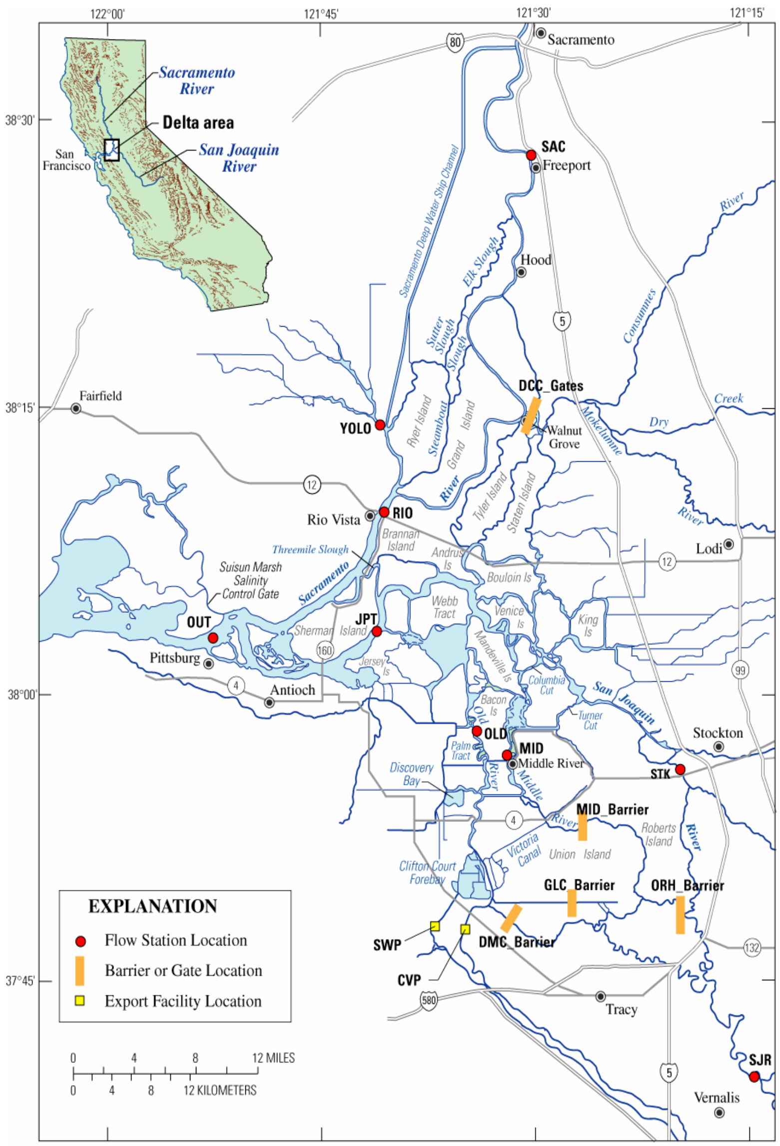
Summary of Delta Hydrology Data
Water Years 1985 - 2004

Joseph Simi and Catherine Ruhl
United States Geological Survey
josimi@usgs.gov or caruhl@usgs.gov
(916) 278-3270 or (916) 278-3129

Introduction

The Sacramento-San Joaquin Delta (Delta) is a complex network of over 700 miles of tidally influenced channels and sloughs (Fig. 1). Over 20 million people depend on the Delta for drinking water; 4.5 million acres of cropland are irrigated with Delta water; and several native threatened or endangered fish species reside in or migrate through the Delta.

There are three strong forcing mechanisms driving circulation, transport, and mixing in the Delta: 1) riverine input from the north, south, and east; 2) tides propagating from the Pacific Ocean through San Francisco Bay from the west; and 3) State and Federal export facilities operating in the Southern Delta. Temporary barriers in the South Delta and the Delta Cross Channel Gates near Walnut Grove, CA add further complexity to the circulation and mixing in the Delta (Fig 1).



Location of flow station sites in the Delta Area of California.

Figure 1: Delta Map showing flow, export, barrier and gate locations.

Data Sources

Flows at key Delta locations; State and Federal export rates; South Delta barrier and Delta Cross Channel gate operations; and X2 data were compiled and analyzed for this summary (Table 1). Data were taken from DAYFLOW model output (http://www.iep.ca.gov/dayflow/); the United States Geological Survey (USGS) Delta Flows Monitoring Network (http://baydelta.wr.usgs.gov/cgi-bin/std_data_retrieval_02.pl?mode=historical); and operational summaries for the South Delta barriers and Delta Cross Channel gates (http://sdelta.water.ca.gov/web_pg/tempbsch.htm and

This is a draft work in progress subject to review and revision as information becomes avialable.

http://www.usbr.gov/mp/cvo/vungvari/Ccgates.pdf). While the period of record for some of these data sets dates back as far as 1955 the focus of this analysis will be on the period of water year 1985 through water year 2004.

