Tidal Hydraulics Modeling (DSM2)
of the
Delta Corridors Plan

Prepared for:

South Delta Water Agency
4255 Pacific Avenue
Stockton CA 95207
Contact: John Herrick
209/956-0150

and

Central Delta Water Agency
PO Box 1461
Stockton CA 95201
Contact: Dante John Nomellini, Sr.
209/465-5883

Prepared by:

Jones & Stokes
2600 V Street
Sacramento, CA 95818-1914
Contact: Russ Brown, PhD
916/737-3000

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Summary

The Delta Corridors (DC) Plan is an alternative to the Peripheral Canal (PC) for protecting Delta fish and improving water quality by eliminating the recycle of San Joaquin River salinity at the exports, and separating the Old River habitat from entrainment effects. It is likely that the elements of the DC Plan could be designed and constructed within a relatively short timeframe and with a much lower cost than the PC. Implementing the DC Plan might be a good strategy for solving many of the Delta fish and water quality issues.

This plan would allow the in-Delta and exported water supply to be conveyed from the Sacramento River to the south Delta pumps using the existing Middle River channel network. The water supply would be protected from seawater intrusion following a major levee failure by the separation of the Old River and Middle River corridors. Only this 50-mile length of levees would need to be repaired to restore the full export capacity. San Joaquin River water could be exported as soon as the pumps were inspected and certified following a major seismic event.

Jones & Stokes simulated the tidal elevations and tidal flows for the existing channel geometry with the Delta Simulation Model II (DSM2) and then modified the geometry and other input data files to allow the DC Plan to be accurately simulated. Results from these initial DSM2 simulations demonstrate the tidal elevation and tidal flow changes from the DC Plan with dredging of about 10 million cubic yards in Middle River and Victoria Canal to a uniform depth of 25 feet with 3:1 side slopes for channel stability. The dredged material could be used to strengthen the levees along the water supply corridor.

Simulated tidal elevation and tidal flow results with full exports and agricultural diversions are shown in this report to introduce the simulated tidal conditions throughout the Delta and demonstrate the feasibility of using the Middle River corridor to convey the full allowable Central Valley Project (CVP) pumping (4,600 cfs) and State Water Project (SWP) pumping (6,680 cfs) to the south Delta. The simulated Sacramento River inflow was about 16,000 cfs and the San Joaquin River inflow was about 2,000 cfs for the month of August 1975, which was used to demonstrate the Delta tidal hydraulics. The simulated tidal stages (elevations) and flows for this moderate inflow month characterize tidal hydraulic conditions within the Delta for existing geometry (but with the south Delta tidal gates). These baseline conditions were then compared to simulated tidal stages and flows with the proposed DC Plan.

The DC Plan would not change anything in Suisun Bay or in Suisun Marsh. The DC Plan would not change the fluctuations in tidal elevations, which would allow the water supply to be transported through the Delta channels by tidal energy. The DC Plan would not need a new pumping plant, as the PC would require.

Initial DSM2 simulations of the DC Plan indicated that tidal flows were reduced in Middle River adjacent to Victoria Island, Victoria Canal, West Canal, and the Delta-Mendota Canal (DMC) intake canal. The cross sections in these channels were modified by deepening to a depth of –25 feet mean sea level (msl) with side slopes of 3:1 (horizontal to vertical) to maintain levee stability. The surface widths of the channels were not changed.

The existing Victoria Canal channel had a moderate water surface slope of about 2.5 feet along the 5.5 miles of Victoria Canal, for a tidal flow of 12,000 cfs. The dredged cross-section area would be increased to about 10,000 square feet, and the average depth would be about 20 feet. This would reduce the required surface slope needed for a tidal flow of 12,000 cfs to about 2.5 inches along the 5.5 miles of dredged Victoria Canal. The dredging along 3.5 miles of Middle River would require about 1.5 million cubic yards. The Middle River channel sections may need to be widened by about 100 feet to provide a cross-section area of 10,000 square feet, adding about 1.5 million cubic yards to the dredging. The dredging in Victoria Canal would require about 5 million cubic yards. The dredging in West Canal and Old River would require about 1 million cubic yards. This is a moderate amount of dredging (total of about 10 million cubic yards at an estimated cost of about $100 million) that would allow full existing exports to be supplied by the Middle River corridor, and allow the entire San Joaquin River flow to be separated from the water supply exports to reduce salinity and reduce fish entrainment impacts.

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Acronyms and Abbreviations

af	acre-feet
BDCP	Bay Delta Conservation Plan
CCF	Clifton Court Forebay
CCWD	Contra Costa Water District
CSDP	Cross Section Development Program
CVP	Central Valley Project
DC	Delta Corridors
DCC	Delta Cross Channel
Delta	Sacramento–San Joaquin River Delta
DMC	Delta-Mendota Canal
DO	dissolved oxygen
DSM2	Delta Simulation Model II
DV	Delta Vision
DWSC	Deep Water Ship Channel
EIR/EIS	Environmental Impact Report/Environmental Impact Statement
kWh	kilowatt-hours
msl	mean sea level
MW	megawatt
NGVD 29	National Geodetic Vertical Datum of 1929
PC	Peripheral Canal
SDIP	South Delta Improvements Program
SR	State Route
SWP	State Water Project

Tidal Hydraulics Modeling (DSM2) of the Delta Corridors Plan

Introduction

The Delta Corridors (DC) Plan has been suggested to the Bay Delta Conservation Plan (BDCP) and Delta Vision (DV) stakeholder groups as an alternative to constructing a Peripheral Canal (PC) to protect Sacramento–San Joaquin River Delta (Delta) fish and improve water quality. This plan would allow the in-Delta and exported water supply to be conveyed from the Sacramento River to the south Delta pumps using the existing Delta channel network. The entire San Joaquin River would be diverted into the head of Old River and be separated from the export pumping via a “river bridge” over Victoria canal to allow the San Joaquin River water to flow down Old River to Franks Tract. The locations of the major components of the DC Plan are shown in Figure 1. The original description of the DC Plan (March 23, 2007) is in the Appendix.

Jones & Stokes has modified the Delta Simulation Model II (DSM2) geometry and other input data files to allow the DC Plan to be accurately simulated. The major changes in the modeled Delta channels and gate operations are:

- A barrier and floodgate across the San Joaquin River just downstream of the head of Old River will be opened for flood control when the Vernalis flow exceeds 10,000 cfs.
- A pump with a capacity of 250 cfs is simulated to provide an upstream flow from the San Joaquin River into the head of Old River near Lathrop.
- The South Delta Improvements Program (SDIP)–planned tidal gates on Old River at DMC and Middle River upstream of Victoria Canal will be operated year-round unless the Vernalis flow is greater than 10,000 cfs. Fish-friendly pumps (250 cfs each) will be required to increase the upstream flow at these tidal gates. A pump also will be needed at Tom Paine Slough.
- Old River between Fabian Tract and Coney Island will be divided to allow the San Joaquin River to flow down Old River and around Coney Island while the water supply flows upstream from West Canal to the Delta-Mendota Canal (DMC) intake and tidal gate on Old River.
- Old River between Victoria Canal and West Canal will be divided and a river bridge will be constructed to allow the San Joaquin River to flow along the

north end of Coney Island and continue down Old River while the water supply flows under the river bridge from Victoria Canal to West Canal.

- Rock barriers with boat locks will be constructed on Woodward Canal, Santa Fe Canal, and Connection Slough. These barriers will separate the water supply corridor along Middle River from the San Joaquin River–estuary corridor along Old River. The barriers can be located at the east or west end of the channels, depending on the selected levee to divide the estuary from the water supply corridor. Pumps may be needed to supply agricultural diversions or flush agricultural drainage located along these channels.
- A rock barrier with a floodgate will be placed across the mouth of Old River, separating Franks Tract from the San Joaquin River. The floodgate will be opened in months when the San Joaquin River flow at Vernalis is greater than 10,000 cfs. An additional barrier may be needed on Fisherman’s Cut.
- The Clifton Court Forebay (CCF) gates will be opened during most of the tidal cycle. The CCF gates will be closed only if the CCF elevation is greater than outside (West Canal).
- The Delta Cross Channel (DCC) gates will be opened unless the Mokelumne River inflows are greater than 5,000 cfs. The greater diversions from the Sacramento River are needed to reduce the flows from the Sacramento River around Sherman Island (reverse QWEST flows) that may cause salinity intrusion and fish entrainment impacts.

DSM2 Model Evaluation Topics

Results from these initial DSM2 simulations will demonstrate the tidal flow and electrical conductivity (EC) changes that are likely to result from the DC Plan and may identify possible weaknesses in the DC Plan. Some of the major issues and potential weaknesses of the DC Plan are discussed below.

- The tidal flows in Middle River upstream of Santa Fe Cut may not be sufficient to transport the water supply with enough tidal elevation to allow full Central Valley Project (CVP) and State Water Project (SWP) pumping (11,280 cfs). The existing channel capacity must be determined, so that any required dredging can be estimated. The existing channel cross-section data will be reviewed and evaluated. Increased tidal flow capacity after dredging can be evaluated with additional model runs.
- The maximum summer diversions of about 1,000 cfs in the south Delta (including 300 cfs between Vernalis and the head of Old River) must be satisfied by flows with adequate salinity (less than 700 µS/cm) from the San Joaquin River–estuary corridor along Old River and Grant Line Canal. The possible effects of relocating some agricultural diversions and drainage discharges can be evaluated with additional model runs.
- The simulated maximum agricultural diversions along Old River between DMC and Doughty Cut are about 300 cfs, and the Tom Paine Slough and

Paradise Slough diversions are about 275 cfs. The Middle River diversions are about 235 cfs. Additional model runs will evaluate the amount of pumping from the water supply corridor that will be needed to satisfy these south Delta diversions.

- Floodflow conditions must be carefully evaluated. This evaluation can be done initially with DSM2, although some of the channel geometry information should be updated to include higher elevations for upstream sections (the DSM2 model assumes walls at the top of levees, rather than overflow sections). More detailed evaluations can be made with HEC-RAS modeling.
- Salinity conditions will be carefully evaluated. The benefits of separating the San Joaquin River from the water supply should be easily demonstrated with the initial model runs, but possible effects of salinity intrusion or San Joaquin River recycle around Webb Tract from False River should be fully evaluated with additional model runs. Some reduction in CVP and SWP pumping to prevent this San Joaquin River recycle may be required in some months. The possible need for a tidal gate on Threemile Slough to control salinity intrusion by increasing the net flow from the Sacramento River can be investigated with additional model runs.

Simulated Tidal Elevations and Tidal Flows for Existing Channels with Future South Delta Improvements Program Tidal Gates

The baseline tidal conditions for evaluating the DC Plan will be the future conditions as simulated for the SDIP Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) (2005). These future south Delta conditions would include tidal gates in the south Delta (in Middle River upstream of Victoria Canal, in Old River upstream of the DMC intake, and in Grant Line Canal at the mouth) to regulate minimum tidal elevations for agricultural diversions and at the head of Old River to protect juvenile San Joaquin River Chinook salmon from diversion into Old River.

The simulated inflows and exports were different from historical inflows and exports and reflect current reservoir operations and Delta objectives (D-1641). The 16-year period of 1976–1991 generally is used by DWR to represent the full range of Delta hydrology (flows) and salinity (EC) conditions. However, only results from August 1975 with full exports and agricultural diversions are shown in this report to introduce the simulated tidal conditions and demonstrate the feasibility of using the Middle River corridor to convey the full allowable CVP pumping (4,600 cfs) and SWP pumping (6,680 cfs) to the south Delta.

The next section provides a discussion of the simulated baseline conditions for August 1975, when CVP exports were 4,500 cfs and SWP pumping was 6,680 cfs. The simulated Sacramento River inflow was about 16,000 cfs and the San

Joaquin River inflow was about 2,000 cfs. The simulated tidal stages (elevations) and flows for this moderate inflow month will characterize tidal hydraulic conditions within the Delta for existing geometry (but with the south Delta tidal gates). These baseline conditions will then be compared to simulated tidal stages and flows with the proposed Delta Corridor plan.

Downstream Boundary and Suisun Bay Tidal Elevations and Tidal Flows

Figure 2 shows the simulated tidal elevations and tidal flows at the downstream end of Suisun Bay, which is the downstream DSM2 model boundary. The semi-diurnal tides (i.e., twice daily tidal cycle) vary each day within the month, but are generally characterized by an unequal tidal fluctuation each day. There is generally a higher-high tide followed by a lower-low tide and then a lower-high tide followed by a higher-low tide. During neap-tide periods (moon and sun offset) the two tides are more moderate and similar in magnitude. The tidal period is about 24.75 hours, so the high tide occurs about 45 minutes later each day. The high tide occurs on the second tidal cycle on August 1, but this high tide crosses the midnight line on August 7 to become the first tidal cycle; then the high tide “switches” to the second tidal cycle about August 10, and switches back to the first tidal cycle on August 24. This sequence of tidal variation will be slightly different for each month.

The tidal energy required to move the water into the estuary and lift (i.e., push) the water to the high-tide elevations can be characterized either by the daily tidal range (high tide minus low tide) or by the total rising tide elevation (cumulative rise during the flood-tide periods) within each day. Both these measures of tidal energy are shown on the top graph of Figure 4. The average tidal range at Martinez was about 5.25 feet and the average tidal rise was about 7.5 feet for the historical August 1975 tides. The minimum tidal range was about 4 feet and the maximum tidal range was more than 6 feet during spring-tide periods (e.g., August 7). The DSM2 model accurately simulates the tidal movements throughout the Delta channels for this range of tidal fluctuations. The simulated tidal variations at Emmaton and Antioch were only slightly smaller than at Martinez. The high tides are slightly less and the low tides are slightly more at these upstream locations. The tidal variations were delayed at these upstream stations, with the high tides delayed by about an hour and the low tides delayed by about 2 hours from the Martinez tides.

Figure 2 also shows the simulated tidal flows at the downstream Martinez boundary and the tidal flows at Antioch (San Joaquin River side of the Delta) and at Emmaton (Sacramento River side of the Delta). The tidal flows at Martinez were very large, with upstream (flood-tide) flows of about 600,000 cfs during flood-tide periods during spring-tide (moon and sun aligned) periods with the greatest tidal range (e.g., August 7). These simulated tidal flows were somewhat reduced because some of the tidal volume fills Suisun Bay, and the tidal flow is then split between the Sacramento and San Joaquin River channels, so the simulated flood-tide flows were about 200,000 cfs at Antioch and about 175,000 cfs at Emmaton.

Tidal Volumes and Tidal Energy in the Delta Channels

Figure 3 shows the calculated tidal volumes in the Sacramento River at Emmaton and in the San Joaquin River at Antioch for future conditions with the SDIP tidal gates for August 1975. The positive (ebb-tide) tidal volume is the cumulative tidal flow volume from high tide to low tide, with the flow moving downstream. The negative (flood-tide) tidal flow is the cumulative tidal flow volume from low tide to high tide, with the flow moving upstream. Emmaton and Antioch are both about 5 miles upstream of the confluence of the Sacramento and San Joaquin Rivers near Collinsville. The tidal volumes at these two locations include all the tidal flow moving into and out of these two major upstream sections of the Delta. The San Joaquin River tidal volume is about 60,000 acre-feet (af) during each flood tide. The Sacramento tidal volume is about 45,000 af during each flood tide. Because of the character of San Francisco Bay tides, the flood tides (negative volume) are more uniform than the ebb tides (positive volume), which usually include a higher-high to lower-low major tidal outflow each day. The flood-tide volume of about 45,000 af on the Sacramento River side of the Delta suggests that the surface area is about 15,000 acres. Filling this area with about a 3-foot tidal prism requires about 45,000 af. Some of the Sacramento tidal flow moves through DCC and Georgiana Slough and Threemile Slough to the San Joaquin River side of the Delta. The flood-tide volume of about 60,000 af on the San Joaquin River side of the Delta suggests that the upstream tidal area is about 20,000 acres (including the Mokelumne River channels). The energy needed to produce these tidal flows can be estimated.

The potential energy of the tidal prism at each high tide is calculated from the volume and the average elevation rise (of about 1.5 feet). The energy (kilowatt-hours [kWh]) in each flood tide is equal to the flood-tide volume (af) times the elevation change (feet) because, conveniently, the unit conversion between these units is about 1. Because there are about 2 high tides each day, the tidal energy of the Sacramento River upstream of Emmaton is about 135,000 kWh per day (i.e., 45,000 af x 1.5 x 2), which is equivalent to a 5.6-megawatt (MW) power plant. The tidal energy of the San Joaquin River upstream of Antioch is about 180,000 kWh per day (i.e., 60,000 af x 1.5 x 2), which is equivalent to a 7.5-MW power plant. This tidal energy is responsible for the movement of the water within the Delta channels, including the transport of Sacramento River water “across” the Delta to the south Delta pumping plants. The daily tidal energy (kWh) at any location can be estimated from the upstream tidal area (acres), assuming the average tidal prism is about 3 feet, as the upstream area (acres) times about 9.

Tidal Elevations and Tidal Flows along the Sacramento River Channels

Figure 4 shows the simulated tidal elevations and flows along the Sacramento River channels for future conditions with SDIP tidal gates during August 1975. The tidal stage variations at Emmaton and Rio Vista were generally the same, with a tidal range of –2 feet to about 4.5 feet mean sea level (msl). The peak tidal flows at Emmaton were about 125,000 cfs, although the daily peak tidal flows ranged from about 110,000 to 140,000 during the month (±10% of the mean). The tidal flows upstream of Rio Vista ranged from about –10,000 cfs to 15,000 cfs. The tidal flows entering Cache Slough ranged from –40,000 cfs to 50,000 cfs during the month. The tidal flows in Cache Slough had a “truncated” shape, where the initial flood or ebb tide is highest and the tidal flow decreases during the remainder of the tidal period. The tidal flows in Threemile Slough, connecting the Sacramento and San Joaquin Rivers, ranged from about 30,000 cfs to about –40,000 cfs. Threemile Slough flows were like flows in a tributary to the Sacramento River, because the flood tide entered Threemile Slough and flowed into the San Joaquin River, while ebb tide flowed from the San Joaquin River into the Sacramento River. The remaining tidal flows at Emmaton filled or drained the Sacramento River channel between Emmaton and Rio Vista.

Figure 5 shows the simulated tidal stages and tidal flows in Sutter and Steamboat Sloughs for future conditions with SDIP tidal gates during August 1975. The tidal stage at the Sutter Slough and Steamboat Slough heads (upstream ends) ranged from about 1 foot to about 4.5 feet msl. The high tides were the same as at Emmaton, but the low tides were controlled by the Sacramento River stage upstream of Walnut Grove, which had a riverine gradient (i.e., downstream slope) during low tides. The ebb-tide diversions into Sutter and Steamboat Sloughs were about 5,000 cfs, and the minimum ebb-tide flows were about 0 cfs to –1,000 cfs (during spring-tide periods). Most of the Sutter Slough flow (upstream Sacramento River diversion) moved into Miners Slough. Steamboat Slough (located just downstream of Sutter Slough) flows returned to the Sacramento River just upstream of Rio Vista.

Figure 6 shows the simulated tidal stages and tidal flows in the Sacramento River near the DCC and Georgiana Slough for future conditions with SDIP tidal gates during August 1975. The DCC and Georgiana Slough diversions depend on the tidal elevation differences between the Sacramento River at Walnut Grove and the Mokelumne River at New Hope Landing. The minimum simulated tide elevation at Ryde (downstream of Georgiana Slough) was about 0.5 foot msl, and the maximum simulated tide elevation was about 4 feet msl. The tidal elevations at Ryde were higher than the corresponding elevations at the DCC at low tide and during flood tide (rising tide elevation), causing a simulated upstream Sacramento River flow with a maximum of about –5,000 cfs during the high tide period of each day. The simulated tidal flows in the DCC and Georgiana Slough were highest during flood tide when upstream tidal flow from Ryde met the downstream river flow and “squeezed” water into the diversion channels. For this example month of August 1975, the simulated Freeport flow was about

16,000 cfs, and diversion flows into DCC and Georgiana Slough ranged from about 2,500 cfs to 12,500 cfs with an average diversion of about 7,250 cfs.

Figure 7 shows the simulated Sacramento River flow upstream of Walnut Grove and the diversion flows into the DCC and Georgiana Slough for future conditions with SDIP tidal gates during August 1975. The simulated DCC flows were greater than the simulated Georgiana Slough flows, because the DCC has a larger simulated cross section. The DCC diversion flows ranged from about 2,000 cfs to about 8,000 cfs, with an average of 4,500 cfs, while the Georgiana Slough diversion flows ranged from about 1,500 cfs to about 4,500 cfs with an average of about 2,750 cfs. The Sacramento River flow upstream of the DCC ranged from about 6,000 cfs to about 15,000 cfs with an average of about 11,000 cfs. About 3,000 cfs was diverted into Sutter Slough and about 1,800 cfs was diverted into Steamboat Slough, both upstream of the DCC.

These tidal flows along the Sacramento River channels, including the diversions from the Sacramento River into Sutter Slough, Steamboat Slough, the DCC, and Georgiana Slough are controlled by the existing channel geometry and the Sacramento River inflow and will not likely be changed substantially by any of the proposed DC features. Threemile Slough diversions from the Sacramento River are controlled by both the Sacramento River flow and the San Joaquin River flow at the two ends of Threemile Slough and may be changed by the DC features.

Tidal Elevations and Tidal Flows in Mokelumne River Channels

Figure 8 shows the simulated tidal stages and tidal flows in the Mokelumne River channels connecting to the San Joaquin River for future conditions with SDIP tidal gates during August 1975. The Sacramento River diversions into DCC and Georgiana Slough, combined with the Mokelumne River and Cosumnes River inflow, provide the net flows in these channels. The tidal stage at the mouth of these Mokelumne River channels ranged from about –1 foot to about 4 feet msl, and was very similar to the tidal fluctuations at Antioch. The simulated net outflow toward the San Joaquin River was about 5,250 cfs for the Mokelumne River, about 1,500 cfs in Little Connection Slough (east side of Venice Island), and about 1,000 cfs in Disappointment Slough (southeast side of Empire Tract). Potato Slough had almost no net flow but had a large tidal flow that moved from the San Joaquin River channel, around Venice Island, and back to the San Joaquin River channel through Little Connection Slough. There was almost no net flow in Fourteen Mile Slough.

