LO224 City of Antioch

CITY OF ANTIOCH
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CALIFORNIA

February 3, 2012

Via email to: eircomments@deltacouncil.ca.gov

To: Phil Isenberg, Chair, Delta Stewardship Council (DSC)
DSC Council Members
Joe Grindstaff, Executive Officer, DSC
Terry McCauley, Interim Chief Deputy Executive Officer, DSC
Clifford Dahm, Lead Scientist, DSC

Re: City of Antioch comments on the Delta Plan EIR

The City of Antioch (Antioch) commends the DSC for its effort in preparing the Delta Plan EIR (EIR) and respectfully submits our comments for your consideration. Our comments are presented in tabular format, with sections, page and line references, to make it easier for Delta Stewardship Council (DSC) members and staff to review. LO224-1

With all due respect to the hard work of the staff and consultants, Antioch remains concerned that our prior comments on the Delta Plan have not been addressed, nor have changes been made to rectify incorrect and misleading information that continues to be used in the EIR.

Impacts to the western Delta are not correctly or consistently presented, and mitigations for these impacts are not proposed. Historical records regarding the salinity of the Delta, and in particular the historically low salinity conditions that occurred in the western Delta, have been disregarded in the EIR, leading to false assumptions about returning to more saline "historical or natural conditions." This incorrect assumption, not based on historical fact, would appear to pave the way toward allowing the Western Delta to become saltier, therefore paving the way for the BDCP preliminary project, which will increase salinity in the Western Delta (see below and attached.) We find this very disturbing for a number of reasons: ignoring historical fact and scientific studies about Delta salinity; using policy science rather than the Independent Science Board and other scientific bodies' findings and recommendations. We strongly urge you to correct this and continue to be happy to engage with you and your staff to provide additional information. LO224-2

This submission by Antioch also includes five attachments that document historic flow and salinity conditions, and indicate that the western Delta was historically a fresh water body. We also submit an excerpt from the BDCP Effects Analysis Appendix C, which shows significant western Delta impacts. The City asks that the following five documents be included in the administrative record for the EIR and considered together with the City's comments, included in revisions to the EIR:

- Comment table (enclosed)
- Attachment 1: CCWD's Historic Salinity Study
- Attachment 2: SWRCB Flow criteria hearing testimony by Susan Paulsen (Flow Science Incorporated) on behalf of the City of Antioch
- Attachment 3: Thomas Means, April 1928, Salt Water Problem, on salinity increases in the Western Delta LO224-3

Response to comment LO224-1

Comment notes.

Response to comment LO224-2

Please refer to the responses to comments LO224-4 to LO224-39 below.

Response to comment LO224-3

Comment noted.

- Attachment 4: City of Antioch comments on Fifth Draft Delta Plan
- Attachment 5: Excerpt from BDCP Effects Analysis, Appendix C, Section C.7.1.3, Salinity, 12/14/2011

LO224-3

Antioch would like to make the following key points for consideration by DSC members and staff. More detailed comments are included in the enclosed comment matrix.

Long Term Impacts

- Most of the EIR discussion focuses on short-term impacts (construction, noise, etc.) that result from implementation of projects expected to lead to long-term improvements. However, the Proposed Project (PP) includes the BDCP, and therefore will result in long-term negative water quality and water supply impacts at Antioch. These must be mitigated. LO224-4

Historical conditions and "natural" flows

- There's clearly a misconception about the "natural" or "historical" flow conditions. Information and data compiled by Antioch and CCWD shows that the western Delta was historically much fresher than it is today. (See the attachments to this letter.) LO224-5
- The PP seems to indicate that a more saline western Delta existed in the past and should be restored. This is not only incorrect, but is misleading and could be construed to "pave the way" for increased exports, resulting in significant impacts to western Delta water quality and flow. LO224-6

Proposed Project Impacts to Antioch and the western Delta

- Current model data from the BDCP "preliminary proposal" effects analyses (Attachment 5 BDCP Appendix C, Section C.7 – Conclusions) clearly show increased salinity impacts in the western Delta as a result of a decrease in the volumes of flow from the Sacramento River that reach the Western Delta (resulting from upstream export) and due to the creation/restoration of tidal habitat in the Delta, upstream of Antioch. LO224-7
- Although the Delta Plan EIR mentions proposed ecosystem restoration projects as a potential cause of increased salinity in the Western Delta, the EIR fails to mention increased exports from the Sacramento River upstream of the Western Delta as a factor in the increased western Delta salinity. This should be corrected. LO224-8
- The Draft EIR is inconsistent in outlining and assigning significance to this impact. Increases in salinity in the western Delta will cause significant impacts to Antioch's water supply quality, availability, and reliability, and as such must be mitigated. LO224-9

Lack of Mitigation

- No mitigation options for western Delta impacts are discussed or outlined in the Delta Plan. A full range of mitigation options for BDCP should be considered in the plan, such as adjustment of Antioch's contract with DWR for compensation, tie-ins to BDCP project, brackish water desalination or other mitigation options. LO224-10

Cumulative impacts to the Delta system as a whole are not discussed in the plan

- There is no discussion of which, if any agency will monitor overall health of the Delta system. For example, who will track the combined impacts of the BDCP, Three Mile Slough and Old and Middle River gates projects on the Delta as a whole? (See Antioch's Fifth Draft comments submitted with this letter.) LO224-11

Thank you for your consideration of these comments. Please contact me if I can be of assistance or provide additional information. LO224-12

Sincerely,

P. Harrington

Phillip Harrington, Director of Capital Improvements/Water Rights
City of Antioch, P.O. Box 5007 Antioch, CA 94531-5007

Response to comment LO224-4

The proposed BDCP is a reasonably foreseeable future project that is being evaluated by the Department of Water Resources as the CEQA lead agency. The cumulative impacts of the proposed Delta Plan, in combination with the impact of the proposed BDCP, are described in EIR Sections 22 and 23. In addition, the Delta Plan must be reviewed at least once every five years and may be revised as the Council deems appropriate pursuant to Water Code section 85300(c). Hence, the Delta Plan would be amended when the BDCP is ready for incorporation. Please refer to Master Response 1. Section 3 of the EIR addresses impacts on water supply and water quality from both construction and operation of the type of projects that would be consistent with the Delta Plan.

Response to comment LO224-5

As describe in Section 3, the EIR agrees that areas such as Suisun Bay have become more saline than during some periods in history. See also Master Response 5.

Response to comment LO224-6

Sections 3 and 4 of the EIR discuss more variability in salinity in the Delta especially prior to construction of the levees and the communities in the Delta. See also Master Response 5.

Response to comment LO224-7

The results from the referenced information are consistent with the EIR's description of significant adverse impacts to water quality due to the SWRCB water quality and flow objectives and criteria for a more natural flow regime and encouragement of Delta ecosystem restoration actions. Please refer to Master Response 5.

Response to comment LO224-8

Please refer to the response to comment LO224-7. As noted in the Draft EIR and RDEIR, it is possible that increased salinity in the western Delta in the summer months could cause adverse impacts to users of Delta water. Future, site-specific environmental analyses conducted at the time such projects are proposed by lead agencies will address project-level impacts. Nonetheless, the EIR conservatively determines that these impacts could be significant.

Response to comment LO224-9

As described in response to comment LO224-7, the results from the referenced information are consistent with the Delta Plan Program EIR description of significant adverse impacts to water quality. However, as described in Section 2B of the EIR and Master Response 2, the Delta Stewardship Council does not propose or contemplate directly authorizing any physical activities, including but not limited to construction or operation of infrastructure. Rather, through the Delta Plan, the Delta Stewardship Council seeks to influence the actions, activities, and/or projects of other agencies, the details of which would be under the jurisdiction and authority of the agencies that will propose them in the future and conduct future environmental review. Without specific details of future projects, it is not possible for the Delta Stewardship Council to develop quantitative thresholds of significance, conduct site-specific quantitative analyses, and design site-specific mitigation measures. Accordingly, in the absence of specific proposed physical projects, this EIR makes a good faith effort to disclose the potentially significant environmental effects of the types of projects that may be encouraged by the Delta Plan and to identify program-level mitigation measures.

Response to comment LO224-10

Please refer to the response to comment LO224-4.

Response to comment LO224-11

This is a comment on the Project, not on the EIR.

Response to comment LO224-12

Comment noted.

Delta Plan EIR Comments from the City of Antioch 2/2/2012

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
Executive Summary	Description of the Proposed Project	ES-2	N/A	**"Reliable Water Supply:** New or expanded reservoirs, groundwater production facilities (wells and pipelines), ocean desalination facilities, and recycled water facilities"	Suggest modifying to read "...ocean and/or brackish water desalination facilities..." Desalination may be an option for mitigating for the impact of higher salinity caused by the proposed project in the western Delta. The water in the western Delta is expected under the proposed project to become too saline for use as municipal supply, but desalting the water in the western Delta is one option for rendering this water usable. Corresponding changes should be made in the relevant chapters of the EIR as well. LO224-13
Executive Summary	Table ES-1 EIR Section 3-3	ES-11	N/A	Substantially Change Water Supply Availability to Water Users that use Delta Water: Significance after Mitigation – Sv/LTS (Less than significant for covered actions. Less than significant for non-covered actions if implementing agencies implement mitigation; significant and unavoidable for non-covered actions because DSC cannot mandate implementation).	Proposed project poses substantial and significant impacts to Antioch and the Western Delta water quality and water supply reliability and will also impact the Delta economy. We have commented on this numerous times in writing and in person, and in the Fifth Draft, yet these impacts are not included in the EIR. Also, we can find no mitigation for these impacts in this EIR. Suggest adding language that describes potential impacts to the Western Delta and also proposes potential mitigation measures for these impacts. LO224-14 Impacts to Antioch include: Water Supply Reliability/Water Quality • Diminished water quality, decreased flow, increased salinity, and changed hydrograph due to effects of upstream restoration projects and the

Response to comment LO224-13

The term "ocean desalination" is used generically throughout the EIR to mean desalination of sea water with salinity that ranges from less than to equal to salinity in ocean water.

