consultant's report to the department of water resources, municipal water quality investigations unit

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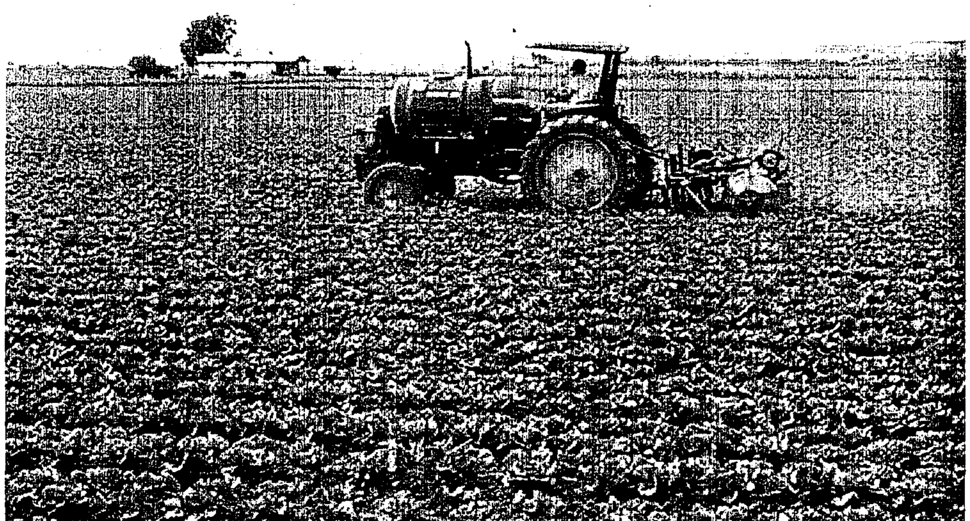
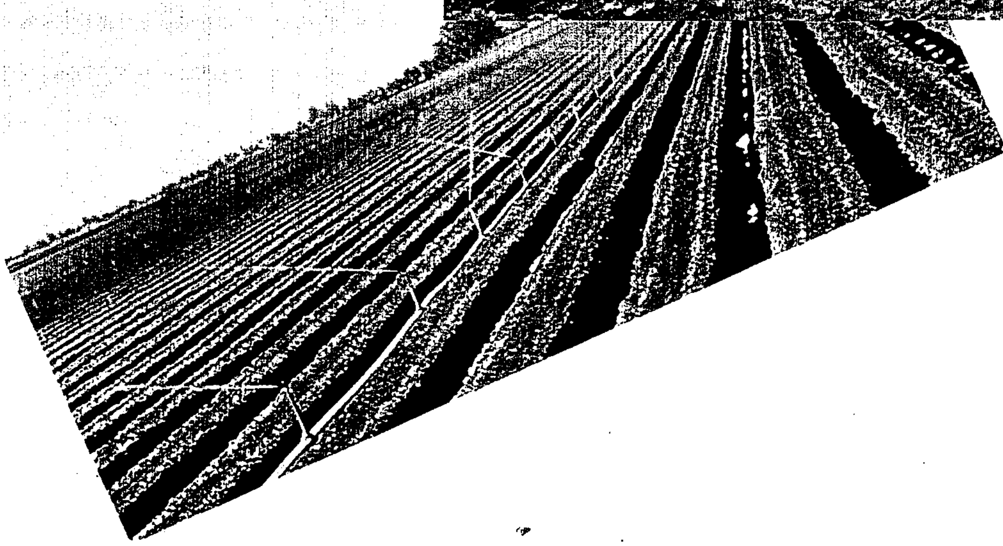
delta island Drainage Volume estimates

1954-1955 versus 1995-1996

This report prepared under DWR contract B80985 by Marvin Jung & Associates, Inc. for the Department of Water Resources, Division of Planning and Local Assistance, Water Quality Assessments Branch

Marvin Jung
Quy Tran





January 1998

Consultant's Report to the Department of Water Resources
Municipal Water Quality Investigations Program

Delta Island Drainage Volume Estimates 1954-1955 versus 1995-1996

Marvin Jung [1]
Quy Tran [2]

1/ Water quality consultant, Marvin Jung & Associates, Inc., 1370 Pebblewood Drive, Sacramento, California 95833-1611, (916) 929-0722.

2/ University of California at Davis Engineering student, 5960 South Land Park Drive #209, Sacramento, California, 95822-3313, (916) 422-4447.

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Table of Contents

List of Tables

List of Figures

1. Introduction

The Department of Water Resources conducted a comprehensive study of applied and irrigation return water in the Sacramento-San Joaquin Delta Lowlands in 1954 and 1955. The results were published in "Quantity and quality of waters applied to and drained from the delta lowlands", DWR Report number 4, 1956. Monthly drain water discharges from May 1954 to October 1955 were computed by using electrical power use and pump test data. Descriptions of crops grown on different soil types and the average mineral concentrations in the water were also presented in the report.

In a cooperative agreement with DWR, the USGS evaluated the feasibility of estimating present-day drainage volumes from power use and pump test records and to compare historical land uses in the delta. Pump efficiency and power use data were obtained for January 1995 to February 1996. The results were published in USGS open-file report 97-350, "Drainage-return, surface-water, and land-use data for the Sacramento-San Joaquin delta with emphasis on Twitchell Island, California".

This consultant's report compares the 1954-55 drainage volume estimates in DWR Report No. 4 (1956) to the recent USGS findings. The approaches, limitations, and assumptions used in the estimates are compared and explained.

Drainage volume data affects DWR computer model results for projecting past and future water use and water quality. Mass load computations of drain water constituents, such as salts and organic carbon, depend on drainage volume estimates. Reasonable mass load estimates are essential for modeling water quality impacts from proposed CALFED alternatives, including the treatment of agricultural drainage to reduce organic carbon. Agreement is needed on what are reasonable drainage volume estimates to use in modeling and in water quality assessment studies of the Sacramento-San Joaquin Delta. It is the first step for comparing current baseline conditions to future alterations in the delta that may affect both agriculture and the reliability of treating water from the delta for domestic and industrial uses.

2. Approach and Results

A comparison was made of the monthly total drainage volumes for the delta lowlands from the two studies. The delta lowlands is geographically defined as those lands at the five-foot contour and below. Additional comparisons were made of rainfall, land use, drainage by subregions and by season, and the completeness of the data sets that were used. If there were significant differences in the drainage estimates of the two studies, these additional comparisons might explain them.

Monthly drainage totals

The monthly total delta lowland drainage results from the two studies are charted in Table 1 and plotted in Figure 1. The dashed lines located above and below the solid lines represent 110 and 90 percent values, respectively. Overall, the 1954 and 1955 volumes were significantly higher (i.e., more than ten percent) than the 1995 and 1996 estimates. The January through October 1954 total was 554,481 AF and the January through December 1995 total was 394,930 AF for the lowland area.

There were some similarities in the seasonal patterns between the two studies. Higher drainage volume was observed in the summer during heavy irrigation, less drainage in the fall after harvest, with another increase in drainage volume in the winter due to rainfall events and some field leaching. The monthly drainage volumes for May through September of 1954 and 1955 were nearly identical. However, the differences in monthly totals between the two study

Table 1. Monthly total delta lowland drainage, 1954, 1955, 1995, and 1996[1]

	Drainage (ac-ft)											
Month	-10%	1954	+10%	-10%	1955	+10%	-10%	1995[2]	+10%	-10%	1996[2]	+10%
January				86101.2	95668.0	105234.8	33222.6	36914.0	40605.4	45047.7	50053.0	55058.3
February				37764.0	41960.0	46156.0	39678.3	44087.0	48495.7	48449.7	53833.0	59216.3
March				29177.1	32419.0	35660.9	54513.9	60571.0	66628.1			
April				33865.2	37628.0	41390.8	35271.0	39190.0	43109.0			
May	50147.1	55719.0	61290.9	44831.7	49813.0	54794.3	37525.5	41695.0	45864.5			
June	63515.7	70573.0	77630.3	63975.6	71084.0	78192.4	24929.1	27699.0	30468.9			
July	72517.5	80575.0	88632.5	72545.4	80606.0	88666.6	30501.0	33890.0	37279.0			
August	63771.3	70857.0	77942.7	64953.0	72170.0	79387.0	42058.8	46732.0	51405.2			
September	40101.3	44557.0	49012.7	38804.4	43116.0	47427.6	16929.0	18810.0	20691.0			
October	42135.3	46817.0	51498.7	27015.3	30017.0	33018.7	11828.7	13143.0	14457.3			
November	41883.3	46537.0	51190.7				9427.5	10475.0	11522.5			
December	77157.9	85731.0	94304.1				19551.6	21724.0	23896.4			