The simulated tidal flows at the mouth of the Mokelumne River were dominated by the ebb tide (outflow toward the San Joaquin River and the bay) because the DCC and Georgiana Slough diversions from the Sacramento River (about 7,500 cfs for August 1975) provided a strong net outflow from these Mokelumne River channels. The simulated peak ebb-tide flows at the Mokelumne River mouth were about 10,000 cfs. The simulated tidal flows at the downstream end of Potato Slough were about 12,000 cfs for both ebb tides and flood tides because this channel behaves like a side-channel to the San Joaquin River. The simulated tidal flows in Little Connection Slough were about 2,000 cfs, and the tidal flows in Disappointment and Fourteen Mile Slough were less than 500 cfs. There may be benefits from dredging some of these Mokelumne River channels to provide more transport of the DCC diversion flow through the South Fork Mokelumne River and Little Potato and Little Connection Sloughs to the San Joaquin River opposite Columbia Cut. This might be done in conjunction with an enlarged DCC (i.e., third gate) to increase the water supply corridor flow along the Mokelumne and Middle River corridor.

Tidal Elevations and Tidal Flows in the San Joaquin River Channels

Figure 9 shows the simulated tidal stages and tidal flows in the lower San Joaquin River between Antioch and San Andreas Landing, just downstream of the mouth of the Mokelumne River. The tidal elevations at Antioch ranged from about –1.5 feet to 4 feet msl. The tidal range at the mouth of the Mokelumne was slightly less, about –1 foot to 3.5 feet msl. The peak tidal flows at Antioch were about 150,000 cfs. The tidal flows upstream at Jersey Point were about 125,000 cfs. The tidal flows in False River, connecting to Franks Tract and Old River, were about 50,000 cfs, and the tidal flows at San Andreas Landing were about 100,000 cfs. The tidal flows at San Andreas include the tidal flows of about 30,000 cfs from Threemile Slough, connecting with the Sacramento River.

Figure 10 shows the simulated tidal stages and tidal flows in the vicinity of Franks Tract. The tidal stage ranged from about –1 foot to about 3.5 feet msl. The tidal fluctuations on Old River at Bacon Island (upstream of Franks Tract) were about 1.5 to 2 hours delayed from the high and low tides at the mouth of Old River or at False River. Three channels connect the San Joaquin River channel to Franks Tract. The downstream connection is Dutch Slough, located upstream of Antioch. The simulated tidal flows in Dutch Slough were about 7,500 cfs, and the net flow was about –500 (upstream). False River is the major channel connecting Franks Tract with the San Joaquin River. The simulated maximum tidal flows in False River ranged from about –40,000 to 50,000 during the month, with a net flow of just 750 cfs. The Old River mouth is across the San Joaquin River from the Mokelumne River mouth and had tidal flows that ranged from about –20,000 cfs (upstream, flood tide) to about 10,000 cfs (downstream, ebb tide). The simulated net flow was about –5,660 cfs (upstream). The simulated Old River flow at Bacon Island, located upstream of Franks Tract, ranged from 5,000 cfs to about –20,000 cfs with a net flow of about –5,710 cfs (upstream). This net upstream flow in Old River supplies just about half of the CVP and SWP exports as well as half the agricultural diversions in the central and south Delta channels.

Figure 11 shows the simulated tidal stages and tidal flows in the San Joaquin River upstream of the Old River mouth. The simulated tidal stage ranged from about –1 foot to about 4 feet msl. The simulated tidal flows above Columbia Cut were about 15,000 cfs, the tidal flows above Turner Cut were about 10,000 cfs, and the tidal flows at Garwood Bridge (upstream of the Stockton Deep Water Ship Channel [DWSC]) were just 2,500 cfs, with a net flow of 1,500 cfs at Garwood and upstream of Turner Cut. Diversions from the San Joaquin River at Turner Cut, Columbia Cut, and the mouth of Middle River into the Middle River channel supplied about half of the CVP and SWP exports as well as half the agricultural diversions in the central and south Delta channels.

Figure 12 shows the simulated tidal elevations and tidal flows along the San Joaquin River upstream from Stockton near the head of Old River. This is the upstream end of the Delta on the San Joaquin River side, and the nearest inflow to the export pumps in the south Delta. The simulated tidal influence extended far upstream of Stockton to the Paradise Weir, located at San Joaquin River mile 61, about 21 miles upstream of Stockton and about 11 miles downstream of Vernalis, which is at San Joaquin River mile 72. The simulated water elevation fluctuated from about 3 feet to 4.5 feet msl at the Paradise Weir. The flood tide reduced the downstream flow of about 2,000 cfs to about 1,500 cfs at the Paradise Weir. The tidal elevation fluctuated from about 2 feet to 4 feet at Mossdale, and the tidal flow varied from about 2,500 cfs during ebb tide to about 500 cfs during flood tide. At Brandt Bridge, located about 5 miles downstream of Mossdale, the tidal elevation fluctuated from about 0 feet to about 3 feet msl. The net flow at Brandt Bridge was reduced by a 500-cfs “forced” diversion into Old River (approximating a future tidal gate partial opening). The tidal flow at Brandt Bridge ranged from –1,000 cfs during strong flood tide to about 2,500 cfs during ebb tide. Therefore, with a Vernalis flow of about 2,000 cfs simulated in August 1975, and with a diversion of 500 cfs into Old River, the tidal flow was not quite strong enough to reverse the river flow at the head of Old River. Reverse (upstream) flow of several hundred cfs may occur for several hours each day during the main flood tide (flood tide flow prior to the high tide) if the Vernalis flow is less than about 1,000 cfs.

Tidal Elevations and Tidal Flows in Old River and Middle River Channels

Figure 13 shows the simulated tidal elevations and tidal flows in the Middle River channels that connect with the San Joaquin River channel for future conditions with SDIP tidal gates during August 1975. The simulated tidal elevations ranged from about –1 foot msl to about 4 feet msl during the month. The tidal elevations were nearly identical at the mouth of Middle River, at Columbia Cut, and at Turner Cut. There was a slight tidal lag of less than an hour between the mouth of Middle River and Turner Cut, located about 6 miles upstream on the San Joaquin River. The simulated tidal flows at the mouth of Middle River were about 10,000 cfs more or less than the average flow of about –3,000 cfs (upstream) because these tidal flows fill and drain the flooded Mildred

Island (1,000 acres) and surrounding channels. The simulated tidal flows at the mouth of Columbia Cut were about 6,000 cfs more or less than the average flow of about –2,000 cfs (upstream). The simulated tidal flows at the mouth of Turner Cut were about 3,000 cfs more or less than the average flow of about –1,000 cfs (upstream). The combined net flows entering Middle River were about 6,000 cfs, and the combined peak tidal flows were about 20,000 cfs.

Figure 14 shows the simulated tidal elevations and tidal flows in Old River for future conditions with SDIP tidal gates during August 1975. The simulated tidal elevations in Old River downstream of the Los Vaqueros intake (State Route [SR] 4 Bridge) ranged from about –1 foot msl to about 3.5 feet msl during the month. The simulated tidal elevations at the DMC intake were about 1 foot lower at high tide and about 0.5 feet lower at low tide, ranging from –1.5 to about 2.5 feet msl. The simulated tidal flows in Old River at Bacon Island ranged from about 5,000 cfs during ebb tides to about –20,000 cfs during flood tides. The simulated tidal flows at the Los Vaqueros intake ranged from about 2,000 cfs for some peak ebb tides to –15,000 cfs during several flood tides. There was almost no tidal flow at the DMC intake, because the CVP pumps operate continuously and were simulated to be pumping about 4,500 cfs in August 1975. The net flow at Bacon Island was about 5,700 cfs upstream, and the net flow at the Los Vaqueros intake was about 7,200 cfs upstream, indicating that about 1,500 cfs was transferred from Middle River through Santa Fe and Woodward Cuts.

Figure 15 shows the simulated tidal flows in the channels connecting Old River and Middle River for August 1975 for future conditions with SDIP tidal gates. The tidal fluctuations are nearly the same as for Franks Tract and the San Joaquin River channel, with the tidal period delayed by about an hour. The tidal flows in these three connecting channels are important for understanding the conveyance of the water supply to the south Delta CVP and SWP export pumps. Connection Slough tidal flows were upstream toward Middle River during flood tides and downstream toward Franks Tract during ebb tides. The maximum flood-tide flow (negative, upstream) in Connection Slough was about –5,000 cfs when the Bacon River flow at Bacon Island was about –15,000 cfs. The tidal flow in Connection Slough had a very interesting characteristic—the ebb tide peaked at the beginning of each ebb-tide period, and then decreased to a more constant ebb flow for the remainder of the ebb tide. The same initial peak tidal flow also was evident during flood tide, but not quite as strong. This was likely caused by the initial tide reduction in Franks Tract occurring about an hour before the tide began to drop in Middle River, so that the initial gradient was stronger than during the remainder of the tidal period.

The tidal flows in Santa Fe Cut and Woodward Cut were strongest during flood tide (upstream negative flow in Old River) with tidal flow moving from Middle River to Old River. The bottom graph shows that during flood-tide periods, the tidal flow in Middle River was reduced at Santa Fe Cut and Woodward Cut. The tidal “transfer” of about 5,000 cfs reduced the Middle River peak flood-tide flow (negative) from about 15,000 cfs to about 10,000 cfs. This reduced tidal flow moved upstream in Victoria Canal to join the Old River flow at West Canal. However, during ebb tides (downstream positive flow in Old River) the flows in

Santa Fe Cut and Woodward Cut were relatively small. During ebb tides, the downstream tidal flow was about zero in Middle River, and only about 5,000 cfs in Old River, because of the high CVP and SWP export pumping.

The net upstream flow in Middle River was reduced from about 6,000 cfs downstream of Santa Fe Cut to about 4,000 cfs at Victoria Canal, with a net flow of 1,150 cfs simulated in Santa Fe Cut and about 850 cfs simulated in Woodward Cut moving toward Old River. The Middle River and Victoria Canal corridor therefore is conveying only about 35% of the CVP and SWP exports, while the Old River channel is conveying about 65% of the CVP and SWP exports (about 11,000 cfs total).

Because the DC Plan will separate Old River from Middle River, these connecting flows between Old River and Middle River will be eliminated, and all the water supply would be conveyed in the Middle River and Victoria Canal channels. Dredging likely will be needed because the existing depth of Victoria Canal is only 15 feet in some sections. Dredging to about 25 feet below msl was assumed to determine whether the full existing exports of about 12,000 cfs could be conveyed through Middle River and Victoria Canal.

Tidal Elevations and Tidal Flows in South Delta Channels

Figure 16 shows the simulated tidal elevations and tidal flows in Old River and Grant Line Canal for August 1975 for future conditions with SDIP tidal gates. Grant Line Canal flows are influenced by downstream tidal flows in Old River at the Los Vaqueros intake, inflows from the head of Old River (500 cfs for August 1975), and the tidal gate modified flows from Old River upstream of the DMC intake and Middle River upstream of Victoria Canal. The simulated tidal gates operate to allow upstream flows during flood-tide periods but then are closed to maintain minimum elevations of more than 0 feet msl upstream of these two tidal gates. An additional tidal gate in Grant Line Canal was simulated as a weir with an elevation of about –1 foot msl to reduce the outflow from these south Delta channels.

The simulated minimum elevations upstream of the two tidal gates were simulated to remain above 0.5 foot msl until the end of the month when about five days had minimum elevations of about 0 feet msl. The highest tide elevations upstream of the tidal gates were simulated to fluctuate between about 1.5 feet msl and 2.5 feet msl. Because of the relatively high agricultural diversions in these south Delta channels, additional upstream flows could be supplied with fish-friendly pumps at the tidal gates. Another important influence on the tidal elevations and flows in Old River and Grant Line Canal is the simulated operation of the CCF gates to allow the highest high tide to flow into the south Delta each day. This is achieved by closing the CCF gates during this flood-tide period each day. The results can be observed from the difference between the simulated tidal elevations at the Los Vaqueros intake and at the mouth of Grant Line Canal, opposite the CCF gates. When the CCF gates are closed, these tidal elevations are about the same, but when the CCF gates are opened, the tidal elevations at Grant Line Canal remain relatively constant because most of the tidal flow in Old River and West Canal is diverted into the CCF.

Figure 16 (bottom graph) shows the tidal inflows to CCF dominate the tidal flows in West Canal most of the time. The CVP pumping produces a nearly constant upstream flow in West Canal. The tidal gates in Old River upstream of the DMC intake and in Middle River at Victoria Canal capture water from the high tide each day and provide a slowly declining flow in Grant Line Canal at Tracy Boulevard and at the mouth of Grant Line Canal, downstream of the future tidal gate (weir). The Grant Line Canal tidal flow is upstream only during the highest tide period each day (when CCF gates are closed). The tidal flows in Old River at the Los Vaqueros intake are nearly always upstream, with peak upstream flows ranging from –12,000 cfs to –15,000 cfs during the month.

Figure 17 shows the tidal elevations and flows near the DMC intake (and C.W. “Bill” Jones Pumping Plant) and upstream of Old River near the DMC tidal gate. This tidal gate was simulated to be open on flood tide whenever the downstream elevation is higher than the upstream elevation, which generally occurred only once each day near high tide. The Old River at DMC tidal gate was closed during ebb tides, with all flow moving upstream toward the upstream end of Grant Line Canal. The water elevations upstream of the DMC tidal gate remained above 0 feet msl. Because the net upstream flow was relatively small (225 cfs) compared to the agricultural diversions along this section of Old River and in Tom Paine Slough, a fish-friendly pump with a capacity of 100–200 cfs may be needed to supply the irrigation water along this section of Old River.

The CVP Jones Pumping Plant was simulated to be pumping about 4,500 cfs (near assumed capacity of 4,600 cfs) in August 1975, and the simulated water elevations fluctuated between about –2 feet and 3 feet msl. The low tide elevations were only slightly lower (by about 1 foot) than the low tide in the San Joaquin River at Antioch (of about –1 foot msl) and indicate that the existing channels were capable of conveying the CVP and SWP exports without much of a tidal “drawdown” (reduced elevation) in the south Delta channels. The tidal energy that produces the high tides in the Delta channels allows this movement of water across the Delta without a corresponding reduction in the low-tide elevations. Water always moves toward lower surface elevations, but the higher tidal elevations provide the water surface gradient needed to move the water toward the pumps during flood-tide periods without requiring the low tides in the south Delta to be lowered by the pumps to provide the water elevation gradient needed for these flows.

Figure 18 shows the simulated tidal elevations and tidal flows in the vicinity of the CCF for August 1975 for future conditions with SDIP tidal gates. The CCF intake gates were assumed to be closed during the flood-tide period before the high tide each day to allow the high tide to flow into the south Delta channels (called “priority 3” CCF gate operation). The simulated tidal elevation in West

Canal at the CCF intake was compared with the tidal elevation at the mouth of Middle River, which represents the full tidal fluctuations along the San Joaquin River. The simulated tidal elevations at West Canal were usually lower than at the mouth of Middle River. The high tides each were about 0.5–1 foot lower, but the lower high tides (when the CCF gate was open and diverting flows into CCF) were 1 to 1.5 feet lower than at the mouth of Middle River. The simulated low tide elevations in West Canal ranged from –1 to –1.5 feet msl, and were only about 0.25 foot lower than the minimum elevation at the mouth of Middle River.

The simulated tidal flows in West Canal were always negative (upstream) and ranged from 0 cfs to about –17,500 cfs. The CVP Jones Pumping Plant produced a constant upstream flow of –4,500 cfs, and the CCF intake gates allowed a maximum diversion of 16,000 cfs. The CCF intake diversion is dependent on the elevation difference between West Canal and the CCF elevation. An elevation difference of 1 foot is enough to provide the maximum gate diversion of 16,000 cfs. The gates are partially closed to maintain this maximum diversion flow when the elevation difference is greater than 1 foot (during high tide periods). The CCF gates are closed whenever the West Canal tidal elevation is below the CCF elevation. The simulated SWP pumping was 6,680 cfs during August 1975, so the daily pumping volume is about 13,250 af. The CCF surface is about 2,000 acres at elevation 0 feet msl, so this pumping will reduce the CCF elevation by about 0.25 foot/hour. When the CCF gates are closed for 4 hours during the flood-tide period each day, the CCF elevation was reduced by about 1 foot. The simulated range of CCF elevation was 0.5 foot to –1.5 feet msl. The CCF elevation is usually maintained above elevation –2 feet msl to prevent cavitation (air entrainment) damage to the pumps at the SWP Banks Pumping Plant, located about 2.5 miles along a canal from the CCF.

Although the simulated August 1975 conditions were not compared with field data to demonstrate calibration of the DSM2 model, comparisons of measured tidal elevations and tidal flows for more recent periods demonstrate that the DSM2 model accurately simulates the tidal flows and elevation gradients throughout the Delta channels. The next section will show the simulated tidal elevations and tidal flows for the DC Plan conditions for this same month (August 1975) and describe the changes in Delta tidal flows that resulted from the barriers, channel divides, and separation of the San Joaquin River flows from the water supply diversions into the DCC, Georgiana Slough, and Threemile Slough that would be conveyed along Middle River and Victoria Canal to West Canal.

Delta Corridors Plan with Dredged Middle River and Victoria Canal

Because most of the DC Plan features are in the central and south Delta, there were few simulated changes in the tidal elevation variations or the tidal flows in Suisun Bay or the Sacramento River channels. There were some changes simulated for the Mokelumne River channels, with a shifting of the net flows toward the channels connecting with the San Joaquin River upstream of the Mokelumne River mouth (i.e., Little Connection, Disappointment, Fourteen Mile Sloughs). Table 1 gives the average (net) flow as well as the average positive (ebb-tide) and average negative (flood-tide) flows for several Delta locations for simulated August 1975 tidal conditions. Graphs of the tidal elevations and tidal flows for most of these locations will not be shown because they would look identical to the graphs already shown for the baseline tidal conditions.

Table 1 indicates that the DCC and Georgiana Slough diversion flows were the same as for the baseline conditions. These diversions depend only on the channel geometry and the Sacramento River flow. Because the DC Plan would include flat-plate fish screens for both the DCC and Georgiana Slough diversions, some reduction in the diversion flows may be associated with the slight head loss across the screens.

It is possible that an installation of low-head jet-pumps may be useful for increasing the diversion flow through the screens during some tidal conditions. Jet-pumps could operate using the Bernoulli principle to increase the velocity through a culvert. Jet-pumps might be installed downstream of the DCC opening and downstream of the head of Georgiana Slough, to reduce the water elevation at the jet-pump, which would allow more flow to move from the Sacramento River through the screens into these diversion channels.

The major changes in tidal flows and corresponding changes in tidal elevations will be in the Old River and Middle River channels, which will be separated from each other with the DC Plan. These simulated changes in net and tidal flows and tidal elevations will be described and the tidal elevation and tidal flow graphs for these Old River and Middle River locations will be shown.

Simulated Changes in Net Channel Flows

The DC Plan will block several central and south Delta channels and separate Old River from Middle River. A tidal gate at the mouth of Old River will divert all of the San Joaquin River flow to flow out of Franks Tract through either Dutch Slough or False River. All of the water supply from the Sacramento River diversions will flow upstream in the Middle River channels. Table 1 summarizes these shifts in net channel flows from the baseline conditions to the DC Plan conditions for August 1975.

