

**TESTIMONY OF DR. RUSS BROWN, DR. PHIL UNGER,
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**Bay-Delta Workshop
June 14, 1994**

**USE OF HISTORICAL DAILY DATA FOR DELTA WATER
SUPPLY AND FISHERIES MANAGEMENT**

This testimony addresses key issues no. 1 and 2 in the notice for the June workshop to review standards for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary:

- What factors, excluding diversions, contribute to the decline of fish and wildlife resources in the Bay-Delta Estuary?
- What modifications have the State Water Program (SWP) and Central Valley Program (CVP) made to their operations to protect endangered species and other species of concern?

At the May Bay-Delta workshop, Jones & Stokes Associates demonstrated the importance of historical daily data for providing an accurate understanding and basis for efficient and effective management of Delta water resources.

Jones & Stokes Associates is serving as the consultant to the California State Water Resources Control Board (SWRCB) and U.S. Army Corps of Engineers in preparing an environmental impact report/environmental impact statement (EIR/EIS) on a proposed in-Delta water supply facility. To support that EIR/EIS, Jones & Stokes Associates has developed several integrated historical Delta daily data files and analytical tools. Jones & Stokes Associates is convinced that daily data and analytical tools offer important advantages for evaluating historical Delta environmental conditions and developing future Delta water and fisheries management strategies. Daily tools were not available during the 1992 hearings and workshops for the proposed D-1630 standards. The use of daily data to support efficient and effective Delta management decisions may require a new approach to Delta decision making that we will refer to as the "Delta Master" concept.

DAILY CHANGES IN DELTA CONDITIONS

Delta standards and water supply impacts have generally been based on analyses of monthly (or longer) periods of hydrologic and fisheries conditions. Delta operations, however, fluctuate in response to daily changes in hydrologic, water quality, and fisheries conditions. The purpose of this testimony is to demonstrate the importance and feasibility of using historical Delta daily data for evaluating environmental conditions and the likely

response of fish populations to historical Delta operations. Evaluation of daily data can provide a more accurate basis for efficient and effective Delta standards.

Three broad categories of changes in daily Delta conditions include:

- hydrologic changes from inflows and tidal effects;
- water quality changes from inflows, salinity intrusion, variations in temperature, and phytoplankton growth; and
- fisheries changes from migration and transport, spawning, growth, and mortality (e.g., entrainment losses) processes.

Daily changes in Delta conditions have important effects on Delta operations, fish distribution and abundance patterns, and compliance with Delta standards. The feasibility of providing historical Delta daily data and daily analytical tools to all parties interested in Delta water and fisheries management issues will be described in this testimony.

The results of monthly models may be adequate for assessing potential Delta impacts and benefits whenever changes in the Delta persist for a month or more. For example, a monthly model may adequately simulate seasonal changes in Delta outflow, salinity gradient location, or abundance of striped bass juveniles or adults. Monthly models, however, do not necessarily represent the mechanisms causing the apparent relationship. Many potentially important short-term changes in Delta conditions, such as storm-event inflows, fish "flushing" transport flows, closure of the Delta Cross Channel (DCC) gates, or spatial and temporal changes in larval fish densities, may not be adequately represented using monthly models.

As described in Jones & Stokes Associates' testimony at the May workshop, the DeltaSOS monthly operations model has been modified to simulate Delta operations with a daily time step. The DailySOS daily operations model can be used to simulate Delta operations and evaluate possible water supply impacts in response to short-term hydrologic events. Potential impacts on water quality and fish were not simulated at a daily time step because sufficient information was not available to accurately assess these daily effects. Existing daily water quality and fisheries data should be used more extensively for developing Delta standards and management strategies, as recommended in this testimony.

A slightly new approach to Delta decision making may be required to use the available daily information to support Delta management efforts. The concept of a Delta Master will be briefly introduced before the use of daily data for Delta water and fisheries management is described in more detail.

THE DELTA MASTER CONCEPT

The concept of a Delta Master is illustrated in Figure 1. Daily operations of Delta water supply and fisheries resources might be coordinated by a designated Delta Master

team, which would be responsible for daily Delta water allocation and control of Delta facilities, much the same as a Water Master is designated to control groundwater basins or appropriated streams in several western states. Perhaps a three-person Delta Master team with water supply and fish protection advocates would facilitate the exchange of information and resource perspectives that will be needed to effectively and efficiently manage Delta resources.

The framework for the Delta Master water allocation and Delta operations decisions would be provided by SWRCB water rights and water quality requirements, Federal Ecosystem Directorate (FED) directives and guidelines, and the existing and future Delta management agencies and facilities.

