Proposed Work Plan for
Sacramento Basin Hydrology Development
For CalSim III

DRAFT – WORK IN PROGRESS

1. INTRODUCTION

The California State Department of Water Resources (Department) and the United States Bureau of Reclamation Mid-Pacific Region (Reclamation) have developed a general-purpose reservoir-river basin simulation model for the planning and management of the State Water Project (SWP) and the federal Central Valley Project (CVP). The model, known as CalSim II, represents the CVP-SWP system and all areas that drain into the Sacramento-San Joaquin Delta.

There is a well recognized need to refine the current representation of Sacramento Valley in CalSim II. Accurate simulation of Delta inflows requires accurate modeling of project demands on project reservoirs, non-project use of surface water, and groundwater pumping. The current coarse, aggregate representation of demands in the Sacramento Valley has several major limitations. It precludes the association of demand with the correct water supply source, and it relies on a simplified an inaccurate method of disaggregating project from non-project demands. Model demands also use outdated water use efficiency parameters to calculate diversion requirements.

This document lays out a workplan for refining the CalSim II representation of water use in the Sacramento Valley, and developing updated input data based on recent field surveys and water budgets undertaken by the Department's district offices. The final product will mark a substantial change to the existing CalSim II, and will be part of a new application known as CalSim III.

This proposed work plan will also serve to better coordinate with the Department's Water Plan Update effort both for the near future and the long term. While the proposed timeline for CalSim-III is the end of 2005 or early 2006, coordinated work will continue beyond this timeline to refine, streamline, and cross-validate the methodologies used to estimate demands and for water budgeting purposes. The proposals in this report for new areas and methodologies for water budgets and developing a hydrology for CalSim-III will be discussed with the members of the Hydrology Development Group (HDG) for consensus or modifications.

Work Plan Outline

The major tasks identified as part of the Sacramento Valley hydrology development are as follows:

1. Development of Water Management Areas

2. Review / revise hydrologic methods
    - Linkage with other models
    - Consideration of intended model use

3. Develop CalSim schematic for Sacramento Basin
4. Develop water budgets for each PWMA
    - Demand development
        - Project agricultural demands
        - Non-Project agricultural demands
        - Project M&I demands
        - Non-Project M&I demands
        - Refuge
    - Calculation of accretion / depletion
    - Develop operational parameters
5. Modify groundwater operations
6. WRESL code development
7. Model refinement and validation
8. CalSim simulation
9. Documentation
10. Meetings and coordination

Work already accomplished

Efforts supported by and/or funded by CALFED, the Department and Reclamation has created the groundwork for developing a new hydrology for the Sacramento Valley. The following are key components of the development that have begun:

- Proposed methodology described in this work plan
- Draft definition of Water Management Areas
- Rice decomposition demands and operation
- Refuge demands and operation

Proposed Project Schedule

The completion target date for the CalSim-III effort is December 31st 2005, with documentation extending through February 2006 (the coordinated effort within the Department and between agencies and stakeholders will continue beyond this date). The following timeline contains an estimate for completion dates for various tasks:

	2004	2005																								2006			
	Dec	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb	
	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End	Mid	End
Review / revise hydrologic methods	■	■																											
Development of WMA	■	■																											
Develop CALSIM schematic		■	■	■	■																								
Develop WMA budgets				■	■	■	■	■	■	■	■	■	■	■	■														
Demand development		■	■	■	■	■	■	■	■	■	■	■	■	■	■														
Land use data		■	■	■	■																								
Accretion / depletion development						■	■	■	■	■	■	■																	
Operational parameters							■	■	■	■	■	■	■	■	■														
Refine groundwater operation																													
WRESL code development				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
Model refinement and validation														■	■	■	■	■	■	■	■	■	■	■	■				
CALSIM simulation																						■	■	■	■				
Documentation																								■	■	■	■	■	
Meetings and coordination	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

DEVELOPMENT OF WATER MANAGEMENT AREAS

A draft proposal for new Water Managements Areas (WMA) (refered to in this report as Proposed Water Management Areas PWMA until consensus on boundaries is reached) for use in CalSimCalSim-III and serve the Department's District efforts have been developed and are displayed in **Figure 1**, a brief description of each area is located in Attachment 1.   These areas are not final yet; they will be reviewed and/or revised by members of the hydrology development group. From CalSim-III's perspective, the Sacramento River basin has been separated into 26 PWMAs based on:

- Water supply source
- Location of stream diversions and return flows
- Resolution required to adequately depict stream flows governing CalSim's simulation
- Compatibility with other models
- Hydrologic characteristics (irrigation practice, water use efficiency, cropping pattern, soil type, etc.)
- Water rights and contracts
- Demand type (Ag, M&I, refuge)
- Data availability for water budgets

Area boundaries are established using existing DAU, DSA, county, water district, and planning area boundaries. Because DAUs DSAs are relied upon extensively by DWR, these boundary lines were used to the maximum extent possible when establishing PWMA boundaries. Some water districts are located in more than one DAU, DSA, or planning area. The PWMAs have been defined so as not to cut water district boundaries. PWMA boundaries are established in GIS; GIS is then used to develop data needed for CalSim hydrology development.

Development of GIS Based Data

The development of land use data for use as an input to CalSim II consisted of five basic steps:

a) Assembly of data
b) Development of new CalSimsub-basins
c) Rectification of overlapping water districts
d) Union of GIS data
e) Generation of summary table

Assembly of GIS based Data

Initially, the land use polygon shapefiles acquired from the Department were divided by county boundaries. The first step taken was to merge them into one shapefile. Following are the counties and survey dates of the land use data used in CalSim II:

County	Year
Butte	1994
Colusa	1993
Glenn	1993
Placer	1994
Sacramento	2000
Shasta	1995
Solano	1994

Sutter	1998
Tehama	1994
Trinity	1996
Yolo	1997
Yuba	1995

To classify the land use in a manner consistent with CalSim II, a conversion from DWR land use codes to CalSim land use codes was implemented through the use of a "table join". The 'water source' attribute, which is included in the DWR land use data, describes whether the water source is surface, ground, mixed, or unknown. This attribute was also used.

In addition to the land use data, several other shapefiles were required. DSA, DAU, and Planning Area boundaries were obtained. Additionally, all water district boundaries in the area of study were assembled into one shapefile.

Development of New CalSim II Sub-Basins

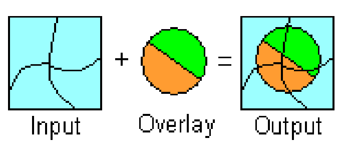
New CalSimsub-basins were developed on the basis of subdividing areas of unique water demands. These sub-basin boundaries were derived from district boundaries, as well as DSA, DAU, and Planning Area boundaries. They were developed by copying polygon shapes out of the original shapefiles, pasting them into a new shapefile, and intersecting, cutting, and combining as necessary. The resulting polygons were then given unique ID numbers, increasing from north to south.

Rectification of Overlapping Water Districts

After assembling the district boundaries, it became apparent that major overlaps existed. To avoid double-counting when the districts were combined with the land use data, these overlapping areas needed to be removed. For each overlapping area, based on our best judgment, the district which supplies water to that area was chosen to supercede the other overlapping district. The superceding polygon was then 'cut into' the other polygon, thereby eliminating the overlap. This was done for each of the CalSimsub-basins where more than 1000 acres of district overlap existed, so minor overlaps do still exist in the data.

Union of GIS Data

In order to be able to query land use in terms of any combination of the other input data layers, all of these layers needed to be combined in a spatial 'union', described by the following diagram:



The files that were united were as follows: DSA, DAU, Planning Areas, water districts, CalSim and land use. The resulting shapefile was then cropped to the extent of the CalSim II sub-basins.

Generation of Summary Table

The final step in the creation of usable tabular data for Microsoft Excel was the generation of a summary table. To do this, a table needed to be generated that showed the total acreage of each unique land use type for each unique combination of all of the data layers. Since ArcView is only capable of summarizing based on one attribute, it was necessary to concatenate (join) all of the desired fields into one field, and then summarize total acreage of that attribute. The fields were concatenated in this order: water source, CalSim II land use code, DSA, DAU, planning area, basin number, and district name. Following is an example:

1-PA-65A-191-509-25-SOLANO I.D.

A table which shows total acreage for each unique value of this concatenation of attributes was then generated. By using lookup tables in Microsoft Excel, the data in this table can be used to determine land use for any conceivable combination of specific regions of any (or all) of the input layers.

SCHEMATIC DEVELOPMENT

The existing CalSim-II schematic for the Sacramento River Basin is structured based on DSAs. In many areas the schematic represents the river system in a conceptual rather than on a physical basis. River flows in the CalSim schematic can only be matched to a physical geographic location at the outlet of some DSA boundaries.

Revision of the schematic for CalSim-III will be accomplished by conforming the structure of the schematic to the PWMAs and basing it on the physical stream system. Key river locations and data needs for other models will be explicitly identified in the revised schematic.

WATER BUDGETS

Water budgets are a method of accounting for all water entering, leaving, or being stored with in a control volume. Through the development of water budgets, relationships between diversions, CUAW, losses, return flows, accretions / depletions, etc. are developed. Water budgets for each PWMA will be performed and the following results will be input to CalSim-III or used for CalSim-III validation:

- Diversion requirements
- Accretions / depletions (local runoff)
- Consumptive Use of Applied Water (CUAW)
- Reuse factors
- On-field/on-farm efficiency by crop type
- Conveyance loss
- Non-recoverable loss
- Deep percolation of applied water
- Return flow / operational spills

A standard will be established for developing budgets for each PWMA so that all calculations are performed in a similar manner. Since each PWMA has unique characteristics and some may require “non-standard” components of the water budget, a procedure for addressing “non-standard” components will be developed. This effort will include coordinating with Department Districts staff

Diversion Requirement / Demands

PWMA demands may be comprised of several different types each with unique operations and water supply availability. Operational parameters will be established for each of the following demand types within each PWMA:

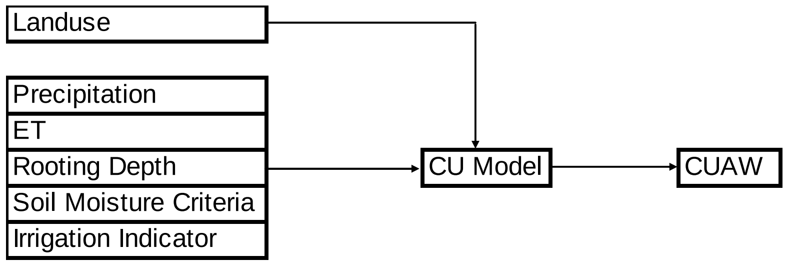
- Project agricultural demands
- Non-Project agricultural demands
- Project M&I demands
- Non-Project M&I demands
- Managed wetlands

Irrigation factors will be estimated though the development of PWMA budgets so that CalSim-III simulates actual stream diversion as accurately as possible. Project and non-project agricultural demands for each type will be developed based on land use. Agricultural demand will be expressed with an explicit representation of on-farm applied water demands, reuse, deep percolation of applied water, and conveyance losses. A representation of the demand methodology is displayed in Figure 2. The current DWR CU model will probably be used to develop CUAW for agricultural demands based on land use (this will require further discussions with the Department Districts staff).

Agricultural Demands

Agricultural demands are based on land use within each PWMA. Land use for each PWMA and type have been developed using GIS and draft PWMA. Table 1 contains land use for each PWMA and demand type. Projected level land use for each PWMA and type will be developed using the DPLA land use data base and allocated to PWMA using GIS. A procedure for allocating projected level land use to PWMA will be developed in coordination with DPLA and documented.

CUAW, often referred to as evapotranspriation of applied water (ETAW), represents the amount of applied water realized as evapotranspriation and does not include water that is lost or returned to the water system. The CUAW for an area is based on irrigated acreage and DWR’s Consumptive Use model (CU model). Irrigated acreage for any particular area is developed using the GIS coverage as described above. Land use is aggregated to 13 crop types based on crops with similar water use. The DWR CU model incorporates monthly precipitation, ET rates, soil moisture criteria, rooting depth, irrigation indicators, and other factors along with land use to estimate the CUAW on a monthly basis. The interaction of the land use and environmental data within the CU model is depicted below.