All of the San Joaquin River inflow will be routed down the Old River channel to Franks Tract and will flow through Dutch Slough or False River toward Antioch. The San Joaquin River flows at Antioch will not change, with a net flow of about –1,640 cfs (upstream). The Dutch Slough flow was –467 (upstream toward Franks Tract) for the baseline and increased slightly (less upstream flow) to –350 cfs with the DC Plan. False River flow was 720 cfs for the baseline and increased to about 1,625 cfs with the DC Plan. The Fisherman's Cut net flow represents a circulation from the San Joaquin River to False River, so the net

Table 1. Summary of DSM2 Modeled Tidal Flows for Baseline Conditions and Dredged Delta Corridors Plan for August 1975

		Baseline SDIP Tidal Gates			Delta Corridors Plan with Dredged Channels		
DSM2 Channel	Location	Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)	Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)
441	Martinez	3,463	339,136	-338,127	3,417	339,589	-337,763
511	Montezuma Slough at Collinsville	-35	3,394	-4,011	-35	3,392	-4,004
434	Sacramento at Emmaton	5,557	78,762	-79,680	5,510	78,910	-79,954
431	Sacramento above Threemile	7,645	50,824	-47,493	7,651	51,038	-47,601
398	Cache Slough Mouth	1,177	25,468	-29,091	1,177	25,522	-29,116
390	Miner Slough	1,617	3,410	-1,785	1,618	3,427	-1,790
383	Steamboat Slough Head	1,828	3,072	-1,358	1,829	3,076	-1,346
379	Sutter Slough Head	2,929	3,259	-445	2,930	3,240	-427
429	Sacramento at Ryde	3,512	7,450	-3,984	3,516	7,425	-3,957
366	Georgiana Slough	2,742	2,742	0	2,754	2,754	0
365	Delta Cross Channel	4,607	4,607	0	4,588	4,588	0
357	N Fork Mokelumne Head	3,335	3,335	0	3,307	3,307	0
337	S Fork Mokelumne Head	1,215	1,215	0	1,223	1,223	0
347	S Fork Mokelumne Mouth	-812	4,377	-6,099	-984	4,383	-6,329
349	Mokelumne Mouth	5,266	7,937	-1,770	5,077	8,342	-2,183
323	Little Potato Slough	1,917	2,157	-253	2,096	2,442	-257
328	Potato Slough to San Joaquin River	-139	8,397	-9,221	-679	8,269	-9,907
319	Little Connection to San Joaquin River	1,454	1,641	-334	1,869	2,059	-280
314	Disappointment Slough						
312	Fourteen Mile Slough	-47	291	-430	111	385	-326

Table 1. Continued

		Baseline SDIP Tidal Gates			Delta Corridors Plan with Dredged Channels		
DSM2 Channel	Location	Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)	Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)
50	San Joaquin River at Antioch	-1,642	104,892	-110,931	-1,640	104,419	-111,029
83	San Joaquin River at Jersey Point	-1,093	88,051	-94,156	-1,208	87,305	-94,361
48	San Joaquin River at Bradford	-1,803	55,522	-61,327	-2,823	53,568	-60,907
45	San Joaquin River at San Andreas	-3,376	67,140	-77,091	-4,767	62,666	-74,974
309	Threemile Slough	-2,031	19,054	-23,315	-2,084	18,948	-23,173
274	Dutch Slough	-467	5,549	-6,688	-350	5,862	-6,870
279	False River	720	32,248	-32,640	1,625	33,075	-32,560
280	Fishermans Cut	398	3,017	-2,635	80	3,479	-3,132
31	San Joaquin River above Columbia Cut	316	10,742	-11,279	-2,479	9,542	-14,104
24	San Joaquin River above Turner Cut	1	7,136	-5,638	1	6,875	-7,649
15	San Joaquin River at Garwood Bridge	1,391	2,515	-952	-314	2,015	-2,649
10	San Joaquin River at Brandt Bridge	1,434	1,708	-492	-271	788	-1,275
7	San Joaquin River at Mossdale	1,958	1,958	0	1,956	1,956	0
1	San Joaquin River at Vernalis	1,986	1,986	0	1,986	1,986	0
124	Old River Mouth	-5,663	6,202	-13,964	2	992	-932
111	Old at Bacon	-5,709	4,200	-12,423	1,338	8,720	-7,504
90	Old at Los Vaqueros Intake	-7,183	1,088	-7,763	1,839	4,156	-2,194
81	Old at DMC Intake	-4,787	0	-4,787	-4,564	0	-4,564
79	Old above DMC	-223	17	-251	0	33	-25
71	Old at Tracy Blvd	-135	83	-210	90	523	-282
55	Old at Head	500	500	0	500	500	0

Table 1. Continued

DSM2 Channel	Location	Baseline SDIP Tidal Gates			Delta Corridors Plan with Dredged Channels		
		Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)	Net Flow (cfs)	Positive Flow (cfs)	Negative Flow (cfs)
161	Middle at Mouth	-2,917	10,247	-15,408	-6,504	12,656	-23,206
160	Columbia Cut	-2,063	2,228	-5,526	-2,564	709	-3,030
159	Middle above Columbia	-4,963	8,923	-16,712	-9,051	9,019	-22,800
248	Connection Slough	6	4,069	-4,345	0	135	-147
172	Turner Cut	-1,102	1,247	-2,938	-2,348	595	-2,898
135	Middle at Victoria	-3,958	931	-4,592	-11,306	40	-11,317
133	Middle at Tracy Blvd	-177	0	-177	-9	24	-45
125	Middle at Head	-81	60	-100	87	119	-55
259	Santa Fe Cut	1,150	1,798	-381	0	214	-238
235	Woodward Cut	863	1,377	-258	0	183	-210
232	West Canal below CCF	-9,098	68	-9,108	-11,266	0	-11,266
	CCF Inflow	6,668	9,308	0	6,688	7,619	0
213	Grant Line Canal Mouth	574	1,453	-2,699	1,877	3,057	-1,656
207	Grant Line Canal at Tracy Blvd	590	1,220	-1,948	1,895	2,588	-972
216	CVP Jones Pumping Plant	-4,543	0	-4,543	-4,543	0	-4,543

DMC = Delta-Mendota Canal
CCF = Clifton Court Forebay
CVP = Central Valley Project

False River outflow changed from about 322 cfs for the baseline to about 1,545 cfs with the DC Plan. The tidal flows in False River did not change with the DC Plan. The average tidal flows (ebb tide and flood tide) were about 32,000 cfs for the baseline and remained about 32,000 cfs. Most of this tidal flow fills and drains the large Franks Tract surface area. The Old River flow at Bacon Island (upstream of Franks Tract) was about –5,709 cfs (upstream) for the baseline and increased to 1,338 cfs (downstream) with the DC Plan. This was a change of about 7,047 cfs between the baseline and the DC Plan conditions. The average tidal flows at Bacon Island were not changed substantially; they were about 8,500 cfs for the baseline and about 8,000 cfs with the DC Plan.

The San Joaquin River reverse (upstream) flow at Bradford Island was –1,803 cfs for the baseline and was increased to about -2,823 cfs (more upstream flow) with the DC Plan. This suggests that the reverse flow during August 1975 for the baseline conditions was increased by the DC Plan because the Old River outflow through False River was increased by routing all of the San Joaquin River inflow down Old River. The Threemile Slough net flow was about –2,031 (toward the San Joaquin River) for the baseline and was increased only slightly to –2,084 cfs with the DC Plan. Although this Sacramento River diversion flow was generally of good quality (i.e., low salinity), the reverse flow in the San Joaquin River at Bradford Island may be higher in salinity (during low Delta outflow periods) and would likely return (recycle) most of the San Joaquin River water flowing from Frank Tract to the San Joaquin River channel. This is a major operational issue that needs to be resolved for the DC Plan, and it will be evaluated in a separate report on the water quality effects of the DC Plan.

The San Joaquin River flow at San Andreas Landing, just downstream from the mouth of the Mokelumne River, was about –3,376 cfs for the baseline and increased (reverse flow) to about –4,767 cfs with the DC Plan. Because the mouth of Old River was blocked under the DC Plan, the San Joaquin River reverse flows to the mouth of Middle River, Columbia Cut, and Turner Cut were increased. The flows at the mouth of Middle River were –2,917 for the baseline and were increased (upstream) to about –6,504 cfs with the DC Plan. The Columbia Cut flows were –2,063 cfs for the baseline and were increased (upstream) to about -2564 cfs with the DC Plan. The Turner Cut flows were –1,102 cfs for the baseline and were increased (upstream) to about –2348 cfs with the DC Plan. These Middle River reverse flows were increased from about –6,082 cfs to about –11,416 cfs, an increase of about 5,334 cfs. The Middle River flow at Victoria Canal was about –3,958 cfs for the baseline and was increased (upstream) to about –11,306 cfs with the DC Plan, which is an increase of about 7,348 cfs. The Connections Slough flow from Middle River to Old River was about 6 cfs for the baseline, and would be 0 cfs with the DC Plan. The Santa Fe Cut flow was about 1,150 cfs from Middle River toward Old River, and the Woodward Cut flow was about 863 cfs from Middle River toward Old River for the baseline, and would be 0 cfs with the DC Plan.

The San Joaquin River flows downstream from the head of Old River would be changed by the DC floodgate that would divert all of the San Joaquin River flow into Old River. In addition, a 250-cfs low-head pump would draw water upstream from Stockton and discharge this dilution water into the Old River channel. The net flow at Brandt Bridge was 1,434 cfs for the baseline and was reduced to –271 cfs (upstream) with the DC Plan. The average tidal flows at Brandt Bridge were about 500 cfs for the baseline and were increased to about 1,000 cfs with the DC Plan because the water elevation would be slightly reduced, allowing a stronger tidal influence. The Old River flow at the head was 500 cfs for the baseline and was increased to about 2,206 with the DC Plan (Mossdale flow plus 250 cfs). The Grant Line Canal flow at the mouth was about 574 cfs for the baseline and was increased to 1,877 cfs with the DC Plan. There was about 330 cfs of net agricultural diversions in the south Delta channels (Grant Line Canal, Middle River to Victoria, and Old River to DMC) for August 1975.

Simulated Changes in Tidal Elevations and Tidal Flows

Figure 19 shows the simulated tidal elevations and tidal flows for the San Joaquin River between Columbia Cut and Garwood Bridge (Stockton) for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 11). The simulated tidal elevations were not changed with the DC Plan. The simulated tidal flows upstream of Turner Cut were about 10,000 cfs, and the simulated tidal flows at the Garwood Bridge (SR 4) near the Stockton Regional Wastewater Control Facility discharge were about 3,000 cfs. All of the tidal flows in the Stockton DWSC and Stockton channels (e.g., Weber Point, Smith, Calaveras) would be water diverted from the Sacramento River, so the new Stockton water supply (located near the mouth of Disappointment Slough) would divert from the water supply corridor, and the low dissolved oxygen (DO) conditions in the DWSC would no longer occur. Although the San Joaquin River net flows were changed by the DC Plan, the San Joaquin River tidal flows were similar to the baseline tidal flows because they were controlled by the upstream tidal surface area, which was reduced only slightly by the floodgate located downstream of the head of Old River.

Figure 20 shows the simulated tidal elevations and tidal flows for the San Joaquin River between Brandt Bridge and Paradise Weir for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 12). The DC floodgate located downstream of the head of Old River increased the minimum tide elevations at Mossdale from 2 feet to about 3 feet msl. The minimum tide elevations at Brandt Bridge were reduced by about 2 feet, from about 0.5 feet to about –1.5 feet msl. The DC Plan would allow full tidal flows into the DWSC and upstream to Brandt Bridge. An upstream average flow of 250 cfs would be pumped into the head of Old River to transport the Stockton wastewater into the Old River–estuary corridor.

Figure 21 shows the simulated tidal elevations and tidal flows in the Middle River channels that connect with the San Joaquin River channel for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 13).

The simulated tidal elevations range from about –1 foot msl to about 4 feet msl during the month. The tidal elevations were nearly identical at the mouth of Middle River, at Columbia Cut, and at Turner Cut. The simulated tidal flows at the mouth of Middle River are about 20,000 cfs more or less than the average flow of about –6,500 cfs (upstream) because these tidal flows fill and drain the flooded Mildred Island (1,000 acres) and surrounding channels. The simulated tidal flows at the mouth of Columbia Cut were about 2,000 cfs more or less than the average flow of about –2,500 cfs (upstream). The simulated tidal flows at the mouth of Turner Cut were also about 2,000 cfs more or less than the average flow of about –2,500 cfs (upstream). The simulated tidal flows in Middle River varied from about –5,000 cfs to about –20,000 cfs with an average flow of –11,250 in Middle River at Victoria Canal. Slightly more than half of the simulated average flows enter the water supply corridor at the mouth of Middle River, about 25% enter at Columbia Cut, and 25% enter at Turner Cut. Additional evaluations may show that dredging of Columbia Cut or Turner Cut would improve the conveyance capacity and further reduce the tidal water elevation gradient (slope) in the Middle River corridor.

Figure 22 shows the simulated tidal elevations and tidal flows in Old River for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 14). The tidal variations at Bacon Island and the Los Vaqueros intake were about the same as for the baseline conditions. The tidal elevations at the DMC were much lower than the baseline because this section of Old River was connected to the water supply corridor with a floodgate at the north end of West Canal. The Old River now would connect with Grant Line Canal and the San Joaquin River at the head of Old River.

Figure 23 shows the simulated tidal elevations and tidal flows in the Old River and Grant Line Canal–estuary corridor for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 16). The DC Plan would block the San Joaquin River below the head of Old River and divert the entire San Joaquin River flow into Old River and Grant Line Canal. The San Joaquin River flow would remain separated from the SWP and CVP pumping flow with a divided channel between the mouth of Grant Line Canal and Coney Island and then by crossing over Victoria Canal (river bridge) and flowing down the Old River channel past the Contra Costa Water District (CCWD) Los Vaqueros intake to Franks Tract. The simulated head of Old River minimum tidal elevations remained above 3 feet. The simulated minimum tidal elevations in Old River at the CCWD Los Vaqueros intake was about 0 feet msl, but the simulated tidal stage at the mouth of Grant Line Canal remained above 1 foot msl because of the San Joaquin River inflow effects on the tidal water elevation.

The simulated San Joaquin River flow of about 2,000 cfs is augmented at the head of Old River with 250 cfs pumped from the San Joaquin River (upstream flow from Stockton). Maximum summer irrigation diversions were simulated along these channels. The average flow at the mouth of Grant Line Canal was about 1,850 cfs, so about 400 cfs was simulated to be depleted (i.e., agricultural diversions minus drainage) by agricultural uses in the south Delta channels. The average simulated flow in Old River at Bacon Island (entering Franks Tract) was about 1,325 cfs, so an additional 500 cfs was simulated to be depleted in the central Delta from Old River and connecting channels for agricultural uses. Additional pumping from the Middle River water supply corridor may be needed in some months to provide adequate salinity (less than about 700 µS/cm) for these central Delta diversions. The simulated tidal flows in Grant Line Canal were about 2,000 cfs more or less than the average flow, and the tidal flows at the Los Vaqueros intake (SR 4) were about 4,000 cfs more or less than the average flow. This was about the same tidal flow variation, but the net flows were higher, so the maximum flood-tide (upstream) flows at the Los Vaqueros intake were about –5,000 cfs (compared with a maximum flood-tide flow of about 15,000 cfs for the baseline conditions).

Figure 24 shows the simulated tidal elevations and tidal flows in Old River near the DMC intake for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 17). The simulated tidal elevations at the DMC intake and at the CVP Jones pumping plant ranged from about –2 feet to 1 foot msl. The simulated high-tide elevations were less than the high-tide tidal elevations for the baseline conditions, but the low-tide elevations were similar to the baseline. This was the result of eliminating the priority 3 operation of the CCF gates, which allowed the high tides to flow into the south Delta channels while the CCF gate remained closed. The SDIP tidal gate was simulated on Old River upstream of the DMC intake, and this maintained a minimum tide elevation of about 1 foot msl in Old River upstream of the tidal gate. No flows were simulated to move upstream through the Old River tidal gate because the downstream elevations were never greater than the upstream elevations.

Figure 25 shows the simulated tidal elevations and tidal flows in West Canal and CCF for August 1975 with the dredged DC Plan (compare to baseline conditions shown in Figure 18). The CCF intake gates were simulated to be open except when the outside (West Canal) elevation was less than the CCF elevation. The simulated tidal elevations ranged from about –2 feet to 1 foot msl. This was considerably less than the tidal range simulated at the mouth of Middle River (shown for comparison). The simulated high-tide elevations in West Canal were less than the high-tide tidal elevations for the baseline conditions, but the low-tide elevations were similar to the baseline elevations. This was the result of eliminating the priority 3 operation of the CCF gates, which allowed the high tides to flow into the south Delta channels while the CCF gate remained closed. The simulated flows into CCF fluctuated from 0 cfs (when West Canal elevations were higher than CCF elevations) to the maximum gate flow of 16,000 cfs.

The simulated average inflow (when the gates were open) to CCF was about 7,619 cfs for the DC Plan, slightly less than the 9,308 cfs inflow simulated for the baseline conditions with priority 3 CCF gate operations, which closed the CCF gates during flood tide prior to the high tide each day. The simulated maximum flood-tide flows in West Canal downstream of the CCF intake were slightly higher (upstream) than for the baseline conditions, because all of the CVP and SWP exports were tidally transported past this location in the water supply corridor. Some of the baseline flow to the DMC intake and CCF came from Grant Line Canal.

These simulated results for the dredged DC conditions generally indicate that the full existing CVP (4,500 cfs) and SWP (6,680 cfs) exports could be tidally transported in the dredged Middle River and Victoria Canal conveyance corridor, while maintaining a CCF water elevation between about 1 foot and –2 feet msl. No pumping of the water supply diversions from the Sacramento River into a conveyance canal would be needed for the DC Plan. The DC Plan allows the tidal energy of the Delta channels to continue to transport the full existing CVP and SWP exports to the south Delta.

Additional evaluation of higher SWP pumping may indicate that this would be possible whenever the San Joaquin River flow is high enough to provide low salinity water (less than 250 µS/cm). This generally occurs when the San Joaquin River flow is greater than about 5,000 cfs. The divided channel in Old River between Grant Line Canal and Coney Island would be opened to facilitate this increased SWP pumping.

Simulated Dredging of Middle River and Victoria Canal

This section describes the changes in Middle River, Victoria Canal, West Canal, and Old River near the DMC intake DSM2 cross sections to simulate the effect of dredging. This process involved the use of the Cross Section Development Program (CSDP), which enables the viewing of Delta bathymetry and the creation or modification of cross-section input files used by DSM2. Initial DSM2 simulations of the DC Plan indicated that tidal flows were reduced in Middle River adjacent to Victoria Island (DSM2 channels 135–138), Victoria Canal (DSM2 channels 226–231), West Canal (DSM2 channels 81 and 232), and the DMC intake canal (channels 214 and 216). The cross sections in these channels had potential to be deepened by dredging to a depth of –25 feet msl with a side slope of 3:1 (horizontal to vertical) to maintain levee stability.

The distance and elevation coordinates for the original cross sections were extracted from the CSDP “network” file. This file contains channel location and cross section information that is used by the CSDP to generate the DSM2 input files for “irregular” cross sections. All elevations in the files used by DSM2 are based on the National Geodetic Vertical Datum of 1929 (NGVD 29), which is very close to mean sea level. The dredged cross sections were the same as the original cross sections for all portions of the cross section located above an elevation of 0 feet NGVD 29. Below an elevation of 0, the new channel was assumed to have a 3:1 slope to a depth of –25 feet.

Figure 26 shows an example of the original and dredged cross sections for Victoria Canal. The new channel was assumed to be dredged all the way across the channel, eliminating the channel island between Victoria Canal and North Canal. The channel width at 0 feet msl was 520 feet, and the original cross-section area below 0 feet msl was 5,290 square feet with an average depth of about 10.2 feet. The perimeter was 526 feet, so the hydraulic radius was about

10.0 feet. This can be used to estimate the water surface slope required to convey 12,000 cfs in Victoria Canal. The flow equation (Manning's) is:

$$\text{Flow (cfs)} = \text{Area} * 1.5/n * R^{0.666} * s^{0.5}$$

Where *Area* is the cross-section area (square feet), *R* is the hydraulic depth (ft), *s* is the water surface slope (ft/ft), and *n* is the Manning's value.

This can be rearranged to give the slope required for a flow of 12,000 cfs with an assumed Manning's n value of 0.027. The required slope is about 0.0000775 or 0.4 foot/mile (5 inches/mile). This is a moderate river slope and would result in a large elevation change of 2.3 feet along the 5.5 miles of Victoria Canal. The dredging would produce a trapezoidal channel with side slopes of 3:1 (about 18.5º slope for stability) and a bottom width of 370 feet. The dredged cross-section area would be increased to 11,125 square feet, so the average depth would be about 21.5 feet. Each side slope has a length of about 80 feet, so the perimeter would be 530 feet, and the hydraulic radius would be increased to 21 feet. The would reduce the required hydraulic slope needed for a tidal flow of 12,000 cfs to about 0.0000065 or 0.03 foot/mile (0.4 inches/mile). This slope is less than 10% of the original Victoria Canal section, and would result in an elevation change of just 0.2 foot along the 5.5 miles of Victoria Canal.

Figure 27 shows a section of the Middle River channel where the dredged cuts along Victoria Island and Jones Tract levees are separated by a wide island. The dredging was assumed to leave the island in the middle of the channel. This will limit the conveyance of the dredged channel, but if sufficient cross section can be achieved with the two dredged channels, leaving the channel island in the center of the Middle River corridor will preserve considerable tidal and aquatic habitat along the island perimeter. The width of the two channels of this section of Middle River was about 400 feet with a cross section area of 5,585 square feet and an average depth of about 14 feet. Dredging without widening the cuts would provide a new cross-section area of 6,250 square feet. This may not be enough for the 12,000-cfs water supply flow, and these two channels will likely need to be widened to provide a cross section of about 10,000 square feet. Other sections of Middle River without a channel island were assumed to be dredged to a depth of 25 feet depth across the entire channel.

Table 2 gives some summary values for the DSM2 channel sections that were modified for dredging evaluation of the DC Plan. The Middle River channel between Woodward Cut and Victoria Canal is about 3.5 miles long and would be dredged from existing depths ranging from about 15 feet to 20 feet to a uniform depth of 25 feet, with a channel width of about 400 feet (250 feet at the bottom). This would increase the average cross-section area from about 5,000 square feet to about 8,000 square feet. Victoria Canal would be dredged from a depth of about 15 feet to a depth of 25 feet, and the center island would be removed. Victoria Canal length is about 5.5 miles, and the channel width is about 500 feet. The cross-section area would be increased from about 5,000 square feet to about

Table 2. Assumed Dredging in Middle River, Victoria Canal, and Old River Channels for the Delta Corridors Plan

Channels with Dredging for Delta Corridors	Cross Section	Channel Length (ft)	Cross-Section Length (ft)	Width at 0 ft elev (ft)	Old Cross-Section Area at 0 ft elev (sq. ft.)	New Cross-Section Area at 0 ft elev (sq. ft.)	Dredge Volume (cubic yards)
81	81_.44	3,857	3,857	240	3,214	4,125	130,138
82	82_.95	2,609	2,609	264	4,238	4,725	47,012
135	135_.16	4,427	708	453	6,109	9,446	87,538
135	135_.75		1,107	464	4,380	9,716	218,742
135	middle part		2,612		5,245	9,581	419,513
136	136_.79	2,266	2,266	383	4,382	7,694	277,939
137	137_.59	3,983	2,350	400	5,584	6,254	58,328
137	137_.85		597	473	4,729	8,077	74,087
137	middle part		1,036	475	5,157	7,166	77,061
138	138_.31	7,131	2,211	417	5,843	8,128	187,046
138	138_.78		1,569		5,230	6,666	83,447
138	middle part		3,352		5,537	7,397	230,929
226	226_.15	4,153	4,153	480	5,761	10,126	671,386
227	228_.01	4,789	4,789	520	5,291	11,137	1,036,978
228	228_.01	3,218	3,218		5,291	11,137	696,804
229	229_.14	3,048	3,048	523	4,687	11,188	733,843
230	230_.02	13,402	5,712	425	4,394	8,743	920,062
230	231_.68		4,313	238	1,895	4,087	350,215
230	85_.08		3,377				0
231	231_.68	4,313	4,313		0	4,087	652,924

Channel Sections	Miles	Cubic yards
Middle River Woodward to Victoria	3.4	1,483,700
Victoria Canal to West Canal	5.4	5,062,212
Old River Victoria to West Canal	0.8	652,924
Old River West Canal to Delta-Mendota Canal Intake	1.2	177,150
Total Dredging		6,953,992
Total Dredging with Middle Rvier widened to provide 10,000 square feet		8,500,000

10,000 square feet. West Canal would be dredged from about 20 feet deep to about 25 feet deep. The length of West Canal is about 1.5 miles, and the width is about 250 feet. The cross-section area would be increased from about 4,000 square feet to about 5,000 square feet.