Response to comment LO224-14

The Delta Plan assumes the encouragement of local and regional water supplies, including water use efficiency, water recycling, desalination, and groundwater conjunctive use programs to meet water demands projected in existing general plans and in response to increased salinity in the Delta due to implementation of reliable water supply, Delta ecosystem restoration, improved water quality, and flood risk reduction actions. Accordingly, the impacts addressed in this comment are deemed to be less than significant after mitigation. See also Master Response 5.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
					implementation of the BDCP preliminary proposal (Attachment 5: Excerpt from BDCP Effects Analysis, Appendix C, Section C.7.1.3, Salinity, 12/14/2011) • Decreased ability to use water in the western Delta for municipal supply Other beneficial uses/Economic Impacts • Recreational boating and fishing is a freshwater industry. Changes to flow, water quality and increased salinity will directly impact the current industry LO224-14
♦ Section 1: Introduction	1.1 Delta Plan Purpose and Project Objectives	1-2	34	Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals	The Purpose and Project Objectives for "water quality improvement" do not include any such positive outcomes for Antioch The Proposed Project degrades water quality in the western Delta, and therefore does not improve Antioch's water quality to meet drinking water goals, due to the Delta Plan's incorporation of the BDCP. Current modeling data from the BDCP (Effects Analyses Technical Appendix C (Flow) Section C.7.1.3 (Attachment 5 excerpt attached) in fact shows that salinity increases in the western Delta, particularly in the May-September timeframe. Section C.7 states that the increases in salinity are a function of reduced Sacramento River flows and are enhanced by the creation of tidal habitat proposed as part of the BDCP preliminary proposal. Antioch suggests that the Delta Plan EIR should acknowledge this fact and propose mitigation for these impacts. LO224-15
♦ Section 1: Introduction	1.1 Delta Plan Purpose and Project Objectives	1-3	29-39	The Delta Plan shall meet all of the following requirements... ..."Be based on the best available	Throughout the EIR, justification for actions appears to be based on public policy research (PPIC) rather than from scientists, like the Independent Science Board (ISB.) LO224-16 Examples include:

Response to comment LO224-15

Please refer to response to comment LO224-7.

Response to comment LO224-16

The discussion referred to in this comment is based on text from the Fifth Staff Draft Delta Plan. Thus, this is a comment on the Project, not on the EIR.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
				scientific information and the independent science advice provided by the Delta ISB."	• ISB has stated (as has SWRCB) that Delta outflow is the key known factor for fisheries health. PPIC states it is a factor but not a key factor. • Historical data show the Western Delta as a tidally influenced fresh water system, not the saline system that PPIC continues to claim. Why aren't these historical data being used? • PPIC uses climate change and sea level rise to postulate catastrophic change to the Delta. However, BDCP modeling of the preliminary proposal shows that salinity increases in the western Delta will result from reduced Sacramento River flow, restoration (increased tidal habitat), and sea level rise. See Attachment 5: Excerpt from BDCP Effects Analysis, Appendix C, Section C.7.1.3, Salinity, 12/14/2011 • The DSC should use scientific information and modeling to capture the relative importance of these factors and should, in any case, acknowledge that the BDCP preliminary proposal would result in increased salinity in the Western Delta on top of the increases that may occur as a result of climate change (i.e., BDCP will exacerbate the situation). Recommend that the EIR use scientific, not public policy group data to describe known and potential impacts, state areas of uncertainty in these data, and not use PPIC information as fact. LO224-16
♦ Section 1: Introduction	1.1 Delta Plan Purpose and Project Objectives	1-4	1-2	"Include a science-based, transparent and formal adaptive management strategy for ongoing ecosystem restoration and management decisions."	As discussed above, The EIR has seemingly ignored some of the independent scientific bodies who have the most up-to-date data as well as the BDCP's effects analyses, in favor of policy-driven science that postulates and looks to meet a certain goal. This sets a poor precedent for meeting this objective. LO224-17
♦ Section 2A:	2.1.2 Covered Actions	2A-2 –	All	Covered Actions	It is not clear whether or not a change in the location of LO224-18

Response to comment LO224-17

This is a comment on the Project, not on the EIR.

Response to comment LO224-18

Please refer to Master Response 1.

4

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
Proposed Project and Alternatives		2A-4			Antioch's point of diversion or construction of a new intake is a covered action or not, based on these definitions. The City has found, in its review of this draft document, that it is exceedingly difficult to ascertain which actions might or might not be covered or included as part of the proposed project, particularly considering that some impacts might result in new projects that might or might not be considered mitigation for other Impacts. For example, higher salinity conditions in the western Delta will be caused by the proposed project (since, as described in these comments, the proposed project includes the BDCP); higher salinity in the western Delta will have a significant impact on Antioch's ability to use water at its intake location. These impacts could be mitigated by tying Antioch into the new BDCP diversion/pipeline, by constructing a desal plant near the current intake, by renegotiating the terms of Antioch's contract with DWR, or by other measures. It is unclear whether these measures would be part of the proposed project, part of mitigation measures necessitated by the impacts of the proposed project, or not included at all within the scope of the current draft EIR. LO224-18
♦ Section 2A: Proposed Project and Alternatives	2.2 Proposed Project			2.2.1.2 Surface Water Projects The Proposed Project policies and recommendations, including WR P1,WR R1, WR R2, WR R3,WR R4, WR R5, WR R6, WR R7, and ER P1, encourage development of local water supplies and reduced reliance on the Delta, which could require construction of: Surface	Antioch has been proposing regional approaches to DWR and the DSC to ensure western Delta water quality and supply. We would ask that DSC support implementation of such an approach. LO224-19

Response to comment LO224-19

This is a comment on the project, not on the EIR.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
				water intake and diversions from streams and rivers	
Section 2A: Proposed Project and Alternatives	2.2.1.8 Delta Conveyance—Bay Delta Conservation Plan	2A-24	16-27	Completion of the BDCP planning process and implementation of the projects now under consideration in that process *would have impacts on the Delta and would affect the Coequal goals.*	Antioch agrees that BDCP will have impacts, and is particularly concerned by the significant increases in salinity that model results indicate will occur as a result of BDCP implementation. BDCP as proposed will impact the western Delta by reducing Delta outflow, causing increased salinity, reduced in-Delta water quality, reduced water supply reliability, and economic impacts related to the boating and fishing industry that is dependent upon a freshwater Delta. Why is mitigation for these impacts not discussed in the EIR? Suggest including language describing the potential for such impacts. See also comments for Section 23-BDCP.
♦ Section 2A: Proposed Project and Alternatives	2.2.2 Delta Ecosystem Restoration	All	All		There is no discussion of the potential physical impacts related to changes in surface water hydrology or water quality, such as increased salinity, that may occur as a result of these projects. As we have stated above, BDCP effects analyses indicate that ecosystem restoration projects will increase Western Delta salinity. Impacts to Western Delta water hydrology and quality should be acknowledged in the Delta Plan EIR.
♦ Section 2A: Proposed Project and Alternatives	2.2.2.4 Modification of Flow Objectives and Flow Criteria in the Delta and Delta Watershed	2A-39	27 - 40		The EIR uses the terminology, "natural flow" and a more "natural flow regime" in the Delta. Historical data indicate that the Delta has been a tidally influenced freshwater Delta, with freshwater extending to or beyond Crockett,

LO224-19

LO224-20

LO224-21

LO224-22

Response to comment LO224-20

Please refer to the response to comment LO224-4.

Response to comment LO224-21

Please refer to response to comments LO224-4 and LO224-7. The EIR does not include implementation of BDCP in the alternatives. Please see Master Response 1.

Response to comment LO224-22

Please refer to Master Response 5.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
					until massive agricultural irrigation diversions were initiated upstream of Antioch at the turn of the century; subsequent diversions and exports have continued to alter the natural flow regime in the Delta. (See Thomas Means, April 1928, Salt Water Problem, on salinity increases in the Western Delta) Antioch and CCWD have provided historical documents that measured water quality norms and the considerable changes that resulted from increased diversions upstream. Other changes, including channelization and the CVP and SWP, moved conditions in the Delta still farther away from the historic baseline. Antioch requests that any discussion of "natural flow" reflect true natural flow regimes, i.e., flows that occurred within the Delta prior to about 1918. Further, Antioch suggests that EIR should acknowledge that the exports of water by the SWP and CVP are a major stressor to the "natural flow regime" and hence to the water quality of the Delta. LO224-22
Section 2A: Proposed Project and Alternatives	2.2.3 Water Quality Improvement *2.2.3.1 Overview of Improved Drinking Water and Environmental Water Quality Programs*	2A-40 - 41			See comments for Chapter 3, below, regarding Western Delta salinity, increased salinity during summer, incorrect Delta "natural conditions" and potential violation of Delta Reform Act. LO224-23
Section 3: Water Resources	3.3.1 - Major Sources of Information	3-3	15-31	Major Sources of Information	We have attached the following documents as factual historical record, so that DSC will incorporate the data in these studies into the EIR and referenced in sources of information for appropriate chapters of the EIR: • Attachment 1: CCWD's Historic Salinity Study • Attachment 2: SWRCB Flow criteria hearing LO224-24

Response to comment LO224-23

Please refer to the response to comment LO224-6 and to Master Response 5.

Response to comment LO224-24

Comment noted. Please refer to response to comment LO224-6.

7

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
					testimony by Susan Paulsen, Flow Science for the City of Antioch • Attachment 3: Thomas Means, April 1928, Salt Water Problem, on salinity increases in the Western Delta • Attachment 4: City of Antioch comments on Fifth Draft Delta Plan • Attachment 5: Excerpt from BDCP Effects Analysis, Appendix C, Section C.7.1.3, Salinity, 12/14/2011 LO224-24
	3.3.3.2 Surface Water Quality	3-10	20-22	The statement that the artificially modified nature of Delta channels and islands "hold saline bay waters farther downstream"	This statement is misleading and inaccurate. In fact, the historic Delta (prior to channel modification) was far fresher than the Delta today. See references detailed in these comments. LO224-25
		3-10	27-29	"A return to more natural, seasonally variable salinity patterns would likely benefit the native fish..."	As detailed throughout these comments, the "natural condition" was actually far fresher than today's condition, and is the "natural condition" to which native species were historically adapted. Analyses of the prospects for recovery of native species would be deficient if they did not include an accurate depiction and analysis of the true historic condition. LO224-26
	3.4.2 – Thresholds of Significance	3-77	1-16	[first bullet] Violate any water quality standards.	Should add "including in-delta water quality." LO224-27
	3.4.3.1 Reliable Water Supply	3-77	28	Ocean desalination projects	Suggest rewriting to "ocean and/or brackish water desalination projects", as desalination of water in the western Delta may be considered as mitigation for the increase in salinity that will result from implementation of the BDCP preliminary proposal. LO224-28
	3.4.3.1.1 ...substantially degrade water quality	3-79	All	Discussion of water quality degradation omits salinity effects	As noted throughout these comments, model results from the BDCP preliminary proposal show substantial increases in LO224-29

Response to comment LO224-25

The sentence referred to in this comment is stating that the salinity gradient is located further downstream into the western Delta, and therefore, the western Delta is characterized by freshwater more frequently than in historic conditions prior to construction of levees and communities in the Delta.

Response to comment LO224-26

Please refer to response to comment LO224-25.