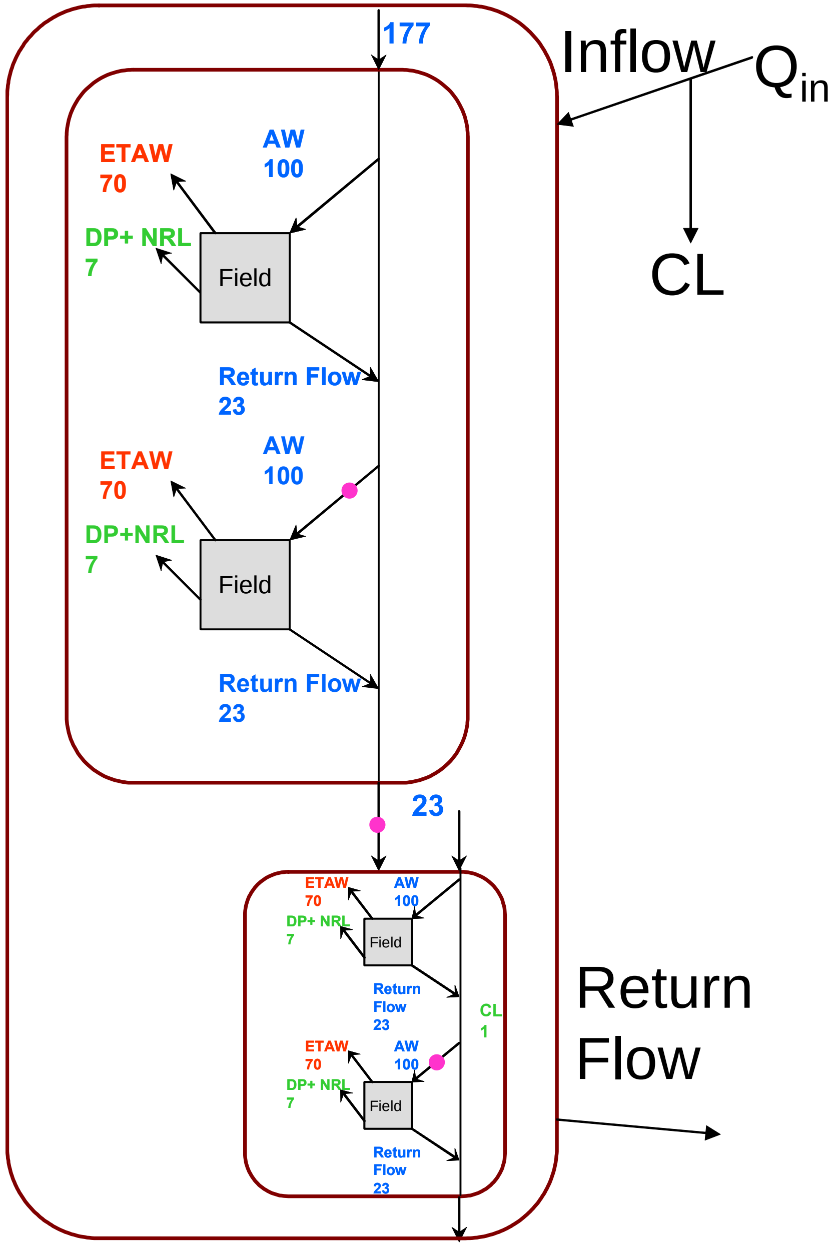


Currently the CU model does not consider temperature in its determination of CUAW (except in the Delta where temperature is used to estimate monthly ET's for crops). This parameter could influence results of the water budgets and thus water district operations. For example, if the temperature is above normal the CUAW would likely be higher than reported by the CU model. A refinement of the CU model and its results could be incorporated into CalSim at a future time.

PWMA Agricultural Demands

As described previously, each demand area can have a unique circumstance that translates demands for CUAW to a diversion requirement. Generically, CUAW is combined with on farm efficiency, reuse factors, conveyance losses, operational spills and tailwater (return flow), non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The diversion requirement is the volume of water that is supplied from surface or ground water, regardless of source. A proposed approach is shown in Figure 2. As mentioned earlier, the proposed methodologies described below will be discussed and evaluated for adoption or revision.

Figure 2 - Representation of Agricultural Demands



$AW = CUAW / Eff_{Field}$

$Inflow = Q_{in} - CL$
$= CUAW / Eff_{Field} * RF$

$RF = Inflow / \sum Aw_i$ (i = 1, number of fields)

$Inflow = Inflow_{Groundwater} + Inflow_{Surface\ Water}$

$Return\ Flow_{Basin} = Inflow - NRL_{Field} - CUAW - DP$

$Return\ Flow_{Basin} = Q_{in} - CL - NRL_{Field} - CUAW - DP$

Q_{in}	**= Basin Diversion Requirement or Supply into Basin**
AW	**= Applied Water**
CUAW	**= Consumptive Use of Applied Water**
Eff_{Field}	**= on Field Efficiency by Crop Type**
RF	**= Reuse Factor**
NRL	**= Non-Recoverable Loss**
DP	**= Deep Percolation**
CL	**= Conveyance Loss (DP + NRL)**

Table 1
Land Use for Revised CalSim Hydrologic Areas in Sacramento River Basin

Area	Sub-Area description	Alfalfa	Cotton	Field Crops	Grain	Non-Consumptive	Native Vegetation	Orchards	Pasture	Rice	Safflower	Sugar Beets	Subtropical fruits	Tomatoes	Truck Crops	Urban	Vineyard	Total
1	Non Project	0	0	0	0	160	595415	0	1268	0	0	0	0	0	0	210		597053
2	Non Project	171	0	137	344	2092	181142	344	1571	0	82	0	1	0	86	10900	7	196878
	SC - Whiskeytown	0	0	40	0	142	12106	105	723	0	0	0	798	0	30	3837	0	17781
	SC - Sacramento River	0	0	0	0	2	9924	0	1	0	0	0	0	0	0	2168	0	12096
	SC - ACID	494	0	292	591	753	8171	1761	10869	0	0	0	7	0	199	6922	0	30057
3	Non Project	186	0	366	978	1600	635366	1446	10874	42	180	0	25	0	177	10438	169	661847
	SC - Shasta	0	0	0	0	14	5037	0	11	0	0	0	0	0	0	4247	0	9310
	SC - Sacramento River	160	0	267	245	516	42240	80	2796	0	0	0	34	0	38	29784	0	76162
4	Non Project	6432	0	5800	13196	10983	388955	24834	17497	1306	1333	1141	5197	0	153	12010	14	488851
	PAG - Corning Canal	658	0	789	2237	4601	10788	2718	4728	2078	0	0	3025	0	17	897	27	32562
	PAG - Tehama-Colusa (	347	0	255	475	400	1866	1472	894	0	0	101	333	0	7	84	0	6235
	SC	5	0	5	11	9	323	21	15	1	1	1	4	0	0	10	0	406
5	Non Project	1257	0	3149	4413	2479	116679	49234	8336	0	1409	757	440	13	339	12005	2	200510
6	Orland water Users	892	0	612	906	1942	4715	2784	9568	0	0	25	2693	0	0	2490	0	26627
7	PAG - Tehama-Colusa (	7685	1109	10806	34448	8585	39481	25951	3983	9918	3354	2875	1092	13928	5543	2031	2822	173612
	Non Project	8070	1302	10795	31940	12381	378349	8148	4311	4315	3429	2828	760	11385	2701	4316	2027	487058
8	SC - GCID	3107	306	4160	11163	11087	22994	2997	5203	101414	2362	781	26	3509	2162	2146	119	173536
	Non Project	2393	0	6729	8534	2827	21549	10706	716	14089	5777	3114	0	5323	3705	3013	0	88475
	SC	3274	1341	7550	8619	4695	9115	2210	1016	79616	10002	1576	20	12137	5201	511	0	146884
9	SC	291	2	2713	2701	1935	9449	3381	91	18357	1195	187	0	147	776	93	0	41318
	Non Project	1329	16	7612	7718	2826	13591	8892	471	5364	1547	1820	0	721	2565	198	0	54669
10	Non Project	674	0	958	2308	1563	64960	26912	2015	11783	508	774	1052	7	135	7460	0	121107
11	Non Project	433	0	67	121	348	714	4671	270	2194	39	0	74	0	24	1008	0	9964
	PAG SWP	1901	11	1412	1140	5441	23291	17376	3459	117963	472	20	1335	0	327	6167	5	180320
12	Non Project	261	0	1018	1646	4464	58725	8014	2115	5145	13	0	980	0	52	8454	0	90887
13	Non Project OWID	0	0	0	346	691	37616	113	598	0	0	0	3251	0	0	6773	0	49389
14	Non Project BVID	59	0	67	95	489	37953	487	3076	3295	0	0	270	0	4	4759	12	50566
15	Non Project	82	0	654	692	1702	12964	11313	2214	2220	125	0	138	0	293	3577	0	35976
	Non Project - YCWA	453	0	653	620	2868	17479	22221	7755	34276	88	0	363	17	132	7958	0	94882
16	Non Project	1675	6	4978	1794	2113	8606	30546	811	4890	877	581	139	436	1498	5141	0	64091
	PAG SWP	327	127	109	1218	1003	1389	5002	820	16066	644	128	62	555	1263	317	4	29035
	M&I SWP	12	0	0	55	106	359	362	0	0	0	0	0	0	111	4599	0	5603
	PAG CVP	6	0	0	9	141	53	6239	34	112	303	0	0	163	701	127	0	7889
17	Non Project	635	413	3208	4142	2002	64261	8850	877	15887	2560	0	24	1727	775	1172	91	106625
18	Non Project	51	51	510	682	76	657	1100	14	440	1069	0	0	438	414	57	0	5559
	SC	76	18	1144	730	181	562	1285	5	4252	4749	0	0	2105	430	80	0	15617
19	Non Project	162	0	1403	844	242	1556	571	4	657	931	0	0	1607	800	88	0	8866
	SC	213	0	6787	5001	393	3100	1007	6	16618	9713	107	0	13820	5495	209	0	62467
20	Non Project	18300	1234	23805	41774	8351	134289	15600	2979	3469	4778	2329	235	22770	3645	28813	1621	313993
21	Non Project	48	0	108	57	18	134	93	0	16	62	0	0	71	7	2	0	617
	SC	3678	0	7621	2157	1321	7485	3340	13	9753	2385	727	0	3261	445	266	0	42452
22	Non Project	142	0	222	830	129	1815	40	209	1435	293	263	0	73	25	1911	0	7388
	SC	682	0	1613	2495	2013	2248	194	848	25720	765	2438	0	436	114	2023	2	41592
23	Non Project - S. Sutter	1206	0	2129	3591	3086	11005	8594	3748	36382	3	366	41	0	6	829	0	70988
	Non Project	0	0	0	0	18	20	0	1	310	0	0	0	0	0	0	0	349
24	Non Project	5	0	711	5053	5274	130083	1279	15765	9362	0	7	126	0	380	19608	40	187693
25	Non Project	20936	0	24945	51983	4991	99687	10129	9931	0	2211	8508	8	19132	1800	15088	105	269453

Deep Percolation of Applied Water
Applied water returns to the stream network, percolates to groundwater or is used consumptively through the process of evapotranspiration. The amount of applied water that contributes to ground water though deep percolation will be based on water budgets prepared by the Department's district offices and modeling of the surface water groundwater system using CVGSM.

Conveyance Losses
Conveyance losses are generally associated with district conveyance and distribution facilities. These losses are comprised of canal leakage, seepage and evaporation. The disposition of these losses (to the atmosphere or the stream network including groundwater) will be identified and included in the PWMA budgets. Losses associated with the major inter-district canals (e.g. Tehema-Colusa Canal) will be modeled explicitly, external to the PWMAs.

Non-Recoverable Losses
A proportion of applied irrigation water is not used in crop evapotranspiration, does not return to the surface or groundwater system, but is depleted or lost. This may happen through:

- Evaporation from canals, laterals and farm reservoirs,
- Percolation to a saline aquifer,
- Miscellaneous Ag. ET,
- Riparian ET in drainage network,
- Disposal of sub-surface drainage using evaporation ponds, and
- Surface runoff to a saline sink or the ocean.

Traditionally for modeling purposes non-recoverable losses have been estimated as 10-15% of CUAW. Estimates of non-recoverable losses will be reviewed. Non-recoverable losses will further be disaggregated into losses at field level, which are independent of the source of water, and losses from the conveyance system, which are a function of the surface water supply. Non-recoverable losses for each PWMA and demand type will be estimated.

Return Flow and Operational Spills
Return flows are agricultural runoff / operations spills that cross a PWMA boundary. Return flows crossing a PWMA boundary must enter the water budget calculation where relationships between diversion and return flow will be developed. The relationship between diversion and return flows will be described through a series of parameters such as on-farm efficiency and reuse factor.

On-Farm efficiency
On farm efficiency describes the relationship between on-farm applied water and on consumptive use of applied water and is calculated as:

$$Efficiency_{Farm} = CUAW / AW$$

The Department's district offices have determined on-farm efficiency by crop, by DAU, and by county. Crop-specific efficiencies will be used together with the current or projected level land use to develop weighted fram efficiencies for each PWMA.

Reuse Factor
The reuse factor describes the amount of agricultural return flow within a PWMA that is diverted and applied to satisfy crop irrigation requirements. Reuse can occur on a farm or district level within a PWMA.

Designation of Project and Non-Project Demands
GIS coverage will be used to determine land use for project and non-project lands that are contained within PWMA boundaries. Separate land use based demands will be developed for project and non-project lands. Individual irrigation factors will be developed for project and non-project demands within a PWMA. The goal is to simulate actual stream diversions at the proper geographic location.

Special attention will be devoted to estimate project demands for CVP Settlement contractors that are not within water district boundaries. Data from their contracts with Reclamation along with available stream diversion records will be used to estimate their demands. Table 2 is a list of the short form settlement contractors, irrigated acreage, contract amounts, and diversion locations:

Refuge Demands
Refuge water demands consist of several components including ponding, irrigation, and flow through. In order to depict refuge demands the entire refuge operation must be simulated. Attachment 2 describes the refuge operation and proposed approach.