The dredging volume was calculated using the difference between the original cross-section area and the dredged cross-section area. These dredge areas were then multiplied by the length of each channel section. The dredging along Middle River would require about 1.5 million cubic yards. A more detailed evaluation may suggest that the Middle River channel sections need to be widened by about 100 feet to increase the average cross section by 2,500 square feet to about 10,000 square feet. This would increase the dredging volume by about 1.5 million cubic yards. The dredging in Victoria Canal would require about 5 million cubic yards. The dredging in West Canal and Old River would require about 1 million cubic yards. This is a moderate amount of dredging (total of about 9 million cubic yards at an estimated cost of about $100 million) that would allow full existing exports to be supplied by the Middle River corridor, and allow the entire San Joaquin River flow to be separated from the water supply exports to reduce salinity and reduce fish entrainment impacts.

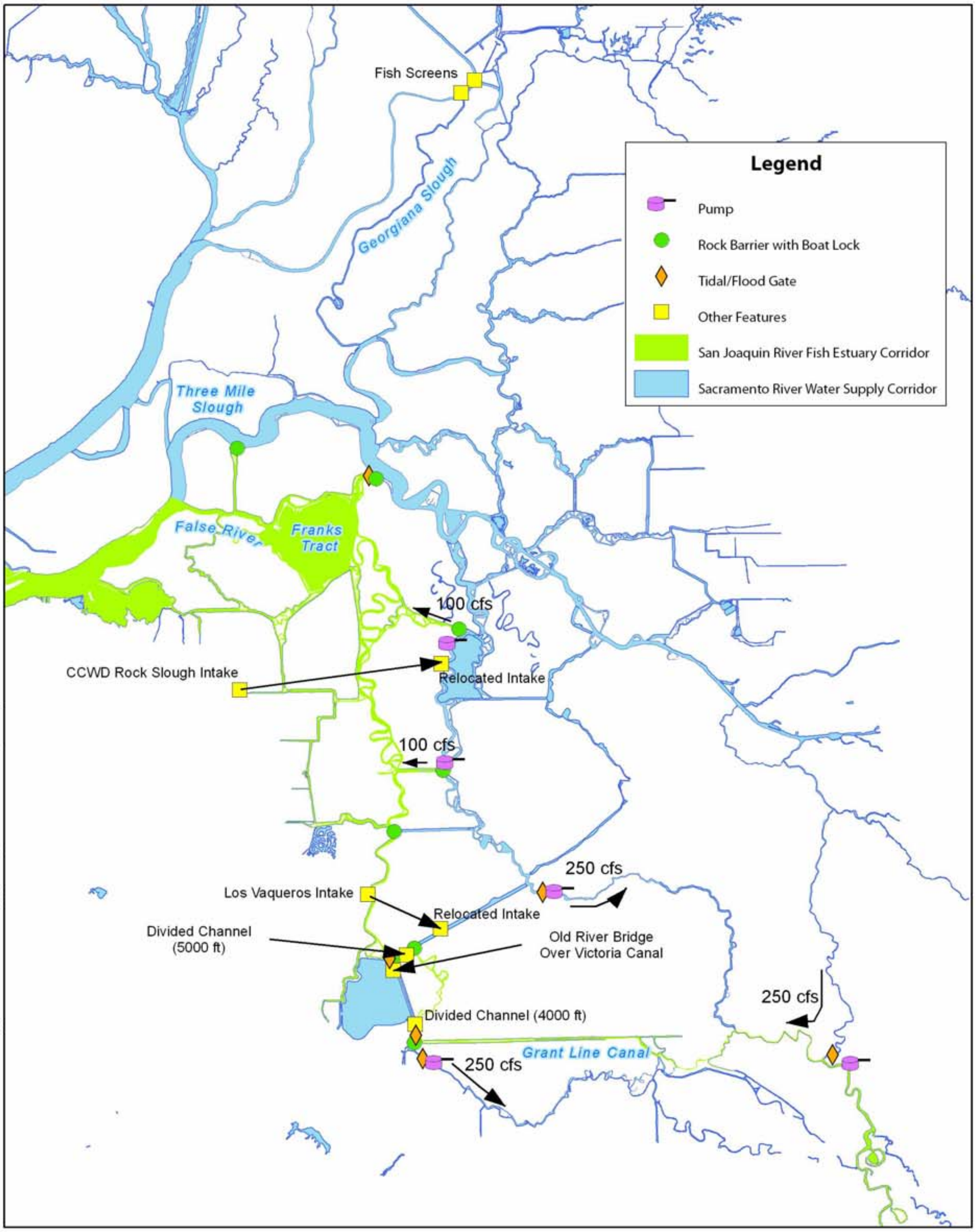

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Figure 1

Locations of the Major Components of the Delta Corridors Plan

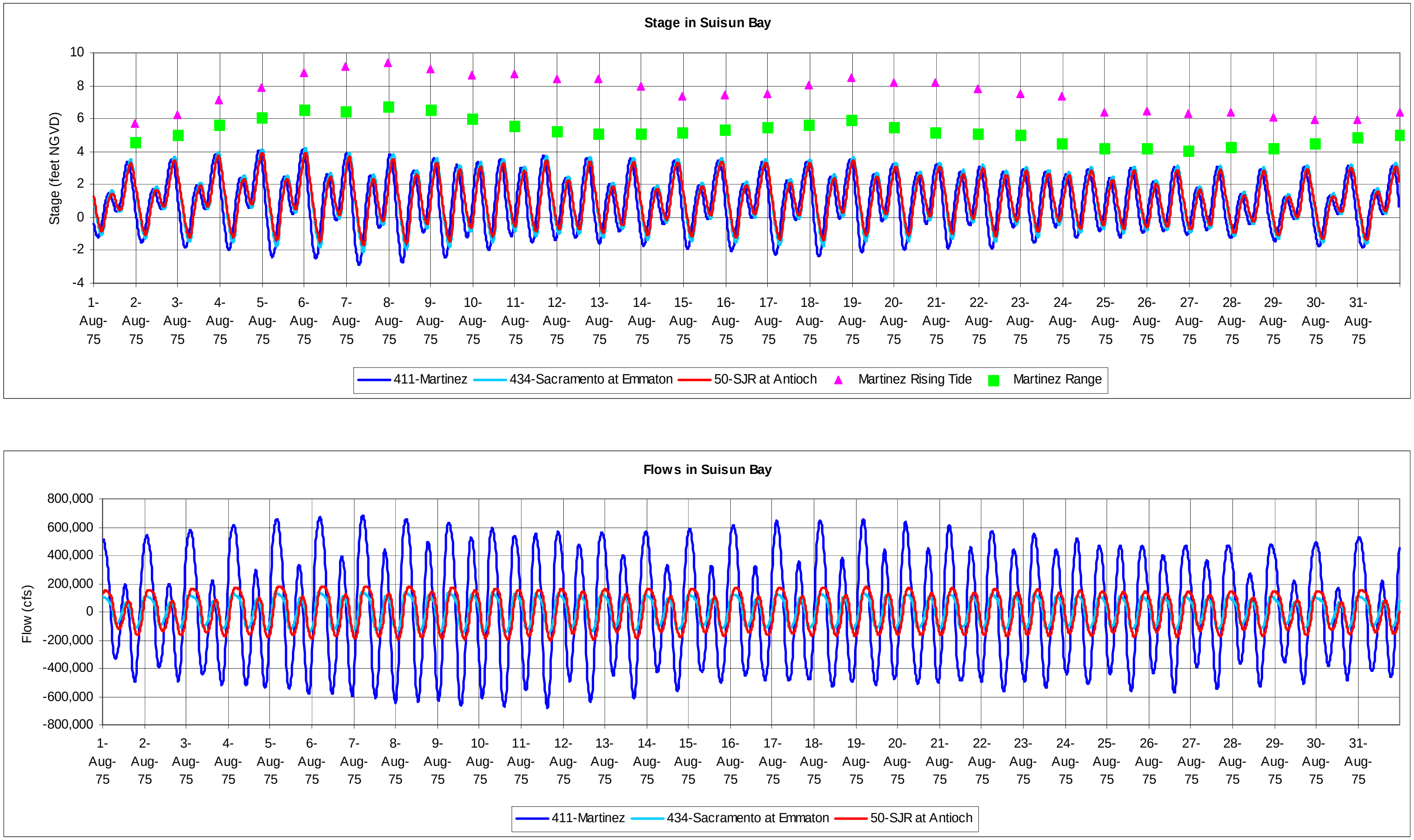

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Figure 2

Simulated Tidal Elevations (Stage) and Tidal Flows at Martinez (Downstream Boundary) and at Antioch and Emmaton during August 1975 for Future Conditions with SDIP Tidal Gates

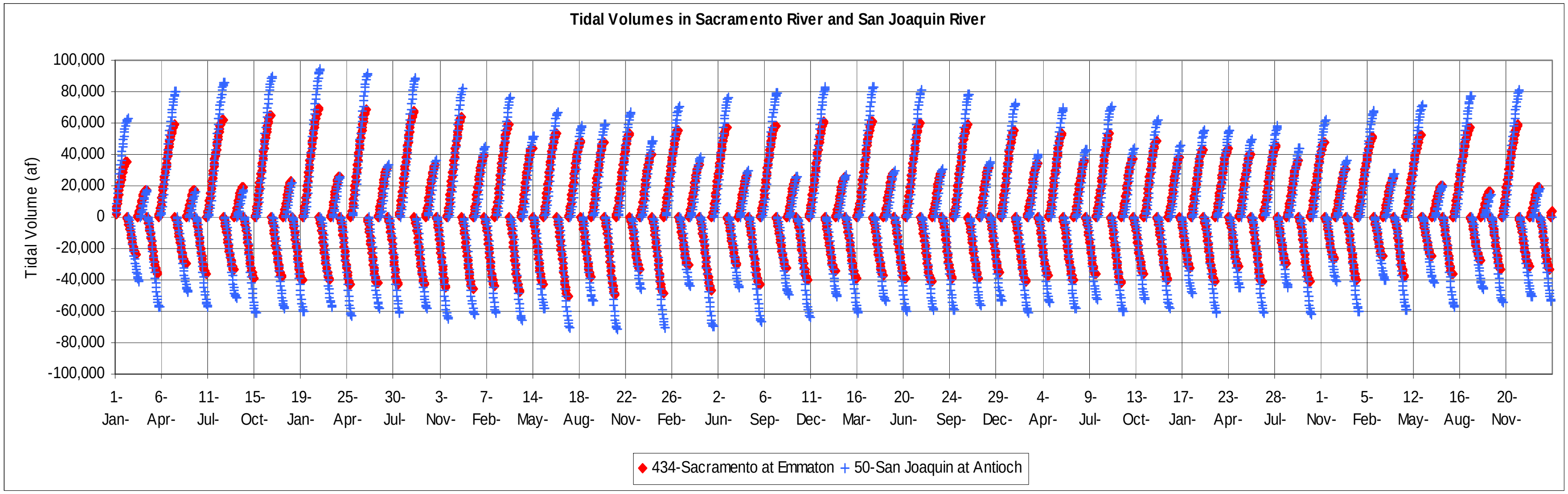
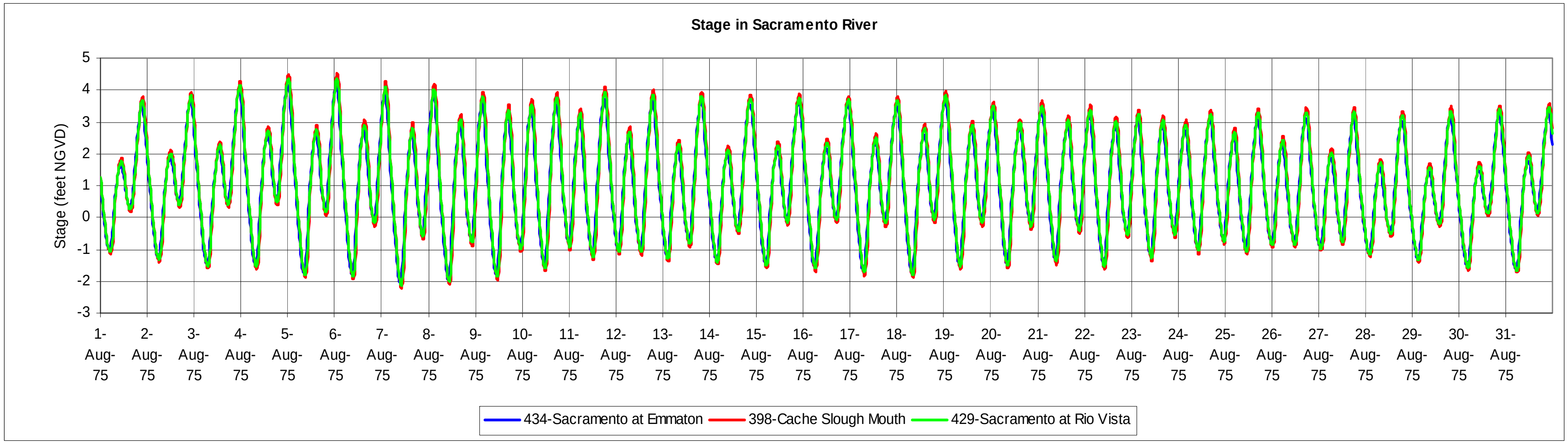


Figure 3

Simulated Tidal Volumes (Ebb Tide Positive, Flood Tide Negative) in the Sacramento River at Emmaton and in the San Joaquin River at Antioch during August 1975 for Future Conditions with SDIP Tidal Gates



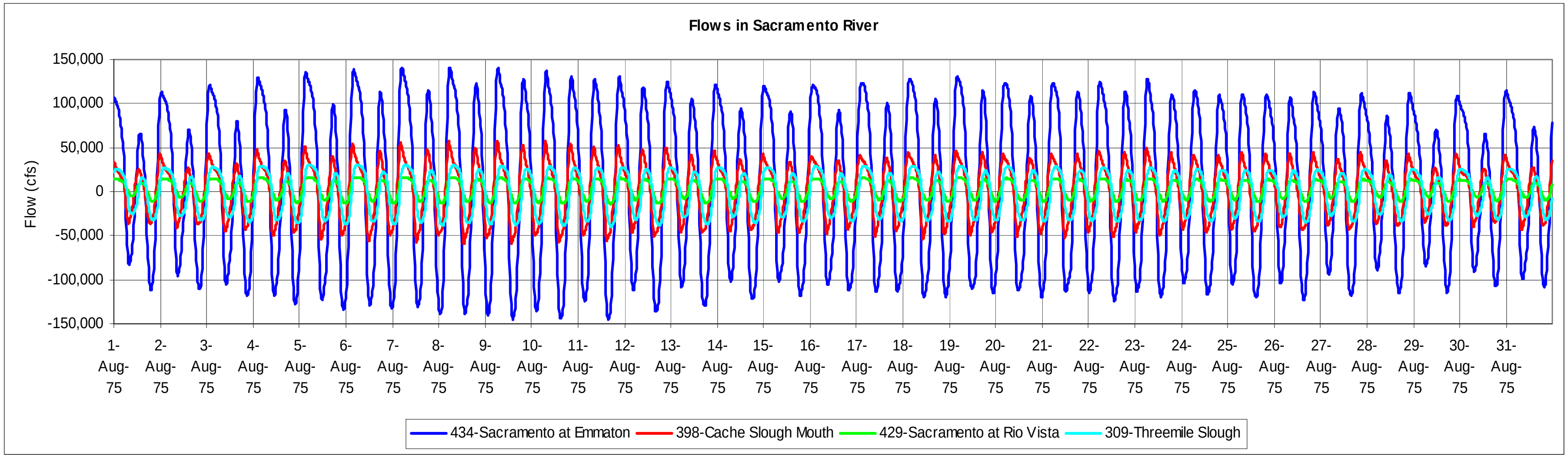


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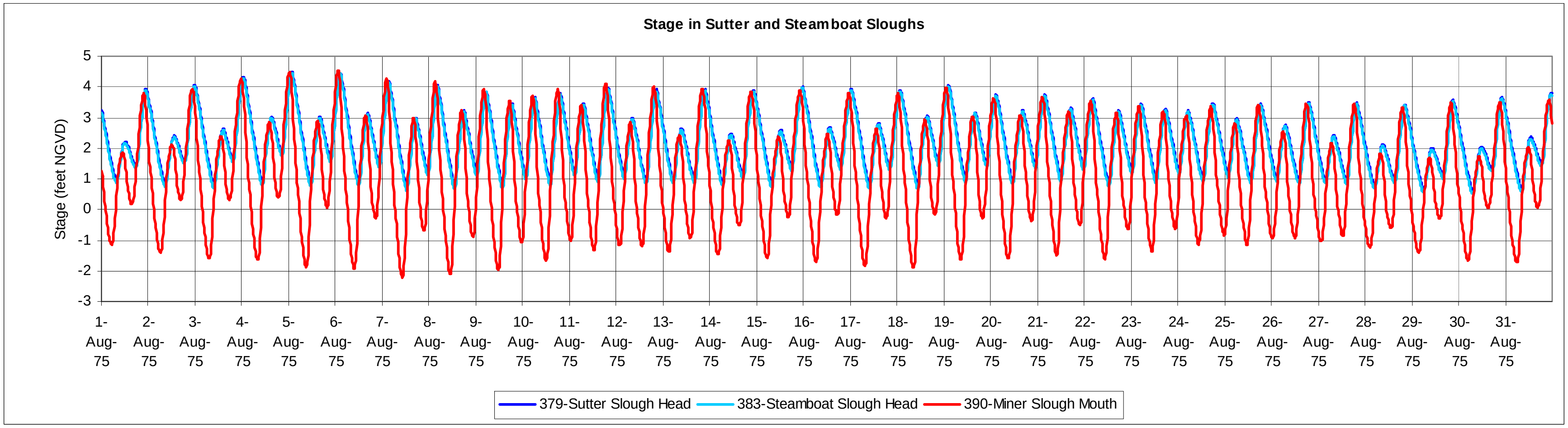
Figure 4

Simulated Tidal Elevations (Stage) and Tidal Flows in Sacramento River Channel during August 1975 for Future Conditions with SDIP Tidal Gates



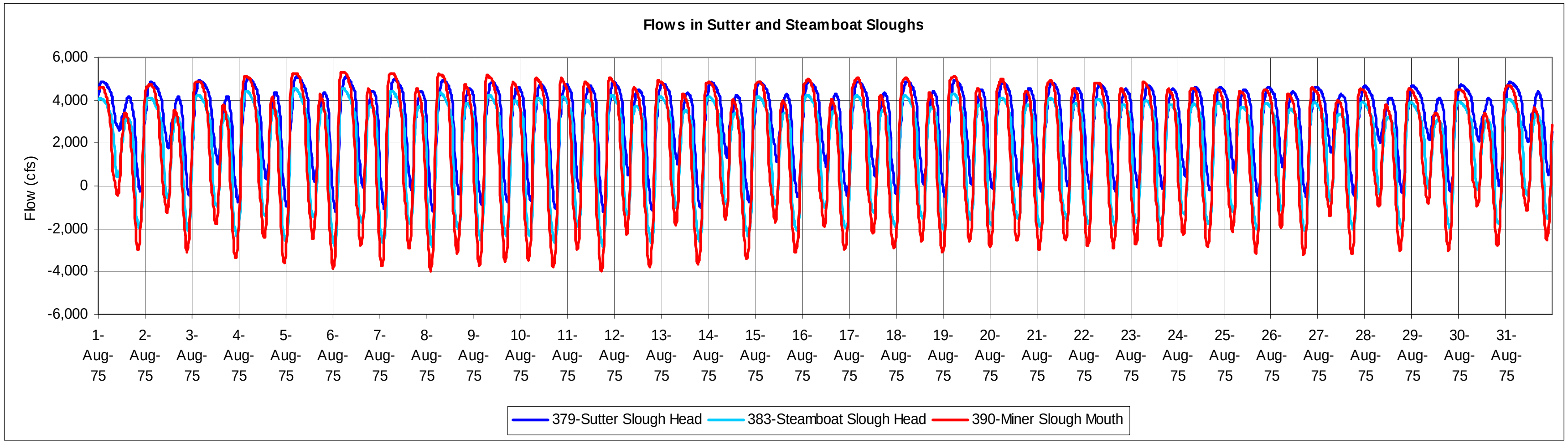


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Figure 5

Simulated Tidal Elevations (Stage) and Tidal Flows in Sutter and Steamboat Sloughs during August 1975 for Future Conditions with SDIP Tidal Gates