Accurate and updated Delta daily data would be essential for the Delta Master team's daily operations decisions. The source of accurate Delta daily data is the Interagency Ecological Program (IEP) staff, which conducts a wide variety of monitoring and sampling programs. Several years of historical Delta daily data could be integrated and distributed in an easily used format to IEP staff and others who are attempting to develop an improved understanding of Delta conditions and fisheries responses. The network of "real time" or "recent time" monitoring programs for various Delta water and fish variables is expanding and improving.

Delta Master Parallel Projections and Allocations

The concept of "parallel" Delta operations for water supply and fisheries management is illustrated in Figure 2. Delta management decisions should be based on updated water supply forecasts and fish population and habitat projections. Water supply forecasts are dependent on hydrologic, reservoir, and diversion data. Fish population and habitat projections require (in addition to biological data) Delta flow, salinity, and temperature data. Daily data could be made more easily available for updating these water supply forecasts and fish population and habitat projections. The California Data Exchange Center (CDEC) is an existing system that might be used for this purpose.

Delta operations affect water supply and fish habitat conditions throughout the Delta simultaneously. For example, closing the DCC gates for Sacramento River fish migration and transport protection or for flood control purposes will reduce San Joaquin River QWEST flows and may require reductions in Delta exports. The combined effects of Delta operations on channel flows, salinity, and fish population distribution and abundance should be accurately accounted for in Delta management decisions.

Delta management should recognize both water supply targets and fish population distribution and abundance targets for multiple species of concern. Water supply advocates should consider how to best provide increased fish protection; fish advocates should consider how to best provide adequate water supply benefits.

In contrast to this proposed "parallel" Delta operations strategy, current Delta management might be termed "tandem" management, with D-1485 standards providing the frame, water supply management in the front seat, and fisheries management pedaling from behind. Recent Endangered Species Act and Clean Water Act directives have perhaps reversed the seating order but have not yet achieved the goal of "parallel" Delta management of fisheries and water supply resources. More accurate accounting of fish habitat and fish population responses to Delta conditions and operations will provide the greatest possible Delta water supply relative to a desired level of fisheries benefits.

Delta Master Daily Decision Making

The importance of historical and updated Delta daily data for the proposed "conditional" operation of the Delta is illustrated in Figure 3. A wide variety of detailed data is currently available for characterizing Delta environmental and fisheries conditions. There may be some unavoidable time lag required for some types of sample processing, but many measurements are now approximately "real time". New measurement programs will certainly be developed and added to the IEP network of sampling programs in the near future.

The Delta Master would have two sets of balancing requirements for Delta management decisions:

- protective minimum flows and water quality standards for fisheries and other beneficial in-Delta uses, and
- conservative minimum water supply export requirements.

These balancing requirements for fisheries and water supply benefits would regulate the extremes but would allow a substantial range of flexibility to allow the Delta Master to operate the Delta in response to daily changes in hydrology, water quality, and fish population conditions.

Fixed monthly standards to provide "optimum" conditions for each water year type would be replaced with flexible rules and guidelines for the appointed Delta Master team to implement on a daily basis. FED directives and Endangered Species Act consultation would be included in these daily Delta Master deliberations, along with CVP and SWP operations.

Daily analytical tools that will allow the likely effects of alternative Delta operations to be "projected" are needed for the proposed Delta Master daily decision making. The DailySOS model, introduced in the May workshop, is an example of such a daily analytical tool. Several other possible daily analytical tools will be described in the next part of this testimony.

DAILY DELTA Analytical tools

There are two basic groups of daily analytical tools available for understanding and managing the Delta (Figure 4). The first group of tools uses the historical Delta daily data to test various hypotheses about the effects of historical environmental conditions and Delta operations on observed fisheries responses. These are termed "descriptive" models. These descriptive models use historical Delta daily data as inputs and for testing the results.

The second group of analytical tools simulates the expected effects of projected future Delta environmental conditions and operations on likely fisheries responses. These are termed "projective" models. Projective models are usually developed from descriptive models that have been confirmed with historical testing. These projective models require historical Delta daily data, including "real time" or "recent time" monitoring data, for updating current Delta conditions to more accurately project future Delta conditions and fisher population responses.

Available Delta Daily Data

There is a wide variety of historical Delta data that has been collected daily or at several-day intervals by IEP staff and others that could be made more widely available. Providing existing daily data to those interested in "parallel" management of Delta water supply and fisher population management would allow development of daily analytical tools that could be used to support daily Delta operations decisions.