Rice Demand
Rice demands are unique and to properly simulate them in CalSim will require enhancement. DWR has already made progress toward incorporation into CalSim. Attachment 3 contains an overview of actual rice operation, including ponding and decomposition demand, and suggested implementation into CalSim.

Table 2 - Sacramento River CVP Settlement Diverters in "Non-district" Areas

Contractor	Contract number	River mile	Bank (Left, Right)	Acres	Base Supply (AF)	Project Supply (AF)	Total Supply (AF)	DSA
COUNTY OF SACRAMENTO	2404A	9.3	L	250	520	230	750	70
UNIVERSITY OF CALF REGENTS	7941A	10.25	L	280	860	200	1,060	70
CHILTON, BARBARA	2065A	10.75	L	88	110	20	130	70
WILEY, EDWIN	3556A	10.75	L	46	75	20	95	70
LAUPPE, HUFFAN	1364A	18.2	L	271	380	480	860	70
LAUPPE, BURTON H., ET UX	1289A	18.45	L	264	720	230	950	70
VERONA FARMING PARTNERSHIP	W0054	18.7	L	130	180	120	300	70
LEAL, ROBERT	8574A	19.6	L	121	220	410	630	70
FURLAN ANTONIO ET UX	1595A	26.8	L	316	1,300	200	1,500	70
FURLAN, EMILE, ET UX	1175A	32.5	L	195	570	350	920	70
RICHTER BROS.	4362A	33.2	L	583	1,750	1,030	2,780	70
STANGHELLINI GIULIO	1176A	33.75	L	72	360	200	560	70
LEISER, WAYNE N.	4178A	33.75	L	14	36	24	60	70
MCM PROPERTIES INC	7827A	33.75	L	201	860	610	1,470	70
G.W. WILLIAMS COMPANY	2973A	1.45	R	27	80	130	210	65
KAISER DEVELOPMENT COMPANY	4217A	3.55	R	140	460	85	545	65
RAMSAY, BEATTY H.	934A	5.3	R	177	470	30	500	65
AMEN, HENRY ET AL	1779A	9.35	R	232	460	200	660	65
WILSON RANCH PARTNERSHIP	4520A	11.1	R	160	370	0	370	65
CONWAY FARMS	7422A	12	R	16,088	50,190	672	50,862	65
KNAGGS, LAYTON	2148A	15.1	R	242	630	0	630	65
JAEGER, WILLIAM	7W0002	16.9	N*	112	385	485	870	65
DESERET FARMS OF CALIF.	2149A	17	R	1,135	4,000	0	4,000	65
HERSHEY ESTATE	7972A	28.1	R	727	2,570	450	3,020	65
RUSSELL, CLAYTON, ET UX	8322A	29.2	R	204	370	60	430	65
WALLACE CONSTRUCTION INC	4604A	29.7	R	820	2,680	960	3,640	65
RUSSELL, CLAYTON	1616A	30.6	R	42	86	34	120	65
GIOVANNEITI	991A	31.5	R	150	470	50	520	65
DRIVER, CLARE, ET AL.	939A	32.5	R	82	60	120	180	65
WILSON, NEIL, ET UX	906A			32	50	80	130	65
DIAMOND LANDS CORP.	8106A	191.5	R		195	230	425	58
MICKE, D.H. + N.J.	7995A	196.6	L	34	81	19	100	58
DRISCOLL STRAWBERRIES, INC	4736A	207.5	L	160	330	490	820	58
LAKE CAL. PROPERTY OWNERS ASSN	4961A	221	R		580	200	780	58
HIGH-LOW NURSERY CO., INC.	W0006	240.2	L	73	70	135	205	58
RIVERVIEW GOLF CLUB	8286A	240.8	L	100	255	25	280	58
J. B. UNLIMITED, INT.	2519A	197	L	154	220	290	510	58
HAROLD B GERMAN	4010A	196.55	L	5	8	4	12	58
HARRY W AND BARBARA M DANIELL	4348A	240.3	L	6	13	7	20	58
LEVIATHAN, INC	7308A	221	R	160	355	345	700	58
RICHARD T AND ILENE MOREY	W0003				55	60	115	58
MOREHEAD, JOSEPH, ET UX	5789A	19.9		48	115	140	255	15
DREW, JERRY	2250A	35.85	L	9	24	12	36	15
QUAD H	2153A	36.2	L	74	190	310	500	15
GIUSTI, RICHARD	4076A	36.2	L	304	850	760	1,610	15
DRIVER, C.A.	1314A	36.45	L	84	150	80	230	15
DRIVER, JOHN A	2398A	36.45	L	6	6	10	16	15
GRAF v. MIRBACH-HARFF	7556A	37.2	L	63	115	75	190	15
MUNSON, JAMES T. ET UX	7049A	37.75	L	78	70	85	155	15
BUCHHOLZ, BRUCE	889A	38.8	L	112	180	20	200	15
RIVER GARDEN FARMS COMPANY	878A	41	R	6,739	29,300	500	29,800	15
CLAUSS,JOHN, JR. ET AL	2045A	45	L	738	4,040	0	4,040	15
HENLE, JOHN R. ET UX	932A	46.5	L	393	935	0	935	15
OJI MASONOBU ET AL	2427A	48.7	L	891	3,430	1,310	4,740	15
HIATT, GLENWOOD J., ET AL	880A	49	L	375	1,320	750	2,070	15
FARGO, HAGGERTY	W0117	50	L	483	2,450	710	3,160	15
NELSON, THOMAS L.	1954A	52	L	43	38	98	136	15
WAKIDA, MASARU, ET UX	1415A	53.9	L	164	50	275	325	15
REYNEN, JOHN, ET AL.	1286A	55.1	L	2,055	8,070	2,000	10,070	15
LAMB, CLIFTON, EST	2486A	57.75	L	120	180	340	520	15
OBRIEN, JANICE	4105A	58.3	L	490	920	336	1,256	15
WAKIDA, MASARU, ET UX (AREA	5200A	58.9	L	80	25	135	160	15
KARY, CAROL	2520A	59.8	L	280	400	600	1,000	15
HOWALD FARMS INC.	1042A	60.4	L	512	1,350	1,410	2,760	15
BUTLER, LESLIE ET UX	2365A	61	L	142	180	280	460	15
GREEN ISLAND FARMS	7W0001	62.3	L	155	350	470	820	15
YOUNG, RUSSELL, ET AL	2552A	63.3	L	4	2	8	10	15
OJI BROS. FARM, INC.	3753A	63.9	L	735	1,340	1,860	3,200	15
ANDERSON, RAY E.	1726A	67.1	L	95	149	88	237	15
FRYE ESTATE TRUST	8658A	67.1	L	260	715	440	1,155	15
GARY DRIVER ET AL	8585A	69.2	R	10	8	22	30	15

Table 2 (continued)

Contractor	Contract number	River mile	Bank (Left, Right)	Acres	Base Supply (AF)	Project Supply (AF)	Total Supply (AF)	DSA
RITCHEY, E. J. ET UX	1426A	70.4	R	61	150	40	190	15
GILLASPY, FAY	8117A	70.4	R	64	120	90	210	15
BECKLEY, RALPH	8118A	70.4	R	92	165	135	300	15
MCLAUGHLIN, JACK E + MARGERY	2514A	72	L	142	430	220	650	15
ANDREOTTI, OTTERENA ET AL	1898A	72.1	L	462	2,060	1,560	3,620	15
DAVIS, GROVER, ET UX	1851A	76.2	L	34	71	14	85	15
PIRES, LAWRENCE, ET UX	7744A	77.9	L	111	485	435	920	15
DAVIS, OLIVE P ET AL	2146A	78	R	9,110	22,000	9,800	31,800	15
HALE, JUDITH A. + MARKS, ALICE	1638A	79	L	31	58	17	75	15
EGGLESTON, RONALD, ET UX	7339A	79	L	28	53	12	65	15
HALE, JUDITH A. + MARKS, ALICE	7572A	79	L	54	117	13	130	15
MUNSON, NINA	7227A	79.5	L	49	75	55	130	15
HULBERT & TARKE	1949A	81.5	L	492	1,700	1,000	2,700	15
REISCHE, CHARLES F, ET AL	1150A	82.5	L	104	220	320	540	15
FEDORA, SIB, ET AL.	2916A	82.7	L	86	190	20	210	15
STEIDLMAYER, FRANCIS J.	874A	83	R	168	610	700	1,310	15
EHRKE, ALLEN	8330A	86.8	L	165	220	160	380	15
CRIBARI, EMILE	5215A	88	R	18	8	27	35	15
M & L FARMA AREA1	1945A	88.2	L	160	295	60	355	15
MAYFAIR FARMS INC	1976A	88.7	L	114	270	10	280	15
BUTTE CREEK FARMS(ARNOLD,H)	5206A	89.24	L	36	40	55	95	15
BUTTE CREEK FARMS	2851A	89.26	L	17	20	16	36	15
MARTIN, ANDREW, ET UX	1827A	92.5	L	120	280	130	410	15
ODYSSEUS FARMS	1664A	93.15	R	758	1,920	150	2,070	15
A&F BOEGER CORP	1053A	95.25	L	1,006	2,170	634	2,804	15
BABER, JACK, ET AL.	1604A	95.6	L	1,068	3,630	2,630	6,260	15
GRIFFIN, J ET AL	2895A	95.8	L	552	1,610	1,150	2,760	15
HOLLINS, MARIETTE	2993A	98.6	L	409	1,360	200	1,560	15
WELLS JOYCE	2896A	98.9	L	422	1,515	300	1,815	15
SEAVER, HELEN, ET AL	3296A	99.3	R	161	200	260	460	15
FORRY DAVID	7691A	99.8	L	506	2,285	0	2,285	15
COLUSA PROPERTIES INC.	2042A	101.8	L	693	940	0	940	15
WESTFALL, RALPH D. ET AL	3591A	102.5	L	200	445	45	490	15
CARTER ROBERT B. ET UX	4617A	102.9	L	636	1,470	0	1,470	15
THOMPSON, MERYLE S.	7206A	103.7	R	23	80	100	180	15
TUTTLE, CHARLES W.	7296A	103.9	R	140	120	270	390	15
SPENCE, RUTH	4829A	104.8	L	209	630	100	730	15
CANELL FRED ET AL	5210A	106	R	286	680	210	890	15
STEGEMAN STATION RANCH	5211A	106	R	184	555	325	880	15
M. AND T. INCORPORATED	940A	141.5	L	6,719	11,320	651	11,971	15
NEWHALL LAND AND FARMING CO.	931A	153.6	L	2,700	6,410	700	7,110	15
CHESNEY, CARSON	930A			149	310	390	700	15
DEAN CLAUDE	W0002				385	485	870	15
MC LANE, ROBERT	4446A	155.6	R	13	17	23	40	10
ALEXANDER, TOM	7754A	155.6	R	5	9	13	22	10
FREEMAN, FRANK ET UX	2212A	156.1	R	8	11	19	30	10
PENNER , ROGER	960A	156.8	R	52	159	21	180	10
RAMOS, MILDRED	2368A	166.8	R	8	11	5	16	10
NATURE CONSEVANCY	3774A	168.85	R	320	210	570	780	10

Accretion / Depletion Development
Accretions / depletions are a direct result of PWMA water budgets. One all water entering and leaving a PWMA is accounted, accretion / depletion is the remaining component. Accretions / depletions represent precipitation runoff, seepage, and all other unaccountable components of the water budget.

Additional runoff
The calculation of additional runoff due to land-use changes would remain at the aggregated level of the existing DSAs. Similarly the calculation of accretions and depletions would remain at the DSA level but might be distributed to several points in the stream network rather than at a single point.

REFINE GROUNDWATER OPERATION

Currently CalSim-II uses an Integrated Finite Difference approach to include modeling ground water in the Sacramento Valley. A different approach is being considered whereby 'response functions' are used instead. Response functions are developed a priori using a detailed ground water simulation model (such as CVGSM2); they provide the response of specific stresses (e.g. ground water pumping) to ground water elevations and to impacts on stream flows.

WRESL CODE DEVELOPMENT

Representation of the Sacramento River Basin, including schematic, demands, relationship between diversion and return flow, groundwater, and more, are input to CalSim-III through WRESL code. WRESL code will be revised to simulate the Sacramento River Basin based on revised schematic, PWMAs and methodologies.

MODEL VALIDATION AND REFINEMENT

Once PWMAs, schematic, and WRESL code have been revised and input to CalSim the model will need to be checked to ensure it is simulating in a valid manner. Simulation of each PWMA will be compared to the operation depicted by its water budget and revised as necessary until an acceptable simulation is achieved. One each PWMA is simulating in an acceptable manner, the interaction of all PWMAs and stream flow will be validated.

CalSim SIMULATION

After CalSim-III's simulation of the Sacramento Basin has been validated, an acceptable simulation must be produced. Current and future level of development must be incorporated into CalSim-III and simulation rules must be adjusted to get a reasonable simulation of the system.