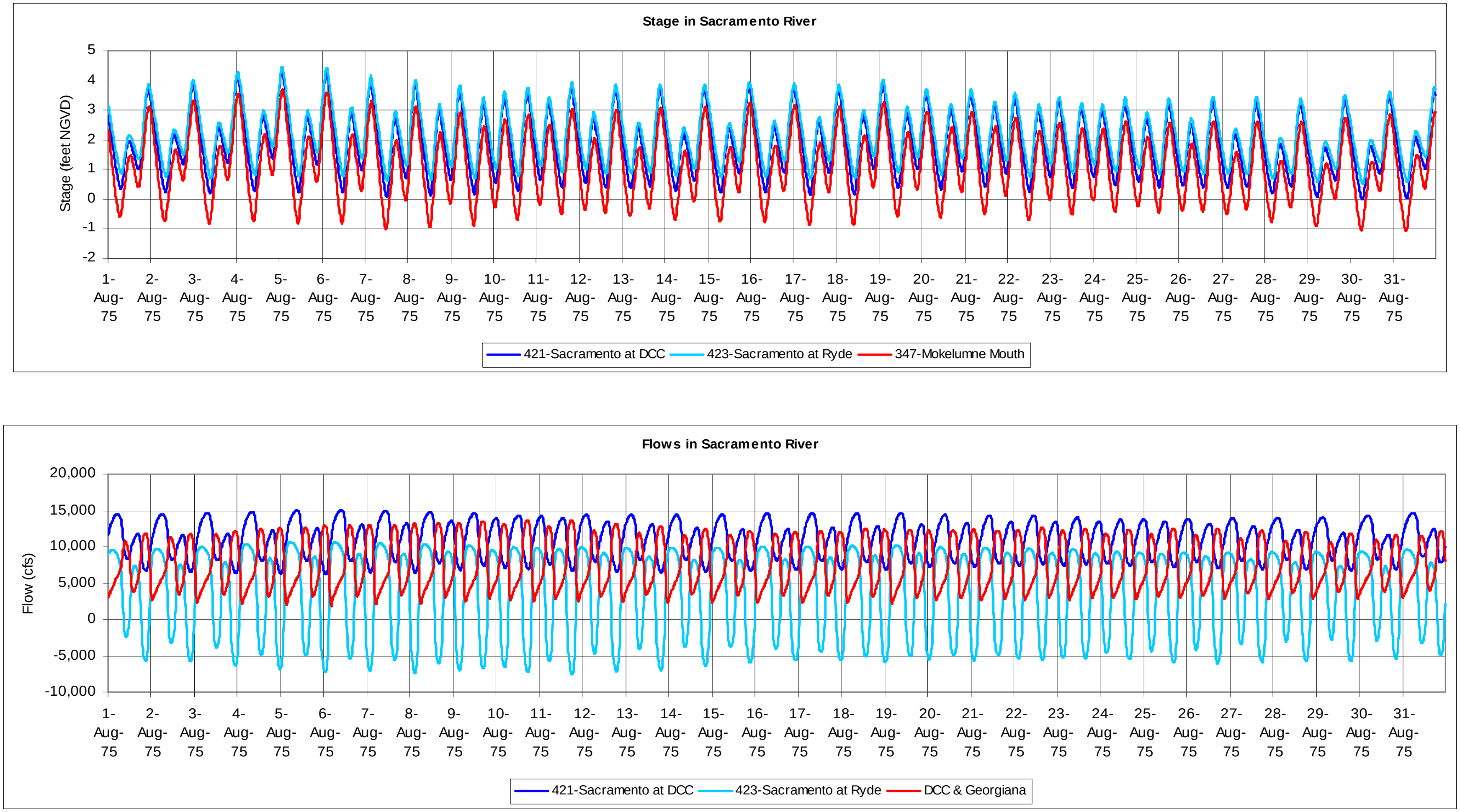

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Figure 6

Simulated Tidal Elevations (Stage) and Tidal Flows in Sacramento River near the Delta Cross Channel and Georgiana Slough during August 1975 for Future Conditions with SDIP Tidal Gates

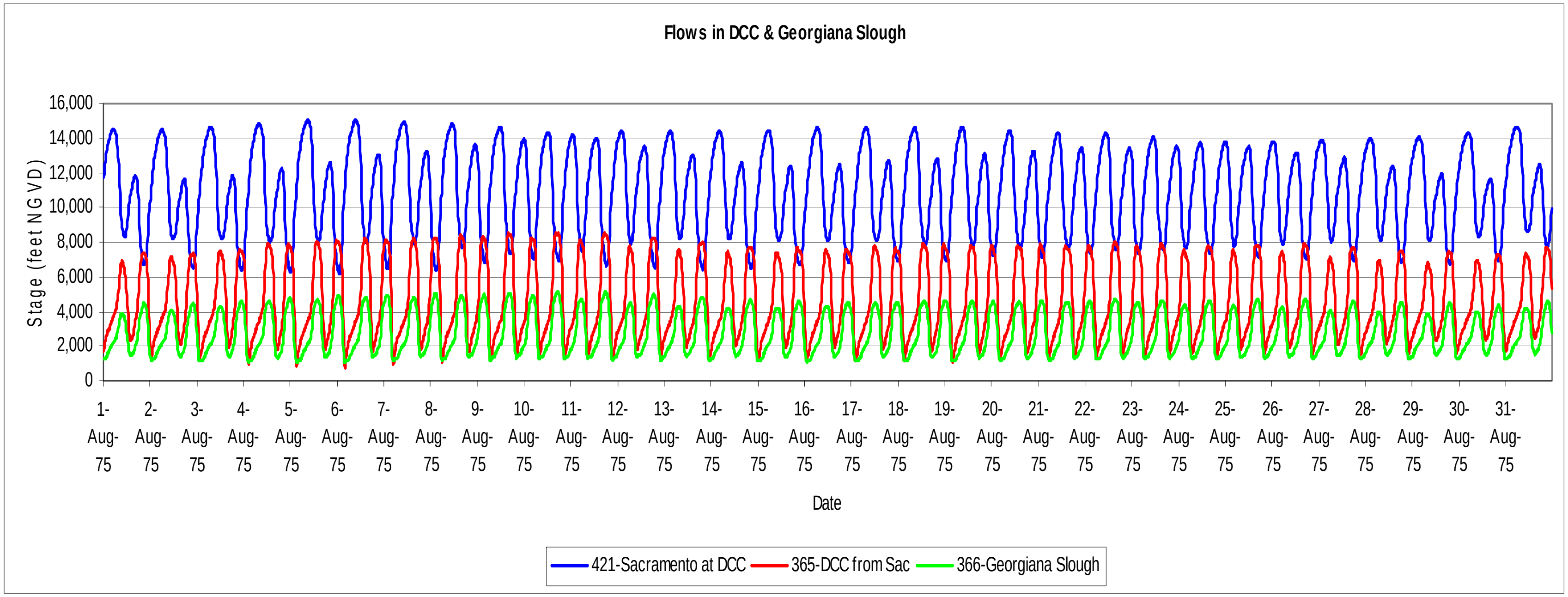

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Figure 7

Simulated Tidal Elevations (Stage) and Tidal Flows in the Delta Cross Channel and Georgiana Slough during August 1975 for Future Conditions with SDIP Tidal Gates

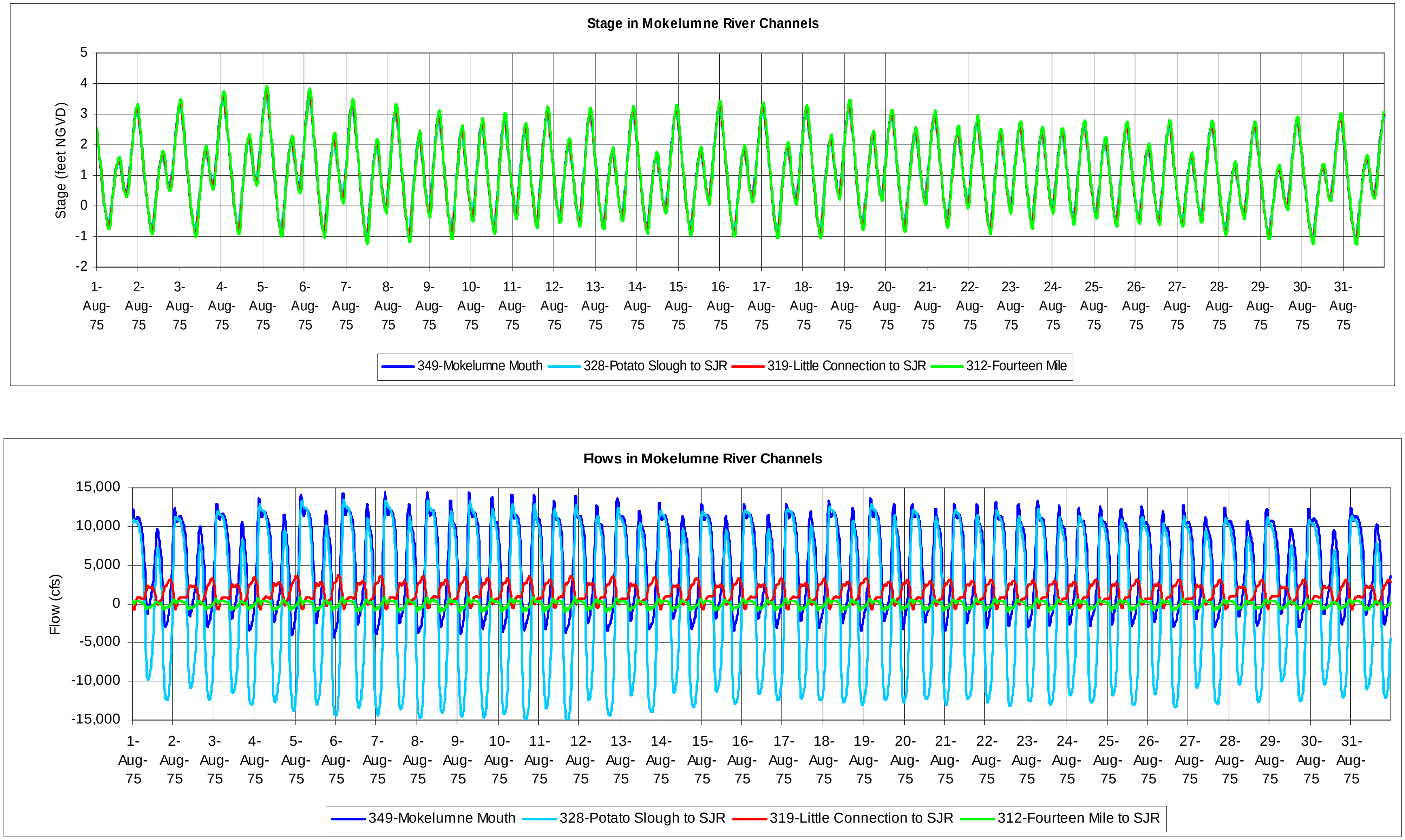

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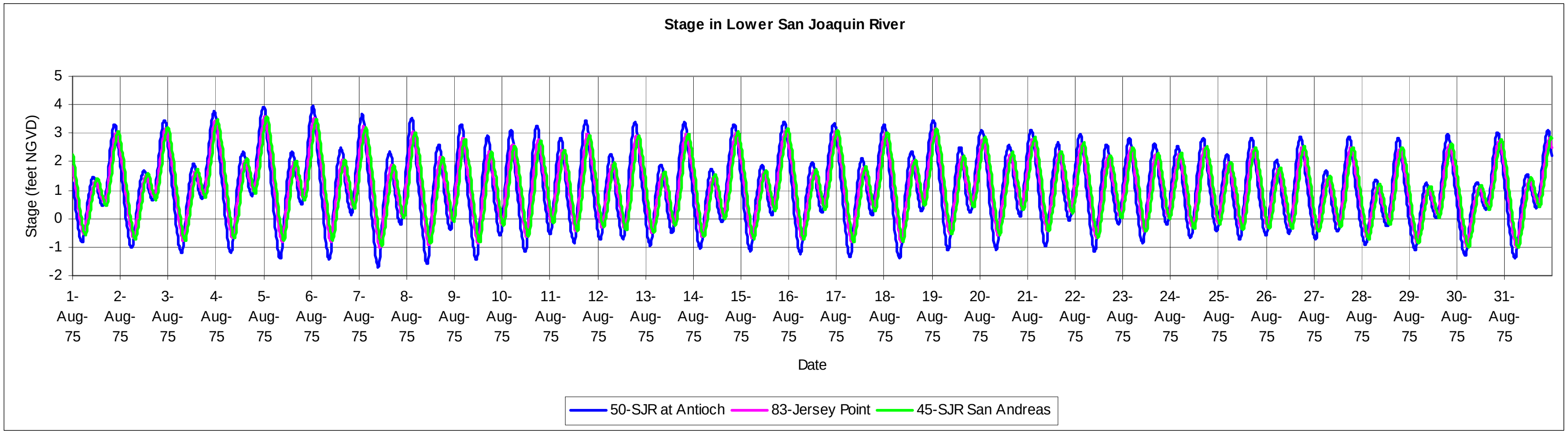
Figure 8

Simulated Tidal Elevations (Stage) and Tidal Flows in the Mokelumne River Channels Connecting with the San Joaquin River during August 1975 for Future Conditions with SDIP Tidal Gates



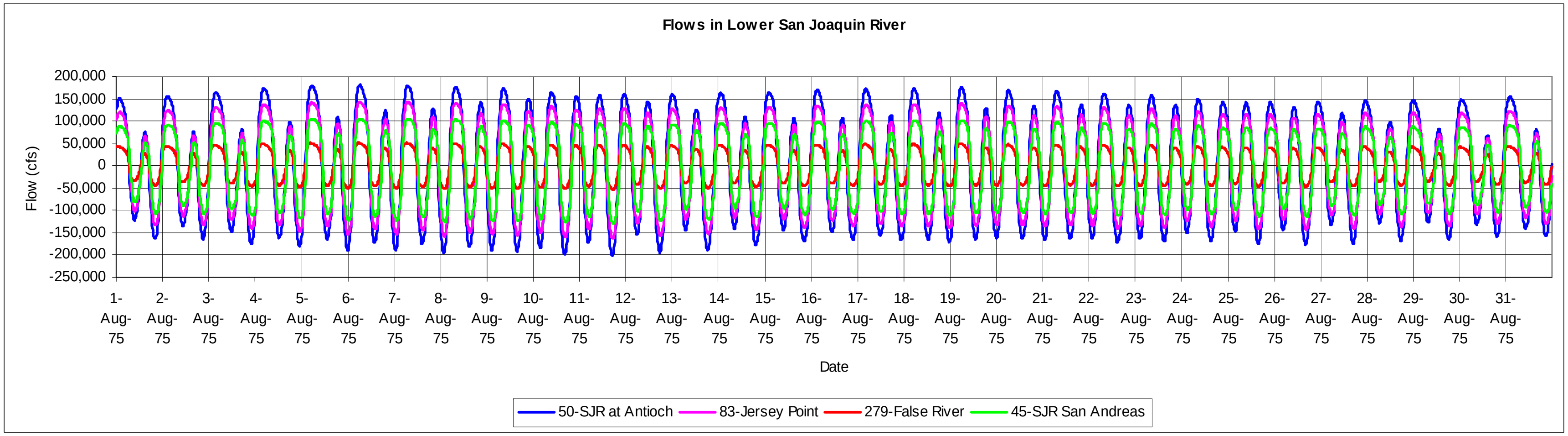


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Figure 9

Simulated Tidal Elevations (Stage) and Tidal Flows in the Lower San Joaquin River Channels during August 1975 for Future Conditions with SDIP Tidal Gates

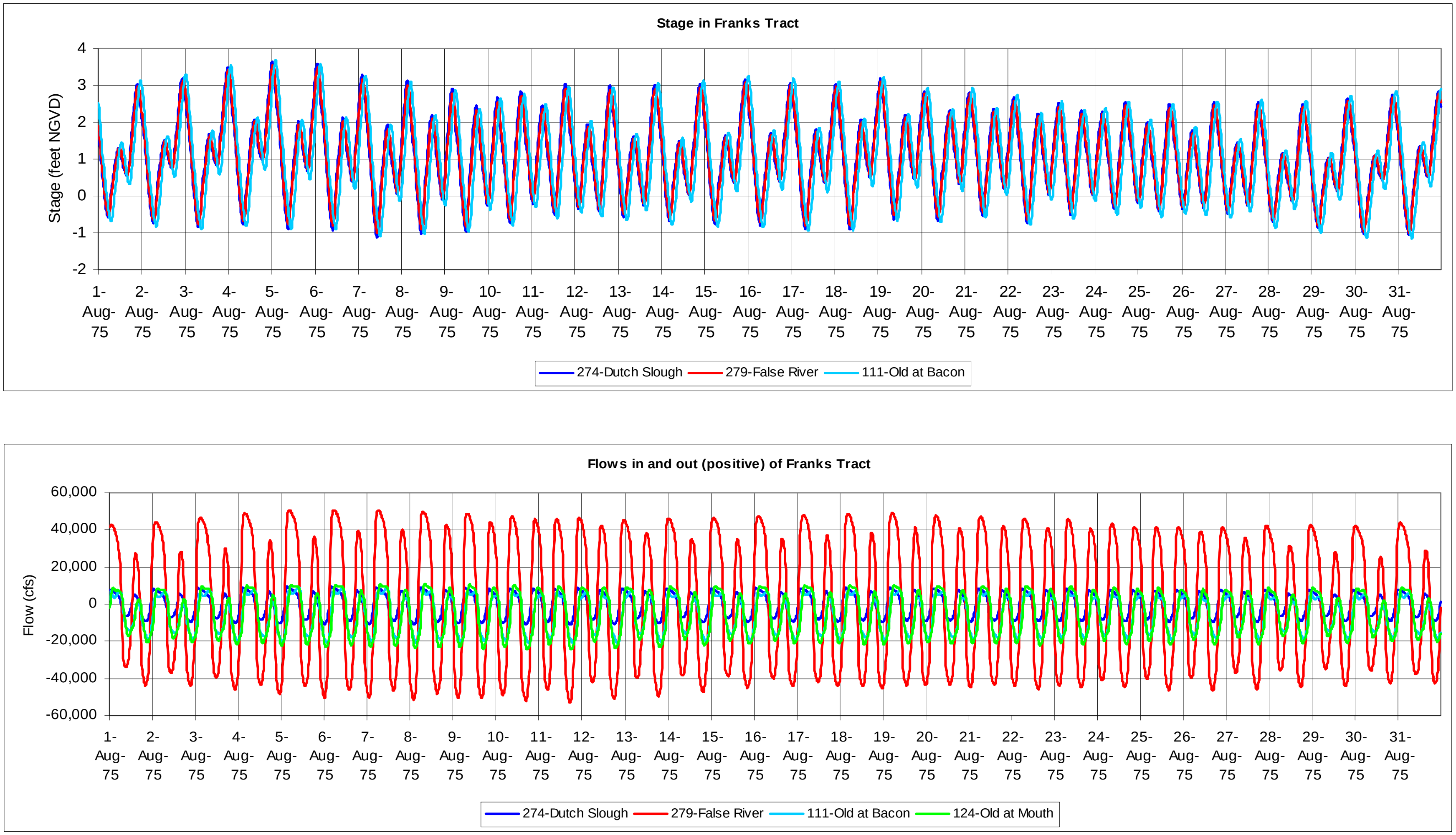

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Figure 10

Simulated Tidal Elevations (Stage) and Tidal Flows near Franks Tract during August 1975 for Future Conditions with SDIP Tidal Gates

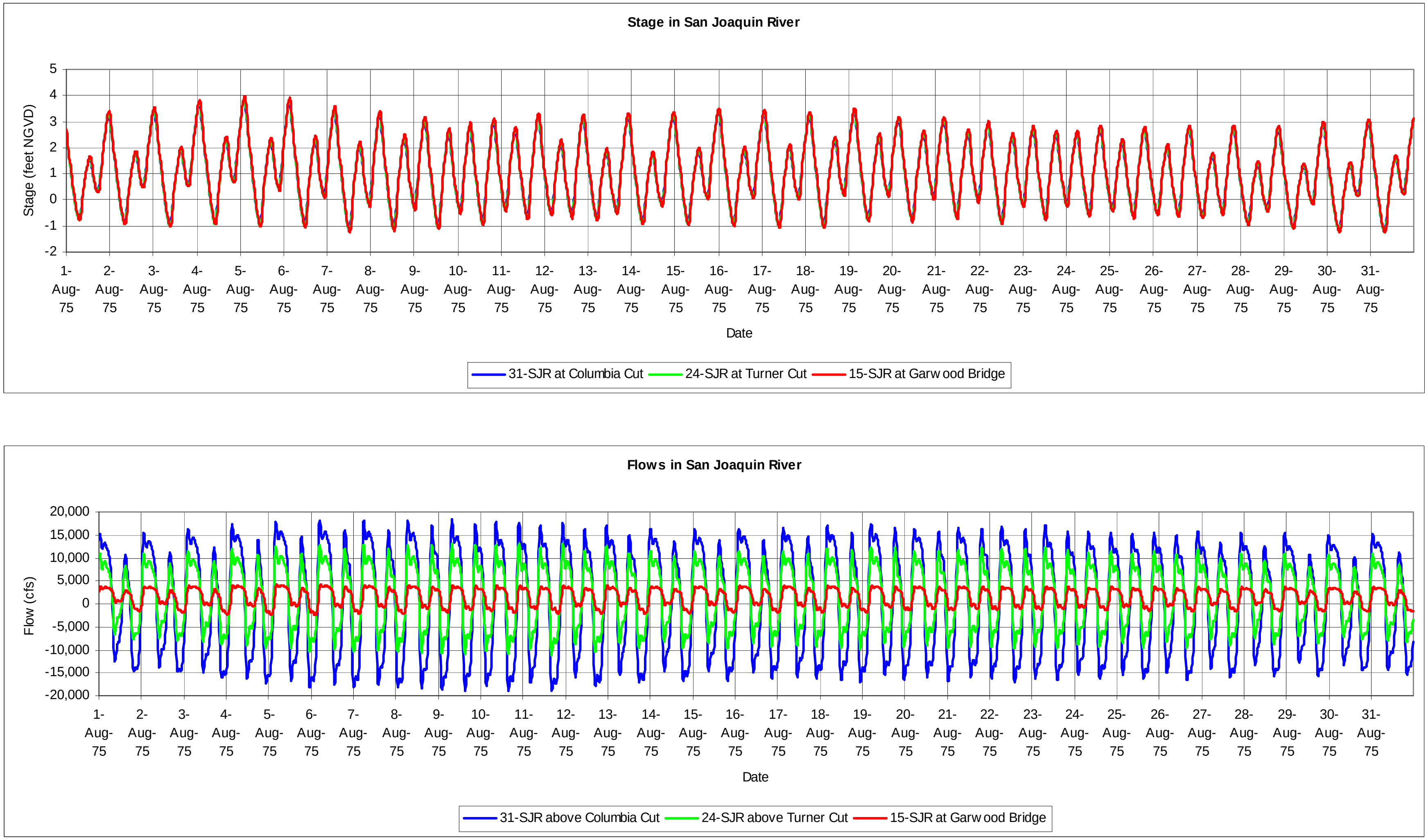

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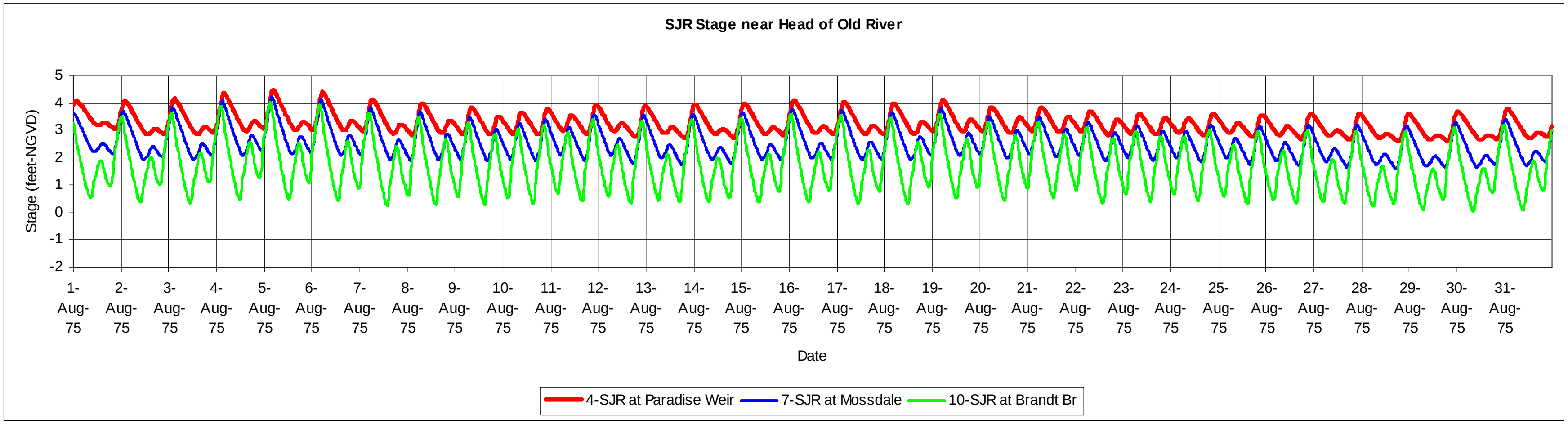
Figure 11