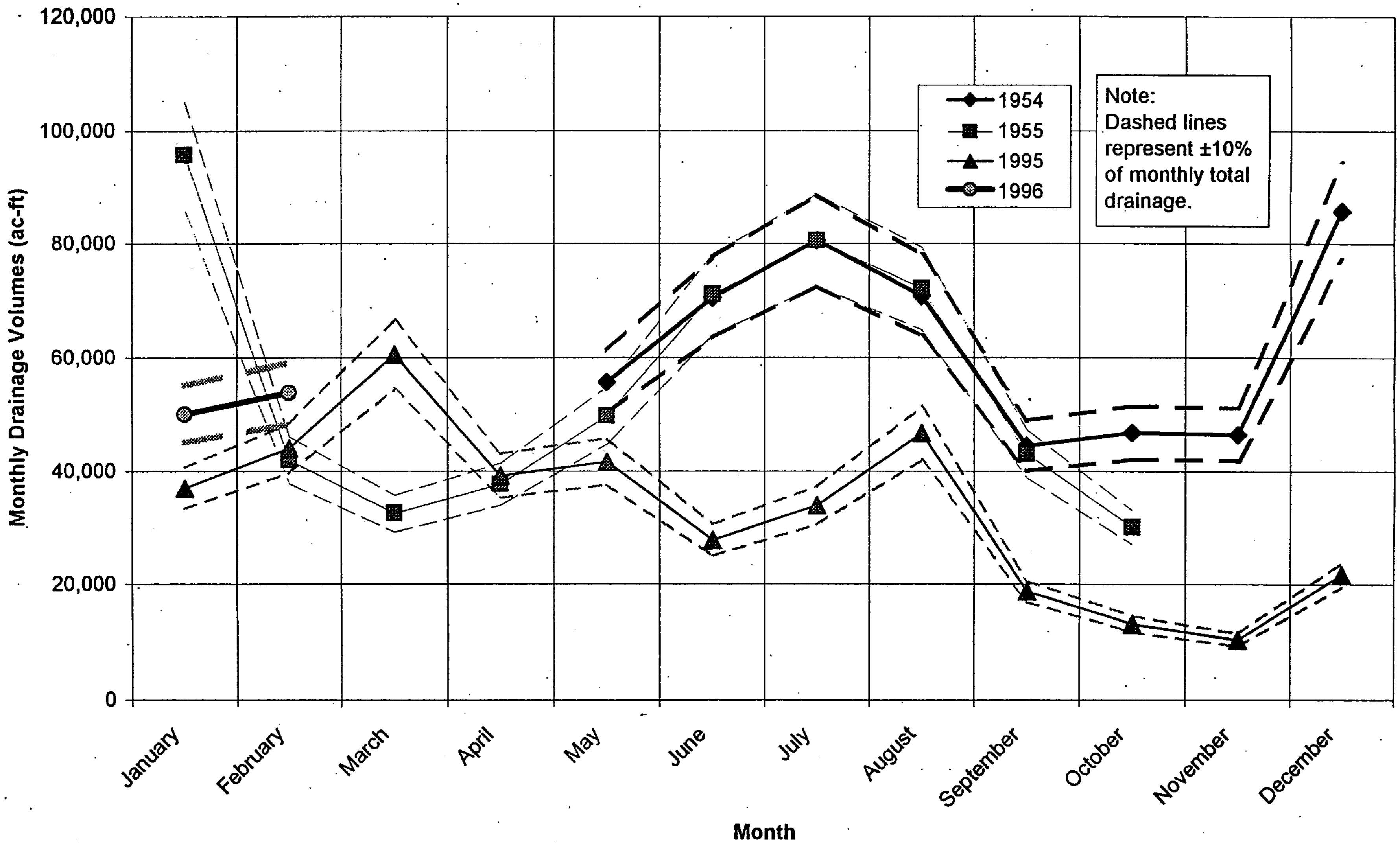
Picture of agricultural drainage pipes on Twitchell Island.

[1] 1954-1955 data published in "Quantity and quality of waters applied to and drained from the delta lowlands", DWR Report number 4, 1956. 1995-1996 data published in USGS open-file report 97-350, "Drainage-return, surface-water, and land-use data for the Sacramento-San Joaquin delta with emphasis on Twitchell Island, California".

[2] 1995 and 1996 drainage were calculated by subtracting drainage from area outside the Delta uplands and lowlands and from Delta uplands from the total amount of drainage in the Delta.

Year	Month	Total	([1])	([2])	Total-([1])-([2])
1995	January	37663.0	5	744	36914.0
	February	45531.0	59	1385	44087.0
	March	61855.0	4	1280	60571.0
	April	42139.0	90	2859	39190.0
	May	45194.0	301	3198	41695.0
	June	33303.0	538	5066	27699.0
	July	38994.0	323	4781	33890.0
	August	53086.0	538	5816	46732.0
	September	23960.0	555	4595	18810.0
	October	16200.0	233	2824	13143.0
	November	11204.0	115	614	10475.0
	December	22050.0	8	318	21724.0
1996	January	50564.0	25	486	50053.0
	February	55073.0	41	1199	53833.0

Figure 1. Monthly total delta lowland drainage, 1954, 1955, 1995, and 1996



periods were significantly different as to warrant a comparison of factors that might explain the disparity between the two studies.

Rainfall

Monthly total rainfall data were obtained for weather stations at the City of Sacramento and Fire station #4 in Stockton (Table 2). The data was tabulated for the months and years of the two studies and one year prior. This was done to determine if less rainfall in the year proceeding the study years might have caused increased leaching of fields to remove salt deposits in the following fall-winter. This, in turn, would have increased water applications and drainage volume in the fall-winter months.

The rainfall data were grouped into years 1953-1955 (Figure 2) and years 1994-1996 (Figure 3). In some instances, there were significant differences in the cumulative monthly totals between the two weather stations but there was general agreement with the seasonal patterns. The wet period was November through May and the dry period extended from June to October. Trace amounts of rainfall occurred during the dry season in all of the years that were compared.

The months with the highest cumulative total of rainfall, measured at Sacramento and at Stockton, respectively, during the two studies were December 1954 (4.93", 3.19"), January 1955 (7.58", 3.84"), January 1995 (12.35", 8.44"), March 1995 (7.84", 6.87"), December 1995 (5.14", 5.86"), and February 1996 (6.09", 4.87").

Table 2. Monthly total rainfall

	Rainfall (inches)											
	Sacramento City						Stockton Fire Station #4					
Month	**1953**	**1954**	**1955**	**1994**	**1995**	**1996**	**1953**	**1954**	**1955**	**1994**	**1995**	**1996**
January	3.51	3.14	7.58	2.16	12.35	3.30	1.81	1.50	3.84	1.76	8.44	4.86
February	0.21	1.33	2.43	3.17	0.19	6.09	0.02	1.60	1.03	2.26	0.43	4.87
March	1.42	0.37	0.03	0.07	7.84	2.30	0.93	3.27	0.57	0.15	6.87	2.33
April	2.69	1.86	1.66	0.77	1.90	1.93	1.76	1.41	2.38	1.32	1.04	1.31
May	0.52	0.96	1.78	1.65	1.01	2.22	0.64	0.28	1.02	1.12	0.78	1.62
June	0.61	0.00	0.00	0.00	0.53	0.00	0.42	0.40	0.00	0.00	0.41	0.00
July	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
August	0.67	0.35	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
September	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.00	0.00
October	0.18	0.02	0.57	0.45	0.00	0.76	0.20	0.00	0.12	0.09	0.00	1.70
November	1.79	3.35		3.96	0.00	1.49	0.69	2.23	1.30	2.36	0.00	3.02
December	0.56	4.93		3.54	5.14	5.82	1.12	3.19	8.42	1.30	5.86	6.49

