Element 6 - Hydrodynamic Modeling (2011)

This chapter presents DSM2 model simulation results of south Delta flows and water levels to help analysis of the impacts on south Delta hydrodynamics due to the installation and operation of the temporary barriers in 2011. Two conditions were simulated with historical Delta inflows, consumptive use, and exports: 1) historical 2011 installation and operation of the temporary barriers, and 2) no installation of south Delta temporary barriers.

DSM2 is a one-dimensional open channel unsteady flow model based on a four-point finite difference solution of equations of momentum and continuity. The model network extends north to Sacramento River at I street, south to San Joaquin River at Vernalis, and west to Martinez where the observed 15-minute time series of water level governs how the tide signal propagates into the Delta.

2011 Delta Boundary conditions

Flow and stage information required at model boundaries were obtained from the California Data Exchange Center. Missing data or errors in data were estimated via simple interpolation. The resulting boundary conditions for the 2011 simulation are shown in Figures 7-1 through 7-4.

Figure 7-1. Daily average historical inflow from the Sacramento River, 2011.

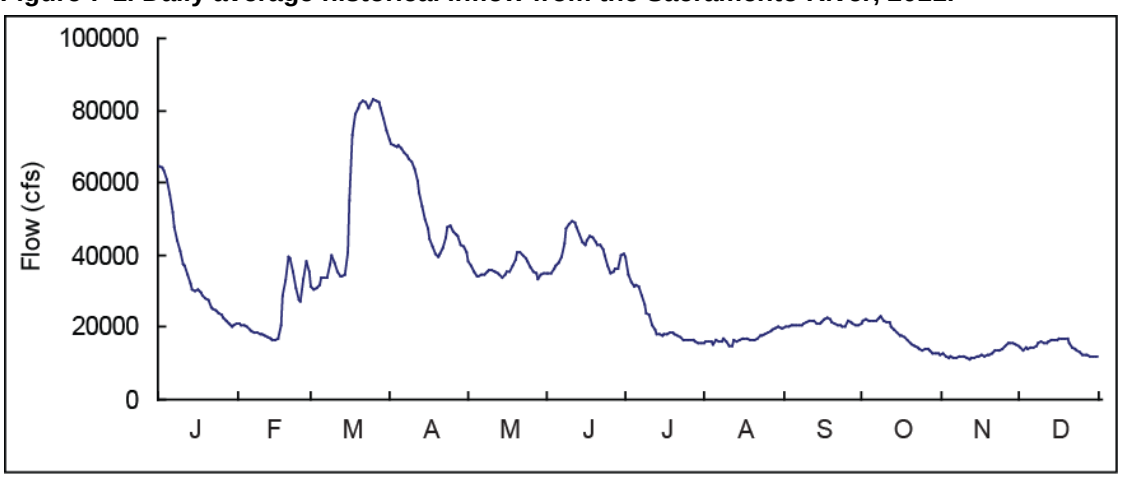


Figure 7-2. Daily average historical inflow from the Yolo Bypass, 2011.

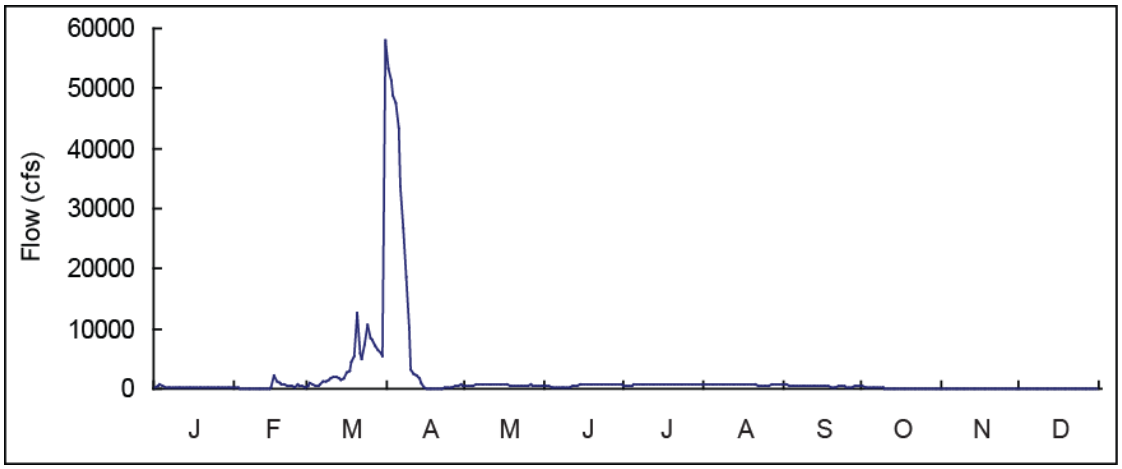


Figure 7-3. Daily average historical inflow from the San Joaquin River, 2011.

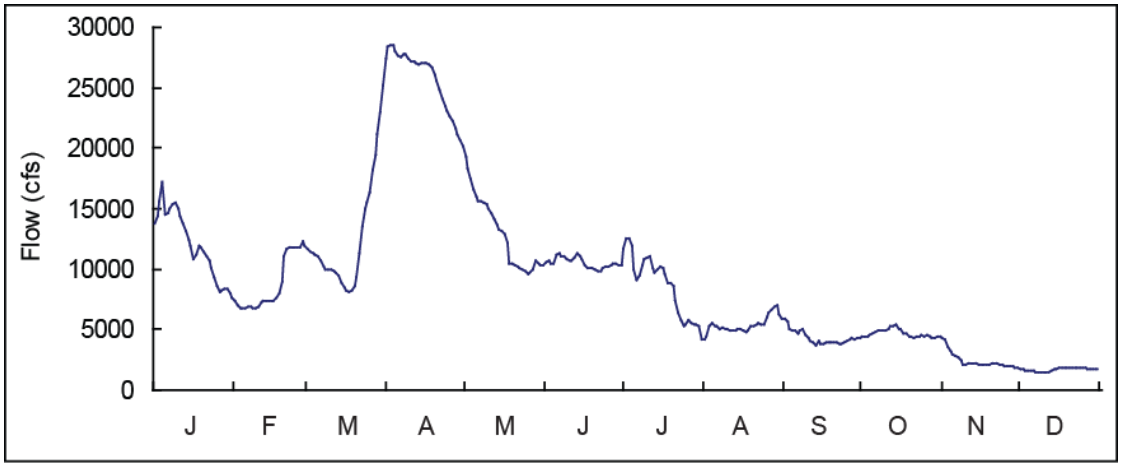
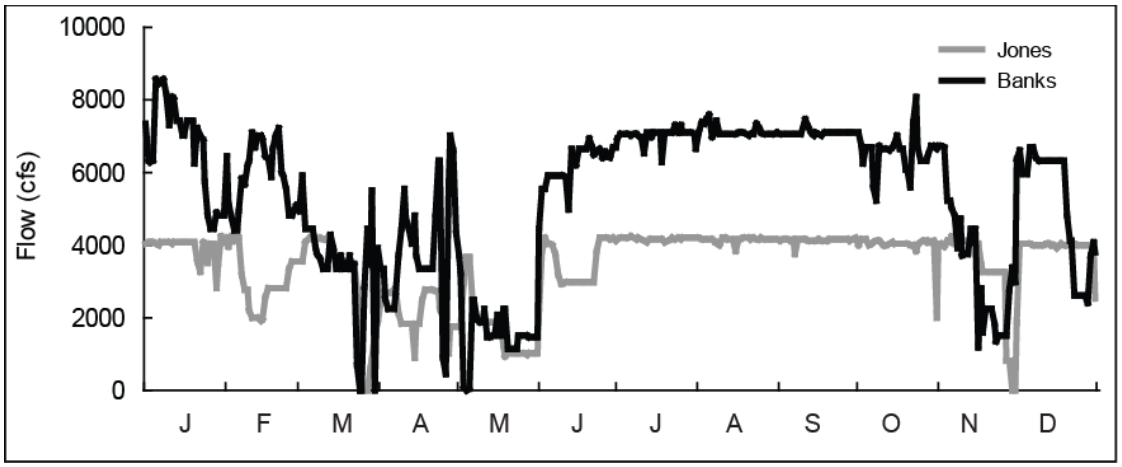


Figure 7-4. Daily average historical pumping at Banks and Jones Pumping Plants, 2011.



2011 Delta consumptive use

The Delta Island Consumptive Use (DICU) model estimated the amount of water diverted from and returned to Delta channels due to agricultural activities. Input to DICU model includes precipitation, pan evaporation data, and water year types. The water year type determines which of two possible cropping patterns in the Delta is assumed, which in turn contributes to the estimation of agricultural water needs.

South Delta Structures

All three temporary agricultural barriers were installed in 2011. Table 7-1 lists the dates and times of barrier installation, operation, and removal as simulated by DSM2. The DSM2 simulation timed the installation and removal of the barriers to the changes in actual observed stages which indicated effective closure or opening of the channel. Flap gates in the barrier culverts were at times tied open and at other times allowed to tidally operate. Closure of the Grant Line Canal barrier was nearly completed on July 14; however, high river flows required the weir elevation to be lowered below design. The Grant Line Canal barrier weir elevation was effectively restored to design level on August 2, 2011. The spring Head of Old River barrier was not installed in 2011 due to high San Joaquin River flows. The fall Head of Old River barrier was not installed as per instructions from the Department of Fish and Game since San Joaquin River flow conditions and dissolved oxygen concentration were acceptable.

Table 7-1. Historical 2011 Timing of South Delta Temporary Barriers Installation, Operation, and Removal as Simulated by DSM2

Barrier	Date	Effective Time	Status	Flap Gates Operation
Middle River	Jun 6	1000	Installed	Fixed open
	Aug 23	1200	Installed	Tidally operated
	Oct 11	1200	Removed	
Old River near DMC	Jun 10	1200	Installed	Fixed open
	Aug 23	1400	Installed	Tidally operated
	Oct 10	1800	Removed	
Grant Line Canal	Jul 14	1800	Installed	Tidally operated
	Aug 2	1200	Installed	Fixed open
	Oct 19	1600	Removed	
Old River at Head (fall)	--	--	--	--
Old River at Head (spring)	--	--	--	--

Delta Downstream Stage at Martinez

The downstream boundary of DSM2 is Martinez where a time series of observed historical 15-minute data from 2011 was used for the simulation.

Delta Cross Channel Operation

The Delta Cross Channel gates were operated in 2011 and modeled in the historical DSM2 simulation as shown in Table 7-2.

Table 7-2. Historical Delta Cross Channel Gates Operation for 2011.

Date	Time	Operation	Date	Time	Operation
Jan 1	0	closed	Oct 14	900	open
Jul 15	1000	open	Dec 1	930	closed
Oct 4	900	closed			

Validation of DSM2 Simulation of Historical 2011 Delta Hydrodynamics

A validation of the DSM2 simulation of historical 2011 Delta hydrodynamics is presented in Appendix C and consists of two types of comparisons. First, simulated daily extremes in water level and flow and average flow are compared to observed values. Second, simulated and observed stage and flow were used to create box and whisker plots of 15-minute flow and stage and schematics showing average flow and minimum stages for discrete periods of time

Effect of Installation and Operation of Temporary Barriers on South Delta Hydrodynamics

The impacts upon flow and water levels caused by the temporary barriers depend in part on other factors: the inflow of San Joaquin River, agriculture diversions and returns, Banks and Jones Pumping Plant operations, and Clifton Court Forebay intake gates operation. To account for this, the results of the simulations of historical conditions and no-temporary barrier installation conditions were partitioned into periods of time for which flows and exports changed relatively little and any of the three temporary barriers were either fully installed or removed. Following this approach, the results of the 2011 simulation were processed according to 21 periods of time as shown in Table 7-3. These intervals exclude periods when barriers were in the process of installation or removal or sharp changes in inflows or exports were occurring: June 5 ,10-13; August 1,2,22,23; and October 10,11,19.