Simulated Tidal Elevations (Stage) and Tidal Flows in the San Joaquin River Channels Upstream of the Mouth of Old River during August 1975 for Future Conditions with SDIP Tidal Gates



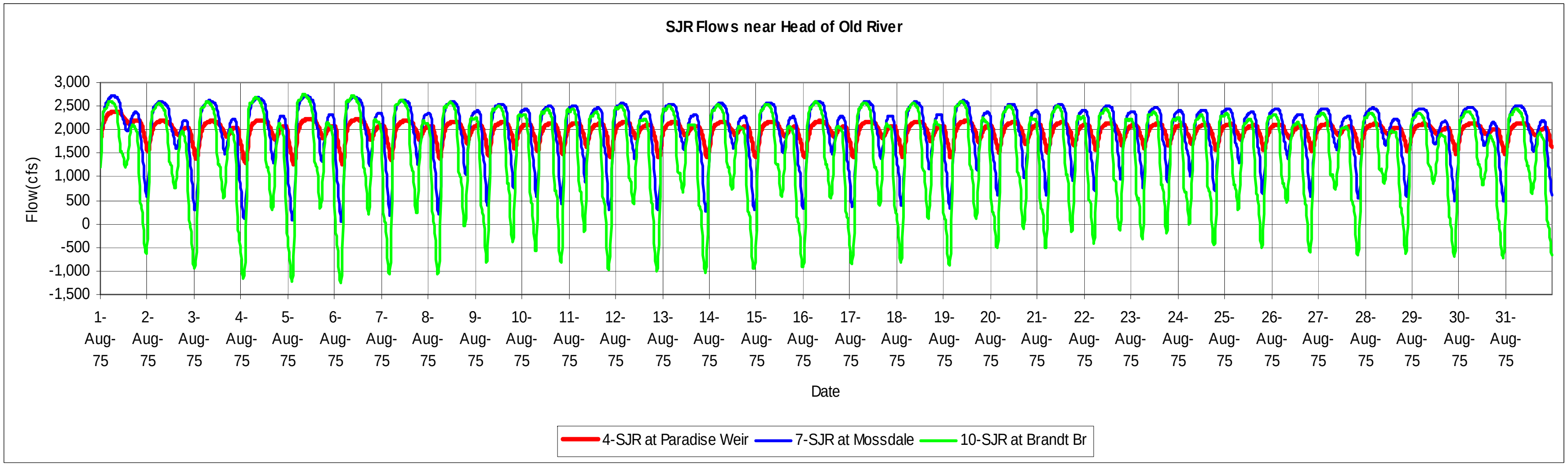


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Figure 12

Simulated Tidal Elevations (Stage) and Tidal Flows along the San Joaquin River near the Head of Old River during August 1975 for Future Conditions with SDIP Tidal Gates

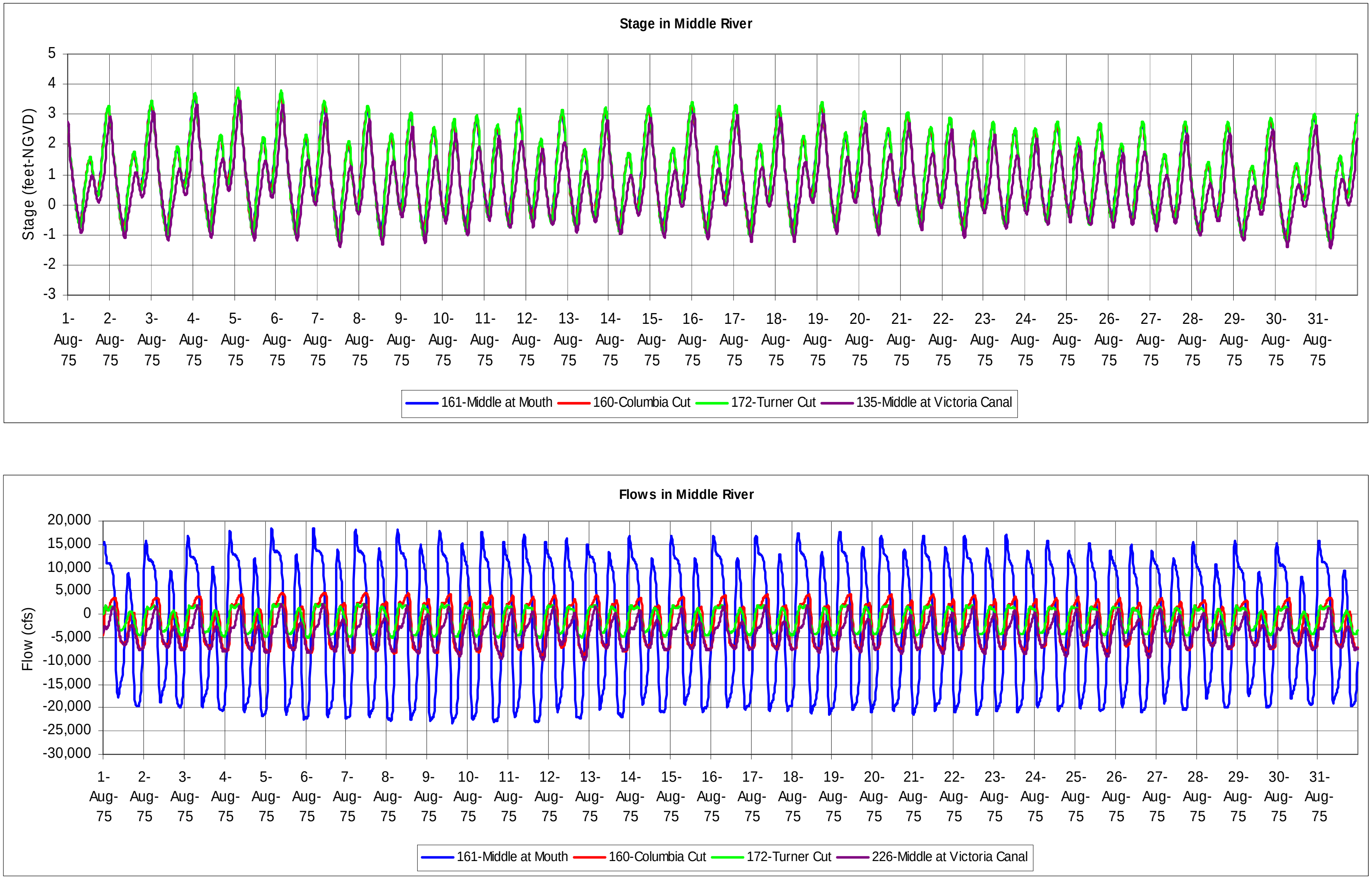

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Figure 13

Simulated Tidal Elevations (Stage) and Tidal Flows in the Middle River Channels Connecting to the San Joaquin River during August 1975 for Future Conditions with SDIP Tidal Gates

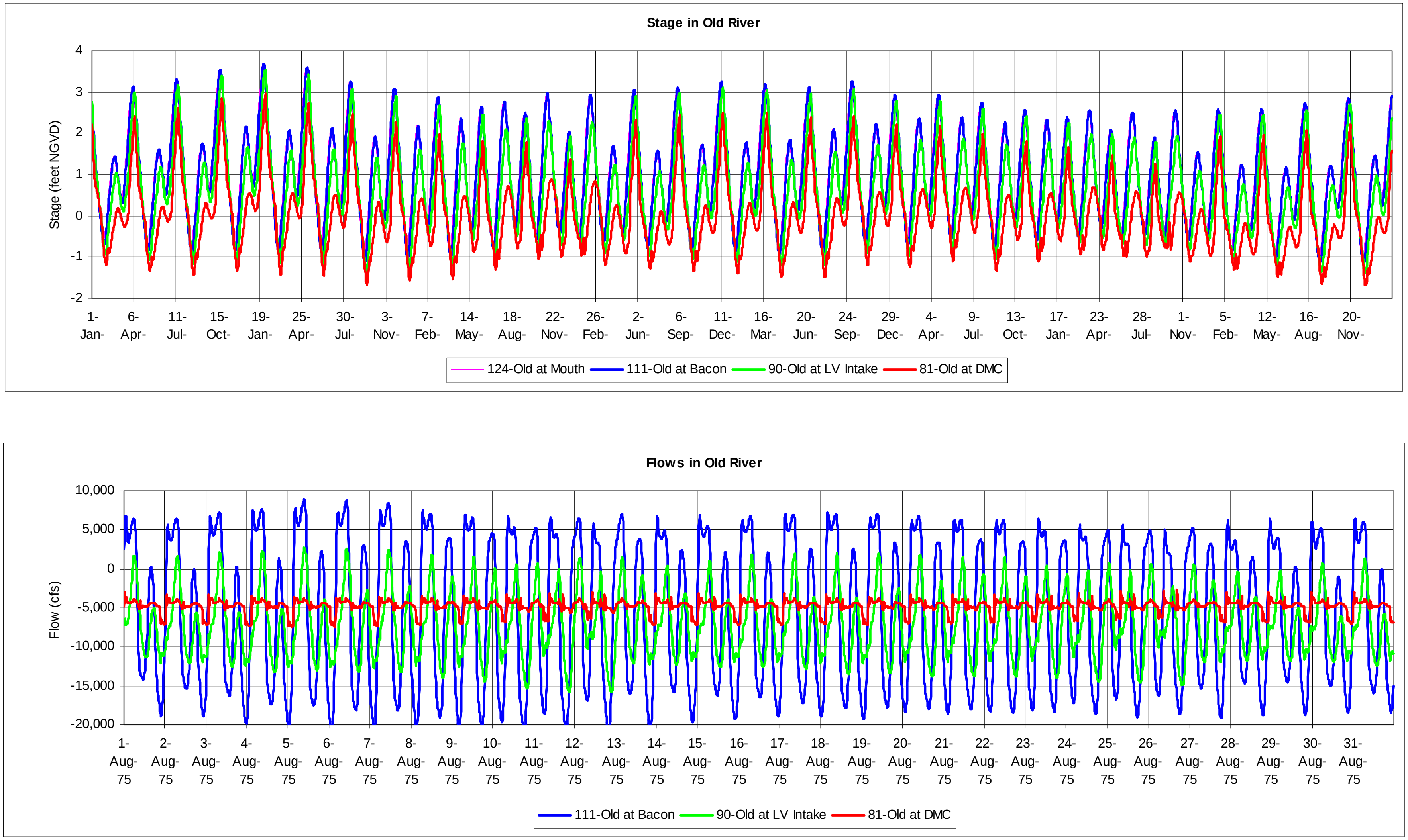

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Figure 14

Simulated Tidal Elevations (Stage) and Tidal Flows in Old River during August 1975 for Future Conditions with SDIP Tidal Gates

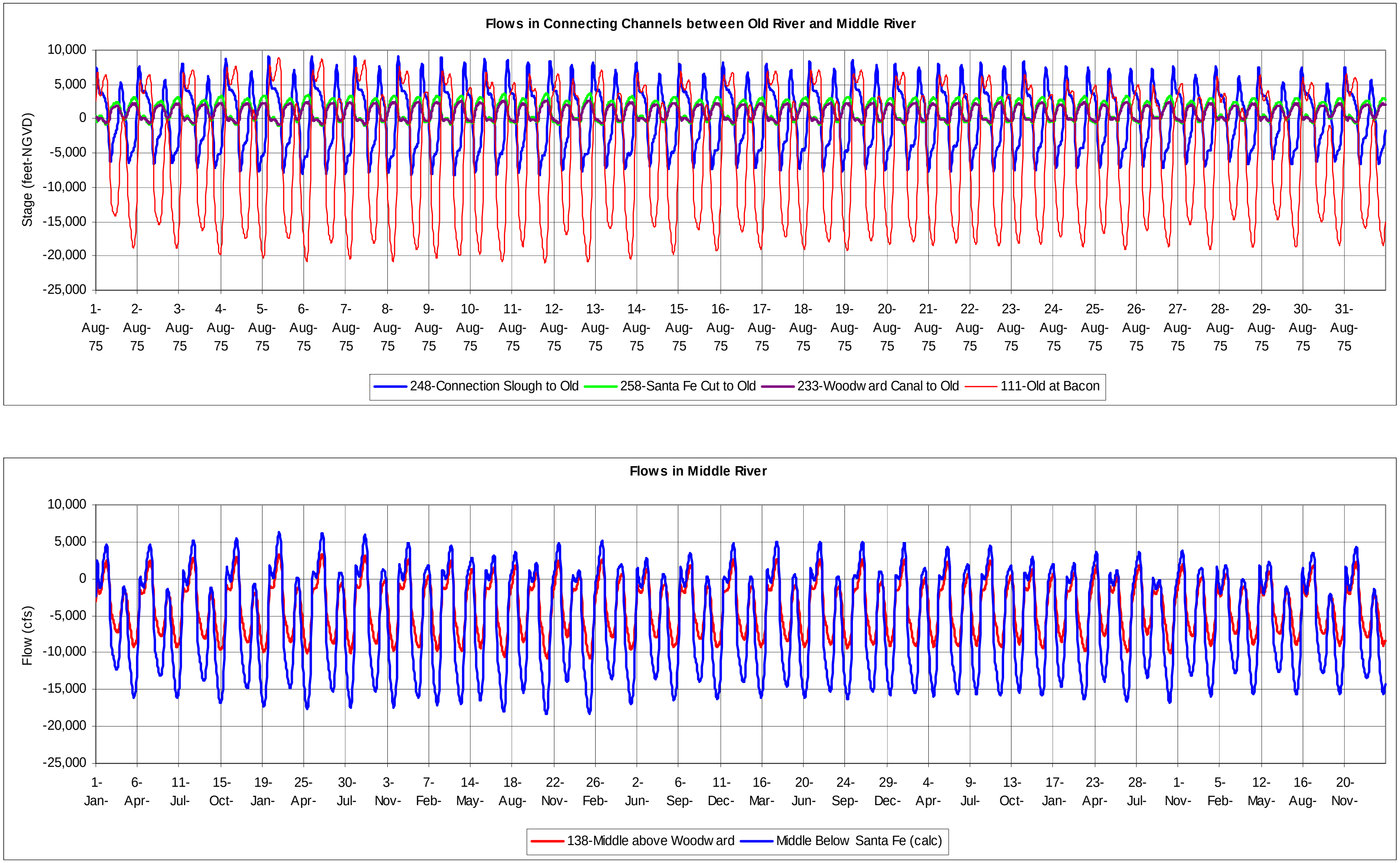

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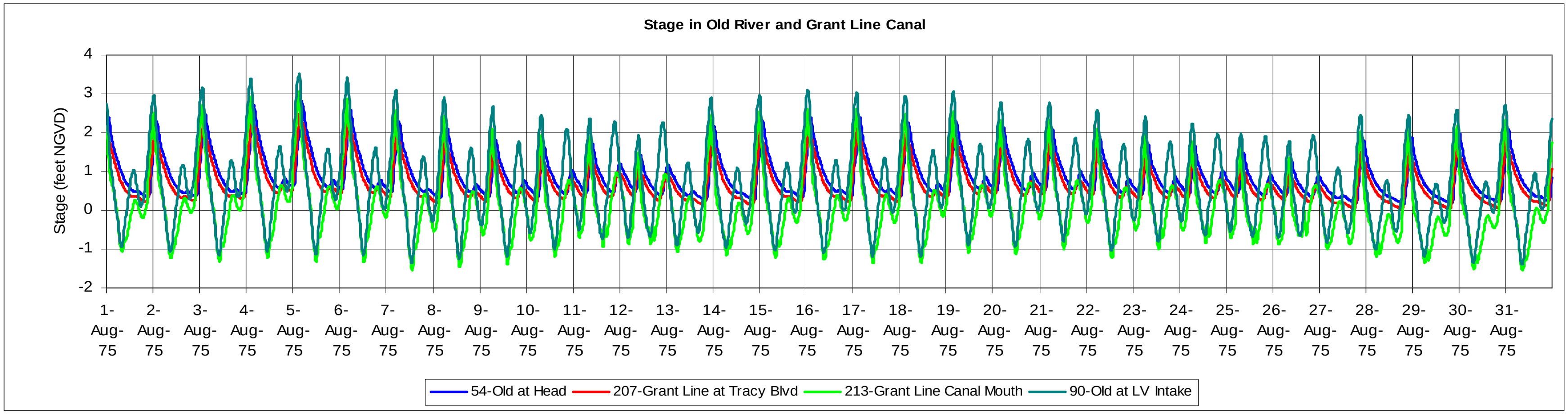
Figure 15

Simulated Tidal Flows in the Middle River and in the Channels Connecting Old River and Middle River during August 1975 for Future Conditions with SDIP Tidal Gates



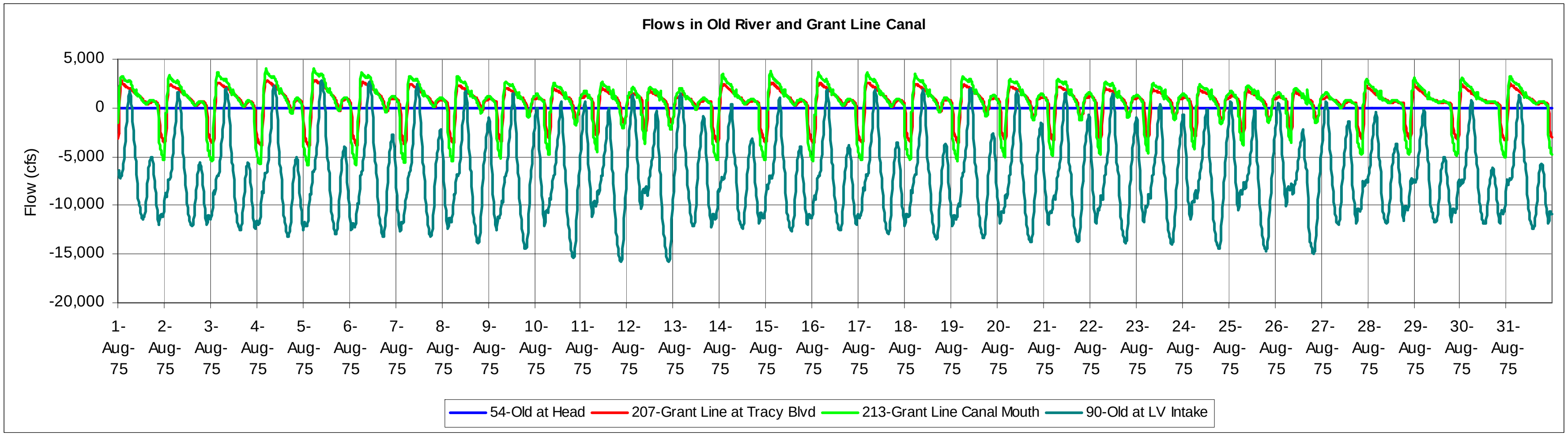


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Figure 16

Simulated Tidal Elevations (Stage) and Tidal Flows in Old River and Grant Line Canal during August 1975 for Future Conditions with SDIP Tidal Gates