Figure 2. Monthly total rainfall, 1953-1955

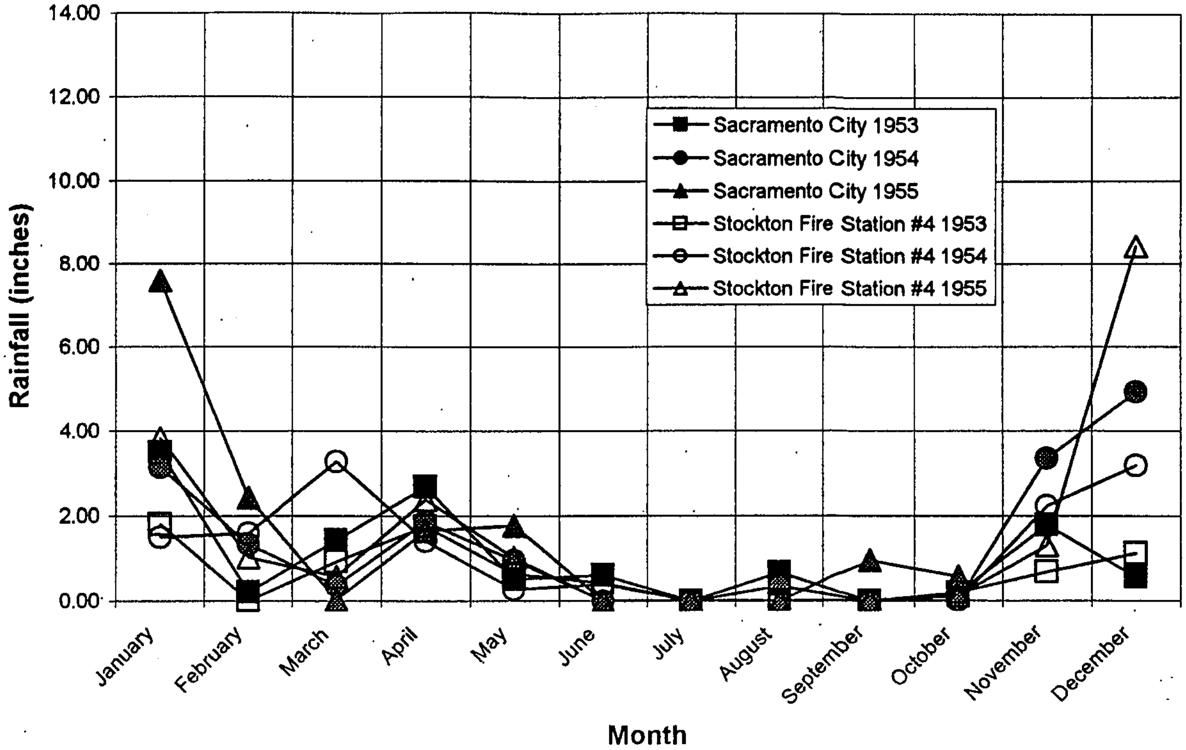
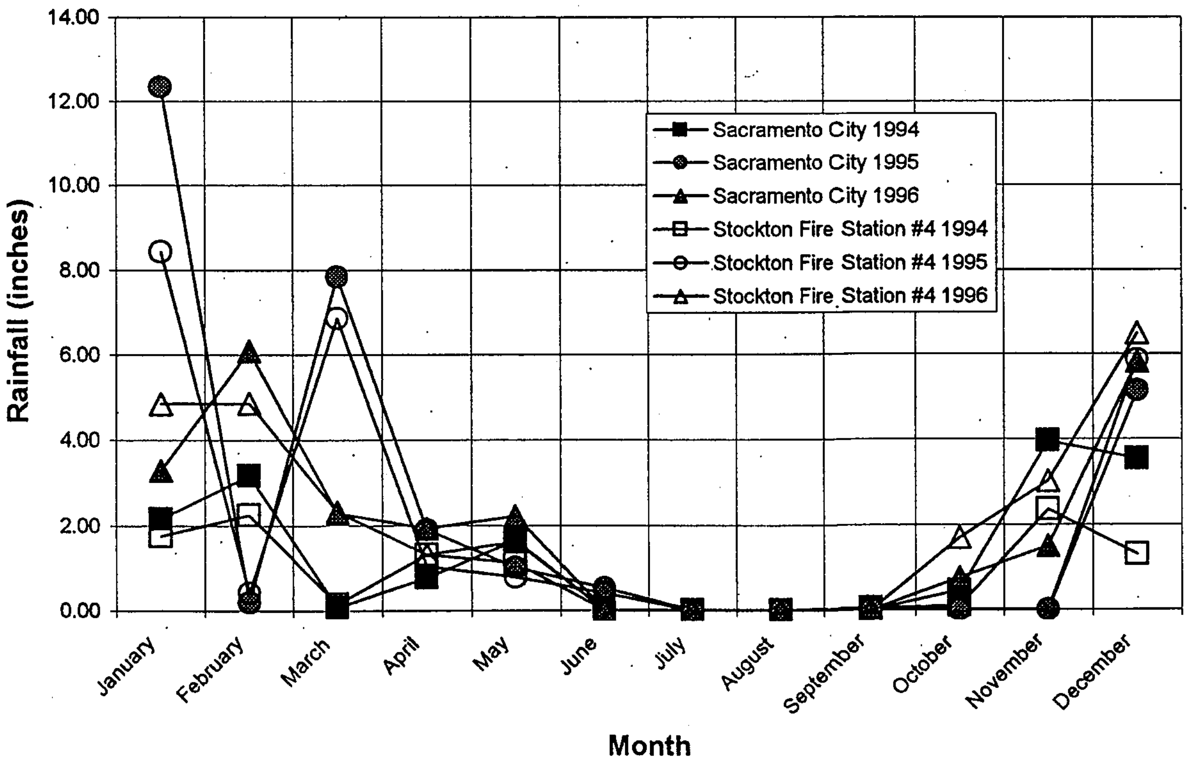


Figure 3. Monthly total rainfall, 1994-1996



If there were a strong relationship between the monthly cumulative rainfall total and the volume of drainage in the wet season when irrigation water is not applied or is minimal, we would expect more drainage to occur during the wettest months. This correlation was more consistently seen in the 1954-55 study than in the 1995-96 study.

The total drainage was over 80,000 acre-feet in December 1954 when 4.93 inches of rain fell in Sacramento (3.19 inches at Stockton). It was over 90,000 acre-feet when 7.58 inches of rain fell in Sacramento (3.84 inches in Stockton) in January 1955.

The December 1954 precipitation in the delta lowlands was estimated to be 127,579 acre-feet with a combined total water disposal from drainage (85,731 AF) and consumptive use (32,915 AF) to be 118,646 AF. The January 1955 precipitation was estimated to be 104,161 acre-feet and combined total water disposal from drainage (95,668 AF) and consumptive use (22,371 AF) to be 118,039 AF.

The January 1995 drainage estimate was under 40,000 acre-feet when rainfall was 12.35 inches in Sacramento (8.44 inches at Stockton). The March 1995 drainage estimate increased to 60,000 acre-feet when rainfall was 7.84 inches in Sacramento (6.87 inches at Stockton). Drainage estimates for December 1995 (20,000 AF) and February 1996 (55,000 AF) increased slightly from the previous months but were not as high as the 80,000 AF December 1954 drainage total when rainfall was much less at 4.93 inches in Sacramento (3.19 inches at Stockton). Therefore, the differences in rainfall amounts that occurred in 1954-55 and 1995-96 cannot account for the significant differences in total monthly drainage in the delta lowlands that were computed in the two studies. There was less rainfall and higher total drainage volume during the wettest months in the 1954-55 study than during the 1995-96 study. We would have expected more drainage in the wettest months of 1995-96 than in 1954-55 because of more rainfall.

Neither study attempted to determine the quantity of water applied for leaching purposes in the fall-winter because of wide variations in leaching practices. However, the December 1954- January 1955 data in DWR Report 4 indicated that precipitation was the major supply of water being drained and consumed (consumptive use) as shown by insignificant applied water volumes.

Drainage by region and season

The drainage volumes of different regions of the delta lowlands were compared to determine if there had been significant reductions in drainage volume at some islands and tracts that might explain the lower total delta lowland drainage estimates in the 1995-96 study.

In the 1954-55 study, the delta lowlands were divided into 27 subdivision units for tabulating drainage volume. Each subdivision unit was comprised of one or more islands or tracts (Figure 4). In the 1995-96 study, the USGS could not release information to the public about pumping data for individual accounts or for areas less than 36 square miles because of a confidentiality agreement with Pacific Gas and Electric Company. To enable a comparison of the past data with current pumping data, the USGS aggregated estimates for drainage return into 15

