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

**25th Annual Progress Report**
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# Chapter 8:
# Real-Time Data and Forecasting Proof of Concept and Development

**Author: Michael Mierzwa and Bob Suits**

# 8 Real-Time Data and Forecasting Proof of Concept and Development

## 8.1 Introduction

Part of the Department's Municipal Water Quality Investigations' (MWQI) mission statement is to monitor and protect the drinking water quality of deliveries to urban State Water Contractors by assisting participating agencies in planning for and achieving future water quality objectives (Breuer, 2002). MWQI's monitoring plan includes the Real-Time Data and Forecasting (RTDF) project whose goals include giving water contractors and stakeholders operational flexibility by predicting water quality in both the Delta and California Aqueduct, and increasing water planners' and decision makers' Delta and California Aqueduct knowledge base.

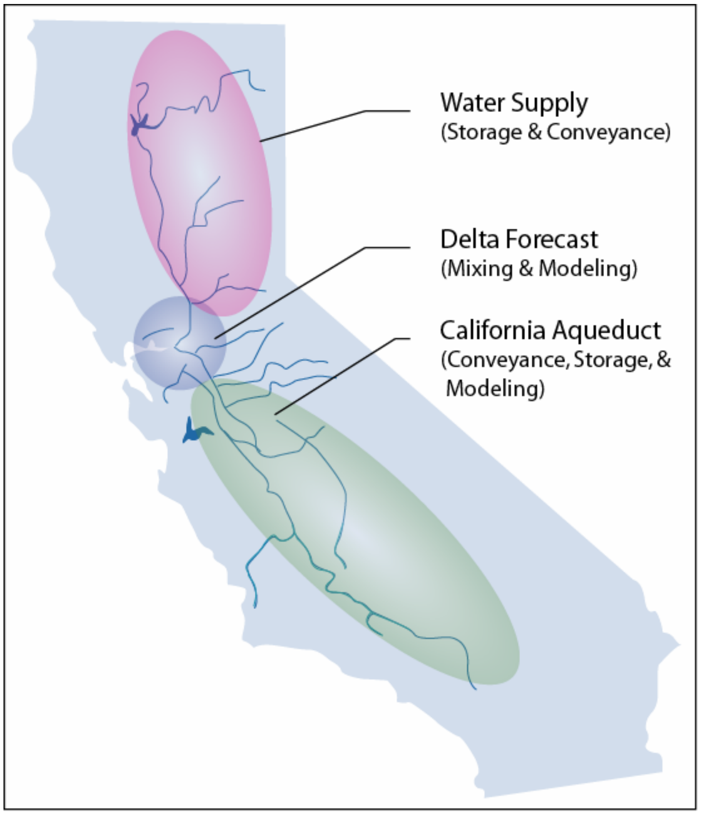


**Figure 8.1: Physical Scope of Real-Time Data and Forecasting Project.**

The physical scope of RTDF modeling needs to include the entire State Water Project (SWP) system (see Figure 8.1). The SWP can be divided into three principal regions: the northern storage and conveyance facilities, the Sacramento-San Joaquin Delta, and the California Aqueduct system which, in addition to providing additional storage, ultimately delivers the majority of the project water to the water contractors and stakeholders. Each of these regions presents different forecasting challenges, but a RTDF modeling system requires coupling the individual models used to forecast water supply, demand, and quality in each of these three regions. This chapter addresses the ability of existing tools like DSM2 to forecast SWP drinking water quality (through the proof of concept) and the future development needed to meet the goals of MWQI's RTDF project.

## 8.2 Background of MWQI and Forecasting

The Department's Division of Environmental Service's Office of Water Quality (OWQ) is responsible for investigating and disseminating water quality data associated with the operation of the State Water Project. Created in July 2002, the OWQ includes water quality programs from the Department's former Environmental Services Office and Division of Planning and Local Assistance and shares an organizational affiliation with the Division of Operation and Maintenance's Office of Water Quality (now known as the State Water Project Water Quality Program Branch). OWQ's Municipal Water Quality Investigations (MWQI) program is directly overseen by a steering committee of the State Water Contractors who receive State Water Project water directly for municipal use (MWQI, 2004). The MWQI steering committee includes members from Urban State Water Contractors, California Urban Water Agencies, Contra Costa Water District, California Department of Health Services, State Water Resources Control Board, and U.S. Environmental Protection Agency

According to the 2002-2004 MWQI Work Plan, one of the main objectives of MWQI is "to acquire, store, assess, and transfer water quality data to the stakeholders and the public" (Breuer, 2002). With this goal in mind, a Real-Time Data and Forecasting (RTDF) steering committee was formed with representatives from the water agencies that take drinking water from the Delta, Operations and Maintenance Division (O&M), Bay-Delta Office Modeling Support Branch, and MWQI. The committee has as its primary responsibilities monitoring, forecasting, and data dissemination.

Monitoring networks provide the real-time historical data that is used as the initial conditions for any forecast. Though current O&M DSM2 forecasts are limited to simulating Delta flow, stage, and electrical conductivity (EC), a major component of the RTDF monitoring activities is to identify the monitoring needs necessary to better understand the entire SWP system. This includes extending the current monitoring network to collect data of other water quality constituents, such as total dissolved solids (TDS), bromide, and organic carbon that can be easily integrated into current water quality forecasts.

The forecasting work of the RTDF is divided into two main tasks: continuing existing forecasts and improving the current forecasting tools. At least once a week O&M forecasts the short-term EC and South Delta water levels using DSM2 (see section 8.3). The development work involved in extending these forecasts to include the entire SWP system, simulating additional water quality constituents, and addressing source water questions (via fingerprinting) is described below (sections 8.5 and 8.6).

## 8.3 History of Forecasting with DSM2

DSM2 has been used as a Delta hydrodynamic and water quality forecasting tool by the Department of Water Resources for several years. O&M's Operations Compliance and Studies Section has been using the existing DSM2 forecasting methodology (Mierzwa, 2001) to produce one or more forecasts of Delta conditions each week. The hydrodynamic and water quality results of these DSM2 forecasts are used by DWR operators to make adjustments to real-time State Water Project and Central Valley Project operations in order to meet Delta flow and water quality standards. An example of a DWR O&M water quality forecast is shown in Figure 8.2.

