State of California

The Resources Agency

Memorandum

Date : March 12, 1986

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To : Jerry D. Vayder

From : Sushil K. Arora
Planning Branch
Department of Water Resources

Subject: Operations Criteria Applied in DWR Planning Simulation Model

This memorandum report was prepared to document the Operations Criteria and Assumptions currently incorporated in the Department of Water Resources Planning Simulation Model. The Simulation Model is quite flexible in that any changes in operational assumptions could be easily made by modifying the input data file. For apparent reasons, more emphasis in this report is placed on the State Water Project Operations than Central Valley Project Operations.

Periodic up date of the report may be necessary in order to maintain up-to-date description of the operations criteria and assumptions.

Attachment

SURNAME	S. Arora			

DWR 155 (REV. 8/83)

CONTENTS

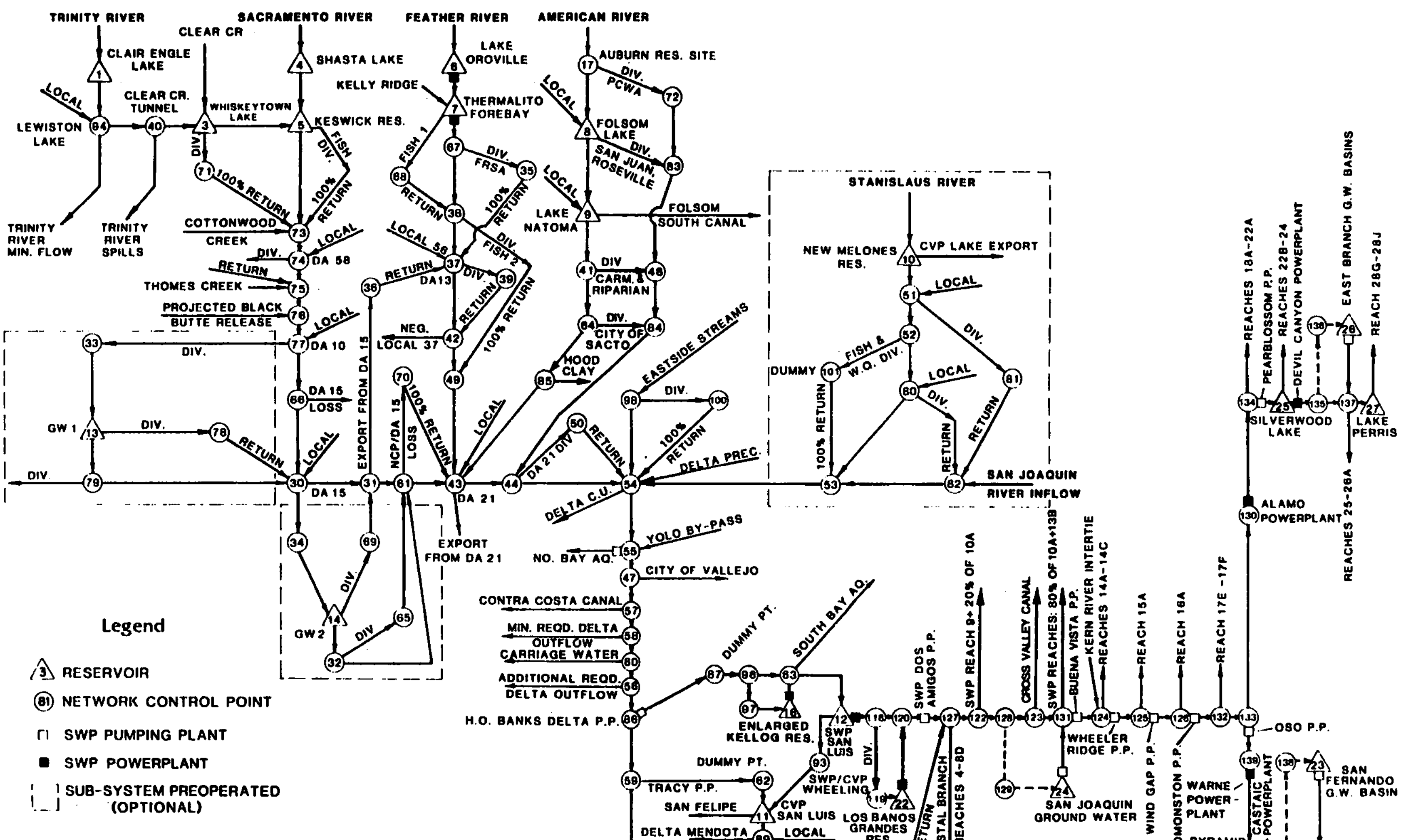
I. INTRODUCTION

This report describes the various types of operations criteria and assumptions currently used in the Department of Water Resources Planning Simulation Model for California (DWRSIM).

The Planning Simulation Model is a generalized computer planning model for California's Central Valley and its two major systems, the Central Valley Project (CVP) and the State Water Project (SWP) (see Figure I.1). It is designed to simulate operation of the CVP-SWP system on a monthly time basis for purposes of water supply, flood control storage, recreation, instream flow maintenance, and hydroelectric power generation. The model represents the actual CVP-SWP systems by a network of control points representing surface reservoirs, ground water reservoirs, and river and canal reaches. Control points are connected by links representing tributary stream inflows, pumping plants, and power generating plants. The program is quite flexible in that changes for almost any configuration of surface reservoirs, ground water reservoirs, river diversions, power generating plants, pumping plants, and conveyance facilities can be incorporated by changes in input data rather than by modifying the model. The schematic representation of the CVP-SWP systems is shown on Figure I.2. For more description of the Simulation Model refer to the Division of Planning's report "The Department of Water Resources Planning Simulation Model for California" January, 1985.

To conduct a typical planning study, certain criteria and assumptions must be pre-specified as input to the model in order to carryout a simulation of the CVP-SWP systems. In particular this operational data includes instream requirements for each river system, storage reservoir operational characteristics, Sacramento-San Joaquin Delta quality and associated outflow requirements, SWP-CVP coordinated operations parameters, San Luis Reservoir operation objectives, California Aqueduct operational constraints, and parameters for conjunctive operation of ground water storage projects when integrated with the SWP. At present planning studies are carried out under hydrologic conditions representing 1980, 1990 and 2000 levels of development. Demands on the systems can be selected for any present or future level.

Since the Department's objective is generally to investigate and evaluate different criteria and facilities of the SWP system, more emphasis in this report is placed on the discussion of SWP operational data. As far as CVP's operational characteristics are concerned, attempt is made to operate the CVP facilities so as to have comparable operations which match the Bureau of Reclamation's (USBR) operations in their planning model.



THE DWR PLANNING SIMULATION MODEL NETWORK REPRESENTATION

Revised January 1985

FIGURE 1

II. TRINITY RIVER SYSTEM

Clair Engle Lake

Clair Engle Lake provides for the regulation and control of Trinity River and for the transbasin diversion of approximately 80 percent of Trinity River water to the Sacramento River Basin to augment the supply and utilization of water in the Central Valley Project (CVP). Figure II-1 shows schematic representation of Trinity River and upper Sacramento River systems.

In the operation of the 2,448 TAF Clair Engle Lake, no specific provisions were originally made for flood control, although flood control reservation is maintained from October through February each year. Flood control space of 98, 498, 598, 388 and 388 TAF respectively, is maintained for the five month period as used by USBR in their operation studies.

Clair Engle Lake is also operated to satisfy minimum flows for fish and wildlife requirements below Lewiston Dam. This release is 287 TAF/yr during most years, reduces to 220 TAF/yr in dry years and further reduces to 140 TAF/yr during critical years. The definition of water year is determined by Shasta criteria and change is made effective March 1. Within the simulation model these flow requirements are shown as a diversion at control point (CP) 94.

Export to Sacramento River (for use in Central Valley Basin) is made via Judge Francis Carr Tunnel and Powerhouse which has a maximum capacity of 3,300 cfs. This export is maintained at about 670 TAF/yr during the critical period but during more normal hydrologic periods exports average closer to 900 TAF/yr.

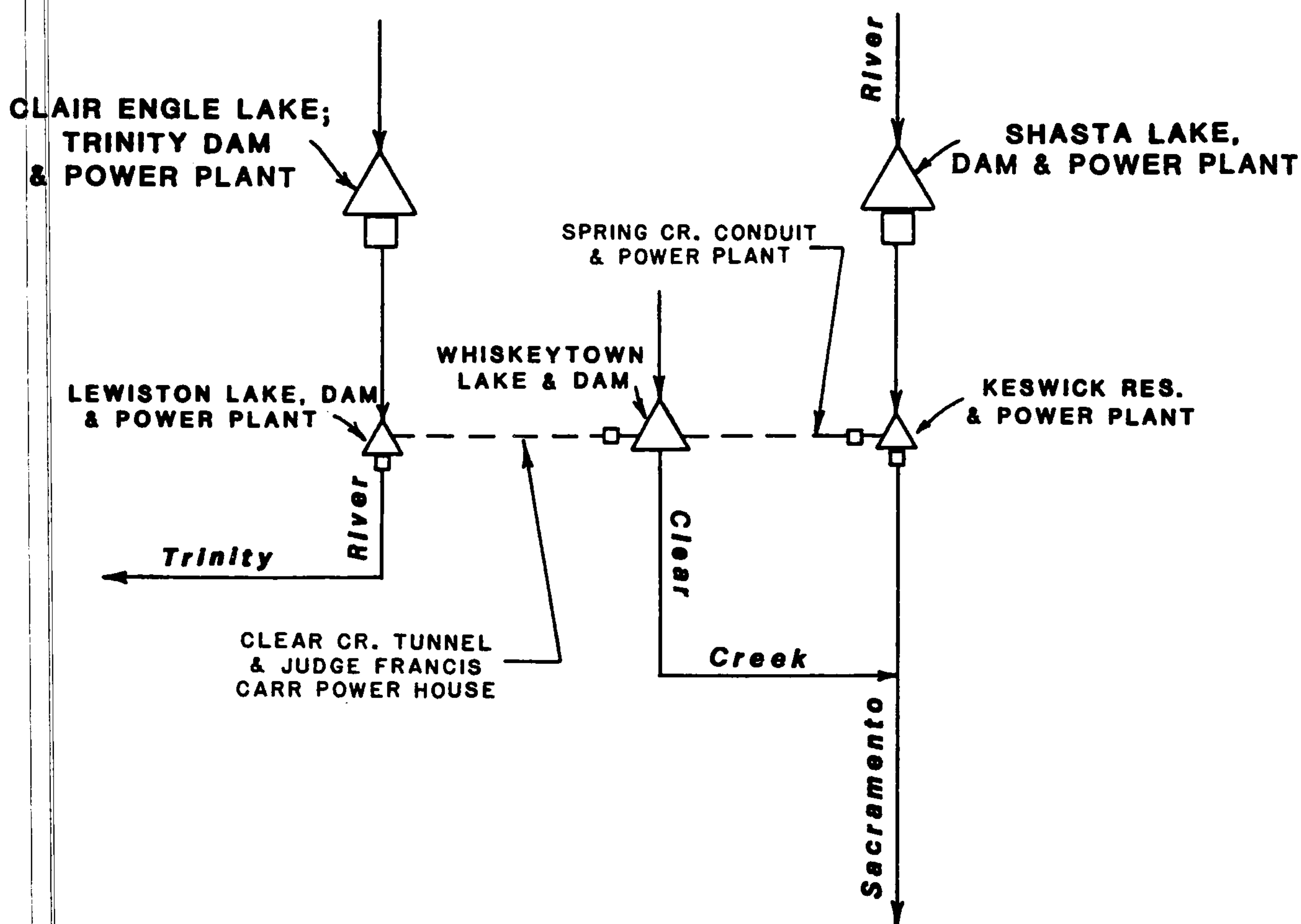
Whiskeytown Lake

Whiskeytown Lake, with 241 TAF of storage, re-regulates the transbasin flow of Trinity River from Lewiston Lake through the Judge Francis Carr Powerplant and into Spring Creek Tunnel with a capacity of 3,600 cfs. It also stores and regulates inflow from Clear Creek.

Releases are made to Clear Creek to meet downstream demands for water rights, streamflow maintenance and project use. The remainder is conveyed to Keswick Reservoir on the Sacramento River via Spring Creek Powerhouse. While not operated to meet defined flood control criteria, about 40 TAF of storage space is maintained during the winter months to help prevent flood releases to Clear Creek.

Additional releases from Clair Engle and/or Whiskeytown may need to be made in order to satisfy Sacramento River demands or Delta demands to achieve balanced storage among the CVP reservoirs serving common downstream demands. This balancing among the reservoirs is achieved by defining target storage levels in the model. The operating rules can be changed by changing the input data.

Figure II.1. SCHEMATIC REPRESENTATION OF TRINITY RIVER AND UPPER SACRAMENTO RIVER SYSTEMS



III. SACRAMENTO RIVER SYSTEM

Shasta Dam and Lake

Shasta Dam is located on the Sacramento River creating a multipurpose reservoir of 4,552 TAF. It provides flood control storage and regulates winter runoff for many purposes including irrigation in the Sacramento and San Joaquin Valleys, maintenance of fishery and navigation flows in the Sacramento River, protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water, provision of water for municipal and industrial use, and generation of hydroelectric energy.

Shasta Powerplant is located just below the dam, and nine miles downstream from Shasta Dam are Keswick Dam and Powerplant, also located on the Sacramento River. Keswick Reservoir creates an afterbay where Trinity River water is combined with Sacramento River water and is used to meet instream flow requirements in Sacramento River and provide irrigation service to lands in Shasta County (see Figure II.1).

Fish and Wildlife in Sacramento River

Minimum releases must be made by the Shasta-Keswick complex to meet fish flow requirements below Keswick in the Sacramento River. The minimum releases as made in our simulation model are based on the data used in USBR operation studies. Table III. 1 shows monthly distribution and total annual values under different types of water years as determined from Shasta Inflow Index.

TABLE III.1

Keswick Fish Flows

(TAF)

Month	Normal Years	Dry Years
January	160	123
February	144	111
March	141	141
April	137	137
May	141	141
June	137	137
July	141	141
August	141	141
September	232	167
October	240	172
November	232	167
December	160	123
Total	2,006	1,701

Navigation Flows in Sacramento River

Additional releases, if necessary, must also be made out of the Shasta-Keswick complex to maintain navigation flows in the Sacramento River. The actual flow requirements and the specific locations vary as the navigation control point (NCP) moves up and down the river between Knights Landing and Colusa. Required flows are keyed to the flow at Knights Landing and reflect the availability of local accretions. The flow data is generally 5,000 cfs during normal years, but drops to 4,000 cfs in the critical period, and sometimes, particularly in November dropping to as low as 3,000 cfs.

Flood Control Protection

One of the main purposes of Shasta Reservoir is to provide protection from floods. During the operational period as used in the simulation model, varying amounts of flood control reservation are provided depending upon the antecedent wetness conditions. To avoid large discharges down the Sacramento River in the month of October, when flood reservations are first needed, storage limits are placed on reservoir storage in the model. These limits act in a manner similar to flood reservation in the summer months. Therefore, in all but the months of May and June, flood control space is provided as shown in Table III.2.

TABLE III.2

Shasta Lake Flood Control Reservations

Month	Flood Control Reservation (TAF)
October	1,152
November	1,300
December	1,172
January	722 to 1,300
February	296 to 1,300
March	0 to 1,136
April	0 to 494
July	252
August	552
September	852

Other releases which must be made when needed from the Shasta-Trinity complex are those to meet CVP Delta exports and CVP's share of Delta water quality and outflow requirements. These release requirements are coordinated with Folsom releases so as to have the most optimum and efficient system-wide operation.

IV. FEATHER RIVER SYSTEM

Oroville-Thermalito Complex

Lake Oroville, principal reservoir of the State Water Project (SWP) with a storage capacity of 3,538 TAF is located near the town of Oroville in Butte County. All branches and forks of the Feather River flow into this reservoir. Water released flows through the Thermalito Complex and the natural channels of the Feather and Sacramento Rivers to the Delta. Other features include Edward Hyatt Powerplant, Thermalito Diversion Dam, Fish Barrier Dam, and the Thermalito Forebay and Afterbay. Figure IV.1 shows schematic representation of Feather River system.

The major function of this complex is to conserve and regulate the flows of the Feather River for subsequent release to the Sacramento-San Joaquin Delta. Here the releases provide salinity control against the incursion of saline water from the ocean and can be exported via the North Bay and California Aqueducts. Additional purposes of the project include hydroelectric power generation, flood control protection, enhancement of fisheries in the Feather River, and recreation.