Response to comment LO224-27

The referenced threshold of significance in table ES-1 was incorrectly reported. The table has been amended to read: "The level of significance after mitigation on page ES-10 has been amended to remain significant. The Proposed Project assumes the encouragement of local and regional water supplies, including water use efficiency, water recycling, desalination, and groundwater conjunctive use programs to meet water demands projected in existing general plans and in response to increased salinity in the Delta due to implementation of reliable water supply, Delta ecosystem restoration, improved water quality, and flood risk reduction actions."

Response to comment LO224-28

Please refer to response to comment LO224-13.

Response to comment LO224-29

Please refer to response to comment LO224-7. The EIR analysis acknowledges that significant adverse water quality impacts would occur. However, the Fifth Staff Draft of the Delta Plan, the Revised Project, and Alternatives 1A, 2, and 3 assume that communities would be encouraged to implement water treatment and local and regional water supplies as part of the actions under these alternatives.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
				in the western Delta	salinity in the western Delta and at the City of Antioch's drinking water intake. These should be explicitly acknowledged within this section as resulting from "Project Operations." LO224-29
	3.4.3 – Reliable Water Supply	3-77	17-37	ALL	This section should include: regional interconnected projects as Antioch discussed with the DSC; re-negotiation of existing water quality and substitute water agreements between DWR and Delta Water Users to provide ensure future water supply reliability based on the Delta Plan and the BDCP; and construction of brackish water desalination facilities in the western Delta. LO224-30
		3-83 to 3-84	3-83 (line 41) through 3-84 (15)	Discussion of benefits of "natural flow regime" to native species	As discussed above, it appears that the proposed project will result in salinity conditions in the western Delta that are significantly higher than occur currently; current salinity levels are, in turn, significantly higher than the "natural" salinity conditions that existed in the early 1900s and before. Thus, and as discussed throughout these comments, the proposed project will significantly increase salinity in the western Delta with respect to the "natural conditions." Thus, the proposed project will not restore "natural flow conditions" in the western Delta and for this reason cannot be cited as a benefit to native species in this region. LO224-31 Antioch is also concerned about the policy of apparently shifting the historic freshwater delta further to the east (e.g. away from Suisun Bay) and the potential impacts on fish and wildlife. These impacts are not adequately discussed in the EIR and there is no mitigation proposed. The Water Resources White Paper, Dec. 8, 2010, concluded that these changes to the historic delta did have adverse impacts to

Response to comment LO224-30

The Delta Plan does not anticipate changes to the existing agreement between the State and the City of Antioch for operations of the State Water Project. Please refer to responses to comments LO224-7.

Response to comment LO224-31

Please refer to responses to comments LO224-7 and Master Response 5.

LO224-31

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
					freshwater and salinity within the Delta.
	3.4.3.1.1 – Project Impacts	3-78 -3-93		Increased salinity in the western Delta in the summer months, however, could cause adverse impacts to water users of Delta water. . . . the potential impacts are significant. [pg. 3-84, lines 8-15].	This section states that water quality in the western Delta will degrade (i.e., salinity will increase) as a result of the Delta Plan. This section also provides that the impacts are significant. However, there is no proposed mitigation. Further, this conclusion is contrary to the conclusion in section 2A which finds the impacts to be less than significant. This section references a "more natural flow regime" but fails to define what this means. The undisputed evidence provided to the DSC shows that summer salinity levels were naturally and historically ***fresher*** than current salinity levels in the western Delta. See for example, the Water Resources White Paper, Dec. 8, 2010 and Delta Ecosystem White Paper, Oct. 10, 2010; CCWD's Historic Salinity Study; Thomas Means, April 1928, *Salt Water Problem*; Antioch's presentation to the SWRCB during the Delta Flow Criteria hearings. In addition, the SWRCB White Paper, Dec. 8, 2010, concluded that these changes to the historic delta did have adverse impacts to freshwater and salinity within the Delta. Antioch has taken water from the Delta since the late 1850s, including during the summer and in dry years, confirming that water in the western Delta has historically been fresher than it is currently, and than it will be under the proposed project. The Cities of Benicia and Pittsburg likewise were able to divert fresh water during the late 1800s, with the exception of late summer periods during droughts. To date, none of the documentation provided by Antioch

LO224-32

Response to comment LO224-32

Please refer to the response to comment LO224-27 and Master Response 5. In response to this comment, please see text changes in Section 5 of the FEIR.

10

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
					regarding the historic salinity conditions in the western Delta has been rebutted. Notably, Chapter 4 of the EIR goes into great detail as to the major changes to Delta inflow and outflow as well as changes to habitat and channel configuration. And yet, section 3 finds that despite such major changes to the Delta Ecosystem and upstream inflow that the Delta was somehow historically more saline during the summer than present conditions. To the extent it is the Delta Plan's objective to increase salinity in the western Delta, what mitigation measures are proposed? The Delta Reform Act directed that the Delta Plan "restore" the Delta ecosystem and improve water quality. The Delta Plan EIR indicates that by increasing salinity levels in the western Delta that the Delta Plan will not achieve either of these goals. Therefore, some form of mitigation must be proposed. As the Council is aware, Antioch presently has a substitute water agreement with the Dept. of Water Resources. That Agreement could be modified to further mitigate the impacts of salinity on Antioch's water supply from the export projects. The DSC and its EIR preparers should meet with Antioch and the Dept. of Water Resources to draft conditions for the agreement that would protect Antioch's water supply from the proposed increased salinity in the Western Delta and could be incorporated as mitigation measures. LO224-32
		3-82	3-10	"The Proposed Project encourages	As stated throughout these comments, the Proposed Project LO224-33

Response to comment LO224-33

Please refer to responses to comments LO224-7 and Master Response 5. As described in Section 2A of the EIR, the Delta Plan and many of the alternatives assume that due to implementation of Proposed Project policies and recommendations (such as WR P1 and ER P1), water users in the Delta and in areas outside of the Delta that use Delta water would be encouraged to implement water use efficiency and conservation programs, recycled water programs, local water storage, and ocean desalination to reduce reliance on the Delta.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
				a variety of actions **to improve local and regional water reliability** while reducing the use of Delta water… Such water supply reliability projects would provide a benefit to water supply availability to water users that use Delta water."	will reduce the availability of drinking water at the City of Antioch's intake by increasing the salinity levels of the western Delta. This impact should be disclosed as a **significant impact to the City of Antioch's water supply**. If the actions discussed in lines 6-8 (recycled wastewater, stormwater, desalination, etc.) are expected to reduce impacts on the City of Antioch's water supply, these should be included either as formal project components or as mitigation measures. LO224-33
♦ Section 4: Biological Resources	4.3.2 Delta and Suisun Marsh	4-3	All	All	Considering the overview of the historic changes to the delta ecosystem such as reduced flows, changed channel geometry and loss of wetlands, it is illogical and incorrect for the Delta Plan EIR to conclude [at 3.4.3.1.1] that the western Delta was historically more saline than present conditions during the summer, especially during the early summer,. The City of Antioch requests that the "natural flow" and salinity conditions be clearly disclosed and discussed. Section 4.3.2.1.10 (Other Water Quality Issues) should add a discussion of salinity in the western Delta, acknowledging that salinity is currently higher in this region of the Delta than for the "natural flow condition." LO224-34
	4.3.2.3.5 [Figures 4.1 and 4.2]	4-29	34-40	Figures 4.1 and 4.2	Section references Figures 4.1 and 4.2 as showing freshwater tidal marsh. The figures do not delineate between brackish and freshwater tidal marsh. It is important for Antioch to understand what the Delta Plan contends is brackish tidal marsh presently and historically in order to assess potential impacts. LO224-35
♦ Section 22: Cumulative Impact	22 – entire section	All	All	All	The cumulative impact analysis is incomplete, as it lacks the following: 1. Antioch has commented in the Fifth Draft that LO224-36

Response to comment LO224-34

Please refer to responses to comments LO224-7 and LO224-25 and to Master Response 5.

Response to comment LO224-35

The level of detail discussed in this comment exceeds that appropriate for the programmatic analysis provided in the EIR. As described in Section 2B of the EIR and in Master Response 2, the Delta Stewardship Council does not propose or contemplate directly authorizing any physical activities, including but not limited to construction or operation of infrastructure. Rather, through the Delta Plan, the Delta Stewardship Council seeks to influence the actions, activities, and/or projects of other agencies, the details of which would be under the jurisdiction and authority of the agencies that will propose them in the future and conduct future environmental review. Accordingly, this EIR makes a good faith effort to disclose the potentially significant environmental effects of the types of projects that may be encouraged by the Delta Plan and to identify program-level mitigation measures, but it does not provide project-specific or necessarily location-specific details in the absence of information about specific projects that may be proposed in the future.

Response to comment LO224-36

As described in the Final Draft Delta Plan, the Delta Stewardship Council will be implementing an adaptive management program to develop, implement, and update the Delta Plan and to determine the best available science used in support of the Delta Plan actions. The projects described in other reports for Three Mile Slough, Georgiana Slough, and relocation of the compliance point for the agreement between the State and North Delta Water Agency are not defined to an adequate detail to be included in the cumulative impact analysis in Section 22 of the EIR. Several of these concepts are being evaluated in the BDCP, a cumulative project discussed in Sections 22 and 23 of the EIR.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
Assessment					Cumulative impacts to the Delta system as a whole are not discussed in the plan: "There is no discussion of creating an oversight or regulatory agency to monitor overall health of the Delta system. For example, who will track the combined impacts of the BDCP, Three Mile Slough and Old and Middle River gates projects on the Delta as a whole?" (See Attachment 4, Antioch Fifth Draft Comments) LO224-36 2. This section fails to list or consider the following projects or changes, which could impact Western Delta hydrology and water quality: 1) the Three Mile Slough Project proposed by the Dept. of Water Resources; or 2) the proposed Georgiana Slough non-physical barrier project; 3) the move of the compliance point from Emmaton to Three-Mile Slough in all project alternatives of the BDCP.
♦ Section 23: Bay Delta Conservation Plan	23.3.2 Initiation of the BDCP	23-7	23-24	"Provide a comprehensive means to coordinate and standardize mitigation and compensation requirements for covered activities within the planning area."	The City is encouraged that the DSC believes that the BDCP preliminary proposal will provide a means to coordinate and standardize mitigation and compensation requirements. However, as indicated throughout these comments, the City finds no evidence in this EIR or in the draft BDCP documents reviewed to date that mitigation is being contemplated or planned to compensate for the increases in salinity in the western Delta that will occur as a result of the proposed project(s). LO224-37 The City requests that explicit mention be made of the various mitigation options, and that various alternatives should be included in the EIR either as formal components of the proposed project or as mitigation measures.