DOCUMENTATION

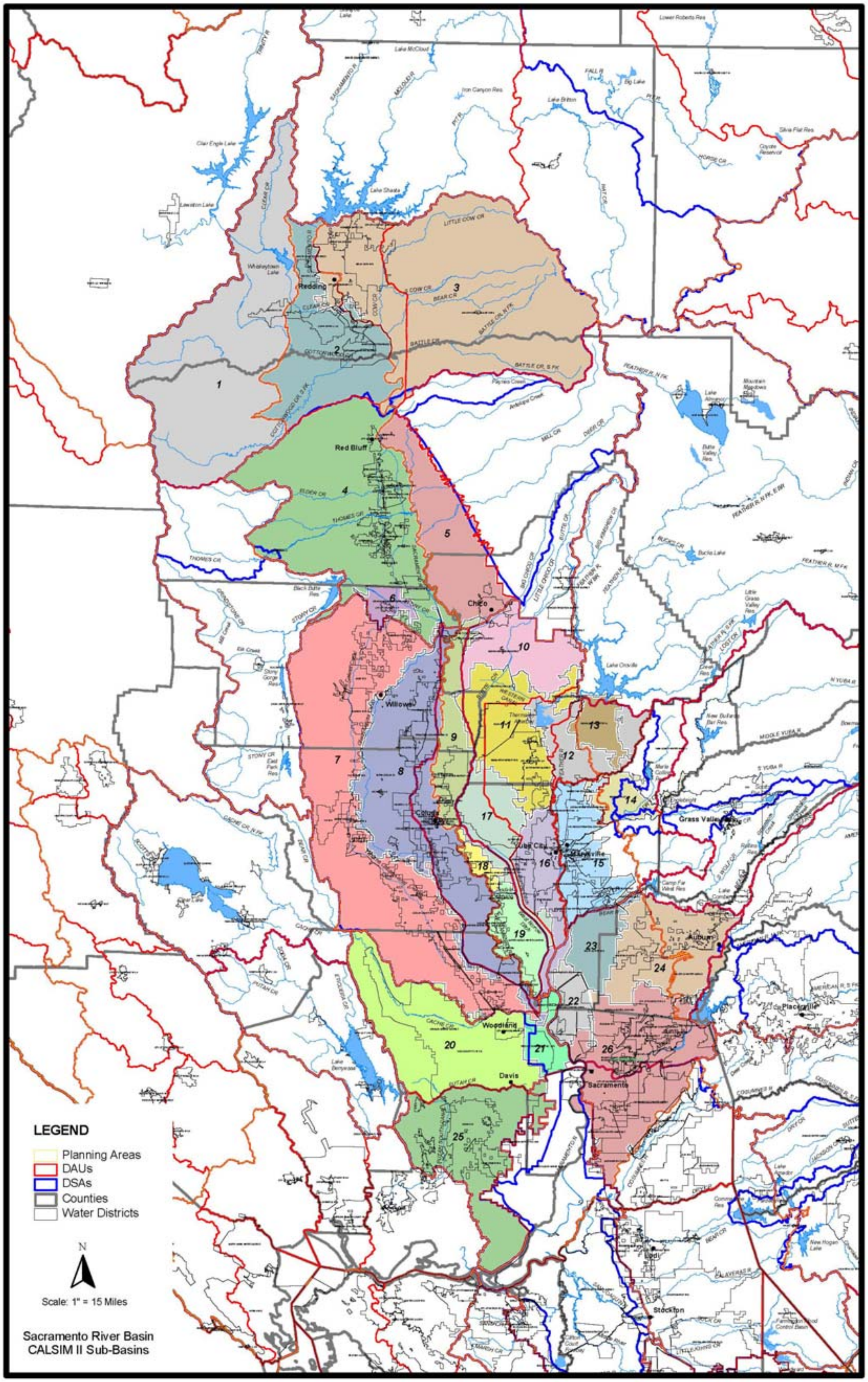
Documentation will be developed throughout the course of hydrology development. Technical memorandums will be produced describing PWMA, land use development, demand development, revised schematic, PWMA water budgets, ground water operation, WRESL code development, and validation. These sections will be review by the hydrology development group then incorporated into a final memorandum that documents all aspects of the hydrology development.

MEETINGS AND COORDINATION

Many meetings along with close coordination are essential to successfully developing the hydrology. Currently the Hydrology Development Group which includes the

Department (BDO and DPLA), Reclamation, the Common Assumptions team, and others will continue to coordinate the review and contributions to this process and ensure that the goals of the participants are satisfied.

Figure 1


Redding
Red Bluff
Chico
Willows
Woodland
Davis
Sacramento
Auburn
Placerville
Grass Valley
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LEGEND
Planning Areas
DAUs
DSAs
Counties
Water Districts
N
Scale: 1" = 15 Miles
Sacramento River Basin
CALSIM II Sub-Basins

ATTACHMENT 1
DESCRIPTION OF PROPOSED WATER MANAGEMENT AREAS

Area 1

West portion of DSA 58, located in DWR planning area 502
Area 1 covers the same area as DAU 137 and is bounded on the North and West by the DSA 58 boundary. The east boundary corresponds to the east boundary of DWR Planning Area 502.

Demands
This Area contains non-project demands only. These demands are satisfied by diversions from Cottonwood Creek, minor streams, and groundwater. This area has no access to Sacramento River flows.

Area 2

Central portion of DSA 58, located in DWR planning area 503
Area 2 has similar borders as DAU 141. Area 2 differs from DAU 141 by excluding the City of Redding service area located west of the Sacramento River and including ACID service area located east of the Sacramento River. This is done to keep the City of Redding and ACID as a separate demand units.

Demands
Water demands in Area 2 are aggregated into four types:

1. Non-Project demands that satisfied by Cottonwood Creek, minor streams, and groundwater
2. CVP Settlement Contractor demands satisfied directly from Whiskeytown Lake
3. CVP Settlement Contractor (non-district) demands satisfied from the Sacramento River
4. CVP Settlement Contractor - Anderson-Cottonwood ID satisfied from the Sacramento River

Notes:
In the GIS work, the border between DSA 58 and DSA 10 follows the DAU boundary rather that the DSA boundary. This should be revised.

Area 3

East portion of DSA 58, located in DWR planning area 504
This west border of Area 3 is common to the east border of Area 2. The north, east, and south border is common with the DSA 58 border.

Demands
Demands in Area 3 are aggregated in to 3 categories:

1. Non-Project demands satisfied by local streams and groundwater
2. CVP Settlement Contractor demands satisfied directly from Shasta Lake
3. CVP Settlement Contractor (non-district) demands satisfied from the Sacramento River

Area 4

DSA 10 west of Sacramento River
Area 4 has similar boundaries as DAU 142, the exception is the exclusion of the Orland Water Users from Area 4.

Demands
Area 4 contains 3 types of demands that are aggregated into 4 demands:

1. CVP Ag service - Corning Canal service area
2. CVP Ag service - TC Canal service area
3. Non-Project demands that satisfied primarily by groundwater, but a small portion of this demand is met by Thomes Creek and a minor amount of Sacramento River Riparian diversion
4. CVP Settlement Contractor (non-district) demands satisfied from the Sacramento River

Area 5
DSA 10 east of Sacramento River
Area 5 boundary is very similar to DAU 144.

Demands
All demands in area 5 are non-project demands with minimal ability to divert from the Sacramento River. The non-project demand is aggregated into 3 categories:

1. Area served from Antelope, Deer, and Mill Creeks. When flows from these creeks are not adequate to satisfy demands ground water is used to meet diversion requirements.
2. Area served from GW only. A large portion of the demand in Area 5 is satisfied from ground water alone.
3. Small amount of riparian diversion

Area 6
Orland Water Users
Area 6 encompasses the entire Orland Water Users service area, which is located in DSA 10.

Demands
Orland Water Users demands are the only ones contained in Area 6. This is a CVP Agricultural demand that is satisfied from diversions from Stony Creek and Black Butte Reservoir.

Area 7
Tehama-Colusa Canal service area and west portion of DSA 12
A majority of the Tehama-Colusa Canal service area demands are located in this area and make up more than half of the agricultural demand. There is no significant inflow, compared to demands, to Area 7 and irrigated land use must receive water through either groundwater pumping or from import through Tehama-Colusa Canal.

There is limited return flow from the Tehama-Colusa Canal service area, however the small amount of return flow that does occur is available for diversion from the Colusa Basin Drain.

Demands

Area 7 demands are aggregated into 2 categories

1. CVP Ag service - TC Canal service area
2. Non-Project demands that satisfied primarily by groundwater

Notes:

Area 7 contains 773 acres of RD108, which should be included in Area 8; adjustment has been made to data table but not to GIS files.

Area 8

East portion of DSA 12 and DSA 15 West side of Sacramento River

Area 8 is located on the west side of the Sacramento River between Knights Landing and Ord Ferry. The western boundary is established by the western boundary of the CVP settlement contractors within the Colusa Sub0basin.

Demands

This area includes CVP settlement contract demands that are satisfied by diversions from the Sacramento River and non-project demands. Demands fall into 4 categories:

1. Non-Project demands that satisfied primarily by groundwater
2. CVP Settlement Contract
    - District demands satisfied from the Sacramento River
    - (non-district) demands satisfied from the Sacramento River
3. CVP Settlement Contract (Glenn-Colusa ID) demands satisfied from Sacramento River diversion at Hamilton City
4. Refuge

Notes:

Area contains about 970 acres that are severed by TCC and should be included in Area 7; this adjustment has not been made to the data or the GIS files.

Need to describe use of drain water by Colusa Drain Mutual Water Company

Area 9

DSA 15 East of Sacramento River and north of Butte Slough

Area 9 encompasses that are east for the Sacramento River from Ord Ferry to Butte Slough. Lands that are served from Sacramento River diversions through CVP settlement contractors and lands that divert from Butte Creek are included in this area.

Butte Creek provides surface water supply to this Area. Butte Creek flows through Western Canal Company in the FRSA, but no water is diverted. Butte Creek flow is diverted by RD1004, located in 9, and by users in Area 17. There are agreements between RD1004 (Area 9) and Duck Clubs (Area 17) to allocate Butte Creek flow as follows:

- Irrigation season (April 15 – September 15)
    70% to Butte Creek available to RD 1004

30% to Sanborn Slough to duck clubs

- Non-Irrigation season (September 15 – about January)
  30% to Butte Creek available to RD 1004
  70% to Sanborn Slough to duck clubs
- Non-Irrigation season (January – April15)
  Uncontrolled

There is a 40 cfs minimum flow requirement for the RD 1004 diversion from Butte Creek. Return flow from RD 1004 flows back into Butte Creek and is available in Area 17 for diversion.

Demands

Demands in this area fall into two categories:

1. Non-Project demands that are satisfied primarily by groundwater
2. CVP Settlement Contract
    - District demands satisfied from the Sacramento River. RD 1004 and M&T Ranch are included in this demand. RD 1004 diverts from both the Sacramento River and Butte Creek while M&T Ranch is a Sacramento River diverter.
    - (non-district) demands satisfied from the Sacramento River

Area 10

Northern portion of DSA 69, north of FRSA

The northern boundary of Area 10 coincides with the northern boundary of DAU 166. The FRSA borders this area to the south and Area 9 is located to the west. This area is primarily served from ground water and has little access to surface water.

Demands

Area 10 only contains non-project demands. There appears to be some surface water available from Butte Creek.

Area 11

Feather River Service Area

Area 11 contains the Feather River Service Area (FRSA) that is served by diversions from Thermalito Forebay and Afterbay. These diversions have a large influence on the operation of Oroville Reservoir.

Demands

The Feather River Service Area contain SWP settlement water users, this is the primary demand in this area. There is a relative small portion of non-project demand that is primarily satisfied by groundwater.

Return flow

Area 12

DSA 69 south east of FRSA and north of YCWA

Area 12 is located south east of the FRSA, west of Oroville-Wyandotte ID, and North of the YCWA service area. This area is primarily served from ground water and has little access to surface water.

Demands
Area 12 only contains non-project demands. These demands have a minor amount of riparian rights along the Feather River.

Notes:
Area contains about 3500 acres of FRSA lands that should be in Area 11, this has been correct in the data but not in the GIS coverage. Contains about 680 acres of lands served by YCWA that should be in Area 15, this has been correct in the data but not in the GIS coverage.

Area 13

South Fork Water and Power (formerly Oroville Wyandotte ID) in DSA 69
This area is located south of Oroville Reservoir and is primarily satisfied from imports from the upper Feather River Basin.

Demands
The entire demand for this region is non-project and met from Forbestown Ditch, Bangor Ditch, and Miners Ranch Canal that convey water from the upper Feather River area to satisfy OWID demands.

Area 14

Browns Valley Irrigation District
Area 14 consists of Browns Valley Irrigation District, which is located within DSA 67, 68, and 69.

Demands
This area contains all non-project demands that are all satisfied by BVID. BVID diverts from the Yuba River under a pre-1914 water right, operates Merle Collins Reservoir, and pumps ground water to meets demands within its service area.

Area 15

Yuba County Water Agency located in DSA 69
YCWA demands that are located in the valley floor are contained in this Area.

Demands
The demands in Area 15 are all non-project, about a fourth of the demands are not within a water district and are largely satisfied from groundwater.