Table 7-3. Characteristics of time intervals for presentation of simulation results, 2011

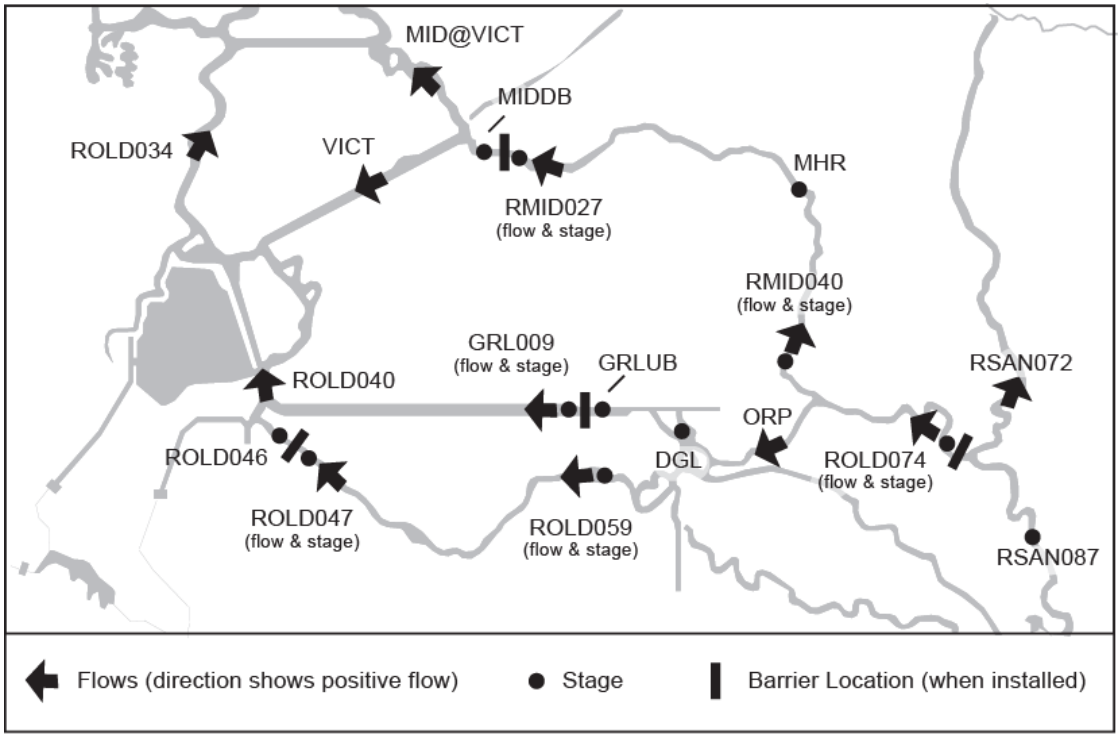
Period in 2011		Period Average Flows (cfs)				Period Barrier Status			
		SAC R +YOLO	SJR	DMC pumping	SWP pumping	MR	OR	GLC	ORH
Jan	1-31	35376	12014	3955	6750				
Feb	1-28	24828	8698	3029	5919				
Mar	1-23	52202	10265	3805	3761				
Mar	24-31	93065	20757	609	2526				
Apr	1-21	73652	27211	2299	3523				
Apr	22-30	45295	22143	2004	4724				
May	1-31	36677	12942	1660	1630				
Jun	1-4	36208	10548	3568	5377				
Jun	6-9	44965	11080	3474	5936	IN			
Jun	14-30	41377	10265	3519	6576	IN	IN		
Jul	1-13	28531	10789	4179	7005	IN	IN		
Jul	15-31	17757	6959	4175	7046	IN	IN	IN	
Aug	3-21	16876	5116	4144	7150	IN	IN	IN	
Aug	24-31	19964	6332	4175	7093	IN	IN	IN	
Sep	1-30	21506	4331	4133	7104	IN	IN	IN	
Oct	1-9	22331	4659	4097	6407	IN	IN	IN	
Oct	12-18	18213	5057	4036	6727			IN	
Oct	20-31	13661	4419	3875	6619				
Nov	1-15	11770	2763	4090	4887				
Nov	16-30	13896	2050	2564	2042				
Dec	1-31	14592	1694	3895	5177				

In order to assess impacts to south Delta hydrodynamics, two scenarios were simulated by DSM2: 2011 historical conditions and the 2011 historical conditions modified by removing temporary barriers (i.e. the “No Barriers Scenario”).

For each time period, 15-minute stage and flow were used to generate box and whiskers plots which graphically show period minimum, maximum, 25% quartile, 75% quartile, and median values. By the usual sign convention, negative flow values correspond to upstream flow. In addition to considering distributions of flow and water levels in the south Delta, flow schematics showing period-average flow and minimum water levels were generated to visually show impact of temporary barriers on circulation and water levels.

The locations where box plots of stage and flow are presented are shown in Figure 7-5 with arrows indicating assumed positive flow direction. Tables containing the numerical values associated with the box plots are presented in Appendix D.

Figure 7-5. Locations where simulated Delta stages and flows for analysis of 2011 conditions are presented.



Figures 7-6 and 7-7 show box plots of simulated stages and flows for time periods just before, during, and just after when at least one barrier was installed. Water levels are reported upstream and downstream of each barrier location and flows are presented throughout the south Delta in order to show the general circulation patterns. Distributions of flow and stage from both the historical simulation and the no-barriers condition are provided to help analysis of the effect of the installation of the barriers.

By showing schematics of flow and minimum water levels with and without the barriers, Figure 7-8 presents the effects that the temporary barriers in 2011 had on flow circulation and minimum water levels in the south Delta under the same time periods.

Figures 7-9 directly presents the changes in minimum water levels at seven locations in the south Delta influenced by barrier installation.

Figure 7-10 shows the period-average flows down Old River at Tracy Road, Grant Line Canal, and Middle River under historical and no-barriers conditions. Also shown are the differences in downstream flow at these locations caused by the historical installation of barriers in 2011.

Figure 7-6. Distribution of DSM2-simulated 15-minute water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

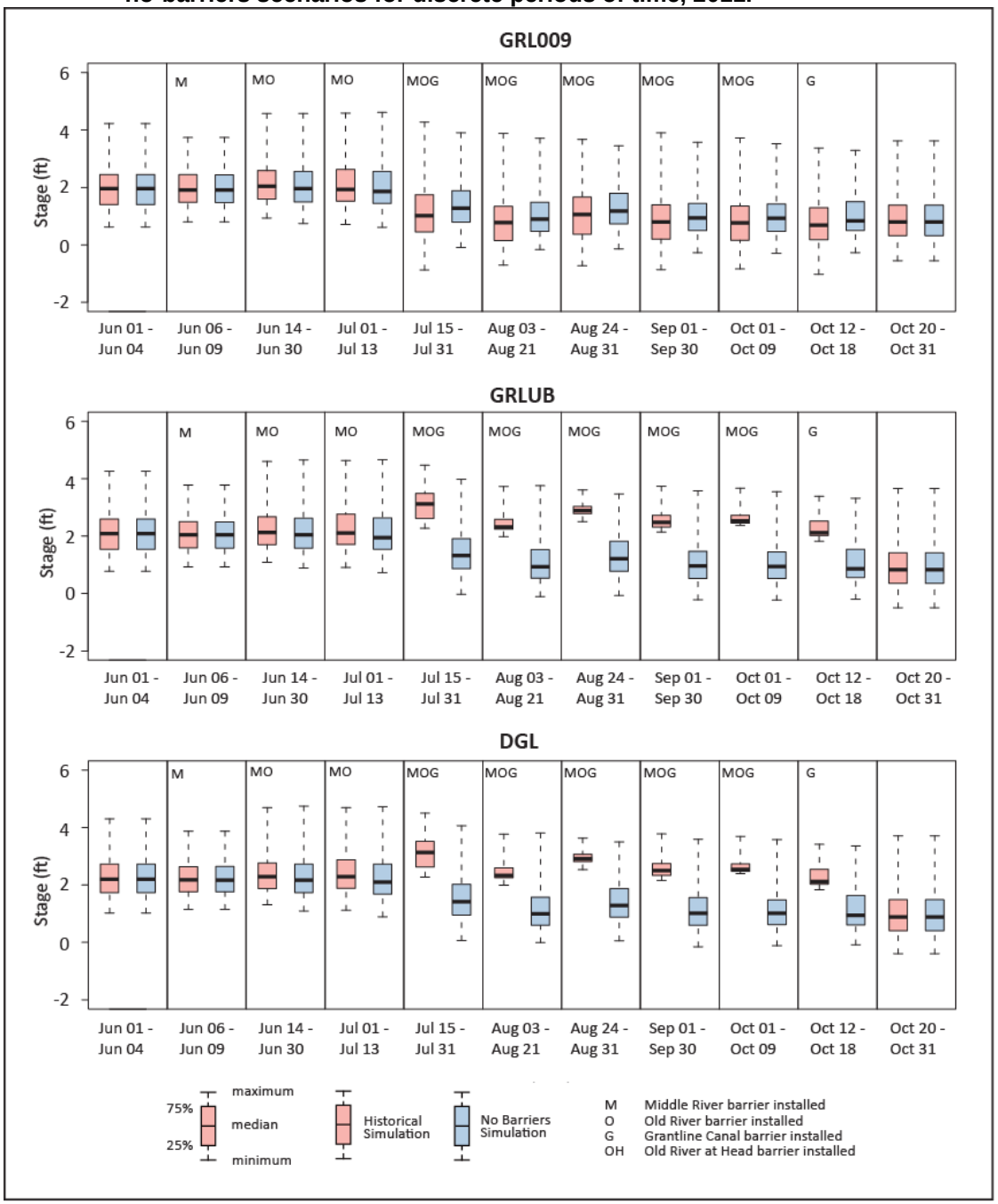


Figure 7-6 (cont). Distribution of DSM2-simulated 15-minute water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

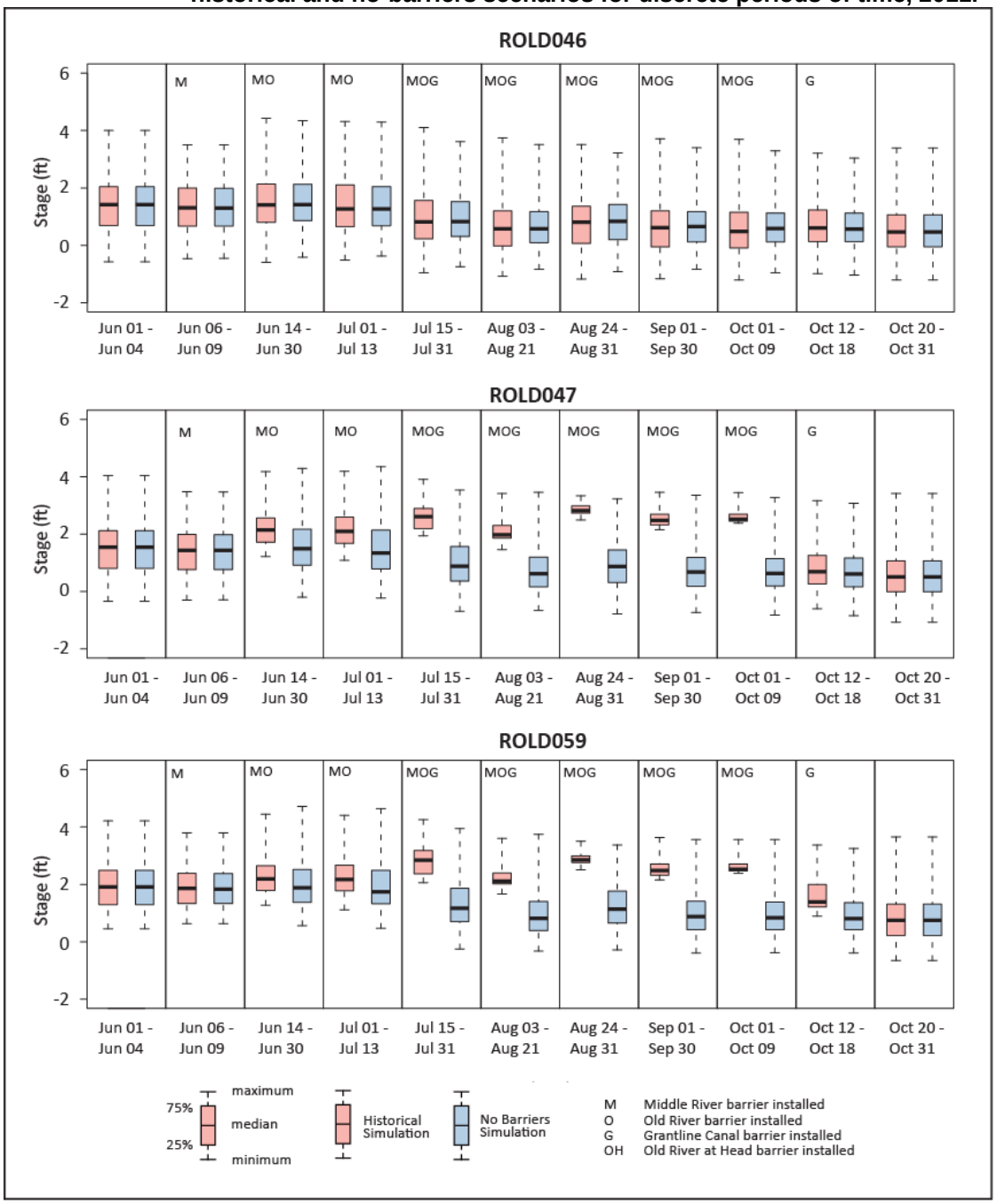


Figure 7-6 (cont). Distribution of DSM2-simulated 15-minute water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