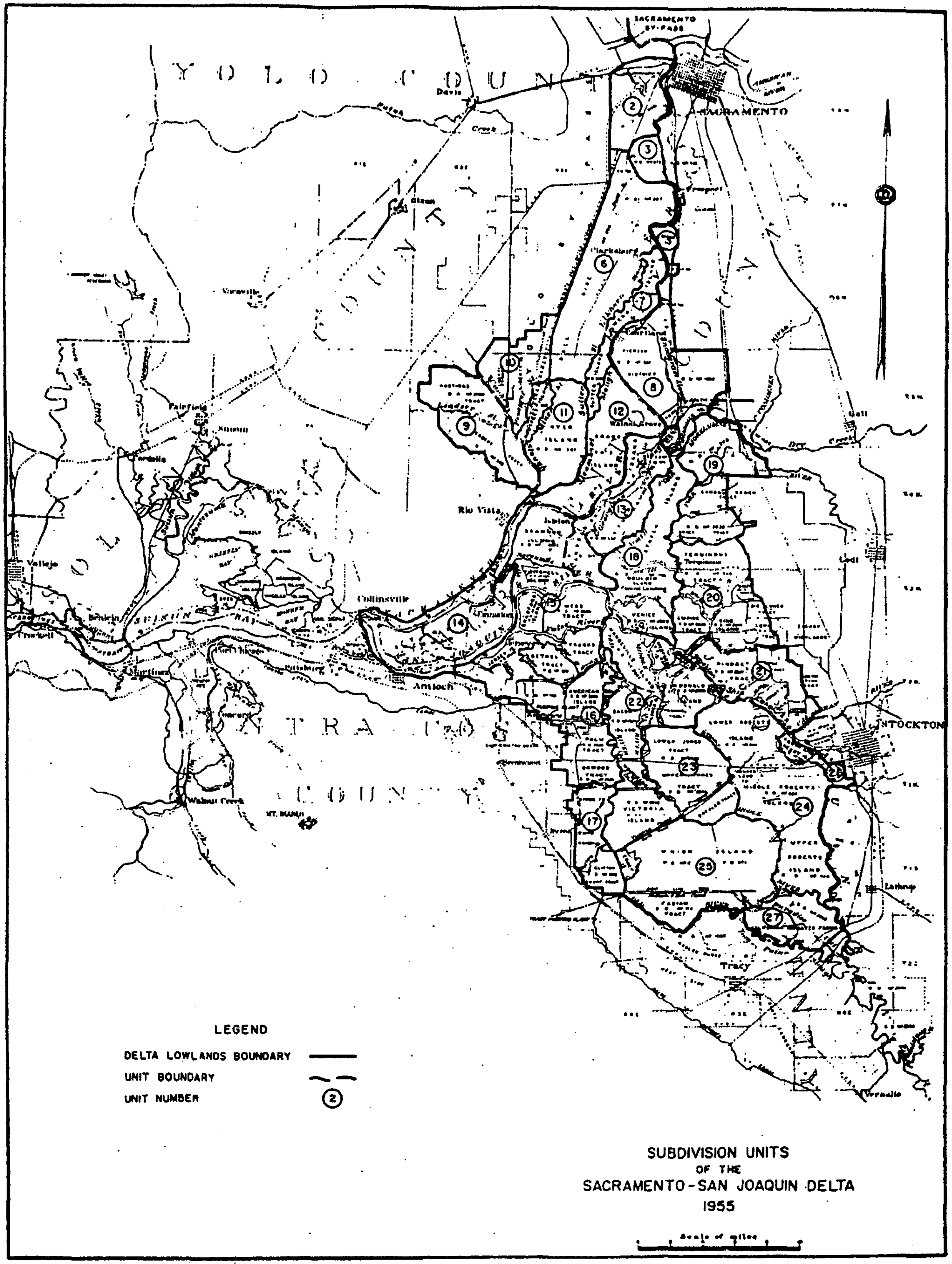


Figure 4. Delta subregions in 1954-1955 Department of Water Resources study

areas for the delta lowlands (Figure 5). Map overlays of subregions from the two studies were used to compile a table showing corresponding delta subunits of both studies for our comparisons of land use and drainage estimates (Tables 3 and 4). In addition, reported in Table 3 are corresponding subareas used in DWR's Delta Island Consumptive Use (DICU) Model. DWR's DICU Model subareas are illustrated in Figure 6.

For both studies, the monthly drainage volumes by subareas are shown in Table 5. The monthly subarea estimates were divided by the monthly delta lowlands total to compute the monthly proportion (in percentage) of total delta lowland drainage from each subarea. The monthly and average proportions are presented in Table 6. The average monthly proportion of total delta drainage by each subarea is shown in Figure 7.

The lowland subareas fell into three subgroups based on the average monthly proportion of total delta lowland drainage. High drainage regions were those areas that discharged a monthly average of more than 11% of the total delta lowland drainage. Medium drainage regions discharged between more than 5% and less than 11% of the total drainage. Low drainage regions discharged less than 5% of the total monthly lowland drainage.

Figure 8 shows these regions of high, medium, and low drainage discharges. The high drainage volume areas were located in the eastern and central delta, the medium drainage volume areas in the western and southern delta, and the lowest drainage areas in the extreme northern and southern delta. For comparison, the high, medium, and low drainage areas of the two studies were color-coded and mapped to determine if drainage discharges had changed

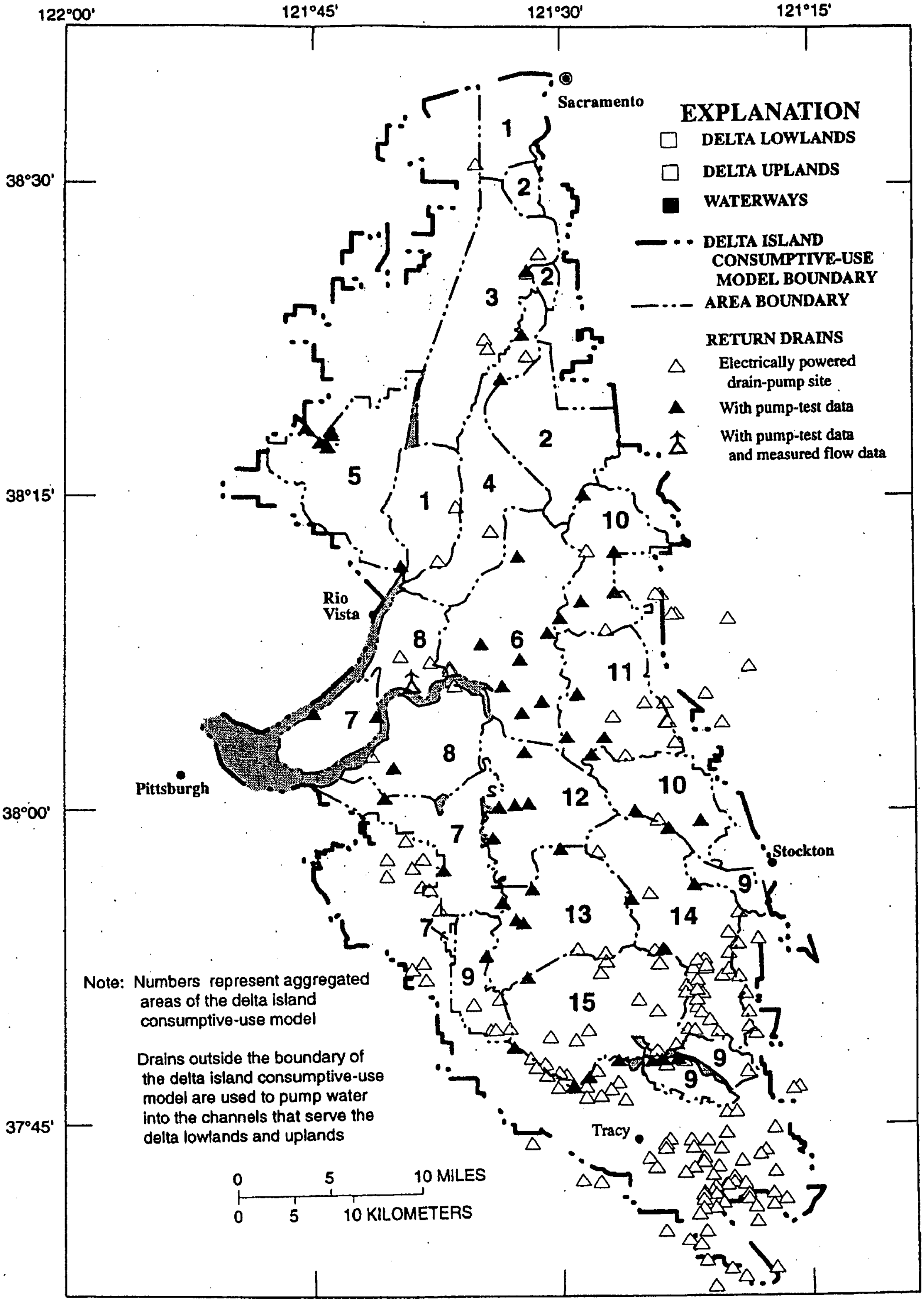


Figure 5. Delta aggregated areas in the 1995-1996 USGS study

Table 3. Subareas of delta studies

USGS Aggregated Areas	DWR DICU Model Subareas	DWR Report #4 Subunits
01	14, 38, 46	02, 11
02	20, 21, 24, 26, 27, 28, 35, 40, 94, 96, 97, 99, 100	03, 08
03	06, 30, 39	06
04	03, 05, 10, 98	07, 12
05	16, 68, 78, 83, 87, 127	09, 10
06	07, 13, 22, 23, 29, 48, 119, 140	13, 18
07	08, 32, 49, 50, 57, 71, 123, 129, 138	14, 16
08	37, 42, 51, 67, 72, 131, 133, 134, 135, 136, 142	15
09	11, 12, 33, 34, 65, 69	17, 26, 27
10	09, 43, 56, 58, 75, 80, 102, 105, 108, 112, 114, 116, 120	19, 21
11	19, 54, 63, 64, 115, 117	20
12	47, 52, 53, 55, 62, 109, 110, 111, 118	22
13	59, 60, 61, 74, 107	23
14	15, 18, 25, 113	24
15	01, 02, 31, 82, 132	25

Table 4. Correspondence of major island names to USGS aggregated areas[1]

USGS Aggregated Areas	Major Islands, Tracts, and Ranches
01	Prospect Island, Ryer Island
02	McCormack Tract, Pierson District
03	Reclamation District No. 999
04	Grand Island, Merritt Island, Sutter Island
05	Egbert Tract, Hastings Tract, Liberty Island
06	Bouldin Island, Staten Island, Tyler Island, Venice Island
07	American Island, Orwood Tract, Palm Tract, Sherman Island
08	Bether Tract, Bradford Island, Brannan Island, Franks Tract, Jersey Island, Twitchell Island, Web Tract
09	Baird Ranch, Byron Tract, California Irrigated Farms, Clifton Court Tract, Rough and Ready Island
10	Brack Tract, Canal Ranch, Rindge Tract, Wright Tract
11	Empire Tract, King Island, Terminous Tract
12	Bacon Island, Mandeville Tract, McDonald Island, Medford Island, Mildred Island
13	Drexler Tract, Lower Jones Tract, Upper Jones Tract, Victoria Island, Woodward Island
14	Lower Roberts Island, Middle Roberts Island, Upper Roberts Island
15	Coney Island, Fabian Tract, Union Island

[1] Not all islands, tracts and ranches were included. Names utilized for orientation purposes.