Table 1: Summary of Delta Hydrology, Operations, and Barrier Data collected

Site	Source	Period of Record
Sacramento River and Yolo Bypass		
Sacramento River at Freeport (SAC)	DAYFLOW	10/1/55 – 9/30/04
Sacramento River at Rio Vista (RIO)	DAYFLOW	10/1/55 – 9/30/04
Yolo Bypass (YOLO)	DAYFLOW	10/1/55 – 9/30/04
San Joaquin River		
San Joaquin River at Vernalis (SJR)	DAYFLOW	10/1/55 – 9/30/04
San Joaquin River at Stockton (STK)	USGS	8/18/95 – 9/30/04
San Joaquin River at Jersey Point (JPT)	USGS	5/11/94 – 1/31/05
Old and Middle Rivers		
Old River at Bacon Island (OLD)	USGS	1/6/87 – 3/20/04
Middle River at Middle river (MID)	USGS	1/9/87 – 12/31/02
Delta Outflow and X2		
Delta Outflow at Chipps Island (OUT)	DAYFLOW	10/1/55 – 9/30/04
X2 position (X2)	DAYFLOW	10/1/96 – 9/30/04
Exports		
Central Valley Project (CVP)	DAYFLOW	10/1/55 – 9/30/04
State Water Project (SWP)	DAYFLOW	10/1/55 – 9/30/04
Barrier and Gate Operations		
Delta Cross Channel (DCC_Gates)	USBR	3/15/85 – 6/14/02
Grant Line Canal (GLC_Barrier)	DWR	6/17/96 – 8/17/05
Delta-Mendota Canal (DMC_Barrier)	DWR	8/14/91 – 8/17/05
Middle River Barrier (MID_Barrier)	DWR	5/15/87 – 8/17/05
Old River Head (ORH_Barrier)	DWR	9/30/68 – 8/17/05

Daily means were compiled for all of the sites listed above (Table 1). Data was taken directly from the posted DAYFLOW summaries. Flow data collected at the USGS flow monitoring sites were processed using a Butterworth filter to remove the influence of the tides and the resulting filtered data were averaged to determine the daily flows. Barrier and gate operating schedules were represented as daily values defining the channel as open (0), partially closed (0.5), or closed (1).

In addition to the data presented in this summary, an excel spreadsheet and graphs of all of the data collected are posted to a public ftp site: ftp://ftpext.usgs.gov/pub/wr/ca/sacramento/pod. Each parameter has the following sets of graphs:

Yearly mean values for the entire period of record.
Monthly mean values for data collected since 1985.
Deviations of monthly values from monthly means for the period since 1985.

Analysis

The data summarized in this report can be broadly categorized into inflows to, outflows from, or barriers to flow within the Delta. Runoff enters the Central Valley watershed primarily from the

Sierra Nevada Mountains to the east and is conveyed into the Delta by the Sacramento River from the north, the San Joaquin River from the south, and east-side streams including the Mokelumne and Cosumnes Rivers. During water years 1985 to 2004, the Sacramento River contributed an average of 85 percent, the San Joaquin River contributed an average of 11 percent, and the east-side streams contributed the remaining 4 percent of the total flow entering the Delta (Fig 2) (DAYFLOW, 1978).

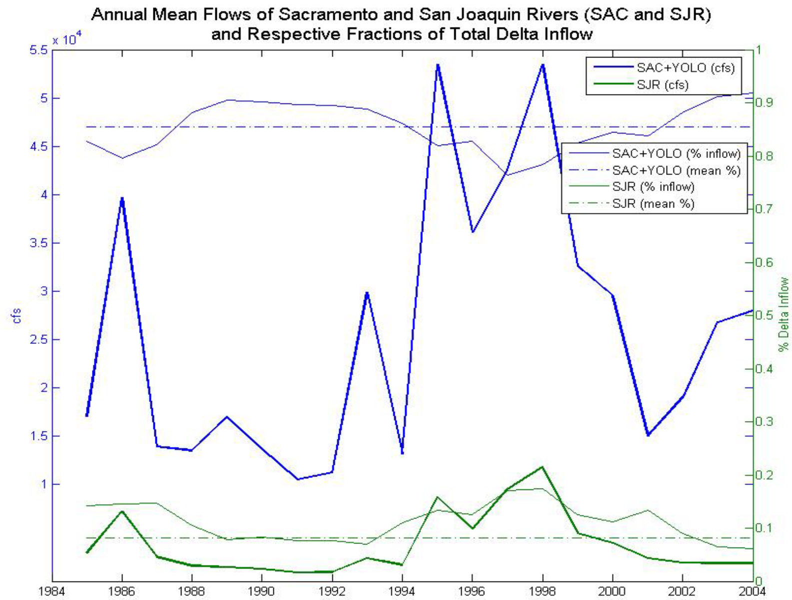


Figure 2: Annual Mean Flows and Percent of Total Inflows of Sacramento and San Joaquin Rivers (SAC+YOLO & SJR)

Since 2000, the percentage of water entering the Delta from the Sacramento River has been increasing (from 84.5 % in water year 2000 to 91.8 % in water year 2004) and the percentage of water entering the Delta from the San Joaquin River has been generally decreasing (from 11.2 % in water year 2000 to 6.2 % in water year 2004).

Flows into the Delta vary seasonally. Flows generally reach their peak during spring and tend to gradually decrease through late-summer to early-fall. The trend is similar on both the Sacramento and San Joaquin Rivers (Fig 3).

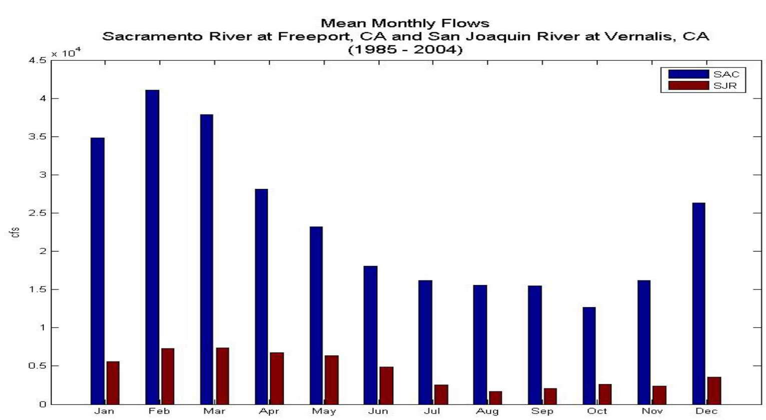


Figure 3: Monthly Mean Flows of Sacramento and San Joaquin Rivers (SAC & SJR)