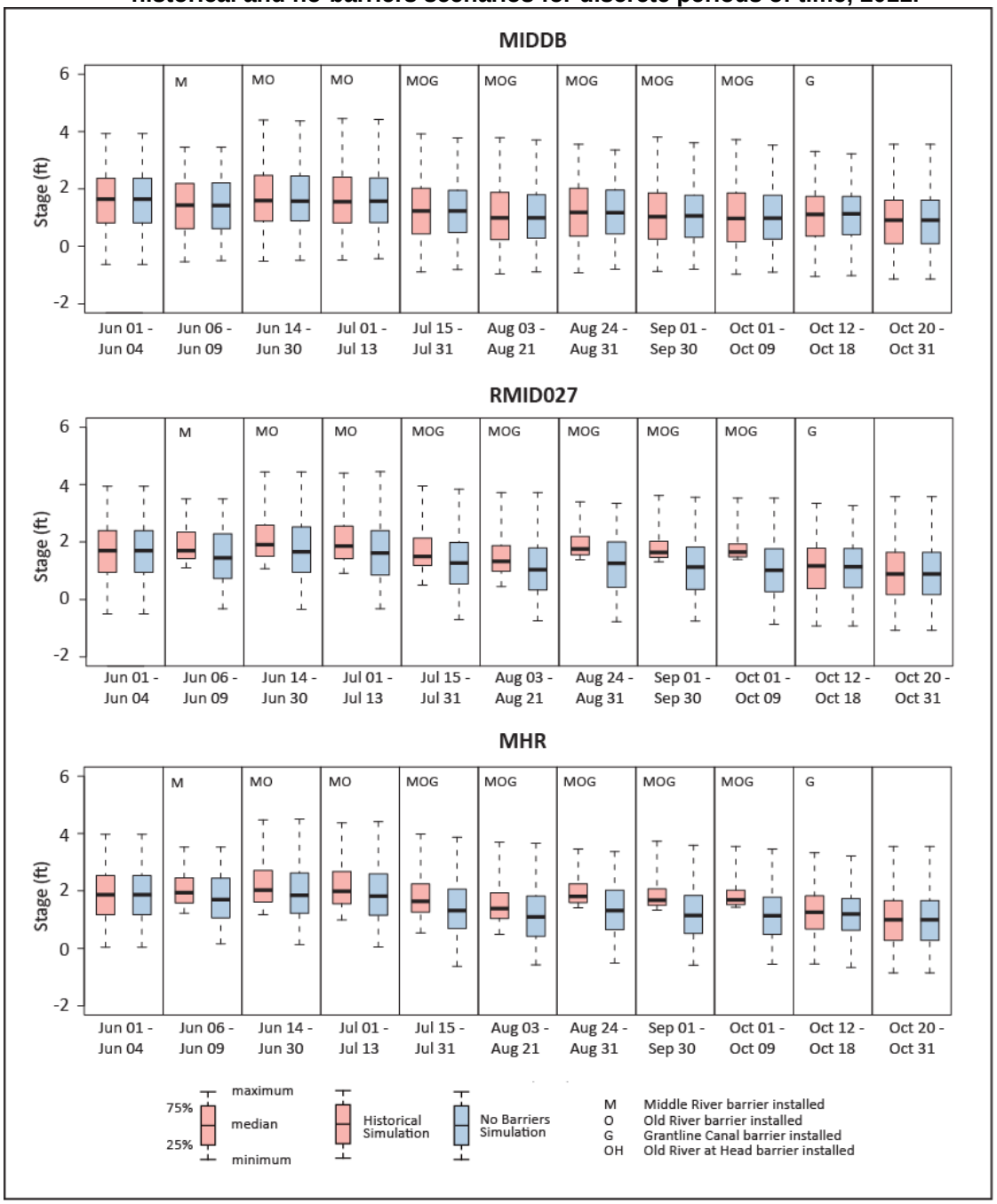


Figure 7-6 (cont). Distribution of DSM2-simulated 15-minute water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

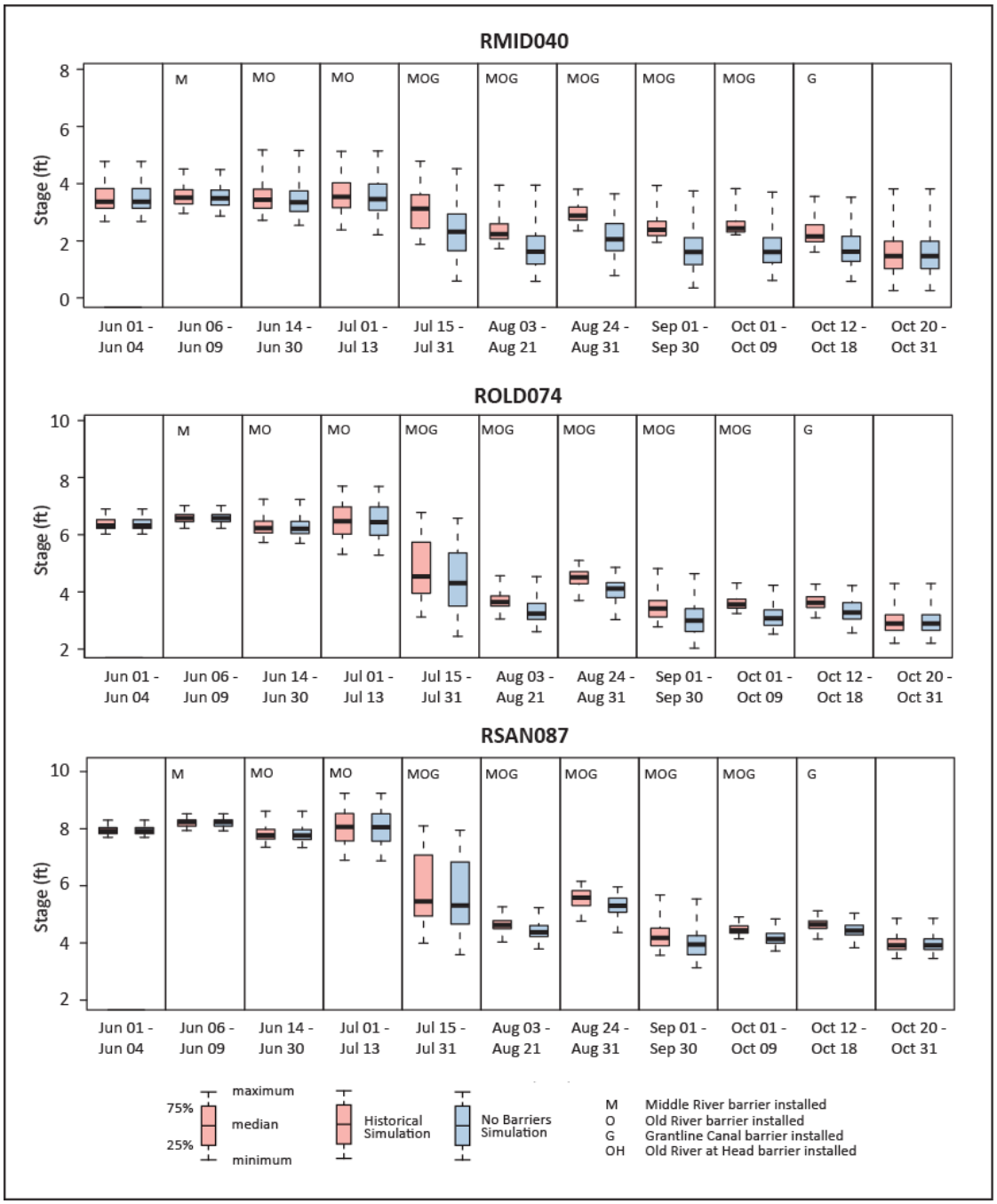


Figure 7-7. Distribution of DSM2-simulated 15-minute flows under historical and no-barriers scenarios for discrete periods of time, 2011.

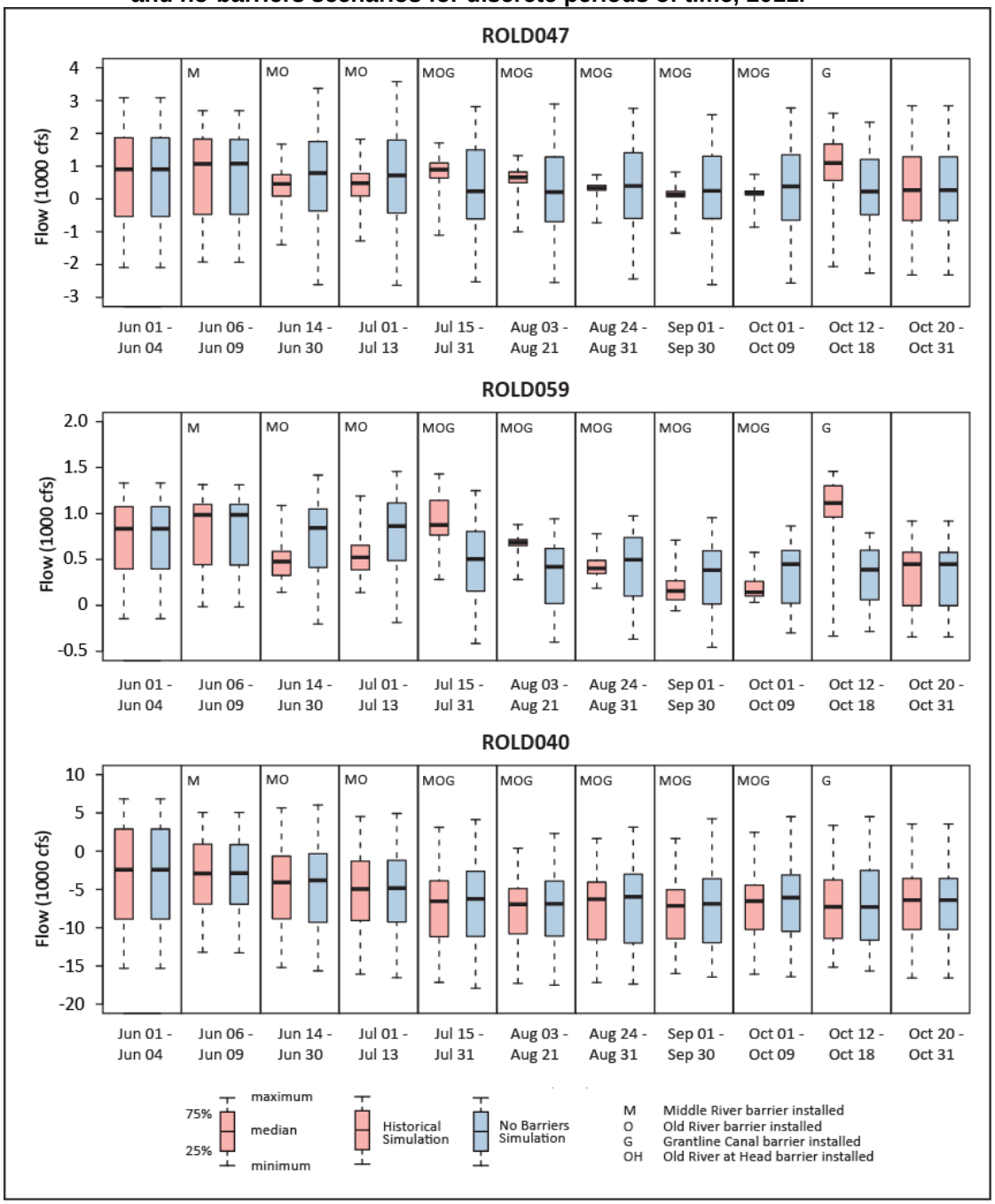


Figure 7-7 (cont). Distribution of DSM2-simulated 15-minute flows under historical and no-barriers scenarios for discrete periods of time, 2011.