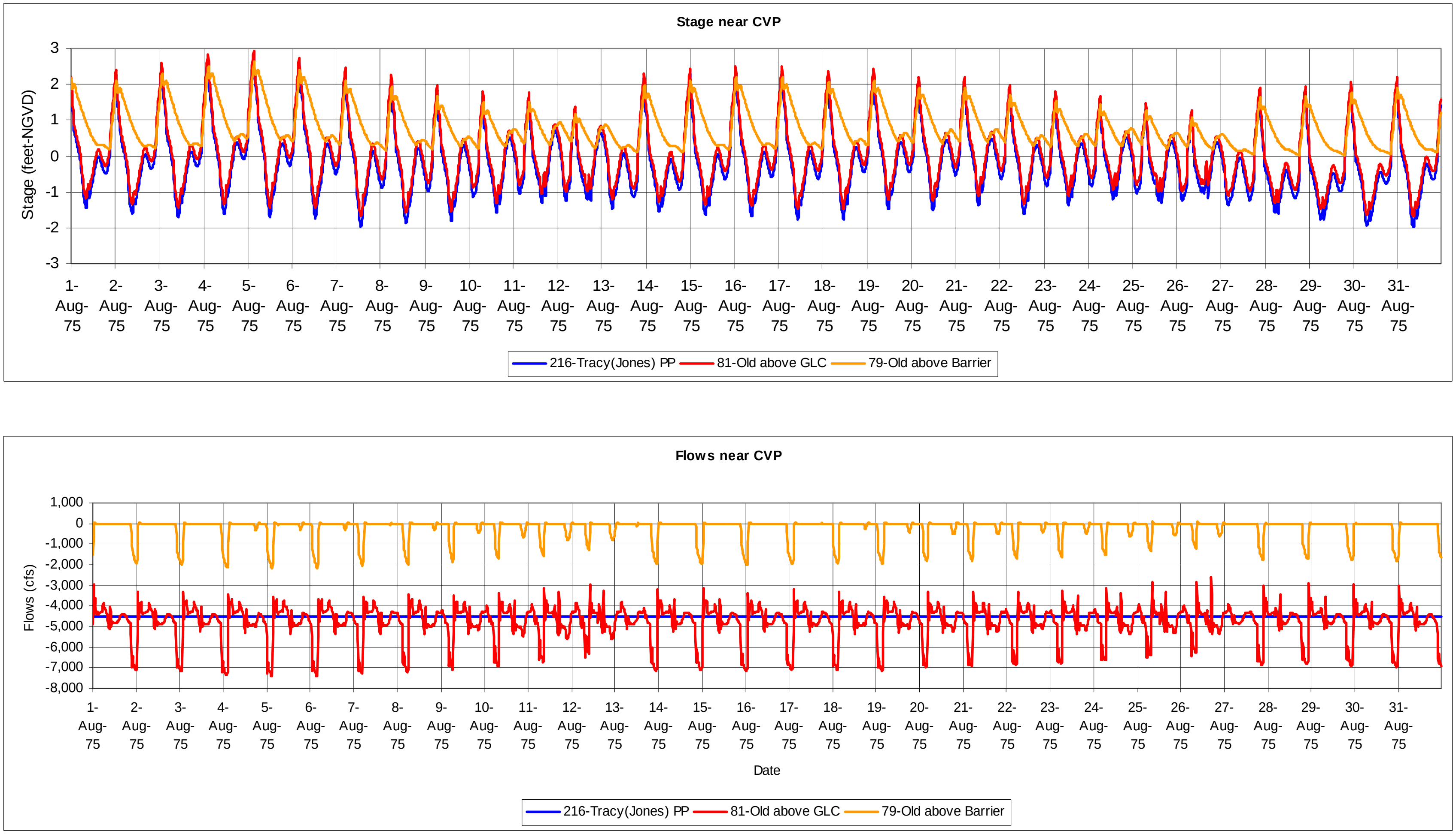

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Figure 17

Simulated Tidal Elevations (Stage) and Tidal Flows near the Delta-Mendota Canal Intake on Old River during August 1975 for Future Conditions with SDIP Tidal Gates

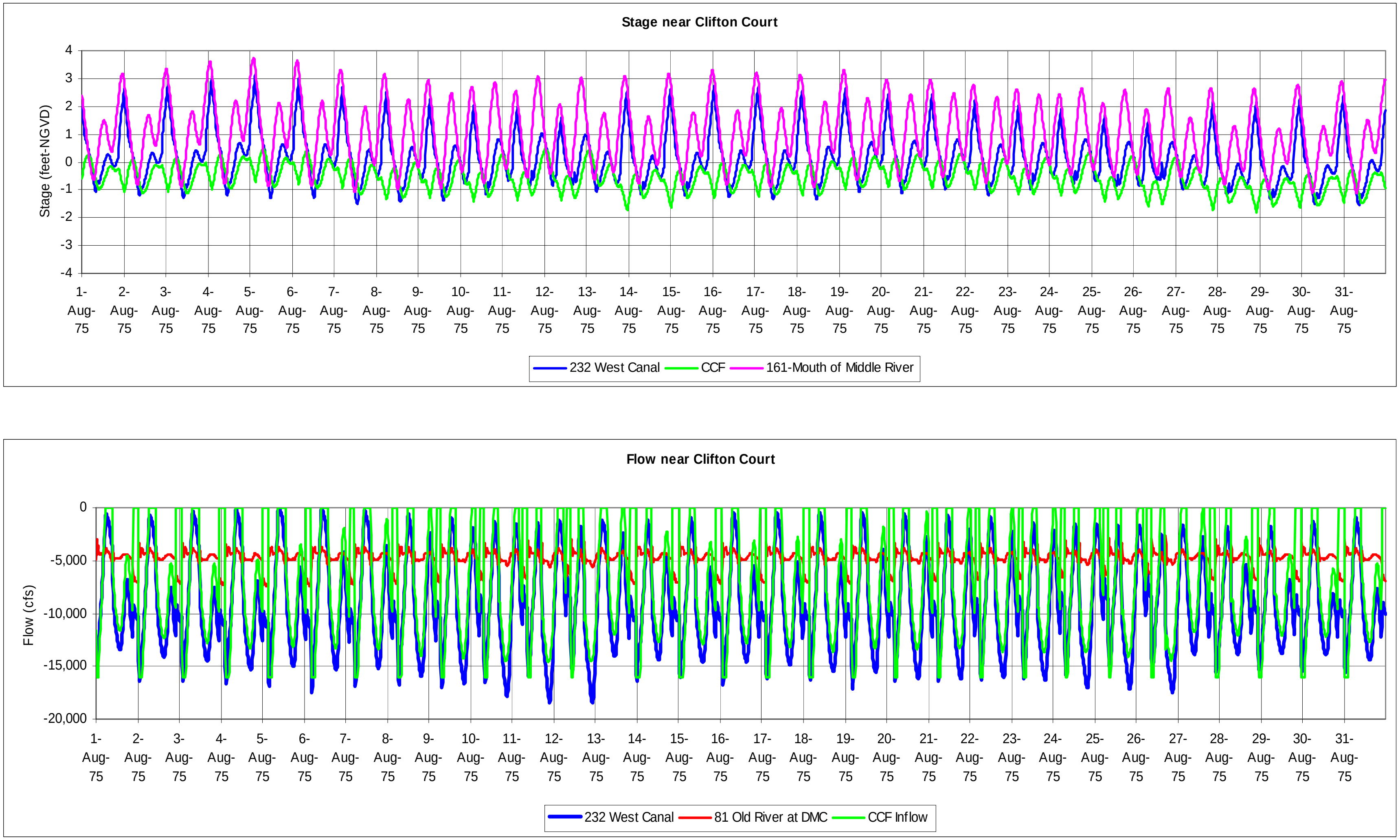
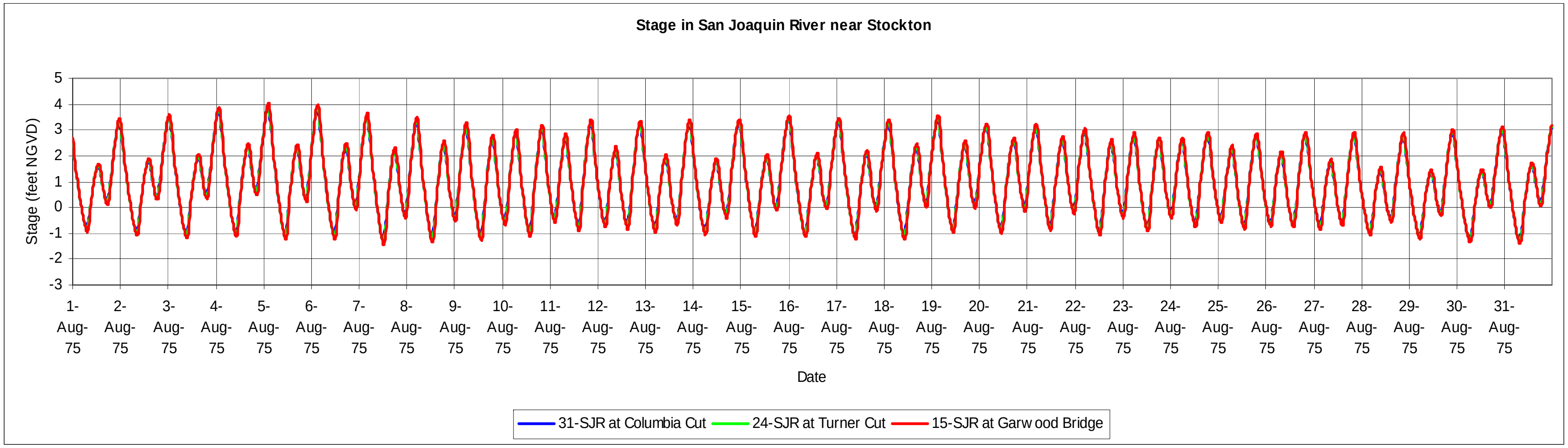


Figure 18

Simulated Tidal Elevations (Stage) and Tidal Flows in West Canal and Clifton Court Forebay during August 1975 for Future Conditions with SDIP Tidal Gates



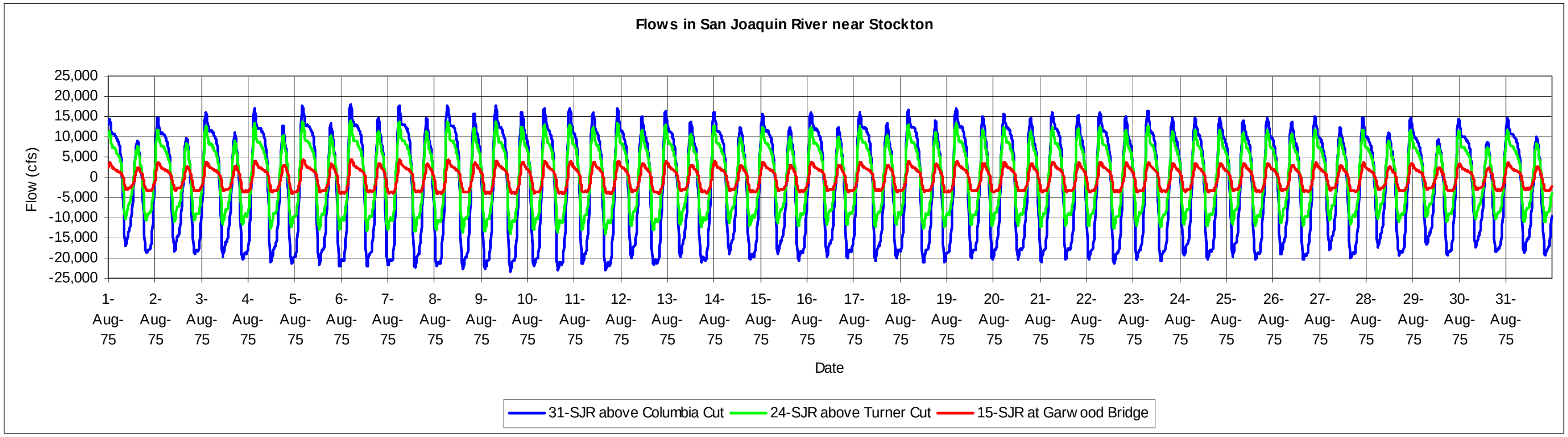


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Figure 19

Simulated Tidal Elevations and Tidal Flows in the San Joaquin River near Stockton during August 1975 for the Dredged Delta Corridors Plan

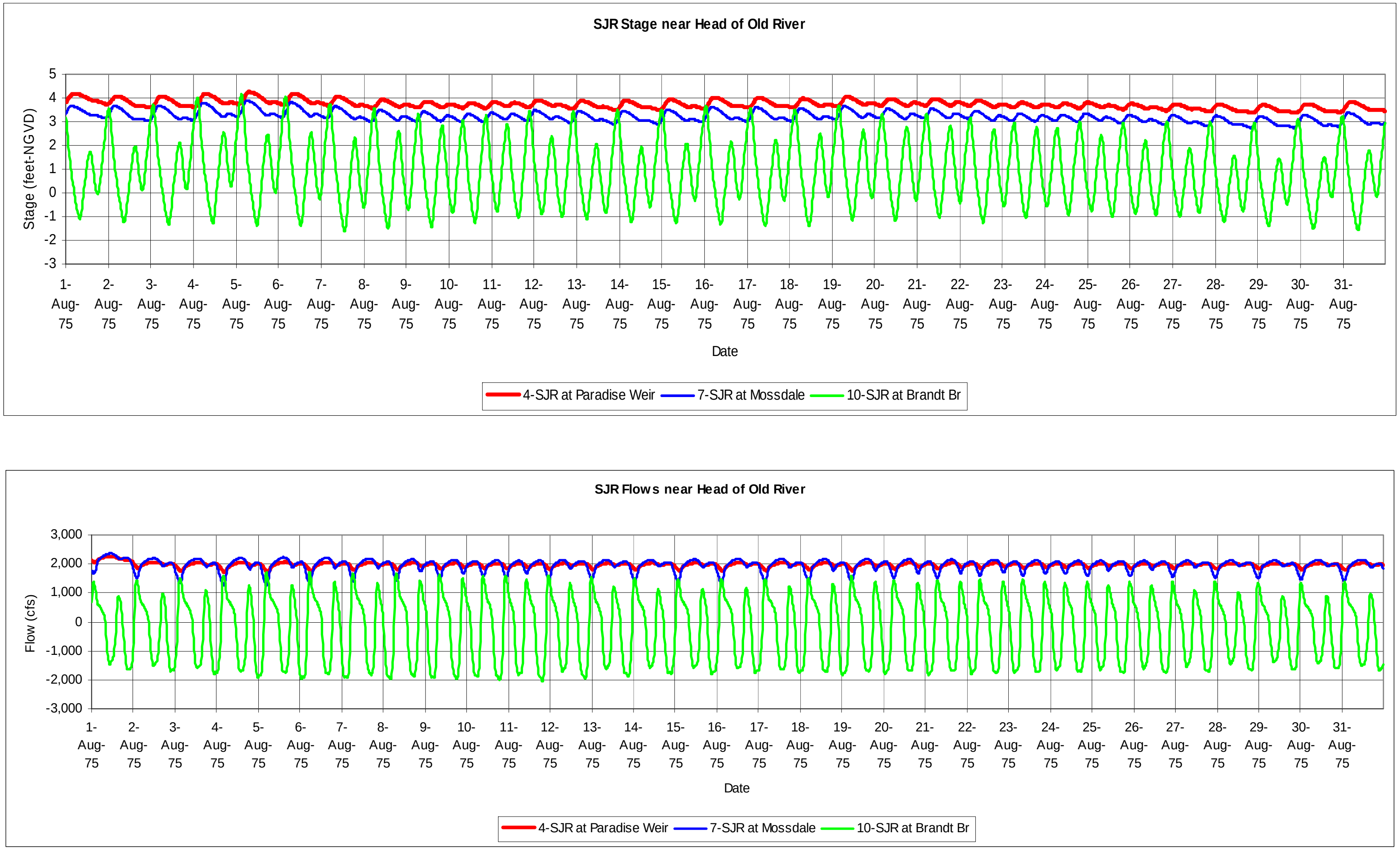

Figure 20

Simulated Tidal Elevations and Tidal Flows in the San Joaquin River near the Head of Old River during August 1975 for the Dredged Delta Corridors Plan

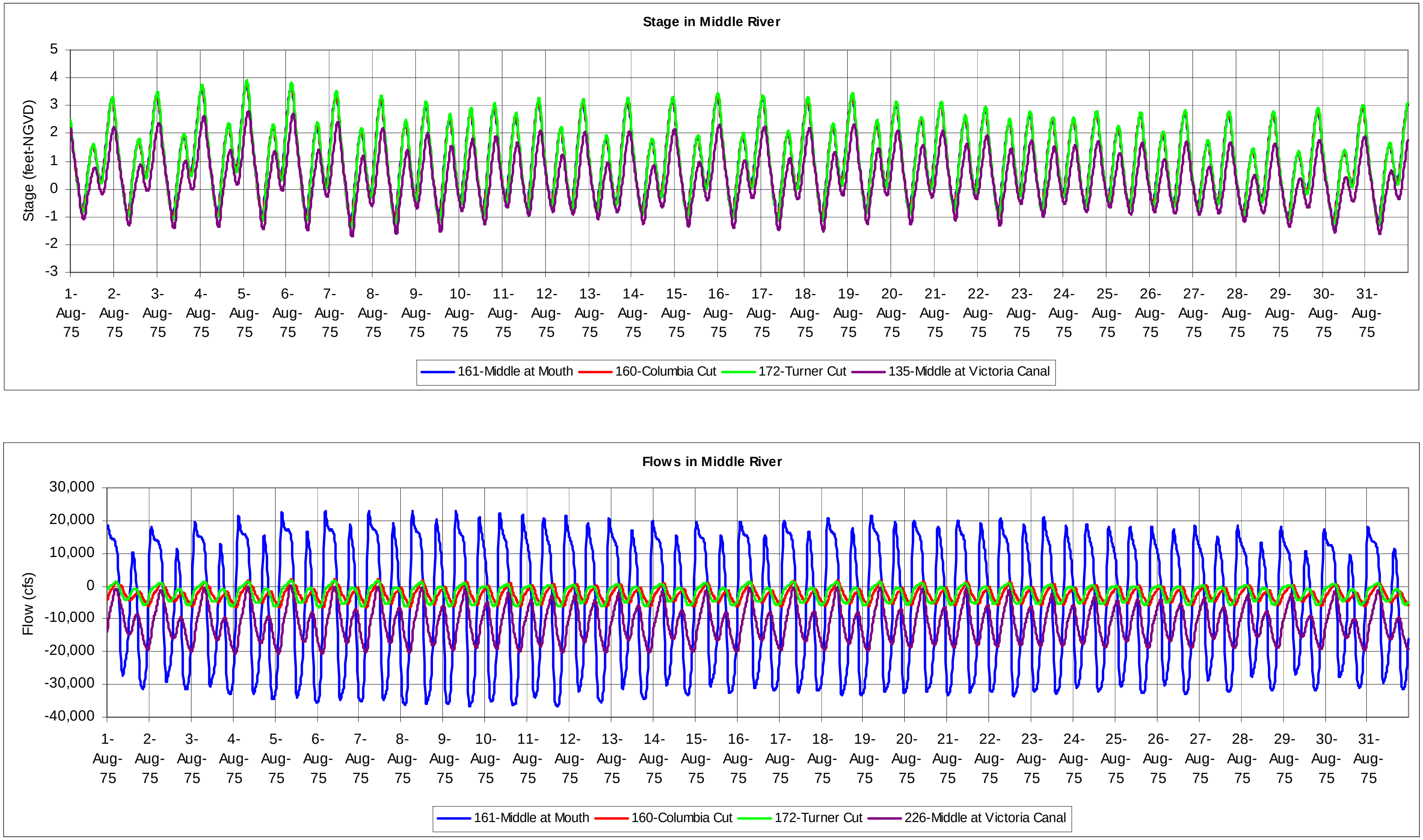

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Figure 21

Simulated Tidal Elevations (Stage) and Tidal Flows in the Middle River Channels Connecting to the San Joaquin River during August 1975 for Dredged Delta Corridors Plan

