**Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh**

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# Chapter 11:
# 16-Year DSM2 Planning Studies with Adjusted Astronomical Tides and Daily Hydrology

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# 11 16-Year DSM2 Planning Studies with Adjusted Astronomical Tides and Daily Hydrology

## 11.1 Introduction

DWR's Delta Modeling Section uses the Delta Simulation model (DSM2) to simulate the hydrodynamics and water quality in the Sacramento-San Joaquin Delta. This chapter discusses the Section's most recent planning mode setup. Planning simulations are used to evaluate proposed long-term structural and/or operational changes in the Delta.

Traditionally, the Delta Modeling Section used a planning mode setup to conduct a 16-year simulation, covering water years 1976 to 1991, using monthly average hydrology rim input. The rationale behind the selection of this period was discussed in detail in the *Status Reports on Technical Studies for the Storage and Conveyance Refinement Process* (DWR, 1997). The monthly average hydrology input was obtained directly from the output of CALSIM. Simulations followed the following procedure:

1. A design repeating tide (which is based on the 19-year mean tide) was used as the stage boundary condition at Martinez with a 25-hour period (Nader-Tehrani, 2001).

2. A separate DSM2-HYDRO run was completed for each month. During each run, the hydrology was kept constant. The model run continued until a condition of dynamic steady state was achieved.

3. The hydrodynamic results (flow, stage, etc.) were saved in a tide file (25 hours long). These conditions were assumed to repeat every day for the entire month.

The main reason for using monthly varying hydrology with a repeating tide approach was to reduce the CPU time and storage requirements. However, due to increases in CPU speed and the drop in price of storage devices (both hard disks and CD/DVDs), these former constraints no longer applied. In summer 2001, the Delta Modeling Section initiated efforts to develop a planning study design that would incorporate daily variations of hydrology.

In the new planning mode setup the design repeating tide is replaced with an adjusted astronomical tide and the monthly hydrology is replaced with a daily hydrology. By including the spring-neap variation in the tide and by accounting for more detailed operations in the Delta, this new planning mode provides more useful results than the previous DSM2 planning studies. Furthermore, recent projects, such as the In-Delta Storage water quality studies, required the daily operations in the Delta to accurately simulate the diversions to and releases from the proposed island reservoirs.

## 11.2 Preprocessing Planning Runs

In order to run HYDRO and QUAL using a daily hydrology, staff addressed several new problems related to generating daily boundary conditions and dynamically changing the operation of structures within the Delta.

### 11.2.1 Changes in HYDRO

Daily varying hydrology input will be obtained directly from the output of a CALSIM run. Therefore, HYDRO will be used to run every day of every month, and an entire 16-year simulation will be conducted in a single run instead of individual model runs (one per month) as in the traditional planning approach. Observed tide data are not available at Martinez for the entire 16-year simulation. An adjusted astronomical tide at Martinez will be used as the stage boundary, since there are no benefits to be gained from using the design repeating tide (Ateljevich, 2001a). This tide includes the spring-neap variation that was not included in the repeating tide used in the previous studies.

As shown in Figure 11-1, flow control structures in the South Delta (Old River, Middle River, and Grant Line Canal) are operated at times to raise the stage upstream of the barriers for agricultural use (Old River at Head is a fish control structure). When all three barriers are operated simultaneously, the water upstream becomes stagnant and the water quality degrades. To prevent such stagnation and improve circulation, a special tidal operation of the flow structures has been introduced.

