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October 29, 2015

BDCP/CA WaterFix Comments
P.O. Box 1919,
Sacramento, California 95812

Subject: Suisun Resource Conservation District Comments on the Draft Bay Delta Conservation Plan (BDCP) / California WaterFix (CA WaterFix) and associated Partially Recirculated Draft Environmental Impact Report and Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS)

Dear BDCP/CA WaterFix:

The Suisun Resource Conservation District (SRCD) is a special district created by the California Legislature as a legal subdivision of the State of California (Public Resources Code, §§ 9003, 9960 et seq.). SRCD has the primary local responsibility for promoting wetland conservation of the Suisun Marsh through improvements in water management practices on private lands within the primary management area of the Suisun Marsh (*Id.* at § 9962.). As a resource conservation district, SRCD is empowered to coordinate resource management efforts for purposes of watershed restoration and enhancement (*Id.* at §§ 9001(b)(1) and (3).

Historically, SRCD has taken the leadership role to ensure adequate water quality in the Suisun Marsh – a condition necessary to promote a diversity of productive waterfowl habitat, enhance the wetland resource values through appropriate management practices, and ensure the wetland and wildlife values of the Suisun Marsh are sustained and protected. This fact makes SRCD and its staff of professional wildlife biologists uniquely qualified to evaluate the adequacy of the BDCP/CA WaterFix (Project) and RDEIR/SDEIS effects analysis and Project impacts on Suisun Marsh managed wetland resources from increased Suisun Marsh salinities and habitat conversion.

The Suisun Marsh landowners and SRCD have been stewards of these wetland and wildlife resources for over a century. They advocated for passage of the 1977 Suisun Marsh Preservation Act to protect these wetland resources from development and degradation associated with salinity intrusion from reduced upstream freshwater flows. Additionally, SRCD is a signatory to the 1987 Suisun Marsh Preservation Agreement (a contractual framework for implementing the 1984 Plan of Protection for the Suisun Marsh – see SWRCB D-1641, p. 50) and the subsequent 2015 Suisun Marsh Preservation Agreement, Monitoring Agreement, and Mitigation Agreement (SMPA). The primary objective of the SMPA is, "to assure that Department of Water Resources (DWR) and the United States Bureau of Reclamation (USBR) *maintain a dependable water supply of adequate quantity and*

quality within the Marsh to mitigate the adverse effects on the Suisun Marsh of the Central Valley Project (CVP) and State Water Project (SWP) and a portion of adverse effects of other upstream diversions." To achieve this objective, DWR and USBR implemented the 1984 Plan of Protection for the Suisun Marsh and DWR continues to operate and maintain DWR's initial facilities, the Suisun Marsh Salinity Control Structure, and water quality monitoring and compliance stations throughout the Suisun Marsh.

The following statements from the SMPA acknowledge the importance of water quality to the health of the Marsh and wildlife, and the threat posed by increased salinity levels:

> A supply of adequate quality water is necessary to protect wildlife habitat in the Marsh. The Parties consider it to be in the public interest to manage the wetlands of the Marsh to produce adequate quality waterfowl habitat and grow certain waterfowl food plants.(2005 Revised SMPA Agreement, p. 2.)
>
> Upstream water use, including diversions by the Central Valley Project ("CVP") and the State Water Project ("SWP") has, at times, reduced outflow from the Delta, resulting in increased salinity in the Marsh. The higher salinity levels have, at times, degraded waterfowl habitat in the Marsh. The Marsh has a salinity gradient between its western portion and its eastern portion, with ocean-derived salinity being greatest in the westerly portion. *(Id.)*

The 1977 Suisun Marsh Preservation Act is intended "to preserve the integrity and assure continued wildlife use of the Suisun Marsh, including the preservation of its waterfowl-carrying capacity and retention of the diversity of its flora and fauna." To achieve the objectives of the 1977 Suisun Marsh Preservation Act, the Bay Conservation and Development Commission (BCDC) established policies and regulations in the Suisun Marsh Protection Plan, and DWR also developed the 1984 Plan of Protection for the Suisun Marsh to mitigate the effects of the Federal CVP and the SWP on the Marsh. To protect Fish and Wildlife Beneficial Uses in the Eastern and Western Suisun Marsh, the State Water Resources Control Board (SWRCB) established and has required USBR and DWR to meet numeric and narrative salinity standards for the Suisun Marsh in Water Rights Decision 1485 (D 1485), Order 95-6, and Decision 1641 (D1641). These salinity standards were further reinforced with execution of the SMPA by and between DWR, USBR, Department of Fish and Wildlife (DFW) and SRCD. Any action of BDCP/CA Water Fix that reduces existing Delta outflows, increases tidal mixing of salts into the Suisun Marsh, or causes an exceedance of the D1641 or SMPA salinity standards would be detrimental to the existing ecological values of the Marsh and a violation of D1641 and the SMPA salinity standards and contractual agreements.

SRCD has reviewed the BDCP/CA WaterFix RDEIR/SDEIS, and has evaluated the proposed Project's future significant and unavoidable negative impacts to the wetland and wildlife resources of the Suisun Marsh from further degradation of water quality conditions (increased salinity) and habitat conversion in the Suisun Marsh from the Project and meeting the mitigation obligations of the existing CVP and SWP operations. The SRCD Board of Directors, which represents the private landowners of Suisun Marsh, cannot support a proposed BDCP/CA WaterFix Project that has identified significant

increases in Suisun Marsh channel water salinity and unidentified impacts and degradation of Suisun Marsh water quality and existing habitat conditions from the Project, which will have cumulative adverse effects with future tidal restoration actions to meet existing CVP and SWP Biological Opinion obligations (now presented as Eco Restore Program). Not only does the RDEIR/SDEIS fail to adequately evaluate and disclose significant Project-specific and cumulative salinity impacts to the Marsh, but it also offers no commitment or regulatory assurances how these impacts will be avoided, minimized, or adequately mitigated. These undisclosed Project-specific and/or cumulative impacts include modification of the Suisun Marsh salinity regime, the degradation of the water quality conditions, the direct conversion and loss of existing managed wetland values and functions, dampening of the tidal stage, redirection of tidal energy, and consequent degradation of the existing ecological characteristics of over 58,000 acres of tidal and managed wetlands in the Suisun Marsh.

With this in mind, SRCD submits the following specific comments.[1]

A. BDCP/CA WaterFix Will Result in Unacceptable Increases in Suisun Marsh Salinities that are Not Adequately Disclosed or Mitigated in the RDEIR/SDEIS

The RDEIR/SDEIS is inadequate because it fails to disclose the impacts of the Project on the salinity of water diverted into Suisun Marsh managed wetlands. In brackish and freshwater tidal marshes, changes in salinity of a few parts per thousand will have substantial adverse effects because the growth, productivity, and survival of most species are highly sensitive to any salinity. (Parker 2011.) Small changes in salinity could significantly affect the diversity and composition of these wetlands. Increases in soil salinity and inundation will differentially affect germination and the physiological limits of species. (Parker 2011.) A primary effect of salinity is that it delays germination and seedling development. Plant loss during this seedling stage can reduce the plant population density to suboptimal levels and significantly reduce yields. (Mass 1993.) The RDEIR/SDEIS effects analysis repeatedly acknowledges increases in Suisun Marsh salinities from existing baseline conditions (Appendix B Supplemental Modeling Results for New Alternatives) for chloride and electrical conductivity (EC). These increases will result in a direct violation of the SMPA and D1641 Suisun Marsh salinity standards and degrade existing wetland habitats in the Suisun Marsh.

1. <u>The RDEIR/SDEIS Fails to Quantitatively Analyze Project Impacts to the Suisun Marsh.</u> The RDEIR/SDEIS discussion of salinity increases is insufficient to properly evaluate impacts to the Marsh, however, due to fundamental insufficiencies and flaws in the modeling approach. Chapter 8 page 8-71 line 9-11 states, "Assessment of the Suisun Marsh EC was conducted *qualitatively*, using average EC for the entire period modeled (1976-1991) to determine the overall change and degree to which EC could be affected by the alternatives." (Emphasis added.) Thus, the RDEIR/SDEIS relies entirely on an insufficient qualitative analysis of the Project's salinity and EC impacts, but fails to

[1] Because Alternative 4A is identified as the preferred Project, SRCD's comments focus on the effects of that alternative. To the extent the other alternatives in the RDEIR/SDEIS have the potential to increase salinity levels in Suisun Marsh, SRCD's comments and concerns also apply to those alternatives.

perform crucial quantitative analysis? Quantitative analysis is imperative to presenting a reasoned analysis of the environmental impacts associated with the Project, and DWR and USBR have Suisun Marsh water quality monitoring data since 1977 as required under D1485.

2. The Salinity Modeling Improperly Relies on Monthly Averages. The modeling approach presents salinity as the average monthly salinities (as represented by electrical conductivity [EC]). This provides a very coarse level of evaluation, which is inadequate to assess daily, monthly and seasonal impacts of the proposed Project operations on the Suisun Marsh salinities and water users. California water quality regulators have determined that protection of beneficial uses from salinity impacts requires assessment high tide salinities, and in this regard the Water Quality Objectives For Fish and Wildlife Beneficial Uses measure the Suisun Marsh salinity objective's compliance as the, "maximum monthly average of *both daily high tide EC values*" (Water Rights D1641 - Table 3, emphasis added.). D1641 requires measuring salinity compliance at high tide because this is the period when channel water salinities are the highest and when managed wetlands are diverting water (by gravity) for habitat management and performing leaching cycles to reduce soil salinities during the spring growing season. In most regions of the Suisun Marsh, the channel water salinity is lowest at low tide, with highest salinities at high tide. Therefore, impact analysis using monthly average salinity (EC) underrepresents impacts of the proposed BDCP/CA WaterFix on Suisun Marsh water users and habitat management capabilities. Additionally using average salinity provides SRCD no way to compare the ability of the Project to meet regulatory compliance requirements or determine the potential extent of violation of the D1641 and the SMPA numeric salinity standards. The decision to qualitatively assess the Suisun Marsh salinities and present the data as average salinities suggests a strategy to diminish, conceal and underreport the direct, indirect and cumulative impacts of the Project on the Suisun Marsh salinities and existing wetland habitats.

3. The RDEIR/SDEIS Fails to Provide Reasonable Salinity Thresholds of Significance. Chapter 2.2.1 - Page 2-8 of the RDEIR/SDEIS states, "Modeling of all alternatives assumed no operation of the Suisun Marsh Salinity Control Gates, but the project description for all alternatives now assumes continued operation of the Salinity Control Gates, consistent with assumptions included in the No Action Alternative. A sensitivity analysis with the gates operational consistent with the No Action Alternative resulted in substantially lower EC levels in Suisun Marsh than indicated in the original modeling results, *but EC levels were still somewhat higher there than EC levels under Existing Conditions and the No Action Alternative for several locations in the Marsh and for several months.*" (Emphasis added.) "Somewhat higher" is not a scientific or quantifiable measurement of Suisun Marsh salinity increases, and the RDEIR/SDEIS provides no threshold against which to measure significance and assess the severity of the impacts. As noted previously, changes in salinity of a few parts per thousand will have considerable effects on the Suisun Marsh because the growth, productivity, and survival of most species are highly sensitive to any salinity. (Parker 2011.)

Chapter 2.2.1 - Page 2-8 of the RDEIR/SDEIS states, "Another modeling run with the gates operational and restoration areas removed resulted in EC levels nearly

equivalent to those found in Existing Conditions and the No Action Alternative, indicating that design and siting of restoration areas has notable bearing on EC levels at different locations within Suisun Marsh. These analyses also indicate that increases in EC levels shown in the modeling conducted for the Draft EIR/EIS were related primarily to the hydrodynamic effects of CM4 under the alternatives assessed (1A, 1B, 1C, 2A, 2B, 2C, 3, 4, 5, 6A, 6B, 6C, 7, 8, and 9), not operational components of CM1. Based on the sensitivity analyses, optimizing the design and siting of restoration areas for these alternatives consistent with proposed environmental commitments, avoidance and minimization measures, and mitigation measures is expected to be able to reduce EC increases, relative to Existing Conditions and the No Action Alternative, *to levels that would be less than significant*. The new alternatives 2D, 4A, and 5A, contain much lower acreage of tidal restoration, and thus *are anticipated to not have significant impacts with respect to EC and chloride in Suisun Marsh*."

The modeling simulations for the new Alternative 4A - show that, "EC levels are still somewhat higher for several locations in the Marsh and for several months", yet the increase in EC levels "would be less than significant" and "are anticipated to not have significant impacts." SRCD strongly disagrees with this determination, which is contradicted by the results of Appendix B Supplemental Modeling Results for New Alternatives (Pages B-114 to 116 and B-131 to 133), which presents average EC levels (mS/cm) in Tables EC-5 for Montezuma Slough at Beldon's Landing, EC-6 for Chadborne Slough near Sunrise Duck Club, and EC-7 Suisun Slough 300 feet south of Volanti Slough. The four simulations are:

- Existing Conditions
- No Action Alternative
- Proposed Project Alternative 4A, (H3) Early Long Term
- Proposed Project Alternative 4A, (H4) Early Long Term

The information in the RDEIR/SDEIS tables disclose salinity levels predicted to result from the Project but provide no context for assessing the degree of change. SRCD has added four columns to Tables EC-5, 6, and 7 showing the percent increase of salinity at each modeled locations. As this evidence demonstrates, and contrary to the RDEIR/SDEIS's suggestion, the Project will result in very large increases in salinity levels in the Marsh.

Table EC-5: Period Average EC Levels (mS/cm) for Montezuma Slough near Beldon Landing, Suisun Marsh for Existing Conditions, the No Action Alternative, and Alternative 4A ELT. This represents an overall average salinity increase of 62%.

	Ex. Cond.	No Act. ELT	Alt 4A H3 ELT	Difference in Salinity from (EC) Ex. Con.	% Increase in Salinity	Alt 4A H4 ELT	Difference in Salinity from (EC) Ex. Con.	% Increase in Salinity
Jan.	3.3	3.3	8.2	4.9	145.0%	8.2	4.9	145.0%
Feb	2.1	2.1	5.5	3.4	162.0%	5.4	3.3	157.0%
Mar	2.5	2.8	4.5	2	80.0%	4.4	1.9	76.0%
Apr	2.9	3.2	4.3	1.4	48.0%	4.1	1.2	41.0%
May	4.3	4.5	5.8	1.5	35.0%	5.4	1.1	25.0%
Jun	6.2	6.6	7.7	1.5	24.0%	7.4	1.2	19.0%
Jul	9.0	9.3	10.0	1.0	11.0%	10.1	1.1	12.0%
Aug	11	11.1	12.2	2.2	20.0%	12.3	2.3	20.0%
Sep	13.1	12.6	13.5	0.4	3.0%	13.6	0.5	3.8%
Oct	7.8	7.1	12.1	4.3	55.0%	12.2	4.4	56.0%
Nov	7.6	6.8	11.6	4	52.0%	11.7	4.1	54.0%
Dec	5.1	4.8	10.5	5.4	106.0%	10.5	5.4	106.0%

Table EC-6: Period Average EC Levels (mS/cm) for Chadbourne Slough near Sunrise Duck Club, Suisun Marsh for Existing Conditions, the No Action Alternative, and Alternative 4A ELT. This represents an overall average salinity increase of 29%.

	Ex. Cond.	No Act. ELT	Alt 4A H3 ELT	Difference in Salinity (EC) from Ex. Con.	% Increase in Salinity	Alt 4A H4 ELT	Difference in Salinity (EC) from Ex. Con.	% Increase in Salinity
Jan.	7.1	7.1	10.2	3.1	44.0%	10.2	3.1	44.0%
Feb	4.8	4.9	7.5	2.7	56.0%	7.4	2.6	54.0%
Mar	3.8	4.1	5.8	2.0	52.0%	5.7	1.9	50.0%
Apr	3.6	4.0	5.5	1.9	53.0%	5.3	1.7	47.0%
May	4.9	5.1	6.6	1.7	35.0%	6.2	1.3	26.0%
Jun	7.0	7.2	8.5	1.5	21.0%	8.1	1.1	16.0%
Jul	9.7	9.9	10.9	1.2	12.0%	10.8	1.1	11.0%
Aug	11.7	11.7	13.0	1.3	11.0%	13.1	1.4	12.0%
Sep	13.7	13.3	14.4	0.7	5.0%	14.5	0.8	6.0%
Oct	12.3	11.2	13.6	1.3	10.0%	13.6	1.3	10.0%
Nov	11.2	10.3	13.1	1.9	17.0%	13.1	1.9	17.0%
Dec	9.4	8.8	12.2	2.8	30.0%	12.2	2.8	30.0%

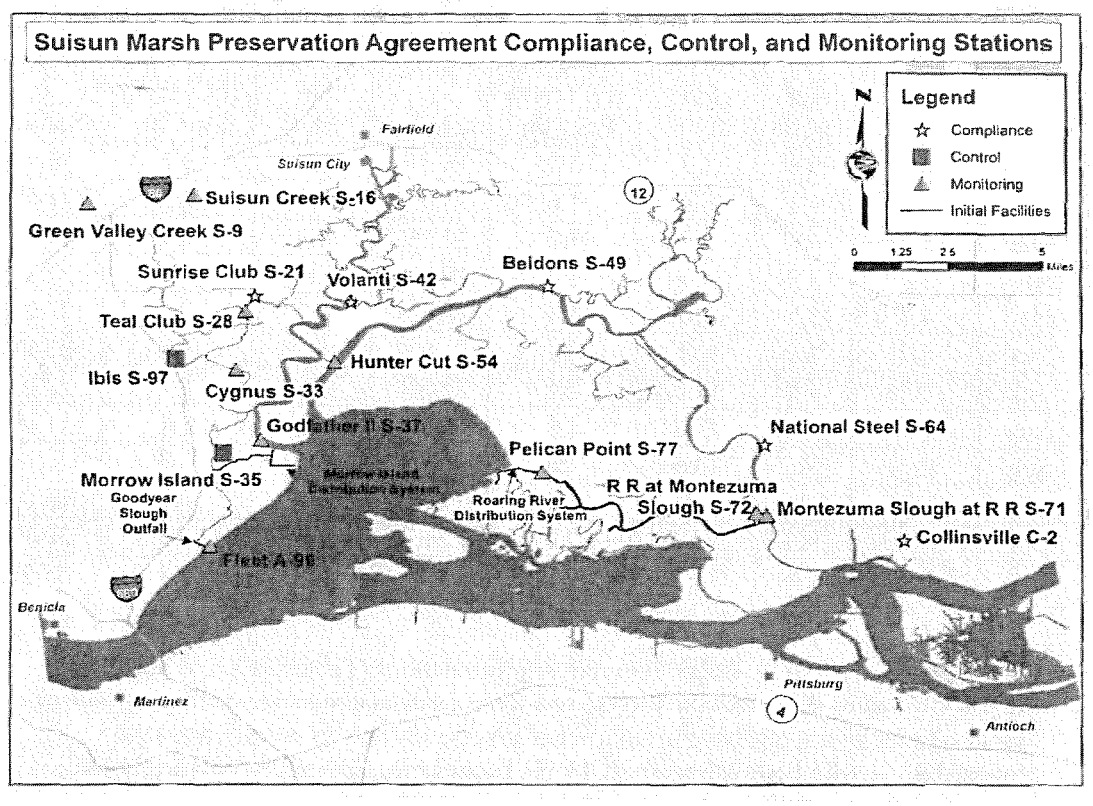
Table EC-7: Period Average EC Levels (mS/cm) for Suisun Slough 300 Feet South of Volanti Slough, Suisun Marsh for Existing Conditions, the No Action Alternative, and Alternative 4A ELT. This represents an overall average salinity increase of 28%.

	Ex. Cond.	No Act. ELT	Alt 4A H3 ELT	Difference in Salinity (EC) from Ex. Con.	% Increase in Salinity	Alt 4A H4 ELT	Difference in Salinity (EC) from Ex. Con.	% Increase in Salinity
Jan.	6.4	6.4	8.7	2.3	36.0%	8.6	2.2	34.0%
Feb	4.4	4.4	6.0	1.6	36.0%	5.9	1.5	34.0%
Mar	3.7	4.0	4.9	1.2	32.0%	4.8	1.1	30.0%
Apr	3.5	3.9	4.9	1.4	40.0%	4.6	1.1	31.0%
May	4.8	5.0	6.6	1.8	38.0%	6.2	1.4	29.0%
Jun	6.7	7.0	8.8	2.1	31.0%	8.5	1.8	27.0%
Jul	9.4	9.7	11.5	2.1	22.0%	11.5	2.1	22.0%
Aug	11.5	11.5	13.8	2.3	20.0%	13.9	2.4	21.0%
Sep	13.6	13.2	14.8	1.2	9.0%	14.9	1.3	9.5%
Oct	11.5	10.6	13.1	1.6	14.0%	13.2	1.7	15.0%
Nov	10.3	9.5	12.4	2.1	20.0%	12.4	2.1	20.0%
Dec	8.4	7.8	11.2	2.8	33.0%	11.2	2.8	33.0%

These BDCP/ CA Water Fix modeling simulations (Tables EC- 5, 6 and 7 and Fig. Cl-4, 5 and 6) show that the Project will have a substantial adverse effect on Suisun Marsh salinity levels, resulting in significant adverse impacts to salinity from the proposed Project for both Alternatives 4A H3 Early Long-term and 4A H4 Early long-term. Project-related increases in the average salinity of the Suisun Marsh tidal sloughs range from 3% to 162% increase (see tables above). These potential increases in salinity portray only half of the Project's potentially significant impacts of increased salinity, however. The RDEIR/SDEIS has omitted future tidal restoration projects impacts from the effects analysis, by omitting the Suisun Marsh region from the analysis.

4. <u>The RDEIR/SDEIS Falsely States That the Suisun Marsh Salinity Gates Will Mitigate Any Salinity Increases Associated With The Project – Yet State and Federal Agencies Acknowledge That The Salinity Gates Do Not Effectively Mitigate Salinity Impacts to the Central and Western Suisun Marsh.</u>

Not only does the salinity analysis fail to disclose or evaluate the significance of the modeled increases in salinities, but a fundamental assumption underlying the impact analysis in Section 4.3.4 Water Quality for Alternative 4A impacts on the increases of Suisun Marsh salinities is flawed and inaccurate. The RDEIR/SDEIS's conclusion that salinity impacts to Suisun Marsh will be less than significant is based in substantial part on the assumption that operation of salinity control gates will reduce salinity levels throughout the Marsh. This assumption is incorrect. It is well known that Suisun Marsh salinity control gate operation is not an effective control of channel water salinity in the central and western Marsh, as measured at salinity control stations S-35 and S-97 and salinity monitoring stations S-54 and S-37.



As shown on the figure above, DWR has extensive salinity monitoring stations throughout the Suisun Marsh.

- Compliance Stations (C-2, S-64, S-49, S-21, and S-42)
- Control Stations (S35 and S-97)
- Monitoring Stations (A-96, S-4, S-28, S-33, S-37, S-54, and S-71).

Of these long term Suisun Marsh salinity monitoring stations, the RDEIR/SDEIS only modeled C-2 Collinsville, S-64 National Steel, S-49 Beldons Landing, S-21 Sunrise Club, and S-42 Volanti (Compliance Stations). The modeling supporting the RDEIR/SDEIS did not evaluate locations representing a significant portion of the Suisun Marsh. Omitting water quality modeling of monitoring stations in the central and western Suisun Marsh underestimates and minimizes the Project's potentially significant effects on Suisun Marsh salinities (EC and chloride) in locations where the salinity control gates are known to be ineffective at reducing salinity. These omissions result in modeling that significantly under represents the effects of the proposed Project on the central and western region of the Suisun Marsh, an area ranging between approximately 8,000 and 11,000 acres of prime wetland habitat. The RDEIR/SDEIS's failure to evaluate salinity impacts at salinity monitoring stations S-35 and S-97 is inexplicable because the lead agency, DWR, knows that operation of the salinity control gates does not effectively control channel water salinity in the Marsh at those locations. This fact is acknowledged in the

RDEIR/SDEIS, which includes the Suisun Marsh Preservation Agreement Amendment Three Actions as a means to provide equivalent or Better Protection than Channel Water Salinity Standards at the Suisun Marsh Stations S-35 and S-97. On page 40 of the DWR – 30 Appendix B Demonstration Document states: "The action of converting compliance stations S-35 and S-97 to monitoring stations is proposed because SMSCG operation is not an effective control of channel water salinity in the Marsh at these locations."

The limited geographic effect of the salinity control gates is acknowledged in other documents as well. For instance, the November 2011 Suisun Marsh Habitat Management, Preservation and Restoration Plan Final EIR/EIS states: "Operations of the SMSCG lowers salinity in *some* Marsh channels, *primarily those in the eastern Marsh*, and results in a net movement of water from east to west." (Emphasis added.) Further, the SMPA, a document to which DWR is a signatory, provides, "Evaluation of the SMSCG operation has shown that the gates can effectively reduce salinity in Montezuma Slough and the eastern regions of the Marsh, *and to a lesser degree in most of the western regions* of the Marsh." (2005 Revised Suisun Marsh Preservation Agreement, p. 3 J.1 (emphasis added).)

These facts fatally undermine the RDEIR/SDEIS's conclusion that, "Alternative 4A in the ELT includes operation of the gates, and includes very little tidal restoration area, it is anticipated that chloride increases in Suisun Marsh predicted via the modeling would not occur, and that chloride in Suisun Marsh under Alternative 4A in the ELT would be very similar to Existing Conditions. For these reasons, any changes in chloride and EC in Suisun Marsh are expected to have no adverse effect on marsh beneficial uses." (RDEIR/SDEIS, Section 4, pp. 4.3.4-15 and 4.3.4-27.)

5. <u>The RDEIR/SDEIS Salinity Mitigation Measures Are Legally Inadequate</u>. The DEIR/DEIS attempted to address potentially significant adverse impacts from EC and chloride by offering Mitigation Measures WQ-7d and WQ-11d. These mitigation measures have numerous problems due to their lack of a firm commitment to mitigate significant impacts. These mitigation measures are not included in the RDEIR/SDEIS because the impact discussion in the RDEIR/SDEIS concludes that impacts from EC and chloride will not be significant because, it is claimed, the modeled increases in EC and chloride will not occur, or will be minor, due to elimination of restoration areas and operation of salinity control gates. (See RDEIR/SDEIS, pp. 4.3.4-15 and 4.3.4-27.) However, these conclusions are based on the assumed effect of major changes in the original preferred project modeled in the DEIR/DEIS. In addition, chloride was not even modeled in the sensitivity analysis, and the salinity analyses were conducted only for the Late Long Term period, not the Early Long Term (ELT) period. The RDEIR/SDEIS provides no evidence or analysis to support its conclusion that such analyses "are expected to generally also apply to the ELT." (RDEIR/SDEIS, p. 4.4.3-15.)

Insufficient information is provided in the RDEIR/SDEIS to demonstrate the validity of applying the sensitivity analyses to the DEIR/DEIS model results, and the RDEIR/SDEIS

indicates a high degree of uncertainty involved with attempting to extrapolate impacts from Alternative 4 to Alternative 4A, given the level of changes in the project description. Moreover, the generalized discussion of impacts, and failure to quantify the actual changes in EC and chloride in the marsh from the revised CA WaterFix project, do not provide sufficient information for SRCD to understand the actual effects to the Marsh. Because modeling of the actual effects of the proposed project did not occur, the RDEIR/SDEIS impact conclusions regarding salinity impacts to the Marsh are based on speculation as to the level of change that the Project would have on Marsh salinity levels, and SRCD is unable to ascertain exactly what level of EC or chloride increase will occur from the Project. Because even minor changes in salinity can have significant adverse impacts, it is insufficient for information and decision making purposes to fail to quantify the *actual* project operations and mitigate for any increase in EC in the marsh.

Tables EC-5, 6 and 7 demonstrate that there are anticipated significant and unmitigated increases in average EC levels in Suisun Marsh. These actions will have adverse impacts on Marsh beneficial uses by degrading existing wetland conditions and reducing habitat values and functions for resident and migratory wildlife. These types of impacts are well documented in published literature. The most likely effects of salinity on plants is a general stunting of growth. (Mass 1993.) Increased salinity requires plants to expend more energy to obtain water from the soil, thereby reducing the amount of energy available for growth. (Mass 1993.) At high levels, salinity can cause physical damage and mortality. (Mass 1993.) Plant loss during this seedling stage can reduce the plant population density to suboptimal levels and significantly reduce yields. (Mass 1993.) An increase in salinity or modification of Delta outflow that increases Suisun Marsh channel water salinity would be detrimental and result in unmitigated impacts to existing beneficial uses and Suisun Marsh wetland habitats.

These anticipated impacts of an average increase of Suisun Marsh channel water salinities (from 25% to 62% a year) will seriously impair the ability of Suisun Marsh landowners to effectively manage wetland habitats, will adversely impact fish and wildlife beneficial uses, and reduce wetland diversity and habitat conditions. Small changes in salinity could significantly affect the diversity and composition of these wetlands. (Parker 2011.) The quality of water plants are exposed to has a direct impact on their survival, growth, and overall health. This is particularly true in regard to salinity. (Warrance and Bauder.) These impacts of increased salinity must be disclosed and mitigated in the RDEIR/SDEIS.

The RDEIR/SDEIS not only fails to adequately evaluate impacts to Suisun Marsh from EC and chloride, relying on speculation about possible effect of major changes in the project description and operation, but it also omits any mitigation should the predicted effects of these Project changes fail to occur. Existing commitments in the RDEIR/SDEIS do not address impacts to the Marsh. Appendix 3B Environmental Commitments, AMMs, and CMs of the (RDEIR/SDEIS) fail to address the project-specific adverse effects and potentially significant

cumulative impacts resulting from the Project in conjunction with future tidal restoration projects (Eco Restore) that will result in increased salinities (EC and chloride) and the direct loss of exiting managed wetlands from conversion to tidal habitats. Page 3B-73 and 74 Other Commitments states only that, "The following commitments are identified separately from environmental commitments for the purpose of addressing other non-environmental consequences of implementing the project. As with environmental commitments, these other commitments are incorporated into the project and would be implemented in the same or similar manner as proposed mitigation measures. These additional commitments are actions that the project proponents commit to implementing *in some manner* to reduce or partially reduce potential effects related to the environmental impacts disclosed in this EIR/EIS and caused by implementation of the project, even if the underlying environmental impact is not fully reduced or remains unchanged." (Emphasis added.)

Mitigation is included, however, for adverse effects on agricultural water purveyors. (See Section 3B.3.1 Agricultural Water Purveyors in Developing Methods to Reduce Potential Water Quality Effects, which states "The project proponents commit to assisting in-Delta municipal, industrial, and agricultural water purveyors that will be subject to significant unavoidable water quality effects from operation of Conservation Measure 1 (CM1) and effects on dissolved organic carbon (DOC) due to implementation of Conservation Measures 2-22 (CM2–21). This commitment shall apply specifically to those purveyors affected by significant unavoidable increases in bromide, electrical conductivity, chloride, and DOC concentrations…".) Also, Section 3B.3.1.1 Chloride and Electrical Conductivity, provides: "The following are concepts that affected purveyors *could consider* to address any significant unavoidable effects of increased chloride concentrations and electrical conductivity…" (Emphasis added.) These so-called commitments are vague and arguably insufficient to mitigate adverse effects to water purveyors. Still, SRCD wonders why a similar acknowledgement of the need for mitigation was not made with respect to Project impacts on the Suisun Marsh, which is equally worthy of attention and required to be protected by the various legislation and agreements discussed at the beginning of this letter.

There are many uncertainties regarding the Project operations and future changes resulting from the Project's vague and undefined "adaptive management." A substantially revised draft EIR/EIS must include mitigation measures that provide, at a minimum, a firm and enforceable commitment to ongoing real-time monitoring of EC and chloride levels in the Suisun Marsh, including observation and mitigation of any adverse effects on marsh plants or wildlife, and a firm commitment to modify Project operations to clearly avoid or substantially lessen any significant impacts due to Project-related or cumulative EC or chloride increases. Mitigation commitments must be consistent with Suisun Marsh Habitat Management, Preservation and Restoration Plan (SMP) environmental commitments, avoidance and minimization measures, and pre and post project salinity modeling and cumulative effects analysis.

In conclusion, the RDEIR/SDEIS still has not fully disclosed or mitigated the Project's significant adverse impacts on salinity in the Suisun Marsh channels. Qualitatively assessing Suisun Marsh salinities and averaging salinities (EC) (Appendix A - RDEIR/SDEIS Chapter 8 at page 8-71 line 9 and 10) masks and fails to disclose significant salinity increases in individual months and on individual days. Large salinity increases in a given year cannot be considered insignificant. These salinity increases must be avoided or fully mitigated by the Project proponents.

B. The RDEIR/SDEIS Inadequately Addresses the Project's Cumulative Impacts From Increased Local and Regional Actions Affecting Salinity

As discussed above, the Project threatens to significantly increase salinity levels in the Marsh, where salinity is already an acknowledged problem. These impacts will be compounded by the Eco Restore tidal restoration actions and other actions described in RDEIR/SDEIS Chapter 5. The RDEIR/SDEIS fails not only to adequately evaluate and disclose Project-level and cumulatively considerable significant salinity impacts to the Marsh but it also fails to identify or mitigate for the Project's considerable contribution to this significant cumulative impact.

Brackish wetlands are floristically distinctive and *contain a greater diversity of plant species* than either the salt marshes of San Francisco Bay or the freshwater wetlands of the Sacramento–San Joaquin Delta. (Byrne 2001.) Since 1978, the SWRCB has maintained Suisun Marsh salinity objectives to "provide water of sufficient quality to the managed wetlands to achieve soil water salinities capable of supporting the plants characteristic of a brackish marsh." (SWRCB D1641, Section 7, p. 40.) It has been shown that, at all sampling scales, the more saline San Pablo Bay sites contained significantly fewer species than the Suisun-Delta sites. San Pablo Bay sites contained approximately half the number of species as Suisun-Delta sites, and the greatest contrast in species richness occurs between San Pablo Bay and the Suisun-Delta. (Vasey 2012.) Additionally, the SMPA was signed to protect the brackish characteristics of the Suisun Marsh from increased salinities from the CVP and SWP and other upstream diverters. These scientific facts reinforce that brackish wetland communities are sensitive to increased salinity, will reduce wetland diversity, and, species richness can be negatively impacted by increased salinities.

The Eco Restore program call for at least 9,000 acres of tidal and sub-tidal habitat restoration in Suisun Marsh and the Cache Slough Complex. This objective has the potential to exceed the Suisun Marsh Habitat Management, Preservation and Restoration Plan (SMP) restoration targets of 5,000 to 7,000 acres over the next 30 years. The Suisun Marsh Plan also requires that tidal restoration projects be regionally distributed (see Table 2-4 SMP 2011 page 2-17) with strict assurances, detailed environmental commitments, avoidance and minimization measures to be implemented, and salinity modeling of restoration design to ensure that local and regional salinity conditions are protected as part of the project development, including post-construction verification. The BDCP/ CA WaterFix impacts to Suisun Marsh salinity combined with the implementation of Eco Restore impacts are likely to have significant cumulative effects and result in unavoidable adverse impacts and habitat degradation of the Suisun Marsh. Yet the BDCP/CA WaterFix makes no commitment to complete pre-restoration salinity modeling or post-restoration water quality monitoring to verify if the pre-project modeling results are accurate and if appropriate mitigation to address these unanticipated impacts has been adequately addressed on adjacent lands.

Chapter 5, page 5-3, California Eco Restore, states, "California Eco Restore will be led by the Delta Conservancy as the lead state agency and will accelerate and implement a suite of Delta restoration actions." This statement is inaccurate. SRCD is a board member of the Delta Conservancy and implementing Eco Restore is not a responsibility of the Conservancy. The RDEIR/SDEIS clearly shows that the lead agencies do not know who will be implementing these restoration actions, and there is no assurance that anyone will be accountable for carrying out required mitigation obligations.

The RDEIR/SREIS further states that the Eco Restore is unassociated with any habitat restoration that may be required as part of the construction and operation of the new Delta point of Diversion and water conveyance facility (Alternative 4A). Yet, Table 5.2.1-1, Interim Implementation Actions: Restoration Projects with Potential to Contribute to Meeting Habitat Conservation Measures or Environmental Commitments, indicates that the Eco Restore program actions will overlap with the effects of the BDCP/CA WaterFix. The cumulative impact analysis failed to adequately and accurately identify the cumulative impact of all these projects on Suisun Marsh wetlands and associated habitat and wildlife species. Because the net effect of these tidal restoration projects likely will be increased salinity, threatening a cumulative impact to the brackish marsh, and the Project will substantially increase salinities in the Marsh, the RDEIR/SDEIS should be revised to acknowledge the Project will contribute considerably to cumulative salinity impacts to the Marsh and mitigation should be included to substantially lessen the Project's contribution to this significant cumulative impact.

Specifically, mitigation must address the site-specific and cumulative impacts of increased salinity of applied water for habitat management, decreased life expectancy of adjacent managed wetland water management infrastructure, and attenuated tidal stage reducing existing gravity drainage capacity of adjacent managed wetlands, undermining and destabilizing existing managed wetlands exterior levee foundations from increased channel velocities and scour, as well as direct loss of managed wetlands from conversion. None of these impacts is adequately addressed in the BDCP/ CA Water Fix RDEIR/SDEIS cumulative effects, nor is there adequate mitigation proposed to address these site-specific or regional impacts on managed wetlands. If BDCP and/or the CA WaterFix moves forward, SRCD requests a formal commitment from BDCP/CA Water Fix and Eco Restore to mitigate tidal restoration project impacts and comply with the SMP objectives, procedures, guidelines, regional distribution of tidal restoration and agreement to the SMP management structure, including the SMP Principals Management Group and Adaptive Management Advisory Team.

BDCP/CA Water Fix and Eco Restore currently has no metric nor method of evaluating the incremental and additive effects and project impacts of increased salinity from the project operations (CM1) and Eco Restore tidal restoration activities in the Suisun Marsh. To partially address this deficiency during BDCP project development, Ducks Unlimited, in partnership with the Central Valley Joint Venture, U.C. Davis, Oregon State University, U.S. Geological Service, and SRCD proposed to BDCP management the following scientific study: *Restoring Tidal Flow to Managed Wetlands in Suisun Marsh: Implications for Wintering Waterfowl and Non-Tidal Wetland Management.* This study would provide detailed information on waterfowl food production in tidal and managed wetland habitats and is needed to address the critical uncertainties of the BDCP / CA WaterFix.

In providing mitigation for the Project's contribution to significant cumulative salinity impacts, the Project proponents should not attempt to rely on DEIR/DEIS Mitigation Measures WQ-7d and WQ-

11d, which were previously included to address the uncontrolled and unmitigated impacts to Suisun Marsh from increased chloride and EC concentrations caused by tidal restoration projects. These mitigation measures are unenforceable and simply pass water quality protection responsibilities to Eco Restore, tidal restoration project proponents and Suisun Marsh stakeholders. The Project states that tidal restoration site design and siting "shall attempt to reduce potential effects to the extent possible" with the "goal of maintaining chloride and EC at levels that would not further impair fish and wildlife beneficial" uses in Suisun Marsh. (Appendix A -RDEIR/SDEIS Chapter 8 page 8-119 and 8-128 and 129) The empty, non-commitments of "Shall attempt to the extent possible" and "a goal of maintaining" do not represent a firm mitigation measure commitment, and it is inappropriate for BDCP/CA WaterFix to avoid addressing the significant and undisclosed impacts of tidal restoration project to adjacent managed wetlands operations and habitat conditions in the Marsh.

C. Conclusion

Throughout the public review of the BDCP DEIR/EIS and in discussions relating to the new BDCP / CA Water Fix and Eco Restore, it has been repeatedly stated that BDCP implementation would continue to comply with existing D-1641 water quality standards and not materially change existing spring and fall Delta outflow requirements. As SRCD has identified in the detailed comments listed above, the BDCP RDEIR/SDEIS modeling results and effects analysis demonstrate that salinity levels in the Suisun Marsh will increase, which directly contradicts the claim that water quality objectives will continue to be met under D1641 water quality standards or the Suisun Marsh Preservation Agreement contractual obligations. Implementing a project that systematically degrades and reduces the existing Suisun Marsh managed wetland habitats, functions, values and water quality is unsupportable by SRCD. The RDEIR/SDEIS fails to address SRCD's concerns, expressed in comments on the DEIR/DEIS and here, about the salinity effects of the North Delta Diversion and CA WaterFix project on Suisun Marsh. Insufficient information has been provided to demonstrate that the Project will not have substantial adverse impacts on the Marsh, or that all feasible mitigation has been considered and proposed to avoid these impacts. SRCD thus requests that DWR not take any further action towards approving the BDCP /CA Water Fix Project unless and until it has revised and recirculated the RDEIR/SDEIS, including redoing the underlying water quality modeling, to fully address the issues and inadequacies that SRCD has identified in this comment letter.

Sincerely,

Jim Waters,
SRCD Board of Directors,
Chair of the Legal Committee

Reference:

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ATTACHMENTS

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Carbon-Isotope, Diatom, and Pollen Evidence for Late Holocene Salinity Change in a Brackish Marsh in the San Francisco Estuary

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Analysis of diatoms, pollen, and the carbon-isotopic composition of a sediment core from a brackish marsh in the northern part of the San Francisco Estuary has provided a paleosalinity record that covers the past 3000 yr. Changes in marsh composition and diatom frequencies are assumed to represent variations in freshwater inflow to the estuary. Three periods of relatively high salinity (low freshwater inflow) are indicated, 3000 to 2500 cal yr B.P., 1700 to 730 cal yr B.P., and ca. A.D. 1930 to the present. The most recent period of high salinity is primarily due to upstream storage and water diversion within the Sacramento–San Joaquin watershed, although drought may also have been a factor. The two earlier high-salinity periods are likely the result of reduced precipitation. Low salinity (high freshwater flow) is indicated for the period 750 cal yr B.P. to A.D. 1930. © 2001 University of Washington.

Key Words: **San Francisco Estuary; Holocene; paleosalinity; pollen; diatoms; carbon isotopes.**

INTRODUCTION

Brackish marshes in the San Francisco Estuary exist at the interface of freshwater inflow from rivers and salt water entering the Golden Gate from the Pacific Ocean. Prior to reclamation in the late 19th century, brackish marshes were especially extensive in Suisun Bay in the northern section of the estuary (Fig. 1). Brackish marshes are floristically distinctive and contain a greater diversity of plant species than either the salt marshes of San Francisco Bay or the freshwater marshes of the Sacramento–San Joaquin Delta (Atwater *et al.*, 1979).

The mean annual salinity in San Francisco Bay ranges from 33‰ at the Golden Gate to 0–1‰ in the Sacramento–San Joaquin Delta (Fig. 2). The slope of the salinity gradient changes daily with the tidal cycle and seasonally with the marked variation in freshwater inflow between winter and summer (Fox *et al.*, 1991; Peterson *et al.*, 1995). The plants of the brackish marshes are well adapted to these cyclical variations and under normal conditions survive in place without significant mortality. However, if winters are moderately dry for several years in a row, as they were between A.D. 1986 and 1992, or extremely dry for even shorter intervals, such as in A.D. 1975–1976 and 1976–1977, the reduced freshwater inflow and resulting increase in salinity causes an up-estuary expansion of salt-tolerant species (e.g., *Spartina foliosa*) and a corresponding retreat of freshwater taxa (e.g., *Scirpus* spp.). In contrast, unusually wet winters, such as 1982–1983 and 1983–1984 have the opposite effect, with freshwater-adapted species extending their ranges toward the Golden Gate (Atwater and Hedel, 1976; Collins and Foin, 1993).

On longer time scales, changes in salinity may be caused by sea-level changes, resulting in an impact on both the location and composition of estuarine marshes. During the past century, estuarine salinity has been affected by human activities. The construction of reservoirs and water diversion systems has significantly changed the amount and timing of freshwater input (Nichols *et al.*, 1986). The volume of the tidal prism has been reduced by sediment accretion resulting from hydraulic mining and tidal marsh reclamation. The ecological consequences of these changes on the surviving areas of brackish marsh are not well understood.

In A.D. 1850, the fringes of Suisun Bay constituted the most extensive area of brackish marsh on the west coast of North America. Since then, over 90% of Suisun Marsh has been reclaimed. Our study site, Rush Ranch, in the northern part of Suisun Bay, is a small, unreclaimed relict of the Suisun tidal marsh (Fig. 1). The marsh is not pristine. During the early 20th

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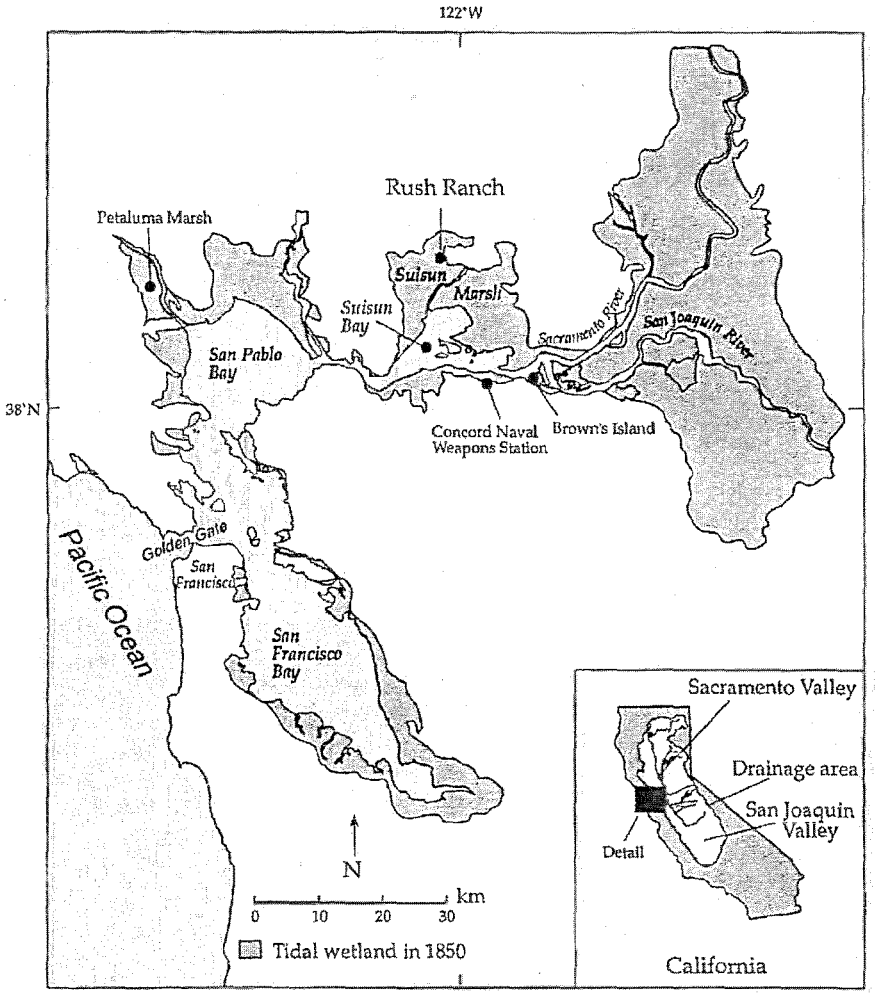

FIG. 1. Map of the study area showing the location of Rush Ranch Marsh in the San Francisco Estuary and the extent of tidal wetland in A.D. 1850.

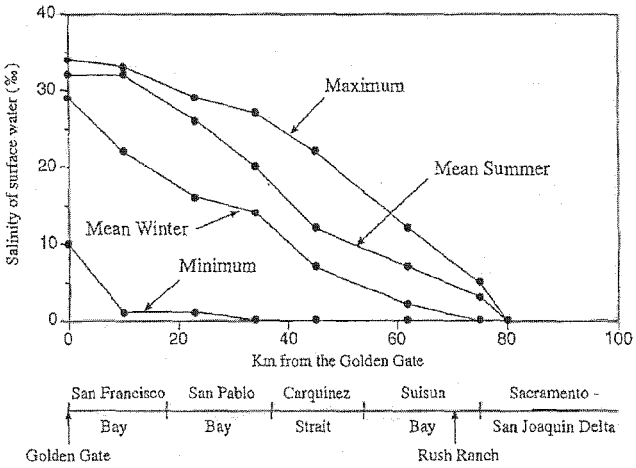

FIG. 2. Surface water salinity (1969–1975) from the Golden Gate to the Sacramento–San Joaquin Delta (Atwater *et al.*, 1979; original data from Conomos and Peterson, 1977).

century it was used for cattle grazing, and since 1940 its hydrology has been significantly influenced by reservoir construction and water diversion (Nichols *et al.*, 1986).

Previous work on stable-isotope variations in cores from San Francisco and San Pablo bays has shown that significant changes in salinity occurred in the estuary throughout the late Holocene (Ingram and Sloan, 1992; Ingram and DePaolo, 1993; Ingram *et al.*, 1996a, 1996b). However, uncertainties in radiocarbon dating of carbonate shells from these cores have made detailed interpretation difficult. In this paper, we establish a secure chronology with a series of AMS dated based almost entirely on *Scirpus* seeds. The record indicates that significant long-term changes in salinity have occurred in the estuary during the last 3000 years.

CARBON ISOTOPES, DIATOMS, AND POLLEN AS PALEOSALINITY PROXIES

Rush Ranch (RR) was selected as a study site because of its central location on the estuary's salinity gradient. We assumed

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that changes in salinity regimes would be more easily detected here than in San Francisco Bay or the Sacramento–San Joaquin Delta. The composition of marsh vegetation at any given location in the San Francisco Estuary is primarily controlled by distance from the Golden Gate, the magnitude of freshwater input, and the duration of tidal submergence (Atwater *et al.*, 1979; Josselyn, 1983). The latter effect is a primary control of the elevational ranges of tidal marsh species, which in turn have been used to define zonal patterns (Hinde, 1954; Macdonald, 1988; Atwater *et al.*, 1979).

Spartina foliosa and *Salicornia virginica* dominate the tidal marshes in the more saline sectors of the estuary, such as San Francisco Bay (Atwater *et al.*, 1979). *Spartina* is important in low marsh areas (0.25 m below to 0.75 m above msl) where mean winter surface-water salinities exceed 15‰ and mean summer salinities are >20‰. *Salicornia* is the dominant species on the less frequently flooded high-marsh plain (ca. 1 m altitude). The seasonal range in salinity is much greater here than in the low marsh because of evaporation. The winter–summer range in salinity in *Salicornia*-dominated areas in Suisun Marsh is from 18.5 to 81‰ (Mall, 1969).

Mean summer salinities range from 8 to 12‰ and winter salinities from 2 to 8‰ in brackish marshes. *Scirpus californicus* replaces *Spartina* in the low marsh, and a diverse mixture of species is typically found in the high marsh (e.g., *Distchlis spicata*, *Salicornia virginica*, *Juncus* spp., *Scirpus maritimus*, and *Scirpus americanus*). In the freshwater marshes of the Sacramento–San Joaquin Delta, *Scirpus acutus* and *Typha* spp. dominate the low marsh and *Scirpus americanus* and a diverse assemblage of herbaceous species are important on the high marsh (Atwater *et al.*, 1979).

Taxa utilizing the C_4 pathway (Table 1) have substantially higher $\delta^{13}C$ values (~−14‰) than those utilizing the C_3 pathway (~−29‰), due to fractionation during carbon fixation within the plant leaf (Smith and Epstein, 1970; O'Leary *et al.*, 1992). *Salicornia* uses the CAM photosynthetic pathway and has $\delta^{13}C$ values similar to those of the C_3 species (~−27‰). The $\delta^{13}C$ value of peat samples can serve as a proxy for changes in vegetation because the carbon isotopic composition of the vegetation is preserved in marsh peat (Ember *et al.*, 1987; Malamud-Roam and Ingram, in press). In particular, the presence or absence of C_4 plants, such as *Spartina* and *Distichlis*, can be detected easily.

TABLE 1
Carbon Isotope Ratios ($\delta^{13}C$) of Plant Species in the San Francisco Estuary

Species	Photosynthetic pathway	$\delta^{13}C$ (‰)
Distichlis spicata	C4	−13.5
Spartina foliosa	C4	−12.7
Cuscuta salina	C3	−29.8
Frankenia grandifolia	C3	−30.2
Grindelia stricta	C3	−26.4
Jaumea carnosa	C3	−27.2
Juncus balticus	C3	−28.4
Lepidium latifolium	C3	−26.6
Scirpus californicus	C3	−27.5
Scirpus maritimus	C3	−25.5
Typha latifolia	C3	−27.8
Salicornia virginica	CAM	−27.2

The use of carbon isotopes for reconstructing changes in marsh composition in the eastern United States is facilitated because (1) eastern C_4 taxa tend to dominate in more saline areas, and (2) C_3 taxa prefer freshwater environments (DeLaune, 1986; Chmura and Aharon, 1995). A parallel dichotomy exists in San Francisco Bay marshes, except that salt-tolerant *Salicornia* is isotopically indistinguishable from the C_3 plants that dominate the freshwater marshes. Fortunately, this complication can be overcome by pollen analysis, because *Salicornia* pollen is easily distinguished from the pollen produced by *Scirpus*, *Typha*, and other freshwater taxa.

Several studies have documented the diatom flora of San Francisco Bay (Wong and Cloern, 1981; Mahood *et al.*, 1986; Laws, 1988), but none have described the flora in detail or utilized diatom assemblages to understand the ecology of this complex ecosystem. The present study represents the first attempt to use diatom assemblages for interpreting regional climate change.

A Diatom Salinity Index (DSI) was developed for the northern San Francisco estuary marshes. The DSI summarizes the proportions of taxa that prefer freshwater, brackish, and marine salinities. These preferences are freshwater (F; 0–2‰), both freshwater and brackish (FB; 0–30‰), brackish (B; 2–30‰), brackish and marine (BM; 2–35‰), and marine (M; 30–35‰): $DSI = (F + FB + 0.5B)/(F + FB + B + BM + M)$. The value for taxa with brackish preference receives reduced weight in the numerator in order to treat the brackish salinities as transitional between freshwater and normal marine salinity values. The index ranges from 0.00 to 0.30 for samples dominated by marine taxa, 0.31 to 0.70 for samples dominated by a mixture of taxa, and 0.71 to 1.00 for samples dominated by freshwater taxa. At Rush Ranch, the DSI corresponds closely to the abundance of freshwater taxa.

Pollen has been used as a paleosalinity proxy in several previous studies (Meyerson, 1972; Mudie, 1975; Davis, 1992). In the San Francisco Estuary, changes in marsh composition along the salinity gradient are easily detected in pollen samples taken from the marsh surface. Chenopodiaceae pollen typically accounts for more than 80% of the aquatic pollen sum in salt marshes. This pollen type is assumed to represent *Salicornia* and *Atriplex*, although the latter is a relatively minor component of the modern marsh. Chenopodiaceae pollen is rare in surface pollen samples taken in upland sites in coastal California (Mudie, 1975). In freshwater marshes, Cyperaceae dominates, being 50 to 80% of the aquatic pollen sum. The Cyperaceae pollen type is probably mostly from *Scirpus*, although *Juncus* and *Cyperus* may also be present. The modern pollen-rain of brackish marshes, with high percentages of Asteraceae, Poaceae, Chenopodiaceae, and Cyperaceae pollen types, is more diverse than that of either the salt marshes or the freshwater marshes.

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METHODS

Field Techniques

Plant specimens and sediment samples were collected from marshes at the Concord Naval Weapons Station (Fig. 1) in the spring of 1997 to measure their carbon isotopic composition for calibration purposes. The specimens have been vouchered and deposited in the herbarium of the University of California Museum of Paleontology Pollen Laboratory.

In February 1996, a 3.5-m core was recovered from an area of high marsh (1 m altitude) at RR in northern Suisun Bay (Fig. 1). The core site is located between a tidal channel and the adjacent upland area. The core was raised with a modified 5-cm-diameter Livingston piston corer equipped with plastic (butyrate) liners. The high clay content of the marsh sediments prevented full recovery of meter-length sections, so cores were taken at overlapping 50-cm depths. The cores were X-radiographed and then split lengthwise for stratigraphic description and subsampling.

Laboratory Techniques

The core was subsampled for carbon-isotope analysis of sedimentary organic-carbon at 5-cm (0–35 cm) and 10-cm (35–355 cm) intervals. Sediment samples were wet-sieved into coarse (>2 mm) and fine (>125 μm, <2 mm) size fractions. The coarse fraction consists of mostly undecomposed plant roots and rhizomes, whereas the fine fraction represents decomposed plant matter and occasional foraminifera.

Thirty-seven samples were analyzed from the coarse fraction and fourteen samples were analyzed from the fine fraction. Samples were pretreated with 1 N hydrochloric acid to remove carbonate material and were combusted to yield CO_2 for isotopic analysis using standard techniques (Boutton, 1991).

Carbon-isotopic ratios ($^{13}C/^{12}C$) were measured on a Fisons Instruments Prism Series II mass spectrometer at the Lawrence Berkeley National Laboratory's Center for Isotope Geochemistry (CIG). Carbon-isotope ratios of modern marsh sediments and plants were measured on a 20/20 Europa Scientific mass spectrometer connected to a Europa Scientific SL carbon–nitrogen analyzer. All carbon-isotopic data ($^{13}C/^{12}C$) are reported in the δ notation relative to the PeeDee Belemnite standard (PDB), where $\delta^{13}C = [(^{13}C/^{12}C_{sample}/^{13}C/^{12}C_{std}) - 1] \times 1000$. The precision is $\pm 0.05‰$ for the $\delta^{13}C$ value.

Twenty-five samples were taken at ~10-cm intervals for pollen analysis. Standard extraction procedures were followed (Faegri and Iversen, 1975), with the addition of sieving through a 125-μm mesh after the KOH treatment. *Lycopodium* spores were added to each sample to permit calculation of absolute concentrations (Stockmarr, 1971). Pollen counting was done with a Leitz Laborlux Microscope at 400× magnification. The mean count, excluding *Lycopodium*, was 389 pollen and spores.

Seventy-one samples were analyzed for diatoms. Sampling intervals varied among 1 cm (0–25 cm), 5 cm (25–150 cm), and 10 cm (150–350 cm). Samples were processed using standard techniques and were pretreated with 30% H_2O_2, 36% HCl, and 16 N HNO_3. Prepared material was mounted on standard microscope slides using Hyrax, and identifications were made using an Olympus BH-2 microscope equipped with 50× and 100× oil immersion lenses. A minimum of 300 specimens were counted on each slide.

The chronology for the RR core is based on four AMS radiocarbon dates (Table 2). Three of these dates are on *Scirpus* seeds picked from the 2-mm sieved fractions. The fourth, from a section of the cores that lacked seeds, is on a *Distichlis spicatum* rhizome. These rhizomes do not penetrate deeply (~10 cm) and are therefore reliable indicators of the age of the marsh surface. The chronology was developed using linear interpolation between calibrated dates. Calibrated ages were chosen using the midpoint of the range given in the CALIB program (MacCalib Rev 3.03c; Stuiver and Reimer, 1993).

RESULTS

Chronology

The radiocarbon dates (Table 2) indicate that the base of the core has an extrapolated age of ca. 3000 cal yr B.P. This is generally consistent with other radiocarbon dates from the estuary, which indicate that marshes began expanding 3000 to 2000 cal yr B.P. (Atwater *et al.*, 1979). The accretion rate at the core site has varied between 0.6 and 1.6 mm/yr over the past 3000 yr.

Stratigraphy

Significant variations in the paleosalinity proxies (the DSI, pollen frequencies, and carbon isotope ratios) occur in the RR core (Fig. 4). Pollen preservation was poor in the lowest 25 cm of the core, and results are therefore only shown from the surface to a depth of 325 cm. For purposes of discussion five stratigraphic units are recognized.

Unit RR-5 (325–275 cm, ca. 2700–ca. 2500 cal yr B.P.)

Unit RR-5 consists of alternating sections of coarsely laminated clayey silt and peaty clay. The organic content ranges from 30 to 60% of the dry bulk density. Ostracods and gastropods are present in the relatively inorganic sediments, but not in the peaty clay. The DSI oscillates around 0.5. Chenopodiaceae pollen is the dominant pollen type in this unit and Cyperaceae pollen is virtually absent. The $\delta^{13}C$ values are highly variable, ranging from −25 to −14‰. The high $\delta^{13}C$ values are positively correlated with peaks in the Poaceae pollen curve.

Unit RR-4 (275–175 cm, ca. 2500–ca. 1750 cal yr B.P.)

Unit RR-4 is characterized by a high organic content (typically, >60%), the organic fraction consisting primarily of decomposed *Scirpus* stems and rhizomes with lesser amounts of *Distichlis* rhizomes. The DSI and pollen frequencies are variable, with the dominant diatom taxa being freshwater taxa. Cyperaceae and Chenopodiaceae pollen both average about 40% of the pollen sum, and Poaceae pollen has a prominent peak at

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TABLE 2
Radiocarbon Dates from Rush Ranch, Browns Island, and Petaluma Marsh

Site—Core	Depth (cm)	Material dated	Laboratory number[a]	Age (^{14}C yr B.P.)	One-sigma age range (cal yr B.P.)[b]
Browns Island—97A	60–61	*Scirpus* seeds	CAMS-46627	240 ± 80	420–0
Browns Island—97A	89–90	*Scirpus* seeds	CAMS-40777	810 ± 80	780–660
Browns Island—97A	129–30	*Scirpus* seeds	CAMS-40778	1060 ± 40	970–930
Browns Island—97A	149–150	*Scirpus* seeds	CAMS-46624	1210 ± 50	1170–1060
Browns Island—97A	179–180	*Scirpus* seeds	CAMS-46625	1270 ± 80	1280–1070
Browns Island—97A	209–210	*Scirpus* seeds	CAMS-46626	1560 ± 50	1520–1360
Browns Island—97A	240–241	*Scirpus* seeds	CAMS-40780	1780 ± 80	1810–1570
Browns Island—97A	322–333	*Scirpus* seeds	CAMS-40781	2330 ± 70	2360–2320
Petaluma Marsh—90.1	42–48	Bulk peat	Beta-53860	200 ± 60	296–0
Petaluma Marsh—90.1	52–58	Bulk peat	Beta-53861	280 ± 60	430–0
Petaluma Marsh—90.1	60–70	Bulk peat	Beta-46829	590 ± 70	648–529
Petaluma Marsh—90.1	80–90	Bulk peat	Beta-52696	480 ± 50	536–501
Petaluma Marsh—90.1	90–100	Bulk peat	Beta-46830	520 ± 50	548–511
Petaluma Marsh—90.1	105–115	Bulk peat	Beta-52697	790 ± 60	733–664
Petaluma Marsh—90.1	120–130	Bulk peat	Beta-46831	880 ± 50	889–724
Petaluma Marsh—87.2	148	Rhizome	AA-2735	1000 ± 50	946–800
Petaluma Marsh—90.1	150–160	Bulk peat	Beta-46832	1220 ± 50	1223–1064
Petaluma Marsh—90.1	180–190	Bulk peat	Beta-46833	1740 ± 70	1716–1544
Petaluma Marsh—90.1	210–220	Bulk peat	Beta-46834	1900 ± 80	1925–1720
Rush Ranch—96A	114–115	*Scirpus* seeds	CAMS-27555	840 ± 60	785–674
Rush Ranch—96A	175–176	*Scirpus* seeds	CAMS-27556	1840 ± 50	1826–1706
Rush Ranch—96A	259–260	*Scirpus* seeds	CAMS-27557	2390 ± 50	2461–2344
Rush Ranch—96A	299–300	*Distichlis* rhizome	CAMS-27558	2400 ± 60[c]	2748–2492

[a] The Beta numbers are conventional ^{14}C dates. The CAMS and AA numbers are AMS-dates.
[b] All radiocarbon dates were calibrated with the bidecadal dataset of MacCALIB Rev. 3.03c (Stuiver and Pearson, 1993).
[c] The calibrated age of this sample was corrected for C4 fractionation by adding 144 years to its radiocarbon age, which represents 16 years for each ‰ difference between its δ^{13}C value of −16‰ and a δ^{13}C value of −25‰.

about 225 cm (ca. 2150 cal yr B.P.). The δ^{13}C values are highly negative in the lower and upper levels of this unit and less negative in levels with high Poaceae pollen percentages.

Unit RR-3 (175–115 cm, ca. 1750–ca. 750 cal yr B.P.)

The organic content is generally near 50% but drops slightly in the upper part of this unit to 40% dry weight. The DSI is generally low, with a minimum of 0.1 at 140 cm (ca. 1250 cal yr B.P.). The brackish to marine taxon *Navicula peregrina* comprises as much as 80% of the total assemblage. At 170 cm (ca. 1750 cal yr B.P.) Cyperaceae frequencies decrease to <5% and Chenopodiaceae increase to >70%. Chenopodiaceae pollen is less important in the upper part of the unit, where Poaceae pollen is >25% of the pollen sum. As in the previous unit, the δ^{13}C values generally parallel the trends in Poaceae pollen, although the lowest δ^{13}C values occur 10 cm below the Poaceae peak.

Unit RR-2 (115–10 cm, ca. 750 cal yr B.P.–ca. A.D. 1930)

The organic content of this unit varies from 30 to 50% of the dry bulk density. In the lower part of the unit, the peat consists primarily of *Scirpus* stems in vertical growth position. The DSI averages ca. 0.9 and shows little variability throughout the unit. *Denticula subtilis*, a freshwater diatom, comprises as much as 80% of the assemblage in this interval. Cyperaceae pollen averages ca. 60% of the pollen sum, and Asteraceae pollen is between 10 and 20%. Chenopodiaceae pollen is rare, typically <5%. Poaceae pollen also is also relatively unimportant, especially in the upper part of the unit. The fine-fraction δ^{13}C samples show little intersample variation and are all highly negative at ca. −27‰. The coarse-fraction samples are more variable but, with the exception of the three youngest samples, are also highly negative, with δ^{13}C values of ca. −26‰.

Unit RR-1 (10 cm–surface, ca. A.D. 1930–Present)

The lower part of Unit RR-1 (20–7 cm) has a low organic content (25–40%). The inorganic fraction consists of clay and silt. All three salinity proxies change abruptly within this unit. The DSI drops from 0.90 at 20 cm to 0.10 at the surface, and *Denticula subtilis* is replaced by a number of taxa that tolerate a greater range of salinities. Cyperaceae and Asteraceae pollen decrease from 50 and 15%, respectively, to <5%. Chenopodiaceae pollen increases from <5 to 70%. Poaceae pollen also increases from <5% at 10 cm to 15% at the surface. The δ^{13}C of both the coarse and fine fractions increase toward the present, although the latter lags the former by about 15 cm.

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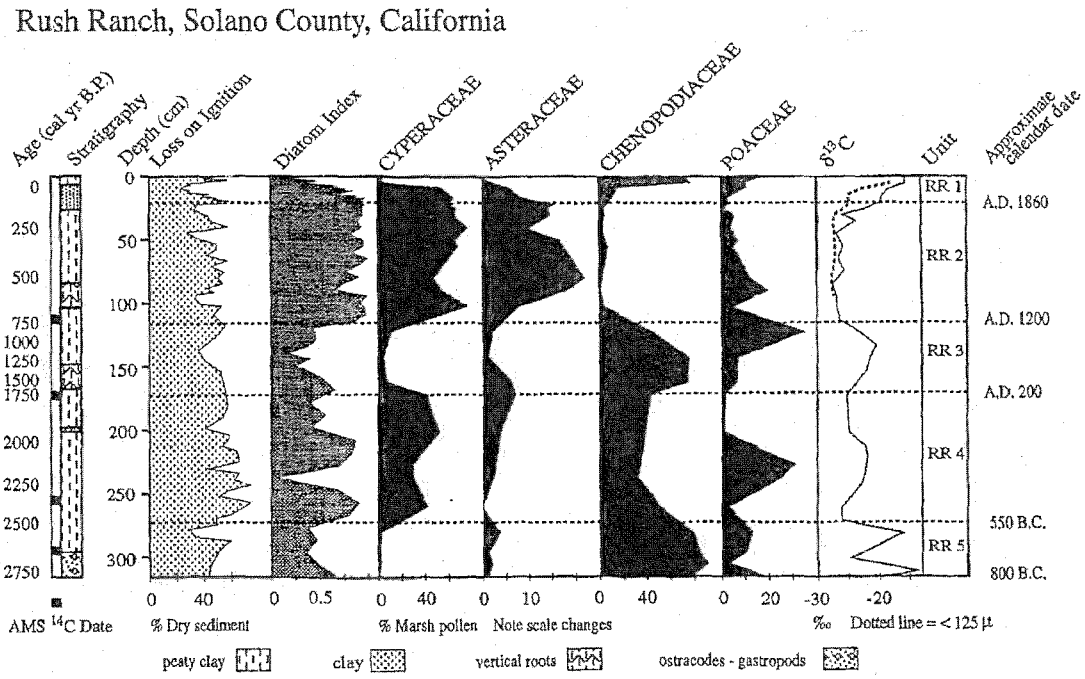

FIG. 3. Stratigraphy, chronology, Diatom Salinity Index, Selected pollen taxa, and $\delta^{13}C$ values from the Rush Ranch core. Pollen represent percentages of total marsh pollen.