Several examples of important available Delta daily (or near-daily frequency) data are:

- streamflow and export pumping records (DAYFLOW);
- tide gages;
- electric conductivity (EC) monitors;
- ultrasonic velocity meter (UVM) channel flow stations;
- SWP Skinner, CVP Tracy, and Pacific Gas and Electric Company (PG&E) fish salvage records;
- California Department of Fish and Game (DFG) and U.S. Fish and Wildlife Service fish sampling;
- DFG, California Department of Water Resources (DWR), and U.S. Bureau of Reclamation (Reclamation) egg and larval sampling;

- minerals and nutrients sampling; and
- phytoplankton and zooplankton sampling.

Most of these Delta daily data have been collected for several years by IEP staff or other responsible agencies. The original field and laboratory measurements are carefully processed and stored in various databases, such as the U.S. Environmental Protection Agency's (EPA's) STORET or DWR's Delta DATA. However, more of this existing data should be made available as integrated daily data files that can be distributed in an easily used format to interested parties so that the data can be transformed into more generally useful information. Analysis of the data by several investigators with different perspectives will certainly yield more complete understanding of Delta hydrologic and fisheries responses to environmental conditions and Delta operations.

Delta Daily Data System Concept

The concept of an integrated Delta daily data system is illustrated in Figure 5. The historical Delta data are the only reliable source of information for better understanding and managing the Delta. The historical Delta data are therefore an important key to successful "parallel" management of Delta water supply and fisheries resources. The proposed Delta daily data system may be called DAYDATA.

The goal of the Delta daily data system is to increase the use of historical data to allow integrated analysis of the effects of environmental conditions and Delta operations on fish habitat, distribution, and abundance in the Delta. Several possible daily data files and analytical tools are described below.

DAYFLOW

The DWR Central District DAYFLOW data file provides estimates of daily Delta inflows, exports, channel depletions, and outflow. This file is updated for each water year. This is considered to be an "integrated" file because each Delta water budget term is included for each day of the year.

There are only a few Delta channel flows estimated in the DAYFLOW files. The combined DCC and Georgiana Slough flows, and QWEST flows are estimated. Other important Delta channel flows, such as Old River diversion, Old and Middle Rivers at Bacon Island, Threemile Slough, False River, Dutch Slough, San Joaquin River at Antioch, Montezuma Slough, and net flow past Chipps Island are not estimated in DAYFLOW. These channel flow estimates, based on Delta hydraulic flow model results, could be added to DAYFLOW files.

Estimates of Delta agricultural diversions and drainage flows, as well as PG&E power plant cooling water flows, North Bay Aqueduct pumping, and other important Delta flows, could be added to DAYFLOW files.

DAYTIDE

Tidal flows are not included in DAYFLOW but could be estimated from Delta hydraulic model results combined with observed tides. The UVM flow measurement stations operated by the U.S. Geological Survey can provide both net and tidal flow information at several Delta locations. It is recommended that these tidal measurements be summarized in a second set of Delta daily data files that could be called DAYTIDE.

DAYSALT

There are approximately 25 stations measuring hourly EC throughout the Delta. These EC data can be summarized with daily minimum, mean, and maximum values. These could be arranged in standardized daily data files for the available period of record: 1968-1993 (26 years). This set of files and associated analytical tools could be called DAYSALT.

An initial set of DAYSALT files has been prepared for the Central Valley Project Improvement Act Programmatic EIS Existing Conditions Habitat Water Quality Technical Appendix. The possible uses for the DAYSALT files are illustrated in a series of graphs that has been prepared for a Delta EC Data Atlas that is provided as an exhibit to this testimony. The relationship between estimated Delta outflow (from DAYFLOW) and mean daily EC measurements from five EC stations (Benicia, Port Chicago, Pittsburg, Collinsville, and Emmaton) in the western Delta and Suisun Bay are shown for each year.

A second graph for each year shows the approximate position of the salinity gradient (1, 3, 5, 7, and 9 mS/cm EC), estimated from the mean daily EC measurements, and the calculated position of the 2 parts per thousand (bottom) salinity, abbreviated as X2 (similar to the 3 mS/cm EC position). A map of the estuarine portion of the Delta and the location in kilometers upstream from the Golden Gate bridge is shown for reference.

The second graph for each year illustrates the use of a daily analytical tool for interpreting the available daily EC measurements. This particular analytical tool supports the evaluation of the estuarine standards proposed by EPA, but many additional analyses with the EC data are possible, once they are made available in the DAYSALT standardized format.

For example, fish sampling survey data along this portion of estuary can be represented by the number of fish collected at each station on a particular date. These data could be combined with the EC gradient estimates to investigate relationships between fish distribution patterns and EC gradient or entrapment zone location.