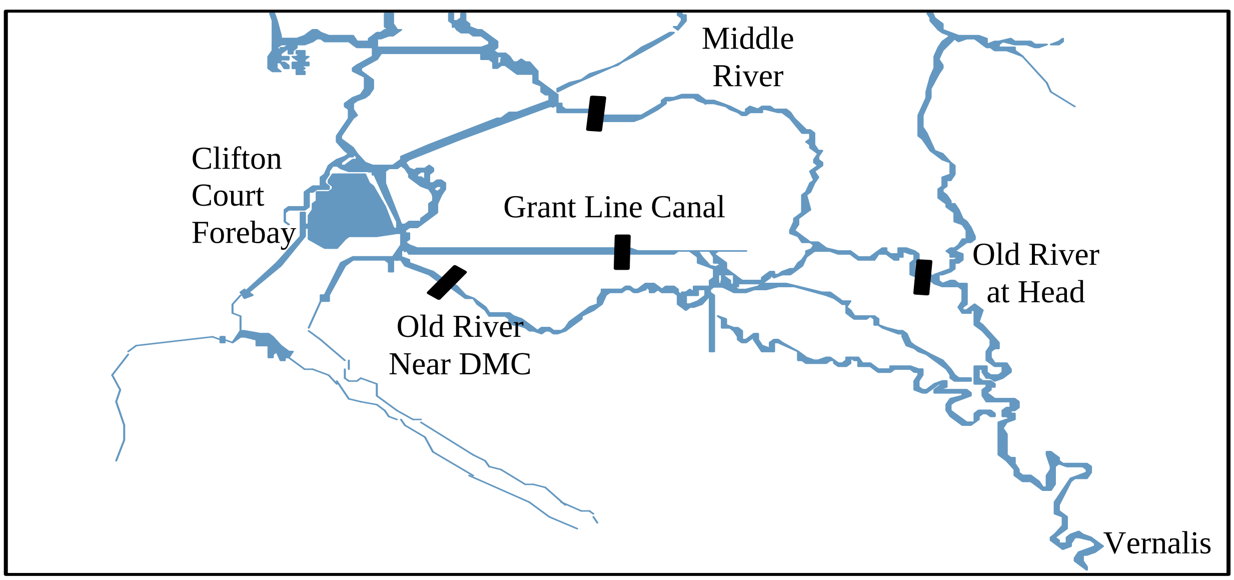


**Figure 11.1: South Delta Flow Control Structures.**

In the monthly planning setup, the design repeating tide has a single defined pattern that repeats every 25-hour period. Therefore, the special tidal operation of South Delta flow structures can be pre-defined in a clear way as shown in Figure 11.2.

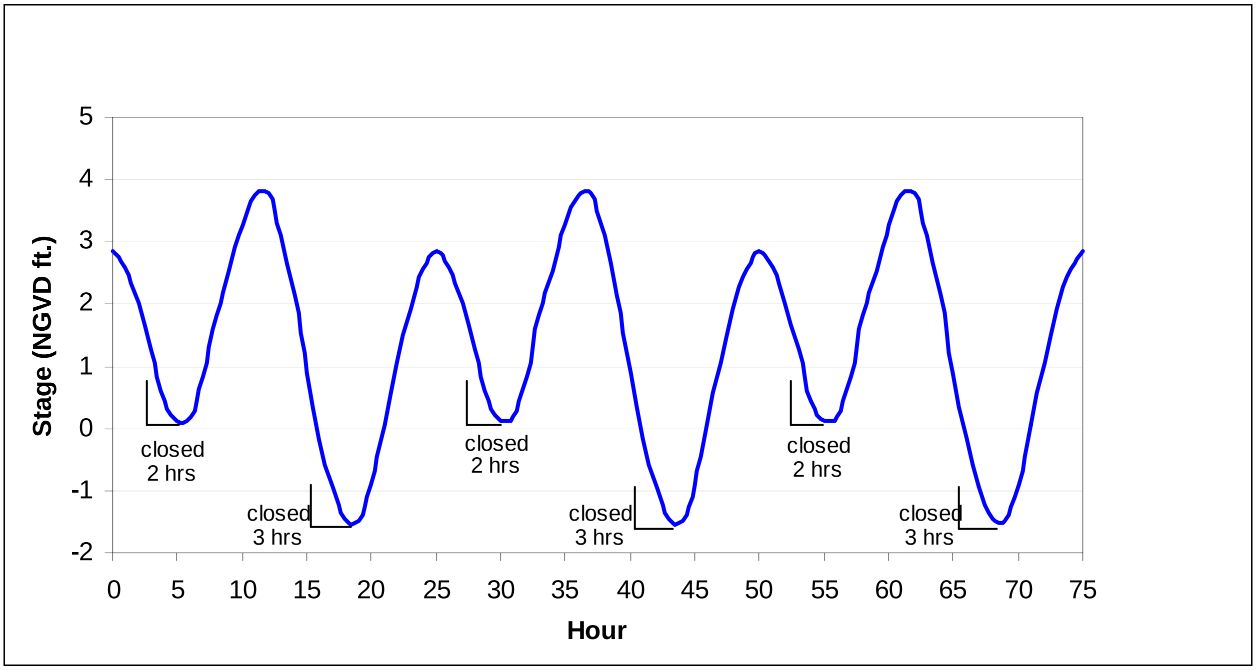


**Figure 11.2: Special Tidal Operation of South Delta Flow Control Structures.**
(taken from DWR, 1999)

With the new setup, the tides do not repeat, making it difficult to define a generalized schedule for the special tidal operations of the South Delta flow control structures. The new special tidal operation is defined based on the tide information (highs and lows) at Martinez and the phase difference (tide lag time) between Martinez and locations of interest in the South Delta.