DISCUSSION

The three paleosalinity proxies from the RR core all show the same basic trends (Fig. 3). Changes in salinity occurred relatively rapidly, e.g., at 2500, 1750, and 750 cal yr B.P., and at A.D. 1930. Salinity conditions remained relatively stable during the intervening periods. The following discussion explores methodological implications of the evidence presented and the extent to which the RR paleosalinity record reflects effects of climatic change (e.g., changes in freshwater flow into the estuary) or nonclimatic factors (e.g., plant succession, changes in sea level, and human impacts). We also compare RR and other paleosalinity records from coastal California.

Methodological Implications

The Rush Ranch carbon-isotope and pollen data are complementary in that they permit a more detailed reconstruction of salinity change than would be the case with either record alone. For example, the positive correlation between Poaceae pollen percentages and $\delta^{13}C$ variations (Fig. 3) strongly supports the idea that the Poaceae pollen was derived from either *Distichlis* or *Spartina*. *Distichlis spicata* is locally important in high-marsh environments from San Pablo Bay to Suisun Bay, whereas *Spartina foliosa* is a low-marsh species, whose contemporary range barely extends eastward into Suisun Bay. The correlation also indicates that Poaceae species, which in central California are C_3 taxa, are an unimportant component. This multiproxy approach can distinguish taxa that are isotopically similar but

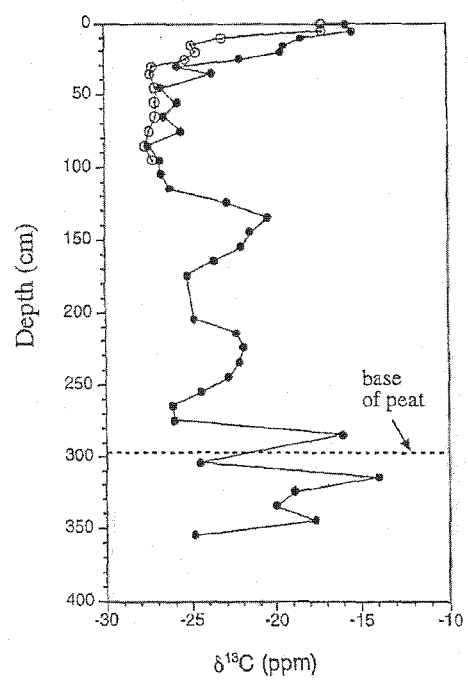

FIG. 4. Carbon isotopes ($\delta^{13}C$) plotted against depth (cm) for the Rush Ranch core. The coarse fraction (>2 mm) is plotted with closed circles and the fine fraction (>125 μm, <2 mm) is plotted using open circles.

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TABLE 3
Sample Depth and Carbon Isotopic Composition of Coarse and Fine Fractions from the Rush Ranch Core

Depth (cm)	$\delta^{13}C$ coarse (>2 mm)	$\delta^{13}C$ fine (>125 μm, <2 mm)
0.5	−15.7	−17.2
5.5	−15.4	−17.2
10.5	−18.4	−23.1
15.5	−19.4	−24.9
20.5	−19.6	−24.6
25.5	−22.0	−25.2
30.5	−25.7	−27.2
35.5	−23.7	−27.3
45.5	−26.7	−27.0
55.5	−25.7	−27.0
65.5	−26.5	−27.0
75.5	−25.5	−27.4
85.5	−27.4	−27.6
95.5	−26.8	−27.2
104.5	−26.7	
114.5	−26.2	
124.5	−22.8	
134.5	−20.4	
144.5	−21.5	
154.5	−22.0	
164.5	−23.6	
174.5	−25.2	
204.5	−24.8	
214.5	−22.3	
224.5	−21.9	
234.5	−22.2	
244.5	−22.8	
254.5	−24.4	
264.5	−26.1	
274.5	−26.0	
284.5	−16.1	
304.5	−24.5	
314.5	−14.0	
324.5	−18.9	
334.5	−20.0	
344.5	−17.7	
354.5	−24.8	

ecologically different. For example, *Salicornia* and *Scirpus* have similar $\delta^{13}C$ values but very different salinity tolerances.

The depth of vertical penetration of roots at Rush Ranch can be inferred from differences between the $\delta^{13}C$ values of the fine (>125 μm, <2 mm)- and coarse (>2 mm)-fraction samples (Fig. 6 and Table 3). The two size fractions show the same trends, but the coarse samples are offset vertically by 10 to 15 cm. *Distichlis*, a C_4 taxon, has resistant roots that are included in the coarse-fraction samples. Thus, the displacement of grain size probably reflects *Distichlis* root penetration.

The Paleosalinity Record: Nonclimatic Effects

Plant succession is an important nonclimatic influence on marsh salinity. The RR stratigraphy indicates that the late Holocene marsh was permanently established ca. 2500 cal yr B.P. Prior to this (Unit RR-5, Fig. 3), alternating periods of marsh and low-energy tidal flat characterized the core site. The Poaceae pollen peaks and corresponding low $\delta^{13}C$ values in RR-5 most likely represent *Spartina foliosa*. The species indicates that mean seasonal salinity perhaps was 15–20‰ as compared with 2–7‰ today. The Chenopodiaceae pollen is probably nonlocal in origin, having been washed or blown into the tidal flat from nearby marshes fringing the eastern upland area (Fig. 1).

Given the ecology of local marsh plants, the initial period of marsh formation, as represented by the lower part of Unit RR-4, involved growth of low-marsh taxa (e.g., *Spartina foliosa* and *Scirpus californicus*). The radiocarbon chronology indicates that a gradual accumulation of marsh peat (ca. 1.3 mm/yr) culminated in the development of a mature high-marsh by 1750 cal yr B.P. (i.e., at the end of Unit RR-4). The reduced frequency of tidal flooding and increased evaporation on the high-marsh plain would have increased the local importance of salt-tolerant taxa, such as *Salicornia* and *Distichlis*. The marsh surface was close to the upper limit of tidal action, which would also have slowed the rate of accretion, as is indicated in the radiocarbon chronology.

The distribution of marsh plants is strongly influenced by the frequency and duration of tidal submergence, so any vertical displacement of the marsh, caused for example by a tectonically induced change in sea level, has important ecological consequences. Perhaps the decline in Cyperaceae and rise in Chenopodiaceae pollen percentages at 1750 cal yr B.P. were caused by an upward displacement of the marsh surface. Similarly, the decrease in Chenopodiaceae and the increase in Cyperaceae pollen percentages at 750 cal yr B.P. may have been caused by a lowering of the marsh surface.

One means of testing these possibilities is to compare the RR radiocarbon chronology with chronologies developed for two other marsh sites in the estuary. Petaluma Marsh in San Pablo Bay and Brown's Island east of Suisun Bay are located on separate fault blocks (Fig. 5). If tectonic activity were the primary determinant of marsh stratigraphy, each marsh should show a somewhat different record of sediment accretion. The age–depth relationships for the three marshes are remarkably similar (Fig. 5). This finding suggests that tectonic activity has not played a major role in changing the floristic composition of the marshes. The three marshes are located close to three different faults, and it seems unlikely that a single earthquake event would affect all three areas in the same way. The average rate of marsh accretion over the last 750 yr has been close to 1.5 mm/yr at all three sites, close to the average rate of sea-level rise at San Francisco for the period A.D. 1855–1986 (Lyles *et al.*, 1988). All of this strongly suggests that the primary control on marsh elevation during the period of record has been eustatic and not isostatic sea-level change.

The final nonclimatic influence on marsh salinity is reduced freshwater flow into the estuary because of diversions for agricultural and urban use (Nichols *et al.*, 1986; Peterson *et al.*, 1995). Storage in reservoirs decreases winter inflow and

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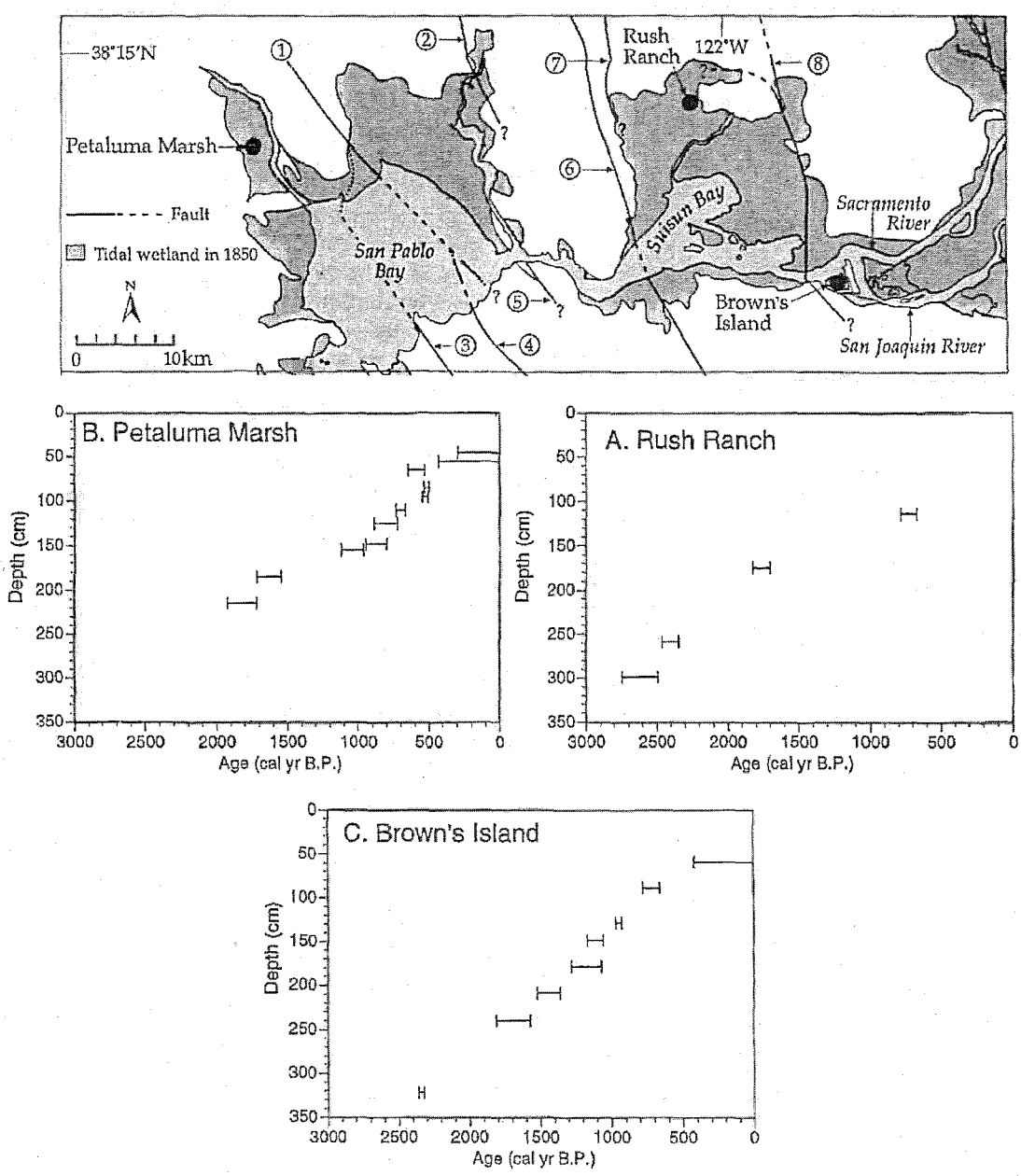

FIG. 5. Map showing the location of major faults and three marsh sites (Brown's Island, Rush Ranch, and Petaluma Marsh) cored in northern San Francisco Bay. Calibrated radiocarbon ages (cal yr B.P.), shown for three marsh locations, are plotted against depth in core. Faults are as follows: (1) Rodger's Creek; (2) West Napa; (3) Hayward; (4) Pinole; (5) Franklin Canyon; (6) Green Valley; (7) Cordelia; (8) Pittsburg–Kirby Hills.

increases summer flow. Russell *et al.* (1982) estimated that the pre-A.D. 1850 inflow to the estuary from the delta averaged 36 km^3/yr and that by A.D. 1978 the flow had been reduced by 44% to 20 km^3/yr. Significant diversion of water first occurred in the period A.D. 1920–1950 when numerous dams and aqueducts were constructed. The California Aqueduct, which diverts water from the delta to southern California, was constructed between A.D. 1960 and 1970.

We interpret the increase in salinity indicated in stratigraphic Unit RR-1 to be the result of water diversion and reduced freshwater flow into the estuary. All three paleosalinity proxies increase significantly at approximately the same depth in the core: we see a shift to isotopically less-negative $\delta^{13}C$ values in the fine-fraction between 10.5 and 5.5 cm, an increase in Chenopodiaceae and decrease in Cyperaceae pollen percentages between 8 and 5 cm, and a drop in the DSI at ca. 10 cm. If the mean

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annual accretion rate for this part of the core is assumed to be 1.5 mm/yr and the increase in salinity is set to the 10 cm depth, the corresponding date would be A.D. 1930. The salinity increase indicated in Unit RR-1 may also be partially due to reduced precipitation in the Sacramento Basin watershed. Earle (1993) used tree-ring evidence to reconstruct Sacramento stream flow for the period A.D. 1560 to 1980 and found that A.D. 1917 to 1950 was the driest interval over the 420-yr period.

The Paleosalinity Record: Climatic Effects

Loss-on-ignition, diatom, pollen, and carbon isotope data indicate that the RR marsh was permanently established by ca. 2500 cal yr B.P. (Fig. 3). This event was preceded by a period (Unit RR-5) of incipient marsh formation that periodically reverted to tidal flat, as indicated by high Chenopodiaceae pollen percentages, an absence of Cyperaceae pollen, high but fluctuating $\delta^{13}C$ values and Poaceae pollen percentages, and high DSI. The values of the paleosalinity proxies in Unit RR-5 are similar to those of Unit RR-1. However, a high marsh similar to that of the 20th century did not exist at the core site prior to 2500 cal yr B.P. An intermittent low marsh with *Spartina* is the more plausible interpretation, suggesting mean seasonal salinity values at the core site could have been 15–20‰ as compared with 2–7‰ today.

The paleosalinity proxies in units RR-1 (A.D. 1930 to the present) and RR-3 (1750 to 750 cal yr B.P.) also show convincing evidence of climatic influences, indicating that average freshwater-inflow levels during Unit RR-3 were as low as they have been during the present century. Russell *et al.* (1982) estimated that 20th century diversions had reduced the freshwater inflow to the estuary by 44% to 20 km^3/yr by A.D. 1978. This magnitude of flow probably was also typical of the period 750–1750 cal yr B.P. This interpretation suggests an equivalent reduction in precipitation for the watershed, since there were no prehistoric, artificial diversions.

Further evidence of climatic effects in the RR record is the marked decrease in all three paleosalinity proxies in Unit RR-2 (750 cal yr B.P. to A.D. 1930). Cyperaceae pollen dominates the records, indicating that tules (probably *Scirpus maritimus* and *Scirpus americanus*) covered most of the high marsh. According to Mall's (1969) data on the salinity tolerances of Suisun Marsh plants, these results imply mean annual salinities on the marsh surface of 7 to 33‰, which is significantly less than the modern 19 to 81‰ mean annual range for *Salicornia*. The mean annual salinity of the surface waters of Suisun Bay was probably proportionally reduced to less than 5‰.

Comparisons with Other California Paleosalinity Records

The relative importance of climate change as an influence on marsh salinity can be clarified by comparison with records from different areas. Relatively few paleosalinity studies have been carried out in coastal California, and even where data are available, chronological control generally is poor. However, a comparison of some of the available records shows several interesting trends (Fig. 6.) The RR and San Joaquin Marsh indices show similar trends for the last 1500 yr, although the low-salinity phases are more pronounced and more prolonged at RR than at San Joaquin Marsh. Both sites show increasing salinity during the last 100 yr.

The Petaluma Marsh and San Pablo Bay records only cover the last 700 yr. The former is based on the Mg/Ca ratios of ostracode valves and the latter on oxygen isotope ratios of *Macoma nasuta*. The Petaluma record shows the same basic trends as the pollen indices, with decreasing salinity from ca. 650 cal yr B.P. until about 200 cal yr B.P., followed by increasing salinity to the present. The San Pablo salinity curve shows little agreement with the other records. We attribute this discrepancy to uncertainties in radiocarbon dating at this site. The chronology was based on four AMS dates that were corrected for an assumed reservoir age of 625 yr. If this correction is too great, the core

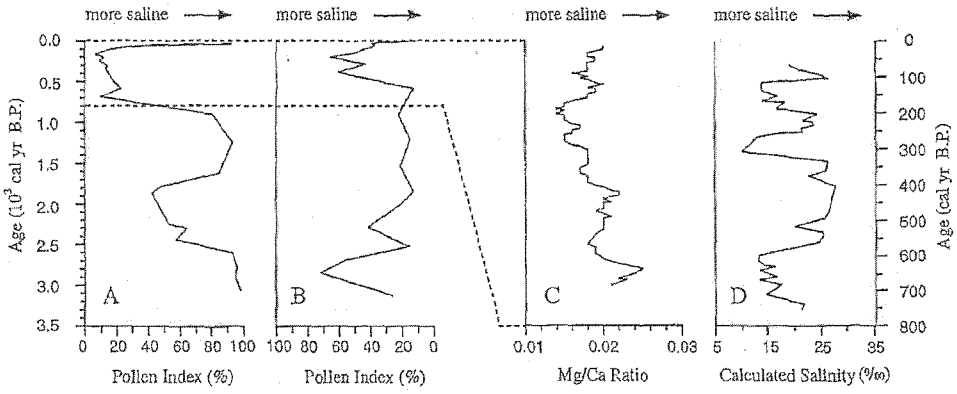

FIG. 6. Paleosalinity records from Coastal California. (A) Rush Ranch Pollen Index. The index represent Chenopodiaceae plus Poaceae pollen as a percentage of Chenopodiaceae, Poaceae, Cyperaceae, and Asteraceae. (B) San Joaquin Pollen Index from Davis (1992). The index represents the percentage of Asteraceae pollen. High percentages represent freshwater conditions. (C) Mg/Ca ratio from ostracods from a Petaluma marsh core. High Mg/Ca ratio indicates higher salinity (from Ingram *et al.*, 1998). (D) Salinity determined by $\delta^{18}O$ measured on fossil mollusk shells from San Pablo Bay (from Ingram *et al.*, 1996a).

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will represent a proportionally longer time period than indicated (Fig. 6D).

CONCLUSIONS

This study documents the results of the analyses of diatoms, pollen, and stable carbon isotopes from a 3.5-m core from RR, a brackish tidal marsh in the northern sector of the San Francisco Estuary. The core spans the last 3000 yr and indicates that the marsh was established ca. 2500 cal yr B.P. The results also indicate that the salinity of water affecting the marsh has changed significantly during this period. These changes are due partially to climatic effects or, more specifically, changes in the magnitude of freshwater inflow into the estuary. Nonclimatic effects, such as plant succession and human impacts were also important. No obvious evidence of tectonic activity was encountered.

Reduced freshwater-flow into the estuary occurred at 3000 to 2500 cal yr B.P., 1750 to 750 cal yr B.P., and ca. A.D. 1930 to the present. During the first period the intermittent presence of the C_4 grass *Spartina foliosa* at the core site indicates that mean seasonal surface salinities may have been in the range of 15 to 20‰. In the second period, all three proxy records indicate salinity conditions similar to those of the present. These results imply a reduction of rainfall in the Sacramento–San Joaquin watershed, possibly by as much as 44% below 20th-century levels. The third period of reduced freshwater inflow coincides with, and is most likely due to, upstream storage and water diversion in the Sacramento–San Joaquin watershed. However, drought may also have been a factor, as the period A.D. 1970 to 1950 was extremely dry in the Sacramento Valley watershed. The period 750 cal yr B.P. to A.D. 1930 was characterized by unusually high freshwater-inflows to the estuary. Mean seasonal salinities during this period were probably analogous to those of the Sacramento–San Joaquin Delta prior to water diversions (i.e., 0‰) both in winter and summer.

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Appendix B

Demonstration Document:

Suisun Marsh Preservation Agreement Amendment Three Actions as a Means to Provide Equivalent or Better Protection than Channel Water Salinity Standards at Suisun Marsh Stations S-35 and S-97

Submitted to the
State Water Resources Control Board

Suisun Marsh Branch
Environmental Services Office
Department of Water Resources
April 1998 Revision

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Purpose

The purpose of this document is to demonstrate that the management actions in Suisun Marsh Preservation Agreement Amendment Three will provide equivalent or better protection than the channel water salinity standards for western Suisun Marsh stations S-35 and S-97 (Figure 1) specified in the 1995 Bay/Delta Plan.

The following information are presented in this document:

- Status of DWR/USBR Suisun Marsh Activities including the process to amend the Suisun Marsh Preservation Agreement;
- Objective(s) of the Suisun Marsh channel water salinity standards and management strategies used on managed wetlands;
- Why large-scale facilities are not needed;
- Description of SMPA Amendment Three actions, implementation schedule, monitoring, and an explanation of providing equivalent or better protection; and
- Letters of Concurrence and References.

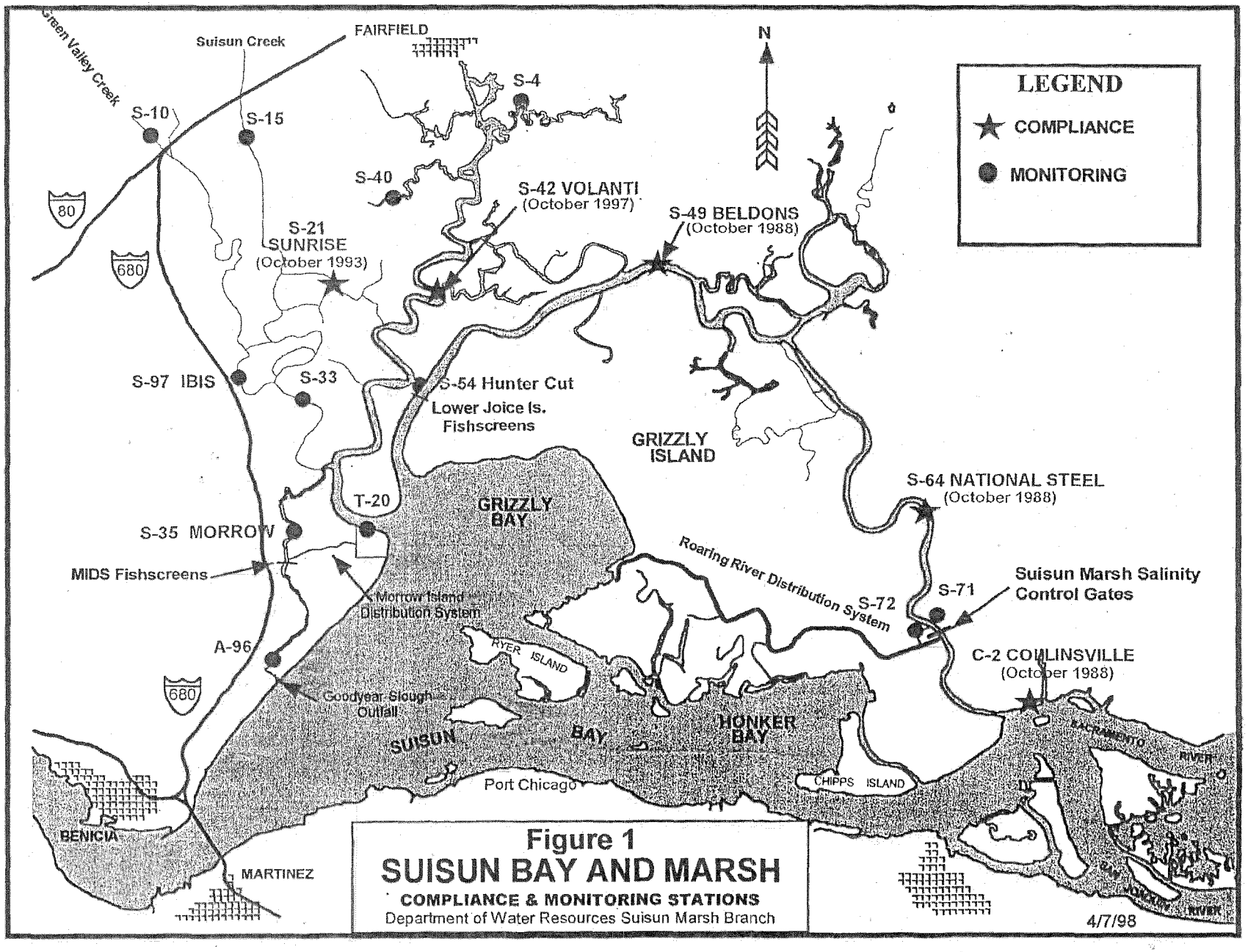

Figure 1
SUISUN BAY AND MARSH
COMPLIANCE & MONITORING STATIONS
Department of Water Resources Suisun Marsh Branch

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Status of DWR/USBR Suisun Marsh Activities

1) Regulatory Framework

In June 1995, the State Water Resources Control Board replaced the Suisun Marsh standards in Decision 1485, Table II, with the standards contained in Attachment B of Order WR 95-6, based on the objectives in the 1995 Bay/Delta Plan, adopted in May 1995. The purpose of the Suisun Marsh salinity objectives is to provide water of sufficient quality to the ***managed wetlands*** to achieve soil water salinities capable of supporting the plants characteristic of a brackish marsh (SWRCB Environmental Report, 1995 Bay/Delta Plan, Appendix 1, page IX-15, et seq.). According to Order WR 95-6, western Marsh objectives were to become effective at stations S-42 (Volanti), S-97 (Ibis), and S-35 (Goodyear) on October 1, 1997, and the Department of Water Resources and the U.S. Bureau of Reclamation were to achieve the indicated mean monthly high tide channel water salinities, *or* demonstrate to the SWRCB that equivalent or better protection is provided at these locations.

In September 1997, DWR and USBR, with the endorsement of DFG and SRCD, petitioned the SWRCB to extend the compliance date specified in Order WR 95-6 for western Marsh stations S-35 and S-97. In October 1997, the SWRCB approved the petition, extending the compliance date to April 1998. A second petition to extend the compliance date for an additional 180 days was submitted and approved in March 1998. The additional time will enable the SMPA parties to execute and begin implementing Amendment Three.

In the Program of Implementation of the 1995 Bay/Delta Plan, the SWRCB suggested that the DWR, USBR, Department of Fish and Game, and Suisun Resource Conservation District implement measures to appropriately control Suisun Marsh soil and channel salinities, including actions identified in the Suisun Marsh Preservation Agreement (SMPA), signed by these parties in 1987. Specifically, the SWRCB recommended the use of water and land management practices and the employment of a water manager to provide more consistent protection for the managed wetlands in Suisun Marsh and the species they support, and to protect the beneficial uses of water more efficiently than under current practices.

The parties to the SMPA have worked cooperatively since the early 1980s to implement the Plan of Protection for the Suisun Marsh (1984), developed in response to Condition 7 of D-1485. To date, DWR and USBR, with input from DFG and SRCD, have completed Phase I (Initial Facilities, 1980) and Phase II (Suisun Marsh Salinity Control Gates (SMSCG), 1988) of the Plan of Protection, and made significant progress on the planning and environmental documentation for Phases III and IV, directed at the western Marsh (1990-1995). However, DWR and USBR suspended work on the Western Suisun Marsh Salinity Control Project in 1995 to reevaluate the needs of the western Marsh under the expected hydrologic conditions imposed by the 1995 Bay/Delta Plan.

2) Contractual Framework

DWR, DFG, USBR, and SRCD signed the *Suisun Marsh Preservation Agreement* (SMPA) on March 2, 1987. An objective of the SMPA is to assure that USBR and DWR mitigate for any adverse effects on managed wetlands in the Marsh of the Central Valley Project (CVP) and State Water Project (SWP), as well as a portion of the adverse effects of other upstream diversions. Under the Original Agreement, this objective is accomplished by constructing large-scale facilities in the Marsh (e.g., the SMSCG) to maintain a dependable supply of adequate quality water within Suisun Marsh channels.

3) Comprehensive Review

The SMPA parties are currently conducting a Comprehensive Review of Suisun Marsh monitoring data gathered since the on-site monitoring began in October 1984. The Comprehensive Review Team is currently working on the first draft of the report, which is scheduled for release by mid-1998, and relevant interim findings are included in this document.

The purpose of the review of the SMPA, described in Article 4 (a), is to determine if the objectives of the Agreement are being achieved and if any adjustments are needed. The objectives of the SMPA are stated in Article 2 and include assuring that USBR and DWR maintain an adequate supply of good quality water within the Marsh; improve Marsh wildlife habitat to the extent feasible; define the scope of the obligations of USBR and DWR to provide the water supply, distribution, redistribution and management facilities; and to assure that USBR and DWR recognize that the water users within the Marsh have been diverting and will continue to divert water for wildlife habitat management within the Marsh. The objectives of the *Suisun Marsh Monitoring Agreement* are to describe a methodology and define the scope of DWR's, USBR's and DFG's obligations to carry out an appropriate monitoring program to meet the objectives of the SMPA. The SMMA has been evaluated in the context of the four stated objectives of the SMPA.

In addition to evaluating the above-mentioned objectives, data being analyzed in the Comprehensive Review include the results of water monitoring, vegetation monitoring, wildlife surveys, and fish monitoring. Water monitoring data include channel water salinity, diversion and drain water salinity, managed wetlands water elevation and salinity, and soil water salinity. Vegetation monitoring data include plant survey data collected from the managed wetlands, and Marsh-wide triennial vegetation survey data. Wildlife survey data include waterfowl species and numbers, and results of salt marsh harvest mouse surveys. Fish monitoring data include abundance of young striped bass and *Neomysis* in Montezuma Slough, salmon sampling, effects of the SMSCG on predation and migration, and measurements of the distribution and abundance of existing fish resources in the Marsh.

4) Status of Suisun Ecological Workgroup

Initial activities of the Suisun Ecological Workgroup (SEW) included developing background information on brackish marsh ecology, the history of Suisun Marsh, management of diked seasonal wetlands, the scientific basis for Decision 1485 Suisun Marsh Standards, and identifying beneficial uses of the Marsh.

SEW's first technical task since these initial investigations has been to evaluate water quality objectives for resources such as plants, wildlife and fishes. To facilitate this, the Workgroup divided into four resource-specific subcommittees: Brackish Marsh Vegetation, Wildlife, Waterfowl, and Aquatic Habitat. Each of these subcommittees will evaluate the effects of existing Western Marsh salinity standards (1995 WQCP and Order 95-6) on the resource being considered, and develop recommendations for resource-specific water quality objectives, as well as for future studies and compliance monitoring programs. A fifth subcommittee is working in conjunction with DWR Suisun Marsh Planning to evaluate water quality and hydrology issues in the Marsh. The subcommittees began meeting independently in October 1995, and produced work plans in February 1996. SEW submitted a status report to the SWRCB in September 1997.

SEW's next step will be to evaluate the impacts of resource-specific objectives and to develop appropriate multi-resource (ecosystem) water quality objectives. In March 1988, an all day workshop was held to facilitate integration of subcommittee recommendations. The recommendations developed in the workshop will be presented in a white paper to be distributed in May for peer review, prior to a May workshop. A final report is scheduled to be completed in September 1998, and SEW will present its recommendations to the SWRCB in October 1988.

For more information about SEW, or to see meeting summaries or subcommittee work plans, please visit the SEW home page at iep.water.ca.gov/sew

5) SMPA Amendment Process

Updating the SMPA

In July 1995, USBR, DWR, DFG, and SRCD began negotiating to update the SMPA, and established an ad hoc Negotiating Team, Technical Group, Drafting Committee, and Environmental Documentation Team.

Based on the analysis of the Technical Group, the SMPA parties agree that additional large scale facilities proposed in the Plan of Protection will *not* be necessary for salinity control in the Suisun Marsh because of the effectiveness of the Suisun Marsh Salinity Control Gates in conjunction with the outflows specified in the 1995 Bay/Delta Plan.

In lieu of large facilities, the Negotiation Team has identified a series of management actions (listed below) consistent with the SMPA objectives. The purpose of these

actions are to: (1) improve water and habitat management on managed wetlands throughout Suisun Marsh; (2) lower diversion water and soil salinity on western Marsh managed wetlands; and (3) provide funds to managed wetlands for more intensive management activities to remove soil salts in response to prolonged drought conditions.

Management Actions

1. Meet Channel Water Salinity Standards in Order 95-6.
2. Converting S-35 and S-97 from Compliance Stations to Monitoring Stations.
3. September Operation of the Suisun Marsh Salinity Control Gates.
4. Water Manager Program.
5. Updating Existing Management Plans.
6. Joint-Use Facilities Program.
7. Managed Wetland Improvement Fund.
8. Portable Diversion Pumps With Fish Screens.
9. Portable Drainage Pumps.
10. Realign and Stabilize Roaring River Distribution System Turnouts.
11. Drought Response Fund.

The SMPA negotiators pursued an alternative with the Fairfield Suisun Sewer District to construct an intertie between the treatment plant and Green Valley Creek and discharge treated effluent into the northwestern Marsh. The SMPA proposal is included in Appendix A. However, FSSD notified the SMPA parties that there are too many obstacles to allow this project to proceed at his time (Appendix B).

SMPA Amendment Three

The Drafting Committee has agreed on provisions to implement and fund the above actions under *SMPA Amendment Three*. DWR and USBR will fund the actions and SRCD will have a significant role in implementing many of the management actions. The amendment will be executed after completion of the necessary environmental documentation. The Environmental Documentation Team has completed a draft Initial Study/Environmental Assessment, and copies of the draft environmental document were provided to the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. The SMPA parties are working to complete the amendment process including the environmental documentation in 1998.

Water Rights Hearing

The SWRCB has included similar management actions as an alternative in its EIR for implementing the 1995 Bay/Delta Plan (September 12, 1996 SWRCB letter to the Bay-Delta mailing list). During the Water Rights Hearing for implementing the 1995 Bay/Delta Plan, the SMPA parties will recommend that the SWRCB select these actions as the next step in implementing the objectives for Suisun Marsh managed wetlands.

Purpose and Basis of Marsh Channel Water Salinity Standards

1) Achieve Target Spring Soil Salinity for Plant Germination

Past food habit studies conducted in Suisun Marsh (George, 1965) indicated that seeds from alkali bulrush (*Scirpus robustus*), fat hen (*Atriplex triangularus*), and brass buttons (*Cotula coronopifolia*) provided the bulk of winter waterfowl food supply. Later studies (DFG, 1969; Rollins 1973) on habitat management conditions necessary for the production of these plants concluded that plant communities in Suisun Marsh are controlled primarily by the depth and duration of soil submergence and secondarily by the concentration of salts in the root zone.

Rollins work, presented as part of the DFG testimony to the SWRCB for Decision 1485, describes the affect of soil salinity and length of soil submergence in May on seed production. It was determined that the most suitable soil salinity in May was about 9 parts per thousand total dissolved solids.

2) Relationship to Channel Water Salinity Standards

The protective water quality standards established in Decision 1485 are based on research by Mall (1969) and Rollins (1973), who investigated the salinity tolerance of alkali bulrush (*Scirpus robustus*) and other important waterfowl food plants in the Suisun Marsh. Results of the research identified maximum applied water salinity that would provide an average of 90 percent of the maximum alkali bulrush seed production and a 60 percent seed germination rate. Table 1, included in DFG's Submittal to the SWRCB for the 1978 Water Quality Control Plan, shows DFG's recommendations for applied water salinity.

The SWRCB used DFG's recommendations as the basis for salinity objectives and developed the Suisun Marsh salinity standards in Decision 1485. Included in the 1978 Board Order implementing D-1485, the State Board stated "For protection of SWRCB, permittees shall.....maintain Suisun Marsh primarily as a brackish water marsh capable of producing high-quality feed and habitat conditions for waterfowl and other marsh-related wildlife using best practical management practices" (SWRCB, 1978, D-1485 pg. 27).

The SWRCB determined that channel water salinities would be reported as the mean of the two daily high tides. The Board used this criterion because, without the use of pumps, wetland managers using gravity systems are only able to divert water at high tides.

Table 1 : Salinity of Applied Water Required to Achieve An Average of 90 Percent of Maximum Alkali Bulrush Seed Production and 60 Percent Seed Germination.

	Applied Water Salinity		Soil Water Salinity		Ratio of Soil Water Salinity to Applied Water Salinity
	EC (mmhos)	PPT TDS	EC (mmhos)	PPT TDS	
OCT	18.8	12 /1	50.0	32	2:1
NOV	15.6	10 /2	37.5	24	2:1
DEC	15.6	10	31.2	20	2:1
JAN	12.5	8	25.0	16	2:1
FEB	7.8	5	15.6	10	1.8:1
MAR	7.8	5	14.1	9	1.8:1
APR	10.9	7	14.1	9	1.3:1
MAY	10.9	7	14.1	9	1.3:1

1/ The salinity of water applied in October dissolves surface salts and is increased by 4 ppt TDS.

2/ The salinity of water applied in November in increased by 2 ppt TDS due to residual surface salts.

3) Relationship to Water Management

The DFG used these salinities as guidelines for long-term management and maintenance of wetlands in Suisun Marsh. Rollins (1981) found these guidelines to represent the most saline water that can be applied regularly to well-managed seasonal wetlands without loss of alkali bulrush seed production.

SRCD prepared water management plans for each of the 158 privately managed wetlands in the Marsh in 1980-81. Water management recommendations and vegetation goals in the plans are based on findings from Rollins' studies.

In recommending water management schedules and improvements in both water and vegetation management, these plans take into account each ownership's mean pond bottom elevation, external (slough) tide elevation range, water control facilities, soils, and habitat goals. SRCD recommends that the clubs periodically change their water management regimes to discourage the production of monocultures and maximize biodiversity in wetland habitats. DFG has prepared its own management plans for State-owned land in the Marsh, which follow a similar management regime and management schedules.

A new waterfowl food preferences study is scheduled to begin during fall 1997. This study was designed and will be conducted by the National Biological Survey and UC Davis, and funded by DWR and USBR. Although this study is limited in scope, its results will help update the existing information on waterfowl food preferences.

Objective of Management Strategies on Managed Wetlands

1) Management Strategies

Most wetland managers in the Suisun Marsh begin flooding the wetlands on October 1 in preparation for the fall migration of waterfowl. To reduce mosquito production in the Marsh, Solano County Mosquito Abatement District does not recommend flooding before October 1, unless the landowner can flood and drain the wetlands within 10 days or is willing to pay for mosquito control spraying.

When possible, wetland managers of the Suisun Marsh use gravity flow to fill and drain their wetland areas. Consequently, the wetlands are filled during high tide, when applied water salinity is the greatest, and the water can flow through the inlet gates (flood facility) into the managed wetlands. The wetlands are drained during low tide, when water elevation in the diked wetlands is higher than that of the slough and water flows out through drain gates and into the slough.

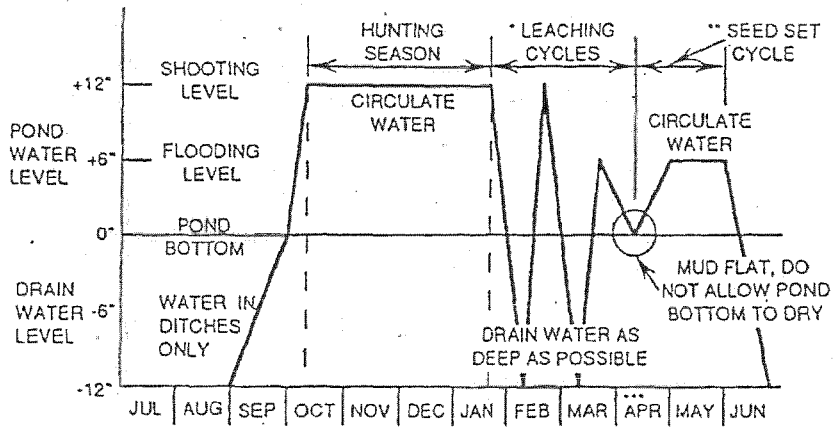
During initial flood-up, the inlet gates are opened and the drain gates remain closed to allow the managed wetlands to fill to an average depth of 8-12 inches (waterfowl management level). After initial flood-up, water is diverted from adjacent sloughs, circulated and then drained while maintaining water at the 8-12 inch depth. Compared to the initial flood-up period, relatively small amounts of water are exchanged between the sloughs and the ponds during circulation. The circulation of water maintains water quality and prevents stagnant areas from developing. Circulation also helps prevent the increase in pond water salinity resulting from evaporation, and helps maintain natural soil salinities. The wetlands are dewatered in late January to begin management activities.

To produce a diverse assemblage of waterfowl and wildlife habitat on managed wetlands in Suisun Marsh, wetland managers must take into account factors such as soil water salinities, depth and duration of soil submergence, and applied water salinity, to prevent the accumulation of soil salinities above natural levels outlined by the USDA Soil Conservation Service (1977) for Suisun Marsh soils. Water level manipulations begin in February and continue through March or June, depending on whether the landowners are following the recommendations of the early or late drawdown water management schedule, as outlined in the old management plans, or some modification of these schedules (Figure 2). See the section below titled "Updating Existing Management Plans" for a discussion on updating the old management plans. Typically, the water remaining within the wetlands is drained from mid-March through mid-June to allow vegetative growth and performance of necessary routine maintenance activities during the summer.

The NMFS and USFWS have imposed water diversion restrictions on unscreened diversions in the Marsh, to avoid adverse impacts to delta smelt (Hypomesus transpacificus), winter-run chinook salmon (Oncorhynchus tshawytscha), and other

FIGURE 2
Late Drawdown and Early Drawdown Water Management Schedules

LATE DRAWDOWN
(ALKALI BULRUSH)
WATER MANAGEMENT SCHEDULE

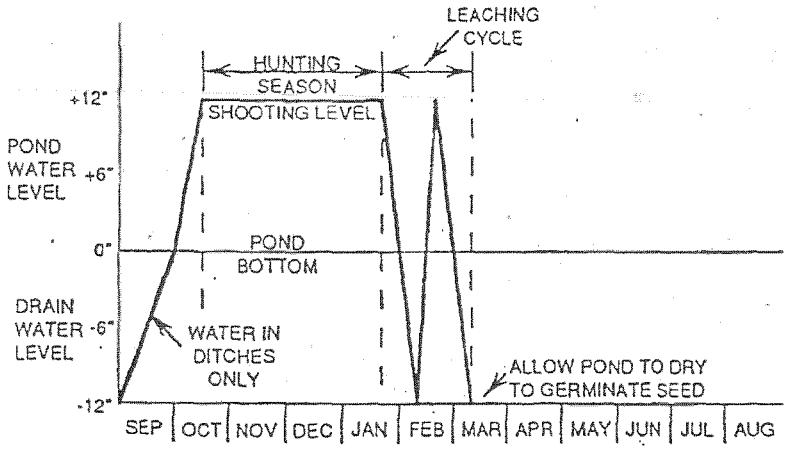


- The leaching cycles are calculated using a 10 day flood and 20 day drain period, however, many clubs can accomplish one total flood and drain cycle in less than 30 days. The flushing cycles should be completed as fast as possible, however, do not cut short the 20 day drain period unless the water level in the ditch is 1" below pond bottom.

** Ideally, stabilized water levels of the seed set cycle should be accomplished before April 1.

*** Stabilized water levels of the seed set cycle should be accomplished before April 1. Any duck club planning to fluctuate pond water levels in April must notify the Solano County Mosquito Abatment District. Pond bottoms are not allowed to dry out during April prior to reflooding for the seed-set cycle.

EARLY DRAWDOWN
(FAT HEN)
WATER MANAGEMENT SCHEDULE



[*Rollins*, 1981]

resident and anadromous fish populations. Therefore, implementing these water management schedules often cannot be achieved. Effective maintenance of soil salinities may not occur on properties with these new diversion restrictions in place, unless a fish screen has been installed.

2) Importance and Consequences of Management

The benefits of active water management on the managed wetlands are significant and are reflected in the soil water salinity and vegetation diversity. Soil water and applied water salinity data collected on the managed wetlands were evaluated for the Comprehensive Review. Figures 3 and 4 show the applied water and soil water salinity for two clubs located in the eastern Marsh and two clubs in the western Marsh. The applied water salinity values were calculated using data for the months of October through May for each water year. These are the primary months during which water is diverted from the channels onto the clubs.

The two eastern Marsh clubs, Mallard and Sprig (Figure 1), are located along the Roaring River Distribution System. Channel water salinity values from monitoring station S-72 at the eastern end of the Roaring River Distribution System were used for applied water salinity. The two western clubs, Goodyear and West Family (Figure 1), are located along Goodyear Slough and divert their water from the Slough. Channel water salinity from monitoring station S-35 on Goodyear Slough was used for applied water salinity. Average soil water salinity for each year was calculated using the months of March through May, the months critical to plant germination. Soil water salinity data were collected at several sites on each club. Average soil water salinity for each club was calculated by averaging the soil water salinity for the individual collection sites.

Of the four, West Family is the only club that actively manages the water on the ponds by circulating pond water and conducting one or two leaches per year. The other three clubs, Goodyear, Mallard and Sprig, do not actively manage the water. Results of the effects of active water management appear to vary with location in the Marsh. Water salinity in the eastern portion of the Marsh is consistently lower than salinity in the western portion. As seen in Figure 3, applied water salinity during October through May in the eastern Marsh ranged from 0.4 to 13.6 mS/cm over the study period. This is significantly lower than western Marsh applied water salinity ranges of 1.7 to 20.2 mS/cm. The eastern Marsh clubs benefit from the lower salinity applied water, achieving lower soil water salinities without active water management. Over the study period, soil water salinities for Mallard and Sprig ranged from 14.38 to 33.7 mS/cm and 8.61 to 38.11 mS/cm, respectively.

The western Marsh clubs show the greatest effects and consequences of active water management (Figure 4). Goodyear, which does not manage, had soil water salinities ranging from 23.40 to 52.90 mS/cm over the study period. West Family, which actively manages, had significantly lower soil water salinities, 13.68 to 26.68 mS/cm over the study period. In fact, with active water management, West Family was often able to achieve lower soil water salinities than the eastern clubs. For example, in 1990, applied

Figure 3. Applied Water and Soil Water Salinity for Sprig and Mallard (Eastern Clubs)

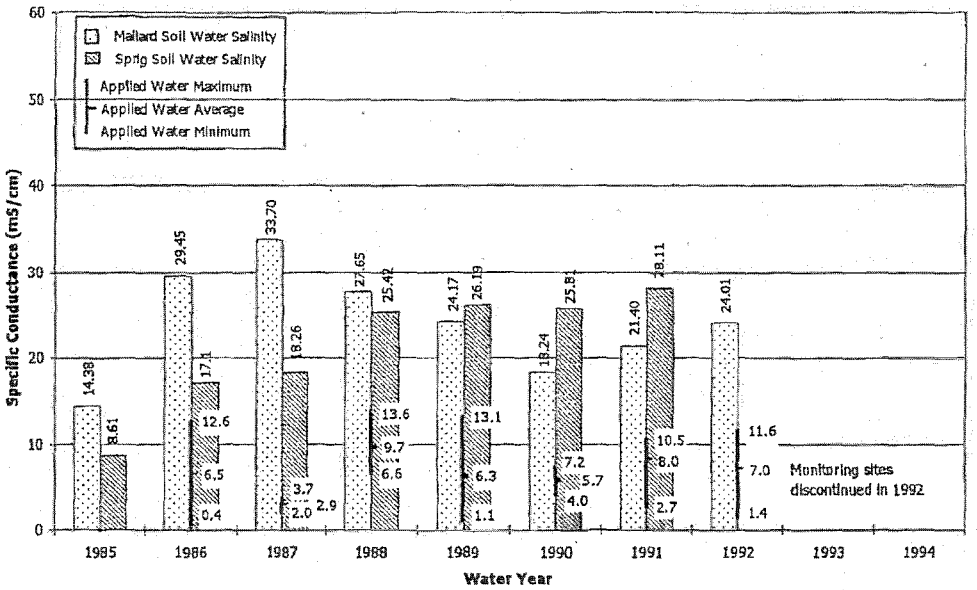
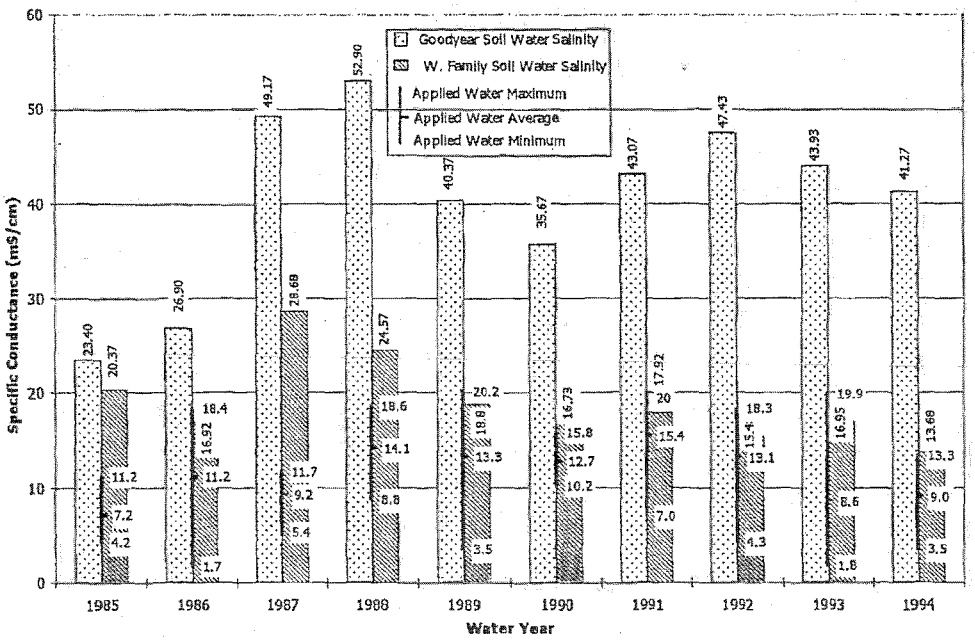


Figure 4. Applied Water Salinity and Soil Water Salinity for Goodyear and West Family (Western Clubs)



water salinity ranged from 4.0 to 7.2 mS/cm in the east and 10.2 to 15.8 mS/cm in the west. During this water year, West Family had an average soil water salinity of 16.73 mS/cm, while Sprig and Mallard had soil water salinities of 25.81 and 18.24 mS/cm, respectively. Therefore, although applying channel water that was about twice as saline as the eastern Marsh channel water, West Family was able to achieve lower soil water salinity than the eastern Marsh clubs.

SRCD conducted a separate soil salinity study during 1996 at Tule Hilton, Ownership No. 412, in the western Marsh (Figure 1) which also illustrates that soil water salinities are lower after a leach cycle is completed. In this study, SRCD collected soil water salinity samples immediately after the first drawdown and then after the pond was reflooded and drawndown (second drawdown) to detect differences in soil salinity levels before and after a leach (drain-flood-drain). Six sites were sampled along each of two 150 meter transects 30 meters apart. Soil samples were separated into three increments, top (0-4"), middle (4-8"), and bottom (8-12"), and specific conductance was measured. Figures 5 and 6 show the results of the soil sampling. In almost all cases, soil water salinity was lower after the leach cycle was completed. If ponds are drained only once immediately following the waterfowl hunting season and not reflooded, high soil salinities result from salts migrating to the soil surface through evaporative loss. Leaching is a critical component to an active water management strategy for controlling soil salt levels.

Benefits of actively managing water are also reflected in the higher diversity of vegetation on the clubs. During each year, transects were conducted along the monitoring sites in the clubs. Starting at the soil monitoring site, ten headings were taken along each of five randomly selected directional headings. The same headings were used every year.

Along each heading, the plant species present at the "toe-point" was recorded every ten feet. Results of this survey are limited in that they only account for species present during the survey and do not represent year round species diversity. In addition, all species present in the survey area may not be accounted for. However, the survey provides a reasonable "picture" of species present at the clubs from year to year.

Table 2 shows the result of the vegetation survey on four managed wetlands during the study period. Review of the table indicates a greater assemblage of species on Mallard, Sprig, and West Family, as compared to Goodyear. As mentioned previously, Mallard and Sprig are in the eastern Marsh and are not actively managed. West Family and Goodyear are in the western Marsh, and West Family is actively managed while Goodyear is not. Generally, the species diversity for Mallard, Sprig and West Family ranged from four to six species, while the diversity at Goodyear ranged from one to three. At Mallard, Sprig, and West Family, alkali bulrush, fat hen, brass buttons, saltgrass, pickleweed, and lowland purslane were all present during most of the study period. Alkali bulrush, saltgrass and lowland purslane were not recorded at Goodyear during any of the study years. This further illustrates that active water management on the western Marsh clubs can result in conditions comparable to those in the eastern Marsh.

Figure 5. Tule Hilton Transect No. 1 Soil Salinity

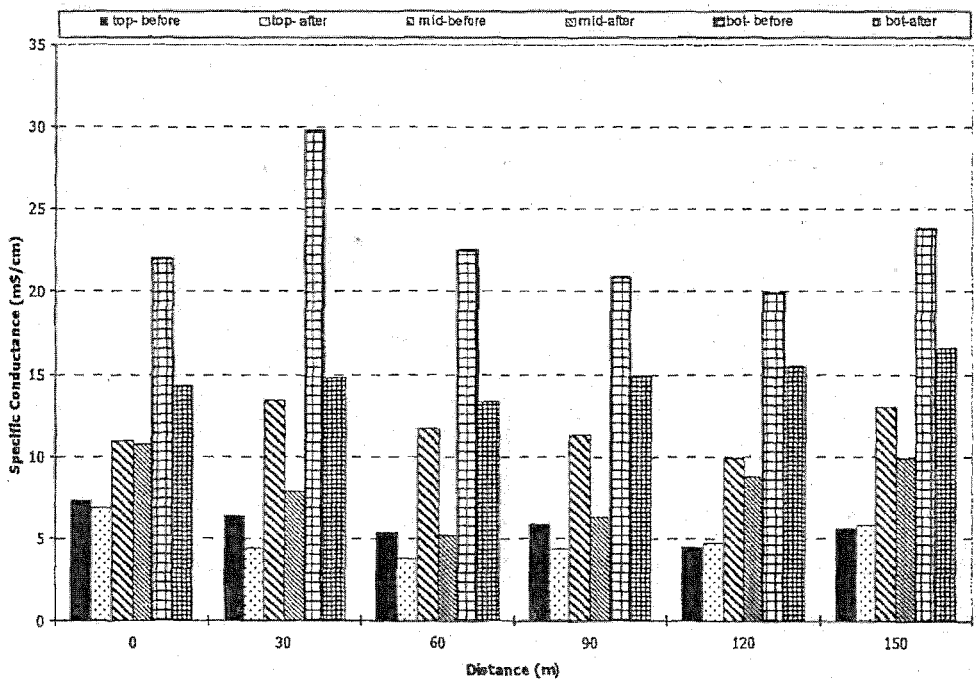
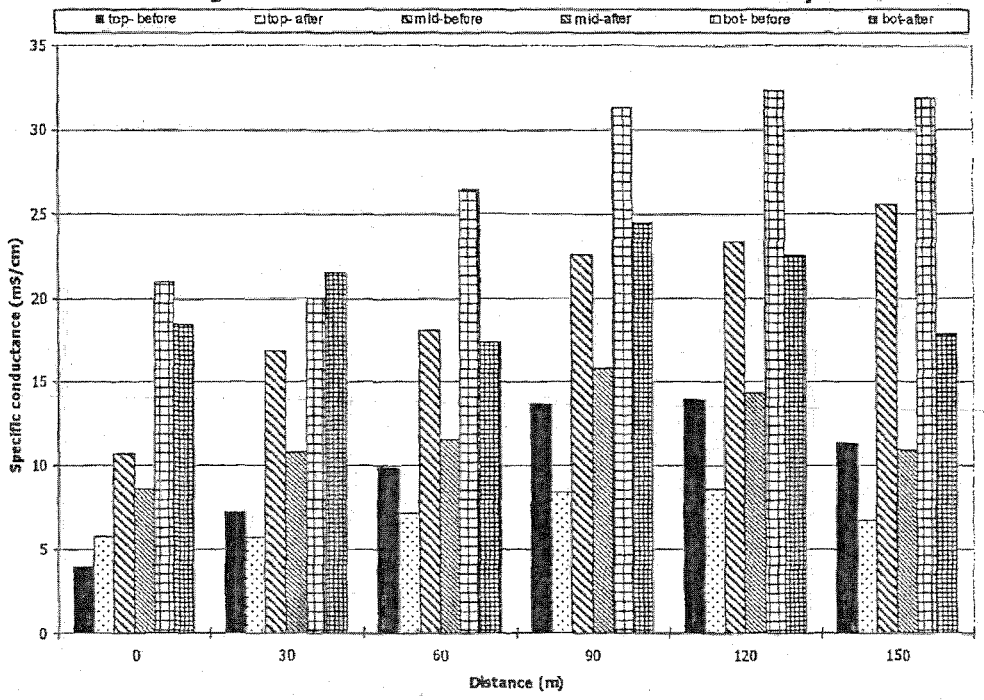


Figure 6. Tule Hilton Club Transect No. 2 Soil Salinity



Specific conductance of soil saturation extracts collected from the top (0-4"), middle (4-8"), and bottom (8-12") of the root zone along a 150 meter transect before (4/8/96) and after (6/18/96) leaching on Tule Hilton, Suisun Marsh.

Table 2. Vegetation Survey Results on Four Suisun Marsh Managed Wetlands

Club	Year	Species					
		Alkali Bulrush	Fat Hen	Brass Buttons	Saltgrass	Pickleweed	Lowland Purslane
Mallard (Eastern Marsh)	1985	X	X	X	X	X	X
	1986	X		X	X	X	X
	1987	X	X	X	X	X	X
	1988	X		X	X	X	X
	1989	X	X	X	X	X	X
	1990	X	X	X	X	X	X
	1991	X	X	X	X	X	X
	1992	X	X	X		X	
	1993			NOT SURVEYED			
	1994			NOT SURVEYED			
Sprig (Eastern Marsh)	1985	X	X	X		X	X
	1986	X	X	X	X	X	
	1987	X	X	X		X	
	1988	X		X	X	X	X
	1989	X	X	X	X	X	X
	1990	X		X	X	X	X
	1991	X		X	X	X	
	1992	X	X	X		X	X
	1993			NOT SURVEYED			
	1994			NOT SURVEYED			
Goodyear (Western Marsh)	1985		X	X		X	
	1986		X			X	
	1987					X	
	1988		X			X	
	1989			NOT SURVEYED			
	1990					X	
	1991			NOT SURVEYED			
	1992			X		X	
	1993					X	
	1994			X		X	
West Family (Western Marsh)	1985	X	X		X		X
	1986	X	X	X	X	X	X
	1987	X	X	X	X	X	
	1988	X	X	X	X	X	
	1989	X	X		X	X	
	1990	X	X	X	X	X	
	1991	X	X		X	X	X
	1992	X	X		X	X	
	1993	X	X	X	X	X	X
	1994	X	X	X	X	X	X

3) Effects of Water Management During Drought Conditions

As discussed earlier, West Family Club actively manages the water on the ponds by circulating pond water and conducting one or two leaches per year, while Goodyear Club does not actively manage the water. Figure 7 shows the average March through May soil water salinity for Goodyear and West Family and the water year type for water years 1985 through 1994. During 1985 and 1986, Goodyear and West Family had similar soil water salinities. Water year 1986 was a wet year and although 1985 was a dry water year, the previous water year was wet. During this wet period, Goodyear was able to achieve soil water salinities similar to West Family without active water management. However, beginning in 1987, the first critical water year, Goodyear consistently had significantly higher soil water salinity than West Family. Therefore, once drought conditions are established, active water management is particularly critical to maintaining low soil water salinities.

This is also illustrated in Figure 8, which shows the percent change in soil water salinity on the clubs over the study period. Changes of 25% or less over the time period were considered stable, while random changes (no apparent increase or decrease) greater than 25% over the time period were considered fluctuating. Soil water salinity was considered increasing or decreasing if there was a consistent pattern of changes greater than 25% over the time period. During the drought conditions, Goodyear had increasing soil water salinity, while West Family maintained a stable, slightly decreasing, soil water salinity.

Minimal data are available to illustrate the effects of active water management during drought conditions on vegetation diversity. Table 2 shows the vegetation observed on four clubs over the study period. Goodyear shows low species diversity over the entire time period, although the highest diversity, three species, is seen in water year 1985, which follows a wet year. The lowest diversity, one species, is seen in water year 1990, in the middle of the drought period. West Family continued to have high species diversity throughout the study period. Although these data cannot be conclusively linked to the drought conditions, it supports previous soil salinity data.

4) Variability of Salinity at High vs. Low Tides

It was noted above that the majority of the managed wetlands fill during high tides using gravity flow. Salinity monitoring throughout the Marsh indicates, however, that at certain stations (regions) there is a significant salinity variation between high and low tides, while at other stations this difference is less pronounced or non-existent. In general, salinity is higher at high tide and lower at low tide.

To examine this more closely, 15-minute salinity and tide data were plotted for several eastern and western Marsh monitoring stations (top panels of Figures 9-16), along with mean daily high tide salinity and mean daily salinity (bottom panels of Figures 9-16). For comparison purposes, two sets of data were examined, namely, the first two weeks of October 1992 (Figures 9-12) and October 1993 (Figures 13-16). October of 1992

Figure 7. Goodyear and West Family Soil Water Salinity and Water Year Types

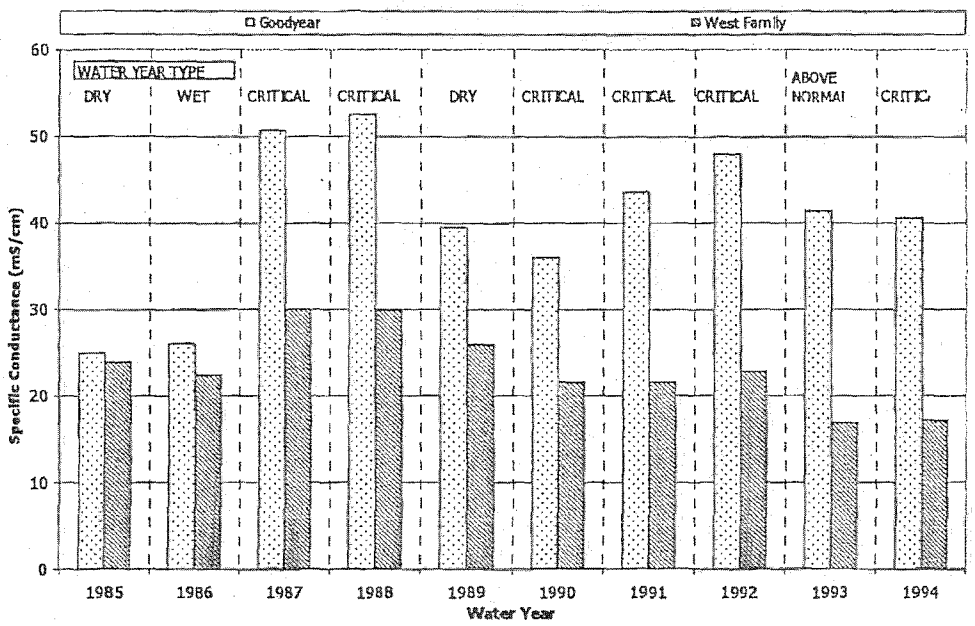
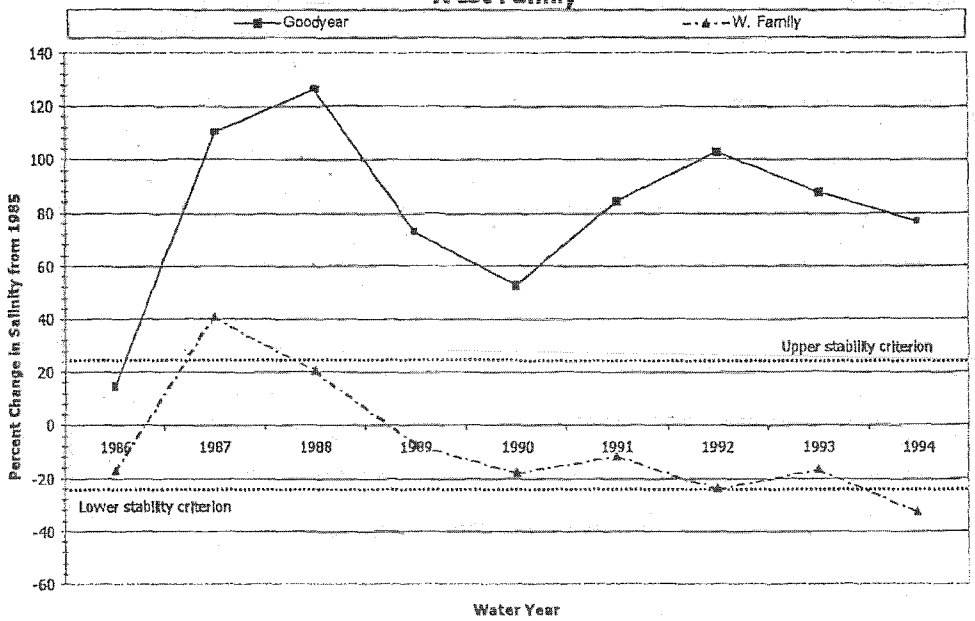
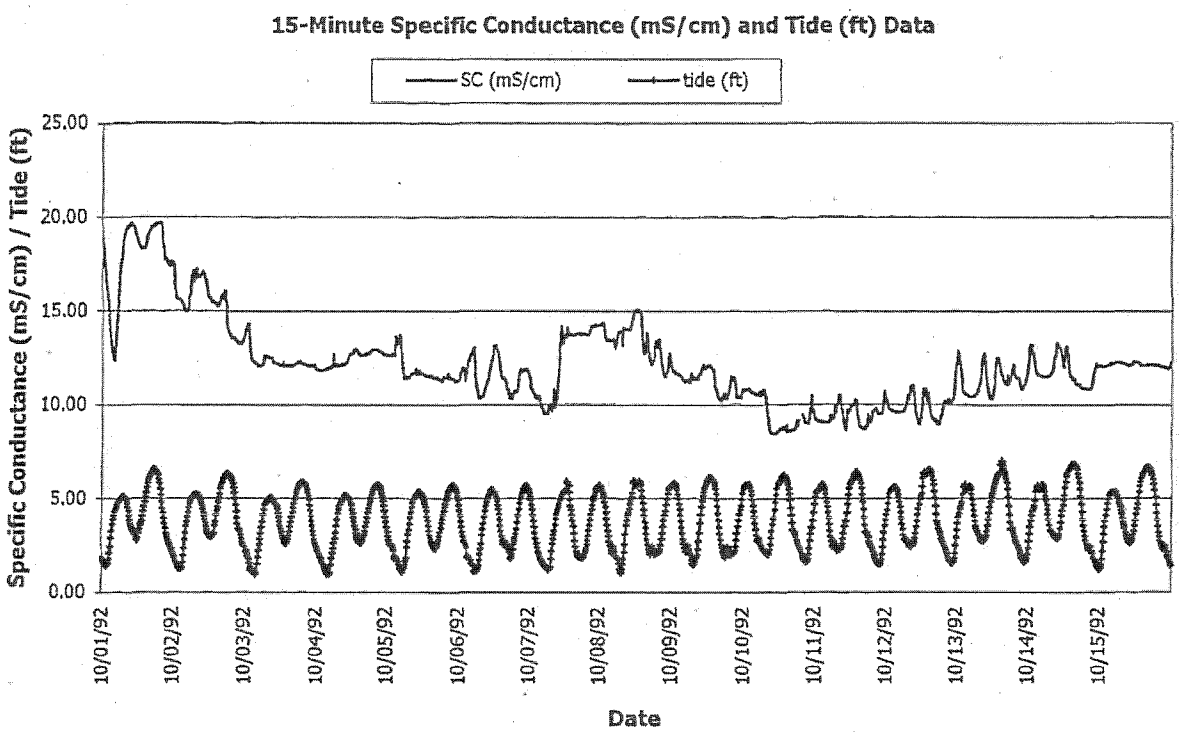


Figure 8. Trend Analysis for Soil Water Salinity at Goodyear and West Family



Note: Figure 7 and 8 water year soil salinity averages based on March through May soil water salinity.