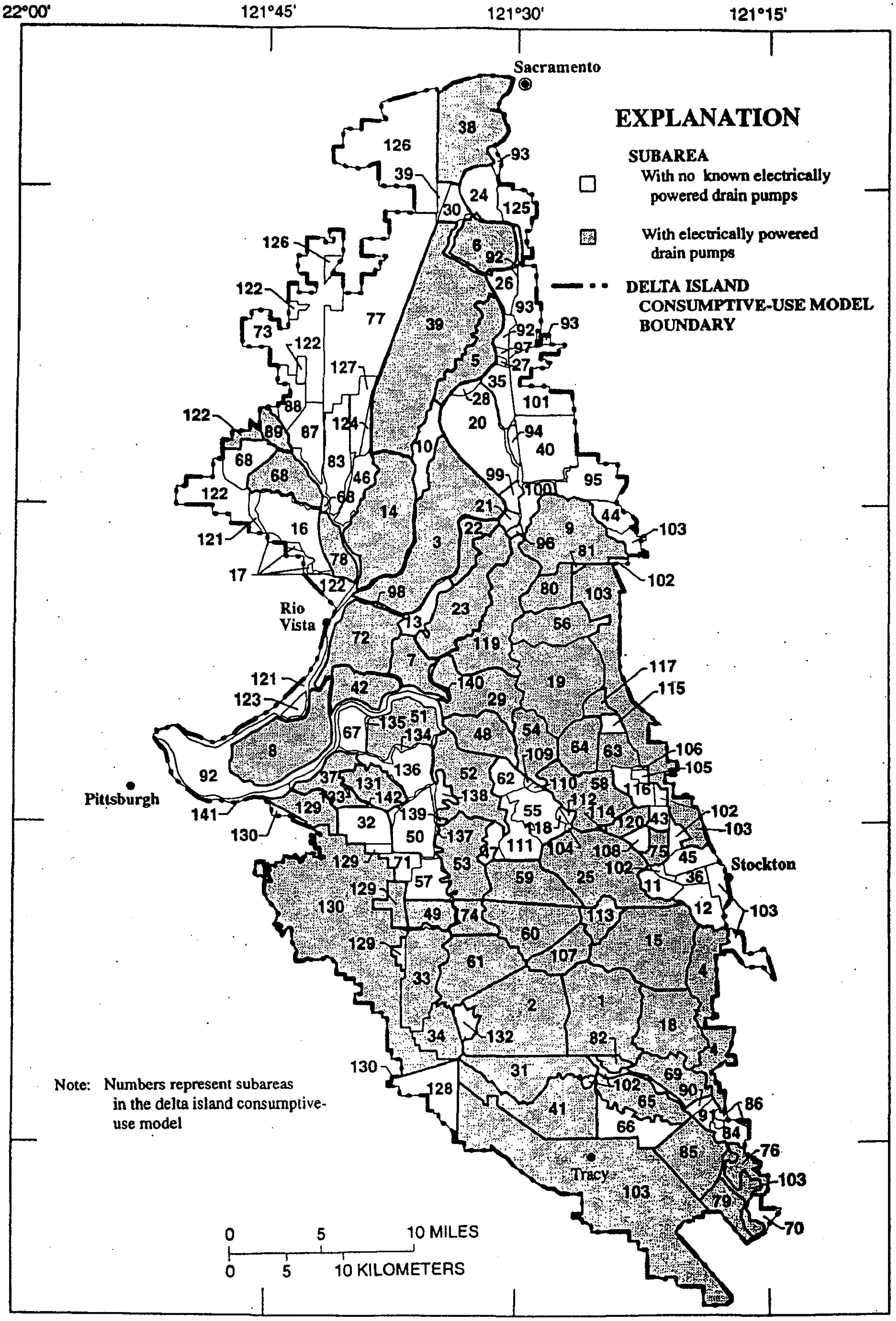


Figure 6. Department of Water Resources delta island consumptive use model subunits

Table 5. Drainage volumes by USGS aggregated area and by month[1,2]

Aggregated Areas of USGS Study	Acres	May-54	Jun-54	Jul-54	Aug-54	Sep-54	Oct-54	Nov-54	Dec-54	Jan-55	Feb-55	Mar-55	Apr-55	May-55	Jun-55	Jul-55	Aug-55	Sep-55	Oct-55
1	25567	1665	1697	1337	1350	770	709	753	2055	2098	955	637	979	792	1349	1433	1411	591	551
3	33027	617	388	339	299	359	358	1480	2541	2944	2159	771	401	293	235	314	269	227	320
4	24387	2918	3261	3663	3031	1514	1073	1664	3295	3774	2056	1911	2811	2430	4110	4141	3810	1093	680
5	27152	1633	2493	3131	3056	1845	1213	1009	1465	1478	604	646	1500	1277	2058	2282	2507	1691	1160
6	35145	5596	10205	13073	9812	7105	7453	4554	7047	6139	3202	2709	2520	4473	7178	12512	10103	4481	3319
7	33014	3844	4565	4374	4107	2795	2748	2559	4970	5969	3115	3024	4161	3321	4230	4600	2890	2356	2402
8	26424	2583	2463	3005	2879	2055	2957	3425	4851	5721	2871	2782	2544	1801	2425	2805	3398	2079	2021
9	23149	1757	1713	2754	2111	1181	1347	1385	4191	3874	1316	1694	2640	2179	2330	3103	2861	1854	810
10	32763	5661	7570	9881	9012	5386	4207	5060	10141	9926	3986	2761	3651	6491	8500	9157	7858	5355	3450
11	21302	5456	9197	10223	10410	4627	4582	5639	10209	14637	3840	2016	3533	6521	10456	11726	11870	8521	3505
12	19357	12368	15756	15252	12942	8629	9306	8637	10635	12773	7385	5127	3949	10734	16862	15557	12826	6142	5302
13	24493	2396	3032	3917	3259	1974	3790	3514	9308	11828	3229	2103	1843	2018	2481	2056	2818	1663	1981
14	32879	2125	2500	2964	2839	1849	2103	2795	8907	9189	3410	2053	2135	2355	2649	2862	2929	2285	1974
15	33212	2335	2197	3773	2289	1237	892	971	3812	3678	2188	1958	2540	2233	2553	3574	3217	2068	922
Total	391871	50954	67037	77686	67396	41326	42738	43445	83427	94028	40316	30192	35207	46918	67416	76122	68767	40406	28397
Acre Feet per Area		0.13	0.17	0.20	0.17	0.11	0.11	0.11	0.21	0.24	0.10	0.08	0.09	0.12	0.17	0.19	0.18	0.10	0.07

Aggregated Areas of USGS Study	Acres	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Feb-96
1	25567	0	0	0	384	0	0	0	0	0	0	0	0	0	0
3	33027	1037	953	838	1413	329	294	164	182	109	9	13	50	276	688
4	24387	0	1638	591	1756	726	4487	406	490	8	216	0	152	404	1146
5	27152	0	1205	2472	288	472	671	1156	1261	0	157	145	264	437	1295
6	35145	3086	6233	19409	3254	9545	5046	4573	8957	1634	1910	2217	7313	13432	9838
7	33014	37	2523	2310	2251	834	885	1345	26	0	41	45	187	208	538
8	26424	95	173	6374	163	13463	525	2425	2865	0	391	662	2175	3451	3828
9	23149	184	1047	225	2098	2246	2095	3436	3614	62	1438	188	372	210	487
10	32763	8383	6941	10683	5367	3953	3542	7133	7529	5197	2594	1971	4286	4361	12391
11	21302	4907	2681	6227	2441	1010	2196	4278	3844	1784	582	592	3000	4635	6252
12	19357	7115	5262	4865	5620	1409	2063	2082	6062	2809	1623	1896	1547	8024	4963
13	24493	7832	11689	3851	10253	2998	2570	1754	6612	2882	1905	1927	1788	10876	7701
14	32879	3627	3626	1297	3586	3277	2596	4015	4368	3879	1875	705	303	3266	3841
15	33212	611	116	1429	316	1433	729	1123	922	446	402	114	287	473	865
Total	391871	36914	44087	60571	39190	41695	27699	33890	46732	18810	13143	10475	21724	50053	53833
Acre Feet per Area		0.09	0.11	0.15	0.10	0.11	0.07	0.09	0.12	0.05	0.03	0.03	0.06	0.13	0.14

[1] 1954-1955 data obtained by summing DWR Report #4 subunits to equivalent USGS aggregated areas.

[2] Unless otherwise noted, drainage volumes are in acre feet.