In the monthly setup, gate operations changed on a monthly time-scale. Because the new planning studies are run continuously, the operation of the barriers are not limited to monthly time-scale only. The operation of the gates can be specified up to a 15-minute time-scale.

### 11.2.2 Changes in QUAL

In the monthly planning setup, an ANN (Artificial Neural Network) was used to estimate tidally averaged salinity (in terms of EC) as a function of Net Delta Outflow (NDO). A predetermined tidal component was added to estimate hourly variations using Kristoff coefficients. These coefficients are a series of 25 hourly values arranged in a tidal pattern that are multiplied by daily averaged salinity to produce a scaled tidal fluctuation. The tidal fluctuation was synchronized with the Martinez repeating tide (stage) so that the hydrodynamic (HYDRO) and water quality (QUAL) results were realistically phased.

Ateljevich (2001b) developed an improved method of salinity estimation for the Martinez boundary in the new daily planning setup. The new method derives 15-minute salinity estimates based on the Martinez tide and NDO.

CALSIM currently provides only average monthly values of EC for the San Joaquin River at Vernalis. The salinity at Vernalis is also an important boundary condition for QUAL. The daily EC at Vernalis is estimated using regression relationships (Equations 11-1a and 11-1b) developed by Scott Humpers (SWRCB). The regression relationships are defined separately for the irrigation and non-irrigation seasons:

Irrigation Season (April – September):

$$EC = 420,306 \times Q^{-0.5486} \quad \text{[Eqn. 11-1a]}$$

Non-Irrigation Season (October – March):

$$EC = 2,171,698 \times Q^{-0.688} \quad \text{[Eqn. 11-1b]}$$

where,

$EC$ = electrical conductivity (umhos/cm), and
$Q$ = daily flow at Vernalis (acre-ft/day).

The estimated daily EC values obtained from the regression relationship are adjusted so that the daily EC estimated from Equations 11-1a and 11-1b are consistent with the monthly EC estimated from CALSIM. The adjustment concept conserves the total salt transport. The adjustment factor, *f*, is computed as the ratio of total salt transport using monthly flow and EC values to the total salt transport in a month using the daily flow and EC values calculated in Equation 11-1.

$$f = \frac{Q_m \times EC_m \times n}{\sum_{d=1}^{n} Q_d \times EC_d} \quad \text{[Eqn. 11-2]}$$

where,

$Q_m$ = monthly average flow,
$EC_m$ = monthly average EC,
$Q_d$ = daily average flow,
$EC_d$ = daily average EC, and
$n$ = number of days in a month.

Using the adjustment factor calculated in Equation 11-2, the daily-adjusted EC is then described in Equation 11-3.

$$EC'_d = f \times EC_d \quad \text{[Eqn. 11-3]}$$

## 11.3 Post Processing

The output from the new planning setup is extensive, and therefore a much more complex analysis may be performed. Traditionally, the Delta Modeling Section reported the monthly average flows, water quality, and monthly minimum water levels. A more detailed analysis, such as the evaluation of tidal extremes, had limited value due to the use of the design repeating tide. In fact, the table of "monthly minimum water surface elevations" presented for some of the monthly planning simulations actually represented the average minimum and not the absolute minimum.

Figure 11.3 shows an example of a typical flow output for a given month utilizing the design repeating tide. The only information recorded in the standard output is a single value representing the monthly average value.