Figure 9
S-64 High Versus Mean Tide Salinity Analysis
October 1-15, 1992



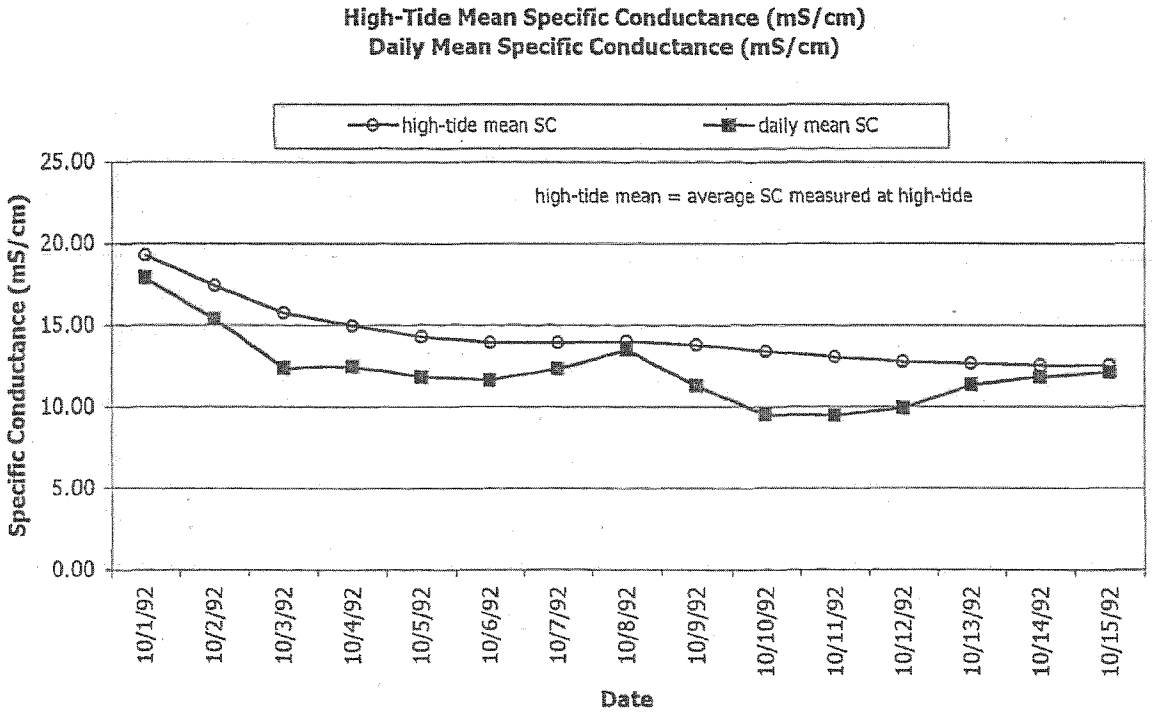
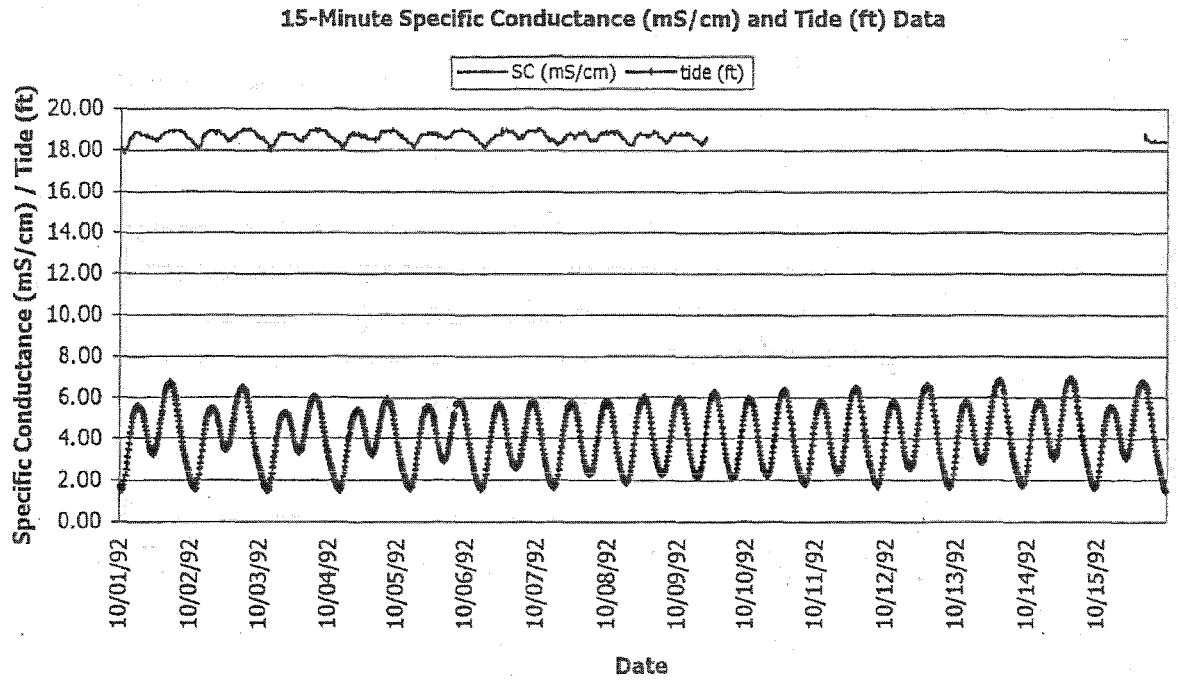


Figure 10
S-42 High Versus Mean Tide Salinity Analysis
October 1-15, 1992



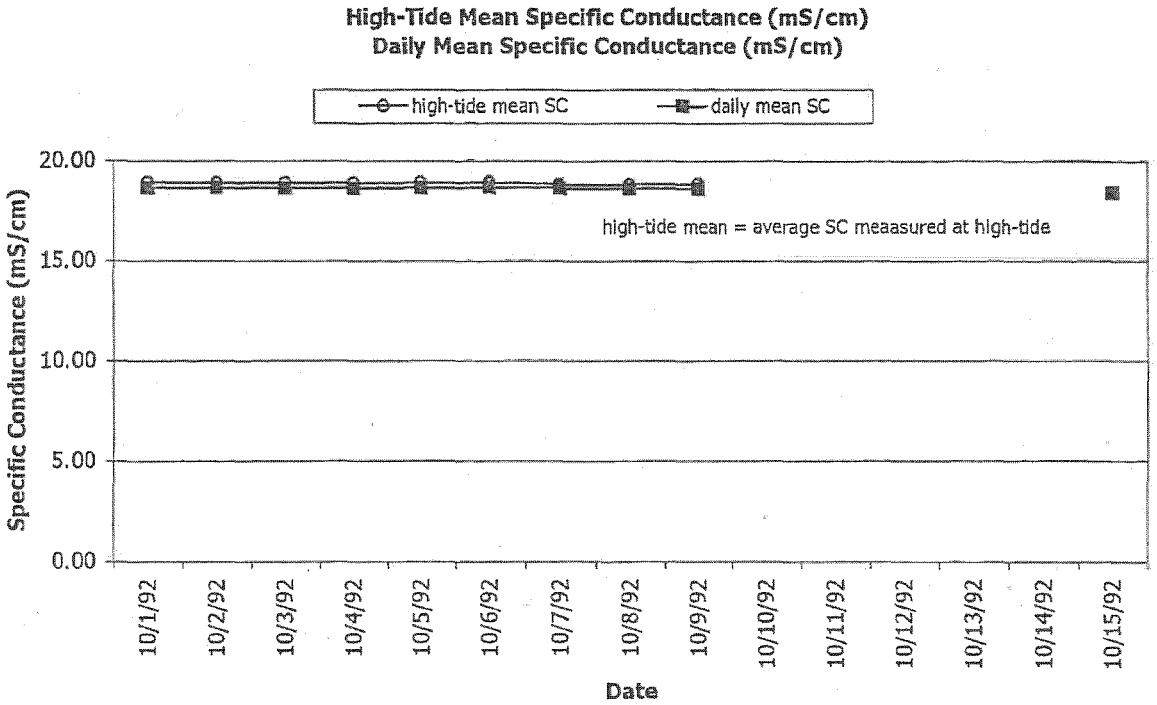
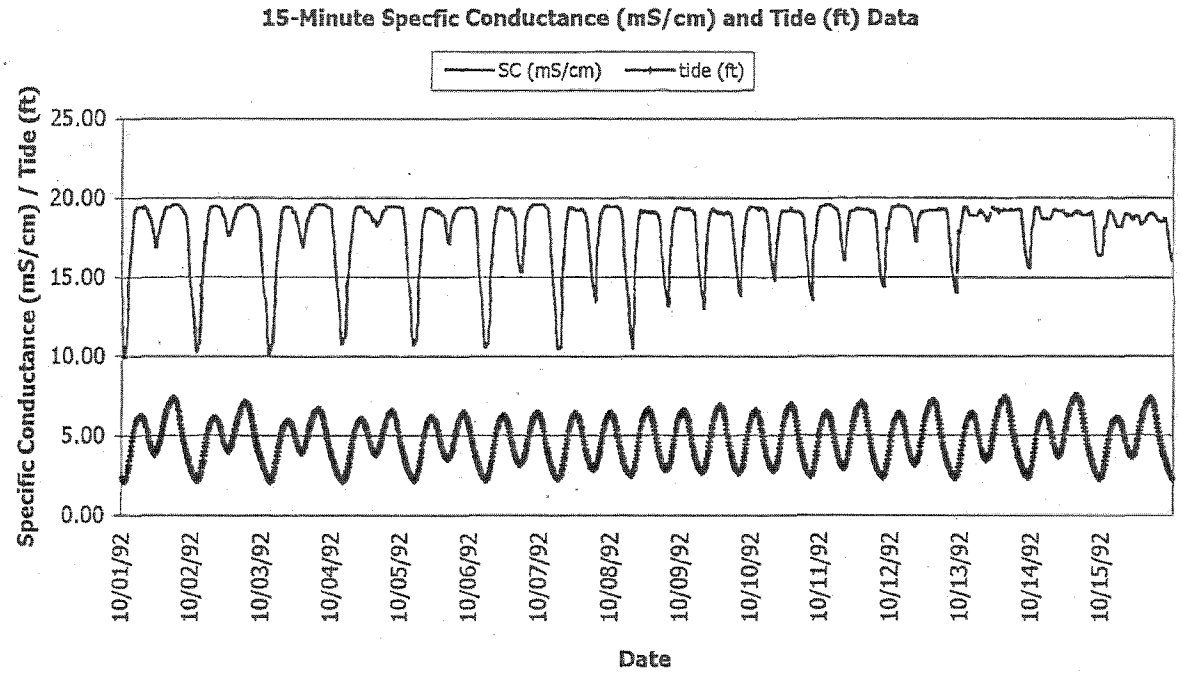


Figure 11
S-21 High Versus Mean Tide Salinity Analysis
October 1-15, 1992



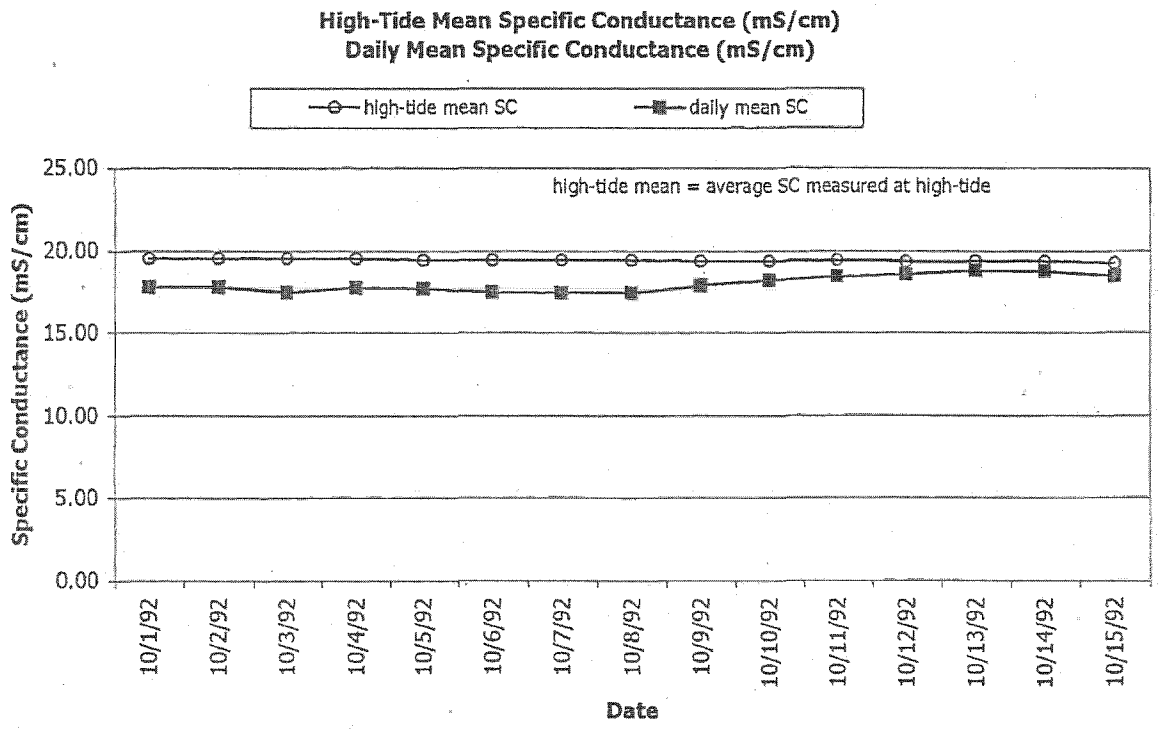
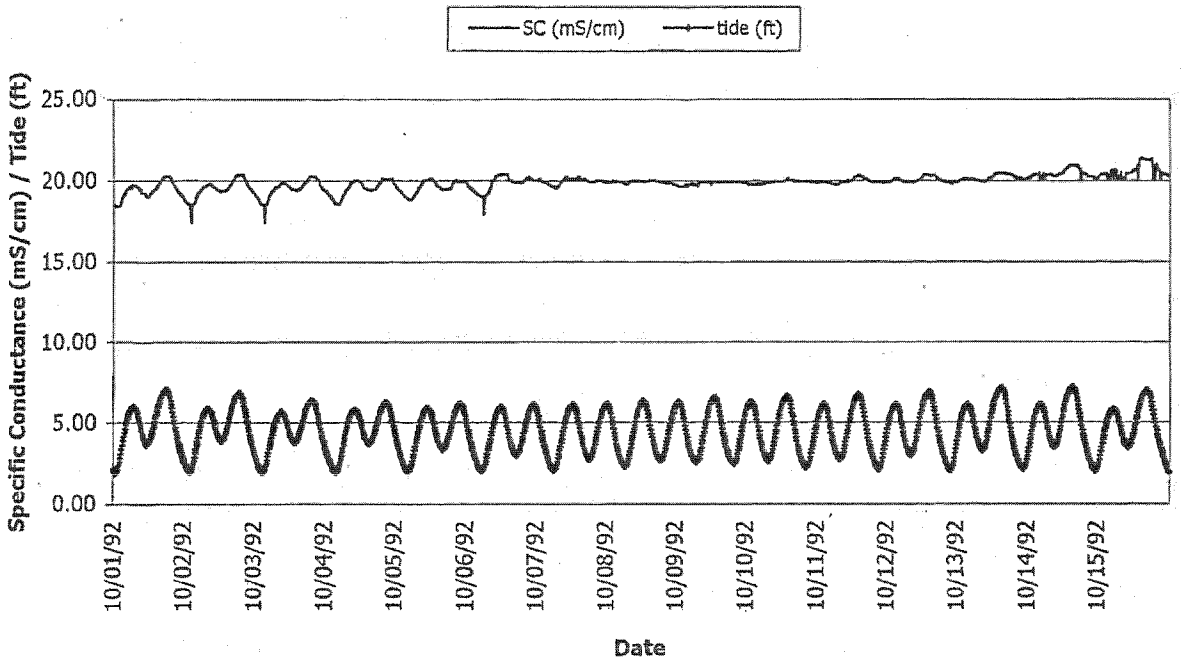


Figure 12
S-97 High Versus Mean Salinity Analysis
October 1-15, 1992

15-Minute Specific Conductance (mS/cm) and Tide (ft) Data



High-Tide Mean Specific Conductance (mS/cm)
Daily Mean Specific Conductance (mS/cm)

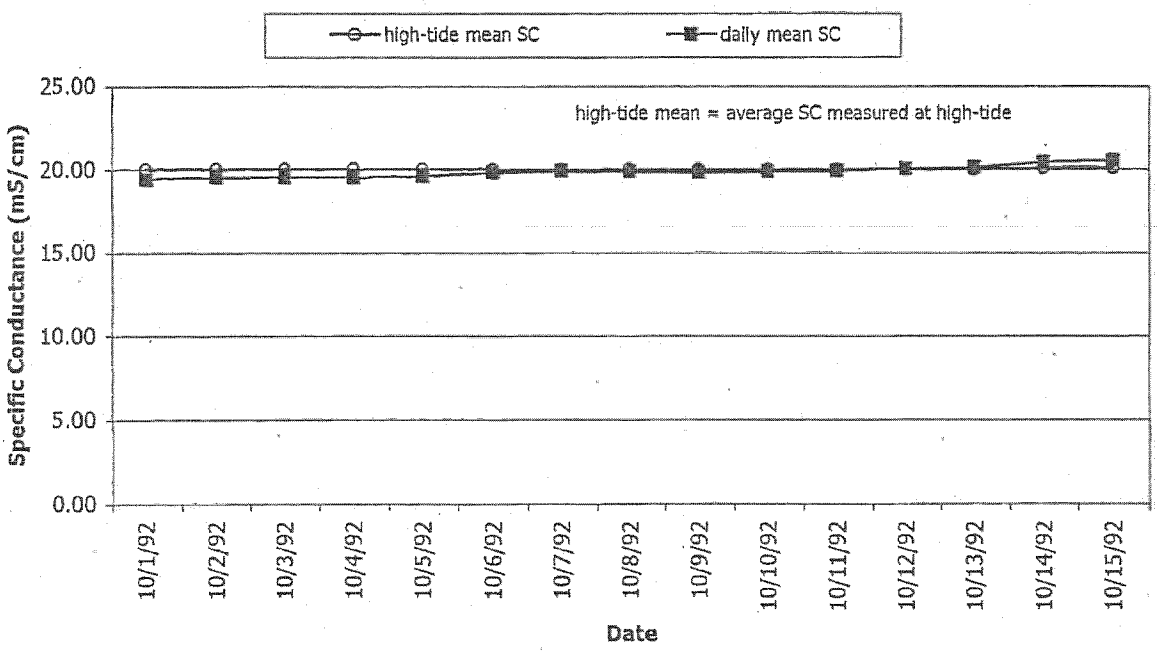
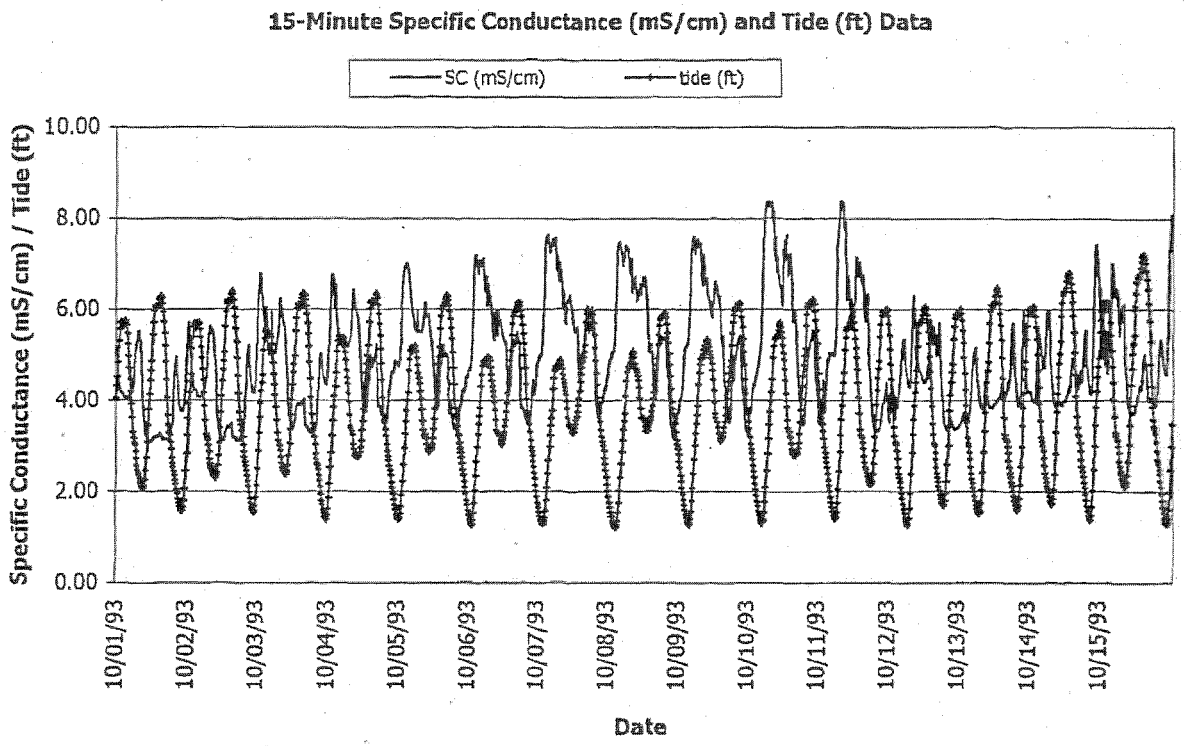


Figure 13
S-64 High Versus Mean Tide Salinity Analysis
October 1-15, 1993



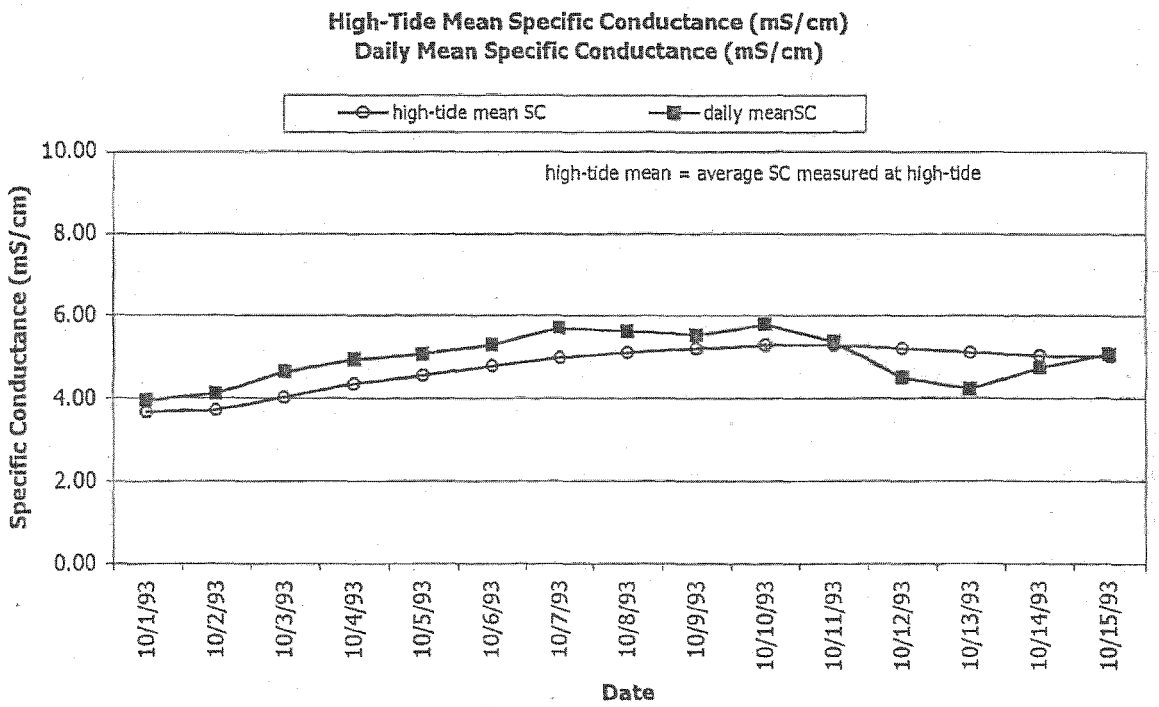
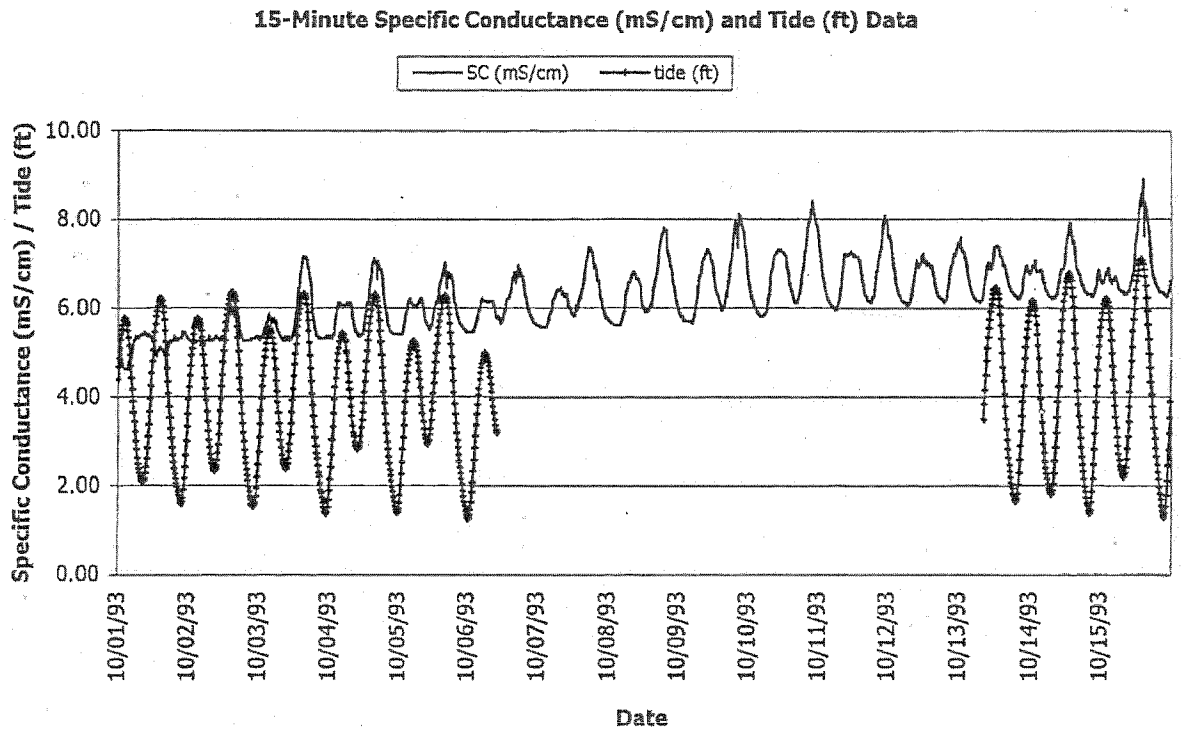


Figure 14
S-42 High Versus Mean Tide Salinity Analysis
October 1-15, 1993



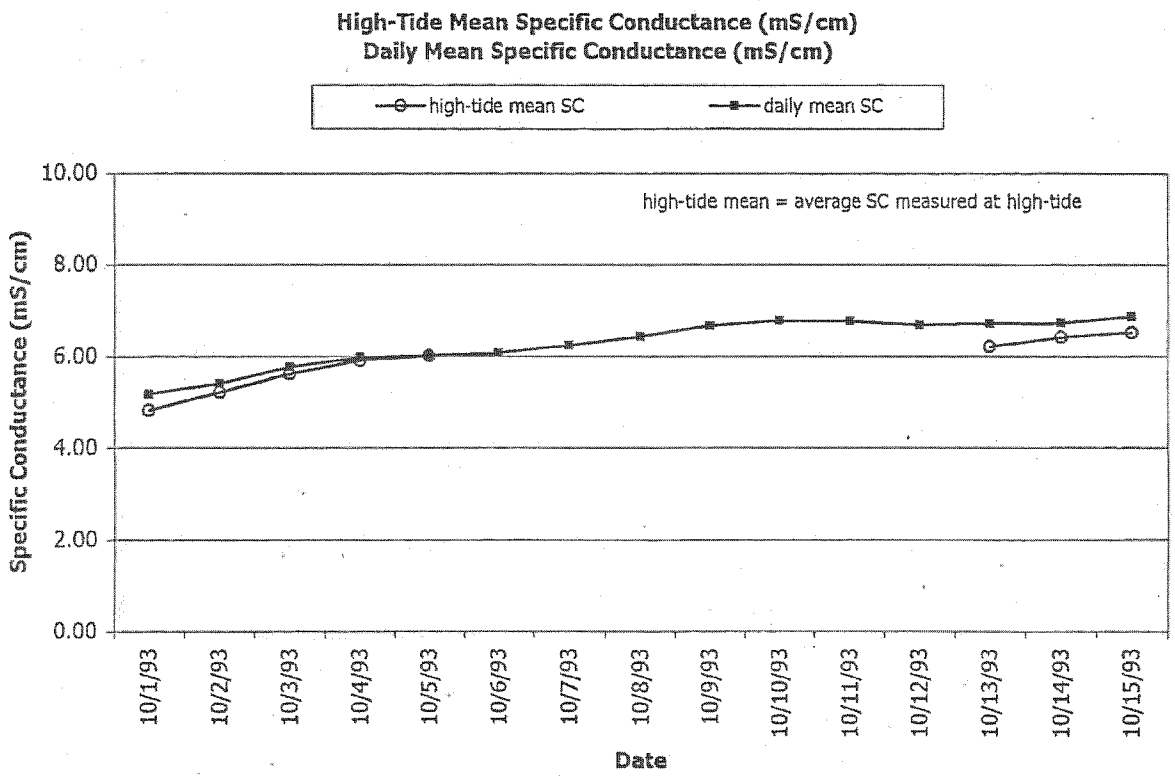
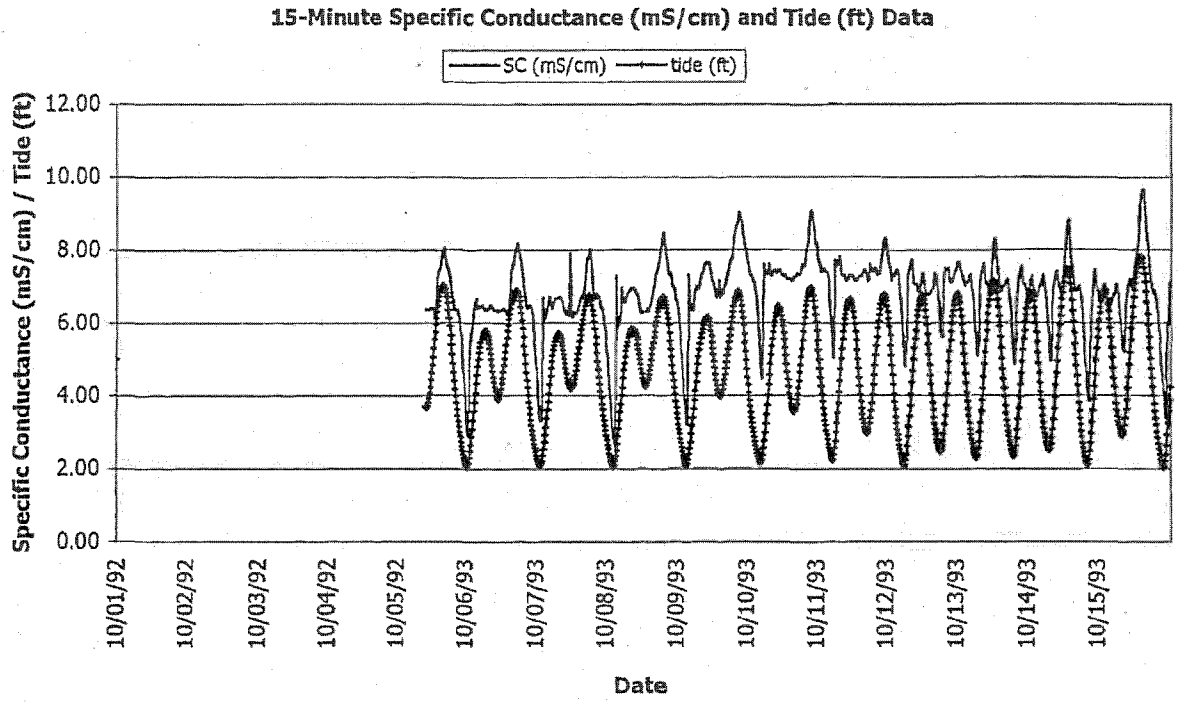


Figure 15
S-21 High Versus Mean Tide Salinity Analysis
October 1-15, 1993



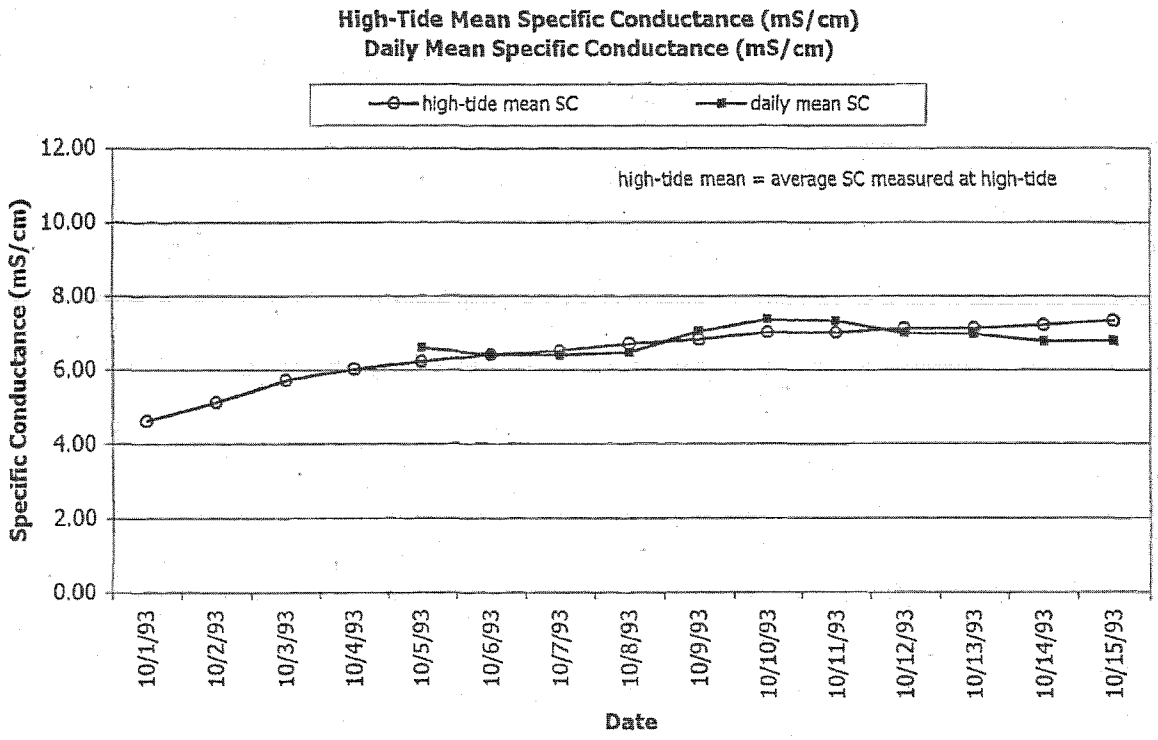
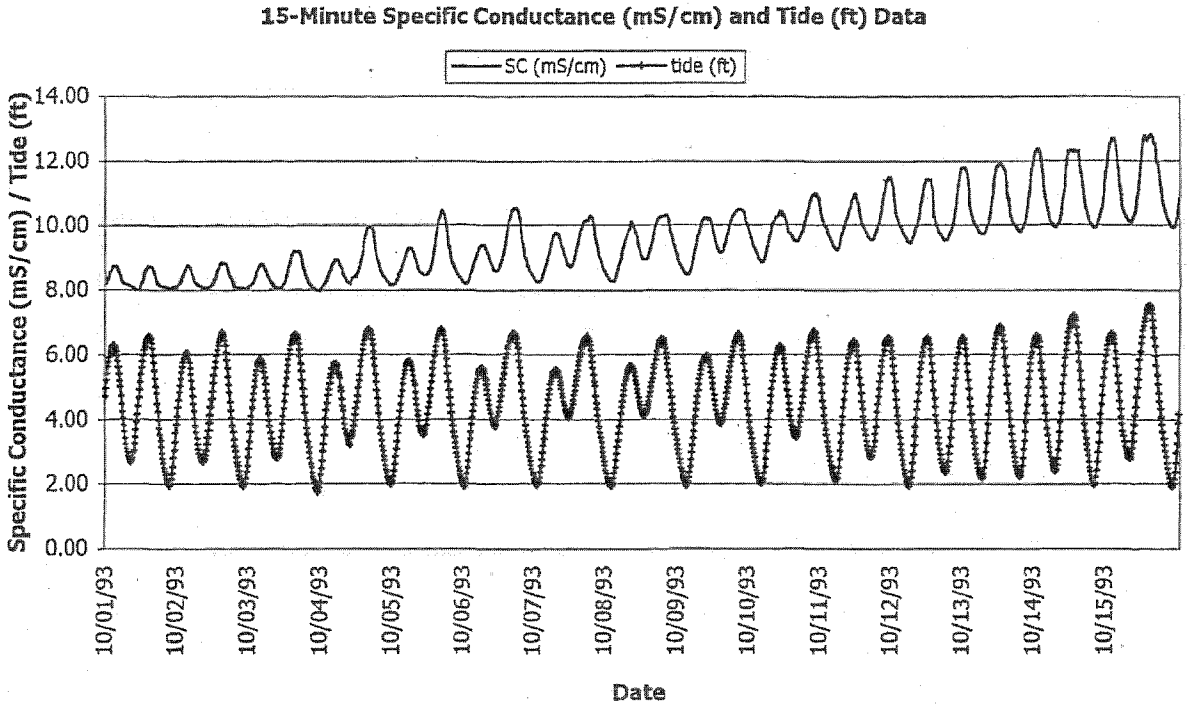
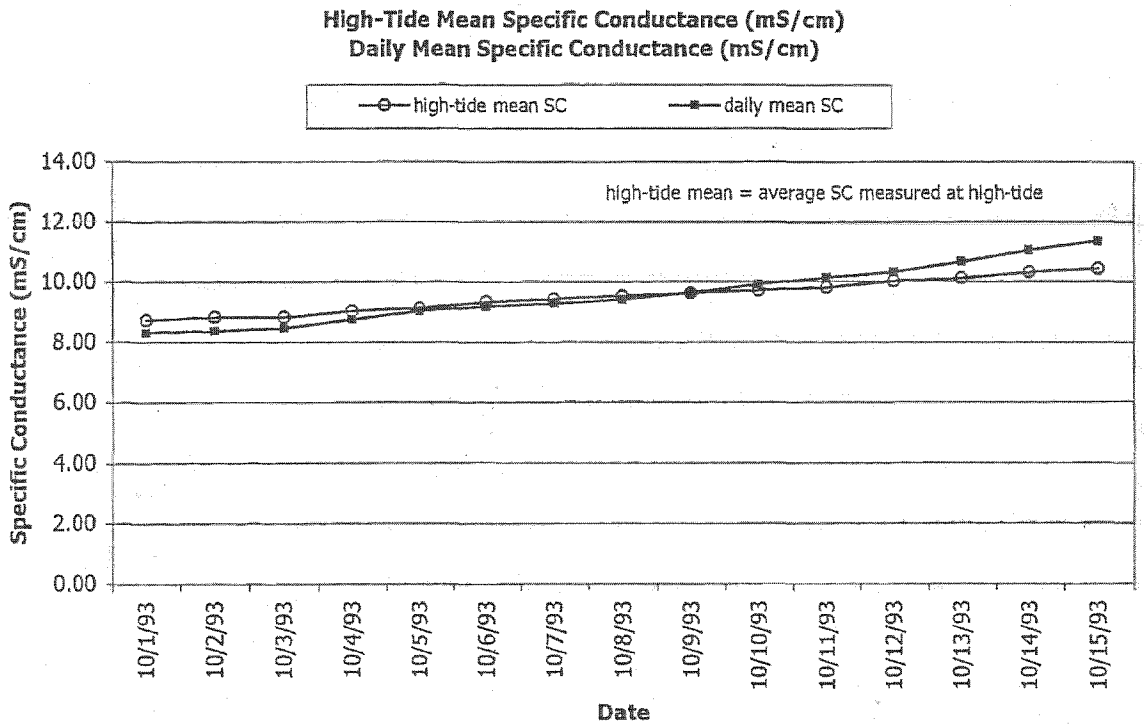


Figure 16
S-97 High Versus Mean Tide Salinity Analysis
October 1-15, 1993





was preceded by a critical water year, while October 1993 was preceded by an above average water year. During October of 1993, salinities recorded at various stations (Figures 13-16) showed much more variation than salinities during October of 1992 (Figures 9-12). The average salinity levels were also anywhere from 2-9 mS/cm lower in 1993 than 1992.

Managed wetlands that would benefit the most from using pumps to fill are those that experience the greatest variation in channel salinity during a tidal cycle. The bottom panel plots indicate that managed wetlands in a significant portion of the Marsh could fill with lower salinity water if they could pump water from the channel throughout the tide and/or selectively pump water during low tides.

Why Large Facilities Are Now Unnecessary

The SMPA parties agree that additional large scale facilities proposed in the Plan of Protection will *not* be necessary for salinity control in the Suisun Marsh because of: 1) the Delta hydrology resulting from implementation of the 1995 Bay/Delta Plan, and 2) the effectiveness of the Suisun Marsh Salinity Control Gates. The parties arrived at this decision based on data collection with SMSCG operation and DWR model studies conducted in support of the 1995 Bay/Delta Plan and the EIR for its implementation as described in this section.

1) Model Studies of Marsh Salinity with 1995 WQCP Conditions

The purpose of this section is to demonstrate that large facilities are now unnecessary under the 1995 Water Quality Control Plan (WQCP) criteria. DWR staff conducted two model studies for the SWRCB to investigate the impact of implementing the 1995 WQCP on channel water salinity in the Suisun Marsh. The DWR Delta Simulation Model 1 (DWRDSM) (Suisun Marsh Version) was utilized to conduct the studies for the following hydrologies:

- The CUWA/AG hydrology[1] over the 6-year drought period between 1987 and 1992;
- The 1995 WQCP hydrology over 73 years (1922-1994)

Model Results with CUWA/AG Criteria Over 6 Drought Years

In support of the Draft Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, SWRCB staff requested DWR Suisun Marsh Planning staff to estimate representative changes in Suisun Marsh channel water salinity that may have occurred during water years 1987-1992, had the CUWA/AG proposal criteria been in effect.

CUWA/AG proposal results were presented in a report to the SWRCB entitled ***Estimate of Salinity Changes in Suisun Marsh for Water Years 1987-1992 With CUWA/AG Criteria (1995).*** The following general conclusions were made based on this study:

- Relative to D1485 hydrology, CUWA/AG hydrology would provide lower channel water salinity throughout the Marsh.
- With CUWA/AG hydrology and Suisun Marsh Salinity Control Gates (SMSCG) operation, DWR and USBR would meet standards at both eastern and western

1 The objective of this procedure was to estimate changes from historic daily Delta rim hydrology for water years 1987-1992 to include the CUWA/AG criteria presented in the document, *Joint Proposal for Resolving San Francisco Bay-Delta Issues; A Briefing Book by Major Agricultural and Urban Water Agencies* (October 1994).

Marsh compliance stations with some exceptions at the far western stations during dry conditions.

- Regardless of D1485 or WQCP hydrology, standards would be exceeded at all Marsh stations except C-2 (Figure 1) without SMSCG operation.

1995 WCQP Criteria Over 73 Years

In support of the EIR to implement the Draft Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, SWRCB staff requested DWR staff model six alternatives over 73 years of hydrology (1922-94), to evaluate the environmental effects of the Suisun Marsh objectives, specifically on the western Marsh sites S35 and S97. This study is complete and DWR is preparing a report to the SWRCB. Some of the findings of this work are discussed below.

Results of this study are displayed in three forms: 1) Area-Frequency table, 2) Area-Frequency plots, and 3) comparative contour plots. Area-Frequency analysis indicates the frequency and magnitude of standard exceedence at each eastern and western Marsh station. An example of the Area-Frequency table and plot are shown in Figure 17. The Area-Frequency table (Figure 18) summarizes the results in tabular form whereas the plots convey the same results in a graphical form. In addition, contour plots provide a regional comparison of the Area-Frequency analysis for two alternatives.

Model results for the following three alternatives are reported in this document:

- Alternative 1: D-1485 standards and hydrology with SMSCG operations,
- Alternative 3: 1995 WQCP standards and hydrology with SMSCG operations, and
- Alternative 3A: Alternative 3 without SMSCG operations.

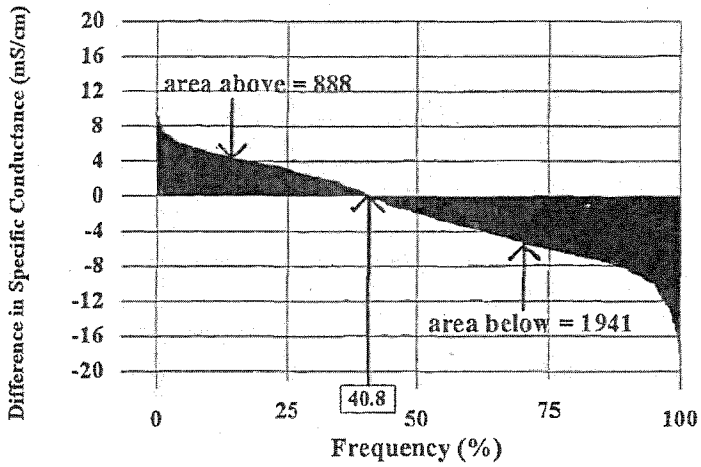
The Area-Frequency Table for this study is shown in Figure 18 with station reference map. For WQCP hydrology, Area-Frequency plots for the eastern Marsh stations are presented in Figure 19, and similar plots for the western Marsh stations are shown in Figure 20. Comparative contour plots are illustrated in Figure 21 for model results for D-1485 vs. 1995 WQCP conditions, and in Figure 22 with and without SMSCG operation under 1995 WQCP hydrology.

These model results support the following general conclusions:

- Under D1485 hydrology with SMSCG operation, all eastern stations would meet standards (with minor exceptions), whereas the western stations would not meet standards at all times.
- Under WQCP hydrology with SMSCG operation, all eastern and western stations would meet standards, except at S-35 and S-97.

FIGURE 17

EXAMPLE OF AREA-FREQUENCY ANALYSIS PLOT AND TABLE FOR SITE X



SITE	Freq. Above Std. %	Exceedence Index %
X	40.8	31.4

OBJECTIVE OF AREA-FREQUENCY PLOTS:

Area-frequency plots are prepared to indicate how often and to what extent salinity at a particular location was either above or below standards or target salinity.

DEFINITION OF FREQUENCY AND EXCEEDENCE:

Frequency above standards: Defined to be where the area frequency plot crosses the zero line.

Exceedence Index: Defined to be the area above the zero line divided by the sum of the areas above and below the the zero line, and multiplied by 100 to convert to a percentage. The equation and an example calculation are shown below:

EXCEEDENCE INDEX = [AREA ABOVE / (AREA ABOVE + AREA BELOW)] X 100

31.4% = [888 / (888 + 1941)] x 100

AREA-FREQUENCY PREPARATION:

To prepare the area-frequency plots, the standards (normal or deficiency) were subtracted from the respective mean monthly high tide salinities for the control season. The differences were then assigned to each month and sorted from the largest positive difference (above the target standard) to the greatest negative difference (below the target standard). The sorted differences were then normalized from 1 to 100 percent and plotted.

DWR, Suisun Marsh Planning
08/25/97

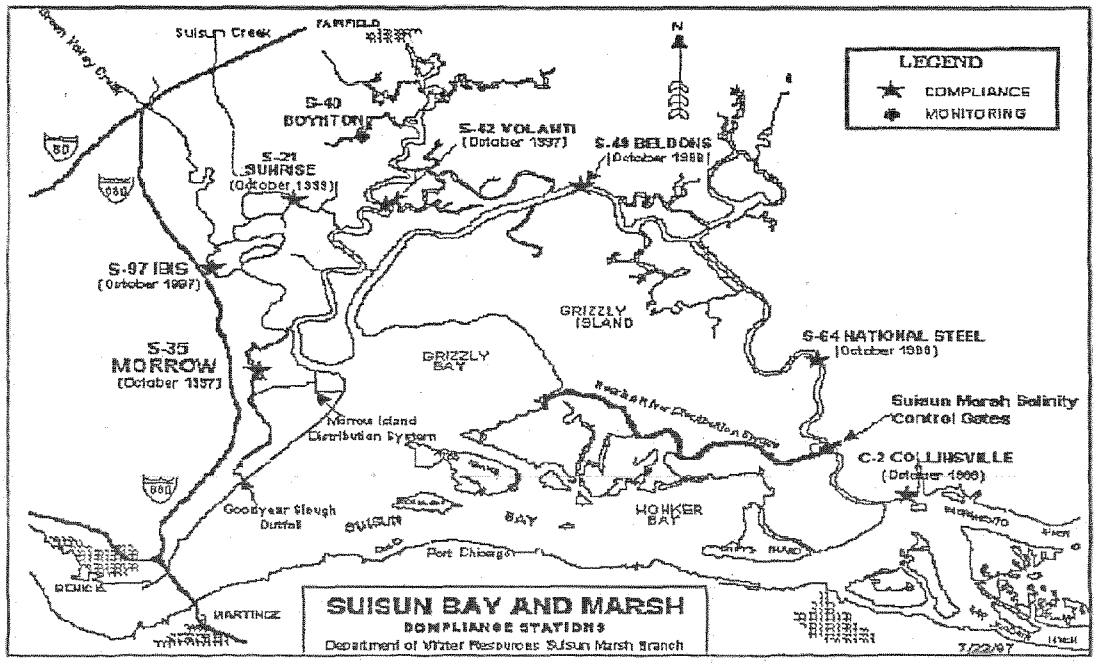
FIGURE 18

SALINITY AREA-FREQUENCY ANALYSIS
OCTOBER THROUGH MAY OF WATER YEARS 1922-94

	SITE	Alternative 1		Alternative 3		Alternative 3A	
		Freq. Above Std. %	Exceedence Index %	Freq. Above Std. %	Exceedence Index %	Freq. Above Std. %	Exceedence Index %
East	C-2	0.7	0.1	0.0	0.0	0.0	0.0
	S-64	0.0	0.0	0.0	0.0	27.1	18.8
	S-49	0.0	0.0	0.0	0.0	36.6	28.3
West	S-42	(0.8) 1.5	(0.1) 0.2	(0.2) 0.2	(0.0) 0.0	31.2	20.0
	S-21	(1.0) 1.9	(0.1) 0.3	(0.2) 0.7	(0.0) 0.0	31.2	19.3
	S-35	(11.9) 20.9	(3.4) 6.1	(10.4) 14.4	(2.3) 3.5	22.1	10.0
	S-97	(33.5) 43.2	(24.3) 35.5	(26.5) 31.2	(13.6) 18.6	40.4	32.0

1/ Salinity was determined with DWRDSM (Suisun Marsh Version)
Values in parentheses were determined without the 13 deficiency years.

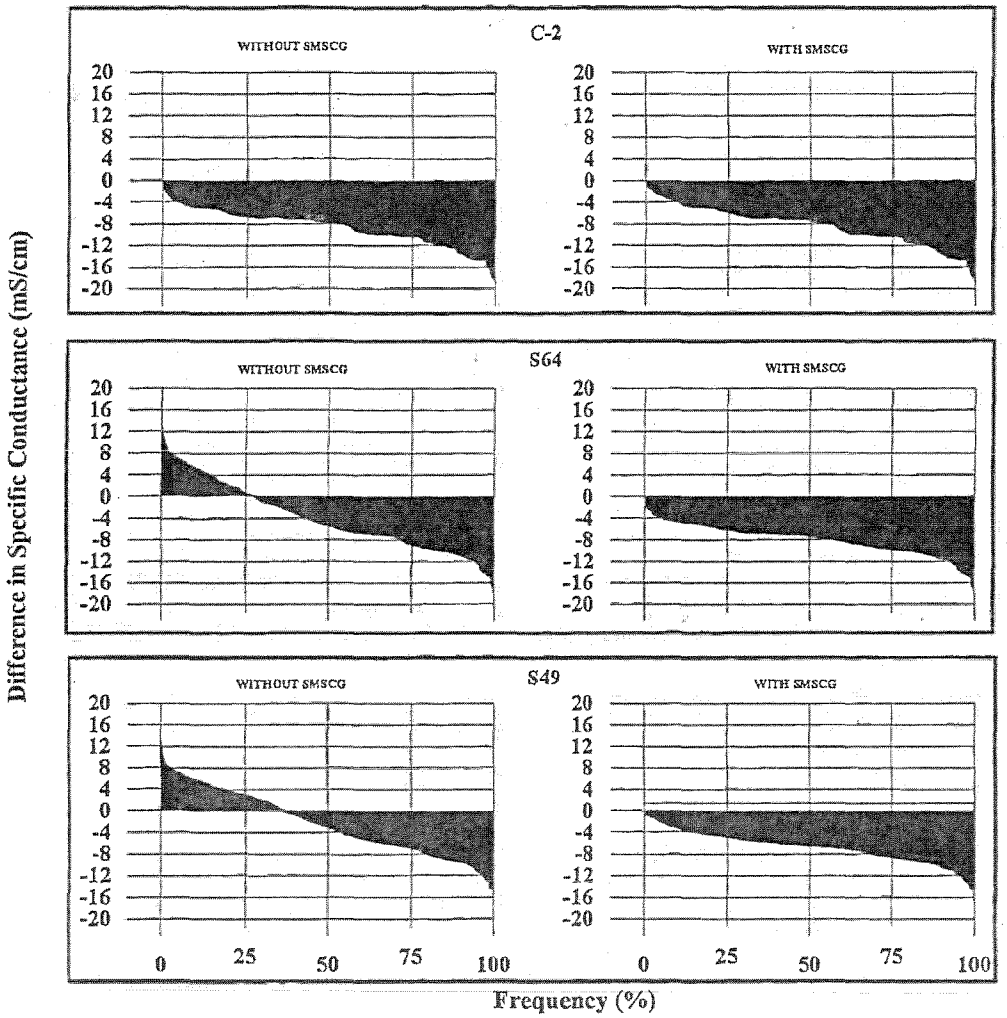
ALTERNATIVES:
1: D1485 standard and hydrology with SMSCG operation.
3: WQCP standard and hydrology with SMSCG operation.
3A: Alternative 3 without SMSCG operation.



DWR, Suisun Marsh Planning
8/21/97

FIGURE 19

EASTERN MARSH STATIONS
SALINITY AREA-FREQUENCY ANALYSIS 1/
OCTOBER THROUGH MAY OF WATER YEARS 1922-94
DWRDSM SALINITY MINUS 1995 WQCP STANDARD



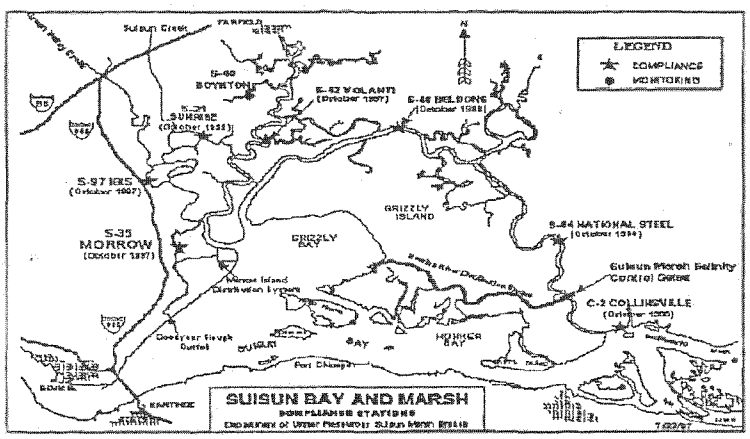


FIGURE 20

WESTERN MARSH STATIONS
SALINITY AREA-FREQUENCY ANALYSIS 1/
OCTOBER THROUGH MAY OF WATER YEARS 1922-94
DWRDSM SALINITY MINUS 1995 WQCP STANDARD

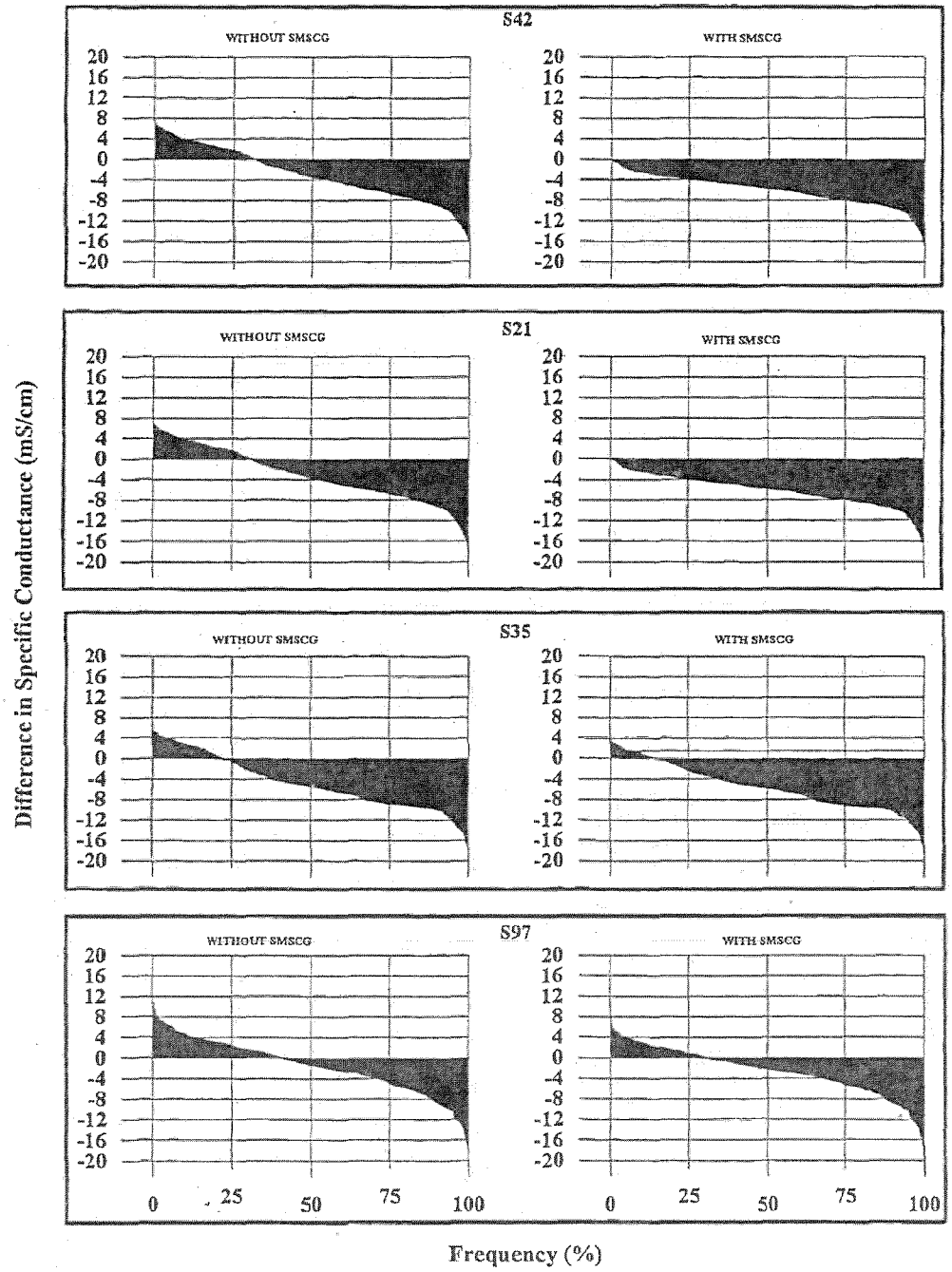
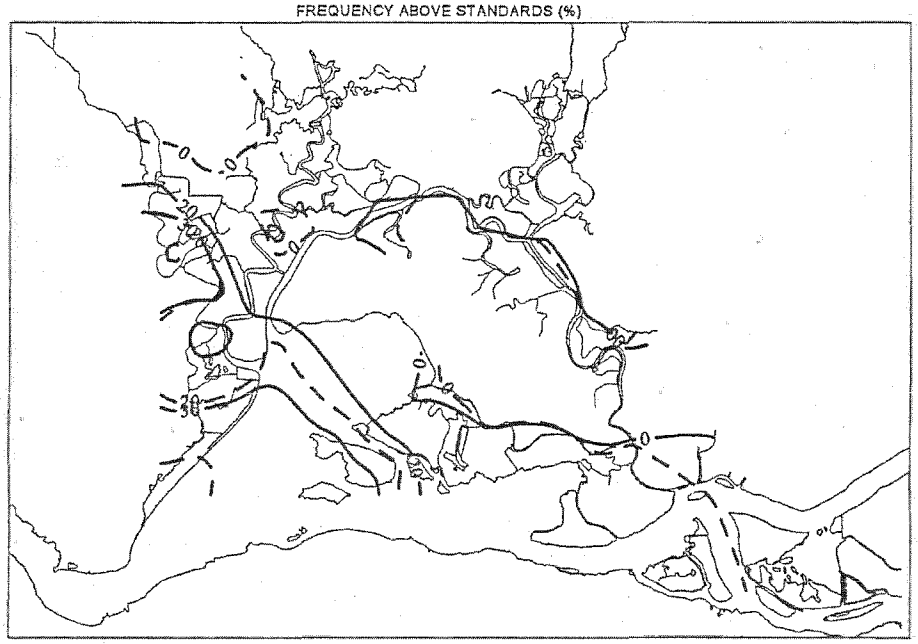


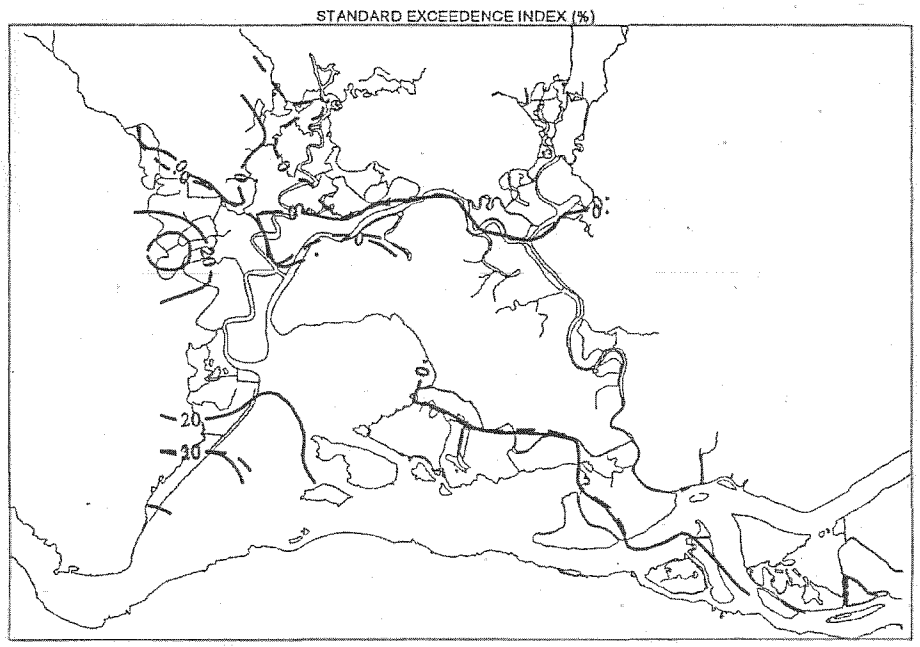
FIGURE 21

DWRDSM (Suisun Marsh Version)
FOR CONTROL SEASONS 1922-94

FREQUENCY ABOVE STANDARDS (%)



STANDARD EXCEEDENCE INDEX (%)



Alternative 1: D1485 standard and hydrology with SMSCG operation
Alternative 3: WQCP standards and hydrology with SMSCG operation

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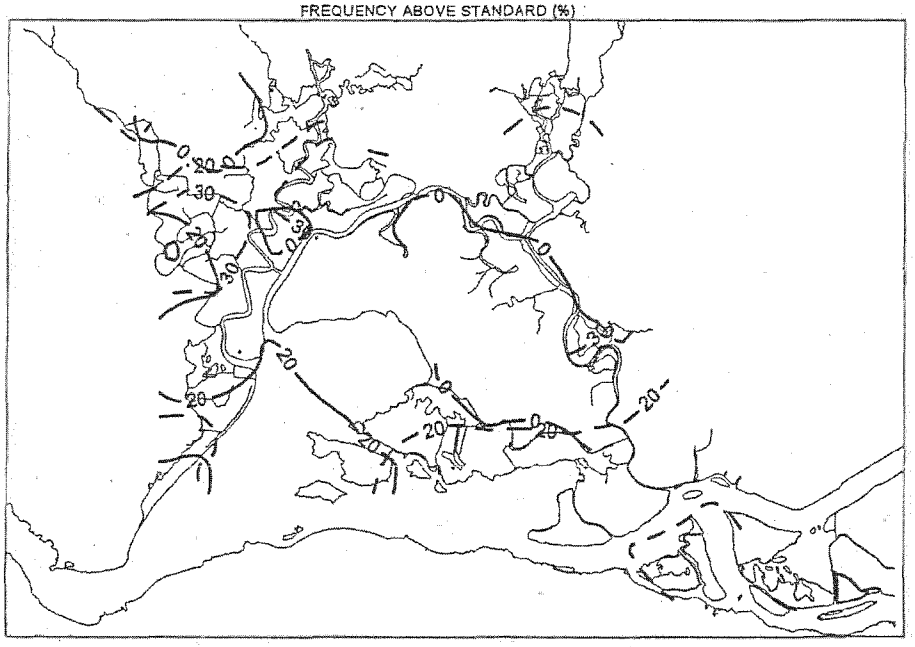
08/25/97

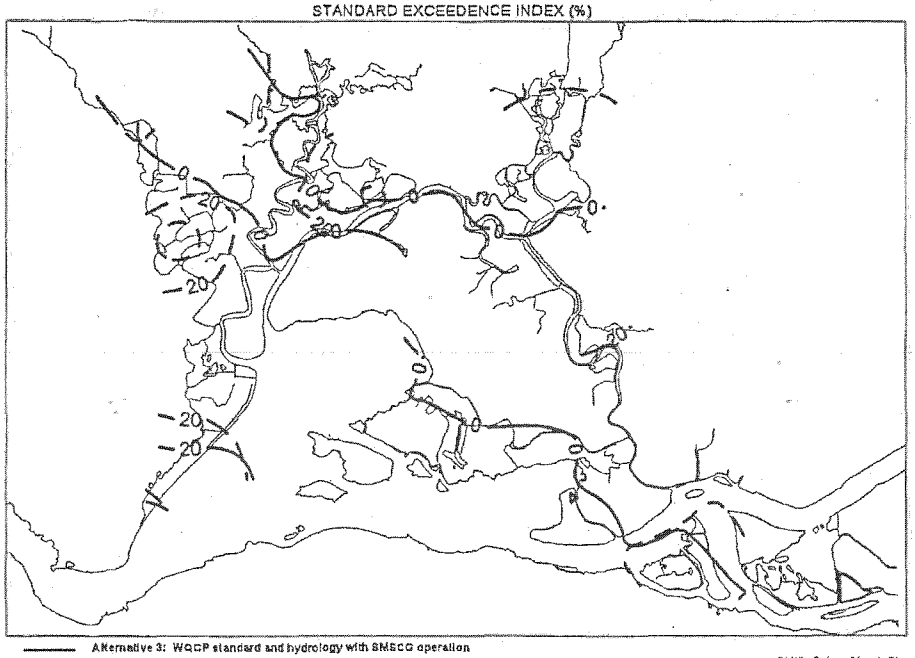
FIGURE 22

DWRDSM (Suisun Marsh Version)
FOR CONTROL SEASONS 1922-94

FREQUENCY ABOVE STANDARD (%)



STANDARD EXCEEDENCE INDEX (%)



Alternative 3: WQCP standard and hydrology with SMSCG operation
Alternative 3A: Alternative 3 without SMSCG operation

DWR, Suisun Marsh Planning
08/25/97

- With SMSCG operation and WQCP hydrology, western Marsh stations S-35 and S-97 would exceed standards less frequently and to a lesser extent than with D1485 hydrology.

- Without SMSCG operation and under WQCP hydrology, both eastern (excluding C-2) and western Marsh stations would exceed standards more frequently and to a greater extent.

In summary, both model studies indicate similar trends. The overall conclusion is that with SMSCG operation and WQCP criteria, standards would be met at all Marsh stations except at S-35 and S-97, and exceedences at S-35 and S-97 would be significantly less frequent and lower. Currently, the WQCP hydrology is in effect and SMSCG is available for operation. Therefore, it is not necessary to build large-scale facilities as previously envisioned with D1485 conditions.

2) Analysis of Suisun Marsh Salinity Response to Operation of the Suisun Marsh Salinity Control Gates

The purpose of this section is to estimate the effectiveness of Suisun Marsh Salinity Control Gates (SMSCG) operation on salinity at Suisun Marsh salinity monitoring stations. Two approaches are taken for this purpose:

- Based on field salinity data, determine the mean and range of salinity response for Suisun Marsh monitoring stations given initiation or termination of SMSCG operation.

- Determine the percentage of time Suisun Marsh salinity standards may be exceeded based on 73-year computer model simulations with and without SMSCG operation.

Analysis of Suisun Marsh Salinity Data During SMSCG Operation Tests

The objective of the first approach is to determine the influence of gate operation (initiation or termination) on monitoring station salinity based on salinity data collected at Suisun Marsh monitoring stations during SMSCG operation testing.