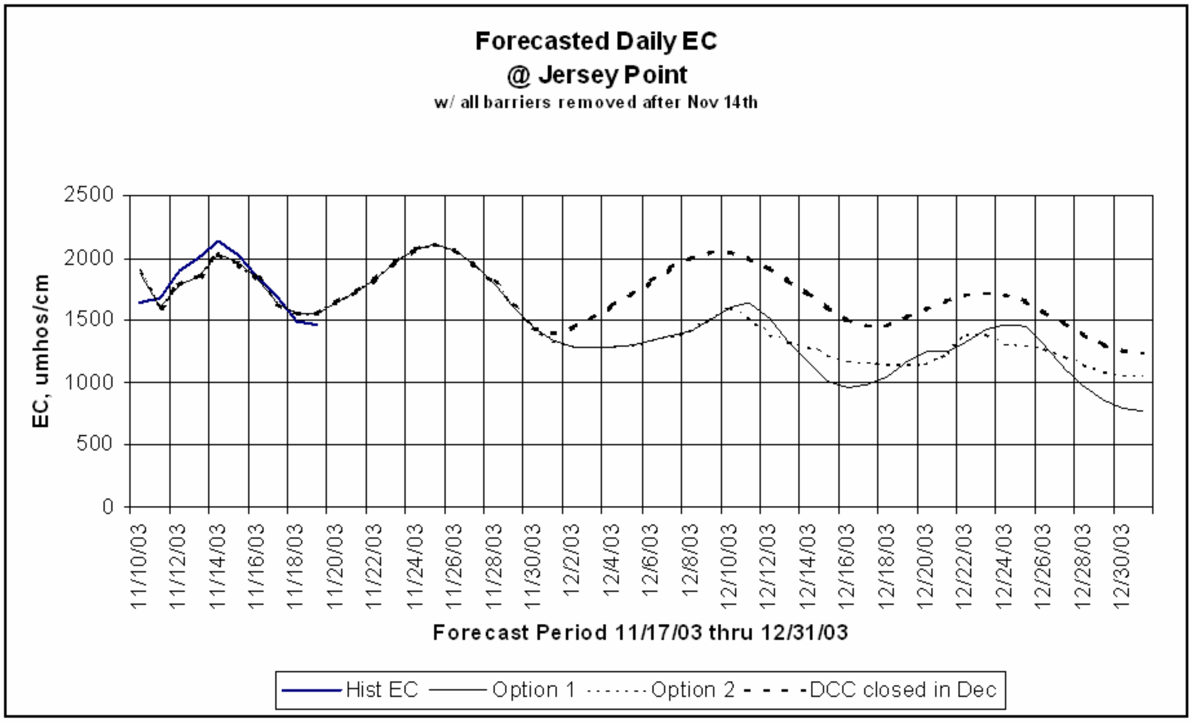


**Figure 8.2: Example of Forecasted Water Quality Using DSM2.**
(taken from Sun, 2004)

DWR's Bay-Delta Office Temporary Barriers and Lower San Joaquin Section uses the weekly O&M DSM2 forecasts to report both the current and anticipated South Delta water levels. An example of one of these real-time water level forecasts near the Grant Line Canal temporary barrier site is shown below in Figure 8.3. These reports are emailed to any public party with an interest in South Delta water levels and are archived at:

http://sdelta.water.ca.gov/web_pg/tempbar/weekly.html

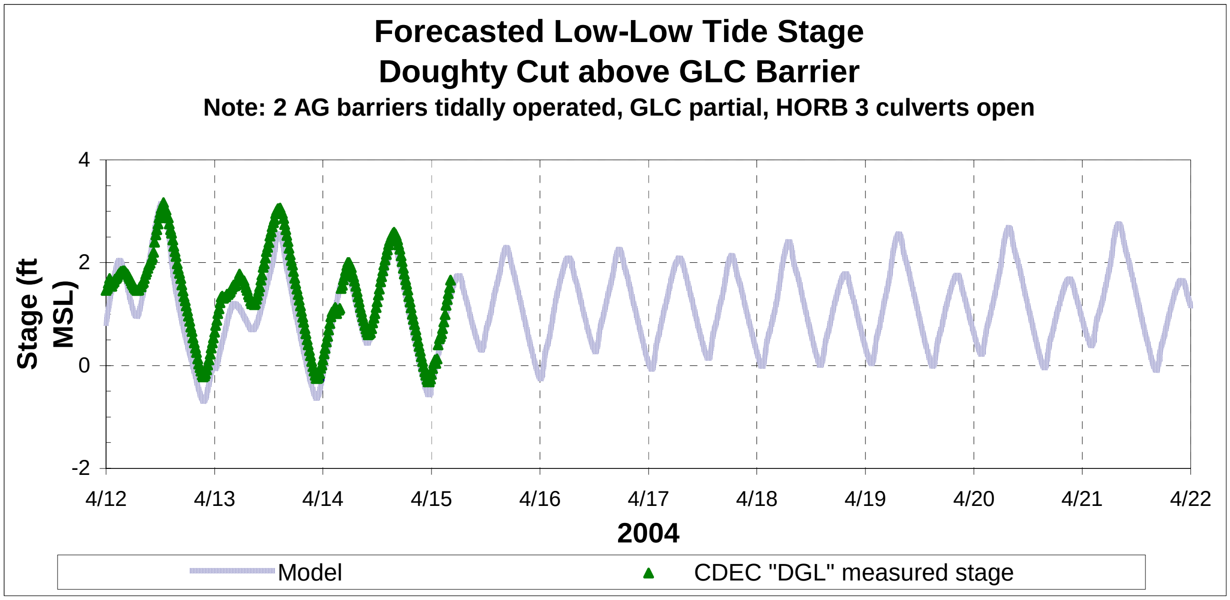


**Figure 8.3: Example of Forecasted Water Levels Using DSM2.**
(taken from Burns, 2004)

O&M generates these weekly forecasts by first using information on current and short-term projected water supply levels and demands to create a daily operations spreadsheet of Delta inflows and exports. The forecast flows and exports based on the spreadsheet operations along with stage estimates (Ateljevich, 2000), salinity estimates (Ateljevich, 2001), and future barrier operations are combined with hourly real-time Delta flow and operations data to produce a short-term DSM2 simulation. The length of the short-term forecast can vary depending on the purpose of the forecast. As shown in Figures 8.2 and 8.3, DSM2 was run for nearly two months in the O&M example forecast, but for only 10 days in the South Delta example forecast. The accuracy of a forecast decreases with the length of the forecast simulation. In both cases, a period of several days to several weeks in length is run before the start of the actual forecast in order to both establish initial hydrodynamic and water quality conditions prior to the actual forecast and validate model performance. This warm-up period uses real-time field data that is screened as part of a pre-processing step before beginning a model run.

At times, more than one forecast simulation is run in order to use DSM2 to help evaluate possible different Delta responses to different operation decisions. Examples of this include delaying the installation and construction of a temporary barrier by a few days, altering upstream releases and/or changing export pumping levels, or changing the operation of the Delta Cross Channel.

O&M's DSM2 Delta forecasts have shown that the DSM2 forecasting tool is effective at providing qualitative information concerning the trends in various hydrodynamic and water quality parameters. However, a more formal analysis of the ability of O&M's current DSM2-based forecasts to provide accurate quantitative results has not been conducted. It should be noted that DSM2 real-time simulations can at times fail to reproduce or predict observed data due to a combination of errors in forecast model input and DSM2 accuracy.

## 8.4 Forecasting Proof of Concept

Although RTDF plans to incorporate the existing O&M short-term forecasts into its water quality reports, the committee has been also developing a long-term water quality forecast (Hutton and Woodard, 2003). Suits and Wilde (2003) originally conducted a proof of concept simulation to determine whether long-term operational forecasts can provide valuable information by using old O&M monthly forecasted hydrology and operations spreadsheets from 1998 to simulate what the "forecast" EC using O&M's spreadsheet forecasts in DSM2 would have been. The forecast EC results were then compared to the 1998 DSM2 historical EC simulation. Other water quality constituents were derived as a function of EC. Suits and Wilde concluded that long-term "forecast" results were consistent with the historical simulation results for some locations and some time periods, but at other times there were significant differences in forecast versus historical simulated EC. These differences could be explained by a combination of factors, including differences in the inflows, exports, Delta Cross Channel operation, and timing of the installation and operation of south Delta temporary barriers (Suits and Wilde, 2003).