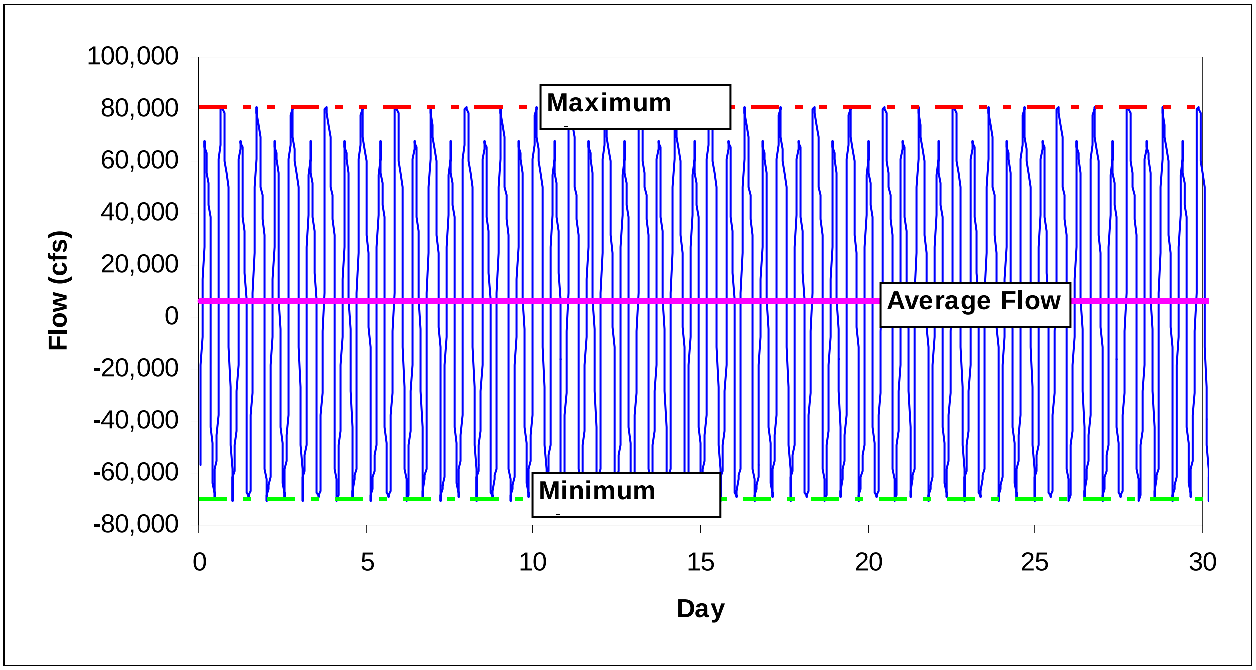


**Figure 11.3: Typical Monthly Planning Study Flow Output.**

Figure 11.4 represents the flow output using the adjusted astronomical tide. While it is possible to obtain and report only the monthly average statistics, a more detailed analysis may be warranted. For example, extreme value analysis can now be performed using the output that is available in a continuous time with spring neap effects due to adjusted astronomical tide.