Notes:
There are about 6000 acres of Plumas Mutual Water Company lands included in this area, this should probable be moved to Area 16. There is a need to research Plumas Mutual Water Company water right or contract to determine ability to divert from Feather River.

Area 16

Lower Feather River located in DSA 69 and 70
Area 16 is located east of the Sutter bypass and west of the Lower Feather River.

Demands
Demands are satisfied by diversion from the Lower Feather River and ground water

There are four demand types located in this area:

1. Non-Project demands that satisfied primarily by groundwater, however there are lands that are riparian to the Lower Feather River. A portion of the riparian demands in Area 16 along the Lower Feather River are physically located in DSA 70 and exports from DSA 69 to DSA 70 were explicit in the previous hydrology.
2. CVP Ag service. Feather Water district is a CVP demand that is satisfied from Feather River diversions.
3. SWP Ag - Sutter Extension WD demands are satisfied by Feather River diversions and partially by return flow from upstream FRSA diverters.
4. M&I SWP – Yuba City demands are satisfied by Lower Feather River diversions.

Area 17

Western DSA 69 and Sutter Bypass

Area 17 is located southwest of the FRSA and includes lands north of the Sutter Buttes and lands in and around the Sutter Bypass. Area 17 includes Grey Lodge WMA and Duck Clubs in the northern most part and irrigated agriculture and Sutter NWR in and around the Sutter Bypass.

Butte Creek and return flows from the FRSA provide surface water supply to this Area. Butte Creek flows through Western Canal Company in the FRSA, but no water is diverted. Butte Creek flow is diverted by RD1004, located in 9, and by users in Area 17. There are agreements between RD1004 (Area 9) and Duck Clubs (Area 17) to allocate Butte Creek flow as follows:

- Irrigation season (April 15 – September 15)
  70% to Butte Creek available to RD 1004
  30% to Sanborn Slough to duck clubs
- Non-Irrigation season (September 15 – about January)
  30% to Butte Creek available to RD 1004
  70% to Sanborn Slough to duck clubs
- Non-Irrigation season (January – April15)
  Uncontrolled

There is a 40 cfs minimum flow requirement for the RD 1004 diversion from Butte Creek.

There is a 1922 Agreement for Western Canal to delivered water up to 250 cfs to duck clubs in Area 17. Once the rice field drainwater from the FRSA begins to decline (usually by mid-September), water flows drop to less than 200 cfs. The manager of the Wild Goose Club makes a call for the delivery of water from Western Canal in order to maintain water levels within the Butte Sink. This generally occurs sometime between September 20 and October 1. Delivered water usually ranges from 150 to 175 cfs and sometimes, though rarely, as much as 200 cfs. Sometimes water flows from storm events and runoff from winter-flooded rice fields are sufficient to satisfy water requirements.

Demands

All agricultural demands in this are classified as non-project. These demands are satisfied from Butte Creek and return flows as previously described and by ground water pumping. In addition to non-project agricultural demands there are refuge and duck club demands. Refuge demands have been developed and input to CalSim while duck club demands are not addressed.   A ponding operation and consumptive demands should be developed for the duck club operation.

Area 18

East portion of DSA 15 from Butte Slough to Tisdale Bypass

Area 18 encompasses an area east for the Sacramento River from Butte Slough to Tisdale Bypass, and is bordered on the east by lands served from Butte Creek. All agricultural return flows enter Tisdale bypass and are available for diversion in Area 17.

Demands

All surface diversions in this area are from the Sacramento River. Demands in this area fall into two categories:

1. Non-Project demands that are satisfied by groundwater and possibly riparian to the Sacramento River
2. CVP Settlement Contract
    - District demands satisfied from the Sacramento River including Meridian Farms and Newhall Land And Farming Co.
    - (non-district) demands satisfied from the Sacramento River

Area 19

East portion of DSA 15 south of Tisdale Bypass

This area includes lands east for the Sacramento River from Tisdale Bypass to the confluence of the Feather River, and is bordered on the east by the Sutter Bypass. All agricultural return flows enter the RD 1500 Drain the flows to the Lower Feather River.

Demands

All surface diversions in this area are from the Sacramento River. Demands in this area fall into two categories:

3. Non-Project demands
4. CVP Settlement Contract
    - District demands satisfied from the Sacramento River. Sutter Mutual Water company makes up a majority of the demand in this area.
    - (non-district) demands satisfied from the Sacramento River

Area 20

Northern portion of DSA 65 served by Cache Creek

The north, south, and west borders of Area 20 follow the border of DAU 162 and Area 21, which is served by the Sacramento River borders to the east.

Demands

The entire demand for this region is non-project and is met by diversions from Cache Creek and ground water. This Area has no access to the Sacramento River.

Area 21

East portion of DSA 65 served by Sacramento River

This Area encompasses lands on the west side of the Sacramento River from Colusa Basin Drain to the Delta service area.

Demands
All surface diversions in this area are met from the right bank of the Sacramento River. Demands in this area fall into two categories:

1. Non-Project demands
2. CVP Settlement Contract
   - District demands satisfied from the Sacramento River.
   - (non-district) demands satisfied from the Sacramento River

Area 22

West portion of DSA 70 served by Sacramento River

This area is located on the east side of the Sacramento River, north from the City of Sacramento Service Area, and south of the Feather River.

Demands
All surface diversions in this area are satisfied from the right bank of the Sacramento River. Demands in this area fall into two categories:

1. Non-Project demands
2. CVP Settlement Contract
   - District demands satisfied from the Sacramento River. This includes Natomas Central MWC and Pleasant Grove Verona MWC.
   - (non-district) demands satisfied from the Sacramento River

Area 23

Northern portion of DSA 70 served by Bear River

This area is located in the northern portion of DSA 70 and is served from Bear River diversions from Camp Far West Reservoir.

Demands
All surface diversions in this area are met from the Bear River. Demands in this area fall into two categories:

1. Non-Project demands met from ground water
2. Non-Project irrigation district demands met from Bear River, which include South Sutter WD and Camp Far West WD.

Area 24

Eastern portion of DSA 70 served by imports from rim basins

The area is located in the north eastern portion of DSA 70, east of Area 23 and north of the American River service area.

Demands
All demands in this area are classified as non-project and are satisfied by imports from the upper Bear and American River basins.

Area 25

Southern portion of DSA 65

This Area has similar boundaries as DAU 191. The Delta service area is located to the south and areas served from Cache Creek is located to the north. This area does not have access to Sacramento River flows.

Demands

All demands in this area are classified as non-project and are satisfied the Solano project and ground water.

Area 26

Southern portion of DSA 70 served from American River

This is the American River service area and is currently addressed in CalSim using the Sacramento Water forum demands.

Attachment 2
Sacramento Valley Refuge Operations

The wetlands of California's Sacramento Valley provide critical habitat for migratory birds and for resident wildlife, including many threatened and endangered animal and plant species. The Sacramento Valley is part of the Pacific Flyway, a migratory waterfowl route extending over Canada, the United States, and Mexico. Management of the Flyway is governed by international treaty between the United States, Mexico, and Japan. The Bureau of Reclamation (Reclamation) is the lead agency in a cooperative effort among Federal, State, and local agencies in planning for the development of dependable water supplies for California's Sacramento Valley refuges.

The Pacific Flyway is the westernmost of four migratory waterfowl routes transecting the North American continent. The Pacific Flyway is unlike the others, however, in that most of the wintering waterfowl concentrate in a relatively small area: California's Central Valley. Historically, the Central Valley contained over 4 million acres of wetlands. However, through the conversion of those lands to other uses, the total available acres of wetlands have been reduced to approximately 300,000 acres. Federal National Wildlife Refuges and State Wildlife Management Areas comprise approximately one third of this acreage, with most of the remainder in private ownership. The single most important role of the Sacramento Valley wetlands and associated riparian and upland corridors is to provide wintering habitat for waterfowl and other wildlife.

HISTORY

Before the intensive settlement of California in the 1800's, much of the Sacramento Valley was subject to annual or periodic flooding caused by winter, spring, and early summer run-off and floodwaters from the Sacramento River and it's tributaries. Depending on the time of year, flooding frequently turned parts of the Valley into an inland sea, as the waters moved slowly towards the Delta. These seasonal marshes resulted in the growth of dense strands of tulles over large areas of the floodplain. Adjacent lands that were not inundated as frequently or were well drained supported strands of riparian woodlands important for nesting and food supply.

The total available acres of wetlands have been reduced to approximately 300,000 acres in California. The major factors responsible for the loss of wetlands have been: (1) Construction of thousands of miles of flood control levees and the subsequent conversion of natural wetlands to agriculture production and urban development; (2) Dredging and filling of estuarine habitat for urban, industrial, and port developments; (3) Construction of flood control and water storage reservoirs; and (4) Canalization of thousands of miles of natural waterways.

As agriculture and other developments continued to claim remaining wetlands, waterfowl were crowded into ever diminishing habitat, and dependence on farm crops for food increased. Sacramento National Wildlife Refuge in Glenn and Colusa Counties, was established in 1937 by purchase of 10,776 acres with funds made available by the Emergency Conservation Fund Act of March 1, 1933 and Emergency Relief

Appropriation, Executive Order No. 7562. The Executive Order reserved and set apart these lands as a refuge and breeding ground for migratory birds and other wildlife. The refuge reduced waterfowl damage on farm crops by providing food and resting areas for wintering ducks and geese. The California Department of Fish and Game established the 8400 acre Gray Lodge Wildlife Management Area in 1931 to provide lands for waterfowl and other wildlife species.

Continued crop losses led to the Lea Act, authorizing and appropriating funds for the purchase of more land for migratory waterfowl refuges in the Sacramento Valley. Between 1944 and 1953 the 4,042-acre Colusa National Wildlife Refuge in Colusa County and Sutter National Wildlife Refuge of 2,591 acres in Sutter County were obtained with these funds. In 1962, the 5,633-acre Delevan National Wildlife Refuge in Colusa County was authorized by the Migratory Bird Conservation Commission and purchased with Migratory Bird Hunting Stamp Act funds. Development of the refuges, including improved farming and herding practices, has made crop loss to ducks and geese a minor problem in the Sacramento Valley. Maps showing the conveyance systems of Sacramento NWR, Delevan NWR, Colusa NWR, Sutter NWR, and Gray Lodge WMA can be found as Attachment 1.

Sacramento National Wildlife Refuge

Sacramento National Wildlife Refuge (NWR) was created in 1937 and is located about 5 miles south of the City of Willows. Prior to the creation of Sacramento NWR, the lands were used for rice production consistent with the surrounding areas of the refuge. The refuge extends into both Glenn and Colusa Counties and encompasses 10,783 acres. The refuge contains permanent ponds, seasonal wetlands, irrigated watergrass units, and uplands. The wetlands support watergrass and invertebrate populations that serve as the primary food source for migratory waterfowl. Upland areas of the refuge support large concentrations of geese, upland birds, and other wildlife species.

Water is used to maintain ponds and seasonal marshes and to irrigate watergrass for waterfowl food. The wetlands area varies annually with the availability of water. The refuge receives Central Valley Project (CVP) water through Glenn Colusa Irrigation District (GCID) facilities. Approximately 90 percent of the water delivered to Sacramento NWR is conveyed through GCID’s Lateral canal 26-2 and Logan Creek. Lateral 26-2 delivers water from GCID’s Main Canal to the northwest corner of the refuge. Once Lateral 26-2 enters the refuge, it splits and delivers water along the northern and western boundaries of the refuge. This system does not deliver an adequate quantity of water to the northeast corner of the refuge because of site topography. GCID Lateral 35-1C also delivers water to the middle of the refuge’s western boundary, primarily during the seasonal flood-up period during September and October. No water is available from GCID facilities from December 1 through mid-March, when GCID’s main canal is shut down and dewatered. During this period, the refuge relies on seasonal precipitation and natural flow in North Fork Logan Creek that passes through refuge lands. Water from Logan Creek is diverted inside the refuge using Weirs DM1 and DM2 that back up water for distribution within the refuge. Two groundwater wells exist on the refuge, but these wells are not used because of the generally poor quality of groundwater, high pumping costs, and low yields.

Colusa National Wildlife Refuge

Colusa NWR was established in 1944 and currently occupies 4,956 acres approximately 2 miles southwest of the town of Colusa in Colusa County. The refuge has recently acquired an additional 467 acres, which is reflected in the 4,956 acre total. The Colusa NWR consists of permanent ponds, seasonal wetlands, watergrass fields, and uplands.

Prior to the creation of Colusa NWR, the lands were used for rice production consistent with the surrounding areas around the refuge. The refuge diverts agriculture runoff from the 2047 Drain (Colusa Drain), which is supplemented with CVP water conveyed through GCID facilities. CVP water is diverted from the Sacramento River via the T-C Canal and GCID facilities. A portion of the water supplied by GCID is agriculture return flow. Under contract with the Fish and Wildlife Service, GCID conveys a maximum of 25,000 acre-feet to the refuge. The Tehama-Colusa Canal is capable of supplying water on a year round basis and can supply water for conveyance during winter months. The refuge has one groundwater well, but it is not in use due to high pumping costs.