At the end of the Delta EC Data Atlas is a diagram showing the approximate relationship between the upstream end of the salt gradient, approximated as the 3 mS/cm EC position, and the upstream freshwater habitat surface area. The Delta outflow required to maintain the salinity gradient at a fixed location is given at the top of the diagram. Historical effects of Delta outflow on estuarine EC conditions and possible effects of various water management strategies on estuarine habitat patterns can be visualized with the help of this diagram and the Delta EC Data Atlas graphs.

DAYTEMP

Water temperature is an important environmental variable that controls primary productivity and the growth and respiration of all aquatic organisms and fish species. Temperature may also be a factor influencing Delta mortality of migrating salmon. Meteorological measurements, solar radiation, and light extinction (Secchi depth) measurements would provide all necessary information for a Delta temperature analytical tool and set of data files that could be called DAYTEMP.

DAYFISH and DAYEGGS

Daily fish salvage records from CVP Tracy and SWP Skinner facilities have been collected for many years and have been recently confirmed and computerized (for 1980-1993) in a standard format by DFG. The 1993 records have been organized in a "demonstration" data file and analytical tool called DAYFISH.

Several types of sampling for Delta fish eggs and larvae are routinely conducted. One example is the DFG striped bass egg and larvae surveys that provide data on eggs and larvae abundance and distribution for several fish species. Another example is the striped bass pump samplers developed by Reclamation on the Sacramento River and similar devices that have been used at the Tracy facility since 1990. A third example is the agricultural diversion samples collected by DWR since 1992 at Bacon Island. A few records for 1993 have been organized in a demonstration data file called DAYEGGS.

Additional Delta Daily Data

These examples certainly do not represent all available historical Delta daily data that could be organized and integrated as part of the proposed DAYDATA system. Because of the recent emphasis on fisheries management and control of Delta operations under the federal Endangered Species Act, and because of current limits on Delta water supply operations, all available data should be used to accurately evaluate historical effects and develop reliable analytical tools that can support informed Delta management and operations decisions.

Demonstration of DAYDATA for 1993

A Delta Fish Habitat Data Atlas for 1993 is provided as a second exhibit for this testimony. Daily Delta inflows, exports, QWEST flows, and outflow conditions for water year 1993 (from DAYFLOW) are shown in a series of graphs. The first graph shows that Sacramento River flow was greater than 25,000 cubic feet per second (cfs) for most of the January through June period, so the DCC gates were closed for both flood control and fish transport protection (striped bass and winter run) during these months. The estimated QWEST flows were slightly reversed for several short periods and remained reversed from July through September.

A second graph shows CVP and SWP exports compared with San Joaquin River flows and illustrates that the source of export water can change dramatically. On some days, all Delta exports could have been supplied by San Joaquin River inflows. On other days, a considerable amount of additional Sacramento River water was required to supply exports. Tidal mixing and the hydraulic operations of Clifton Court may create additional differences in the source of CVP and SWP export water. An analytical tool is needed to estimate the source of export water for each export location.

The possible magnitude of the spring-neap tidal filling and draining cycle is illustrated in a third graph. An approximate net daily tidal outflow volume can be estimated using the mean daily (24-hour) record of tide at Mallard Slough (Chipps Island).

The surface area of Delta channels upstream of Chipps Island is approximately 45,000 acres. Therefore, a 1-foot change in mean tide represents an upstream volume of about 45,000 acre-feet (af). If the change in mean tide occurred in 1 day, this would be equivalent to a net daily tidal flow of 22,500 cfs. The magnitude of the net daily tidal outflow was estimated to be several thousand cfs on many days. This may be an important effect during periods of low Delta outflow (e.g., end of December). Estimates of this tidal outflow term, from historical tide measurements, could be added to the DAYTIDE and DAYFLOW files.

A fourth graph shows the daily mean EC data from several Delta stations (Chipps Island and upstream). The rapid increase in EC observed near the end of December appears to illustrate the combined effects of relatively low Delta outflow and net tidal inflow (upstream movement of salt gradient). Salinity was less than 1 mS/cm at Chipps Island from mid-January through June. These 1993 EC records were obtained from the DWR Delta Operations Water Quality bulletin board and CDEC. The downstream EC station records were not easily available.

A fifth graph shows the daily minimum and maximum water temperatures at Freeport and Vernalis. Additional measurement stations in the Delta, if available, should be compared with these inflow temperatures. Meteorological data, from the CIMIS stations (Davis, Lodi, Byron) should be included in the DAYTEMP files.

The remainder of the Delta Fish Habitat Data Atlas graphs show available fish density data, in units of fish per acre-foot (fish/af). The first fish density data are a combination of striped bass egg, larvae, and juvenile data from the Sacramento River (Reclamation data) and Bacon Island agricultural diversion entrainment from Middle River (DWR preliminary data) for water year 1993.