Feather River Service Area (FRSA)

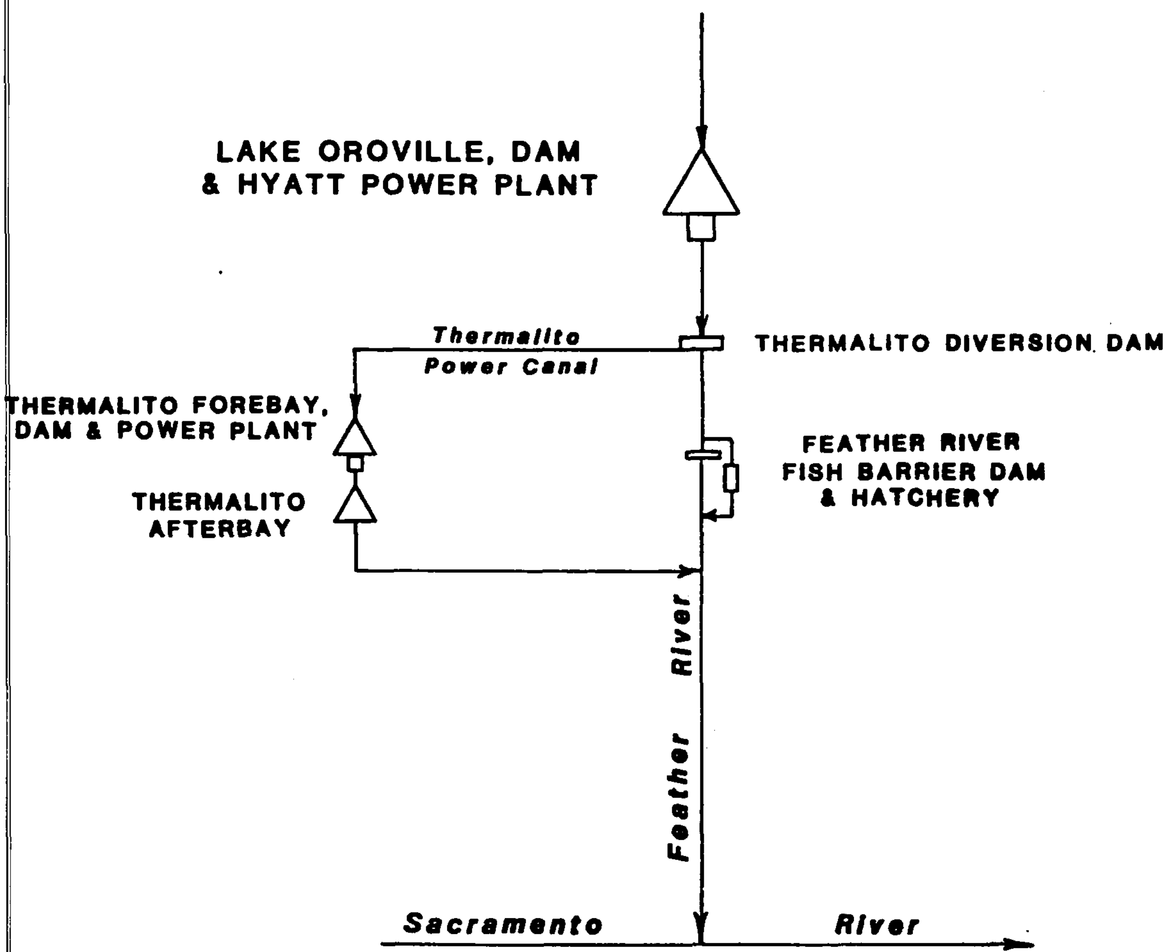
Diversion requirements for the FRSA are made available at Thermalito Afterbay and cover the water rights for Richvale Irrigation District, Biggs-West Gridley Water District, Butte Water District, Sutter Extension Water District, and PGandE as per the agreements signed on May 27, 1969, between these agencies and Department of Water Resources. Total agreed supply is 955 TAF. With allowances for drought deficiencies the supply is reduced 144 TAF for a 25 percent deficiency and 287 for 50 percent deficiency. Monthly pattern and values are representative of the diversions in the historic record 1968-1980, as reported from Jan Rogers in her memo to Jerry Vayder dated May 26, 1983. The criteria for applying deficiencies has been spelled out in the agreements signed and generally is in phase with the criteria used in applying deficiencies to Project contractors south of the Delta. Project deliveries for Yuba City and Butte County are added to the FRSA demands.

Fish and Wildlife in the Feather River

Operation of Oroville for the purpose of management of fish and wildlife in the Feather River is made as per agreement between Department of Fish and Game and Department of Water Resources dated August 26, 1983. As per this agreement:

(i) A minimum flow of 600 cfs (400 cfs until a diversion dam power plant becomes operational) must be released into the Feather River from the Thermalito Diversion Dam. Such flow will be the total of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Figure IV.1. SCHEMATIC REPRESENTATION OF FEATHER RIVER SYSTEM



(ii) Based on the April thru July unimpaired runoff of Feather River near Oroville of the preceding water year (Oct. 1 thru Sep. 30), additional water must also be released from the Thermalito Afterbay river outlet to maintain flows in the Feather River immediately below this outlet and to the mouth of the Feather River at Verona in accordance with the following schedule, provided that such additional release will not cause Oroville Reservoir to be drawn below elevation 733 feet (approximately 1,500 TAF).

TABLE IV.1

Feather River Fish Flows

The preceding April thru July Unimpaired Runoff of The Feather River near Oroville, Percent of Normal**	Minimum Flow Schedule in Feather River Below Thermalito Afterbay: Oct Thru Feb	March	April Thru September
55% or greater	1,700 cfs	1,700 cfs	1,000 cfs
Less than 55%	1,200 cfs	1,000 cfs	1,000 cfs

** Normal is defined as the April thru July 1911-1960 mean unimpaired runoff near Oroville of 1942 TAF.

(iii) If the April 1 runoff forecast in a given water year indicates that, under normal operation of SWP, the reservoir level will be drawn to elevation of 733 feet (approximately 1,500 TAF), releases for fish life in the above schedule may suffer monthly deficiencies in the same proportion as the respective monthly deficiencies imposed upon deliveries of water for agricultural use from the Project. However, in no case shall the fish water releases in the above schedule be reduced by more than 25 percent.

(iv) If for two or more consecutive water years the April thru July unimpaired runoffs average less than 60 percent of normal, then the minimum flow shall be as shown in the above schedule for runoff of less than 55 percent.

(v) If during the period of October 15 thru November 30, the combined project releases into the Feather River from the Thermalito Diversion Dam and Thermalito Afterbay exceeds 2,500 cfs (except for flood control releases or other emergency reasons), then the minimum flow in the Feather River as specified in Paragraph (i) for the period of October thru March will be modified such that flow is not less than 500 cfs below the combined projected releases.

Minimum Required Delta Outflow

Oroville Reservoir must make additional releases, if necessary, to meet its obligation of Delta outflow requirements, including carriage water. Minimum required Delta outflow necessary to satisfy the water quality objectives set forth in Decision 1485 of State Water Resources Control Board must first be satisfied from uncontrolled flows arriving in Delta, and storage releases if necessary. The share of storage releases to be made from Oroville, as well as from CVP reservoirs, is determined in accordance with the sharing provision of May 20, 1985 draft CoordinatedOperation Agreement with USBR.

SWP Contractors Demands

Thirty agencies have contracted for a long-term water supply from the State Water Project totalling 4.22 million acre-feet annually, of which 4.11 million acre-feet are for contracting agencies with service areas south of Delta.

In order to meet entitlement requests during any given year, Harvey O. Banks Delta Pumping Plant must export water from the south Delta, either for direct delivery or for re-regulation in the SWP portion of San Luis Reservoir. In some months, during an operational cycle, Oroville Reservoir must make a conservation release to meet export demands. These releases are coordinated with the operation of San Luis Reservoir storage.

Flood Control Protection

One of the purposes of the SWP is to provide flood control protection. Storage in Lake Oroville must be lowered every year to make room for the winter rains and spring snowmelt that could cause flooding.

Monthly flood control space requirements for the period of record (1922 thru 1978) has been provided by the U. S. Army Corps of Engineers for flood operation of Oroville Reservoir. In all but four months (May, June, July, and August) flood control space is provided based on antecedent precipitation and ground wetness conditions. Range of flood control space for the operational period is shown in Table IV.2.

TABLE IV.2

Oroville Lake Flood Control Reservations

Month	Flood Control Reservation (TAF)
October	375 to 700
November	375 to 750
December	375 to 750
January	375 to 750
February	375 to 750
March	375 to 750
April	68 to 450
September	188 to 375

V. AMERICAN RIVER SYSTEM

Folsom-Nimbus Complex

Folsom Lake with 1,010 TAF storage capacity is located on the main stem of the American River near the town of Folsom and 20 miles upstream from Sacramento. Other features of this project include Folsom Powerplant, Nimbus Dam and Powerplant, and Folsom South Canal. Lake Natoma, created by Nimbus Dam, is used for re-regulation of the Folsom Lake releases to the American River and also is used for Folsom South Canal diversions. Figure V.1 shows schematic representation of American River system.

Folsom Lake is a multiple-purpose project and provides the water supply and regulation to satisfy (a) local demands and water rights in the lower American River Basin, (b) Folsom South Canal contracts, (c) stream maintenance flows for fishery and recreation below Nimbus, (d) salinity repulsion in the Sacramento-San Joaquin Delta, (e) augmentation of CVP supply to meet its Delta export demands, (f) generate hydroelectric power, and (g) provides flood protection to Sacramento and to adjacent suburban areas.

Local Demands, Water Rights and Contracts

Folsom Lake is operated to release enough water to meet local demands by City of Folsom, San Juan Suburban Water District, City of Roseville, North Fork and Natomas Ditches and Folsom Prison. In addition to these demands water is also released to meet demands for the City of Sacramento, Carmichael, Folsom South Canal exports, and riparian use along the American River.

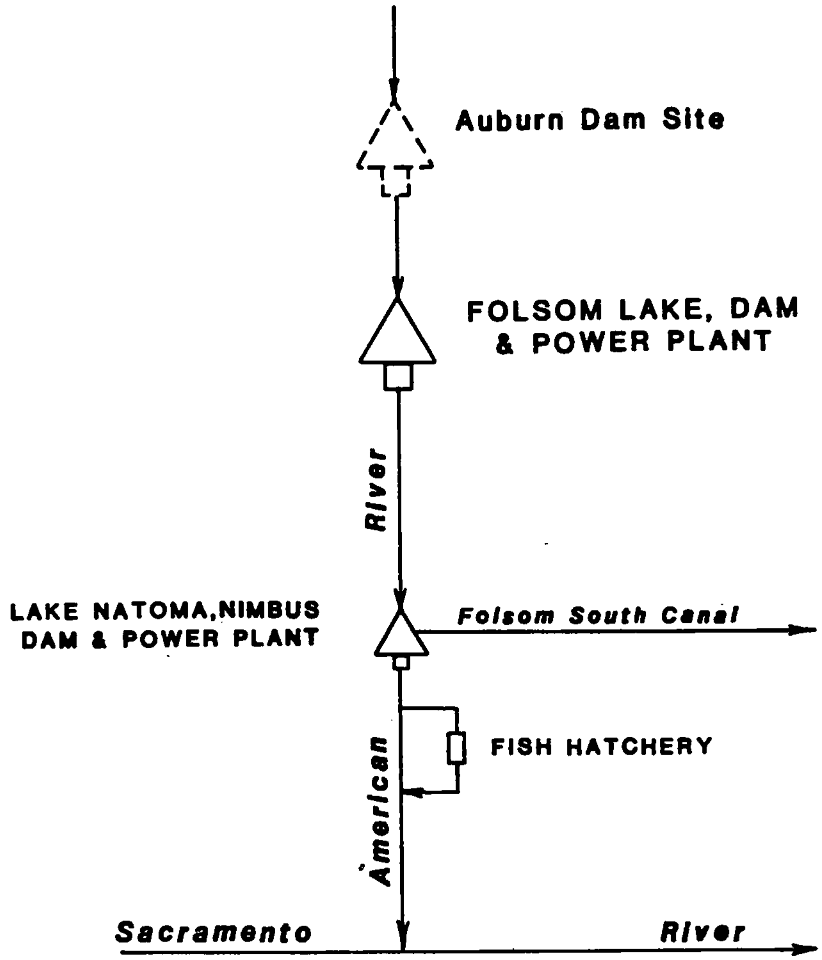
In the absence of Auburn Reservoir in the system, diversions for Placer County Water Agency (PCWA) are deducted from the inflow to Folsom. El Dorado County demands are also deducted from inflow to Folsom Reservoir. Normally deficiencies are applied only to the project diversions for PCWA, San Juan Suburban, and Roseville. However, when the Folsom South Canal exports include water for agricultural use, deficiencies are applied as per CVP contract provisions.

Fish and Recreation Releases

Folsom Lake must make releases in accordance with SWRCB Decision 893 such that after meeting local demands there is enough flow in the American River to maintain the fishery below Nimbus Dam. In 1957 the Bureau entered into an agreement with Department of Fish and Game regarding American River flow releases. This agreement provides for minimum fishery flows of 250 cfs from January 1 through September 14, and 500 cfs from September 15 through December 31, except for critically dry years when deficiencies up to 50 percent could be applied. Under normal conditions with other conservation releases, the minimum flows below Nimbus Dam are usually higher than these amounts.

In 1972, in connection with the water right application for Auburn Dam and Reservoir, Decision 1400 of State Water Resources Control Board was issued prescribing a minimum flow of 1,250 cfs between October 15 and July 15 for fishery purposes, and 1,500 cfs between May 15 and October 14 for recreational purposes.

Figure V.1. SCHEMATIC REPRESENTATION OF AMERICAN RIVER SYSTEM



At present our simulation studies attempt to follow USBR practice and meet as a minimum, D-1400 flows to the City of Sacramento diversion point. In critical dry periods it is necessary to drop to D-893 requirements. The selection of flows to be met is based on storage in the reservoir. In the simulation model the operational criterion is the reservoir target storage Level 2 (RL2) value. As long as the storage in Folsom Lake is greater than RL2 value, the reservoir makes the releases to meet D-1400 ("maximum target" amounts) and switches to D-893 ("minimum target" flows) during the period when storage in Folsom drops below RL2. Also, minimum flows below the Sacramento Treatment Plant diversion point are always specified as D-893 flows.

Delta In-Basin Uses and CVP Exports

Besides meeting American River requirements, Folsom complex is operated in conjunction with Shasta-Trinity complex to meet any additional requirements from the Delta for the CVP system. These demands include CVP share of Delta In-Basin uses and exports from the Delta to meet CVP contractual demands. Effort is made so that the CVP system as a whole is operated as one system and to minimize unnecessary surpluses in the Delta.

Flood Control Protection

One of the main purposes of Folsom Lake is to provide protection from floods to Sacramento and suburban areas. During the operational period, as used in the simulation model, varying amount of flood control reservation are provided depending upon the antecedent wetness conditions. All but for the months of May and June, flood control space is provided as tabulated in Table V.1. As explained in the section dealing with Shasta Lake, reservoir levels are brought down during the early fall months(*) so that it will not be necessary to make large releases when the flood reservation requirement starts.

TABLE V. 1

Folsom Lake Flood Control Reservations

Month	Flood Control Reservation (TAF)
October	330
November	400
December	400
January	232 to 400
February	252 to 400
March	150 to 350
April	0 to 89
July*	50
August*	150
September*	230

VI. STANISLAUS RIVER SYSTEM

New Melones Lake

New Melones Lake is located on Stanislaus River about 35 miles northeast of Modesto. Figure VI.1 shows schematic representation of Stanislaus River system. The reservoir has a total storage capacity of 2,400 TAF and is operated to satisfy local water needs, fishery enhancement, and water quality improvement of the San Joaquin River. It also generates hydroelectric power and provides flood control protection. Operation of New Melones Lake is partially controlled by Decision 1422 issued by the State Water Resources Control Board in April 1973 as discussed below.

Local Irrigation Water Demands

New Melones is operated to meet the local irrigation demands within Stanislaus, Calaveras, Tuolumne and San Joaquin Counties. At present no use of water is made outside these areas. The local districts have contracts totalling 49 TAF of firm supply and 106 TAF of interim supply per year. The total 155 TAF is reduced to 102.3 TAF in critical years.

Fish and Wildlife Releases

Additional releases of water up to 98 TAF per year must be made in the lower Stanislaus River below Goodwin Dam for preservation and enhancement of fish and wildlife. Deficiencies are allowed during dry conditions. Actual monthly distribution during a normal year is established by Department of Fish and Game.

Maintenance of Water Quality

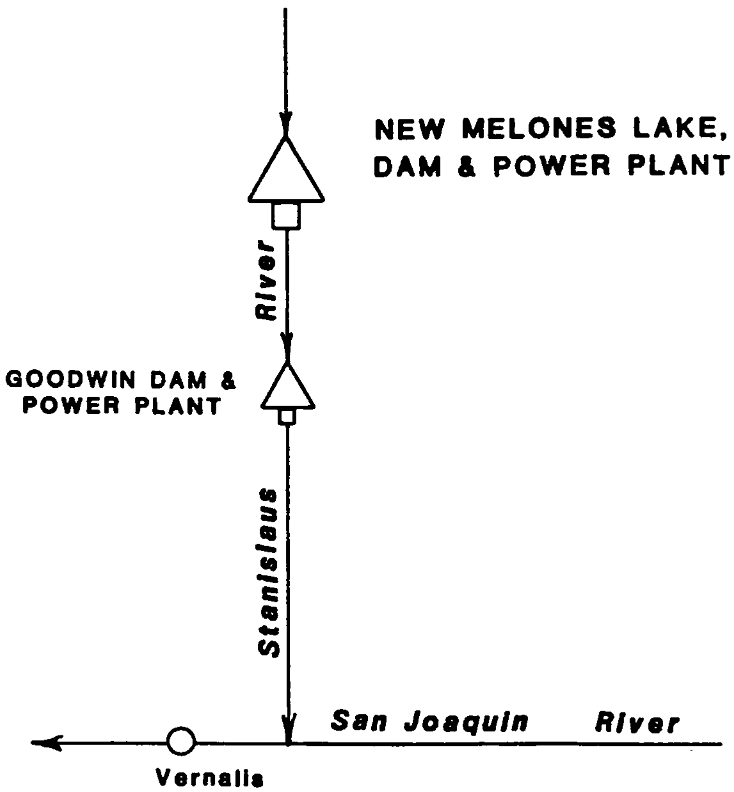
Releases from the project are also made to maintain water quality of no more than 500 ppm TDS at "Vernalis" on the San Joaquin River and a dissolved oxygen content of 5 ppm in the Stanislaus River. Additional releases are made as necessary, over and above the 98 TAF fish flow mentioned earlier. For the purpose of simulation, combined releases to meet fish requirements and water quality are lumped together at C.P. 52.

No additional releases are made in current simulations for the specific purposes of recreation, hydroelectric power generation, or Delta water supply. Of course most of the water released for local demands as well as for other project purposes is used for power generation.

Flood Control Protection

One of the major purposes of New Melones is to provide flood protection to agricultural land in the flood plain of Stanislaus River and to suburban areas of Ripon, Oakdale, and Riverbank. Also, in conjunction with storage projects on the Tuolumne River, the project provides flood protection to agricultural land along the San Joaquin River below the mouth of the Stanislaus River, agricultural land in the Sacramento-San Joaquin Delta, and to suburban areas south of the City of Stockton.

Figure VI.1. SCHEMATIC REPRESENTATION OF STANISLAUS RIVER SYSTEM



Flood control reservation during the various months is shown in Table VI.1.