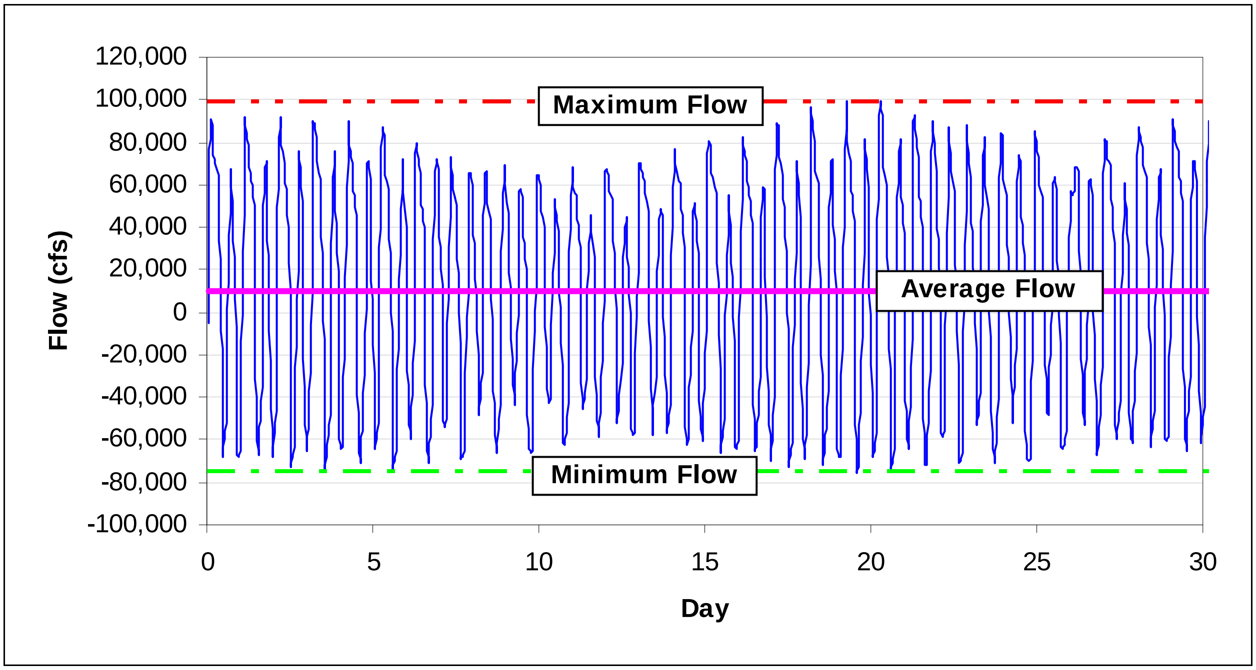


**Figure 11.4: Typical New Daily Planning Study Flow Output.**

A potential data presentation technique is to provide box and whisker plots as shown in Figure 11-5. The box and whisker plot gives all the statistics such as mean, median, upper and lower quartiles, and outliers in a single plot.

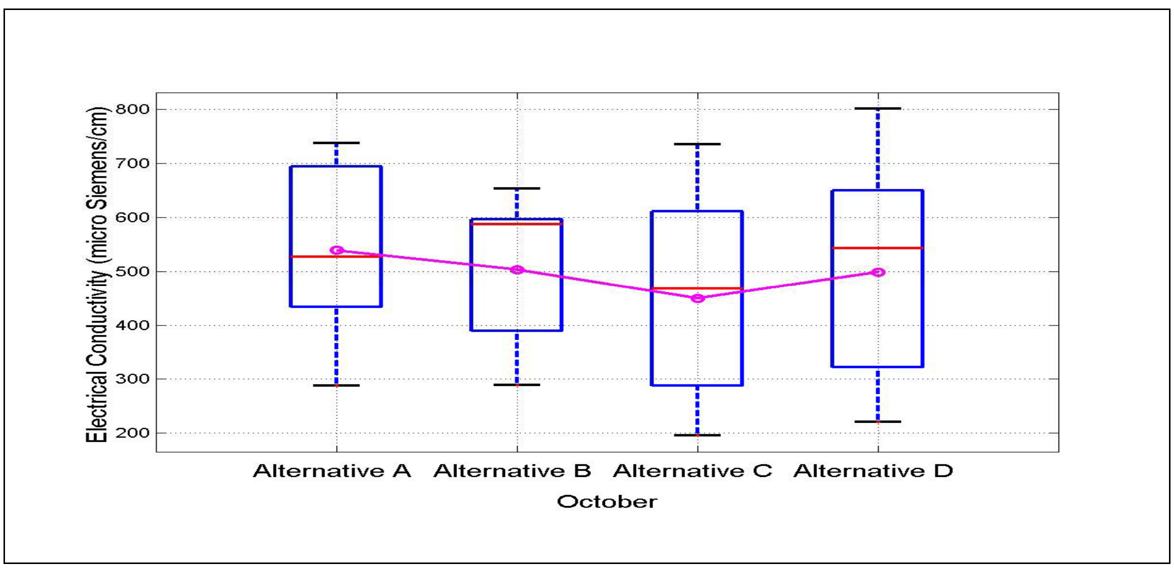


**Figure 11.5: Typical Box and Whisker Plot.**

The probability of exceedence plot as shown in Figure 11-6 is another potential data presentation technique that is more credible with the new planning setup. Probability plots provide information to help decision-makers select alternatives based on the alternative's risk tolerance in engineering and operational design.

