99%	0.462	0.459	0.457	0.461	0.460	0.455	1%
	Stn. 136 (Grant Line Canal, positive westward)						
1%	-0.564	-0.470	-0.357	-0.552	-0.443	-0.345	99%
5%	-0.436	-0.341	-0.290	-0.427	-0.329	-0.284	95%
25%	-0.207	-0.185	-0.161	-0.206	-0.179	-0.149	75%
50%	0.041	0.061	0.084	0.042	0.068	0.090	50%
75%	0.180	0.185	0.192	0.180	0.186	0.195	25%
95%	0.738	0.821	0.887	0.743	0.834	0.905	5%
99%	0.821	0.900	0.972	0.830	0.919	0.996	1%
	Stn. 137 (Old R near Tracy, positive westward)						
1%	-0.154	-0.047	-0.017	-0.149	-0.043	-0.023	99%
5%	-0.100	-0.028	-0.011	-0.099	-0.029	-0.014	95%
25%	-0.012	-0.006	-0.004	-0.042	-0.014	-0.007	75%
50%	-0.002	-0.002	-0.001	-0.006	0.007	0.006	50%
75%	0.038	0.034	0.069	0.066	0.039	0.078	25%
95%	0.351	0.431	0.502	0.360	0.447	0.524	5%
99%	0.396	0.473	0.547	0.406	0.493	0.573	1%
	Stn. 141 (Head of Old R, positive westward)						
1%	-0.638	-0.293	-0.125	-0.721	-0.365	-0.204	99%
5%	-0.537	-0.207	-0.070	-0.594	-0.242	-0.126	95%
25%	0.000	0.001	0.001	-0.285	-0.099	-0.048	75%
50%	0.002	0.003	0.003	0.103	0.112	0.072	50%
75%	0.403	0.769	0.949	0.617	0.858	1.445	25%
95%	1.028	1.533	2.022	1.119	1.649	2.166	5%
99%	1.135	1.657	2.130	1.216	1.768	2.275	1%
	Stn. 130 (Old R @ Hwy 4, positive northward)						
1%	-1.668	-1.610	-1.753	-1.661	-1.593	-1.545	99%

5%	-1.333	-1.296	-1.509	-1.325	-1.294	-1.275	95%
25%	-1.018	-0.986	-1.070	-1.015	-0.980	-0.947	75%
50%	-0.302	-0.242	-0.381	-0.302	-0.238	-0.186	50%
75%	0.377	0.386	0.440	0.378	0.387	0.394	25%
95%	0.878	0.962	1.000	0.879	0.975	1.046	5%
99%	1.004	1.064	1.086	1.008	1.076	1.134	1%

Water Surface Elevation (Stage)

Computed water surface elevation (i.e., stage) data at the five monitoring stations for all twelve scenarios for the months of April and May (April 1 to May 30, inclusive) were used to generate both tidally-averaged and 15-minute cumulative probability plots, as shown in Tables 7 and 8 and Figures 12 through 16 and Tables 9 and 10 and Figures 17 through 21, respectively. The data are the water surface elevation relative to National Geodetic Vertical Datum (1929) (NGVD-1929) level. Detailed model output showing stage at each of the five monitoring stations for all twelve scenarios is shown in Figures A-61 to A-120 of Appendix A.

Figure 12 presents the tidally-averaged stage at Victoria Canal for all scenarios modeled. As San Joaquin River flow rates increase and more water is conveyed through Victoria Canal, the tidally-averaged stage rises. The removal of the HORB has little effect on the tidally-averaged stage in Victoria Canal. Figure 13 shows that the tidally-averaged stage in Grant Line Canal increases slightly (up to 0.2 feet) as San Joaquin River flows increase; the HORB has little effect on stage. As shown in Figures 14 and 15, the tidally-averaged stage in Old River near Tracy and at the head of Old River increases significantly as San Joaquin River inflows to the Delta increase; this impact is expected, and reflects the increase in the hydraulic grade line (head) as additional flow enters the Delta. Figure 16 shows that the increase in tidally-averaged stage at Old River near Highway 4 (i.e., more distant from the location at which San Joaquin River flows enter the Delta) is less than 0.2 feet, even though significant additional flow passes this location, as shown in Figure 6.

The tidal amplitude distributions are illustrated in Figures 17-21, which provide cumulative probability plots for 15-minute values of stage. As shown in Figures 17 and 18, the tidal amplitude in Victoria Canal and Grant Line Canal, respectively, are relatively invariant and do not change significantly in response to either added San Joaquin River inflows or the removal of the HORB. Consistent with the net stage changes shown in Figures 14 and 15, Figures 19 and 20 demonstrate that the 15-minute stage in Old River near Tracy and at the head of Old River rise significantly as inflows increase and the HORB is removed. In Old River near Tracy (Figure 19) in 1988, there is a significant change (increase) in surface elevation in the simulations where the HORB was removed. As with the tidally-averaged stage in Old River at Highway 4 (Figure 16), Figure 21 shows that the 15-minute stage at this location is relatively constant, even when San Joaquin River inflows are added, or when the HORB is removed.

Table 7. Cumulative probability for 25-hr running average surface elevation data during April and May, 1964

Cumulative probability	Scenarios						Exceedance probability
	S64	S64 +3000	S64 +6000	S64HORB0	S64HORB0 +3000	S64HORB0 +6000	
	Stn. 117 (Victoria Canal)						
1%	0.76	0.81	0.85	0.76	0.81	0.85	99%
5%	0.80	0.85	0.90	0.80	0.85	0.90	95%
25%	0.91	0.96	1.01	0.91	0.96	1.01	75%
50%	1.04	1.11	1.17	1.04	1.12	1.18	50%
75%	1.19	1.25	1.30	1.19	1.25	1.31	25%
95%	1.32	1.36	1.41	1.32	1.37	1.42	5%
99%	1.38	1.43	1.47	1.38	1.43	1.48	1%
	Stn. 136 (Grant Line Canal)						
1%	0.68	0.73	0.78	0.68	0.73	0.78	99%
5%	0.73	0.78	0.82	0.73	0.78	0.82	95%
25%	0.84	0.89	0.94	0.84	0.89	0.94	75%
50%	0.99	1.08	1.16	0.99	1.09	1.16	50%
75%	1.14	1.21	1.28	1.15	1.22	1.29	25%
95%	1.25	1.32	1.40	1.25	1.33	1.41	5%
99%	1.31	1.37	1.47	1.31	1.37	1.50	1%
	Stn. 137 (Old R near Tracy)						
1%	0.79	1.23	1.63	1.08	1.42	1.68	99%
5%	0.88	1.32	1.66	1.12	1.46	1.71	95%
25%	1.16	1.49	1.81	1.80	3.38	4.40	75%
50%	1.44	1.88	2.36	2.56	4.35	6.53	50%
75%	1.81	3.61	5.20	2.79	5.11	7.45	25%
95%	2.26	3.96	6.25	3.10	5.22	7.52	5%
99%	2.36	3.97	6.27	3.23	5.31	7.57	1%
	Stn. 141 (Head of Old R)						
1%	0.79	1.23	1.73	1.29	2.02	2.73	99%
5%	0.88	1.32	1.82	1.33	2.04	2.74	95%
25%	1.29	1.86	2.36	1.83	3.53	4.68	75%
50%	1.51	2.01	2.60	2.57	4.36	6.53	50%
75%	1.82	3.70	5.33	2.80	5.11	7.45	25%
95%	2.27	3.96	6.23	3.11	5.23	7.52	5%
99%	2.37	3.96	6.25	3.25	5.31	7.57	1%
	Stn. 130 (Old R @ Hwy 4)						

1%	0.74	0.79	0.83	0.74	0.79	0.83	99%
5%	0.79	0.83	0.88	0.79	0.83	0.88	95%
25%	0.89	0.95	0.99	0.89	0.95	0.99	75%
50%	1.02	1.09	1.15	1.03	1.10	1.15	50%
75%	1.18	1.23	1.28	1.18	1.23	1.28	25%
95%	1.30	1.35	1.39	1.30	1.36	1.41	5%
99%	1.36	1.41	1.46	1.36	1.42	1.46	1%

Table 8. Cumulative probability for 25-hr running average surface elevation data during April and May, 1988

Cumulative probability							Exceedance Probability
	Scenarios						
	S88	S88 +3000	S88 +6000	S88HORB0	S88HORB0 +3000	S88HORB0 +6000	
	Stn. 117 (Victoria Canal)						
1%	0.67	0.71	0.75	0.67	0.71	0.75	99%
5%	0.71	0.76	0.80	0.71	0.76	0.80	95%
25%	0.89	0.96	1.01	0.89	0.96	1.01	75%
50%	1.06	1.12	1.19	1.06	1.12	1.20	50%
75%	1.28	1.33	1.37	1.28	1.33	1.38	25%
95%	1.44	1.49	1.55	1.44	1.49	1.56	5%
99%	1.48	1.55	1.62	1.48	1.56	1.63	1%
	Stn. 136 (Grant Line Canal)						
1%	0.60	0.65	0.69	0.60	0.65	0.69	99%
5%	0.65	0.69	0.73	0.65	0.69	0.73	95%
25%	0.84	0.90	0.95	0.84	0.91	0.95	75%
50%	1.01	1.10	1.19	1.02	1.11	1.21	50%
75%	1.23	1.28	1.36	1.23	1.29	1.36	25%
95%	1.41	1.50	1.61	1.41	1.51	1.63	5%
99%	1.49	1.60	1.70	1.50	1.61	1.72	1%
	Stn. 137 (Old R near Tracy)						
1%	-1.25	-0.79	-0.31	1.04	1.37	1.64	99%
5%	-1.14	-0.68	-0.20	1.11	1.46	1.73	95%
25%	-0.36	0.10	0.58	1.57	3.09	4.14	75%
50%	1.16	1.47	1.77	2.44	4.20	6.37	50%
75%	1.54	2.53	4.10	2.82	5.10	7.43	25%
95%	2.17	3.79	6.02	3.15	5.28	7.55	5%
99%	2.24	3.85	6.05	3.25	5.32	7.58	1%
	Stn. 141 (Head of Old R)						

1%	-1.25	-0.79	-0.31	1.26	1.97	2.71	99%
5%	-1.14	-0.68	-0.19	1.34	2.07	2.80	95%
25%	-0.36	0.10	0.59	1.68	3.27	4.46	75%
50%	1.34	1.93	2.49	2.47	4.21	6.37	50%
75%	1.63	2.79	4.41	2.84	5.10	7.43	25%
95%	2.19	3.79	6.02	3.17	5.28	7.55	5%
99%	2.25	3.85	6.06	3.26	5.32	7.58	1%
	Stn. 130 (Old R @ Hwy 4)						
1%	0.65	0.70	0.74	0.65	0.70	0.74	99%
5%	0.69	0.74	0.79	0.69	0.74	0.79	95%
25%	0.88	0.94	1.00	0.88	0.94	1.00	75%
50%	1.05	1.10	1.17	1.05	1.11	1.17	50%
75%	1.27	1.31	1.36	1.27	1.32	1.36	25%
95%	1.43	1.48	1.53	1.43	1.48	1.53	5%
99%	1.47	1.53	1.59	1.47	1.54	1.60	1%

Table 9. Cumulative probability for 15-min surface elevation data during April and May, 1964

Cumulative probability							Exceedance probability
	Scenarios						
	S64	S64 +3000	S64 +6000	S64HORB0	S64HORB0 +3000	S64HORB0 +6000	
	Stn. 117 (Victoria Canal)						
1%	-0.98	-0.93	-0.88	-0.98	-0.93	-0.88	99%
5%	-0.73	-0.68	-0.63	-0.73	-0.68	-0.63	95%
25%	0.19	0.25	0.31	0.19	0.25	0.31	75%
50%	1.17	1.23	1.28	1.17	1.23	1.29	50%
75%	1.86	1.92	1.98	1.86	1.93	1.98	25%
95%	2.63	2.68	2.73	2.63	2.68	2.74	5%
99%	3.15	3.21	3.26	3.15	3.22	3.26	1%
	Stn. 136 (Grant Line Canal)						
1%	-1.11	-1.07	-1.01	-1.11	-1.06	-1.01	99%
5%	-0.85	-0.80	-0.75	-0.85	-0.80	-0.75	95%
25%	0.15	0.22	0.30	0.15	0.23	0.30	75%
50%	1.13	1.20	1.27	1.13	1.21	1.28	50%
75%	1.80	1.88	1.94	1.80	1.89	1.95	25%
95%	2.54	2.60	2.67	2.54	2.60	2.68	5%
99%	3.09	3.14	3.18	3.09	3.14	3.20	1%
	Stn. 137 (Old R near Tracy)						
1%	0.04	0.33	0.64	0.07	0.39	0.72	99%

5%	0.54	0.84	1.12	0.57	0.89	1.18	95%
25%	1.13	1.52	1.95	1.82	3.07	3.76	75%
50%	1.57	1.99	2.43	2.50	4.20	6.41	50%
75%	1.85	3.63	5.82	2.79	5.10	7.44	25%
95%	2.37	3.97	6.24	3.13	5.25	7.54	5%
99%	2.67	4.13	6.35	3.46	5.40	7.63	1%
	Stn. 141 (Head of Old R)						
1%	0.42	1.18	1.71	0.50	1.35	2.26	99%
5%	0.77	1.27	1.82	0.90	1.66	2.49	95%
25%	1.18	1.68	2.25	1.86	3.50	4.12	75%
50%	1.60	2.07	2.61	2.53	4.20	6.39	50%
75%	1.89	3.65	5.81	2.80	5.10	7.44	25%
95%	2.39	3.98	6.23	3.13	5.24	7.53	5%
99%	2.65	4.11	6.33	3.47	5.40	7.63	1%
	Stn. 130 (Old R @ Hwy 4)						
1%	-0.96	-0.91	-0.87	-0.96	-0.91	-0.86	99%
5%	-0.72	-0.67	-0.62	-0.72	-0.67	-0.62	95%
25%	0.18	0.24	0.30	0.18	0.24	0.30	75%
50%	1.17	1.22	1.27	1.17	1.22	1.27	50%
75%	1.83	1.89	1.94	1.83	1.89	1.95	25%
95%	2.58	2.64	2.68	2.58	2.64	2.68	5%
99%	3.12	3.17	3.20	3.12	3.18	3.22	1%

Table 10. Cumulative probability for 15-min surface elevation data during April and May, 1988

Cumulative probability	Scenarios						Exceedance probability
	S88	S88 +3000	S88 +6000	S88HORB0	S88HORB0 +3000	S88HORB0 +6000	
	Stn. 117 (Victoria Canal)						
1%	-1.05	-1.00	-0.95	-1.05	-1.00	-0.95	99%
5%	-0.79	-0.75	-0.70	-0.79	-0.74	-0.69	95%
25%	0.14	0.20	0.26	0.14	0.20	0.26	75%
50%	1.16	1.21	1.26	1.16	1.21	1.26	50%
75%	1.93	2.00	2.05	1.93	2.00	2.05	25%
95%	2.97	3.03	3.07	2.98	3.03	3.08	5%
99%	3.55	3.60	3.64	3.56	3.61	3.64	1%
	Stn. 136 (Grant Line Canal)						
1%	-1.19	-1.15	-1.09	-1.19	-1.14	-1.08	99%

5%	-0.92	-0.87	-0.82	-0.92	-0.88	-0.82	95%
25%	0.10	0.17	0.24	0.10	0.17	0.24	75%
50%	1.10	1.17	1.24	1.10	1.17	1.24	50%
75%	1.91	1.99	2.05	1.91	1.99	2.06	25%
95%	2.96	3.03	3.09	2.96	3.03	3.09	5%
99%	3.56	3.61	3.65	3.57	3.61	3.66	1%
	Stn. 137 (Old R near Tracy)						
1%	-1.26	-0.81	-0.33	0.08	0.44	0.78	99%
5%	-1.16	-0.70	-0.22	0.56	0.89	1.19	95%
25%	-0.35	0.11	0.59	1.69	3.21	3.59	75%
50%	1.05	1.42	1.79	2.45	4.17	6.28	50%
75%	1.69	3.23	5.01	2.82	5.09	7.42	25%
95%	2.38	3.78	6.01	3.25	5.30	7.56	5%
99%	2.77	4.04	6.16	3.51	5.44	7.66	1%
	Stn. 141 (Head of Old R)						
1%	-1.26	-0.81	-0.33	0.58	1.44	2.35	99%
5%	-1.15	-0.70	-0.21	0.91	1.69	2.54	95%
25%	-0.35	0.11	0.59	1.75	3.29	4.11	75%
50%	1.18	1.75	2.37	2.49	4.17	6.28	50%
75%	1.74	3.27	5.04	2.83	5.09	7.43	25%
95%	2.39	3.79	6.03	3.26	5.29	7.56	5%
99%	2.83	4.11	6.15	3.50	5.43	7.65	1%
	Stn. 130 (Old R @ Hwy 4)						
1%	-1.03	-0.98	-0.94	-1.03	-0.98	-0.93	99%
5%	-0.78	-0.74	-0.69	-0.78	-0.73	-0.68	95%
25%	0.13	0.18	0.24	0.13	0.19	0.24	75%
50%	1.15	1.20	1.25	1.15	1.20	1.25	50%
75%	1.92	1.98	2.03	1.92	1.98	2.03	25%
95%	2.96	3.00	3.05	2.96	3.01	3.05	5%
99%	3.53	3.58	3.62	3.54	3.58	3.62	1%

In summary, the simulation results show that impacts to stage and flow velocity are most pronounced near the location where San Joaquin River flows enter the Delta (i.e., near the head of Old River and in Old River near Tracy). Farther from that point, changes in stage are attenuated, and the overall tidal range is smaller farther from the entrance to the Delta (e.g., in Old River at Highway 4).

Fate of San Joaquin Water

Results showing the fate of San Joaquin River water that entered the Delta between April 15 and May 15 are summarized in Table 11. The fraction of San Joaquin River water that is exported at

Tracy (CVP) and Banks (SWP) pumping plants, or diverted by CCWD or the North Bay Aqueduct, declines as additional San Joaquin River inflow is added to the Delta. This occurs because export and diversion pumping rates were held steady, so that the same volume of water was exported or diverted for each model run, implying that the amount exported/diverted was a smaller fraction of the total inflow. Thus, as more San Joaquin River inflow was added to the model, the fraction of San Joaquin River water that left the Delta via outflow to the Bay increased approximately five-fold, from about 0.5% to 2.5%, but this is still a small fraction of the San Joaquin River flow entering the Delta. The fraction of San Joaquin River flow that either remains in the Delta or that is removed for in-Delta consumptive uses rises significantly, from 22% to about 60% for the WY88 runs and from about 45% to 72% for the WY64 runs, as San Joaquin River inflows are added to the model simulations. Because the residence time of water in the Delta is typically shorter than six months (the time from the tracer release to the end of the simulation period), it is assumed that the large majority of water that "remained in the Delta and/or was removed as in-Delta consumptive use" was actually consumed by in-Delta uses.

Detailed plots of the "fate" of tracer added to San Joaquin River flows between April 15 and May 15 are presented in Appendix A in Figures A-121 to A-132. Notations in those figures are as follows:

- "E, D, and O" denotes the total volume of San Joaquin River water that entered the Delta between April 15 and May 15 and that was subsequently transported out of the Delta system (via exports, diversions, and outflow)
- "Banks PP" denotes the cumulative volume of mid-April to mid-May San Joaquin River inflows that were exported through Banks Pumping Plant (SWP)
- "Tracy PP" denotes the volume of mid-April to mid-May San Joaquin River inflows that were exported through Tracy Pumping Plant (CVP)
- "CCWD" denotes the fraction of mid-April to mid-May San Joaquin River inflows that were diverted by Contra Costa Water District
- "Bay" denotes the fraction of tracer leaving the Delta and flowing into San Francisco Bay
- "NBA" denotes the fraction of mid-April to mid-May San Joaquin River inflows that were diverted to the Northbay Aqueduct through the Barker Slough Pumping Plant
- "In Delta + DICU" denotes the fraction of mid-April to mid-May San Joaquin River inflows that remained in the Delta and were supplied to Delta island consumptive use (DICU).

The cumulative volume of mid-April to mid-May San Joaquin River inflows that passed these locations are also shown as a function of time in Figures A-133 to A-152 of Appendix A. All results are expressed as the percentage of the total volume of San Joaquin River water inflow at Vernalis between April 15 and May 15. Because all other barriers are in operation between April 15 and May 15, whether the head of Old River barrier is in operation or not in that period, makes little difference to the fate of upstream San Joaquin River water.

Table 11 - Fate (at the end of the water year) of San Joaquin River (SJR) water that entered the Delta between April 15 and May 15, in terms of the fraction of SJR inflow

Scenario	Tracy (SWP) Export (%)	Banks (CVP) Export (%)	CCWD & NBA Diversion (%)	Flow to Bay (%)	Remained in Delta and/or removed as In-Delta Consumptive Use (DICU) (%)
S64	48.8	25.3	3.4	0.5	22.0
S64+3k	34.4	15.6	2.9	1.4	45.8
S64+6k	24.7	10.3	2.1	2.5	60.4
S88	9.3	40.5	4.2	0.9	45.0
S88+3	5.9	26.8	3.0	1.7	62.6
S88+6	4.4	19.2	2.0	2.5	72.0
S64HORB0	48.8	25.3	3.4	0.5	22.0
S64HORB0+3k	34.4	15.6	2.9	1.4	45.7
S64HORB0+6k	24.7	10.3	2.1	2.6	60.4
S88HORB0	9.3	40.4	4.3	1.0	45.0
S88HORB0+3	5.9	26.8	3.0	1.7	62.6
S88HORB0+k	4.3	19.1	2.0	2.5	72.1

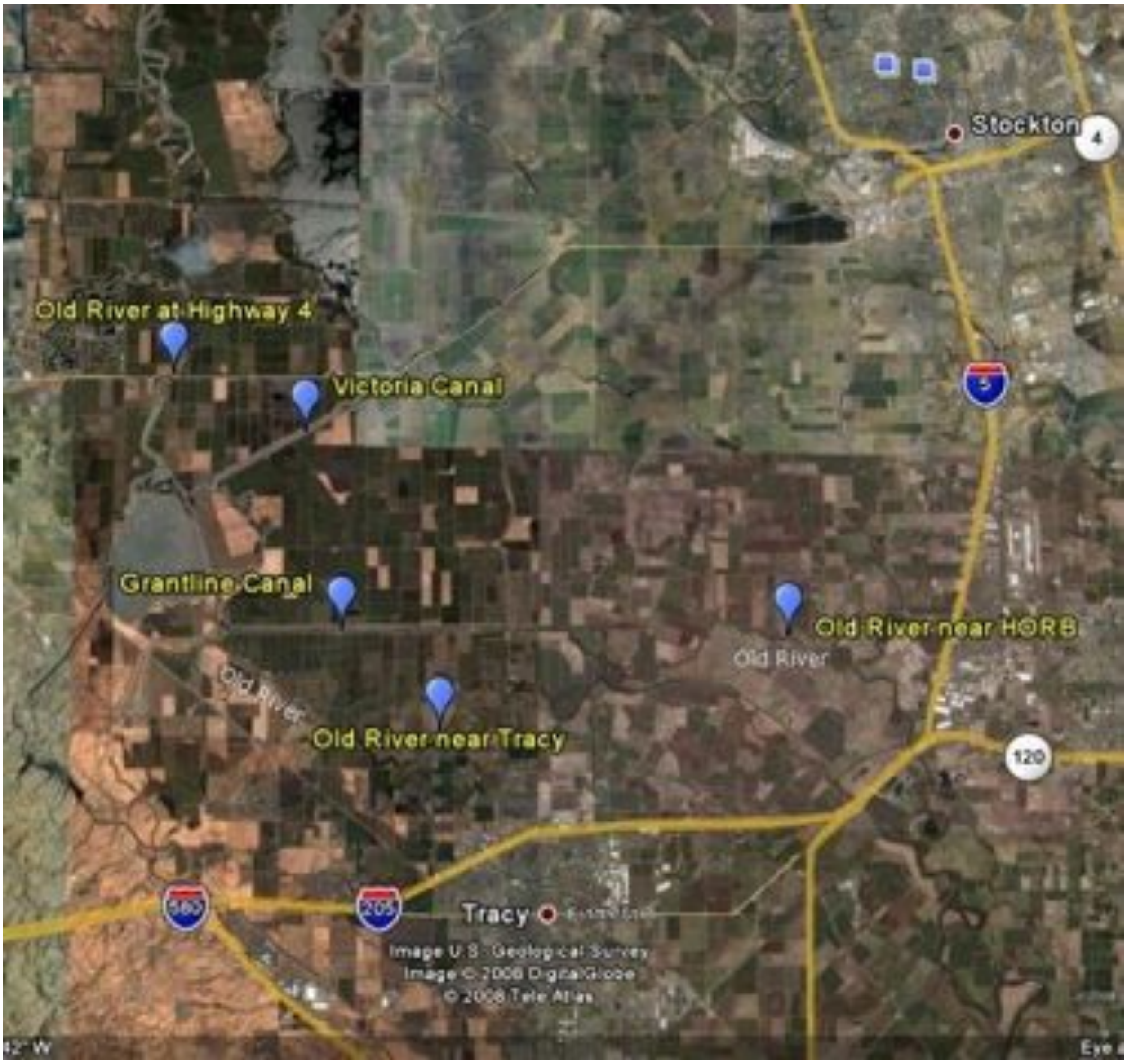

Figure 1. Location map showing five monitoring stations for the results of surface elevations and flow velocities.

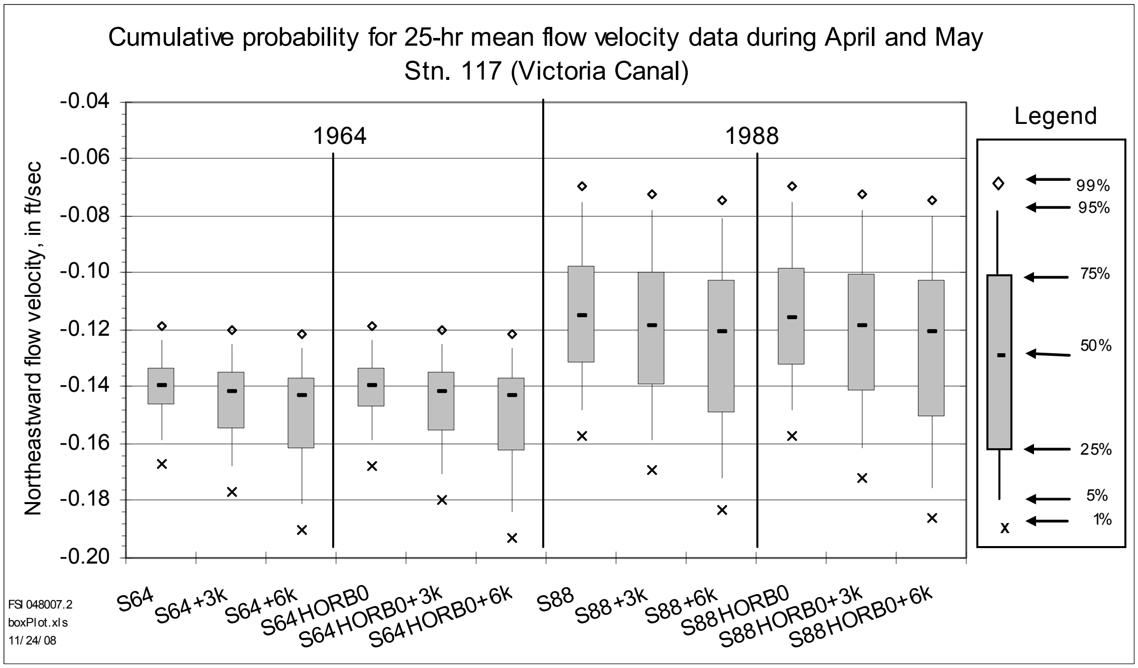

Figure 2. **Cumulative probability of 25-hr running average flow velocity values during April and May, at Stn. 117 (Victoria Canal).**

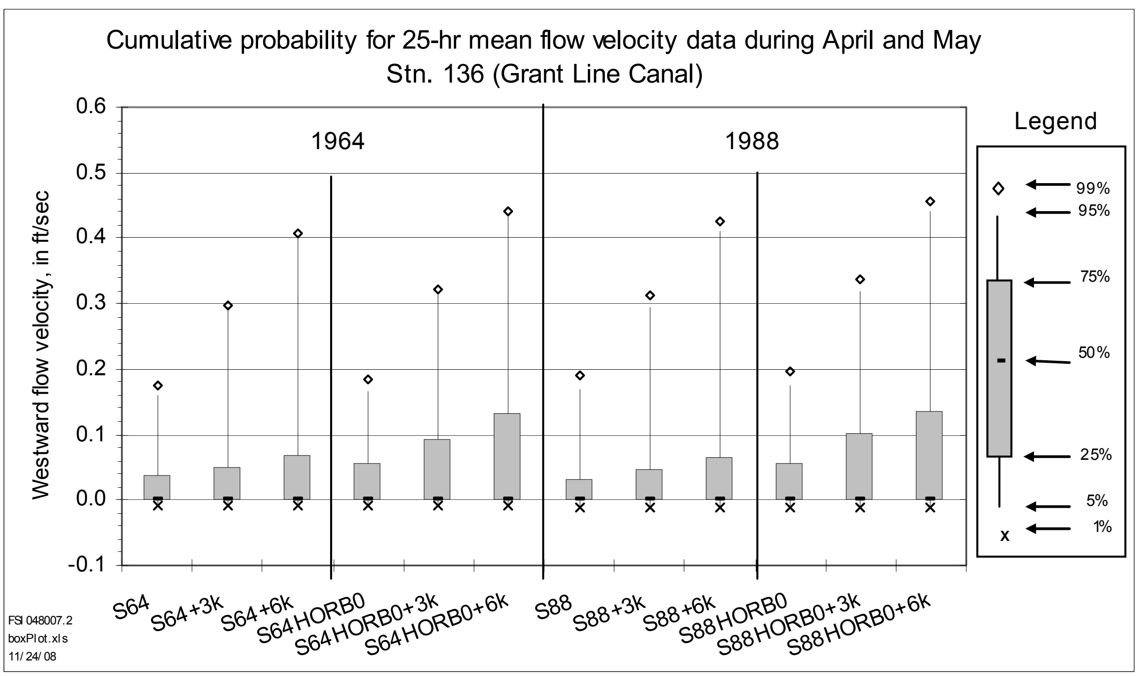

Figure 3. **Cumulative probability of 25-hr running average flow velocity values during April and May, at Stn. 136 (Grant Line Canal).**

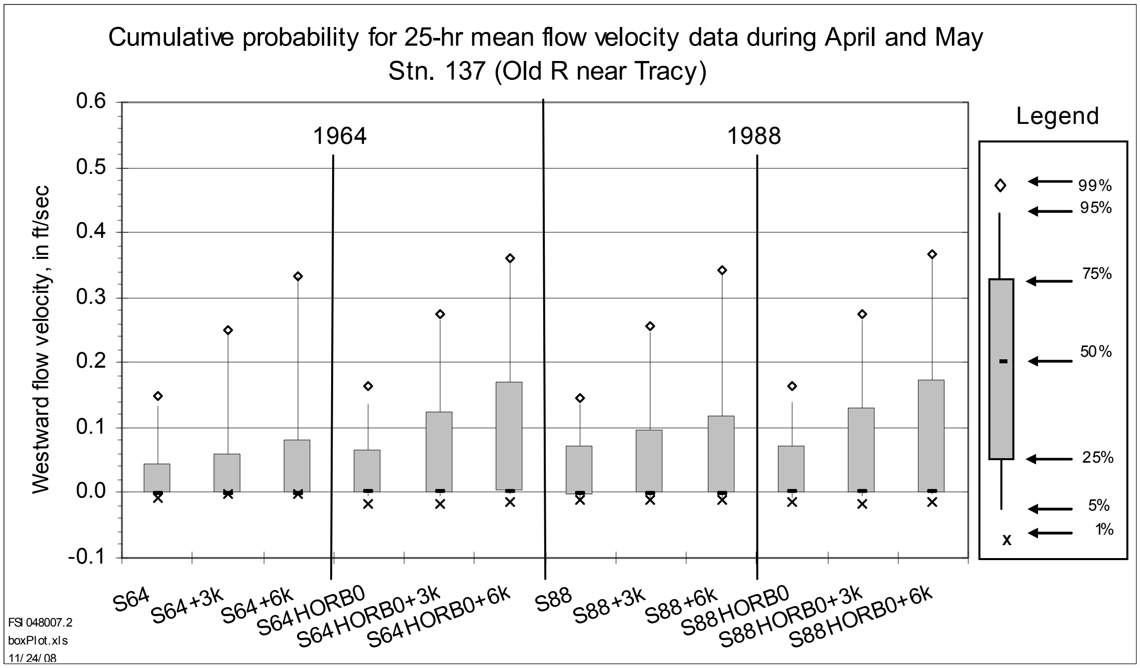

Figure 4. **Cumulative probability of 25-hr running average flow velocity values during April and May, at Stn. 137 (Old River near Tracy).**

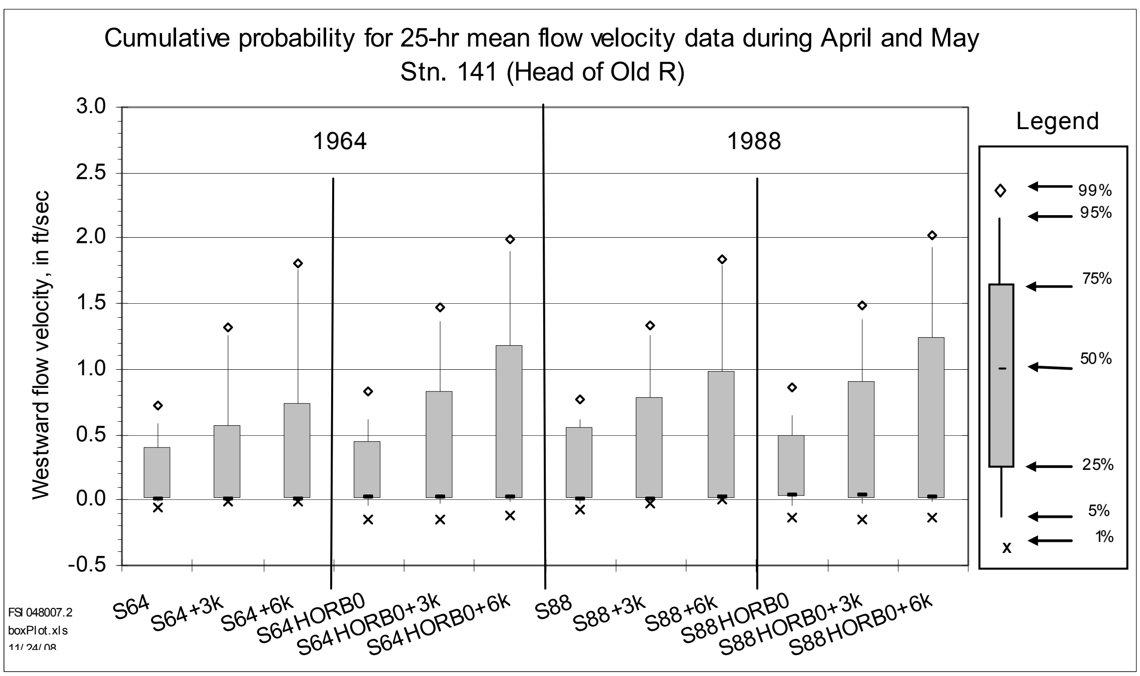

Figure 5. **Cumulative probability of 25-hr running average flow velocity values during April and May, at Stn141 (Head of Old River).**

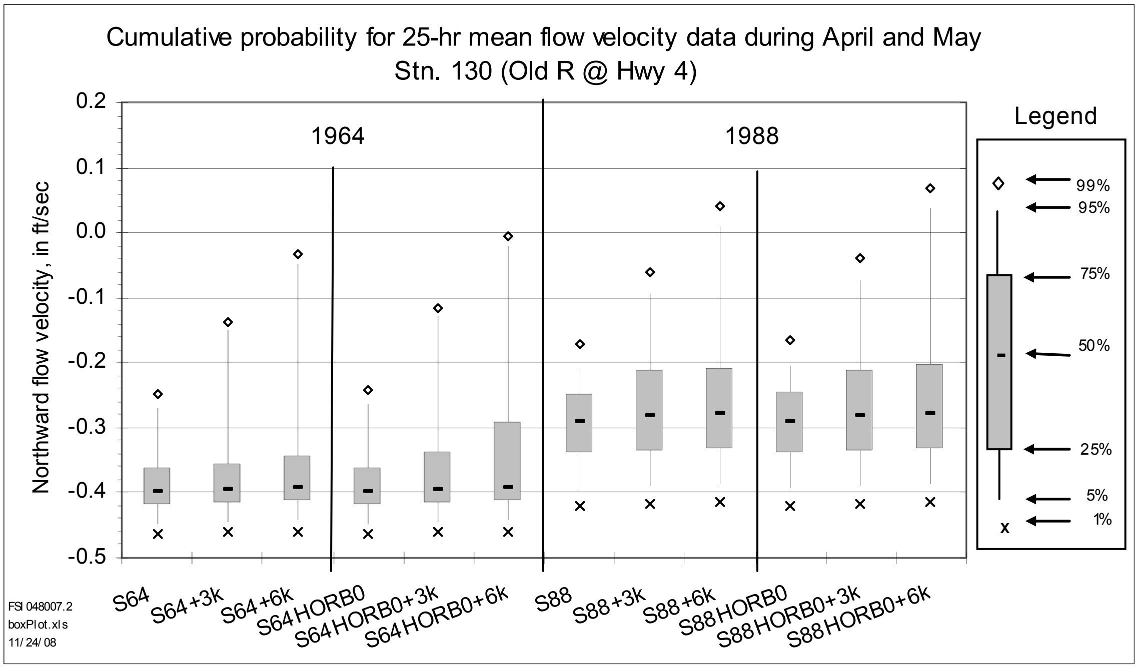

Figure 6. **Cumulative probability of 25-hr running average flow velocity values during April and May, at Stn. 130 (Old R @ Hwy 4).**

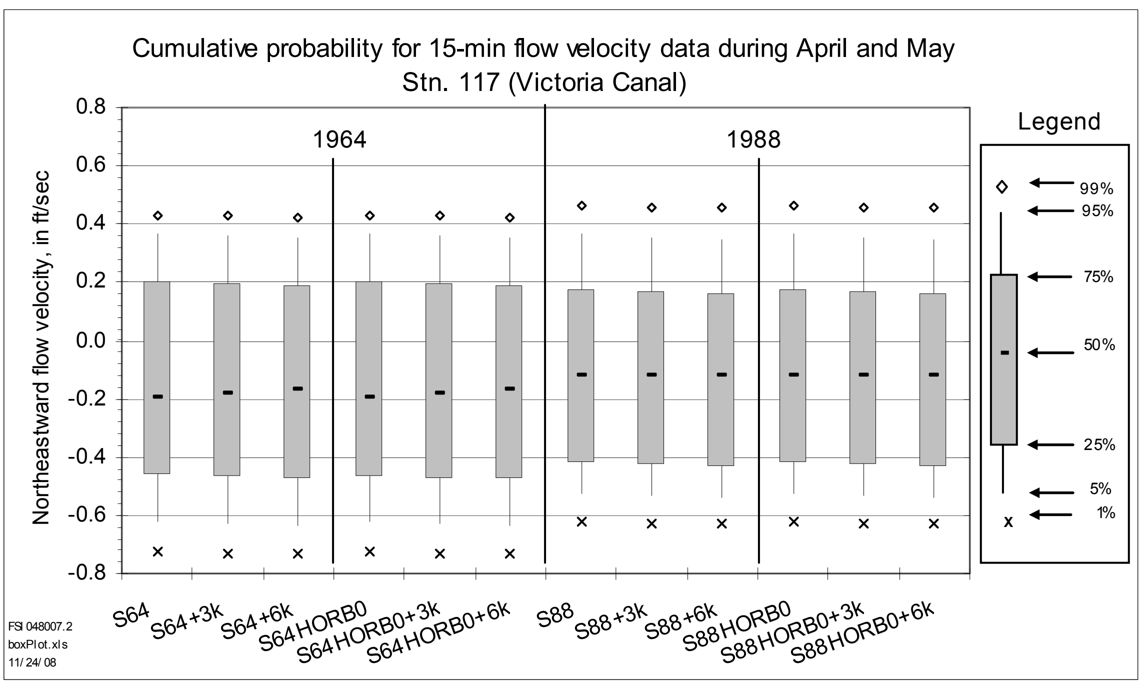

Figure 7. **Cumulative probability of 15-min flow velocity values during April and May, at Stn. 117 (Victoria Canal).**

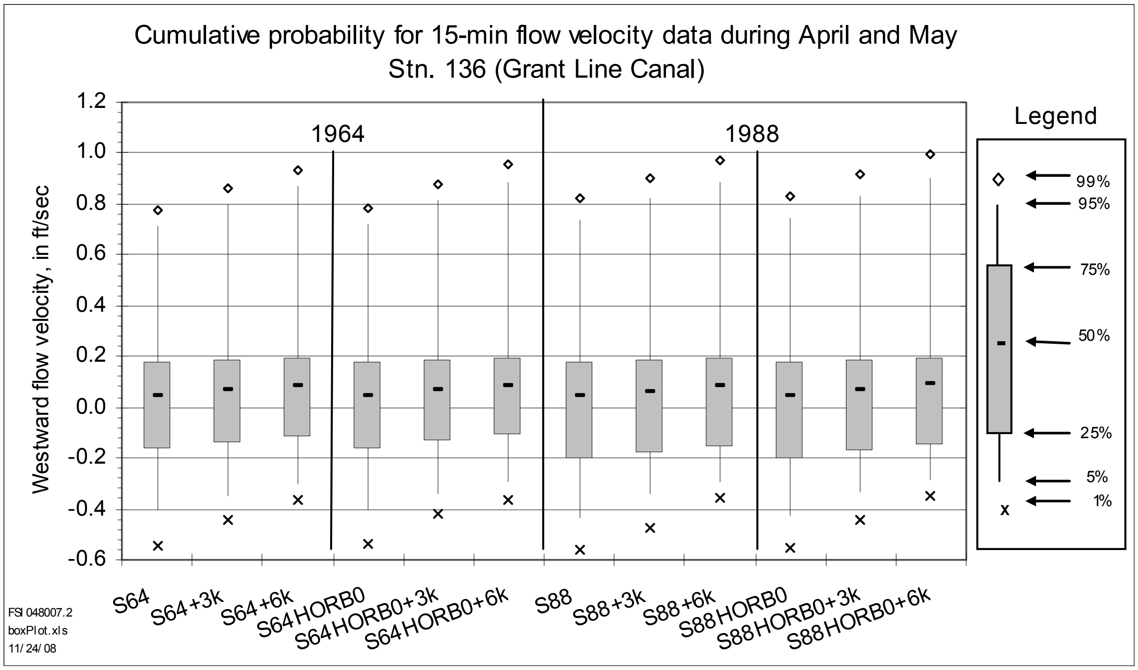

Figure 8. **Cumulative probability of 15-min flow velocity values during April and May, at Stn. 136 (Grant Line Canal).**