Sacramento River and Yolo Bypass

Figure 4 summarizes monthly flow data for three sites which characterize the hydrology along the Sacramento River: Sacramento River at Freeport (SAC); Yolo Bypass (YOLO); and Sacramento River at Rio Vista (RIO). The highest flows are recorded at the Sacramento River at Rio Vista as this site receives contributions from both the Sacramento River at Freeport and the Yolo Bypass. The highest monthly flow at Rio Vista during this period was 20,300 cubic feet per second (cfs) in February of 1997 and the lowest was 2169 cfs in December of 1993.

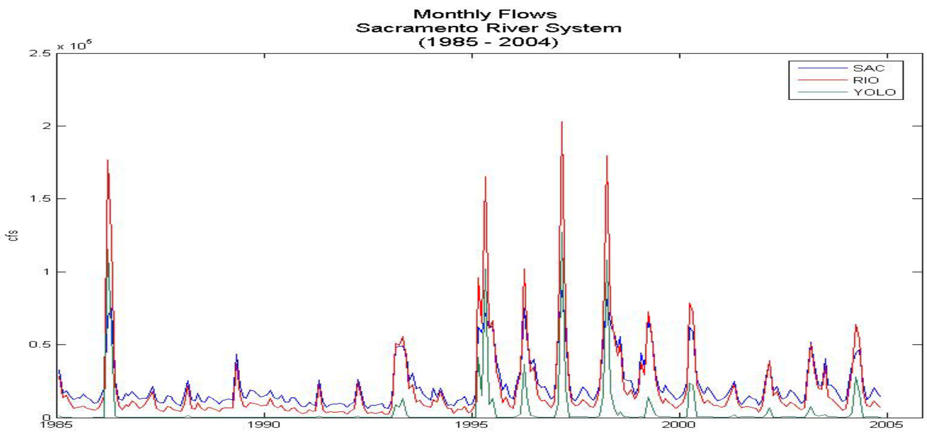


Figure 4: Monthly flows in Sacramento River system, 1985 – 2004 at Sacramento River at Freeport (SAC); Sacramento River at Rio Vista (RIO); and Yolo Bypass (YOLO).

Since 2000, the Sacramento River reached a relative low in 2001 with increasing peak and annual mean flows since that time. The Yolo Bypass as spilled in each year since 2000, ranging from a peak of approximately 5150 cfs in 2001 to a peak of approximately 105,000 cfs in 2004.

San Joaquin River

Figure 5 summarizes the average monthly flows on the San Joaquin River at three sites: San Joaquin River at Vernalis (SJR), San Joaquin River near Stockton (STK), and San Joaquin River at Jersey Point (JPT). The highest flow during this period at SJR was 35,000 cfs recorded in March of 1997; the lowest recorded monthly flow was 446 cfs, recorded in August of 1993.

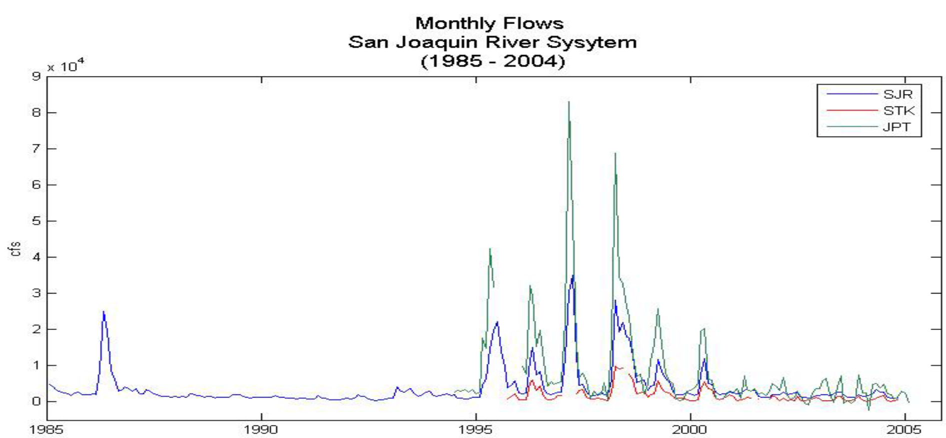


Figure 5: Monthly flows in San Joaquin River system, 1985 – 2004 at San Joaquin River at Vernalis (SJR); San Joaquin River at Stockton (STK); and San Joaquin River at Jersey Point (JPT).

The flows are consistently lower on the San Joaquin River at Stockton than on the San Joaquin River at Vernalis because the flow split at Old River allows San Joaquin River water to flow towards the export facilities. During the spring and fall, the South Delta temporary barriers may be in place which changes the flow split at the San Joaquin River / Old River junction, keeping more water in the main-stem San Joaquin River.

The flows on the San Joaquin River at Jersey Point are somewhat decoupled with upstream San Joaquin River flows because of the influences of the Mokelumne River system to the east, and San Francisco Bay to the west.

Peak flows measured at the San Joaquin River at Vernalis (SJR) since 2001 have been significantly lower than the period 1995 – 2000. In addition, monthly average flows have been consistently below the period (1985 – 2004) average through all seasons (Fig. 6).