### 8.4.1 Expanding the Delta Water Quality Forecast Proof of Concept

Based on the initial findings of the above study, an extended proof of concept simulation that examined the significance of different exceedence level forecasts and two additional years, was conducted. Long-term O&M January, March, and May operations spreadsheets from 1998, 1999, and 2000 were used to conduct 23 different DSM2 forecasts (see Table 8.1). Each month, O&M uses the water supply outlook forecasts to develop multiple monthly hydrology and operations spreadsheets for each month based on different probabilities of water supply. These different probability-based forecasts are called "exceedence levels". Different exceedence level forecasts have different inflows and exports. By running multiple exceedence level DSM2 forecasts for the same month, a range of expected water quality results can be provided.

**Table 8.1: Summary of O&M Forecasts Used in DSM2 Proof of Concept.**

| | | ***Forecast Exceedence Level*** | | |
|---|---|---|---|---|
| ***Forecast Start Date*** | | 50% | 75% | 90% |
| 1998 | January | ✓ | ✓ | ✓ |
| | March | ✓ | ✓ | ✓ |
| | May | ✓ | ✓ | ✓ |
| 1999 | January | ✓ | Not available | ✓ |
| | March | ✓ | Not available | ✓ |
| | May | ✓ | Not available | Not available |
| 2000 | January | ✓ | ✓ | ✓ |
| | March | ✓ | ✓ | ✓ |
| | May | ✓ | ✓ | ✓ |

The water supply outlook forecasts are based on the unimpaired runoff from the watersheds that provide the SWP with its water and are described as exceedence probabilities. An example of the exceedence probabilities associated with the historical unimpaired Sacramento River Valley runoff is shown in Figure 8.4. Higher exceedence probabilities are associated with drier events (i.e. lower runoff). In this example, the 50% percentile exceedence probability is associated with normal conditions (i.e. an unimpaired runoff of 16.7 maf), while the 90% percentile exceedence probability is associated with drier conditions (unimpaired runoff of 8.2 maf).

The O&M long-term operational forecasts take into account current conditions. They can be generalized as moving from anticipated real-time conditions to more generalized historical patterns. A forecast of March conditions made in February will tend to be more accurate than a one made in January.

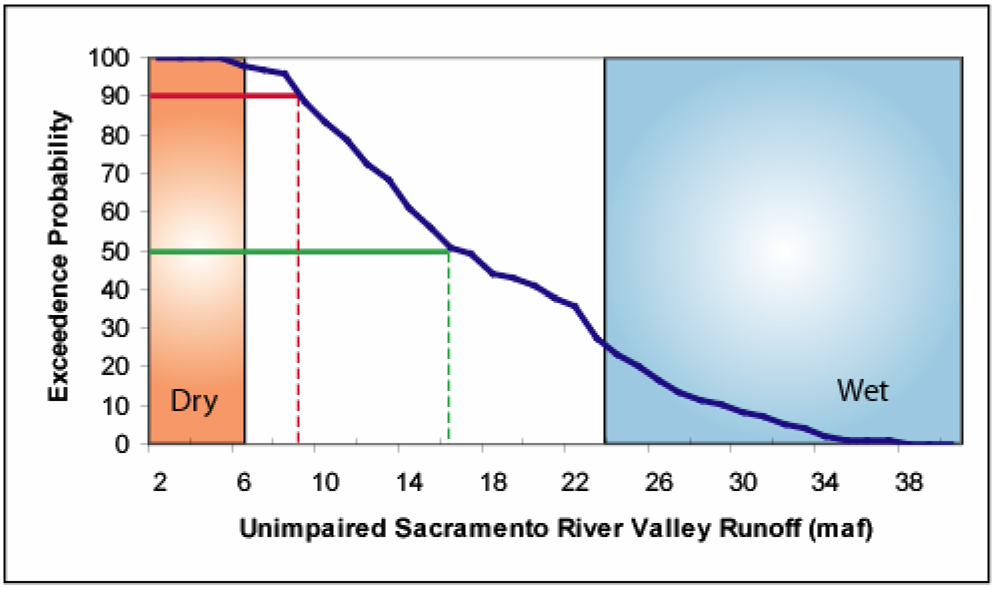


**Figure 8.4: Example of Forecast Exceedence Levels.**

**Table 8.2: Example of Inflows into Lake Oroville from the 1998 Operations Forecasts.**

| | January Forecast Exceedence Probability | | | March Forecast Exceedence Probability | | |
|---|---|---|---|---|---|---|
| | 50% | 75% | 90% | 50% | 75% | 90% |
| Jan | 5,490 | 4,147 | 15,563 * | - | - | - |
| Feb | 8,503 | 6,224 | 4,441 | - | - | - |
| Mar | 7,798 | 7,091 | 5,282 | 16,231 | 14,783 | 14,426 |
| Apr | 9,439 | 8,127 | 6,155 | 15,209 | 13,243 | 12,352 |
| May | 7,347 | 6,314 | 4,734 | 14,149 | 11,693 | 10,897 |
| Date of Forecast | 11/24/97 | 12/15/97 | 1/1/98 | 3/9/98 | 3/9/98 | 3/27/98 |

An example of O&M inflows into Lake Oroville is shown in Table 8.2. In this example, three different forecasts were made starting in January 1998 and three additional forecasts were made starting in March 1998. In general, forecast flows into Lake Oroville decrease with increasing exceedence probability levels. An exception is the January 1998 90% exceedence level for the January forecast. The other months for the January forecast follow the usual trend, but the 90% January flows into Lake Oroville are 10,000 cfs greater than the 50% exceedence level because the 50% exceedence flows were forecast in December while the 90% exceedence level flows were forecast in January.

### 8.4.2 Executing the Delta Proof of Concept

Although the historical DSM2 base-line study was run from 1990 through 2002, the initial conditions for each forecast were taken by stopping the DSM2-QUAL historical simulation on the start date for each group of forecast simulations: Jan. 1$^{st}$, Mar. 1$^{st}$, and May 1$^{st}$, 1998 and applying the exact model state (i.e. model results) to the forecast start (see Figure 8.5). The Jan. 1$^{st}$ forecasts ran from Jan. 1$^{st}$ through Dec. 31$^{st}$, 1998. Similarly, the Mar. 1$^{st}$ forecasts ran from Mar. 1$^{st}$ through Dec. 31$^{st}$, 1998, and the May 1$^{st}$ forecasts ran from May 1$^{st}$ through Dec. 31$^{st}$, 1998. The results of all of the 1998 simulations were compared to 1998 simulated historical EC. This process was repeated for the 1999 and 2000 forecasts.