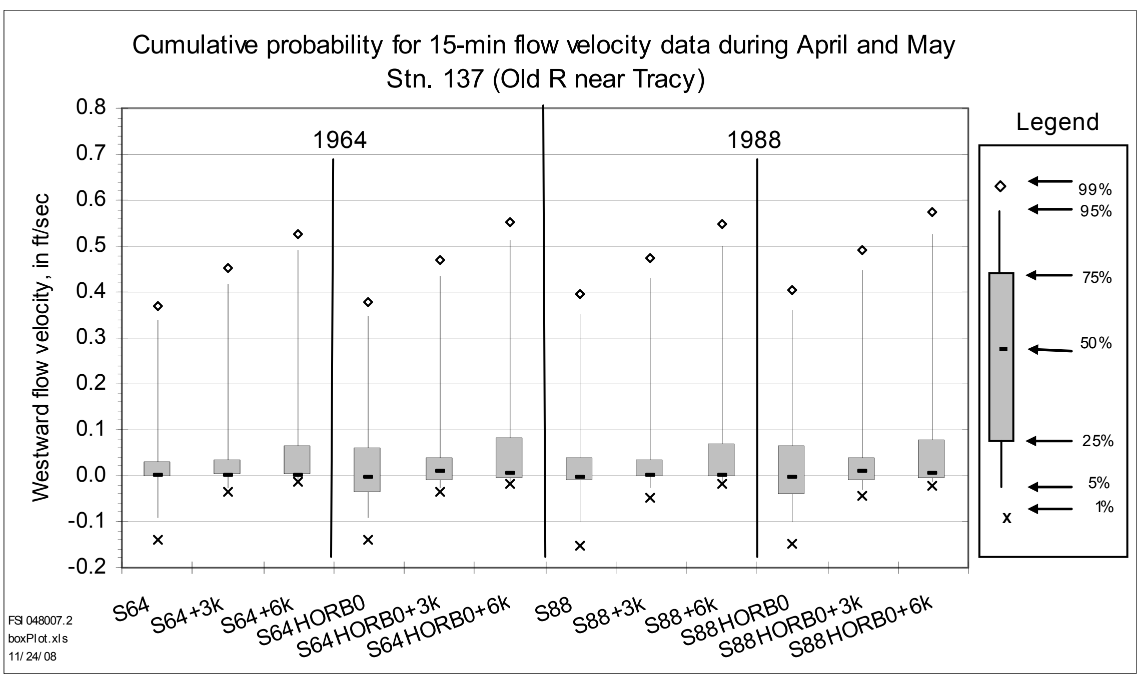

Figure 9. **Cumulative probability of 15-min flow velocity values during April and May, at Stn. 137 (Old River near Tracy).**

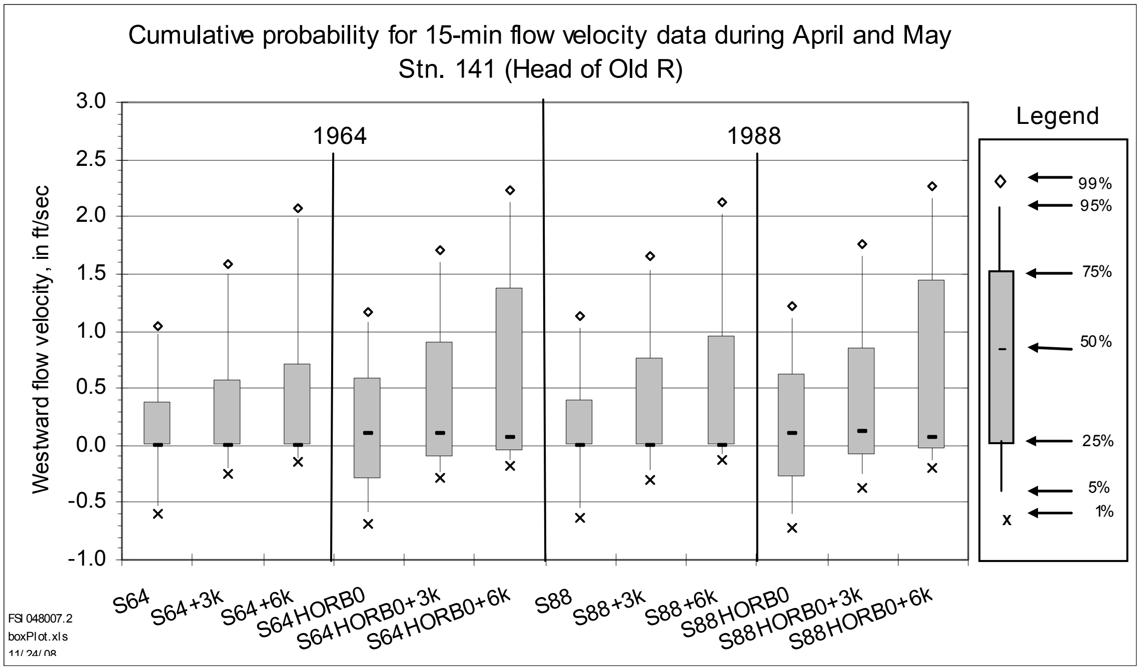

Figure 10. **Cumulative probability of 15-min flow velocity values during April and May, at Stn141 (Head of Old River).**

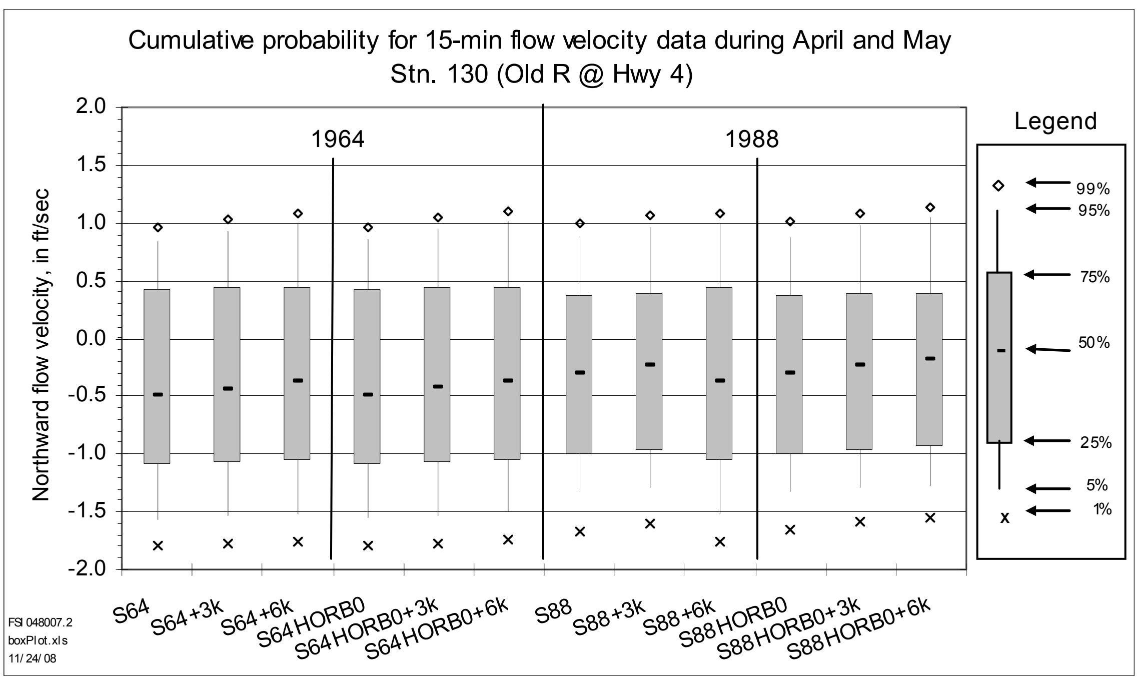

Figure 11. **Cumulative probability of 15-min flow velocity values during April and May, at Stn. 130 (Old R @ Hwy 4).**

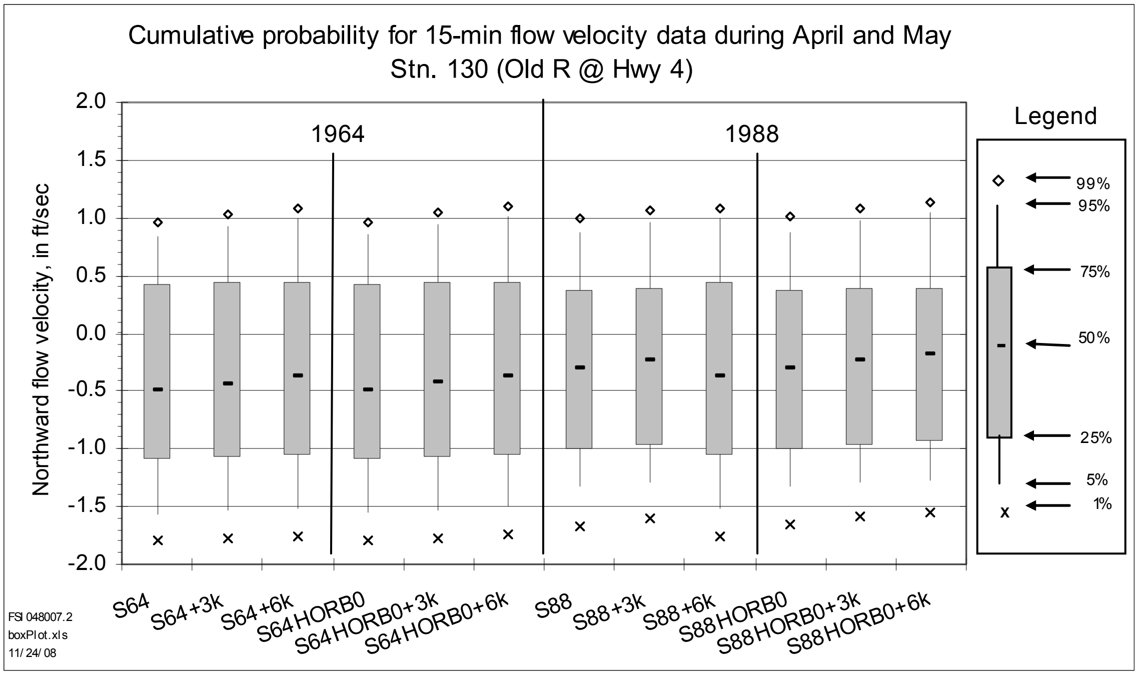

Figure 12. **Cumulative probability of 25-hr running average surface elevation values during April and May, at Stn. 117 (Victoria Canal).**

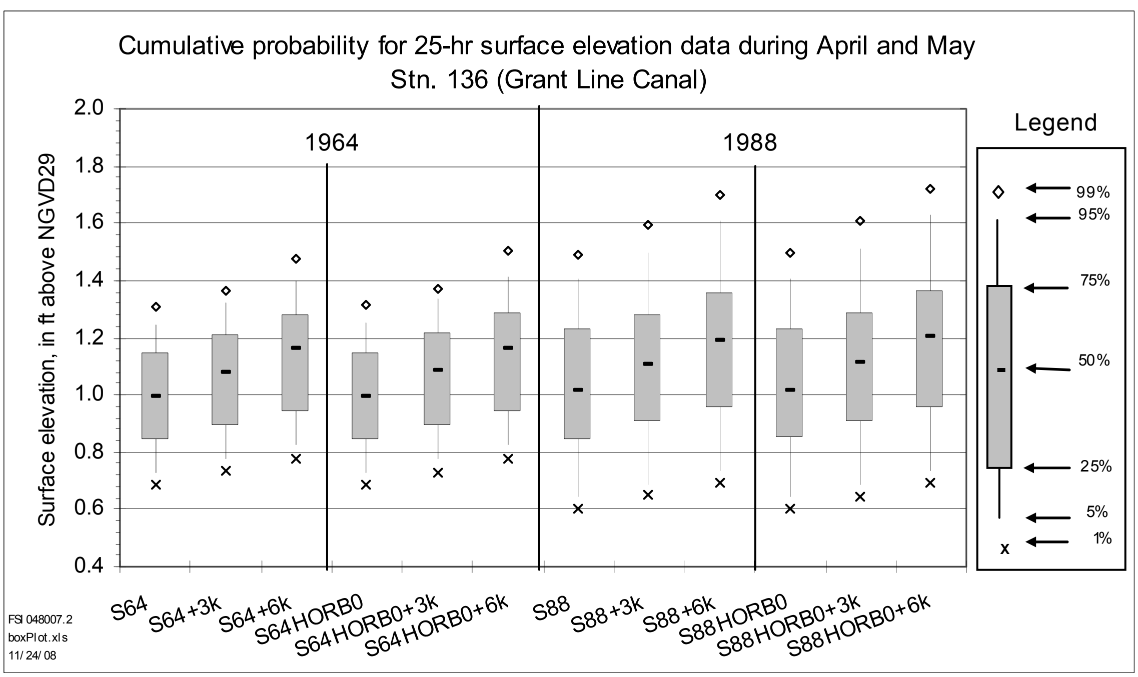

Figure 13. **Cumulative probability of 25-hr running average surface elevation values during April and May, at Stn. 136 (Grant Line Canal).**

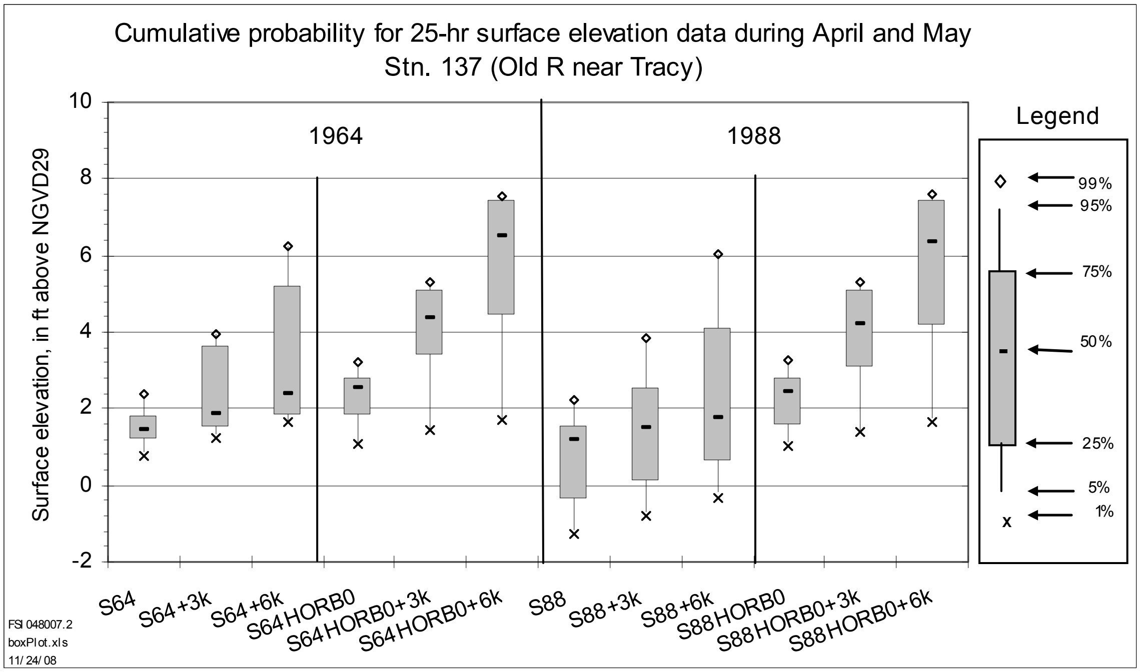

Figure 14. Cumulative probability of 25-hr running average surface elevation values during April and May, at Stn. 137 (Old River near Tracy).

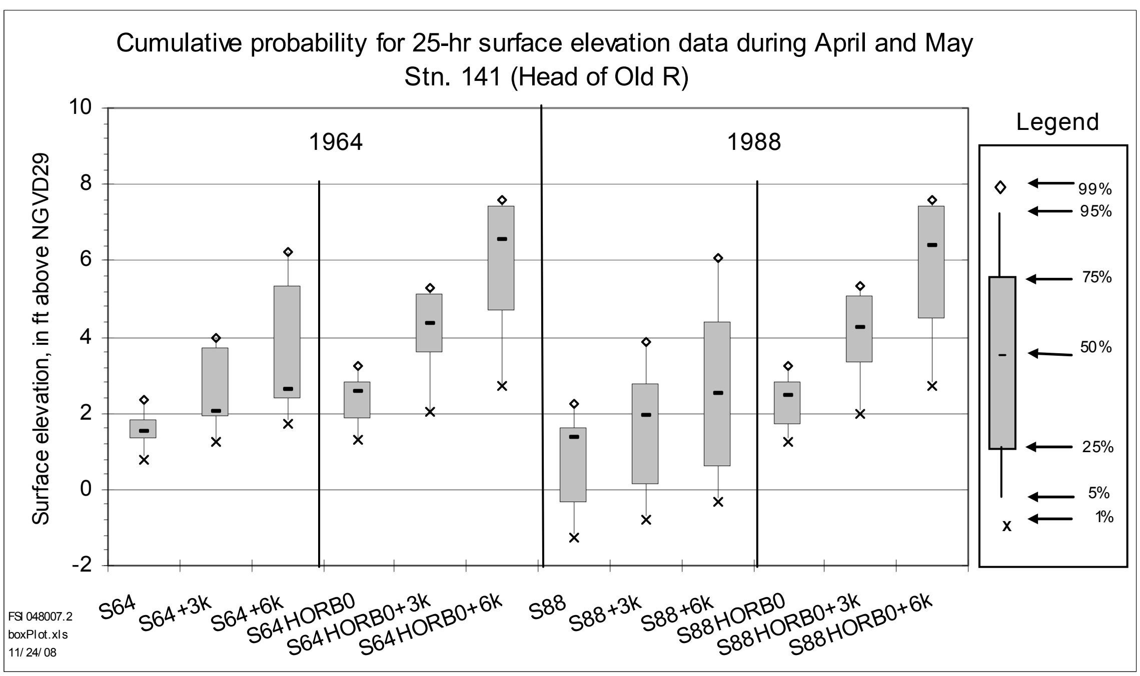

Figure 15. Cumulative probability of 25-hr running average surface elevation values during April and May, at Stn141 (Head of Old River).

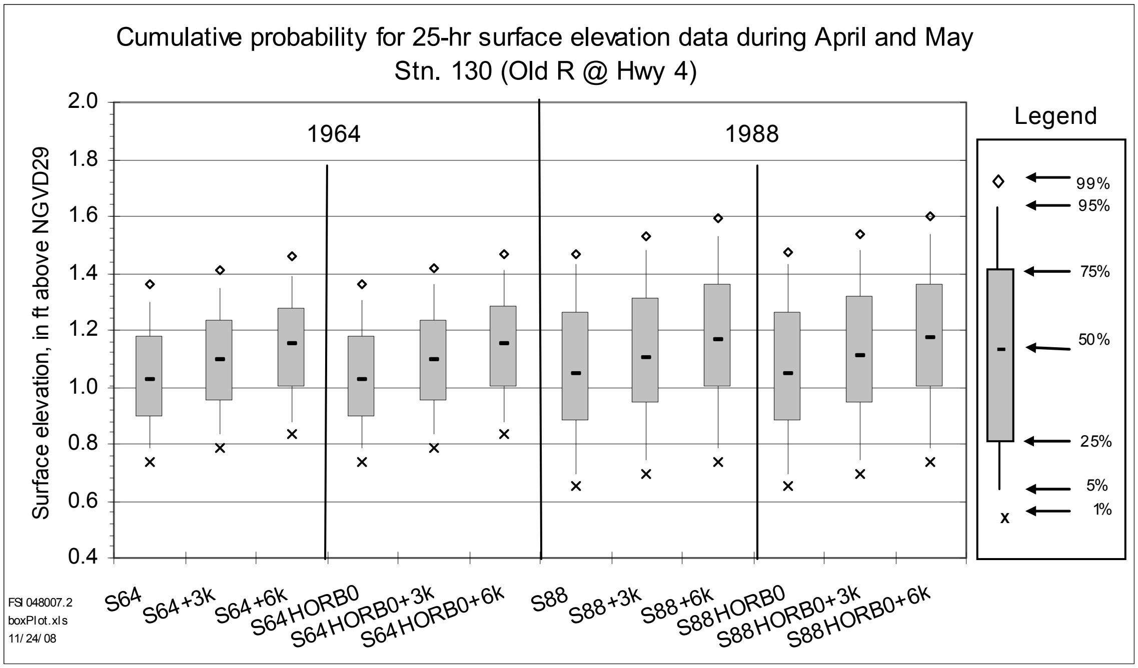

Figure 16. **Cumulative probability of 25-hr running average surface elevation values during April and May, at Stn. 130 (Old R @ Hwy 4).**

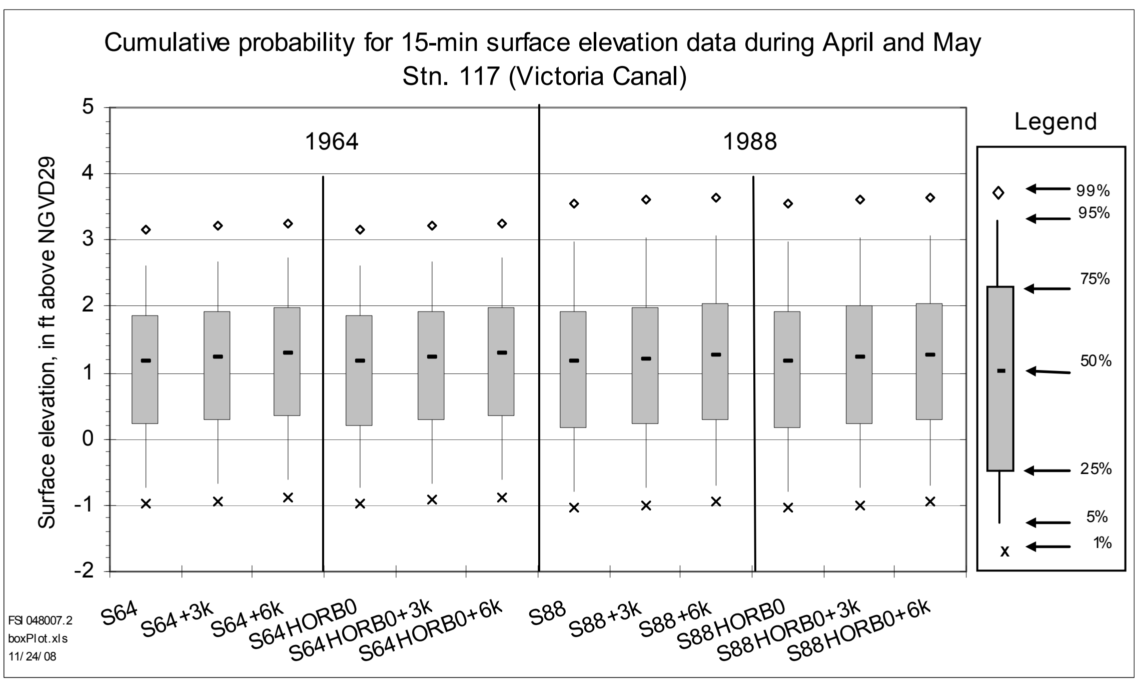

Figure 17. **Cumulative probability of 15-min surface elevation values during April and May, at Stn. 117 (Victoria Canal).**

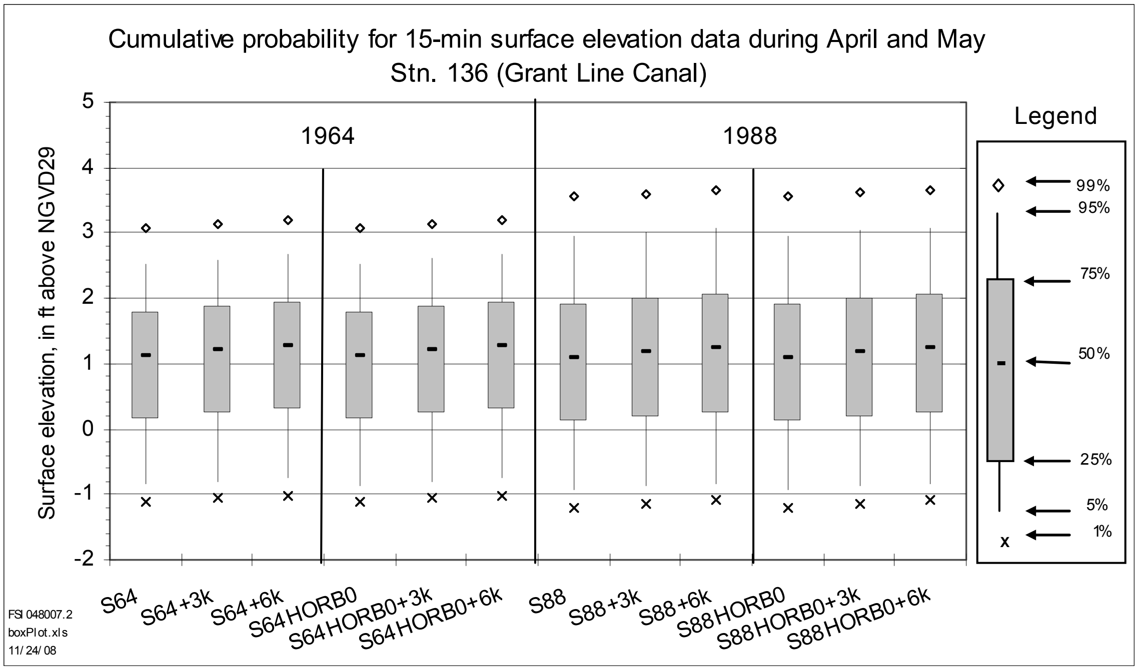

Figure 18. **Cumulative probability of 15-min surface elevation values during April and May, at Stn. 136 (Grant Line Canal).**

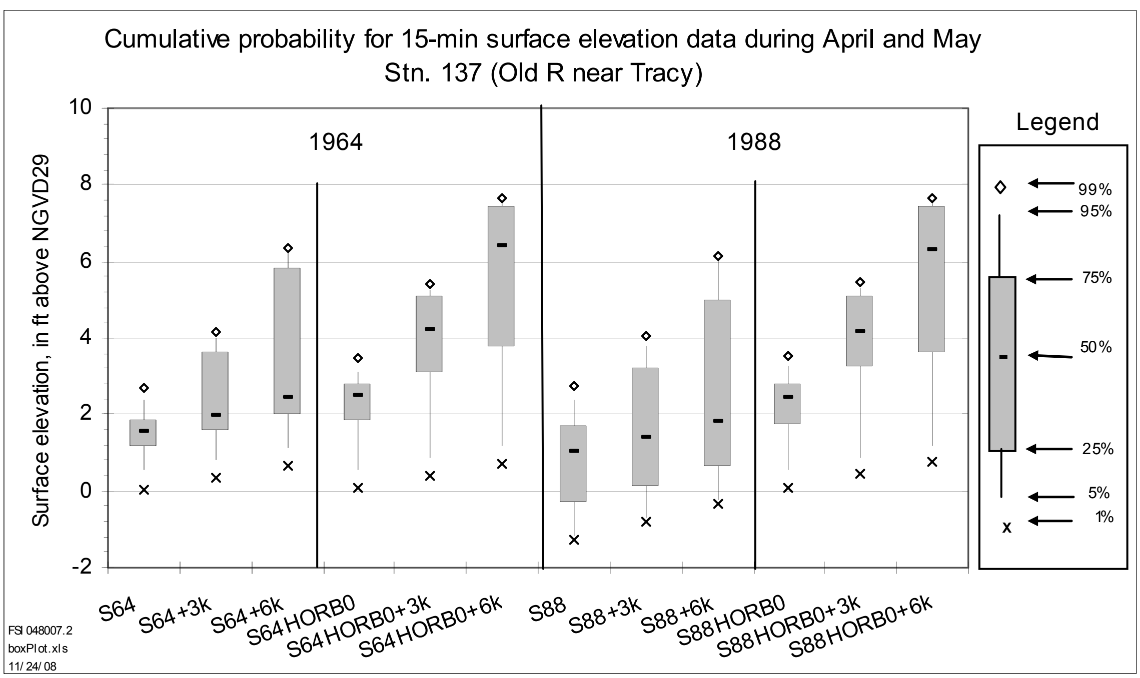

Figure 19. **Cumulative probability of 15-min surface elevation values during April and May, at Stn. 137 (Old River near Tracy).**

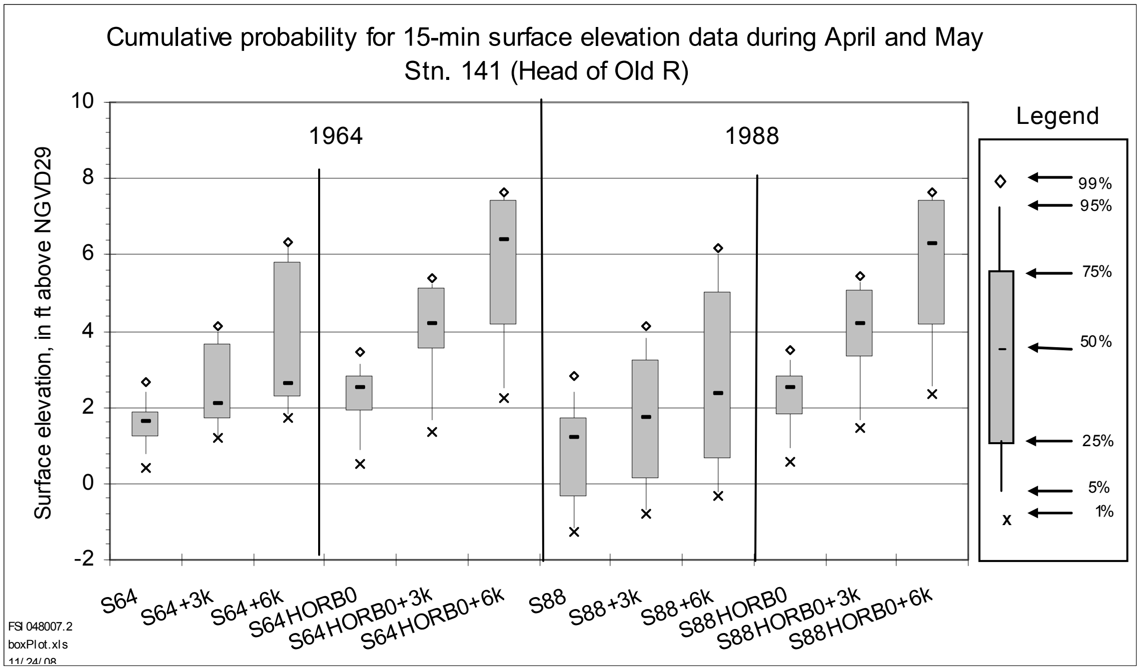

Figure 20. **Cumulative probability of 15-min surface elevation values during April and May, at Stn141 (Head of Old River).**

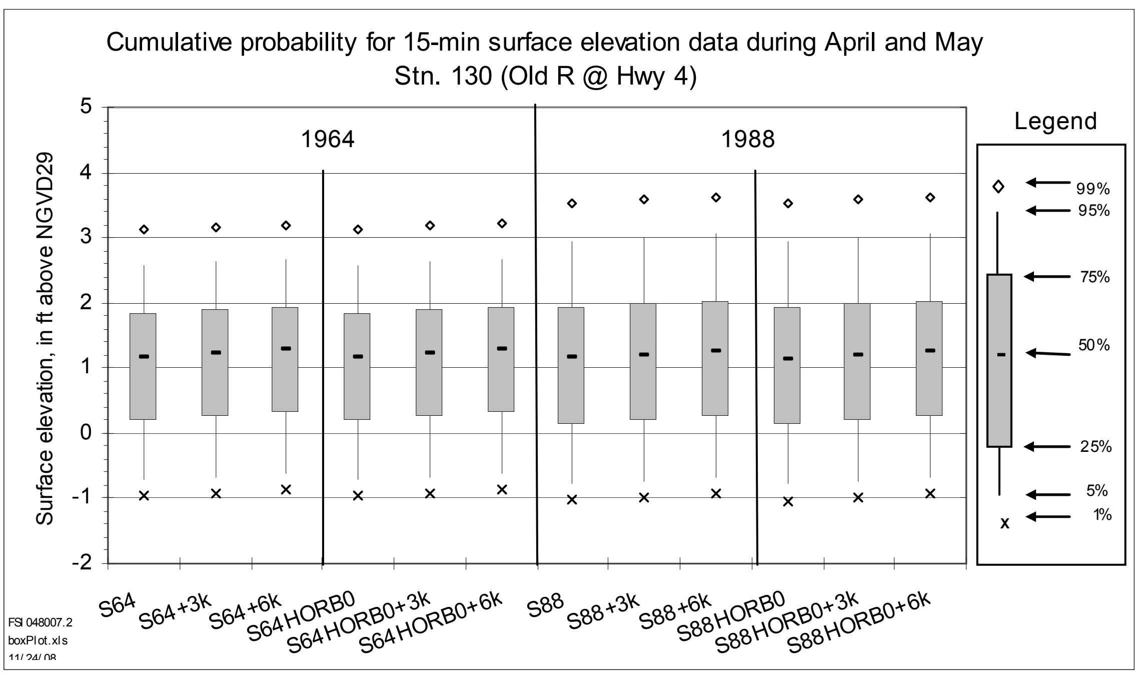

Figure 21. **Cumulative probability of 15-min surface elevation values during April and May, at Stn. 130 (Old R @ Hwy 4).**

APPENDIX A

Figures

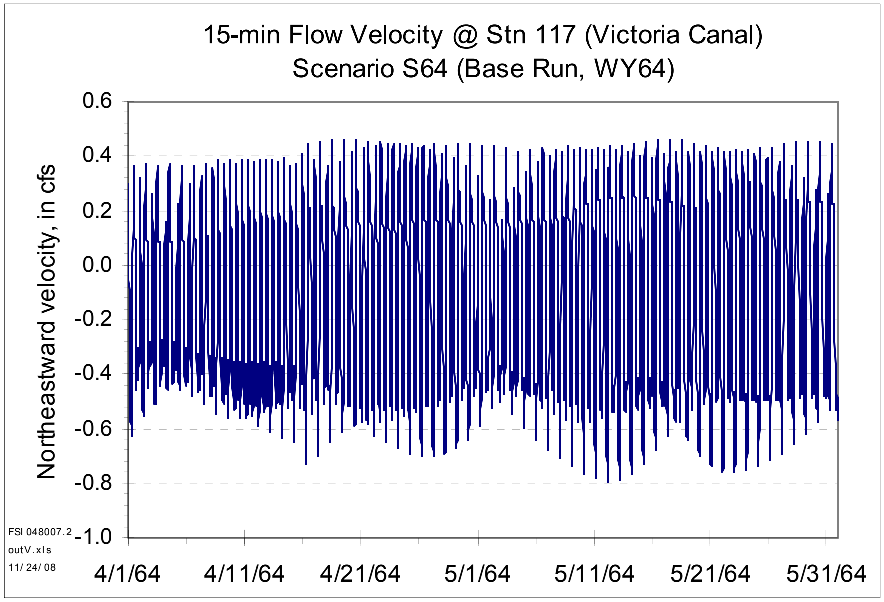

Figure A-1. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64.

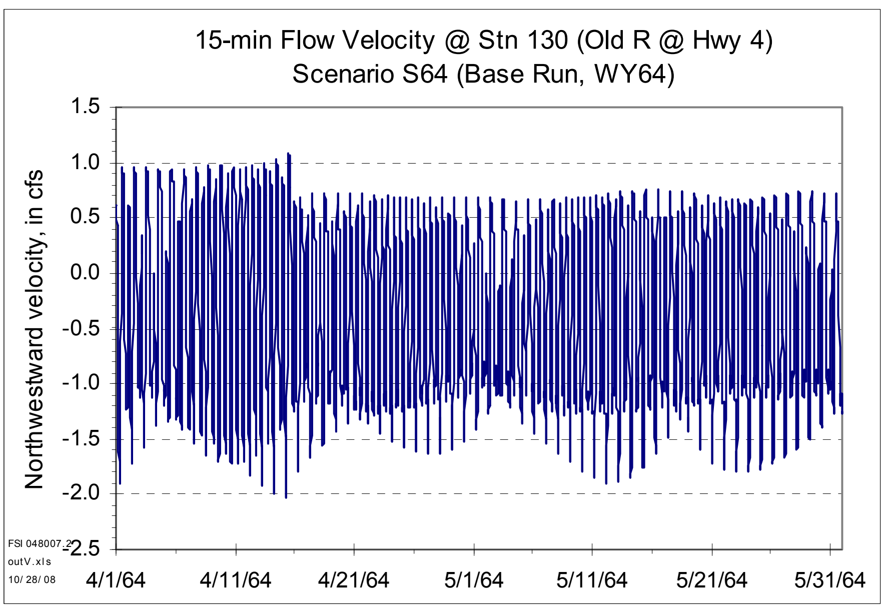

Figure A-2. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64.

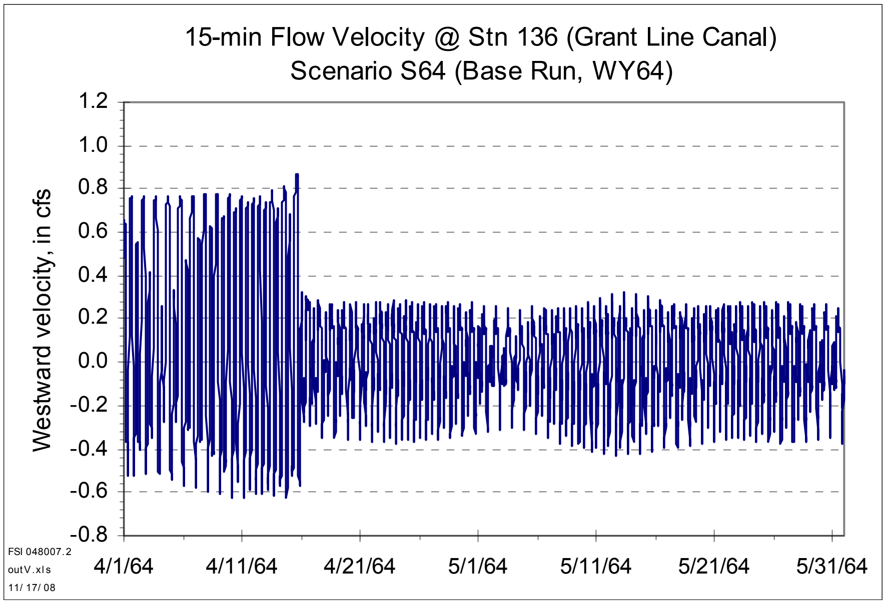

Figure A-3. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64.

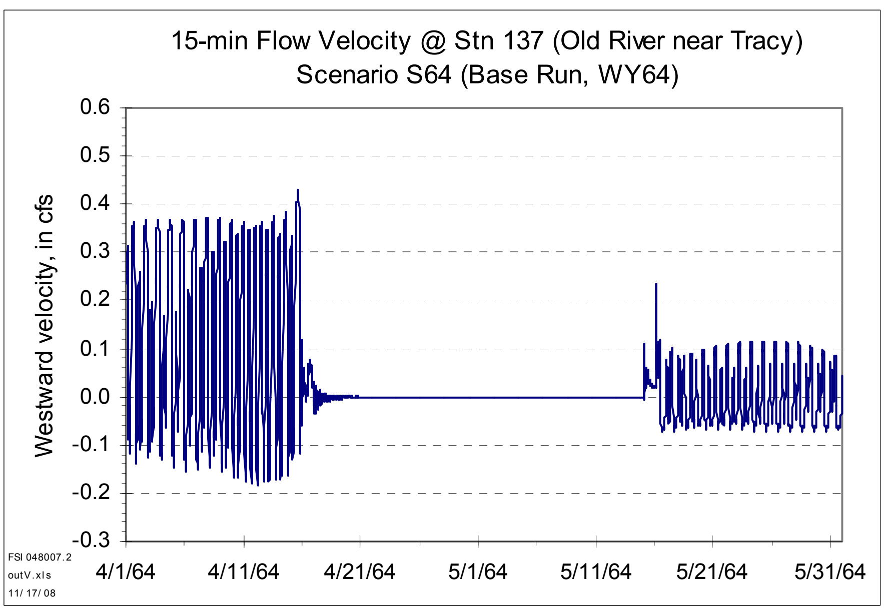

Figure A-4. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64.

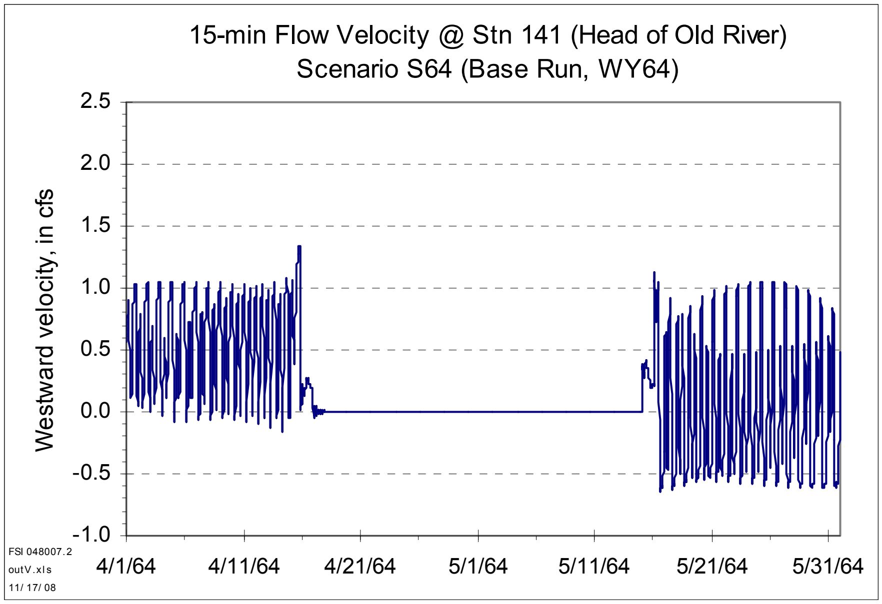

Figure A-5. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64.

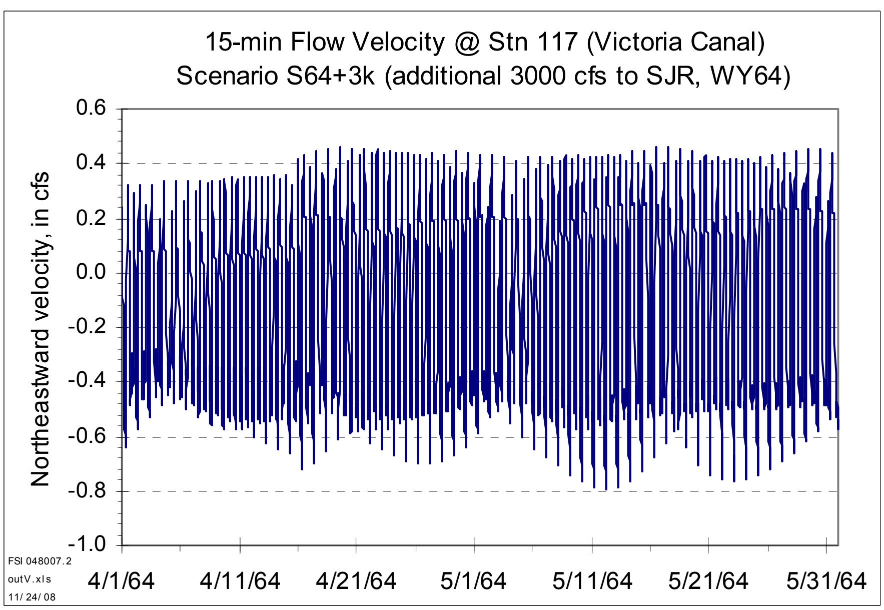

Figure A-6. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64+3k.