Delevan National Wildlife Refuge

Delevan NWR was authorized in 1962 under the Migratory Bird Conservation Commission and encompasses 5,794 acres. The refuge is located in Colusa County midway between Sacramento NWR and Colusa NWR, approximately 7 miles east of the City of Maxwell. The Delevan NWR consists of permanent ponds, seasonal wetlands millet fields, and uplands. Prior to the creation of the refuge, lands within the boundaries were generally used for rice production. The Delevan NWR receives CVP water through GCID facilities. Under contract with the Fish and Wildlife Service, GCID conveys a maximum of 30,000 acre-feet of water to the refuge (a portion of this water is agriculture return flow). This contract allows for a 25 percent conveyance loss. Other facilities that convey water to GCID and then to the refuge are the TC Canal and the Tehama-Colusa Canal Intertie. The Tehama-Colusa Canal is capable of supplying water on a year round basis and can supply water for conveyance during winter months. The safe groundwater yield of the refuge is estimated to be 6,800 acre-feet; however, the refuge has no groundwater wells (Reclamation, 1995).

Sutter National Wildlife Refuge

Sutter NWR was established in 1944, and it encompasses 2,591 acres in Sutter County 8 miles southwest of Yuba City. Most of the refuge is located within the Sutter Bypass, north of its confluence with the Tisdale Weir. The refuge is the only publicly owned wetland habitat area in the Sutter Basin. Historically, flood flows from the Sacramento River, Butte Sink, and the Feather River inundated large portions of the Sutter Basin. However, most of this land is now protected from flooding by levees and has been developed for agriculture production. Water is used on the refuge to maintain ponds and moist soil plants, and to irrigate millet fields. The refuge has five groundwater wells to supplement surface-water flows under a conjunctive use program. The groundwater is not currently used because it contains high levels of arsenic and possibly mercury, and because of high pumping costs. More than 85 percent of the water supply for the refuge comes from irrigation and return flows in the East and West Borrow Ditches of the Sutter Bypass, if and when they are available. Agriculture return flows make up the majority of the summer flows, while rainfall, runoff, and flood flow make up the majority of winter flows. Water has been purchased from Sutter Extension Water District in the past for the refuge area located outside of Sutter Bypass.

Gray Lodge Wildlife Management Area

Gray Lodge Wildlife Management Area (WMA) was established in 1931, and it encompasses 8,400 acres in Sutter and Butte counties near the City of Gridley. The WMA is managed by the California Department of Fish and Game. Gray Lodge WMA is located adjacent to the Butte Sink, an overflow area of Butte Creek and the Sacramento River, and supports ponds, marshlands, wheat fields and uplands.

Gray Lodge currently receives water from a combination of surface-water and groundwater sources. As a customer of Biggs-West Gridley Water District (BWGWD), Gray Lodge WMA has both primary and secondary surface-water rights, which are supplied from the Thermalito Afterbay, through A-Joint Canal and BWGWD's Belding Canal, to four delivery points at the Gray Lodge WMA boundary via the Rising River, Schwind, Jakey, and Cassidy laterals. Additional water purchased through the State Water Project (SWP) is also conveyed from the Thermalito Afterbay through these same facilities. BWGWD facilities are shut down from mid-January to mid-April for maintenance. Gray Lodge also has appropriative water rights supplied from diversions on the RD 833 and the RD 2054 Drain, where these drains cross the WMA boundary. The amount of water available in these drains during the normal irrigation season has been decreasing over time as area farms improve irrigation efficiency and implement drainage capture and reuse programs.

Groundwater is also used to supply a portion of the annual demand on Gray Lodge WMA. Twenty-one deep groundwater wells are used onsite, as necessary, to supplement surface water deliveries and to supply water to portions of the refuge that cannot be reached by gravity flow from surface supplies. Annual groundwater pumping varies considerably, with a maximum amount of groundwater extracted in 1994 when 16,158 acre-feet were pumped.

WATER USE

Prior to the formation of the refuges in the 1930's and 1940's, much of the lands that are now habitat were in rice production consistent with the surrounding areas of the refuges today. For the purpose of this report we will estimate the acres of refuge land in rice production prior to the establishment of wildlife habitat to be equivalent to the overall rice production in the Sacramento Valley for that year. This estimation was made after detailed conversations with Ben Pennock of GCID and Greg Mensik of Sacramento NWR. Water use prior to the establishment of refuges is already addressed through historical land use.

The formation of the waterfowl refuges in the 1930's and 1940's, and again in 1962 (Delevan NWR) brought about a change in the water demand for these specified lands. These refuges were established when excess water was available, and thus no firm water supplies were secured to supply a guaranteed amount of water to the refuges. As a result, in most years and especially in dry years like 1976 and 1977, there was insufficient water to flood all of the available refuge land as wintering habitat. (Bureau of Reclamation, 1978) The availability of water for delivery to the refuges was highly variable from year to year, and few if any measurements of diverted water to refuges exist before 1970. Conversations with Greg Mensik of Sacramento NWR, Dale Garrison of FWS, Todd Hillaire of DWR, Paul Forsburg of DFG, and Andy Atkinson of Gray Lodge WMA turned up very little information of historical water use at the various refuges before1993. The staff at the refuges were hesitant to release their historical diversions before that time, and instead have pointed to the Level 2 Refuge Water Supply Needs, a value specified in Section 3406 (d) (5) of the Central Valley Project Improvement Act (CVPIA), Public Law 102-575, Title XXIV. Enacted in October, 1992, Level 2 Water Supply Needs establish a firm supply to be delivered based on average historical water deliveries. The monthly Level 2 Water Supply Needs for the five Sacramento Valley refuges are included as Table 1. The Annual Level 2 Refuge Water Supply is as follows (Final Environmental Assesement/Initail Study for the Conveyance of Refuge Water Supply Project, 1997):

Refuge	Level 2 Supply (ac/ft)*	Level 2 (w/ losses)
Sacramento NWR	46,400	61,867 (25%)
Delevan NWR	20,950	27,935 (25%)
Colusa NWR	25,000	33,333 (20%)
Sutter NWR	23,500	26,111 (10%)
Gray Lodge WMA	35,400	40,602 (17 %)
Total	**151,250 AF**	**189,848 AF**

*Does not include conveyance losses

Table 1

Refuge Water Requirements

Level 2 Requirements

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sacramento NWR	1,200	1,200	300	300	2,100	2,600	4,000	6,300	7,500	9,300	8,300	3,300	**46,400**
Colusa NWR	1,200	800	350	770	1,440	2,500	2,880	2,880	3,840	3,840	2,400	2,100	**25,000**
Delevan NWR	1,650	1,300	450	100	450	900	1,550	2,200	3,050	4,350	3,050	2,900	**21,950**
Sutter NWR	950	1,000	1,000	950	1,100	1,300	1,300	3,800	4,500	3,800	1,900	1,900	**23,500**
Gray Lodge WMA	1,050	1,050	1,050	1,050	2,500	3,500	2,500	2,850	7,100	6,750	4,600	1,400	**35,400**

Level 4 Requirements

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Sacramento NWR	1,250	1,250	1,250	300	2,250	2,750	4,200	6,850	8,700	8,900	8,800	3,500	**50,000**
Colusa NWR	1,200	800	350	770	1,440	2,500	2,880	2,880	3,840	3,840	2,400	2,100	**25,000**
Delevan NWR	2,375	1,875	625	125	625	1,250	2,250	3,125	4,325	4,375	4,375	4,675	**30,000**
Sutter NWR	1,800	2,300	3,420	1,200	1,440	1,680	1,680	1,680	4,000	4,800	3,500	2,500	**30,000**
Gray Lodge WMA	1,320	1,320	1,320	1,320	3,080	4,400	3,080	3,520	8,800	8,360	5,720	1,760	**44,000**

West Sacramento Valley Refuges (Sacramento, Colusa, Delevan)

After speaking with various sources affiliated with the refuges and water districts that serve the refuges, we have concluded these Level 2 historical averages were established to ensure adequate supply in the highest demand years. Based on the historical records we did receive from GCID, this level of water supply has rarely if ever been delivered to the refuges that GCID serves (Sacramento, Delevan, and Colusa). The historical GCID deliveries to refuges as recorded in GCID's Annual Report on Water Measurement can be found in Table 2. The Level 2 Refuge Water Supply Needs for Sacramento, Delevan, and Colusa NWR is 123,135 AF/year (including conveyance losses).

The GCID Report on Water Measurement allows for a 20% loss factor for delivery to the refuges. The maximum amount of water historically delivered to the refuges through GCID facilities based on the Water Measurement Report occurred in 1996 when 83,150 acre-feet were delivered to the three refuges served by GCID. According to GCID Staff, the refuges have never been able to make full use of allotted Level 2 supplies. GCID is unable to deliver water to the refuges from December through mid-March because the GCID main canal is dewatered for maintenance. During this time, refuges depend on seasonal precipitation and flows from local streams (Logan Creek, Hunters Creek, and 2047 Drain). Water is generally served to Refuges before April and after October but is not reported because it is outside the USBR Contract period and therefore not measured by USBR.

Table 2

GCID Deliveries to Sacramento NWR, Colusa NWR, and Delevan NWR

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1963	0	3600	5500	7400	7800	5300	4100	33700
1964	600	900	3200	3300	4100	2800	5800	20700
1965	100	1400	2500	3500	4900	4600	4200	21200
1966	800	700	3300	1900	5200	4600	6600	23100
1967	0	900	1600	4800	5100	5700	5500	23600
1968	800	1400	1800	3600	2900	5100	5800	21400
1969	300	1600	1600	4200	3400	5200	6900	23200
1970	600	1900	2300	2700	6100	5100	6400	25100
1971	600	1700	1800	4500	5300	4800	5900	24600
1972	600	2700	2800	6100	5000	4400	3000	24600
1973	800	2100	2100	5000	4000	4200	4900	23100
1974	500	2500	3300	3900	4500	5600	5600	25900
1975	500	3000	4400	5500	6200	8100	7800	35500
1976	2200	3400	5600	7500	6100	6800	10000	41600
1977	400	800	2300	3100	5100	7700	9600	29000
1978	1100	4500	4500	5000	6000	7400	10600	39100
1979	1200	4600	5200	6800	8100	8700	9000	43600
1980	1400	4500	5300	7500	9000	17800	16900	62400
1981	1000	4600	6100	7100	14000	17400	17000	67200
1982	0	3900	6300	8200	10800	19300	13100	61600
1983	0	1600	4900	6600	12200	17200	16200	58700
1984	0	3800	6100	7000	9600	17400	20000	63900
1985	400	2800	5000	5500	9500	13300	18000	54500
1986	400	1600	3900	5000	10900	17300	20600	59700
1987	0	2300	3100	2800	7800	20300	17600	53900
1988	0	900	2400	3700	8300	18800	19900	54000
1989	0	400	2200	3400	8800	18400	13100	46300
1990	100	300	2300	3700	9700	17100	12900	46100
1991	0	0	300	700	4800	10200	11600	27600
1992	0	0	400	500	4600	13500	19200	38200
1993	0	2700	1300	1400	6700	13100	20200	45400
1994	1300	600	2000	3200	7200	17800	22200	54300
1995	0	1600	4100	2900	7900	16700	21600	54800
1996	1000	2000	4100	1900	11300	20300	27400	68000
1997	2700	1900	3500	2500	9900	19100	19700	59300
1998	400	1300	1300	2600	7200	17200	20300	50300
1999	900	1500	1600	1600	4500	14400	19200	43700
Average	**627**	**2303**	**3636**	**4745**	**8015**	**13112**	**14497**	**46936**

The Bureau of Reclamation has provided records of refuge surface diversions from 1993 to 2002; these deliveries are summarized in Table 3.