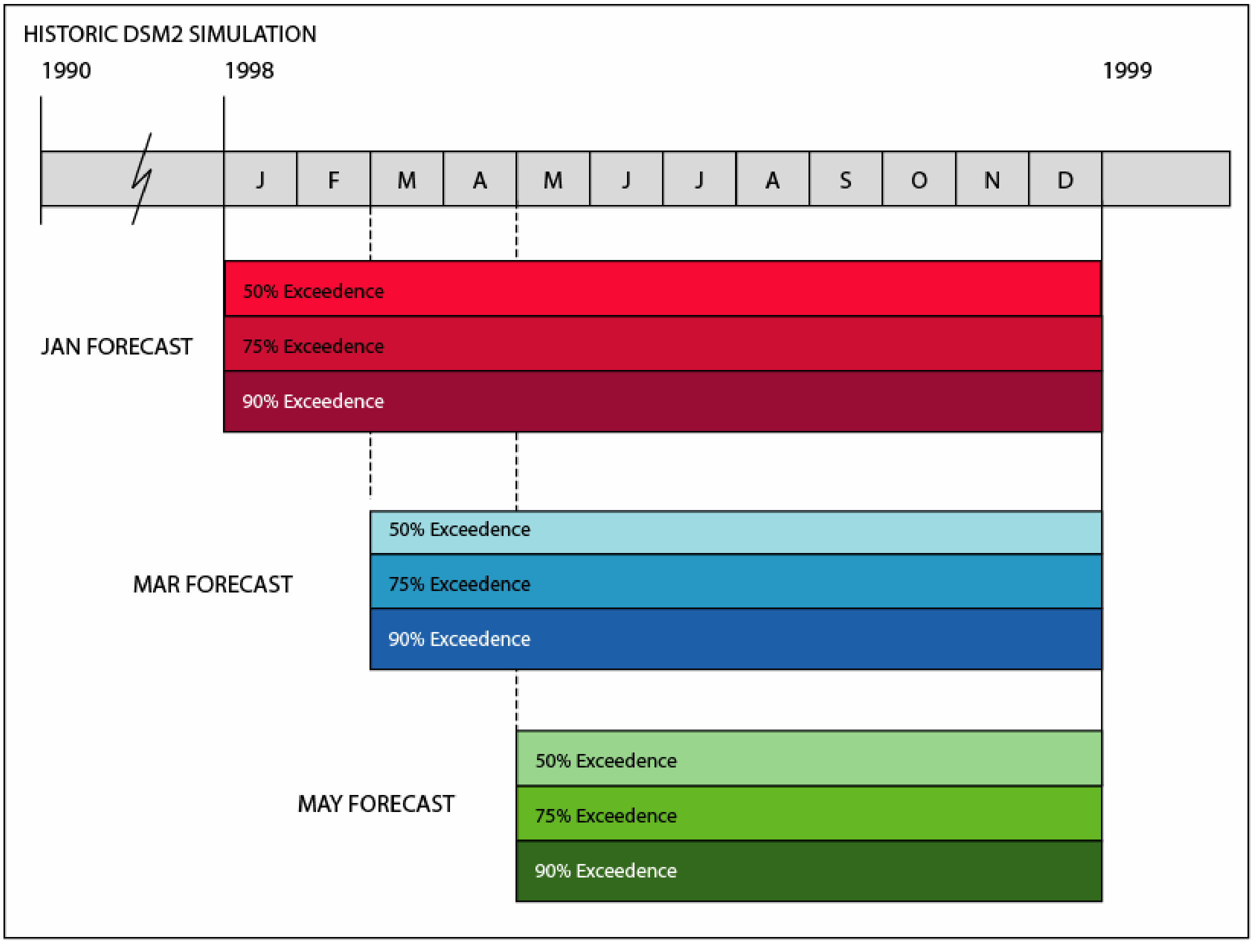


**Figure 8.5: Time line for 1998 "Forecast" Proof of Concept DSM2 Simulations.**

Since the goal of the proof of concept was to test the value of forecasting water quality associated with long-term operations forecasts, only the flow data that is presented in the O&M operational and hydrologic forecasts was used in the DSM2 forecasts. These spread sheets include the major Delta inflows and exports and estimated Delta consumptive use.

### *Flows / Exports*

The flow inputs to the Delta included the Sacramento River, the San Joaquin River, and the Eastside Streams (which includes the Mokelumne and Cosumnes Rivers). The monthly flows for the Sacramento and San Joaquin Rivers were converted into daily values using a mass conservative spline in order to smooth out any steep changes in monthly averaged flow. Monthly Eastside Streams flows were taken directly from the O&M spreadsheet.

Exports from the Delta included: the State Water Project (SWP) Banks Pumping Plant, Central Valley Project (CVP) Pumping Plant, and Contra Costa Water Districts' (CCWD) combined diversions. The CCWD diversions were considered to occur at Rock Slough Pumping Plant #1.

### *Operation of Delta Structures*

The Delta Cross Channel (DCC) operation is included in the O&M spreadsheet forecasts in terms of the percentage of time open each month. The operation of the DCC in the field is determined by both Sacramento River flow and the time of year. The O&M spreadsheets took into account the rules that govern the operation of the DCC; thus, if the forecast Sacramento River flows were higher than the flows in either the historical or other forecast simulations, a different operation of the DCC could potentially affect the internal Delta circulation patterns and salinity movement.

The installation and operation of south Delta temporary agricultural barriers in Old River, Middle River, and Grant Line Canal and the fish protection barrier at the head of the Old River are dependent upon the time of year and the flow in the San Joaquin River. Like the operation of the DCC, deviations in the forecast San Joaquin River flows between the historical and other forecast simulations, such as the high flows associated with the 1998 historical simulation, could lead to significant differences in flow patterns in the south Delta.

### *Consumptive Use*

The forecast total Delta consumptive use was used to create forecast Delta island diversions and return flows using the Adjusted Delta Island Consumptive Use (ADICU) model. A unique set of Delta island diversions and return flows was calculated for each forecast simulation; for example, the consumptive use data used for the Jan. 50% exceedence forecast was different than the consumptive use data use for the Jan. 75% exceedence forecast.

### *Stage*

The DSM2 forecasts were treated as if Martinez stage was unavailable available during the 1998 through 2000 period. For short-term forecasts, a tool is used to blend real-time stage observations to an astronomical modeled stage (Ateljevich, 2000); however, after a few days, a pure astronomical modeled stage is applied at Martinez. This astronomical stage was used for the seasonal forecasts.

### *EC*

Daily EC for the San Joaquin River at Vernalis (the upstream boundary for DSM2) was calculated based on observed regressions between San Joaquin flow and EC (Suits and Wilde, 2003). Ocean salinity was calculated using a modified G-model with O&M forecast monthly net Delta outflow and the astronomical tide as inputs. The EC associated with inflows from the Sacramento River and Eastside Streams was kept constant throughout the entire forecast period.