Response to comment LO224-37

Please refer to the response to comment LO224-4.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
♦ Section 23: Bay Delta Conservation Plan	23.6 Cumulative Impacts of Implementation of BDCP	23-29 23- 30	27-41 1-3	"Physical improvements associated with BDCP-related operation of ecosystem restoration and enhancement, reduction of other stressors, and Delta conveyance, in addition to the Delta Plan, could change water quality in some portions of the Delta by increasing the extent and duration of time for fresh water or saline water. For example, expansion of tidal marsh areas in the western Delta or Suisun Marsh could expand areas with brackish or saline water in those areas. Another example would involve increased Delta outflow in accordance with Fall X2 provisions would extend the period of time that fresh water conditions would occur in the western Delta during fall months. Changes in Through-Delta conveyance also could change water quality in the central and south Delta if barriers were used along the San Joaquin River to convey most of the San Joaquin River flows through Old River instead of the existing San Joaquin River channel."	There is no mention of the impacts to Western Delta water quality caused by **increased exports**, nor does it mention the impacts from the move of the Western Delta compliance point from Emmaton to Three-Mile slough. Both would increase salinity per BDCP Effects Analysis Technical Appendix C, Section C.7 (Attachment 5: Excerpt from BDCP Effects Analysis, Appendix C, Section C.7.1.3, Salinity, 12/14/2011) LO224-37
♦ Section 23: Bay Delta	23.6 Cumulative Impacts of	23-35 23-36	37-42 1-4	"Physical improvements associated with BDCP-related	Antioch has a ferry project in the planning process. Would this project be a covered action, and will BDCP impact this LO224-39

LO:

Response to comment LO224-38

Please refer to the response to comment LO224-4.

Response to comment LO224-39

Please refer to the response to comment LO224-4.

EIR Section	Subsection	Page number	Line number	Text	Comment / Suggested Language
Conservation Plan	Implementation of BDCP			ecosystem restoration and enhancement, reduction of other stressors, and Delta conveyance, in addition to the Delta Plan, could conflict with adopted plans and policies for navigation, ports, waterways, and ferries."	plan?

L0224-39

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

No comments

- n/a -

Acknowledgements

CCWD would like to thank the City of Antioch for their contribution towards funding a technical review of CCWD's draft report "Trends in Hydrology and Salinity in Suisun Bay and the Western Delta" (June 2007); their review substantially improved the work and led to the final report "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay". CCWD is grateful to the many reviewers including Richard Denton, Matthew Emrick, Gopi Goteti, Phil Harrington, E. John List, Susan Paulsen, David Pene, Mat Rogers, and Peter Vorster. We also thank the following for sharing their data and analyses: Roger Byrne, Chris Enright, Spreck Rosekrans, and Scott Starratt, and we thank Ann Spaulding for her contributions.

No comments

- n/a -

Foreword - Establishing the Historical Baseline

The watershed of the Sacramento–San Joaquin Delta (Delta) provides drinking water to more than 23 million Californians as well as irrigation water for millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. The Delta estuary as we know it began to form about 6,000 years ago, following the end of the last ice age. Because the estuary is connected to the Pacific Ocean through San Francisco Bay, seawater intrusion causes the salinity of Suisun Bay and the Delta to vary depending on hydrological conditions. This seawater intrusion into the Delta affects estuarine species as well as drinking water and irrigation water supplies.

Successful restoration of the Delta ecosystem requires an understanding of the conditions under which native species evolved. Contra Costa Water District's report on "Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay" presents a detailed review of more than 100 years of studies, monitoring data, scientific reports, and modeling analyses that establish an historical record of the salinity conditions in the Western Delta and Suisun Bay.

No comments

- n/a -

No comments

- n/a -

Executive Summary

The historical record and published studies consistently show the Delta is now managed at a salinity level much higher than would have occurred under natural conditions. Human activities, including channelization of the Delta, elimination of tidal marsh, and water diversions, have resulted in increased salinity levels in the Delta during the past 150 years.

Eighty years ago, Thomas H. Means wrote ("Salt Water Problem, San Francisco Bay and Delta of Sacramento and San Joaquin Rivers," April 1928, pp 9-10):

> "Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominately of salt water types around San Pablo Bay and of fresh water types around Suisun Bay….
>
> The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted….
>
> At present [1928] salt water reaches Antioch every year, in two-thirds of the years running further [sic] upstream. It is to be expected that it will continue to do so in the future, even in the years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.
>
> The cause of this change in salt water condition is due almost entirely to the works of man."

In 1928, Thomas Means had limited data over a short historical period from which to draw these conclusions. Nonetheless, his conclusions remain accurate and have been confirmed by numerous subsequent studies, including paleosalinity records that reveal salinity conditions in the western Delta as far back as 2,500 years ago. The paleosalinity studies indicate that the last 100 years are among the most saline of periods in the past 2,500 years. Paleoclimatology and paleosalinity studies indicate that the prior 1,500 years (going back to about 4,000 years ago) were even wetter and less saline in San Francisco Bay and the Delta. The recent increase in salinity began after the Delta freshwater marshes had been drained, after the Delta was channelized and after large-scale upstream diversions of water, largely for agricultural purposes, had significantly reduced flows from the tributaries into the Delta. It has continued, even after the construction of reservoirs that have been used in part to manage salinity intrusion.

No comments

- n/a -

Increased Salinity Intrusion into the Delta

Studies and salinity measurements confirm that despite salinity management efforts, Delta salinity is now at or above the highest salinity levels found in the past 2,500 to 4,000 years. Under equivalent hydrological conditions, the boundary between salt and fresh water is now 3 to 15 miles farther into the Delta than it would have been without the increased diversions of fresh water that have taken place in the past 150 years.

Reservoir operations artificially manage salinity intrusion to conditions that are saltier than had been experienced prior to the early 1900's. While these managed conditions are certainly fresher than would occur in today's altered system if operated without any salinity management, they are still saltier than what the Delta experienced under similar hydrological conditions in the past. While the Delta is being managed to a somewhat acceptable saline condition to meet many beneficial uses, it is still managed at a more saline condition than would have occurred prior to the anthropogenic changes of the past 150 years.

For example, the 1928-1934 drought was one of the driest periods in the past 1,000 years (Meko *et al*., 2001a), and occurred after tidal marshes within the Delta had been reclaimed and water diversions began removing substantial amounts of fresh water from the Bay-Delta system. Nonetheless, the Delta freshened during the winter in those drought years. This winter freshening of the Delta has not occurred during recent droughts. While salinity intrusion into the Delta was previously only seen in the driest years, significant salinity intrusion now occurs in nearly every year – exceptions are only found in the wettest conditions.

Changed Variation in Salinity

The variability of fresh and saline conditions in the Delta has considerably changed because of upstream and in-Delta water diversions and water exports (Enright and Culberson, 2009). This change in variability results largely from the lack of fresh conditions in Suisun Bay and the western Delta, especially in the winter and spring. Restoring a variable salinity regime that more closely approximates conditions prior to the early 1900's would require much higher flows and much fresher conditions than current management practices provide, with larger outflows in the fall in most years and much larger outflows in the late winter and spring in all years.

Key Conclusions

The major conclusions of this study are:

1. Salinity intrusion during the last 100 years has been among the highest levels over the past 2,500 years. The Delta has been predominantly a freshwater tidal marsh for the last 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep ship channels, and diversion of water, have resulted in the increased salinity levels in the Delta.

No comments

- n/a -

3. Conditions in the Delta during the early 1900's were much fresher than current conditions for hydrologically similar periods. Salinity typically intrudes 3 to 15 miles farther into the Delta today.
4. The historical record and published studies uniformly demonstrate and conclude the Delta is now managed at a salinity level that is much higher than would have occurred under pre-1900 conditions. Operation of new reservoirs and water diversion facilities for salinity management reduces salinity intrusion somewhat, but the levels still exceed pre-1900 salinities.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is largely the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of time during the year when fresh water is present has been greatly reduced or, in some cases, largely eliminated.

Background

Flows and water quality in the Sacramento-San Joaquin Delta (Delta) are strongly influenced by freshwater inflow from the rivers, by the tides in San Francisco Bay and by salinity from Bay waters. Prior to human influence, the historical distribution of salinity in the Delta was controlled primarily by the seasonal and inter-annual distribution of precipitation, the geomorphology of the Bay and Delta, daily tides, the spring-neap[1] tidal cycle, and the mean sea level at Golden Gate. Extended wet and dry periods are both evident in the historical record. Since about 1860, a number of morphological changes to the Delta landscape and operational changes of reservoirs and water diversions have affected flows and the distribution of salinity within the Delta.

Between 1860 and 1920, there was significant modification of the Delta by humans:
(i) marsh land was reclaimed,
(ii) hydraulic mining caused extensive deposition and then erosion of sediment, and,
(iii) Delta channels were widened, interconnected and deepened.

Large-scale reservoir construction began in about 1920 and continued through the 1970's, changing the timing and magnitude of flows to the Delta. Large volumes of water began to be diverted for agricultural use upstream of and within the Delta in the same time period. In more recent times, California's Delta water resources have been extensively managed to meet the water supply needs of the State's municipal, industrial, and agricultural water users, with attempts made to also provide flow and water quality conditions to meet fishery needs.

Proposals for significant additional alteration of the Delta and of flows within the Delta are currently being developed as part of the Bay-Delta Conservation Plan process[2]. To

[1] During a spring tide, the gravitational forces from the sun and moon are largely the same direction and the high-low tidal range is greatest. During a neap tide, the gravitational forces sun and moon are largely not aligned and the tidal range is the lowest. The spring-neap tidal cycle, from strong spring tides through weak neap tides and back to spring tides, in San Francisco Bay has a period of about 14 days.
[2] www.baydeltaconservationplan.com

No comments

- n/a -

understand the effect of those proposals, it is important to accurately establish historical conditions. For example, for ecological restoration to be successful, it is necessary to establish and understand the conditions to which native species have previously adapted and survived in order to predict their response to future changes in climate or water management. This report uses available data and modeling to examine the consequences of structural changes in the Delta (channelization, channel dredging), increased diversions of water upstream of the Delta, reservoir operations, climate and sea level effects, and other factors on Delta salinity.

Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

Approach

Available data were used to characterize historical and present-day fresh water extent and salinity intrusion into the Delta. The data examined in this report include paleohistorical records (over geologic time scales) of river flow and salinity (Section 2), instrumental observations of hydrology and salinity (Section 3), and literature reports on the extent of fresh water in the Delta (Section 4). Additional details and supplemental information are presented in the Appendices to this report.