Table 6. Percentage of total delta drainage contributed by each USGS aggregated area

USGS Aggregated Areas	May-54	Jun-54	Jul-54	Aug-54	Sep-54	Oct-54	Nov-54	Dec-54	Jan-55	Feb-55	Mar-55	Apr-55	May-55	Jun-55	Jul-55	Aug-55	Sep-55	Oct-55	Average
1	3.3%	2.5%	1.7%	2.0%	1.9%	1.7%	1.7%	2.5%	2.2%	2.4%	2.1%	2.8%	1.7%	2.0%	1.9%	2.1%	1.5%	1.9%	2.1%
3	1.2%	0.6%	0.4%	0.4%	0.9%	0.8%	3.4%	3.0%	3.1%	5.4%	2.6%	1.1%	0.6%	0.3%	0.4%	0.4%	0.6%	1.1%	1.5%
4	5.7%	4.9%	4.7%	4.5%	3.7%	2.5%	3.8%	3.9%	4.0%	5.1%	6.3%	8.0%	5.2%	6.1%	5.4%	5.5%	2.7%	2.4%	4.7%
5	3.2%	3.7%	4.0%	4.5%	4.5%	2.8%	2.3%	1.8%	1.6%	1.5%	2.1%	4.3%	2.7%	3.1%	3.0%	3.6%	4.2%	4.1%	3.2%
6	11.0%	15.2%	16.8%	14.6%	17.2%	17.4%	10.5%	8.4%	6.5%	7.9%	9.0%	7.2%	9.5%	10.6%	16.4%	14.7%	11.1%	11.7%	12.0%
7	7.5%	6.8%	5.6%	6.1%	6.8%	6.4%	5.9%	6.0%	6.3%	7.7%	10.0%	11.8%	7.1%	6.3%	6.0%	4.2%	5.8%	8.5%	6.9%
8	5.1%	3.7%	3.9%	4.3%	5.0%	6.9%	7.9%	5.8%	6.1%	7.1%	9.2%	7.2%	3.8%	3.6%	3.7%	4.9%	5.1%	7.1%	5.6%
9	3.4%	2.6%	3.5%	3.1%	2.9%	3.2%	3.2%	5.0%	4.1%	3.3%	5.6%	7.5%	4.6%	3.5%	4.1%	4.2%	4.6%	2.9%	4.0%
10	11.1%	11.3%	12.7%	13.4%	13.0%	9.8%	11.6%	12.2%	10.6%	9.9%	9.1%	10.4%	13.8%	12.6%	12.0%	11.4%	13.3%	12.1%	11.7%
11	10.7%	13.7%	13.2%	15.4%	11.2%	10.7%	13.0%	12.2%	15.6%	9.5%	6.7%	10.0%	13.9%	15.5%	15.4%	17.3%	21.1%	12.3%	13.2%
12	24.3%	23.5%	19.6%	19.2%	20.9%	21.8%	19.9%	12.7%	13.6%	18.3%	17.0%	11.2%	22.9%	25.0%	20.4%	18.7%	15.2%	18.7%	19.0%
13	4.7%	4.5%	5.0%	4.8%	4.8%	8.9%	8.1%	11.2%	12.6%	8.0%	7.0%	5.2%	4.3%	3.7%	2.7%	4.1%	4.1%	7.0%	6.1%
14	4.2%	3.7%	3.8%	4.2%	4.5%	4.9%	6.4%	10.7%	9.8%	8.5%	6.8%	6.1%	5.0%	3.9%	3.8%	4.3%	5.7%	7.0%	5.7%
15	4.6%	3.3%	4.9%	3.4%	3.0%	2.1%	2.2%	4.6%	3.9%	5.4%	6.5%	7.2%	4.8%	3.8%	4.7%	4.7%	5.1%	3.2%	4.3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

USGS Aggregated Areas	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Feb-96	Average
1	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
3	2.8%	2.2%	1.4%	3.6%	0.8%	1.1%	0.5%	0.4%	0.6%	0.1%	0.1%	0.2%	0.6%	1.3%	1.1%
4	0.0%	3.7%	1.0%	4.5%	1.7%	16.2%	1.2%	1.0%	0.0%	1.6%	0.0%	0.7%	0.8%	2.1%	2.5%
5	0.0%	2.7%	4.1%	0.7%	1.1%	2.4%	3.4%	2.7%	0.0%	1.2%	1.4%	1.2%	0.9%	2.4%	1.7%
6	8.4%	14.1%	32.0%	8.3%	22.9%	18.2%	13.5%	19.2%	8.7%	14.5%	21.2%	33.7%	26.8%	18.3%	18.6%
7	0.1%	5.7%	3.8%	5.7%	2.0%	3.2%	4.0%	0.1%	0.0%	0.3%	0.4%	0.9%	0.4%	1.0%	2.0%
8	0.3%	0.4%	10.5%	0.4%	32.3%	1.9%	7.2%	6.1%	0.0%	3.0%	6.3%	10.0%	6.9%	7.1%	6.6%
9	0.5%	2.4%	0.4%	5.4%	5.4%	7.6%	10.1%	7.7%	0.3%	10.9%	1.8%	1.7%	0.4%	0.9%	4.0%
10	22.7%	15.7%	17.6%	13.7%	9.5%	12.8%	21.0%	16.1%	27.6%	19.7%	18.8%	19.7%	8.7%	23.0%	17.6%
11	13.3%	6.1%	10.3%	6.2%	2.4%	7.9%	12.6%	8.2%	9.5%	4.4%	5.7%	13.8%	9.3%	11.6%	8.7%
12	19.3%	11.9%	8.0%	14.3%	3.4%	7.4%	6.1%	13.0%	14.9%	12.3%	18.1%	7.1%	16.0%	9.2%	11.5%
13	21.2%	26.5%	6.4%	26.2%	7.2%	9.3%	5.2%	14.1%	15.3%	14.5%	18.4%	8.2%	21.7%	14.3%	14.9%
14	9.8%	8.2%	2.1%	9.2%	7.9%	9.4%	11.8%	9.3%	20.6%	14.3%	6.7%	1.4%	6.5%	7.1%	8.9%
15	1.7%	0.3%	2.4%	0.8%	3.4%	2.6%	3.3%	2.0%	2.4%	3.1%	1.1%	1.3%	0.9%	1.6%	1.9%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Figure 7. Average drainage percentages for aggregated areas of the USGS study

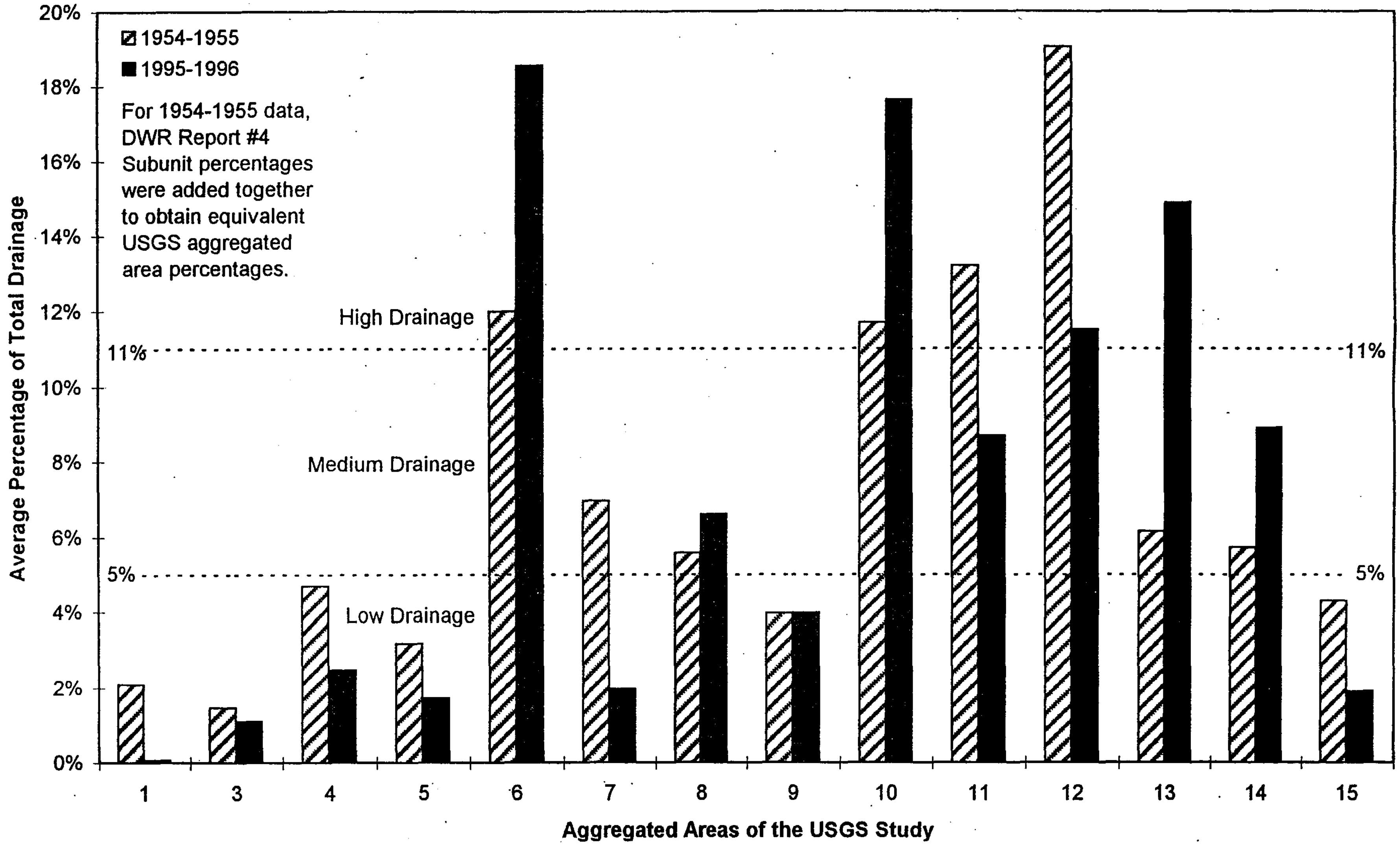
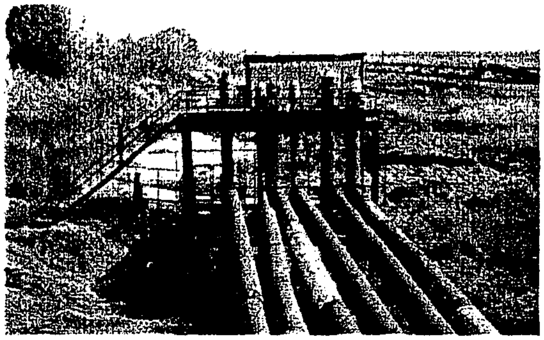
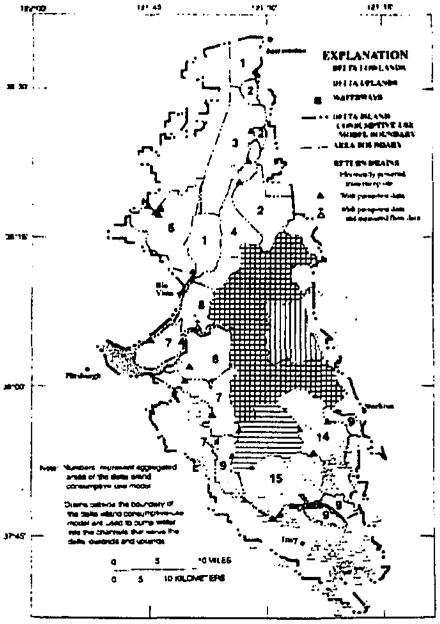