Density of striped bass eggs and larvae was at a maximum on the Sacramento River in early May, with densities of between 3,000 and 8,000 fish/af. Densities of striped bass larvae in Bacon Island diversions were greatest in late May and early June, with densities of between 100 and 600 fish/af. Juvenile striped bass densities in Bacon Island diversions were also at a maximum in late May and early June, with densities of between 10 and 70 fish/af.

The next graph shows the CVP Tracy and SWP Skinner salvage records for striped bass density. Salvage of striped bass at the SWP Skinner facility occurred predominantly from mid-May through mid-July. SWP salvage density during this period was between 10 and 80 fish/af. A total of 8,583,710 striped bass were salvaged at the SWP facility. The corresponding CVP Tracy salvage occurred generally in June, with striped bass density ranging from 10 to 50 fish/af. A total of 4,699,512 striped bass were salvaged at the CVP facility.

The following 20 graphs show the salvage density records for the 20 most abundant fish species at the salvage facilities. Threadfin shad were salvaged predominantly at the SWP facility in July and August, with a total of almost 7 million fish recorded. A total of about 1.5 million fish were salvaged at the CVP facility.

Differences in salvage fish density at the two facilities may be caused by a combination of Delta hydrologic conditions (source of pumped water) and different hydraulic characteristics of the CVP and SWP intake structures. Predation and resident fish in Clifton Court may also influence salvage records. Although further interpretation of fish salvage data by fisheries biologists familiar with fish life histories and salvage facility operations is required, the salvage data provide a demonstration of available daily fish information that could be used to support daily Delta operations decisions beyond the current limited use under the federal Endangered Species Act.

Daily Delta Analytical Tools

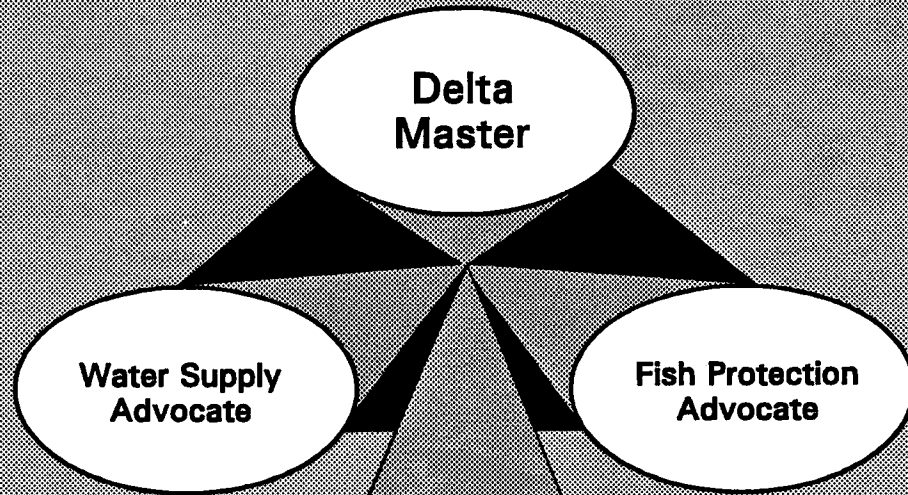
Several example analytical tools have been described as part of the Delta EC Data Atlas and Delta Fish Habitat Data Atlas exhibits. The DailySOS model that simulates the effects of possible Delta standards on daily Delta operations was introduced at the May workshop. A wide variety of creative and useful analytical tools will certainly be developed as a direct result of making the historical Delta daily data more easily accessible to a larger number of interested parties.

Many worthwhile efforts are underway to develop accurate and reliable Delta water and fish models. These relatively complex computer models (e.g., DWR particle transport model) might be viewed as the necessary scientific basis for simplified analytical tools that should also be developed for general purpose use by all those involved in solving the dilemma of "parallel" management of Delta fisheries and water supply resources.