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

No comments

\- n/a -

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

- n/a -

Acronyms

C&H	California and Hawaiian Sugar Refining Corporation
CCWD	Contra Costa Water District
CDEC	California Data Exchange Center
Cl	Chloride concentration
CVP	Central Valley Project
DPW	Department of Public Works
DSM2	Delta Simulation Model 2
DWR	California Department of Water Resources
DWSC	Deep water ship channel
EC	Electrical conductivity
ENSO	El Niño/Southern Oscillation
ESA	Endangered Species Act
IEP	Interagency Ecological Program
M&I	Municipal and Indutrial
NDO	Net Delta Outflow
PDO	Pacific Decadal Oscillation
PPIC	Public Policy Institute of California
SWRCB	State Water Resource Control Board
SRI	Sacramento River Index
STORET	Storage and Retrieval
SWP	State Water Project
TBI	The Bay Institute
TDS	Total Dissolved Solids

Units

AF	Acre-feet
MAF	Million acre-feet
TAF	Thousand acre-ft
µS/cm	MicroSiemens per centimeter, a measure of EC
cfs	Cubic feet per second
mg/L	Milligrams per liter
ppm	Parts per million
ppt	Parts per thousand

No comments

- n/a -

No comments

- n/a -

1. Introduction

1.1. Background

The Sacramento-San Joaquin River Delta (Delta) is fed by fresh water from the Sacramento River and the San Joaquin River basins (Figure 1-1). The Delta is connected to the San Francisco Bay through Suisun and San Pablo Bays, and the movement of water back and forth between the Delta and the Bay results in mixing between saline water from the Pacific Ocean and fresh water from the rivers flowing into the Delta. The extent to which salty ocean water intrudes into the Delta is a function of natural processes such as ocean tides and precipitation and runoff from the upstream watersheds. It has also been greatly influenced by anthropogenic activities (e.g. construction of artificial river channels, removal of tidal marsh, removal of floodplain connections to channels, deepening of channels for navigation purposes, reservoir storage and release operations, and water diversions).

Proposals for significant additional alteration of Delta channels and marshland, of flows within the Delta, and of reoperation of upstream reservoirs are currently being developed as part of the Bay-Delta Conservation Plan, which builds upon earlier work by the Delta Vision Blue Ribbon Task Force[3], and others (e.g., see Lund *et al.*, 2007). To understand the context and effect of those proposals, it is important to accurately understand the historical conditions previously experienced by Delta species.

An analysis of the salinity trends and variability in northern San Francisco Bay since the 1920's and the factors controlling those salinity trends has recently been published (Enright and Culberson, 2009), with a focus on a comparison of pre-1968 salinity and flows with post-1968 conditions. This report includes analysis and review of reports, data and information from the period prior to Enright and Culberson's analysis, and includes the review of salinity trends using paleohistorical data.

Historically, reproduction of most species in the Bay-Delta (biotic production phase) occurred during the high-flow periods (winter and spring) and biotic reduction occurred in the low-flow periods (summer and fall) (Baxter *et al.*, 2008). Multi-year wet periods most likely resulted in population increases, whereas drought periods likely resulted in reduced reproduction and increased predation. The recent report on Pelagic Organism Decline (POD, Baxter *et al.*, 2008) indicated that reduced flow variability under the current water management conditions may have exacerbated the effects of predation on the population abundance of pelagic fish species in the Bay-Delta estuary. Native species of the Bay-Delta system adapted to the historical salinity conditions that occurred prior to large-scale water management practices and physical changes in the Delta. The historical salinity conditions in the Delta provide insight into the response of fish species to proposed ecosystem restoration actions, and the response of species to future changes in climate or water management.

[3] Delta Vision Blue Ribbon Task Force was appointed by California Governor Arnold Schwarzenegger in February 2007 and adopted the Delta Vision Strategic Plan in October 2008.

No comments

- n/a -

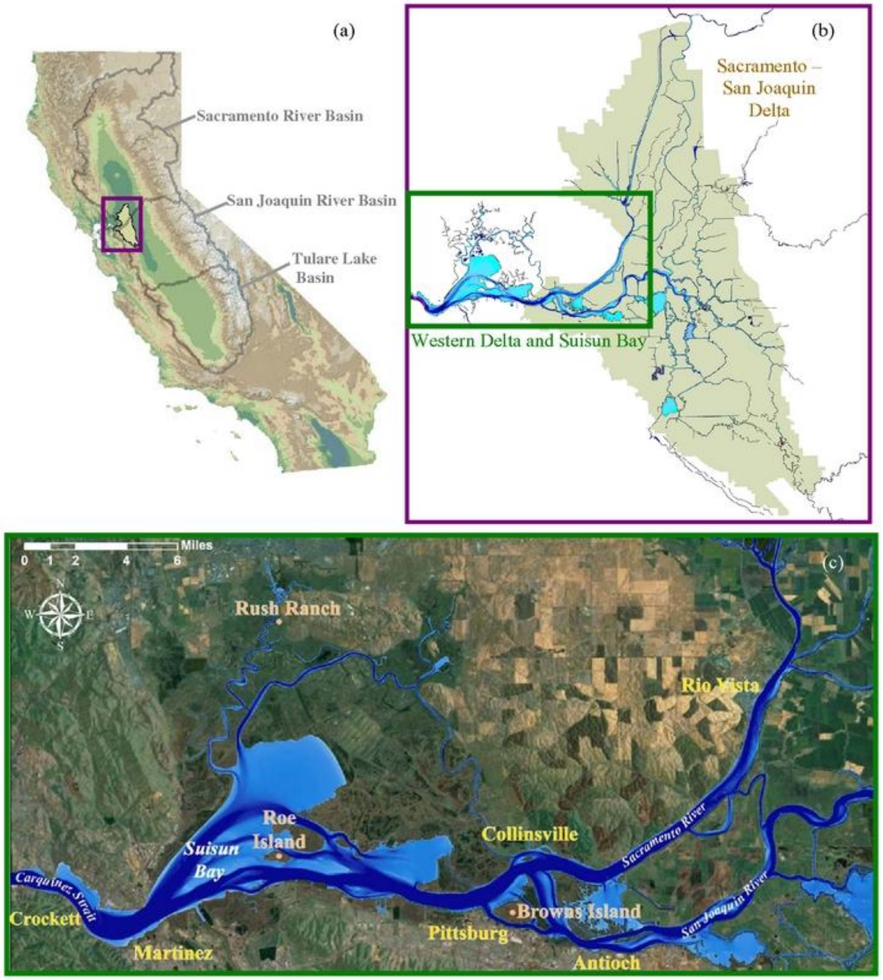


Figure 1-1 – Map

(a) Topographical map of California, with outlines of the Sacramento River, San Joaquin River, and Tulare Lake basins; purple rectangle indicates the extent of the inset in panel (b). (b) Sacramento – San Joaquin Delta and Suisun Bay region; green rectangle indicates the extent of the Western Delta and Suisun Bay enlarged in panel (c). (c) Extent of salinity evaluations considered within this study, including names of locations referenced throughout this report.

No comments

- n/a -

The salinity concentrations in San Francisco Bay and the Delta are the result of tides that move seawater into the system and are controlled in large part by the amount of fresh water passing through the system (Denton, 1993; Uncles and Peterson, 1996; Knowles *et al*., 1998). The salinity distribution is driven by the motion of the tides, which convey ocean water into the system on the flood tide and draw a mixture of ocean and river water back out again on the ebb tide. These tides act on natural diurnal (repeating twice per day) and spring-neap (repeating every 14 days) cycles driven by the gravitational forces of the sun and moon (Oltmann and Simpson, 1997; Burau *et al*., 1999).

Other factors affecting Bay-Delta salinity (discussed in Appendix A) may be smaller but are not insignificant. When comparing historical salinity conditions in the Bay-Delta watershed, it is often helpful to compare periods with similar hydrological conditions so that the changes due to other factors can be discerned. This will reveal if there is an anomalous change in salinity, even if the specific cause of that change in salinity is not known.

Major anthropogenic modifications to the Delta that affect salinity intrusion began with the European settlement of the region and can be classified into two categories: physical modifications of the landscape (e.g., removal of tidal marsh, separation of natural floodplains from valley rivers, construction of permanent artificial river channels, and land-use changes) and water management activities (e.g. diversion of water for direct agriculture, municipal, or industrial use, and reservoir storage and release operations).

As shown in Figure 1-2, tidal marsh acreage in the Delta decreased significantly from nearly 346,000 acres in the 1870's to less than 25,000 acres in the 1920's and has since continued to decrease. Even after hydraulic mining for gold was banned in California in 1884, large quantities of mining debris continued to be carried by runoff into the Delta, where it was deposited as sediment, filling channels in the Delta and Suisun Bay. Between 1887 and 1920, Suisun Bay became an erosional environment and continued to lose sediment through 1990. Enright and Culberson (2009) discuss the effects of the changes in Suisun Bay bathymetry on salinity intrusion. Major dredging projects on the main Delta channels to create the Stockton and Sacramento Deep Water Ship Channels (DWSC) have also changed how flows and, therefore, salinity are distributed throughout the Delta.

Each of these factors has changed the salinity regime: loss of tidal marsh lands has allowed increased tidal energy deeper into the Delta, increasing tidal flows and salinity dispersion (Enright and Culberson, 2009), net erosion and increasing depth within Suisun Bay likely increased dispersive transport of salt up the estuary (Enright and Culberson, 2009), and deeper channels allow increased salinity intrusion due to increased baroclinic circulation and increased tidal flow and dispersion..

However, these physical modifications generally have had less effect on salinity intrusion in the Delta than the major water management activities that have resulted in large-scale diversion of water for reservoir storage and agricultural, domestic, and industrial water use (Nichols *et al*, 1986; Knowles, 2002). As will be seen in data presented in this document, early diversions before large-scale storage projects resulted in greatly increased salinity intrusion, especially in the summer irrigation season, peaking in September. Later, reservoir operations reduced salinity intrusion in the summer and fall, but increased it in the winter and

No comments

- n/a -

spring, up until the mid-1980's. Subsequent water operations have resulted in increased salinity intrusion year round.

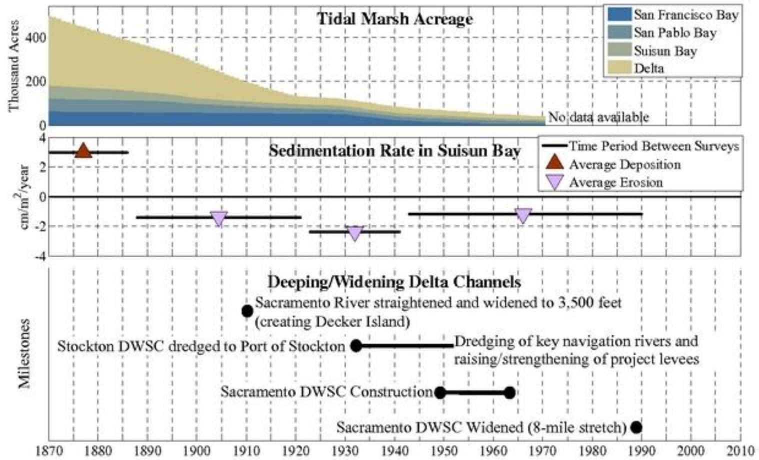


Figure 1-2 – Chronology of anthropogenic modifications to the Bay-Delta landscape

Bay-Delta landscape has undergone significant changes since the mid-1800's. Tidal marsh acreage (top panel) has been significantly reduced (data from Atwater, et al., 1979). Suisun Bay received a pulse of sediment from hydraulic mining in the late 1800's (middle panel), but lost sediment from 1887 to 1990 (data from Cappiella et al., 1999). Numerous efforts to widen and deepen the main channels within the Delta have occurred throughout the 20th Century (bottom panel).