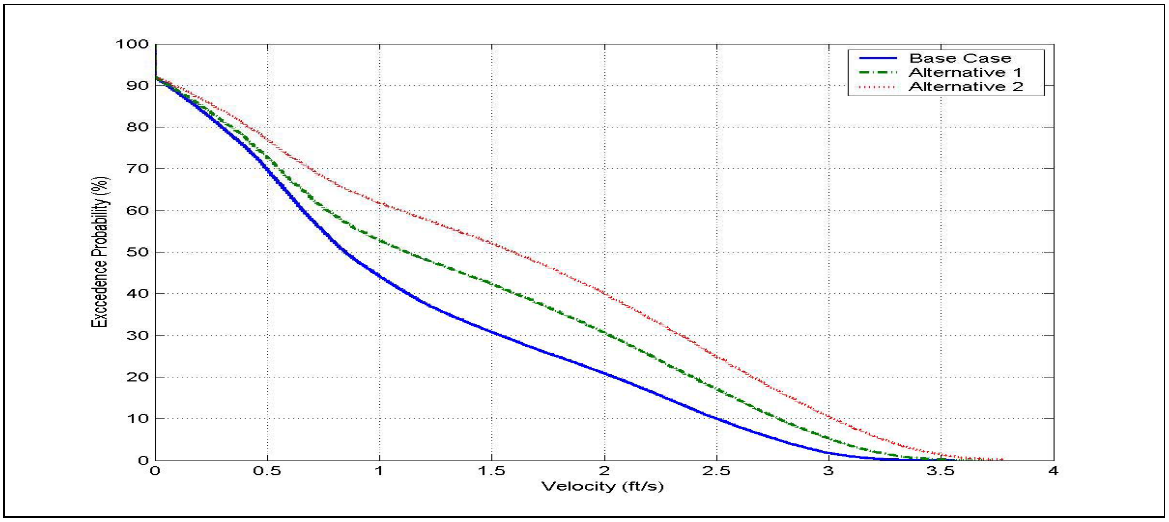


**Figure 11.6: Typical Probability of Exceedence Plot.**

The Delta Modeling Section is currently working on developing a post processor to provide a user-friendly analysis of the new planning study setup. The choice of data presentation techniques is expected to be an ever-evolving process based on the needs of the projects and clients.

## 11.4 Summary

Table 11.1 highlights the major differences between the new setup versus the traditional setup, as well as the current efforts and possible solutions for the limitations of the new setup. The comparisons made were based on a 1 GHz PC operating in the Windows 2000 environment.

**Table 11.1: Comparison between Traditional Monthly Planning Studies and the New Daily Planning Studies.**

| | Traditional Monthly Planning Study | New Daily Planning Study | Remarks |
|---|---|---|---|
| Run Time | HYDRO and QUAL:<br>16 hrs | HYDRO and QUAL:<br>34 hrs | Current work on parallel processing of HYDRO may reduce the HYDRO run times by 50%, which is about 13 hours. However, this will require a network of computers. |
| Disk Space | HYDRO and QUAL output: 250 MB | HYDRO and QUAL output: 4 GB | Though a single HYDRO and QUAL run will fit on a DVD, the binary output files can be compressed to reduce the required disk space to around 3 GB. |
| Model Setup / Runs | Complex text-based setup, with a specific file structure.<br><br>Monthly gate operations entered into a text file.<br><br>Separate DSM2 runs made for each month. | Complex text-based setup, with a specific file structure.<br><br>Daily gate operations generated by a series of scripts.<br><br>One complete DSM2 run made for the entire simulation period. | Current work on a GUI based input database is discussed in Chapter 13. |
| Accuracy / Post Processing | Monthly average results only.<br><br>Tide repeats over a 25-hour period. | Daily results available.<br><br>Spring-neap variation accounted for in tide. | The use of daily hydrology and a tide that includes the spring-neap variation will allow for the true extremes to be analyzed. |

One of the major advantages of the new setup over the traditional setup is that it simulates conditions closer to reality. This is primarily due to the fact that the new setup uses the adjusted astronomical tide at Martinez boundary, which captures the spring-neap effects. This was not possible using the traditional monthly setup when a repeating tide was used.

## 11.5 References


Ateljevich, E. (2001a). "Chapter 10: Planning Tide at the Martinez Boundary." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

Ateljevich, E. (2001b). "Chapter 11: Improving Estimates of Salinity at the Martinez Boundary." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

California Department of Water Resources. (1997). *Status Reports on Technical Studies for the Storage and Conveyance Refinement Process.* California Department of Water Resources. Sacramento, CA.

California Department of Water Resources. (1999). *Delta Simulation Model Studies, CALFED Bay-Delta Program: Vol. I.* California Department of Water Resources. Sacramento, CA.

Nader-Tehrani, P. (2001). "Chapter 9: Use of Repeating Tides in Planning Runs." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 22nd Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.