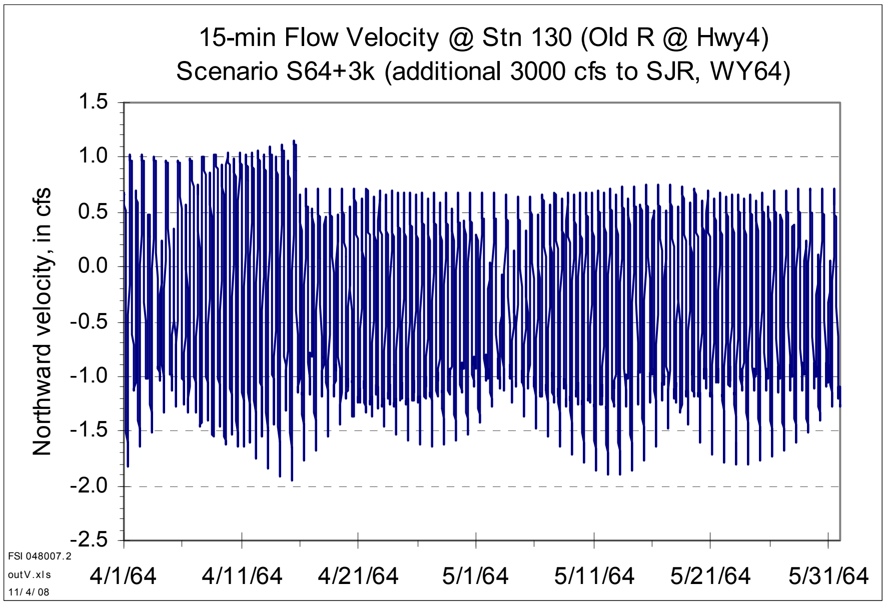

Figure A-7. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64+3k.

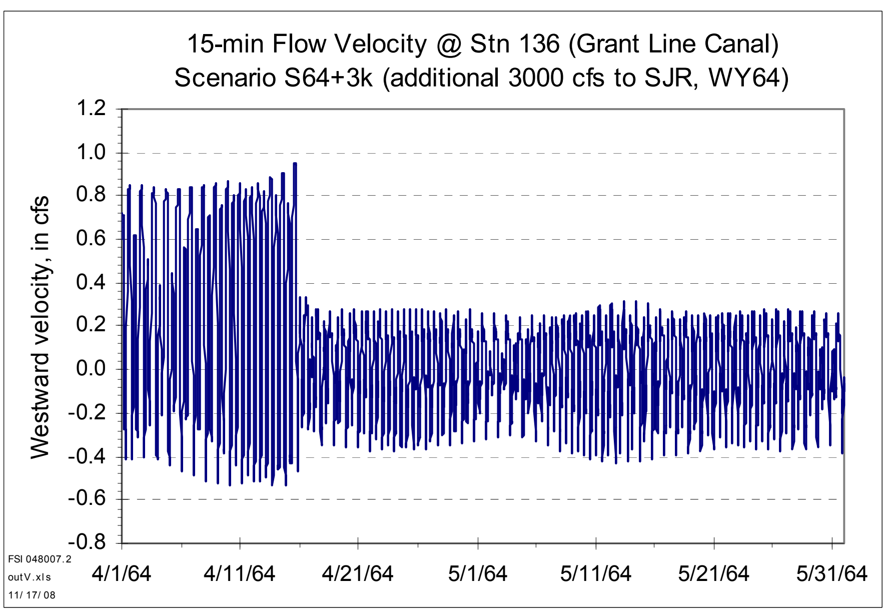

Figure A-8. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64+3k.

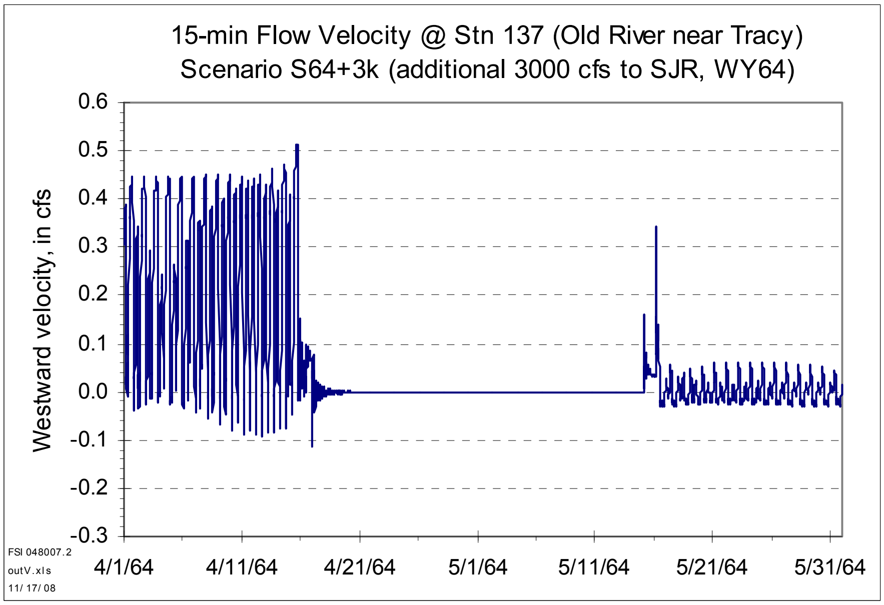

Figure A-9. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64+3k.

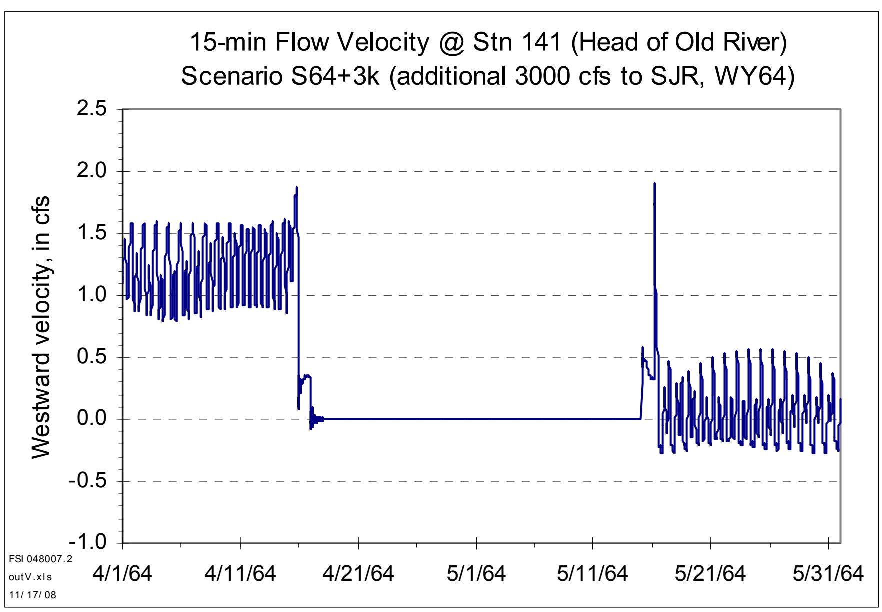

Figure A-10. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64+3k.

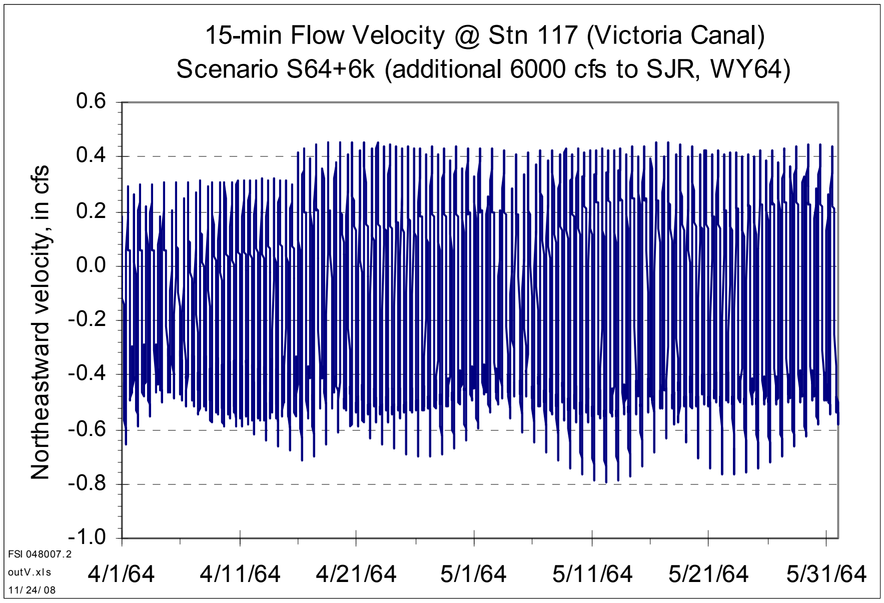

Figure A-11. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64+6k.

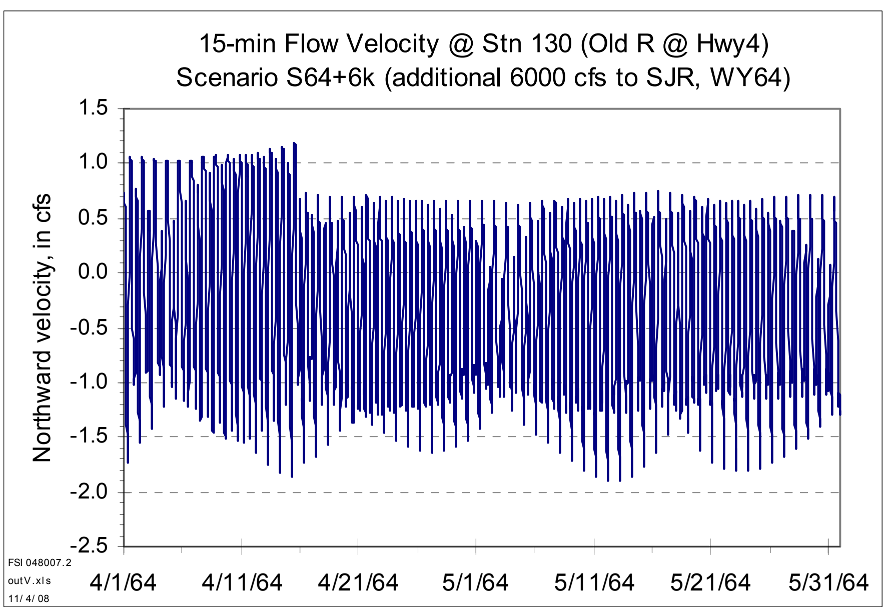

Figure A-12. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64+6k.

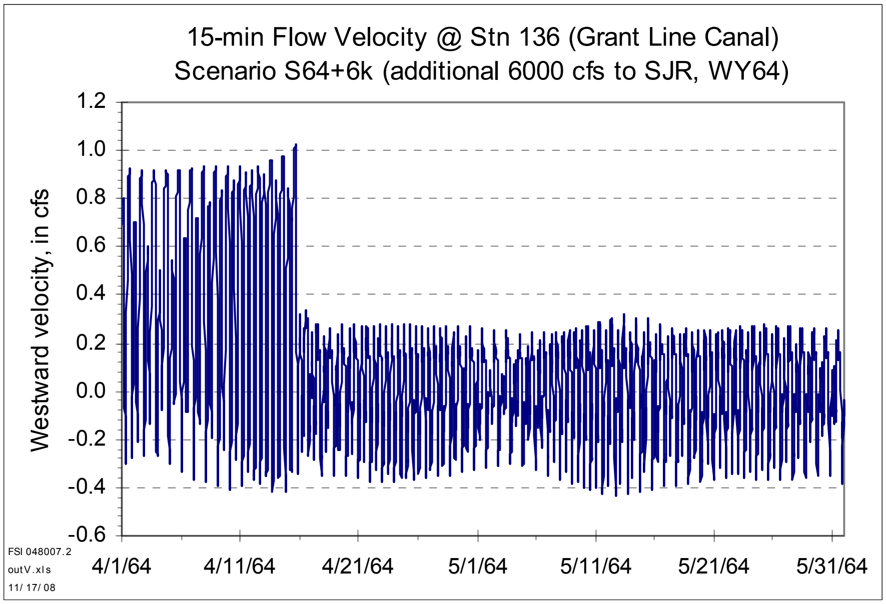

Figure A-13. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64+6k.

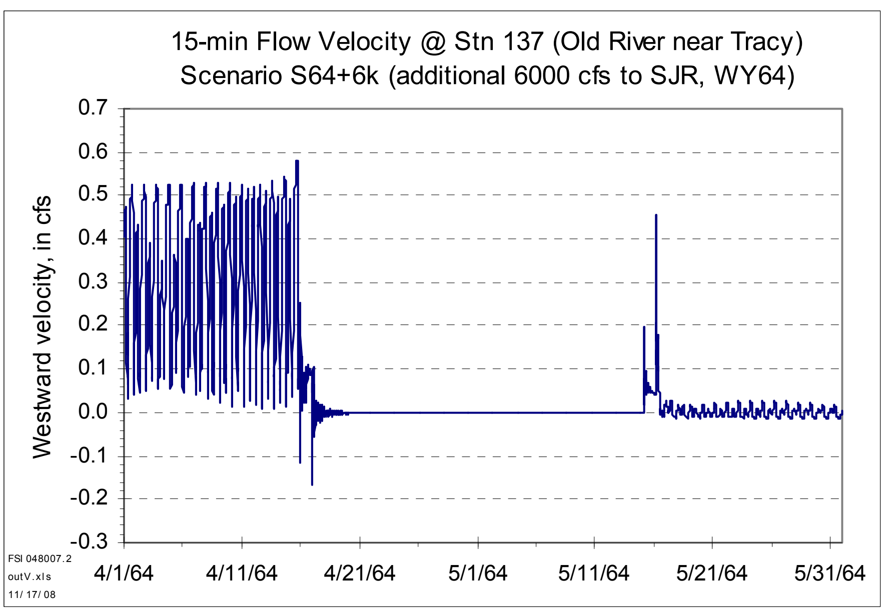

Figure A-14. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64+6k.

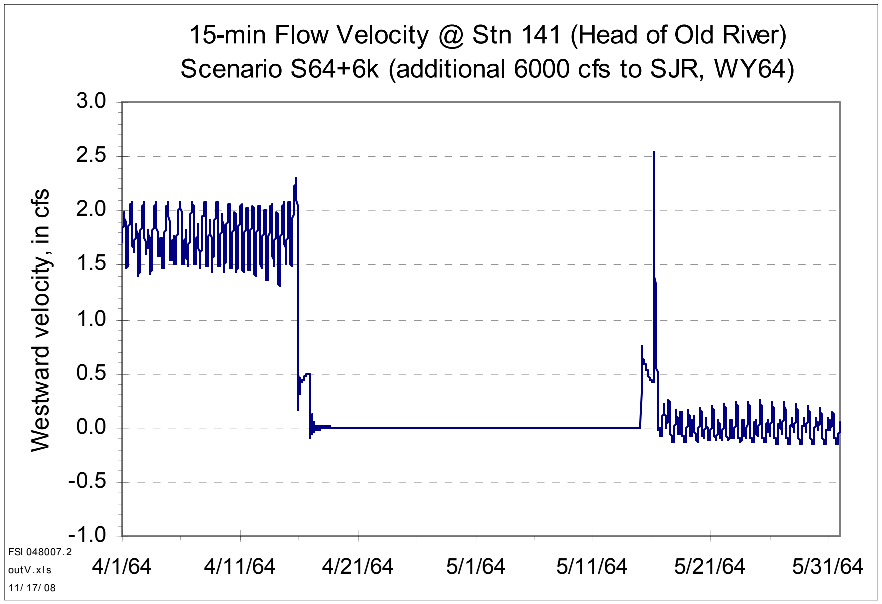

Figure A-15. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64+6k.

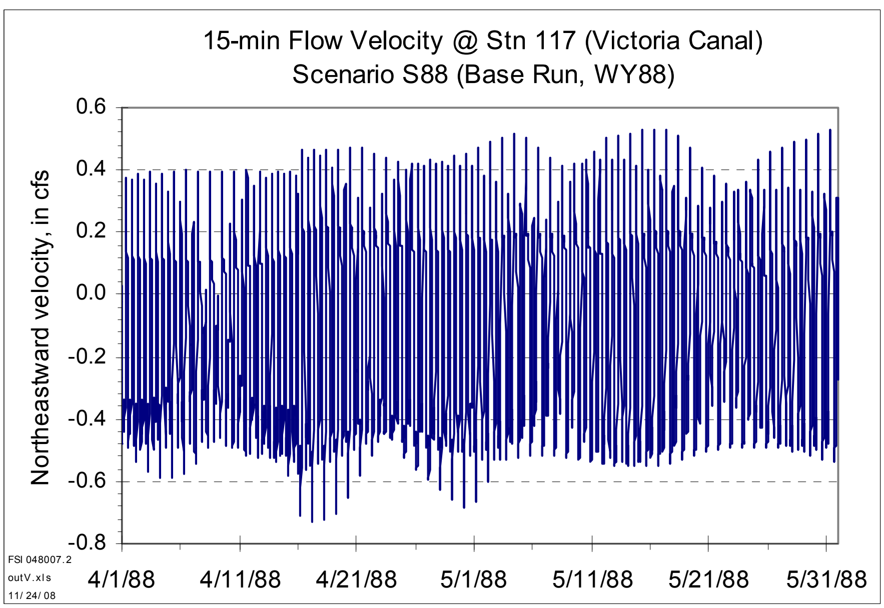

Figure A-16. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88.

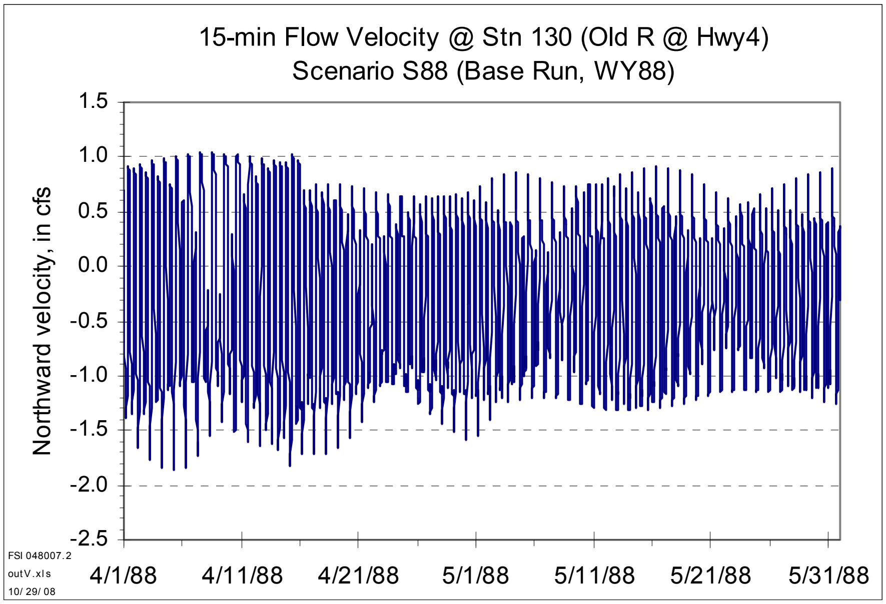

Figure A-17. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88.

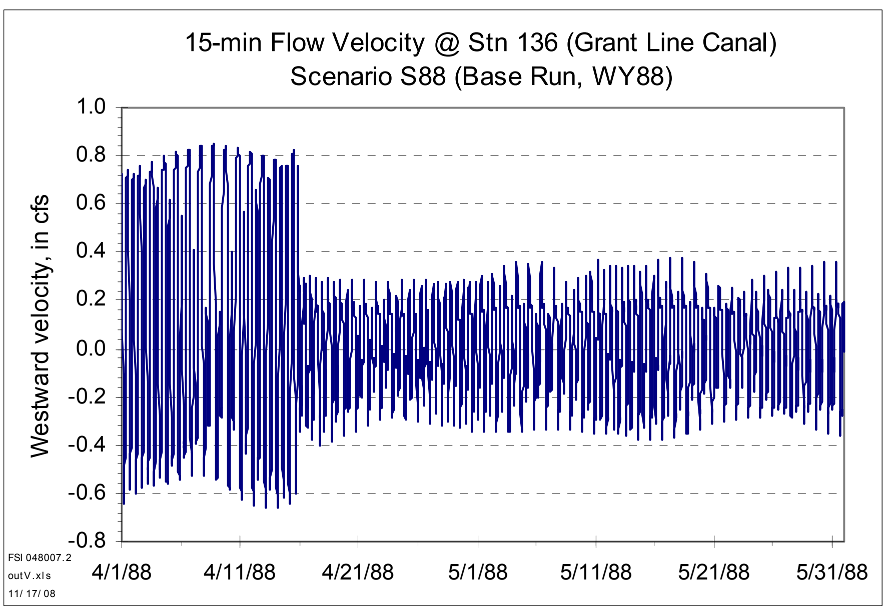

Figure A-18. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88.

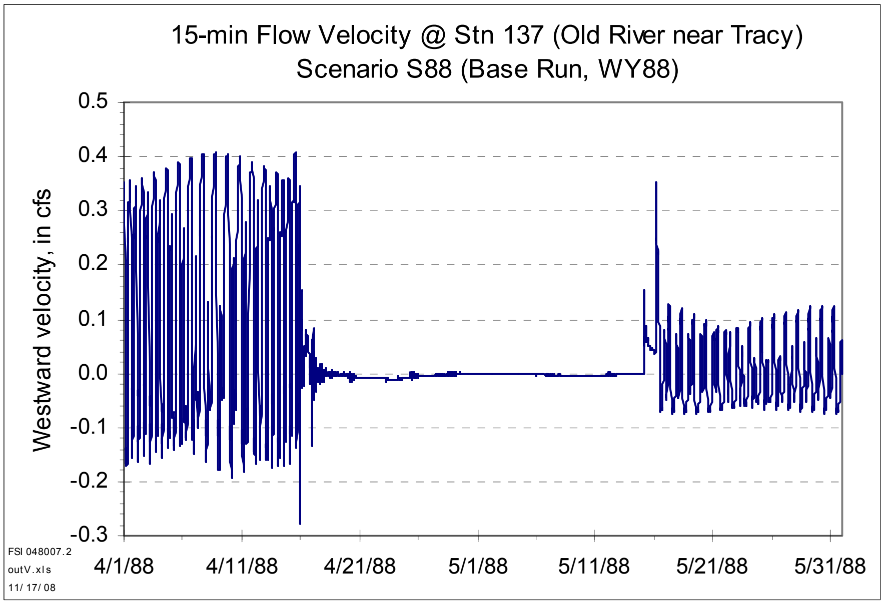

Figure A-19. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S88.

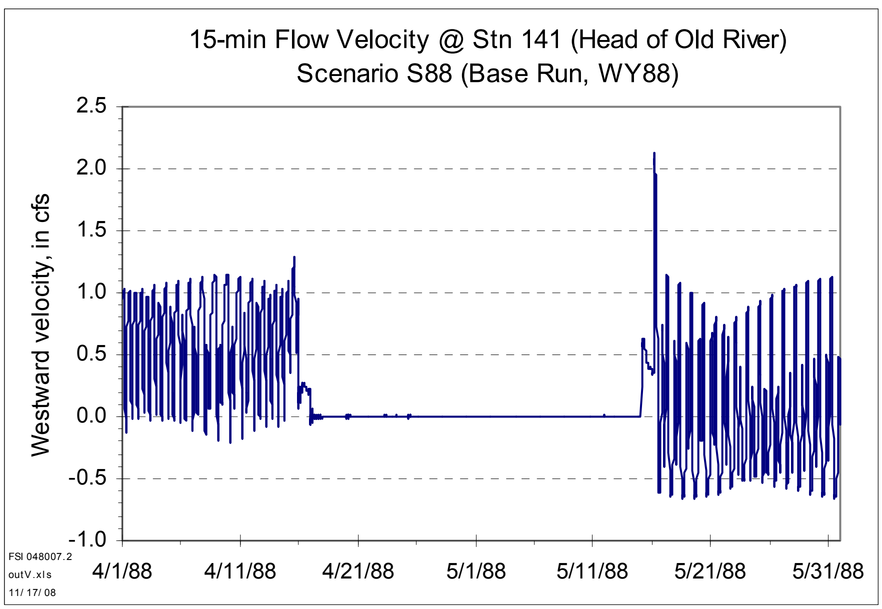

Figure A-20. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88.

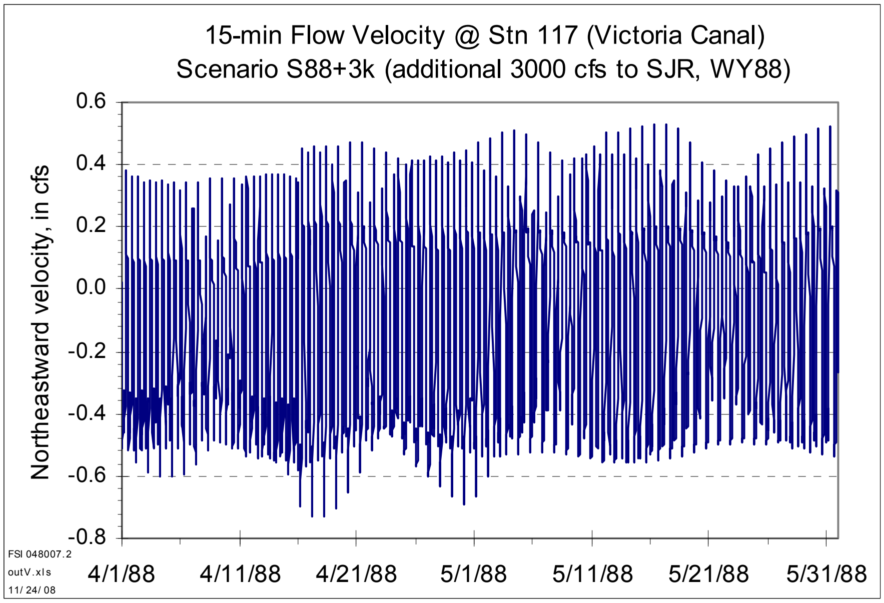

Figure A-21. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88+3k.

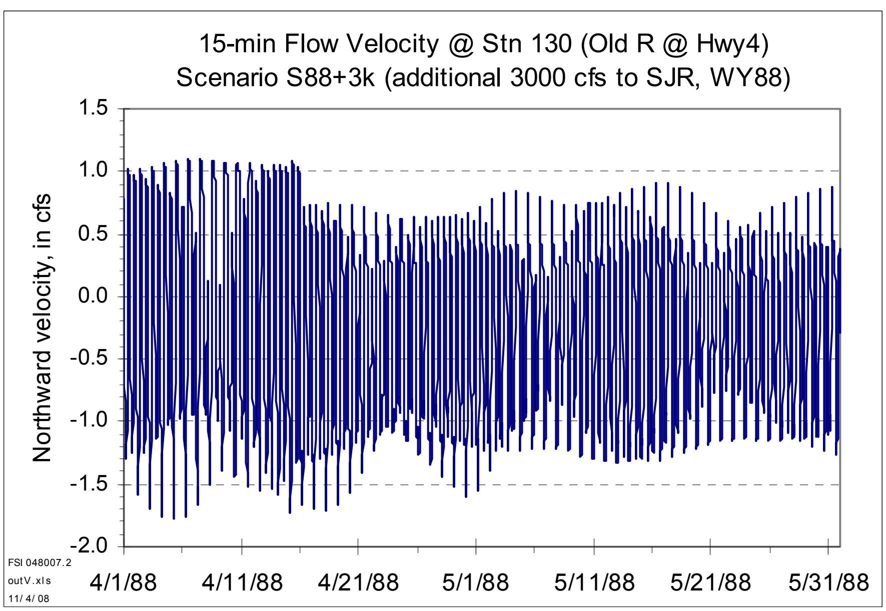

Figure A-22. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88+3k.

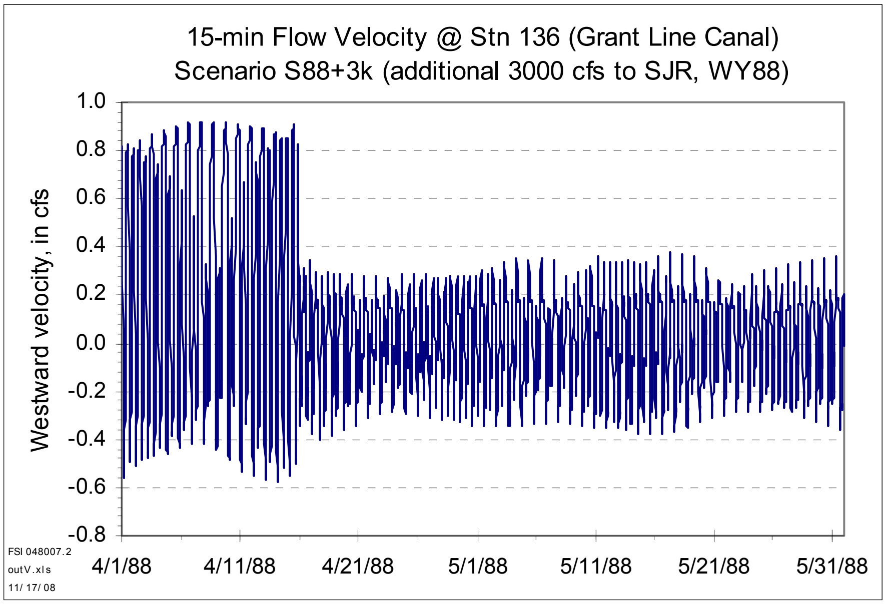

Figure A-23. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88+3k.

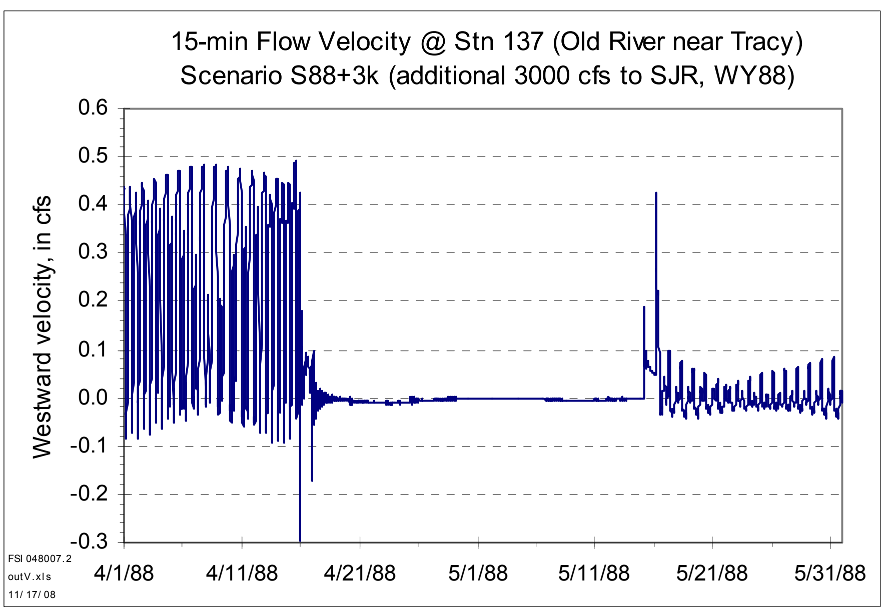

Figure A-24. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S88+3k.

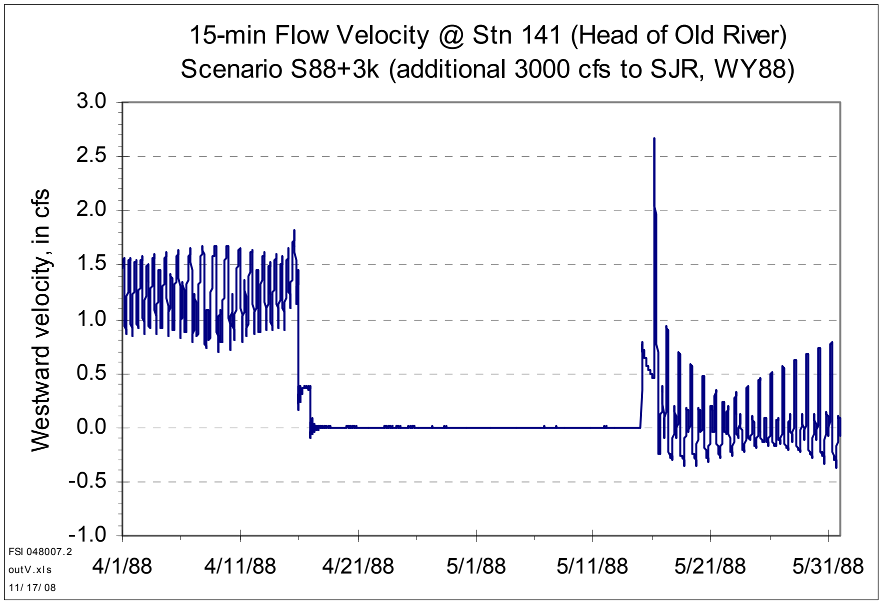

Figure A-25. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88+3k.

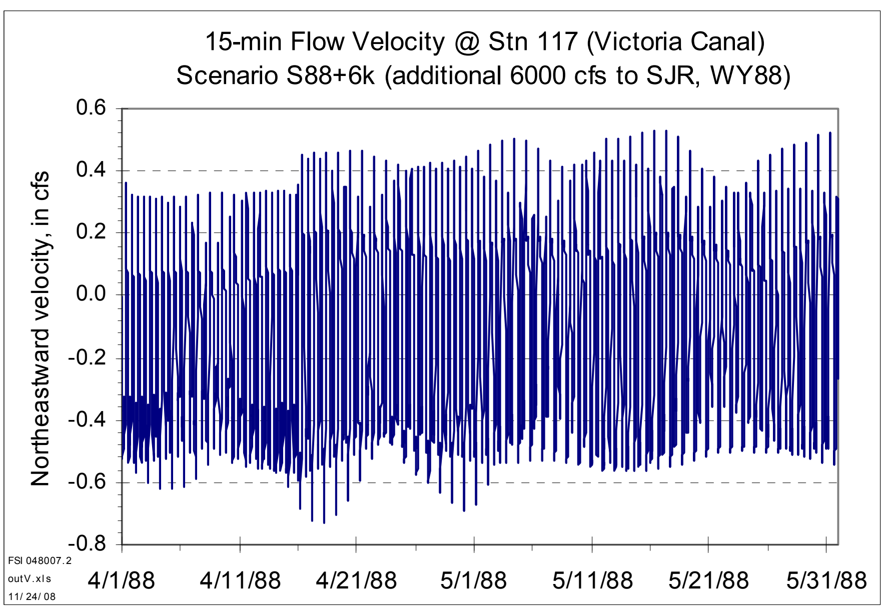

Figure A-26. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88+6k.

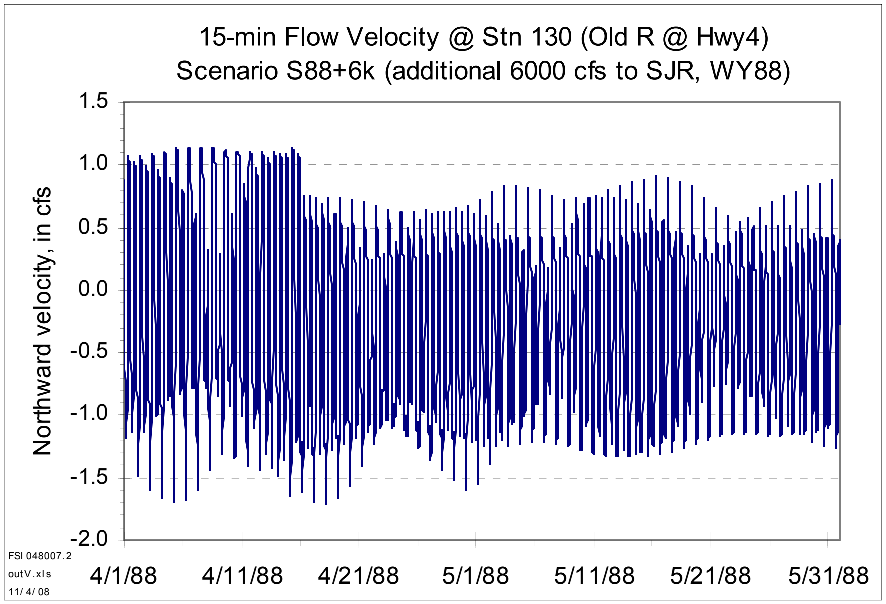

Figure A-27. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88+6k.

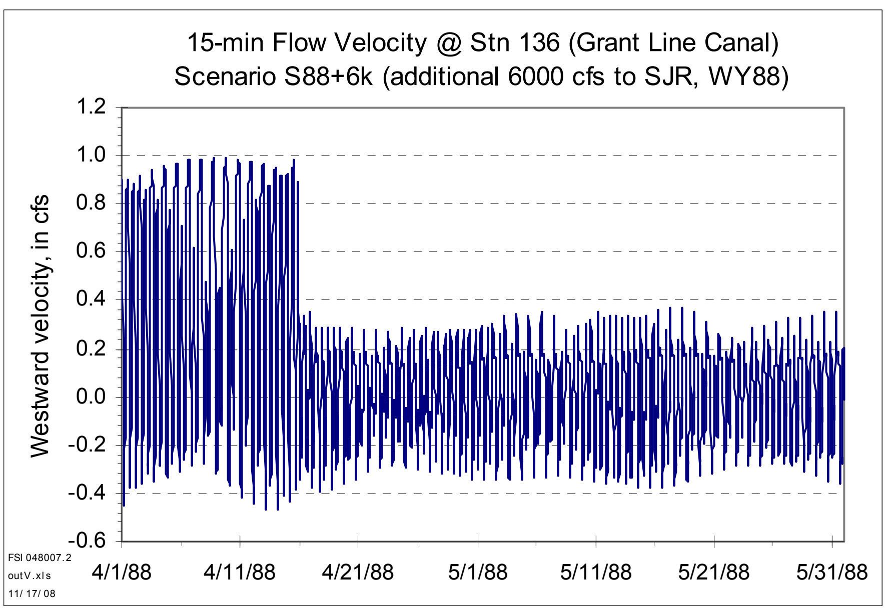

Figure A-28. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88+6k.

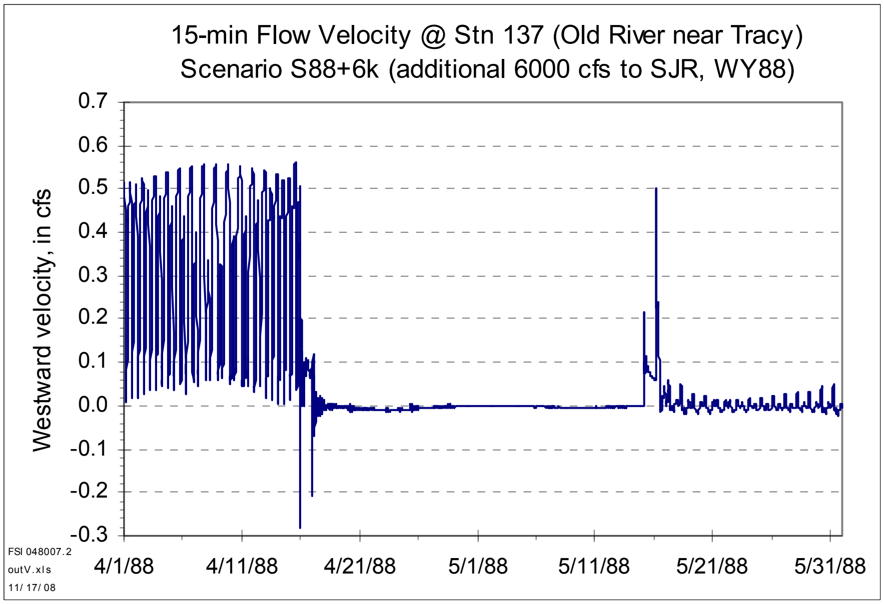

Figure A-29. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S88+6k.

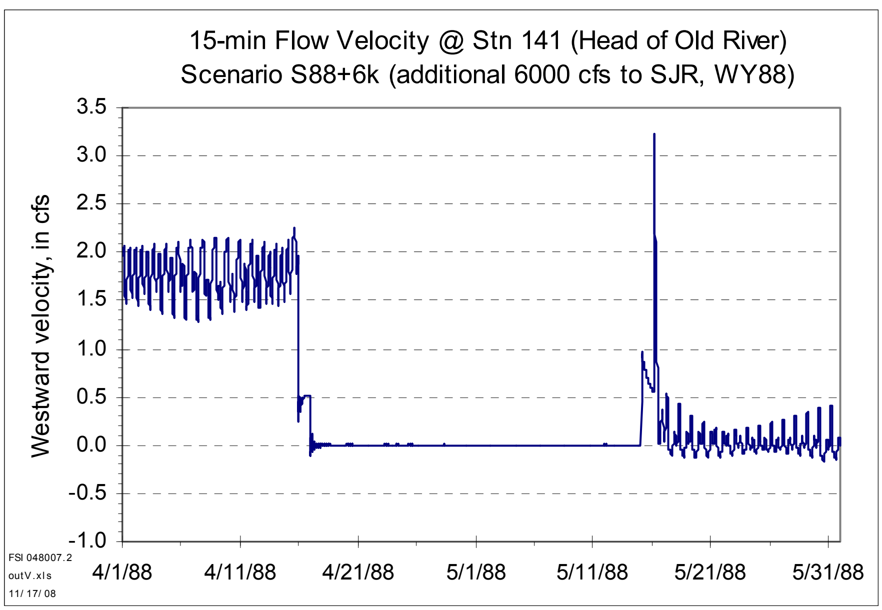

Figure A-30. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88+6k.

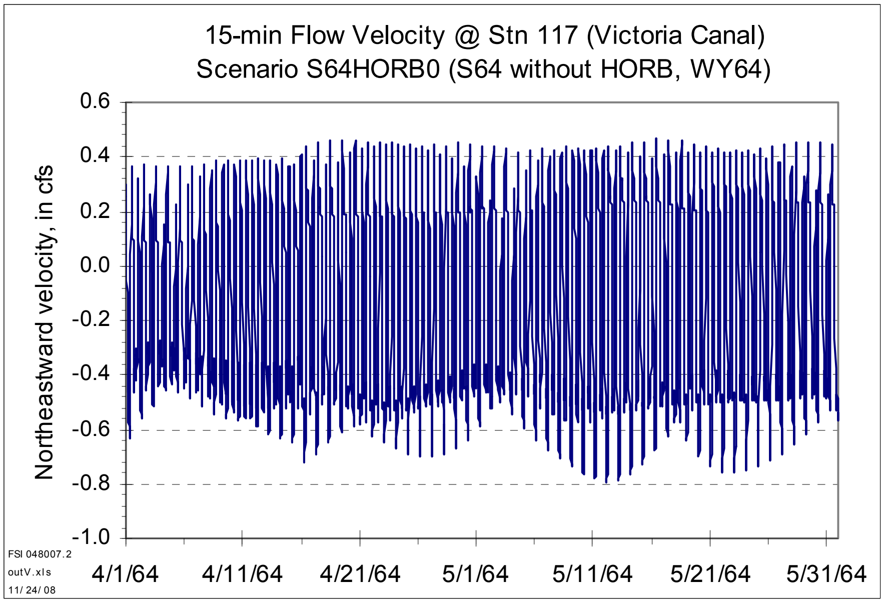

Figure A-31. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64HORB0.