Hourly near-surface salinity (as specific conductance) data for six monitoring locations within Suisun Marsh were used for the analysis. The monitoring locations include S64 on Montezuma Slough at National Steel, S49 on Montezuma Slough at Beldon's Landing, S54 on Montezuma Slough at Hunter Cut, S42 on Suisun Slough at Volanti Slough, S21 at Sunrise Club on Chadbourne Slough, and S35 on Goodyear Slough at Morrow Island (Figure 1). The salinity data coincide with SMSCG operation tests conducted in 1989 and 1991 (DWR, 1989; DWR, 1991). The gate operation tests include three periods of "full-bore" gate operations with installed stop-logs, and one period after gate operation was terminated and stop-logs removed.
The task was to discern the relative influence of SMSCG operations and hydrologic conditions on salinity at monitoring sites within Suisun Marsh. Salinity changes due to

hydrology were estimated using Chipps Island and Collinsville specific conductance along with historical tidally averaged outflow from the Sacramento-San Joaquin Delta.

The analysis was conducted by visually inspecting time-series plots of monitoring station salinity and hydrology indicators during the month after SMSCG operation was either initiated or terminated. Priority analysis was given to periods when hydrologic indicators were relatively constant. The apparent change in salinity due to a SMSCG operation change (initiate or terminate "full bore" gate operations) was noted for each monitoring station. The results are summarized in Table 3. Under each operation category (initiate or terminate), the mean change in channel water salinity is shown along with the observed range of salinity responses. Table 3 shows only those changes apparently caused by SMSCG operation.

TABLE 3

INFLUENCE OF SUISUN MARSH SALINITY CONTROL GATE ON SUISUN MARSH MONITORING STATION SALINITY

	Initiate Full-Bore Operation		Terminate Gate Operation	
Station	Mean Change	Range	Mean Change	Range
S64	-8.0	0.0:-10.0	+4.0	+2.0:+5.0
S49	-6.0	-5.0:-8.0	+6.0	+5.0:+7.0
S54	-4.0	+2.0:-5.0	+3.0	+2.0:+4.0
S42	-3.0	-2.0:-4.0	+4.0	+4.0:+4.0
S21	-2.0	-2.0:-3.0	+3.0	+3.0:+3.0
S35	-1.0	-1.0:NC	+2.0	+2.0:-1.0

NC = "No Change"; Negative = reduction; Positive = increase

Analysis Of 73-Year Computer Model Results

The objective of the second approach was to determine the percentage of time Suisun Marsh salinity standards may be exceeded based on 73-year computer model simulations with and without SMSCG operation.

The Delta Simulation Model 1 (Suisun Marsh Version) was used for the analysis. The input data for the simulation are monthly average Delta inflows and water project exports from the statewide planning model DWRSIM. Based on a constant level of future water demand and historical (1922-1994) monthly average unimpaired reservoir inflows, DWRSIM simulates State Water Project operations given water user demands and operational and environmental constraints. The monthly average 73-year hydrology used for this analysis is based on DWRSIM operation study 1995C6F-SWRCB-469 which conforms to 1995 Water Quality Control Plan requirements.

To directly simulate the impact of the SMSCG on Marsh salinity, two 73-year simulations were conducted based on the same input hydrology, one without SMSCG operation,

and one with SMSCG operation. The without gate operation scenario was run first and the monthly progressive daily mean high tide salinity was recorded. Based on these results, and assuming that the SMSCG is only operated between October and May when required to meet standards, a 73-year schedule for SMSCG operation was determined. Using this schedule of gate operations, the same 73-year hydrology was re-run and the progressive daily mean high tide salinity again recorded.

Modeling results are summarized by using "Area-Frequency Analysis" to show the frequency and extent that monitoring station salinity standards would be exceeded with and without SMSCG operation. For both scenarios, the progressive daily mean high tide salinity output for the October through May period between 1922 and 1994 were compared with the corresponding salinity standard and the difference was recorded. Differences were ranked and a percentage frequency was calculated for each value. Plotting the ranked differences versus the frequency provides an estimate of the amount of time salinity standards would be exceeded under each scenario. Comparison of the with and without gate operation scenarios shown by the area frequency plots impart the following observations. Figures 19 and 20 show the area-frequency plots for eastern and western monitoring stations respectively.

- Without SMSCG operation, standards are exceeded more often, and by a larger magnitude than with SMSCG operation.
- Only station C2 near Collinsville always meets standards under both scenarios.
- Without SMSCG operation, the frequency of standard exceedence is approximately 25% at S64 (near National Steel), 37% at S49 (Beldon's Landing), 30% at S42 (Volanti Slough), 30% at S21 (Sunrise Club), 21% at S35 (Goodyear Slough) and 40% at S97 (Cordelia Slough at Ibis Club).
- With SMSCG operation, the frequency of standard exceedence is approximately 18% at S35, and 30% at S97. No standard exceedences occurred at other monitoring stations.
- At stations where standards are exceeded in both scenarios (S35 and S97), the magnitude of exceedence is less under SMSCG operation.

Actions proposed in SMPA Amendment Number Three

Eleven actions included in SMPA Amendment Three are briefly described in this section, with a demonstration of why they would provide equivalent or better protection than the channel water salinity objectives at western Marsh stations S-35 and S-97. Many of the actions will also provide better protection to other regions in both the eastern and western Marsh.

1) Meet Channel Water Salinity Standards in Order 95-6

Channel salinity standards of Amendment Three would be modified to correspond to the salinity standards in the SRWCB 1995 WQCP as shown in Table 4.

The Original SMPA was written so that, upon construction of large-scale facilities, the Initial Standards would be replaced with the interior Marsh salinity standards. The standards are implemented under the Amendment Three without construction of these facilities because of the increased outflows under the 1995 WQCP, effective SMSCG operation, and the proposed management actions that would be substituted for the large facilities. Therefore, it is appropriate to replace the Initial Standards with the interior Marsh Standards (See DWR 1984 for detailed discussion of implementation of standards and water quality in the Marsh).

Although the SMPA will be amended to no longer require the Initial Standards, the minimum monthly Delta outflow standards continue to be required under Order WR 95-6. When the SWRCB adopted WR 95-6, the order retained certain requirements of D-1485, which included these outflows. In addition, the increased outflow requirements of the 1995 WQCP (e.g. X2 for February through June, See Table 3 of WQCP and Footnotes 13 and 14) call for greater outflows than the Suisun Marsh outflow standards. Therefore, deleting the Initial Standards from the SMPA will not be the source of any changed environmental conditions in the Marsh since the outflow and salinity requirements of the 1995 WQCP and WR 95-6 have replaced the Initial Standards.

This action would provide equivalent or better protection because the implementation of these standards has already occurred through the SWRCB water rights process whereby DWR and USBR have been meeting these Marsh standards as a permit condition under Order WR 95-6.

2) Converting S-35 and S-97 from Compliance Stations to Monitoring Stations

Compliance stations S-35 and S-97 will become monitoring stations in the northwestern Marsh. Salinity will be monitored at these stations in order to determine if SMSCG

TABLE 4. SUISUN MARSH STANDARDS[1] (TABLE 1 OF SMPA)

Compliance Location	Interagency Station Number	Description	Time Period	Value
EASTERN MARSH				
Sacramento River at Collinsville	C-2 (RSAC081)	Maximum monthly average of both daily high tide Electrical Conductivity (EC) values (mmhos/cm)	All Water Year Types, except under circumstances described in Art. III B.	
Montezuma Slough at National Steel	S-64 (SLMZU25)			
Montezuma Slough near Beldons Landing	S-49 (SLMZU11)		October	19.0 EC
			Nov. - Dec.	15.5
			January	12.5
			February - March	8.0
			April - May	11.0
WESTERN MARSH				
Chadbourne Slough at Sunrise Duck Club	S-21 (SLCBN1)	Maximum monthly average of both daily high tide Electrical Conductivity (EC) values (mmhos/cm)	All Water Year Types, unless a Deficiency Period, then apply Standards below.	
Suisun Slough, 300 feet south of Volanti Slough	S-42 (effective date is Oct. 1, 1997) (SLSUS12)		October	19.0 EC
			November	16.5
			December	15.5
			January	12.5
			February - March	8.0
			April – May	11.0
			Deficiency Period	
			October	19.0 EC
			November	16.5
			December - March	15.6
			April	14.0
			May	12.5

1. The Parties recognize that lower channel salinity will be present at some Compliance Stations due to a salinity gradient within the Marsh.
2. Parenthetical contains the River Kilometer Index station number.
3. During Deficiency Periods a good faith effort will be made to meet the Standards in Table 1 at the eastern Marsh stations C-2, S-64, and S-49 and the following conditions apply:
   a) If the standards are not met in one or two months during a Control Season at one or more of the eastern stations, the Parties agree to waive the Standards during these months.
   b) If the Standards are not met for more than 2 months during a Control Season at one or more of the eastern stations, the Parties agree to waive the Standards during these months and the Drought Response Fund will be deemed triggered and funded as provided in Article VII B.
   c) If the Standards are not met for more than 4 months in any two consecutive Control Seasons at one or more of the eastern stations, the Parties agree that the basis for this Agreement is in error and will initiate discussions to amend the Agreement as provided for in Article XV.

operations should begin in September (see action #3 below) and to trigger the Drought Response Fund (see action #11 below).

This action of converting compliance stations S35 and S97 to monitoring stations is proposed because SMSCG operation is not an effective control of channel water salinity in the Marsh at these locations. (See Figure 20 and technical analysis showing salinities with and without gate operation) The area of these stations is influenced by local conditions, especially runoff from the watershed north of the area. The stations will monitor salinity conditions of the area to indicate channel water conditions and determine whether additional management actions should be funded such as actions described in Article VII, Drought Response Fund. DWR and USBR will operate existing facilities, to the extent feasible, to achieve similar water salinities at these stations as are required at the compliance stations.

Implementation of this action will provide equivalent or better protection because:

- These compliance stations have never gone into effect under the Agreement or under SWRCB requirements and changing the requirement to monitoring will not cause a change in the existing environment.

- The intent of the salinity objectives will still be met. As described above, the salinity standards were set with the goal of waterfowl food plant production. Also, as shown above and demonstrated in Table 2, providing channel water salinities does not necessarily mean increased waterfowl food plant production and wildlife habitat. Appropriate and effective management is critical to meeting habitat goals.

- The objective of increased waterfowl food plant production and wildlife habitat will be achieved because:

    1. DWR and USBR will operate existing facilities, to the extent feasible, to achieve similar water salinities at these stations;

    2. If target salinities are exceeded, the drought response fund will be triggered allowing landowners to conduct more extensive management to attain habitat goals; and

    3. S-35 would still be used to trigger SMSCG operation, including September operation as described in Action # 3 below.

    4. The implementation of other actions in this Agreement, which specifically focus on management actions, will assist landowners in effective management.

3) September Operation of the Suisun Marsh Salinity Control Gates

This action establishes criteria to commence Suisun Marsh Salinity Control Gate (SMSCG) operations in September. The purposes of operating the gates in September

are: (1) to help meet October salinity standards in Suisun Marsh, and (2) to enable wetland managers to flood with lower salinity water at the beginning of the season. The SMSCG was implemented as Phase II of the Plan of Protection for the Suisun Marsh. The primary objective of the gates is to tidally pump lower salinity water through Montezuma Slough into the central Marsh to help meet D-1485 channel water salinity standards. The SMSCG is essential for maintaining D-1485 standards in the eastern and central Suisun Marsh and lowering salinity in the western Marsh. The SMSCG have operated four times in September since the SMSCG began operating in October 1988.

DWR and USBR shall operate the SMSCG in September when the 7-day running average mean daily high tide salinity in September at any Compliance Station or at the S-35 Monitoring Station is 17.0 m S/cm or greater. The running averages for September 1-6 will be determined using salinity data from the last 6 days of August.

It is most likely that salinities recorded at S-35 will trigger September operations because, due to its location in the southwestern Marsh, it is often the most saline. S-97 was excluded from triggering September operations because the SMPA Parties agree that salinity at S-97 cannot be controlled with SMSCG operations.

September operation of the SMSCG would provide equal or better protection because:

- Implementation of this action will enable the managed wetlands to be initially flooded with lower salinity water. Wetland managers typically begin flooding on October 1 to prepare for the opening of the waterfowl that begins at the end of October. If the gates have been operating during September, then lower salinity water will be available for the initial flood up. DWR estimates that it takes approximately four days of gate operation for lower salinity water to reach S-49, 7 days to reach S-21 and S-42, and 10-14 days to reach S-35 in the southwestern Marsh. See the discussion above and Table 3 for an analysis of Suisun Marsh response to the operation of the SMSCG.

- Flooding with water of low salinity in October may decrease soil salinity in the Marsh throughout the year, and potentially improve the effectiveness of leaching and waterfowl food plant production. Comprehensive Review data for West Family Club illustrate the importance of initial flood up water quality on soil water salinity. West Family Club was used because the club is consistently managed from year to year. During both water years 1993 and 1994, water was circulated and two leach cycles were conducted on the ponds. The average channel water salinity (S-35) for October through May was only slightly higher during water year 1994, 9.0 mS/cm, as compared to 8.6 mS/cm in 1993. However, the channel water salinity in October and November was significantly higher in water year 1993. During the remainder of the months, channel water salinities were similar, or were higher in water year 1994. Soil water salinity for the two years actually decreased from about 17.0 mS/cm in water year 1993 to about 14.0 mS/cm in water year 1994 (Figure 4). Therefore, although the average channel water salinities were similar, the year with lower channel water salinities during the flood up period had lower soil water salinity.

Table 5: Channel Water Salinity at S-35 (1993-94)

Time Period	Channel Water Salinity at S-35 (mS/cm)	
	1993	1994
Average (Oct.-May.)	8.6	9.0
October	19.9	11.8
November	18.8	13.3

- Operational restrictions imposed during the spring for the protection of delta smelt and winter-run Chinook salmon (USACE 1995) make it difficult to conduct leach cycles; therefore, it is especially important that the salt load be reduced during the initial filling of the managed wetlands.

4) Water Manager Program

SRCD shall institute a Water Manger Program and employ support staff to help coordinate and improve water management practices throughout the Marsh. DWR and USBR will provide SRCD a maximum of $160,000 the first year and a maximum of $140,000 in subsequent years to fund the Water Manager Program.

Utilizing a water manager in Suisun Marsh was suggested by the State Water Resources Control Board in the May 1995 Water Quality Control Plan. The WQCP stated there is a need for a watermaster to direct the timing and amounts of water diverted in the Marsh to ensure that the water is used efficiently and the protection of beneficial uses is maximized (1995 WQCP, p. 40).

The duties of the water manager include, but are not limited to:

- Overseeing compliance with Individual Ownership Management Plans. The operation of diversion and drain facilities on the seasonal managed wetlands would occur when needed; instead of at the convenience of the landowner, who may only be available to manage on weekends, if at all.
- Implementing the Portable Pump Program as described below.
- Monitoring the operation and maintenance of fish screens.
- Obtaining agreements between landowners and SRCD for coordinated water management and Joint-Use Facilities.
- Promoting efficient use of available channel water to protect and maximizing the beneficial uses for habitat.
- Recommending habitat improvements and water management techniques.

This action would provide equal or better protection because:

- A Water Manager could provide on-site input and assistance, using the best available information for effective management of the managed wetlands of Suisun Marsh.

- The duties of the Water Manager (listed above) include activities that would facilitate effective management of the managed seasonal wetlands, essential for meeting the goal of Suisun Marsh water quality objectives. As shown in Figures 4 through 6, active management results in lower soil water salinities, which helps to promote more diverse assemblage of vegetation (Table 2), increased waterfowl food plant productivity and wildlife habitat, thus meeting the objectives of the D-1485 salinity standards for Suisun Marsh.

5) Updating Existing Management Plans

Updating the Individual Ownership Management Plans would enable SRCD to collect field information and write descriptions of existing facilities (i.e., diversion or drainage pipes or gates), existing Marsh habitat conditions and hydrology, and engineering calculations for performing the recommended 30 day flood and drain cycles.

The Management Plans were developed in 1980-81 utilizing the best available information at the time. Since then, hydrodynamic modeling has improved the understanding of water movement through the Marsh. Since the development of the original Management Plans, recommended management regimes have been modified and expanded to include a target of more diversity among waterfowl food plants. In addition, many of the clubs are unable to follow the prescribed Management Plans for a variety of reasons, including conditions of the USACE Regional General Permit to protect fishery resources in Suisun Marsh channels.

Amendment Three provides a maximum of $75,000 to update the 158 Individual Ownership Management Plans. DWR and USBR have already paid $18,800 prior to Amendment Three and the USBR has advanced an additional $56,200 to fund this program.

Updating the Management Plans would provide equivalent or better protection because:

- As described above, effective management is essential to meet the Suisun Marsh water quality objectives. Updating the Management Plans would facilitate effective management and meet the objectives of the salinity standards. As shown in Figure 4, the active management results in lower soil water salinities, and promotes more diverse assemblage of vegetation (Table 2), increased waterfowl food plant productivity, and wildlife habitat, thus meeting the objectives of the D-1485 salinity standards for Suisun Marsh.

- Leaching reduces soil water salinities as shown in Figures 5 and 6.

- The Management Plans provide the basis for management actions on the managed wetlands, including several actions described in Amendment Three.

- The updated plans would be developed using the best available information.

6) Joint-Use Facilities Program

The purpose of the Joint-Use Facilities Program is to improve efficient and cooperative use of water delivery systems to managed wetlands. This action would provide funding for the infrastructure to manage properties more efficiently. The maximum amount expended by DWR and USBR for Joint-Use Facilities shall be $1,700,000. SRCD will be responsible for administration and implementation of the Joint Use Facility Program. Implementation includes a water manager (See Action #4 above) who will coordinate needed improvements and operations.

Joint-Use Facilities are structures or activities used by two or more property owners to manage water either separately or jointly as agreed upon. Specific joint-use activities identified are creating new interior circulation ditches, cleaning drainage and circulation ditches, coring common levees, installing new interior water control structures and new exterior drainage gates, pumps, and fish screens. Joint-Use Facilities can include either newly constructed facilities or improvements to existing facilities.

This action would provide equivalent or better protection because:

- Full implementation of this program will enhance water management capability and efficiency on many properties throughout the Marsh. As shown in Figure 4, active management results in lower soil water salinities, which helps to promote more diverse assemblage of vegetation (Table 2), increased waterfowl food plant productivity and wildlife habitat, thus meeting the objectives of the D-1485 salinity standards for Suisun Marsh.

- Participating in a Joint-Use Facility would enable wetland managers to make the necessary improvements to infrastructure to improve management capabilities on their properties.

7) Managed Wetland Improvement Fund

This action provides for $2,000,000 (plus any remaining funds from the Original Agreement) to be utilized between two cost share programs for improvements on private managed wetlands.

The 75/25 Cost Share Program provides funds to Individual Ownerships to purchase and install new, larger, lowered, or relocated discharge facilities (discharge gates, culverts, flashboard risers, and pumps) that are necessary to enable the Individual

Ownership to implement the 30-day flood and drain cycle as required in their Individual Ownership Management Plan.

The 50/50 Cost Share Program helps landowners fund actions to improve the leaching and draining efficiency of individual ownerships, and assist the landowner to manage the property according to the leaching recommendations described in the Individual Ownership Management Plan. Activities eligible for 50/50 include cleaning, widening, and deepening primary and secondary ditch systems; adding spreader ditches from pond bottom sinks and large poorly drained areas to primary and secondary drainage ditches; raising pond bottom sinks; and offsetting electric and fuel costs for portable and stationary diversion and drainage pumps.

This action would provide equivalent or better protection because:

- Implementation of this program will enhance water management abilities on many properties throughout the Marsh. As shown in Figure 4, active management results in lower soil water salinities, which helps to promote more diverse assemblage of vegetation (Table 2), increased waterfowl food plant productivity and wildlife habitat, thus meeting the objectives of the D-1485 salinity standards for Suisun Marsh.

- Implementation of this program would improve the leaching capability on these managed wetlands. As described above and illustrated in Figures 5 and 6, leaching lowers soil water salinities, which promotes a more diverse assemblage of vegetation, increased waterfowl food plant productivity and wildlife habitat.

- A cost-share arrangement will enable a greater number of wetland managers to make the necessary improvements to management capabilities on their properties.

8) Portable Diversion Pumps With Fish Screens

The use of portable diversion pumps equipped with fish screens would provide the landowners in portions of the Marsh, the opportunity to apply lower salinity slough water at low tides to the managed wetlands, and to fill more quickly.

In many regions of the Suisun Marsh the channel water salinity is lowest at low tide. Under the current flooding system, properties located in these areas of the Marsh are only able to flood through gravity flow floodgates at high tides. This management constraint results in the application of higher salinity water to the managed wetlands, than is available at low tide. With the use of pumps, lower salinity water can be used to fill managed wetlands. The application of this lower salinity water would reduce the accumulation of salts in the soil profile. Utilizing lower salinity water would assist in the effective leaching of salts from the soils within the managed wetlands, and increase the wetland diversity especially in areas of the Marsh where operation of the Suisun Marsh Salinity Control Gates currently has little or no effect on channel water salinity.

The pumps will be screened in accordance with California Department of Fish and Game's criteria. The screens will be designed to ensure compliance with U. S. Fish & Wildlife Service delta smelt fish screen approach velocity criteria of 0.20 ft/s and National Marine Fisheries Service salmonids approach velocity criteria of 0.33 ft/s.

A maximum of $400,000 will be expended to purchase 20 portable pumps and $100,000 for 20 detachable fish screens required for the intake pumps.

This pump pool would be managed by the SRCD in conjunction with the Water Manager Program. SRCD shall oversee the portable pump operation and maintenance while assisting the landowners in proper use. These same pumps will be used to assist landowners to drain managed wetlands and conduct leach cycles as described in Action # 10 below.

This action would provide equivalent or better protection because:

- The SWRCB determined that channel water salinities would be reported as the mean of the two daily high tides. The Board used these criteria because, without the use of pumps, wetland managers use gravity systems and are only able to divert water at high tides. By allowing managers to selectively flood wetlands with portable pumps, the salinity of applied water can be as much as 4 mS/cm lower (Figures 9-16) than is possible with current flooding methods. See the discussion above under the section titled "Variability of Salinity at High vs. Low Tides".

- The use of portable pumps would allow managers to actively flood their wetlands with lower salinity water than is available with passive flooding methods. Rather than depending on weirs and high tide levels, pumps could be used at various times and locations to take advantage of the lower salinity water available throughout the tidal cycle. This ability to selectively flood wetlands would ultimately decrease the salt load carried in wetland soils.

- The use of portable pumps would allow managers to fill their wetlands more quickly to achieve the recommended 10-day fill. This would particularly help wetlands with relatively high pond bottom elevation.

9) Portable Drainage Pumps

The use of twenty diesel-powered portable pumps would improve drainage capabilities of managed wetlands to reduce soil salinities by pumping drainage water that currently cannot be effectively removed by tidal drainage. This program would provide managers with the ability to perform essential leach cycles and appropriate water management schedules during critical growth periods in the Marsh.

In July of 1995, the SRCD evaluated the Suisun Marsh managed wetlands and identified 73 properties in need of pumps to achieve effective drainage. On those properties with low pond bottom elevations, pumps would be used to effectively remove or accelerate

the drainage time of high salinity water. The ability to drain managed wetlands within a 20-day period is a requirement of each of the properties Management Plans.

These pumps may be used year around to achieve the goal of effective habitat management, but the primary use would begin in the winter and spring when leaching of soil salts from the wetland plants root zone is most critical.

A maximum of $400,000 will be expended to purchase 20 portable pumps.

The portable pump pool would be managed by the SRCD in conjunction with the Water Manager Program. SRCD shall oversee the portable pump operation and maintenance while assisting the landowners in proper use. These same pumps will be used to assist landowners to fill managed wetlands with lower salinity water as described in Action # 9 above.

This action would provide equivalent or better protection because:

- Effective leaching is critical to lowering soil water salinity. As shown in Figures 5 and 6, leaching lowers soil water salinity within the managed wetlands.
- The pumps would improve the effectiveness of leaching. Wetland managers with low pond bottom elevations who rely on gravity systems would be able to remove soil water to one foot below the soil surface, as recommended in the Management Plans.
- The use of pumps would reduce the time required for draining and leaching utilizing gravity systems. Reducing the time required to drain the ponds is important in light of the ACOE operational constraints for the protection of fishery resources in Suisun Marsh. During the spring, these restrictions severely limit the time that wetland managers can fill their ponds to conduct leach cycles. If wetland managers can drain more rapidly, they would be in a position to fill their ponds and conduct a leach cycle if USACE restrictions allow for taking in water.

10) Realign and Stabilize Roaring River Distribution System Turnouts

DWR and USBR will provide a maximum of $60,000 to SRCD to facilitate the repair (realigning and stabilizing) of 20 turnouts along the Roaring River Distribution System.

The turnouts were installed when the RRDS was installed in 1980 as part of the Initial Facilities. Since installation, the ends of the culvert pipes have lifted, making it difficult for adjacent landowners to flood from the RRDS. Repair of these facilities will improve water management on Individual Ownerships and DFG lands.

This action provides equivalent or better protection because:

- Implementation will allow wetland managers to follow their Management Plans. Under current conditions, properties along the Roaring River Distribution System are unable to fill their ponds within the time recommended. If the turnouts are repaired, then the Management Plans can be followed, and the ponds could be filled in a timely manner. As shown in Figure 4, active management results in lower soil water salinities, which helps to promote more diverse assemblage of vegetation (Table 2), increased waterfowl food plant productivity and wildlife habitat, thus meeting the objectives of the D-1485 salinity standards for Suisun Marsh.

- The RRDS is part of the Initial Facilities required in D-1485. Implementation of this maintenance activity would result in this facility being operated as designed.

11) Drought Response Fund

The Drought Response Fund (DRF) would compensate landowners (including DFG for lands in managed wetlands in the Marsh) that apply higher salinity channel water to their managed wetlands because of prolonged drought conditions. When triggered, the DRF provides a maximum of $72,000 per year to SRCD for drought response activities including disking, seeding, preparing the seedbed, creating V-ditches, and portable pump operation to increase leaching efficiency. SRCD would provide DFG up to $10,000 of this fund per year triggered, for similar activities on affected DFG lands.

The drought response criteria and allocation of funding is described in Amendment Three, Article VII (B) (3). The DRF will be made available any year the drought response criteria is triggered, and for one year beyond the last drought year the fund is triggered.

This action provides equal or better protection because:

- The intent of the salinity objectives will still be met. As described above, the salinity standards were set with the goal of waterfowl food plant production. Also, as shown above and demonstrated in Figures 3 and 4, providing channel water salinities does not necessarily mean increased waterfowl food plant production and wildlife habitat. Appropriate and effective management is critical to meeting habitat goals.

- Implementation of the DRF will provide wetland managers with additional funding to conduct specific management activities. The management activities are designed to improve leaching effectiveness. Effective leaching results in lower soil water salinities as shown in Figures 5 and 6.

- Actively managing water on the clubs can be especially critical during extended drought conditions. Data from the Comprehensive Review encompass six continuous years of either critical or dry conditions. The effects of active

management during this period can be illustrated with soil water salinity and vegetation data from Goodyear and West Family clubs and is discussed above in the section titled "Effects of Water Management During Drought Conditions".

Implementation of Actions

1) Implement Three Actions Immediately

Of the eleven actions proposed in Amendment Three, three can be implemented immediately, namely: (1) September SMSCG operation, (2) converting S-97 and S-35 from compliance stations to monitoring stations, and (3) updating the Individual Ownership Management Plans. These actions do not require the physical modification of facilities or contractual agreements.

2) Complete Environmental Documentation and Execute Amendment Number Three

The SMPA parties are nearing completion of Amendment Three.

USFWS and NMFS are reviewing the Initial Study/Environmental Assessment under informal consultation. Once concurrence is received from these agencies, the documents will be filed. After finalizing the environmental documentation, the Amendment will be executed.

3) Fund SRCD to Implement Other Actions

Once the environmental documentation is completed and Amendment Three is finalized and signed, DWR and USBR will prepare the contracts with SRCD needed to fund the remaining actions.

The timing of implementation of the remaining actions depends on the specific action. Any action, which requires physical modifications to the Marsh, can only be implemented during the Suisun Marsh construction season. The construction season varies according to specific activities and specific areas throughout the Marsh because of endangered species restrictions. Actions in this group include Joint-Use Facilities, Managed Wetland Improvement Fund, and Roaring River Distribution System turnout maintenance. All construction must be timed to avoid impacts to California clapper rail.

Actions that only require the purchase of equipment can be implemented immediately after Amendment Three is signed and funding is available. Included in this group are portable pumps and fish screens, Water Manager Program, and Drought Response Fund.

Monitoring and Reports to the SWRCB

The SMPA parties will provide the SWRCB the following information and reports to monitor the implementation of the Amendment Three Actions.

1) Monitor tide and salinity at compliance and monitoring stations (map).
2) Conduct triennial aerial photo and vegetation surveys.
3) Monthly Compliance Monitoring Report
4) Quarterly Water Manager Report
5) Annual Data Summary Report
6) D-1485 Condition 7(d) Annual Report

Concurrences

The following letters of concurrence for implementing Amendment Three actions are included in Appendix C.

1) DFG Letter
2) SRCD Letter
3) NMFS Letter

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Testing Crops for Salinity Tolerance

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ABSTRACT

The capability of crops to grow on saline soils varies among species and depends on the concentration of salts present in the rootzone and on various environmental and cultural conditions. Information on the relative tolerance of different crops is essential to the successful management of salt-affected agricultural lands and waters. Results from over 50 years of research have produced salt tolerance data that relate yield reductions of over 90 different crops to soil salinity. These data are presented in tabular form and give threshold salinity values and percent yield reductions expected at salinities exceeding the threshold. The recommended procedure to acquire reliable data, the yield response function used to quantify salt tolerance data, and factors to consider when evaluating or using these data are also described.

INTRODUCTION

Sustained and profitable production of crops on salt-affected soils requires appropriate on-farm management decisions. Growers must know how plants respond to salinity, the relative tolerances of different crops and their sensitivity at different stages of growth, and how different soil and environmental conditions affect salt-stressed plants. For more than 50 years, scientists at the U. S. Salinity Laboratory in Riverside have determined the responses of many important agricultural crops to soil and water salinity. The results of those studies as well as those obtained at various other locations are crucial for estimating potential yields of crops grown under different levels of salinity.

The most common effect of salinity on plants is a general stunting of growth. The plants usually appear normal, although if compared with nonstressed plants, they may have darker green leaves that, in some cases, are thicker and more succulent. Visual symptoms, such as leaf burn, necrosis, and defoliation occur in some species, particularly woody crops, but these symptoms are rare in herbaceous crops unless plants are severely stressed Consequently, it is difficult to diagnose a moderately salt-affected crop in the field without having a nonstressed crop nearby for comparison.

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The most certain method to identify a salinity problem is to determine the salt concentration of the soil. If soil salinity in the rootzone exceeds the tolerance of the crop, yield losses can be estimated from the salt tolerance data.

Crop response to salinity can be quantified by plotting relative growth or yield as a continuous function of increasingly higher levels of soil salinity. This response function generally follows a sigmoidal relationship, i.e., yields tend to be independent of soil salinity, or decrease slowly, at low salt concentrations, then decrease at a greater, but relatively constant, rate at intermediate concentrations; and finally at high concentrations, they begin to decrease more slowly, approaching zero yield asymptotically. With some crops, plants may die before seed or fruit yields have reached zero, thus eliminating the lower part of the sigmoidal curve. In either case, yields at extreme salinity stress are too low to be of commercial value so that accuracy in this part of the response curve is not critical.

PLANT RESPONSE

Plant sensitivity to soil salinity continually changes during the growing season. Most crops are tolerant during germination, but the young developing seedlings are susceptible to injury during emergence from the soil and during early juvenile development. Once established, plants generally become increasingly tolerant during later stages of growth. One of the primary effects of salt stress is that it delays germination and seedling emergence. Delays can be fatal if the emerging seedlings, already weakened by salt stress, encounter additional stresses, such as water stress, extreme temperature fluctuations and/or soil crusting. Because of evaporation at the soil surface, the salt concentration in the seed bed is often greater than at deeper depths. Consequently, the juvenile roots of emerging seedlings are exposed to a greater degree of stress than indicated by the usual measurements of salinity made on composite soil samples taken from throughout the soil profile. The loss of plants during this crucial phase can reduce the plant population density to suboptimal levels and significantly reduce yields.

Experiments designed to test the relative effects of salt stress at different stages of growth indicate that sorghum '(*Sorghum bicolor* (L.) Moench), wheat (*Triticum aestivum* L.), and cowpea (*Vigna unguiculata* (L.) Walp.) are most sensitive during the vegetative and early reproductive stages, less sensitive during flowering, and least sensitive during the grain-filling stage (Maas et al., 1986; Maas and Poss, 1989a; 1989b). Suppression of tiller formation is the most serious effect of salt stress during the vegetative and

early reproductive stage of cereals. Apparently, most crops become more tolerant at later stages of growth, but there are some exceptions. For example, salt stress affects pollination of some rice (Oryza *sativa* L.) cultivars, thereby decreasing seed set and grain yield. (see Maas and Grattan, 1994, for further discussion and references).

ESTABLISHMENT OF EXPERIMENTS

Traditionally, salt tolerance data have been obtained in small experimental plots. To the extent possible, crops are grown according to commercial practices with adequate moisture and nutrients. Several salinity treatments (preferably six or more, replicated three times) are imposed by irrigating the test crop with artificially-salinized water. A mixture of NaCl and $CaCl_2$ (1:1 by wt.) is added to nonsaline irrigation water to obtain a range of salt concentrations that cause yield reductions of 0 to 50% or more. The soil profiles are leached with the respective treatment waters to presalinize the expected rootzone. However, to ensure an acceptable plant stand, all plots are irrigated with approx. 5 cm of nonsaline water just prior to sowing to provide a nonsaline seedbed. Saline irrigations are imposed after the seedlings have emerged and are continued throughout the growing season.

The soil should be sufficiently permeable to allow adequate leaching. Without leaching, salt concentration increases with depth in the rootzone and can vary from that of the irrigation water near the soil surface to concentrations many times higher at the bottom of the rootzone. With such variable salinity, it is difficult to estimate the degree of salt stress to which the plant is responding. Even with the recommended leaching fraction of 50%, salt concentrations roughly double from the top to the bottom of the rootzone.

Having accurate measurements of soil salinity in the rootzone during the growing season is essential to obtain reliable salt tolerance data. This requires monitoring salinity at several depths at various times during the season. These salinity values are averaged to estimate the mean soil salinity encountered by the crop. Soil salinity is conveniently estimated from the electrical conductivity (EC) of water extracted from the soil at some reference water content, e.g. that present in a saturated soil paste. Although the EC of the saturated-soil extract (EC_e) is approximately half that of the soil water at field capacity, it has commonly been used to express the salinity of the soil. It is a reproducible value that is directly proportional to the salt concentration in the soil water. For further details and a description of other

methods that measure EC of the soil water directly or indirectly, the reader is referred to Rhoades and Miyamoto (1990).

Many soil and environmental factors interact with salinity to influence crop salt tolerance. Therefore, these factors must be considered before planning any salt tolerance experiments. The soil should be adequately fertilized because the lack of nutrients, rather than salinity, can be the primary factor limiting growth. Plants tested on infertile soils, therefore, may appear more salt tolerant than those grown on fertile soils. Maintaining adequate soil water throughout the growing season is also essential to obtain reliable data. If water is limiting, plants not only must endure water stress, but they are exposed to higher salt concentrations as they extract and concentrate the soil water. It should be noted that salt-stunted plants grown in saline treatments will probably require less water than normal-sized control plants.

The sorghum experiment described by Francois et al. (1984) is typical of the salt tolerance experiments conducted by the U. S. Salinity Laboratory. Usually, two cultivars are tested simultaneously in 6-m-square plots. Including additional cultivars in the small plots, while desirable, compromises the reliability of the plant growth and yield data. Our experience also indicates that six levels of salinity replicated three times are required to obtain reliable data. Furthermore, experiments are normally repeated a second year and the data are combined, although only one year's data were reported for sorghum. The two cultivars, Asgrow Double TX and Northrup Ring NK-265, responded alike to increasing soil salinity. A similar experiment was conducted at Brawley, CA on two cultivars of pearl millet (Pennisetum *glaucum* (L.) R. Br, cvs. 18DB and 23DB). The reduction in shoot dry matter production with increasing salinity indicated that pearl millet is moderately tolerant (L. E. Francois, personal communication). Unfortunately, seed production was well below normal, possibly because pollination was affected by the extreme summer temperatures. The only known data on seed yield also indicate that pearl millet is moderately tolerant (Singh and Chandra, 1979).

YIELD RESPONSE CURVE

Maas and Hoffman (1977) proposed that the yield response curve for agricultural crops could be represented by two linear lines, one, a horizontal line depicting no response to increasing salinity at low concentrations, and the second, a concentration-dependent line whose slope indicates the yield reduction per unit increase in salinity at higher concentrations. The point

at which the two lines intersect designates the "threshold", i.e. the maximum soil salinity that does not reduce yield below that obtained under nonsaline conditions. Figure 1 shows the two-piece model fitted to actual grain yields obtained in a salt tolerance experiment on corn (Zea mays L.). This two-piece linear response function provides a reasonably good fit for commercially acceptable yields when plotted against time- and depth-averaged salinity in the rootzone. For soil salinities exceeding the threshold of any given crop, relative yield (Y_r) can be estimated with the following equation:

$$Y_r = 100 - b(EC_e - a)$$

where a = the salinity threshold expressed in dS/m (1 dS/m = 1 mmho/cm); b = the yield reduction, or slope, expressed in % per dS/m; and EC_e = the mean electrical conductivity of saturated-soil extracts taken from the rootzone.

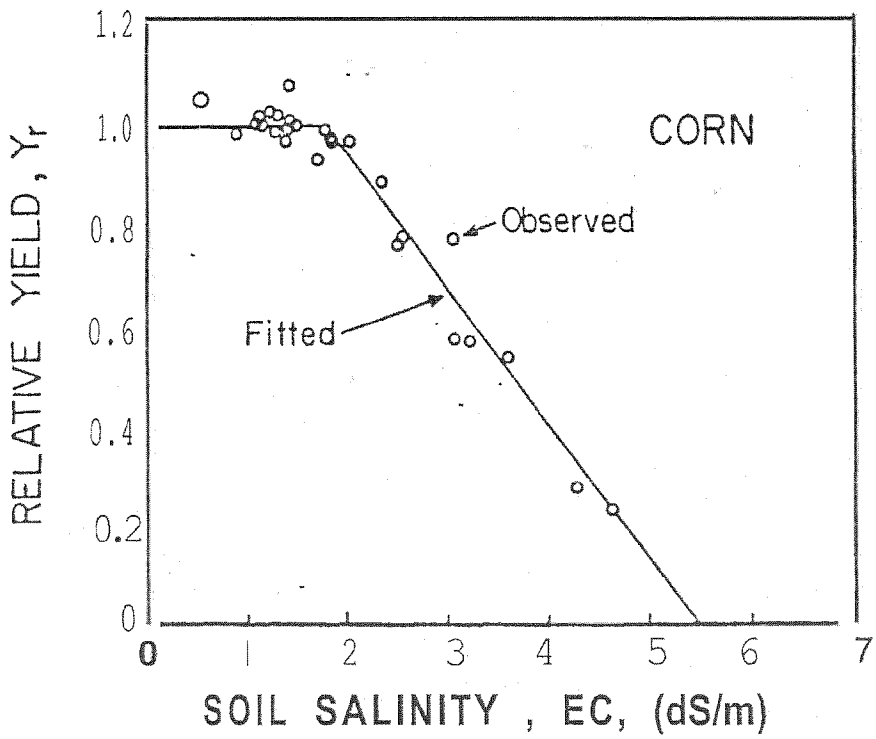

Fig.1. The piece-wise linear response function fitted to actual yield data obtained from corn. Data from Hoffman et al. (1983).

SALT-RESPONSE THRESHOLDS

Tables 1 and 2 list threshold and slope values for over 90 crops in terms of EC_e. Most of the data were obtained where crops were grown under conditions simulating recommended cultural and management practices for commercial production. Consequently, they indicate relative tolerances of different crops grown under different conditions and not under some standardized set of conditions. Furthermore, the data apply only where crops are exposed to fairly uniform salinities from the late seedling stage to maturity. Where crops have particularly sensitive stages, the tolerance limits are given in the footnotes. These data are also intended to apply where chloride is the predominant anion. Plants grown on gypsiferous soils will tolerate EC_e's approximately 2 dS m^{-1} higher than those listed in Table 1. The last column provides a qualitative salt tolerance rating that is useful in categorizing crops in general terms. The limits of these categories are illustrated in Figure 2. Some crops are listed with only a qualitative rating because experimental data are inadequate to calculate the threshold and slope.

Table 1. Salt tolerance of herbaceow crops.'

Common name	Botanical name[b]	Tolerance based on:	Threshold[c] (EC_e) dS/m	Slope (% per dS/m)	Rating[d]
Fiber, grain, and special crops					
Artichoke, Jerusalem	Hellanthus tuberosus L.	Tuber yield	0.4	9.6	MS
Barley[e]	*Hordeum vulgare L.*	Grain yield	8.0	5.0	T
Canola or rapeseed	Brassica campestris L [syn. B. rapa L.]	Seed yield		—	T
Canola or rapeseed	*B.napus L.*	Seed yield		—	T
Chick pea	Cicer *arietinum* L.	Seed yield			MS
Corn[f]	Zea mays L.	Ear FW	1.7	12	MS
Cotton	Gossyplum *hirsutum* L.	Seed cotton yield	7.7	5 2	T
Crambe	Crambe abyssinica Hochst. ex R.E. Fries	Seed yield	2.0	8.5	MS
Flax	*Unum usitatissimum L.*	seed yield	1.7	12	MS
Guat	*Cyamopsis tetragonoloba* (L). Taub.	Seed yield	8.8	17	T
Kenal	Hibiscus *cannabinus* L	stem DW	8.1	11.6	T
Milet, channel	*Echinochloa tumerana (Domin)* J.M. Black	Grain yield			T
Millet, pearl	*Pennisetum gloucum* (L) R.Br	Seed yield		—	MT'
Oats	Avena sativa L.	Grain yield	—	—	T
Peanut	Arachis *hypogaea* L.	Seed yield	3.2	29	MS
Rice	*Oryza* sativa L.	Grain yield	3.0[g]	12[g]	S
Roselle	Hibiscus *sabdariffa* L.	Stem DW	—	—	MT
Rye	Secale cereale L.	Grain yield	11.4	10.8	T
Safflower	Carthamus tinctorius L.	Seed yield	—	—	MT
Sesame[h]	*Sesamum indicum* L.	PodDW	—		S
Sorghum	*Sorghum bicolor* (L.) Moench	Grain yield	6.8	16	MT
Soybean	*Glycine* max (L.) Merrill	Seed yield	5.0	20	MT
Sugarbeet[j]	Beta vulgaris L.	Storage root	7.0	5.0	T
Sugarcane	*Saccharum officinarum* L.	Shoot DW	1.7	5.9	MS
Sunflower	Helanthus *annuus* L.	Seed yield	—	—	MT
Triticate	X *Triticosecale* Wittmack	Grain yield	6.1	2.5	T

Common name	Botanical name[b]	Tolerance based on:	Threshold[c] (E C ,) dS/m	Slope(% per dS/m)	Rating[d]
Wheat	*Triticum aestivum* L	Grain yield	6.0	7.1	MT
Wheat (semidwarf)[j]	T. aestivum L	Grain yield	8.6	3.0	T
Wheat, Durum	*T. turgidum* L var. *durum* Desf.	Grain yield	5.9	3.6	T
Grasses and forage crops					
Alfalfa	Medicago *sativa* L	Shoot DW	2.0	7 9	MS
Alkaligrass, Nuttall	Puccinellia airoides (N ats. & Coult	Shoot DW		—	T*
Alkali sacaton	Sporobolus airoides To	Shoot DW			T*
Barley (forage)[e]	Hordeum vulgare L.	Shoot DW	6.0	7.1	MT
Bentgrass, creeping	Agrostis stolonifera L	Shoot DW	—	—	MS
Bermudagrass[k]	Cynodon dactylon (L.) Pem.	Shoot DW	6.9	6.4	T
Bluestem, Angleton	Dichanthium aristatum (Poir.) C.E. Hubb. [syn. Andropogon nodosus (Willem) Nash]	Shoot DW			MS*
Broadbean	Vida faba L.	Shoot DW	1.0	9.6	MS
Brome, mountain	Bromus marginatus Nees ex Steud.	Shoot DW	—		MT*
Brome. smooth	B. inermis Leyss	Shoot DW	—		MT
Buffelgrass	Pennisetum *ciliare* (L.). Unk. [syn. *Cenchrus ciliaris*]	Shoot DW	—		MS*
Burnet	*Poterium sanguisorba* L.	Shoot DW	—		MS*
Canarygrass, read	*Phalaris arundinacea* L	Shoot DW	—	—	MT
Clover, alsike	*Trifolium hybridum* L	Shoot DW	1 . 5	12	MS
Clover, Berseem	*T. alexandrinum* L.	Shoot DW	1.5	5.7	MS
Clover, Hubam	*Melilotus alba* Dost. var. *annua* H.S. Coe	Shoot DW	—		MT*
Clover, ladino	*Trifoloim repens* L.	Shoot DW	1.5	12	MS
Clover, Persian	*T. resupinatum* L	Shoot DW	—		MS*
Clover, red	*T. pratense* L	Shoot DW	1.5	12	MS
Clover, strawberry	*T. fragiferum* L	Shoot DW	1.5	12	MS
Clover, sweet	*Melilotus* sp. Ml.	Shoot DW	—	—	MT*
Clover, white Dutch	*Trifolium repens* L	Shoot DW	—		MS*
Corn (forage)	*Zea* mays L	Shoot DW	1.6	7.4	MS
Cowpea(forage)	*Vigna unguiculata* (L.) Walp.	Shoot DW	2.5	11	MS
Dallsgrass	*Paspalum dilatatum* Pdr.	Shoot DW	—		MS*
Dhaincha	*Sesbania bispinosa* (Linn.) W.F. Wight [syn. *Sesbania aculeata* (Willd.) Pdr]	Shoot DW	—	—	MT
Fescue. tall	*Festuca elatior* L [syn. *F. arundinacea*]	Shoot DW	3.9	5.3	MT
Fescue. meadow	*Festuca pratensis* Huds.	Shoot DW			MT*
Foxtail. meadow	*Alopecurus pratensis* L	Shoot DW	1.5	9.6	MS
Glycine	*Neonotonia wightii* [syn. *Glycine wightii* or *javanica*]	Shoot DW	—		MS
Gram, black or Urd bean	*Vigna mungo* (L.) Hepper [syn. *Phaseolus mungo* L.]	Shoot DW	—		S
Grama. blue	*Bouteloua gracilis* (HBK) Lag. ex Steud.	Shoot DW		—	MS*
Guinea grass	*Panicum maximum* Jacq.	Shoot DW		—	MT
Hardinggrass	*Phalaris tuberosa* L var. *stenoptera* (Hack) A.S. Hitchc.	Shoot DW	4.6	7.6	MT
Kallargrass	*Leptochloa fusca* (L) Kunth [syn. *Diplachne fusca* Beauv.]	Shoot DW	—	—	T
Lablab bean	*Lablab purpureus* (L) Sweet [syll. *Dolichos lablab* L.]	Shoot DW	—	—	MS
Lovegrass[l]	*Eragrostis* sp. N.M. Wolf	Shoot DW	2.0	6.4	MS
Milkvetch, Cicer	*Astragalus cicer* L.	Shoot DW	—	—	MS*
Millet, Foxtail	*Setaria italica* (L.) Beauvois	Dry matter	—		MS
Millet, pearl	*Pennisetum glaucum* (L) R. Br	Dry matter	—	—	MT*

cmirnm name	Botanical name[b]	Tolerance based m:	Threshold[c] (E C.)	Slope (% dS/m per dS/m)	Rating[d]
Oatgrass, tall	*Arrhenatherum elatius* (L) Beauvois ex J. Presl & K. Presl	Shoot DW	—	—	MS*
Oats (forage)	*Avena sativa* L	Straw DW	—	—	T
Orchardgrass	*Dactylis glomerata* L	shoot DW	1.5	6.2	MS
Panicgrass, blue	*Panicum antidotale* Retz.	Shoot DW	—	—	MS*
Pigeon pea	*Cajanus cajan* (L.) Hum [syn. C. *indicus* (K..) Spre ,	Shoot DW	—	—	S
Rape (forage)	*Brassica napus* L			—	MT'
Rescuegrass	*Bromus unioloides* HBK	Shoot DW	—	—	MT'
Rhodesgrass	*Chloris Gayana* Kunth.	Shoot DW	—	—	MT
Rye (forage)	*Secale cereale* L.	Shoot DW	7.8	4.9	T
Ryegrass, Italian	*Lolium multiflorum* Lam.	Shoot DW	—	—	MT'
Ryegrass, perennial	*Lolium perenne* L.	Shoot DW	5.6	7.8	MT
Ryegrass, Wimmera	*L. rigidum* Gaud.		—		MT*
Saltgrass, desert	*Distichlis spicta* L var. *stricta* (Torr.) Bettle	Shoot DW	—	—	T*
Sesbania	*Sesbania exaltata* (Rat.) V.L. Cory	Shoot DW	2.3	7.0	MS
Sirato	*Macroptilum atropurpureum (DC.)* Urb.	Shoot DW	—	—	MS
Sphaerophysa	*Sphaerophysa salsula* (Pall.) DC	Shoot DW	2 2	7.0	MS
Sudangrass	*Sorghum bicolor* (L) Moench [syn. *S. sudanense* (Piper) Stapf]	Shoot DW	2.9	4.3	MT
Timothy	*Phleum pratense* L	Shoot DW	—	—	MS*
Trefoil, big	Lotus *pedunculatus* C	Shoot DW	2.3	19	MS
Trefoil, narrowleaf birdsfoot	*L. corniculatus* var *tenuifolium* L	Shoot DW	5.0	10	MT
Trefoil, broadleaf birdsfoot	*L corniculatus* L var *arvenis* (Schkuhr) Ser.ex DC	Shoat DW	—	—	MS
Vetch, common	*Vicia angustifolia* L	Shoot DW	3.0	11	MS
Wheat (forage)[j]	*Triticum aestivum* L	Shoot DW	4.5	2.0	MT
Wheat Durum (forage)	*T. turgidum* L. var *durum* Desf.	Shoot DW	2.1	2.5	MT
Wheatgrass, standard crested	*Agropyron sibiricum* (Willd.) Beauvois	Shoot DW	3.5	4.0	MT
Wheatgrass, fairway crested	*A cristatum* (L.) Gaerm.	Shmt DW	7.5	9.9	T
Wheatgrass, Intermediate	*A. intermedium* (Host) Beauvois	Shoot DW		—	MT*
Wheatgrass, slender	*A trachycaulum* (Link) Malte	Shoot DW	—	—	MT
Wheatgrass, tall	*A elongatum* (Hort) Beauvois	Shoot DW	7.5	4 2	T
Wheatgrass, western	A. *smithii* Rydb.	Shoot DW	—	—	MT'
Wildrye, Altai	*Elymus angustus* Trin.	Shoat DW	—	—	T
Wildrye, beardass	*E. triticoides* Buckl.	Shoot DW	2.7	6.0	MT
Wildrye, Canadian	*E. canadensis* L.	Shoot DW	—	—	MT'
Wildrye, Russian	*E. junceus* Fisch.	Shoot DW	—	—	T
Vegetables and fruit crops					
Artichoke	*Cynara scolymus* L	Head yield	—	—	MT*
Asparagus	Asparagus *officinalis* L	Spear yield	4.1	2.0	T
Bean, common	*Phaseolus vulgaris* L	Seed yield	1.0	19	S
Bean, lima	*P. lunatus* L.	Seed yield	—	—	MT*
Bean, mung	*Vigna radiata* (L.) A. Wilcz	Seed yield	1.9	20.7	S
Cassava	*Manihot esculenta* Crantz	Tuber yield	—	—	MS
Beet, red'	*Beta vulgaris* L	Storage root	4.0	9.0	MT
Broccoli	*Brassica oleracea* L. (Botrytis Group)	Shoot FW	2.8	9.2	MS
Brussel Sprouts	*B. oleracea* L. (Gemmifera Group)			—	MS*
Cabbage	*B. oleracea* L. (Capitata Group)	Head FW	1.9	9.7	MS

cmimon name	Botanical name[b]	Tolerance based on:	Threshold[c] (EC_e) dS/m	Slope (% per dS/m)	Rating[d]
Carrot	*Daucus carota* L	Storage root	1.0	14	S
Caulliflower	*Brassica oleracea* L (Botryti Group)		—	—	MS*
Celery	*Apium graveolens* L var *dulce* (Mill.) Pen.	Petiole FW	1.6	6.2	MS
Corn, sweet	*Zea mays* L.	Ear FW	1.7	12	MS
Cowpea	*Vigna unguiculata* (L.) Walp.	Seed yield	4.9	12	MT
Cucumber	*Cucumis sativus* L	Fruit yield	2.5	13	MS
Eggplant	*Solanum melongena* L. var *esculentum* Nees.	Fruit yield	1.1	6.9	MS
Garlic	*Allum sativum* L	Bulb yield	1.7	10	MS
Gram, black or Urd bean	*Vigna mungo* (L) Hepper [syn. Phaseolus *mungo* L.]	Shoot DW			S
Kale	*Brassica oleracea* L (Acephala Group)		—		MS*
Kohlrabi	*Brassica oleracea* L (Gongylodes Group)		—	—	MS*
Lettuce	*Lactuca sativa* L.	Top FW	1.3	13	MS
Muskmelon	*Cucumis melo* L. (Reticulatus Group)	Fruit yield	1.0	6.4	MS
Okra	*Abelmoschus esculentus* (L) Moench	Pod yield	—	—	MS
Onion (bulb)	*Allum cepa* L	Bulb yield	1.2	16	S
Onion (seed)		Seed yield	1.0	6.0	MS
Parsnip	*Pastinaca sativa* L		—	—	S*
Pea	*Pisum sativum* L	Seed FW	3.4	10.0	MS
Pepper	*Capsicum annuum* L	Fruit yield	1.5	14	MS
Pigeon pea	*Cajanus cajan* (L) Huth [syn *C. indicus* (K.) Spreng.]	Shoot DW	—	—	S
Potato	*Solanum tuberosum* L	Tuber yield	1.7	12	MS
Pumpkin	*Cucurbita pepo* L var *Pepo*		—	—	MS*
Purslane	*Portulaca oleracea* L.	Shoot FW	6.3	9.6	MT
Radish	*Raphanum sativus* L	Storage root	1.2	13	MS
Spinach	*Spinacia oleracea* L	Top FW	2.0	7.6	MS
Squash, scallop	*Cucurbita pepo* L var *melopepo* (L) Alef.	Fruit yield	3.2	16	MS
Squash, zucchini	*C. pepo* L var *melopepo* (L) Alef.	Fruit yield	4.7	9.4	MT
Strawberry	*Fragaria* x *Ananassa* Duch.	Fruit yield	1.0	33	S
Sweet potato	*Ipomoea batatas* (L) Lam.	Fleshy root	1.5	11	MS
Tepary bean	*Phaseolus acutifolius* Gray		—	—	MS*
Tomato	*Lycopersicon lycopersicum* (L) Karst ex Farw. [syn. *Lycopersicon esculentum* Mill.]	Fruit yield	2.5	9.9	MS
Tomato, cherry	*L. lycopersicum* var. *Cerasiforme* (Dunal) Alef.	Fruit yield	1.7	9.1	MS
Turnip	*Brassica rapa* L (Rapifera Group)	Storage root	0.9	9.0	MS
Turnip (greens)		Top FW	3.3	4.3	MT
Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Fruit yield	—	—	MS*
Winged bean	*Psophocarpus tetragonolobus* L. D.C.	Shoot DW	—	—	MT

[a]These data serve mly as a guideline to relative tolerances among crops. Absolute tolerances vary, depending on climate, soil conditions, and cultural practices. Source: Maas and Grattan (1994).
[b]Botanical and common names Mbw convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) if possible.
[c]In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.
[d]Ratings are defined by the boundaries in Figure 2. Ratings with an * are estimates.
[e]Less tolerant during seedling stage, EC, at this stage should not exceed 4 of 5 dS/m.
[f]Grain and forage yields of DeKalb XL-75 grown m an organic mu& soil decreased about 26% per dS/m above a threshold of 1.9 dS/m (Hoffman et al., 1983).
[g]Because paddy rice is grown under flooded conditions, values refer to the electrical conductivity of the soil water while the plants are submerged. Less tolerant during seedling stage.
[h]Sesame cultivars, Sesaco 7 and 8, may be more tolerant than indicated by the S rating.
[i]Sensitive during germination and emergence, EC, should not exceed 3 dS/m.
[j]Data from me cultivar, "Probred".
[k]Average of several cultivars. Suwannee and Coastal are about 20% more tolerant, and common and Greenfield are about 20% less tolerant than the average.
[l]Average for Boer, Wilman, Sand, and Weeping cultivars. Lehmann seems about 50% more tolerant.

Table 2. Salt tolerance of woody crops[a].

Common name	Botanical name[b]	Td erance based on:	Thresholds (EC_e) dS/m	Slope % per dS/m	Rating[d]
Almond	*Prunus dudis* (Ml.) DA. Web4	Shoot growth	1.5	10	S
Apple	*Malus syivestris* Mll.		—	—	S
Apricot	*Prunus armeniaca* L	Shoot growth	1.6	24	S
Avocado	*Persea americana* Mll.	Shoot growth		—	S
Banana	*Musa acuminata Cd la*	Fruit yield	—	—	S
Blackberry	*Rubus macropetalus Doug.* ex Hook	Fruit yield	1.5	22	S
Boysenberry	*Rubus ursinus* Cham. and Schlechtend	Fruit yield	1.5	22	S
Castorbean	*Ricinus communis* L ,			—	MS'
Cherimoya	*Annona cherimola* Mll.	Fdlar injury		—	S
Cherry, sweet	*Prunus avium* L	Foliar injury	—	—	S'
Cherry, sand	*Prunus besseyi* L. H. Baley	Fdlar injury, stem growth		—	S'
Coconut	Cocos *nucifera* L		—	—	MT'
Currant	*Ribes sp.* L.	Fdlar injury, stem growth	—	—	S'
Date palm	*Phoenix dactylifera* L	Fruit yield	4.0	3.6	T
Fig	*Ficus carica* L.	Plant DW	—	—	MT'
Gooseberry	*Ribes* sp. L.			—	S'
Grape	*Vitis vinifera* L	shoot growth	1.5	9.6	MS
Grapefruit	*Citrus x paradisi* Maclady	Fruit yield	1.2	13.5	S
Guava	*Psidium guajava* L	shoot & root growth	4.7	9.8	MT
Guayule	*Parthenium argentatum* A. Gray	Shoot DW Rubber yield	8.7 7.8	11.6 10.8	T T
Jambolan plum	*Syzygium cumini* L.	shoot growth	—	—	MT
Jojoba	*Simmondsia chinensis* (Link) C.K. Schneid	shoot growth	—	—	T
Jujube, Indian	*Ziziphus mauritiana* Lam.	Fruit yield	—	—	MT
Lemon	*Citrus limon* (L) Burm. f.	Fruit yield	1.5	12.8	S
Lime	*Citrus aurantifolia* (Chrisbn.) Swingle		—	—	S'
Loquat	*Eriobotrya japonica* (Thunb). Lindl,	Foliar injury		—	S'
Macadamia	*Macadamia integrifolia* Malden & Betche	Seedling growth	—	—	MS'
Mandarin orange: tangerine	*Citrus reticulata* Blanco	Shoot growth	—	—	S'
Mango	*Mangifera indica* L	Fdlar injury	—	—	S
Natal plum	*Carissa grandiflora* (E.H. Mey) A. D.C.	Shoot growth	—	—	T
Olive	*Olea europaea* L	Seedling growth Fruit yield	—	—	MT
Orange	*Citrus sinensis* (L) Osbeck	Fruit yield	1.3	13.1	S
Papaya	*Carica papaya* L.	Seedling growth Fdlar injury	—	—	MS
Passion fruit	*Passiflora edulis* Sims.		—	—	S'
Peach	*Prunus persica* (L) Batsch	shoot growth, Fruit yield	1.7	21	S
Pear	*Pyrus communis* L		—	—	S
Pecan	*Carya illinoinensis* (Wangenh.) C. Koch	Nut yield, trunk growth	—		MS
Persimmon	*Diospyros virginiana* L		—	—	S
Pinneapple	*Ananas comosus* (L.) Merrill	Shoot DW	—	—	MT
Pistachio	*Pistacia vera* L	Shoot growth	—	—	MS
Plum; Prune	*Prunus domestica* L.	Fruit yield	2.6	31	MS
Pomegranate	*Punica granatum* L	Shoot growth	—	—	MS

Common name	Botanical name[b]	Tolerance based on:	Threshold[c] (EC_e) dS/m	Slope % per dS/m	Rating[d]
Popinac, white	*Leucaena leucocephala* (Lam.) de Wit [syn. *Leucaena glauca* Benth.]	Shoot DW	—	—	MS
Pummelo	*Citrus maxima* (Burm.)	Foliar injury	—	—	S*
Raspberry	*Rubus idaeus* L.	Fruit yield	—	—	S
Rose apple	*Syzygium jambos* (L.) Alston	Foliar injury	—	—	S*
Sapote, white	*Casimoroa edulis* Llave	Foliar injury	—	—	S*
Scarlet wisteria	*Sesbania grandiflora*	Shoot DW	—		MT
Tamarugo	*Prosopis tamarugo* Phil.	Observation	—	—	T
Walnut	*Juglans* spp.	Foliar injury	—	—	S*

[a]These data serve only as a guideline to relative tolerances among crops. Absolute tolerances vary, depending on climate, soil conditions, and cultural practices. The data are applicable when rootstocks are used that do not accumulate Na^+ or Cl^- rapidly or when these ions do not predominate in the soil. Source: Maas and Grattan (1994).
[b]Botanical and common names follow the convention of Hortus Third (Liberty Hyde Bailey Hortorium Staff, 1976) where possible.
[c]In gypsiferous soils, plants will tolerate EC_e's about 2 dS/m higher than indicated.
[d]Ratings are defined by the boundaries in Figure 2. Ratings with an * are estimates.

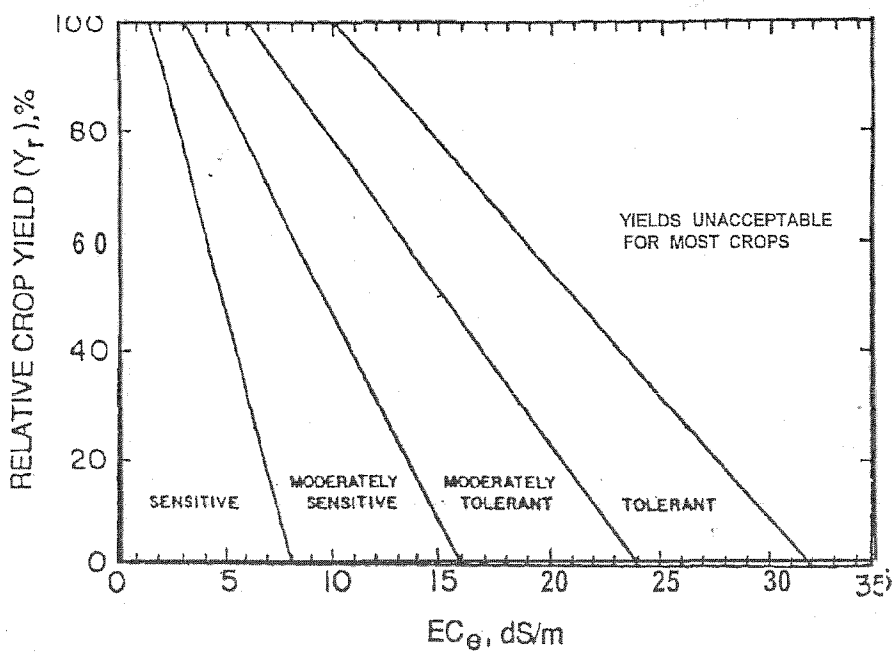

Fig. 2. Divisions for classifying crop tolerance to salinity.

The salt tolerance of trees, vines, and other woody crops is complicated because of additional detrimental effects caused by specific ion toxicities. Many perennial woody species are susceptible to foliar injury caused by the toxic accumulation of Cl- and/or Na' in the leaves. Because different cul tivars and rootstocks absorb Cl' and Na' at different rates, considerable variation in tolerance occurs within anindividual species. In the absence ofspecific-ion effects, the salt tolerance data for woody crops are reasonably accurate. Because of the cost and time required to obtain fruit yields, tolerances of several crops are based on vegetative growth. In contrast to other crop groups, most woody species are salt sensitive, even in the absence of specific ion effects. Guayule (*Parthenium argentatum* A. Gray) and date palm (*Phoenix dactylifera* L.) are relatively salt tolerant and olive (Olea *europaea* L.) and a few others are believed to be moderately tolerant.

SPRINKLER-INDUCED FOLIAR INJURY

The salt tolerance data in Table 1 apply to crops irrigated with surface methods, such as furrow or basin-type flooding. Sprinkler-irrigated crops are subject to additional damage from salt spray on the foliage (Maas, 1985). Salts may be directly absorbed by the leaves, resulting in injury and loss of leaves. In crops that normally restrict salt movement from the roots to the leaves, foliar salt absorption can cause serious problems not normally encountered with surface irrigation systems. For example, compared to nonsaline water (EC = 0.6 dS/m), water with an EC = 4.5 dS/m reduced pepper (*Capsicum annuum* L.) yields by over 50% when applied by sprinkler, but only 16% when applied to the soil surface (Bernstein and Francois, 1973).

Unfortunately, no information is available to predict yield losses as a function of salinity levels in sprinkler irrigation water. Table 3 lists some susceptible crops and gives approximate salt concentrations in sprinkler water that can cause foliar injury. The degree of injury depends on weather conditions and water stress. For instance, leaves may contain excessive levels of salt for several weeks without any visible injury symptoms and then become severely burned when the weather becomes hot and dry.

Saline irrigation water will assumably reduce yields of sprinkled crops at least as much as those of surface-irrigated crops. Additional reductions in yield could be expected for crops susceptible to sprinkler-induced foliar injury. Sorghum accumulates salt very slowly through the leaves and is relatively tolerant of saline sprinkling waters (Maas, 1985). No data are available to judge the sensitivity of pearl millet.

Table 3. Relative susceptibility of crops to foliar injury from saline sprinkling waters.[a]

Na or Cl concentration (mol m^{-3}) causing foliar injury[b]			
<5	5-10	10-20	>20
Almond	Grape	Alfalfa	Cauliflower
Apricot	Pepper	Barley	Cotton
Citrus	Potato	Corn	Sugarbeet
Plum	Tomato	Cucumber	Sunflowa
		safflower	
		Sesame	
		Sorghum	

Susceptibility based on direct accumulation of salts through the leaves. Source: Maas and Grattan (1994).
bFoliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for daytime sprinkling.

ENVIRONMENTALINTERACTXON

Generally, salt tolerance data are only valid for the climatic conditions in which the data were obtained. Temperature, relative humidity, and air pollution all significantly affect plant responses to salinity. Most crops tolerate more salinity stress if the weather is cool and humid than if it is hot and dry. The combined effects of salinity and conditions of high evaporative demand, whether caused by high temperature, low humidity, wind, or drought, are more stressful than salinity alone. Because climate has a pronounced effect on plant response to salinity, the time of year salt tolerance experiments are conducted can affect the outcome. For example, if the salt tolerance of cool-season vegetable crops was assessed in hot, dry climates, results may underestimate the level of salinity they can tolerate when grown in their normal environment, which is cooler with a lower evaporative demand. Conversely, crops tested in cooler and damper (high humidity) environment than they normally grow in would appear more tolerant than normal.

Air pollution, which is a serious problem around industrial and urban areas, increases the apparent salt tolerance of oxidant-sensitive crops. Ozone, a major air pollutant, decreases the yield of some crops more under nonsaline than saline conditions. Consequently, air-polluted areas should be avoided when evaluating the response of crops to soil salinity stress.

SUMMARY

Salt tolerance ratings cannot provide accurate estimates of actual crop yields that depend on many other growing conditions, including weather, soil type and fertility, water stress, insects, and disease. The ratings are useful, however, in predicting how one crop might fare relative to another on saline soils. As such, they are valuable aids in managing salinity problems in irrigated agriculture.

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Climate Change and San Francisco Bay–Delta Tidal Wetlands

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ABSTRACT

Climate change will affect tidal wetlands with higher rates of sea-level rise and higher concentrations of salt in brackish and freshwater tidal systems, in addition to causing increases in atmospheric CO_2 concentration, warmer temperatures, and shifts in precipitation. In the San Francisco Bay–Delta, the areas most likely to be affected–brackish and freshwater tidal wetlands–are also the sites with the majority of endemic plant species and the greater biodiversity and productivity. Effects on the San Francisco Bay–Delta estuary are complex and difficult to predict, but a few things are clear. Biodiversity of the tidal wetland system in the San Francisco Bay–Delta region will decline, with subsequent effects on ecosystem functioning and services. Altered plant production, physiological tolerances, and shifts in rates of mortality will modify wetland plant communities in ways not yet predictable. Lower ecosystem productivity from salinity increases will affect both primary and detrital-based food webs. Such changes will cascade via the food webs into invertebrate, bird, and pelagic systems. Tidal wetlands are especially sensitive to processes that climate change will alter. Several of these altered processes are exacerbated by water diversions from the Delta.