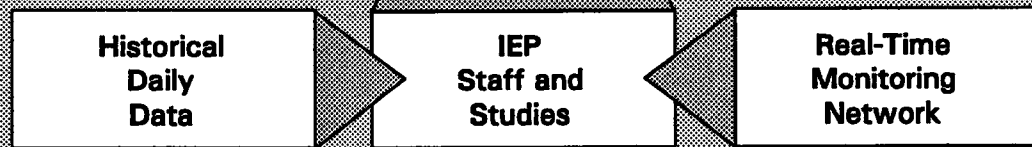


The Delta Master Concept

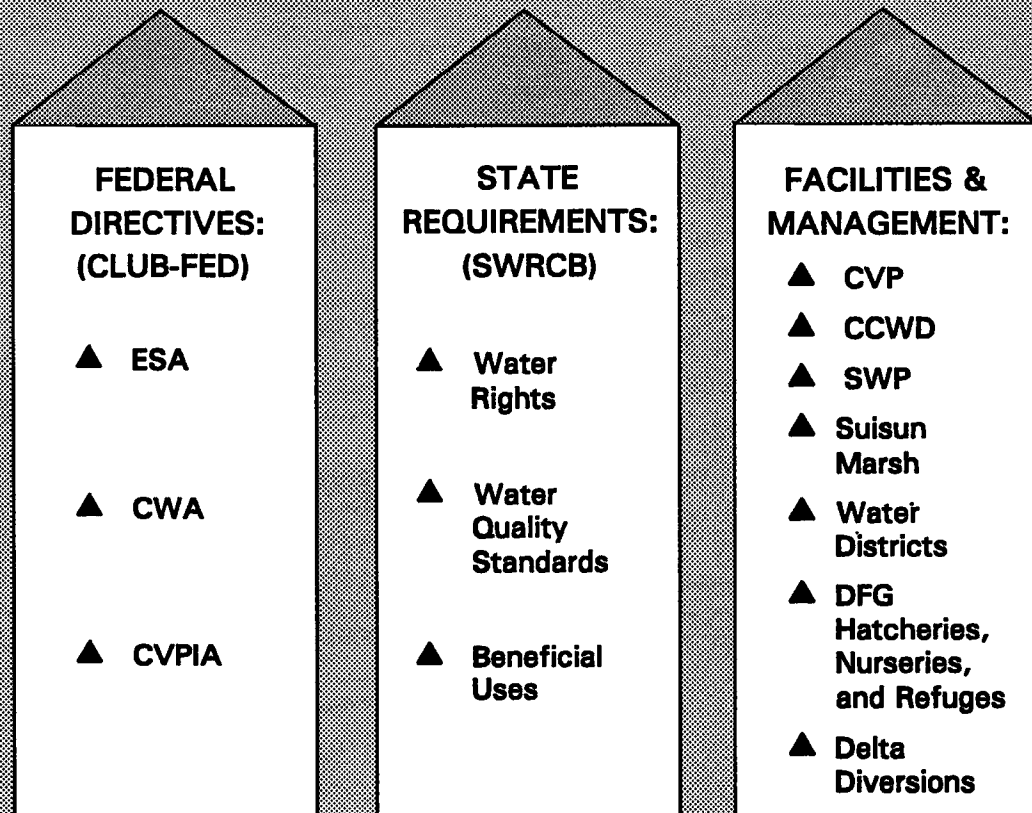
**Daily Consensus
and Operations
Decisions**