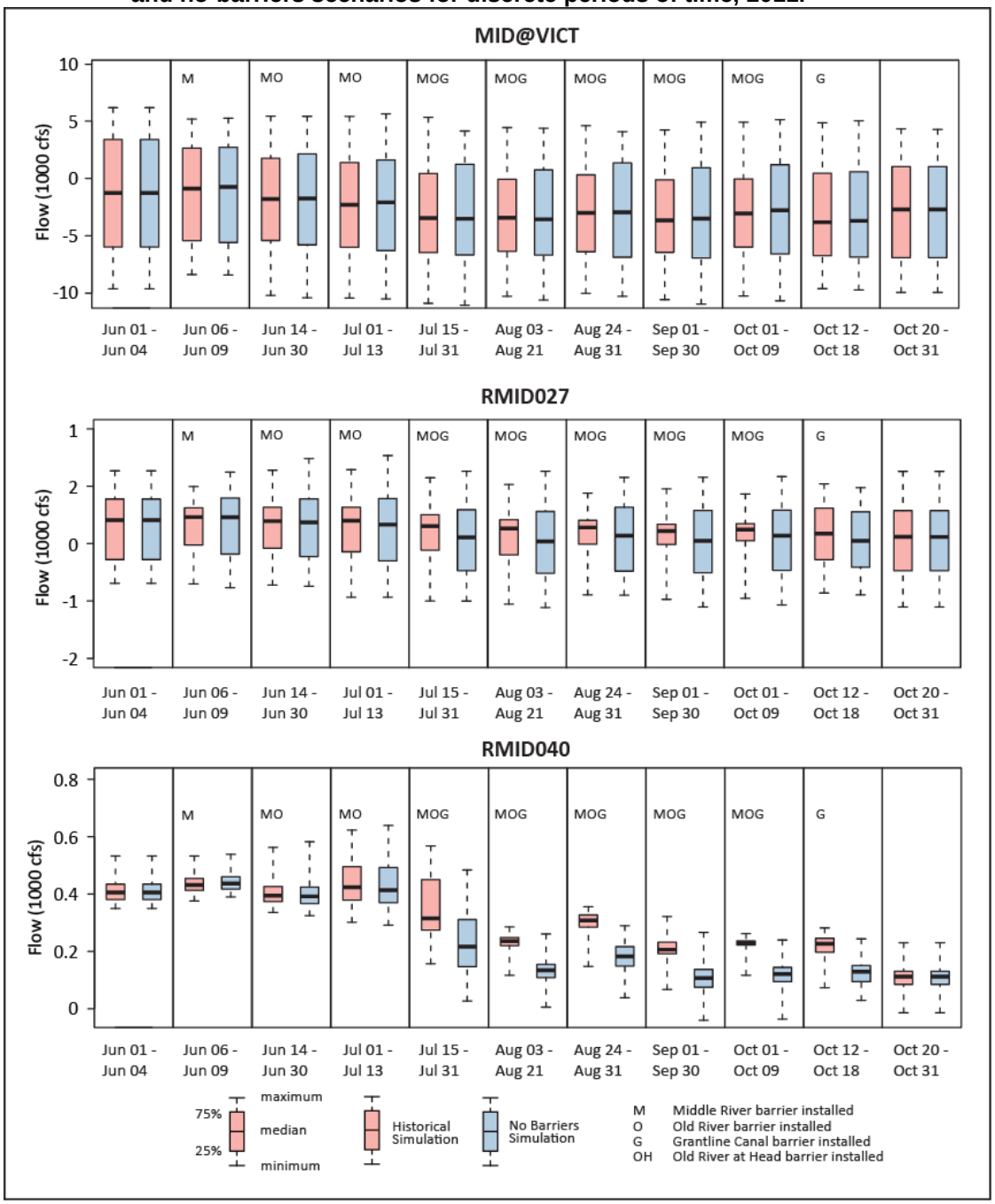


Figure 7-7 (cont). Distribution of DSM2-simulated 15-minute flows under historical and no-barriers scenarios for discrete periods of time, 2011.

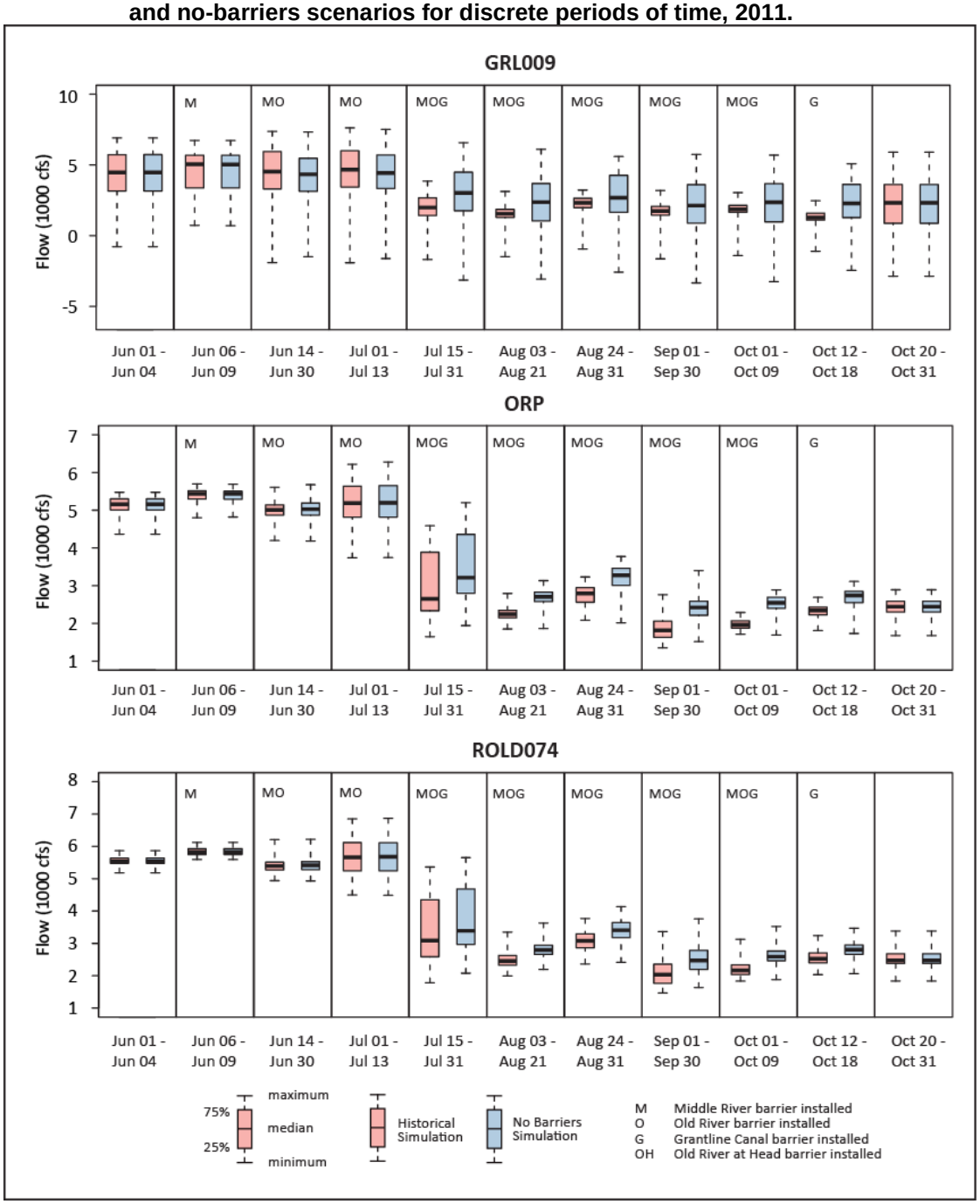


Figure 7-7 (cont). Distribution of DSM2-simulated 15-minute flows under historical and no-barriers scenarios for discrete periods of time, 2011.