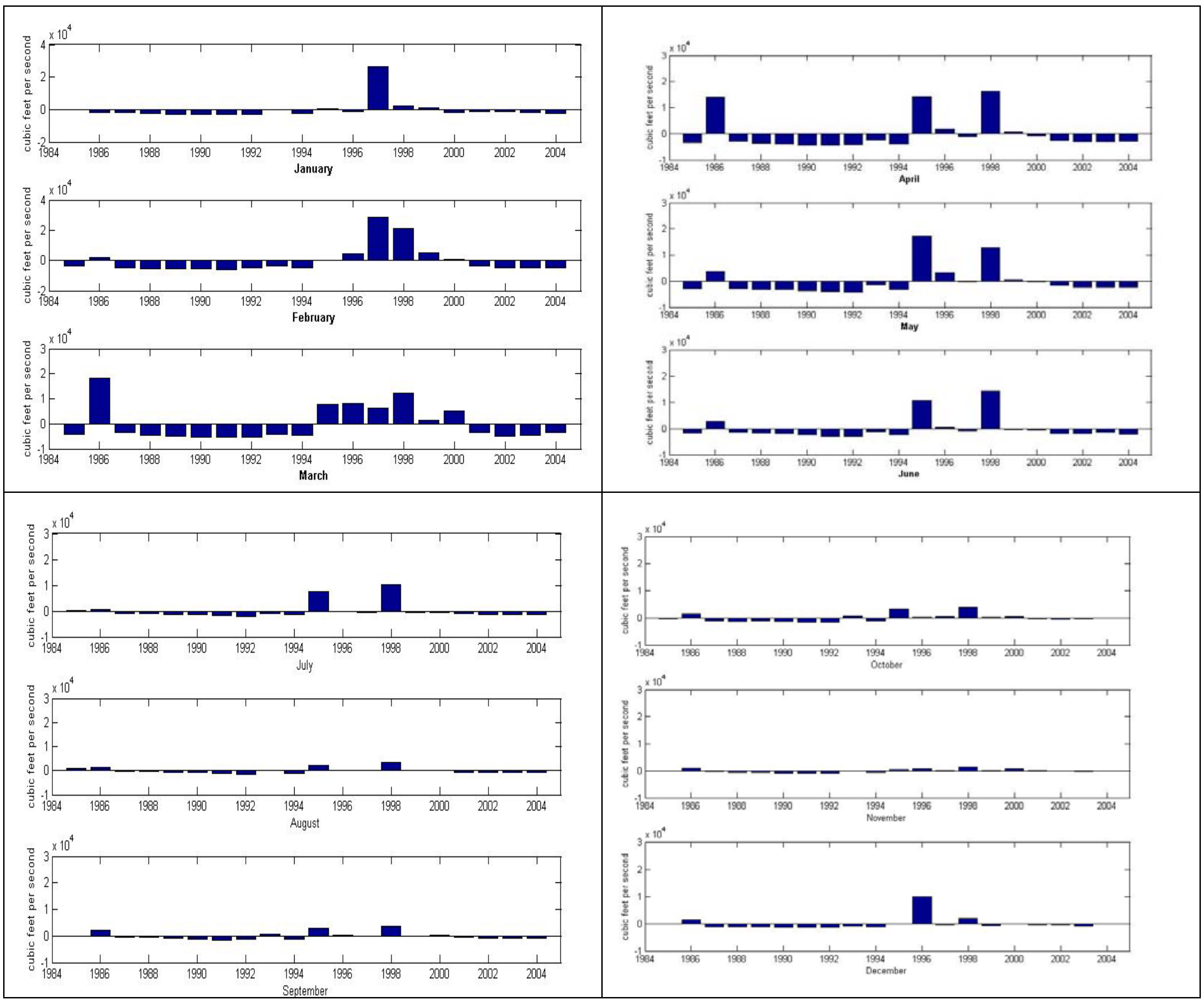


Figure 6: Deviations from Mean Monthly Flows, San Joaquin River at Vernalis (SJR)

This is a draft work in progress subject to review and revision as information becomes avialable.

Old and Middle Rivers

The flows in Old and Middle River are tightly coupled with export operations in the South Delta. Even short duration reductions in exports are reflected as abrupt increases in the daily flow data at Old and Middle River (Fig. 7).

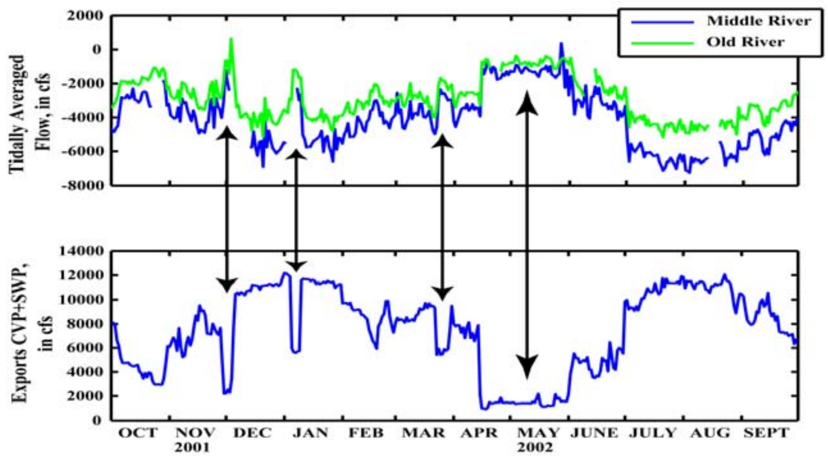


Figure 7: Relation of Flows on Old and Middle Rivers to Exports from the Delta

In general, the export facilities pull sufficient water to have a net draw of water from the north. Only once, in 1998, was the net annual flow on Old and Middle Rivers northward, away from the export facilities. Since 2000, the flows on Old and Middle Rivers have been increasingly negative (southward), though there was a slight rise in 2001 (Fig. 8).