TABLE VI.1

New Melones Lake Flood Control Reservations

Month	Flood Control Reservation (TAF)
October	431
November	431
December	431
January	431
February	431
March	381
April	199
September	147

VII. SACRAMENTO-SAN JOAQUIN DELTA OPERATIONS

The Central Valley contains three major basins: Sacramento, San Joaquin and Tulare Lake. The Sacramento Valley is drained by California's largest river system, the Sacramento. Major tributaries include the McCloud, Pit, Yuba, Feather, and American Rivers. Tulare Lake Basin is closed and drains internally except in rare instances when floodwaters overtop a low divide and flow into the drainage of the San Joaquin River. The northern portion of the San Joaquin Valley is drained by the San Joaquin River. Major tributaries to the San Joaquin include the Merced, Tuolumne, and Stanislaus Rivers.

The area in the center of the Central Valley, where the Sacramento and San Joaquin Rivers merge, coincides with a break in the coastal mountains bordering the basins on the west. Here the Sacramento River, the much smaller San Joaquin River, and other east side streams meet in the Sacramento-San Joaquin Delta before flowing into San Francisco Bay and on toward the Pacific Ocean. This delta, unlike most river deltas, is wide at the landward side and narrow at the seaward side. It forms the upstream portion of an estuary that extends into Suisun Bay, San Pablo Bay, and San Francisco Bay. Historically the Carquinez Straits, a narrow break in the Coast Ranges, has been noted as the dividing line between the saline San Francisco Bay and the fresh water Delta. Operations in Sacramento-San Joaquin Delta plays a pivotal role in the availability of water supplies to be exported to San Joaquin Valley and Southern California.

The Sacramento River, controlled largely by CVP's Shasta Lake and augmented by water from the Trinity River, supplies water to irrigated areas in the Sacramento Valley. Releases from the SWP-controlled Feather River joins the

Sacramento River 21 river miles above the City of Sacramento, and at this point the Sacramento River is augmented by flows entering from the CVP-controlled American River. Thus, waters managed by the SWP mingle with and become indistinguishable from those of the CVP and flows commingled into the Delta. A portion of the water entering the Delta takes a direct course toward Suisun Bay, and some finds its way into the interior Delta through natural channels aided by the CVP's Delta Cross Channel. Releases from CVP and SWP reservoirs augment the supply of fresh water flowing into the Delta during the drier months of the year.

Some of the water reaching the Delta is used to meet local demands. Estimates of Delta consumptive use and Delta channel depletions used in the planning model are based on a cooperative study conducted in 1981 by the Department and the Bureau of Reclamation. These values, which are based on estimates of historic use, are entered as data for various levels of development, viz. year 1980 and year 2000.

Currently the major exporter of fresh water available in the Delta is the CVP, which pumps water from the southern Delta at its Rock Slough and Tracy pumping plants. Rock Slough Pumping Plant serves the Contra Costa Canal, providing water mainly to municipal and industrial users in parts of Contra Costa County.

Tracy Pumping Plant serves the Delta Mendota Canal (DMC), which conveys water to agricultural users in the San Joaquin Valley and to facilities of the CVP's San Luis Unit. Some of the water provided in the San Joaquin Valley is delivered on an exchange basis to areas that used water from the San Joaquin River before construction of the CVP's Friant Dam.

Also in the southern Delta, the SWP operates Clifton Court Forebay and Harvey O. Banks Delta Pumping Plant. The forebay takes in Delta water at high tide, then its gates are closed, and export water is pumped from the forebay. The pumps lift the water to the beginning of the 444-mile California Aqueduct, for regulatory storage in San Luis Reservoir and for meeting SWP Contractor requests.

Export of water from the southern Delta is limited by the pumping capacity of the two projects. The CVP can pump 4,600 to 4,800 cubic feet per second (cfs) into the Delta Mendota Canal. In some months Tracy PP must be constrained because of DMC capacity or because of the relift pumping capacity (4,200 cfs) between the DMC and O'Neill Forebay. Contra Costa Canal has an export capacity of 350 cfs. The SWP can currently pump 6,400 cfs at the Banks Pumping Plant. With additional units added to the Banks Pumping Plant, the export capacity of SWP can be increased to 10,300 cfs, the maximum carrying capacity of the first reach of the California Aqueduct. However, without channel improvements in the southern Delta, this export capacity is limited to an average of 7,300 cfs in wet months and 6,680 cfs in other months as allowed by a USCE permit.

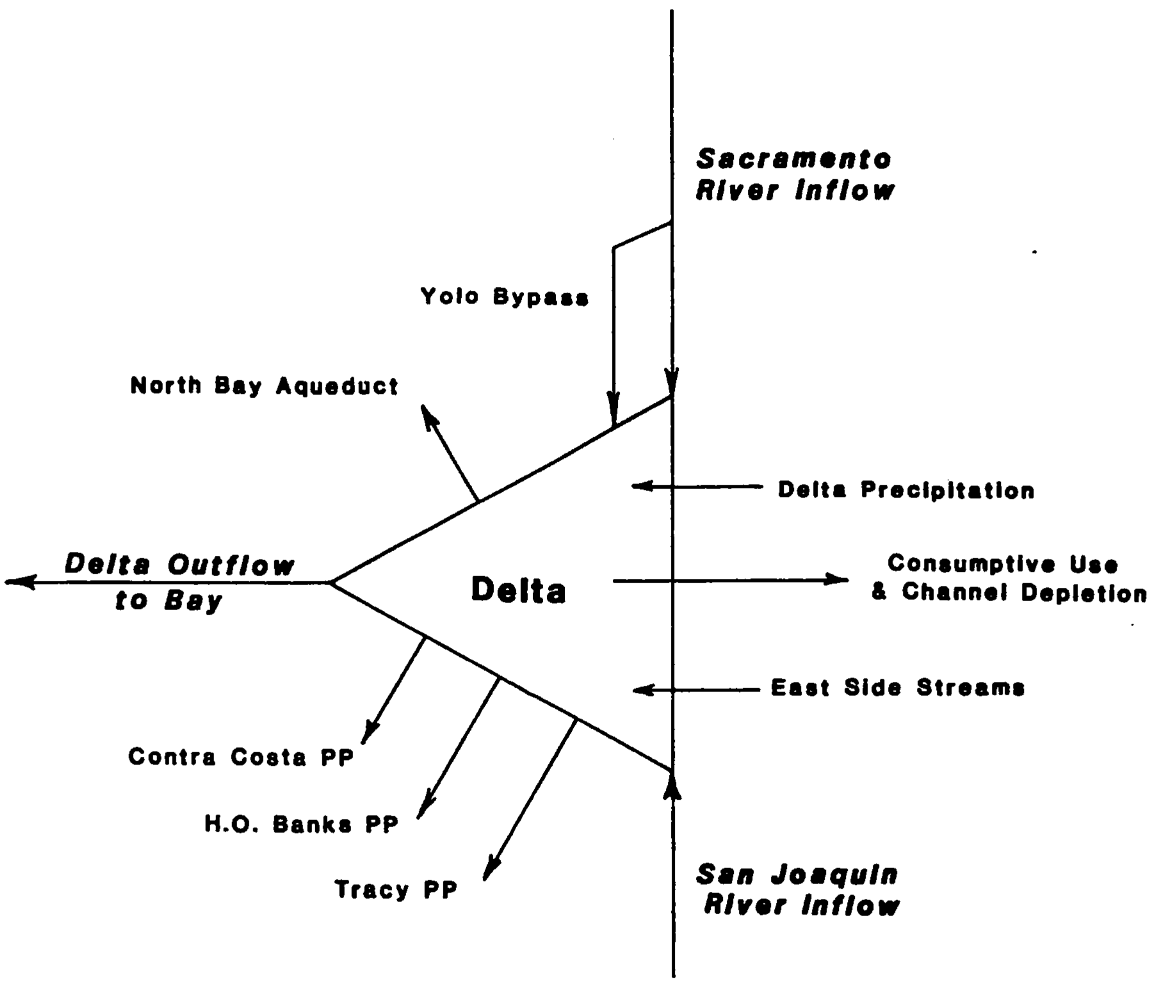
The first stage of the North Bay Aqueduct is purchasing Solano Project water and delivering it to Napa County. In the future, the North Bay Aqueduct will provide water to Napa and Solano Counties by direct export from the north Delta.

Salinity control is necessary because the Delta is contiguous with San Francisco Bay and the ocean and its channels are at or below sea level. Unless repelled by a continuous seaward flow of fresh water, sea water will advance up the estuary into the Delta, particularly as exports from the southern Delta increase. This is discussed in more detail in the following section. Different components of water balance in the Delta can be summarized schematically as shown in Figure VII.1.

Delta Outflow Requirements to Meet Delta Quality Standards

Operation of SWP and CVP export facilities in the Delta are coordinated with the upstream SWP and CVP reservoirs to meet applicable water quality standards for the Delta and Suisun Marsh. Present standards are those set forth in Water Rights Decision 1485 (D-1485 established in August 1978) of the State Water Resources Control Board. These standards are for protection of all reasonable, beneficial uses of water in the Sacramento-San Joaquin Delta, including municipal and industrial, agricultural, and fish and wildlife. Decision 1485 is intended to provide the same level of protection to these beneficial uses that would have been available had the two projects not been constructed. In addition to minimum flow and water quality requirements, project diversions are limited in May, June, and July to protect striped bass spawning. The water quality and flow standards included in the proposed Coordinated Operations Agreement (COA) are the same as those of Decision 1485, except that certain standards for Suisun Marsh, are omitted.

Figure VII.1. DELTA WATER BALANCE COMPONENTS



Many of the D-1485 standards are specified in terms of electrical conductivity or chloride (both measures of salinity) at specific locations in the Delta. The Department and the Bureau of Reclamation have conducted separate studies to determine the minimum flows required to meet the quality standards. Appendix A contains more details on various types of data sets available under different assumptions for use in the simulation model. The simulation model incorporates these standards as minimum required monthly flows at Control Point 58. They are based on tables that account for year type determined by the Four-River Index, month of the year, San Joaquin River inflow, and the previous month's inflow to the Delta. The Four-River Index is the sum of the natural flows from the Sacramento, Feather, Yuba and American Rivers.

"Carriage Water" represents the additional Delta outflow required to maintain water quality standards when export rates from the southern Delta are increased beyond an empirical breakpoint. As the southern Delta pumping plants (Tracy, Rock Slough and Banks) increase their export rates, more water is drawn from the western Delta. To maintain the salinity balance, saline San Francisco Bay water must be repelled by additional Delta outflow. Figure VII.2 shows a typical export-outflow relationship. It is obvious that outflow required for D-1485 at times overrides the carriage water requirements.

Export-Outflow relationships for water quality control, as used in the simulation model, have been calculated by DWR and are listed on a series of 12 tables for each type of water year. These tables cover the most critical standards applicable during each month and each water year classification. If a thru Delta transfer system is assumed at any future level of development, then such a system would eliminate the reverse flow and salt pickup in the western Delta and would save the carriage water required.

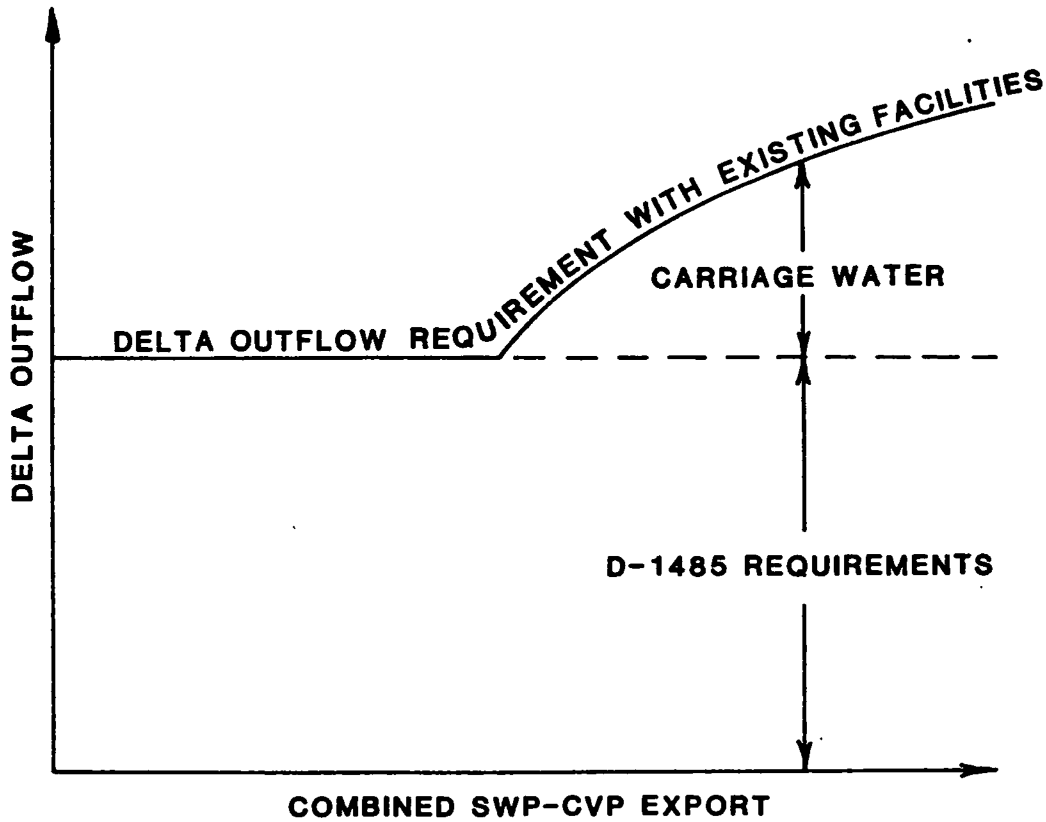
<u>Additional Outflow Requirements to Meet North Delta Water Agency Contract</u>

SWP operation must also meet criteria set forth in a contract with North Delta Water Agency. The North Delta Water Agency represents agricultural water users in northern and western portions of the Delta. In January 1981, the Department and the Agency signed a contract that ensures a dependable water supply of adequate quality to the Agency. The contract sets water quality standards to be met by the State Water Project that are parallel to Decision 1485 standards, but at times are more stringent. The extra outflow required to meet these more stringent standards must be released from Oroville and thus can reduce the available supply of the State Water Project by as much as 100,000 acre-feet per year. The contract also provides that "the State may provide diversion and overland facilities to supply and distribute water to Sherman Island", and that "after the facilities are constructed and operating, the water quality criteria ... shall apply at the intake of the facilities." No additional outflow requirements would be needed with Sherman Island overland facilities in place.

<u>Operation of CVP-SWP Reservoirs to Meet Delta Demands</u>

Operation of CVP and SWP reservoirs to meet their respective export demands and share of responsibility for in-basin uses in the Delta are controlled by a "sharing formula" as negotiated by USBR and DWR for coordinated operation. Export demands on each project are imposed (triggered) by San Luis

Figure VII.2. TYPICAL DELTA EXPORT-OUTFLOW REQUIREMENTS RELATIONSHIP



Reservoir target storages and direct delivery demands as discussed in a later section. The sharing formula stipulates two types of percentage splits:
(a) Sharing responsibilities to maintain Sacramento Valley in-basin use, which includes Delta consumptive use, minimum Delta outflow and water quality requirements as specified by D-1485, and carriage water if necessary;
(b) Sharing available water supplies in the Delta for export and storage. Sharing and coordinated operation is discussed in more detail in a later section.

In case each project's Delta export needs are greater than its share of available Delta inflow, as determined by the sharing formula, each project must then make additional releases to meet its export demand and San Luis target storages, provided pumping plant capacity is not constraining. Once this additional release from a project is determined, it can be distributed among the reservoirs of that project to achieve better balancing in their storages.

VIII. COORDINATED OPERATION OF CVP-SWP SYSTEMS

The SWP and CVP use the Sacramento River and Delta channels to convey water to their export pumps in the south Delta. Coordinated operation is required to assure that each project obtains its share of water from the Delta and bears its share of obligations to protect other beneficial uses in the Delta and the Sacramento Valley. Furthermore, coordinated operation, by agreed upon criteria, can increase the effectiveness and efficiency of both projects.

Sharing of water supplies and responsibilities is controlled by sharing formulas. These formulas are determined by simulating the operation of CVP and SWP facilities under current conditions but assuming a repeat of the dry period hydrology of 1928-1934. A description of the most recent simulation study is contained in the "Technical Report on Determination of Annual Water Supplies for Central Valley Project and State Water Project" dated March 1984. The sharing formulas are structured around the necessity to meet the in-basin use requirements in the Sacramento Valley and the Delta, including Delta outflow and water quality requirements as per State Water Resources Control Board Decision 1485.

When water is plentiful in the Sacramento River system, both projects can store and export water to their full capabilities, and in-basin use requirements will still be met. As runoff subsides, a time comes when water for storage and export must be allocated among the two projects. This time is signaled when conditions in the Delta approach the D-1485 standards and "surplus" outflow no longer exists. When the Delta reaches such a condition, known as "balanced water conditions", the Bureau and the Department operate their projects in accordance with a sharing formula to maintain those conditions. Balanced water conditions occur in all but a few very wet years. Typically, balanced conditions begin in late spring and continue through early fall.