The largest reservoir of the federal Central Valley Project (CVP), Lake Shasta, was completed in 1945, and the largest reservoir of the State Water Project (SWP), Lake Oroville, was completed in 1968. Total upstream reservoir storage capacity increased from 1 MAF in 1920 to more than 30 MAF by 1979. The CVP began exporting water from the southern Delta through Jones Pumping Plant (formerly known as the Tracy Pumping Plant) in 1951, and the SWP began exports through Banks Pumping Plant in 1968. By 1990, the combined export of water from the southern Delta through the Banks and Jones Pumping Plants was about 6 MAF per year.

Figure 1-3 shows that the greatest increase in upstream reservoir storage occurred from the 1920's through the 1960's. Prior to the construction of major water management reservoirs, irrigated acreage grew to about 4 MAF. The construction of the reservoirs allowed irrigated acreage to increase to about 9 MAF. Since 1951, when the first south Delta export facility was completed, annual diversions from the Delta have increased to a maximum of about 8 MAF; total annual diversions from the system are estimated at up to 15 MAF.

No comments

- n/a -

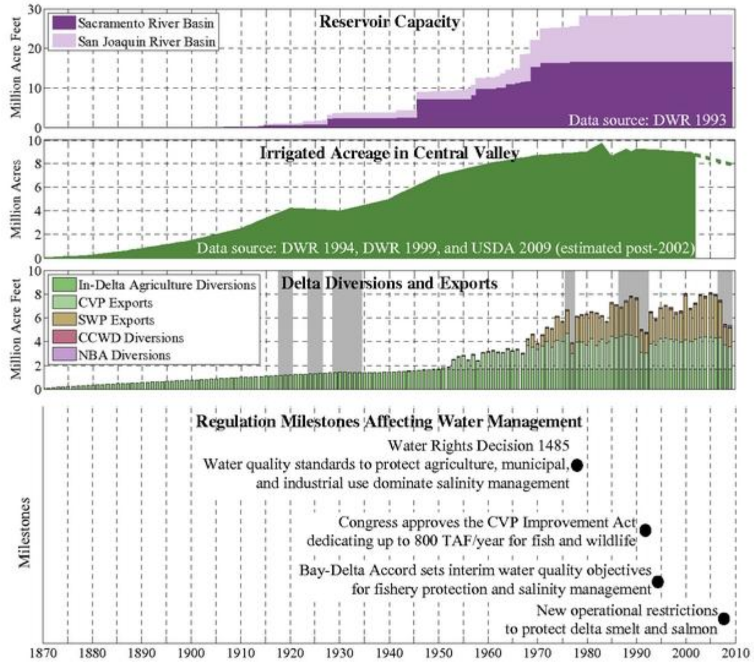


Figure 1-3 – Chronology of anthropogenic activities that affect water management

Reservoirs (top panel) and irrigated crops in the Central Valley (second panel) alter the timing and magnitude of water flow to reach the Delta. Diversions and exports within the Delta (third panel) further reduce the amount of water to flow through the Delta to Suisun Bay. Regulations (bottom panel) require modifications to water management activities to meet specific flow and water quality objectives.

Figure 1-3 also presents the timeline for recent regulatory milestones that have affected Delta water quality. Salinity management was dominated by water quality standards to protect Delta agriculture and municipal and industrial (M&I) uses in the 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485. The Bay-Delta Accord of 1994 and subsequent SWRCB Water Rights Decision 1641 made fishery protection the dominant factor for salinity management with new estuarine habitat or "X2 Standards"[4] from February through June, with minimum outflows for the remainder of the

[4] X2 is the distance, in kilometers from the Golden Gate, to the location of the 2 part per thousand salinity line. A larger X2 means salinity has intruded farther into the Delta.

No comments

- n/a -

year. The relationship between X2 and estuarine habitat is discussed in detail in Jassby *et al.* (1995).

These regulations apply throughout the year and have modified how the large-scale water management reservoirs and export facilities are operated. For instance, delta smelt was listed as a threatened species under the federal Endangered Species Act in 1993, and Sacramento River winter-run salmon was listed as endangered in 1994. The subsequent biological opinions, 1994 Bay-Delta Accord, and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995, required increased reservoir releases in some months for temperature control in the Sacramento River below Shasta and for salinity control in Suisun Bay. They also applied additional limits on pumping at the export facilities in the south Delta.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

1.2. Comparing Historical Conditions

Flow and salinity conditions prior to human interference varied according to seasonal and annual hydrological conditions, short-term and long-term drought cycles and other natural changes, so "natural" conditions include variability that must be considered in any analysis. Hydroclimatic variability is described by "unimpaired" runoff, which represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

As discussed above, large-scale water management operations during the last 100 years superimposed on the anthropogenic modifications to the Delta landscape have significantly changed Delta conditions. It is possible to remove the effect that water management operations have had on flows and generate a corresponding set of unimpaired flows. However, it is not possible, without complex assumptions and modeling, to also remove the additional effect of the land use, channel and tidal marsh modifications to the Delta.

The historical conditions presented in this report have been determined from records in paleoclimatic fossils and measured directly with various scientific instruments. The paleoclimatic data start well before human influence, but continue through the 20th Century when anthropogenic modifications became significant.

Because of the natural hydroclimatic variability, no past historical period may fully represent "natural" conditions. Therefore, this report summarizes the available historical salinity information with reference to the time period of the observations, and then compares each period to the salinity regime during present day periods with similar upstream unimpaired hydrology. Where there are significant changes in salinity, despite similar upstream unimpaired hydrology, other factors such as landscape modifications and water management operations must be contributing factors.

No comments

- n/a -

1.3. Objective

The objective of this report is to answer two major questions regarding the historical extent of fresh water and salinity in the western Delta and Suisun Bay:

I. What was the extent of fresh water and what were the salinity conditions prior to large-scale reservoir operations and water diversions (i.e., prior to early 1900's) and prior to structural changes in the Delta (i.e., prior to the 1860's)?

II. What are the effects of large-scale water management practices (reservoir operations and diversions) on salinity conditions in the western Delta and Suisun Bay?

1.4. Report Structure

The remainder of this report is organized as follows:

Section 2: Paleoclimatic Evidence of the Last 10,000 Years

Estimated river flow data and salinity records for the past several thousand years have been obtained from paleoclimatic records, such as tree rings and sediment cores. These records capture the hydroclimatic variations over decadal and centennial time scales and are useful tools in understanding the freshwater flow and salinity regimes before modern instrumentation.

Section 3: Instrumental Observations of the Last 140 Years

Long-term precipitation and river runoff records from the 1870's to the present provide context for the salinity observations. Climatic variability of precipitation and runoff in the upper watershed has a significant influence on salinity intrusion, with greater salinity during dry periods and lower salinity during wet periods. If, for example, the salinity is greater or less than what would be expected based on the natural climatic variability, as measured by unimpaired runoff, other factors must be influencing salinity intrusion.

Reservoir operations, diversions and consumptive use (collectively termed "water management") alter the amount of runoff from the upper watershed that actually flows out of the Delta. Observations and common computer models are used to assess the effects of this water management on Net Delta Outflow (the net quantity of water flowing from the Delta to the Suisun Bay) and on salinity in the western Delta and Suisun Bay. Observations include measurements of salinity indicators by the California & Hawaiian Sugar Refining Corporation (C&H) from the early 1900's and long-term monitoring data from the Interagency Ecological Program (IEP). Modeling tools include the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[5]

[5] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

- n/a -

equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993).

Section 4: Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

Qualitative observations on salinity conditions in the western Delta and Suisun Bay from an early water rights lawsuit and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. The 1920 lawsuit filed by the Town of Antioch against upstream irrigation districts alleged that the upstream water diversions were causing increased salinity intrusion at Antioch (Town of Antioch v. Williams Irrigation District, 1922). Briefings and testimony from the legal proceedings are indicative of the salinity conditions prevailing in the early 1900's, as are literature reports of conditions in the western Delta and Suisun Bay. These reports contain both qualitative observations and anecdotal information regarding historical salinity conditions. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate the extent of salinity intrusion in the Delta prior to their diverting water. Note that the Supreme Court did not base its final decision on the evidence of whether or not Antioch had continuous access to fresh water. The Court's decision was based on the State policy to irrigate as much land as possible for agriculture; the Court did not pass judgment on the accuracy of the testimony of either side.

Section 5: Conclusions

This section synthesizes the findings from Sections 2 through 4 and presents the overall conclusions regarding trends in the historical Delta salinity.

No comments

- n/a -

2. Paleoclimatic Evidence of the Last 10,000 Years

Paleoclimatic evidence from the watershed of San Francisco Bay (Bay) and Sacramento-San Joaquin Delta (Delta), obtained from proxy information such as tree rings and sediment deposits, provides a history of conditions before modern direct instrumental observations. Evidence of major regional climatic events that represent long-term wet period and drought cycles will be discussed, followed by discussions of Delta watershed runoff and Delta salinity, as measured by flow and electrical conductivity instrumentation.

2.1. Major Regional Climatic Events

The modern Bay-Delta is relatively young in terms of geologic timescales. The estuary started forming around 8,000 to 10,000 years ago (Atwater *et al.* 1979), when rapid sea level rise allowed the ocean to enter the Golden Gate. At this time, there was no Bay or Delta, but simply river valleys. Rapid sea level rise continued, such that approximately 6,000 years ago, the outline of San Francisco Bay, including San Pablo Bay and Suisun Bay, resembled the modern extent. At about the same time, sea level rise slowed to a more moderate pace, allowing tidal marshes to begin to form.

Malamud-Roam *et al.* (2007) review paleoclimate studies in the Bay-Delta watershed, summarizing evidence of climate variability through the development of the present day Bay-Delta system (Table 2-1).

Table 2-1 – Climate during the evolution of the Bay-Delta estuary

Overview of precipitation, temperature, and sea level conditions during the last 10,000 years based on data from Malamud-Roam et al. (2007) and Meko et al. (2001). Time periods are given in terms of number of years ago (represented as age, a; or ka for 1,000 year ago) and the Common Era (BCE/CE) calendar system. The shading indicates relatively dry periods.