**Supporting
Staff and
Information**



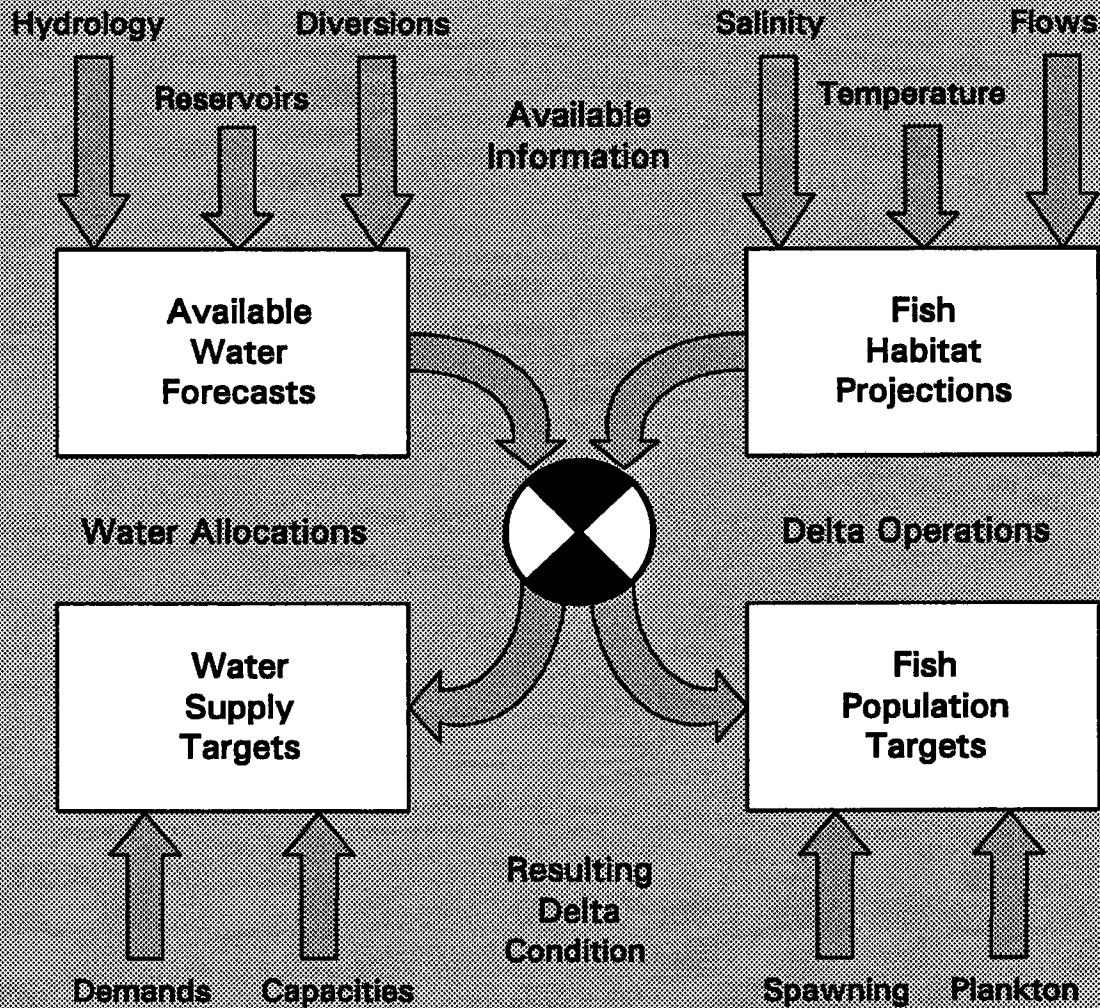
**Framework
for Allocation
Decisions**





Jones & Stokes Associates, Inc.

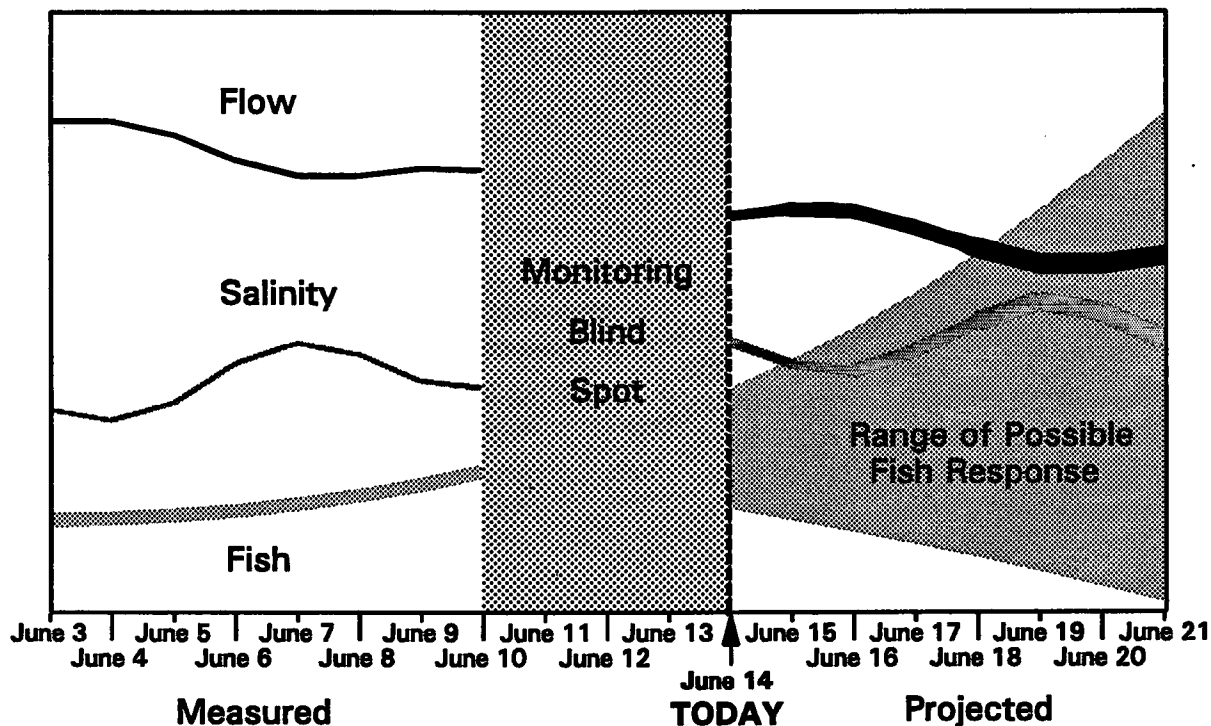
Delta Master Parallel Projections and Allocations



Accurate accounting of fish habitat and responses will provide the greatest possible Delta water supply.