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KEY WORDS

Brackish tidal wetlands, climate change, freshwater tidal wetlands, salinity, salt marshes, sea-level rise, Mediterranean climate

INTRODUCTION

Climate change will have significant global impacts on tidal wetland ecosystems. In addition to responses to changes in CO_2, temperature, and precipitation that all biotic communities will experience, tidal marshes also will experience shifts in salinity and sea level. The root causes of these global changes are increases in atmospheric greenhouse gases such as CO_2 (Meehl and others 2007; Richardson and others 2009). Plants will experience both direct effects from CO_2 increases as well as the indirect effects of CO_2-mediated climate change (Hayhoe and others 2004; Meehl and others 2007; Church and others 2008). For example, increases in CO_2 concentrations–because of its role as a plant resource–might favor some wetland species at the expense of others because of different physiological adaptations (e.g., C3 over C4 species, Drake and Rasse 2003; Rasse and others 2005).

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CO_2-influenced climate change will affect plant respiration, rates of decomposition, soil carbon storage, soil nutrient cycling, mycorrhizal symbionts, and herbivory. By itself, increases in sea level will account for some losses of tidal wetlands, and, globally, estimates range from a 22% to 70% loss of coastal wetlands (Nicholls and others 1999; Najjar and others 2000; but see Hughes 2004). As a consequence, the San Francisco Bay–Delta estuary is predicted to change dramatically under every scenario of future climate change and sea-level rise.

We will examine current patterns of global change in more detail as the context for analyzing potential future changes in tidal wetlands in the San Francisco Bay–Delta (Cayan and others 2008a, 2008b). We will first consider scenarios of how California's climate and other processes are suggested to change in the near future. Using those changes as a framework, we will then examine potential plant responses. Wetland vegetation will respond in a complex manner to these shifting processes, but an underlying lack of knowledge about most plant species means that we have great uncertainty about any projection of climate-change related effects. Some species favored by increases in atmospheric CO_2 concentration, for example, may not respond well to temperature increases in the growing season, while others may respond favorably. Productivity and survival of other species certainly will be reduced simply by salinity increases. Overall, there will likely be significant shifts in wetland composition, especially in the brackish and freshwater portion of the estuary.

CURRENT PATTERNS OF TIDAL WETLAND VEGETATION

The salinity gradient formed by the mixing of freshwater from the San Francisco Bay–Delta watersheds and saltwater from the Pacific Ocean form the template for the distribution of a variety of wetland types. In freshwater areas, sites are dominated principally by large and very productive plants such as *Schoenoplectus acutus* and *Salix lasiolepis*. These wetlands are quite high in annual net productivity, exceeding 2,000 to 2,400 gm m^{-2} yr^{-1} (Atwater and others 1979; Parker and others, unpublished data). Species richness is also quite high in freshwater tidal sites and we have found up to 58 different plant species in as few as ten, 0.1-ha plots at Sand Mound Slough near the mouth of the Delta (Vasey and others, submitted).

At the other end of the salinity gradient, salt marshes contain few species, and the marsh plains are dominated almost exclusively by *Sarcocornia pacifica* (formerly *Salicornia virginica*). Species such as *Spartina foliosa* are found in low marsh sites or restricted to channel or upland edges, or both, such as *Grindelia stricta* var. *angustifolia*, *Jaumea carnosa*, or *Distichlis spicata*. For example, a comparable random sample of ten, 0.1-ha plots at China Camp State Park, a remnant salt marsh in lower San Pablo Bay, and part of the San Francisco Bay National Estuarine Research Reserve, yielded just ten tidal marsh species (Vasey and others, submitted). Annual net productivity is low compared to freshwater wetlands of the bay-delta, ranging from 400 to 1,200 gm m^{-2} yr^{-1} depending on site conditions (Mahall and Park 1976).

Between the salinity and freshwater extremes are a range of brackish marshes with intermediate and variable species richness and productivity that depend on patterns of salinity and inundation. Many of the endemic species of the San Francisco Bay–Delta, such as *Lathyrus jepsonii* and *Cirsium hydrophilum* var. *hydrophilum*, are restricted to brackish wetlands. All the tidal wetlands also connect with adjacent terrestrial and pelagic systems as a resource base for food webs in those ecosystems. Consequently, because of cross-boundary ecosystem subsidies (Polis and Hurd 1996; Harding 2002), the influence of climatic change is likely to be critical not only to tidal wetlands but also to the adjacent systems with which they are linked.

CHANGES IN THE COMPOSITION OF THE ATMOSPHERE AND SUBSEQUENT EFFECTS

In the last 20 to 30 years, concentrations of CO_2 and other greenhouse gases have increased dramatically (Meehl and others 2007; Richardson and others 2009). Current levels of greenhouse gases are already believed to have affected global climates (Meehl and others 2007). Models indicate these gases may increase in the future; depending on assump-

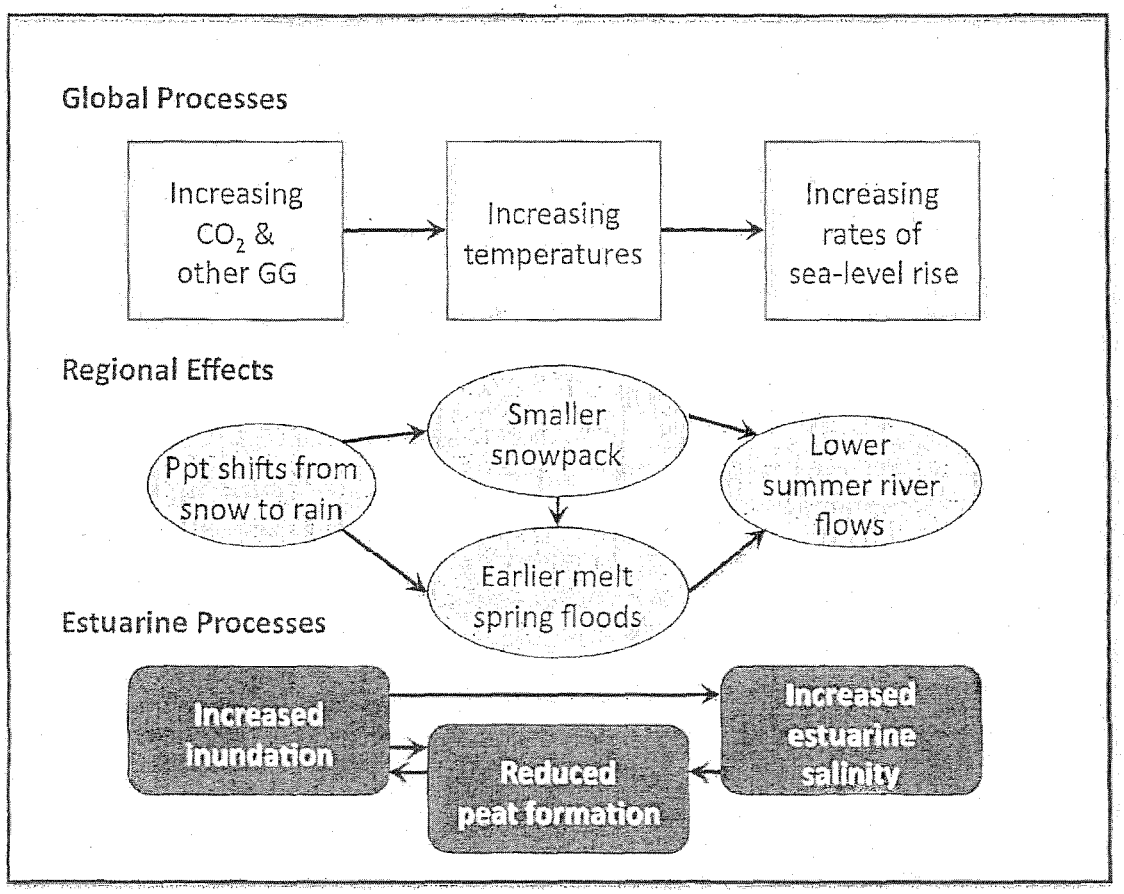

Figure 1 Principal processes governing effects of climate change on the San Francisco Bay–Delta estuary. The first level containing CO_2 and greenhouse gases, increasing temperature, and sea-level rise represent global processes. Below that are regional processes that are either the result of direct or indirect effects of global processes on the Sacramento–San Joaquin watershed. The final level indicates processes within the estuary in addition to the global and regional processes that will directly affect tidal vegetation.

tions, by 2100 CO_2 will increase to 400 ppm or up to nearly 1,000 ppm (Meehl and others 2007; Cayan and others 2008b). Current rates of increase in CO_2 concentration are on a pace to reach the higher values (Richardson and others 2009). Such increases will facilitate continued and dramatic climate change. For example, in California, models suggest that temperatures may rise significantly during the 21st century, from 1.5° to 7 °C for a variety of scenarios that involve increases in greenhouse gases (Dettinger 2005, 2006; Cayan and others 2008b).

Directly or indirectly, the changes resulting from increases in greenhouse gases will affect the physical dynamics of tidal wetlands, plants and their interactions within these wetlands, and animals that live in them or depend upon them. Most predicted changes for northern California—including increases in temperature, unpredictable effects on precipitation, major losses in watershed snowpack, shifts in runoff patterns, and increases in the rate of sea-level rise—will all affect tidal wetland dynamics. Taking these processes together, critical changes in tidal wetlands will result in eventual increases in wetland salinity and

duration of inundation (Figure 1). The rest of this paper examines these probable effects in the context of the San Francisco Bay–Delta estuary and its tidal wetlands.

EFFECTS OF RISING TEMPERATURES ON THE BAY–DELTA ESTUARY: SEA-LEVEL RISE AND SALINITY

Increasing temperatures will act globally, regionally, and locally to affect wetlands (Figure 1). For example, temperature increases that drive both thermal expansion of the world's oceans and melting of terrestrial ice sheets are believed to be primarily responsible for increases in rate of global sea-level rise, which has been close to 2 to 3 mm yr^{-1} over the last few decades (e.g., Stevenson and others 2002; Meehl and others 2007; Church and others 2008). Historical rates before 1930 were generally less than 1 mm yr^{-1}, rising to 2 mm yr^{-1} between the 1930s to the 1950s, and declining during the 1960s and 1970s due to increases in global volcanic activities (Church and others 2005). Increases in rates of sea-level rise are reported in most parts of the world (Cazenave and Nerem 2004; Holgate and Woodworth 2004; Hughes 2004; Church and White 2006), and recent re-evaluations of global data suggest even faster rates (Richardson and others 2009). Since approximately 1992, rates are now over 3 mm yr^{-1} (Holgate and Woodworth 2004; Beckley and others 2007; Church and others 2008). The IPCC estimated sea-level rise to be 10 to 59 cm by 2100, but later raised estimates to 18 to 79 cm (Meehl and others 2007). The higher range would be more than a doubling of current rates, even though these rates are quite conservative because the IPCC did not include changes in the melting rates of large ice sheets like Antarctica or Greenland. Melting has increased in the last decade (Rignot and Kanagaratnam 2006); therefore, rates of sea-level rise actually may increase much more than predicted (Rahmstorf 2007; Vermeer and Rahmstorf 2009). The most recent estimates of sea-level rise are suggesting more than a meter increase by 2100 (Richardson and others 2009; Vermeer and Rahmstorf 2009); process models attempting to account for ice sheet melting are just beginning, and bring uncertainty to these rates, which could be significant under-estimates (Richardson and others 2009; Vermeer and Rahmstorf 2009).

Historical rates of sea-level rise in the bay-delta have been similar to global averages, with the exception of localized regions or time periods of high subsidence rates, and future increases are also likely to mirror global predictions (Cayan and others 2008a). Models of sea-level rise for the San Francisco Bay–Delta, however, are complicated by other forces. For example, during the negative phase of the Pacific Decadal Oscillation (PDO), climate change effects on the rate of sea-level rise will be slowed, while a shift to the positive phase may result in an accelerated rise (Ramp and others 2009; Largier and others 2010). Combined with other processes (e.g., El Niño Southern Oscillation [ENSO]), fluctuations in sea-level rise may have a greater effect on wetlands than a steady increase.

Locally, other influences from increased average temperatures will be just as great on estuarine wetlands (Figure 1). The primary effects will result from several changes. One is the shift in precipitation toward an increase in rain at the expense of snow in the Sierran watershed (Lettenmaier and Gan 1990; Knowles and Cayan 2002; Miller and others 2003; Hayhoe and others 2004; Knowles and others 2006; Cayan and others 2008b). These changes in snowpack storage will shift the timing of freshwater flows into the estuary, increasing flows in winter with potential flooding (Knowles and Cayan 2002; Miller and others 2003; Hayhoe and others 2004). The remaining smaller snowpack (Hayhoe and others 2004; Cayan and others 2008b), will lead consequently to reduced summer river flows entering the estuary. Lower flows will shift the freshwater–marine mixing interface eastward, progressively encroaching upon the Delta, and increasing salinity in brackish regions of the Napa River, Suisun Bay and potentially up into the western Delta (Goman and Wells 2000; Byrne and others 2001; Stahle and others 2001; Malamud-Roam and others 2007). Current water-management actions have not changed the net climatic influence on estuary salinity, and likely will not influence even greater future effects (Enright and Culberson 2010). The net result of all of these changes will be an estuary with

higher mean sea level, increased duration and frequency of inundation, and higher salinities.

Bay–delta wetlands also are affected by Mediterranean-style summer droughts. Porewater in high-marsh areas in salt marsh and brackish tidal wetlands significantly increases in salinity during the warmer, rainless growing season. Our monitoring of wetland soil salinities across the estuary indicates that by late summer salinity only a few meters away from channels is two to three times its concentration in adjacent estuarine waters (unpublished data). Increasing average temperatures (Meehl and others 2007; Richardson and others 2009), increased frequency of heat waves (Cayan and others 2008b), and additional salt inputs from sea-level rise will exacerbate these summer rises in high-marsh salinity. As a consequence, gradual increases in salinity in the San Francisco Bay–Delta estuary will promote the conversion of brackish wetlands to salt marshes, and intruding brackish waters, affecting areas that are currently fresh.

CLIMATE CHANGE EFFECTS ON BAY–DELTA WETLAND VEGETATION

Among wetlands, freshwater and brackish tidal systems will exhibit the greater sensitivity, with large shifts in plant composition and productivity in response to elevated salinity levels—effects that will likely cascade into terrestrial and pelagic food webs. Currently, brackish wetlands are most prominent up the Napa River and in much of the Suisun region. These brackish wetlands transition to freshwater tidal systems farther up the Napa River and into the Delta. Because so many processes are changing simultaneously, however, these tidal systems are likely to change dramatically with multiple species increasing or declining unpredictably.

The San Francisco Bay–Delta system currently experiences seasonal and annual variation in salinity (Fox and others 1991; Peterson and others 1995), and, historically, the brackish zones have shifted across parts of the estuary (Atwater and others 1979; Goman and Wells 2000; Byrne and others 2001; Malamud-Roam and others 2007). More recently, the brackish zones have experienced increased salinity from water diversions upstream, with subsequent shifts in plant composition (Stahle and others 2001; Malamud-Roam and others 2007). Such a historical perspective leads to confidence that wetlands have some resilience in the face of global changes. The changes that will be experienced in the future, however, will be accompanied not only by increased salinity in the system, but also by shifts in CO_2 concentrations, higher temperatures, accelerated sea-level rise, and increasing water diversions—all within the context of a highly urbanized estuary.

Decreases in summer–fall watershed freshwater flow and sea-level rise will shift the saltwater–freshwater mixing zone inland up the estuary, expanding saline influences and increasing wetland soil salinities through time (Figures 1 and 2). Temperature increases will accelerate rates of evapotranspiration, further escalating soil salinities in areas not flushed daily by tides and further influenced by the dry-summer Mediterranean climate compared to many temperate regions (Figure 2). Brackish wetland plant communities will shift toward plants with greater salinity tolerance, for example, *Sarcocornia pacifica*, *Spartina foliosa*, and *Distichlis spicata* (Mall 1969). The latter two, however, are C4 plants and may be at a metabolic disequilibrium with C3 plants that have some salinity tolerance. Further, these changes will be occurring simultaneously in the context of other globally shifting processes, such as increased frequency and duration of inundation due to sea-level rise (Figures 1 and 2). We have found that *S. pacifica* produces biomass at very different rates throughout the northern Bay wetland system, depending on frequency and duration of inundation along a salinity gradient (Schile and others 2011). In well-drained areas, *S. pacifica* seems indifferent to changes in soil salinity, and produces relatively high amounts of biomass. In poorly drained areas, plants are sensitive to salinity, and decrease in productivity with increases in salinity. An estuary with increasing salinity will shift to more salt-tolerant species such as *S. pacifica*, but if inundation frequency and duration increase from a rising sea level, salt marshes in the lower bay-delta may actually be lost, and overall estuarine productivity could decline considerably.

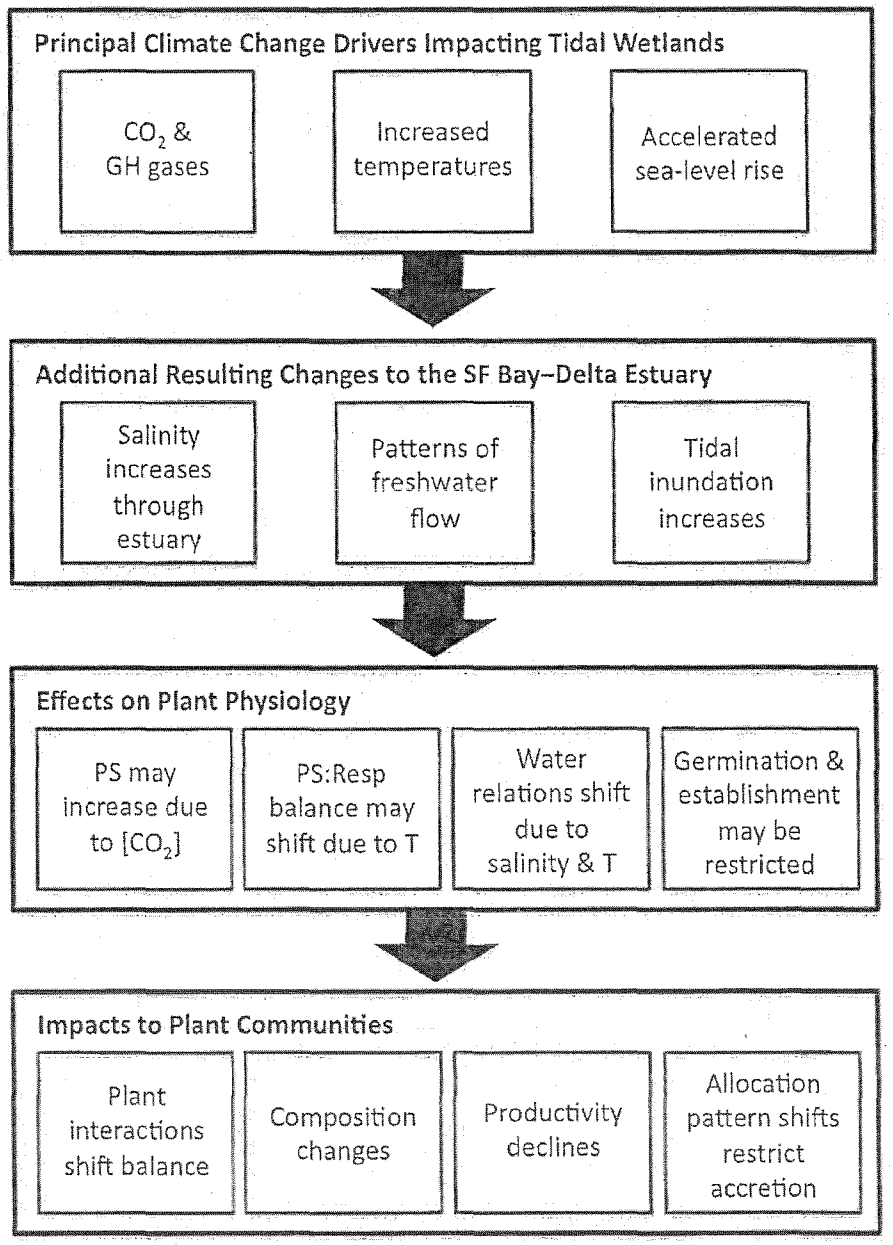

Figure 2 Cascading effects of global climate change processes on tidal wetlands. Effects of increased concentration of carbon dioxide (CO_2) and other greenhouse gases (GH), increased temperature (T) and accelerated sea-level rise (SLR) will directly and indirectly influence plant physiology and stress. Subsequently, changes will occur in the outcome of plant interactions resulting from shifts in physiological performance, for example, of photosynthesis (PS) and cellular respiration (RESP). Composition of wetlands will change, productivity will decline, and these changes may restrict the organic component of vertical accretion.

These environmental shifts will not affect all species within tidal marshes equally. Changes in hydrology, salinity, and other effects of climate change will shift interactions among plants. CO_2, temperature, and increased inundation and soil salinity will strongly influence plant metabolism (Figure 2). CO_2 is an essential plant resource required for photosynthesis (Figure 2). Long-term studies, particularly in the Chesapeake Bay, indicate that a number of ecosystem processes will be affected by increased concentration of CO_2 alone, including photosynthesis, carbon storage and cycling and soil nitrogen fixation and nitrogen dynamics (Drake and others 2003; Johnson and others 2003; Rasse and others 2003; Pendall and others 2004; Hungate and others 2005, 2006; Marsh and others 2005; Rasse and others 2005). Changes in the carbon composition of plants and their structural characteristics may reduce herbivore attack or their effects (Stiling and others 2003; Cornelissen and others 2004).

Experimental studies indicate that overall increases in CO_2 seem to differentially favor plants with C3 photosynthesis at the expense of those with a C4 metabolism (Rasse and others 2005). While these studies found that some acclimation occurred, not all plants fully acclimated, and, some still revealed increased rates of photosynthesis or plant density even after 17 years (Rasse and others 2005). Other wetland research focused on C4 plants found that salt marshes are resilient to modest warming and large shifts in precipitation, although they conclude that interactive effects of multiple changes resulting from climate change may strongly affect wetland composition and function (Charles and Dukes 2009). While most of the species in the San Francisco Bay-Delta wetlands are C3 plants, *Spartina foliosa* and *Distichlis spicata* are C4 plants that are dominant in some parts, and are likely to become comparatively less competitive.

At the same time, increasing temperatures will have both direct and indirect effects. Metabolic systems for any plant ecotype are adapted to limited ranges of temperatures, and enzymes involved in photosynthesis, respiration and other metabolic processes change in efficiency as temperature shifts away from their optimum. Generally, as temperature increases, photosynthesis and respiration rates both increase in

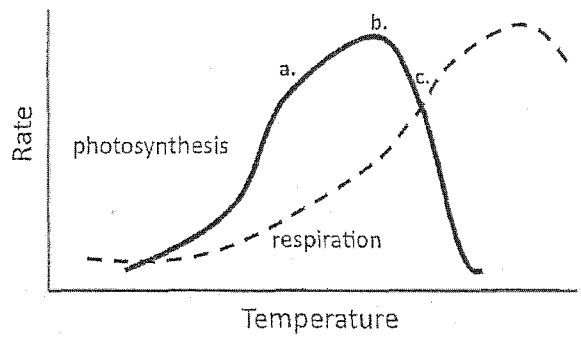

Figure 3 The potential effect of increasing temperatures on the relative balance between photosynthesis and respiration in wetland plants. Depending on their current temperature optima, any particular species might have a different balance in these metabolic rates. For example, if these processes are currently at temperature "a," then the balance between photosynthesis, and respiration will be weighted in favor of photosynthesis and further increases in temperatures in the short term will maintain or increase that ratio. At temperature "b," photosynthesis will have peaked, and further increases in temperature means a decrease in plant productivity, as photosynthesis declines but respiration continues to increase. Finally, at temperature "c," the rate of respiration now exceeds that of photosynthesis, and mortality will occur after carbon reserves are used.

an individual plant. At some point, photosynthetic enzymes reach a peak, and photosynthesis declines past that threshold while respiration continues to increase (Figure 3). This will first affect productivity and later plant survival as increasing respiration rates consume stored carbon. Most studies of climate change effects on ecosystems have focused more on CO_2 concentration than temperature (e.g., Rasse and others 2005). Yet long-term research suggests that the shift in the balance between photosynthesis and respiration is already decreasing forest productivity (Clark and others 2003). Unlike increases in CO_2, temperature shifts are more likely to favor C4 plants over C3, complicating our ability to predict the overall response of wetland vegetation to climate changes. Additionally, future climate scenarios suggest up to 7 °C average temperature increases for California, significantly greater than average global increases (Dettinger 2005, 2006; Cayan and others 2008b). Such extreme increases are more likely to reduce

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growth and increase mortality rates in wetland plant species.

Historically, wetlands maintain themselves against sea-level rise by both accretion and upland retreat. A number of uncertainties exist about future rates of sea-level rise, such as estimates of glacial and icepack melt input (Meier and others 2007; Vermeer and Rahmstorf 2009). The most recent model of estimated rates of sea-level rise for the San Francisco Bay–Delta indicate that the estuary has had historical rates equivalent to the global average (Cayan and others 2008a). If the San Francisco Estuary continues to parallel global averages, this suggests a conservative estimate of a rise of 11 to 79 cm by 2070 to 2099 (Meehl and others 2007), with the real possibility of a 1-m to nearly 2-m rise by 2100 (Richardson and others 2009; Vermeer and Rahmstorf 2009). While wetland accretion in the San Francisco Bay–Delta has generally kept up with increases in sea level during the last several thousands of years (Goman and Wells 2000; Byrne and others 2001; Orr and Williams 2003; Malamud-Roam and others 2007), the amount of suspended sediment in bay-delta water suggests that accretion rates may not be able to keep up with accelerated sea-level rise, and upland retreat is blocked by levees or development in many places. Clearly, the relationship among marsh accretion, inundation, and salinity will have variable impacts on tidal marsh species that are difficult to predict (Watson and Byrne 2009).

The future of tidal wetlands in this context of predicted sea-level rise is challenging (Stralberg and other 2011). Because of human development on or near the Bay and Delta, areas for wetland retreat are limited, wave energy will increase, and wetlands are likely to erode in a shoreward direction (e.g., Crooks 2004). While wetlands likely could keep pace with moderate increases in sea level of up to 6 mm yr^{-1} (Patrick and DeLaune 1990; Orr and others 2003), this may not occur with higher rates of sea-level rise that other researchers suggest may occur (Meier and others 2007; Church and others 2008; Richardson and others 2009; Vermeer and Rahmstorf 2009). Suspended sediment in estuary waters may be insufficient for compensatory wetland accretion after a threshold rate of sea-level rise is reached (Orr and Williams 2003); past that threshold, only the organic contribution by plant growth remains as the driving mechanism for wetland accretion. Current models suggest that wetlands have a lag in response to rising sea level, with a significant variation in productivity. Wetlands appear to be stable when the wetland surface is above the optimal elevation (Morris and others 2002). Unless belowground plant productivity compensates with large increases in biomass production, the result will be increases in the frequency and duration of tidal inundation (Figure 2), leading to increased plant stress. Existing low-marsh areas would be converted to mudflats, and low-marsh plants would migrate into areas previously dominated by marsh plain vegetation (e.g., Donnelly and Bertness 2001). Depending on conditions along the wetland–upland border, wetlands will migrate inland. In many cases around the Bay–Delta, however, migration will be restricted by adjacent dikes and development—a process often referred to as coastal squeeze (Titus 1991; French 2001). Finally, many wetlands have been converted to islands and lack any chance for migration. Increased rates of sea-level rise will differentially affect the viability of restoration projects in the bay-delta region by reducing the opportunity for plants to establish in newly restored wetlands (see Table 1 in Callaway and others 2007).

Another effect that is poorly understood is the combination of (1) increases in estuarine salinity, (2) rates of sea-level rise, and (3) reductions in plant productivity on the dynamics of physical–biological processes that create substrates within wetlands. Specifically, wetland substrates change in tandem with the salinity gradient. Within freshwater tidal regions, the substrate is highly organic. These substrates become increasingly mineral in more saline areas, such that the salt marsh substrates have lower organic content than freshwater wetlands and are dominated by fine clays (e.g., Nyman and others 1993). As the estuary increases in salinity and plant productivity declines, including in the rooting zone, even greater rates of mineral sediment inputs will be required for wetlands to remain stable with sea-level rise, because of the reduction in belowground productivity and corresponding decrease in the organic composition of substrates.

In addition to altered growth rates as a result of climate shifts, other types of effects will occur (Jin 2008, Figure 2). Increases in soil salinity and inundation will differentially affect germination and the physiological limits of species. For example, the salt marsh shrub *Grindelia stricta* var. *angustifolia*, while tolerant of high salinities, requires a considerable reduction in salinity for germination; complete inhibition of germination occurs by salinities at or above 23 ppt (Wayne 1995). Six years of drought in the late 1980s to early 1990s and corresponding salinity increases during germination resulted in more than a 90% reduction in population size at China Camp salt marsh (V. Thomas Parker, unpublished data). Such effects on germination and survival will result in a shift in species composition through time, regardless of how environmental changes affect productivity. In salt marshes within the bay-delta, wetland productivity will only decline slowly without large composition or structural changes. However, in brackish and freshwater tidal marshes, changes in salinity of a few parts per thousand will have considerable effects because the growth, productivity, and survival of most species are highly sensitive to any salinity. Small changes in salinity could significantly affect the diversity and composition of these wetlands.

Lastly, as part of the California Floristic Province, the bay-delta presents relatively high levels of local species endemism, particularly in the brackish marshes of San Pablo Bay, Suisun Bay, and the lower Delta. As highlighted by Loarie and others (2008), local endemic species are highly susceptible to the forces of rapid climate change, particularly in cases where their dispersal is likely to be constrained by impermeable barriers. Endemic flowering plant species in the bay-delta (e.g., *Cirsium hydrophilum*) could be particularly susceptible to the kinds of changes described above.

CONCLUSIONS AND IMPLICATIONS

In summary, global climate changes are differentially affecting tidal wetlands compared to temperate terrestrial ecosystems (Nicholls and others 1999; Ellison 2000; Stevenson and others 2002) and may already be shifting these ecosystems into novel states (Donnelly and Bertness 2001). Effects on the San Francisco Bay–Delta estuary are complex and difficult to predict, but a few points are clear. Biodiversity of the tidal wetland system in the San Francisco Bay–Delta region will decline, with subsequent effects on ecosystem functioning and services (e.g., Hooper and others 2005). Changes in concentrations of carbon dioxide—as well as increased temperatures—will affect plants directly and their direct and indirect effects (Figure 1) will alter plant production, physiological tolerances, and rates of mortality (Figure 2). The result of shifting tolerances and the changes in the balance among plant interactions will lead to altered wetland plant communities. The earliest recognizable changes in estuary wetlands will be from salinity increases, because even with current levels of water management, climate patterns govern shifts of salinity in the estuary (Enright and Culberson 2010). As summer temperatures rise and Sierra snowmelt decreases, we should expect saline ecosystems to increase both in distribution and in area upstream, with losses principally in brackish and freshwater tidal wetlands and their local endemic species, leading to overall lower ecosystem productivity. Increases in sea-level rise will further shift plant distributions, with an increase in species that are more tolerant of inundation (e.g., *Spartina foliosa*, *Schoenoplectus* spp., *Typha*) at moderate rates of sea-level rise and outright loss of wetlands at higher rates. These changes will affect both primary and detrital-based food webs, and cascade via these food webs into invertebrate, bird, and pelagic systems (e.g., Galbraith and others 2002; Hughes 2004).

What is also clear is that under current policies and social perspectives, long-term and appropriate management of the estuary will conflict with other resource demands of California. The San Francisco Bay–Delta estuary is beginning to reverse a century of tidal wetland loss through large-scale wetland restoration projects across the estuary (Callaway and others 2007, 2011), but current bay-delta development at low elevation, and increasing demands on freshwater supply, will emerge as major threats to the estuary, as will shifts in the overall sediment budget of the estuary. Globally, a consensus is emerging that policies need to accommodate and adapt to changes that will accompany climate change. Attempts to

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maintain and defend estuarine and coastal developments inevitably will become increasingly costly (Crooks 2004), at the expense of the estuarine ecosystem and the ecological services provided.

Great uncertainties underlie much of the modeling that suggests the future scenarios for the San Francisco Bay–Delta estuary. We did not consider predicted extreme events, such as longer series of hot or cold years, large earthquakes, severe storms, normal shifts in precipitation patterns, increased frequencies in flooding, or other changes that will occur as temperatures and sea-levels rise (Cayan and others 2008b). Changes in wetland vegetation will not follow simple gradient shifts because of these extreme events, but rather change opportunistically following episodic droughts or heat waves that result in large diebacks or reduced growth after thresholds in salinity or heat tolerances are reached. These will undoubtedly have major effects on the system as well. For example, a brief heat wave early in the spring 2001 growing season caused a temporary setback in the restoration of a newly formed marsh on the Petaluma River (Tuxen and others 2008). Other uncertainties are more global, for example, rates of melting of Greenland or the Antarctic, disruptions of the Atlantic thermohaline circulation, shifts in decadal processes such as the El Niño–Southern Oscillation, or other "tipping points" that may cause rapid disruptions in the estuary (Lenton and others 2008).

At present, we need more research into a number of issues to fully understand how climate change will affect the San Francisco Bay estuary, so that appropriate policies and management actions can be developed (e.g., Sutherland 2004). Clearly, new wetlands need to be restored rapidly so that their development will not be inhibited by the increased erosive energy that will result from future increases in sea-level rise. Once established, restored marshes with well-developed vegetation are more likely to resist the effects of sea-level rise or other environmental changes. However, restoration priorities need to focus on sites not subjected to potential coastal squeeze, or else site barriers need to be modified to retreat along with the wetland restoration. In addition, a number of issues not discussed here need further research, such as the effect of invasive species. Changes in precipitation or temperature have already helped to spread wetland invasive species (Minchinton 2002; Loebl and others 2006). Invasive invertebrates are eroding marshes in southeastern Britain at relatively rapid rates, and the increased temperatures of climate change may stimulate that process (Hughes 2004); ironically, the bay-delta has any number of plant and invertebrate invasive species that will potentially synergize with climate change to create an even greater effect on this ecosystem in the future. We are unsure exactly how dominant wetland species will respond to the range of changes resulting from climate change. We lack information on the links between biodiversity in brackish and freshwater tidal wetlands and ecosystem functioning. Finally, we do not know the effectiveness of current conservation measures and policies governing human development and potential paths for biotic retreat in areas increasingly threatened in the near future. Natural ecosystems such as the bay-delta provide too many ecological services to society to be ignored or reduced in priority.

The San Francisco Bay–Delta estuary embodies a nexus of natural ecosystems and socio-economic policies that have come into conflict in the face of rapid environmental change. This iconic region is at risk, as is the economic health and vitality of the human society that depends upon it. As we shift toward mitigating greenhouse gas emissions, we also must embrace adaptating to the suite of potential ecological changes described above. Innovative use of water storage and flows, land use policies that favor corridors and refugia to accommodate wetland migration, restricted infrastructure in or adjacent to wetlands, and many other measures will be needed to break the traditional pattern of sacrificing ecosystems for short-term gain. The manner in which we face this challenge realistically and act accordingly, will determine the ecosystem's—and our—continuing vitality.

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STATE OF CALIFORNIA

STANDARD AGREEMENT AMENDMENT

STD. 213 A (Rev 6/03)

☐ CHECK HERE IF ADDITIONAL PAGES ARE ATTACHED 1 Pages

AGREEMENT NUMBER	AMENDMENT NUMBER
4600000633	1
REGISTRATION NUMBER	

1. This Agreement is entered into between the State Agency and Contractor named below:

   STATE AGENCY'S NAME
   Department of Water Resources

   CONTRACTOR'S NAME
   U.S. Bureau of Reclamation, Department of Fish and Game, and Suisun Resource Conservation District

2. The term of this Agreement is March 2, 1987 through In perpetuity

3. The maximum amount of this Agreement after this amendment is: $In perpetuity

4. The parties mutually agree to this amendment as follows. All actions noted below are by this reference made a part of the Agreement and incorporated herein:

   1. To revise the Scope of Work to reflect significant events and changed conditions that have occurred since the original Agreement was signed. Exhibit A, Revised Suisun Marsh Preservation Agreement including attachments, are attached and made a part of this Agreement by this reference.

   2. To add Exhibit B with budget detail language. Exhibit B, Budget Detail and Payment Provisions, is attached and made a part of this Agreement by this reference.

   3. To add Exhibit C, General Terms and Conditions applicable to SRCD, which is attached and made a part of this Agreement by this reference.

   4. To add Exhibit CI, Special Terms and Conditions for the Department of Water Resources applicable to SRCD as a local public entity, which is attached and made a part of this Agreement by this reference.

   5. To add Exhibit D, General Terms and Conditions for Interagency Agreements applicable to DFG, which is attached and made a part of this Agreement by this reference.

   6. To add Exhibit D1, Special Terms and Conditions for the Department of Water Resources applicable to DFG, which is attached and made a part of this Agreement by this reference.

   7. To add Exhibit E, Special Terms and Conditions for the Department of Water Resources applicable to the U.S. Bureau of Reclamation, which is attached and made a part of this Agreement by this reference.

   8. To add Exhibit F, Standard Contract Provisions Regarding Political Reform Act Compliance, which is attached and made a part of this Agreement by this reference.

All other terms and conditions shall remain the same.

IN WITNESS WHEREOF, this Agreement has been executed by the parties hereto.

CONTRACTOR		CALIFORNIA Department of General Services Use Only
CONTRACTOR'S NAME *(If other than an individual, state whether a corporation, partnership, etc.)* See Signature Page 33		
BY *(Authorized Signature)*	DATE SIGNED *(Do not type)*	APPROVED JUN 20 [redacted] DEPT OF GENERAL SERVICES
PRINTED NAME AND TITLE OF PERSON SIGNING		
ADDRESS		
STATE OF CALIFORNIA		
AGENCY NAME See Signature Page		
BY *(Authorized Signature)*	DATE SIGNED *(Do not type)*	
PRINTED NAME AND TITLE OF PERSON SIGNING		☐ Exempt per:
ADDRESS		

EXHIBIT A

REVISED SUISUN MARSH PRESERVATION AGREEMENT

Contract No. 4600000633.1
Exhibit A

REVISED
SUISUN MARSH PRESERVATION AGREEMENT

Among

United States Bureau of Reclamation
California Department of Water Resources
California Department of Fish and Game
Suisun Resource Conservation District

VERSION DATED
June 20, 2005

Contract No. 4600000633.1
Exhibit A

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ATTACHMENTS

The following attachments are made a part of this Revised SMPA by reference:

A. Description of Existing Facilities

B. Responsibility for Suisun Marsh Facilities and Activities

C. Net Delta Outflow Index and Percent Inflow Diverted

D. Sacramento Valley Water Year Hydrologic Classification

E. Original Agreement

Contract No. 4600000633.1
Exhibit A

REVISED
SUISUN MARSH PRESERVATION AGREEMENT

Among
United States Bureau of Reclamation,
California Department of Water Resources,
California Department of Fish and Game, and
Suisun Resource Conservation District

THIS REVISED SUISUN MARSH PRESERVATION AGREEMENT ("Revised SMPA") is made this [20th] day of [June], 2005, among the United States Bureau of Reclamation ("USBR"), California Department of Water Resources ("DWR"), California Department of Fish and Game ("DFG"), and the Suisun Resource Conservation District ("SRCD") (hereinafter referred to collectively as the "Parties").

On March 2, 1987, the Parties entered into the Suisun Marsh Preservation Agreement ("SMPA") which supersedes the Contract of Initial Facilities dated December 18, 1978 for the primary purpose of improving wildlife habitat on the Suisun Marsh managed wetlands. The Parties amended the SMPA by letter Amendment One, dated October 14, 1988, and letter Amendment Two, dated March 28, 1994. The SMPA and its letter amendments are referred to collectively as the "Original Agreement" of which a copy is attached to this Revised SMPA as Attachment E. For the reasons and on the terms set forth in this document, the Parties agree that the Original Agreement is hereby amended and known as the Revised SMPA and reads in its entirety as follows:

RECITALS

A. In Section 29002 of the Public Resources Code, the California Legislature has found and declared that the Suisun Marsh ("Marsh") represents a unique and irreplaceable resource to the people of the State and the Nation and that it is the policy of the State to preserve and protect resources of this nature for the enjoyment of the current and succeeding generations. Further, Section 29003 of the Public Resources code provides that in order to preserve the integrity and assure continued wildlife use of the Marsh, including the preservation of its waterfowl carrying capacity and retention of the diversity of its flora and fauna, there is a need for the following:
   1. Provisions for establishment and maintenance of adequate water quality.
   2. Improvement of present water management practices, including drainage and other water control facilities within the Marsh.
   3. Establishment of criteria for the production of valuable waterfowl food plants.

4. Provisions for future supplemental water supplies and related facilities to assure that adequate water quality will be achieved within the wetland areas.

These concerns have been recognized in the Plan of Protection ("Plan") developed by DWR.

B. Public Law 99-546 authorizes the USBR to participate in the preservation of the Marsh. The value of preserving wetlands is recognized in Presidential Executive Order 11990 (Protection of Wetlands) dated May 24, 1977.

C. A supply of adequate quality water is necessary to protect wildlife habitat in the Marsh. The Parties consider it to be in the public interest to manage the wetlands of the Marsh to produce adequate quality waterfowl habitat and grow certain waterfowl food plants.

D. Upstream water use, including diversions by the Central Valley Project ("CVP") and the State Water Project ("SWP") has, at times, reduced outflow from the Delta, thus increasing salinity in the Marsh. The higher salinities have, at times, degraded waterfowl habitat in the Marsh. The Marsh has a salinity gradient between its western portion and its eastern portion, with ocean-derived salinity being greatest in the westerly portion.

E. The Parties recognize that the water quality resulting from this Revised SMPA may, at times, be different than the quality of water which would be available in the Marsh in the absence of the SWP, the CVP, and other diversions by upstream users. Consequently, at times, landowners in the Marsh will need to employ more intensive management practices in the production of desirable waterfowl food plants.

F. Resource conservation districts are authorized to enter into contracts with the United States and the State in furtherance of their powers.

G. The SRCD is granted the primary local responsibility by Public Resources Code Section 9962 for regulating and improving water management practices on privately owned lands within the primary management area of the Marsh.

H. The Parties recognize that the benefits and costs of implementing the Plan cannot be determined precisely. The division of responsibilities contained herein is deemed to represent a reasonable balance of equities.

I. Article 4 of the Original Agreement requires periodic review of the effectiveness of the protective measures developed under that Agreement and a determination of whether its objectives are being achieved and if adjustments, made by amending that Agreement, are needed. In addition, Article 8(h) of the Original Agreement requires the Parties to renegotiate and amend that Agreement if either the Marsh model predictions or the Delta outflow/salinity relationships upon which that

Agreement is based are found to be substantially in error. Article 17 of the Original Agreement provides that it may be amended at any time by mutual agreement of USBR, DWR, DFG, and SRCD.

1. In November 2002, the Parties agreed to open negotiations to amend the Original Agreement based on Articles 4, 8(h), and 17 of that Agreement, and as a result of the events and changed conditions described below in Recital J.

2. The Parties wish to amend the Original Agreement to provide measures that provide soil salinities for improved growth of forage for wildlife on managed wetlands and to meet the objectives of the Original Agreement.

J. Since the date of the Original Agreement, the following events and changed conditions have led the Parties to this Revised SMPA:

1. In November 1988, DWR and USBR began operating the Suisun Marsh Salinity Control Gates ("SMSCG"). Evaluation of the SMSCG operation has shown that the gates can effectively reduce salinity in Montezuma Slough and the eastern regions of the Marsh, and to a lesser degree in most of the western regions of the Marsh. The SMSCG operation has proven to be more effective than was predicted.

2. On December 15, 1994, federal and State agencies, and urban, agricultural, and environmental groups signed the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government" ('Principles for Agreement'), also known as the "1994 Bay-Delta Accord".

3. In May 1995, the State Water Resources Control Board (SWRCB) adopted the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary ("1995 WQCP") which incorporates many of the Principles for Agreement standards as water quality objectives for the Bay/Delta; and in July 1995, the SWRCB began the water rights hearing process for allocating responsibility for implementing the 1995 objectives.

4. In December 1999, and as revised March 15, 2000, the SWRCB issued Water Rights Decision 1641 ("D-1641") to implement the water quality objectives in the 1995 WQCP. For protection of the Suisun Marsh, D-1641 requires DWR and USBR to report to the SWRCB by September 30 of each year on progress toward implementation of mitigation facilities and on water quality conditions in the Suisun Marsh during the previous salinity control season (D-1641, Condition 10, p. 149).

5. Construction of large scale water conveyance facilities throughout the Marsh, other than the Initial Facilities and the SMSCG, prescribed in the Original Agreement is no longer needed because:

   a. Operation of the SMSCG has been more effective in helping to achieve the channel salinities described in Article III of this Revised SMPA than was predicted;

   b. Implementation of the SWRCB D-1641 has significantly increased Delta outflow exceeding requirements of Decision 1485, and has resulted in lower salinity in Suisun Marsh channels than was anticipated when the Original Agreement was negotiated; and

   c. Computer model simulations of Suisun Marsh channel salinity using the 1995 WQCP outflow objectives have shown

      (1) Channel water salinity standards of the Original Agreement at stations C-2, S-64, S-49, S-21, and S-42 can be met with operation of the SMSCG except under rare circumstances which are provided for in Article III of this Revised SMPA.

      (2) Channel water salinity standards of the Original Agreement near stations S-97 and S-35 can be met most of the time, with exceedences expected only in dry and critical years.

6. The CALFED Record of Decision[1] was released in August 2000. Following this release, CALFED requested that the SMPA agencies and the U.S. Fish and Wildlife Service (USFWS) work collaboratively to develop a "Charter" for resolving Suisun Marsh issues. The Charter was finalized and adopted in March 2001.

7. The CALFED Record of Decision identified programmatic actions for the Bay-Delta, including habitat restoration in Suisun Marsh. Specific restoration goals for the Marsh are identified in the Ecosystem Restoration Program (ERP) Plan[2] and include: (1) restoring tidal action to 5,000 - 7,000 acres in the Marsh and (2) enhancing 40,000 - 50,000 acres of managed seasonal wetlands. CALFED asked the Suisun Marsh Charter agencies to develop a comprehensive long-term implementation plan for meeting the ERP goals, while simultaneously meeting Suisun Marsh Charter needs for protection and enhancement of 1) pacific flyway

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1 CALFED Bay Delta Program. 2000. Programmatic Record of Decision. Department of Water Resources. Sacramento, CA 134 pp. plus appendices.

2 Ecosystem Restoration Program Plan, 1999. Ecosystem Restoration Program Plan: Volume 2 – Ecological Management Zone Visions. Draft Programmatic EIS/EIR Technical Appendix. Department of Water Resources. Sacramento, CA. 459 pp.

and existing wildlife values in managed wetlands; 2) endangered species; 3) tidal marshes and other ecosystems; and 4) water supply quality including, but not limited to, the maintenance and improvement of levees. Completion of the Habitat, Management, Preservation and Restoration Plan for Suisun Marsh (Suisun Marsh Plan), including necessary environmental documentation, is expected to take approximately two years, subject to availability of funding.

8. In lieu of large-scale water conveyance facilities, the Parties identified interim actions and additional future actions consistent with the Original Agreement objective to improve Marsh habitat. These interim actions, described in Articles VI, VII, and VIII of this Revised SMPA, are needed to: (1) provide funding for activities which assist in re-establishing a diverse plant assemblage and return soil salinities to levels characteristic of Suisun Marsh brackish soils; (2) maintain soil salinities within natural ranges as outlined by the Soil Conservation Service (1977); (3) improve water and wildlife habitat on managed wetlands throughout the Suisun Marsh; and (4) broaden mitigation activities to emphasize management, restoration projects, and studies to mitigate for impacts of this Revised SMPA to listed and sensitive species.

9. The Parties recognize that the actions referenced in Recital J.8 may be carried out by SRCD and DFG under the April 2000, U.S. Army Corps of Engineers Regional General Permit Number 3 (Permit File Number 24215N) obtained by SRCD and DFG pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act of 1899 or as it may be subsequently amended to permit certain work activities within the Marsh.

10. Water management plays a pivotal role in achieving soil salinity and habitat goals beneficial to waterfowl in Suisun Marsh managed wetlands, and many of the additional actions referenced in Recital J.8 are intended to assist in providing such management.

11. Creek flows entering the northwestern Suisun Marsh affect channel water salinities in this region. State Water Project and Central Valley Project operations and other diversions upstream of Chipps Island have not affected flow or water quality patterns in creeks north and west of Suisun Marsh. However, water users in the Marsh watershed have modified creek inflows to the Marsh. For example, urbanization and land development north and west of the Marsh affect the pattern of creek inflow, sediment, and water quality entering the Marsh.

12. Increasing Delta outflow (as measured by the Net Delta Outflow Index) above D-1641 objectives is not an effective or practical method for controlling channel water salinity in the western Suisun Marsh.

K. SRCD intends to facilitate the formation of reclamation districts necessary to protect the facilities constructed or actions implemented pursuant to this Revised SMPA.

L. Where rights of way are required for work to be done under this Revised SMPA, SRCD intends to facilitate acquisition by DWR and/or USBR of the necessary easements and/or other appropriate title for each facility.

NOW, THEREFORE, in consideration of the mutual obligations in this Revised SMPA, the Parties agree as follows:

REVISED SMPA

Article I. Definitions.

When used herein, the term:

A. "1995 WQCP" shall mean the State Water Resources Control Board 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary adopted in May 1995.

B. "Channel Water Salinity" shall mean salinity of water in a channel of Suisun Marsh in which a Compliance Station, Control Station, or Monitoring Station is located.

C. "Compliance Station" shall mean a water quality compliance monitoring station listed in Table 5 of D-1641 at which the SWRCB has defined a salinity water quality standard. Data collected at these stations is used to evaluate compliance with the water quality standards. Compliance stations are listed in Table 1 and shown in Figure 1 of this Revised SMPA.

D. "Construction Season" shall mean the period February 15 to October 15 of any year.

E. "Control Season" shall mean the period October 1 of any year through May 31 of the following year.

F. "Control Station" shall mean a Monitoring Station (defined below) at a location listed in Table 2 and shown in Figure 1. Salinity data from the Control Stations will be used to trigger the Drought Response Program as described in Article VII.B.4.

G. "D-1641" shall mean the State Water Resources Control Board Water Right Decision 1641 *Implementation of Water Quality Objectives for the San Francisco Bay/Sacramento San-Joaquin Delta Estuary* adopted in December 1999 and revised on March 15, 2000.

H. "Deficiency Period" shall mean: (1) a Critical Year following a Dry or Critical Year; or (2) a Dry Year following a year in which the Four Basin Index was less than 11.35 MAF; or (3) the second consecutive Dry Year following a Critical Year. The determination of a Deficiency Period is made using the prior year's final Water Year Type determination and a Forecast of the current year's Water Year Type; and

remains in effect until a subsequent water year is other than a Dry or Critical water year as announced by DWR and USBR as the final water year determination.

I. "Delta" shall mean the Sacramento-San Joaquin Delta as it is presently defined in Section 12220 of the Water Code.

J. "Electrical Conductivity" ("EC") shall mean the electrical conductivity of a water sample measured in millimhos per centimeter (mmhos/cm) corrected to a standard temperature of 25 degrees Celsius (which is the same as specific conductance expressed as milliSiemens/cm) determined in accordance with procedures set forth in the publication entitled, "Standard Methods of Examination of Water and Waste Water", published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation, 20th Edition, 1998, including such revisions thereof as may be made subsequent to the date of this Revised SMPA which are approved in writing by the Parties.

K. "Existing Facilities" shall mean the Initial Facilities, Suisun Marsh Salinity Control Gates ("SMSCG", also referred to as the Montezuma Slough Control Structure), Cygnus Unit, and Lower Joice Island Unit with fish screen, as described in Article VII and Attachment A. Ownership and management of Existing Facilities is specified in Attachment B.

L. "Exterior Levees" shall mean levees which protect the Marsh against inundation and uncontrolled flooding and are identified in the "Suisun Marsh Levee Evaluation" report dated February 1983, prepared by Ramlit Associates for the U.S. Army Corps of Engineers.

M. "Forecast" shall mean a preliminary determination of the Water Year Type made by DWR at the beginning of each February, March, April, and May and published in DWR Bulletin 120, Water Conditions in California.

N. "Four Basin Index" or "Sacramento River Index" shall mean the sum of the unimpaired runoff in the Water Year as published in DWR Bulletin 120 for the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total unimpaired inflow to Oroville Reservoir; Yuba River at Smartville; American River, total unimpaired inflow to Folsom Reservoir.

O. "Individual Ownership" shall mean separate, privately owned parcels of land in the Marsh, or contiguous parcels owned by the same legal entity, other than those on Roe, Ryer, Freeman, and Snag Islands or the owners thereof.

P. "Individual Ownership Management Plan(s), also known as Individual Ownership Adaptive Management Habitat Plan(s)" shall mean the plan(s) prepared by SRCD consisting of a water, land and vegetation management program for each managed wetland in private ownership within the Marsh primary management area and

includes site specific information to enable effective and efficient management of these lands. The plans are authorized pursuant to the Suisun Marsh Preservation Act of 1977, Section 29413 of the Public Resources Code.

Q. "Initial Facilities" shall mean the facilities for the Roaring River Slough Unit (also known as Roaring River Distribution System), the Goodyear Slough Outfall, and the Morrow Island Distribution System constructed pursuant to the contract of December 18, 1978.

R. "Marsh" shall mean the Suisun Marsh as it is presently defined in Section 29101 of the Public Resources Code.

S. "Marsh Model" shall mean the DWR Delta Simulation Model (Suisun Marsh Version 8A (1996)) consisting of hydrodynamic, salinity transport, and managed wetland operations. The computer model was: (1) originally developed by Hugo Fischer, Inc., as MRSHFLO and MRSHQAL under contract with USBR; (2) modified by USBR and DWR for the Original Agreement; (3) incorporated into the Fischer Delta Model (Version 7E) by Flow Science, Inc.; and (4) modified to its current version by DWR, Suisun Marsh Branch.

T. "Monitoring Station" shall mean a water quality monitoring station necessary to collect information for stage and salinity analysis. Monitoring stations are listed in Table 3 and shown in Figure 1.

U. "Net Delta Outflow Index" shall mean an index of net Delta outflow estimated daily by USBR and DWR, as described on page 190 of D-1641, and archived in the DWR DAYFLOW database. (See Attachment C.)

V. "Plan of Protection" or "Plan of Protection for the Suisun Marsh" or "Plan" shall mean the plan prepared by DWR dated February 1984 in fulfillment of Condition 7 of SWRCB Decision 1485 to mitigate the effects of the CVP and SWP and other diverters upstream of Chipps Island.

W. "Progressive Daily Mean (PDM)" shall be defined as the monthly average of both daily high-tide specific conductance values. The mathematical equation is shown below. New PDM calculations begin at the start of each calendar month.

$$PDM = \Sigma \text{ daily average of high tide EC} / \text{\# days of the month}$$

X. "Water Year" or "Year" shall mean the period October 1 of any year through September 30 of the following year.

Y. "Water Year Type" (i.e., "Wet Year", "Above Normal Year", "Below Normal Year", "Dry Year" and "Critical Year") are defined on page 188 of D-1641. (See Attachment D.)

Article II. Objective

The objectives of this Revised SMPA are:

A. To assure that USBR and DWR maintain a dependable water supply of adequate quantity and quality within the Marsh to mitigate the adverse effects on the Marsh of the CVP and SWP and a portion of the adverse effects of the other upstream diversions;

B. To improve Marsh wildlife habitat to the extent that such improvement is compatible with other CVP and SWP purposes;

C. To define the scope of the obligations of USBR and DWR to provide the water supply, distribution, redistribution, and management facilities; and supplemental actions necessary to accomplish the objectives in A and B; and

D. To assure that USBR and DWR recognize that the water users within the Marsh have been diverting and will continue to divert water for wildlife habitat management within the Marsh.

Article III. Channel Water Salinity Standards

A. DWR and USBR shall meet the channel water salinity standards shown in Table 1 with operation of facilities as specified in Article VII.A. During a Deficiency Period, as described under Article I.H., the standards for "All Water Year Types" shall be replaced with the standards for "Deficiency Period" and shall only apply to S-21 and S-42. During a deficiency period, standards for C-2, S-64, and S-49 are suspended.

B. The parties recognize that lower channel water salinity will be present at some Compliance Stations due to the salinity gradient within the Marsh

C. During Deficiency Periods a good faith effort will be made to meet the Standards in Table 1 at the eastern Marsh stations C-2, S-64, and S-49, and the following conditions apply:

1. If the Standards are not met in one or two months during a Control Season at one or more of the eastern stations, the Parties agree to waive the Standards during these months.

2. If the Standards are not met for more than 2 months during a Control Season at one or more of the eastern stations, the Parties agree to waive the Standards during these months and the Drought Response Program will be deemed triggered and funded as provided in Article VII.B.

3. If the Standards are not met for more than 4 months in any two consecutive Control Seasons at one or more of the eastern stations, the Parties agree that the basis for this Revised SMPA is in error and will initiate discussions to amend this Agreement as provided for in Article XIV.

D. DWR and USBR will notify DFG and SRCD in the event any standard in Table 1 is projected to be exceeded by more than 0.2 mS/cm to discuss and resolve any concerns consistent with the procedures in Article XII.A. and Article XIII.B.

E. DWR and USBR will bear the burden of proving that their efforts to meet the Standards were made in good faith.

Article IV. Review of Operations

A. Every fifth year after this Revised SMPA is executed the Parties will review the effectiveness of the forecasting and planning tools, operations, facilities, and actions taken pursuant to this Revised SMPA. The purpose of the review will be to determine if objectives of this Revised SMPA are being achieved and if any adjustments are needed. Information on the relationships among water salinity, soil water salinity, and plant salinity tolerance gained from the Marsh monitoring program, effectiveness of the implementation of the revised Individual Ownership Management Plans, and performance and accuracy of the Marsh Model shall be considered during the review. Results of the review will be considered to determine whether a need exists to amend this Revised SMPA to achieve the Revised SMPA objectives.

B. Any necessary adjustments as determined by the Parties will be made by amending this Revised SMPA, the Suisun Marsh Mitigation Agreement, and/or the Suisun Marsh Monitoring Agreement.

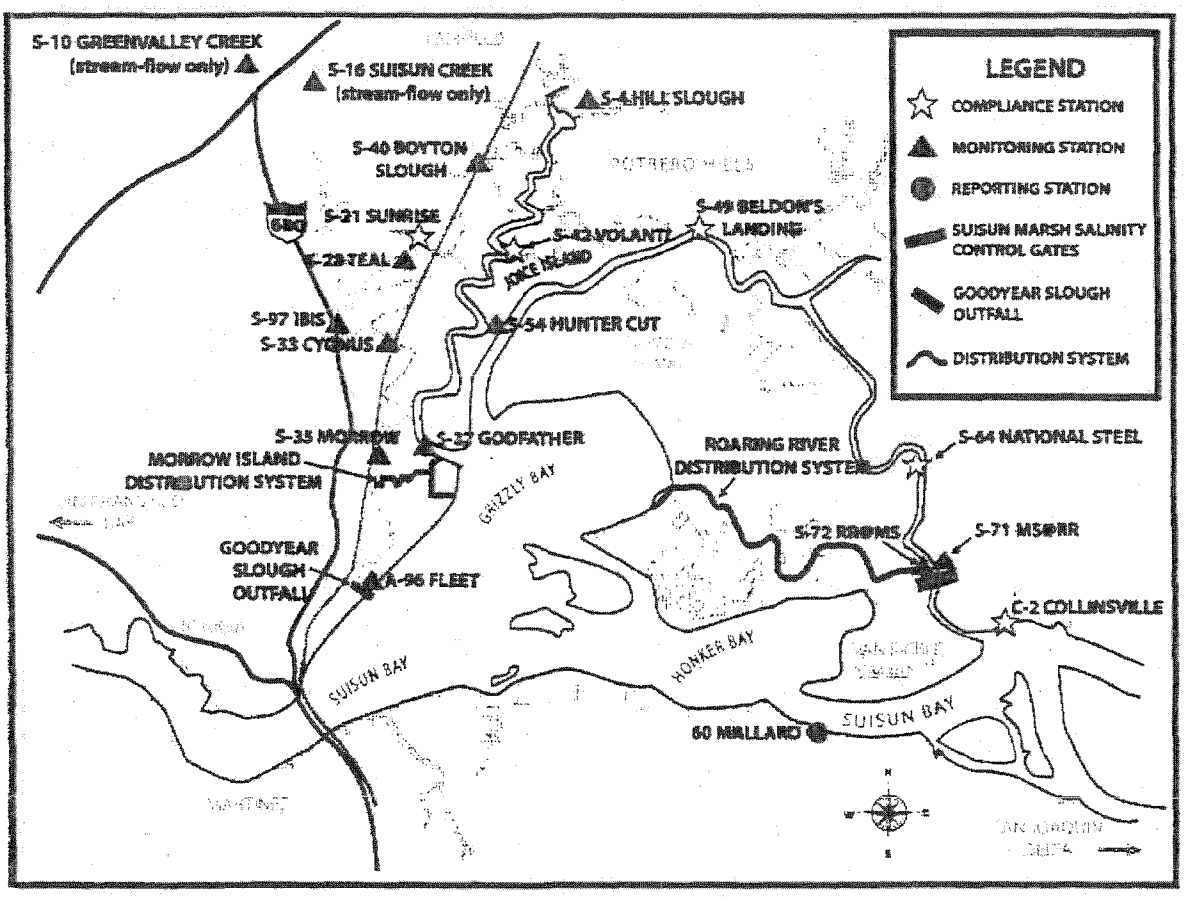
TABLE 1. SUISUN MARSH CHANNEL WATER STANDARDS

Compliance Location	Interagency Station Number [1]	Description	Time Period	Value (EC)
EASTERN MARSH				
Sacramento River at Collinsville	C-2 (RSAC081)	Progressive Daily Mean = mean of daily average high-tide EC of the month. See Article I.W for the mathematical equation.	**All Water Year Types**	
Montezuma Slough at National Steel	S-64 (SLMZU25)		October	19.0
			November - December	15.5
			January	12.5
			February - March	8.0
Montezuma Slough near Beldon Landing	S-49 (SLMZU11)		April - May	11.0
WESTERN MARSH		Progressive Daily Mean	**All Water Year Types**	
Chadbourne Slough at Sunrise Duck Club	S-21 (SLCBN1)		October	19.0
			November	16.5
			December	15.5
			January	12.5
Suisun Slough, 300 feet south of Volanti Slough	S-42 (SLSUS12)		February - March	8.0
			April - May	11.0
			Deficiency Period[2]	
			October	19.0
			November	16.5
			December - March	15.6
			April	14.0
			May	12.5

TABLE 2. SUISUN MARSH CONTROL STATIONS

Control Station Location	Interagency Station Number[1]	Drought Response Fund Trigger Value (PDM in mS/cm)	
Goodyear Slough at Morrow Island Clubhouse	S-35 (SLGYR003)	October	20.0
		February – March	9.0
		April – May	12.0
Cordelia Slough at Ibis Club	S-97 (SLCRD006)		

1. Parenthetical contains the River Kilometer Index station number. See Figure 1 for locations.
2. See definition of "deficiency period" in Article I.H. These Deficiency Period standards are only applicable to S-21 and S-42.



Contract No. 4600000633.1
Figure 1

Article V. Monitoring

A. The Parties to this Revised SMPA will monitor and report in accordance with the Monitoring Agreement to provide for monitoring in the Marsh dated March 2, 1987 ("Monitoring Agreement") or as it may be revised or amended. Monitoring Stations for the Suisun Marsh are listed in Table 3 "Suisun Marsh Monitoring Stations" and shown in Figure 1.

B. The Parties shall revise or amend the Monitoring Agreement to include: monitoring of activities required by this Revised SMPA; the evaluation described in Article XV.F.; and SRCD as a participant in the Revised Monitoring Agreement and monitoring program.

C. The monitoring program shall include stage and channel water EC monitoring at Goodyear Slough at Morrow Island Clubhouse ("S-35") and at Cordelia Slough at Ibis Club ("S-97"). The monitoring stations at S-97 and S-35 are important indicators of western Marsh salinity conditions and will be used in triggering SMSCG operation to meet standards in Table 1, as well as the Drought Response Program described in Article VII.B.

Article VI. Mitigation

A. USBR, DWR, and DFG shall provide wetlands mitigation specified in the Suisun Marsh Mitigation Agreement among DWR, DFG and USBR, dated March 2, 1987, or as it may be revised or amended, and in accordance with applicable U.S. Army Corps of Engineers permits and with biological opinions required for activities in the Marsh. The measures set forth in the Revised Suisun Marsh Mitigation Agreement will provide:

1. Multispecies habitat for the adverse impacts on wetland habitat, listed and sensitive species, and waterfowl in the Suisun Marsh resulting from implementing actions and construction required under this Revised SMPA.

2. Multispecies habitat for any adverse effects on Roe, Ryer, Snag, and Freeman Islands resulting from upstream water diversions.

3. Restoration of tidal wetlands and acquisition, management, and maintenance of conservation lands to achieve the goal of 2,500 acres of preferred salt marsh harvest mouse habitat.

TABLE 3. SUISUN MARSH MONITORING STATIONS

Monitoring Location	Interagency Station Number (River Kilometer Index)	Monitoring Parameters
Goodyear Slough at Goodyear Slough Outfall	A-96 (SLGYR008)	EC
Hill Slough at Grizzly Island Road	S-4 (SLHIL002)	Stage/EC
Green Valley Creek above Interstate 80	S-9 (SLMZS9)	Stage/Flow
Suisun Creek at Cordelia Road	S-16 (SLCSS16)	Stage/Flow
Teal Club	S-28 (SLFHN002)	EC
Cordelia Slough at Cygnus	S-33 (SLCRD003)	Stage/EC
Goodyear Slough at Morrow Island Clubhouse[1]	S-35 (SLGYR003)	Stage/EC
Suisun Slough at Godfather	S-37 (SLGFI011)	EC
Boynton Slough near SP tracks	S-40 (SLBOY003)	Stage/EC
Hunter Cut at Montezuma Slough	S-54 (SLMZU003)	Stage/EC
Montezuma Slough at Roaring River Distribution System	S-71 (SLMZU029)	Stage/EC/Temp.
East end of Roaring River Distribution System at Hammond Pond	S-72 (SLRAR000)	Stage/EC
Cordelia Slough at Ibis Club[1]	S-97 (SLCRD006)	Stage/EC

1. These stations are SWRCB baseline monitoring stations (Table 5, D-1641).

B. The Environmental Coordination Advisory Team ("ECAT"), established under Article XII, will ensure compliance with mitigation requirements of Revised SMPA and related permits and biological opinions.

C. The USBR and DWR shall evaluate and develop measures to mitigate impacts of the SMSCG on adult Chinook salmon passage in a manner consistent with Articles II and III of this Revised SMPA.

D. The Parties shall revise or amend the Mitigation Agreement to include SRCD as a party thereto.

Article VII. Construction and Operation of Facilities and Implementation of Actions

A. Construction and Operation of Existing Facilities

1. USBR and DWR will operate the Initial Facilities and the SMSCG for the purposes of meeting the channel water salinity standards in Article III. DWR shall construct the Annie Mason Island Unit by the end of the second construction season following repairs of the Exterior Levees that are mutually agreeably by the Parties to the Revised SMPA.

2. The Initial Facilities and the SMSCG will be operated, and actions required by this Revised SMPA will be taken, to provide lower channel water salinities in the Marsh than those specified in Table 1, but only so far as such operations or actions significantly benefit wildlife habitat, do not create a need for additional upstream water releases, do not limit exports, do not harm fishery resources, and do not require that the SMSCG stoplogs remain in place beyond the time otherwise required to meet this Revised SMPA. The Coordination Committee (described in Article XII) will discuss the significance of potential impacts to fishery and wildlife resources attributed to SMSCG operations or other actions required by this Revised SMPA before any changes are made to such SMSCG operations or actions.

3. If structural impairments require repairs of the SMSCG that result in a prolonged outage such that it is inoperable and meeting provisions of Article III is not possible, the Parties agree to waive the Table 1 Standards until the month following completion of repairs. If any structural failure results in the inability to operate the SMSCG, DWR and USBR shall repair the SMSCG as quickly as reasonably possible, unless mutually agreed to by the parties to this Agreement.

4. If SMSCG operations are significantly changed by regulatory actions, making it infeasible to meet Table 1 Standards of Article III, the Parties agree that this

represents a significant project modification and will: (1) initiate discussions to amend this Revised SMPA, (2) continue operating the SMSCG to the extent possible to accomplish the purposes of this Revised SMPA, including a good faith effort to meet the Standards in Table 1, and (3) waive enforcement of Table 1 Standards during the period of Agreement renegotiation.