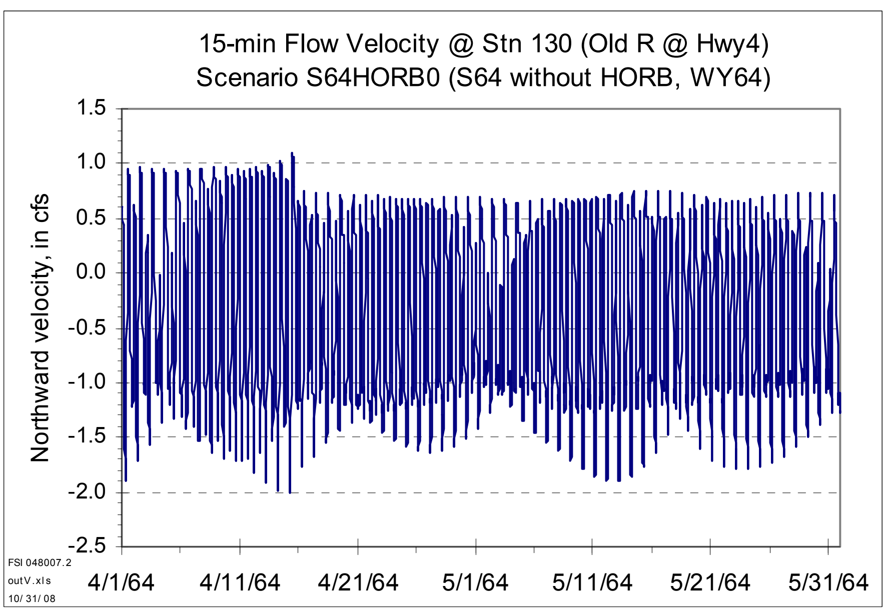

Figure A-32. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64HORB0.

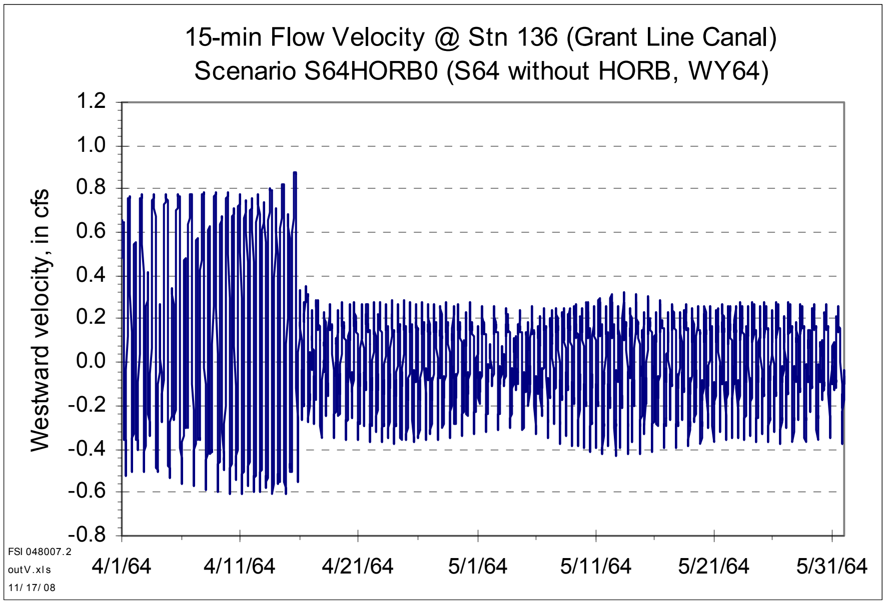

Figure A-33. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64HORB0.

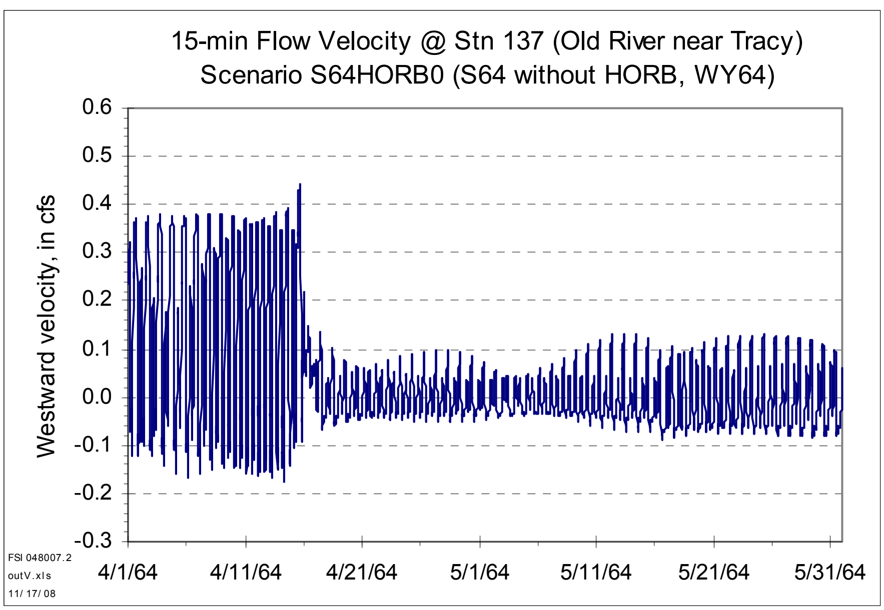

Figure A-34. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64HORB0.

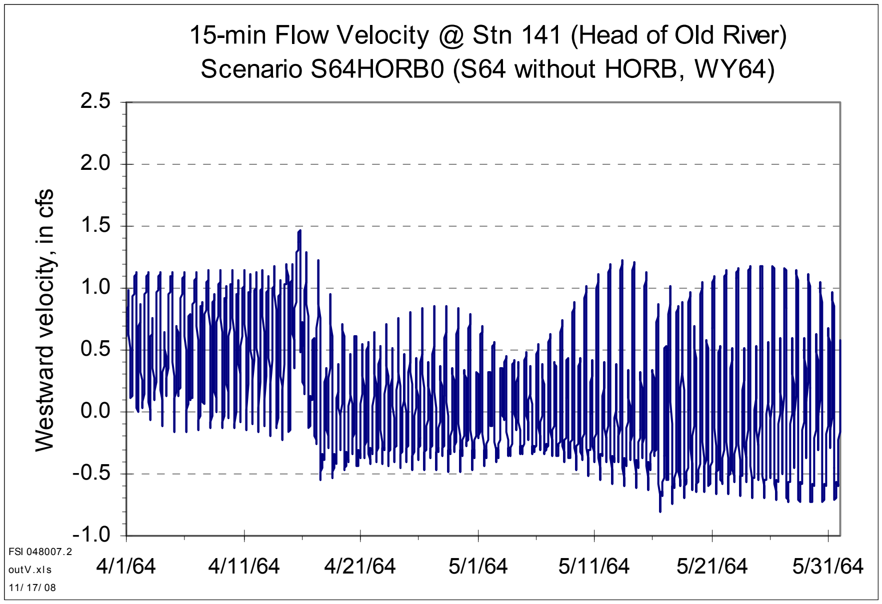

Figure A-35. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0.

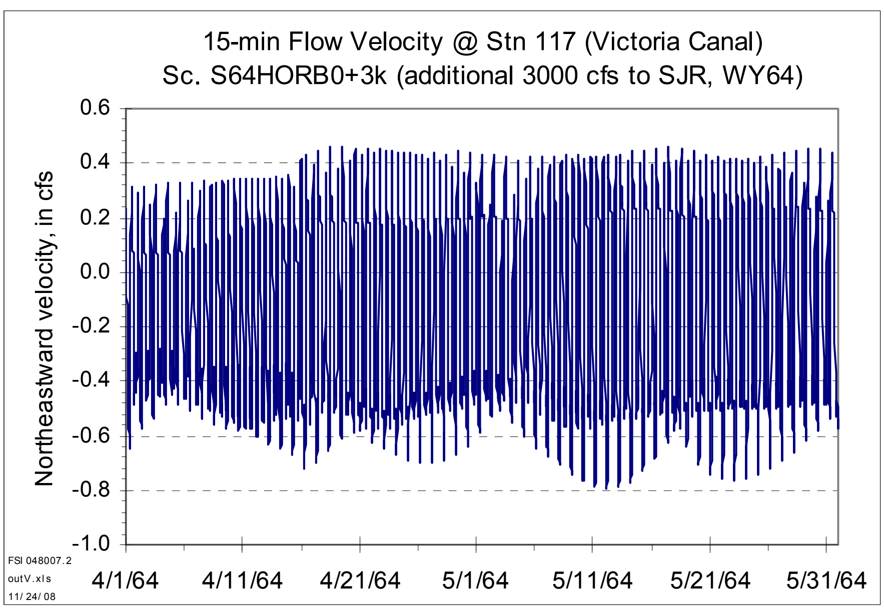

Figure A-36. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64HORB0+3k.

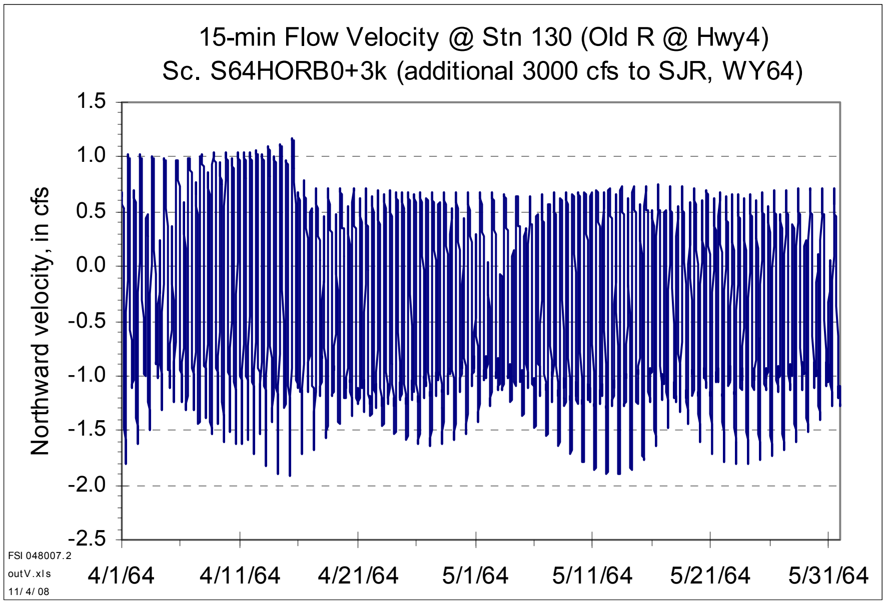

Figure A-37. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64HORB0+3k.

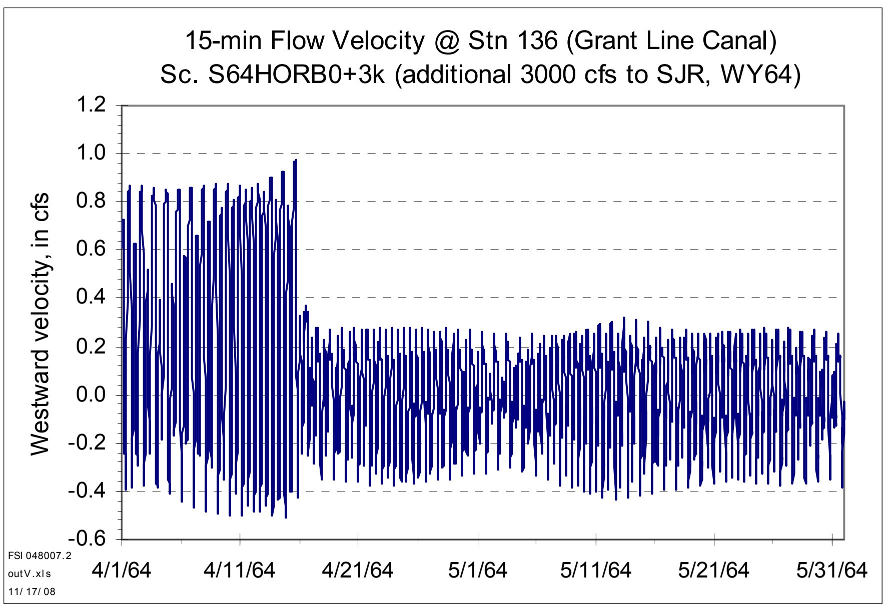

Figure A-38. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64HORB0+3k.

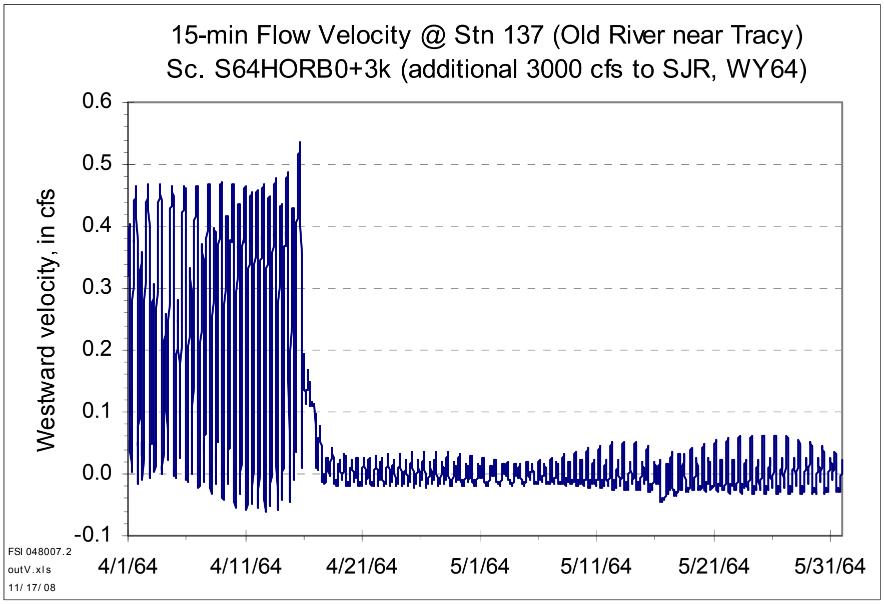

Figure A-39. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64HORB0+3k.

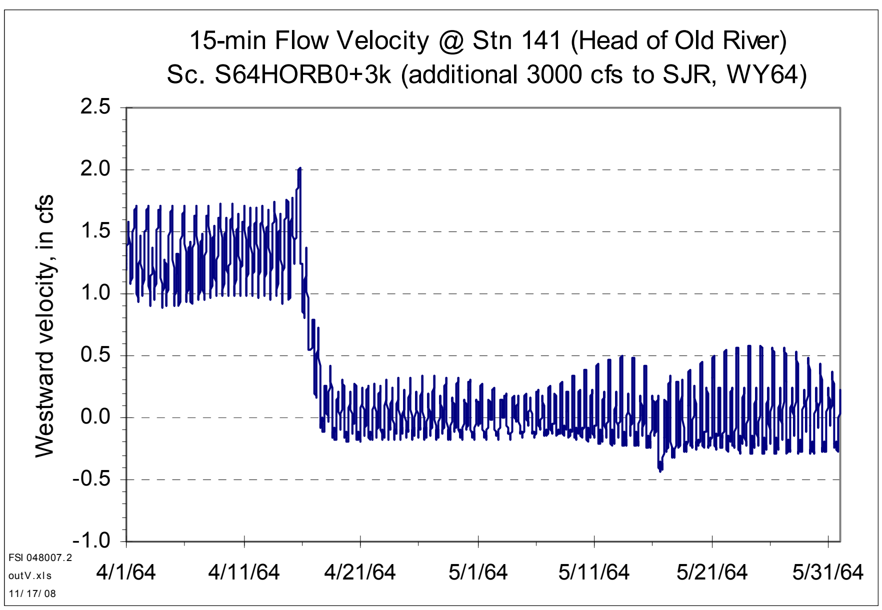

Figure A-40. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0+3k.

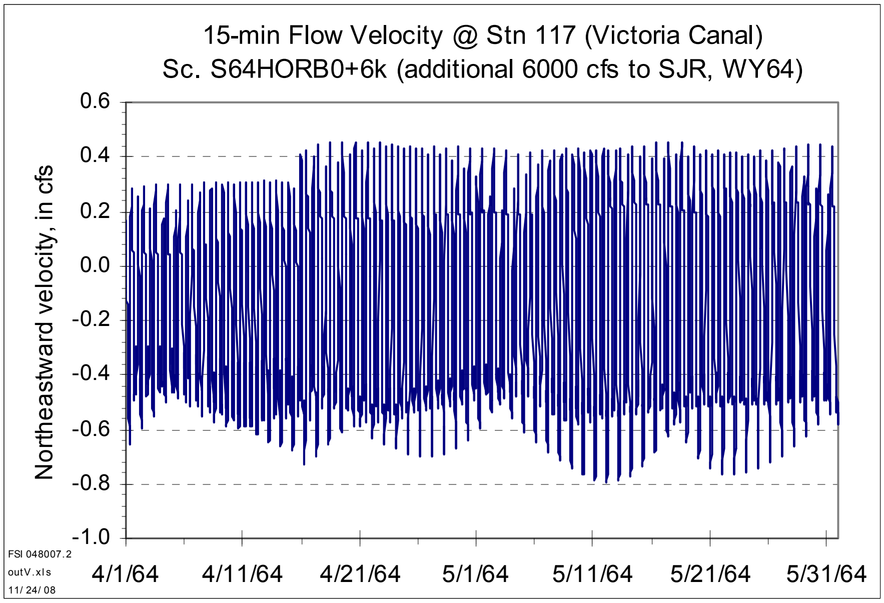

Figure A-41. Flow velocity at Station 117 (in Victoria Canal), for Scenario S64HORB0+6k.

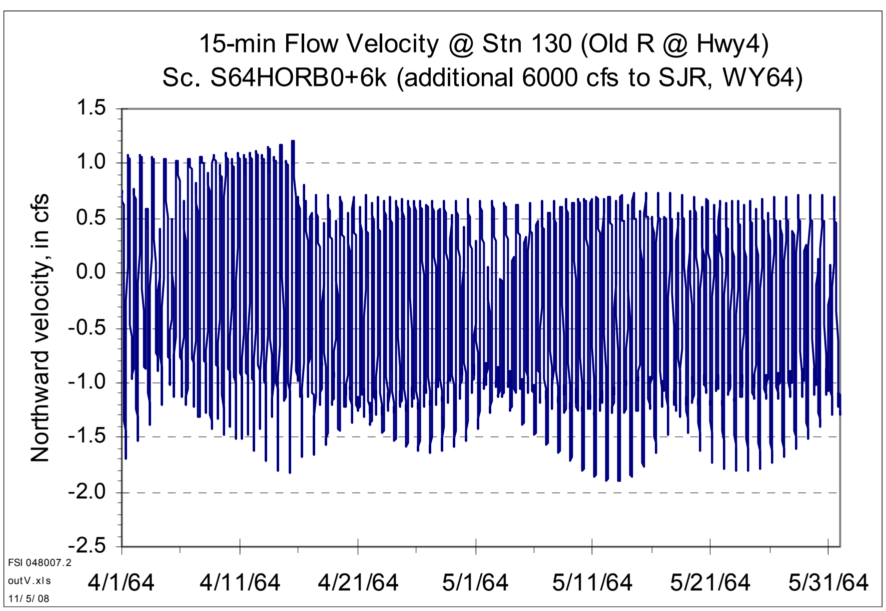

Figure A-42. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S64HORB0+6k.

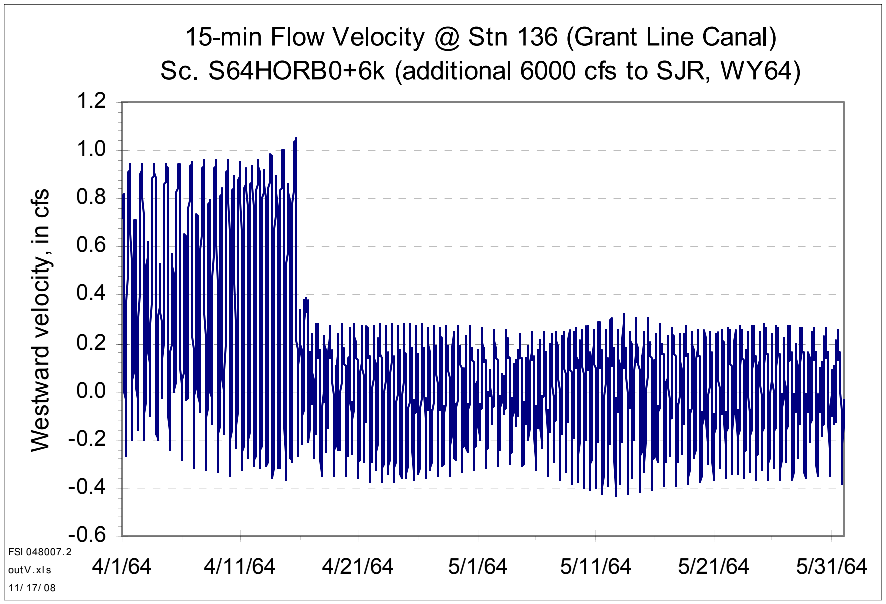

Figure A-43. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S64HORB0+6k.

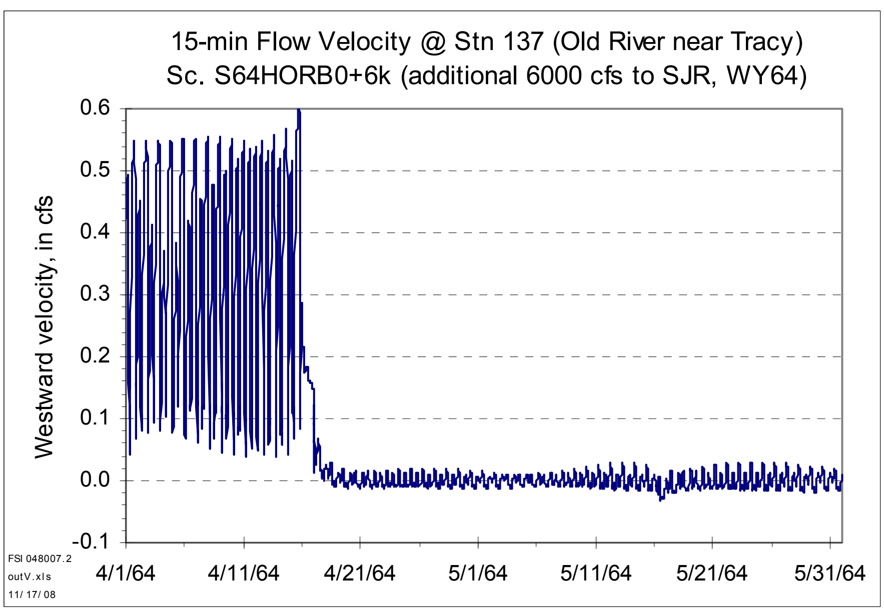

Figure A-44. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S64HORB0+6k.

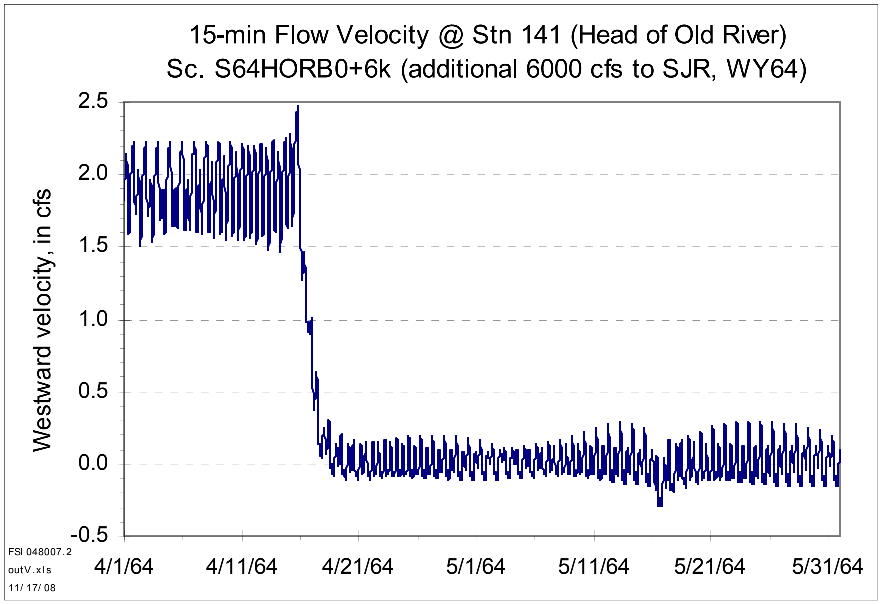

Figure A-45. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0+6k.

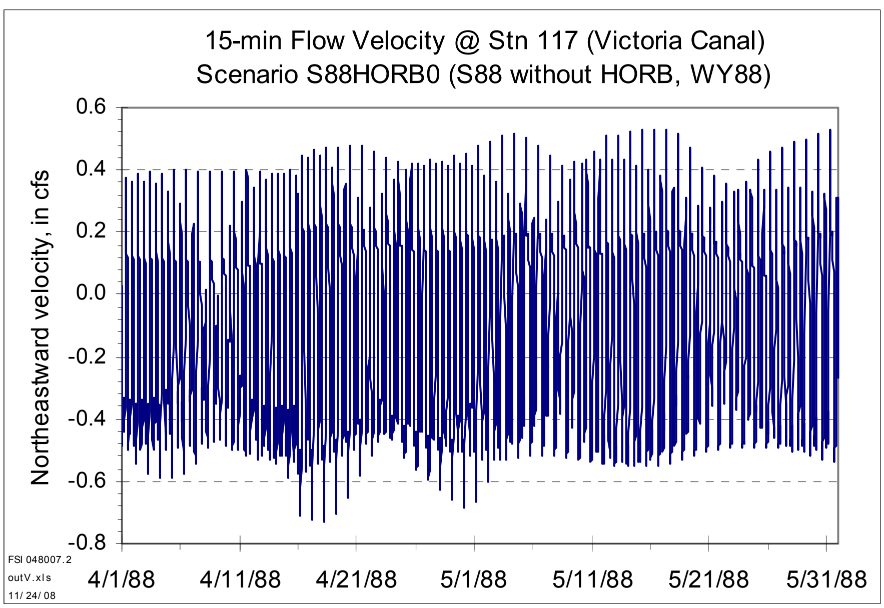

Figure A-46. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88HORB0.

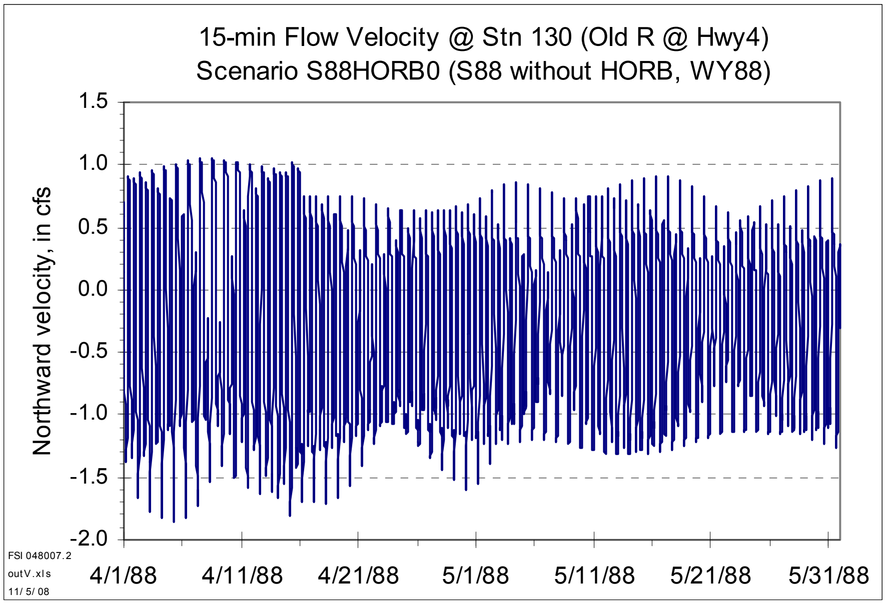

Figure A-47. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88HORB0.

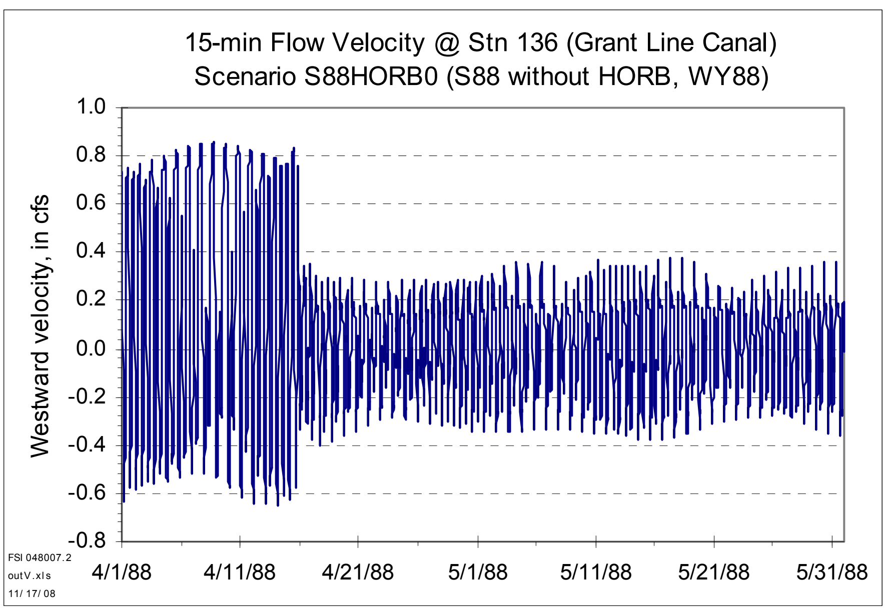

Figure A-48. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88HORB0.

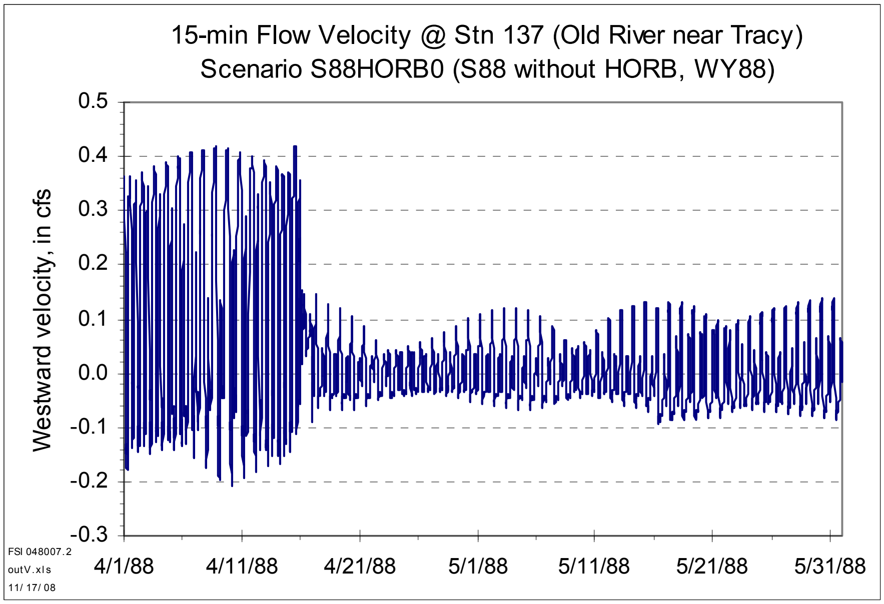

Figure A-49. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S88HORB0.

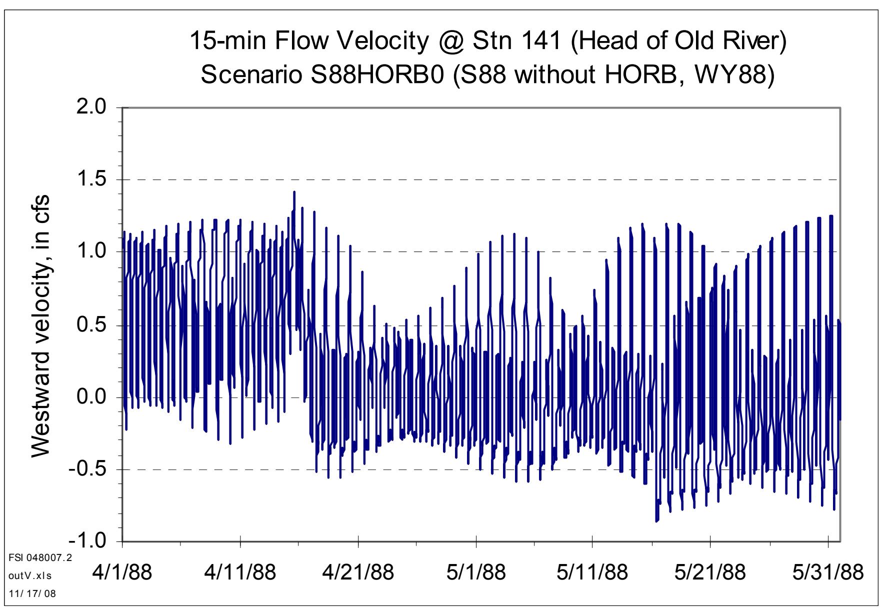

Figure A-50. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0.

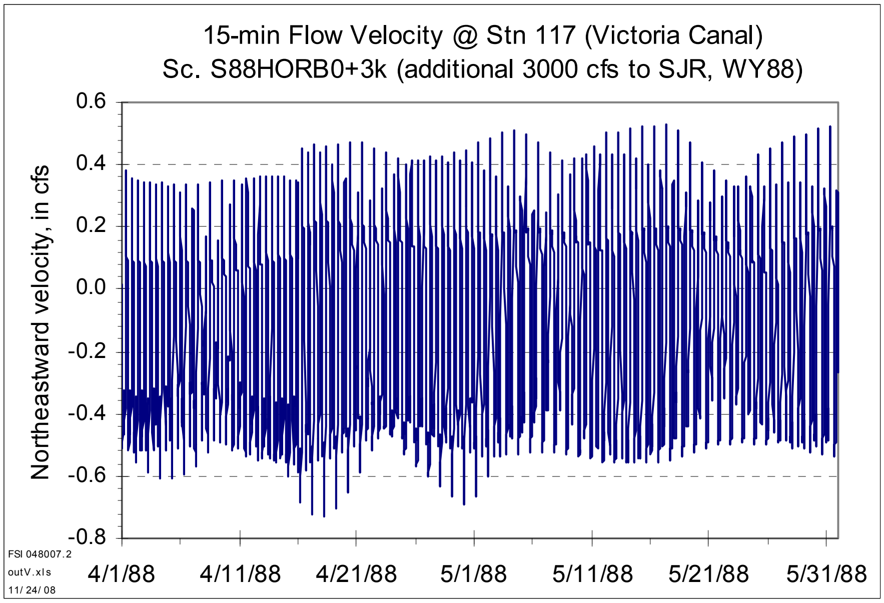

Figure A-51. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88HORB0+3k.

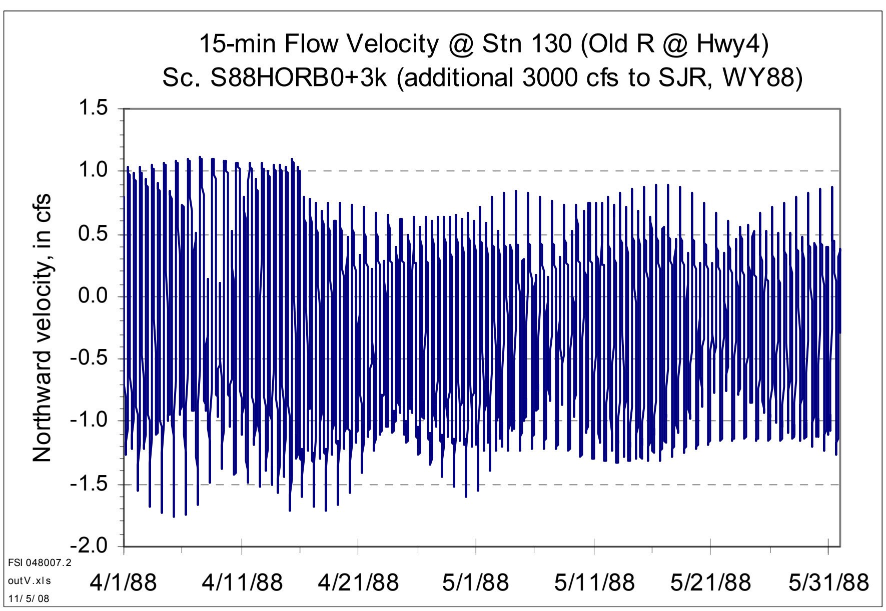

Figure A-52. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88HORB0+3k.

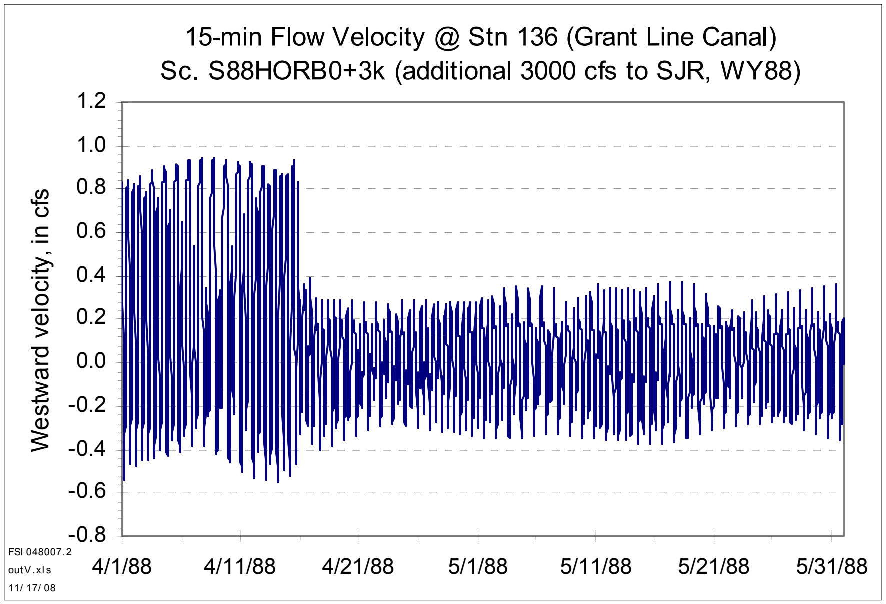

Figure A-53. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88HORB0+3k.

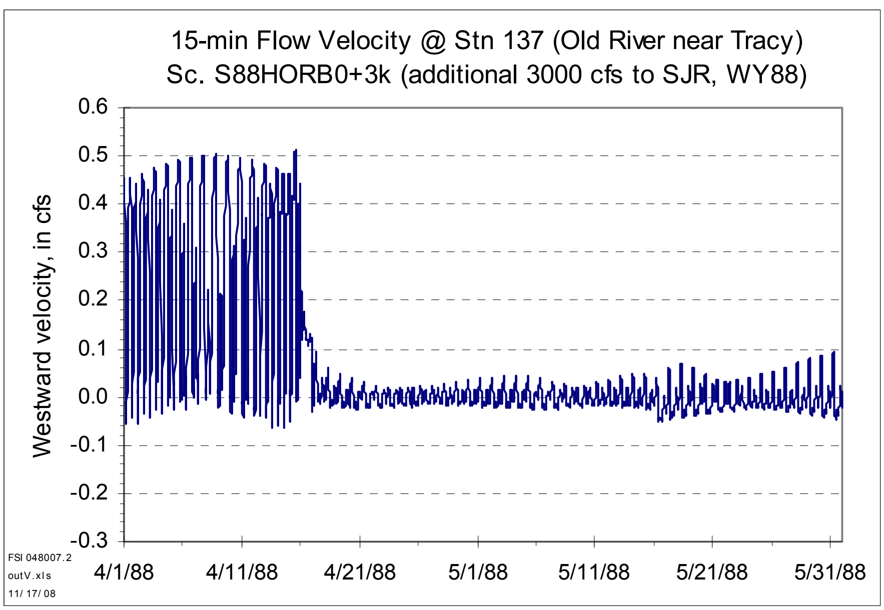

Figure A-54. Flow velocity at Station 137 (in Old River near Tracy), for Scenario ***S88HORB0+3k.***

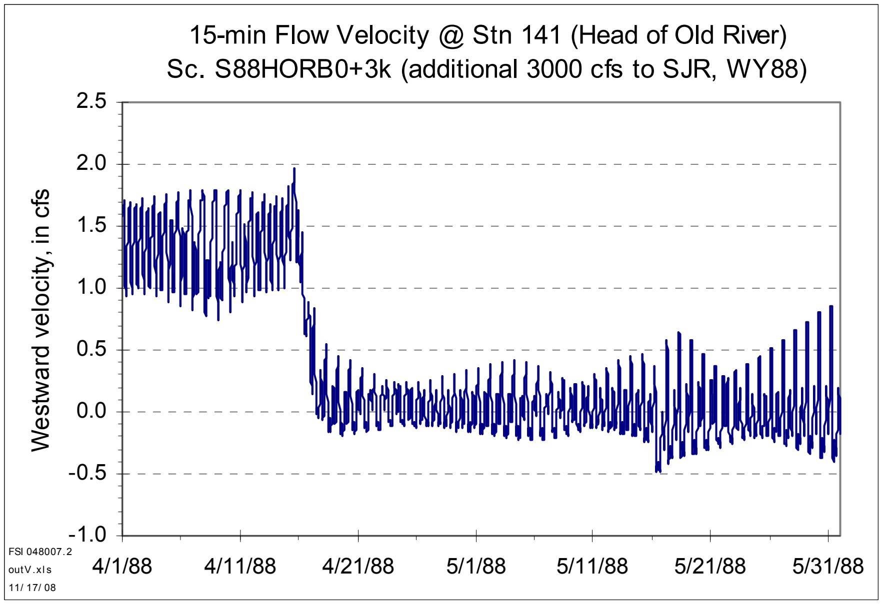

Figure A-55. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0+3k.