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### 8.4.3 Water Quality Results of Proof of Concept in the Delta

Modeled EC at the SWP Banks Pumping Plant for the 50% exceedence level forecast for the 1998, 1999, and 2000 simulations and the simulated historical EC are shown in Figure 8.6. The difference between the forecast and historical results varies from month to month for all three years. At times the results of the simulations match well, such as in the case of the May 1998 50% exceedence level forecast. However, there are also times when the results of the forecast and historical simulated EC diverge. An example of one such period is November through December 2000 when the forecasted hydrology did not account for early winter storms and higher Delta flows.

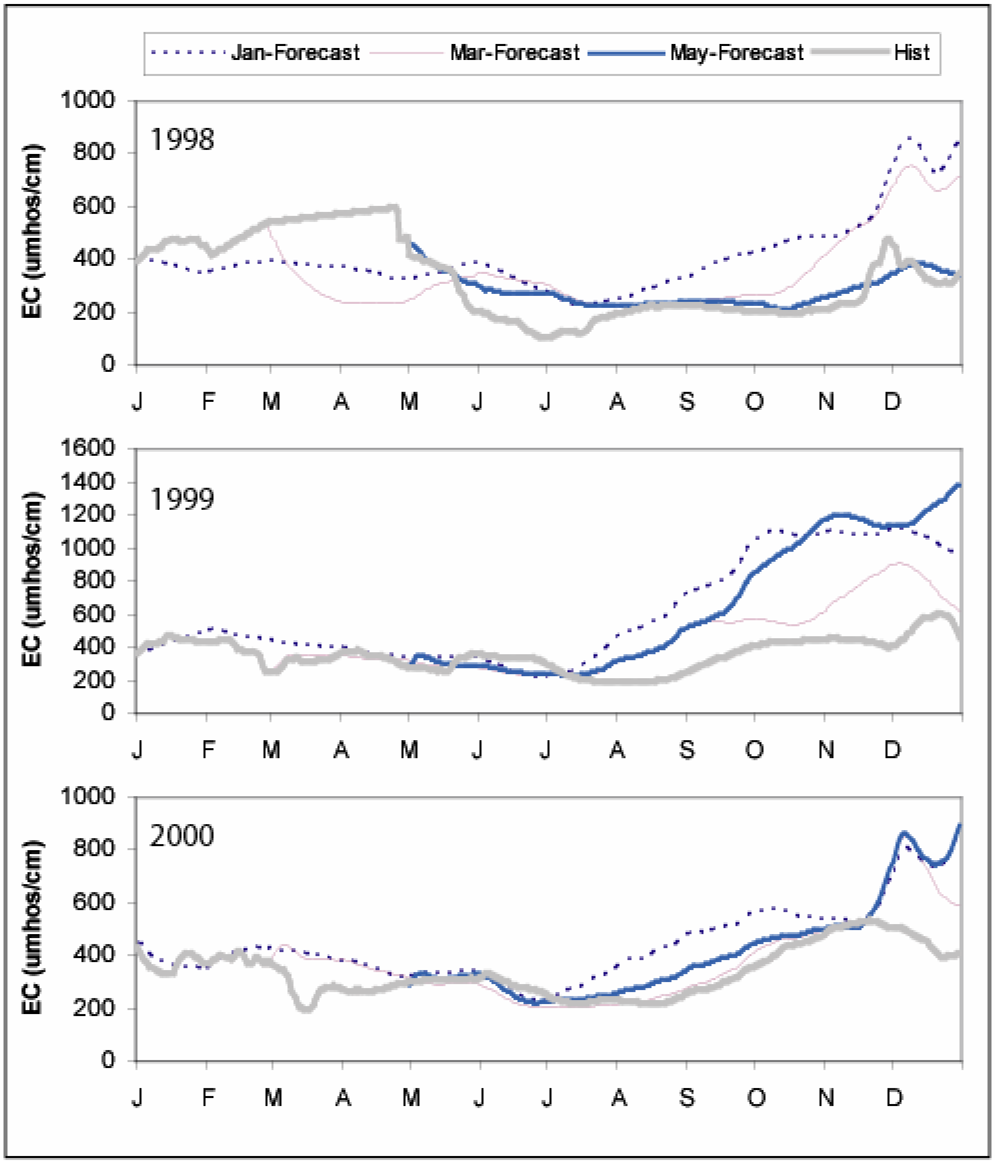


**Figure 8.6: EC at Banks Pumping Plant (SWP) for DSM2 Historical Simulation and Nine DSM2 50% Exceedence Level Long-Term Forecasts.**

### 8.4.4 Extending the Proof of Concept to the California Aqueduct

Since the RTDF committee is concerned with the quality of water that is delivered to the water contractors, the original proof of concept consisted of a Delta component (Suits and Wilde, 2003) and the California Aqueduct (Liudzius, 2003). SWP Banks Pumping Plant and CVP Tracy Pumping Plant EC results from the 1998 three 50% exceedence level DSM2 forecasts: January, March, and May, the 1998 historical simulation, and an O&M forecast that included the operations for the California Aqueduct were used as the input in two daily time step models:

- O'Neill / San Luis Model – blends water in the O'Neill Forebay, and
- California Aqueduct Model – simulates water downstream of O'Neill Forebay.

Since inflows to the O'Neill Forebay come from three sources: California Aqueduct, the CVP's Delta Mendota Canal, and releases from San Luis reservoir, Delta water was blended with the San Luis releases before being used as input into the California Aqueduct Model (Liudzius, 2003).

The 1998 O&M forecasts did not include all of the input data required by the California Aqueduct Model, therefore assumptions were made to estimate some of the demands and diversions along the California Aqueduct (Liudzius, 2003). Liudzius adopted an approach to estimate South of Delta demands and inflows by maintaining an overall water balance and then making estimates based on historical operations and use patterns. These estimates took into account physical limitations.

1998 EC at the O'Neill Forebay outlet for the Metropolitan Water District's California Aqueduct Model for the three 50% exceedence level forecasts and the historical simulation are shown below in Figure 8.7. Liudzius (2003) pointed out that the results at downstream locations along the California Aqueduct generally follow the trend of water quality predicted by DSM2 at the SWP intake and to a lesser degree the trends of the DMC intake. Again, the California Aqueduct extension proof of concept indicates that developing and conducting long-term water quality forecasts is promising. However, further study in how accurate forecasts of fall Delta inflow needs to be in order to obtain useful forecast EC at the SWP remains to be investigated.