The sharing formula applies to two different situations that occur during balanced water conditions. One situation apportions the responsibility for making storage withdrawals to supply in-basin uses when flow other than from storage withdrawals (unstored flow) is insufficient to provide the full supply required to meet D-1485 standards and Delta export demands. The formula for sharing this responsibility as negotiated for current conditions is:

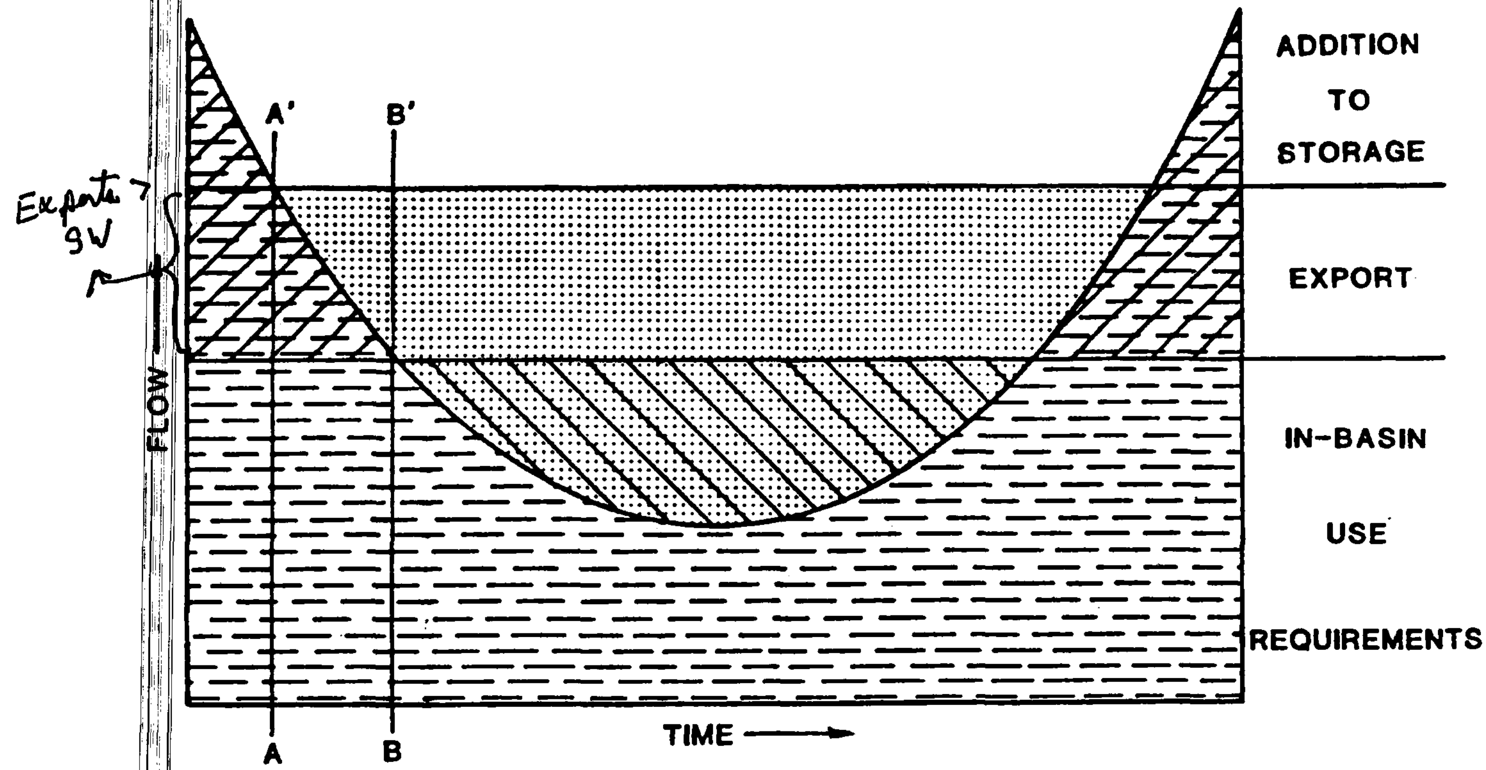
Central Valley Project	75 percent
State Water Project	25 percent

The other situation defines the rights of the two parties to store or export water when unstored flow is available in excess of in-basin use requirements (including D-1485). The formula for sharing this water for the current conditions is:

Central Valley Project	55 percent
State Water Project	45 percent

Figure VIII.1 is a simplified illustration of how the formula operates -- simplified in that it assumes a smooth decline and buildup of runoff, constant export levels, and constant in-basin use requirements. The left side of the

Figure VIII. 1. UNSTORED FLOW AND STORAGE WITHDRAWALS UNDER BALANCED WATER CONDITIONS



UNSTORED FLOW

UNSTORED FLOW AVAILABLE FOR PROJECT EXPORT OR STORAGE
(Shared 55% for CVP, 45% for SWP)

STORAGE WITHDRAWAL

STORAGE WITHDRAWAL TO MEET IN-BASIN USE REQUIREMENTS
(Responsibility shared 75% CVP, 25% SWP)

figure represents conditions as they might exist in the spring, when periods of balanced water conditions often begin. Project exports plus additions to project storage take all the unstored flow that is excess to in-basin use requirements.

As unstored flow declines with decreasing runoff, additions to project storage must be eliminated to maintain exports and in-basin use. On a certain day, represented by line A-A' on Figure VIII.1, water is no longer available to add to storage and withdrawals from storage must begin thereafter to maintain exports. Until the day represented by line B-B', each project may export an amount of water equal to its storage withdrawal plus its share (as determined by the 55:45 formula) of unstored flow in excess of in-basin use requirements.

On day B-B', there is no longer any excess unstored flow to contribute to exports or to be shared 55:45, and exports must be supported by storage withdrawals. Thereafter, storage withdrawals must be increased to maintain exports in the amount that allows in-basin use requirements to be fully met. The responsibility to make such storage withdrawals for in-basin use is borne by the Central Valley Project and State Water Project in the proportions 75:25. While the 75:25 formula is in effect, both projects are entitled to export an amount equal to their storage withdrawals, less their allocated contributions to in-basin use.

As unstored flow increases in fall and early winter, the steps are reversed. The early increases in unstored flow eliminate the need for storage withdrawals to meet in-basin use, and the 75:25 formula goes out of effect. The 55:45 formula then takes over to apportion excess unstored flow. Finally, unstored flow exceeds the sum of in-basin use, exports, and additions to storage, and neither formula is needed; "excess water conditions" exist.

When a project's share of available Delta water supply exceeds its export capability, the excess flow may be exported or held in storage by the project that has the capability to do so, without affecting either project's future responsibilities.

In simulation model studies at the current level of development and with existing facilities, the sharing formula is as developed during COA negotiations and contained in the May 20, 1985 draft. In order to perform simulation studies in which future SWP or CVP facilities are added, it is necessary to determine the effect or adjustment that the new facilities would have on the COA sharing formula. For example, if a new SWP facility were added to the system, the yield of the existing CVP system must not be adversely affected, and therefore, the operational sharing formula must be adjusted accordingly. The sharing formula must also be adjusted to account for change in upstream hydrology with time.

IX. SYSTEMS OPERATION OF UPSTREAM RESERVOIRS

In order to meet the demands placed on project reservoirs efficiently and with minimum spills, integrated operating rules must be defined for each reservoir upstream of the Sacramento-San Joaquin Delta.

The primary mechanism for achieving efficient operation is by dividing each reservoir into imaginary horizontal levels, called target storage levels (RL data sets). Corresponding to each level is a reservoir elevation, storage, surface area and outlet capacity. Differences between levels are zones of potential storage volume. At present five levels have been defined to establish operating rules. The lowest level corresponds to the minimum reservoir level as determined by the elevation of the outlet works, the second lowest is bottom of the conservation pool or the minimum operating storage, the third level is the top of and an intermediate buffer zone, the fourth level is the top of the conservation storage pool, and the highest level is the gross reservoir storage. Additional levels can be established to facilitate individual reservoir operating criteria.

Each reservoir is operated to meet downstream demands at specified locations in the system. These operational points are specified for each reservoir by identifying those points for which the reservoir does not operate. Priority of withdrawals from reservoirs serving the same location can be established by specifying additional levels. Withdrawals are first made from the highest storage zone, then from the second highest and so on down to the lowest, keeping all reservoirs in the system in balance to the extent possible. Table IX.1 presents typical values for target storage levels as used in the simulation model.

Figure IX.1 illustrates how the reservoir target levels work. Assume Reservoirs A and B are Shasta and Folsom Reservoirs of the CVP system and Control Point C refers to a common demand location on the CVP system in the Delta. If both Reservoir A and Reservoir B start out full at level 5, the program determines the amount of reservoir release needed to satisfy the demand at the commonly served Control Point C. In this example, there is no space in Reservoir B allocated between level 5 and level 4. Therefore, the demand at Control Point C will be met from Reservoir A until Reservoir A reaches level 4. Then both reservoirs will be drawn down equally, by percentage of storage space remaining, between levels 4 and 3. When both reservoirs reach level 3, releases will occur from Reservoir B only until Reservoir B reaches level 2 as there is no space allocated between levels 3 and 2 in Reservoir A. The process is continued until the reservoirs are depleted. If desired, one or both of the reservoirs could be set so as not to meet any demand at Control Point C. It is also important to note that these target storage levels can be changed each month.

Figure IX.1. STORAGE BALANCING AMONG RESERVOIRS

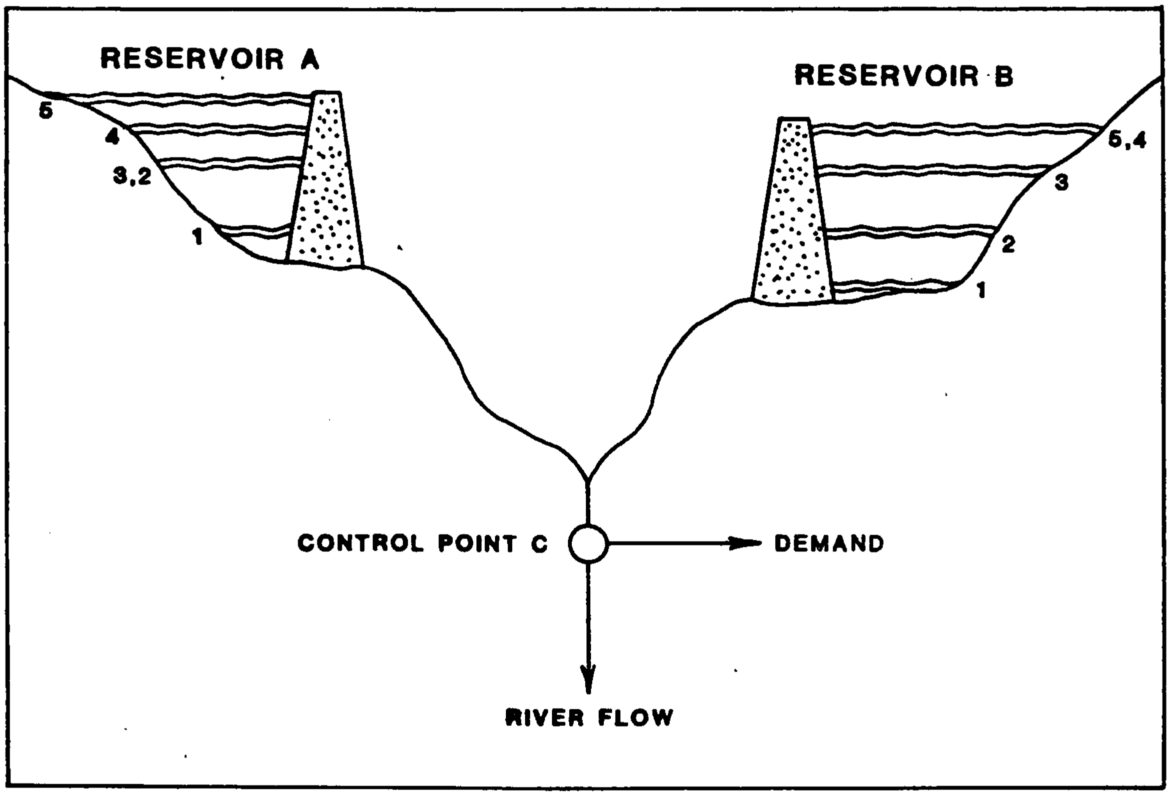


TABLE IX.1

Typical Reservoir Target Storage Values

(TAF)

Storage Level (RL Value)		Reservoir				
		Clair Engle	Shasta	Oroville	Folsom	New Melones
Dead	1	10	116	30	1	2
Minimum Pool	2	313	500	852	88	310
Intermediate	3	1,850	2,500	2,470	300	1,000
Flood Control	4	12 values:* 1,850 to 2,448	12 values* 3,252 to 4,552	12 values* 2,931 to 3,538	12 values* 610 to 1,010	12 values* 1,969 to 2,400
Maximum	5	2,448	4,552	3,538	1,010	2,400

*RL4 data suppressed by use of variable YL4 set.

X. SWP WHEELING FOR THE CVP

Wheeling arrangements involve the use of excess capacity in the pumping and conveyance facilities of the SWP to increase the amount of water the CVP can deliver from the Delta. With its present Delta export facilities, the CVP lacks the pumping and conveyance capacity to deliver to all of its existing and potential contractors south of the Delta. The SWP has capacity in the California Aqueduct for wheeling CVP supplies even though the existing SWP's capacity at Banks Pumping Plant is only about 60 percent of the California Aqueduct capacity. Additional pumps currently planned for 1992 must beinstalled to allow a significant increase in wheeling for the CVP.

CVP Delta export capacity at Tracy Pumping Plant is between 4,600 and 4,800 cfs, but actual export amounts at Tracy Pumping Plant may vary due tocapacity limitations in the Delta Mendota Canal. Also, CVP must reduce its export to 3,000 cfs in May and June each year to meet D-1485 standards, included as Exhibit A in the draft Coordinated Operations Agreement. The procedure to overcome this operational constraint is set forth in Exhibit D of the draft agreement.

Since wheeling is an important part of the simulated operation of CVP San Luis Reservoir and the calculation of the CVP rule curve, it is necessary to understand the methods and rules under which wheeling occurs in the simulation model.

Generally there are four different purposes for which CVP water can be wheeled by the SWP; the first three are mentioned in Article 10 of the COA.

(1) The SWP will wheel the amount of CVP water necessary to compensate for the CVP pumping curtailment from 4,600 cfs to 3,000 cfs in May and June. [Article 10(b)]

(2) The SWP will wheel CVP water for scheduled and unscheduled maintenance and unforeseen outages of the CVP. [Article 10(c) and (d)]

(3) The SWP will wheel water for the CVP as may be agreed in the future to make more efficient use of water project facilities and available water supplies. [Article 10(h)]

In a separate agreement, the SWP will wheel water to meet CVP Cross Valley Canal demands through 1995 provided there is available SWP pumping capacity at Delta Pumping Plant.

In the simulation model, the SWP Delta Pumping Plant is normally operated to meet all sWP requirements each month before any wheeling of CVP water is permitted. It is possible, however, to dedicate a portion of the pumping plant to the CVP. The following procedure is normally used.

(1) There must be unused capacity available at the Harvey O. Banks Pumping Plant. This condition occurs only after it has pumped as much water as is available to the SWP from the Delta, or as necessary to meet SWP demands and fill SWP San Luis storage. Water available to the SWP in May and June does not consider the 1,600 cfs of CVP share of Delta supply as unused federal water and therefore available to the SWP. If SWP excess pumping capacity is available in May or June it will be used to wheel all or part of the 1,600 cfs of CVP water.

(2) The amount of CVP water wheeled in any month (whether from CVP share of unstored flow or upstream storage releases) will be limited to that amount necessary to reach the target storage specified by the CVP San Luis rule curve. Once the rule curve storage level is reached, no further wheeling will occur—even if surplus water is still available in the Delta.

(3) When it is decided that wheeling is mandatory, a portion of the Banks Pumping Plant will be removed and added to the Tracy Pumping Plant.

In actual simulation model studies there are usually months in which wheeling of CVP water is requested to correspond with the demand pattern but cannot be delivered due to lack of available capacity at the Banks Pumping Plant. As a result of such situations the end-of-month storage in CVP San Luis Reservoir will be below the rule curve target. This scenario is anticipated in the simulation model and normally does not cause operational problems or CVP shortages. In subsequent months CVP storage in San Luis Reservoir will be filled to the rule curve level as soon as excess pumping capacity becomes available, either directly from the CVP Tracy Pumping Plant or by wheeling through the SWP pumping plant.

XI. ALTERNATIVE MODES OF OPERATION STUDIES

Two types of planning simulation operation studies are normally conducted using DWRSIM, the Planning Simulation Model. They are:

(a) Firm Yield Operation Studies
(b) Long-Term Operation Studies

Firm Yield Operation Studies

A "firm yield study" determines the nominal annual quantity of water that can be delivered to a service area (i.e., SWP contractors) with a specified system of facilities in operation and with certain allowable deficiencies. A simulated operation covering water years 1927 through 1935, a period that includes the most prolonged dry period of record in the Central Valley, will normally assure that all system reservoirs are at maximum operating level in the spring of 1928 and will be drawn down to minimum level late in 1934. By definition, the allowable deficiency is 100% of the normal annual agricultural delivery over a seven year period but no more than 50% in any one year.

This type of study involves some trials so as to bring the SWP reservoirs to their minimum operating levels (i.e. 858 TAF in Lake Oroville and 42 TAF in SWP portion of San Luis). Also, to be consistent, no surplus water is delivered during the 9-year operational period. Such studies may also be run using a simplified version of the model network in which all the SWP contractors are lumped into a few control points.

Long-Term Operation Studies

This type of operation study is conducted to ascertain the delivery performance of specified SWP facilities under a wide variety of hydrologic conditions. It is normally accomplished by simulating the system for an operational period of 57 years, water years 1922-1978. The goal is usually to maximize averagedelivery but at the same time protect the firm yield of the given system of facilities as determined from a corresponding firm yield operation study. Onevariation is to sacrifice firm yield protection and determine the increase in potential average delivery.

Additional data on the operation of the system must be supplied as discussed below.

(1) Variable Demand Data:

When total contractor requests for entitlement water exceed the firm yield capability of completed SWP facilities, it will be frequently necessary to limit annual water deliveries to maintain predetermined carry-over storage in system reservoirs. A variable demand data set must be supplied which includes seven monthly distribution patterns; namely DT1 through DT7. In this set, DT5 data is the same as firm yield determined from a firm yield study, and DT3 represents total "entitlement requests" as requested by contractors and compiled by SWPAO. Normally DT4 represents demand data between DT5 and DT3. DT2 and DT1 data sets represent scheduled surplus and unscheduled surplus requests respectively, if assumed to be met in a given study. DT6 data is 25% deficiency of the agricultural portion of DT5, and DT7 is 10% deficiency of M&I portion in DT5.

(2) Target Carry-over Storage Bounds:

This information defines lower and upper bounds of desired SWP system carry-over storages (normally Oroville plus SWP portion of San Luis) as of September 30 of any water year. At present there are nine delivery classes, DC1 through DC9, thus there are nine target storage ranges, one for each class. In order to provide adequate protection to firm yield in the critical period, and also to achieve some system-wide storage at the end of the critical period, target carry-over storages for delivery classes DC5 through DC9 are based on the corresponding firm yield study end-of-September storages. The carry-over storages for delivery classes DC1 through DC4 are generally the same and the difference in lower and upper bounds is very narrow. Any adjustments to actual deliveries during a delivery year (March Through February) in the simulation model are made (upwards or downwards) so that actual end-of-September storages will fall within the prescribed range. Table XI.1 contains a sample of this data.