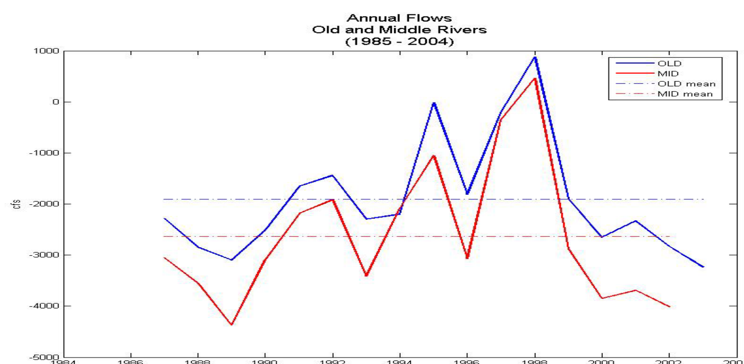


Figure 8: Mean Annual Flows on Old and Middle Rivers

Although there is substantial scatter in the data, there is a strong relationship between the flows on Old and Middle River and the export rates (Fig. 9). The scatter may be due to the exact timing of the Clifton Court Forebay operations, the spring-neap cycle, and the configuration of the barriers (notches, flap gates, culverts, etc).

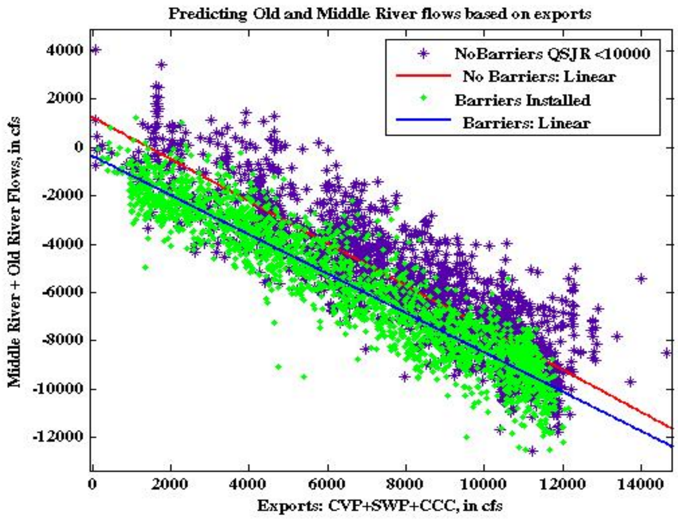


Figure 9: Predicting Old and Middle river Flows Based on Exports

Using these relationships we can estimate the percentage of water arriving at the export facilities from the north as opposed to from the east. When the South Delta barriers are not in place 60% to 75% of the water is delivered to the export facilities through Old and Middle Rivers. However, when the South Delta barriers are installed 85% or more of the water is delivered to the export facilities through Old and Middle River. The percentages depend on the export rate as well as factors like the barrier configuration (notches, flap gates, culverts, etc.).

Delta Outflow and X2

Seasonal trends dominate the inverse relationship between the X2 distance and Delta Outflow to the San Francisco Bay. As freshwater flows from the Delta to the Bay, the location of the 2 ppt salinity threshold is driven back toward mouth of the Bay. Outflow from the Delta reaches its peak during February and March and consequently X2 is at its lowest during those times (Fig. 10a).
From the peak in 1998, Delta outflow has fallen sharply and since 2000 have remained below the average for the period of 1985 – 2004. This decline in Delta outflows have resulted in a corresponding increase to the X2 value. X2 peaked in 2001 and has remained above average since 2000 (Fig 10b).

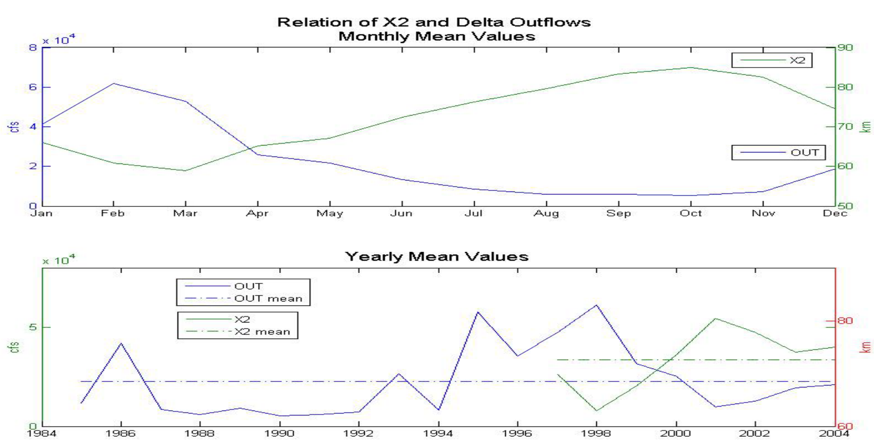


Figure 10: a) Monthly Mean Values for Delta Outflows and X2; and b)
b) Annual Mean Values for Delta Outflows and X2

Exports

In addition to outflows of water from the Delta to San Francisco Bay water is also exported from the Delta via the Central Valley Project (CVP) and State Water Project (SWP). Exports via the CVP and SWP tend to peak with demand during the late-summer and are at a minimum during the spring (Fig. 11).