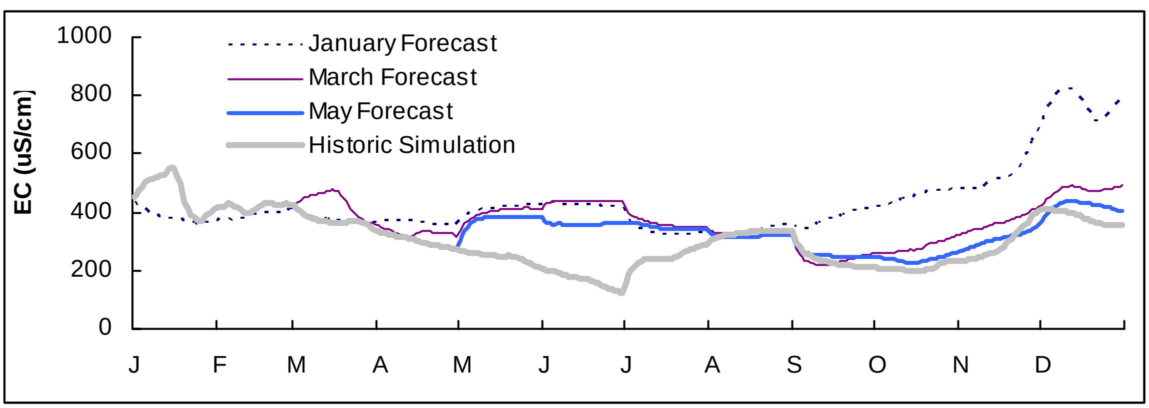


**Figure 8.7: EC at O'Neill Outlet for MWD California Aqueduct Model Based on DSM2 Historical and Long-Term Forecast Simulations.**
**(taken from Liudzius, 2003)**

## 8.5 Short- vs. Long-Term Forecasts

Two types of water quality forecasts that have been discussed: weekly (short-term) – O&M production Delta water quality and stage forecasts, and seasonal (long-term) – Delta and California Aqueduct proof of concept work. Each type of water quality forecast can be used to answer different questions. Generally, the short-term forecasts are used to answer immediate operations needs, but since these forecasts are typically limited to simulating 1 to 2 months, they have little value for making long-term operational decisions. In contrast, the seasonal (long-term) forecasts make less use of real-time field data, but can be used to address possible management decisions several months in the future.

In the example shown in Figure 8.8, two forecasts start on Feb. 27. The weekly forecast ends three weeks later, while the seasonal forecast continues through Dec. 31. Although the weekly forecast incorporates real-time field data into its initial conditions, as the simulation moves further away from the Feb. 27 start data, the weekly forecast values approach the accuracy of the values used in the seasonal forecast. In other words, there is no real benefit to extending the weekly forecast beyond a month or two.

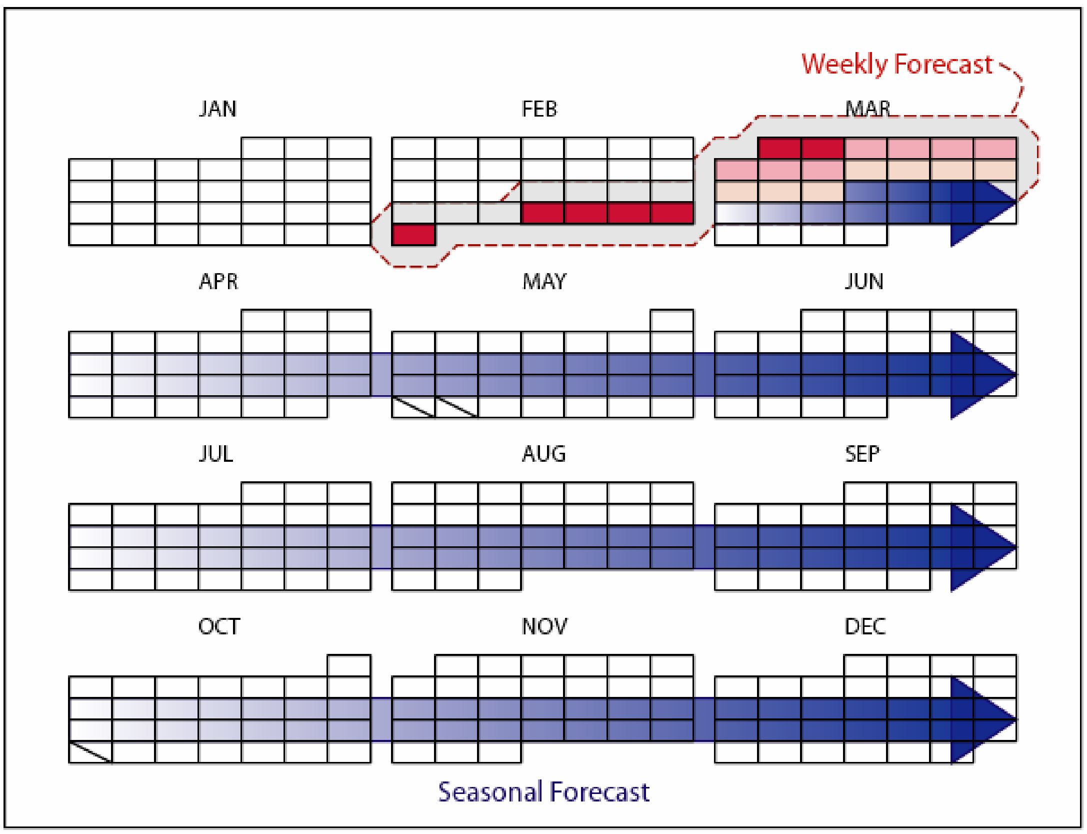


**Figure 8.8: Time Frame of Short- (Weekly) vs. Long-Term (Seasonal) Forecasts.**

### 8.5.1 Differences Between Weekly and Seasonal Forecasts

The primary differences between the weekly and seasonal forecasts are listed in Figure 8.9. The weekly forecasts are used to forecast water quality at the urban intakes and south Delta stage, while the seasonal forecasts usually focus solely on water quality at the urban intakes. When the seasonal model is coupled with MWD's O'Neill / San Luis and California Aqueduct models, water quality in the California Aqueduct is also simulated. O&M typically uses a single forecasted daily hydrology per weekly DSM2 simulation, but has used the model to produce multiple forecasts for the same time frame by changing the modeled operation (i.e. by changing the installation / removal dates or the position of tidal flap gates) of the south Delta temporary barriers. In contrast, the use of the seasonal model has focused on examining the long-term trends associated with different exceedence level forecasts.

Since the short-term forecast is concerned with accurate short-term results, it is necessary to transition from the real-time (historical) tidal boundary condition into a forecast tide. The method for doing this has been proven to be accurate, but within a month, the tidal boundary condition is completely based on the astronomical tide, changing from the historical tide.

| WEEKLY | SEASONAL |
|---|---|
| ***Output:***<br>- South Delta: Stage & Water Quality<br>- Urban Intakes: Water Quality | ***Output:***<br>- Urban Intakes: Water Quality<br>- California Aqueduct: Water Quality |
| ***Hydrology:***<br>- Single Forecast<br>- Daily Flows | ***Hydrology:***<br>- Multiple Exceedence Forecasts<br>- Monthly Flows |
| ***Ocean Boundary:***<br>- Historic transitions to Astronomical | ***Ocean Boundary:***<br>- Astronomical |
| ***Barriers:***<br>- Operations based on Expected Construction Schedules / Contracts | ***Barriers:***<br>- Operations based on Previous Operations and Design |

**Figure 8.9: Comparison of Weekly vs. Seasonal Forecasts.**

Although the seasonal forecast from water quality uses a real-time historical simulation to generate initial conditions, the hydrodynamic simulation in a seasonal forecast is uncoupled from the real-time data. There is no point in transitions real-time stage data into an astronomical model when the decisions made using the seasonal forecast will likely extend beyond the influence of the observed tidal data. Instead, a pure astronomical based tide is used.