(3) Initial Delivery Class:

To facilitate determination of the delivery level during a delivery year, an initial delivery class is assigned. This class is based upon the four month spring snowmelt runoff calculated for the four basin index (i.e. April through July). This initial class value ranges from DC2 through DC5. Final deliveries are determined during the simulation and apply for the March through February period.

The procedure for deciding what final level of deliveries to make is carried out as follows. Based on the initial delivery class for the current year of simulation, end-of-September carry-over storage in SWP system reservoirs is computed after the first cycle of study. At that point it is checked against the lower and upper bounds of carry-over storage for that delivery class (as shown in Table XI. 1). If the storage is above the upper bound, then the difference is computed and the delivery class changed to the next class (increasing the amount of diversion). In this step, the delivery class could also be interpolated if that is what is needed to bring the actual carry-over storage to within the revised delivery class's carry-over storage range. Once it is found to satisfy the end-of-September condition, the revised delivery class is carried over to the following October through February period. At that time the procedure is repeated starting with March of the next delivery year. This was the case when end-of-September storage was in a 'surplus' situation. The procedure to revise the delivery class is identical if computed carry-over storage is found to be below the lower bound of the diversion class, except that now the delivery would be decreased when changed to the next class. No revision is needed if the initial diversion class brings the actual carry-over storage to within the range of prescribed carry-over storage.

TABLE XI. 1

Delivery Classes and
Carry-over Storage Ranges[1]
(TAF)

Diversion Class	Title	Carry-Over Storage Lower Limit	Carry-Over Storage Upper Limit	Annual[2] Delivery (TAF)
DC1	Entitlement Requests + Scheduled Surplus + Unscheduled Surplus	2,650	2,700	3,833
DC2	Entitlement Requests + Scheduled Surplus	2,650	2,700	3,833
DC3	Nominal Yield + 100% Unmet Entitl.	2,650	2,700	3,589
DC4	Nominal Yield + 50% Unmet Entitl.	2,650	2,700	3,251
DC5	Nominal Yield	1,600	2,700	2,913
DC6	Nominal Yield - 25% Ag. Diver.	1,000	2,700	2,701
DC7	Nominal Yield - 50% Ag. Diver.	1,000	1,025	2,490
DC8	Nominal Yield - 60% Ag. Diver. - 10% M&I Diver.	1,000	1,025	2,208
DC9	Nominal Yield - 80% Ag. Diver. - 30% M&I Diver.	1,000	1,025	1,644

1 This includes Oroville, San Luis and Los Banos Grandes Reservoir, if any.
2 Does not include Feather River Service Area.

XII. SAN LUIS RESERVOIR OPERATIONS

San Luis Reservoir is a joint federal-State facility located near the California Aqueduct in western Merced County. Of the total capacity of 2,038 TAF, 971 TAF is allocated to CVP storage and the remaining 1,067 TAF to SWP storage. Its primary purpose is to store water in winter months for subsequent use in meeting summer demands.

San Luis Reservoir is normally operated in a cyclic pattern that fills the reservoir to capacity each winter, and then empties it to meet project demands each summer. The operation of CVP and SWP portions of San Luis are controlled in the model by their respective "rule curves". These rule curves specify the desired pattern of minimum end-of-month storage requirements, which when maintained will result in an efficient cyclic operation of Sacramento Basin storage and use of unregulated inflow to the Delta.

The mode of operation for San Luis Reservoir plays a significant role in the simulation model operation. An operational objective that seeks to fill San Luis early or to maintain high levels during the summer can trigger releases from Oroville storage or establish monthly export patterns from the Delta. Operational objectives for the CVP portion of San Luis can be used to trigger wheeling by the SWP for the CVP when desired.

General Concepts for San Luis Rule Curves

In both the CVP and SWP San Luis storage operations there are two distinct components of the annual rule curve cycle. These are the winter season filling mode and the summer season withdrawal mode. The goal of the filling mode operation is to fill San Luis storage to its maximum capacity utilizing surplus unregulated Delta inflow to the maximum extent. In the summer months the operational goal is to withdraw water from storage in a manner that will meet summer demands and require minimum storage withdrawals from Sacramento Basin reservoirs for direct pumping from the Delta.

During the winter mode of operation, maximum project yield and total delivery capability are achieved by filling San Luis storage from surplus Delta inflows whenever available. Thus, the rule curves are designed to specify minimum end-of-month storage levels that will not require filling of San Luis storage until as late as possible into the winter season. In this manner the maximum amount of empty capacity in San Luis Reservoir is available for the storage of surplus Delta water. In a dry winter with little or no unregulated flow, San Luis storage can still be filled in accordance with the monthly rule curve requirements via storage withdrawals from upstream reservoirs.

The summer portion of the San Luis rule curves are dependent on the relationship between total south of Delta demands (including aqueduct losses and reservoir evaporation) and the total water supply available in storage.The rule curves are generally designed to fully utilize the available storage in San Luis Reservoir, and then supplement that storage supply with additional direct pumping from the Delta as needed. In situations where greater pumping plant capacity is available than will be needed, the rule curve can be designed to trigger upstream storage releases and pumping from the Delta to occur in any or all summer and fall months (when inflows into the Delta are usually lowest). Summer month rule curve storages can, to some extent, be designed to optimize energy generation and use, recreation levels, and reduce seepage-problems. Since rule curves are designed to balance water supply capability with total demands south of the Delta, it follows that any significant changes in demand projections (totals and distribution patterns), capacities of CVP and SWP pumping plants, or any constraints on operation of San Luis Reservoir may necessitate the recalculation of rule curves. In addition, changes in Delta outflow requirements (such as D-1485 striped bass restrictions or carriage water requirements) or the addition of new system facilities (such as a Los Banos Reservoir, or a thru-Delta facility) may impact the calculation of a San Luis rule curve.

CVP San Luis Rule Curve

For any study the calculation of a CVP San Luis rule curve is carried out in three steps: (1) determination of the monthly export capacity of Tracy Pumping Plant; (2) tabulation of total CVP demands to be met from CVP San Luis storage and Tracy Pumping Plant; and (3) calculation of end-of-month target storages. All three steps are usually carried out twice, once for total CVP demands in normal delivery years, and a second time for reduced CVP demands which occur in critical years, when deficiencies are imposed. If wheeling is to be provided on pattern by the SWP, such as for Kern Cross Valley Canal, these demands are not included in step 2. To model wheeling for D-1485 "Condition 3" make-up water, the full export capacity of Tracy Pumping Plant is used in step 1.

The maximum and minimum target storages for the operation of CVP San Luis Reservoir in a normal year are fixed at 971 TAF (full) at the end of March and 38 TAF (minimum pool) at the end of August. A desirable minimum storage at the end of August is 167 TAF, the CVP share of the desirable minimum recreation level. However, this storage is not mandatory. By comparing the monthly Tracy Pumping Plant capacities with the monthly demands, a preliminary evaluation of the amount of water needed from CVP San Luis storage can be made. In general, the total CVP demands south of the Delta will approach, or sometimes exceed, the annual capacity of the Tracy Pumping Plant, since the pumping plant and the limited capacity of the Delta Mendota Canal to O'Neill Forebay are currently constraints in the CVP delivery system.

CVP San Luis rule curve storage is set at full capacity for the end of March (beginning of high demand summer months i.e., April through August). Thus, CVP demand during this period could be met with direct pumping by Tracy Pumping Plant, an agreed level of SWP wheeling, and utilizing San Luis storage. If for some reason there is excess CVP pumping capacity available during this period it is usually allocated to September and October.

Similar guidelines can be established for the winter mode (September through March) of operation of San Luis Reservoir. In these months the rule curve must be designed to meet monthly CVP demands and refill San Luis Reservoir to its full capacity by end of March.

As mentioned earlier, it is usually advisable to calculate a different San Luis rule curve for those years when CVP imposes deficiencies on its normal demands. There is usually greater flexibility in how the CVP operates because Tracy Pumping Plant capacity is more than is needed to meet the reduced level of demands. The end of February target storage should be similar to a normal year rule curve so that when the rule curves are switched between reduced delivery and normal delivery, San Luis can be filled as needed to meet demands under either operational mode. Other criteria which may be kept in mind is to maximize pumping during winter months (November through March) and thus capturing Delta surplus flows as much as possible, and which in turn, will reduce storage releases and summer pumping to a minimum.

SWP San Luis Rule Curve

The SWP San Luis rule curve is also developed in three steps: (1) determination of the monthly export capacity of Banks Delta Pumping Plant; (2) tabulation of total SWP demands to be met from SWP San Luis storage and direct pumping from the Delta; and (3) computation of end-of-month target storages. These steps may have to be repeated depending on the range of demands to be met in the study.

One of the current methods of simulating the operation of the SWP is to utilize the March forecast of Central Valley runoff and calculate the amount of delivery that can be made to SWP contractors that will produce an end-of-September carry-over storage in project reservoirs within an acceptable range. The procedure is discussed in the section entitled "Alternative Modes of Operation Studies". Under this concept the maximum delivery equals entitlement requests plus scheduled and unscheduled surplus. Minimum delivery usually occurs in 1977, an extremely critical year, when carry-over storage is allowed to drop to minimum operating levels. This variable delivery operational mode only affects step 2 in the process of determining San Luis rule curves.

At the present time three rule curves are considered sufficient to operate the SWP portion of San Luis Reservoir. One of these would be calculated based on entitlement request, one on firm yield capability, and the third assuming an agricultural deficiency of 33%. Since rule curve target storages must be included as data (Tape 5), they can be selected in a manner similar to the "initial delivery class" previously discussed. Rule curves based on deficient year deliveries can be inserted in those years in which shortages occur; 1924, 1931, 1933, 1934 and 1977.

Other considerations in developing the San Luis rule curves for SWP operation are similar to those for the CVP. Maximum and minimum target storages for the operation of SWP San Luis are fixed at 1,065 TAF (1,067 TAF is full) at the end of April and 183 TAF at the end of August (SWP share of desirable San Luis storage of 350 TAF recreation pool up to Labor Day). Minimum storage can be 42 TAF for SWP San Luis. Normally it is easy to meet the total SWP demands since Banks Pumping Plant capacity is larger than maximum delivery levels.

As a general guideline, San Luis is filled in the winter using surplus Delta flows, but not later than the end of April. At the same time, during this filling cycle, the rule curve must be able to meet the maximum delivery level.

XIII. CALIFORNIA AQUEDUCT OPERATIONS

The California Aqueduct is the major conveyance facility of the State Water Project and extends 444 miles from Sacramento-San Joaquin Delta to Perris Reservoir in Southern California. Its basic function is to transport water supplies from the Delta to the San Joaquin Valley and Southern California and through branch aqueducts to the south San Francisco Bay Area and to Santa Barbara and San Luis Obispo Counties.

In the south Delta, Clifton Court Forebay is a 28,653 AF reservoir at sea level from which Harvey O. Banks Delta Pumping Plant lifts water to an elevation of 244 feet where it flows by gravity in a concrete-lined canal with a maximum capacity of 10,300 cfs to Bethany Reservoir. This reservoir acts as the forebay for the South Bay Pumping Plant of the South Bay Aqueduct, which supplies water to Alameda and Santa Clara Counties. The California Aqueduct from Bethany Reservoir to O'Neill Forebay is a concrete-lined canal with a capacity of 10,000 cfs. The 300 cfs reduction reflects the diversions to the South Bay Aqueduct. Most of the water pumped at Banks Pumping Plant flows into the California Aqueduct for conveyance to O'Neill Forebay. From O'Neill water can continue to flow southward by gravity to Dos Amigos Pumping Plant or be pumped into San Luis Reservoir, operated jointly by the Department of Water Resources and the Bureau of Reclamation. A pumping-generating plant with a pumping capacity of 11,000 cfs lifts the water 327 feet under maximum head conditions to this reservoir. The pumping head is a function of total water in storage at San Luis.

The San Luis Division, extending southward from O'Neill Forebay to Kettleman City, a distance of about 103 miles, is a joint-use facility with a maximum design capacity of 13,100 cfs of which 7,100 cfs is provided for State use. The capacity decreases to 8,350 cfs at the lower end of this facility (Check 21) of which 7,050 cfs is for State use. Project demands in the future could require an increase in the State capacity to 8,100 cfs at the head of the joint-use facilities. Dos Amigos Pumping Plant is located in this reach of the aqueduct. The plant has six pumping units that can lift 13,200 cfs of water 113 feet under normal static head from where it flows the remaining 86 miles to Kettleman City.

The conveyance system from Kettleman City to A. D. Edmonston Pumping Plant includes about 120 miles of concrete-lined canal and Buena Vista, Wheeler Ridge and Wing Gap Pumping Plants. Aqueduct capacity decreases from 8,100 cfs below check 21 to 4,400 cfs through this portion of canal, reflecting water deliveries to various water contractors along the way as well as diversion of flow to the Coastal Branch. The Coastal Branch, when completed, will serve Santa Barbara and San Luis Obispo Counties. From Kettleman City to Buena Vista Pumping Plant there is about 79 miles of concrete-lined canal with gravity flow. The Buena Vista Pumping Plant is the starting point for a series of pumping lifts required to bring water to the foot of the Tehachapi Mountains. Buena Vista Pumping Plant, with 10 pumping units, including one spare unit, has the capacity to lift 5,405 cfs about 205 feet. The Wheeler Ridge Pumping Plant, with nine pumping units, including one spare unit, has a combined capacity of 5,445 cfs and lifts water an additional 233 feet. The Wind Gap Pumping Plant provides the final 518 feet of lift in this chain with nine pumping units, including one spare unit, that have a combined capacity of 4,995 cfs.

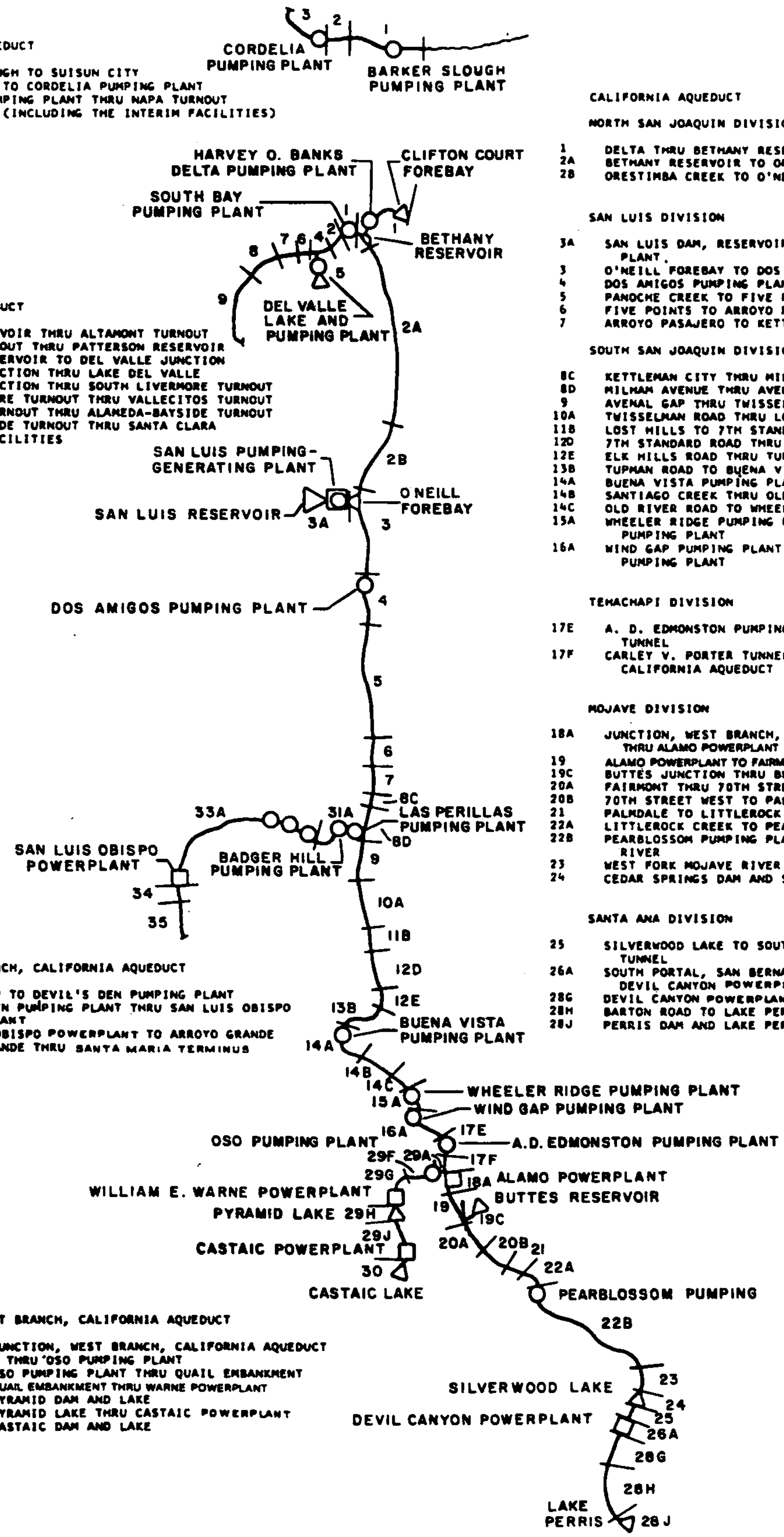
At the Tehachapis, the giant A. D. Edmonston Pumping Plant raises the water 1,970 feet in a single lift into the Tehachapi Crossing, 8.5 miles of tunnels and siphons which traverse the mountain range. After crossing the Tehachapis, the aqueduct divides. The East Branch carries water through Antelope Valley and into Silverwood Lake in the San Bernardino Mountains. From Silverwood, the water enters the San Bernardino Tunnel and drops 1,418 feet into Devil Canyon Powerplant, then flows through a buried pipeline to Lake Perris southeast of Riverside, the southernmost terminus of the project. Water in the West Branch is pumped into Quail Lake, from which it drops through the William E. Warne Powerplant into Pyramid Lake in northwest Los Angeles County, through the Angeles Tunnel into the Castaic Powerplant, and then into Elderberry Forebay and Castaic Lake, terminus of the West Branch.