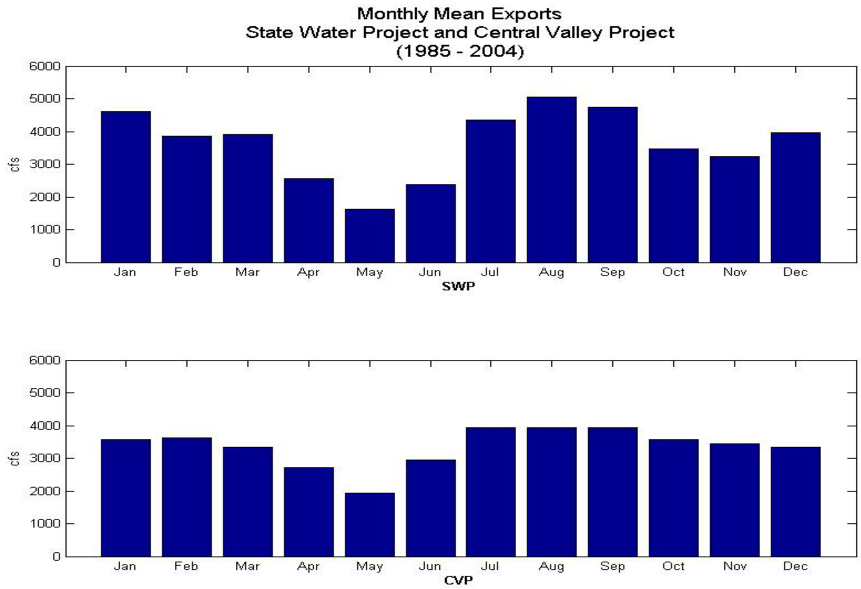


Figure 11: Monthly Mean Export Values for State Water Project and Central Valley Project

Exports via the CVP and SWP have risen since the 2000 water year (Fig. 12). Over the same period, flows on the San Joaquin River at Vernalis have been decreasing while flows on the Sacramento River have been increasing (Fig. 2).

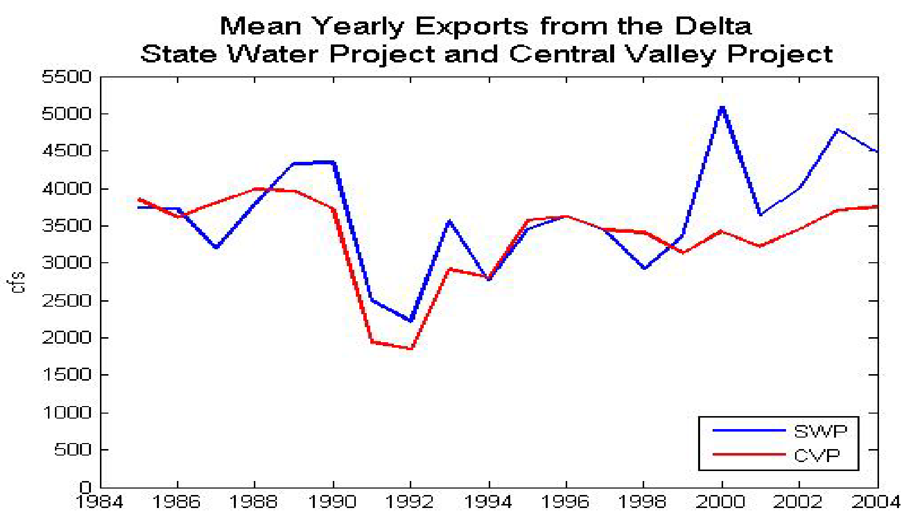


Figure 12: Annual Mean Exports for State Water Project and Central Valley Project

In addition to generally higher export rates overall since 2001; there have also been changes in the timing of exports from the Delta. Since 2000 exports from the Delta from both the CVP and SWP during the spring have been minimized, particularly during April and May as a part of the Vernalis Adaptive Management Program (VAMP). At the CVP in the summer and fall months of 2000 – 2004, there have been consistent increases in exports as compared to the average export rates for the month. During the winter months there is no consistent trend, though since 2002 there have generally been higher exports during the winter months (Fig 13).