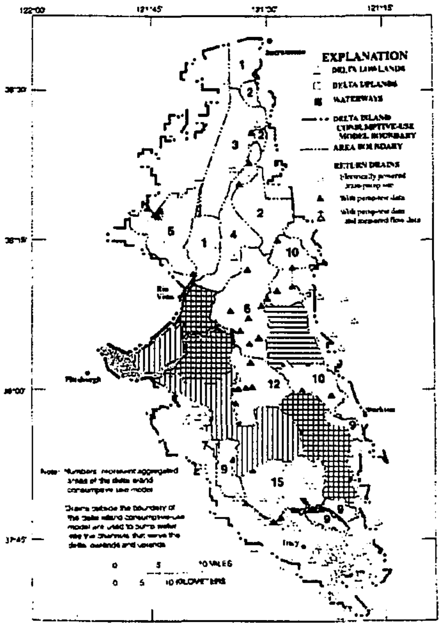
Figure 8. Correlation of various drainage percentages to USGS aggregated areas



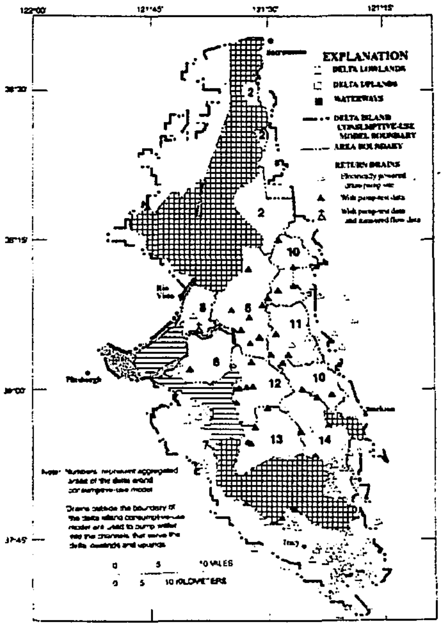
Picture of Upper Jones Tract drainage pump station



High Drainage
Greater than 11%
1995-1996
1954-1955
Overlap



Medium Drainage
Between 5% and 11%
1995-1996
1954-1955
Overlap



Low Drainage
Less than 5%
1995-1996
1954-1955
Overlap

over time for the same area. With some exceptions, the high, medium, and low drainage areas in the 1954-55 study corresponded to similarly classified areas in the 1995-96 study. These areas appear as the overlapped areas in Figure 8. Areas that were dissimilar are shown as the non-overlapping areas in Figure 8. These indicated differences in the proportion of total delta lowland drainage from each area in the two studies.

The seasonal drainage volumes for each subarea were also examined to determine how those subtotals might have affected the lower total delta lowland drainage estimates for 1995-96 (Figure 9). The four seasons were defined as: Fall (September, October, November), Winter (December, January, February), Spring (March, April, May), and Summer (June, July, August). Overall, the 1995-1996 seasonal volumes were less than the 1954-1955 seasonal volumes. There were some exceptions when drainage in some areas during the Spring of 1995 were higher than in the Spring of 1955.

Land use changes

Drainage volume in some areas of the delta lowlands could be partially attributed to land use changes (Table 7) that have occurred over the past four decades. For example, the high drainage areas identified in the two studies were generally in agreement except at USGS aggregated areas 11 and 13. In 1954-1955, the predominant crops grown at areas 11 and 13 were field corn, sugar beets, and tomatoes. These crops require large amounts of irrigation water during the growing season (May to October). In contrast, in 1995-1996, grain, hay, and other field crops that require about half as much water were grown in

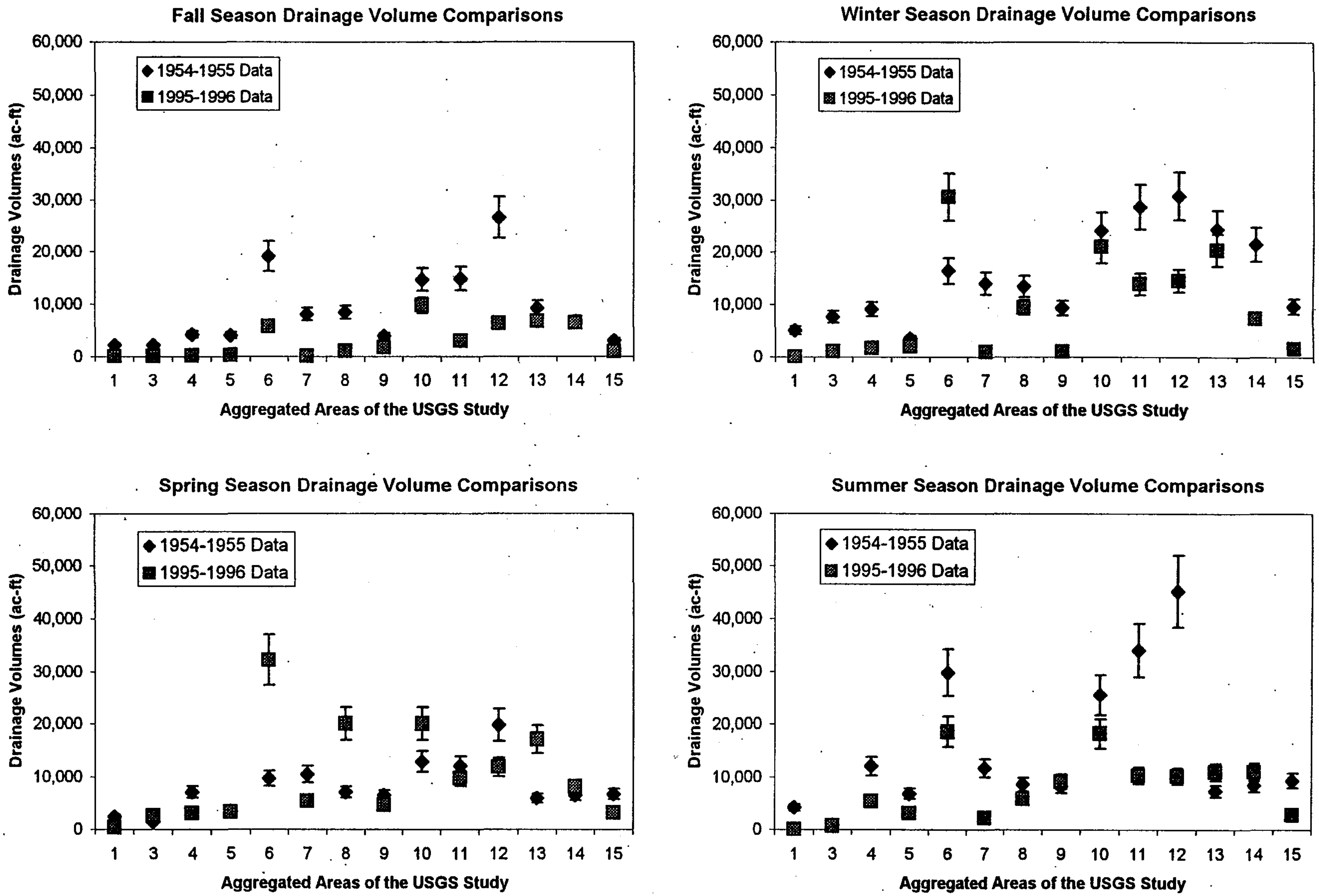


Figure 9. Seasonal drainage volume comparisons between 1954-1955 data and 1995-1996 data (with ±15% bars)

Table 7. Land use comparisons

1955		
Land Use	**Acres**	**Percent of total**
Pasture	22,997	4.91%
Alfalfa	34,481	7.36%
Rice	2,103	0.45%
Field crops	181,910	38.82%
Truck crops	124,431	26.55%
Fruits and nuts	5,141	1.10%
Grapes	110	0.02%
Native vegetation	11,904	2.54%
Fallow and bare	1,360	0.29%
Idle crop land	1,103	0.24%
Duck ponds	203	0.04%
Urban	6,914	1.48%
Tule and swamp	4,581	0.98%
Levee and berm	16,616	3.55%
Interior water surface	5,585	1.19%
Exterior water surface	42,168	9.00%
Islands in channels	7,027	1.50%
Total	468,634	100.00%

1991		
Land Use	**Acres**	**Percent of total**
Subtropical fruits	84	0.02%
Deciduous fruits and nuts	9,071	2.05%
Grain and hay crops	73,693	16.67%
Field Crops	133,466	30.19%
Truck and berry crops	60,816	13.76%
Pasture	59,086	13.37%
Vineyards	7,867	1.78%
Rice	18	0.00%
Idle	14,182	3.21%
Semiagricultural	3,805	0.86%
Native	60,496	13.68%
Urban	19,427	4.39%
Undesignated	50	0.01%
Total	442,061	100.00%

areas 11 and 13. Grain crops are generally winter crops that need less irrigation and would result in less drainage. However, there was not enough data to draw the conclusion that some land use changes had caused a significant reduction in the total delta lowland drainage volume.