State Water Project Analysis Office (SWPAO) has subdivided the California Aqueduct into repayment reaches (see Figure XIII.1). The project contractors draw their water supplies at different turnouts along the various reaches. For the purpose of simulation the deliveries to the contractors from the various reaches have been aggregated into control point diversions. Some specific locations on the Aqueduct can be identified with Control Points in the simulation model. Tables XIII.1 and XIII.2 list the relationship between reaches and control points. Figure XIII.2 shows this relationship along with flow carrying capacity of the various reaches and at the control points.

Operation of the California Aqueduct is affected by physical limits at various locations to convey water to the downstream users. These physical limits are placed on the aqueduct as input to the model. The limits, as shown in Table XIII.2 at the various control points along the aqueduct, are chosen based on the carrying capacity of the aqueduct and/or pumping plant capacity, which ever is applicable for that control point.

Figure XIII.1 CALIFORNIA AQUEDUCT REPAYMENT REACHES

PROJECT TRANSPORTATION FACILITIES



NORTH BAY AQUEDUCT

1 BARKER SLOUGH TO SUISUN CITY
2 SUISUN CITY TO CORDELIA PUMPING PLANT
3 CORDELIA PUMPING PLANT THRU NAPA TURNOUT RESERVOIR (INCLUDING THE INTERIM FACILITIES)

SOUTH BAY AQUEDUCT

1 BETHANY RESERVOIR THRU ALTAMONT TURNOUT
2 ALTAMONT TURNOUT THRU PATTERSON RESERVOIR
4 PATTERSON RESERVOIR TO DEL VALLE JUNCTION
5 DEL VALLE JUNCTION THRU LAKE DEL VALLE
6 DEL VALLE JUNCTION THRU SOUTH LIVERMORE TURNOUT
7 SOUTH LIVERMORE TURNOUT THRU VALLECITOS TURNOUT
8 VALLECITOS TURNOUT THRU ALAMEDA-BAYSIDE TURNOUT
9 ALAMEDA-BAYSIDE TURNOUT THRU SANTA CLARA TERMINAL FACILITIES

CALIFORNIA AQUEDUCT

NORTH SAN JOAQUIN DIVISION

1 DELTA THRU BETHANY RESERVOIR
2A BETHANY RESERVOIR TO ORESTIMBA CREEK
2B ORESTIMBA CREEK TO O'NEILL FOREBAY

SAN LUIS DIVISION

3A SAN LUIS DAM, RESERVOIR AND PUMPING-GENERATING PLANT.
3 O'NEILL FOREBAY TO DOS AMIGOS PUMPING PLANT
4 DOS AMIGOS PUMPING PLANT TO PANOCHE CREEK
5 PANOCHE CREEK TO FIVE POINTS
6 FIVE POINTS TO ARROYO PASAJERO
7 ARROYO PASAJERO TO KETTLEMAN CITY

SOUTH SAN JOAQUIN DIVISION

8C KETTLEMAN CITY THRU MILHAM AVENUE
8D MILHAM AVENUE THRU AVENAL GAP
9 AVENAL GAP THRU TWISSELMAN ROAD
10A TWISSELMAN ROAD THRU LOST HILLS
11B LOST HILLS TO 7TH STANDARD ROAD
12D 7TH STANDARD ROAD THRU ELK HILLS ROAD
12E ELK HILLS ROAD THRU TUPMAN ROAD
13B TUPMAN ROAD TO BUENA VISTA PUMPING PLANT
14A BUENA VISTA PUMPING PLANT THRU SANTIAGO CREEK
14B SANTIAGO CREEK THRU OLD RIVER ROAD
14C OLD RIVER ROAD TO WHEELER RIDGE PUMPING PLANT
15A WHEELER RIDGE PUMPING PLANT TO WIND GAP PUMPING PLANT
16A WIND GAP PUMPING PLANT TO A. D. EDMONSTON PUMPING PLANT

TEHACHAPI DIVISION

17E A. D. EDMONSTON PUMPING PLANT TO CARLEY V. PORTER TUNNEL
17F CARLEY V. PORTER TUNNEL TO JUNCTION, WEST BRANCH, CALIFORNIA AQUEDUCT

MOJAVE DIVISION

18A JUNCTION, WEST BRANCH, CALIFORNIA AQUEDUCT THRU ALAMO POWERPLANT
19 ALAMO POWERPLANT TO FAIRMONT
19C BUTTES JUNCTION THRU BUTTES RESERVOIR
20A FAIRMONT THRU 70TH STREET WEST
20B 70TH STREET WEST TO PALMDALE
21 PALMDALE TO LITTLEROCK CREEK
22A LITTLEROCK CREEK TO PEARBLOSSOM PUMPING PLANT
22B PEARBLOSSOM PUMPING PLANT TO WEST FORK MOJAVE RIVER
23 WEST FORK MOJAVE RIVER TO SILVERWOOD LAKE
24 CEDAR SPRINGS DAM AND SILVERWOOD LAKE

SANTA ANA DIVISION

25 SILVERWOOD LAKE TO SOUTH PORTAL, SAN BERNARDINO TUNNEL
26A SOUTH PORTAL, SAN BERNARDINO TUNNEL THRU DEVIL CANYON POWERPLANT
28G DEVIL CANYON POWERPLANT TO BARTON ROAD
28H BARTON ROAD TO LAKE PERRIS
28J PERRIS DAM AND LAKE PERRIS

COASTAL BRANCH, CALIFORNIA AQUEDUCT

31A AVENAL GAP TO DEVIL'S DEN PUMPING PLANT
33A DEVIL'S DEN PUMPING PLANT THRU SAN LUIS OBISPO POWERPLANT
34 SAN LUIS OBISPO POWERPLANT TO ARROYO GRANDE
35 ARROYO GRANDE THRU SANTA MARIA TERMINUS

WEST BRANCH, CALIFORNIA AQUEDUCT

29A JUNCTION, WEST BRANCH, CALIFORNIA AQUEDUCT THRU OSO PUMPING PLANT
29F OSO PUMPING PLANT THRU QUAIL EMBANKMENT
29G QUAIL EMBANKMENT THRU WARNE POWERPLANT
29H PYRAMID DAM AND LAKE
29J PYRAMID LAKE THRU CASTAIC POWERPLANT
30 CASTAIC DAM AND LAKE

XIV. CONJUNCTIVE OPERATION OF GROUND WATER STORAGE

In order to maximize the use of surplus water in the Delta, ground water storage projects south of the Delta may be established and operated as an integrated system with the surface water storage north of the Delta.

The simulation model, at present, treats the integrated ground water projects as simple reservoirs in the network and part of the SWP system. Conjunctive operation of ground water projects provides that storage releases from Oroville and San Luis Reservoirs, as well as Delta surpluses, are used for recharge. One or more ground water projects, as represented on the network diagram in Figure I.2, may be simulated.

The recharge pattern for ground water basins may be set as a constant amount or it may be varied on a 12-month pattern. In the same manner, ground water withdrawals may be assumed as constant or variable each month. Depending on water year type, as determined by the four river index, the model will assume that either recharge or withdrawals occur beginning in March and continuing through the following February. The model was designed to assume that when withdrawals are necessary, they begin in March to assist in meeting demands during the operation year. The rationale for this is that under actual SWP operation project operators could forecast the need for supplement supply and not wait until summer to determine that ground water withdrawals would be needed. It would then be too late to provide much delivery assistance since the monthly ground water withdrawal rates would be limited.

The model has the flexibility to establish which year types will have recharge and which year types will have withdrawals. For example, one may specify to recharge in wet, above normal, and even below normal year types. Additional rules also govern the operation of the integrated ground water reservoirs. Regardless of the year type, ground water recharge will be discontinued if Oroville Reservoir falls below a particular monthly target level (established at the beginning of the study). At present, level two (RL2) at Oroville Reservoir is used for this purpose. Further, ground water withdrawals will begin if Oroville Reservoir falls below still another specified target level at the end of February. Ground water withdrawals will be discontinued during those months in critical years when (1) there is surplus Delta outflow, (2) all SWP storage facilities south of the Delta are full, and (3) there is Delta Pumping Plant space and aqueduct capacity available to meet demands directly from the Delta. Various other recharge and withdrawal assumptions can be easily incorporated.

Ground water projects south of the Delta can also be viewed as local ground water facilities that are not fully integrated into the SWP system. In these instances, the local ground water projects are simply viewed by the model as additional water demands on some specified pattern, and the operation of the local ground water reservoirs per se are not simulated.

TABLE XIII.1

Control Points Representation of Reaches
of the California Aqueduct

Control Point Number	Control Point Label	Aqueduct Reaches
55	North Bay Aqueduct	1NB, 2NB, 3NB
63	South Bay Aqueduct	1SB, 2SB, 4SB, 5SB, 6SB, 7SB, 8SB, 9SB 1, 2A, 2B, 3
127	Coastal Branch; Reaches 4-8D	4, 5, 6, 7, 8C, 8D, 31A, 33A, 34, 35
122	SWP Reaches 9+20% 10A	9, 20% of 10A
123	Cross Valley Canal	12E
131	SWP Reaches 80% 10A - 13B; Buena Vista PP	11B, 12D, 12E, 13B, 80% of 10A
124	SWP Reaches 14A - 14C; Wheeler Ridge PP	14A, 14B, 14C
125	SWP Reach 15A; Wind Gap PP	15A
126	SWP Reach 16A; Edmonston PP	16A
132	SWP Reaches 17E - 17F	17E, 17F
134	SWP Reaches 18A-22A Pearblossom PP	18A, 19, 20A, 20B, 21, 22A
25	SWP Reaches 22B-24; Silverwood Lake	22B, 23, 24
137	SWP Reaches 25, 26A	25, 26A
27	SWP Reaches 28G-28J; Lake Perris	28G, 28H, 28J
28	SWP Reaches 29A-29J; Pyramid Reservoir	29A, 29F, 29G, 29H, 29J
140	SWP Reach 30 Castaic Reservoir	30

TABLE XIII.2

Maximum Flow Carrying Capacities at Various Control Points

Control Point	Aqueduct Facility	Capacity CFS	QM[1] (cfs)	Comments
86	Delta Pump (exist)	6,400	6,240	allow 2.5% outage
86	Delta Pump (enl'g)	10,920		5.7% outage
	Pool 1	10,300	10,300	
63	Below Bethany	10,000	10,000	
12	Dos Amigos Pump	8,374*		
	Pool 19 (exist)	7,050*	7,066	allows for Reach 4&5 losses
	Pool 14 (future)	8,100*	8,100	3.3% outage
127	Coastal Branch			
	Pool 23	7,300	7,300	
122	Pool 25	6,350	6,350	
123	Pool 28 and Cross Valley Canal			
131	Buena Vista Pump	5,405		6.6% outage
	Pool 30	5,050	5,050	
124	Wheeler Ridge Pump	5,445		15.5% outage
	Pool 35	4,600	4,600	
125	Wind Gap Pump	4,995		12.0% outage
	Pool 37	4,400	4,400	
126	Edmonston Pump	4,410	4,090	1 unit kept as spare
	Pool 41	5,360		
132	Pool 41	5,360		
133	Birfurcation Pool 42	2,388	2,388	
130	Alamo PH	1,642		
	Pool 43 (exist)	1,637	1,637	
	Pool 43 (future)	3,037	3,037	East Branch Enl
134	Pearblossom Pump	1,450		5.2% outage
	Pool 59 (exist)	1,375	1,375	
	Pool 59 (future)	2,775	2,775	East Branch Enl
25	Devil Canyon PH	1,340		
135	Pool 65 Penstock	1,200	1,200	
	Pool 66 Afterbay	1,200		
	Pool 65 (Future)	2,600	2,600	
137	Santa Ana Pipeline	550	730	
133 Div	Oso Pump	3,252		3.8% outage
	Pool 1	3,129	3,129	
139	Pyramid PH	3,100		
	Peace Valley Pipe & Gorman Cr	2,414	2,414	
	PH (Future)	3,196	3,196	

*SWP share
1 Controlling flow capacity for the Control Point

Figure XIII.2 CALIFORNIA AQUEDUCT CAPACITY CONSTRAINTS

Feature	Reach	Capacity cfs	Simulation Model Control Point	QM Existing cfs	Future cfs
Clifton Court FB H O Banks Delta PP	1	10,300	86	6,240	10,300
Bethany Res (South Bay PP) Check 1	2A		63	10,000	
Check 9	2B	10,000			
Check 12 O'Neill FB (San Luis Res)	3		12	7,100	8,100
Diversion to Los Banos Grandes Res		7,100 (13,100)	118		
Dos Amigos PP	4		120	7,066	8,100
Check 15	5	7,100 (11,800)			
Check 18	6	7,050 (9,350)			
Check 19	7	7,050 (8,350)			
Check 21 Kettleman City	8C				
Diversion to Coastal Branch	8D	8,100	127	7,300	
Check 22	9	7,300			
Check 23	10A	7,150	122	6,350	
Check 24	11B	6,350			
Check 25 Tupman	12D 12E	5,950	123		
Check 28	13B	5,350	131		
Buena Vista PP	14A	5,050		5,050	
Check 32	14B	4,900			
Check 34	14C				
Wheeler Ridge PP	15A	4,600	124	4,600	
Wind Gap PP	16A	4,400	125	4,400	

Feature	Reach	Capacity cfs	Simulation Model Control Point	QM Existing cfs	Future cfs
A D Edmonston PP	17E	5,360	126	4,090	
	17F		132		
Bifurcation	18A	2,388	133		
Cottonwood PH			130	1,637	3,037
	19	1,637			
Check 46	20A	1,520			
Check 50	20B	1,449			
Check 53	21	1,418			
Check 56	22A	1,397			
Pearblossom PP	22B		134	1,375	2,775
		1,375			
Check 64	23	1,193			
Silverwood Lake	24		25		
	25	2,020		1,200	2,600
Devil Canyon PH		1,196			
	26A	1,200			
Check 66			137	550	730
Santa Ana Pipeline	28G 28H	469			
Lake Perris	28J		27		
West Branch					
Bifurcation			133	3,129	
Oso PP	29A 29F	3,129			
Peace Valley Pipe	29G		139	2,414	3,196
Pyramid PH	29H	1,564			
Pyramid Reservoir			28		
Castaic PH	29J	18,000	29		
Castaic Lake	30		140		

XV. OPERATION OF SOUTHERN CALIFORNIA TERMINAL RESERVOIRS

On the East Branch of the California Aqueduct there are two regulating reservoirs, Silverwood Lake and a terminal reservoir at Perris. They provide an annual regulatory storage of about 60 TAF. Water held in storage also serves as insurance in case there is a prolonged outage in the California Aqueduct. Water flows by gravity from Silverwood Lake through San Bernardino Tunnel, through Devil Canyon Powerplant and finally to Lake Perris.

On the West Branch of the California Aqueduct there are two more regulatory reservoirs. Pyramid Lake contains a gross capacity of 171 TAF and Castaic Lake serves as the terminal reservoir on the West Branch with a gross capacity of 324 TAF. Both of these reservoirs provide opportunities for generation of hydroelectric power.

There are several fundamental considerations which must be kept in mind while setting target storages for the terminal reservoir operations:

(1) Under the water supply contracts with the SWP Contractors these reservoirs are not considered conservation facilities, and hence, should not be considered other than limited annual cyclic storage for the purpose of contributing to project yield.

(2) For Pyramid Lake the reservoir should not be allowed to drop below the 170 TAF level as agreed upon by DWR and LADWP. Lower operations would only be allowed for short time periods or under emergency conditions.

(3) For Castaic Lake the drawdown between April and September should not exceed 90 ft (164 TAF storage) as per Memo of Understanding with USFS dated January 9, 1970.

(4) Based on information supplied by Division of Operations and Maintenance the following minimum and maximum operating storages may be used for the four reservoirs.

	Silverwood	Perris	Pyramid	Castaic
		(All Values in TAF)		
Minimum Storage	44.0	31.0	120.0	55.0
Normal Cycle Minimum	44.0	97.0	170.0	125.0
Maximum Storage	75.0	131.0	171.0	324.0

Note that minimum storage of 120 TAF in Pyramid Lake is to maintain power generation head.

Based upon the above considerations and keeping in mind that the reservoirs are operated to deliver some of the entitlement water in summer months. The following set of rule curves, target end-of-month storages (TABLE XV.1) have been designed and may be used for simulation purposes for any present or future level studies, irrespective of the demand being placed on the system.

TABLE XV.1

Rule Curves For Terminal Reservoirs
End of Month Storage in TAF

Month	Silverwood	Perris	Pyramid	Castaic
October	44	97	170	125
November	50	98	170	155
December	55	104	170	185
January	60	111	170	220
February	65	119	170	255
March	70	124	170	290
April	73	127	170	324
May	70	124	170	295
June	65	121	170	265
July	60	117	170	230
August	55	113	170	195
September	50	108	170	160

Appendix A

Delta Outflow Requirements for Use In Planning Simulation Model

This Appendix describes the assumptions and procedures currently used in the development of data sets for (I) D-1485 minimum required delta outflows (C.P. 58 Diversion), (II) additional delta outflows required by DWR's contract with North Delta Water Agency (C.P. 56 Diversion), and (III) carriage water requirements (C.P. 60 Diversion). For any simulation model study the total Delta outflow requirement will always be the sum of these three diversion components as they appear in the study results (output Tape 7). Much of the basic outflow data has been provided by Central District personnel, since they developed the relationships necessary to convert D-1485 water quality requirements (electrical conductivity, total chlorides, etc.) into corresponding flow units (cfs).

I. Derivation of D-1485 Minimum Delta Outflow Requirements:

The data library currently contains four versions of the D-1485 minimum outflow requirements as shown in the accompanying Tables A-1 through A-4. These four versions are based on (1) two flow/salinity relationships for the Emmaton agricultural standard, and (2) the choice of assuming either Interim or Permanent Suisun Marsh criteria. These two alternative criteria, as well as other assumptions common to all four versions of the C.P. 58 diversion sets, are described as follows:

A. Emmaton Flow/Salinity Relationship:

Central District currently has two estimates of the amount of flow required to maintain the Emmaton agricultural water quality requirement (EC units). For example, the "old" relationship calls for a flow of 6,200 cfs to maintain a 0.45 EC, while the more recent "new" relationship requires a flow of 7,583 cfs to maintain the same 0.45 EC at Emmaton. We are currently using the "new" Emmaton relationship in most simulation model studies, since it produces total outflow requirements that are similar to that used in the COA studies.