5. USBR and DWR shall provide funds to SRCD for realigning and stabilizing turnouts from the Roaring River Slough Unit to improve water management on Individual Ownerships and DFG lands. SRCD shall coordinate construction of improvements with DWR.

6. DWR and USBR have constructed and completed testing of a fish screen for the Lower Joice Island. This fish screen has become the property of the Individual Ownership which is responsible for operation and maintenance. DWR and USBR shall have no further responsibilities for operation and maintenance and/or for any costs associated with the fish screen.

7. Control stations S-97 and S-35 EC values will be used as water quality indicators to determine SMSCG operations to meet the water quality standards in Table 1.

B. Additional Actions

SRCD shall implement the following four actions, which will be funded by DWR and USBR as provided by Article VIII. The actions may be implemented concurrently and the listing below does not indicate any required order of implementation. Certain responsibilities related to the activities are further described in Attachment B.

1. Water Manager Program

SRCD shall institute a Water Manager Program and employ support staff to help coordinate and improve water management practices on Individual Ownerships throughout the Marsh. The Water Manager Program shall include, but not be limited to, the following services or duties throughout the Marsh:

a. Assist in implementation of yearly management strategies as outlined in the Individual Ownership Adaptive Management Habitat Plans ("IOAMHP") (described in Subarticle B.3) and agreed to by the landowners.

b. Promote and encourage wetland management activities such that flooding, draining and circulation occur at the appropriate critical times of the year to produce desired wildlife habitats.

c. Provide technical support in the field to answer questions and educate landowners on beneficial management techniques, the protection and

enhancement of endangered species habitat, management of water application, and provide new scientific information pertaining to common management activities.

d. Supervise and coordinate the portable pump program (described in Subarticle B.2) to ensure proper maintenance and operation of the pumps.

e. Assist landowners in planning yearly maintenance and enhancement projects.

f. Assist landowners in completing the USACE yearly maintenance permit application.

g. Annually update the IOAMHP (Subarticle B.3).

h. Activities may include assisting DFG on water management of State owned property, assisting in yearly salt marsh harvest mouse monitoring, California clapper rail surveys, and inspections of levees during storms to identify damages and assist in flood fight coordination.

2. Portable Pumps Program

a. SRCD shall implement this Program in coordination with the Water Manager Program. The Water Manager, under SRCD's direction, will use portable pumps provided by this Program for the benefit of Marsh managed wetlands to provide better removal of soil salts during drainage. The pumps shall be moved throughout the Marsh to provide the most benefit as determined by the Water Manager to obtain an effective leach.

b. SRCD shall be responsible for and oversee the operation and maintenance and distribution of the portable pumps. SRCD shall be required to obtain any necessary permits and meet permit obligations for the portable pump operation. DWR, DFG, and the USBR will cooperate and support SRCD's efforts to obtain any necessary permits and meet permit obligations for the portable pump operation.

c. SRCD shall make the pumps available for draining operations on Individual Ownerships and DFG lands, as described below:

(1) In those managed areas of low pond bottom elevations, portable pumps will be used to effectively remove or accelerate the drainage of high saline soil water and to facilitate the ability to flood and drain within 30 days. Most of the Marsh can tidally drain if mean pond bottom elevation (mean low low water (MLLW) at the Golden Gate) is 2.7 feet or higher. The controlling elevation becomes 3.3 feet in the northwest corner of the Marsh due to silting of the sloughs.

(2) The entire Suisun Marsh will benefit from portable pumps for drainage where: the mean pond bottom elevations of the wetlands are lower than the elevations stated above, and pumps are needed to drain and leach the property, and to drain isolated low wetlands to remove barren spots with high soil salts; the lowest tides do not have enough dwell time to permit tidal drainage; or pumping is necessary to avoid evaporative salt buildup throughout the soil profile.

(3) The pumps will not be used during times, and in the locations of, known low dissolved oxygen events, including Boynton and Peytonia Sloughs. These areas are adjacent to higher elevation wetlands, thus pumps will not be needed.

3. Individual Ownership Adaptive Management Habitat Plans Program

   a. SRCD shall update the IOAMHP annually. These IOAMHP will provide landowners multiple management strategies, incorporate new science and management techniques, and protect and conserve brackish marsh diversity while enhancing and sustaining wildlife values within the managed wetlands. Each IOAHMP shall include the following information:

      (1) Description and location of existing facilities
      (2) Description and location of new facilities
      (3) Description and location of needed improvements
      (4) Soil classification maps
      (5) A management strategy
      (6) Vegetation Identification Booklet
      (7) Suisun Marsh facility standards
      (8) Elevation on water control facilities with relationship to tidal datum.

   b. Upon completion of each IOAHMP, SRCD shall provide a copy to SMPA Parties as requested.

4. Drought Response Program

   a. The purpose of the Drought Response Program is to compensate landowners, including DFG for lands it manages in the Marsh, who, because of drought conditions, have no alternative but to apply higher salinity channel water and, therefore, must more intensively manage these lands.

   b. During any year that "drought response criteria" as described in the following Subarticle c trigger the need for drought response activities and for one additional year beyond the last year of drought response, DWR and USBR shall provide funding and payment as described in Article VIII.

c. The following drought response criteria and allocation of funding are based on a frequency of monthly occurrence of salinity values above Table 1 standards, specifically a 40% frequency (2 out of 5 months) and 1.0 mS/cm exceedence of the Progressive Daily Mean over Table 1 values. These criteria are intended to represent probable drought impact on accumulated soil salinity.

(1) Drought response criteria and funding shall occur in any of the following two conditions:

i. Deficiency Period is in effect and trigger values of Table 2 are exceeded at Monitoring Stations S-35 or S-97 when ownerships are filling from affected sloughs or channels in any two or more of the following months: October, February, March, April, or May; or,

ii. Deficiency Period has been in effect for more than one year and trigger values of Table 2 are exceeded at any Compliance Station from Table 1 when ownerships are filling from affected sloughs or channels in any two or more of the following months: October, February March April or May; or,

(2) If condition 1(i) occurs, then SRCD shall allocate all drought response funds to the western Suisun Marsh. If condition 1(ii) occurs, then SRCD shall allocate at least 75 percent of the drought response funds to the western Suisun Marsh and may allocate up to 25 percent of the drought response funds to the eastern Suisun Marsh. For purposes of this section, the western Suisun Marsh includes all lands that divert water from sloughs west of Suisun Slough, but not including Suisun Slough. SRCD shall consider recommendations and data provided by the Water Manager to determine allocation of the drought response funds to the Individual Ownerships. When the trigger values are exceeded the Water Manager may monitor channel salinity adjacent to Individual Ownership water inlet facilities to assist SRCD in determining affected lands and the need for funding.

C. Descriptions of facilities and actions under this Article VII will be furnished to the Coordination Committee, described in Article XII, for review and comments. Comments must be provided within 30 working days of receipt of the description.

D. USBR and DWR shall modify the Existing Facilities or their operation in accordance with Subarticle C above to provide Individual Ownerships, DFG, or SRCD the ability to achieve adequate water levels for waterfowl food production consistent with the IOAHMP within the constraints identified in Article III and/or any additional regulatory constraints.

E. The responsibility for planning, environmental documentation, implementation, funding, operation and maintenance of facilities and actions implemented shall be as listed in Attachment B. USBR and DWR shall coordinate in funding of Attachment B responsibilities in accordance with Articles XI and XXV.

Article VIII. Funding Amount and Payment to SRCD for SMPA Activities

A. For activities undertaken by SRCD pursuant to Articles VII and VIII of this Revised SMPA and any amendments, DWR and USBR shall provide funds, paid through DWR, in accordance with Articles XI and XXV, to SRCD by payment methods described in this Article:

1. DWR shall make payments to SRCD not more frequently than monthly for the actions and programs required under this Revised SMPA, following the receipt by DWR of SRCD's itemized invoice for work performed. Invoices must be identified by contract number 4600000633 and appropriate Internal Order Number and addressed to:

   Department of Water Resources
   Attn: Suisun Marsh Preservation Agreement Coordinator
   3251 'S' Street
   Sacramento, CA 95816

2. Where necessary, other agreements may be executed to implement the specific actions and programs required under this Revised SMPA. Such agreements shall not increase the funding available for these actions and programs unless all Parties agree to an increase and have appropriately amended this Revised SMPA. Such agreements shall provide that DWR and USBR shall make payments to SRCD as in Subarticle A.1. above and will include, where appropriate, provisions for progress payments to SRCD.

3. DWR and USBR may take actions they deem necessary including the right to inspect installed facilities, the right to audit accounts relating to the facilities, and the right to protect their interest in case of default to verify compliance with requirements of this Article.

B. In partial fulfillment of its mitigation requirements to SRCD, under SWRCB D-1641, for DWR and USBR operation of the SWP and CVP and effects in Suisun Marsh, DWR and USBR shall provide a one-time payment of $218,200 to SRCD upon execution of the Revised SMPA.

1. SRCD shall use $58,200 of this payment for start-up costs of the Water Manager and IOAHMP Programs and $160,000 for the Portable Pumps Program, which is included as part of the maximum funding for these programs.

2. SRCD shall document and report these expenditures to DWR and USBR in the quarterly progress reports required below under Subarticle D. If SRCD uses these monies for purposes not in accordance with this subarticle, SRCD shall repay to DWR and USBR the amount expended with interest at the rate of 10 percent per annum calculated from the date payment was provided to SRCD.

C. Maximum funding from DWR and USBR to SRCD for actions specifically described in Article VII shall be:

1. Water Manager and IOAHMP Programs:

The Water Manager and IOAHMP Programs will be funded as an annual activity conducted by SRCD. The Water Manager staffing will be phased in as landowner participation and implementation of the programs dictate.

a. The maximum amount expended for annual operating costs each year the program continues shall not exceed $234,190.

b. The maximum amount expended for start-up costs shall not exceed a total of $130,600. This includes the first-year start-up costs of $58,200 to be paid upon execution of the Revised SMPA.

c. DWR shall make monthly payments based on itemized invoices which will include, but are not limited to, labor, equipment, materials, travel, overhead, and costs. SRCD's estimated annual operating budget and start-up costs for these Programs are shown in Tables 4 and 5.

2. Portable Pumps Program:

a. Except as allowed below by Subarticle C.2.b, the maximum amount expended shall not exceed $547,757 for portable pumps, portable fuel tanks, maintenance equipment, and associated maintenance costs, including funds provided above pursuant to Subarticle B.

b. Upon agreement of the parties, the funding shall be increased to purchase additional portable pumps.

c. DWR shall make payments based on SRCD's itemized invoice identifying the costs of each portable pump, portable fuel tank, maintenance equipment and associated maintenance costs. The estimated cost for each pump is $20,000.

Table 4. Annual Estimated Operating Budget for Water Manager and IOAHMP Programs [1]

Item	Quantity	Unit Cost (Dollars)	Extended Costs [2] (Dollars)
Supervisor [3]	One half-time	48,000	24,000
Water Manager [3]	Three full-time	37,000	111,000
Payroll Tax and Staff Benefits	32.6 percent		44,010
Operating Expenses			18,100
Overhead	18.8 percent		37,080
Annual Total Cost			$234,190

1. This Budget does not include administrative start-up costs of the Water Manager and IOAHMP programs.

2. These are estimated amounts and SRCD may transfer funds among budget line items if less than or equal to 20 percent of the item total. SRCD may transfer more than 20 percent of the line item total with prior written approval of USBR and DWR.

3. Employees will be hired for duties needed to fulfill requirements of Article VII.

Table 5. Estimated Start-up Costs for Water Manager and IOAHMP Programs

Item	Quantity	Unit Cost (Dollars)	Extended Costs (Dollars)
Office Space	1	22,000	22,000
Vehicles	3	26,000	78,000
All Terrain Vehicle	3	5,500	16,500
Computer	3	1,700	5,100
Equipment and Supplies	3	1,500	4,500
Office Furniture	3	1,500	4,500
Total Cost			$130,600[1]

1. Includes $58,200 that will be paid to SRCD upon execution of the Revised SMPA for first-year start-up costs.

2. These are estimated amounts and SRCD may transfer funds among budget line items if less than or equal to 20 percent of the item total. SRCD may transfer more than 20 percent of the line item total with prior written approval of USBR and DWR.

3. Improvements to Roaring River Slough Unit Turnouts:

   a. The maximum amount expended for this action shall not exceed $67,164.

   b. DWR shall make payments based on SRCD's itemized invoice identifying the location and cost of each turnout improvement.

4. Drought Response Fund:

   $80,596 per year, adjusted for inflation as provided below by Subarticle F, and shared in accordance with Articles XI and XXV, shall be paid to SRCD for payment to private landowners and to DFG for drought response activities on adversely affected lands. Of the $80,596, SRCD shall reserve $11,194 for DFG drought response activities.

D. SRCD shall provide to DWR and USBR the following:

   1. An annual budget forecast on or before January 1 for activities funded under this Revised SMPA for the upcoming State Fiscal Year (July 1 - June 30).

   2. Quarterly progress reports on or before: July 1, October 1, January 1, and April 1, identifying activities undertaken pursuant to this Revised SMPA, including an accounting of costs of those activities.

E. Any real or personal property purchased by SRCD, at its expense, necessary for the actions, programs, or facilities required under Articles VII or VIII shall become the property of SRCD in consideration of SRCD meeting obligations of this Revised SMPA. SRCD shall have full responsibility for operation and maintenance of such property and DWR and USBR shall have no obligation or incur additional expenses for such property. SRCD shall hold DWR and USBR harmless for any damages, claims, or liability associated with such property.

F. Each year in July, the Annual Estimated Budget for the Water Manager and IOAHMP Program (Table 4) shall be adjusted to July 2003 dollars, plus or minus such amounts, if any, as may be justified by ordinary fluctuations in costs using USBR's "Water Systems Operational Maintenance Cost Trends". Similarly, any unexpended funds of the Estimated Start-up Costs for the Water Manager and IOAHMP Program (Table 5) shall be adjusted to July 2003 dollars, plus or minus such amounts, if any, as may be justified by ordinary fluctuations in costs using USBR's "Water Systems Operational Maintenance Cost Trends".

Article IX. Public Access

Lands owned or to be acquired in fee title by the State, which are used for the construction or maintenance of the Existing Facilities or as mitigation lands under this Revised SMPA, may be accessible to the public for recreation use. With the exception of lands under DFG ownership and management, USBR and DWR shall mutually determine after consultation with DFG and SRCD the extent to which such lands should be used for recreation consistent with safety, operational needs and potential damage to other lands.

Article X. Rights of Way

Delay in acquisition of rights of way that are required for work to be done under this Revised SMPA may delay completion or maintenance of a facility or implementation of an action but shall not change the responsibility of DWR and USBR to complete that facility or implement an action as expeditiously as possible.

Article XI. DWR and USBR Cost Sharing

A. USBR shall pay Forty Percent (40%) and DWR shall pay Sixty Percent (60%) of the costs assigned to DWR and USBR pursuant to Articles III, IV, V, VI, VII, VIII, XII, and XXV, whether incurred prior to the date of this Revised SMPA or thereafter. The term "costs" shall include costs of planning, design, environmental documentation, construction, operation (including boat lock passage), maintenance, and mitigation. The term "costs" shall also include all administrative overhead, costs of liability insurance or pooling programs and other costs similar to those normally incurred by USBR and which will be incurred by DWR in performance of the obligations under this Revised SMPA.

B. USBR's share of design, planning, environmental documentation, mitigation and construction costs shall not exceed $50 million, July 1985 dollars, plus or minus such amounts, if any, as may be justified by reason of ordinary fluctuation in construction costs, as indicated by the "Engineering News-Record's" cost indexes.

C. The United States shall pay to DWR the costs determined to be allowable by USBR in accordance with the terms of this Revised SMPA and with provisions of Federal Acquisition Regulations (FAR), Part 31, Subpart 6, 48 CFR Sections 31.601-31.603. If DWR uses any funds provided pursuant to this Revised SMPA for purposes not in accordance with this Revised SMPA or not in compliance with FAR Part 31, Subpart 6, DWR shall reimburse USBR for the amount of any such improperly used funds.

D. USBR shall submit quarterly statements to DWR for costs incurred pursuant to this Revised SMPA and, DWR shall adjust the DWR quarterly invoices to reflect USBR costs. DWR shall submit its quarterly invoices for payment to USBR for DWR costs

incurred pursuant to this Revised SMPA and adjusted for amounts reflecting USBR costs.

E. Each year on or before October 1, DWR shall, to the extent possible, provide USBR a proposed three-year Suisun Marsh budget reflecting DWR's estimated annual costs for three years beginning one year after the date of submittal to implement programs and actions under Articles III, IV, V, VI, VII, VIII, and XII of this Revised SMPA. This estimated budget will be used by USBR to estimate future funding requirements for both operation and maintenance and construction costs associated with the Suisun Marsh programs and actions. USBR shall notify DWR by the following September 15th of its full or partial approval of DWR's proposed budget for year one, including any rationale for unapproved costs. USBR's approval shall not be unreasonably withheld. In the event that USBR does not approve DWR's year one budgeted costs, such unapproved costs shall not be eligible for reimbursement by USBR until such time as they are mutually agreed upon by DWR and USBR. DWR and USBR shall coordinate on estimated budgets for years two and three as needed for their respective budget planning purposes.

Article XII. SMPA Coordination Committee and ECAT

A. Each party to this Revised SMPA shall appoint a representative ("Coordinator") to the SMPA Coordination Committee to review and approve, as necessary, actions and operations undertaken pursuant to this Revised SMPA. To the extent possible, the Coordination Committee shall review and resolve issues and disputes that arise under this Revised SMPA as described in Article XVIII. The Committee shall convene as needed.

B. Each party to this Revised SMPA shall appoint a representative to the SMPA Environmental Coordination Advisory Team. The ECAT will have responsibility for: (1) ensuring compliance with mitigation and monitoring requirements of this Revised SMPA and related permits and biological opinions, and (2) provide technical guidance and oversight of Suisun Marsh monitoring, management and restoration programs conducted as part of the SMPA, including its monitoring and mitigation agreements.

1. The ECAT will be patterned after DWR's Environmental Coordination Advisory Team and will include participation from other federal and State agencies, such as USFWS and NOAA Fisheries.

2. The ECAT will report, at least annually, through the four Agency Coordinators to the Agency Directors.

3. The ECAT's tasks will be to: (1) develop and/or update protocol for SMPA monitoring activities in cooperation with USFWS and other

regulatory agencies, and (2) develop recommendations for use of the last installment of DWR and Reclamation mitigation payments contained in the Suisun Marsh Mitigation Agreement, consistent with Article VI of this Revised SMPA, which shall include activities that mitigate for impacts to listed and sensitive species. ECAT will give high priority to mitigation actions which provide opportunities for multi-species recovery.

Article XIII. Assurances

To assure the effectiveness of the actions implemented and facilities operated pursuant to Articles III, VI, and VII:

A. SRCD shall diligently exercise its authority to require that Individual Ownerships be managed and operated in accordance with their IOAHMP and so as not to interfere with the implementation of actions and operation of Existing Facilities.

B. DWR and USBR shall neither be required to meet:

1. The channel water salinity standards of Article III; nor

2. The requirements of Subarticle VII.D as it applies to the specifically affected Individual Ownerships

during any period where the Parties agree that an Individual Ownership, by its acts or omissions, substantially interferes with the operation of any of the actions or Existing Facilities.

C. Nothing herein shall constitute a waiver of any rights USBR and DWR may have to pursue claims of damage due to failure to maintain the Exterior Levees. If USBR and DWR are unable to meet the Article III standards because the Exterior Levees are in disrepair, USBR and DWR shall not be required to meet the standards to the extent the Exterior Levees are responsible.

D. DWR and USBR shall make a good faith effort to repair, in an expeditious manner, any facilities or compliance or monitoring stations under DWR control that fail, in order to avoid impacts to management of Marsh wetlands.

E. The Parties acknowledge that the actions in this Revised SMPA may not provide an equivalent level of protection to the managed wetlands as described in the Original Agreement with regard to channel water salinity objectives at S-35 and S-97. The parties agree to develop an amendment to this Revised SMPA which will contain actions that provide an equivalent or better level of protection as originally described as SMPA Amendment Three, and contained in D-1641 (pages 49-53) for the managed wetlands.

Article XIV. Changes Leading to Renegotiation

The Parties agree if any of the changes listed below occur, then they will renegotiate and amend as necessary this Agreement, consistent with these changes. This Revised SMPA may be amended for other reasons not listed below pursuant to Article XVII.

A. A regulatory requirement that changes the configuration or operation of the SMSCG causing a significant project modification that makes meeting provisions of Article III infeasible.

B. Future SWRCB water rights actions reduce requirements for Delta Outflow significantly from the requirements in D-1641.

C. The salinity values at S-21 and S-42 exceed the Article III Deficiency Standards in Table 1 for more than four months in any two consecutive Control Seasons during a Deficiency Period with the SMSCG fully operating, terms and conditions for Delta outflow of the SWP and CVP water right permits being met, and with Delta outflows occurring as described by the D-1641 Outflow Objectives.

D. Local inflow into the Marsh is significantly changed which impairs the Parties' ability to meet the objectives of this Revised SMPA.

Article XV. Miscellaneous Provisions

A. USBR and DWR have no objection to Individual Ownerships diverting water from the Marsh channels for wildlife habitat management on lands within the Marsh. USBR and DWR shall not disturb or challenge said diversions and uses so long as they are consistent with this Revised SMPA while it is in full force and effect.

B. SRCD and DFG shall not claim any right against USBR or DWR in conflict with the provisions hereof so long as this Revised SMPA remains in full force and effect. However, this provision shall not limit in any way DFG's authority to exercise its responsibilities as a State Trustee agency under California law, including as against USBR or DWR when applicable.

C. This Revised SMPA shall not affect, bind, prejudice, impair, restrict, or limit water rights pertaining to lands within the Marsh.

D. SRCD consents to the storage of water and export of water from the Delta by the CVP and SWP so long as this Revised SMPA remains in full force and effect and USBR and DWR are in compliance herewith.

E. DWR agrees to forego the use of eminent domain proceedings to acquire water rights in the Marsh.

F. In consideration of Chinook salmon passage issues at the SMSCG and in order to determine appropriate response to such issues and other protected species needs, the Parties agree to continue to implement tests as necessary to determine how to modify the SMSCG structure or operation to minimize fish passage impedance during SMSCG operations.

G. DFG shall provide SRCD a mutually agreeable location within the Grizzly Island Wildlife Area, DFG headquarters compound, or other location in the Suisun Marsh to permanently place the office trailer identified in the Water Manager Program. DFG shall also provide SRCD a secure location for storage and shall provide shop access for maintenance, repairs to, and service of the pumps in the Portable Pump Program.

Article XVI. Term of the Revised SMPA

This Revised SMPA shall become effective upon execution by the Parties, and execution of the Revised Monitoring Agreement (referenced in Article V) and the Revised Mitigation Agreement (referenced in Article VI) and approval of the California Department of General Services of this Revised SMPA, the Revised Monitoring Agreement and Revised Mitigation Agreement. This Revised SMPA shall remain in full force and effect until terminated by written agreement of all the Parties.

Article XVII. Amendments and Integration of Terms

This Revised SMPA may be amended at any time by mutual written agreement of USBR, DWR, DFG and SRCD and approval by the California Department of General Services. No alterations or variation of the terms of this contract shall be valid unless made in writing and signed by the Parties, and no oral understanding or agreement not incorporated in this Revised SMPA shall be binding on any of the Parties.

Article XVIII. Dispute Resolution and Remedies

A. Disagreement among the Parties regarding performance under this Revised SMPA shall first be presented to the SMPA Coordination Committee as provided in Article XII, and if unresolved, then be brought before the agency directors and the SRCD Board of Directors for discussion and possible resolution. The Parties agree that an exceedence of a monthly salinity standard of less than 0.2 mS/cm is not sufficient as to require a remedy.

B. As a condition precedent to a Party or Parties bringing any suit for breach of this Revised SMPA, that Party or Parties must first notify the other Party or Parties in writing of the nature of the purported breach and seek in good faith to resolve the dispute through negotiation 90 days in advance. If the Parties cannot resolve the dispute through negotiation, they may agree to a mutually acceptable method of non-binding alternative dispute resolution with a qualified third party acceptable to the Parties. The Parties involved in the dispute shall each pay an equal proportion of any costs for the services provided by such a third party as such costs are incurred. The existence of a dispute shall not excuse the Parties from performance pursuant to this Revised SMPA.

C. Neither DWR nor USBR is responsible for the other's obligation under this Revised SMPA.

D. The terms of Article XXIII (Release of Liability) shall be interpreted consistent with, and not supplant, the terms of this Article.

Article XIX. Opinions and Determinations

Where the terms of this Revised SMPA provide for action to be based upon the opinion, judgment, approval, review, or determination by the Parties, such terms are not intended to be and shall not be construed as permitting such opinion, judgment, approval, review, or determination to be arbitrary, capricious or unreasonable.

Article XX. Successors and Assigns Obligated

This Revised SMPA and all of its provisions shall apply to and bind the successors and assigns of the Parties hereto. No assignment is valid without the written consent of all the Parties.

Article XXI. Books, Records, Reports and Inspections

Subject to the applicable federal and State laws and regulations, each party shall have the right, for a period of three years after final payment under this Revised SMPA, to examine and make copies of each others books and official records relating to matters covered by this Revised SMPA and to request entry onto property or facilities for inspections.

Article XXII. Waiver of Rights

Waiver at any time by any Party hereto of its rights with respect to a default, or any other matter arising in connection with this Revised SMPA, shall not be deemed to be a waiver with respect to any other default or matter.

Article XXIII. Release of Liability

A. SRCD, and its agents and employees, in the performance of this Revised SMPA, shall act in an independent capacity and not as officers or employees or agents of the State of California or the federal government.

B. Disagreements among the Parties regarding performance under this Revised SMPA shall be governed exclusively by Article XVIII.

C. Each Party shall be responsible for the consequences of its own actions taken in connection with this Revised SMPA, and in connection with any work undertaken in accordance with this Revised SMPA. Within thirty days of receipt by any Party to this Revised SMPA of any third party claim for liability arising from actions or omissions within the scope of this Revised SMPA, the Party receiving the claim shall notify each of the other Parties to this Revised SMPA of such claim and provide a copy of the claim to each of the other Parties to this Revised SMPA, if it is in written form. Nothing in this Article shall be construed to limit the right of any Party to this Revised SMPA to assert such affirmative defenses and file such cross-complaints as may be appropriate in relation to any claim affecting the liability of such Party to this Revised SMPA.

Article XXIV. Notices

All notices that are required either expressly or by implication to be given by one party to another shall be in writing and deemed to be given if delivered personally, by facsimile (FAX), or enclosed in a properly addressed postage prepaid envelope with return receipt requested and deposited in a United State Post Office or by Federal Express or equivalent delivery system. Unless or until formally notified otherwise, notices to the Parties shall be addressed as follows:

Regional Resources Manager
U. S. Bureau of Reclamation, MP-400
2800 Cottage Way
Sacramento, CA 95825-1898

Regional Manager
Department of Fish and Game
Central Coast Region
Yountville, CA 94599

Chief, Division of Environmental Services
Department of Water Resources
3251 S Street
Sacramento, CA 95816

Chief, Central Valley Bay-Delta
Branch
Department of Fish and Game
4001 North Wilson Way
Stockton, CA 95205

Executive Director
Suisun Resource Conservation
District
2544 Grizzly Island Road
Suisun, CA 94585

Article XXV. Contingent Upon Availability of Funds

A. Forty percent of the total funds to be paid under this Revised SMPA shall be paid using State Water Project funds and twenty percent of the total funds to be paid under this Revised SMPA are contingent on the appropriation of other State funds.

B. The expenditure or advance of any money and the performance of any work by the United States or the State of California under this Revised SMPA which may require appropriation of money by the Congress or the State Legislature, respectfully, or the allotment of funds shall be contingent upon such appropriation or allotment being made. No liability shall accrue to the United States or the State of California in case such funds are not appropriated or allotted.

Article XXVI. Standard Clauses

The Parties shall comply with the applicable standard clauses in Exhibits C, C1, D, D1, E, and F, however, where a standard clause conflicts or is inconsistent with any provision of this Revised SMPA (also referred to as Exhibit A), the provisions of this Revised SMPA shall control. And, specifically, Conditions 5 and 7 of Exhibit C shall not be applicable as these conditions are inconsistent with Articles XXIII and XVI of this Revised SMPA, respectively.

Article XXVII. Counterparts

This Agreement may be executed simultaneously or in one or more counterparts, each of which will be an original but all of which together will constitute one and the same document.

Contract No. 4600000633.1
Exhibit A

IN WITNESS WHEREOF, the Parties hereto have entered into this Revised SMPA (also referred to as Exhibit A) on the date first written above. The terms of this Revised SMPA together with the cover page and Exhibits B, C, C1, D, D1, E and F constitute the whole agreement among the Parties.

Approved as to legal form and sufficiency:

James E. Turner

Office of the Regional Solicitor
Department of the Interior

Chief Counsel
Department of Water Resources

Chief Counsel
Department of Fish and Game

Counsel
Suisun Resource Conservation District

U.S. BUREAU OF RECLAMATION

Regional Director, Mid-Pacific Region

MAY 23 2005

Date

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

Director

Date

DEPARTMENT OF FISH AND GAME

Director

Date

SUISUN RESOURCE CONSERVATION DISTRICT

President, Board of Directors,

Date

Contract No. 4600000633.1
Exhibit A

IN WITNESS WHEREOF, the Parties hereto have entered into this Revised SMPA (also referred to as Exhibit A) on the date first written above. The terms of this Revised SMPA together with the cover page and Exhibits B, C, C1, D, D1, E and F constitute the whole agreement among the Parties.

Approved as to legal form and sufficiency:

Office of the Regional Solicitor
Department of the Interior

Chief Counsel
Department of Water Resources

Chief Counsel
Department of Fish and Game

Counsel
Suisun Resource Conservation District

U.S. BUREAU OF RECLAMATION

Regional Director, Mid-Pacific Region

Date

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

Director

Date

DEPARTMENT OF FISH AND GAME

Director

May 17, 2005
Date

SUISUN RESOURCE CONSERVATION DISTRICT

President, Board of Directors,

Date

Contract No. 4600000633.1
Exhibit A

IN WITNESS WHEREOF, the Parties hereto have entered into this Revised SMPA (also referred to as Exhibit A) on the date first written above. The terms of this Revised SMPA together with the cover page and Exhibits B, C, C1, D, D1, E and F constitute the whole agreement among the Parties.

Approved as to legal form and sufficiency:

U.S. BUREAU OF RECLAMATION

Regional Director, Mid-Pacific Region

Office of the Regional Solicitor
Department of the Interior

Date

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

cc Chief Counsel
Department of Water Resources

Director

Date

Chief Counsel
Department of Fish and Game

DEPARTMENT OF FISH AND GAME

Director

Counsel
Suisun Resource Conservation District

Date

SUISUN RESOURCE CONSERVATION DISTRICT

President, Board of Directors,

5/20/05

Date

Contract No. 4600000633.1
Exhibit A
Attachment A

Attachment A
Description of Existing Facilities

I. Roaring River Slough Unit

The Roaring River Slough Unit includes the following:

Intake Facilities – Fish screens, control gates, culverts, tide gates, and the levee and road over the culverts.

Hammond Island Reservoir – 40 acres in the southeast corner of Department of Fish and Game property adjacent to Montezuma Slough and Roaring River. Includes the levees surrounding the reservoir.

Roaring River Channel – Includes the north and south levees, the Mud Slough arm, including its north and south levees, and the crossing structures.

Wheeler Island – Boat ditches, levee and control gates.

Drainage Facility – Control gate and culvert.

Individual ownership water intake and discharge facilities - These facilities include control gated culverts and access thereto.

II. Goodyear Slough Outfall

The Goodyear Slough Outfall includes the following:

Goodyear Ditch – Channel dredged from the end of Goodyear Slough to the Bay.

Drainage Facility – Structure consisting of culverts and control gates.

Trash Rack – Structure at the beginning of Goodyear Ditch to minimize debris entering Goodyear ditch.

III. Morrow Island Distribution System

Intake Structure – Intake culverts, control gates, and the levee and road over the culverts.

Morrow Island Ditch – Includes the north and south levees and the crossing structures.

Drainage facility – Includes the culverts and control gates.

Individual ownership water intake and/or drainage facilities – These facilities include control gated culverts and access thereto.

IV. Suisun Marsh Salinity Control Gates (also known as Montezuma Slough Control Structure

The facility consists of three radial gates, a 20-foot wide boat lock, and a flashboard opening 66 feet wide.

V. Cygnus Unit

A drain facility consisting of a 36-inch culvert and gate on Individual Ownership No. 424.

VI. Lower Joice Island Unit

Fill facility consisting of a 36-inch culvert and gate and connection to the existing distribution system on Individual Ownership No. 424.

4600000633.1
Agreement #_____
Attachment B

RESPONSIBILITY FOR SUISUN MARSH FACILITES AND ACTIVITIES

Item	Environmental Documentation	Design	Construction	Operation	Maintenance	Ownership
Suisun Marsh Salinity Control Gates						
All facilities	DWR	DWR	DWR	DWR	DWR	DWR
Cygnus Unit						
Turnouts	SRCD	DWR [1]	DWR [1]	Landowner	Landowner	Landowner
Roaring River Slough Unit						
Intake structures	DWR	DWR	DWR	DWR	DWR	DWR
Fish Screens	DWR	DWR	DWR	DWR	DWR	DWR
Modified Channel (including pond)	DWR	DWR	DWR	DWR	DWR	DWR
Levees [2]	DWR	DWR	DWR	—	DFG/DWR [3]	Landowner [6]
Laterals	DWR	DWR	DWR	—	DWR	DWR
Crossing structures	DWR	DWR	DWR	DWR	DWR	DWR
Turnouts	DWR	DWR [1]	DWR [1]	Landowner	Landowner [4]	Landowner [4]
Turnout (ArticleVII.A.5) repair	SRCD	SRCD	SRCD	Landowner	Landowner	Landowner
Morrow Island Distribution System[2]						
Intake Structures	DWR	DWR	DWR	—	DWR	DWR
M-Line Outfall	DWR	DWR	DWR	DWR	DWR	DWR
C-Line Outfall	DWR	DWR	DWR	DWR	DWR	DWR
Levees	DWR	DWR	DWR	—	DWR	DWR
Turnouts and drainage facilities	DWR	DWR [1]	DWR [1]	Landowner	Landowner [4]	Landowner
Goodyear Slough Unit						
Intake structures	DWR	DWR	DWR	DWR	DWR	DWR
Outfall structure	DWR	DWR	DWR	DWR	DWR	DWR
Channel	DWR	DWR	DWR	—	DWR	DWR
Lower Joice Island Unit						
Turnout	SRCD	DWR	DWR	Landowner	Landowner [4]	Landowner
Connection to existing distribution system	SRCD	DWR	DWR	—	DWR	Landowner
Fish screen	SRCD	DWR	DWR	Landowner	Landowner [5]	Landowner
Portable Pumps	SRCD	SRCD	SRCD	SRCD	SRCD	SRCD
Water Manager Program						
All equipment	SRCD	—	—	SRCD	SRCD	SRCD

1. Specific turnouts and drain gates to be identified on design plans.
2. Main channel water control levees only.
3. DFG as landowner shall be responsible for maintaining the North Levee on Roaring River except for subsidence which prevents the River Unit from meeting its design purposes.
4. DWR and USBR shall correct any deficiency due to design or construction which prevents any water facility from passing its design flow rate until May of the third operating season after the water facility becomes operational. After this period, all necessary corrections shall be the responsibilityof the Individual Ownership.
5. DWR and USBR shall correct any deficiency due to design or construction which prevents the fish screen from passing its design flow rate until May of the first operating season after the fish screen becomes operational. After this period, all necessary corrections shall be the responsibility of the Individual Ownership.
6. DWR has an easement on the levee to perform necessary maintenance.

Contract No. 4600000633.1
Exhibit A

Attachment C
NDOI and PERCENT INFLOW DIVERTED [1]

The NDOI and the percent inflow diverted, as described in this footnote, shall be computed daily by the DWR and the USBR using the following formulas (all flows are in cfs):

NDOI = DELTA INFLOW - NET DELTA CONSUMPTIVE USE - DELTA EXPORTS

PERCENT INFLOW DIVERTED = (CCF + TPP) ÷ DELTA INFLOW

where *DELTA INFLOW = SAC + SRTP + YOLO + EAST + MISC + SJR*

SAC	=	Sacramento River at Freeport mean daily flow for the previous day; the 25-hour tidal cycle measurements from 12:00 midnight to 1:00 a.m. may be used instead.
SRTP	=	Sacramento Regional Treatment Plant average daily discharge for the previous week.
YOLO	=	Yolo Bypass mean daily flow for the previous day, which is equal to the flows from the Sacramento Weir, Fremont Weir, Cache Creek at Rumsey, and the South Fork of Putah Creek.
EAST	=	Eastside Streams mean daily flow for the previous day from the Mokelumne River at Woodbridge, Cosumnes River at Michigan Bar, and Calaveras River at Bellota.
MISC	=	Combined mean daily flow for the previous day of Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrison Creek.
SJR	=	San Joaquin River flow at Vernalis, mean daily flow for the previous day.

where *NET DELTA CONSUMPTIVE USE = GDEPL - PREC*

GDEPL	=	Delta gross channel depletion for the previous day based on water year type using the DWR's latest Delta land use study.[2]
PREC	=	Real-time Delta precipitation runoff for the previous day estimated from stations within the Delta.

and where *DELTA EXPORTS*[3] *= CCF + TPP + CCC + NBA*

CCF	=	Clifton Court Forebay inflow for the current day.[4]
TPP	=	Tracy Pumping Plant pumping for the current day.
CCC	=	Contra Costa Canal pumping for the current day.
NBA	=	North Bay Aqueduct pumping for the current day.

---

1 Not all of the Delta tributary streams aregaged and telemetered. When appropriate, other methods of estimating stream flows, such as correlations with precipitation or runoff from nearby streams, may be used instead.

2 The DWR is currently developing new channel depletion estimates. If these new estimates are not available, DAYFLOW channel depletion estimates shall be used.

3 The term "Delta Exports" is used only to calculate the NDOI. It is not intended to distinguish among the listed diversions with respect to eligibility for protection under the area of origin provisions of the California Water Code.

4 Actual Byron-Bethany Irrigation District withdrawals from Clifton Court Forebay shall be subtracted from Clifton Court Forebay inflow. (Byron-Bethany Irrigation District water use is incorporated into the GDEPL term.

Contract No. 4600000633.1
Exhibit A

Attachment D
Sacramento Valley
Water Year Hydrologic Classification

Year classification shall be determined by computation of the following equation:

$$\text{INDEX} = 0.4 * X + 0.3 * Y + 0.3 * Z$$

Where: X = Current year's April – July Sacramento Valley unimpaired runoff

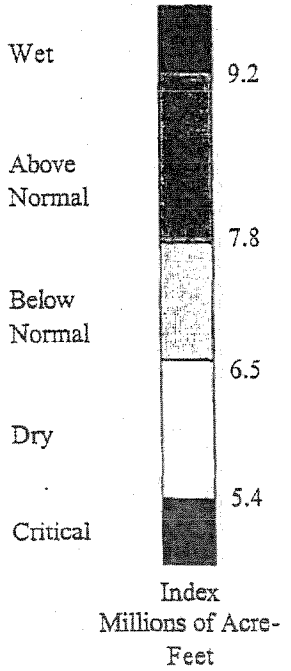
Y = Current October – March Sacramento Valley unimpaired runoff

Z = Previous year's index[1]

The Sacramento Valley unimpaired runoff for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year), as published in California Department of Water Resources Bulletin 120, is a forecast of the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March, and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

Classification	Index Millions of Acre-Feet (MAF)
Wet.....	Equal to or greater than 9.2
Above Normal.....	Greater than 7.8 and less than 9.2
Below Normal.....	Equal to or less than 7.8 and greater than 6.5
Dry.....	Equal to or less than 6.5 and greater than 5.4
Critical.....	Equal to or less than 5.4

YEAR TYPE [2]
All Years for All Objectives



[1] A cap of 10.0 MAF is put on the previous year's index (Z) to account for required flood control reservoir releases during wet years.

[2] The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.

Attachment E. Original Suisun Marsh Preservation Agreement

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SUISUN MARSH PRESERVATION AGREEMENT
Among
United States Bureau of Reclamation,
California Department of Water Resources,
California Department of Fish and Game, and
Suisun Resource Conservation District

THIS AGREEMENT, dated this 2 day of March, 1987, is hereby entered into among the United States Bureau of Reclamation (USBR), California Department of Water Resources (DWR), the California Department of Fish and Game (DFG), and the Suisun Resource Conservation District (SRCD), and supersedes that contract for the Initial Facilities dated December 18, 1978.

R E C I T A L S

(a) In Section 29002 of the Public Resources Code, the California Legislature has found and declared that the Suisun Marsh (Marsh) represents a unique and irreplaceable resource to the people of the State and the Nation and that it is the policy of the State to preserve and protect resources of this nature for the enjoyment of the current and succeeding generations. Further, Section 29003 of the Public Resources code provides that in order to preserve the integrity and assure continued wildlife use of the Marsh, including the preservation of its waterfowl carrying capacity and retention of the diversity of its flora and fauna, there is a need for the following:

(1) Provisions for establishment and maintenance of adequate water quality.

(2) Improvement of present water management practices, including drainage and other water control facilities within the Marsh.

(3) Establishment of criteria for the production of valuable waterfowl food plants.

(4) Provisions for future supplemental water supplies and related facilities to assure that adequate water quality will be achieved within the wetland areas.

These concerns have been recognized in the Plan of Protection (Plan) developed by DWR.

(b) Public Law 99-546 authorizes the USBR to participate in the preservation of the Marsh. The value of preserving wetlands is recognized in Presidential Executive Order 11990 (Protection of Wetlands) dated May 24, 1977.

(c) In Decision 1485 (D-1485) the State Water Resources Control Board (SWRCB) considered the problems of the Marsh and directed the USBR and DWR to develop and implement a plan to protect the Marsh. A Plan of Protection for the Suisun Marsh was furnished to the SWRCB by DWR in February 1984. D-1485 required the Plan's implementation by October 1, 1984. By letter of July 26, 1982, DWR notified SWRCB of its inability to meet that deadline. In the meantime, DWR and USBR are providing partial mitigation through certain Initial Facilities constructed pursuant to Order 7(c) of D-1485 and the contract among SRCD, DFG and DWR dated December 18, 1978. Under a contract between USBR and DWR, dated February 18, 1982, the USBR reimbursed DWR for $2,500,000 of the federal share of the cost of the Initial Facilities, as authorized by Public Law 96-495.

(d) A supply of adequate quality water is necessary to protect wildlife habitat in the Marsh. The parties consider it to be in the public interest to manage the wetlands of the Marsh to produce adequate quality waterfowl habitat and grow certain waterfowl food plants.

(e) Upstream water use, including diversions by the Central Valley Project (CVP) and the State Water Project (SWP) has, at times, reduced outflow from the Delta, thus increasing salinity in the Marsh. The higher salinities have, at times, degraded waterfowl habitat in the Marsh. The Marsh has a salinity gradient between its western portion and its eastern portion, with ocean-derived salinity being greatest in the westerly portion.

(f) The parties recognize that the water quality provided in this Agreement may, at times, be different than the quality of water which would be available in the Marsh in the absence of the SWP, the CVP, and other diversions by upstream users. Consequently, at times, landowners in the Marsh will need to employ more intensive management practices in the production of desirable waterfowl food plants.

(g) Resource conservation districts are authorized to enter into contracts with the United States and the State in furtherance of their powers.

(h) The SRCD is granted the primary local responsibility by Public Resources Code Section 9962 for regulating and improving water management practices on privately owned lands within the primary management area of the Marsh.

(i) The parties recognize that the benefits and costs of implementing the Plan cannot be determined precisely. The division of responsibilities contained herein is deemed to represent a reasonable balance of equities.

A G R E E M E N T

1. Definitions.

When used herein, the term:

(a) "Become(s) Operational" shall mean the time when a facility constructed pursuant to Article 8 is accepted by DWR with the concurrence of USBR in a formal written acceptance issued to the construction contractor.

(b) "Construction Season" shall mean the period February 1, to October 1.

(c) "Control Station" shall mean a location as listed in Table II.

(d) "Deficiency Period" shall mean (1) a Critical Year following a Dry or Critical Year; or (2) a Dry Year following a year in which the Four Basin Index was less than 11.35; or (3) the second consecutive Dry Year following a Critical Year.

(e) "Delta" shall mean the Sacramento-San Joaquin Delta as it is presently defined in Section 12220 of the Water Code;

(f) "Delta Outflow Index" shall mean an index of Delta outflow computed daily by USBR and DWR, as described on page IV-7 of the "Water Quality Control Plan, Sacramento-San Joaquin Delta and Suisun Marsh", dated August 1978, prepared by SWRCB.

(g) "Electrical Conductivity" (EC) shall mean the electrical conductivity of a water sample measured in millimhos per centimeter (mmhos/cm) corrected to a standard temperature of 25 Celsius determined in accordance with procedures set forth in the publication entitled, "Standard Methods of Examination of Water and Waste Water", published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation, 13th Edition, 1971, including such revisions thereof as may be made subsequent to the date of this Agreement which are approved in writing by the parties.

(h) "Exterior Levees" shall mean levees which protect the Marsh against inundation and uncontrolled flooding and are identified in the "Suisun Marsh Levee Evaluation" report dated February, 1983, prepared by Ramlit Associates for the United States Corps of Engineers.

(i) "Four Basin Index" shall mean the sum of the unimpaired runoff in the Water Year as published in California

Department of Water Resources Bulletin 120 for the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total unimpaired inflow to Oroville Reservoir; Yuba River at Smartville; American River, total unimpaired inflow to Folsom Reservoir.

(j) "Individual Ownership" shall mean separately owned parcels of land in the Marsh, other than those on Roe, Ryer, Freeman, and Snag Islands or the owners thereof. Contiguous parcels owned by the same legal entity comprise a single Individual Ownership.

(k) "Initial Facilities" shall mean the facilities for the Roaring River Slough Unit, the Goodyear Slough Outfall, and the Morrow Island Distribution System constructed pursuant to the contract of December 18, 1978.

(l) "Marsh" shall mean the Suisun Marsh as it is presently defined in Section 29101 of the Public Resources Code.

(m) "Marsh Model" shall mean the computer model consisting of MRSHFLO and MRSHQAL originally developed by Hugo Fischer, Inc. under contract with USBR as modified by USBR and DWR.

(n) "Overall Facilities" shall mean water delivery, distribution, redistribution, intake and drainage facilities as shown in Attachment A, which is made a part of this Agreement. These facilities are described in the Plan. The Initial Facilities are a part of the Overall Facilities.

(o) "Plan of Protection" (Plan) shall mean the plan prepared by DWR dated February, 1984 to mitigate the effects of the CVP and SWP on the Marsh and any subsequent modifications.

(p) "Scheduled Water" shall mean firm supplies of the CVP or SWP, plus such additional water ordered from the SWP by a contractor the previous September which does not exceed the maximum annual entitlement of that contractor.

(q) "Water Year" or "Year" shall mean the period October 1 of any year through September 30 of the following year.

(r) "Wet Year", "Above Normal Year", "Below Normal Year" and "Subnormal Snowmelt Year" are as defined in Footnote 2 of Table II of D-1485 as adopted by the SWRCB in August 1978. "Critical Year" and "Dry Year" are also as defined in Footnote 2 of Table II of D-1485 except that runoff for the remainder of the water year shall be assumed to be equal to the lower value of the 80 percent probability range, as shown in the most recent issue of Bulletin 120, "Water Conditions in California".

2. Obj tives

The objectives of this Agreement are:

(a) To assure that USBR and DWR maintain a dependable water supply of adequate quantity and quality within the Marsh to mitigate the adverse effects on the Marsh of the CVP and SWP and a portion of the adverse effects of the other upstream diversions;

(b) To improve Marsh wildlife habitat to the extent that such improvement is compatible with other CVP and SWP purposes;

(c) To define the scope of the obligations of USBR and DWR to provide the water supply, distribution, redistribution and management facilities necessary to accomplish the objectives in (a) and (b); and

(d) To assure that USBR and DWR recognize that the water users within the Marsh have been diverting and will continue to divert water for wildlife habitat management within the Marsh.

3. Water Quality Standards

The water quality standards to be met under this Agreement are:

(a) Initial Standards;

The standards of this subarticle are to be met only until DFG and SRCD request, based on evaluation of facilities constructed pursuant to Article 8, that the standards specified in subarticles (b) and (c) be put into effect, subject to the provisions of subarticle 8(h). These are:

(i) The 28-day running average of mean daily EC at O&A Ferry Landing on Chipps Island shall not exceed 12.5 mmhos from October through May, except that the comparable EC shall be 15.6 mmhos from October through December in any calendar year when the CVP or the SWP water contractors are taking a deficiency in Scheduled Water.

(ii) The minimum mean monthly Delta Outflow Index during the period January through May shall be 6,600 cfs whenever storage is at or above the minimum level in the flood control reservation envelope at any two of the following: Shasta Reservoir, Oroville Reservoir, and CVP storage on the American River. In addition, in Above Normal and Below Normal Years, the minimum 14-day running average Delta Outflow Index will be 12,000 cfs for 60 consecutive days in the period January through April. In Wet Years the minimum mean monthly Delta Outflow Index

from February through May will be 10,000 cfs, except in Subnormal Snowmelt years when the period shall be February through April.

(b) Normal Standards

(i) As each facility constructed pursuant to Article 8 Becomes Operational, and after the Initial Standards are no longer in effect pursuant to (a) above, the standards in Table I shall be met, except during Deficiency Periods, at the Control Stations (Table II and Figure I) listed for each facility as follows:

Facility	Control Stations
Montezuma Slough Control Structure	C-2, S-64 and S-49
Boynton-Cordelia Unit	S-21 and S-97
Cordelia-Goodyear Unit	S-75
Grizzly Island Unit	No additional station
Potrero Hills Unit	S-42

(ii) The Initial Facilities and those facilities constructed pursuant to this Agreement will be operated to minimize water salinities in the Marsh only so far as such operations do not create a need for additional upstream water releases, do not limit exports, do not harm fishery resources, significantly benefit wildlife habitat, and do not require that the Montezuma Slough Control Structure stoplogs remain in place beyond the time otherwise required to meet this Agreement.

TABLE I[1/]

MEAN MONTHLY HIGH TIDE[2/] ELECTRICAL CONDUCTIVITY (mmhos/cm)

Month	Normal Standards
October	19.0
November	16.5
December	15.5
January	12.5
February	8.0
March	8.0
April	11.0
May	11.0

1/The same standards apply at all Control Stations in effect, although it is recognized that better quality water will be present at some Control Stations due to a salinity gradient within the Marsh.

2/The monthly mean of both daily high tide ECs.

TABLE II
CONTROL STATIONS

Sacramento River at Collinsville Road in Collinsville (C-2)1/

Montezuma Slough at National Steel (three miles south of Mein's Landing) (S-64)1/

Montezuma Slough near Beldon Landing (0.35 miles east of Grizzly Island Bridge) [S-49]2/

Suisun Slough 300 feet south of Volanti Slough (S-42)1/

Goodyear Slough south of proposed Goodyear Slough Control Structure [Proposed S-75]2/

Cordelia Slough at Cordelia-Goodyear Ditch [Proposed S-97]2/

Chadbourne Slough at Chadbourne Road [Proposed S-21]2/

Cordelia Slough, 500 feet west of the Southern Pacific crossing at Cygnus (S-33)3/

Goodyear Slough at the Morrow Island Clubhouse (S-35)3/

1/ D-1485 station numbers shown in parentheses.
2/ These stations will be proposed to SWRCB as substitutes for existing D-1485 Control Stations.
3/ Existing D1485 Control Station. To be replaced by alternate station unless retained as provided for in Article 8.

(c) Deficiency Standards

After the Initial Standards are no longer in effect pursuant to (a) above, Table III standards shall be substituted for Table I standards during Deficiency Periods, but other requirements of subdivision (b) above will continue in effect. The designation of a Deficiency Period shall continue until a Year is determined to be other than a Dry or Critical Year.

TABLE III[1/]

MEAN MONTHLY HIGH TIDE[2/] ELECTRICAL CONDUCTIVITY (mmhos/cm)

Month	Deficiency Standards
October	19.0
November	16.5
December	15.6
January	15.6
February	15.6
March	15.6
April	14.0
May	12.5

1/ The same standards apply at all Control Stations in effect, although it is recognized that better water quality will be present at some Control Stations due to a salinity gradient within the Marsh.
2/ The monthly mean of both daily high tide EC's.

4. Review of Operations

(a) Every fifth year after this Agreement is executed the parties will review the effectiveness of the facilities constructed pursuant to this Agreement. The purpose of the review will be to determine if objectives of this Agreement are being achieved and if any adjustments are needed. During the review, recognized authorities such as U. C. Extension Service and U. S. Salinity Laboratory shall be asked to comment. Information on the relationships among water salinity, soil water salinity, and plant salinity tolerance gained from the Marsh monitoring program shall be considered during the review.

(b) Any necessary adjustments will be made by amending this Agreement.

5. Monitoring

DWR and DFG will monitor and report on surface water and soil water qualities, water elevations, marsh vegetation and wildlife species in accordance with the agreement among DWR, DFG, and USBR to provide for monitoring in the Marsh dated March 2, 1987 (monitoring agreement) or as it may be amended. Monitoring data will be available for inspection by SRCD.

FIGURE 1

SUISUN MARSH

CONTROL STATION LOCATIONS

C-2 SACRAMENTO RIVER AT COLLINSVILLE
S-21 CHADBOURNE SLOUGH AT CHADBOURNE ROAD
S-33 CORDELIA SLOUGH 500 FEET WEST OF SPRR
S-35 GOODYEAR SLOUGH AT MORROW ISLAND CLUBHOUSE
S-42 SUISUN SLOUGH 500 FEET SOUTH OF VOLANTI SLOUGH
S-49 MONTEZUMA SLOUGH NEAR BELDON LANDING-0.35 MILES EAST OF GRIZZLY ISLAND BRIDGE
S-64 MONTEZUMA SLOUGH THREE MILES SOUTH OF MEN'S LANDING
S-75 GOODYEAR SLOUGH SOUTH OF CONTROL STRUCTURE
S-97 CORDELIA SLOUGH AT CORDELIA-GOODYEAR DITCH

NOTE: THIS MAP FOR REFERENCE ONLY. THE SPECIFIC LOCATIONS ARE AS DESCRIBED IN TABLE II OR ARTICLE 8(b).

1 0 1 2 3 4
APPROXIMATE SCALE IN MILES

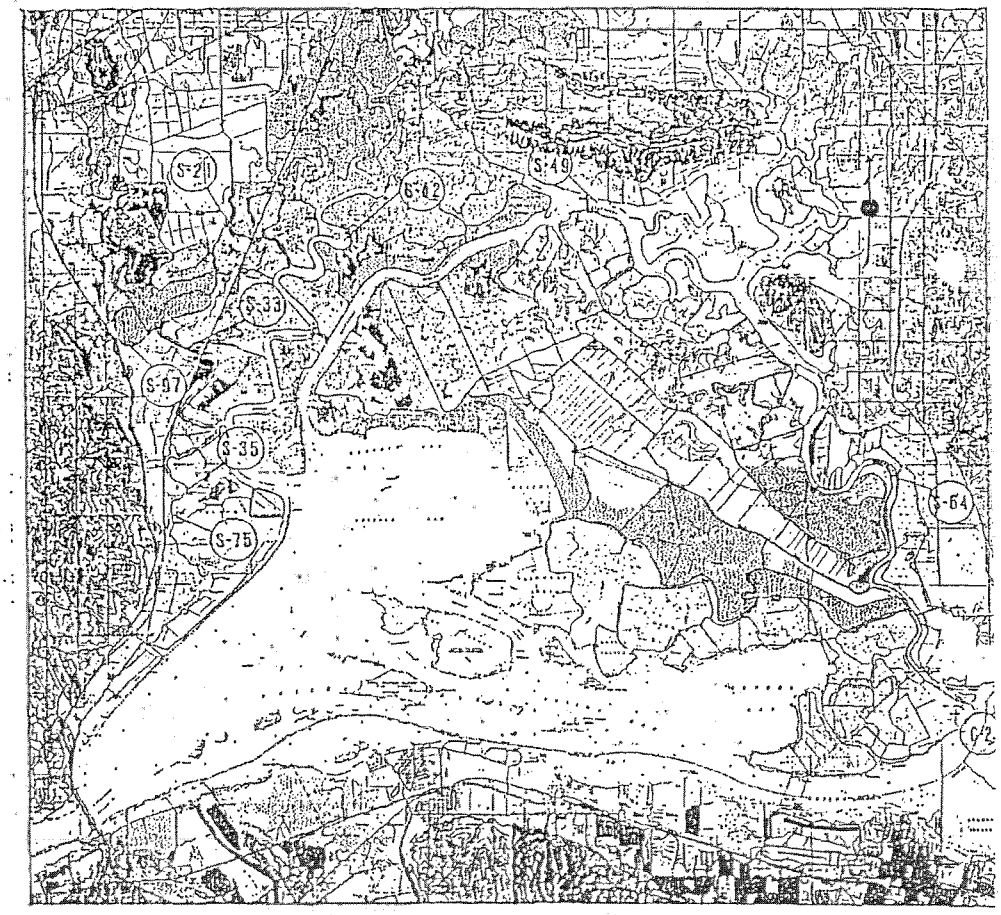


figure 1

6. Mitigation

USBR and DWR shall provide wetlands mitigation in accordance with the agreement among DWR, DFG, and USBR to provide waterfowl habitat in the Suisun Marsh dated March 2, 1987 for:

(1) the impacts on wetland habitat resulting from construction required under this Agreement, and

(2) adverse effects on Roe, Ryer, Snag, and Freeman Islands resulting from upstream water diversions.

7. Individual Ownership Facilities

(a) USBR and DWR will reimburse each Individual Ownership through SRCD fifty (50) percent of the initial cost of purchasing and installing any water intake and discharge facilities, other than those provided for in I through XI of Attachment A, necessary to enable the Individual Ownership to flood and drain its property within 30 days where such operation is necessary to achieve adequate levels of waterfowl food production as determined by DFG. It is recognized that water intake and discharge facilities on an Individual Ownership may supply water to or drain water from other Individual Ownerships. The total reimbursement obligation of USBR and DWR under this Article shall be limited to the amount specified in subarticle (c) and shall only be used for those water intake and discharge gates, culverts, flashboard risers, and pumps identified in the engineering level Individual Ownership Management Program developed for the property by SRCD, approved by DFG, and certified by the San Francisco Bay Conservation and Development Commission (BCDC).

(b) Prior to reimbursement pursuant to subarticle (a) the Individual Ownership shall first enter into an agreement with USBR, DWR, and SRCD which shall provide that the Individual Ownership will either follow the "needed practices" identified in its Individual Ownership Management Program or will repay with interest the funds provided by USBR and DWR.

(c) The obligation of USBR and DWR under this Article shall not exceed $995,000 (July 1, 1985 dollars, plus or minus such amounts, if any, as may be justified by ordinary fluctuations in construction costs, as indicated by the "Engineering News-Record's" cost indexes), shared in accordance with Article 12. USBR and DWR obligations under this Article shall terminate four years after the Montezuma Slough Control Structure Becomes Operational, or four years after the execution of this Agreement, whichever is later.

8. Construction and Operation of Facilities

(a) DWR shall construct the Montezuma Slough Control Structure, the Cygnus Unit, the Lower Joice Island Unit and the Annie Mason Island Unit by the end of the 1988 Construction Season provided that the work on Annie Mason Island shall not begin until the Exterior Levees of the Island are intact, which may delay completion of that unit until after 1988.

(b) When the Montezuma Slough Control Structure Becomes Operational, USBR and DWR shall test and evaluate its effectiveness in meeting the standards of subarticles 3(b) and (c), and decide which additional facilities are needed to meet those standards. Not later than three years after the Montezuma Slough Control Structure Becomes Operational:

(i) either Station S-33 will be substituted for Station S-97 in subarticle 3(b)(i) and DWR and USBR shall meet the standards in subarticle 3(b) and (c) at Stations S-21 and S-33, or DWR shall construct the Boynton-Cordelia Unit, or an alternate facility, and DWR and USBR shall meet the standards of subarticles 3(b) and (c) at Stations S-21 and S-97 not later than the end of the fifth full construction season after the Montezuma Slough Control Structure Becomes Operational; and

(ii) either DWR and USBR shall meet the standards in subarticle 3(b) and (c) at Station S-35, with that station being substituted for Station S-75 in Article 3(b)(i), or DWR shall construct the Cordelia-Goodyear Unit, or an alternate facility, and DWR and USBR shall meet the standards of subarticle 3(b) and (c) at Station S-75 not later than the end of the sixth full construction season after Montezuma Slough Control Structure Becomes Operational.

(c) USBR and DWR shall evaluate the need for the Grizzly Island Unit or an alternate facility to supply water meeting the standards of subarticles 3(b) and (c) to the area to be served by the Grizzly Island Unit. If the Grizzly Island Unit or an alternate facility is needed, DWR shall construct it in accordance with one of the following schedules:

(i) By the end of the seventh full Construction Season after the Montezuma Slough Control Structure Becomes Operational, if both the Boynton-Cordelia and Cordelia-Goodyear Units or alternate facilities are constructed; or

(ii) By the end of the sixth full Construction Season after the Montezuma Slough Control Structure Becomes Operational, if either the Boynton-Cordelia Unit or the Cordelia-Goodyear Unit or alternate facilities are not constructed.

(d) After the facility provided for in Subarticle (c) Becomes Operational or has been determined to not

be needed, USBR and DWR shall evaluate their ability to meet the standards of subarticle 3(b) and (c) at Station S-42 with the existing facilities. If USBR and DWR, based on the results of that evaluation, determine that further construction is unnecessary then they shall meet the standards in subarticles 3(b) and (c) at Control Station S-42 not later than three years from the date the facility provided for in subarticle (c) Becomes Operational or has been determined to not be needed. However, if they determine from that evaluation that the Potrero Hills Unit is needed, they shall complete construction of that unit or an alternate facility by the end of the fifth full Construction Season from the date the facility provided for in subarticle (c) Becomes Operational.

(e) Preliminary plans and specifications shall be furnished to USBR, SRCD, and DFG for review and comments. USBR and DWR shall consider the comments if received within thirty working days of the date the preliminary plans and specifications are furnished for review. Responses to comments will be provided on request of the parties. After comments and revisions have been considered, the plans and specifications shall be submitted to USBR for approval. The approval process shall be completed within 30 working days of the time DWR submits the plans to USBR for approval. All facilities shall be constructed substantially in accordance with the plans and specifications jointly approved by USBR and DWR.

SRCD, DFG, and the Individual Ownerships will incur no liability for the adequacy or suitability of any design as depicted in the preliminary plans and specifications by providing comments. Right-of-way agreements with Individual Ownerships will describe those design features which will be owned and operated by the Individual Ownership concerned.

(f) Before a facility Becomes Operational, it shall be operated to meet the applicable standards in subarticles 3(b) and (c) insofar as reasonably possible.

(g) The parties agree that if the facilities constructed pursuant to this Article do not provide the applicable water quality as specified in subarticles 3(b) and (c) due to inadequate design or construction, then USBR and DWR shall promptly modify the appropriate facility as necessary in accordance with subarticle 8(e). Pending completion of the modifications, USBR and DWR shall be relieved of the responsibility for meeting any standards dependent on the defective facility. To the extent possible, the defective facility will be operated to meet the objectives of this Agreement. Isolated minor incidents of failure to meet the applicable standards shall not be construed as requiring modification of a facility.

(h) The parties agree that if either the Marsh Model predictions or the Delta outflow/salinity relationships upon which this Agreement is based are substantially in error, they will renegotiate this Agreement. Pending renegotiation: (1) no

further facilities will be constructed; (2) the standards in effect prior to construction of the last facility will be met; and (3) the last facility will be operated to meet the standards provided for in this Agreement insofar as reasonably possible.

(i) If an Individual Ownership is unable to flood and drain within a thirty-day period due to either the design, construction, or operation of the Initial Facilities or facilities constructed pursuant to this Article, and, if the 30-day flood and drain capacity is necessary for that Individual Ownership to achieve adequate levels of waterfowl food production, as determined by DFG, then USBR and DWR shall modify the facilities or their operation as is necessary in accordance with subarticle 8(e).

(j) When the Montezuma Slough Control Structure Becomes Operational, USBR and DWR shall monitor and evaluate the quality of the water supply for Van Sickle and Chipps Island as measured at the O&A Ferry Landing on Chipps Island, or its equivalent.

DWR and USBR shall design, construct, and operate facilities, in accordance with subarticle 8(e), to provide water of the required quality, if either:

(i) the monitoring indicates that the EC of the water supply for either or both of the islands has actually exceeded the applicable standards in subarticles 3(b) and (c) for any four months in any two consecutive years, or

(ii) the evaluation projects that the EC of the water supply for either or both of the islands will exceed the applicable standards in subarticles 3(b) and (c) by more than ten percent for any four months in any two consecutive years.

If the evaluation indicates facilities will not be needed, the parties shall reassess the evaluation during each Review of Operation provided for in Article 4.

If facilities are determined to be needed, the scheduling of construction of these facilities shall be through consultation with SRCD and DFG.

(k) The responsibility for operation and maintenance of facilities shall be as listed in Attachment B which is made a part of this Agreement. DWR is shown as acting as the lead agency in Attachment B. However, USBR and DWR share responsibility for funding in accordance with Article 12.

9. Public Access

Lands owned or to be acquired in fee title by the State which are used for the construction or maintenance of the Overall Facilities may be accessible to the public for recreation use. With the exception of lands under DFG management, USBR and

DWR shall mutually determine after consultation with DFG and SRCD the extent to which such lands should be used for recreation consistent with safety, operational needs and potential damage to other lands.

10. Rights of Way

Where rights of way are required for work to be done under this Agreement, SRCD will exercise its best efforts to assure that the necessary easements and/or other appropriate title for each facility are granted. Delay in acquisition may delay completion of a facility within the time requirements provided for in Article 8 but shall not change the responsibility to complete that facility as expeditiously as possible.

11. Assurances

To assure the effective utilization of the water to be provided:

(a) SRCD shall diligently exercise its authority to require that Individual Ownerships be managed and operated in accordance with their Individual Ownership Management Programs, and so as not to interfere with the operation of the Overall Facilities.

(b) If the parties agree that an Individual Ownership by its acts or omissions interferes with the operation of any of the Overall Facilities and as a result the provisions of Article 3 cannot be met, then during the period of the Individual Ownership's interference, DWR and USBR shall neither be required to meet:

(i) the water quality standards which are affected by that interference; nor

(ii) the requirements of Subarticle 8(i) as it applies to the specifically affected Individual Ownerships.

(c) SRCD shall facilitate the formation of levee maintenance districts necessary to protect the facilities constructed pursuant to this Agreement. If USBR and DWR are unable to meet the standards because the Exterior Levees are in disrepair, USBR and DWR shall not be required to meet the standards to the extent the Exterior Levees are responsible.

(d) Nothing herein shall constitute a waiver of any rights USBR and DWR may have to pursue claims of damage due to failure to maintain the Exterior Levees.

12. Cost Sharing

(a) USBR shall pay Forty Percent (40%) and DWR shall pay Sixty Percent (60%) of the costs assigned to DWR and

USBR pursuant to Articles 5, 6, 7 and 8, whether incurred prior to the date of this Agreement or thereafter. The term "costs" shall include costs of planning, design, construction, operation, maintenance, and recreation. The term "costs" shall also include all administrative overhead, costs of liability insurance or pooling programs and other costs similar to those normally incurred by USBR which will be incurred by DWR in performance of the obligations under this Agreement.

(b) Specifically concerning design, planning, and construction costs, it is further agreed that USBR's share of these costs shall not exceed $50 million, July 1985 dollars, plus or minus such amounts, if any, as may be justified by reason of ordinary fluctuation in construction costs, as indicated by the "Engineering News-Record's" cost indexes.

(c) The United States shall pay to DWR the costs determined to be allowable by the Contracting Officer in accordance with the terms of this Agreement and with provisions of Federal Acquisition Regulations (FAR), Part 31, Subpart 6, 48 CFR Sections 31.601-31.603. If DWR uses any funds advanced pursuant to this Agreement for purposes not in accordance with this Agreement or not in compliance with FAR Part 31, Subpart 6, DWR shall reimburse USBR for the amount of any such improperly used funds.

(i) The USBR's share of costs incurred by DWR prior to the date of this Agreement plus the interest from the dates such costs were incurred, at the State Surplus Money Investment Fund rates, shall be paid to DWR in a lump sum payment following an audit of such costs by an authorized representative of the USBR, to be completed within six months after the execution of this Agreement.

(ii) On or before the first day of each month, after the date of this Agreement, USBR shall advance its contributions specified in this Article, in accordance with a billing statement furnished by DWR regarding expenditures estimated to be incurred during the month. Adjustments for overpayments or underpayments during a quarter shall be made in the quarter immediately following. Advances will be maintained at a level commensurate with current needs.