Delta Master Daily Decision Making



Standards and Directives to Guide Delta Master Decisions

Conditional Standards

Example:
Required Delta outflow
is a function of
unimpaired flow

Flexible Standards

Example:
Export is a function of
Delta outflow and
QWEST requirements

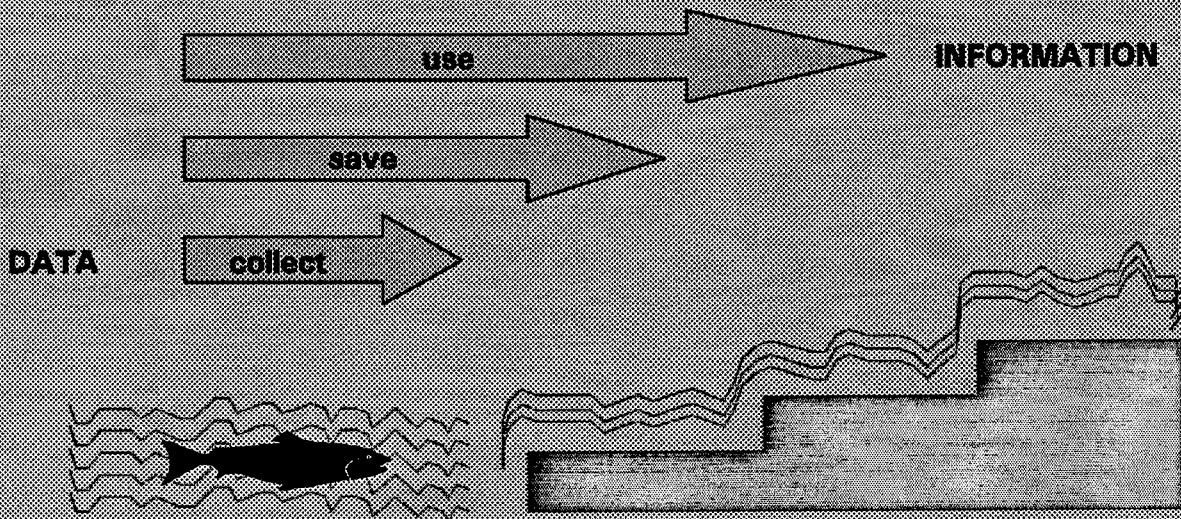
Protective
Flow and Salinity
Standards

~~Fixed
Monthly
Standards~~

Conservative
Water Supply
Requirements



Delta Master Tools for Analysis



Daily Data Sources:

- ▲ Streamflow and pumping records
- ▲ Tidal gages
- ▲ EC monitors
- ▲ Ultrasonic Velocity Meter (UVM) measurements
- ▲ Banks, Tracy, and PG&E fish salvage records
- ▲ Fish net sampling
- ▲ Egg and Larvae Sampling

Daily Analysis Tools:

- ▲ Descriptive models that interpret daily historical data
- ▲ Projective models that predict likely future daily environmental conditions and fisheries responses



Delta Daily Data and Analysis Tools

Goal:

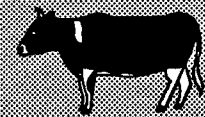
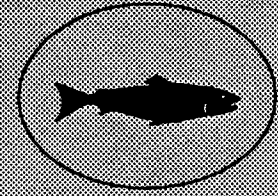
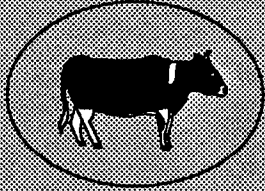
To accurately account for likely fish responses to potential Delta operations.

Premise:

Historical daily data is our only reliable source of information for better understanding and managing the Delta.

Proposed Action:

To organize historical daily data into integrated data files and daily models to provide interpretation of fish habitat, transport, spawning, distribution, and abundance in the Delta.



Proposed Delta Daily Data System (DAYDATA):

Daily Integrated Data Files:

Daily Interpretive Models:

- | | | |
|------------|---|------------------------------------|
| ▲ DAYFLOW | ➔ | Channel flows and fish transport |
| ▲ DAYTIDE | ➔ | Tidal flows and mixing |
| ▲ DAYSALT | ➔ | Estuarine habitat |
| ▲ DAYTEMP | ➔ | Primary production and fish growth |
| ▲ DAYEGGS | ➔ | Fish spawning simulation |
| ▲ DAYFISH | ➔ | Fish density and entrainment loss |
| ▲ DAY_____ | | DailySOS: Standards and operations |
| ▲ DAY_____ | | FISHPOP: Fish population estimates |
| ▲ DAY_____ | | |