Table 3

Historical Refuge Delivery

Sacramento NWR

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
1993	1475	167	1250	298	803	3432	7500	9300	7308	1276	1048	476	34385
1994	714	416	95	468	833	4540	9502	9572	6816	0	0	0	32956
1995	0	0	476	1480	1461	3553	8667	9864	7617	1849	889	1036	36892
1996	0	226	464	628	337	5240	8993	14874	6153	1533	1445	316	40209
1997	788	148	536	690	294	4662	8748	7465	6181	0	1384	Flooded	30896
1998	0	43	310	428	820	2964	6870	6396	5450	0	0	0	23521
1999	220	286	310	458	366	1768	5732	7652	4762	0	0	0	21554
2000	240	720	502	618	638	2818	6409	6586	4565	4958	3908	2684	34646
2001	0	360	442	1726	576	3034	8078	9290	4232	3204	2468	1480	34890
2002	1504	827	853	1080	1216	2822	7304	8195	6003	5655	2094	1356	38909
Average	494	319	524	787	734	3483	7780	8919	5909	1848	1324	816	32886

Delevan NWR

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
1993	36	609	180	889	1423	1730	3700	4992	3709	0	0	0	17268
1994	36	609	160	889	1423	1730	3700	4992	3709	0	0	0	17248
1995	0	0	630	1515	660	2214	3660	5414	4354	1246	0	0	19693
1996	0	280	850	2236	1200	2788	4615	4949	4100	0	0	0	21018
1997	960	1312	545	1792	1455	2269	4804	6291	4361	0	0	0	23789
1998	158	191	460	378	1057	2688	5097	6045	3458	0	544	288	20364
1999	496	452	835	901	968	2032	4123	5460	4451	0	60	127	19905
2000	0	50	359	1167	531	2270	4232	5111	3208	2522	1464	536	21450
2001	80	185	629	1071	1031	2224	4452	4650	2965	1222	506	555	19570
2002	403	456	542	940	502	2505	4329	5101	3770	1603	0	970	21121
Average	217	414	519	1178	1025	2245	4271	5301	3809	659	257	248	20143

Colusa NWR

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
1993	335	0	454	180	194	814	4239	4472	4834	600	1981	1901	20790
1994	1002	0	196	410	681	550	3914	5726	4437	1626	0	0	18542
1995	0	0	251	410	85	1915	3162	5457	4257	3099	3192	2713	24541
1996	2321	635	684	514	54	2022	4362	4397	4235	3744	3254	2624	28846
1997	3135	1176	743	716	610	1976	3014	3940	4748	2736	2616	Flooded	25410
1998	710	403	319	330	300	300	2702	4806	6180	3410	3410	3438	26308
1999	2490	402	455	308	310	390	2426	3190	2664	1640	1320	360	15955
2000	373	53	119	490	317	322	2000	4578	2156	2164	1650	1508	15730
2001	227	339	651	558	459	537	3130	5138	2300	2059	864	777	17039
2002	1576	415	296	877	502	443	2799	3951	2162	1588	1743	1455	17807
Average	1217	342	417	479	351	927	3175	4566	3797	2267	2003	1642	21097

Sutter NWR

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
1993	1178	900	806	1260	806	558	2234	2716	2220	1860	1674	1456	17668
1994	1393	360	600	130	60	0	1750	3212	1835	1600	264	530	11734
1995	430	202	246	958	260	206	2211	3037	1844	1390	1040	200	12024
1996	257	237	209	996	186	466	2640	1514	1516	780	212	354	9367
1997	936	627	780	590	250	370	3050	2890	2100	2150	1594	560	15897
1998	540	80	160	480	302	84	3582	3410	2262	872	1628	816	14216
1999	660	764	1106	712	406	93	3442	3442	2578	2108	1670	420	17401
2000	410	560	1026	1066	330	298	3420	3210	2880	2048	1802	1396	18446
2001	495	566	1331	492	286	338	2240	2444	2796	1056	620	1674	14338
2002	1376	157	752	586	198	62	1350	3336	3318	1396	930	740	14201
Average	768	445	702	727	308	248	2592	2921	2335	1526	1143	815	14529

Gray Lodge WMA

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total
1996	0	0	505	1662	1795	1843	3946	5227	2676	1818	468	0	19940
1997	305	447	2636	2536	2818	3833	5984	6584	4215	3072	1255	0	33685
1998	0	0	810	1552	2102	2704	5479	7534	3737	3609	1906	233	29666
1999	180	134	2591	2285	2723	3126	5811	5880	4110	3503	2884	14	33241
2000	0	1130	2257	2110	2181	2226	5675	5917	3182	3299	3685	51	31713
2001	0	694	2133	2110	2102	4019	6701	6242	3711	1883	1551	111	31257
2002	74	934	1785	2502	2326	3572	4578	7843	4493	3674	589	22	32392
Average	80	477	1817	2108	2292	3046	5453	6461	3732	2980	1763	62	30271

Gray Lodge WMA

Historical diversion data for Gray Lodge WMA (Gray Lodge Actual Water Use 1996 – 2002) was obtained from Paul Forsburg of DFG. The maximum total combined diversion of surface and ground water during this period is 33,685 Acre-feet in 1997. The average diversion amount for this time period is 31,970 acre-feet per year, about 10% below the firm supply established in the CVPIA as Level 2 Refuge Water Needs. It is important to note that Level 2 firm supply is for surface water deliveries, and the actual water use at Gray Lodge includes groundwater pumped from the 21 deep groundwater wells on the property.

Sutter NWR

Historical surface delivery data at Sutter NWR was provided by Natalie Wolder (Bureau of Reclamation) for the last 10 years. The amount of water that is available in the East and West Borrow Ditch of the Sutter Bypass is highly variable, and has often overflowed into the Sutter NWR as winter precipitation and runoff create flood conditions. During the summer months, the available water is limited to agriculture return flows. The Sutter NWR water rights for the East and West borrow ditch do not have a high priority and are not a dependable source of water. Sutter NWR has historically been delivered less water than the specified amount under Level 2 conditions.

MODEL OF REFUGE PONDING OPERATIONS

All 5 of the wildlife refuges located in the Sacramento Valley follow the same basic annual model of operation, consisting of maintaining permanent ponds, flooding up and drawing down seasonal ponds, and irrigating crops for waterfowl feed. The land use acreages for Sacramento, Delevan, Colusa, and Sutter NWR are included as Table 3. Greg Mensik of Sacramento NWR has provided us with a 2000 Water Year Data Sheet for Sacramento, Delevan, and Colusa NWR's detailing the monthly operations of water supply and outflow. Sutter NWR and Gray Lodge WMA did not have a Water Use spreadsheet available, according to the refuge managers, but generally follow the same schedule as set forth in the spreadsheet provided by Greg Mensik.

Based on the Water Use spreadsheets provided by Greg Mensik and annual GCID water measurement reports dating back to 1963, we have developed a monthly operating model to describe the inflows and outflows of the refuge system. The model was developed to represent operations at all five wildlife refuges in the Sacramento Valley, and can be applied to the actual land use of each refuge to accurately estimate the monthly flow of water that has often not been measured in the past.

Table 3

National Wildlife Refuge Land Use (acres)

	Sacramento NWR				Colusa NWR				Delevan NWR				Sutter NWR			
Year	Wetland	Ag (Rice)	Upland	Total	Wetland	Ag (Rice)	Upland	Total	Wetland	Ag (Rice)	Upland	Total	Wetland	Ag (Rice)	Upland	Total
2002/03	7579	0	3204	10783	4558	0	1239	5797	3525	0	982	4626	1958	0	633	2591
2001/02	7559	0	3224	10783	4546	0	1251	5797	3406	0	1101	4507	1958	0	633	2591
2000/01	7587	0	3196	10783	4536	0	1261	5797	3414	0	1093	4507	1958	0	633	2591
1999/00	7604	0	3179	10783	4536	0	1261	5797	3205	0	1302	4507	2019	0	572	2591
1998/99	7614	0	3169	10783	4536	0	1261	5797	3162	0	1345	4507	2019	0	572	2591
1997/98	7619	0	3164	10783	4536	0	1261	5797	3162	0	1345	4507	2019	0	572	2591
1996/97	7632	0	3151	10783	4536	0	1261	5797	3162	0	1345	4507	2019	0	572	2591
1995/96	7644	0	3139	10783	4536	0	1261	5797	3095	0	945	4040	1927	0	664	2591
1994/95	7604	0	3179	10783	4632	0	1165	5797	3129	0	911	4040	1994	0	597	2591
1993/94	7488	0	3295	10783	4472	0	1161	5633	3129	0	911	4040	1986	0	605	2591
1992/93*	7192	0	3591	10783	4472	0	1161	5633	3129	0	911	4040	1973	0	618	2591
1991/92*	6679	0	4104	10783	4092	0	1541	5633	3131	0	909	4040	1984	0	607	2591
1990/91*	6952	0	3831	10783	4146	0	1487	5633	3131	0	909	4040	1984	0	607	2591
1989/90*	6524	0	4209	10783	3903	0	1730	5633	3131	0	909	4040	1984	0	607	2591
1988/89	7429	0	3354	10783	4381	0	1252	5633	3131	0	909	4040	1984	0	607	2591
1987/88	7049	146	3588	10783	4295	88	1250	5633	3131	0	909	4040	1984	0	607	2591
1986/87	7045	236	3502	10783	3896	175	1562	5633	3131	0	909	4040	1984	0	607	2591
1985/86	7004	185	3594	10783	3776	158	1699	5633	3058	86	896	4040	2081	0	510	2591
1984/85	6625	340	3818	10783	3687	158	1788	5633	2473	130	1437	4040	2128	0	463	2591
1983/84	6524	647	3612	10783	3473	202	1958	5633	2740	128	1172	4040	2049	0	542	2591
1982/83	6165	818	3800	10783	3549	496	1588	5633	2496	318	1226	4040	1628	425	538	2591
1981/82	6153	815	3815	10783	3328	623	1682	5633	2217	516	1307	4040	1595	618	378	2591
1980/81	6195	809	3779	10783	2270	602	2761	5633	1970	517	1553	4040	1266	630	695	2591
1979/80**		850		10783	2060	725	2848	5633	1826	516	1698	4040	1507	635	449	2591

Data supplied by the Bureau of Reclamation for refuge deliveries from 1993-2002 was recorded, and then averaged to create a baseline average delivery for each refuge. That base delivery figure was then used to estimate historical deliveries to refuge lands using GCID delivery measurements that date back to 1963. Water year type and water supply trends were used to estimate historical deliveries before 1963. Because Gray Lodge WMA and Sutter NWR both lie in the Eastern Sacramento Valley and are not serviced by GCID, we have developed a separate set of annual factors to apply to the land use that take into consideration water year type and water supply trends to those refuges. A monthly description of operations is as follows:

January - Refuge is at full capacity; all ponds and marshes are maintained at maximum habitat depth. System is closed to prevent any outflow.

February – As the hunting season comes to an end, water deliveries are reduced to low levels and some seasonal marshes begin to draw down water levels. There is little outflow, as most of the refuge systems remained closed to trap water for late waterfowl habitat.

March – Draw down of seasonal marshes and ponds as waterfowl migrate out of the Sacramento Valley. Little or no water deliveries to the refuges during March, as stored water from seasonal ponds and marshes return into the system as outflow.

April – Continued draw down of seasonal marshes results in outflow back to the system via drainage canals and the bypass system. Little or no water deliveries to the refuges.

May – Permanent ponds and some summer water ponds are maintained at habitat water depth. Increasing deliveries to refuges as GCID and other conveying water districts begin providing water for irrigation operations. Little or no outflow is returned to the system.

June – Continued maintenance of permanent and summer ponds as water deliveries continue to increase. Watergrass/wheat/millet field crops begin irrigation cycle to provide food for wildlife species in the habitat area. Little or no outflow is returned to the system.

July – Water deliveries tend to slow down as crop irrigation needs reach maximum levels, permanent ponds are maintained at habitat water depths of 24", and planted crops for wildlife feed continue to be irrigated. There is some outflow into the system as summer ponds are drawn down.

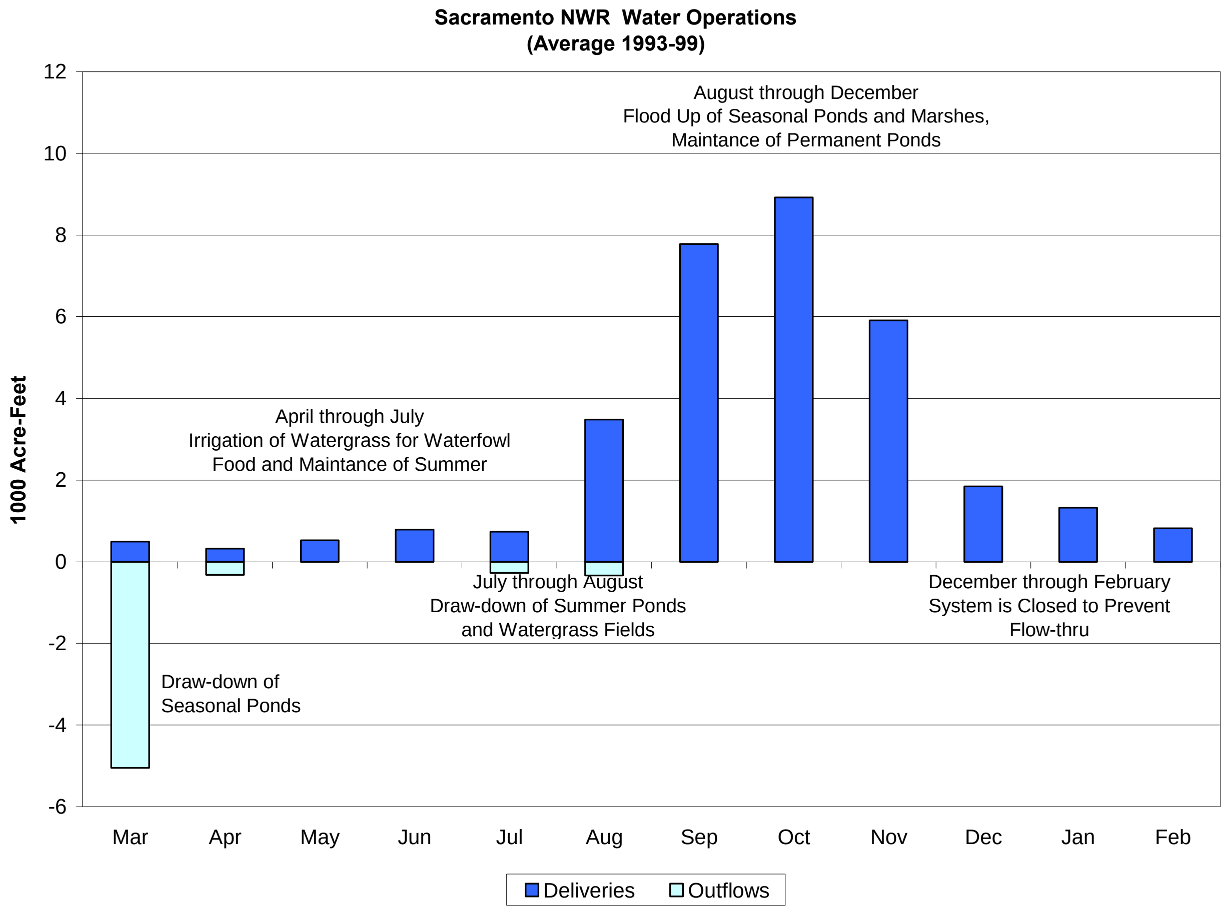
August – Water deliveries increase significantly as seasonal ponds begin to fill in preparation of the upcoming waterfowl migration. Additional watergrass and other crops are flooded to provide adequate food supply for wildlife. Summer ponds are drawn down and outflow returns to system or is reused to flood seasonal marshes.