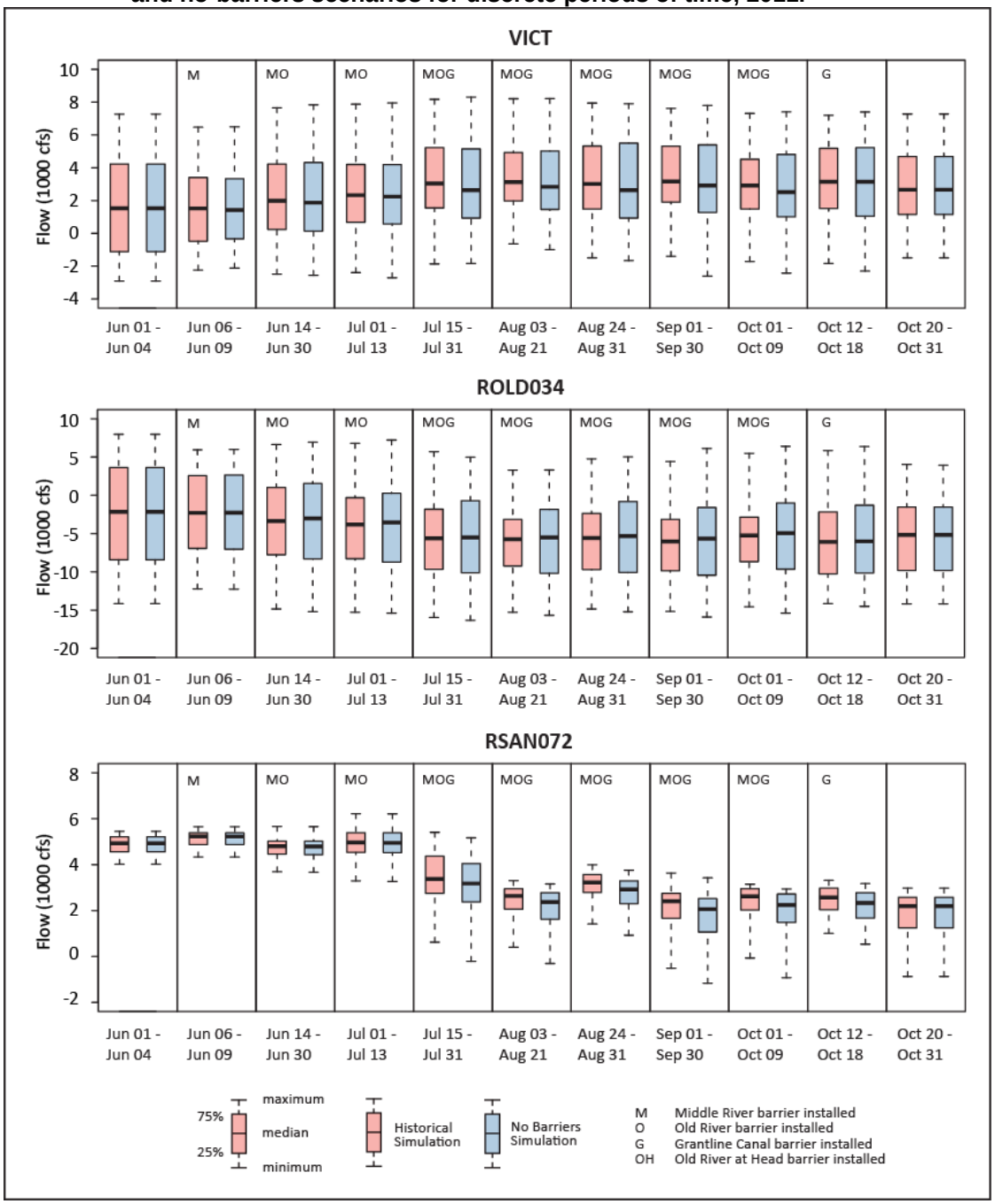


Figure 7-8. DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

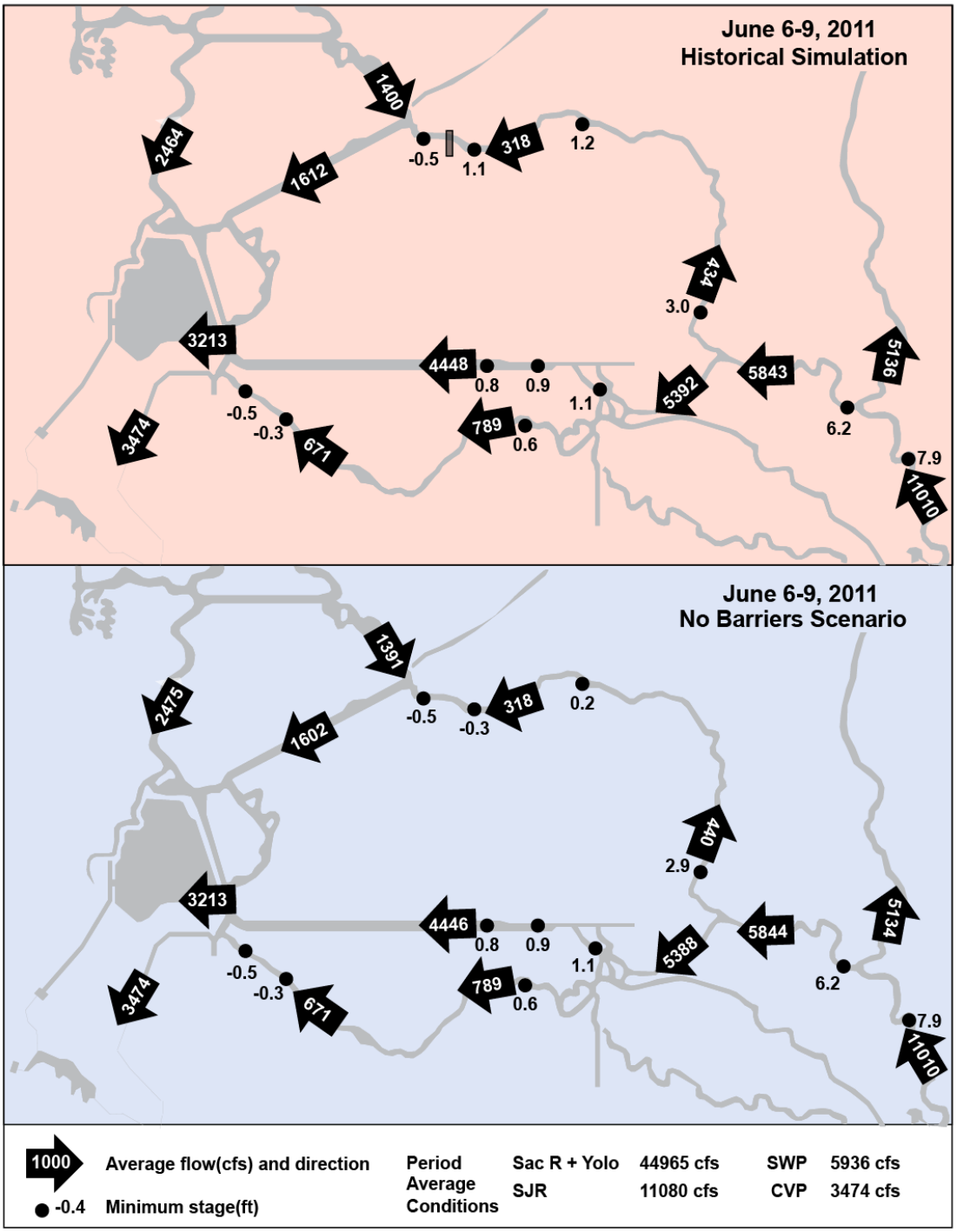


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

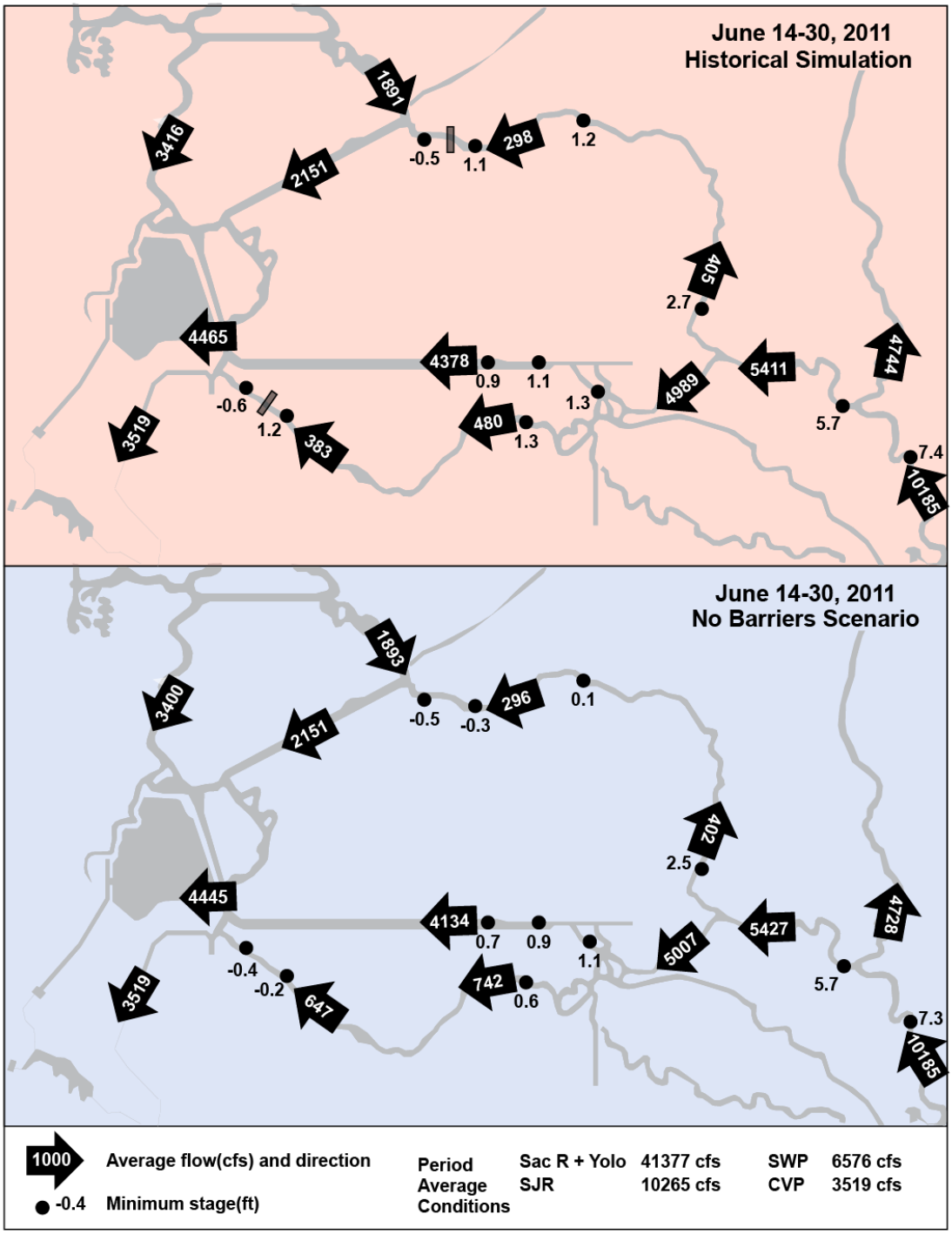


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

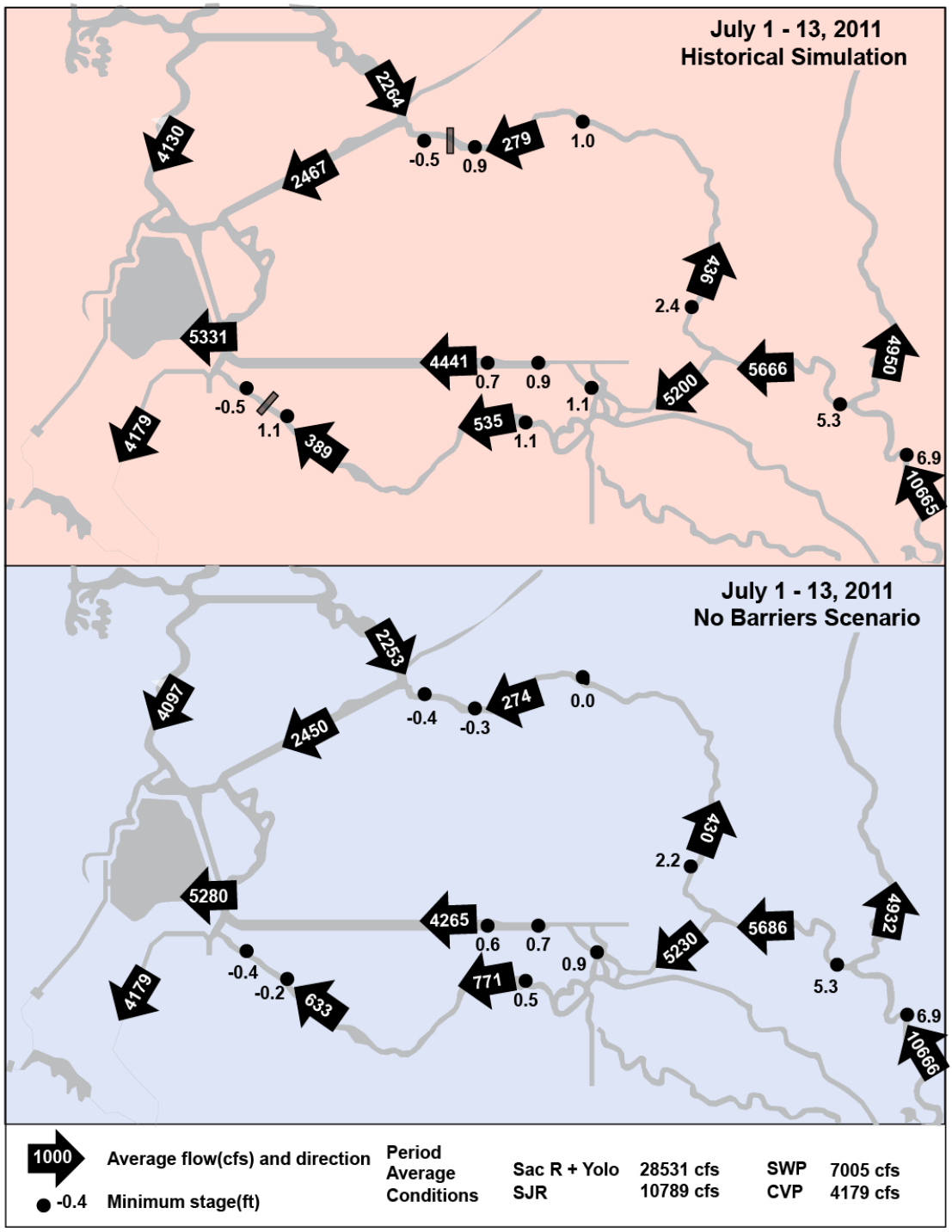


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