B. Interim or Permanent Suisun Marsh Criteria:

Two versions of D-1485 outflow requirements have been established regarding fish and wildlife standards for the Suisun Marsh area. As specified in D-1485, the Interim Marsh requirements (primarily at Chipps Island) are to be maintained until that time in the future when permanent facilities are constructed to improve Suisun Marsh conditions (initially the Montezuma Slough Control Structure). Once these permanent facilities are in operation, D-1485 specifies that alternate (often lower) flow requirements will be allowed at Chipps Island. These alternate D-1485 criteria with Permanent Suisun Marsh facilities are estimated requirements (by Central District), and will be subject to change, depending on how well the proposed Permanent Facilities actually work. Since there are five distinct Chipps Island standards specified in D-1485, switching from Interim to Permanent Suisun Marsh criteria involves numerous specific changes to the YD58 data sets.

It should also be noted that the two YD58 data sets with Permanent Marsh standards do not include any additional water for diversion into Suisun Marsh via the Montezuma Slough Control Structure. Central District has recently evaluated various estimates (800 cfs diversion for eight months each year), but the amount needed for this diversion has not been finalized. Thus, the two YD58 data sets with Permanent Marsh standards may underestimate the total amount of required Delta outflow.

Additional assumptions common to all four YD58 data sets are as follows:

C. April 1 - May 5 deficiency year outflow relaxation for Antioch Waterworks fish and wildlife criteria:

As specified in D-1485, this outflow standard can be relaxed (reduced) from April 1 through May 5 in any Dry or Critical year when either the CVP or SWP impose deficiencies on their contract water deliveries. The amount of outflow relaxation allowed varies in proportion to the total (both CVP and SWP) system-wide project deficiency imposed in MAF/year units. Therefore, the amount of relaxation of this standard will vary with each simulation model study, depending on the level of CVP and SWP demands assumed. The four YD58 sets in the data library have April 1 through May 5 outflow relaxations incorporated in deficiency years, based on the following CVP and SWP assumptions:

- o both the CVP and SWP imposed 25% agricultural deficiencies in the following years: 1924, 1929, 1931, 1933, 1934 and 1976; plus a 50% agricultural deficiency in 1977.

- o the combined CVP and SWP 25% deficiency is assumed to be 1.776 MAF/year, based on average year 2000 level demands.

D. Special October through December deficiency year relaxation for use only when Interim Suisun Marsh criteria are assumed:

As specified in D-1485, the Interim Suisun Marsh criteria allow an additional outflow relaxation from October 1 through December 31 of any Dry or Critical year in which either the SWP or CVP imposes a deficiency on project demands. This is a fixed outflow relaxation from 4,500 cfs to 3,500 cfs (based on Central District data), and is imposed in full or not at all. When Permanent Suisun Marsh facilities are assumed this special relaxation criteria is eliminated.

Thus, the two versions of YD58 data sets with Interim Marsh criteria assume this relaxation in all the CVP and SWP deficiency years listed in the preceeding Section.

E. D-1485 M&I standard for chloride levels (mg/l) at Antioch Waterworks Intake on the San Joaquin River:

This criteria is not included in the four YD58 data sets currently used in the simulation model, and is difficult to evaluate. Since the units are specified in mg/l, relationships must be developed by Central District personnel to convert this criteria to flow units in cfs. However, such a relationship is difficult to develop, since chloride concentrations in mg/l can vary for any given flow rate. As an alternative Central District does have the capability to evaluate total Delta outflows resulting from our Planning Simulation Model studies, in order to verify that M&I standards (for chlorides) have been maintained.

F. D-1485 fish and wildlife criteria at Rio Vista for salmon migrations:

For September 1 through December 31, this criteria for minimum fishery flows in the lower Sacramento River is <u>not</u> modeled in the four YD58 data sets currently used. Except for Wet year classifications (with a 5,000 cfs fishery flow requirement), this flow is always smaller than other D-1485 standards for the same period and thus is not a controlling outflow requirement.

For the 5,000 cfs Sept.-Dec. flow requirement in Wet years, the four YD58 data sets assume that a "thru-Delta" facility does not exist. As such it is assumed that CVP and SWP water for export will flow past Rio Vista before being diverted across the Delta to the CVP and SWP pumping plants. Thus, 5,000 cfs Rio Vista fish flow is still maintained, partly by water for CVP and SWP export and partly by the next lower D-1485 outflow standard.

It is important to note that the above assumption (and the resulting YD58 data sets) will not be valid when a "thru-Delta" facility does exist, since water for CVP and SWP export could be diverted from the Sacramento River above Rio Vista. Thus, for studies with a "thru-Delta" facility, the four YD58 data sets should be modified by increasing the D-1485 outflow requirement to 5,000 cfs for September through December in Wet water years.

G. The lowest allowable minimum Delta outflow requirement is assumed to be 2,500 cfs in the four YD58 data sets, even though some of the D-1485 standards actually specify lower amounts (down to 1,000 cfs) in the summer and fall months of Dry and Critical years. The specific reason for the 2,500 cfs minimum flow is not documented, but it is generally assumed that 2,500 cfs would be the minimum acceptable flow for Delta operations, navigation, and salinity repulsion.

II. Derivation of SWP additional Delta outflow requirements as specified in the DWR contract with the North Delta Water Agency (NDWA):

This agreement between DWR and the NDWA specifies a set of agricultural water quality standards (in EC) for several locations in the Delta. At times these standards require Delta flows that are larger than the corresponding period D-1485 requirements, while at other times no additional outflow is needed (D-1485 requirements are higher). When additional flows are needed to maintain these NDWA requirements, the water must be released from SWP facilities only (primarily Oroville Reservoir). These additional outflow requirements in excess of the D-1485 standards (YD58) are represented as C.P. 56 diversions in the results of simulation model studies.

As shown in Tables 5 and 6 two versions of the YD56 data sets are available; one using the "old" Emmaton flow/salinity relationship, and the other with the "new" Emmaton relationship. Both data sets were developed by Central District personnel in mid-1982, and should be used with the corresponding version of D-1485 outflows (old or new Emmaton versions of YD58). The YD56 input data sets for the Planning Simulation Model contain the full flow requirements necessary to comply with the NDWA requirements, whereas the YD56 diversions shown in the results of a study will only represent the incremental YD56 flow in excess of the D-1485 requirement at YD58 (which will always be less than the full YD56 input data set).

The additional outflow requirements specified by the YD56 data sets are generally used in simulation model studies where existing Delta facilities are assumed. However, a future Delta project known as the "Sherman Island Overland Water Facilities" is being planned to supply good quality water to agricultural lands served by the NDWA. When these Overland Facilities are completed (in future level simulation model studies), additional YD56 Delta flows would not be needed to satisfy the NDWA requirements. Under this assumption the incremental NDWA outflow requirements drop to zero, and no YD56 data sets are used.

III. Description of Carriage Water Requirements:

Carriage water is generally defined as additional Delta outflow required to control sea water intrusion from San Francisco Bay and the ocean. This outflow is required in addition to the basic outflows specified by the D-1485 standards (YD58), and varies as a function of (1) CVP and SWP Delta export pumping and (2) south Delta inflow from the San Joaquin River and the Eastside stream group (Cosumnes, Mokelumne and Calaveras Rivers). In general, carriage water requirements will increase when total export pumping increases, and will decrease in relation to increases in south and east Delta inflows.

Carriage water requirements are treated as an in-basin use and are specified as a diversion at C.P. 60 in all simulation model studies that assume the existing Delta configuration and facilities. However, for studies assuming the completion of a "thru-Delta" facility or other Delta channel improvements, the carriage water requirements (and input data) are eliminated. This is based on the presumption that the improved Delta flows and circulation resulting from a thru-Delta facility would be able to control sea water intrusion, and thus eliminate the need for carriage water.

When carriage water is required, it would not be distinguishable from other required outflow and would therefore be supplied from both CVP and SWP reservoirs, in accordance with the sharing ratios specified by the COA.

In the simulation model carriage water data consists of a single set of total export pumping/Delta outflow relationships (DP/DF data) which are inserted at C.P. 60 in the input data file. Currently only one version of the carriage water data file exists, as developed by Central District personnel. This carriage water data set actually contains 72 distinct DP/DF relationships, one for each month of the year for six different Water Year classifications (Wet, Above Normal, Below Normal, Dry, Critical and Critical following Critical).

For each year type and month, the simulation model will calculate the total CVP and SWP export pumping; adjust for Eastside streams and San Joaquin River inflow; and then use the appropriate DP/DF relationship to determine the <u>Total</u> Delta outflow needed to control sea water intrusion. Next the simulation model will compare this total outflow with the D-1485 minimum required outflow (YD58) for the corresponding month, and calculate the carriage water (C.P. 60 diversion) as the difference between the two Delta outflows. If the D-1485 outflow requirement is greater than the total Delta outflow for sea water intrusion, the total Delta outflow requirement becomes diversion at C.P. 58 and the carriage water requirement will be zero.

Since carriage water varies as a function of CVP and SWP Delta pumping, it is important to note that any changes in the months when export pumping occurs can significantly alter carriage water requirements for a given study. In general, minimizing CVP and SWP exports during the summer and fall months at the Tracy and Banks Pumping Plants will reduce carriage water requirements and maximize project deliveries.

TABLE A.1: D-1485 MIN. REQUIRED DELTA OUTFLOW, SET FOR 2000 LEVEL DEFICIENCY YEARS
WITH NEW EMMATON SALINITY/FLOW RELATION, + INTERIM SUISUN MARSH CRITERIA
(1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	277	268	277	277	666	738	460	798	637	473	278	149	5298
1923	277	268	277	738	666	377	451	663	565	400	239	149	5070
1924	277	268	277	277	259	277	268	277	229	237	194	149	2989
1925	215	208	215	277	666	738	450	798	637	473	278	149	5114
1926	277	268	277	277	250	362	451	466	364	286	218	149	3645
1927	277	268	277	277	555	615	595	821	833	615	305	149	5587
1928	277	268	277	277	690	738	451	466	451	413	278	149	4735
1929	277	268	277	277	250	277	268	277	229	237	194	149	2980
1930	215	208	215	277	250	362	451	466	407	330	239	149	3569
1931	277	268	277	277	250	277	268	277	229	237	194	149	2980
1932	215	208	215	277	259	362	451	466	407	330	239	149	3578
1933	277	268	277	277	250	277	268	277	229	237	194	149	2980
1934	215	208	215	277	250	277	268	277	229	237	194	149	2796
1935	215	208	215	738	666	377	451	798	637	473	278	149	5205
1936	277	268	277	738	690	362	451	798	637	473	278	149	5398
1937	277	268	277	277	666	738	450	663	565	400	239	149	4979
1938	277	268	277	277	555	615	595	821	833	615	305	149	5587
1939	277	268	277	277	250	277	399	299	229	237	194	149	3133
1940	277	268	277	736	690	362	451	798	637	473	305	149	5425
1941	277	268	277	277	555	615	595	821	823	615	305	149	5587
1942	277	268	277	277	555	615	595	821	833	615	305	149	5587
1943	277	268	277	277	555	615	595	821	833	615	305	149	5587
1944	277	268	277	277	259	362	451	466	364	286	219	149	3654
1945	277	268	277	277	666	738	460	663	565	400	239	149	4979
1946	277	268	277	738	666	377	451	798	637	473	278	149	5389
1947	277	268	277	277	250	362	451	466	364	286	218	149	3645
1948	277	268	277	277	259	723	714	798	637	473	278	149	5130
1949	277	268	277	277	250	362	451	466	364	286	218	149	3645
1950	277	268	277	277	666	738	460	663	565	400	239	149	4979
1951	277	268	277	277	555	615	595	466	451	466	305	149	4701
1952	277	268	277	277	575	615	595	821	833	615	305	149	5607
1953	277	268	277	277	555	615	595	821	833	615	305	149	5587
1954	277	268	277	738	666	377	451	798	637	473	278	149	5389
1955	277	268	277	277	250	362	451	466	364	286	218	149	3645
1956	277	268	277	277	575	615	595	821	833	615	305	149	5607
1957	277	268	277	277	666	738	450	663	565	400	239	149	4979
1958	277	268	277	277	555	615	595	821	833	615	305	149	5587
1959	277	268	277	277	250	362	451	466	364	286	218	149	3645
1960	277	268	277	277	690	738	451	466	407	330	239	149	4569
1961	277	268	277	277	250	362	451	466	364	286	218	149	3645
1962	277	268	277	277	666	738	450	663	565	400	239	149	4979
1963	277	268	277	277	555	615	595	821	833	615	305	149	5587
1964	277	268	277	277	259	362	451	466	364	286	218	149	3654
1965	277	268	277	277	555	615	595	821	833	615	305	149	5587
1966	277	268	277	738	666	377	451	466	407	330	239	149	4645
1967	277	268	277	277	555	615	595	821	833	615	305	149	5587
1968	277	268	277	277	690	738	451	466	407	330	239	149	4569
1969	277	268	277	277	555	615	595	821	833	615	305	149	5587
1970	277	268	277	277	555	615	595	466	451	466	305	149	4701
1971	277	268	277	277	555	615	595	821	833	615	305	149	5587
1972	277	268	277	738	690	362	451	466	407	330	239	149	4654
1973	277	268	277	277	555	615	595	821	833	615	305	149	5587
1974	277	268	277	277	555	615	595	821	833	615	305	149	5587
1975	277	268	277	738	666	377	451	798	637	473	278	149	5389
1976	277	268	277	277	259	277	268	277	229	237	194	149	2989
1977	215	208	215	277	250	277	268	277	229	237	194	149	2796
1978	215	208	215	277	555	615	595	821	833	615	305	149	5403
57 YR AVG	269	261	269	356	495	506	481	619	559	432	259	149	4651

TABLE A.2: D-1485 MIN. REQUIRED DELTA OUTFLOW, SET FOR 2000 LEVEL DEFICIENCY YEARS WITH NEW EMMATON SALINITY/FLOW RELATION, + PERMANENT SUISUN MARSH CRITERIA (1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	154	167	172	209	255	366	451	798	637	473	278	149	4109
1923	154	167	172	209	255	366	451	663	565	400	239	149	3790
1924	154	167	172	209	265	283	254	241	229	237	194	149	2554
1925	154	167	172	209	255	366	451	798	637	473	278	149	4109
1926	154	167	172	209	255	366	451	466	364	286	218	149	3257
1927	154	167	172	209	255	366	451	798	833	615	305	149	4474
1928	154	167	172	209	265	366	451	466	451	413	278	149	3541
1929	154	167	172	209	255	283	254	241	229	237	194	149	2544
1930	154	167	172	209	255	366	451	466	407	330	239	149	3365
1931	154	167	172	209	255	283	254	241	229	237	194	149	2544
1932	154	167	172	209	265	366	451	466	407	330	239	149	3375
1933	154	167	172	209	255	283	254	241	229	237	194	149	2544
1934	154	167	172	209	255	283	254	241	229	237	194	149	2544
1935	154	167	172	209	255	366	451	798	637	473	278	149	4109
1936	154	167	172	209	265	366	451	798	637	473	278	149	4119
1937	154	167	172	209	255	366	451	663	565	400	239	149	3790
1938	154	167	172	209	255	366	451	798	833	615	305	149	4474
1939	154	167	172	209	255	283	399	265	229	237	194	149	2713
1940	154	167	172	209	265	366	451	798	637	473	305	149	4146
1941	154	167	172	209	255	366	451	798	833	615	305	149	4474
1942	154	167	172	209	255	366	451	798	833	615	305	149	4474
1943	154	167	172	209	255	366	451	798	833	615	305	149	4474
1944	154	167	172	209	265	366	451	466	364	286	218	149	3267
1945	154	167	172	209	255	366	451	663	565	400	239	149	3790
1946	154	167	172	209	255	366	451	798	637	473	278	149	4109
1947	154	167	172	209	255	366	451	466	364	286	218	149	3257
1948	154	167	172	209	265	366	451	798	637	473	278	149	4119
1949	154	167	172	209	255	366	451	466	364	286	218	149	3257
1950	154	167	172	209	255	366	451	663	565	400	239	149	3790
1951	154	167	172	209	255	366	451	466	451	466	305	149	3511
1952	154	167	172	209	265	366	451	798	833	615	305	149	4484
1953	154	167	172	209	255	366	451	798	833	615	305	149	4474
1954	154	167	172	209	255	366	451	798	637	473	278	149	4109
1955	154	167	172	209	255	366	451	466	364	286	218	149	3257
1956	154	167	172	209	265	366	451	798	833	615	305	149	4484
1957	154	167	172	209	255	366	451	663	565	400	239	149	3790
1958	154	167	172	209	255	366	451	798	833	615	305	149	4474
1959	154	167	172	209	255	366	451	466	364	286	218	149	3257
1960	154	167	172	209	265	366	451	466	407	330	239	149	3375
1961	154	167	172	209	255	366	451	466	364	286	218	149	3257
1962	154	167	172	209	255	366	451	663	565	400	239	149	3790
1963	154	167	172	209	255	366	451	798	833	615	305	149	4474
1964	154	167	172	209	265	366	451	466	364	286	218	149	3267
1965	154	167	172	209	255	366	451	798	833	615	305	149	4474
1966	154	167	172	209	255	366	451	466	407	330	239	149	3365
1967	154	167	172	209	255	366	451	798	833	615	305	149	4474
1968	154	167	172	209	265	366	451	466	407	330	239	149	3375
1969	154	167	172	209	255	366	451	798	833	615	305	149	4474
1970	154	167	172	209	255	366	451	466	451	466	305	149	3611
1971	154	167	172	209	255	366	451	798	833	615	305	149	4474
1972	154	167	172	209	265	366	451	466	407	330	239	149	3375
1973	154	167	172	209	255	366	451	798	833	615	305	149	4474
1974	154	167	172	209	255	366	451	798	833	615	305	149	4474
1975	154	167	172	209	255	366	451	798	637	473	278	149	4109
1976	154	167	172	209	265	283	254	241	229	237	194	149	2554
1977	154	167	172	209	255	283	229	237	220	237	194	149	2515
1978	154	167	172	209	255	366	451	798	833	615	305	149	4474
57 YR AVG	154	167	172	209	257	354	425	607	558	432	259	149	3745