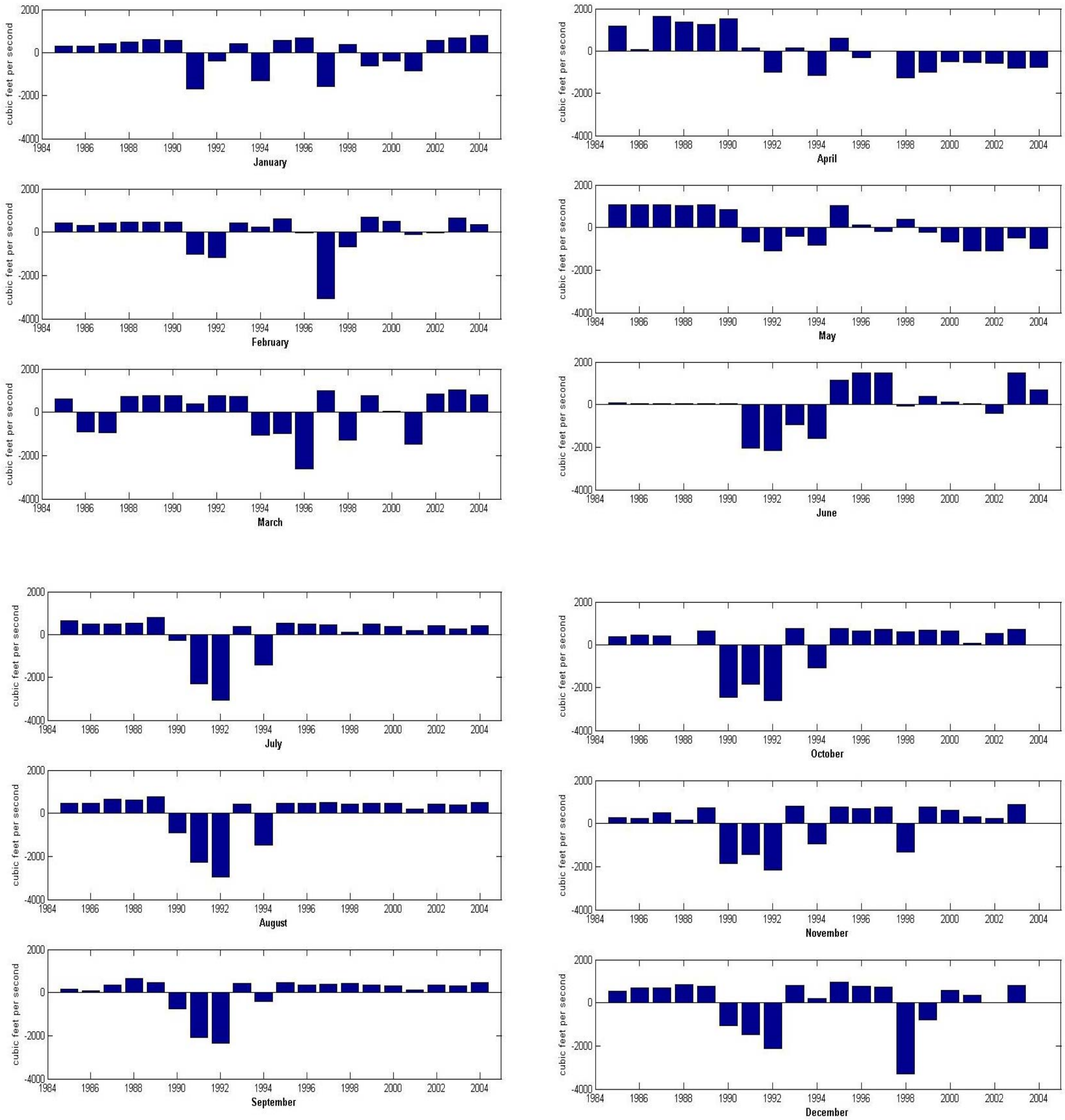


Figure 13: Deviations from Mean Monthly Exports, Central Valley Project

From 2000 to 2004 the SWP has shifted exports to the winter and early-summer as compared to average monthly export rates from 1985 – 2004. Specific trends at other times of the year are difficult to discern (Fig 14).