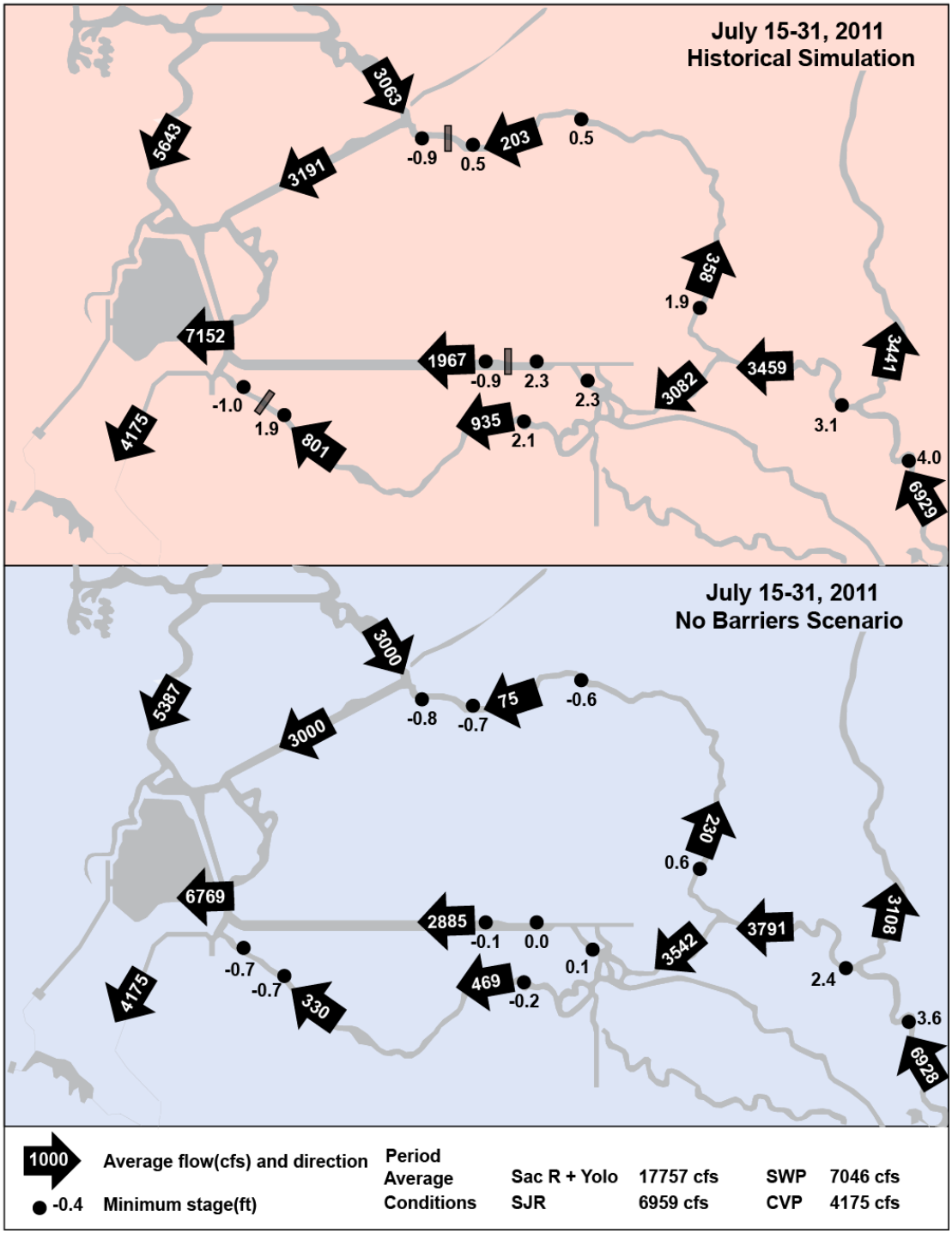


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

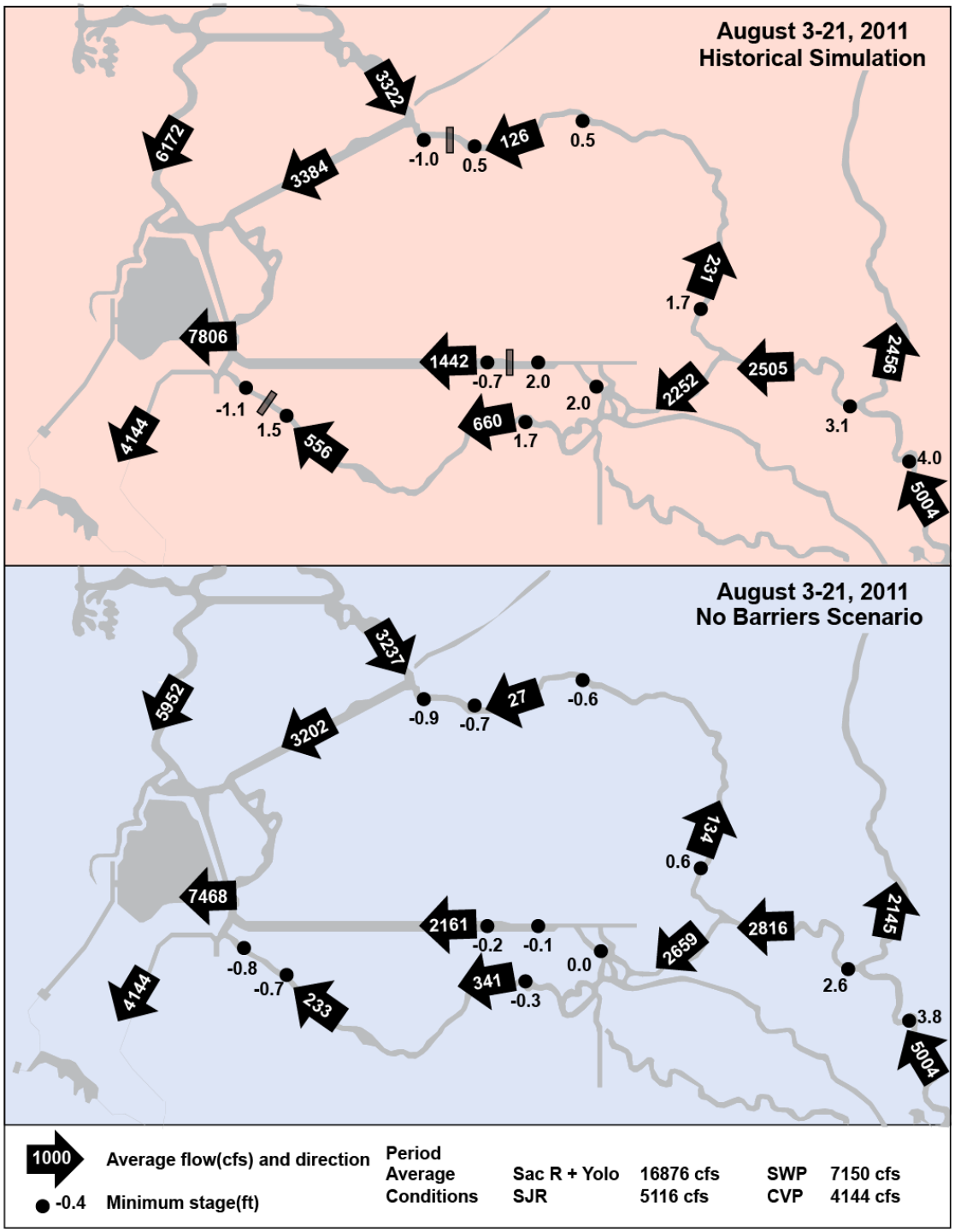


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

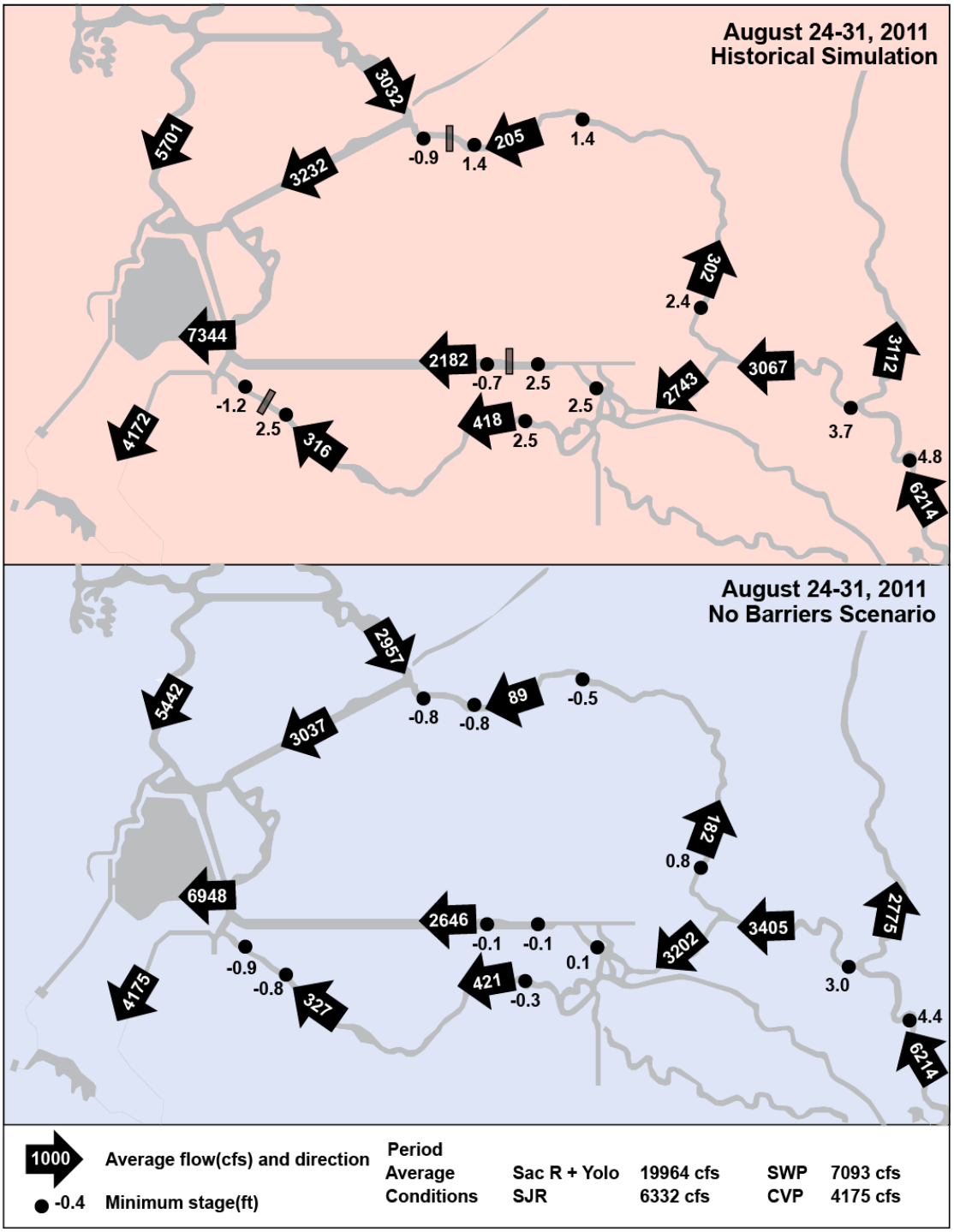


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

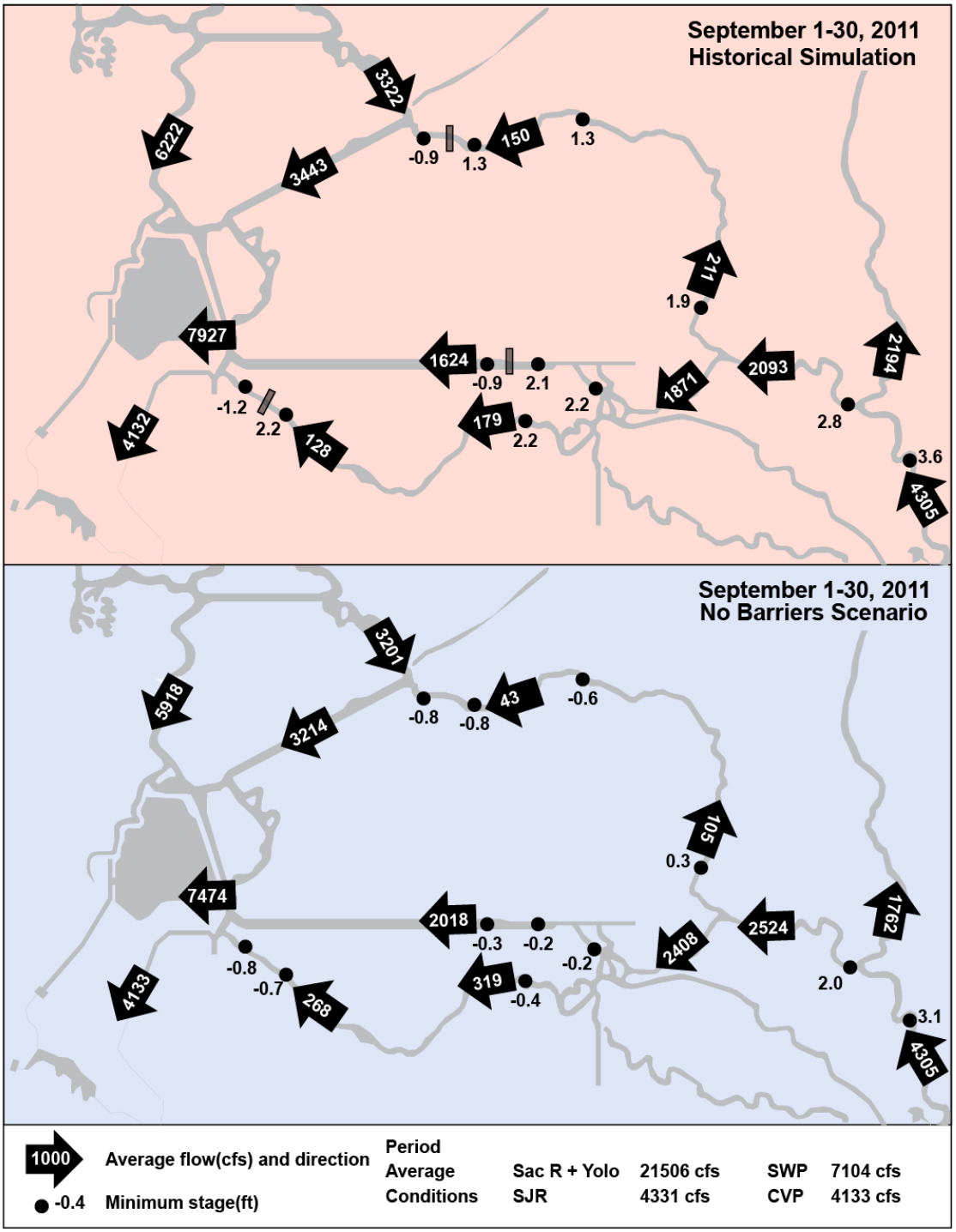