September – Deliveries continue to increase towards peak levels as massive flood-up operations create additional wetland habitat to accommodate approaching migration of ducks and geese. There is no outflow into the system.

October – Continued flood–up of seasonal ponds and marshes to habitat water depth of 12" for preparation of upcoming waterfowl season. Permanent ponds are maintained at full depth (24"), and watergrass/wheat/millet crops are also maintained to provide food for winter waterfowl. Water deliveries to the refuges are at maximum levels. Refuge ponds are approaching full capacity, and there is no measurable outflow returning to the system.

November – All ponds are maintained at full capacity, and water is applied to crops for waterfowl feed. There is no measurable outflow.

December – Refuge is at full capacity; all ponds and marshes are maintained at maximum habitat depth. System is closed to prevent any outflow.


Sacramento NWR Water Operations
(Average 1993-99)
1000 Acre-Feet
12
10
8
6
4
2
0
-2
-4
-6
August through December
Flood Up of Seasonal Ponds and Marshes,
Maintance of Permanent Ponds
April through July
Irrigation of Watergrass for Waterfowl
Food and Maintance of Summer
July through August
Draw-down of Summer Ponds
and Watergrass Fields
December through February
System is Closed to Prevent
Flow-thru
Draw-down of
Seasonal Ponds
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Deliveries
Outflows

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1. U.S. Fish and Wildlife Service. 1968. National Wildlife Refuges – California.

2. Glenn – Colusa Irrigation District. 1963, 1973, 1983, 1992, 1996, 1999. Report on Water Measurement Program.

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4. U.S. Bureau of Reclamation, California Department of Fish and Game. December 1997. East and West Sacramento Valley Study Area – Conveyance of Refuge Water Supply Environmental Assessment and Initial Study.

5. U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service. September 1993. Implementation of the Central Valley Project Improvement Act.

6. Greg Mensik. Interviewed by phone during 6/2003. Sacramento National Wildlife Refuge, Willows, California

7. Ben Pennock. Interviewed by phone during 6/2003. Glenn-Colusa Irrigation District

8. Paul Forsburg. Interviewed by phone during 6/2003. California Department of Fish and Game

9. Andy Atkinson. Interviewed by phone during 6/2003. Sutter National Wildlife Refuge

10. Natalie Wolder. Interviewed by phone during 6/2003. U.S. Bureau of Reclamation

Attachment 3
Rice Irrigation Operations

The purpose of this exercise is to develop a better representation of rice irrigation practice in CalSim. CalSim currently uses the Department of Water Resources Consumptive Use (CU) model to develop the operation of rice water. The CU model simulates rice field ponding by using increases in soil moisture to represent ponding. This does an adequate job of representing ponding, but does not address flow-through water or applied water for seed germination. This paper suggests an operation that could be applied to the DWR CU model to better represent these operations.

Background

An ideal climate and a high level of sophisticated technology have given rise to California's unique water-seeded method of rice production, which produces the highest average annual rice yields in the world. Commercial rice production began in Butte County in 1912 and is now an important field crop in acreage and value. More than 90 percent of California's rice acreage is located in the Sacramento Valley; the remainder is in the north to central San Joaquin Valley. (Hill, et all)

California's rice is grown under a Mediterranean climate characterized by warm, dry clear days, and a long growing season favorable to high photosynthetic rates and high rice yields. Rice is grown mostly on fine-textured, poorly drained soils with impervious hardpans or claypans. These soils are well suited to rice production, since their low water permeability enhances water use efficiency. Most of the irrigation water for California rice comes from surface water. Less than 10 percent of rice irrigation water is pumped from wells in areas where surface water is not available, or as a supplement to surface supplies (Hall, et all). Surface water and most ground water are of very good quality for rice irrigation.

WATER MANAGEMENT

Rice in California is grown primarily in a continuously flooded, flow-through system. Water is supplied in a series from the topmost to the bottommost basin, and regulated by irrigation boxes placed in the levees between basins. However, outlets at the bottom of the system must be blocked during the growing season to reduce water movement for long periods in order to reduce pesticide release. Alternatively, water may be supplied to each basin via a head ditch or recirculated from the lowest point of the system.

Water depth in a rice field is controlled by rice boxes (weirs) placed in levees. Depth is increased or decreased by adding or removing "flash" boards in the boxes. The goal of early season water management is to establish a vigorous, healthy, weed-free crop stand. Shallow water promotes rice growth and root anchorage, but also favors weed growth. Deep water (7 to 8 inches) delays early season growth and tillering, but also greatly inhibit barnyard grass and watergrass, the most competitive weed species. A continuous flood of 4 to 5 inches generally provides good stand establishment and, coupled with an herbicide, good weed management. Drainage at any time during stand establishment may stimulate the germination and growth of new weeds.

Water depth is commonly raised to 8 inches or more soon after panicle initiation, submerging the reproductive organs and acting as a heat sink to buffer against colder nighttime temperatures. Exposure of the developing panicle to temperatures of 55°F or lower at 10 to 15 days before heading may significantly increase floret sterility (blanking). Growers greatly reduce or eliminate water inflow about 5 weeks before harvest, allowing water in the field to subside in preparation for drainage. Very flat fields may be difficult to drain.

The timing of drainage is critical, since residual moisture must be available throughout grain filling, but the soil should be dry enough at harvest to support heavy equipment. Generally, fields are drained when the panicles are fully tipped and golden. Rice variety, soil type, and lateness of the season influence drainage strategy.

Typical seasonal water delivery for California's rice has been estimated to be as high as 6 to 7.5 acre-feet per acre in continuous, flow-though systems. However, 3 to 3.5 acre-feet are required for evapotranspiration, and in most rice soils 0.5 to 2 acre-feet go to deep percolation. The balance flows through the field and may be reused many times within irrigation districts before it is returned to public waters. Although rice is flooded throughout most of the growing season, net water use is similar to that of pasture, alfalfa, cotton, and several tree and vegetable crops.

MONTHLY RICE IRRIGATION OPERATIONS

The water operations for rice are described in terms of depth of applied water on a monthly basis. Figure 1 contains a summary of the monthly operation. Todd Hillaire of DWR Northern District and Jack Williams of the UC Davis Sutter Extension supplied monthly applied water unit duties. Unit Duties were created for winter rice straw decomposition practices based on the draft report "Rice Straw Decomposition Practices", created by MBK Engineers in May of 2003. Monthly flow-thru was estimated from the information provided to us by Todd Hillaire and Jack Williams. A monthly description of water inflows and outflows is as follows:

> **January** – Seasonal precipitation is captured and used to maintain water levels for rice straw decomposition. Water levels may subside as hunting season comes to a close and system is opened to allow flow-thru.
>
> **February** – Water levels subside as ponds are drawn-down and flow through the system. High levels of precipitation prevent any tillage of the soil.
>
> **MARCH –** SYSTEMS REMAIN OPEN TO ALLOW FLOW-THRU OF SEASONAL PRECIPITATION AND RICE DECOMPOSITION WATER.
>
> **April** – Begin tillage of field to prepare for planting, construction of levee checks and installation of rice boxes (weirs) to control water flow between basins

May – Early May flood up ~ 6 inches → 3 inches of recharge to saturate soil and 3 inches of water depth for seep application. Mid-May discharge ~ 3 inches after seeding. Late-May gradually flood-up to 3-4 inches water depth.

June – Flood-up to reach a June/early July cultural water depth of roughly 5 inches. Herbicide application – assume 30 day lock-up for no flow-through in system (continued into July depending on planting date).

July –Herbicide application – assume continued 30 day lock-up for no flow-through in system in late seasons. Water level is maintained at 5-7 inches.

August –Flood-up to reach a final cultural water depth of 6-8 inches. In colder years water depths of 8-12 inches are used to create overnight heat storage.

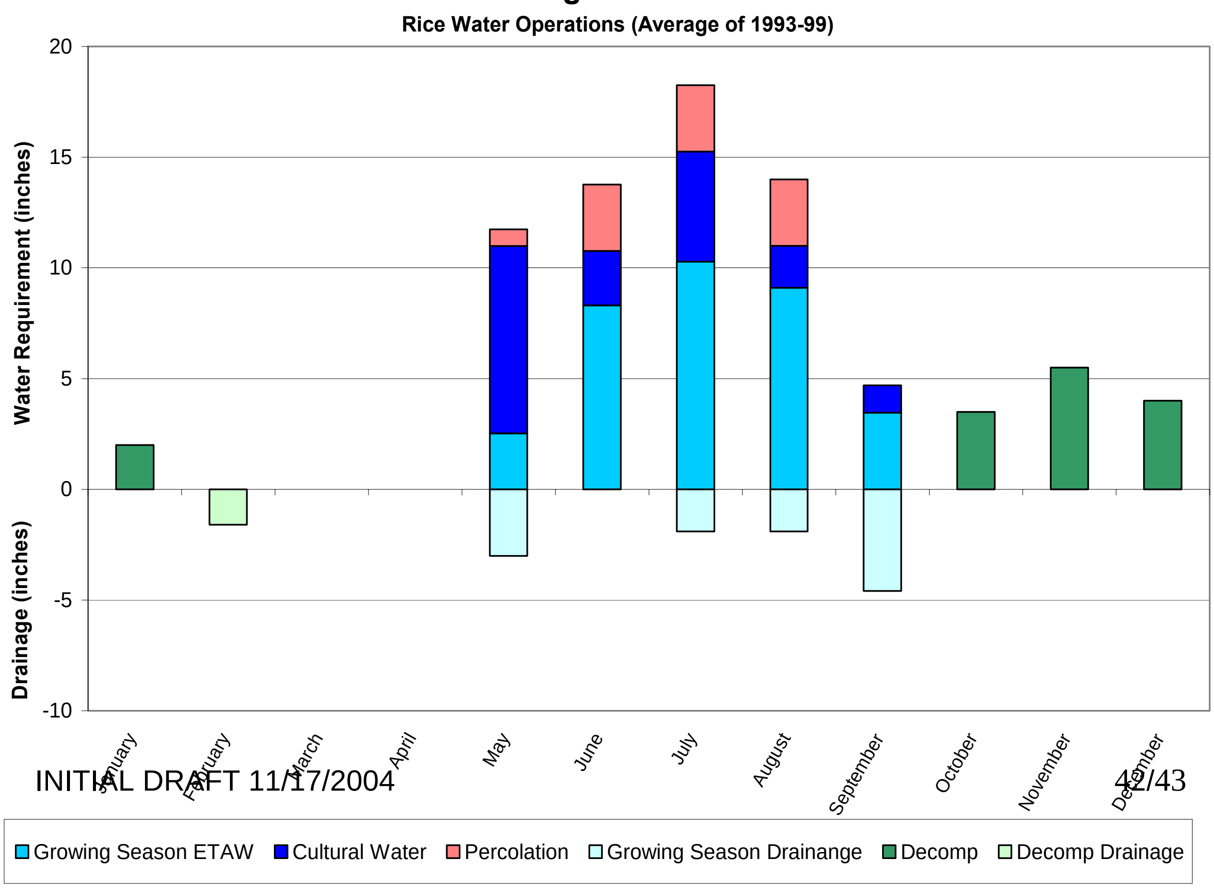
September –Fields are gradually lowered to 4-5 inches in total water depth through percolation and ETAW. As water deliveries are cut off, ET is still occurring in the plant. Deep percolation and flow thru still apply to water in field. Fields must be dry enough to support heavy equipment for harvest.

October – Rice is harvested and removed from fields. Straw is chopped and spread by combine or chopping implement. Fields may begin flood-up for rice straw decomposition and waterfowl habitat if water is available.

November – Begin / maintain flood-up ~ for rice straw decomposition and waterfowl habitat, system is closed to prevent flow-thru

December – Continue to maintain winter ponds at 2-6 inches for rice straw decomposition and waterfowl habitat, system is closed to prevent flow-thru

Figure 1



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