Finally, the methodology used to operate the barriers and gates in the Delta is different between the two forecasts. In weekly forecasts, the planned operation of the barriers is available via scheduled installation or removal contracts. However, since it is difficult to foresee the exact timing of the scheduled construction or operation of a barrier or gate months in advance, the general operating rules for all of the Delta structures are determined based on time of year and forecast flows and are consistent with assumptions in planning studies connected to CALSIM output. The process used to govern seasonal gate and barriers operations under hypothetical San Joaquin inflows is described in more detail in Suits and Wilde (2003).

### 8.5.2 Seasonal Methodology

The methodology used to simulate just the flows and water quality in the expanded Delta proof of concept (see Section 8.4.2) is illustrated below in Figure 8.10. This methodology will be used in future Delta seasonal forecasts as well, but does not include the process used to model the California Aqueduct.

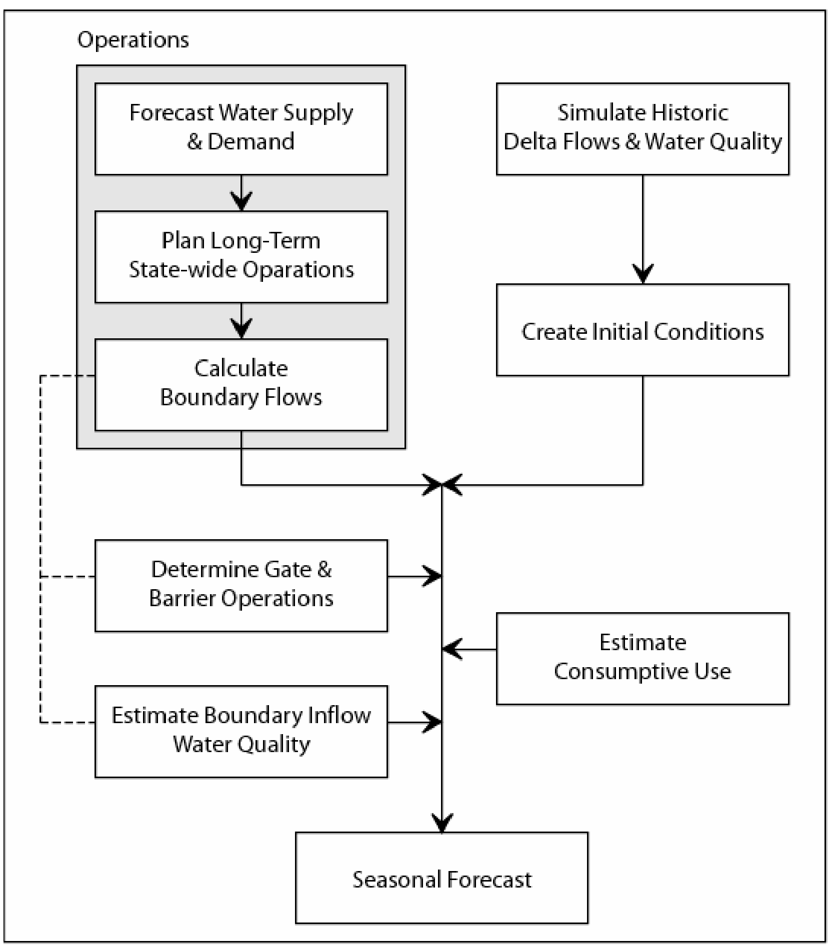


**Figure 8.10: Seasonal Forecast Methodology.**

Seasonal forecasting in the Delta can be described by four primary tasks: generating an operations forecast, generating corresponding forecast boundary conditions, updating the real-time (historical) simulation in the Delta, and then combining the operations forecast with the real-time historical simulation. The seasonal forecasts typically begin on the first of a month and continue through the end of the calendar year. Historical simulations are only used to generate the initial water quality throughout the Delta. Currently, DSM2 forecasts are limited to simulating EC, which is sometimes converted to TDS and bromide using the EC results.

O&M already forecasts water supply and demand when creating long-term state-wide operations. The boundary flows into the Delta can be taken directly from the O&M long-term operations forecasts. The operation of gates and barriers and the EC at the Delta boundaries are calculated using the O&M boundary flows. The O&M long-term operations forecasts estimate the net Delta consumptive use, which is then distributed to represent various island diversions and return flows based on the ADICU model.

### 8.5.3 Weekly Methodology

The original methodology described by Mierzwa (2001) is still being used by O&M when conducting weekly forecasts. However, the pre-processing and post-processing methods have been slightly modified. First, the MS Access Forecast form is not being used to convert the MS Excel spreadsheet based forecasts into the DSS time-series format for DSM2 use. Instead of using the GUI, the spreadsheet based forecasts are converted into DSS using scripts. Next, the data for each forecast is not being saved on a central server. This means that different users will not be able to share forecasting input.

Typically weekly forecast results are used in adjusting current field operations, thus the most pressing need of the DSM2 short-term forecasting system is to produce valuable results in short order. Although some of the original GUI based tools were developed with repeatability in mind, they are not as timely to use as simple scripts.

## 8.6 Development Tasks

Understanding that the O&M weekly forecasts have been adapted to facilitate short-term decision and operations support, but also recognizing the value illustrated in the long-term seasonal forecasts to longer term planning, RTDF has decided to improve both the existing weekly forecasting and develop a ready-to-use seasonal forecasting tool. For both the weekly and seasonal forecasts, the major development phases and the milestones associated with the completion of each of these phases are listed in Figures 8.11 and 8.12.

| | |
|---|---|
| **PHASE 0: Existing Production Runs**<br>- EC<br>- Stage<br>- TDS & Bromide Conversions | **PHASE 4: Direct TDS & Bromide Simulation**<br>- Re-calibrate DSM2<br>- Develop Warm Start |
| **PHASE 1: Basic Improvements**<br>- Fingerprinting<br>- Standard Water Quality Results Report<br>- Forecast Delta Consumptive Use<br>- Historic DSM2 Simulation | **PHASE 5: Forecast Organic Carbon**<br>- Boundary Conditions<br>- Improve Historic DSM2 Simulations<br>- Forecast Precipitation and Storm Runoff |
| **PHASE 2: Develop Aqueduct Model**<br>- Determine Data Needs<br>- Investigate Sensitivity of Aqueduct Operations / Deliveries<br>- Develop Network to Share Data | **PHASE 6: Couple DSM2-Aqueduct Extension**<br>- Complete DSM2-Aqueduct Model<br>- Link DSM2 and Aqueduct Extension |
| **PHASE 3: Improved TDS & Bromide**<br>- Boundary Conditions<br>- Link to Fingerprinting | **PHASE 7: Couple DSM2-SJR Extension**<br>- Investigate Data Availability Upstream of Vernalis |