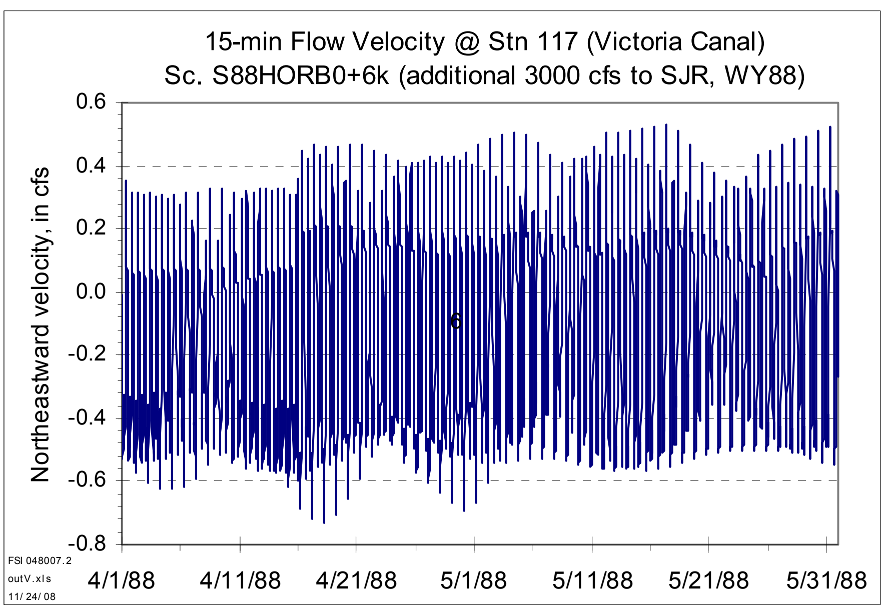

Figure A-56. Flow velocity at Station 117 (in Victoria Canal), for Scenario S88HORB0+6k.

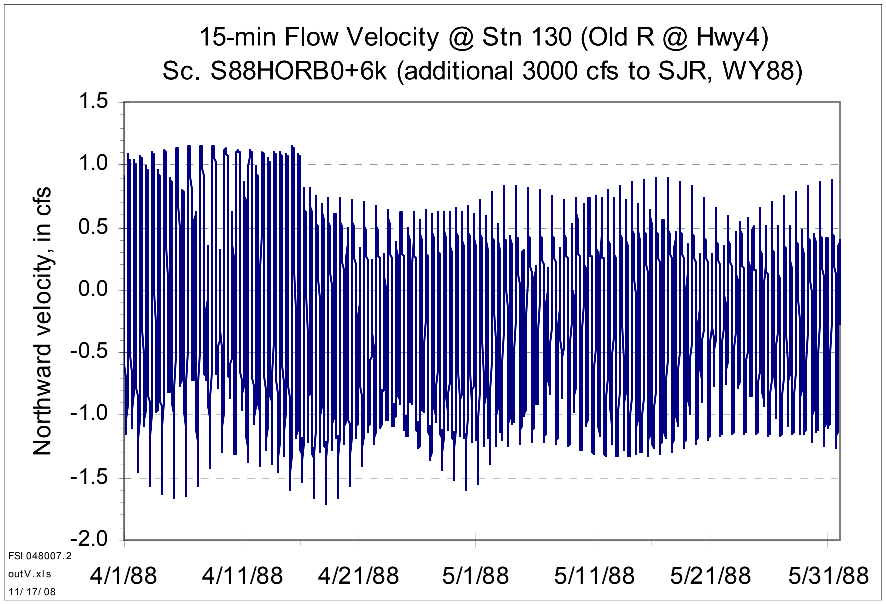

Figure A-57. Flow velocity at Station 130 (Old River at Highway 4), for Scenario S88HORB0+6k.

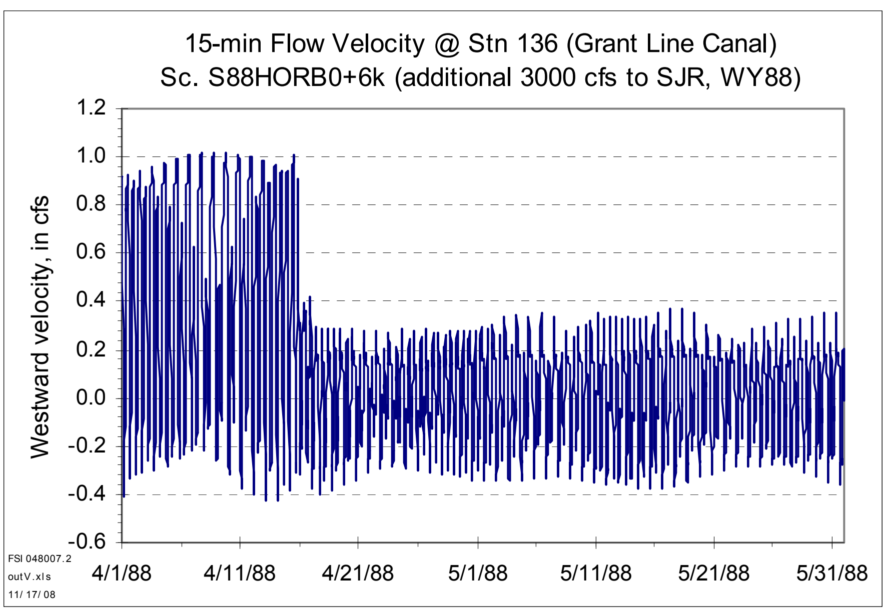

Figure A-58. Flow velocity at Station 136 (in Grant Line Canal), for Scenario S88HORB0+6k.

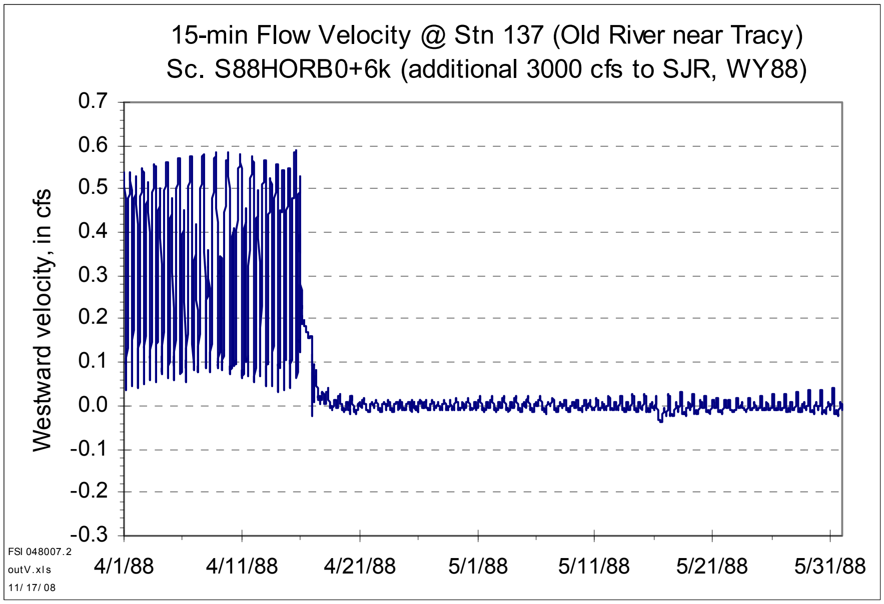

Figure A-59. Flow velocity at Station 137 (in Old River near Tracy), for Scenario S88HORB0+6k.

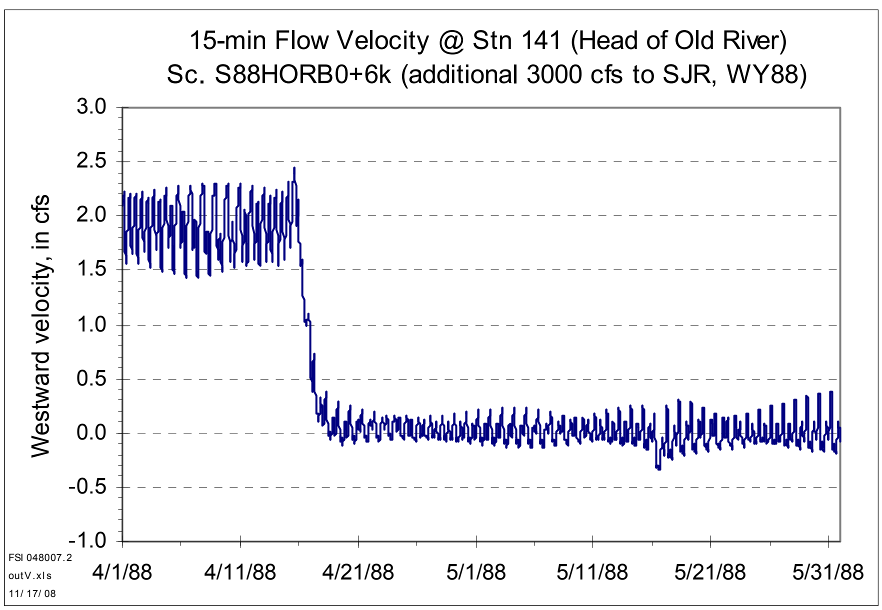

Figure A-60. Flow velocity at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0+6k.

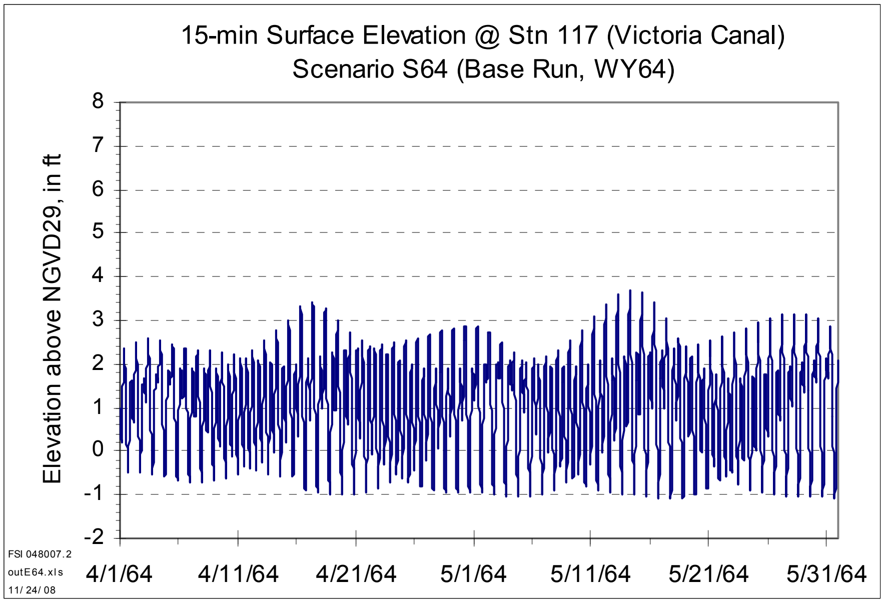

Figure A-61. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64.

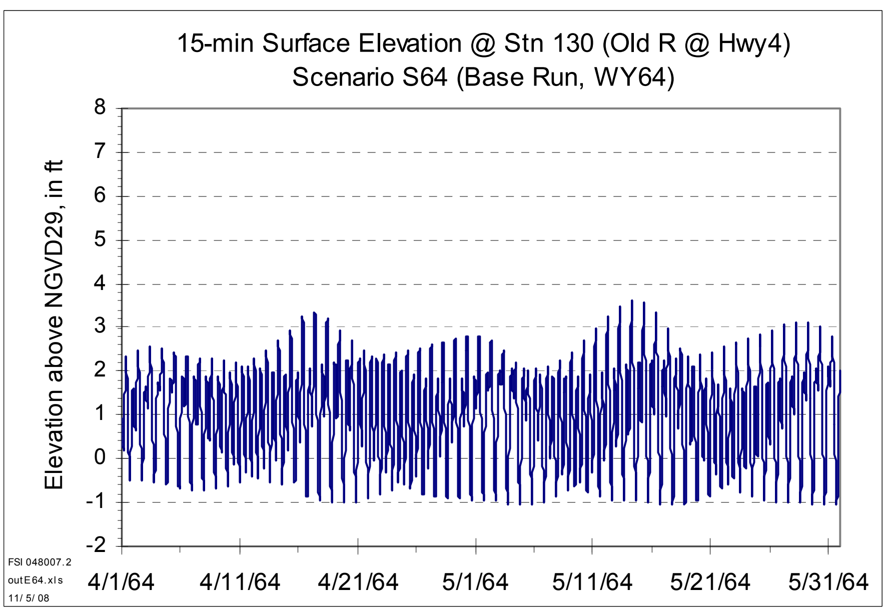

Figure A-62. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64.

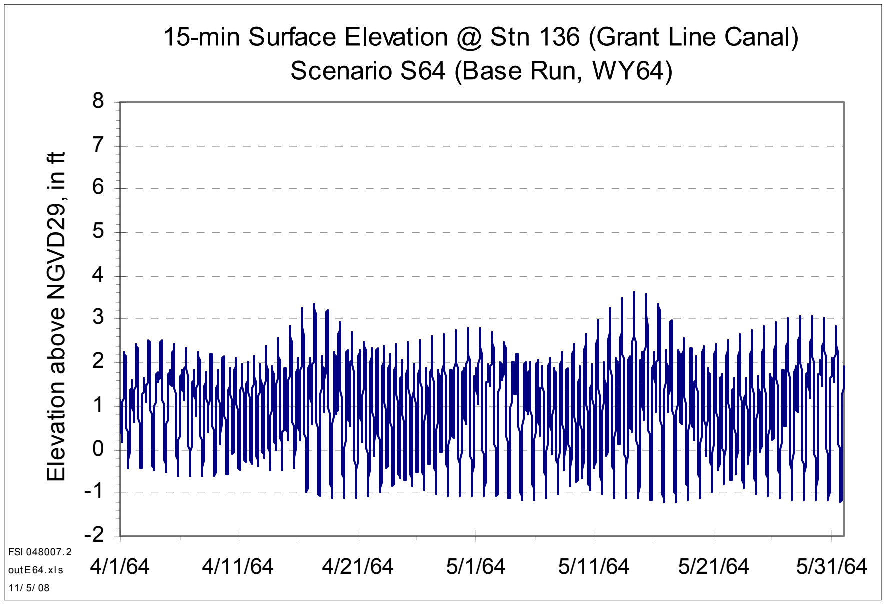

Figure A-63. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64.

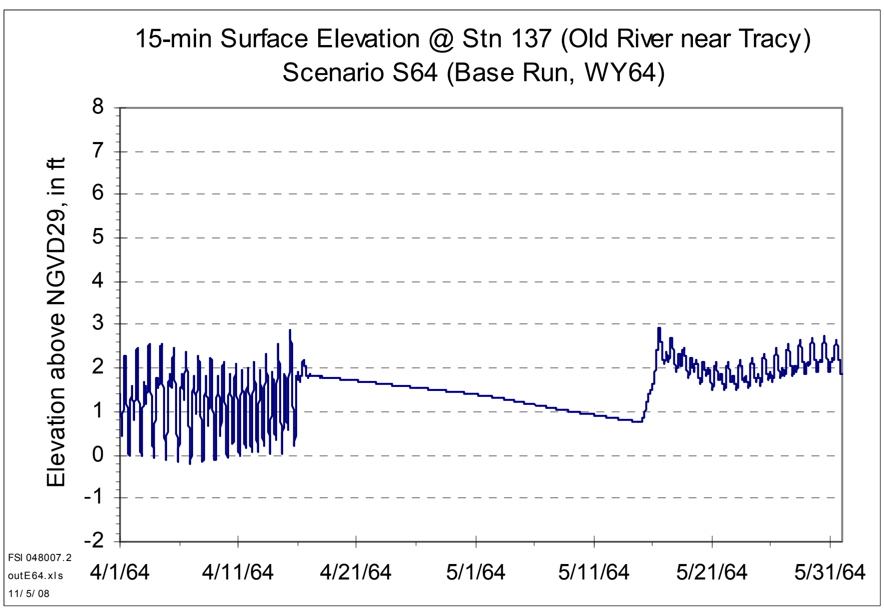

Figure A-64. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64.

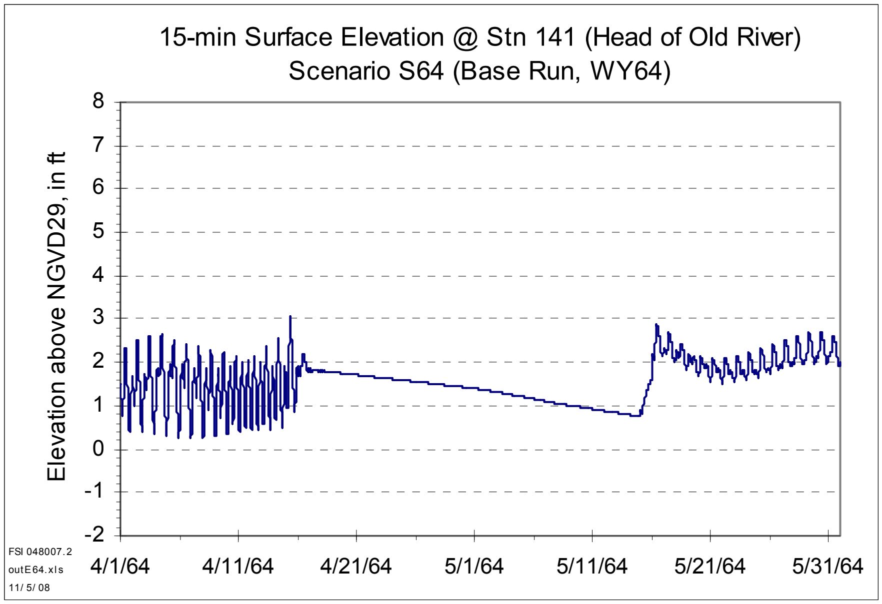

Figure A-65. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64.

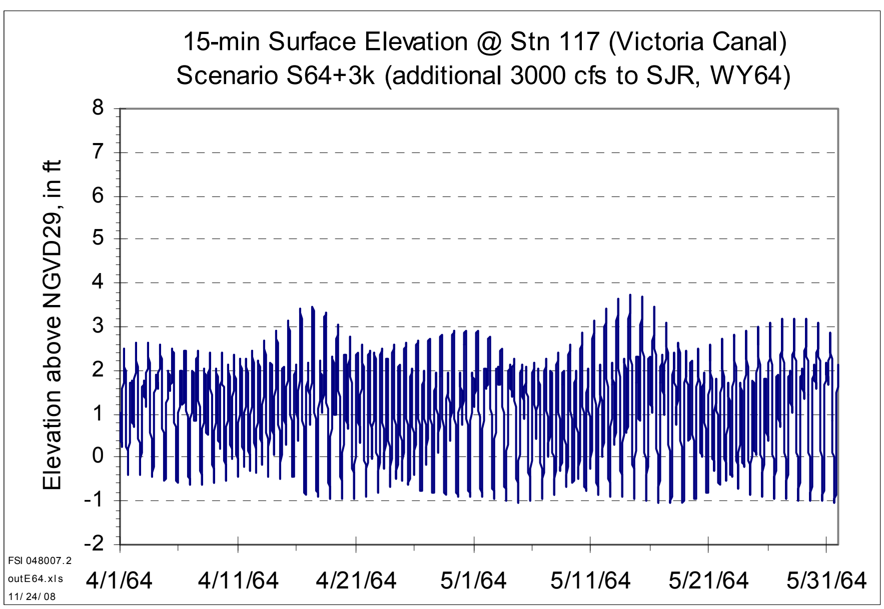

Figure A-66. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64+3k.

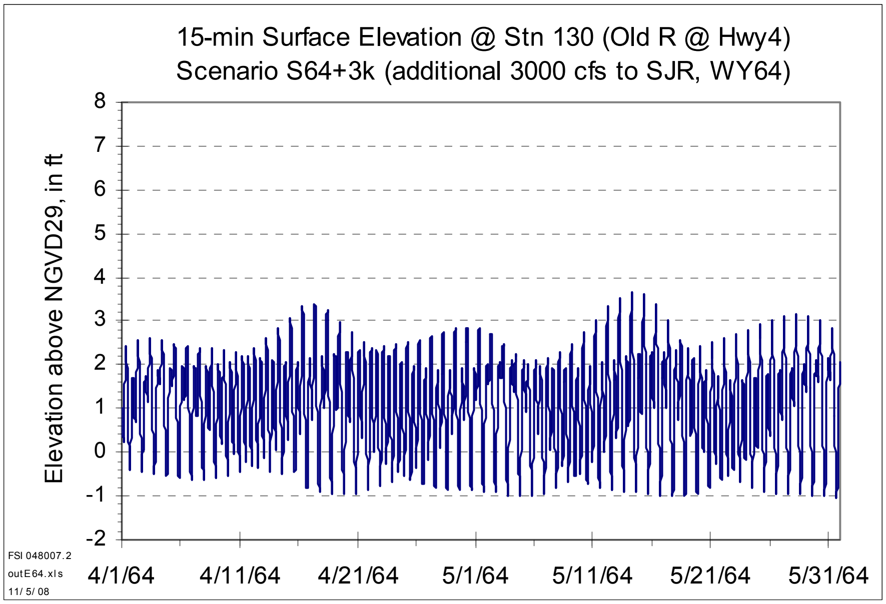

Figure A-67. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64+3k.

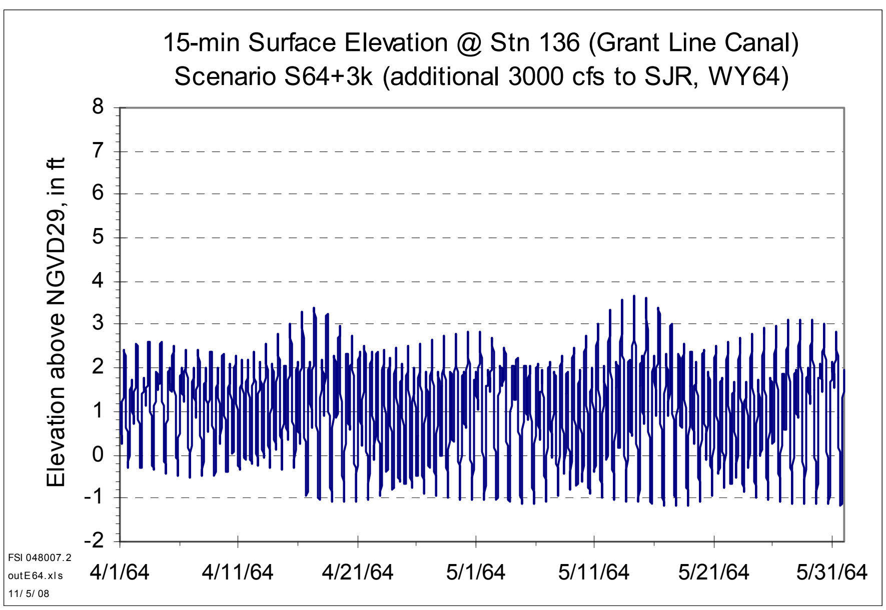

Figure A-68. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64+3k.

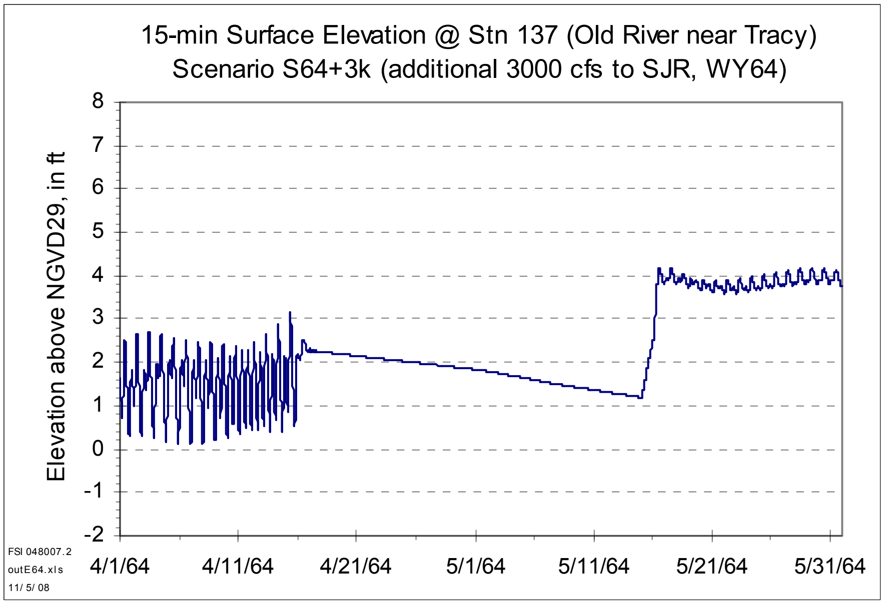

Figure A-69. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64+3k.

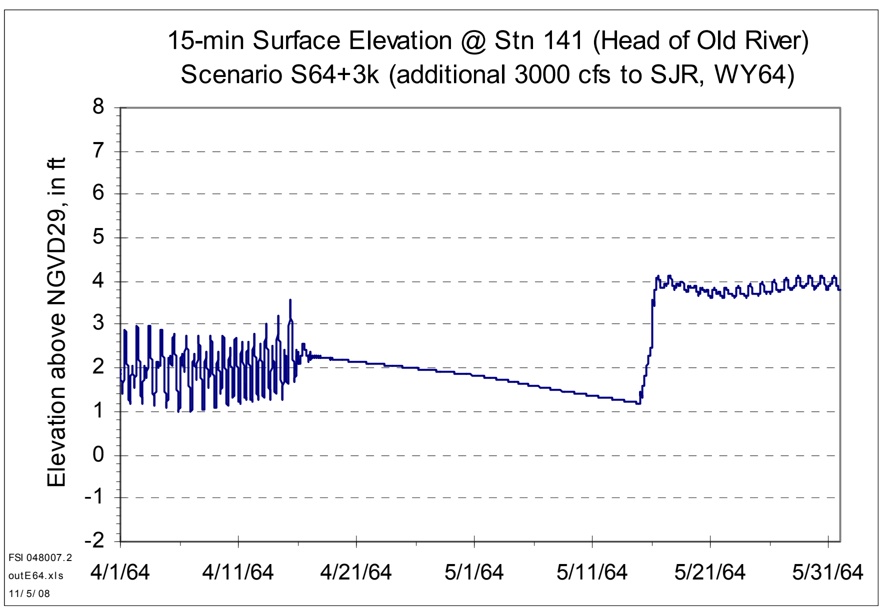

Figure A-70. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64+3k.

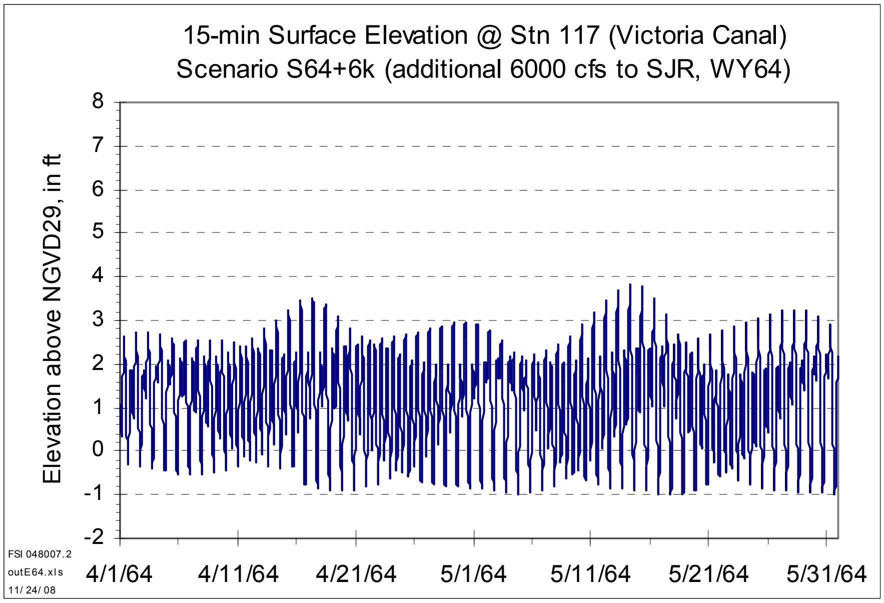

Figure A-71. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64+6k.

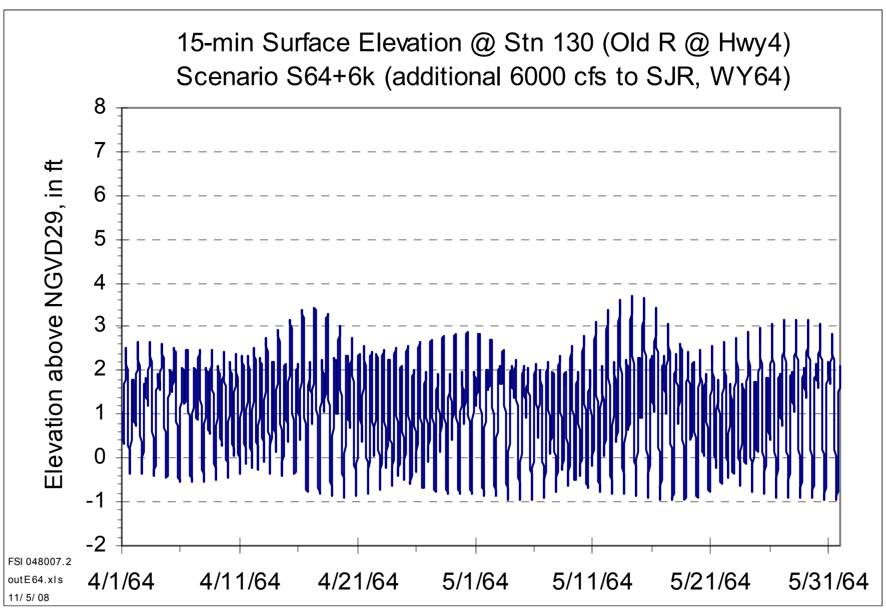

Figure A-72. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64+6k.

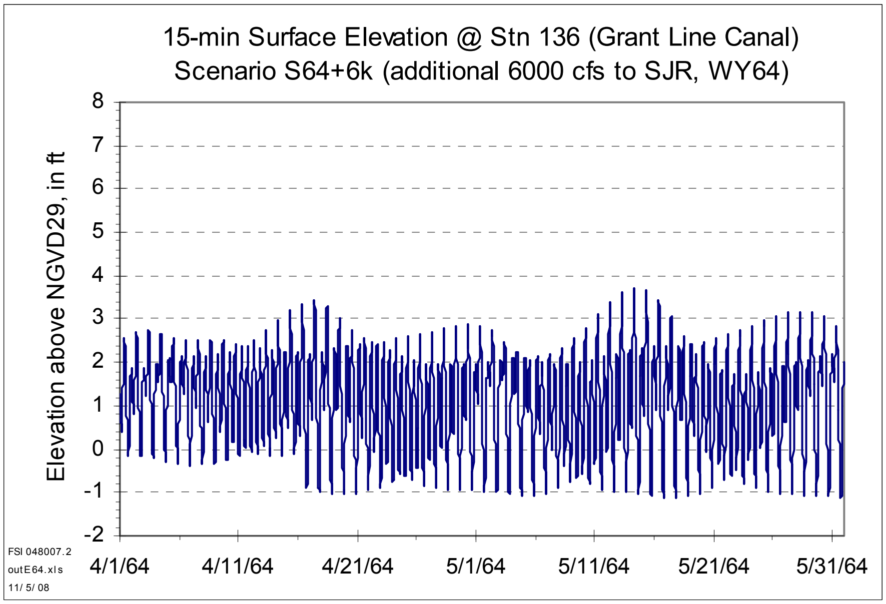

Figure A-73. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64+6k.

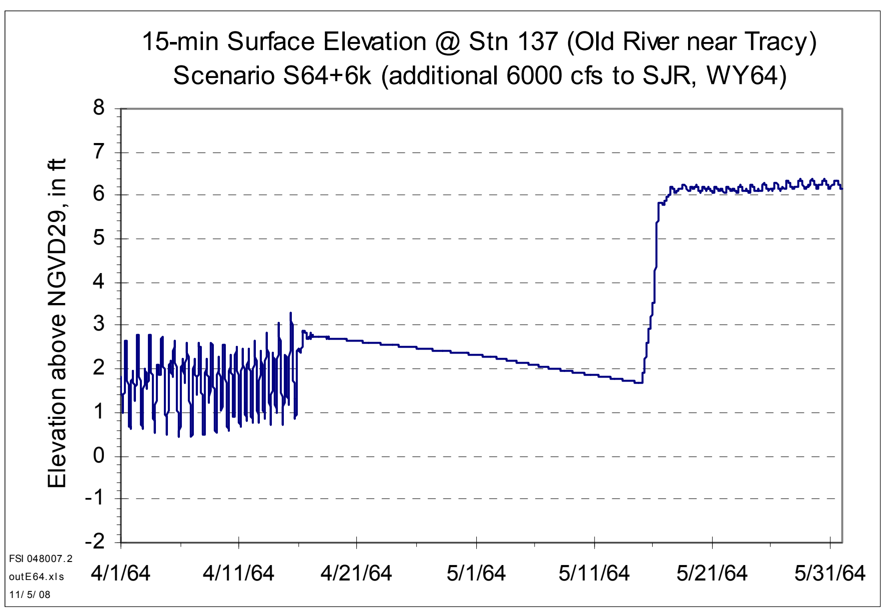

Figure A-74. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64+6k.

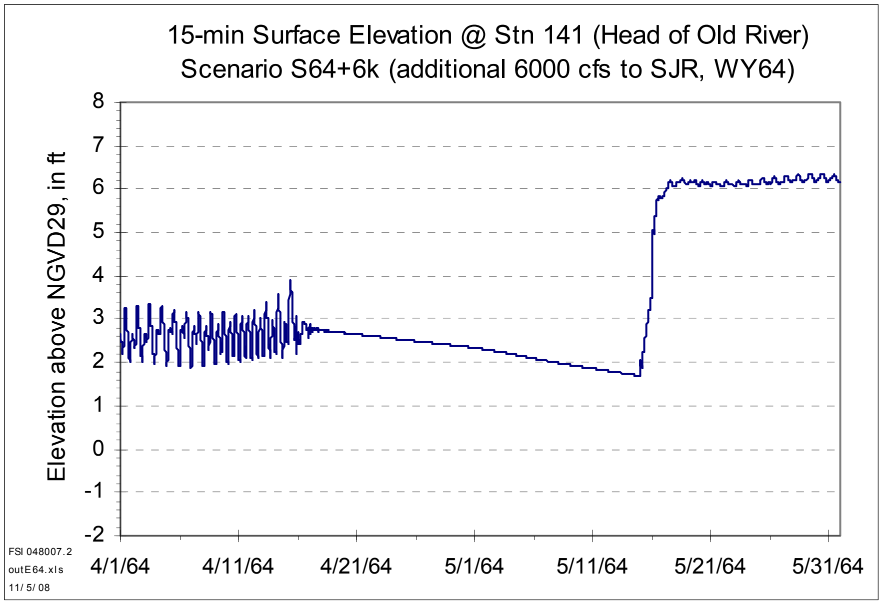

Figure A-75. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64+6k.

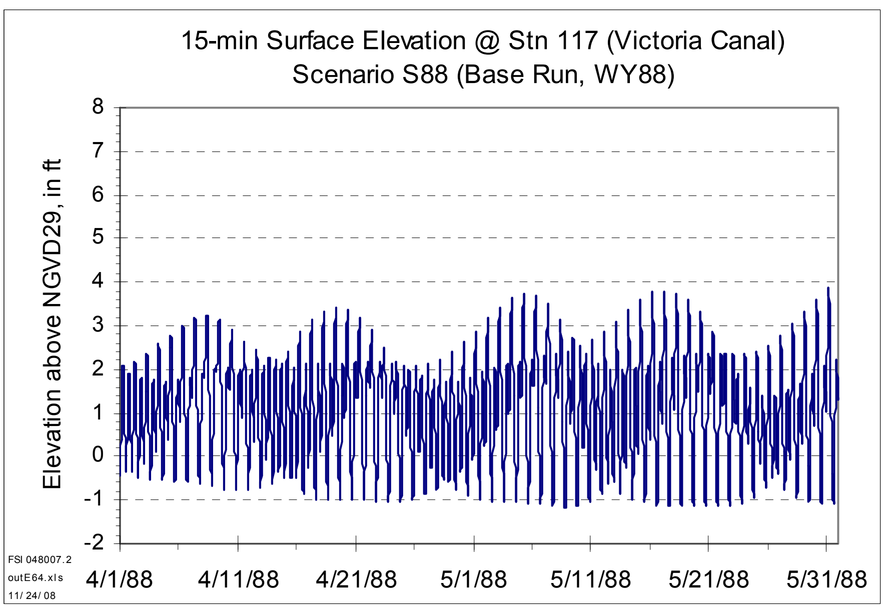

Figure A-76. Surface elevation at Station 117 (in Victoria Canal), for Scenario S88.

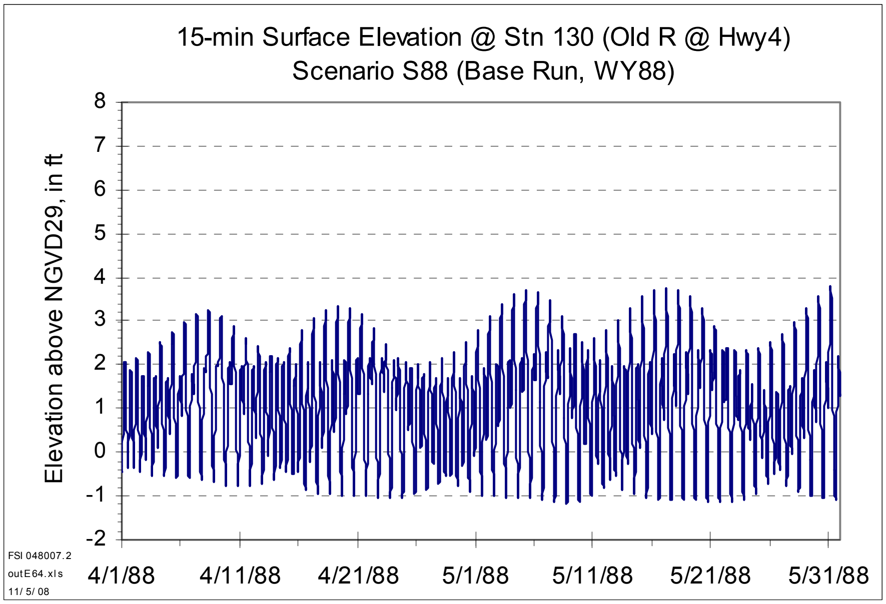

Figure A-77. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88.

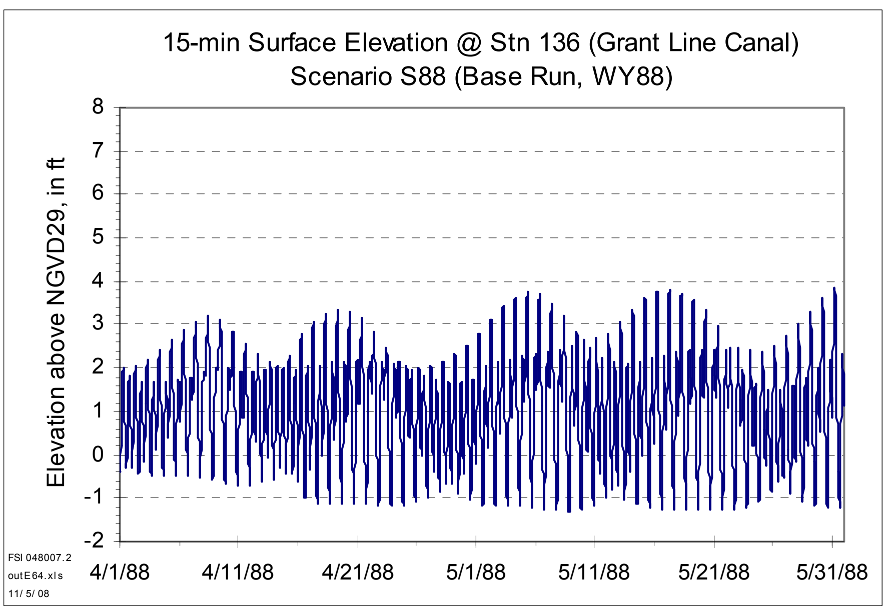

Figure A-78. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88.

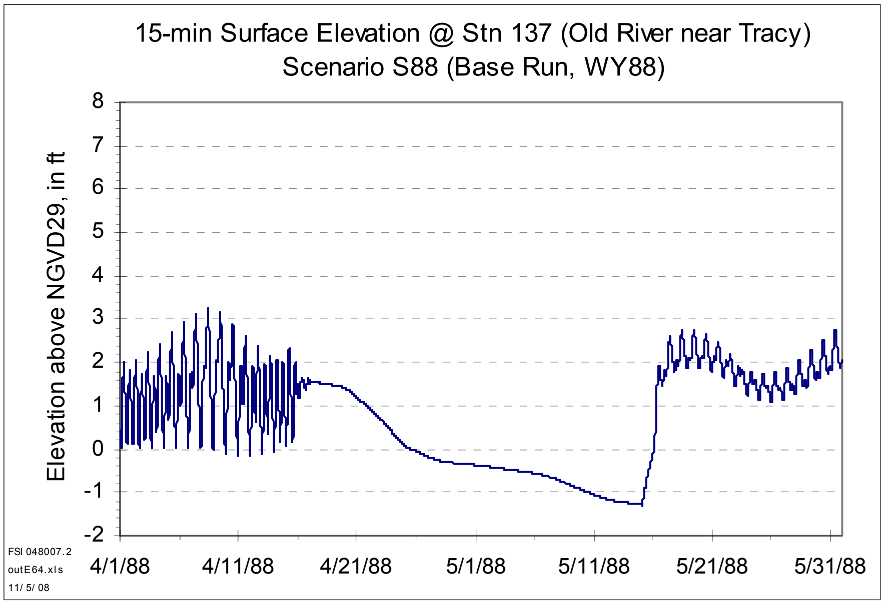

Figure A-79. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88.

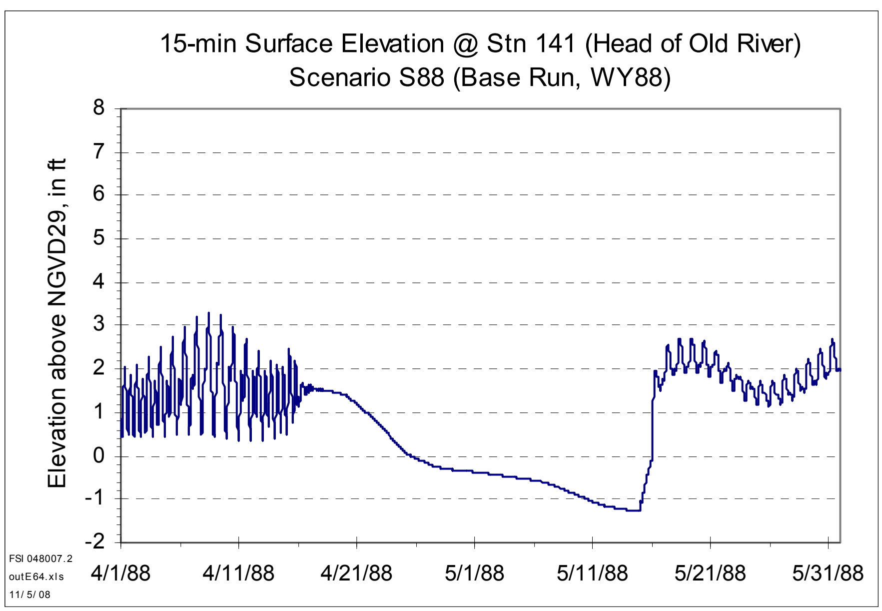

Figure A-80. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88.