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

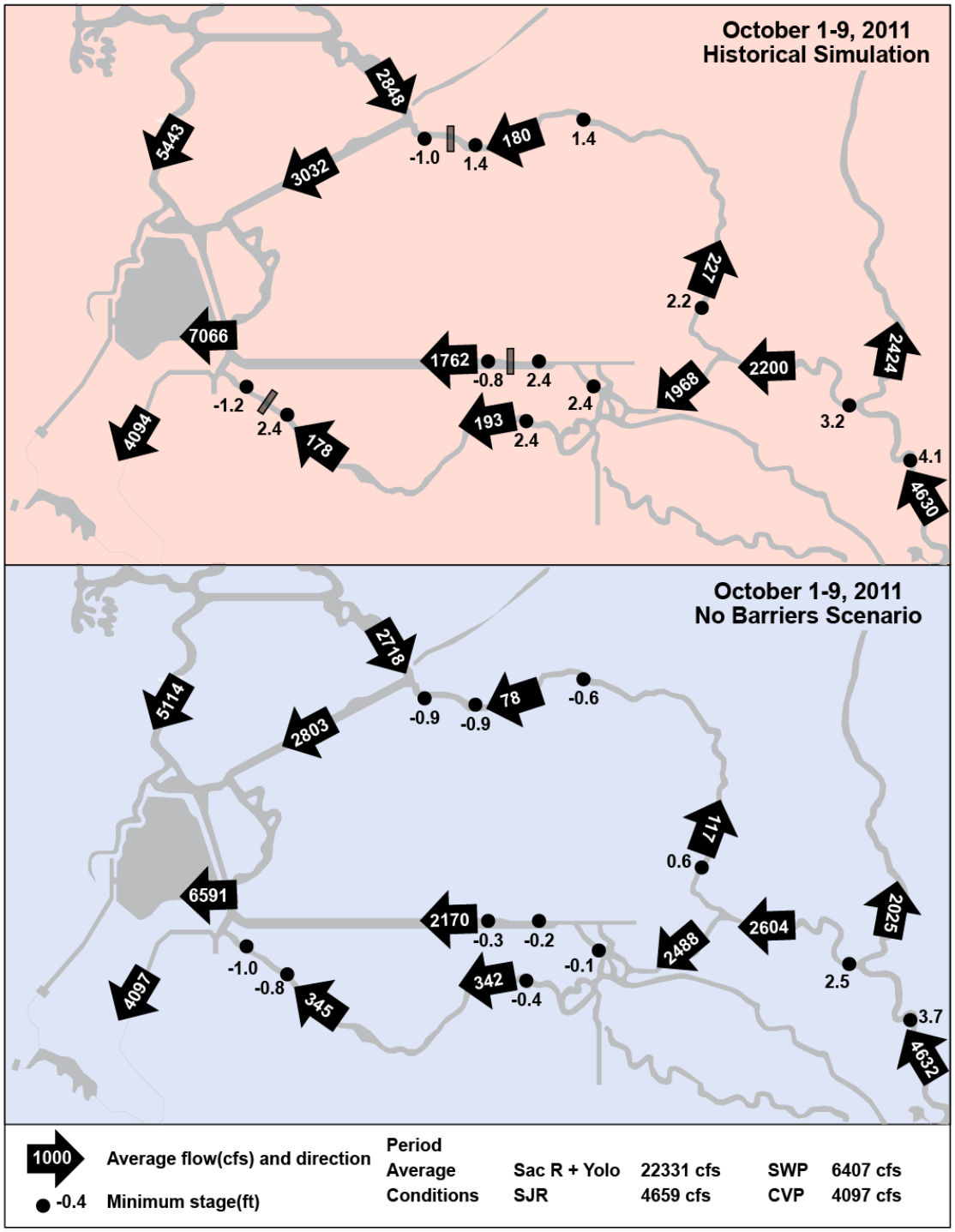


Figure 7-8 (cont). DSM2-simulated average flows and minimum water levels under historical and no-barriers scenarios for discrete periods of time, 2011.

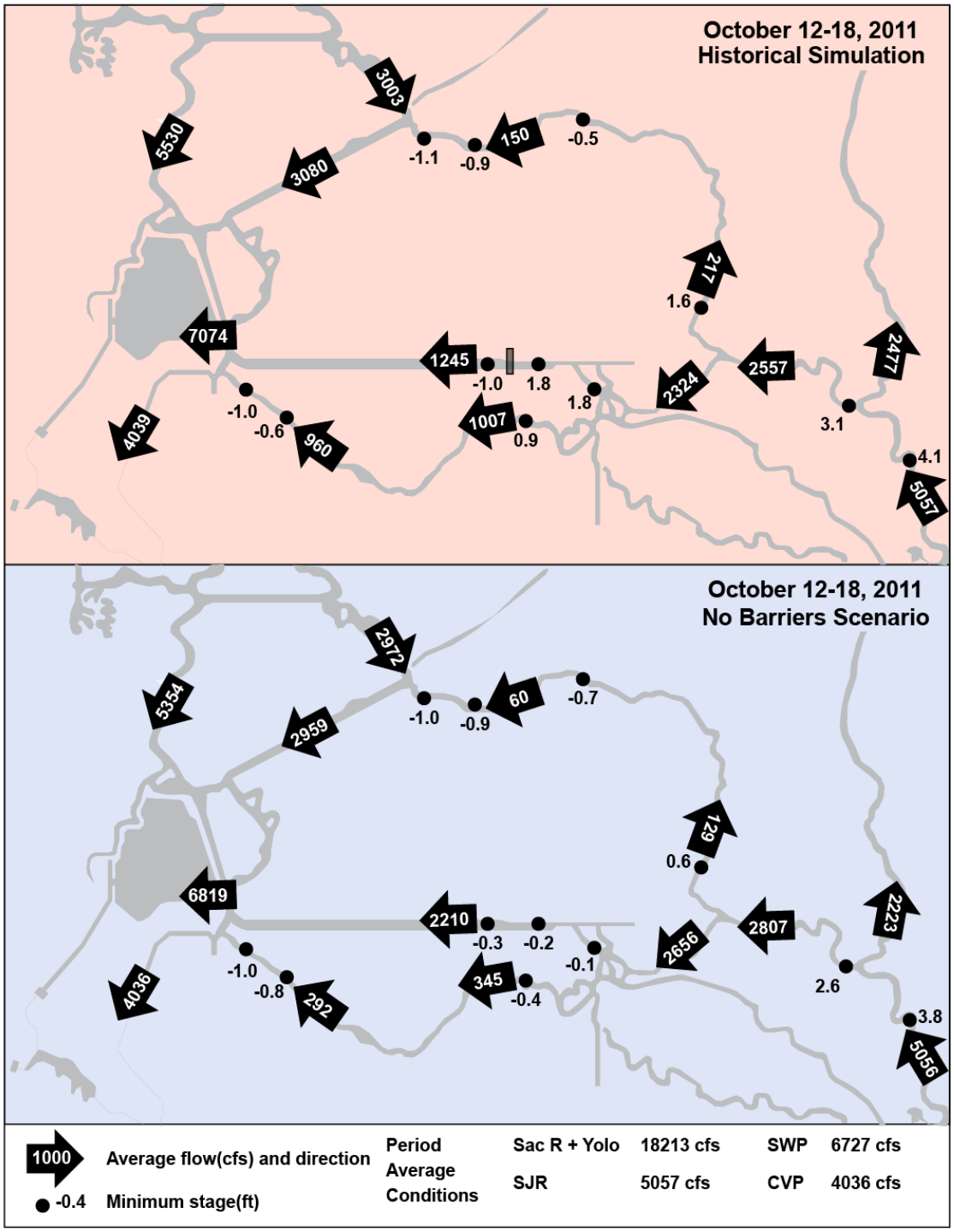


Figure 7-9. Increase in minimum water levels in south Delta due to installing temporary barriers in 2011.