Completeness of records

The PG&E database used by USGS appeared to be incomplete in its list of delta pump stations. Some pump stations identified in a 1986-87 survey by DWR were not identified in the USGS 1995-96 study (Figure 10). Some possible reasons could include improper coding in the PG&E database or coding of pump stations to billing addresses outside of the delta. The absence of data from these missing pump stations could, in part, explain the lower drainage estimates by USGS.

Pump efficiencies and power use records for eighty-two (82%) percent of the delta lowland pumps were obtained to compute the 1954-55 drainage discharges. Data were collected from 255 pumps located at 162 pumping plants. Drainage volume for the remaining eighteen (18%) percent of the pumps were estimated by assuming similar pumping plant rating factors or using correlations with computed drainage-per-acre in adjacent lands.

In contrast, USGS was only able to obtain PG&E pump efficiency test data and power use records for 58 of 236 drains in the delta. There were 220 pump efficiency tests done at the 58 drains. They used the mean pump efficiency value of the 220 tests performed at the 58 drains to compute the

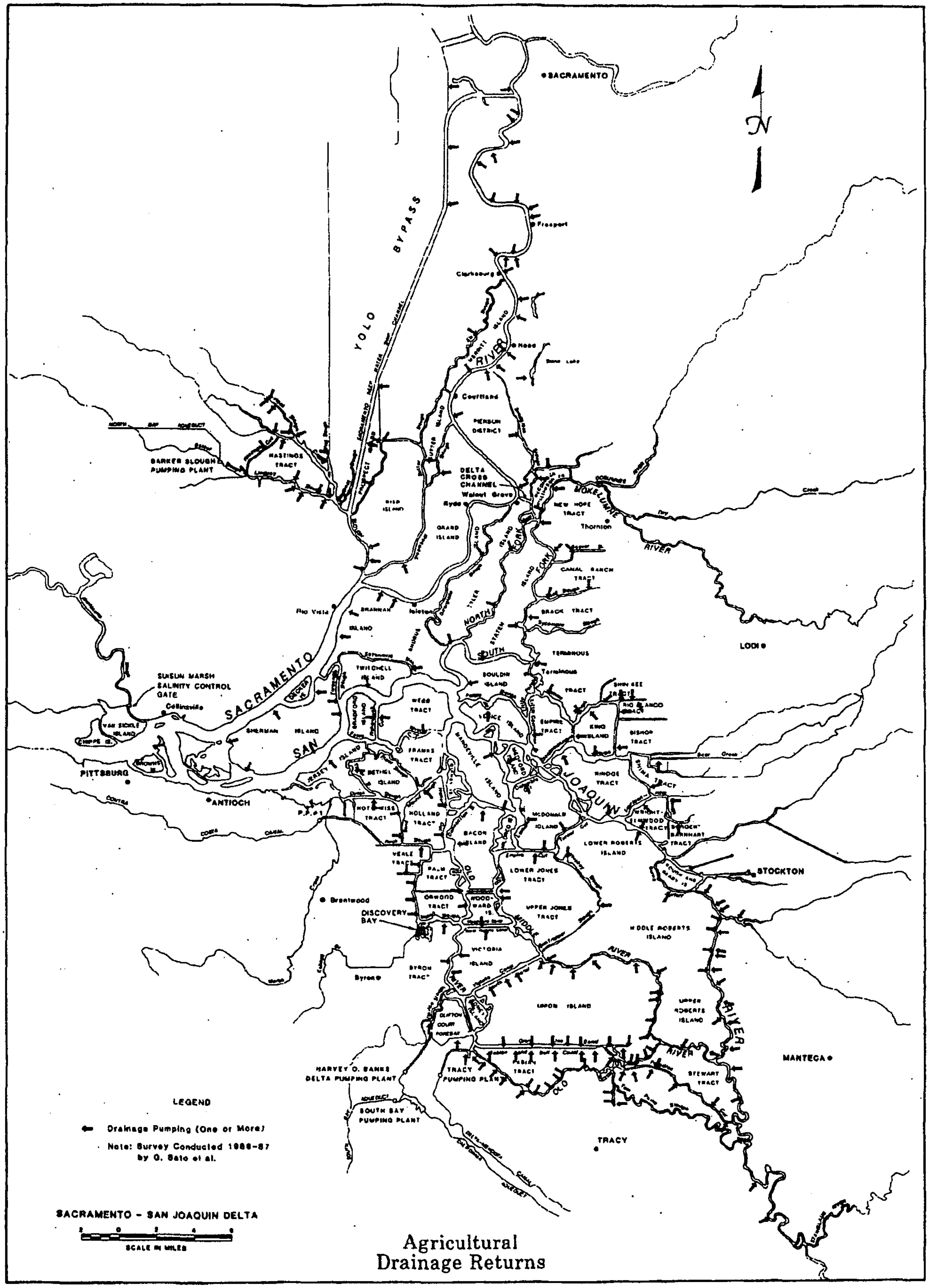


Figure 10. Agricultural drainage returns within the delta

drainage discharge for the remaining 178 drains because there was poor correlation between pump horsepower and pump performance. DWR Report number 4 did not contain data to compare pump-efficiency or power use data during the 1954-55 study to the USGS mean unit-use coefficient of 40.6 kilowatt hours per acre-foot of pumped drainage.

Most of the pumps that lacked pump efficiency test data were in the areas classified as medium and low drainage areas (open triangles in Figure 5). It was at these areas where there was little agreement in monthly drainage rates (e.g., high, medium, and low) between the two studies.

These two factors, fewer identified pump stations and few pump efficiency test data, most likely accounted for the lower drainage volume estimates in the 1995-96 tabulation. Drainage estimates in the 1954-55 study were based on a more complete set of delta pump station records that contained both power use and pump efficiency test data than in the 1995-96 study.

3. Conclusions

The USGS 1995-96 delta lowland drainage volume estimates were much lower than the computed total for 1954-55. Several possible factors that could have contributed to the different results were examined. These included comparisons of rainfall, regional monthly and seasonal drainage discharge volumes, land use changes, and completeness of the data sets that were used in the two studies. We concluded that the USGS study drainage estimates were lower because of unavailable data on all pump stations in the delta. Some pump stations identified in a 1986-87 survey by DWR were not identified in the P.G. & E. database that was used in the 1995-96 USGS study.

Drainage estimates were based on a more complete data set in the 1954-55 study than in the 1995-96 study. Pump efficiencies and power use records for eighty-two (82%) percent of the delta lowland pumps were obtained to compute the 1954-55 drainage discharges. Drainage volume for the remaining eighteen (18%) percent was based on an average pump efficiency derived from the 82%. In contrast, USGS was able to obtain pump efficiency data for about 20% of the delta pumps. They used a mean pump efficiency value to compute the drainage discharge for the remaining 80% of the pumps.

In the MWQI Five-Year Summary Report, 1987-91 (DWR, 1994), a simple model was made to estimate the contribution of DOC from delta drainage. Predictions of delta channel DOC based on 1954-55 drainage estimates were in close agreement with observed average DOC values. This suggests that the current volume of drainage discharges may not have changed significantly since the 1950s.

Both studies showed that accurate drainage volume discharge information could be achieved if both power use records and pump test efficiency data are both available for a pump station. The recent USGS study showed that this requirement could be met for about 20 percent of the delta drainage pump stations. The lack of pump test efficiency data for 80 percent of pumps in the delta suggest that some reclamation districts may not be concerned with power costs or that routine pump maintenance (e.g., annual overhauls, impeller replacements) is occurring as to not warrant pump tests. Some drains are pumped during off-peak hours when electrical rates are discounted by the Pacific Gas & Electric Company. Deliberately pumping during off-peak time periods might be compensating for wasted power consumption by the lower efficiency pumps.

Future attempts to obtain accurate drainage discharge data will require cooperation and permission directly from landowners and reclamation districts to periodically run pump efficiency tests and to obtain power use records or to install flowmeters at each pump. Due to a confidentiality agreement with PG&E, USGS could not release specific information about individual pumps and had to aggregate the data for areas no less than 36 square miles in size. This prevented us from identifying drainage volume from specific islands and tracts.

We conclude that the significant difference in the estimated amount of delta lowland drainage in the USGS 1995-96 study and in the DWR 1954-55 study was the result of a less complete database in the former study.

4. References

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