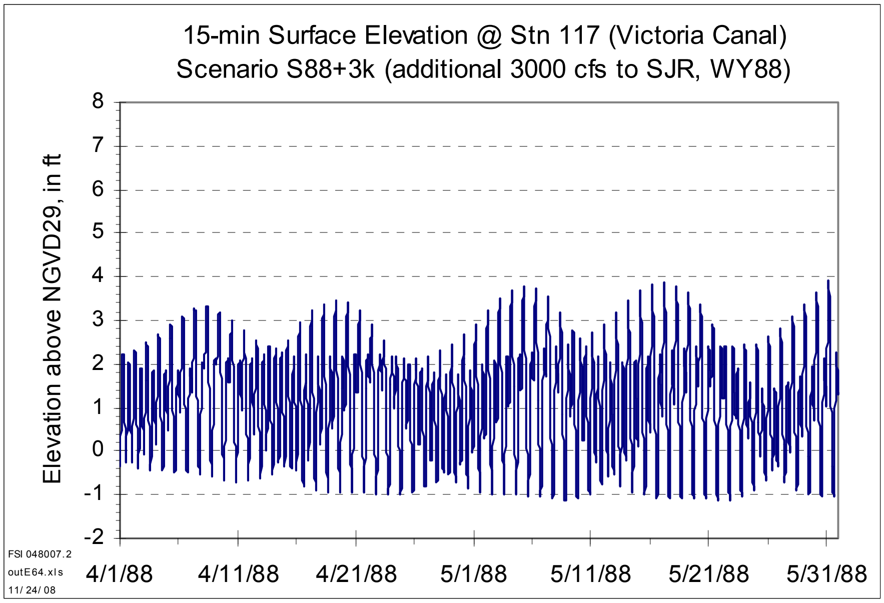

Figure A-81. Surface elevation at Station 117 (in Victoria Canal), for Scenario S88+3k.

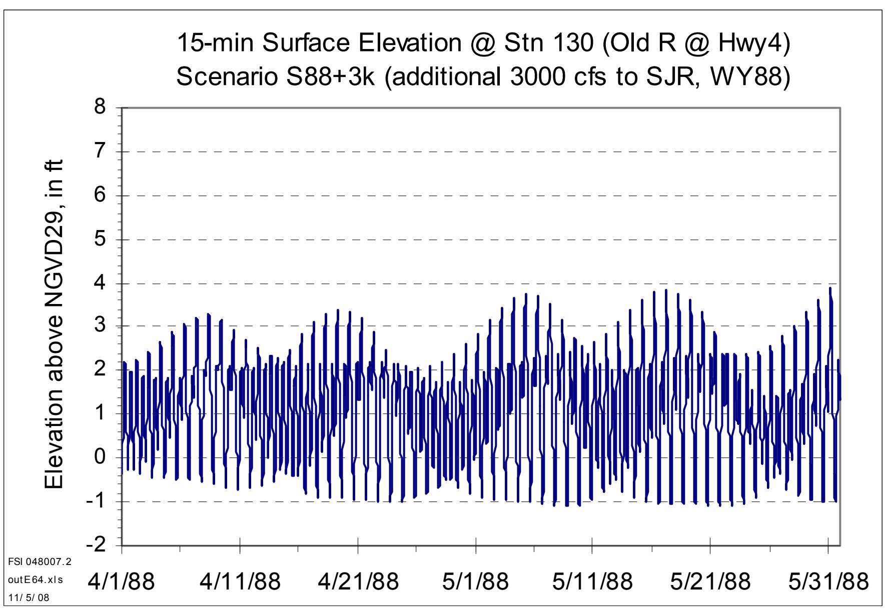

Figure A-82. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88+3k.

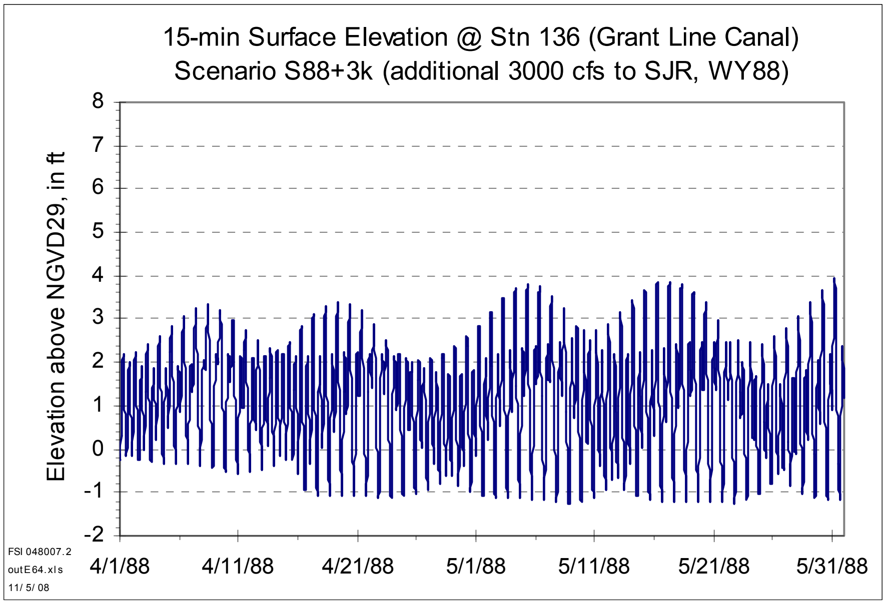

Figure A-83. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88+3k.

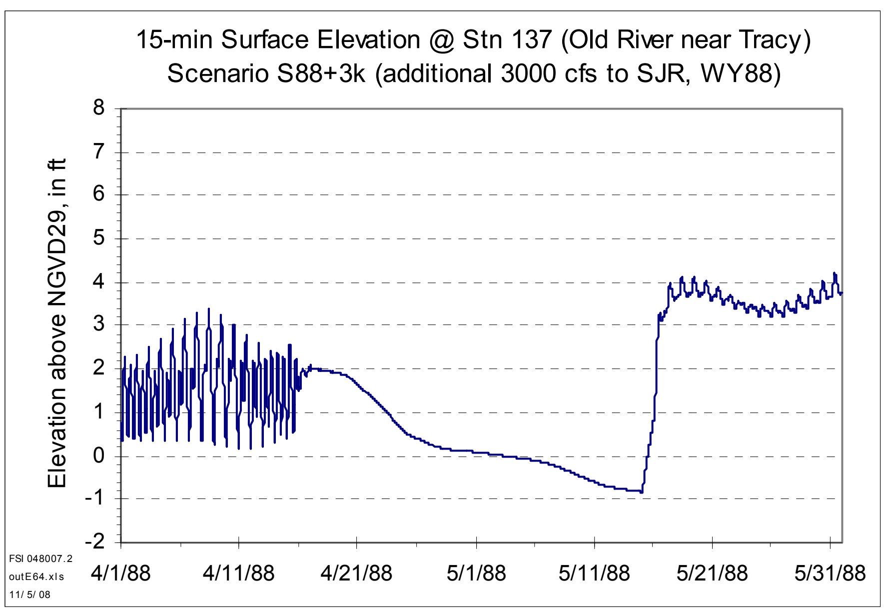

Figure A-84. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88+3k.

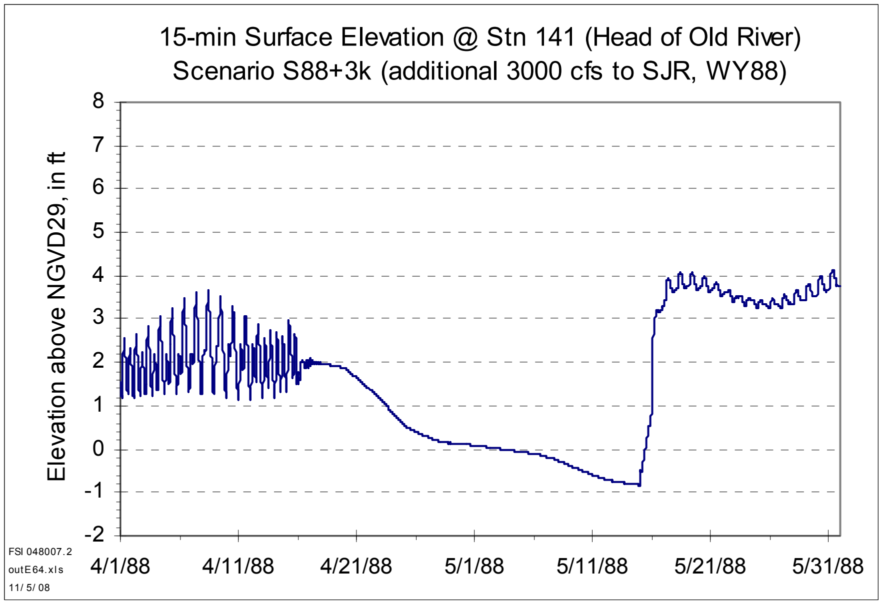

Figure A-85. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88+3k.

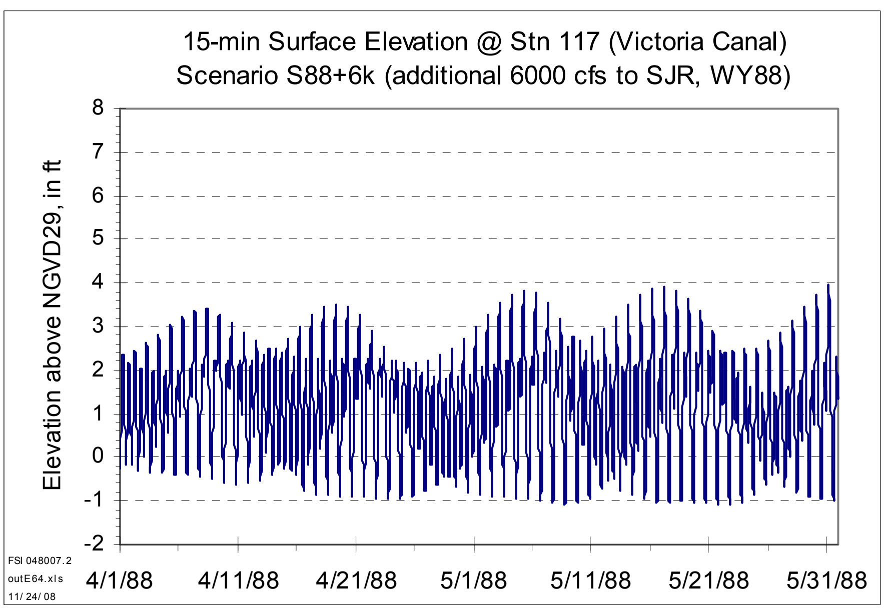

Figure A-86. Surface elevation at Station 117 (in Victoria Canal), for Scenario S88+6k.

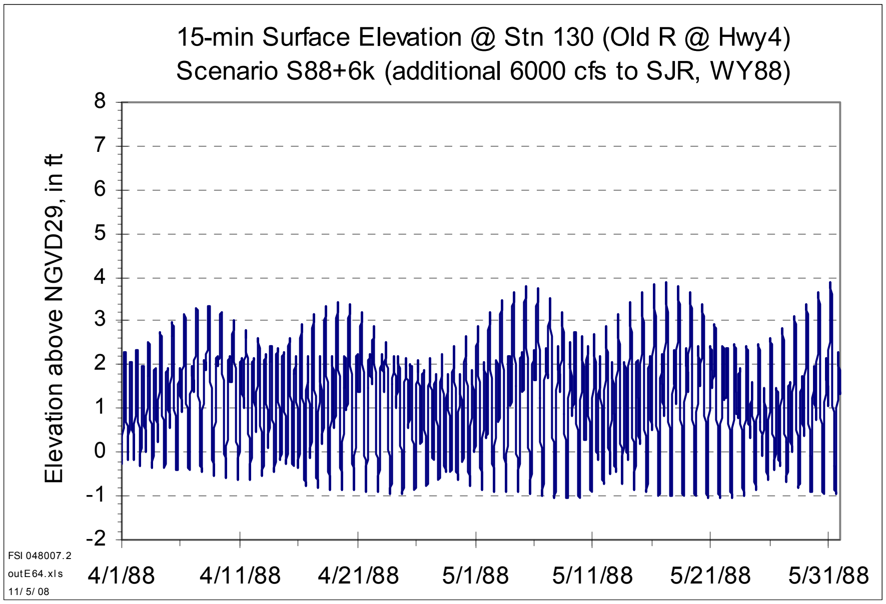

Figure A-87. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88+6k.

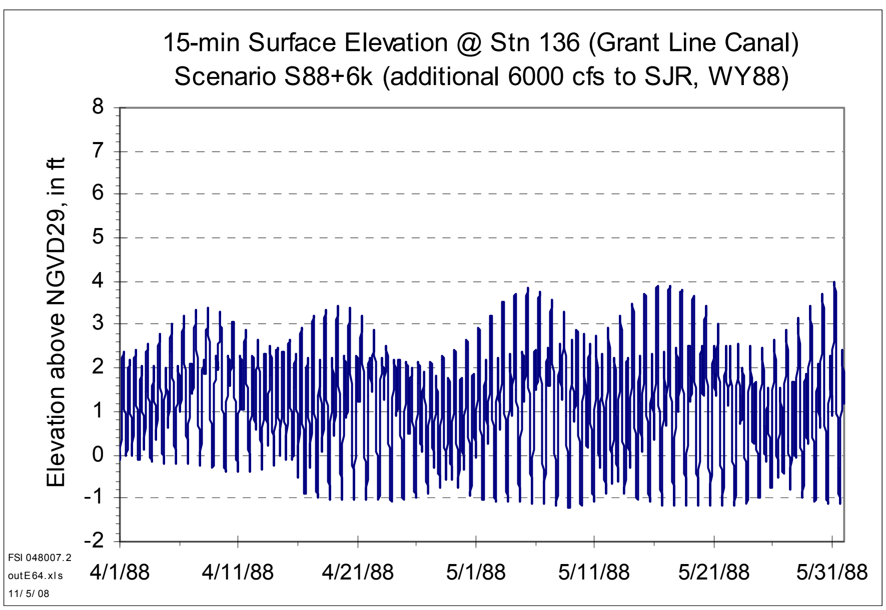

Figure A-88. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88+6k.

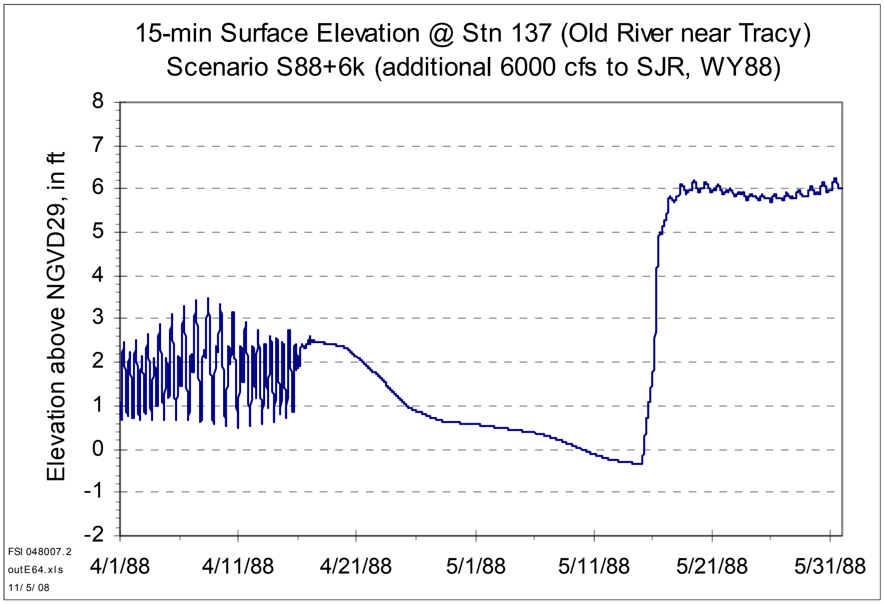

Figure A-89. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88+6k.

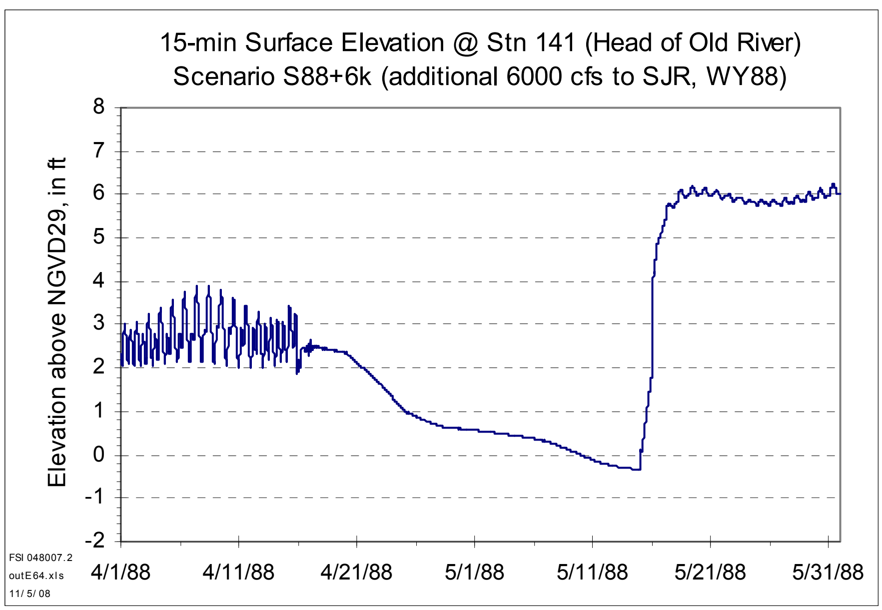

Figure A-90. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88+6k.

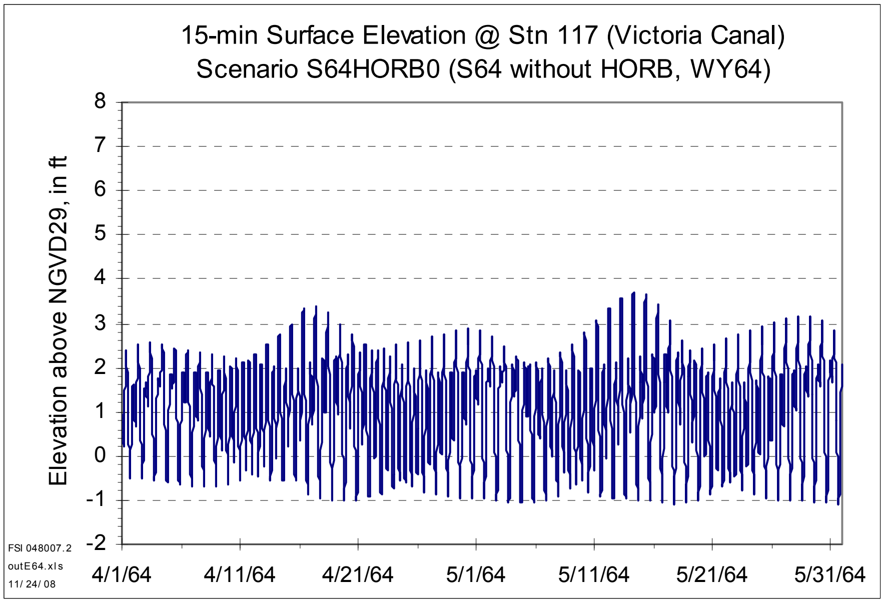

Figure A-91. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64HORB0.

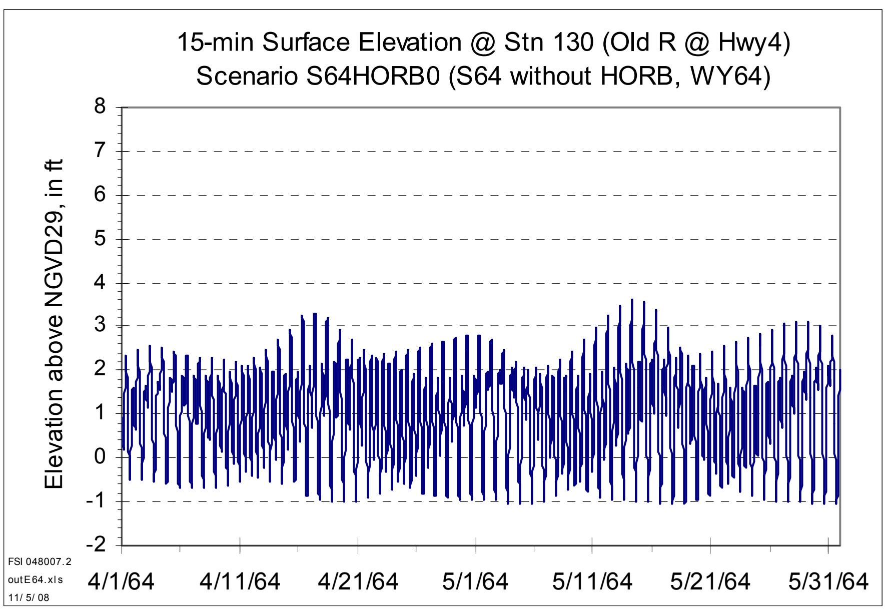

Figure A-92. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64HORB0.

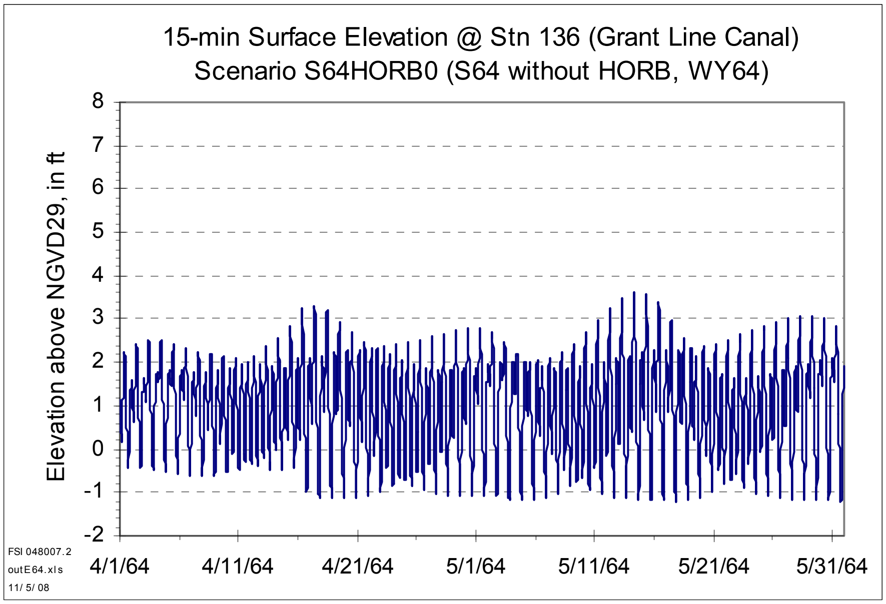

Figure A-93. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64HORB0.

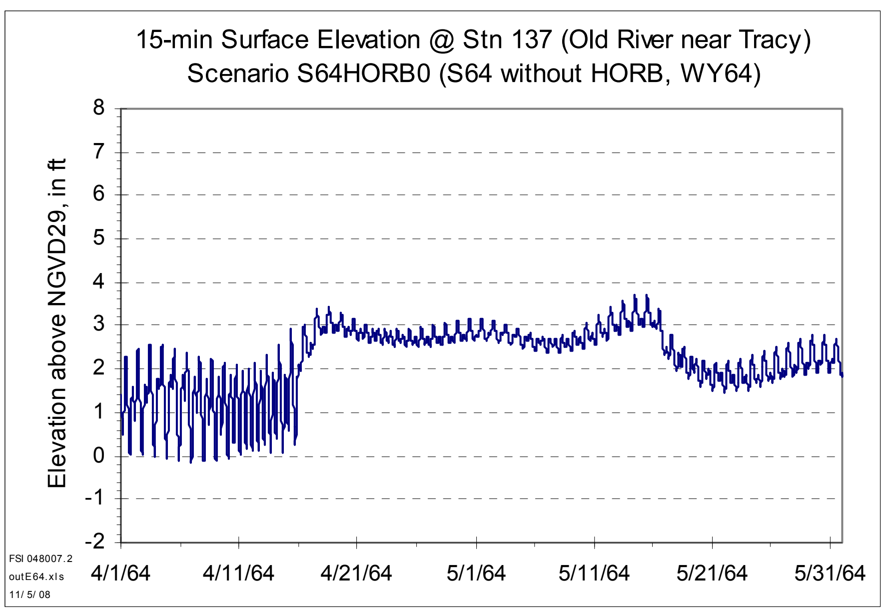

Figure A-94. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64HORB0.

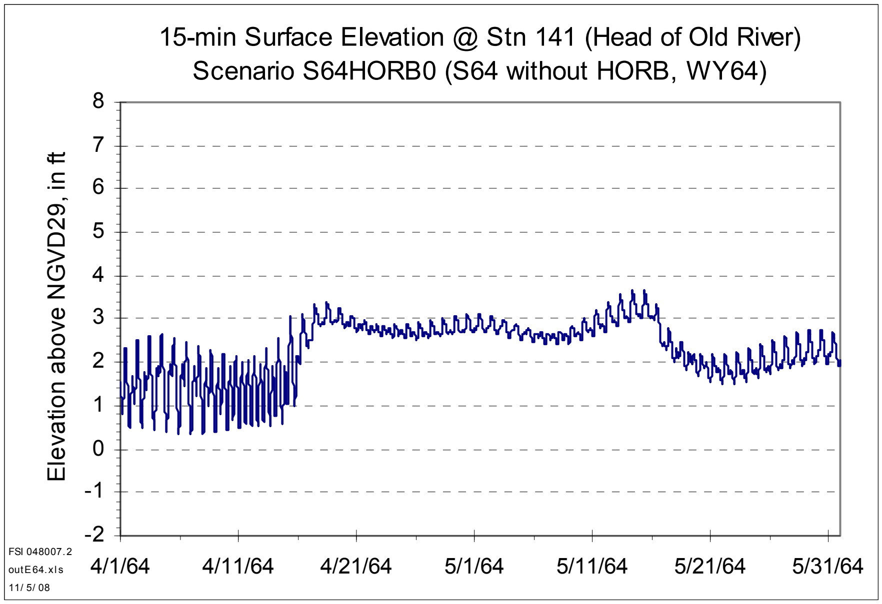

Figure A-95. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0.

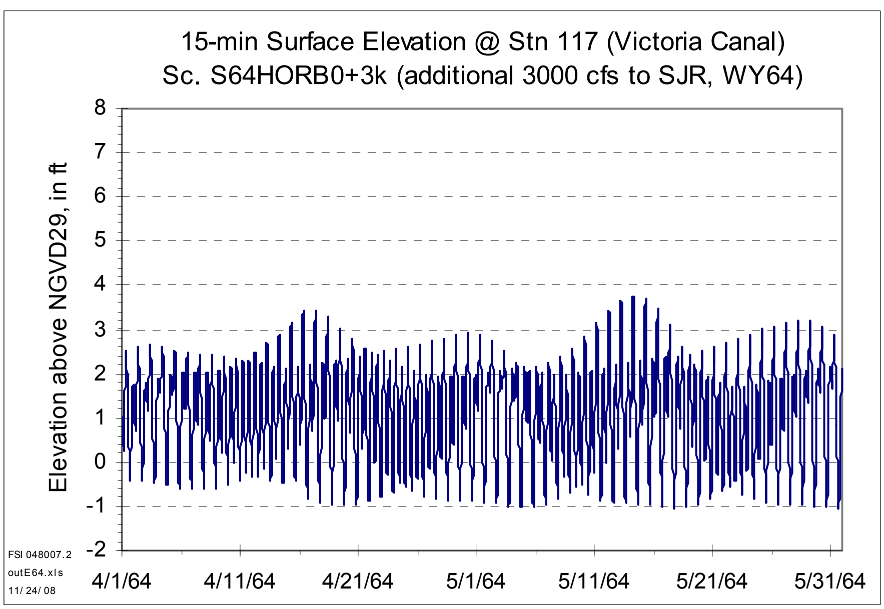

Figure A-96. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64HORB0+3k.

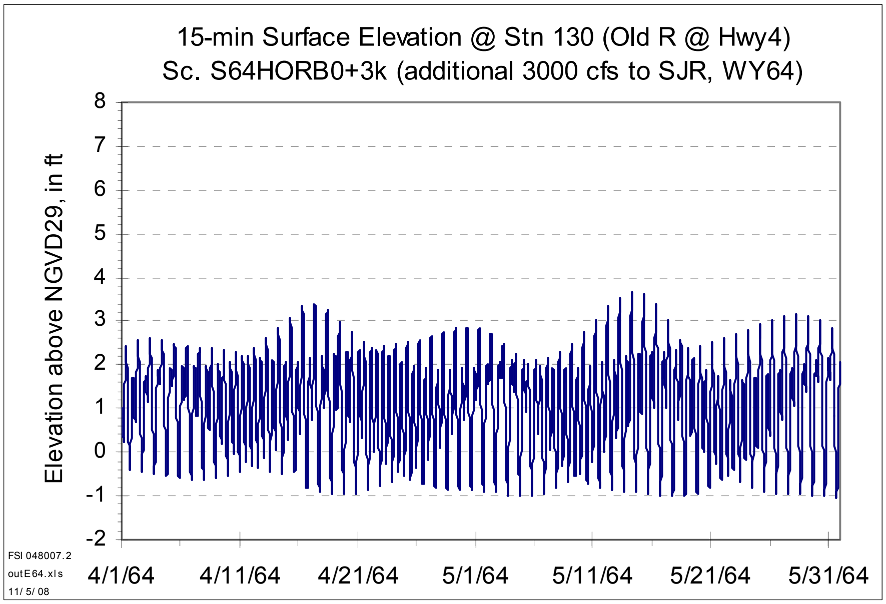

Figure A-97. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64HORB0+3k.

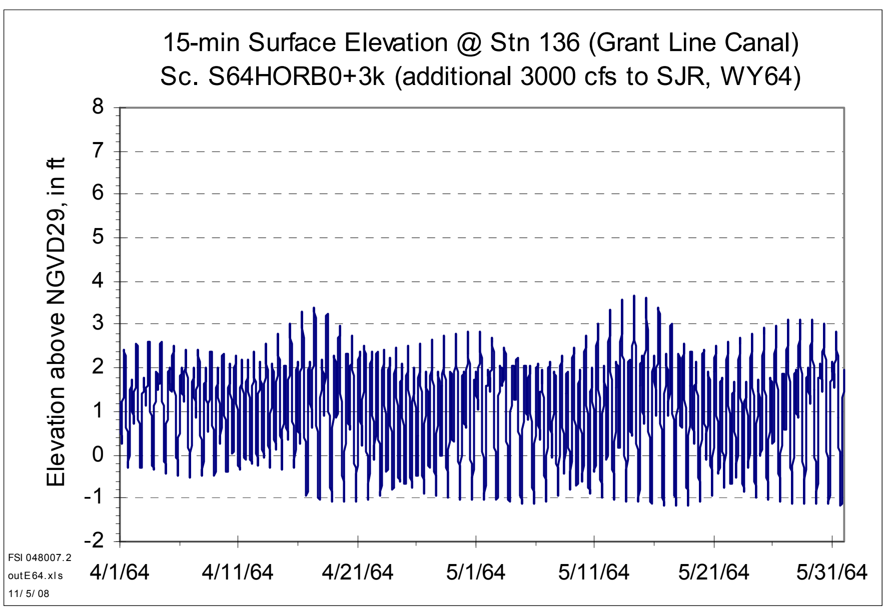

Figure A-98. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64HORB0+3k.

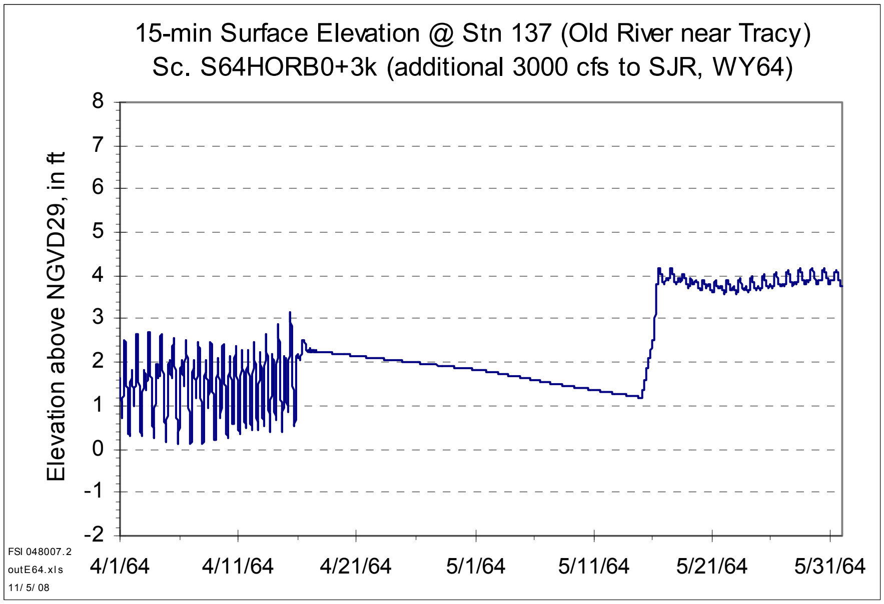

Figure A-99. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64HORB0+3k.

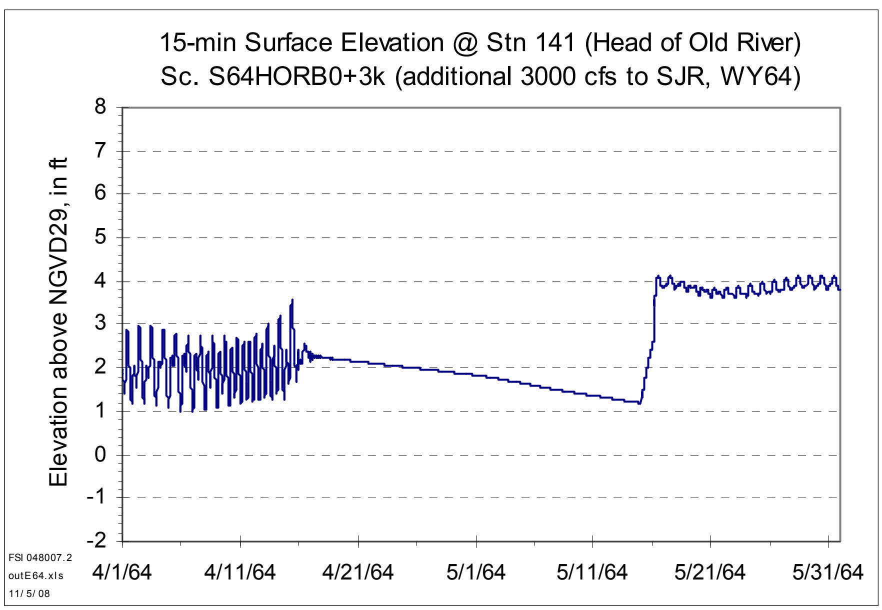

Figure A-100. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0+3k.

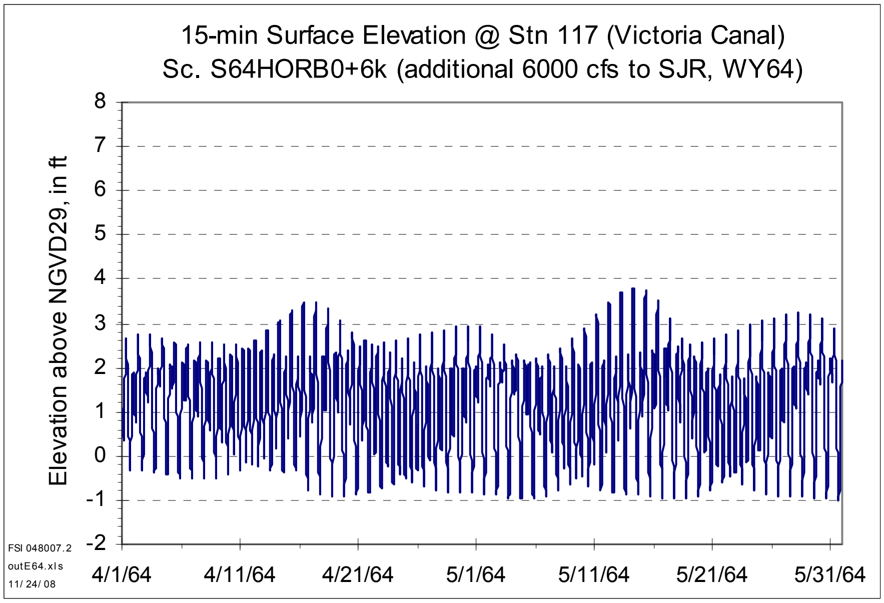

Figure A-101. Surface elevation at Station 117 (in Victoria Canal), for Scenario S64HORB0+6k.

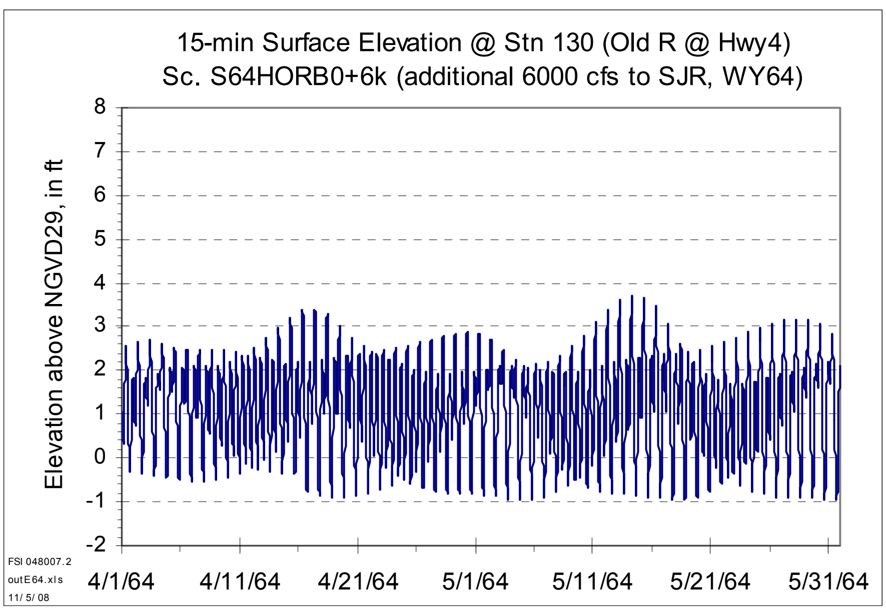

Figure A-102. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S64HORB0+6k.

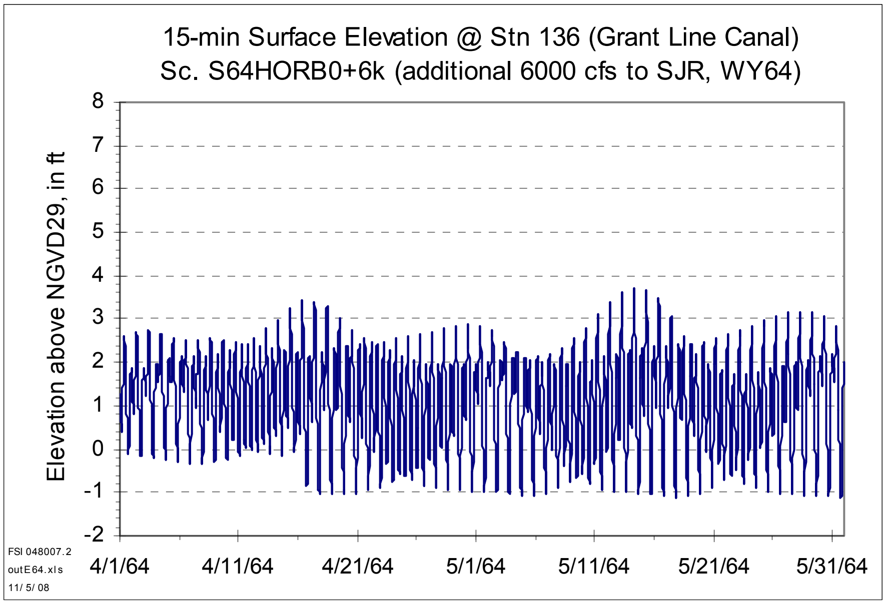

Figure A-103. **Surface elevation at Station 136 (in Grant Line Canal), for Scenario S64HORB0+6k.**

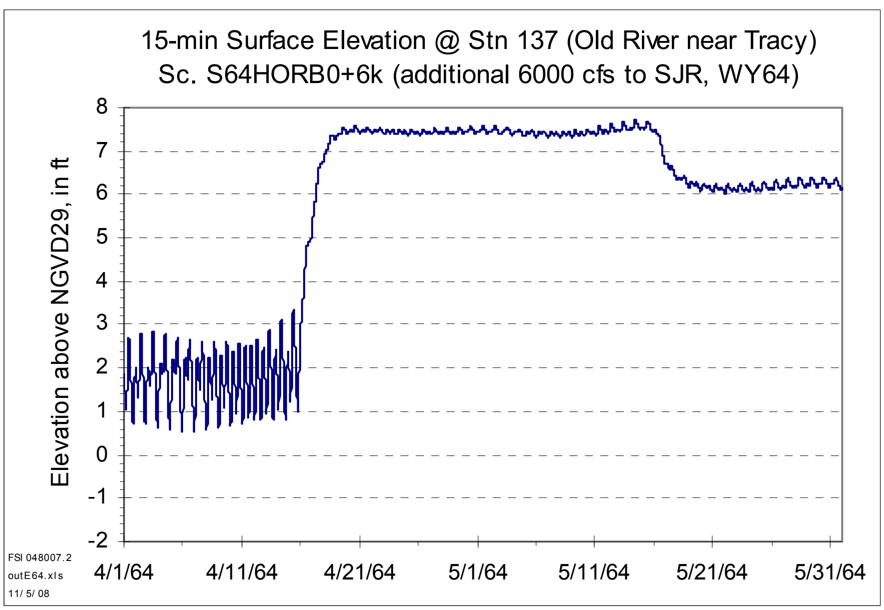

Figure A-104. **Surface elevation at Station 137 (in Old River near Tracy), for Scenario S64HORB0+6k.**

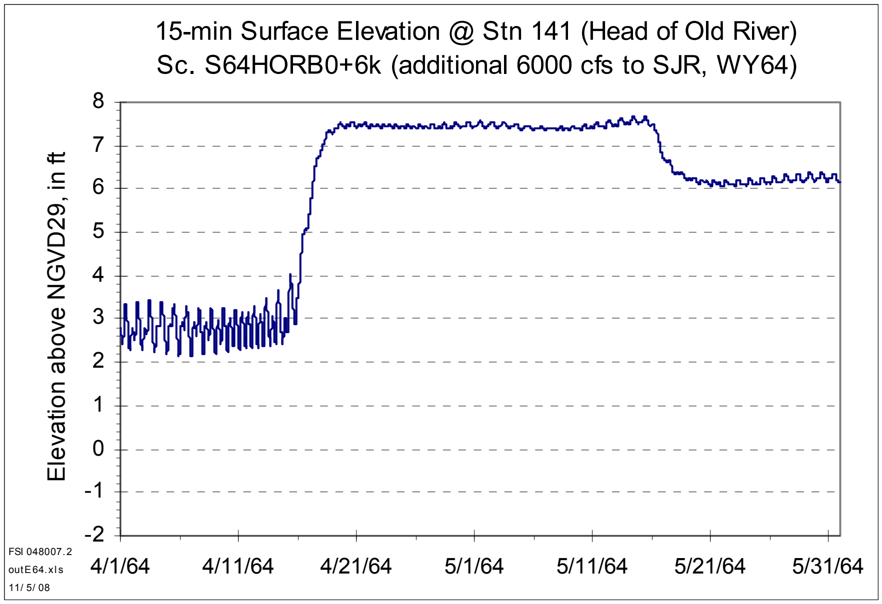

Figure A-105. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S64HORB0+6k.