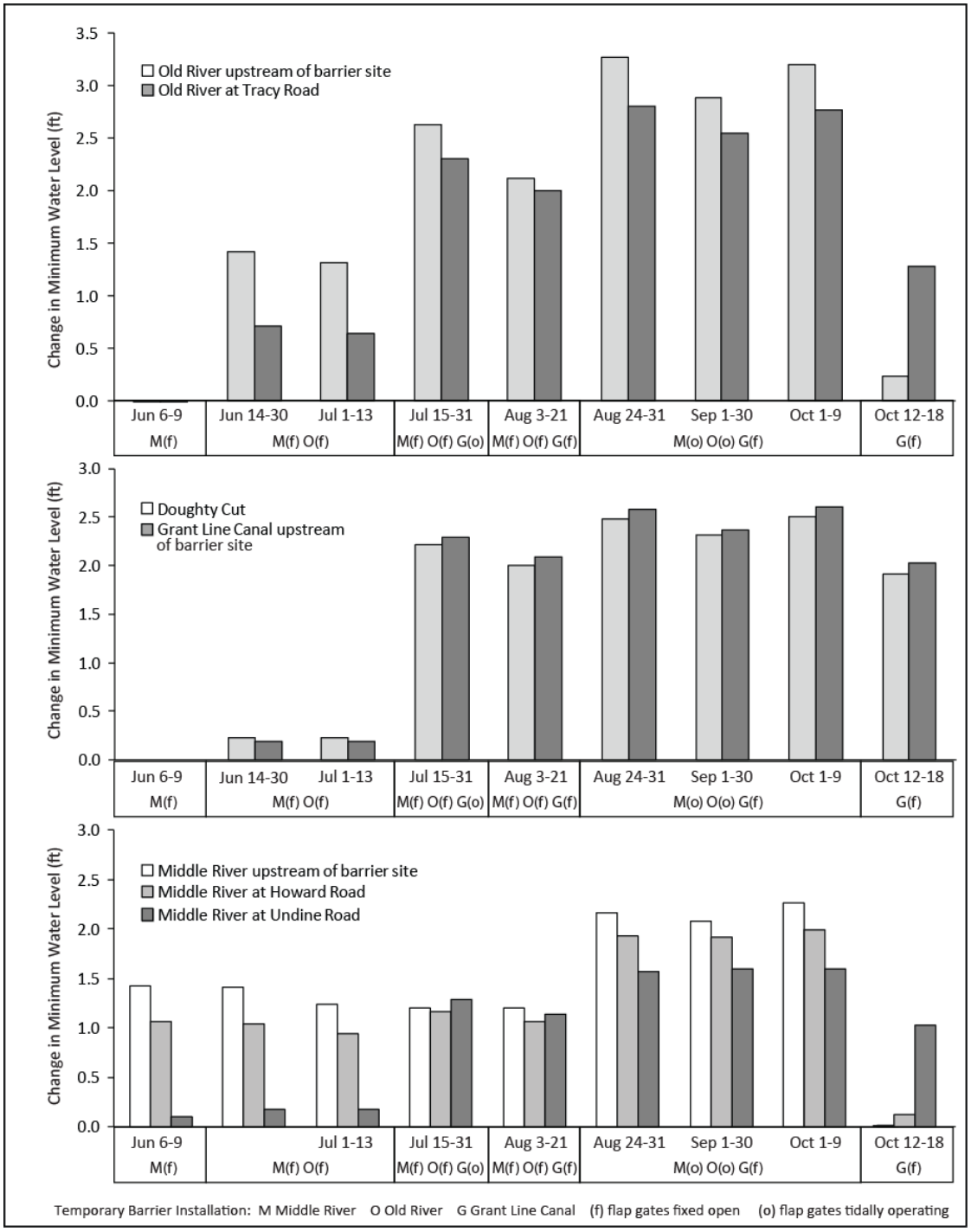
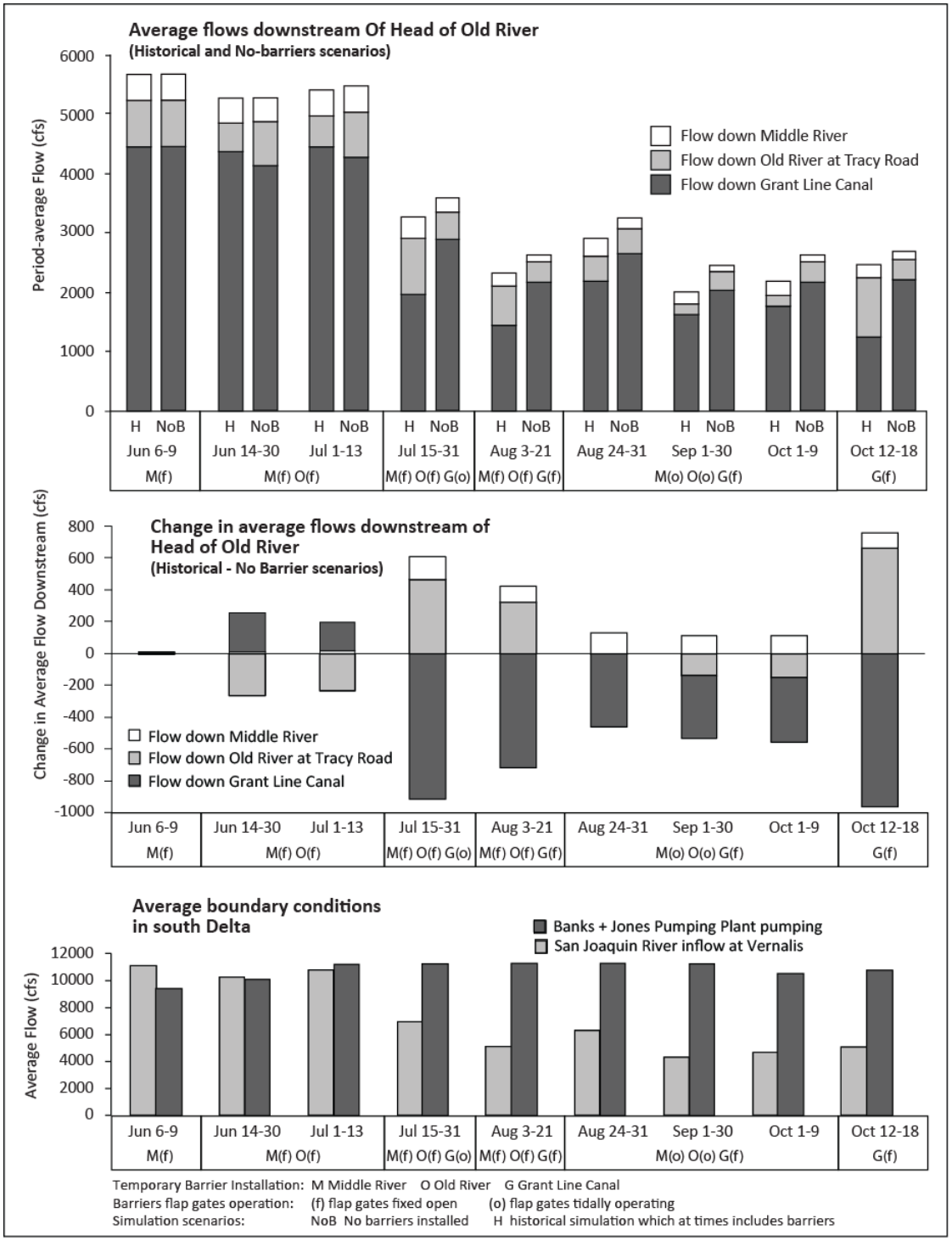


Figure 7-10. Impact of temporary barriers on average flows in south Delta, 2011.



Discussion

The installation of the Middle River temporary barrier in early June of 2011 with flap gates fixed open raised minimum water level immediately upstream of the barrier (RMID027) by approximately 1½ feet. This improvement diminished with distance upstream and was negligible by RMID040. This trend has been previously reported in simulations of previous years. During the period of June 6, 2011 through June 9, 2011 the Middle River barrier was the only barrier installed. By itself, this barrier had very little effect on flows in the south Delta and only significantly affected water levels in Middle River.

The installation of the Old River barrier in mid-June of 2011 with flap gates fixed open raised minimum water levels immediately upstream of the barrier approximately 1½ feet, an increase which diminished further upstream—increasing about ½ foot at Old River at Tracy Road (ROLD059) and about 0.2 feet at Doughty Cut (DGL) and the east end of Grant Line Canal. The Old River barrier by itself had little effect on water levels in Middle River and Grant Line Canal. During the periods of June 14-23, 2011 and July 1-13, 2011, the Old River and Middle River barriers were both installed and operating with flap gates fixed open. This combination of barriers had very little effect on the flow down the Head of Old River, decreasing average flow by less than 1%. However the two barriers had a measurable effect on the split of flows down Grant Line Canal and Old River, causing more flow down Grant Line Canal and significantly less flow down Old River at Tracy Road. For the two time periods, average flow down Grant Line Canal increased 244 cfs (6%) and 177 cfs (4%), while average flow down Old River at Tracy Road decreased 262 cfs (-35%) and 236 cfs (-30%) respectively.

The full installation of the temporary barrier in Grant Line Canal in mid July of 2011 with flap gates tidally operating caused significant additional changes in both minimum water levels and average flows in the south Delta. The increase in minimum water levels in Old River ranged from about 2½ feet just upstream of the barrier (ROLD047) to about 0.7 feet at the Head of Old River (ROLD074). Minimum water levels in Grant Line Canal upstream of the barrier and in Doughty Cut were raised over 2 feet. The previous over 1 foot increase in minimum water level seen just above the Middle River barrier was extended upstream to Old River (RMID040). The installation of all three barriers during the period of July 15-31, 2011 reduced the average flow down the Head of Old River by 333 cfs (-9%) and the split of this flow down Middle River, Old River at Tracy Road, and Grant Line Canal was significantly changed. Average flow down Grant Line Canal decreased 918 cfs (-32%) while flow down Middle River and Old River at Tracy Road increased (128 cfs, +56% and 466 cfs, +99% respectively). During the period of August 3-21, the Grant Line Canal barrier's flap gates were changed from operating tidally to being fixed open, which resulted in similar changes as seen for the July 15-31, 2011 period.

From August 24 through October 9, Old River and Middle River barriers' flap gates were allowed to tidally operate while the Grant Line Canal barrier's flap gates

remained fixed open. This change in barrier operation caused additional changes to minimum water levels and flow patterns. Under this operation, minimum water levels in Old River further increased a foot just upstream of the barrier and ½ foot further upstream. Figure 7-11 shows that this simulated amount of additional increase is evident in observed data as well. Minimum water levels in Grant Line Canal upstream of the barrier and in Doughty Cut also further increased about ½ foot. Minimum water levels in Middle River further increased a foot just upstream of the barrier and about ½ foot further upstream. Allowing the Middle River barrier and Old River barrier flap gates to tidally operate somewhat further reduced the portion of San Joaquin River flow down the Head of Old River. More significantly, the new operation significantly reduced the flow down Old River at Tracy Road. The ratio of average Grant Line Canal flow to Old River at Tracy Road flow changed from about 2:1 for August 3-21 to about 5:1 for August 24-31 (660cfs/1442cfs vs. 418cfs/2182cfs).

During the period of October 12-18, 2011 the Grant Line barrier was the only barrier installed. Its flap gates were again fixed open. Minimum water levels in Grant Line Canal upstream of the barrier site and Doughty Cut were increased about 2 feet. This increase dampened moving away from this area: about a 1-foot increase in Middle River near Old River and in Old River at Tracy Road and little increase just upstream of the Old River and Middle River barrier sites. Changes in flow were similar to those shown during the July 15-31 period when Old and Middle River barriers were in but with flap gates tied open: a decrease in flow down the Head of Old River (-250 cfs,-9%), a significant increase in flow down Old River at Tracy Road (662 cfs,+192%) , a significant decrease in flow down Grant Line Canal (-965 cfs,-44%), and an significant increase in flow down Middle River (88 cfs,+68%).

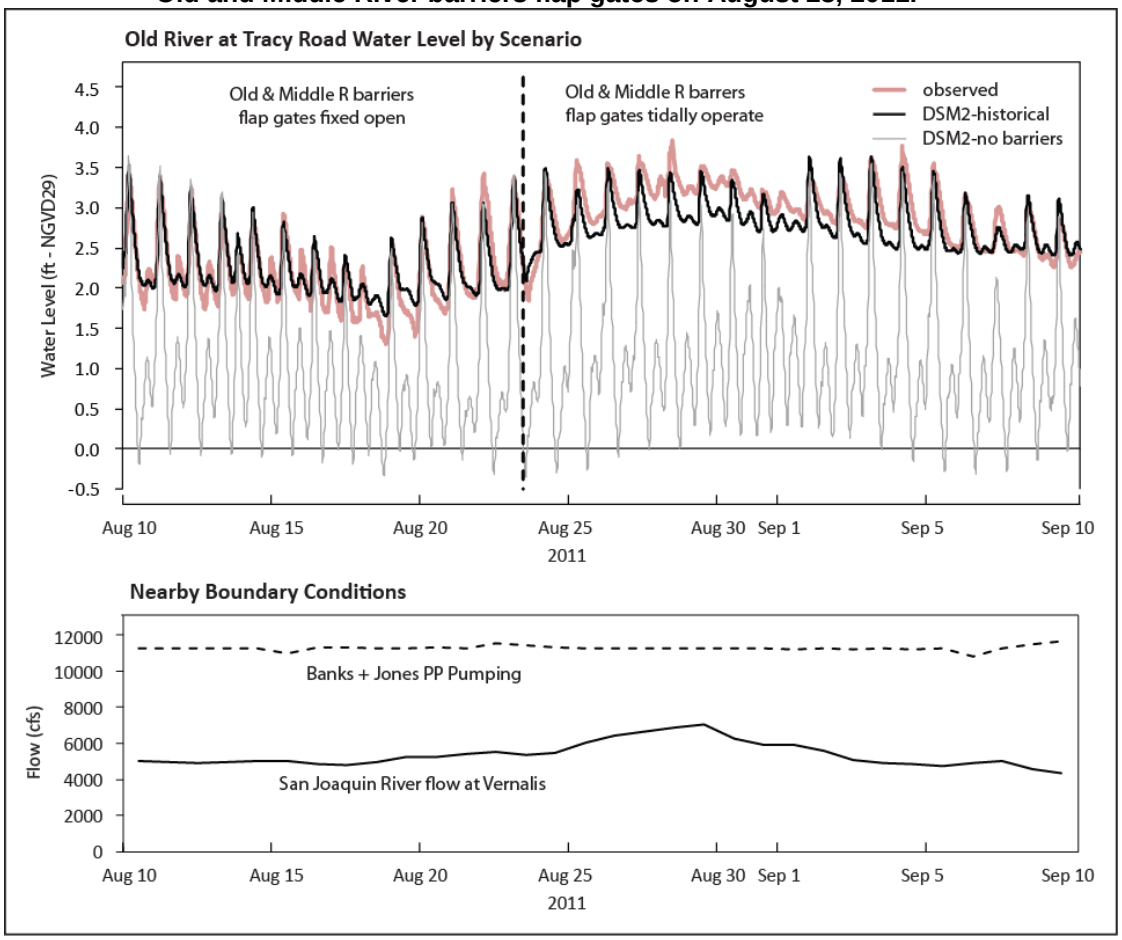



Figure 7-11. Impact on water levels in Old River at Tracy Road due to tidally operating Old and Middle River barriers flap gates on August 23, 2011.