**Figure 8.11: Future Development Phases and Milestones for Weekly DSM2 Forecasts.**

| | |
|---|---|
| **PHASE 0: Proof of Concept**<br>- Historic DSM2 Simulation<br>- EC & Fingerprinting<br>- TDS & Bromide Conversions | **PHASE 4: Direct TDS & Bromide Simulation**<br>- Re-calibrate DSM2<br>- Develop Warm Start |
| **PHASE 1: Regular Updates**<br>- Historic DSM2 Simulation<br>- Develop Network to Share Data<br>- Forecast Delta Consumptive Use<br>- Investigate Sensitivity of Water Supply Forecasts<br>- Standard Water Quality Results Report | **PHASE 5: Couple DSM2-Aqueduct Extension**<br>- Complete DSM2-Aqueduct Model<br>- Link DSM2 and Aqueduct Extension |
| **PHASE 2: Develop Aqueduct Model**<br>- Determine Data Needs<br>- Investigate Sensitivity of Aqueduct Operations / Deliveries<br>- Develop Network to Share Data | **PHASE 6: Couple DSM2-SJR Extension**<br>- Investigate Data Availability Upstream of Vernalis |
| **PHASE 3: Improved TDS & Bromide**<br>- Boundary Conditions<br>- Link to Fingerprinting | NOTE: Highlighted Phases are unqiue to Seasonal Forecast Modeling. |

**Figure 8.12: Future Development Phases and Milestones for Seasonal DSM2 Forecasts.**

Most of the development associated with the weekly forecasts can be directly used in the seasonal forecasts. The primary difference between the two forecasting approaches lies in the earlier development phases. The milestones associated with each of the phases are described below.

### 8.6.1 Phase 0: Existing Production Runs / Proof of Concept

Currently, O&M is using DSM2 weekly forecasts to aid in adjusting operations in order to meet Delta salinity standards. These same DSM2 forecasts are used by the Temporary Barriers and Lower San Joaquin Section to disseminate information on forecast water levels to the public.

This phase represents the on-going work associated with both forecasting systems. When needed, EC results from either model are simply being converted to TDS or bromide based on relationships between those constituents and EC. Development work on this phase is finished.

### 8.6.2 Phase 1: Basic Improvements / Regular Updates

Fingerprinting is the methodology used to determine the relative contributions of water sources to either a total volume or water quality constituent concentration at a specified location (Anderson, 2002). Although fingerprinting results have been integrated into the seasonal forecasts, they have not yet been incorporated into the weekly forecasts. The key to producing meaningful short-term source water fingerprints is finding a way to estimate the initial conditions prior to starting the forecast run. Initial source water fingerprints are conceptually no different than finding the initial EC conditions for a DSM2-QUAL run. Any water quality constituent initial condition can be found by assuming a uniform initial concentration of zero for all constituents and allowing mixing over the course of several months to distribute and blend the concentrations associated with the boundary inflows throughout the Delta. This process is often referred to as a cold start.

The length of time required for complete mixing can be measured by checking for the conservation of mass for a series of volumetric fingerprints. The general fingerprinting methodology introduced by Mierzwa and Wilde (2004) was modified for use in the improved proof of concept (see Section 8.4.1). The volumetric fingerprints found that the minimum length of time required for complete mixing, which is necessary for a cold start initialization, depends not only on the time of year (start date of a forecast), but on the flows associated with the start date. In general, drier conditions require longer cold start initialization periods ranging from 2 to 4 months.

Fingerprinting in both forecasts will be accomplished by continually updating the historical DSM2 simulation and using the final state of its water quality constituents as the initial conditions for the forecasts. Since the historical simulation goes back to 1990, achieving a long enough simulation to account for complete mixing will be simple. Each update of the historical simulation will be appended to the previous historical updates.

Finally, the RTDF will work to facilitate both regular updates to the historical and forecast simulations in addition to standardizing the results of the DSM2 forecasts. Forecast results will be included in MWQI's water quality update.

### 8.6.3 Phase 2: Develop Aqueduct Model

Simultaneous to the work on streamlining the dissemination of forecast results and inclusion of fingerprinting, work has already begun on determining the data needs and design of a California Aqueduct extension for forecasting. This phase is focused on determining the data necessary to model the aqueduct and developing a communication network to ensure that real-time data and forecasts for SWP demands and deliveries will be available for later work when the Aqueduct model is coupled to DSM2.

### 8.6.4 Phase 3: Improved TDS & Bromide

TDS and bromide forecast results were estimated by converting modeled EC results using TDS / EC and bromide / EC relationships. These relationships were developed for different Delta urban intakes. The regressions used to convert EC into TDS and bromide will be improved and can make use of the fingerprinting results that will be available after the completion of Phase 1.

### 8.6.5 Phase 4: Direct TDS & Bromide Simulation

Using the improved TDS and bromide regressions developed in Phase 3, it will be possible to apply those boundary conditions directly into DSM2 and begin the process of re-calibrating and validating DSM2 for these constituents. A cold start process similar to that discussed above in Phase 1 (see Section 8.6.2) can be used to determine the initial TDS and bromide conditions in production forecast simulations. Nonetheless, modifications to the current EC warm start routine will also allow the weekly forecasts to directly simulate TDS or bromide in the same manner that they currently simulate EC.

### 8.6.6 Phase 5: Forecast Organic Carbon (short-term only)

Though there is a strong interest in forecasting the concentration of organic carbon in the SWP system, peak organic carbon concentrations in the Delta are highly correlated with early winter runoff events. The ability to forecast the increase of organic carbon in the Delta is tied to the ability to accurately forecast the approximate date of the early storm events. Although it may be possible to produce meaningful short-term organic carbon simulations based on precipitation forecasts, seasonal forecasting will be problematic in the first months since significant flows in the Sacramento and San Joaquin rivers originate from overland flow instead of reservoir releases. Instead, the focus of this phase will be to develop accurate flow / precipitation – organic carbon relationships that can be used to recreate the historical boundary conditions and forecast the future boundary conditions necessary for short-term weekly organic carbon forecasts.

### 8.6.7 Phase 6 / 5: Couple DSM2-Aqueduct Extension

Building upon the work of Phase 2, a stand-alone DSM2-Aqueduct model is being developed by CH2M-Hill. The model can be run independently from DSM2 or linked to DSM2 as needed. It will need to use of California Aqueduct forecasts, including aqueduct demands and deliveries. The basic development of this model is schedule to be completed by the end of 2004.

### 8.6.8 Phase 7 / 6: Couple DSM2-SJR Extension

The last development task to meet the immediate RTDF forecasting goals will be to investigate the data availability of flow and water quality information upstream of Vernalis in order to extend the DSM2 forecasting system to the San Joaquin River. Like the DSM2-Aqueduct extension, the DSM2-SJR extension can either be used with the DSM2 forecasts as a stand along model or an extension. By including the San Joaquin River in the forecasts, the regressions used to relate water quality constituents to flow at Vernalis can be replaced by simulations that account for variable source water and associated water quality characteristics.

## 8.7 Conclusions

The seasonal forecasting proof of concept work in the Delta and along the California Aqueduct combined with the usefulness of the weekly DSM2 Delta forecasts have shown that there may be value in developing parallel water quality forecasting systems for the SWP system. The focus of the weekly forecasts already is and will continue to be to aid short-term operations decision making, and RTDF will continue to develop a long-term seasonal forecasting system whose potential for providing useful information to water managers will be further investigated.

## 8.8 References

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