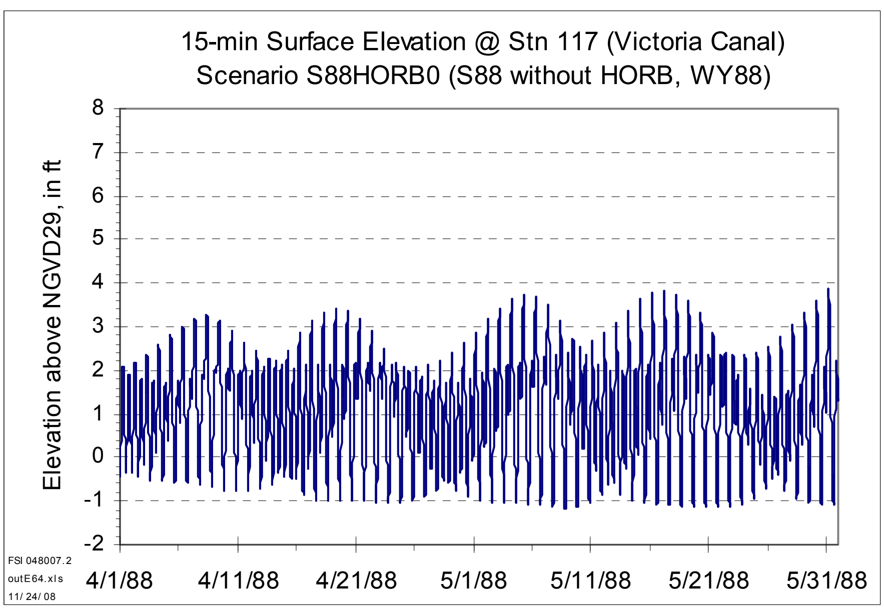

Figure A-106. Surface elevation at Station 117 (in Victoria Canal), for Scenario S88HORB0.

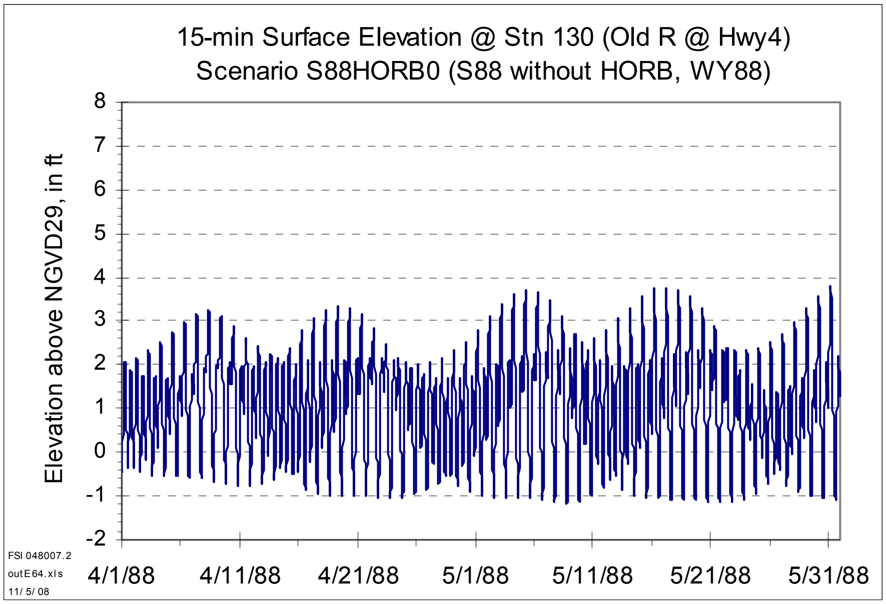

Figure A-107. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88HORB0.

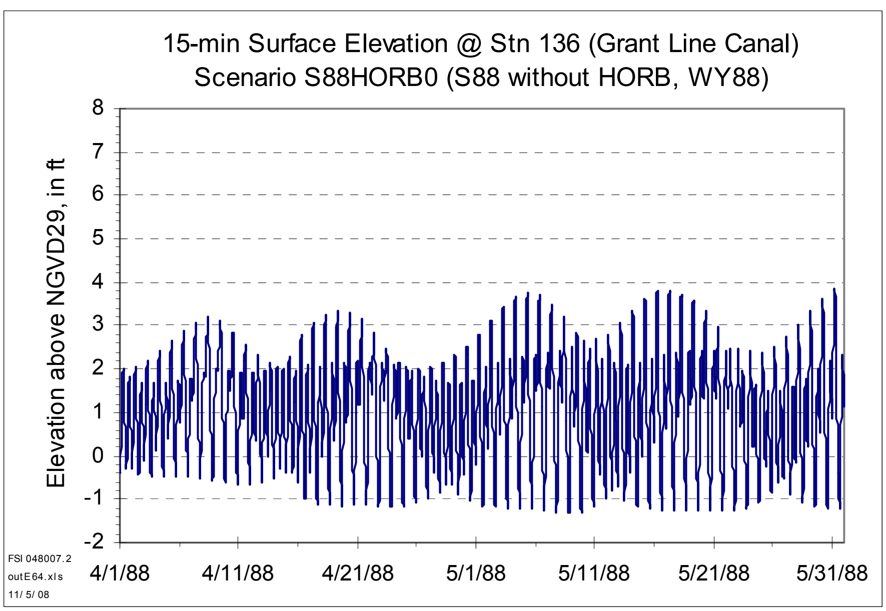

Figure A-108. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88HORB0.

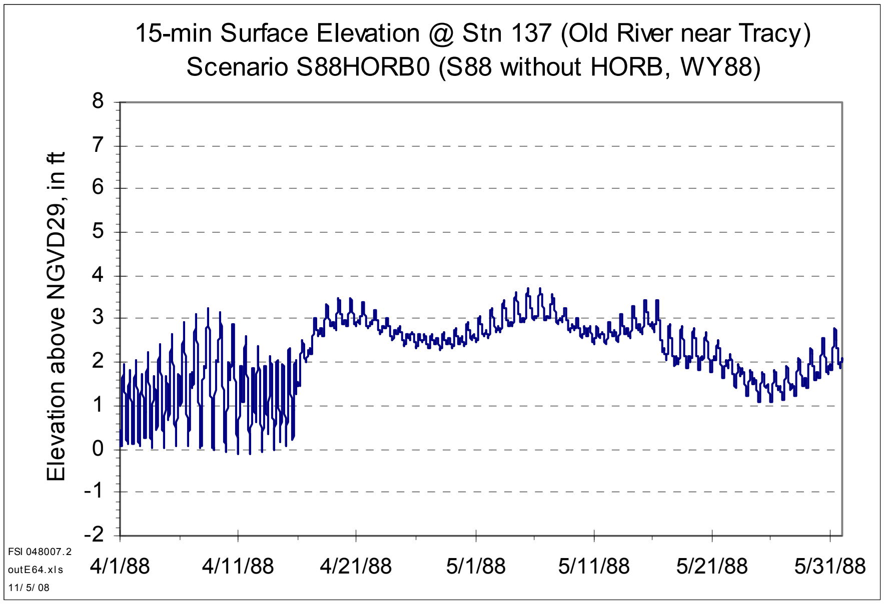

Figure A-109. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88HORB0.

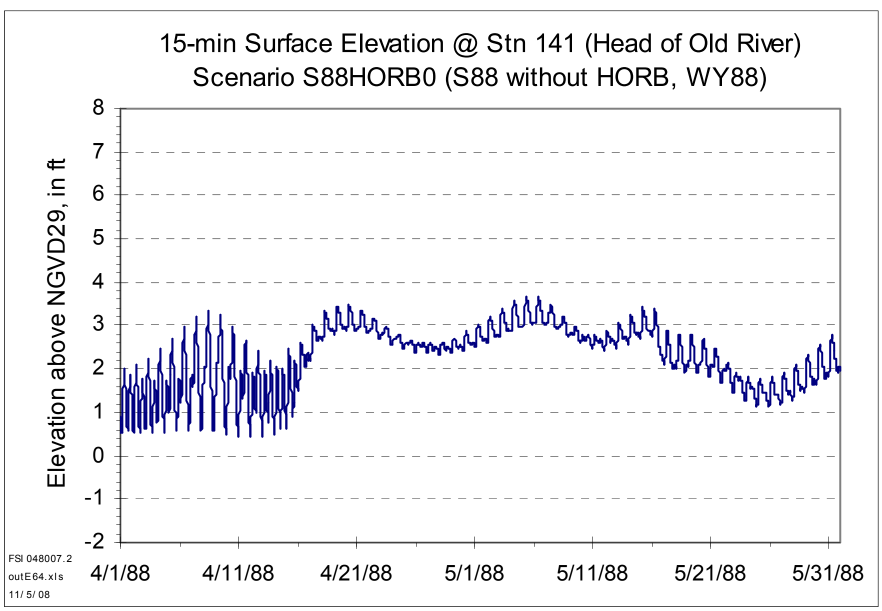

Figure A-110. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0.

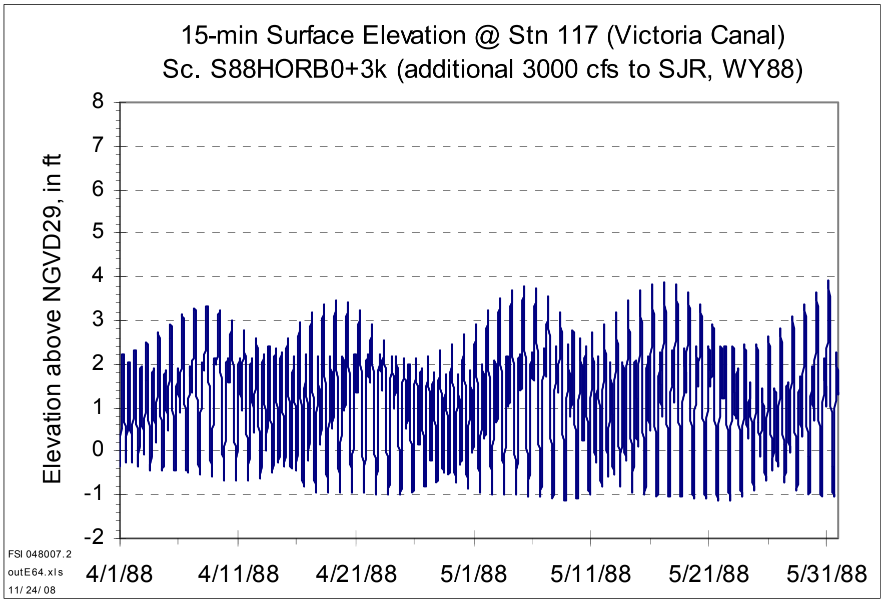

Figure A-111. Surface elevation at Station 117 (in Victoria Canal), for Scenario S88HORB0+3k.

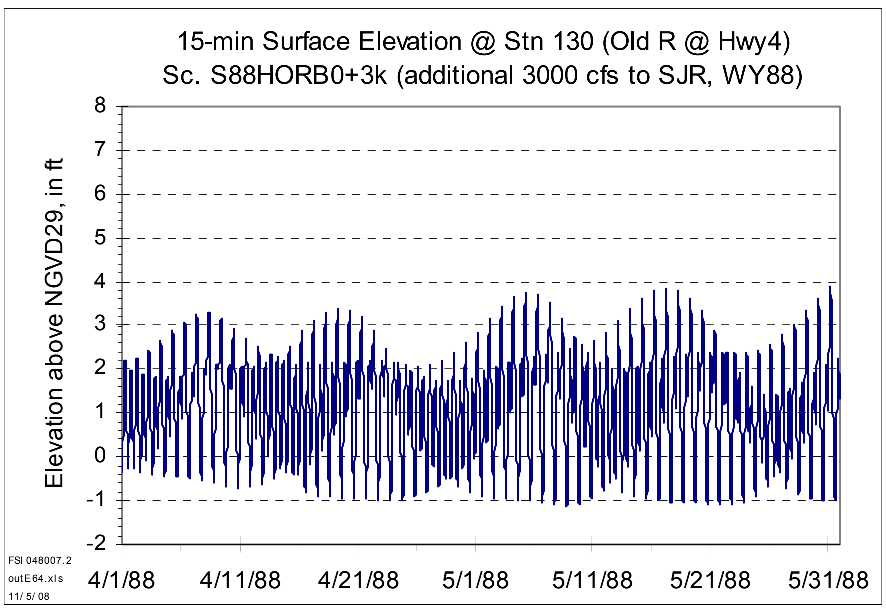

Figure A-112. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88HORB0+3k.

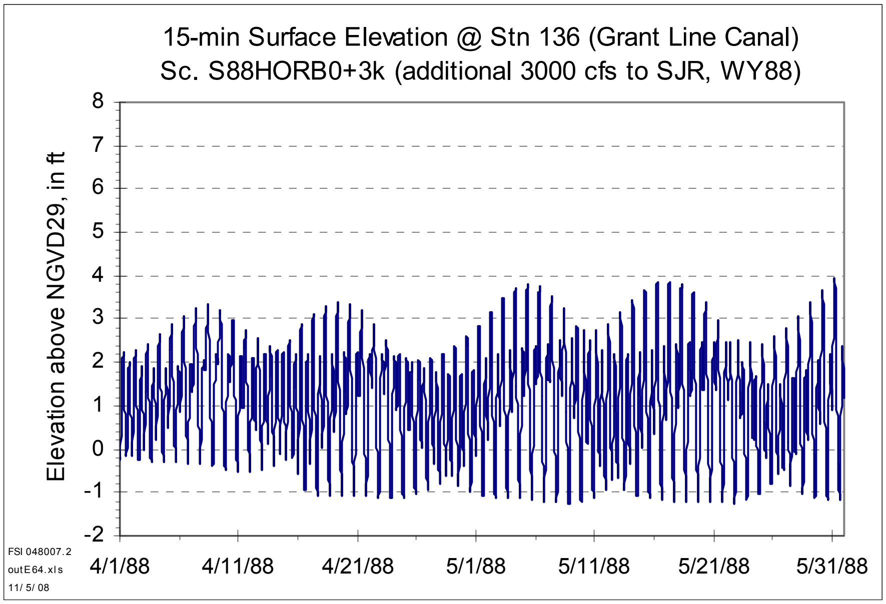

Figure A-113. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88HORB0+3k.

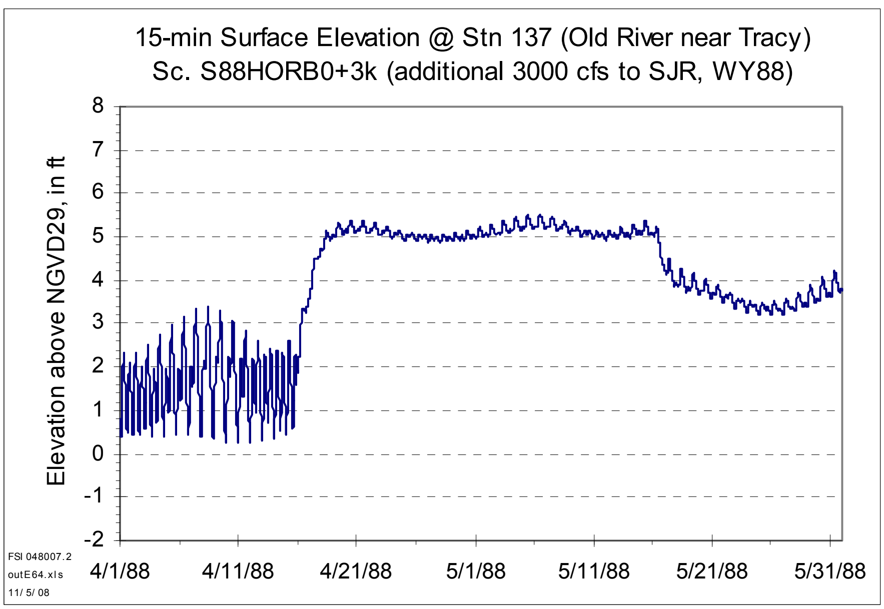

Figure A-114. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88HORB0+3k.

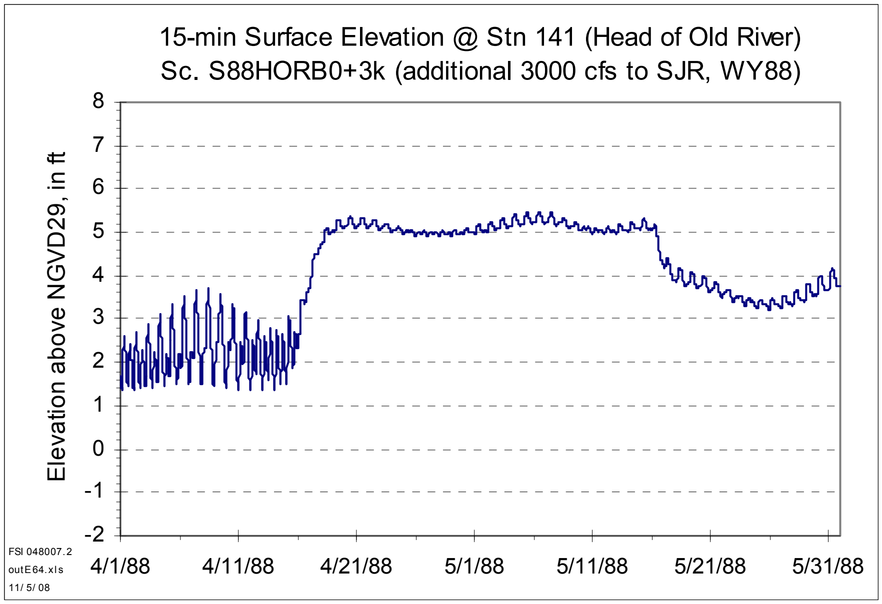

Figure A-115. **Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0+3k.**

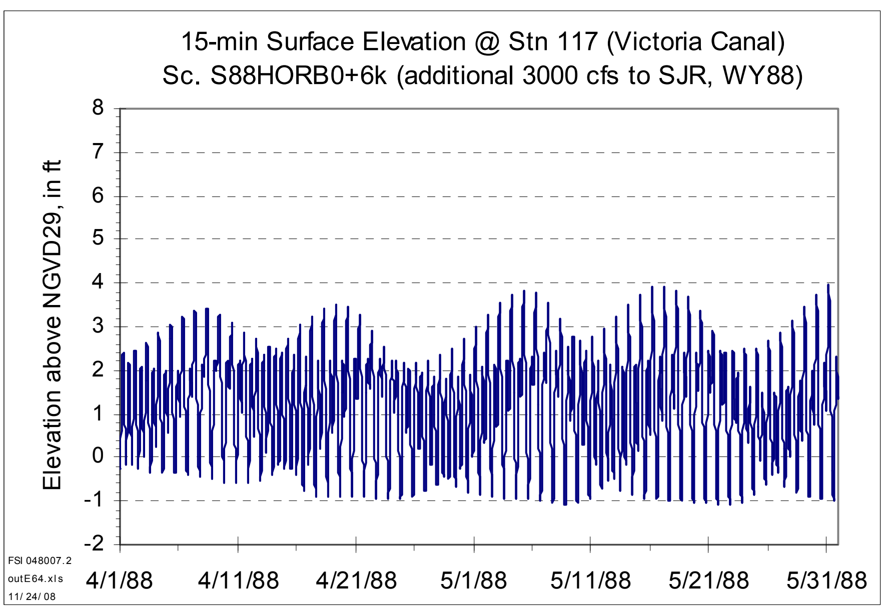

Figure A-116. **Surface elevation at Station 117 (in Victoria Canal), for Scenario S88HORB0+6k.**

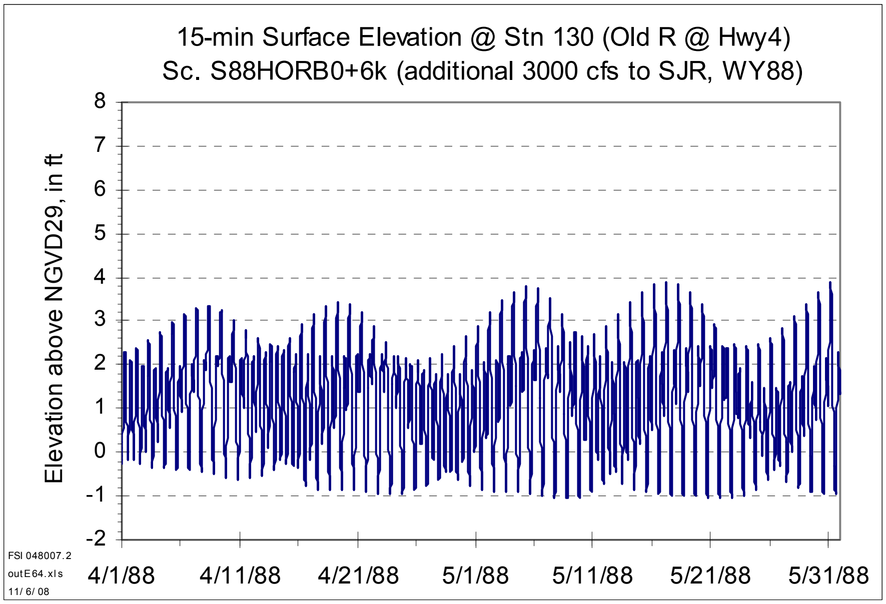

Figure A-117. Surface elevation at Station 130 (Old River at Highway 4), for Scenario S88HORB0+6k.

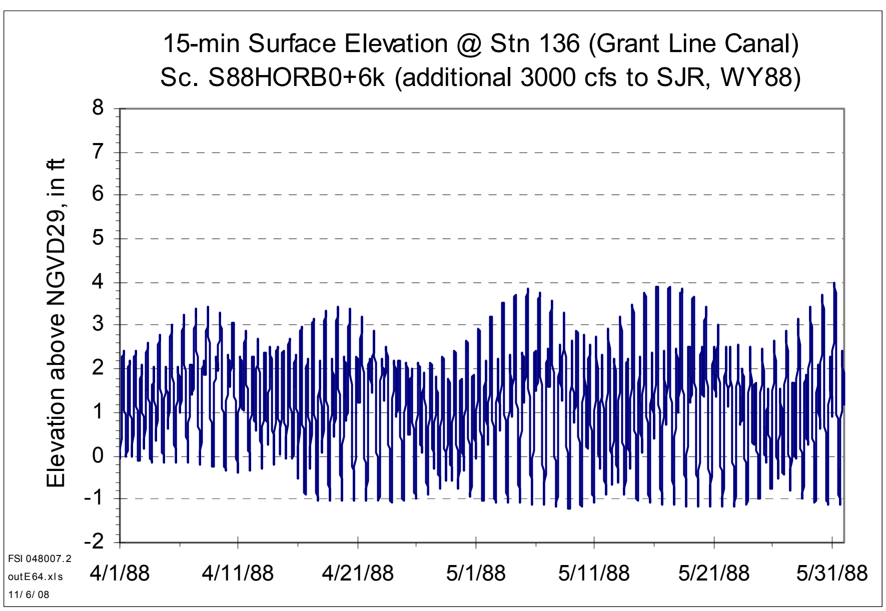

Figure A-118. Surface elevation at Station 136 (in Grant Line Canal), for Scenario S88HORB0+6k.

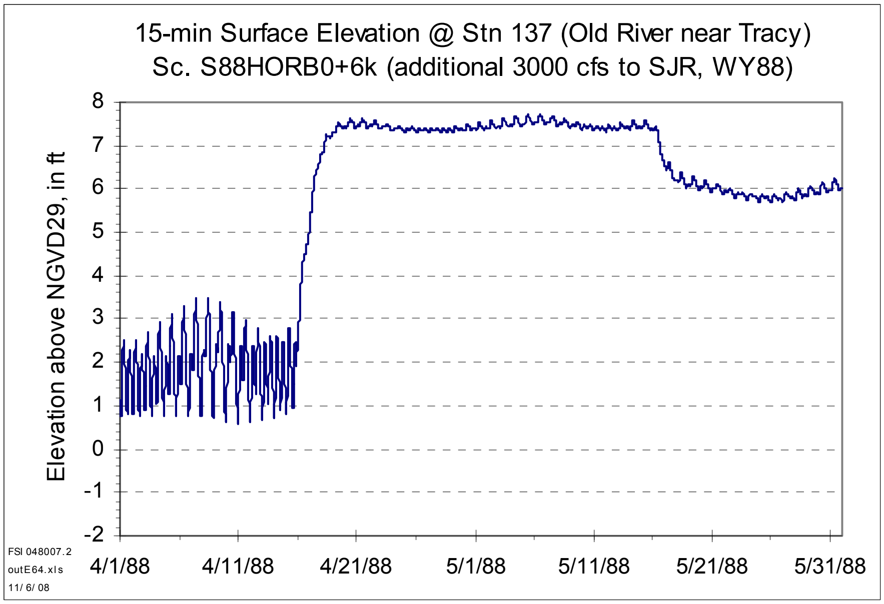

Figure A-119. Surface elevation at Station 137 (in Old River near Tracy), for Scenario S88HORB0+6k.

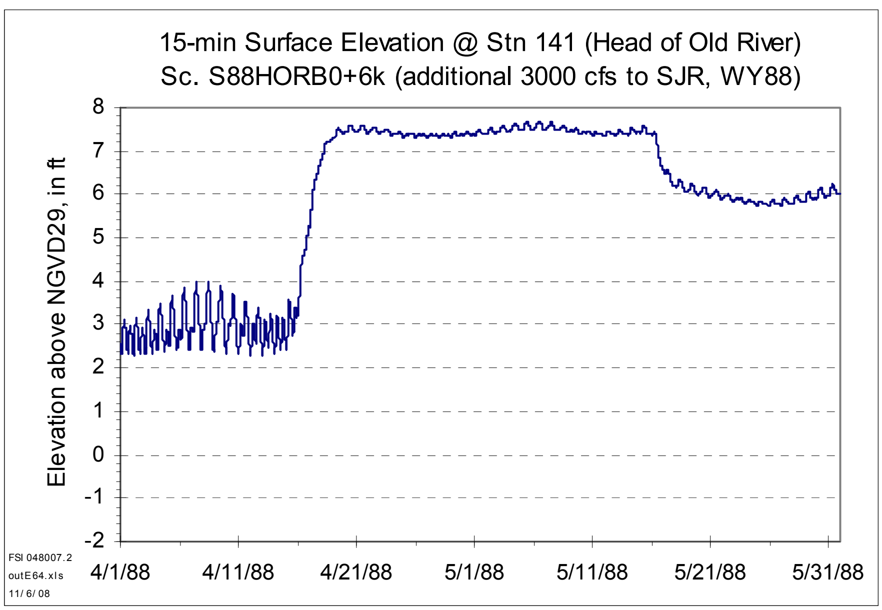

Figure A-120. Surface elevation at Station 141 (in Old River near the head of Old River), for Scenario S88HORB0+6k.

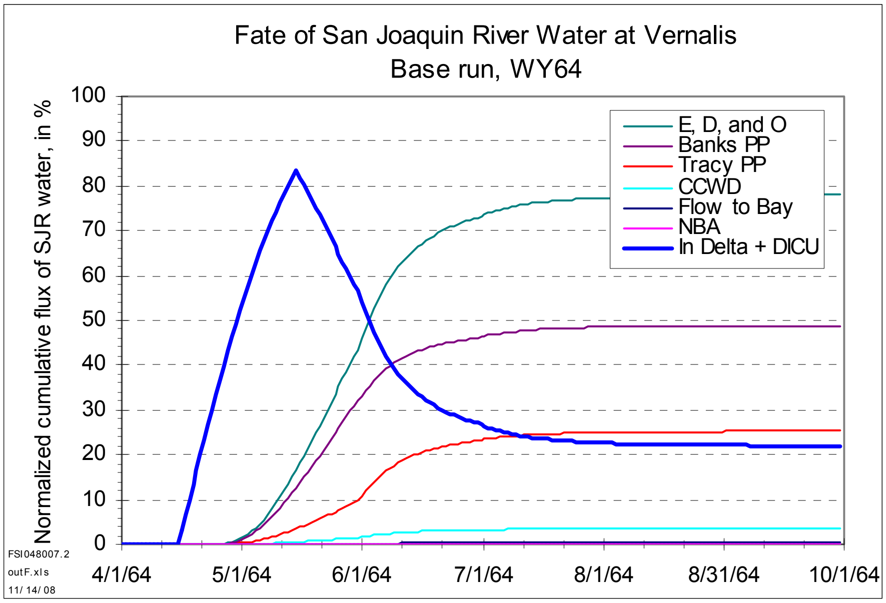

Figure A121. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64.

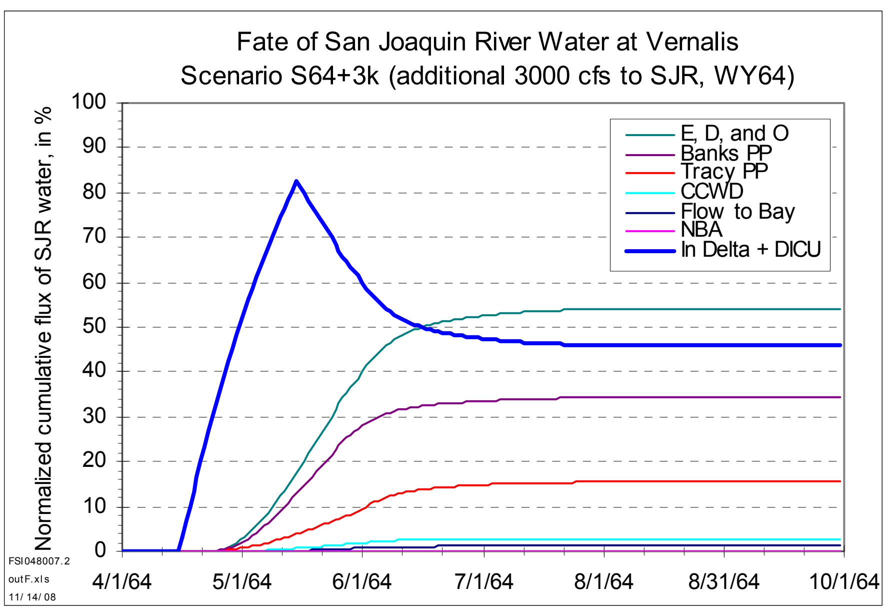

Figure A122. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64+3k.

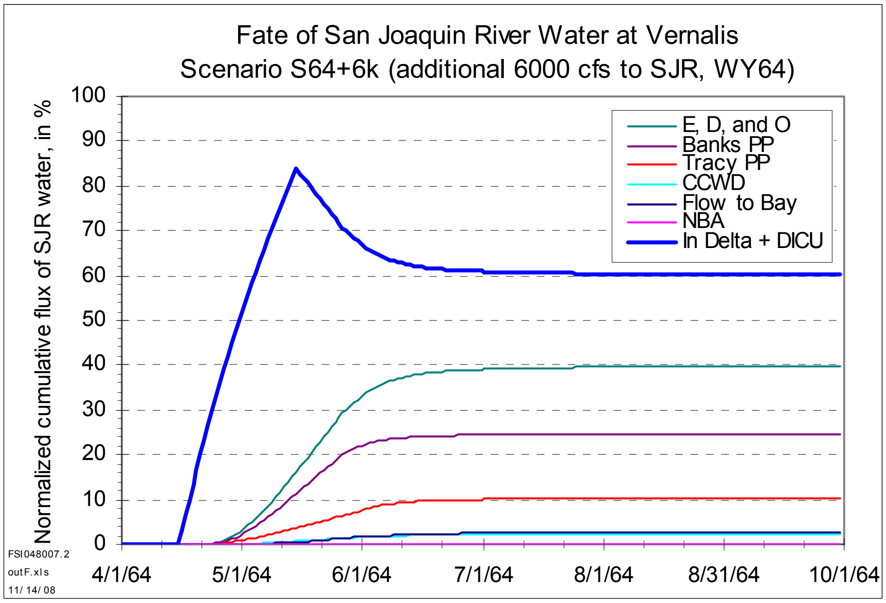

Figure A123. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64+6k.

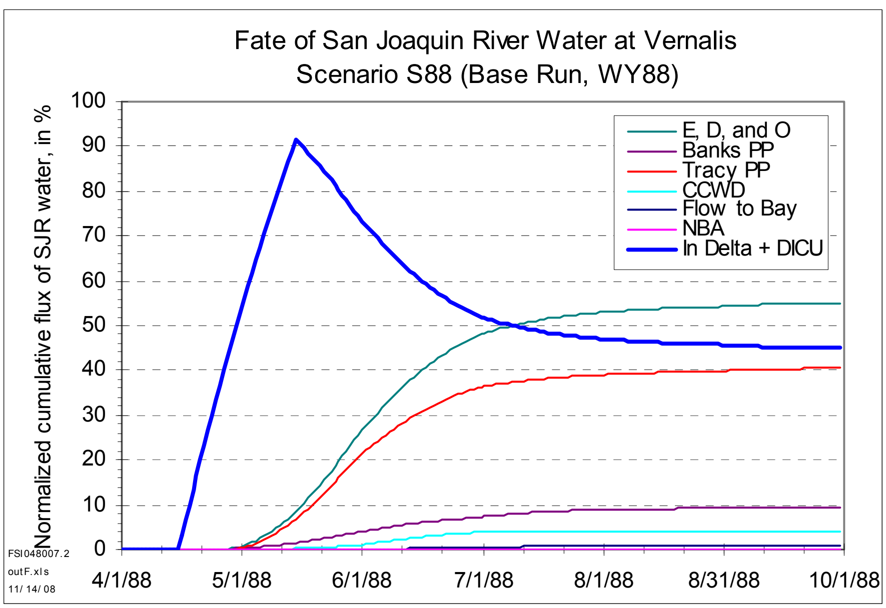

Figure A124. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88.

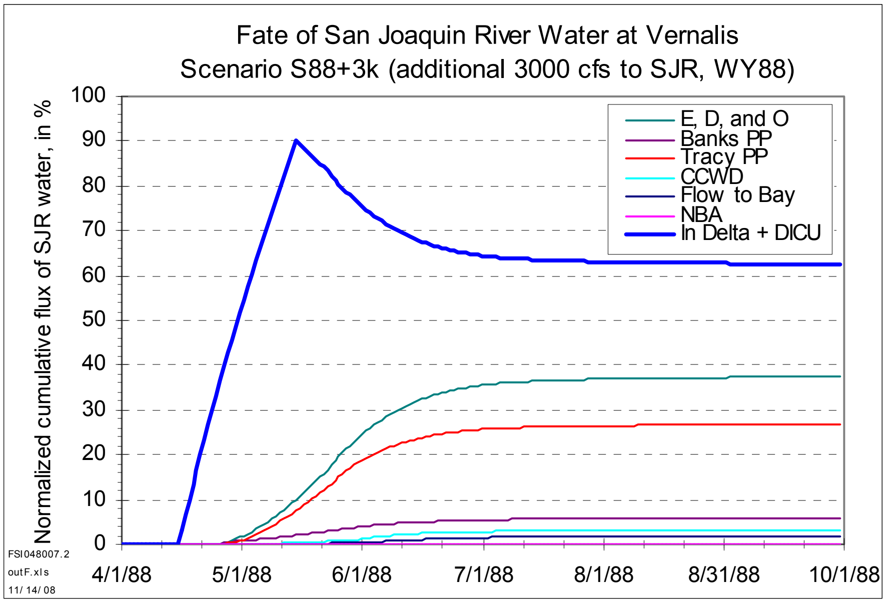

Figure A125. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88+3k.

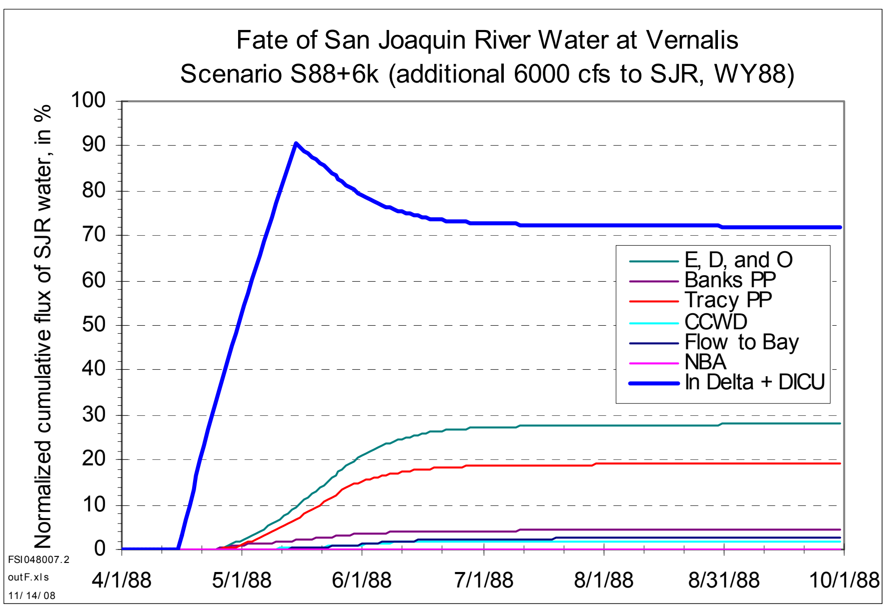

Figure A126. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88+6k.

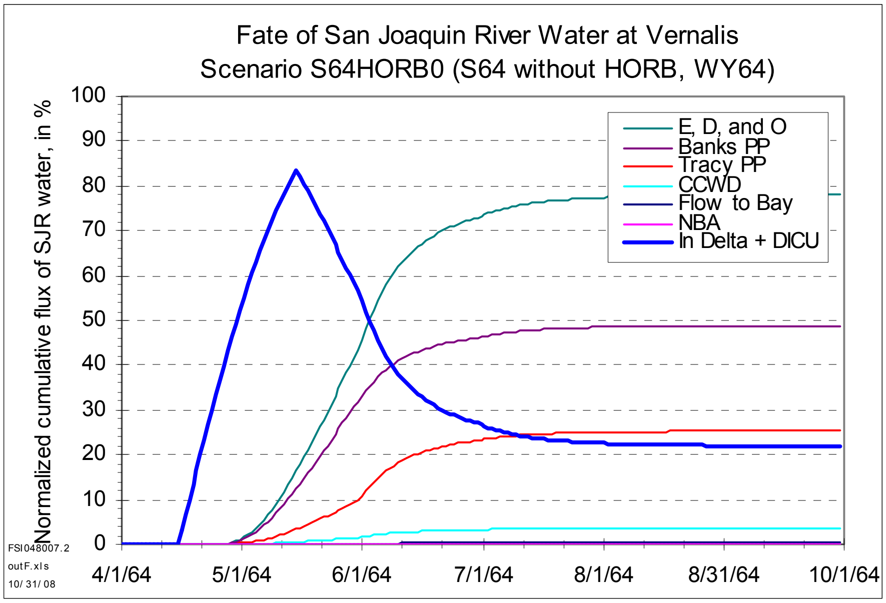

Figure A127. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64HORB0.

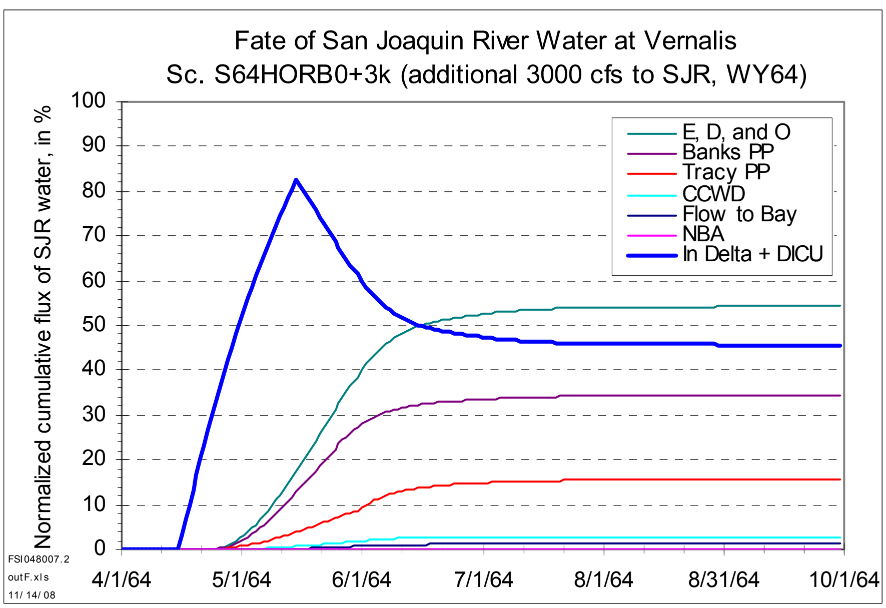

Figure A128. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64HORB0+3k.

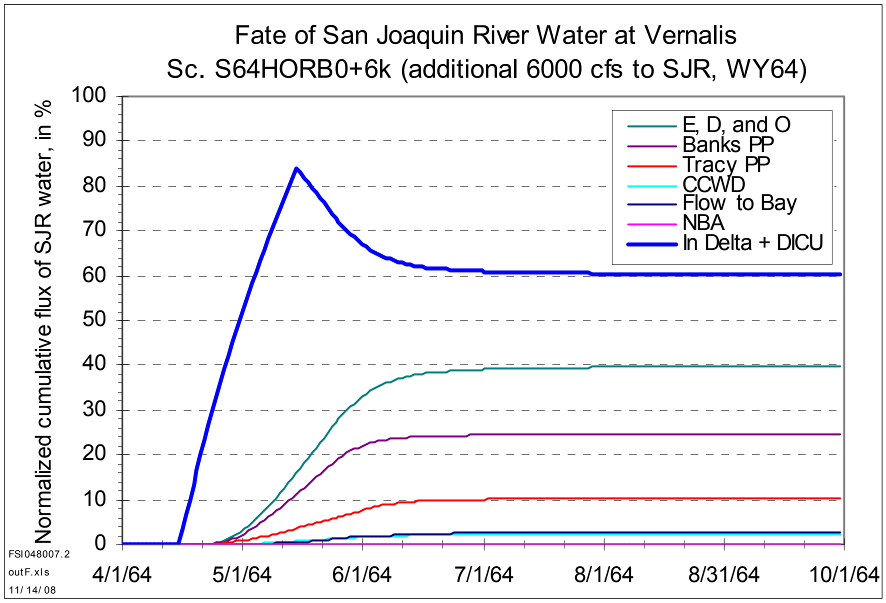

Figure A129. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S64HORB0+6k.