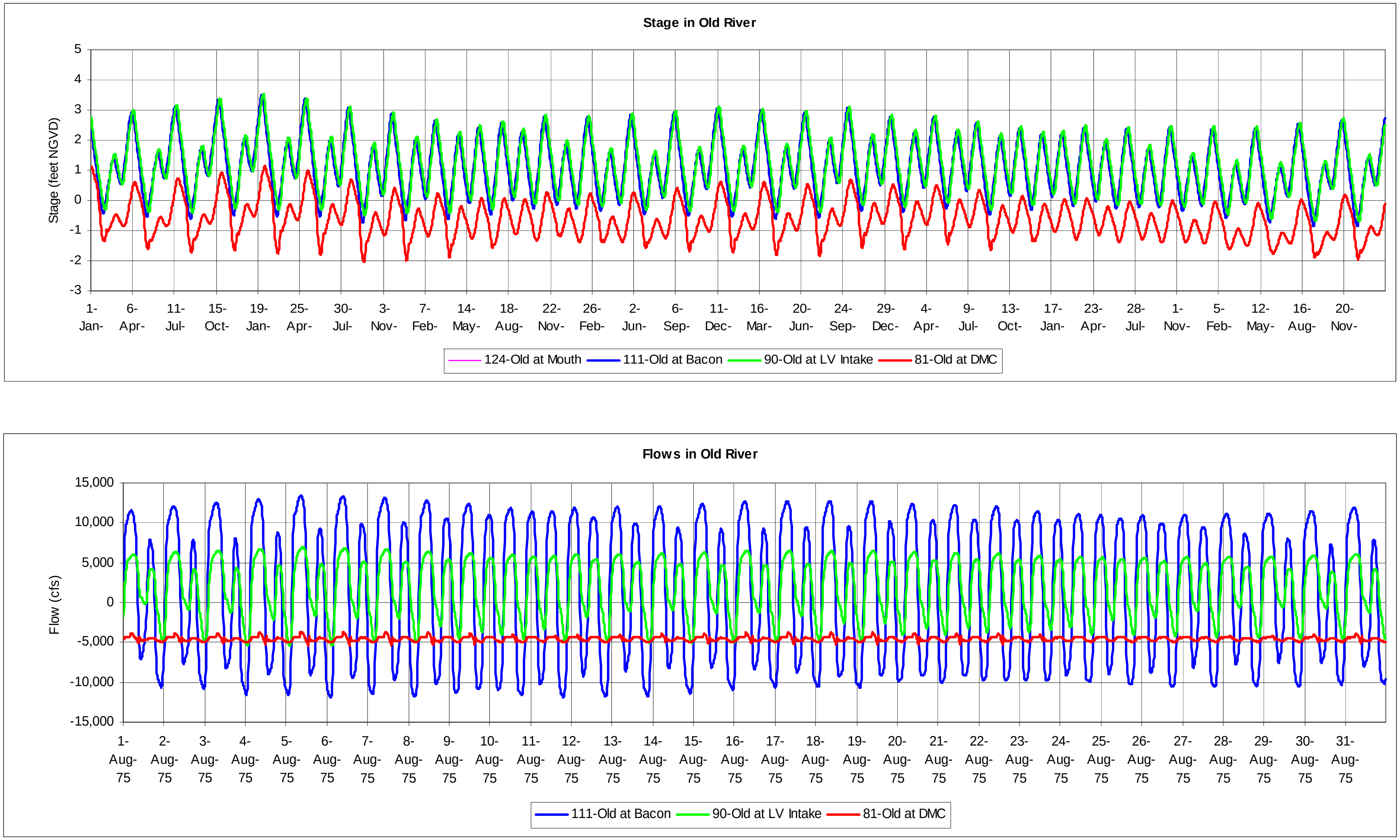

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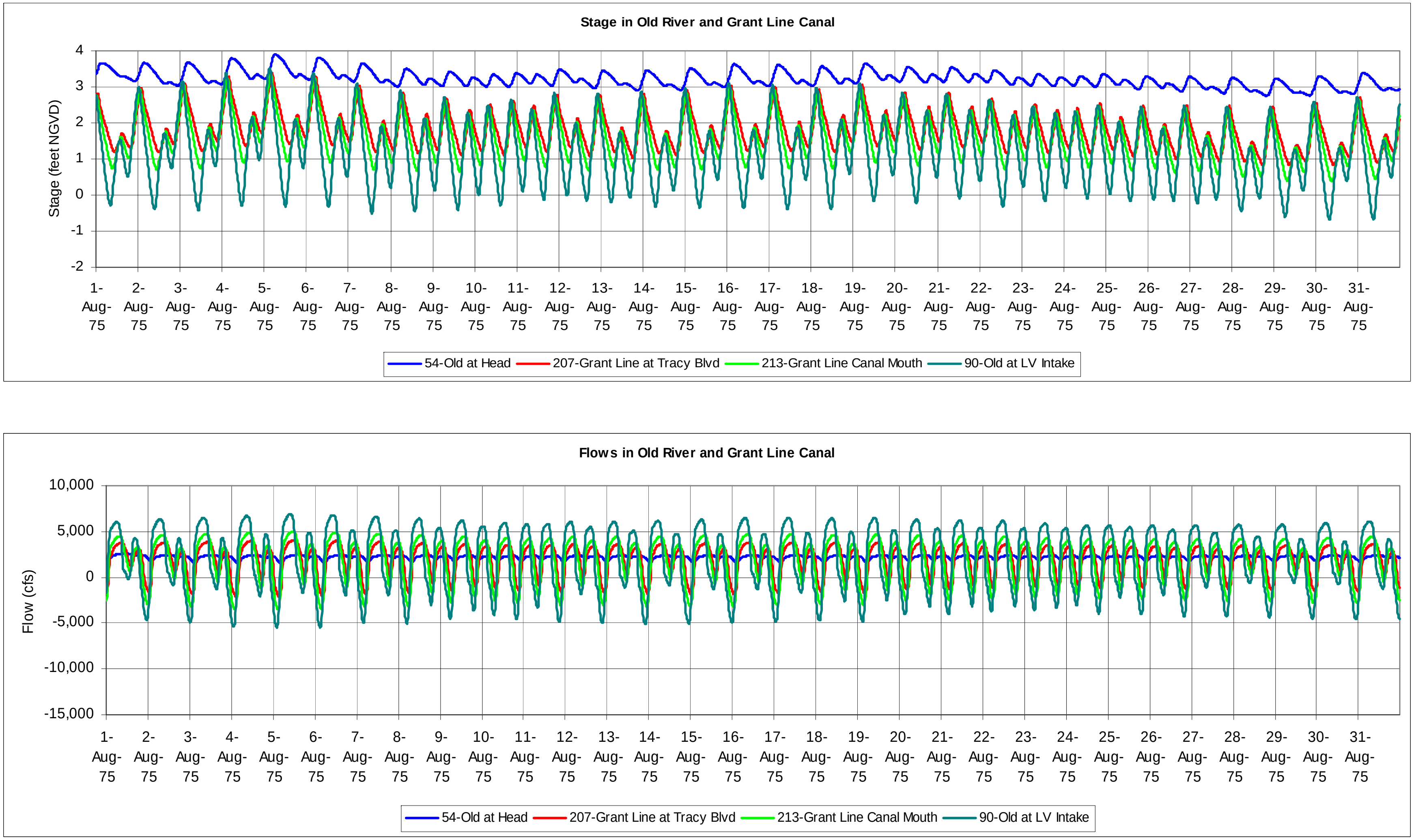
Figure 22

Simulated Tidal Elevations (Stage) and Tidal Flows in Old River during August 1975 for Dredged Delta Corridors Plan


Stage in Old River and Grant Line Canal

Flows in Old River and Grant Line Canal

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Figure 23

Simulated Tidal Elevations (Stage) and Tidal Flows in Old River and Grant Line Canal during August 1975 for Dredged Delta Corridors Plan

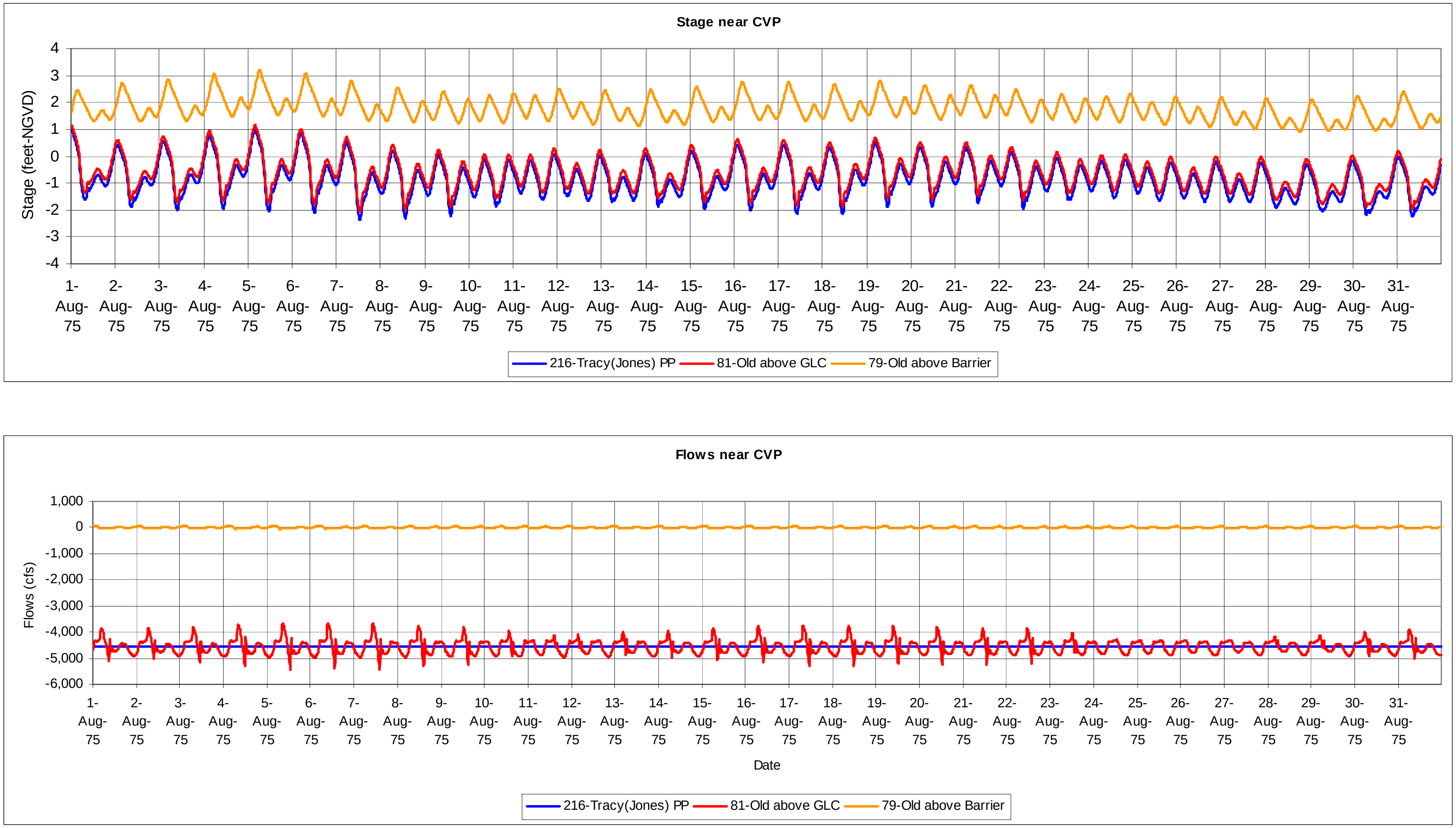

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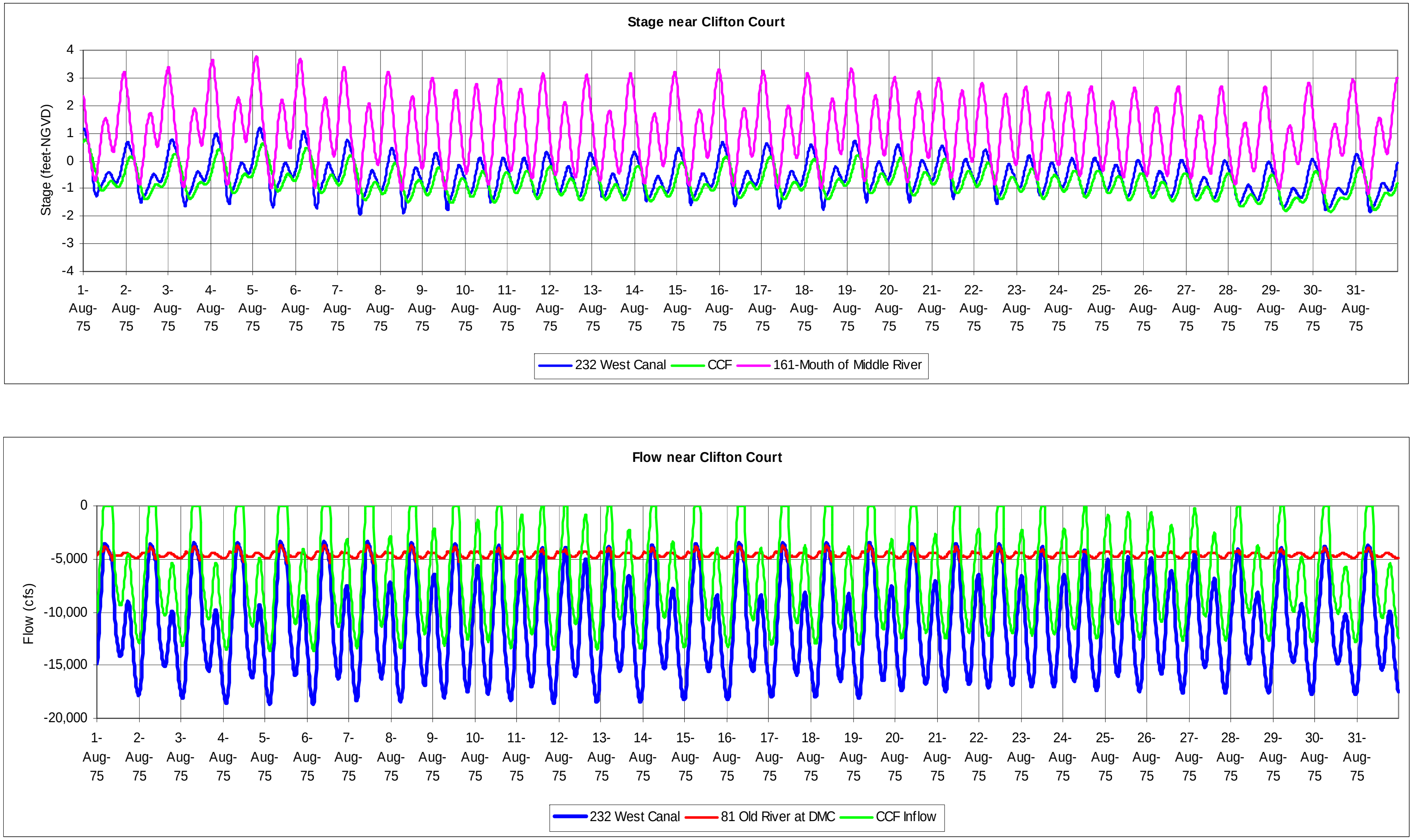
Figure 24

Simulated Tidal Elevations (Stage) and Tidal Flows near the DMC Intake on Old River during August 1975 for Dredged Delta Corridors Plan



00881.07

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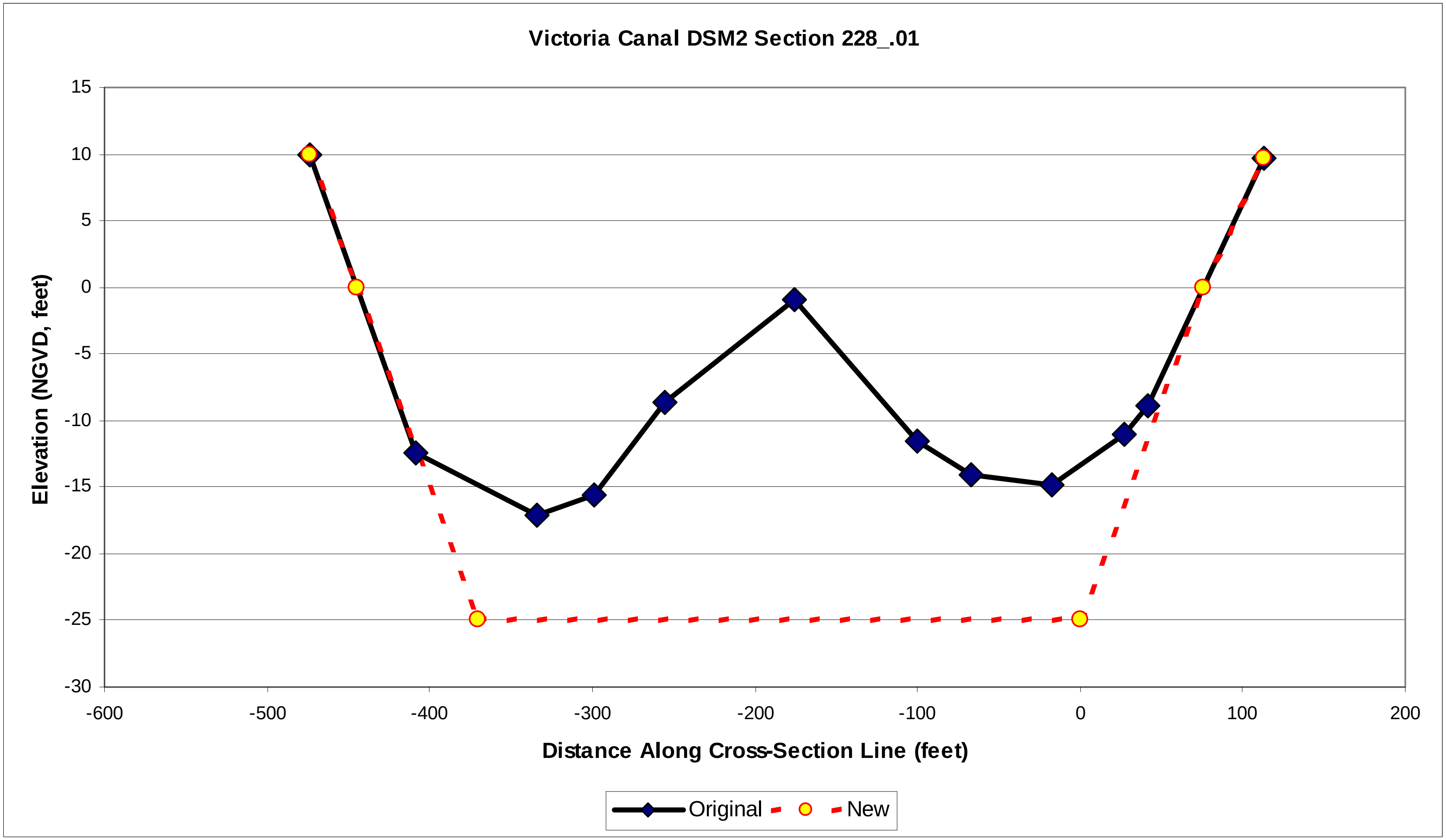
Figure 25

Simulated Tidal Elevations (Stage) and Tidal Flows in West Canal and Clifton Court Forebay during August 1975 for Dredged Delta Corridors Plan

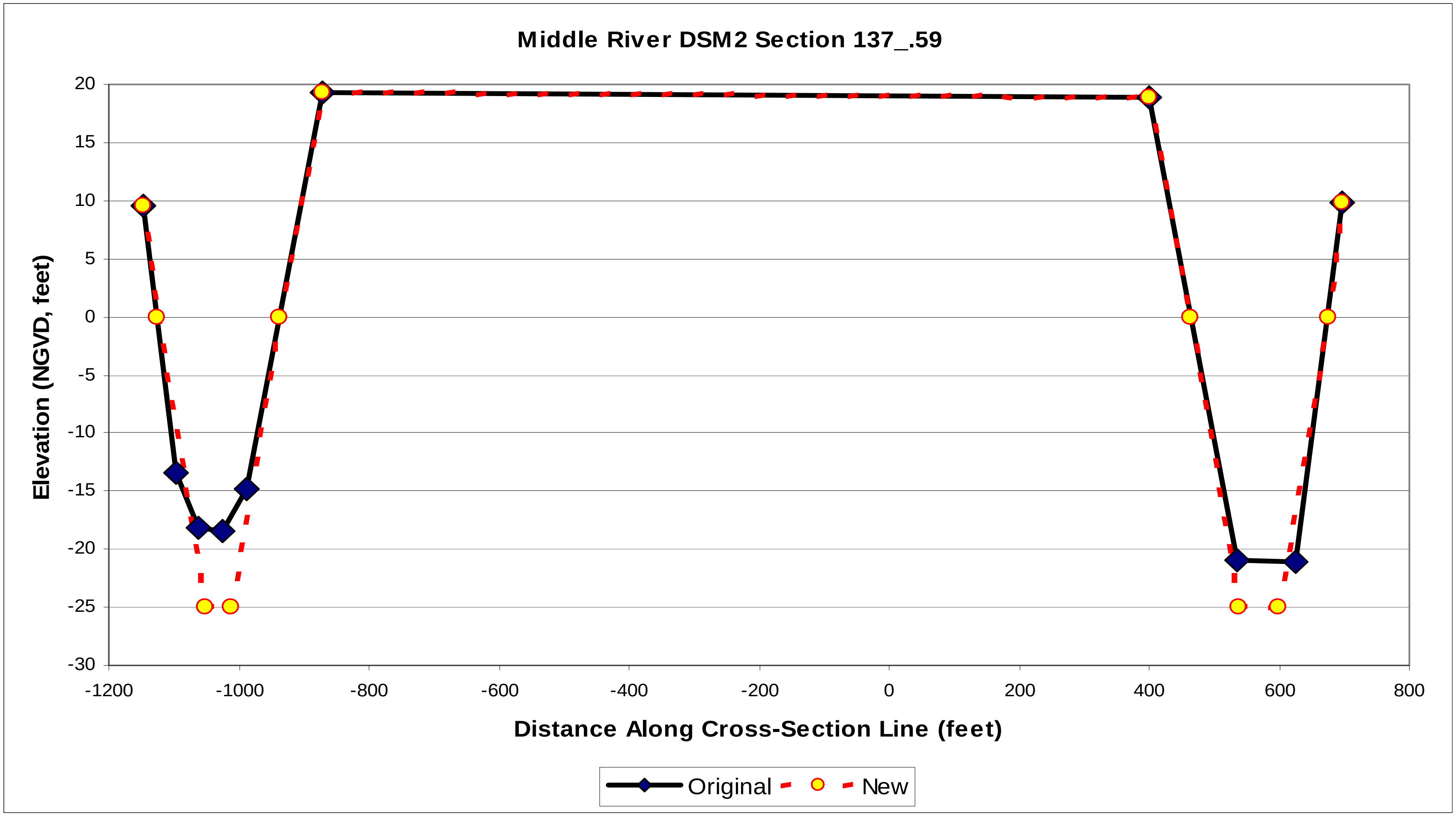


Channel width is 520 feet at 0 feet msl (NGVD) and the cross section area is 5,290 square feet with average depth of about 10 feet. Dredged cross section area is 11,125 square feet with average depth of about 21.5 feet.

Jones & Stokes

Figure 26

Comparison of Original and Dredged DSM2 Channel Section 228.01
Located along Victoria Canal



Channel width is 400 feet at 0 feet msl (NGVD) and the cross section area is 5,585 square feet with average depth of about 14 feet. Dredged cross section area is 6,250 square feet with average depth of about 15.5 feet. This section may require widening to provide cross section area of about 10,000 square feet to convey the full existing water supply exports of about 12,000 cfs.

00881.07

Jones & Stokes

Figure 27

Comparison of Original and Dredged DSM2 Channel Section 137.59
Located along Middle River Upstream of Woodward Cut