(d) Each year on or before September 15, DWR shall furnish to USBR a proposed budget of the estimated costs by quarter to be incurred under Articles 5, 6, 7 and 8 of this Agreement during the fiscal year beginning a year later on October 1, and the respective contributions of the parties. USBR shall notify DWR by the following September 15 of its full or partial approval of DWR's proposed budget. USBR's approval shall not be unreasonably withheld. In the event that USBR does not approve all budgeted costs, such unapproved costs shall not be eligible for reimbursement by USBR until such time as they are mutually

agreed upon by DWR and USBR. To facilitate USBR's review, each year's proposed budget should:

(i) include a schedule by physical feature or descriptive title of estimated operation and maintenance costs, supplemented with a narrative description which adequately describes and explains all major aspects of the fiscal year's proposed O&M program; and

(ii) include a schedule of estimated construction costs identifying major structures, facilities and related activities of the fiscal year's proposed construction program.

(e) Separate cost accounts shall be maintained by physical feature or descriptive title to permit ready audit.

13. Miscellaneous Provisions

(a) USBR and DWR have no objection to Individual Ownerships diverting water from the Marsh channels for wildlife habitat management on lands within the Marsh. USBR and DWR shall not disturb or challenge said diversions and uses so long as they are consistent with this Agreement while it is in full force and effect.

(b) SRCD and DFG shall not claim any right against USBR or DWR in conflict with the provisions hereof so long as this Agreement remains in full force and effect.

(c) This Agreement shall not affect, bind, prejudice, impair, restrict, or limit water rights pertaining to lands within the Marsh.

(d) SRCD consents to the storage of water and export of water from the Delta by the CVP and SWP so long as this Agreement remains in full force and effect and USBR and DWR are in compliance herewith.

(e) The parties agree to defend as reasonable and beneficial the water qualities established in this Agreement.

(f) DWR agrees to forego the use of eminent domain proceedings to acquire water rights in the Marsh.

14. SWRCB Approval

After this Agreement is executed by all the parties, they shall jointly petition the SWRCB to find that:

(a) DWR and USBR are taking appropriate action to mitigate the impacts of the CVP and SWP on the Marsh; and

(b) the Agreement is to be substituted for the Marsh standards in the CVP and SWP water rights permits.

15. Sharing of Water

When appropriate, the criteria identified in Article 6 of the "Agreement Between the United States and the California Department of Water Resources for the Coordinated Operation of the Federal Central Valley Project, and California State Water Project" (COA), dated November 24, 1986 shall be amended in accordance with the provisions of Article 14 of the COA to reflect the provisions of this Agreement.

16. Term of Agreement

This Agreement and any amendments hereto shall continue in full force and effect until terminated by the written agreement of all the parties.

17. Amendments

This Agreement may be amended at any time by mutual agreement of USBR, DWR, DFG and SRCD.

18. Remedies

Neither DWR nor USBR is responsible for the other's obligation under this Agreement.

19. Opinions and Determinations

Where the terms of this Agreement provide for action to be based upon the opinion, judgment, approval, review, or determination by the parties, such terms are not intended to be and shall not be construed as permitting such opinion, judgment, approval, review, or determination to be arbitrary, capricious, or unreasonable.

20. Successors and Assigns Obligated

This Agreement and all of its provisions shall apply to and bind the successors and assigns of the parties hereto.

21. Books, Records, Reports and Inspections

Subject to the applicable Federal and State laws and regulations, each party shall have the right to examine and make copies of each others books and official records relating to matters covered by this Agreement.

22. Waiver of Rights

Waiver at any time by any party hereto of its rights with respect to a default, or any other matter arising in connection with this Agreement, shall not be deemed to be a waiver with respect to any other default or matter.

23. Notices

All notices that are required either expressly or by implication to be given by one party to another shall be deemed to be given if delivered personally, or if enclosed in a properly addressed certified postage prepaid envelope with return receipt requested deposited in a United State Post Office. Unless or until formally notified otherwise, notices to the parties shall be addressed as follows:

Regional Director,
U. S. Bureau of Reclamation
2800 Cottage Way
Sacramento, CA 95825

Director, Department of Water Resources
P. O. Box 388
Sacramento, CA 95802

Director, Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

Manager, Suisun Resource Conservation District
P. O. Box 426
Suisun, CA 94585

24. Contingent Upon Availability of Funds

(a) Twenty percent of the funds to be expended for design and construction pursuant to Articles 5, 6, 7 and 8 shall be contingent on the appropriation of funds by the State Legislature for such purposes.

(b) The expenditure or advance of any money or the performance of any work by the United States hereunder which may require appropriation of money by the Congress or the allotment of funds shall be contingent upon such appropriation or allotment being made. No liability shall accrue to the United States in case such funds are not appropriated or allotted.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement on the date first written above.

Regional Director, Mid-Pacific Region
United States Bureau of Reclamation

Date 3/2/87

Director, Department of Water Resources

Date: 3/2/87

Director, Department of Fish and Game

Date: 3/2/87

Suisun Resource Conservation District

Date: 3/2/87

FORM | POLICY | BUDGET

Department of General Services
APPROVED
AUG 28 1987
By ELIZABETH YOST
Chief Deputy Director

I hereby certify that all conditions for exemption set forth in State Administrative Manual Section 1209 have been complied with, and this document is exempt from review by the Department of Finance.

Signature

Approved as to legal form and sufficiency:

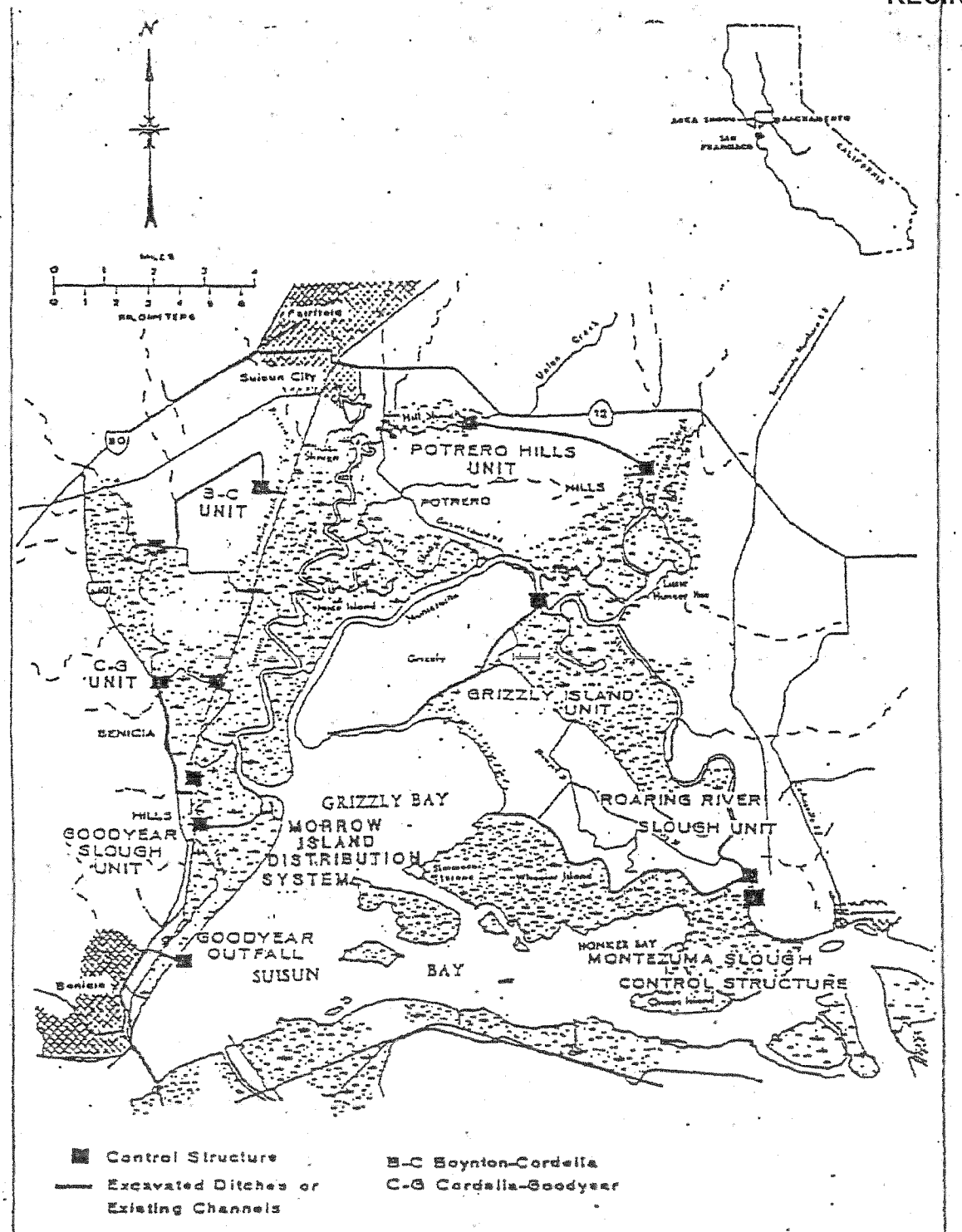
Asst. Chief Counsel, DWR

AUG 10 1987 1:1

SEP - 1987

FEB 24 1987 1:1 ... 1987 1:1

ATTACHMENT A



CONCEPTUAL PLAN OF THE
SUISUN MARSH OVERALL FACILITIES

ATTACHMENT "A"

OVERALL FACILITIES

I. Roaring River Slough Unit (Constructed)

A. Intake Facilities, including fish screens, control gates, culverts, tide gates, and the levee and road over the culverts.

B. Hammond Island Reservoir, 40 acres in the southeast corner of DF&G property adjacent to Montezuma Slough and Roaring River and the levees surrounding the reservoir.

C. Roaring River channel, including its north and south levees, the Mud Slough arm, including its north and south levees, and the crossing structures.

D. Wheeler Island boat ditches, levee and control gates.

E. Individual Ownership water intake and discharge facilities. These facilities include control gated culverts and access thereto.

F. A drainage facility, consisting of a control gated culvert.

II. Goodyear Slough Unit (Constructed)

A. Goodyear Slough Outfall, including a structure consisting of culverts with control gates discharging to a channel dredged from Goodyear Slough to the Bay.

B. Morrow Island Distribution System, including an intake structure consisting of a levee with control gated culverts through it, a ditch with levees on both sides, outlet structures consisting of levees with control gated culverts through them and access thereto.

C. Individual Ownership water intake facilities. These facilities include control gated culverts and access thereto.

D. The drainage facilities from the certain Individual Ownerships. These facilities include control gated culverts and access thereto.

E. The pond levee with flow controlled culverts north of Morrow Island Ditch.

III. Montezuma Slough Control Structure

A. Three radial gates, a boat lock 20 feet wide, and a flashboard opening 66 feet wide.

IV. Grizzly Island Unit

A. Intake Facilities, including fish screens, control gates, culverts, tide gates and the levee and road over the culverts.

B. Reservoir, 120 acres regulating reservoir.

C. Grizzly Island channel, including its north and south levees.

D. Lateral water supply ditches, including their east and west levees.

E. Individual Ownership water intake and discharge facilities. These facilities include control gated culvert(s) and access thereto.

V. Potrero Hills Unit

A. Intake and outlet facilities, including control gates, culverts, the levee and road over the culverts.

B. Potrero Hills channel, including its north and south levees and the crossing structures.

C. Ponds, two 15 acre ponds.

D. Necessary dredging in Luco and Hill Sloughs.

VI. Cordelia-Goodyear Unit Ditch

A. Intake and outlet facilities, including control structures, control gates, culverts, tide gates, and the levees and road over the culverts.

B. Cordelia-Goodyear channel, including its east and west levees and crossing structures.

C. Pond, one 20 acre pond.

D. Provision to handle storm runoff from the existing highway culverts.

E. Individual Ownership intake and discharge facilities. These facilities include control gated culvert(s) and access thereto.

F. Goodyear Slough Control Structure, including control gates and the levee and road over structure.

VII. Cygnus Unit

A. Drain facility consisting of 36-inch culvert, gate and flashboard riser on Individual Ownership No. 415.

VIII. Boynton-Cordelia Ditch Unit

A. Intake and outlet facilities, connection from Fairfield Suisun Sanitary District treatment plant.

B. Boynton Cordelia channel, including north and south levees, Chadbourne Road crossing structure and two siphons.

C. Necessary dredging in Boynton Slough relocation of Reclamation Ditch, provision of facility to handle sheet runoff.

IX. Lower Joice Island Unit

A. Fill facility consisting of 36-inch culvert and gate on Individual Ownership No. 424.

B. Connection to existing distribution system on Individual Ownership No. 424.

X. Annie Mason Island Unit

A. Installation of a diesel powered pump on Individual Ownership No. 801.

B. Connection to existing distribution system on Individual Ownership No. 801.

XI. Van Sickle/Chipps Island Unit (to be constructed when and if needed).

XII. Individual Ownership Facilities

A. Individual Ownership water management facilities as provided for in Article 7 of the Agreement.

ATTACHMENT B

ATTACHMENT "B"

RESPONSIBILITY FOR
SUISUN MARSH PLAN OF PROTECTION FACILITIES

Item	Design	Construction	Operate	Maintain
Montezuma Slough Control Structure				
All facilities	DWR	DWR	DWR	DWR
Grizzly Island Unit				
Intake structure	DWR	DWR	DWR	DWR
Fish screens	DWR	DWR	DWR	DWR
Ditch (including pond)	DWR	DWR	--	DWR
Laterals	DWR	DWR	--	DWR
Levees 2/	DWR	DWR	--	DWR
Crossing structures	DWR	DWR	--	DWR/County 6/
Turnouts	DWR 1/	DWR 1/	Landowner	Landowner 4/
Potrero Hills Unit				
Intake and outlet structures including dredging in Luco and Hill Sloughs	DWR	DWR	DWR	DWR
Ditch	DWR	DWR	--	DWR
Crossing structures	DWR	DWR	--	DWR/County 6/
Cordelia-Goodyear Unit				
Intake and outlet structures	DWR	DWR	DWR	DWR
Ditch (including ponds)	DWR	DWR	--	DWR
Laterals	DWR	DWR	--	DWR
Levees	DWR	DWR	--	DWR
Crossing structures	DWR	DWR	--	DWR/County 6/
Turnouts	DWR 1/	DWR 1/	Landowner	Landowner 4/
Goodyear Slough Control Structure	DWR	DWR	DWR	DWR
Boynton-Cordelia Unit 5/				
Intake and outlet structures	DWR	DWR	DWR	DWR
Ditch	DWR	DWR	--	DWR
Levees	DWR	DWR	--	DWR
Crossing structures	DWR	DWR	--	DWR

Item	Design	Construction	Operate	Maintain
Cygnus Unit				
Turnouts	DWR 1/	DWR 1/	Landowner	Landowner
Roaring River Unit				
Intake structures	DWR	DWR	DWR	DWR
Fish screens	DWR	DWR	DWR	DWR
Modified Channel (including pond)				
Levees 2/	DWR	DWR	--	DFG/DWR 3/
Laterals	DWR	DWR	--	DWR
Crossing structures	DWR	DWR	DWR	DWR
Turnouts	DWR 1/	DWR 1/	Landowner	Landowner 4/
Goodyear Slough Unit				
Intake structure	DWR	DWR	DWR	DWR
Outfall structure	DWR	DWR	DWR	DWR
Channel	DWR	DWR	--	DWR
Morrow Island Distribution System 2/	DWR	DWR	--	DWR
Turnouts and drainage facilities	DWR 1/	DWR 1/	Landowner	Landowner 4/
Lower Joice Island Unit				
Turnout	DWR	DWR	Landowner	Landowner 4/
Connection to the existing distribution system	DWR	DWR	--	DWR
Annie Mason Island Unit				
Pump	DWR	DWR	Landowner	DWR
Connection to the existing distribution system	DWR	DWR	--	DWR
Van Sickle/Chipps Island Unit	To be determined if constructed			

1/ Specific turnou.. and drain gates to be id.ified on design plans.

2/ Main channel water control levees only.

3/ DFG shall be responsible for maintaining the North Levee on Roaring River except for subsidence which prevents the Roaring River Unit from meeting its design purposes.

4/ DWR and USBR shall correct any deficiency due to design or construction which prevents any water facility from passing its design flow rate until May of the third operating season after the water facility Becomes Operational. After this period, all necessary corrections shall be the responsibility of the landowner of the Individual Ownership.

5/ An outfall is to be constructed to the Boynton-Cordelia pond from its treatment plant by Fairfield-Suisun Sanitary District (FSSD) at its expense.

6/ To be determined by separate agreement.

RESOLUTION OF THE BOARD OF DIRECTORS

OF THE SUISUN RESOURCE CONSERVATION DISTRICT

WHEREAS, the Suisun Resource Conservation District (District) has participated in negotiations which have led to a contractual agreement among the District, the State Departments of Fish and Game and Water Resources, and the U.S. Bureau of Reclamation; and

WHEREAS, the overall goal of this agreement is to provide improved water quality and wildlife habitat in the Suisun Marsh; and

WHEREAS, Dr. William Coon, past President of the District, has been instrumental in seeking ways to achieve this goal since the inception of the District in 1963;

NOW, THEREFORE, BE IT RESOLVED that the Board of Directors of the Suisun Resource Conservation District authorizes Dr. William Coon to sign the four agency contract on behalf of the District.

The foregoing resolution was passed unanimously by the Board of Directors of the Suisun Resource Conservation District this 5th day of November, 1986. Effective November 5, 1986.

Gail Presley

Gail Presley, Secretary

RECIRC2633

CONTRACT TRANSMITTAL AND PRE-EVALUATION

STD 15 (REV. 2/86)

DEPARTMENT TRANSMITTING CONTRACT: Water Resources

DIVISION, BUREAU, OR OTHER UNIT: Central District

AGENCY BILLING CODE	DATE	CONTRACT NUMBER
81000	3/2/87	B-56323

PLEASE NOTE: ITEMS 1 THROUGH 11 ON THE FRONT SIDE OF THIS FORM MUST BE COMPLETED FOR EVERY CONTRACT, REGARDLESS OF CONTRACT AMOUNT (WHETHER THE CONTRACT MUST BE SUBMITTED TO THE DEPARTMENT OF GENERAL SERVICES FOR REVIEW. IN ADDITION, ITEMS 1 THROUGH 6 ON T REVERSE SIDE MUST BE COMPLETED FOR ALL CONTRACTS FOR SERVICES. A COPY OF THE COMPLETED FORM MUST ACCOMPANY EACH CONTRA SUBMITTED TO GENERAL SERVICES FOR REVIEW. A COPY OF THE COMPLETED FORM MUST BE RETAINED IN AGENCY FILES FOR 3 YEARS FROM DA CONTRACT WAS EXECUTED.

1. NAME OF CONTRACTOR
U.S. Bureau of Reclamation, Department of Fish and Game, Department of Water Resources, Suisun Resource Conservation District

2. CONTRACTOR I.D. NUMBER (IF REQUIRED BY S.A.M. SECTION 1248.
NA

3. DIGEST OF CONTRACT (WORK TO BE PERFORMED, AMOUNT TO BE PAID, TERM). INCLUDE ANY SPECIAL OR UNUSUAL TERMS AND CONDITION

See Attached

4. REASON FOR CONTRACT (IDENTIFY SPECIFIC PROBLEM, ADMINISTRATIVE REQUIREMENT, PROGRAM NEED OR OTHER CIRCUMSTANCE MAKING THE CONTRACT NECESSARY)

To assure that a dependable water supply is maintained to mitigate adverse effects on the Marsh of the Central Valley Project and State Water Project and a portion of the adverse effects of other upstream diversions. Also see B-56321 and B-56322

5. IS THIS A RENEWAL OF A PREVIOUS CONTRACT OR SERVICE? YES ☐ NO ☒

6. SUMMARY OF BIDS:
A. LIST BIDDERS AND AMOUNTS BID
B. EXPLAIN:
1. AWARD OF CONTRACT IF TO OTHER THAN LOW BIDDER NA Interagency Agreement
2. IF SOLE SOURCE WHAT IS JUSTIFICATION?
3. IF ONLY ONE BID WAS RECEIVED OR SOLE SOURCE, BASIS FOR CONCLUDING REASONABLENESS OF CONTRACT RATE OR PRICE

Work Order No.: 1382-Var-6503; Randy Brown
1382-Var-6502; Carol Nelson
4126-Var)
6220-Var) Frank Lombard
5760-Var)

7425)
7423) Mike Cunnagin
7564)

Project Manager: George Barnes

ETHNIC CODES:

	MALE	FEMALE		MALE	F
BLACK AMERICANS	1	A	AMERICAN INDIANS/ALASKAN NATIVES	7	
ASIAN-PACIFIC AMERICANS	2	B	FILIPINO AMERICANS	8	
HISPANIC AMERICANS	4	D	ASIAN-INDIAN AMERICANS	9	
PACIFIC ISLANDERS	6	F	CAUCASIAN/WHITE	5	

(FOR ASSISTANCE WITH ITEMS 7 AND 8 BELOW, CALL THE OFFICE OF SMALL AND MINORITY BUSINESS IN THE DEPARTMENT OF GENERAL SERVICES.)

7. ENTER ETHNICITY OF CONTRACTOR FROM LIST ABOVE AS DEFINED IN S.A.M. SECTION 1204.4
NA

8. WAS THIS CONTRACT AWARDED TO A SMALL BUSINESS AS DEFINED IN S.A.M. SECTION 1204.17 ☐ YES ☐ NO NA

9. FOR CONTRACTS IN EXCESS OF $5,000 HAS THE LETTING OF THIS CONTRACT BEEN REPORTED TO THE DEPARTMENT OF FAIR EMPLOYMENT AND HOUSING PURSUANT TO S.A.M. SECTION 1212.11? ☐ YES ☐ NO NA

10. AUTHORIZED SIGNATURE
James U. McDaniel

11. NAME AND TITLE
James U. McDaniel, Chief, Central District

86

RECIRC2633

PRE-EVALUATION SECTION—MUST BE COMPLETED WHEN REQUESTING APPROVAL OF ANY CONTRACT FOR SERVI

1. JUSTIFICATION FOR CONTRACT (CHECK ONE)

☐ THIS CONTRACT IS TO BE EXECUTED TO ACHIEVE COST SAVINGS PURSUANT TO S.A.M. SECTION 1230.1. THE STATE PERSONNEL BO HAS BEEN SO NOTIFIED

☐ THIS CONTRACT IS TO BE EXECUTED PURSUANT TO CIVIL SERVICE CONSIDERATIONS CONTAINED IN S.A.M. SECTION JUSTIFICATION FOR THE CONTRACT IS DESCRIBED BELOW

NA

2. DESCRIBE THE SERVICE OR FINAL PRODUCT WHICH WILL RESULT, ITS BENEFIT AND THE ESTIMATED NUMBER OF PERSONS SERVED BY SU BENEFIT

NA

3. HOW WILL THE AGENCY USE THE CONTRACT PRODUCT? HOW WILL ITS USE BENEFIT THE AGENCY'S PROGRAM?

NA

4. WHY IS CONTRACTING THE MOST EFFECTIVE METHOD OF ACHIEVING THE AGENCY'S PURPOSE?

NA

5. WHAT BIDDING METHOD WAS USED TO SELECT THE VENDOR?

☐ REQUEST FOR PROPOSAL ☐ INVITATION FOR BID ☐ OTHER, EXPLAIN—USE ATTACHMENTS IF NECESSARY NA

PROOF OF PUBLICATION IN THE STATE CONTRACTS REGISTER MUST BE ATTACHED. IF SUCH PROOF IS NOT AVAILABLE, A REQUEST FOR EXEMPTION CONTRACT ADVERTISING, STD. FORM 621 MUST BE ATTACHED. (SEE S.A.M. SECTION 1212.6)

6. DOCUMENT EFFORTS MADE TO DETERMINE WHY PERSONNEL IN YOUR AGENCY OR IN OTHER STATE AGENCIES CANNOT PROVIDE THIS WORK. LIST WHIC SERVICE CLASSES WERE CONSIDERED, NAMES OF AGENCIES CONTACTED, AND EXPLAIN WHY THEY CANNOT PROVIDE THE REQUESTED SERVICES.

NA

7. HAVE ALL REQUIREMENTS GOVERNING THE USE OF CURRENT AND FORMER STATE EMPLOYEES AS SPECIFIED IN S.A.M. SECTION 1248 BEEN COMPLIED WITH?

☐ YES ☐ NO NA

3. DWR and DFG will monitor in the Marsh in accordance with the Suisun Marsh Monitoring Agreement. USBR and DWR will provide wetlands mitigation in the Marsh in accordance with the Suisun Marsh Mitigation Agreement. USBR and DWR will reimburse Individual Ownerships through SRCD, 50% of the initial cost of individual ownership facilities in accordance with Article 7 of the Agreement. DWR will construct and operate facilities in the Marsh in accordance with Article 8 of the Agreement.

Agreement amount - Article 12(a) requires the USBR to pay 40% of the costs incurred by DWR (including costs of planning, design, construction, operation, maintenance, and recreation prior to the Agreement) for monitoring, mitigation, individual ownership facilities, and Suisun Marsh facilities. Article 12(b) requires that the USBR's share of the design, planning, and construction costs not exceed $50 million. Total cost unknown at this time.

Agreement term - until terminated by the written agreement of all parties.

OCT 14 1988

David G. Houston, Regional Director
Mid-Pacific Region
Bureau of Reclamation
U. S. Department of the Interior
2800 Cottage Way, Room W1105
Sacramento, CA 95825-1898

Peter F. Bontadelli, Director
Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

Leland C. Lehman, President
Suisun Resource Conservation District
P. O. Box 426
Suisun City, CA 94585

Gentlemen:

This letter is to request your concurrence with the amendment of Table II and Subarticle 8(a) of the Suisun Marsh Preservation Agreement in accordance with Article 17 of that Agreement.

The Suisun Marsh Salinity Control Gates will be operable in October 1988 as required by Article 8(a) of the Agreement. A plan for testing and evaluating the effectiveness of the Control Gates is currently being developed. A network of monitoring locations on both the east and west sides of the Marsh has been selected to provide the information to be used in this evaluation.

Table II of the Agreement states that one of these sites, referred to as proposed S-21, is to be located in Chadbourne Slough at Chadbourne Road. We believe that while the monitoring location should remain in Chadbourne Slough, the proposed Chadbourne Road site is very vulnerable to known vandalism. Local club managers have stated that past structures built in this area have been quickly and thoroughly destroyed. A location that offers a greater degree of security would be in Chadbourne Slough on the west bank, approximately 150 feet above the bifurcation on the Sunrise Club. The club manager has indicated he would allow access to this area. This modification would move the S-21

site approximately 200 yards upstream of the proposed site at Chadbourne Road bridge. Electrical conductivity samples taken above and below the bifurcation indicate similar quality water between the two monitoring points.

Construction of the S-21 site cannot begin until permits or exemptions are granted from various agencies. In addition, Subarticle 8(a) of the Agreement also requires the construction of the Cygnus Unit, Lower Joice Unit and Annie Mason Unit by the end of the 1988 construction season. We plan to postpone the construction of the Cygnus and Lower Joice Island units until after the current duck hunting season, with all work to be completed before October 1, 1989. The landowner on Annie Mason Island has not completed the prerequisite repair work on exterior levees and, therefore, construction and installation of the pump and supply lines at that site would be premature.

Discussions among Suisun Resource Conservation District, the Department of Water Resources, and the Bureau of Reclamation have been proceeding for several months to enable the Suisun Resource Conservation District to administer construction contracts for the Lower Joice and Cygnus facilities. However, several aspects of this approach need further resolution. Due to time constraints, it will be necessary to schedule construction of these facilities after the upcoming duck hunting season. Landowners from both Lower Joice Island and Cygnus Island have consented to this postponement.

Therefore, I am requesting that the Suisun Marsh Preservation Agreement be amended as follows:

1. Modify the proposed monitoring site location for S-21 described in Table II entitled Control Stations in Article 3(b) from "Chadbourne Slough at Chadbourne Road" to "Chadbourne Slough 150 feet north of the bifurcation with Frank Horan Slough". The new location is: latitude 38°, 11', 04" north; and longitude 122°, 04', 56" west.

2. Substitute "1989" for "1988" on line three and line six of Subarticle 8(a) of the Agreement.

If you agree with the two recommended changes, please countersign all the copies of this letter and return them to me. When all the parties have executed the letter, we will furnish you with a conformed copy. Please feel free to contact me at (916) 445-6582, or George Barnes of our Central District office at (916) 445-1820, if you have any questions.

Sincerely,

Original Signed By
John P. Gaffrey

David N. Kennedy
Director

CONCUR:

Lawrence F. Hancock
Bureau of Reclamation

Date: 12-13-88

CONCUR:

Richard O. LeDallis
Department of Fish and Game

Date: 11-18-88

CONCUR:

Leland C. Lehman, Pres.
Suisun Resource Conservation District

Date: 11-2-88

APPROVED FOR LEGAL SUFFICIENCY:

Original signed by

Susan Weber, Chief Counsel

cc: See attached list

cc: Honorable Gordon K. Van Vleck
Secretary for Resources
The Resources Agency
1416 Ninth Street, Room 1311
Sacramento, CA 95814

Orville L. Abbott
Executive Officer and
Chief Engineer
California Water Commission
1416 Ninth Street, Room 1104-4
Sacramento, CA 95814

bcc: Rita Singer
Randy Brown
Ted Tsuruda
Jerry Cox

Harlan Proctor:ik
Text Area: HPBureau

STATE OF CALIFORNIA—THE RESOURCES AGENCY

PETE WILSON, Governor

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

MAR 28 1994

Mr. Roger Patterson, Regional Director
Mid-Pacific Region
Bureau of Reclamation
U. S. Department of the Interior
2800 Cottage Way, Room W1105
Sacramento, California 95825-1898

Mr. Boyd Gibbons, Director
Department of Fish and Game
1416 Ninth Street
Sacramento, California 95814

Mr. George Tillotson, President
Suisun Resource Conservation District
2516 A Grizzly Island Road
Suisun, California 94585

Gentlemen:

This letter is to request your concurrence with amendments to Article 7 Individual Ownership Facilities of the Suisun Marsh Preservation Agreement in accordance with Article 17 of that Agreement.

CURRENT ARTICLE 7 LANGUAGE

7. Individual Ownership Facilities

(a) USBR and DWR will reimburse each Individual Ownership through SRCD fifty (50) percent of the initial cost of purchasing and installing any water intake and discharge facilities, other than those provided for in I through XI of Attachment A, necessary to enable the Individual Ownership to flood and drain its property within 30 days where such operation is necessary to achieve adequate levels of waterfowl food production as determined by DFG. It is recognized that water intake and discharge facilities on an Individual Ownership may supply water to or drain water from other Individual Ownerships. The total reimbursement obligation of USBR and DWR under this Article shall be limited to the amount specified in subarticle (c) and shall only be used for those water intake and discharge gates, culverts, flashboard risers, and pumps identified in the engineering level Individual Ownership Management Program developed for the property by SRCD, approved by DFG, and certified by the San Francisco Bay Conservation and Development Commission (BCDC).

(b) Prior to reimbursement pursuant to subarticle (a) the Individual Ownership shall first enter into an agreement with USBR, DWR, and SRCD which shall provide that the Individual Ownership will either follow the "needed practices" identified in its Individual Ownership Management Program or will repay with interest the funds provided by USBR and DWR.

(c) The obligation of USBR and DWR under this Article shall not exceed $995,000 (July 1, 1985 dollars, plus or minus such amounts, if any, as may be justified by ordinary fluctuations in construction costs, as indicated by the "Engineering News-Record's" cost indexes), shared in accordance with Article 12. USBR and DWR obligations under this Article shall terminate four years after the Montezuma Slough Control Structure Becomes Operational, or four years after the execution of this Agreement, whichever is later.

PROPOSED ARTICLE 7 LANGUAGE

7. Individual Ownership Facilities

(a) USBR and DWR will reimburse each Individual Ownership through SRCD ~~fifty (50)~~ **seventy five (75)** percent of the initial cost of purchasing and installing any water intake and discharge facilities regardless of when the facilities were approved for payment, other than those provided for in I through XI of Attachment A, necessary to enable the Individual Ownership to flood and drain its property within 30 days where such operation is necessary to achieve adequate levels of waterfowl food production as determined by DFG. It is recognized that water intake and discharge facilities on an Individual Ownership may supply water to or drain water from other Individual Ownerships. The total reimbursement obligation of USBR and DWR under this Article shall be limited to the amount specified in subarticle (c) and shall only be used for **the development of engineering level Individual Ownership Water Management Plans meeting SRCD standards and** those **facilities** ~~water intake and discharge gates, culverts, flashboard risers, and pumps~~ identified **as needed improvements** in the engineering level Individual Ownership Management Program developed for the property by SRCD, approved by DFG, USBR and DWR, and certified by the San Francisco Bay Conservation and Development Commission (BCDC).

Payment to SRCD for the preparation of the engineering level Individual Ownership Management Plans meeting SRCD standards shall be a total of $12,900 for the period July 1, 1992 through June 30, 1993 and a total of $26,700 for the period July 1, 1993 through June 30, 1994.

Payment to SRCD for the period July 1, 1992 through June 30, 1993 will be made after DWR and USBR receive a progress report from SRCD detailing: 1) the results of the spot checks for elevations; 2) the new formulas developed to determine the water management facility plan for each ownership; and 3) the files detailing the computerized descriptions for each ownership.

Payment to SRCD for the period July 1, 1993 through June 30, 1994 will be made after DWR and USBR receive the following information from SRCD:

- A digitized copy of the data base.
- A digitized copy of the computer program used to establish the channel water elevations at the fill and drain sites and a digitized copy of the data files used to compute the water surface elevations and;
- A full Marsh map illustrating ownership boundaries and the location of bench marks used to establish ground elevations for the ownerships;

For each ownership:

- Ownership name, number and contact person;
- A description of the ownership's specific habitat objective, a copy of the current DFG and BCDC approved and the proposed management plan detailing required improvements;
- An ownership map illustrating the location and dimensions of channel fill and drain facilities (culverts, weir boxes, flow controllers and pumps), internal water distribution ditches, and the internal fill and drain flow patterns;
- Water surface elevations (relative to mean lower low water at the Golden Gate) for the higher high water and lower low water used in the determination of fill and drain durations;

- Total area in acres;
- Total flooded area in acres;
- Average pond bottom elevation relative to mean lower low water at the Golden Gate or other known datum;
- Average shooting depth above average pond bottom;
- A description of ownership's revised fill and drain practices including when filling starts, how long it takes to fill, when draining starts, how long to drain to one foot below average pond bottom (if possible) and the number of leach cycles performed each year; and
- Assumptions and special considerations (if any) applied during the determination of the revised plan.

(b) Prior to reimbursement for the cost of needed improvements pursuant to subarticle (a) the Individual Ownership shall first enter into an agreement with USBR, DWR, and SRCD which shall provide that for the useful life of the facility, the Individual Ownership will either follow the "needed practices" identified in its Individual Ownership Management Program or will repay with interest the funds provided by USBR and DWR.

(c) The obligation of USBR and DWR under this Article shall not exceed $995,000 (July 1, 1985 dollars, plus or minus such amounts, if any, as may be justified by ordinary fluctuations in construction costs, as indicated by the "Engineering News-Record's" cost indexes), shared in accordance with Article 12. USBR and DWR obligations under this Article shall terminate ~~four years after the Montezuma Slough Control Structure Becomes Operational, or four years after the execution of this Agreement, whichever is later~~ October 1, 1998, or the date the Western Suisun Marsh Salinity Control Project facilities becomes operational, whichever comes later.

If you agree with these changes, please countersign all copies of this letter and return them to me as soon as possible. When all parties have executed the letter, we will furnish you with a copy.

For further information, you may wish to contact Dwight Russell at (916) 323-8888.

Sincerely,

(sgd) David N. Kennedy

David N. Kennedy
Director

CONCUR:

U. S. Bureau of Reclamation

Date: 5/27/94

CONCUR:

Department of Fish and Game

Date: 5/17/94

CONCUR:

Suisun Resource Conservation District

Date: 4/6/94

APPROVED FOR LEGAL SUFFICIENCY:

Original signed by:

Susan N. Weber

Susan Weber, Chief Counsel

Date: MAR 1 6 1994

cc: (See attached list)

FORM | POLICY | PROC.

Department of Fish and Game

APPROVED

JUN 2 1 1994

BY ORIGINAL SIGNED BY GARRY NESS

Ass't. Chief Counsel

Mr. Garry Sackett
U. S. Bureau of Reclamation
2800 Cottage Way
Sacramento, California 95825

Mr. Lee Lehman
Suisun Resources Conservation District
2516 A Grizzly Island Road
Suisun, California 94585

Mr. Perry Herrgesell
Department of Fish and Game
4001 North Wilson Way
Stockton, California 95205

Mr. Frank Wernette
Department of Fish and Game
4001 North Wilson Way
Stockton, California 95205

Mr. Randall L. Brown
Department of Water Resources
Environmental Services Office
3251 S Street
Sacramento, California 95816

Mr. Harlan Proctor
Department of Water Resources
Environmental Services Office
3251 S Street
Sacramento, California 95816

Ms. Bellory Fong
Department of Water Resources
Environmental Services Office
3251 S Street
Sacramento, California 95816

Mr. Dwight Russell
Department of Water Resources
Environmental Services Office
3251 S Street
Sacramento, California 95816

Ms. Rita Singer
Department of Water Resources
Office of the Chief Counsel
1416 Ninth Street, Room 1118-10
Sacramento, California 95814

Contract No. 4600000633.1

EXHIBIT B
BUDGET DETAIL AND PAYMENT PROVISIONS

1. INVOICING AND PAYMENT: Contractor shall submit three (3) copies of the invoice to the State only after receiving **verbal** notice of satisfactory completion or acceptance of work by the DWR Contract Manager. **The State will not accept an invoice for which work has not been approved and will return the invoice as a disputed invoice to the Contractor.**

Itemized invoices may be submitted no more often than monthly, in arrears, bearing the contract number, the period covered, and a short description of the deliverables including, but not limited to, labor, equipment, materials, travel, overhead, and costs.

Submit two (2) copies of each invoice to the Contract Manager at the following address:

Department of Water Resources
Environmental Services Office
Attention: SMPA Contract Manager
3251 "S" Street
Sacramento, California 95816

Submit one (1) additional copy of each invoice simultaneously to the DWR Accounting Office at the following address in order to expedite approval and payment:

DWR Accounting Office, Contracts Payable Unit
P. O. Box 942836
Sacramento, California 94236-0001

Undisputed invoices shall be **approved for payment** within 45 days of the date received by the Contract Manager and/or the Accounting Office, whichever date occurs later.

2. BUDGET CONTINGENCY CLAUSE: It is mutually agreed that if the Budget Act of the current year and/or any subsequent years covered under this Agreement does not appropriate sufficient funds for the program, this Agreement shall be of no further force and effect. In this event, the State shall have no liability to pay any funds whatsoever to the Suisun Resource Conservation District (SRCD) or to furnish any other considerations under this Agreement and SRCD shall not be obligated to perform any provisions of this Agreement.

If funding for any fiscal year is reduced or deleted by the Budget Act for purposes of this program, the State shall have the option to either: cancel this Agreement

with no liability occurring to the State, or offer an Agreement Amendment to SRCD to reflect the reduced amount.

The contract amount is divided between Programs (1) through (4) as shown in Table B-1 and described in Article VIII of the Revised Suisun Marsh Perservation Agreement (Exhibit A).

Table B-1. Distribution of costs by task

Program Title	Initial Program Costs[1]	Annual Expenditure[2]
Water Manager Program/Individual Ownership	$130,600	$234,190
Adaptive Habitat Management Plans		
Drought Response Program	–	$80,596[3]
Portable Pumps Program	$547,757	–
Improvements to Roaring River turnouts	$67,164	–
TOTAL	$745,521	$314,786

1. Each year in July any unexpended funds will be adjusted for inflation as described in Article VIII.F of Exhibit A.
2. Each year in July these values will be adjusted for inflation as described in Article VIII.F of Exhibit A.
3. Expenditures from the Drought Response Program are on an as needed basis as defined in Article VII.B.4 of Exhibit A.

The distribution of costs in Table B-1 may be modified without amendment based on changes in actual costs for performing work under this Agreement, as allowed by State Administrative Manual, Section 8752. The Contractor shall inform DWR in writing that the distribution of costs will differ from those listed in the attached exhibits, immediately after the Contractor determines that costs will differ. The Contractor shall provide a new written revised budget to DWR; if so requested by DWR, prior to performing work.

Contract No. 4600000633.1

GTC 304

EXHIBIT C
Applicable to SRCD

GENERAL TERMS AND CONDITIONS

1. APPROVAL: This Agreement is of no force or effect until signed by both parties and approved by the Department of General Services, if required. Contractor may not commence performance until such approval has been obtained.

2. AMENDMENT: No amendment or variation of the terms of this Agreement shall be valid unless made in writing, signed by the parties and approved as required. No oral understanding or Agreement not incorporated in the Agreement is binding on any of the parties.

3. ASSIGNMENT: This Agreement is not assignable by the Contractor, either in whole or in part, without the consent of the State in the form of a formal written amendment.

4. AUDIT: Contractor agrees that the awarding department, the Department of General Services, the Bureau of State Audits, or their designated representative shall have the right to review and to copy any records and supporting documentation pertaining to the performance of this Agreement. Contractor agrees to maintain such records for possible audit for a minimum of three (3) years after final payment, unless a longer period of records retention is stipulated. Contractor agrees to allow the auditor(s) access to such records during normal business hours and to allow interviews of any employees who might reasonably have information related to such records. Further, Contractor agrees to include a similar right of the State to audit records and interview staff in any subcontract related to performance of this Agreement. (GC 8546.7, PCC 10115 et seq., CCR Title 2, Section 1896).

5. INDEMNIFICATION: Contractor agrees to indemnify, defend and save harmless the State, its officers, agents and employees from any and all claims and losses accruing or resulting to any and all contractors, subcontractors, suppliers, laborers, and any other person, firm or corporation furnishing or supplying work services, materials, or supplies in connection with the performance of this Agreement, and from any and all claims and losses accruing or resulting to any person, firm or corporation who may be injured or damaged by Contractor in the performance of this Agreement.

6. DISPUTES: Contractor shall continue with the responsibilities under this Agreement during any dispute.

7. TERMINATION FOR CAUSE: The State may terminate this Agreement and be relieved of any payments should the Contractor fail to perform the requirements of this Agreement at the time and in the manner herein provided. In the event of such termination the State may proceed with the work in any manner deemed proper by the State. All costs to the State shall be deducted from any sum due the Contractor under this Agreement and the balance, if any, shall be paid to the Contractor upon demand.

8. INDEPENDENT CONTRACTOR: Contractor, and the agents and employees of Contractor, in the performance of this Agreement, shall act in an independent capacity and not as officers or employees or agents of the State.

9. RECYCLING CERTIFICATION: The Contractor shall certify in writing under penalty of perjury, the minimum, if not exact, percentage of recycled content, both post consumer waste and secondary waste as defined in the Public Contract Code, Sections 12161 and 12200, in materials, goods, or supplies offered or products used in the performance of this Agreement, regardless of whether the product meets the required recycled product percentage as defined in the Public Contract Code, Sections 12161 and 12200. Contractor may certify that the product contains zero recycled content. (PCC 10233, 10308.5, 10354)

10. NON-DISCRIMINATION CLAUSE: During the performance of this Agreement, Contractor and its subcontractors shall not unlawfully discriminate, harass, or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, physical disability (including HIV and AIDS), mental disability, medical condition (cancer), age (over 40), marital status, and denial of family care leave. Contractor and subcontractors shall insure that the evaluation and treatment of their employees and applicants for employment are free from such discrimination and harassment. Contractor and subcontractors shall comply with the provisions of the Fair Employment and Housing Act (Government Code Section 12990 (a-f) et seq.) and the applicable regulations promulgated thereunder (California Code of Regulations, Title 2, Section 7285 et seq.). The applicable regulations of the Fair Employment and Housing Commission implementing Government Code Section 12990 (a-f), set forth in Chapter 5 of Division 4 of Title 2 of the California Code of Regulations, are incorporated into this Agreement by reference and made a part hereof as if set forth in full. Contractor and its subcontractors shall give written notice of their obligations under this clause to labor organizations with which they have a collective bargaining or other Agreement.

Contractor shall include the nondiscrimination and compliance provisions of this clause in all subcontracts to perform work under the Agreement.

11. CERTIFICATION CLAUSES: The CONTRACTOR CERTIFICATION CLAUSES contained in the document CCC 304 are hereby incorporated by reference and made a part of this Agreement by this reference as if attached hereto.

12. TIMELINESS: Time is of the essence in this Agreement.

13. COMPENSATION: The consideration to be paid Contractor, as provided herein, shall be in compensation for all of Contractor's expenses incurred in the performance hereof, including travel, per diem, and taxes, unless otherwise expressly so provided.

14. GOVERNING LAW: This contract is governed by and shall be interpreted in accordance with the laws of the State of California.

15. ANTITRUST CLAIMS: The Contractor by signing this agreement hereby certifies that if these services or goods are obtained by means of a competitive bid, the Contractor shall comply with the requirements of the Government Codes Sections set out below.
a. The Government Code Chapter on Antitrust claims contains the following definitions:
1). "Public purchase" means a purchase by means of competitive bids of goods, services, or materials by the State or any of its political subdivisions or public agencies on whose behalf the Attorney General may bring an action pursuant to subdivision (c) of Section 16750 of the Business and Professions Code.
2). "Public purchasing body" means the State or the subdivision or agency making a public purchase. Government Code Section 4550.

b. In submitting a bid to a public purchasing body, the bidder offers and agrees that if the bid is accepted, it will assign to the purchasing body all rights, title, and interest in and to all causes of action it may have under Section 4 of the Clayton Act (15 U.S.C. Sec. 15) or under the Cartwright Act (Chapter 2 (commencing with Section 16700) of Part 2 of Division 7 of the Business and Professions Code), arising from purchases of goods, materials, or services by the bidder for sale to the purchasing body pursuant to the bid. Such assignment shall be made and become effective at the time the purchasing body tenders final payment to the bidder. Government Code Section 4552.

c. If an awarding body or public purchasing body receives, either through judgment or settlement, a monetary recovery for a cause of action assigned under this chapter, the assignor shall be entitled to receive reimbursement for actual legal costs incurred and may, upon demand, recover from the public body any portion of the recovery, including treble damages, attributable to overcharges that were paid by the assignor but were not paid by the public body as part of the bid price, less the expenses incurred in obtaining that portion of the recovery. Government Code Section 4553.

d. Upon demand in writing by the assignor, the assignee shall, within one year from such demand, reassign the cause of action assigned under this part if the assignor has been or may have been injured by the violation of law for which the cause of action arose and (a) the assignee has not been injured thereby, or (b) the assignee declines to file a court action for the cause of action. See Government Code Section 4554.

16. CHILD SUPPORT COMPLIANCE ACT: "For any Agreement in excess of $100,000, the contractor acknowledges in accordance with, that:

a). The contractor recognizes the importance of child and family support obligations and shall fully comply with all applicable state and federal laws relating to child and family support enforcement, including, but not limited to, disclosure of information and compliance with earnings assignment orders, as provided in Chapter 8 (commencing with section 5200) of Part 5 of Division 9 of the Family Code; and

b) The contractor, to the best of its knowledge is fully complying with the earnings assignment orders of all employees and is providing the names of all new employees to the New Hire Registry maintained by the California Employment Development Department."

17. UNENFORCEABLE PROVISION: In the event that any provision of this Agreement is unenforceable or held to be unenforceable, then the parties agree that all other provisions of this Agreement have force and effect and shall not be affected thereby.

18. UNION ACTIVITIES For all contracts, except fixed price contracts of $50,000 or less, the Contractor acknowledges that:

By signing this agreement Contractor hereby acknowledges the applicability of Government Code Section 16645 through Section 16649 to this agreement and agrees to the following:
a) Contractor will not assist, promote or deter union organizing by employees performing work on a state service contract, including a public works contract.
b) No state funds received under this agreement will be used to assist, promote or deter union organizing.
c) Contractor will not, for any business conducted under this agreement, use any state property to hold meetings with employees or supervisors, if the purpose of such meetings is to assist, promote or deter union organizing, unless the state property is equally available to the general public for holding meetings.
d) If Contractor incurs costs, or makes expenditures to assist, promote or deter union organizing, Contractor will maintain records sufficient to show that no reimbursement from state funds has been sought for these costs, and that Contractor shall provide those records to the Attorney General upon request.

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EXHIBIT C1

SPECIAL TERMS AND CONDITIONS FOR DEPARTMENT OF WATER RESOURCES

APPLICABLE TO SRCD AS A LOCAL PUBLIC ENTITY (PAYABLES)

Exhibit C1
Special Terms and Conditions for Department of Water Resources Applicable to SRCD as a Local Public Entity (Payables)

1. COMPUTER SOFTWARE: For contracts in which software usage is an essential element of performance under this Agreement, the Contractor certifies that it has appropriate systems and controls in place to ensure that state funds will not be used in the performance of this contract for the acquisition, operation or maintenance of computer software in violation of copyright laws.

2. SEVERABILITY: If any provision of this Agreement is held invalid or unenforceable by any court of final jurisdiction, it is the intent of the parties that all other provisions of this Agreement be constructed to remain fully valid, enforceable, and binding on the parties.

3. EQUIPMENT RENTAL AGREEMENTS: This provision shall apply to equipment rental agreements. The State shall not be responsible for loss or damage to the rented equipment arising from causes beyond the control of the State. The State's responsibility for repairs and liability for damage or loss to such equipment is restricted to that made necessary or resulting from the negligent act or omission of the State or it's officers, employees, or agents.

4. CONFLICT OF INTEREST:

   a. Current and Former State Employees: Contractor should be aware of the following provisions regarding current or former state employees. If Contractor has any questions on the status of any person rendering services or involved with the Agreement, the awarding agency must be contacted immediately for clarification.

      (1) Current State Employees: (PCC §10410)

         (a) No officer or employee shall engage in any employment, activity or enterprise from which the officer or employee receives compensation or has a financial interest and which is sponsored or funded by any state agency, unless the employment, activity or enterprise is required as a condition of regular state employment.

         (b) No officer or employee shall contract on his or her own behalf as an independent contractor with any state agency to provide goods or services.

      (2) Former State Employees: (PCC §10411)

         (a) For the two-year period from the date he or she left state employment, no former state officer or employee may enter into a contract in which he or she engaged in any of the negotiations, transactions, planning, arrangements or any part of the decision-making process relevant to the contract while employed in any capacity by any state agency.

         (b) For the twelve-month period from the date he or she left state employment,

no former state officer or employee may enter into a contract with any state agency if he or she was employed by that state agency in a policy-making position in the same general subject area as the proposed contract within the 12-month period prior to his or her leaving state service.

b. Penalty for Violation:

(a) If the Contractor violates any provisions of above paragraphs, such action by Contractor shall render this Agreement void. (PCC §10420)

c. Members of Boards and Commissions:

(a) Members of boards and commissions are exempt from this section if they do not receive payment other than payment of each meeting of the board or commission, payment for preparatory time and payment for per diem. (PCC §10430 (e)

d. Financial Interest in Contracts:

Contractor should also be aware of the following provisions of Government Code §1090:
"Members of the Legislature, state, county district, judicial district, and city officers or employees shall not be financially interested in any contract made by them in their official capacity, or by any body or board of which they are members. Nor shall state, county, district, judicial district, and city officers or employees be purchasers at any sale or vendors at any purchase made by them in their official capacity."

e. Prohibition for Consulting Services Contracts:

For consulting services contracts (see PCC §10335.5), the Contractor and any subcontractors (except for subcontractors who provide services amounting to 10 percent or less of the contract price) may not submit a bid/SOQ, or be awarded a contract, for the provision of services, procurement of goods or supplies or any other related action which is required, suggested, or otherwise deemed appropriate in the end product of such a consulting services contract (see PCC §10365.5).

5. PAYMENT RETENTION CLAUSE: Ten percent of any progress payments that may be provided for under this contract shall be withheld per Public Contract Code Sections 10346 and 10379 pending satisfactory completion of all services under the contract.

6. RENEWAL OF CCC: Contractor shall renew the Contractor Certification Clauses or successor documents every (3) years or as changes occur, whichever occurs sooner.

7. AGENCY LIABILITY: The Contractor warrants by execution of this Agreement, that no person or selling agency has been employed or retained to solicit or secure this Agreement upon agreement or understanding for a commission, percentage, brokerage,

or contingent fee, excepting bona fide employees or bona fide established commercial or selling agencies maintained by the Contractor for the purpose of securing business. For breach or violation of this warranty, the State shall, in addition to other remedies provided by law, have the right to annul this Agreement without liability, paying only for the value of the work actually performed, or otherwise recover the full amount of such commission, percentage, brokerage, or contingent fee.

8. POTENTIAL SUBCONTRACTORS: Nothing contained in this Agreement or otherwise shall create any contractual relation between the State and any subcontractors, and no subcontract shall relieve the Contractor of its responsibilities and obligations hereunder. The Contractor agrees to be as fully responsible to the State for the acts and omissions of its subcontractors and of persons either directly or indirectly employed by any of them as it is for the acts and omissions of persons directly employed by the Contractor. The Contractor's obligation to pay its subcontractors is an independent obligation from the State's obligation to make payments to the Contractor. As a result, the State shall have no obligation to pay or enforce the payment of any moneys to any subcontractor.

9. REPORT RECYCLED CONTENT CERTIFICATION: In accordance with Public Contract Code Sections 10233, 10308.5 and 10354, the contractor must complete and return the form DWR 74, Recycled Content Certification, for each required product to the Department at the conclusion of services specified in this contract. Form DWR 74 is attached to this Exhibit and made part of this contract by this reference.

10. REIMBURSEMENT CLAUSE: If applicable, travel and per diem expenses to be reimbursed under this contract shall be at the same rates the State provides for unrepresented employees in accordance with the provisions of Title 2, Chapter 3, of the California Code of Regulations. Contractor's designated headquarters for the purpose of computing such expenses shall be: [redacted].

EXHIBIT D

GENERAL TERMS AND CONDITIONS FOR INTERAGENCY AGREEMENTS

APPLICABLE TO DFG AND DWR

Contract No. 4600000633.1

Exhibit D

GIA101 – General Terms and conditions for Interagency Agreements Applicable to DFG and DWR

1. APPROVAL: This Agreement is not valid until signed by both parties and approved by the Department of General Services, if required.

2. AUDIT: The agency performing work under this Agreement agrees that the awarding department, the Department of General Services, the Bureau of State Audits, or their designated representative shall have the right to review and to copy any records and supporting documentation pertaining to the performance of this Agreement if it exceeds $10,000. The agency performing work agrees to maintain such records for possible audit for a minimum of three (3) years after final payment, unless a longer period of record retention is stipulated.

3. PAYMENT: Costs for this Agreement shall be computed in accordance with State Administrative Manual Section 8752 and 8752.1.

4. AMENDMENT: No amendment or variation of the terms of this Agreement shall be valid unless made in writing, signed by the parties, and approved as required. No oral understanding or agreement not incorporated in the Agreement is binding on any of the parties.

5. SUBCONTRACTING: All subcontracting must comply with the requirements of the State Contracting Manual, Section 3.06.

6. ADVANCE PAYMENT: The parties to this interagency agreement may agree to the advancing of funds as provided in Government Code Sections 11257 through 11263.

7. DISPUTES: The agency performing work under this Agreement shall continue with the responsibilities under this Agreement during any dispute.

8. TIMELINESS: Time is of the essence in this Agreement.

EXHIBIT D1

SPECIAL TERMS AND CONDITIONS FOR DEPARTMENT OF WATER RESOURCES

APPLICABLE TO DFG AND DWR

Contract No. 4600000633.1

Exhibit D1
Special Terms and Conditions for Department of Water Resources Applicable to DFG and DWR

1. COMPUTER SOFTWARE: For contracts in which software usage is an essential element of performance under this Agreement, the Department of Fish and Game (DFG) and Department of Water Resources (DWR) certify that they have appropriate systems and controls in place to ensure that state funds will not be used in the performance of this contract for the acquisition, operation or maintenance of computer software in violation of applicable copyright laws.

2. SEVERABILITY: If any provision of this Agreement is held invalid or unenforceable by any court of final jurisdiction, it is the intent of the parties that all other provisions of this Agreement be constructed to remain fully valid, enforceable, and binding on the parties.

3. CONFLICT OF INTEREST:

   a. Current and Former State Employees: DFG and DWR should be aware of the following provisions regarding current or former state employees. If DFG or DWR have any questions on the status of any person rendering services or involved with the Agreement, the awarding agency must be contacted immediately for clarification.

      (1) Current State Employees: (PCC §10410)

         (a) No officer or employee shall engage in any employment, activity or enterprise from which the officer or employee receives compensation or has a financial interest and which is sponsored or funded by any state agency, unless the employment, activity or enterprise is required as a condition of regular state employment.

         (b) No officer or employee shall contract on his or her own behalf as an independent contractor with any state agency to provide goods or services.

      (2) Former State Employees: (PCC §10411)

         (a) For the two-year period from the date he or she left state employment, no former state officer or employee may enter into a contract in which he or she engaged in any of the negotiations, transactions, planning, arrangements or any part of the decision-making process relevant to the contract while employed in any capacity by any state agency.

         (b) For the twelve-month period from the date he or she left state employment, no former state officer or employee may enter into a contract with any state agency if he or she was employed by that state agency in a policy-making position in the same general subject area as the proposed contract within the 12-month period prior to his or her leaving state service.

b. Penalty for Violation:

(a) If DFG or DWR violate any provisions of above paragraphs, such action shall render this Agreement void. (PCC §10420)

c. Members of Boards and Commissions:

(a) Members of boards and commissions are exempt from this section if they do not receive payment other than payment of each meeting of the board or commission, payment for preparatory time and payment for per diem. (PCC §10430 (e)

d. Financial Interest in Contracts:

DFG and DWR should also be aware of the following provisions of Government Code §1090:
"Members of the Legislature, state, county district, judicial district, and city officers or employees shall not be financially interested in any contract made by them in their official capacity, or by any body or board of which they are members. Nor shall state, county, district, judicial district, and city officers or employees be purchasers at any sale or vendors at any purchase made by them in their official capacity."

e. Prohibition for Consulting Services Contracts:

For consulting services contracts (see PCC §10335.5), DFG or DWR and any of their subcontractors (except for subcontractors who provide services amounting to 10 percent or less of the contract price) may not submit a bid/SOQ, or be awarded a contract, for the provision of services, procurement of goods or supplies or any other related action which is required, suggested, or otherwise deemed appropriate in the end product of such a consulting services contract (see PCC §10365.5).

EXHIBIT E

SPECIAL TERMS AND CONDITIONS FOR DEPARTMENT OF WATER RESOURCES

APPLICABLE TO THE U.S. BUREAU OF RECLAMATION

Contract No. 4600000633.1

Exhibit E
Special Terms and Conditions for Department of Water Resources Applicable to the U.S. Bureau of Reclamation

1. OFFICIALS NOT TO BENEFIT: No member of or delegate to Congress or Resident Commissioner shall be admitted to any share or part of this Agreement or to any benefit that may arise herefrom. This restriction shall not be construed to extend to this agreement if made with a corporation for its general benefit.

2. NONDISCRIMINATION CLAUSE: During the performance of this Agreement, U.S. Bureau of Reclamation (USBR) and its subcontractors shall not unlawfully discriminate, harass, or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, physical disability (including HIV and AIDS), mental disability, medical condition (cancer), age (over 40), marital status, and denial of family care leave. USBR and its subcontractors shall insure that the evaluation and treatment of their employees and applicants for employment are free from such discrimination and harassment. USBR and its subcontractors shall give written notice of their obligations under this clause to labor organizations with which they have a collective bargaining or other Agreement.

   USBR shall include the nondiscrimination and compliance provisions of this clause in all subcontracts to perform work under the Agreement. This provision shall apply to the extent provided by federal laws, rules, and regulations.

3. INDEPENDENT CONTRACTOR: The USBR, and its agents and employees, in the performance of this Agreement, shall act in an independent capacity and not as officers or employees or agents of the State.

4. SEVERABILITY: If any provision of this Agreement is held invalid or unenforceable by any court of final jurisdiction, it is the intent of the parties that all other provisions of this Agreement be constructed to remain fully valid, enforceable, and binding on the parties.

5. TIMELINESS: Time is of the essence in this Agreement.

6. SOFTWARE COPYRIGHT: For contracts in which software usage is an essential element of performance under this Agreement, the USBR certifies that it has appropriate systems and controls in place to ensure that state funds will not be used in the performance of this contract for the acquisition, operation or maintenance of computer software in violation of applicable copyright laws.

EXHIBIT F

DEPARTMENT OF WATER RESOURCES STANDARD CONTRACT PROVISIONS REGARDING POLITICAL REFORM ACT COMPLIANCE

APPLICABLE TO DFG AND SRCD

Contract No. 4600000633.1
Exhibit F

California Department of Water Resources

Standard Contract Provisions Regarding Political Reform Act Compliance

1. POLITICAL REFORM ACT REQUIREMENTS:

   a. Form 700 Disclosure: The Department of Water Resources (DWR) considers that the Contractor, subcontractor(s), and/or their key staff may be a consultant, i.e., a public official, within the meaning of the Political Reform Act, specifically Government Code §82048 and Title 2, California Code of Regulations §18701. Accordingly, as specified by DWR, such persons shall complete and submit to the DWR Personnel Officer a Form 700, Statement of Economic Interests, within 30 days of the earlier of the date work commences or the effective date of this agreement, updated both annually and when changes in key staff or duties occur. The financial interests disclosed shall be for Disclosure Category 1. Contractors may access the Form 700 on the Fair Political Practices Commission website at www.fppc.ca.gov. Any questions regarding completion of the Form 700 should be addressed to the FPPC at its website or at (866) 275-3772 (866/ASK-FPPC). A leaving office statement must also be filed upon completion of all contract assignments.

   b. Financial Conflict of Interest Prohibition: Contractor must review the Form 700s filed by its key staff and subcontractors and determine whether, in the light of the interests disclosed, performance under the contract could violate Government Code §87100. Contractor shall notify DWR immediately of any potentially disqualifying conflict of interest. Government Code §87100 provides:

      > "No public official at any level of state or local government shall make, participate in making or in any way attempt to use his official position to influence a governmental decision in which he knows or has reason to know he has a financial interest."

   c. Consequences of Failure to Comply with Political Reform Act Requirements: Any one of the following shall constitute a breach of this Contract and shall be grounds for immediate termination of this Contract:

      (1) Failure to complete and submit all required Form 700s within the 30-day period as required in paragraph A above, or respond to any

request from the DWR Personnel Officer for additional information regarding any such Form 700s;

(2) Failure to notify DWR of a potentially disqualifying conflict of interest;

(3) The determination by DWR or the Contractor that any individual, who is a contractor, subcontractor, and/or a key member of their staff, has a financial interest that could result in a violation of Government Code §87100 provided, however, that DWR may opt to waive such breach if Contractor replaces any such individual within two working days after a determination of such financial interest.

RECIRC2633

AUGUST 2012

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

Tidal Wetland Vegetation in the San Francisco Bay-Delta Estuary

Michael C. Vasey[1,4], V. Thomas Parker[1], John C. Callaway[2], Ellen R. Herbert,[1] and Lisa M. Schile[3]

ABSTRACT

We analyzed tidal wetland vegetation patterns in the San Francisco Bay–Delta estuary (Bay–Delta) and discuss their significance for future conservation. Our objective was to conduct a balanced, random sample of six historic "remnant" tidal wetlands along a salinity gradient that ranged from southern San Pablo Bay to the lower Delta. We also wanted to compare diversity among these sites at five different scales, ranging from small subplots to total species per site. We randomly established twenty 0.1-ha plots at each site, and sampled ten 7-m^2 circular subplots (subplot scale) in each plot for species presence and cover. We calculated total species per plot (plot scale) and total species per site (site scale) based on these subplot data. We calculated importance values for each species found in subplots based on frequency of occurrence and proportion of total cover at each site. In addition, we recorded species found within the 0.1-ha plot but not sampled in subplots (plot_all scale), and calculated the total species for each site based on these plot_all data (site_all scale). Thus, richness at each site was evaluated at five different scales that ranged from 7 m^2 to 20,000 m^2. We conducted a one-way ANOVA that compared mean richness among three scales with continuous data: subplot, plot, and plot_all. At lower estuary (San Pablo Bay) sites, richness values at these three scales were significantly lower than upper estuary (Suisun–Delta) sites. In Suisun–Delta sites, significant differences in richness varied, depending on sampling scale. Rush Ranch, a brackish wetland, had the highest average number of species per plot, whereas Sand Mound Slough, a freshwater wetland, had the highest average number of species at the subplot scale and the most total species at the site_all scale. Sand Mound Slough also had the highest number of unique species (22) compared to the other sites. We found a strong negative correlation ($r^2 = 0.99$) between total species number and salinity (the most in the Delta at the lowest salinity, and the least at China Camp with the greatest salinity). Our analysis suggests the following conservation recommendations: (1) restore habitat for freshwater plant species diversity in the Delta; (2) restore transitional brackish wetland habitat in salt marshes of the San Pablo Bay and San Francisco Bay; and (3) focus on control of pepperweed (*Lepidium latifolium*) in brackish marshes.

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KEY WORDS

San Francisco Bay-Delta, tidal wetland vegetation, sampling scale, species richness, importance value, salinity gradient, conservation strategies

INTRODUCTION

At approximately 3,400 km^2 (Atwater and others 1979), the San Francisco Bay-Delta (Bay-Delta) is the largest and most complex embayment along the Pacific coast of North America. Over 55% of the historic tidal wetlands in California were originally located in this once vast estuary (Macdonald and Barbour 1974). Subsequently, approximately 95% of Bay-Delta tidal wetlands have been modified by various human practices (Atwater and others 1979). Hardest hit was the freshwater Delta region that once covered ca. 140,000 ha (Atwater and others 1979) and was diked and "reclaimed" for agriculture by the early 1920s. In the late 1800s and early 1900s, the margins of the Suisun, San Pablo, and San Francisco Bays were impacted by a variety of land use practices, including agriculture, creation of seasonal duck hunting ponds, salt pond production, and bay fill for urban development. By some estimates, thirty percent of the open water of the Bay-Delta has been lost through diking and filling (Goals Project 1999). During the 20th century, tidal wetlands began to regenerate in the Bay-Delta as levees degraded and former wetlands were reclaimed by natural processes. Wetland plant species colonized extensive outboard mudflats created by the legacy of sediments deposited by upstream hydraulic gold mining, so called "centennial marshes" (PWA and Faber 2004). This marsh recovery has been augmented in the latter part of the century by intentional restoration, at first for mitigation purposes (Josselyn 1982) and, as the ecological importance of tidal wetland habitats became more fully appreciated, through large-scale wetland restoration projects (Williams and Faber 2001; Callaway and others 2011).

The floristic composition of Bay-Delta tidal wetlands is still poorly documented (Macdonald and Barbour 1974). Given the size and complexity of the Bay-Delta, difficulties of access, and the scale of historic human impacts, we have limited knowledge of tidal wetland species composition from relatively few localities (e.g., Atwater and others 1979). In San Francisco and San Pablo bays, transitional habitats between salt marsh plains and adjacent uplands have been so heavily affected by human practices that their former species are now largely extirpated, and the flora of these transitional areas is not generally recognized as part of the Bay-Delta wetland ecosystem (Baye and others 2000). One of the reasons China Camp State Park and Rush Ranch Open Space Preserve are valuable is because they both contain upland-wetland transition habitats, which are now extremely rare (Baye in press; Whitcraft and others 2011). Both of these sites are components of the San Francisco Bay National Estuarine Research Reserve (NERR) and the focus of this special issue.

Salt and brackish wetlands of Suisun Bay, San Pablo Bay, and San Francisco Bay have received the most study, while there has been much less focus on freshwater tidal wetlands of the Delta (e.g., Josselyn 1983; Goals Project 1999; Baye and others 2000; Grewell and others 2007). This focus on the more saline portions of the estuary has confounded a deeper understanding of the Bay-Delta wetland ecosystem as a whole. Today, Delta tidal wetlands are the poorest known element of Bay-Delta vegetation, despite their former widespread extent, and their contribution to the broad intermingling of freshwater, brackish, and saltwater wetland species that occur in the Bay-Delta.