TABLE A.3: D-1485 MIN. REQUIRED DELTA OUTFLOW, SET FOR 2000 LEVEL DEFICIENCY YEARS
WITH OLD EMMATON SALINITY/FLOW RELATION, + INTERIM SUISUN MARSH CRITERIA
(1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	277	268	277	277	666	738	409	788	637	473	243	149	5202
1923	277	268	277	738	666	339	399	654	565	400	219	149	4951
1924	277	268	277	277	259	277	268	277	184	184	168	149	2865
1925	215	208	215	277	666	738	409	788	637	473	243	149	5018
1926	277	268	277	277	250	324	399	386	294	228	189	149	3318
1927	277	268	277	277	555	615	595	821	833	615	263	149	5545
1928	277	268	277	277	690	738	399	401	369	339	243	149	4427
1929	277	268	277	277	250	277	268	277	184	184	168	149	2856
1930	215	208	215	277	259	324	399	386	339	289	219	149	3270
1931	277	268	277	277	250	277	268	277	184	184	168	149	2856
1932	215	208	215	277	259	324	399	386	339	289	219	149	3270
1933	277	268	277	277	250	277	268	277	184	184	168	149	2856
1934	215	208	215	277	250	277	268	277	184	184	168	149	2672
1935	215	208	215	738	666	339	399	788	637	473	243	149	5070
1936	277	268	277	736	690	324	399	788	637	473	243	149	5263
1937	277	268	277	277	666	738	409	654	565	400	219	149	4899
1938	277	268	277	277	555	615	595	821	833	615	263	149	5545
1939	277	268	277	277	250	277	399	299	184	184	168	149	3009
1940	277	268	277	738	690	324	399	788	637	473	263	149	5283
1941	277	268	277	277	555	615	595	821	833	615	263	149	5545
1942	277	268	277	277	555	615	575	821	833	615	263	149	5545
1943	277	268	277	277	555	615	595	821	833	615	263	149	5545
1944	277	268	277	277	259	324	399	386	294	228	189	149	3327
1945	277	268	277	277	666	738	409	654	565	400	219	149	4899
1946	277	268	277	738	666	339	399	788	637	473	243	149	5254
1947	277	268	277	277	250	324	399	386	294	228	189	149	3318
1948	277	268	277	277	259	723	714	798	637	473	243	149	5095
1949	277	268	277	277	250	324	399	386	294	228	189	149	3318
1950	277	268	277	277	666	738	409	654	565	400	219	149	4899
1951	277	268	277	277	555	615	595	401	369	381	263	149	4427
1952	277	268	277	277	575	615	595	821	833	615	263	149	5565
1953	277	268	277	277	555	615	595	821	833	615	263	149	5545
1954	277	268	277	738	666	339	399	788	637	473	243	149	5254
1955	277	268	277	277	250	324	399	386	294	228	189	149	3318
1956	277	268	277	277	575	615	595	821	833	615	263	149	5565
1957	277	268	277	277	666	738	409	654	565	400	219	149	4899
1958	277	268	277	277	555	615	595	821	833	615	263	149	5545
1959	277	268	277	277	250	324	399	386	294	228	189	149	3318
1960	277	268	277	277	690	738	399	401	353	289	219	149	4337
1961	277	268	277	277	250	324	399	386	294	228	189	149	3318
1962	277	268	277	277	666	738	409	654	565	400	219	149	4899
1963	277	268	277	277	555	615	595	821	833	615	263	149	5545
1964	277	268	277	277	259	324	399	386	294	228	189	149	3327
1965	277	268	277	277	555	615	595	821	833	615	263	149	5545
1966	277	268	277	738	666	339	399	401	353	289	219	149	4375
1967	277	268	277	277	555	615	595	821	833	615	263	149	5545
1968	277	268	277	277	690	738	399	401	353	289	219	149	4337
1969	277	268	277	277	555	615	595	821	833	615	263	149	5545
1970	277	268	277	277	555	615	595	401	369	381	263	149	4427
1971	277	268	277	277	555	615	595	821	833	615	263	149	5545
1972	277	268	277	738	690	324	399	401	353	289	219	149	4384
1973	277	268	277	277	555	615	595	821	833	615	263	149	5545
1974	277	268	277	277	555	615	595	821	833	615	263	149	5545
1975	277	268	277	738	666	339	399	788	637	473	243	149	5254
1976	277	268	277	277	259	277	268	277	184	184	168	149	2865
1977	215	208	215	277	250	277	258	277	184	184	168	149	2572
1978	215	208	215	277	555	615	595	821	833	615	263	149	5361
57 YR AVG	269	261	269	350	495	496	435	595	532	408	227	149	4504

TABLE A.4: D-1485 MIN. REQUIRED DELTA OUTFLOW, SET FOR 2000 LEVEL DEFICIENCY YEARS
WITH OLD EMMATON SALINITY/FLOW RELATION. + PERMANENT SUISUN MARSH CRITERIA
(1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	154	167	172	209	255	327	399	788	637	473	243	149	3973
1923	154	167	172	209	255	327	399	654	565	400	219	149	3670
1924	154	167	172	209	265	283	254	228	184	184	168	149	2417
1925	154	167	172	209	255	327	399	788	637	473	243	149	3973
1926	154	167	172	209	255	327	399	386	294	228	189	149	2929
1927	154	167	172	209	255	327	399	788	833	615	263	149	4331
1928	154	167	172	209	265	327	399	401	369	339	243	149	3194
1929	154	167	172	209	255	283	254	228	184	184	168	149	2407
1930	154	167	172	209	255	327	399	386	339	289	219	149	3065
1931	154	167	172	209	255	283	254	228	184	184	168	149	2407
1932	154	167	172	209	265	327	399	386	339	289	219	149	3075
1933	154	167	172	209	255	283	254	228	184	184	168	149	2407
1934	154	167	172	209	255	283	254	228	184	184	168	149	2407
1935	154	167	172	209	255	327	399	788	637	473	243	149	3973
1936	154	167	172	209	265	327	399	788	637	473	243	149	3983
1937	154	167	172	209	255	327	399	654	565	400	219	149	3670
1938	154	167	172	209	255	327	399	788	833	615	263	149	4331
1939	154	167	172	209	255	283	399	252	184	184	168	149	2576
1940	154	167	172	209	265	327	399	788	637	473	263	149	4003
1941	154	167	172	209	255	327	399	788	833	615	263	149	4331
1942	154	167	172	209	255	327	399	788	833	615	263	149	4331
1943	154	167	172	209	255	327	399	788	833	615	263	149	4331
1944	154	167	172	209	265	327	399	386	294	228	189	149	2939
1945	154	167	172	209	255	327	399	654	565	400	219	149	3670
1946	154	167	172	209	255	327	399	788	637	473	243	149	3973
1947	154	167	172	209	255	327	399	386	294	228	189	149	2929
1948	154	167	172	209	265	327	399	788	637	473	243	149	3983
1949	154	167	172	209	255	327	399	386	294	228	189	149	2929
1950	154	167	172	209	255	327	399	654	565	400	219	149	3670
1951	154	167	172	209	255	327	399	401	369	381	263	149	3246
1952	154	167	172	209	265	327	399	788	833	615	263	149	4341
1953	154	167	172	209	255	327	399	788	833	615	263	149	4331
1954	154	167	172	209	255	327	399	788	637	473	243	149	3973
1955	154	167	172	209	255	327	399	386	294	228	189	149	2929
1956	154	167	172	209	265	327	399	788	833	615	263	149	4341
1957	154	167	172	209	255	327	399	654	565	400	219	149	3670
1958	154	167	172	209	255	327	399	788	833	615	263	149	4331
1959	154	167	172	209	255	327	399	386	294	228	189	149	2929
1960	154	167	172	209	265	327	399	401	353	289	219	149	3104
1961	154	167	172	209	255	327	399	386	294	228	189	149	2929
1962	154	167	172	209	255	327	399	654	565	400	219	149	3670
1963	154	167	172	209	255	327	399	788	833	615	263	149	4331
1964	154	167	172	209	265	327	399	386	294	228	189	149	2939
1965	154	167	172	209	255	327	399	788	833	615	263	149	4331
1966	154	167	172	209	255	327	399	401	353	289	219	149	3094
1967	154	167	172	209	255	327	399	788	833	615	263	149	4331
1968	154	167	172	209	265	327	399	401	353	289	219	149	3104
1969	154	167	172	209	255	327	399	788	833	615	263	149	4331
1970	154	167	172	209	255	327	399	401	369	381	263	149	3246
1971	154	167	172	209	255	327	399	788	833	615	263	149	4331
1972	154	167	172	209	265	327	399	401	353	289	219	149	3104
1973	154	167	172	209	255	327	399	788	833	615	263	149	4331
1974	154	167	172	209	255	327	399	788	833	615	263	149	4331
1975	154	167	172	209	255	327	399	788	637	473	243	149	3973
1976	154	167	172	209	265	283	254	228	184	184	168	149	2417
1977	154	167	172	209	255	283	214	221	184	184	168	149	2360
1978	154	167	172	209	255	327	399	788	833	615	263	149	4331
57 YR AVG	154	167	172	209	257	321	390	578	532	408	227	149	3554

TABLE A.51 NO. DELTA WATER AGENCY TOTAL OUTFLOW REQUIREMENTS (CP56 DATA SET)
WITH OLD EMMATON SALINITY/OUTFLOW RELATIONSHIP
(1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	229	221	319	286	334	370	375	387	361	336	301	206	3725
1923	213	206	319	286	216	239	375	387	338	244	230	189	3242
1924	195	189	319	286	146	156	169	175	169	175	175	168	2322
1925	174	168	319	286	323	357	375	387	351	295	269	200	3504
1926	207	200	319	286	173	191	291	301	270	219	210	182	2849
1927	188	182	319	286	334	370	375	387	375	387	341	221	3765
1928	229	221	319	286	343	366	375	387	355	310	281	203	3675
1929	210	203	319	286	141	156	177	183	175	175	175	168	2368
1930	174	168	319	286	230	255	375	387	339	248	233	190	3204
1931	197	190	319	286	141	156	159	175	169	175	175	168	2320
1932	174	168	319	286	218	233	375	387	337	243	229	189	3158
1933	195	189	319	286	141	156	185	191	181	178	177	168	2366
1934	174	168	319	286	141	156	180	186	177	175	175	168	2305
1935	174	168	319	286	328	363	375	387	353	304	277	202	3536
1936	209	202	319	286	346	370	375	387	358	321	299	204	3666
1937	211	204	319	286	220	243	375	387	338	245	231	189	3248
1938	196	189	319	286	334	370	375	387	375	387	341	221	3780
1939	229	221	319	286	141	156	174	179	173	177	176	168	2399
1940	174	168	319	286	346	370	375	387	375	387	341	221	3749
1941	229	221	319	286	334	370	375	387	375	387	341	221	3845
1942	229	221	319	286	334	370	375	387	375	387	341	221	3845
1943	229	221	319	286	334	370	375	397	375	387	340	217	3840
1944	225	217	319	286	154	165	221	228	212	196	191	175	2589
1945	180	175	319	286	313	346	375	387	346	277	255	197	3456
1946	203	197	319	286	334	370	375	387	359	325	292	205	3652
1947	212	205	319	286	149	165	221	228	212	196	191	175	2559
1948	180	175	319	286	332	354	375	387	350	292	267	200	3517
1949	206	200	319	286	177	196	339	319	284	223	213	184	2916
1950	190	184	319	286	308	341	375	387	343	263	245	194	3435
1951	200	194	319	286	334	370	375	387	375	387	341	221	3789
1952	229	221	319	286	346	370	375	387	375	387	341	221	3857
1953	229	221	319	286	334	370	375	387	375	387	339	214	3836
1954	221	214	319	286	334	370	375	387	358	321	289	204	3678
1955	211	204	319	286	158	175	244	252	233	208	201	178	2669
1956	184	178	319	286	346	370	375	387	375	387	341	221	3769
1957	229	221	319	286	313	346	375	387	345	373	252	196	3642
1958	202	196	319	296	334	370	375	397	375	387	341	221	3793
1959	229	221	319	286	177	196	309	319	284	223	213	194	2960
1960	190	184	319	286	218	233	375	387	337	243	229	189	3190
1961	195	189	319	286	177	196	309	319	284	223	213	184	2894
1962	195	184	319	286	313	346	375	387	346	277	255	197	3475
1963	203	197	319	286	334	370	375	387	375	387	341	221	3795
1964	229	221	319	286	162	173	240	248	228	203	197	177	2583
1965	183	177	319	286	334	370	375	387	375	387	341	221	3755
1966	229	221	319	286	207	229	375	387	337	241	228	198	3247
1967	195	188	319	286	334	370	375	387	375	387	341	221	3778
1968	229	221	319	286	244	261	375	387	339	250	235	191	3337
1969	197	191	319	286	334	370	375	387	375	387	341	221	3783
1970	229	221	319	286	334	370	375	387	375	387	341	221	3845
1971	229	221	319	286	334	370	375	387	375	307	341	221	3845
1972	229	221	319	286	232	248	375	387	339	247	232	190	3304
1973	196	190	319	286	334	370	375	387	375	387	339	214	3772
1974	221	214	319	286	334	370	375	387	375	387	341	221	3830
1975	229	221	319	286	334	370	375	387	371	373	328	211	3804
1976	218	211	319	286	146	156	175	181	174	175	175	168	2384
1977	174	168	319	286	141	156	169	175	169	175	175	168	2275
1978	174	168	319	286	334	370	375	387	375	387	341	221	3737
57 YR AVG	205	199	319	286	267	293	332	343	319	296	268	199	3326

TABLE A.6: NO. DELTA WATER AGENCY TOTAL OUTFLOW REQUIREMENTS (CP56 DATA SET)
WITH NEW EMMATON SALINITY/OUTFLOW RELATIONSHIP
(1000 ACRE FEET)

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1922	298	288	396	360	405	448	451	466	438	414	375	272	4611
1923	281	272	395	360	279	309	451	466	412	315	299	252	4092
1924	260	252	396	360	201	215	229	237	229	237	237	228	3081
1925	236	228	396	360	394	436	451	466	426	369	342	265	4369
1926	274	265	396	360	231	256	364	377	341	287	277	244	3672
1927	253	244	396	360	405	448	451	466	451	466	417	288	4645
1928	298	288	396	360	417	446	451	466	430	385	353	267	4557
1929	276	267	396	360	194	215	238	246	236	237	237	228	3130
1930	236	228	396	360	295	326	451	466	413	320	303	253	4047
1931	262	253	396	360	194	215	229	237	229	237	237	228	3077
1932	235	228	396	360	284	303	451	466	412	313	298	252	3999
1933	260	252	396	360	194	215	247	256	243	240	239	228	3130
1934	236	228	396	360	194	215	241	250	238	237	237	228	3060
1935	236	228	396	360	400	443	451	456	429	381	350	267	4407
1936	276	267	396	360	419	448	451	456	434	398	364	270	4549
1937	279	270	396	360	284	314	451	466	413	316	300	253	4102
1938	261	253	396	360	405	448	451	456	451	466	417	288	4662
1939	298	288	396	360	194	215	234	242	233	237	237	228	3162
1940	236	228	396	360	419	448	451	466	451	466	417	288	4626
1941	298	288	396	360	405	448	451	466	451	466	417	298	4734
1942	298	288	396	360	405	448	451	466	451	466	417	288	4734
1943	298	288	396	360	405	448	451	466	451	466	416	284	4729
1944	294	284	396	360	211	226	288	237	279	261	256	236	3387
1945	244	236	396	360	384	425	451	466	421	350	327	261	4321
1946	270	261	396	360	405	448	451	466	435	403	367	270	4532
1947	273	270	396	360	204	226	288	297	278	261	256	236	3351
1948	244	236	396	360	405	433	451	466	425	366	339	264	4385
1949	273	264	396	360	236	261	383	396	356	292	281	246	3744
1950	254	246	396	360	377	418	451	466	417	336	315	258	4294
1951	266	258	396	360	405	448	451	466	451	466	417	288	4672
1952	298	288	396	360	419	448	451	466	451	466	417	288	4748
1953	298	288	396	360	405	448	451	466	451	466	415	280	4724
1954	289	280	396	360	405	448	451	466	434	398	364	270	4561
1955	279	270	396	360	214	237	313	323	299	271	264	239	3465
1956	247	239	396	360	419	448	451	466	451	466	417	288	4648
1957	298	288	396	360	382	423	451	466	420	346	323	260	4613
1958	269	260	396	360	405	448	451	466	451	466	417	288	4677
1959	298	288	396	360	236	261	383	396	356	292	281	246	3793
1960	254	246	396	360	284	303	451	466	412	313	298	252	4035
1961	260	252	396	360	236	261	393	396	356	292	281	246	3719
1962	254	246	396	360	384	425	451	466	421	350	327	261	4341
1963	270	261	396	360	405	448	451	466	451	466	417	288	4679
1964	298	288	396	360	220	235	308	318	295	269	263	239	3489
1965	247	239	396	360	405	448	451	466	451	466	417	288	4634
1966	298	288	396	360	270	298	451	456	411	312	297	251	4098
1967	260	251	396	360	405	446	451	466	451	466	417	288	4659
1968	298	288	396	360	312	333	451	466	414	321	304	254	4197
1969	262	254	396	360	405	448	451	466	451	466	417	288	4564
1970	298	288	396	360	405	448	451	466	451	466	417	288	4734
1971	298	288	396	360	405	448	451	466	451	466	417	288	4734
1972	298	288	396	360	299	320	451	466	413	318	302	253	4164
1973	261	253	396	360	405	446	451	466	451	466	415	279	4651
1974	289	279	396	360	405	448	451	466	451	466	417	288	4716
1975	298	288	396	360	405	448	451	466	448	452	404	276	4692
1976	285	276	396	360	201	215	236	244	234	237	237	228	3149
1977	236	228	396	360	194	215	229	237	229	237	237	228	3026
1978	236	228	396	360	405	448	451	466	451	466	417	288	4612
57 YR AVG	272	263	396	360	333	364	405	419	392	367	339	263	4173