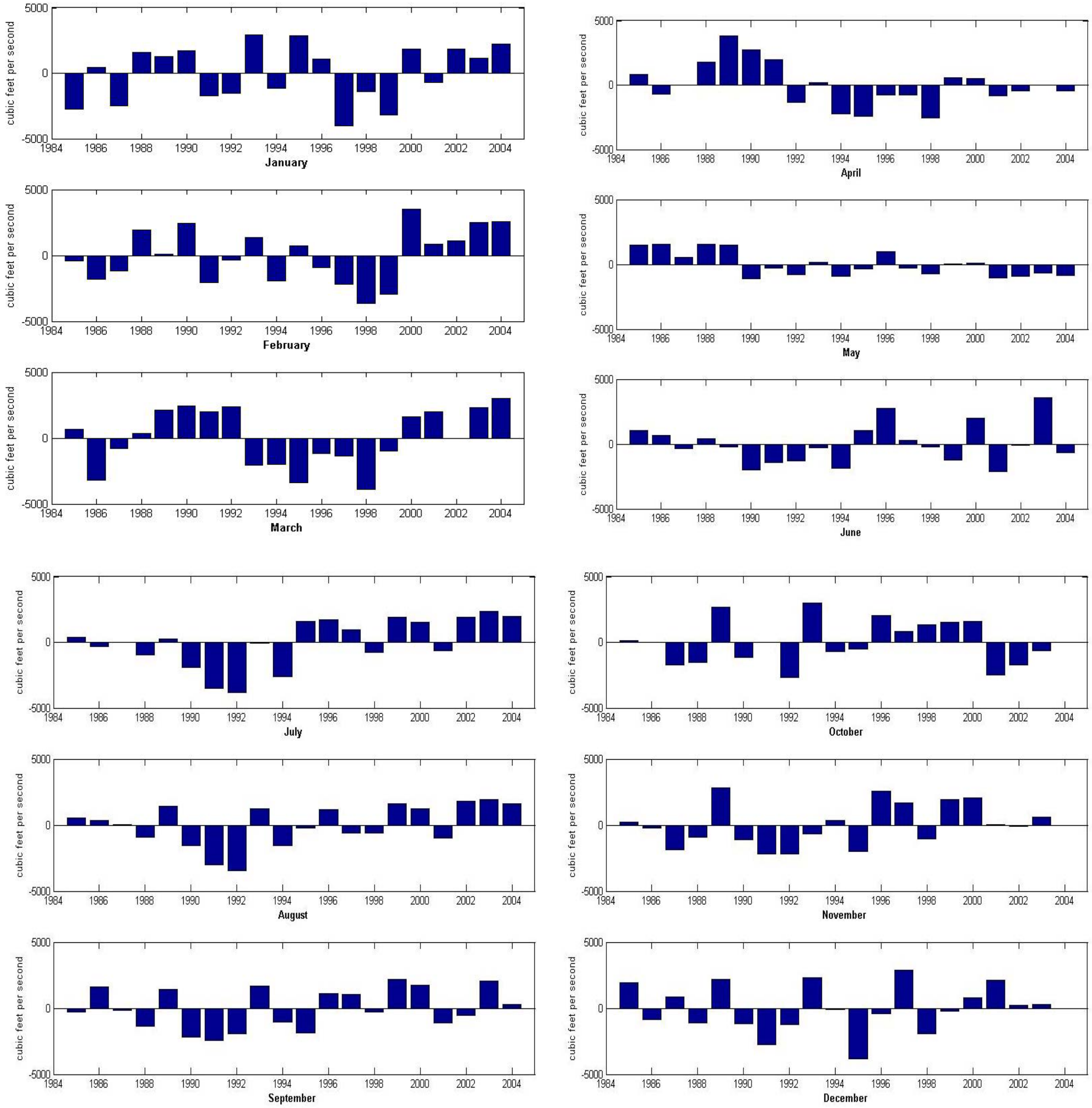


Figure 14: Deviations from Monthly Mean Exports, State Water Project

South Delta Barriers and Delta Cross Channel Gate Operations

Operations of temporary barriers within the Delta substantially impacts flows and circulation patterns within the Delta. The Grant-Line Canal, Old River near Delta-Mendota Canal and Middle River barriers are installed in the spring and remain in place throughout the growing season. These three barriers tend to follow similar operational patterns. The Old River head barrier is installed briefly during spring and fall runs of Chinook salmon to aid fish passage. The Delta Cross Channel operations are determined by several factors including water quality within the Delta, fish migrations, and flow levels on the Sacramento River. Operations of the radial gates at the Delta Cross Channel differ from the South Delta Temporary Barriers in that periods of closure are often not continuous through the year. Gates can be opened and closed daily, weekly or seasonally. Barrier and gate operations within the Delta are summarized in Fig 15.

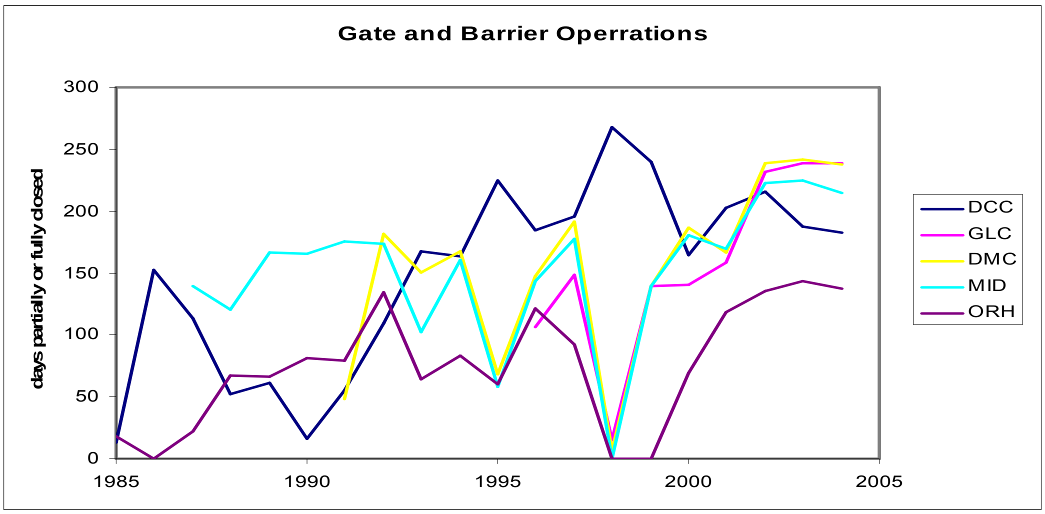


Figure 15: Gate and Barrier Operations Summary

High flows on the San Joaquin River in 1998 prevented the installation of all of the South Delta Temporary Barriers. Barrier installation at Old River Head was also prevented by high San Joaquin River flows in 1995 and 1999. In 2003, South Delta Temporary Barrier operation began to include notches in the barriers at Delta-Mendota, Middle River, and Old River Head and flashboard adjustments at Grant Line Canal to allow some passage of water beyond the barriers.

Durations of barrier placement at all four South Delta Temporary Barriers have risen in the years since 2000 and are now in place well over half of the year. As the duration of the South Delta Barriers installation period increases, so does the fraction of water delivered to the export facilities through Old and Middle Rivers (see discussion regarding Old and Middle Rivers).

No substantial changes in duration of Delta Cross Channel gate closures have occurred in the last several years. However, a number of studies during the fall were conducted to investigate the relationship between outmigrating salmon smolts to velocitiy distributions in North Delta junctions. Some of these experiments have integrated tidal operations of the Delta Cross Channel gates.

Conclusions

There have been substantial changes in the system since 2000. Some of these changes are based on the regional hydrology, such as the inflows from the Sacramento and San Joaquin Rivers; some of these changes are based on operational strategies that are implemented within the Delta, such as the duration or configuration of the South Delta Temporary Barriers. Since 2000, the percentage of water entering the Delta from the Sacramento River has been increasing (from 84.5 % in water year 2000 to 91.8 % in water year 2004) and the percentage of water entering the Delta from the San Joaquin River has been generally decreasing (from 11.2 % in water year 2000 to 6.2 % in water year 2004). During this same time, the duration of the South Delta barriers has been steadily increasing, peaking at nearly 250 days of closure or partial closure in 2002 and 2003. The South Delta barriers increase the draw of water toward the export facilities through Old and Middle Rivers from the north; though new configurations at the barriers include culverts, notches, and flashboards allowing some flow past the barriers. With VAMP program being initiated in 2000, spring exports from both the SWP and CVP have been reduced. Exports have generally been proportionally to winter and early-summer.