In this study, we employed a balanced, random quantitative analysis of six historic remnant wetlands that span the salt-to-freshwater gradient that characterizes the Bay-Delta region (Figure 1). While we have multiple research goals and activities, we present preliminary results of ongoing tidal wetland vegetation studies. Although these sites were selected for a variety of research purposes, they reflect the extent of historic remnant wetlands along the Bay-Delta regional salinity gradient. We explored different scales of vascular plant species richness. We used frequency of occurrence and proportion of total cover to calculate an importance value (IV) index to characterize dominance and diversity relationships for each individual species at each site. While we recognize that many factors influence local vegetation patterns

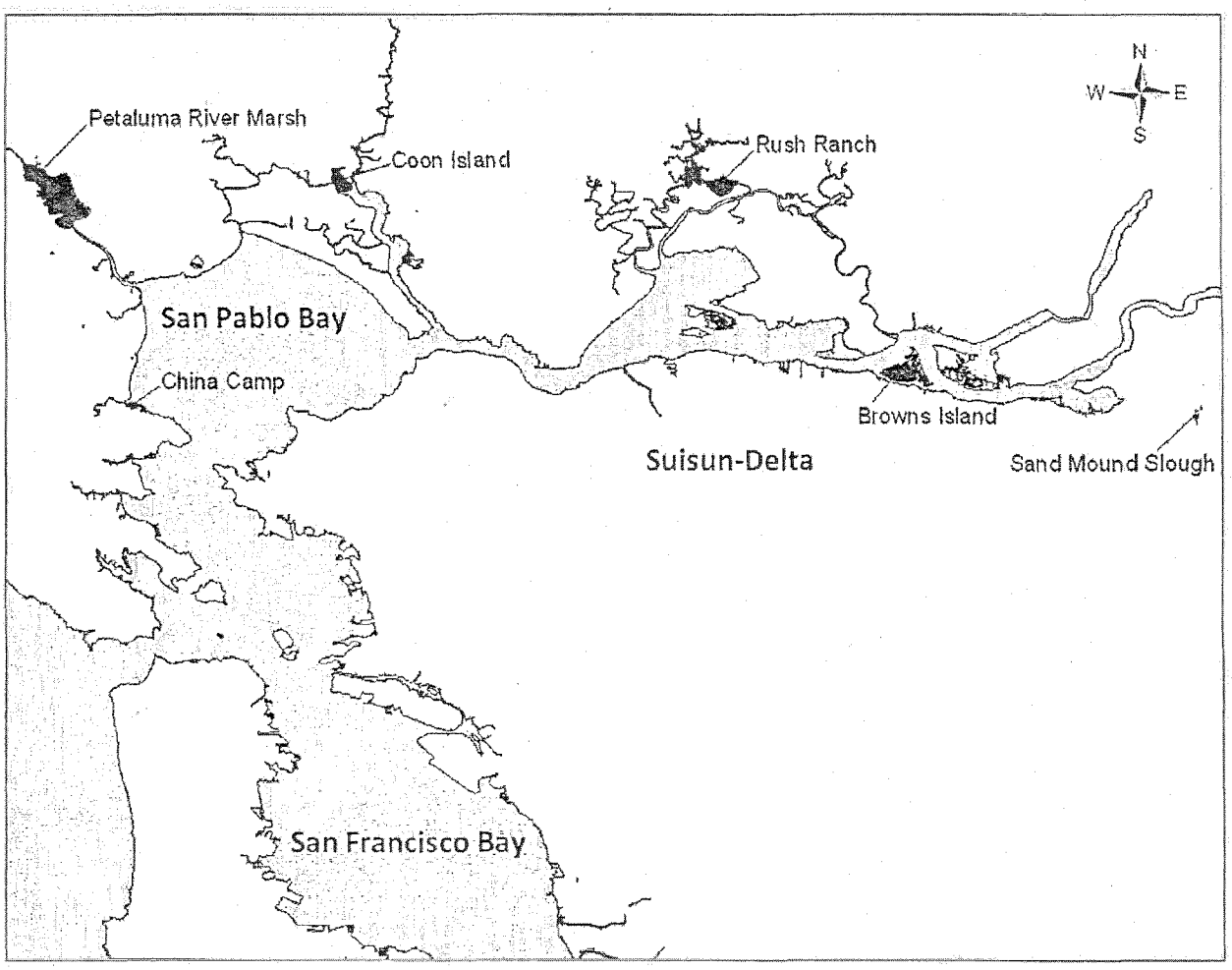

Figure 1 Distribution of six sample sites in the San Francisco Bay-Delta estuary. Different subregions are identified in bold font.

other than ambient salinity regimes (e.g., duration of inundation; see Schile and others 2011), we focused on a regional scale at which salinity generally drives compositional shifts within the tidal wetland species pool throughout the Bay–Delta (Grewell and others 2007). One of the primary concerns about rapid climate change is its potential to shift salinity gradients at a regional scale (Parker and others 2011). Based on our findings, we offer some recommendations for regional conservation actions that apply to Bay–Delta tidal wetland vegetation.

METHODS

We investigated six sites across the Bay–Delta salinity gradient: three sites in the lower estuary (hereafter referred to as San Pablo Bay) that have been influenced by relatively high salinity regimes and three sites in the Upper Estuary (hereafter referred to as Suisun–Delta) that have been influenced by brackish and freshwater conditions (Table 1). The San Pablo Bay sites included China Camp State Park (China Camp), Petaluma Marsh State Reserve (Petaluma Marsh), and Coon Island State Reserve (Coon Island).

Table 1 Geographic and salinity profiles for the six study sites sampled in two subregions of the San Francisco Bay-Delta estuary. Salinity regimes are based on the Venice system (Anonymous 1959). Salinity ranges were obtained at tidal creek margins for each site during summer and fall 2008 to 2010.

Code	Site	Area	Subregion	Latitude	Longitude	Salinity	ppt
CC	China Camp	125 ha	San Pablo Bay	38° 0.745 N	122° 29.300 W	Polyhaline	28±4
PM	Petaluma Marsh	800 ha	San Pablo Bay	38° 11.315 N	122° 33.550 W	Polyhaline	27±4
CI	Coon Island	175 ha	San Pablo Bay	38° 11.630 N	122° 19.500 W	Polyhaline	21±3
RR	Rush Ranch	400 ha	Suisun-Delta	38° 12.000 N	122° 2.000 W	Mesohaline	6±2
BI	Browns Island	200 ha	Suisun-Delta	38° 2.350 N	121° 51.800 W	Oligohaline	4±2
SMS	Sand Mound Slough	25 ha	Suisun-Delta	38° 0.275 N	122° 37.400 W	Limnetic	0±0

The Suisun-Delta sites included Rush Ranch Open Space Preserve (Rush Ranch), Browns Island Regional Shoreline (Browns Island) and Sand Mound Slough. China Camp, located in western San Pablo Bay, is the most saline of these tidal wetlands, and its vegetation is generally typical of central and south San Francisco Bay wetlands (Josselyn 1983, Grewell and others 2007). It is dominated by a large high marsh plain with fringing low marsh and an elaborate, dendritic network of channels. Petaluma Marsh occurs at the upper reaches of Petaluma River Slough, a major tidal slough that drains a watershed in northwestern San Pablo Bay and consequently receives seasonal freshwater influence. Petaluma Marsh is the largest remnant historic salt marsh in the San Francisco Bay estuary and also has a well-developed system of tidal creeks. Coon Island is a brackish wetland in the tidally influenced portion of the Napa River that enters northeastern San Pablo Bay. The larger watershed of the Napa River provides more freshwater influence than that received by the Petaluma Marsh.

Of the three Suisun-Delta sites, Rush Ranch is the most saline, and occurs along the upper reaches of Suisun Slough in the western Suisun Marsh. Rush Ranch is the largest remnant tidal wetland in the Suisun region. Browns Island is a large island at the margin of the eastern Suisun Bay and western Delta, while Sand Mound Slough is an archipelago of six small islands in the south-central Delta between diked former freshwater wetlands. Tidal creeks in the Suisun-Delta tend to be fewer and less dendritic than those in San Pablo Bay, and all three of these sites have lower annual salinity regimes than the three San Pablo Bay sites (Table 1).

For each of these six sites, we randomly chose pairs of spatial coordinates on ArcMap version 8.0 (ESRI Anaheim, CA, USA) using Hawth's tools (Beyer 2004). Sampling was not stratified by a preconceived vision of vegetation types because our intention was to randomly sample twenty 20 × 50 m plots at each site within intact natural wetland vegetation, incorporating less than 10% open water, and with no obvious human disturbances. We navigated to sample sites using a hand-held Garmin 76S GPS receiver (1- to 5-m accuracy), and established 20 × 50 m plots (0.1 ha) (long axis east to west). Within each 0.1-ha plot, all species present were identified; abundance was assessed using ten randomly positioned, 3-m diameter (~7.0 m^2) circular subplots employing a modified Daubenmire cover class approach (Daubenmire 1959). Sampling was conducted during the summers of 2007 and 2008. Teams of two to four people sampled each plot. Additionally, we sampled pore-water salinity concentrations at tidal creek margins from each site during late summer and fall 2008 to 2010 using a refractometer. We obtained 5 to 12 readings from each site during this interval. Although salinity at these sites shifts annually and seasonally, the regional salinity gradient is generally consistent, and provides a relatively robust context in which to compare species composition in these widely spaced sites (Table 1).

Data from each wetland were analyzed at different spatial scales (see Figure 2 for design). Richness (i.e.,

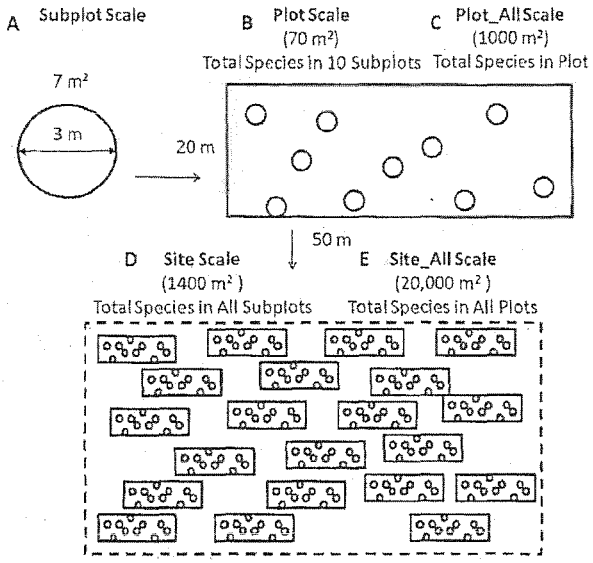

Figure 2 Sampling scales for species richness. **A.** Subplot scale: circular plots 3-m diameter, 7-m^2 area; **B.** Plot scale: 10 subplots within 0.1-ha plot, 70-m^2 area; **C.** Plot_all scale: all species found within 0.1-ha plot, both in and out of subplots, 1,000-m^2 area; **D.** Site scale: total of all subplots (200) within 20 plots at each site, 1,400 m^2 area; **E.** Site_all scale: all species found in and out of subplots within 20 plots at each site, 20,000 m^2 area.

the number of species per sample unit) was based on species presence-absence at each scale. We calculated the mean number of species per subplot (subplot scale =7.0 m^2), mean number of species per 0.1-ha plot using only subplot data (plot scale = 70 m^2), and total number of species per 0.1-ha plot (plot_all scale = 1,000 m^2), including all species recorded in subplots as well as species found in the 0.1 ha plot but not in subplots. We then calculated the total number of species per site based on the 200 subplot data (site scale = 1,400 m^2), and total number of all species found in the sites, including those not found in the subplots (site_all scale = 20,000 m^2).

At each site, we added midpoint cover class values for all species in all subplots (n =200), summed these values for all species, and then divided each species total by the sum of the total cover for all species, yielding a proportion of total cover for each species (relative abundance). We then totaled the number of subplot occurrences for each species and divided this total by 200 to yield the relative frequency of occurrence for each species. An IV was then calculated for each species as: [(relative abundance + relative frequency) / 2 × 100]. This IV index ranges from 0 to 100, and integrates both the proportion of total abundance and frequency of occurrence data for individual species so that, for example, widespread species with relatively low cover values (e.g., herbaceous dicots) are given greater weight than if only species abundance values were considered (Barbour and others 1987).

We analyzed data with JMP 8.0 (SAS Cary, NC, USA) for differences between sites at subplot, plot, and plot_all scales by separate one-way ANOVAs. We estimated differences among sites using a Tukey HSD test of *post hoc* contrasts. Before running the one-way ANOVAs, data were analyzed for normality. Plot and plot-all data met the assumptions of normality, but sub-plot data required square root transformation. To explore the possible relationship between total number of species per site (site_all scale), salinity, and area, we ran two linear regression models with total species per site as the dependent variable, and area or salinity as independent variables. In both models, residuals were normal, and Cook's Distance values were less than one (i.e., there was no problem with outliers). We collected voucher specimens of sampled species and deposited them at San Francisco State University.

RESULTS

At all sampling scales, the more saline San Pablo Bay sites contained significantly fewer species than the Suisun–Delta sites (Table 2, Figure 3). For example, at the subplot (7 m^2), plot (70 m^2), and plot_all (1,000 m^2) scales, San Pablo Bay sites contained approximately half the number of species as Suisun–Delta sites. While the greatest contrast in species richness occurs between San Pablo Bay and the Suisun–Delta, there are more subtle contrasts between the three Suisun–Delta sites at different scales (Table 2). At the plot and plot_all scales, for example, Rush Ranch averaged significantly more species than

Table 2 Mean and standard error values for species richness from six sites at subplot (7 m^2), plot (70 m^2), and plot_all (1,000 m^2) scales. Site (1,400 m^2) and site_all (20,000 m^2) values represent total species from all subplots per plot and all species per plot (including species not found in subplots), respectively. Superscript letters for subplot, plot, and plot_all represent significant differences based on one-way ANOVA and post hoc Tukey HSD tests. F values and subscript df are provided where applicable.

Site	CC	PM	CI	RR	BI	SMS	F value	P
Subplot	2.5ab±0.1	2.8b±0.1	2.3a±0.1	5.2cd±0.2	4.7c±0.2	5.4d±0.2	5,1191=31.4	<0.0001
Plot	5.2a±0.5	5.8a±0.5	4.8a±0.6	12.4c±0.6	10.4b±0.6	10.8bc±0.8	5,1141=29.8	<0.0001
Plot_All	6.2a±0.4	7.1a±0.7	6.2a±0.7	15.9b±0.7	13.2b±0.8	13.4b±1.1	5,1141=32.4	<0.0001
Site	10	14	21	39	48	44	NA	NA
Site_All	10	17	23	44	55	56	NA	NA

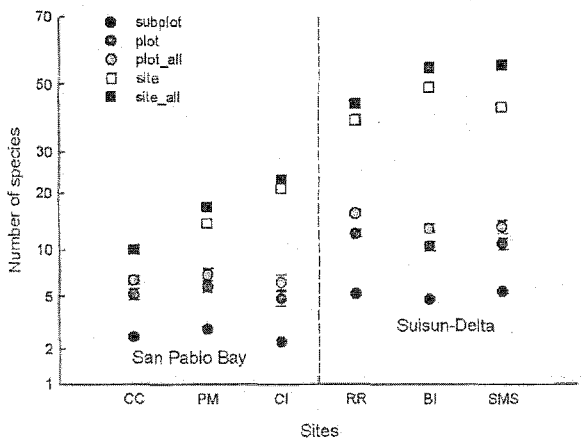

Figure 3 Mean (± S.E.) species richness at subplot, plot, and plot_all scales, and total number of species at site and site_all scales for each site.

either Browns Island or Sand Mound Slough. Yet, at the site and site_all scales, Browns Island and Sand Mound Slough contained more total species based on all twenty plots. Sand Mound Slough had the highest number of species recorded (56) for all sites, slightly greater than Browns Island (55). We found no relationship between site area and total number of species per site. On the other hand, there was a significant relationship between salinity levels and all sample scales for richness. This relationship is the most robust at the site_all scale (total species per site), where the regression coefficient is $R^2 = 0.99$ ($P < 0.0001$) (Figure 4).

The table of IV differences (Table 3) also illustrates the scope of the distinction between San Pablo Bay and Suisun-Delta sites. An IV value above 10 is relatively high (the species is either encountered relatively frequently or is relatively abundant wherever it is encountered). All three San Pablo Bay sites were dominated by *Sarcocornia pacifica* with IVs above 60. China Camp and Petaluma Marsh host four additional species that all had IVs greater than 10—*Distichlis spicata*, *Jaumea carnosa*, *Grindelia stricta*, and *Cuscuta salina*—all typical of high salt marsh plains. Tidal wetland vegetation in the three Suisun-Delta sites was more rich and diverse than in the San Pablo Bay sites. Both Rush Ranch and Browns Island retain species that are characteristic of the high marsh plain in San Pablo Bay (*Sarcocornia pacifica*, *Distichlis spicata*, and *J. carnosa*); however, *D. spicata* had a higher IV than *S. pacifica* at these two Suisun-Delta localities, and *J. carnosa* had a higher IV than *S. pacifica* at Browns Island. An unusual tidal wetland species in the Bay-Delta found only at Browns Island during this survey, *Anemopsis californica*, was located in this high marsh habitat. The great majority of the tidal marsh plain in these two Suisun-Delta sites, however, is dominated by a middle marsh assemblage consisting primarily of *Schoenoplectus americanus* and species such as *Juncus balticus*, *Triglochin maritima*, *Euthamia occidentalis*, *Symphyotrichum lentum*, *Epilobium ciliatum*, *Eleocharis macrostachya*, and *Glaux maritima*. A listed species largely confined to Rush Ranch, *Cirsium hydrophilum*, occurs along shallow channels in this habitat. At the margins of deep channels and low areas where water stands, a third low-marsh

assemblage contributes to the heterogeneity of these sites. Here, species such as *Schoenoplectus acutus, Typha latifolia, Typha domingensis, Typha angustifolia*, and *Schoenoplectus californicus* provide a structural matrix in which species such as *Calystegia sepium, Persicaria maculosa* and *Samolus parviflorus* occur.

The eight species with highest IVs (>10) at Sand Mound Slough in descending order were *Schoenoplectus acutus, Schoenoplectus americanus, Calystegia sepium, Phragmites australis, Typha latifolia, Rubus discolor, Salix lasiolepis*, and *Typha domingensis*. Together, these species create tall, dense thickets that are difficult for people to penetrate; however, many species such as the fern *Atherium felix-femina*, flowering plants such as *Potentilla palustris, Hibiscus lasiocarpus, Lycopus asper, Stachys albus* and *Mimulus guttatus*, emergent wetland species such as *Sparganium eurycarpum* and *Sagitaria latifolia*, sedges such as *Carex obnupta* and *C. pellita*, and other woody species such as *Cephalanthus occidentalis* and *Cornus sericeus* were interwoven within and between these dominants (Table 3).

In total, 82 species were found in the combined subplot samples for all sites (site scale, Table 3), and 94 species were observed in all 120 plots, including those species not picked up in the subplot sampling (site_all scale, Table 4); therefore, although the site samples covered an area of only 1400 m^2 compared to the 20,000 m^2 for the site_all samples (i.e., about 7% of the total area surveyed), the subplot sampling picked up 87% of the total number of species observed in all plots per site. Twenty-nine species occurred in San Pablo Bay: six were restricted to San Pablo Bay and 23 species were shared among one or more Suisun-Delta sites (Table 4). Conversely, 88 species occurred in the Suisun-Delta sites and 65 of these were restricted to the Suisun-Delta region. Of the shared 23 species, 12 were shared only by Coon Island and other Suisun-Delta sites. No species were found exclusively at China Camp, two (both exotics) were found at Petaluma Marsh, none at Coon Island, seven at Rush Ranch, five at Browns Island, and 22 (23% of all species picked up in the survey) at Sand Mound Slough. There were far more native species found in these wetlands than exotic species (81 native to 13 exotic; 86% to 14%; Table 4) and, with the exception of *Lepidium latifolium*, these all had low IVs (Table 3).

DISCUSSION

The results of this analysis were generally consistent with past studies that include quantitative vegetation samples from the Bay-Delta (Atwater and Hedel 1976; Atwater and others 1979; Watson and Byrne 2009). At a regional scale, tidal wetland vegetation in the Bay-Delta is influenced by ambient salinity regimes (Figure 4). At different sampling scales, species richness tends to increase from salt marshes (low richness) to mild brackish and freshwater wetlands (high richness; Table 2, Figure 3). In terms of frequency of occurrence and proportion of total abundance per occurrence, there is a distinct shift of species composition and dominance from a narrow suite of salt-tolerant species in salt marshes to a diverse array of species in the brackish and freshwater tidal wetlands of the Suisun-Delta (Table 3). These findings have important implications for understanding patterns of plant species diversity in Bay-Delta wetlands, and, potentially, for the future conservation management of Bay-Delta wetlands to maintain and increase this diversity in the face of rapid environmental change.

Patterns of Bay-Delta Tidal Wetland Plant Species Diversity

Despite the pioneering work by Atwater and others (1979), there has been a persistent belief that brackish wetland vegetation of the Suisun Bay region is more diverse than the freshwater Delta. For example, Byrne and others (2001, p. 66) state:

> Brackish wetlands are floristically distinctive and *contain a greater diversity of plant species* than either the salt marshes of San Francisco Bay or the freshwater wetlands of the Sacramento-San Joaquin Delta. [emphasis added]

A recent paper reiterates this perspective, and argues that with anticipated sea-level rise resulting from

Table 3 Species codes, species names, and Importance Values (IVs) for species found in subplots at all six sites. Relatively high IVs (above 10) are highlighted in bold. Species are generally arranged in descending ranks from highest IV to lowest IV at each site, except where species are found in more than one site. Note that out of 82 species sampled, 57 were sampled only in the Suisun-Delta, 2 in San Pablo Bay, and 23 were found in both subregions.

	Code	Species	Status	CC	PRM	CI	RR	BRI	SMS
1	Sapa	*Sarcorcornia pacifica*	N	**85.4**	**86.5**	**64.9**	**28.9**	6.2	
2	Disp	*Distichlis spicata*	N	**20.6**	**17.5**	3.3	**34.1**	**30.2**	
3	Jaca	*Jaumea carnosa*	N	**17.5**	**18.7**	4.0	**13.7**	**11.7**	
4	Grst	*Grindelia stricta* var. *angustifolia*	N	**12.7**	9.9	6.2	**20.4**	2.5	
5	Cusa	*Cuscuta salina*	N	**15.0**	**23.3**		0.5		
6	Frsa	*Frankenia salina*	N	5.2	16.1				
7	Lica	*Limonium californicum*	N	6.5	1.1				
8	Cusu	*Cuscuta subinclusa*	N	3.0	3.7		1.3		
9	Boma	*Bolboschoenus maritimus*	N	1.6	2.3	**36.3**		0.3	
10	Spfo	*Spartina foliosa*	N	7.2		1.1			
11	Acmi	*Achillea millefolium*	N		2.2	0.3	2.1	1.0	
12	Lela	*Lepidium latifolium*	E		7.3		**12.6**	2.0	
13	Bapi	*Baccharis pilularis*	N		2.2				
14	Attr	*Atriplex triangularis*	N		0.8	1.9	**13.8**		
15	Rucr	*Rumex crispus*	N		0.3	0.3	0.8	0.3	0.8
16	Scam	*Schoenoplectus americanus*	N			11.0	**41.8**	**64.2**	**48.9**
17	Scac	*Schoenoplectus acutus*	N			6.5	4.1	**23.3**	**56.0**
18	Poan	*Potentilla anserina*	N			5.6	**15.7**	**14.4**	3.7
19	Tyan	*Typha angustifolia*	N			4.9	4.9		6.7
20	Juba	*Juncus balticus*	N			2.6	**36.5**	9.9	
21	Ardo	*Artemisia douglasiana*	N			1.3		1.2	
22	Scca	*Schoenoplectus californicus*	N			1.5		0.3	0.9
23	TySp	*Typha* spp.	N			9.0			5.7
24	Tyla	*Typha latifolia*	N			0.8	0.3	0.8	**19.5**
25	Tydo	*Typha domingensis*	N			0.8	6.4	19.7	10.6
26	Bado	*Baccharis douglasii*	N			0.3	0.9	0.3	
27	Chmu	*Chenopodium multifidum*	E			0.3			
28	Case	*Calystegia sepium*	N				**10.7**	**12.0**	**31.3**
29	Trma	*Triglochin maritima*	N				**16.4**	**15.5**	
30	Euoc	*Euthamia occidentalis*	N				4.0	**15.3**	0.3
31	Pepu	*Persicaria punctata*	N				4.0	1.9	6.1
32	Epci	*Epilobium ciliatum*	N				4.1	3.3	0.5
33	Plod	*Pluchea odorata*	N				1.3	2.1	0.3
34	Glma	*Glaux maritima*	N				8.4	1.5	
35	Asle	*Aster lentus*	N				6.8	0.8	
36	Elma	*Eleocharis macrostachya*	N				0.4	8.8	1.4
37	Sapar	*Samolus parviflorus*	N				0.8	1.5	0.8
38	Gatr	*Galium triflorum*	N				0.5	1.6	
39	Sysu	*Symphyotrichum subulatum*	N				0.5	0.3	

	Code	Species	Status	CC	PRM	CI	RR	BRI	SMS
40	Ruca	*Rumex californicus*	N				0.3		
41	Apgr	*Apium graveolens*	E				3.0		
42	Sool	*Sonchus oleraceus*	E				1.0		
43	Trco	*Triglochin concinum*	N				2.0		
44	Asra	*Aster radulina*	N				0.8		
45	Sodo	*Solanum douglasii*	N				0.3		
46	Sasu	*Salicornia subterminalis*	N				0.3		
47	Cihy	*Cirsium hydrophilum*	N				0.3		
48	Heec	*Helminthotheca echiodes*	E				0.5		
49	Lyca	*Lythrum californicum*	N					2.7	0.3
50	Migu	*Mimulus guttatus*	N					5.5	
51	Lyam	*Lycopus americanus*	N					3.1	1.9
52	Caob	*Carex obnupta*	N					2.3	0.4
53	Cape	*Carex pellita*	N					2.0	8.1
54	Hyve	*Hydrocotyle verticillata*	N					1.3	1.0
55	Lyas	*Lycopus asper*	N					1.4	0.8
56	Hyum	*Hydrocotyle umbellata*	N					1.2	0.3
57	Rudi	*Rubus discolor*	E					0.9	17.3
58	Peam	*Persicaria amphibia*	N					0.8	6.7
59	Lima	*Lilaeopsis masonii*	N					0.5	0.5
60	Mear	*Mentha arvensis*	N					0.6	1.9
61	Irps	*Iris pseudacorus*	E					0.3	2.6
62	Anca	*Anemopsis californica*	N					1.2	
63	Sisu	*Sium suave*	N					0.3	
64	Laje	*Lathyrus jepsonii* var. *jepsonii*	N					1.1	
65	Soam	*Solanum americanum*	N					0.3	
66	Dece	*Deschampsia cespitosa*	N					0.3	
67	Pema	*Persicaria maculosa*	N					8.3	8.9
68	Phau	*Phragmites australis*	N						**24.3**
69	Sala	*Salix lasiolepis*	N						**13.6**
70	Atfi	*Athyrium filix–femina*	N						8.5
71	Popa	*Potentilla palustris*	N						7.0
72	Salat	*Sagittaria latifolia*	N						6.8
73	Speu	*Sparganium eurycarpum*	N						6.5
74	Stal	*Stachys albens*	N						2.4
75	Lupe	*Ludwigia peploides*	N						1.4
76	Juxi	*Juncus xiphioides*	N						0.3
77	Cima	*Cicuta maculata* var. *bolanderi*	N						0.3
78	Hila	*Hibiscus lasiocarpos*	N						0.5
79	Cose	*Cornus sericeus*	N						0.9
80	Scmi	*Scirpus microcarpus*	N						0.8
81	Ceoc	*Cephalanthus occidentalis*	N						0.3
82	Hyra	*Hydrocotyle ranunculoides*	N						0.3

Table 4 Species codes, species names, and species status (N=native, E=exotic) present at each site, including species not recorded in the subplots (site_all scale). Presence of a species at a site is indicated by a "+".

	Code	Species	Status	CC	PRM	CI	RR	BRI	SMS
1	Frsa	*Frankenia salina*	N	+	+				
2	Lica	*Limonium californicum*	N	+	+				
3	Spfo	*Spartina foliosa*	N	+	+	+			
4	Cusu	*Cuscuta subinclusa*	N	+	+		+		
5	Cusa	*Cuscuta salina*	N	+	+		+		
6	Boma	*Bolboschoenus maritimus*	N	+	+	+		+	
7	Disp	*Distichlis spicata*	N	+	+	+	+	+	
8	Jaca	*Jaumea carnosa*	N	+	+	+	+	+	
9	Grst	*Grindelia stricta* var. *angustifolia*	N	+	+	+	+	+	
10	Sapa	*Sarcocornia pacifica*	N	+	+	+	+	+	+
11	Chal	*Chenopodium multifidum*	E		+				
12	Coma	*Conium maculatum*	E		+				
13	Bapi	*Baccharis pilularis*	N		+	+			
14	Lela	*Lepidium latifolium*	E		+	+	+	+	
15	Acmi	*Achillea millefolium*	N		+	+	+	+	
16	Attr	*Atriplex triangularis*	N		+	+	+	+	
17	Rucr	*Rumex crispus*	N		+	+	+	+	+
18	Tysp	*Typha* spp.	N			+		+	+
19	Ardo	*Artemisia douglasiana*	N			+		+	
20	Tyan	*Typha angustifolia*	N			+	+		+
21	Bado	*Baccharis douglasii*	N			+	+	+	
22	Juba	*Juncus balticus*	N			+	+	+	
23	Scac	*Schoenoplectus acutus*	N			+	+	+	+
24	Poan	*Potentilla anserina*	N			+	+	+	+
25	Scca	*Schoenoplectus californicus*	N			+	+	+	+
26	Scam	*Schoenoplectus americanus*	N			+	+	+	+
27	Tyla	*Typha latifolia*	N			+	+	+	+
28	Tydo	*Typha domingensis*	N			+	+	+	+
29	Euoc	*Euthamia occidentalis*	N			+	+	+	+
30	Pomo	*Polypogon monspeliensis*	N				+		+
31	Sasu	*Salicornia subterminalis*	N				+		
32	Civu	*Cirsium vulgare*	E				+		
33	Sool	*Sonchus oleraceus*	E				+		
34	Loco	*Lotus corniculatus*	E				+		
35	Trco	*Triglochin concinum*	N				+		
36	Cihy	*Cirsium hydrophilum*	N				+		
37	Heec	*Helminthotheca echiodes*	E				+		
38	Glma	*Glaux maritima*	N				+	+	
39	Asle	*Aster lentus*	N				+	+	
40	Apgr	*Apium graveolens*	E				+	+	
41	Gatr	*Galium triflorum*	N				+	+	
42	Sysu	*Symphyotrichum subulatum*	N				+	+	
43	Sodo	*Solanum douglasii*	N				+	+	
44	Ruca	*Rumex californicus*	N				+	+	
45	Sisu	*Sium suave*	N				+	+	
46	Trma	*Triglochin maritima*	N				+	+	+

	Code	Species	Status	CC	PRM	CI	RR	BRI	SMS
47	Case	*Calystegia sepium*	N				+	+	+
48	Epci	*Epilobium ciliatum*	N				+	+	+
49	Pepu	*Persicaria punctata*	N				+	+	+
50	Plod	*Pluchea odorata*	N				+	+	+
51	Sapar	*Samolus parviflorus*	N				+	+	+
52	Lyca	*Lythrum californicum*	N				+	+	+
53	Elma	*Eleocharis macrostachya*	N				+	+	+
54	Anca	*Anemopsis californica*	N					+	
55	Laje	*Lathyrus jepsonii*	N					+	
56	Soam	*Solanum americanum*	N					+	
57	Dece	*Deschampsia cespitosa*	N					+	
58	Pema	*Persicaria maculosa*	N					+	
59	Migu	*Mimulus guttatus*	N					+	+
60	Lyam	*Lycopus americanus*	N					+	+
61	Caob	*Carex obnupta*	N					+	+
62	Carex	*Carex pellita*	N					+	+
63	Hyve	*Hydrocotyle verticillata*	N					+	+
64	Lyas	*Lycopus asper*	N					+	+
65	Hyum	*Hydrocotyle umbellata*	N					+	+
66	Rudi	*Rubus discolor*	E					+	+
67	Peam	*Persicaria amphibia*	N					+	+
68	Lima	*Lilaeopsis masonii*	N					+	+
69	Juxi	*Juncus xiphioides*	N					+	+
70	Cima	*Cicuta maculata* var. *bolanderi*	N					+	+
71	Irps	*Iris pseudacorus*	E					+	+
72	Mear	*Mentha arvensis*	N					+	+
73	Phau	*Phragmites australis*	N						+
74	Sala	*Salix lasiolepis*	N						+
75	Atfi	*Athyrium filix-femina*	N						+
76	Popa	*Potentilla palustris*	N						+
77	Salat	*Sagittaria latifolia*	N						+
78	Speu	*Sparganium eurycarpum*	N						+
79	Stal	*Stachys albens*	N						+
80	Lupe	*Ludwigia peploides*	N						+
81	Hila	*Hibiscus lasiocarpos*	N						+
82	Cose	*Cornus sericeus*	N						+
83	Scmi	*Scirpus microcarpus*	N						+
84	Ceoc	*Cephalanthus occidentalis*	N						+
85	Bila	*Bidens laevis*	N						+
86	Oesa	*Oenothera sarmentosa*	N						+
87	Vebo	*Verbena bonariensis*	E						+
88	Hyra	*Hydrocotyle ranunculoides*	N						+
89	Asle	*Aster radulina*	N						+
90	Eicr	*Eichornia crassipes*	E						+
91	Lesp	*Lemna* sp.	N						+
92	Vela	*Verbena lasiostachys*	N						+
93	Vebo	*Verbena bonariensis*	E						+
94	Scga	*Scutellaria galericulata*	N						+

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climate change, "increasing salinity may just move the center of diversity eastward" (Watson and Byrne 2009, p. 126). Yet, based on original wetland vegetation surveys by Atwater and Hedel (1976), Atwater and others (1979, p. 363) state:

> Diversity generally increases from San Francisco Bay to the Delta. Whereas individual marshes around San Francisco Bay typically contain 13 or 14 species of native plants, specific sites in the Delta contain 40 species. Composite regional lists imply even greater differences in diversity: only 15 native species reportedly live in tidal marshes around San Francisco Bay but about 30 reportedly live around San Pablo Bay and Carquinez Strait, 40 around Suisun Bay, and 80 in the Delta.

Atwater and others (1979, p. 369) continue:

> Tidal-marsh plants of San Pablo Bay, Carquinez Strait, and Suisun Bay provide an intricate, mutable transition between salt marshes of San Francisco Bay and freshwater marshes of the Delta ... Species from opposite ends of the spectrum overlap to varying degrees in the middle ...

These observations by Atwater and others (1979) are consistent with our findings. While all of the Suisun-Delta sites are significantly richer than San Pablo Bay sites in terms of species richness, we recorded the greatest total species richness at Sand Mound Slough in the Delta (56) and Browns Island in the western Delta (55), and the least species richness in the more brackish wetlands of Rush Ranch in the western Suisun Bay region (44) (Table 2, Figure 3D). We also found that Rush Ranch and Browns Island contain a rich mixture of species, characteristic of the eastern San Pablo Bay site (Coon Island) as well as the Suisun-Delta sites, perhaps constituting the heart of the "intricate, mutable transition" vegetation described by Atwater and others (1979) above. If Sand Mound Slough is a reasonable indicator of Delta plant species diversity compared to these other wetlands, and there is little data to suggest otherwise, many species that occur in Delta freshwater wetlands simply do not establish in more saline reaches of the

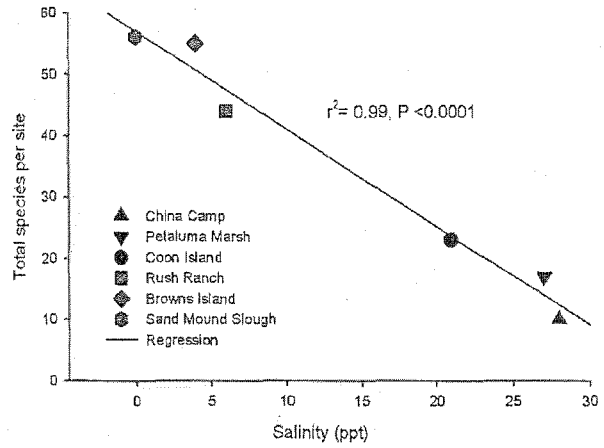

Figure 4 Linear regression comparing total number of species (site_all scale) as dependent variable and mean salinity (ppt) as independent variable.

estuary. For example, Sand Mound Slough had 22 species that were not found downstream (Table 4). This suggests that the species pool for vegetation in the Bay-Delta ecosystem is richest in the Delta and progressively attenuates as higher levels of ambient salinity are encountered. The significant correlation between ambient salinity and total number of species per site in this limited study strongly suggests this relationship (Figure 4).

We suspect that the reason Watson and Byrne (2009) found more species at South Hampton Bay and Hill Slough in the Suisun Bay region, compared to Sand Mound Slough in the Delta, is that the area they sampled at Sand Mound Slough was not sufficient to detect the greater number of species that we found there. Since their design was based on Atwater and Hedel (1976), who originally sampled a comparatively small transect at Sand Mound Slough compared to South Hampton Bay and Hill Slough, this is understandable. As pointed out, in a comparison of richness at the 1,000-m^2 plot scale between Rush Ranch, Browns Island, and Sand Mound Slough, Rush Ranch had the highest richness; whereas at the site_all scale (20,000 m^2), Sand Mound Slough had 12 more species than Rush Ranch (Table 2). These data suggest that Rush Ranch has more species that are fre-

quently encountered at local scales, but that Sand Mound Slough has more species that are infrequently encountered at the larger site scale.

While our study provides evidence that the greatest number of tidal wetland plant species occurs in the Delta, this is not to say that the brackish wetlands of Suisun Bay are not diverse, but rather that their diversity, compared to the Delta, may be more a function of species endemism than species numbers. Suisun Bay is well known for its concentration of local endemic plant species in Bay-Delta tidal wetlands. A good example is *Cirsium hydrophilum*, and there are other brackish wetland examples, such as *Lathyrus jepsonii* var. *jepsonii* and *Chloropyron molle* (CNPS 2009). Conversely, none of the species we encountered at Sand Mound Slough are classified as local endemics. Rather, the Delta species are more widespread freshwater wetland plants that present a greater diversity of life histories than Suisun wetlands, including trees, shrubs, vines, ferns, floating aquatic species, and other more typical wetland herbaceous plants.

Another important source of Bay-Delta tidal wetland plant diversity that has been generally overlooked formerly occurred in the salt marshes of the historic San Pablo Bay and San Francisco Bay. As Baye and others (2000) describe, many locally rare herbaceous species today were once found in wetlands historically concentrated on the edges of tidal salt marshes where seasonal pools, freshwater springs, and intermittent creeks created a system of small, brackish, tidally influenced wetlands. Unfortunately, most of these marginal wetland habitats are now gone because the Bay-Delta has been transformed by human activity in the post-European settlement era. Our tidal wetland sampling of the San Pablo Bay sites did not record any of these species, and, clearly, the more saline regions of the estuary would be regarded as a more diverse wetland ecosystem if these species were still present. This potential for incomplete sampling, and the previous discussion of brackish and freshwater wetlands, raises the issue of sampling methods that we address below.

The Benefits and Costs of Balanced, Random Sampling

In this study, we intentionally designed a balanced, random sample of tidally influenced vegetation at each historic wetland site that represented a range of positions along the salinity gradient within the Bay-Delta (Figure 1, Table 2). The advantage of this approach is that it provides an unbiased estimate of species richness, relative abundance, and frequency of occurrence at a variety of scales, to ensure an equal comparison among sites. As such, we can state with some confidence that species numbers in the Suisun-Delta are more likely greater than in San Pablo Bay, and that there appears to be a strong correlation between ambient (water column) salinity and numbers of species at tidal wetlands arrayed along the estuarine salinity gradient (Figure 4). One cost of random sampling, especially in a system with strong local gradients such as tidal wetlands, is that it is inherently biased toward recording species that are relatively abundant and spatially well-distributed (Greig-Smith 1983). Rare species that are patchily distributed—particularly in uncommon, specialized habitats—generally require large numbers of randomly distributed samples (Greig-Smith 1983). For example, while the Coon Island tidal wetland is more species-rich than either China Camp or Petaluma Marsh at the site scale, richness is obscured when the data is viewed at smaller sampling scales, such as subplots and plots (Table 2, Figure 3). This may be an example of how brackish species found more commonly in Suisun Bay wetlands are more patchily distributed on Coon Island, and therefore more likely to be missed in small-scale, random samples. The balanced random-sampling approach, for similar reasons, would not be effective at detecting fine-scale diversity of transitional brackish habitats such as those described by Baye and others (2000). Consequently, for large-scale questions—such as those that address the potential effects of climate change on Bay-Delta plant species along the estuarine salinity gradient—the balanced, random approach is useful. However, for more local-scale questions, and for questions that involve species in specialized habitats, a more targeted approach is likely to be more effective (Parker and others 2011).

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Conservation Implications

Our study has implications for the conservation of Delta tidal wetland vegetation. The Sacramento–San Joaquin Delta once encompassed approximately 260,000 ha of wetlands, of which approximately 140,000 ha were tidally influenced (Atwater and others 1979). According to Hart (2010), this Delta wetland habitat was not monolithic. The north Delta was shaped by powerful flows of the Sacramento River. Natural levees, 6 to 7 m high, were deposited by these flows, and colonized by tall gallery forests of valley oak, cottonwoods, sycamores, and alders. The south Delta was shaped by more moderate flows of the San Joaquin River, levees were lower, and riparian woodlands sparser. Behind these natural levees were extensive stands of freshwater wetlands, characterized by tules, cattails, and other tidal wetland species that gradually gave way to seasonal wetlands, vernal pools, grasslands, and oak savanna. This mosaic of freshwater wetland plant diversity must have been extraordinary; however, as the Delta was "reclaimed," over 95% of this habitat was lost. Today, small remnants of this diversity persist in remote corners of the Delta, such as at Sand Mound Slough, and one compelling question is: If conditions in the Delta become more saline with sea-level rise and potentially greater diversion of freshwater from upstream, where will these species go? At the moment, conservation alternatives are limited by the lack of available habitat and restoration opportunities; however, an expanding restoration movement exists in the Delta (*http://www.deltacouncil.ca.gov/*), and we hope that the broader community of the public, scientists, and policy-makers recognize that plant species diversity in the Delta is remarkable, despite its general appearance to the contrary (as one cruises by on a boat). While the vegetation of Sand Mound Slough may not represent the entire Delta, its high diversity compared to other historic wetlands in the Bay–Delta provides the impetus to recognize that future Delta restoration efforts should be viewed as an opportunity to re-create this diversity, as well as to provide for vegetation structure and ecosystem services that support other wildlife and microbial organisms.

This study also highlights the importance of the Suisun Bay region for plant diversity at a variety of scales. Tidal wetlands in the Suisun are a convergence between salt tolerant and freshwater dependent plant species, including several species that are endemic to this region. Although partially salt-tolerant species in the brackish portion of the estuary should be able to retreat upstream in the face of salinity intrusion (Watson and Byrne 2009), this presupposes that marsh plain habitat will be (or become) available to colonize. Of possibly greater conservation concern for Bay–Delta brackish wetlands is the spread of an invasive non-native species, *Lepidium latifolium*. We found that this species has a relatively high IV at Rush Ranch compared to other species, was well established at Browns Island and Petaluma Marsh, and also was present at Coon Island (Table 3, Table 4). *Lepidium latifolium* is particularly problematic at Rush Ranch, where it dominates habitat in which *Cirsium hydrophilum* occurs. Invasive *L. latifolium* has become so well integrated into sensitive brackish wetland habitat that it poses a particularly onerous control challenge. Further research and pilot control studies are under way and need full support.

Although our assessment did not sample the kinds of marginal brackish habitat in San Pablo Bay and San Francisco Bay that Baye and others (2000) have highlighted, and which have been largely extirpated, it does underscore the importance of brackish habitat to greater plant diversity in the Bay–Delta. Landscapes with intact transition habitat at the margin of salt and brackish wetlands are highly limited, and this is one of the reasons San Francisco Bay NERR components such as China Camp and Rush Ranch are so valuable from a conservation perspective. The greatest opportunity for large-scale habitat restoration in the Bay–Delta is currently focused on these more saline portions of the estuary. Given the importance of these marginal brackish habitats to plant diversity in the Bay–Delta as a whole, we advocate that more effort be made to establish conditions favorable for these marginal habitats in tidal wetland restoration projects in San Francisco Bay and San Pablo Bay. This could greatly enhance the potential for greater plant diversity in the Bay–Delta.

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Salinity, Sodicity and Flooding Tolerance of Selected Plant Species of the Northern Cheyenne Reservation

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Preface

This document was prepared in response to numerous questions raised regarding the tolerance and/or sensitivity of native and culturally significant plants on the Northern Cheyenne Reservation to salinity, sodicity, and flooding that might be a consequence of natural gas exploration and extraction in southeast Montana. Initially, a list of native and culturally significant plant species was obtained from the Department of Environmental Protection and the Northern Cheyenne Tribe. A thorough search of references dealing with salinity, sodicity, flooding, and pH tolerances for the plants in question was then undertaken, with journals, reference books and Internet sources all providing pertinent information. The goal was to gain an accurate prediction as to how native and culturally significant plants would be likely to respond to increases in salinity, sodicity, flooding, and pH/ alkalinity, all possible consequences of proposed natural gas extraction in southeast Montana. Where no data were found for a specific plant tolerance, indicator species were used. Indicator species were either plants in the same genus or plants commonly found in the same habitats or communities as the plant in question. Some of the primary sources of information used were Ayers and Westcot's 1976 "Water Quality for Agriculture", E.V. Maas' 1993 "Testing crops for salinity tolerance", Frank F. Munshower's Forbs, Shrubs, and Trees for Revegetation of Disturbed Lands in the Northern Great Plains and Adjacent Areas with comments about some wetland species, James Small's 1946 pH and Plants: An Introduction for Beginners,

K.K. Tanji's Agricultural Salinity Assessment and Management, The United States Department of Agriculture website, Utah State University's Extension Service, and B. Wolf's The Fertile Triangle.

Scientific Basis

Salinity: A multitude of references have been published within the scientific literature assigning various ranges of soil solution salinity to categories of salt tolerant plants. Using these ratings systems, most plant species are assigned to categories such as degree of sensitivity or degree of tolerance to salinity. For purposes of reference, Table 1 presents two frequently cited salt tolerance rating systems (Miller and Donahue, 1995; Maas, 1993). Using the composite information from these two references, a general rating system was prepared for use in this report. Plant species identified in this report as "sensitive" were those determined to be adversely affected by EC_e values < 2 dS/m. At the other extreme, plant species reportedly tolerant and capable of reasonably normal growth under conditions of EC_e values > 6 dS/m were rated as tolerant. For further purposes of reference, a saline soil is generally considered to be one with an EC_e (saturated paste extract) greater than 3.0 dS/m (Miller and Donahue, 1995).

Table 1. Salinity Tolerance Ratings

Miller and Donahue, 1995	Maas, 1993 (EC_e[1] (dS/m))	This report	Symbol
0-2 few plants affected	<1.5 sensitive	<2 sensitive	S
2-4 some senitive plants affected	1.5 - 3.0 moderately sensitive	2-4 moderately sensitive	MS
4-8 many plants affected	3-6 moderately tolerant	4-6 moderately tolerant	MT
8-16 most crop plants affected	6-10 tolerant	>6 tolerant	T
>16 few plants tolerant	> 10 very tolerant		

For purposes of this assessment, plant species determined to be adversely affected by salinity values < 2 dS/m were rated as sensitive; those adversely affected by salinity values between 2 and 4 dS/m were rated as moderately sensitive; those affected by salinity values between 4 and 6 dS/m were rated at moderately tolerant; plant species tolerant to EC > 6 dS/m were rated as tolerant.

Sodium Tolerance Ratings: The scientific literature contains few specific references to individual plant species' tolerances to sodicity, which may be expressed as SAR (sodium adsorption ration), ESP (exchangeable sodium percentage) or specific sodium concentration. Sodium is known to have an adverse effect on most plant tissue when in direct contact with leaves at high concentrations. Generally, however, effects of sodium on plant performance are indirect and a response to sodium-induced alterations in soil physical and chemical properties. For purposes of reporting herein, species exhibiting a high degree of sensitivity to sodium are listed as extremely sensitive (ES). Other species may be affected indirectly by sodium, through a change in soil physical structure. Species reportedly very tolerant of sodium (able to tolerate ESP of as much as 60%) are identified as VT. Where no ratings is presented, data were not available to justify a rating. Shainberg and Oster (1978) report that all deciduous fruits are extremely sensitive to sodium, with ESP 2 -10 % having a negative impact on plants and fruit production. Primary sodium toxicity symptoms are leaf burn and leaf wilting. In general, it is not uncommon for sodium toxicity to occur when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance Ratings: (conventions used in this report)

Intolerant - unable to withstand flooding for more than a few days

Moderately Tolerant - able to withstand short-term flooding, approximately two weeks in duration, but not long term flooding

Tolerant - able to withstand relatively long flooding, up to a year or more, but may still be damaged by consecutive years of flooding

pH/Alkalinity Tolerance Ratings: (conventions used in this report) Ideal pH ranges are given. While plant species may be able to survive outside of the given ranges, they are likely to be negatively impacted, either through direct physical damage or through competition with species better adapted to the given pH.

Summary of Findings

The following table (Table 2) provides a summary of the primary information in the text, specifically plant tolerances to salinity, given as an overall sensitivity rating and threshold ECe value (where salinity begins to have a negative impact), sodicity, flooding, and pH. The text itself provides a complete listing of all relevant data pertaining to the above criteria, as well as general habitat descriptions and other relevant information.

Table 2. Summary of sensitivity ratings of thirty one native and culturally significant plant species of the Northern Cheyenne Reservation to soil solution salinity (EC_e), exchangeable sodium percentage, flooding, and changes in soil pH.

Common Name	Scientific Name	SALINITY Rating	SALINITY Acceptable Upper Limit EC_e (sat) dS/m	SODIUM Tolerance Rating	Flooding Rating Limits, Inundation	pH range
1. June Servie Berry	*Amelanchier alnifolia*	S	2.0	ES; ESP 2-10, SAR 1.6-8.0	MT short term, 2 weeks	no data
2. Red Osier Dogwood	*Cornus stolinifera*	S	2.0	no data available	MT short term, 2 weeks	6.5-7.9
3. Common spikerush	*Eleocharis palustris*	MS	4.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
4. Horsetail, Field	*Equisetum arvense*	MS	4.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.2
5. Wild licorice/American	*Glycyrrhiza lepidota*	MT	6.0	VT; ESP 60, SAR 48	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.2
6. Goose Berry, red shoot	*Ribes setosum*	S	2.0	ES; ESP 2-10, SAR 1.6-8.0	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
7. Mint/Field	*Mentha arvensis*	S/MS	2.0	ES; ESP 2-10, SAR 1.6-8.0	no data available	4.8-7.9

8. Horsemint/W. Bergamot	*Monarda fistulosa*	MS	4.0	no data available	no data available	5.5-7.9
9. Water Plant/Water Cress	*Nasturium officinale*	MS	4.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.2
10. Sweet Medicine	*Oxtropis lamnbertii*	MS	4.0	no data available	no data available	5.5-7.9
11. Chokecherry	*Prunus virginiana*	S	2.0	ES; ESP 2-10, SAR 1.6-8.0	I very short term; < 2 weeks	4.8-7.9
12. Cottonwood, G. Plains	*Populus deltoides*	MS	4.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
13. Box Elder	*Acer negundo*	MT	6.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
14. Green ash	*Fraxinus pennsylvania*	MT	6.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	6.5-7.9
15. Sand bar willow	*Salix exigua*	MS	4.0	no data available	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
16. Snow Berry	*Symphoricarpos occidentalis*	MS	4.0	ES; ESP 2-10, SAR 1.6-1.8	T long term, 1 year -; not tolerant to permanent flooding	4.8-7.9
17. Cattail	*Typha latifolia*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
18. Wild Plum	*Prunus americana*	S	2.0	ES; ESP 2-10, SAR 1.6-1.8	T long term, 1 year +; not tolerant to	no data

					permanent flooding	
19. Sweet grass	*Hierochloe odorata*	MS	4.0	no data available	no data available	4.8-7.2
20. Quaking aspen	*Populus tremuloides*	S	2.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	no data
21. Saw beak sedge	*Carex stipata*	MS	4.0	no data available	T long term, 1 year	5.0-7.9
22. Leafy aster	*Aster foliactus*	S	2.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.2
23. Stinging nettle	*Urtica dioica*	MS	2.0	no data available	I very short term, < 2 weeks	4.8-7.2
24. Bulrush	*Scirpus nevadensis*	MT/T	6.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
25. Arrow leaf	*Sagittaria latifolia*	MS	4.0	no data available	T long term, 1 year +; not tolerant to permanent flooding	4.8-7.9
26. Golden currant	*Ribes aureum*	MS	4.0	ES; ESP 2-10, SAR 1.6-8.0	no available data	4.8-7.9
27. Skunkbush sumae	*Rhus trixobata*	MT	6.0	no data available	MT short term, 2 weeks	6.5-7.9
28. Milkweed, showy	*Asclepias speciosa*	MS	4.0	no data available	I very short term, < 2 weeks	4.8-7.2
29. Western yarrow	*Achillea millelolium*	MS	4.0	no data available	I very short term, < 2 weeks	4.8-7.9
30. Raspberry red	*Rubes idaue*	S	2.0	ES; ESP 2-10, SAR 1.6-8.0	no data available	4.8-7.9
31. Rose Bush	*Rosa arkansa*	MS	4.0			4.8-7.9

				no data available	MT short term, 2 weeks	

Explanations and Descriptions of Plant Responses to Salinity, Sodicity, pH/Alkalinity, and Bicarbonates

Salinity: The quality of water plants are exposed to has a direct impact on their survival, growth, and overall health. This is particularly true in regard to salinity. Published research supports the premise that the salinity of water plants will actually have available to utilize, the soil EC, EC_e, or EC_{sat} (saturated paste extract), is on average as much as three times the salinity of applied irrigation water due to evapotranspiration (Ayers and Westcot, 1976). Schafer (1983b) reports an increase in EC_{sat} of as much as 5 dS/m for each dS/m of applied water. Hence it is important to distinguish the condition being referred to with regard to salt tolerance, i.e., salinity of applied water or salinity of the soil solution. Most salinity tolerance listings, including those outlined here, use soil saturated paste extract EC measurements, referred to as EC_e or EC_{sat}.

An extensive amount of research has been published regarding cultivated crop species' tolerances to salinity. Less data are available for plants normally considered non-agricultural. Figure 1 illustrates the relative crop yield of plants of varying sensitivity to soil water salinity, EC_e. Shainberg and Oster (1978) identified five categories of plants with respect to salinity tolerance. In their rating system, sensitive plants demonstrated reductions in performance at EC_e values as low as 1.5 dS/m and death occurred in the sensitive species at EC_e = 8.0 dS/m. At the other extreme, plants rated as tolerant did not demonstrate measurable yield reductions until EC_e exceeded 6 dS/m and 100 % reduction did not occur until EC_e reached 32 dS/m. This same rating system was subsequently reported by Maas (1993) and constitutes part of the report contained herein. Generally most agricultural plants demonstrate some degree of impairment when EC_e exceeds 8 dS/m (Schafer, 1983a).

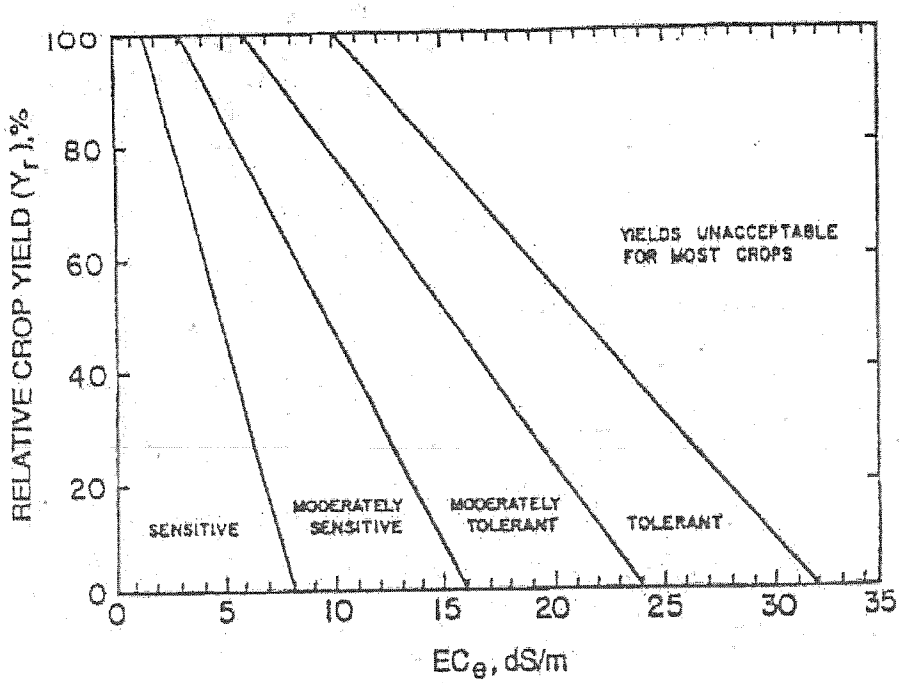

Figure 1. Relative crop yield as affected by soil salinity.

The most likely effect of salinity on plants is a general stunting of growth. Increased salinity requires plants to expend more energy to obtain water from the soil, thereby reducing the amount of energy available for growth. **Moderately salt-stressed plants usually appear normal, although their leaves may be darker green, thicker and more succulent than non-stressed plants. Visual symptoms (leaf burn, necrosis, and**

defoliation) sometimes occur, particularly in woody species. At high levels, salinity can cause physical damage and mortality. Plant sensitivity to salinity changes throughout the growing season. While most crops are relatively tolerant to salinity during germination, young developing seedlings are particularly susceptible to salinity damage during emergence and early juvenile development. After they are established, plants generally become increasingly tolerant to salinity in later growth stages (Maas, 1993).

A primary effect of salinity is that it delays germination and seedling development. This delay may prove fatal if the salt-stressed seedlings encounter additional stresses, such as water stress, extreme temperature fluctuations and, or soil crusting. Additionally, because of evaporation at the soil surface, the salt concentration in the seedbed is often higher than deeper down in the soil profile. Hence, roots of emerging seedlings are exposed to a greater degree of stress than that indicated by usual salinity measurements which are generally derived from composite soil samples taken throughout the soil profile (Western Fertilizer Handbook,1995). Plant loss during this seedling stage can reduce the plant population density to suboptimal levels and significantly reduce yields (Maas, 1993).

Sodium: Two potential risks of elevated sodium levels in the soil solution are well documented in the scientific literature. The first is the direct toxic effect of sodium, which can result in leaf burn, defoliation, or death (Western Fertilizer Handbook, 1995). The second is the effect that alteration of soil physical structure may have on plant growth. This second risk is an indirect one, due to sodium-induced disperson, but one which has potential to impact plant growth and development (Ayers and Westcot, 1999; Miller and Donahue, 1995). If SAR of the soil solution or ESP values of the soil exchange complex (a measurement of the relative concentrations of sodium to calcium and magnesium) become sufficiently elevated, soils, particularly those high in clay content, may disperse. When this soil reforms, a concrete-like surface crust is generally formed. This causes a decline in hydraulic conductivity, reduced water infiltration, and the potential for increased runoff. This physical condition may also make seedling establishment very difficult, if not impossible (Shainberg and Letey, 1984).

These dispersed conditions, common to sodic soils, also make it difficult for plant roots to obtain water and nutrients. Sodic soils are likely to become and remain waterlogged. This reduces drainage, and may lead to anaerobic conditions. If anaerobic conditions persist for any length of time, generally more than a few days, roots are unable to gain sufficient oxygen, leading to reduced plant growth, plant injury and very likely eventual death (Western Fertilizer Handbook, 1995).

Additionally, a significant decline in drainage often leads to saline conditions. If water containing salts is not allowed to drain beneath the root zone, the salt concentration of the remaining water will continue to increase as plants take up water, by transpiration, and water is lost to the atmosphere by evaporation (Western Fertilizer Handbook, 1995). (For more information on sodic soils, see "Basics of EC/ SAR Effects on Soil Physical Properties").

Tisdale et al, (1985) proposed that reductions in crop yield could be assigned to one of four categories of sodic soil, along with a corresponding ESP (%) and SAR (Table 3). As previously noted, plants are not generally evaluated with respect to sensitivity to either SAR or ESP, in as much as these two diagnostics are generally specific to soil physical responses.

Table 3. Typical reductions in crop yield at various exchangeable sodium percentages (ESP) (Tisdale, 1985)

Type of Soil	ESP (%)	SAR (average)	Decrease in Crop Yield (%)
slightly sodic	7-15	<12	20-40
moderately sodic	15-20	12-16	40-60
very sodic	20-30	16-24	60-80
extremely sodic	>30	>24	>80

pH/Alkalinity The presence of carbonates and bicarbonates increases soil solution alkalinity. However, the direct effect of alkalinity on plant performance is not well known. It is well documented that most plant species demonstrate optimal performance within defined soil acidity/ alkalinity conditions. A sharp increase in alkalinity may cause a shift in the plant community, as plants more adapted to acidic conditions get outcompeted. Similarly, a shift toward acidic conditions will favor plants favorable to acid soils. However, it is more likely that salinity and sodicity will cause a shift in community structure and composition (Western Fertilizer Handbook, 1995). In general, most native plants and cultural plants in arid and semi-arid environments are adapted to slightly, moderately, or strongly alkaline conditions (Munshower, 1998).

Bicarbonates: Carbonates and bicarbonate salts are common in waters and soils of eastern Montana (Schafer, 1983a). The known effect of bicarbonates on plants is the potential for leaf burn when bicarbonate rich water at sufficiently elevated levels comes in direct contact with growing leaf tissue (ATTRA website, 2002). However, it is unlikely that bicarbonates will have a negative impact on native wetland plants. Only a few very sensitive crops are negatively affected by bicarbonates, and levels high enough to adversely affect plants are unlikely to occur under normal irrigation with good drainage. Under conditions of continuous flooding or frequent inundation, this situation could change (Western Fertilizer Handbook, 1995).

APPENDIX

Detailed description of tolerances, sensitivities and pecularities of selected native plants occurring on the Northern Cheyenne Reservation.

1) June/Service Berry (Amelanchier alnifolia): June/ Service Berry is typically found in thickets in association with other shrubs (Prunus sp., Cratuegus sp.), in coulees, drainage bottoms and moist grasslands (Munshower, 1995).

Salinity Tolerance

Poor	(Munshower, 1995) (Only qualatative ratings were given in Dr. Frank F. Munshower's ratings. Hence plants which occupy similar habitats and community types were used as indicator species in order to obtain quantitative ratings.) (*Ribus* sp. was used as an indicator species because of similar habitat and general plant structure) (Maas, 1993). threshold EC_e - 1.5 dS/m (yield reduction occurs at ECe greater than this value) % decrease in yield - 22 % for each 1 dS/m increase in EC_e Rating - sensitive to salinity - see Figure 1 (Maas, 1993).

Sodium Tolerance (ESP)

extremely sensitive	(all deciduous fruits) (ESP 2-10 has a negative impact) A reduction in growth response under field conditions. Sodium toxicity symptoms (leaf burn, leaf wilting) even at low ESP values (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic effect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

Flooding Tolerance

Poor - moderate	(Munshower, 1995)

2) Red Osier Dogwood (*Cornus stolinifera*): Dogwood grows best in well-drained soils but is commonly found in riparian areas, moist woodlands, streambanks and other mesic sites. Essential requirement is well-drained rooting medium and abundance of oxygen in root zone (Munshower, 1995).

Salinity Tolerance

Sensitive	>2dS/m soil EC (EC_e) will cause damage (yield reduction, injury) (Wolf, 1999).
Fair	(Munshower, 1995)

Flooding Tolerance

Intolerant	(Flowering dogwood (*Cornus florida*) was used as an indicator species.) 4 - 10 inches of water for ten days leads to defoliation or death (U.S. Department of Agriculture Website). Red osier dogwood is considered moderately tolerant to periodic flooding in rapidly drained soils. Good (Munshower, 1995). The discrepancy in ratings indicates that dogwood will tolerate water but not continuous flooding/ anaerobic conditions.

pH/ Alkalinity Toelerance
Cornus sp.:alka-tolerant; will tolerate pH 6.5-7.9 (Small, 1946)

3) Common spike rush (*Eleocharis palustris*): Often found in fens and riparian areas, and in association with members of the *Salix* family. Because of their common association with Salix, similar habitat and responses, the genus Salix (willow) was used as an indicator where quantitative ratings are given (Munshower's ratings are for *Eleocharis palustris*) (USGS website, 2002).

Salinity Tolerance

Sensitive	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately Tolerant	(injury at 4- 6 dS/m EC_e) (golden willow as indicator species)
Good	(Munshower, 1995)

Flooding Tolerance

Tolerant	(black willow (*Salix nigra*) used as an indicator species): able to survive deep, prolonged flooding for more than one year (Wolf, 1999). Very good (Munshower, 1998).

pH/alkalinity Tolerance
Spike rush is a calciphile (plants that prefer alkaline environments) (U.S. Department of Agriculture Website, 2002.); alka-tolerant (*Salix* sp. as indicator) (pH above 4.8/5.2 up to 7.5/9 or above) (Small, 1946).

4) Horsetail/ Field (*Equisetum arvense*): Horsetail is also commonly found with members of the *Salix* family, often in marshes or other mesic sites. Because of similar habitat and responses to flooding/salinity, *Salix* was used as an indicator (Wild Rivers Commission Webpage, 2002).

Sensitivity Tolerance

Sensitive/	(injury at > 2 dS/m EC_e)(arctic blue willow as indicator species)/
Moderately Tolerant	(injury at 4-6 dS/m EC_e)(golden willow as indicator)species) (Wolf, 1999).

Flooding Tolerance

Tolerant	(black willow (*Salix nigra*) used as an indicator species) able to survive deep, prolonged flooding for more than one year (U.S. Department of Agriculture Website, 2002).

pH/ alkalinity tolerance
Mesophilous (pH 4.8 up to pH 7.0/7.2) (*Equisetum* sp.) (Small, 1946). Not likely to tolerate extremely alkaline conditions.

5) Wild licorice/American (*Glycyrrhiza lepidota*): Wild licorice is often found associated with members of the wheat (*Agropyron*) family. Both are found in grasslands and open plains and do relatively well in mesic conditions (Wolf, 1999). Additionally, wild licorice is often found with green ash as part of the overstory, and ferns as part of the understory (National Park Service website, 2002).

Salinity Tolerance

Moderately tolerant to salinity - see Figure 1.	(standard crested wheatgrass, *Agropyron sibiricum*) was used as an indicator) threshold EC_e - 3.5 dS/m % decrease in yield - 4 % for each 1 dS/m increase in ECe above threshold (Maas, 1993).

Sodium (ESP) Tolerance

Most Tolerant	(*Agropyron* sp. used as indicator) (ESP > 60 negatively impacts plant (stunted growth, usually due to adverse physical conditions of soil) (Shainberg and Oster, 1978).

Flooding Tolerance

Tolerant/	Green ash (*Fraxinus pennsylvania* as indicator) (able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year)
Very tolerant	(able to survive deep, prolonged flooding for more than one year) (U.S. Department of Agriculture website, 2002). Good (Munshower, 1995).

pH/alkalinity Tolerance
Ferns in general: mesophilous (pH 4.8 up to 7.0/2) not likely to tolerate extreme alkaline conditions (Small, 1946).

6) Goose berry, red shoot (*Ribes setosum*): Gooseberry is either found in thickets or as individual plants, commonly on disturbed sites or along streambanks (Munshower, 1995).

Salinity Tolerance
Sensitive - see Figure 1 Ribes sp.:

Sodium Tolerance (ESP)

Extremely sensitive	(ESP 2-10 will cause damage) (Shainberg and Oster, 1978). Very sensitive to sodium; may show its toxic affect when flood irrigation water has an SAR as low as 4.5 and/or spray irrigation water that wets the foliage has a sodium content > 70 mg/L or SAR >3.0 (DPI website, 2002).

pH/ Alkalinity Tolerance
Ribes sp.: alka-tolerant (above pH 4.8/ 5.2 up to 7.5/9 pH or above) (Small, 1946).

7) Mint/ Field (*Mentha arvensis*): Mint is commonly found in wetlands, floodplains or other relatively moist environments. For this reason, *Salix* sp. was used as an indicator (U.S. Department of Agriculture website, 2002).

Salinity Tolerance

Sensitive/	(injury at > 2 dS/m EC_e) (arctic blue willow as indicator species)
Moderately tolerant	(injury at 4-6 dS/m EC_e) (Golden willow as indicator species)(Wolf, 1999).

Flooding Tolerance
Tolerant

From: Corene Rodder <crodder@somachlaw.com>
Sent: Friday, October 30, 2015 1:12 PM
To: BDCPcomments
Cc: Nick Jacobs; Steve Chappell; Jim Waters
Subject: SRCD comments on the BDCP/CA WaterFix and RDEIR/SDEIS
Attachments: image.gif; ATT00001.htm; 10-30-15 SRCD Cal WaterFix RDEIR Comment Ltr - w Attachments.pdf.zip; ATT00002.htm

Good afternoon,

Please see the attached containing SRCD's comment letter and attachments.

If you have any questions please do not hesitate to call our office.

Sincerely,

Corene Rodder | *Legal Secretary for Nicholas A. Jacobs*

500 Capitol Mall, Suite 1000 | Sacramento, CA 95814
Office 916.446.7979 | **Direct** 916.469-3814 | **Fax** 916.446.8199 | crodder@somachlaw.com
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