Approximate Time Period	*Prevailing Climate and Geomorphology*
10 ka to 8 ka 8000 BCE to 6000 BCE	▪ Rapid sea level rise ▪ Ocean enters Golden Gate ▪ San Francisco Bay is just a river valley ▪ Cooler than 20th Century, but becoming warmer and drier
6 ka to 5 ka 4000 BCE to 3000 BCE	▪ Sea level rise slows to more moderate pace ▪ Outline of San Francisco Bay resembles modern extent ▪ Tidal marsh begins to form in the Delta ▪ Temperature reaches a maximum of the last 10,000 years ▪ Relatively dry conditions ▪ Central Valley floodplain system began to develop

No comments

- n/a -

Approximate Time Period	Prevailing Climate and Geomorphology
4 ka to 2 ka 2000 BCE to 1 CE	▪ Cooling trend with increased precipitation ▪ Large flood occurred ~ 3,600 years ago (1600 BCE)

2 ka to 0.6 ka
1 CE to 1400 CE
	▪ Trend to more arid, dry conditions
	▪ Severe droughts:
	  ▪ 1,100 to 850 years ago (900 CE to 1150 CE)
	  ▪ 800 to 650 years ago (1200 CE to 1350 CE)

0.6 ka to 0.2 ka 1400 CE to 1800 CE	▪ Relatively cool and wet conditions ▪ Numerous episodes of extreme flooding ▪ Includes "Little Ice Age" (1400 CE to 1700 CE)

90 a to 50 a
1910 CE to 1950 CE
	▪ Dry period in the Sacramento River Basin.
	  ▪ Longest dry period in the last 420 years (34 years centered on the 1930's)
	  ▪ Driest 20-year period in the last 370 years (1917 CE to 1936 CE)

A number of scientific studies have used paleo-reconstruction techniques to obtain long-term (decadal, centennial and millennial time scale) records of river flow (e.g., Earle, 1993; Meko *et al.*, 2001) and salinity of the Bay and Delta (e.g., Ingram and DePaolo, 1993; Wells and Goman, 1995; Ingram *et al.*, 1996; May, 1999; Byrne *et al.*, 2001; Goman and Wells, 2000; Starratt, 2001; Malamud-Roam and Ingram, 2004; Malamud-Roam *et al.*, 2006; Malamud-Roam *et al.*, 2007; and Goman *et al.*, 2008). The reconstructions described in the following sections focus on the 2,000 years before present. As indicated in Table 2-1, this period was relatively dry with two extreme regional droughts, followed by relatively cool and wet conditions during the "Little Ice Age," then by a return of dry conditions at the early part of the 20th Century.

2.2. Reconstructed Unimpaired Sacramento River Flow

Meko *et al.* (2001a,b) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow[6] for approximately the past 1,100 years (for the period 869 CE – 1977 CE). As discussed in Section 1.2, unimpaired flow is an estimate of the flow that would occur in the basin without the effects of water management activities.

The 1,100-year record shows strong variability between individual water years (Figure 2-1), with annual flow ranging from approximately 8% of average to 265% of average, where average is defined here for practical purposes as the average observed unimpaired flow from

[6] Meko *et al.* (2001a) used the annual unimpaired flow record for the Sacramento River provided by the Department of Water Resources, which is the sum of the following: flow of the Sacramento River at Bend Bridge, inflow of the Feather River to Lake Oroville, flow of the Yuba River at Smartville, and the flow of the American River to Folsom Lake. This definition is consistent with the definition typically used in hydro-climatic studies of this region (e.g., http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

- n/a -

1906 to 2009 of 18 million acre-feet per year (MAF/yr). The reconstructed record shows alternating periods of wet and dry conditions and is consistent with historical droughts (such as the drought in the Mono Lake region of California in the medieval period, around 1150 CE) reported by other paleoclimate studies (Malamud-Roam *et al.*, 2006).

As indicated by the shading in Figure 2-1, the driest long-term drought in the Sacramento River basin in the last 1,100 years occurred from approximately 1130 CE to 1415 CE when the 50-year average flow was seldom above normal for nearly 300 years. Following this drought, conditions were relatively wet (from approximately 1550 CE to 1900 CE). The timing of these droughts and wet periods will be compared to paleosalinity records in the following section.

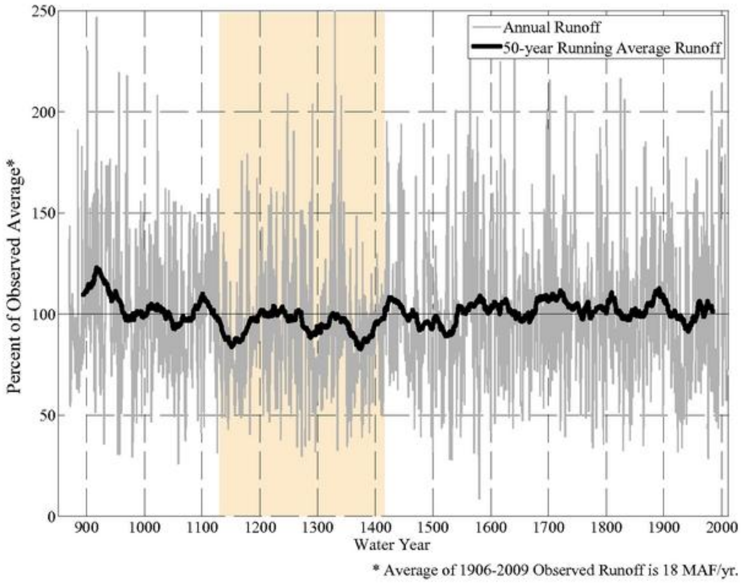


Figure 2-1 – Reconstructed annual unimpaired Sacramento River flow 869 CE to 2009 CE

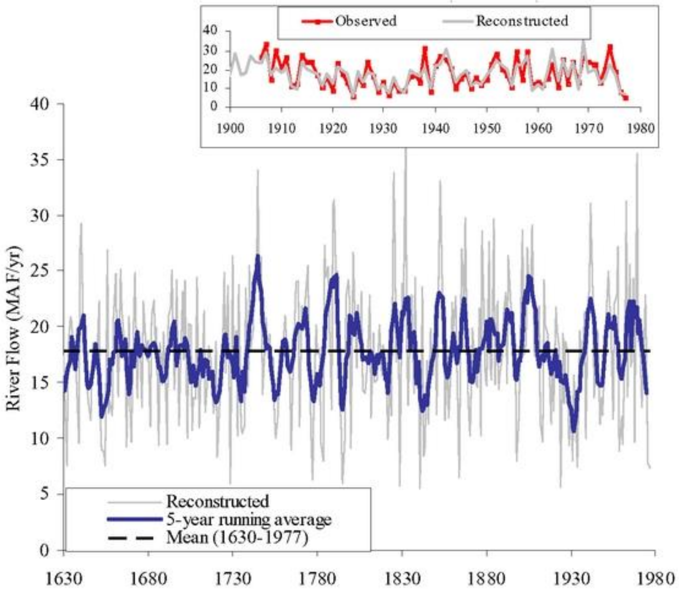
Annual reconstructed unimpaired Sacramento River flow (grey line) as a percentage of the average annual observed runoff from 1906 to 2009 shows strong variability between years. The 50-year running average (thick black line) illustrates there were extended periods of above-normal and below-normal runoff conditions. The orange shading highlights an extended dry period in the reconstructed unimpaired Sacramento River data when the 50-year average flow is seldom above normal for nearly 300 years. Data for 869 CE to 1905 CE were reconstructed by Meko et al. (2001b); data for 1906 CE to 2009 CE are observed records from the California DWR (2009).

No comments

- n/a -

Meko *et al.* (2001a) indicated that for their 1,100-year reconstructed period, the 1630-1977 data are more reliable than the earlier time period, because of better availability of tree-ring information and superior regression model statistics. Figure 2-2 shows the reconstructed time series of annual unimpaired Sacramento River flow from 1630 to 1977 from Meko *et al.* (2001b). The inset in Figure 2-2 shows there is a good match between the reconstructed flows (grey line) and the observed annual flows (red line) during the period of overlap between the reconstructed and observed records (from 1906 to 1977).

Multi-decadal periods of alternating wet and dry conditions are pervasive throughout the reconstructed record. The wet conditions of the late 1800's and early 1900's, which were followed by severe dry conditions in the 1920's and 1930's, are consistent both with observed precipitation and estimated Sacramento River runoff for these time periods (see Section 3) and with literature reports of historical conditions (see Section 4).



No comments

- n/a -

Figure 2-2 – Reconstructed annual unimpaired Sacramento River flow from 1630-1977.

Annual reconstructed unimpaired Sacramento River flow (grey line in main panel and inset) for the 1630 to 1977 time period was identified by Meko et al. (2001a) as the most accurate period of reconstruction. Inset panel illustrates the comparison between observed (red) and reconstructed (grey) unimpaired flows during the overlap period. The mean of the reconstructed unimpaired flow for 1630-1977 is 17.7 MAF/yr (dashed horizontal line in main panel). The 5-year centered running average (thick solid blue line in main panel) illustrates the decadal trends.

Meko *et al.* (2001a) identified the severe drought periods in the reconstructed Sacramento River flow record (1630-1977) by computing the lowest *n*-year moving average. For instance, to determine the most severe 6-year drought, Meko *et al.* calculated the moving average using a 6-year window for the entire data set and then identified the lowest 6-year average. Meko *et al.* found that the period from the early 1920's to late 1930's experienced the lowest 6-year, 10-year, 20-year, and 50-year averages (or droughts), both in the reconstructed and observed records. The observed droughts in Table 2-2 have been updated through present (1906-2009) using the same analysis; this update did not change the drought time periods identified by Meko *et al*. The reconstructed record of unimpaired Sacramento River flow shows the period from early 1920's to late 1930's experienced some of the worst drought conditions since 1630. Additional data are presented in Appendix B.

Table 2-2 – Periods of drought from the reconstructed and observed records of unimpaired Sacramento River flow

Severe drought periods in the reconstructed Sacramento River flow record (1630-1977) were determined by Meko et al. (2001a) by computing the lowest n-year moving average of the reconstructed annual unimpaired Sacramento River flow. The same method was used to determine the most severe droughts of the observed record (1906-2009).

	Period of lowest *n*-Year moving average Sacramento River flow					
	1-Year	3-Year	6-Year	10-Year	20-Year	50-Year
Reconstruction (1630-1977)	1924	1775 to 1778	1929 to 1934	1924 to 1933	1917 to 1936	1912 to 1961
Observations (1906-2009)	1977	1990 to 1992	1929 to 1934	1924 to 1933	1918 to 1937	1917 to 1966

Conclusions

Reconstruction of unimpaired Sacramento River flow indicates:

- Annual precipitation is highly variable. Even during long dry periods, individual years can be very wet.
- The Sacramento River basin experienced a multi-century dry period from about 1100 C.E. to 1400 C.E.
- The drought period in the 1920's and 1930's represents some of the worst drought conditions in the last 400 years.