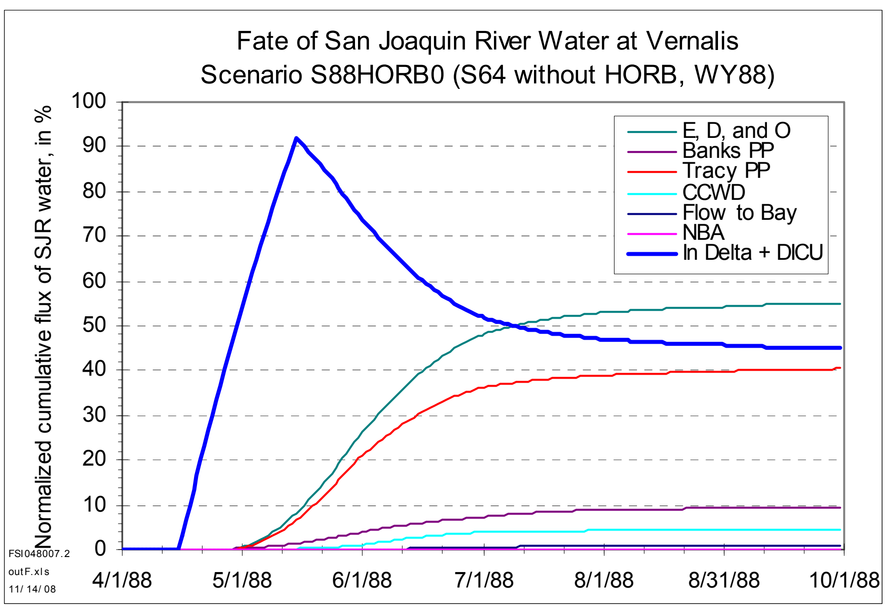

Figure A130. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88HORB0.

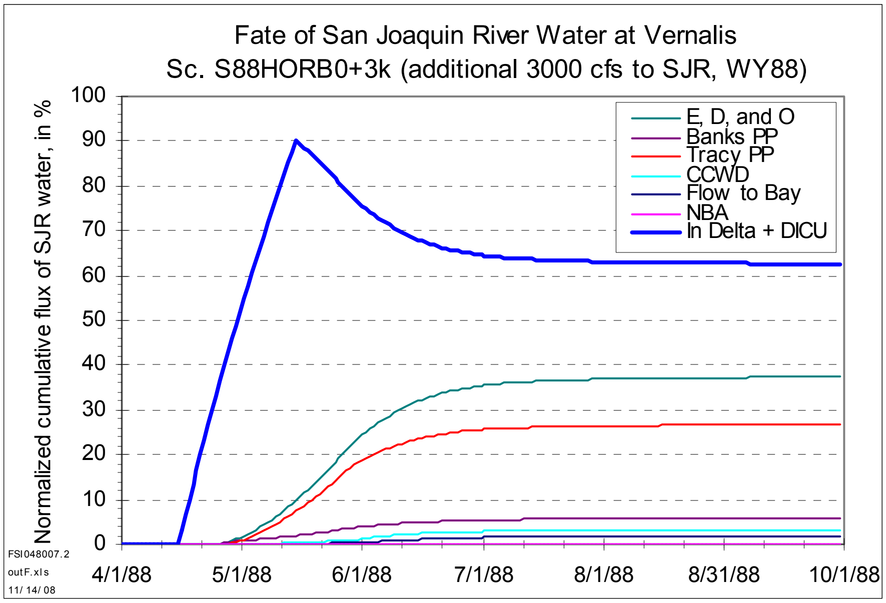

Figure A131. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88HORB0+3k.

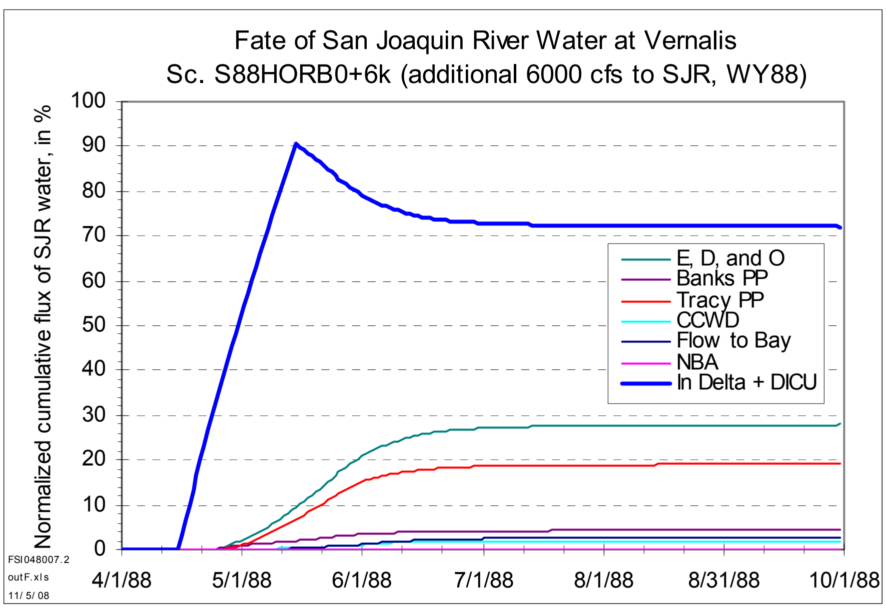

Figure A132. Fate of San Joaquin River water released at Vernalis between April 15 and May 15, for Scenario S88HORB0+6k.

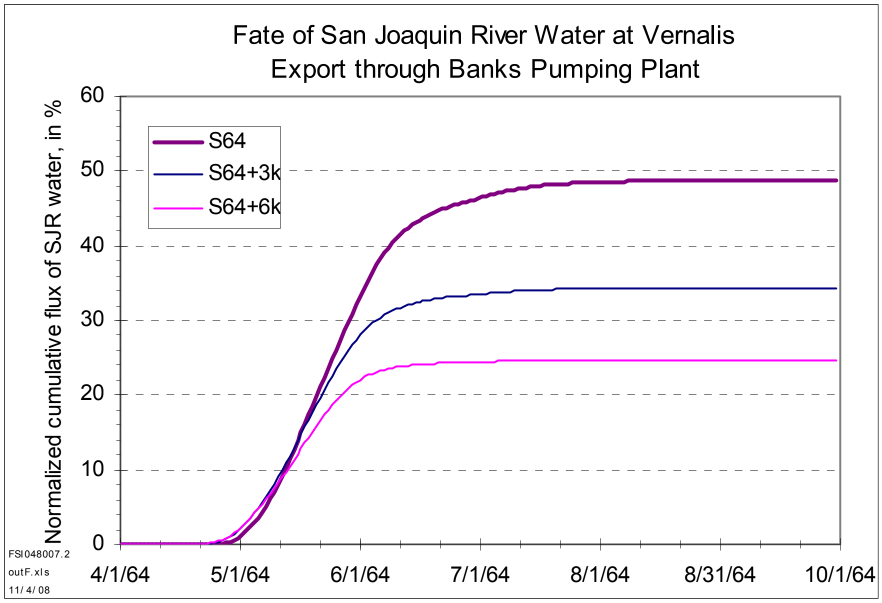

Figure A133. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Banks Pumping Plant, a comparison among Scenarios S64, S64+3k, and S64+6k.

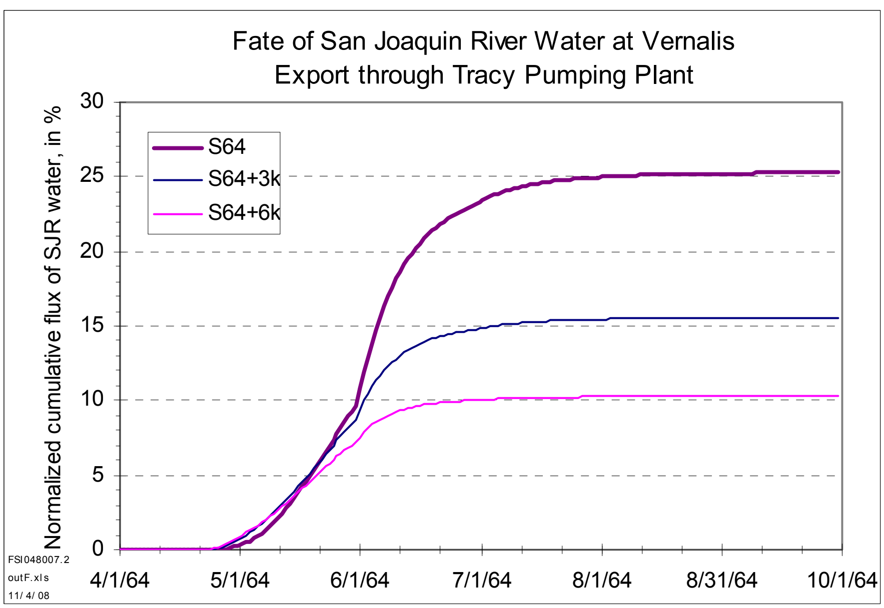

Figure A134. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Tracy Pumping Plant, a comparison among Scenarios S64, S64+3k, and S64+6k.

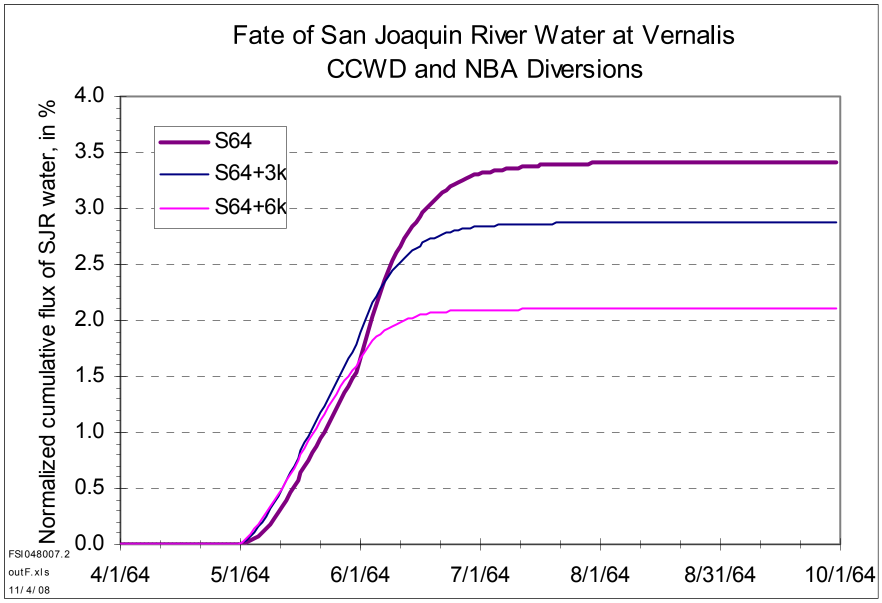

Figure A135. Diversion of San Joaquin River water, released at Vernalis between April 15 and May 15, to Contra Costa Water District and to Northbay Aqueduct, a comparison among Scenarios S64, S64+3k, and S64+6k.

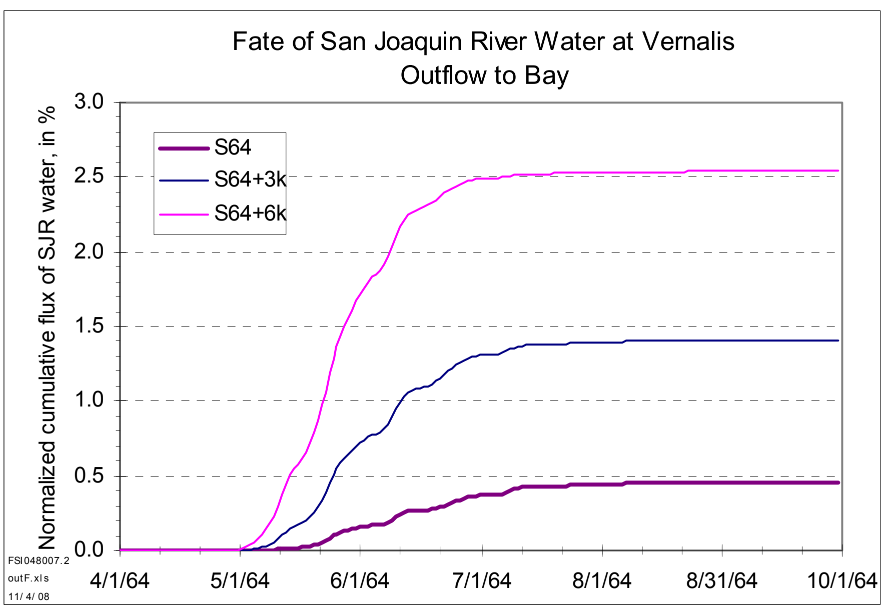

Figure A136. Outflow of San Joaquin River water, released at Vernalis between April 15 and May 15, to San Pablo Bay, a comparison among Scenarios S64, S64+3k, and S64+6k.

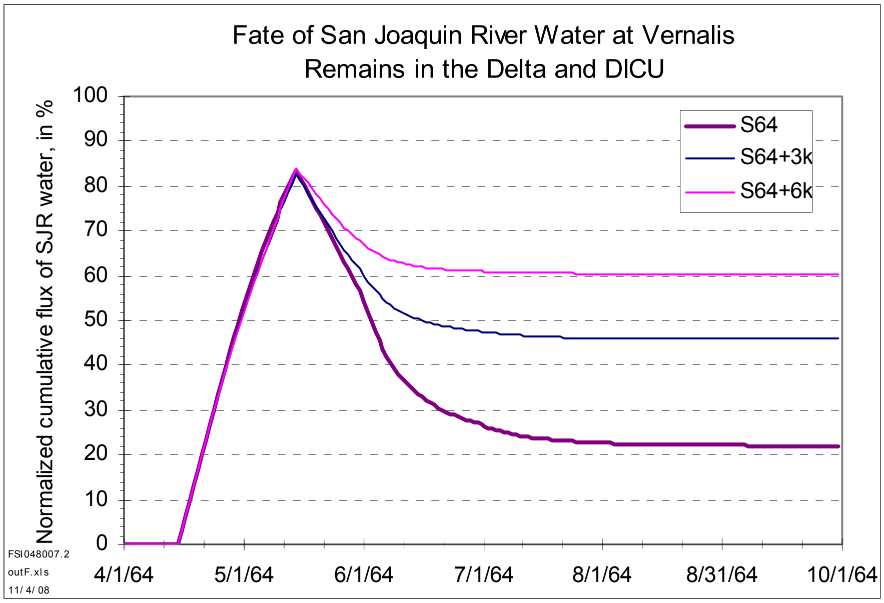

Figure A137. Fraction of San Joaquin River water, released at Vernalis between April 15 and May 15, remains in the Delta and supplied to Delta island consumptive use, a comparison among Scenarios S64, S64+3k, and S64+6k.

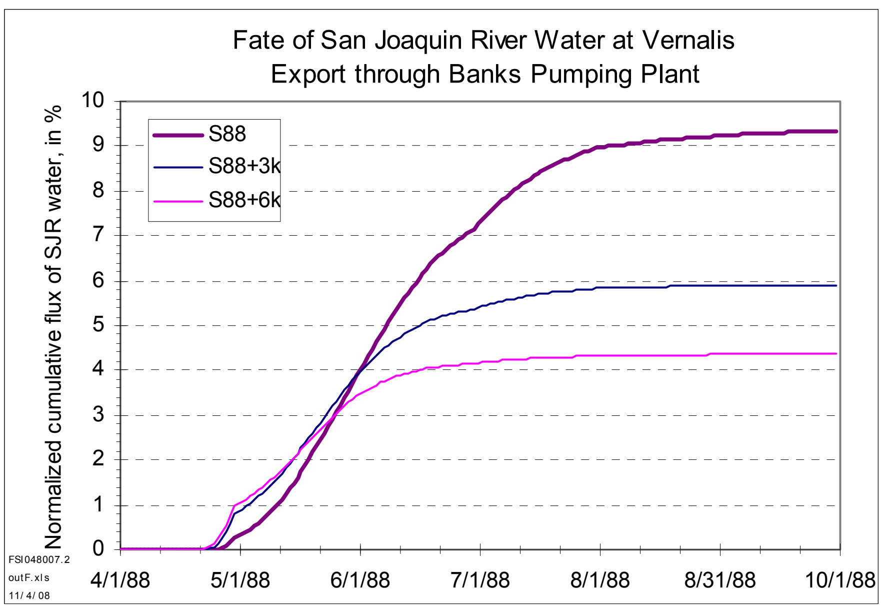

Figure A138. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Banks Pumping Plant, a comparison among Scenarios S88, S88+3k, and S88+6k.

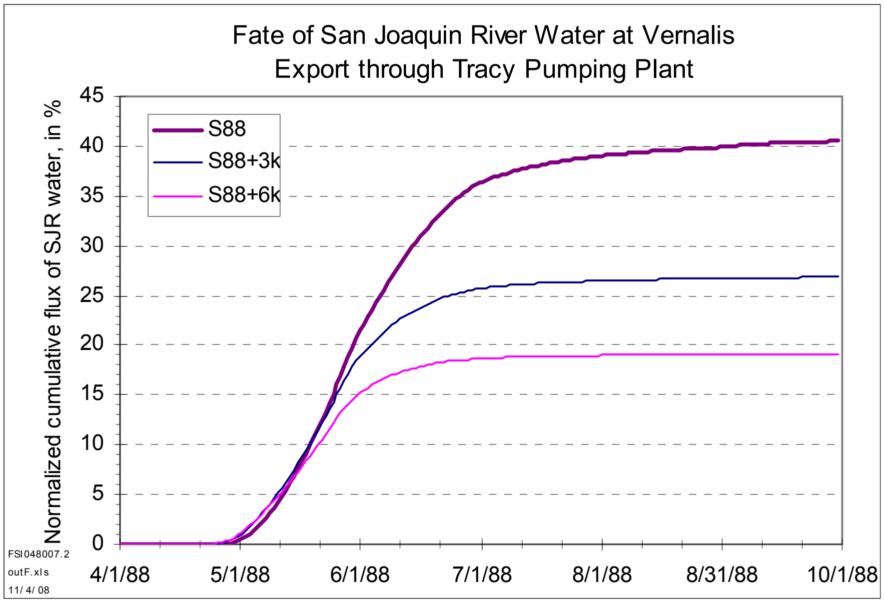

Figure A139. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Tracy Pumping Plant, a comparison among Scenarios S88, S88+3k, and S88+6k.

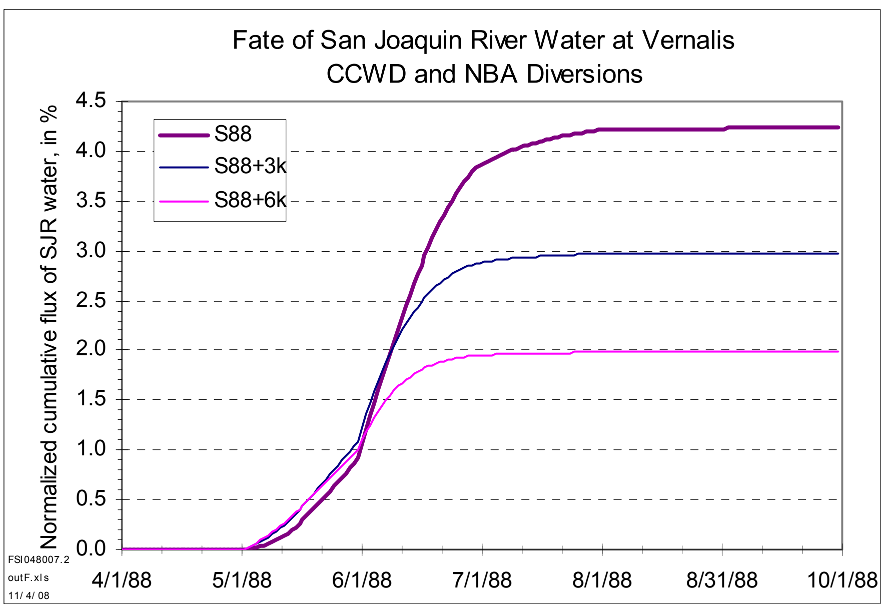

Figure A140. Diversion of San Joaquin River water, released at Vernalis between April 15 and May 15, to Contra Costa Water District and to Northbay Aqueduct, a comparison among Scenarios S88, S88+3k, and S88+6k.

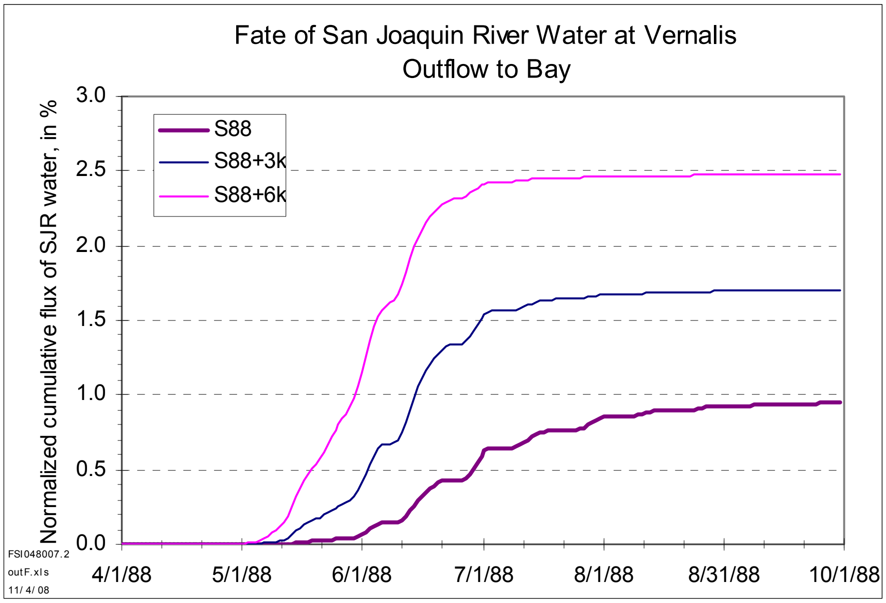

Figure A141. Outflow of San Joaquin River water, released at Vernalis between April 15 and May 15, to San Pablo Bay, a comparison among Scenarios S88, S88+3k, and S88+6k.

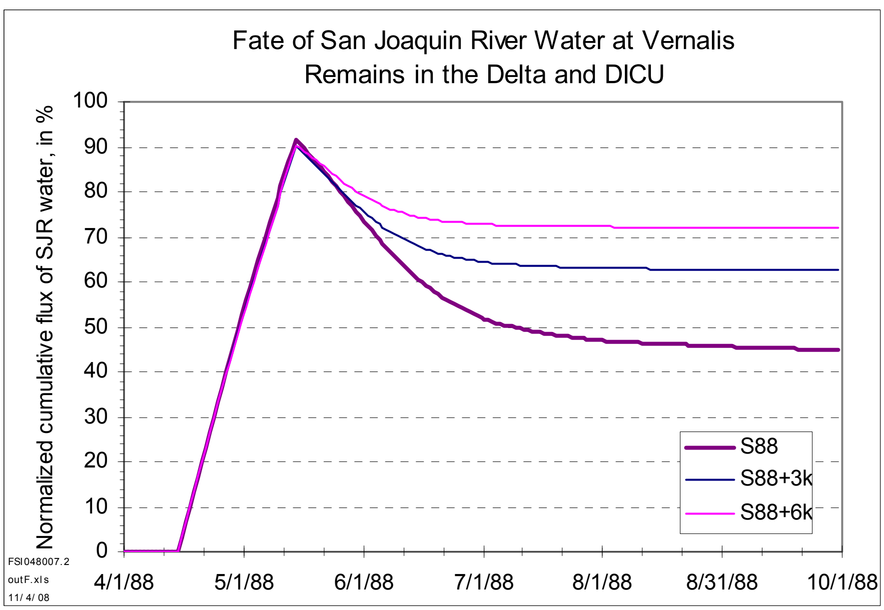

Figure A142. Fraction of San Joaquin River water, released at Vernalis between April 15 and May 15, remains in the Delta and supplied to Delta island consumptive use, a comparison among Scenarios S88, S88+3k, and S88+6k.

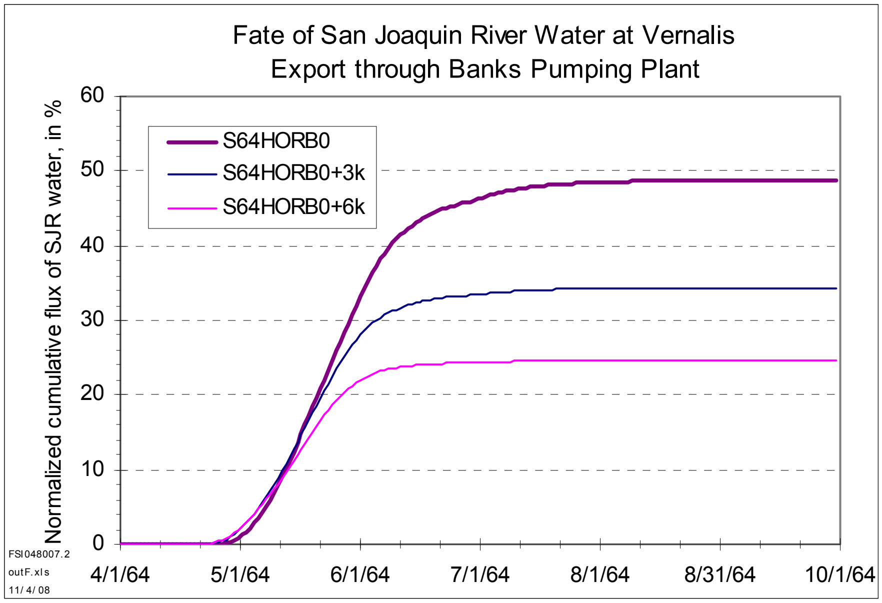

Figure A143. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Banks Pumping Plant, a comparison among Scenarios S64HORB0, S64HORB0+3k, and S64HORB0+6k.

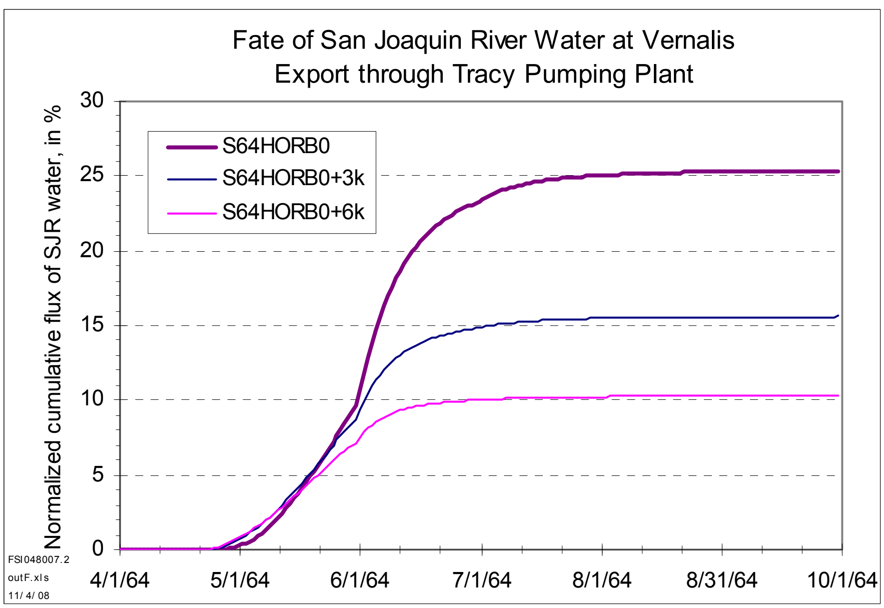

Figure A144. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Tracy Pumping Plant, a comparison among Scenarios S64HORB0, S64HORB0+3k, and S64HORB0+6k.

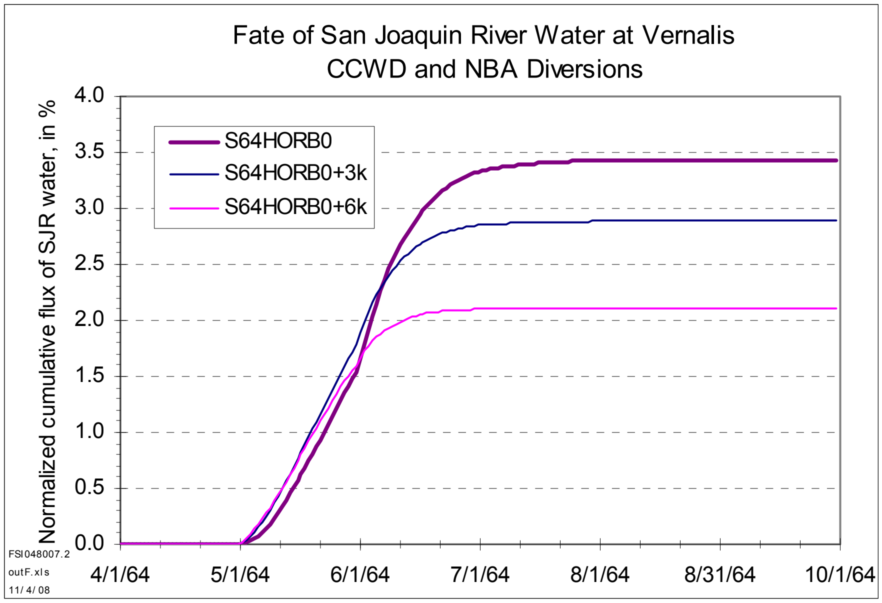

Figure A145. Diversion of San Joaquin River water, released at Vernalis between April 15 and May 15, to Contra Costa Water District and to Northbay Aqueduct, a comparison among Scenarios S64HORB0, S64HORB0+3k, and S64HORB0+6k.

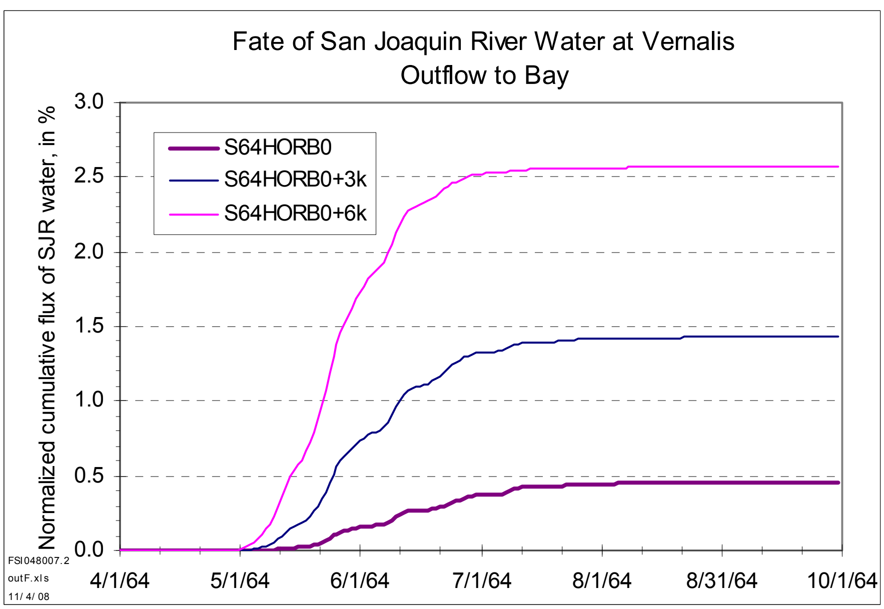

Figure A146. Outflow of San Joaquin River water, released at Vernalis between April 15 and May 15, to San Pablo Bay, a comparison among Scenarios S64HORB0, S64HORB0+3k, and S64HORB0+6k.

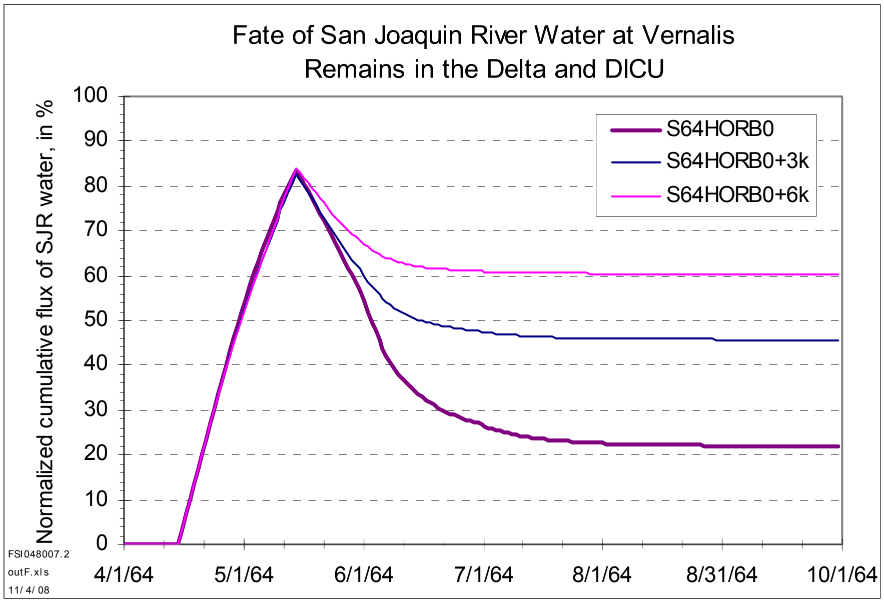

Figure A147. Fraction of San Joaquin River water, released at Vernalis between April 15 and May 15, remains in the Delta and supplied to Delta island consumptive use, a comparison among Scenarios S64HORB0, S64HORB0+3k, and S64HORB0+6k.

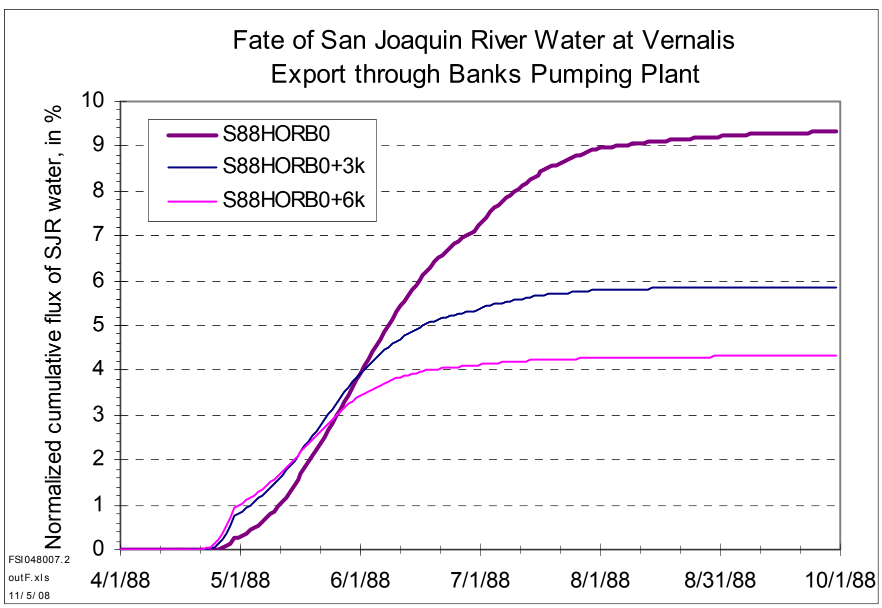

Figure A148. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Banks Pumping Plant, a comparison among Scenarios S88HORB0, S88HORB0+3k, and S88HORB0+6k.

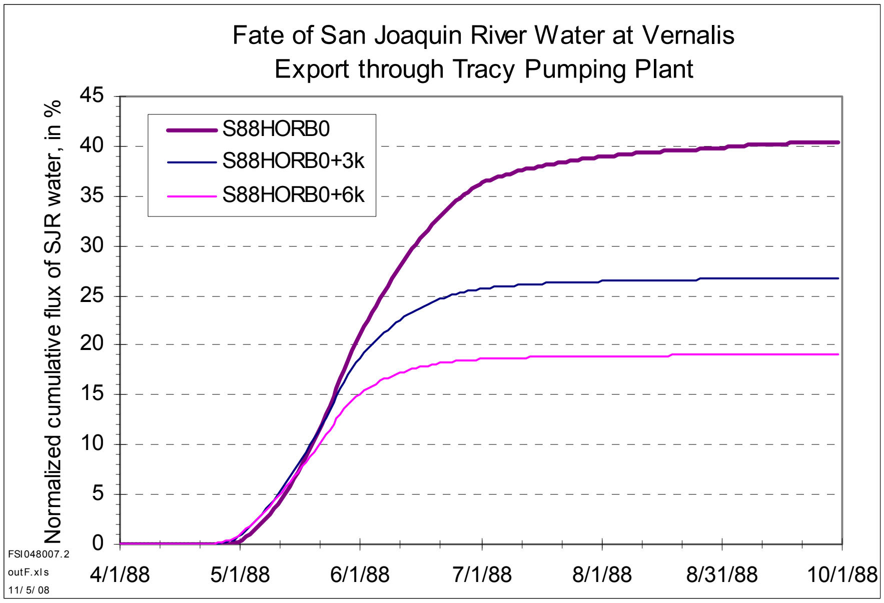

Figure A149. Export of San Joaquin River water, released at Vernalis between April 15 and May 15, through Tracy Pumping Plant, a comparison among Scenarios S88HORB0, S88HORB0+3k, and S88HORB0+6k.

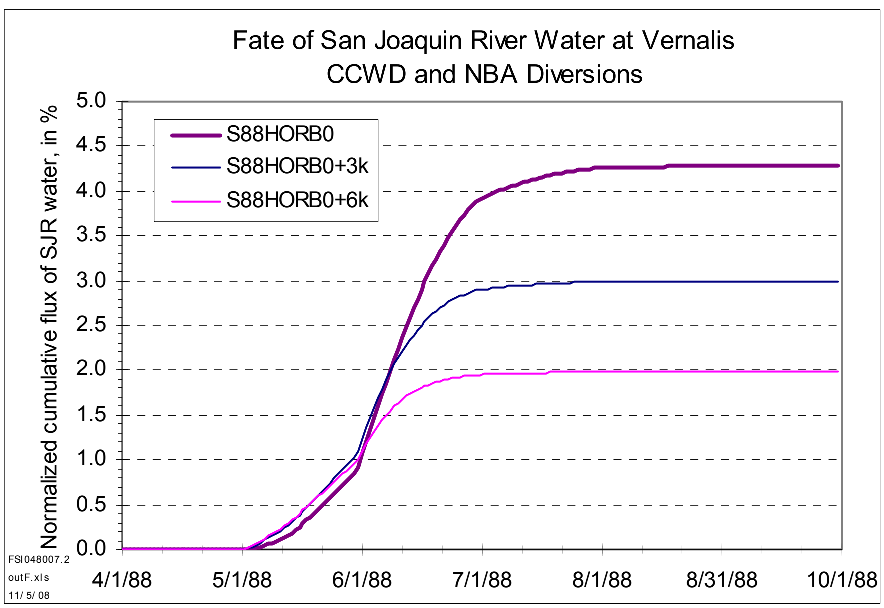

Figure A150. Diversion of San Joaquin River water, released at Vernalis between April 15 and May 15, to Contra Costa Water District and to Northbay Aqueduct, a comparison among Scenarios S88HORB0, S88HORB0+3k, and S88HORB0+6k.

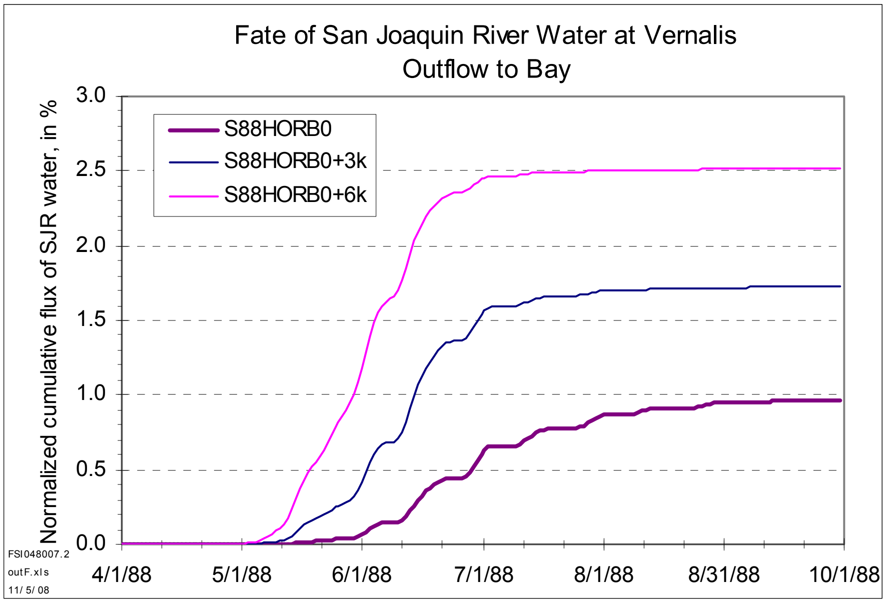

Figure A151. Outflow of San Joaquin River water, released at Vernalis between April 15 and May 15, to San Pablo Bay, a comparison among Scenarios S88HORB0, S88HORB0+3k, and S88HORB0+6k.

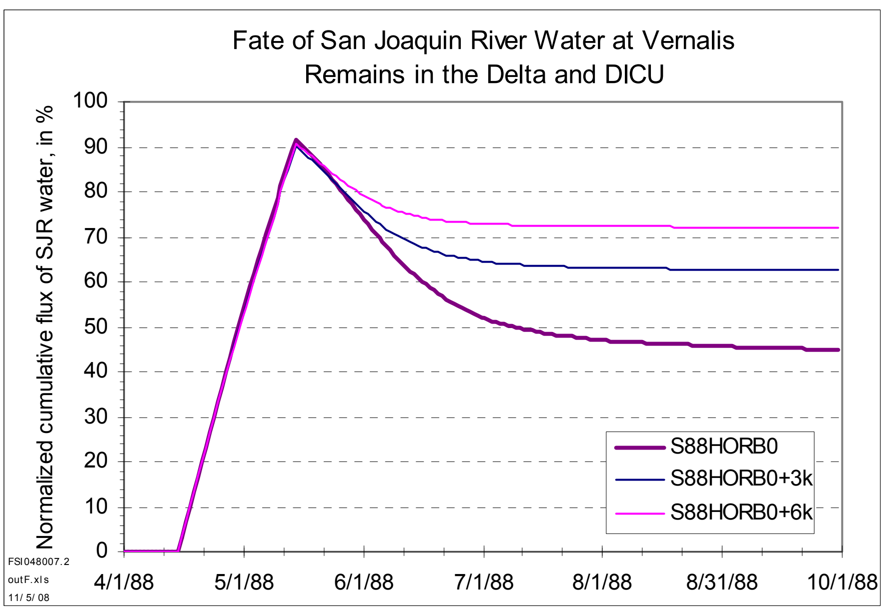

Figure A152. Fraction of San Joaquin River water, released at Vernalis between April 15 and May 15, remains in the Delta and supplied to Delta island consumptive use, a comparison among Scenarios S88HORB0, S88HORB0+3k, and S88HORB0+6k.