No comments

- n/a -

2.3. Reconstructed Salinity in the Bay-Delta Estuary

Tree Ring Data

The interaction between saline ocean water from the Pacific Ocean and fresh water from the rivers flowing into the Delta determines the ambient salinity conditions in the Delta and the Bay. Estimates of historical precipitation derived from tree ring data can therefore be used to estimate the corresponding salinity conditions in the Delta.

Stahle *et al.* (2001) used tree ring chronologies from blue oak trees located in the drainage basin to San Francisco Bay to reconstruct salinity at the mouth of San Francisco Bay. Recognizing that a number of factors influence salinity other than precipitation (estimated from tree rings), the authors chose a time period prior to substantial water development when the salinity data were fairly constant in mean and variance. During the calibration period (1922-1952), annual tree ring growth correlates well with average salinity near the Golden Gate Bridge (r^2=0.81). Using this transfer function, Stahle *et al.* (2001) reconstructed annual average January to July salinity for all years 1604 to 1997.

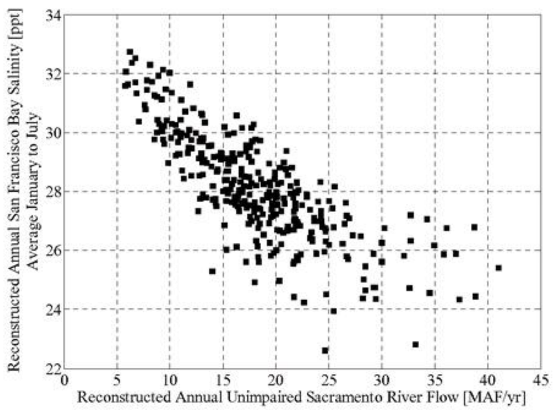


Figure 2-3 – Reconstructed salinity near the mouth of San Francisco Bay compares well with reconstructed unimpaired Sacramento River flow in the upper watershed
For each year from 1630 to 1952, the annual unimpaired Sacramento River flow (from Meko et al., 2001b) is plotted against the annual average salinity at Fort Point (from Stahle et al., 2001).

As shown in Figure 2-3, the salinity reconstruction by Stahle *et al*. (2001) compares well with the unimpaired flow reconstruction by Meko *et al*. (2001b). The data follow the expected inverse exponential relationship between flow and salinity. Over the period from

No comments

- n/a -

1630 to 1952, reconstructed salinity increases as reconstructed unimpaired Sacramento River flow decreases. The agreement is strongest in dry years. The increased scatter in wet years may reflect the limitations in the tree ring methods.

Stahle *et al.* (2001) identified an increasing divergence of observed salinity relative to predicted (reconstructed) salinity after 1952 (Figure 2-4) and suggested that the majority of differences are due to increased water diversions. During the calibration period (1922-1952), the observed salinity is typically within +/- 5% of the reconstructed salinity. However, from 1953-1994, the data show an increasing trend for observed salinity to be greater than predicted, exceeding reconstructed salinity by over 15% in 1978, 1979, 1991, and 1993. Since 1969, observed salinity has exceeded reconstructed salinity in all years except the extremely wet years of 1982 and 1983.

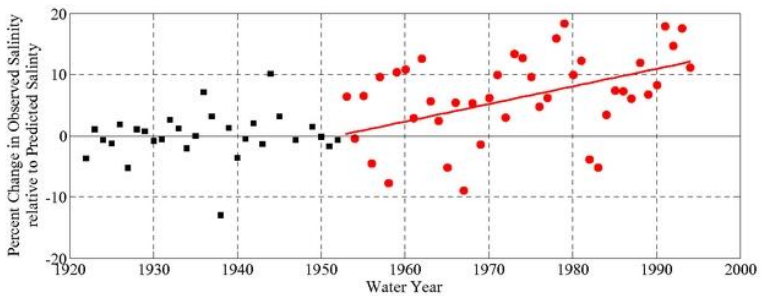


Figure 2-4 – Percent change in observed salinity relative to predicted (reconstructed) salinity for the period 1922 to 1994

The reconstructed salinity record by Stahle et al. (2001) overlaps with the observed salinity record from 1922 to 1994. During this period, the percent change of observed salinity relative to predicted salinity is determined as (observed salinity – reconstructed salinity) divided by reconstructed salinity, with positive values indicating when observed salinity exceeded the reconstructed salinity prediction. The calibration period is indicated with black squares, with the period outside the calibration window indicated by red circles. The straight red line is the linear trend in the post-calibration period, indicating observed salinity is increasingly diverging from predicted (reconstructed) salinity.

These data suggest that since the 1950's, water management operations have increased salinity, with an escalating effect over the period of record. In addition, it is worth noting that significant anthropogenic modifications to the landscape and water usage had already occurred prior to the 1922-1953 calibration period (see Figure 1-2 and Figure 1-3). Although this study is unable to evaluate the effect of anthropogenic modifications prior to 1953, the following section examines salinity prior to human interference at multiple sites in the Bay-Delta.

Tree ring reconstructions such as Meko *et al.* (2001a) and Stahle *et al.* (2001) have the advantage of providing high temporal resolution (i.e. annual) over approximately the last 1,000 years. However, a possible disadvantage of this method is the age of trees, limiting

No comments

- n/a -

high accuracy estimates to approximately the last 400 years. A second possible disadvantage of using tree ring reconstructions for paleosalinity is the remote location of the trees relative to the estuary. Paleosalinity estimates from tree rings in the upper basin necessarily assume that the precipitation patterns archived in the tree rings are representative of the quantity of water that reaches the estuary. However, as observed by Stahle *et al.*, anthropogenic water management affects the amount of water that flows through the estuary.

Sediment Core and Fossil Data

Because of uncertainties in estimates of precipitation and salinity derived from tree ring data, other paleosalinity methods that rely on local fossils to determine local salinity have also been explored. Organic deposits accumulated in the sediments contain signatures of the ambient conditions that can be used to infer the variations in salinity over geologic time scales. Although reconstructions from sediment cores have a coarser temporal resolution than tree rings, the variations in climate and landscape responses to change are better defined geographically because the evidence of localized climate change is preserved as a time series *in situ*, at the site of interest.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions from sediment cores. Changes in wetland plant and algae communities are the dominant response in the Bay and Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by:

- quantification and taxonomic identification of
  - (i) diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004),
  - (ii) plant seeds and roots (Goman *et al.*, 2008),
  - (iii) plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004), and,
- measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Results from plant pollen identification for three sites in the western Delta and Suisun Bay and Marsh are summarized below in Figure 2-5. The data indicate that Browns Island tidal marsh, near the confluence of the Sacramento and San Joaquin Rivers in the western Delta (Figure 2-5) was predominately a freshwater system for 2,500 years, even during century-long droughts. This condition prevailed until the early 1900's. The shading in Figure 2-5 corresponds to the nearly 300-year dry period identified in the reconstructions of annual unimpaired Sacramento River flow (Figure 2-1). Although salinity intrusion occurred during this period in Suisun Bay at Roe Island, and during earlier long drought periods, salinity did not affect the western Delta to the same degree. This suggests a change in spatial salinity gradient characteristics, and is possibly due to the effect on salinity intrusion of the vast tidal marshes that existed in the Delta until the early 20th Century.

No comments

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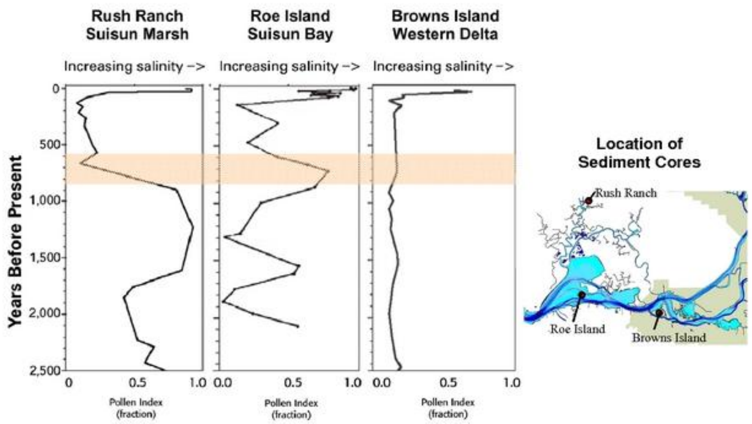

Figure 2-5 – Paleosalinity evidence derived from pollen data

Salinity variability over the last 2,500 years at Rush Ranch in Suisun Marsh (left panel), Roe Island in Suisun Bay (center panel), and Browns Island in the Western Delta (right panel). Data are reproduced from Malamud-Roam and Ingram (2004). Orange shading across each panel corresponds to the nearly 300-year dry period identified in the annual unimpaired Sacramento River flow reconstruction (see Section 2.2) Locations of each of the sediment cores are illustrated in the map on the right.

Malamud-Roam *et al.* (2006) attributed the differences between sites to a combination of methodological issues (such as sampling frequency and core chronology) and site-specific ecological differences (such as site elevation, location relative to channel and sedimentation rates over time). However, all of the paleosalinity reconstructions based on pollen, diatoms and carbon isotopes are in general agreement and suggest that salinity increased abruptly about 100 years ago, reaching or exceeding salinity levels at any other time in the 2,500 years of reconstructed records.

This increase in salinity may correspond to the reduction in unimpaired Sacramento River flow evidenced in the tree ring reconstructions by Meko *et al.* (2001a), which determined that the 1920's and 1930's experienced the worst droughts in the last 400 years. However, the droughts in the 1920's and 1930's do not appear to be as severe as the droughts between 1100 CE to 1400 CE (600 to 900 years ago), as categorized by unimpaired Sacramento River flow. Yet salinity in Suisun Bay and the western Delta appears to meet or exceed the level of the medieval droughts, indicating factors besides natural precipitation and runoff patterns have affected salinity in the last 100 years.

No comments

- n/a -

Conclusions

Reconstructions of salinity in the Bay and Delta indicate:

- Precipitation in the drainage basin for San Francisco Bay (as recorded in tree rings) is a good indicator of salinity near the mouth of the Bay for the period 1922-1953; however, since 1953, increased water diversions have increased observed salinity above the level predicted from precipitation estimates.
- The Delta was a predominately freshwater system for 2,500 years, until the early 1900's, even during century-long droughts.
- The multi-century dry period identified in unimpaired Sacramento River flow reconstruction is evident in Suisun Bay sediments but not in Delta sediments, indicating that salinity did not intrude as far into the Delta during past droughts as it has during the last 100 years.
- The evidence from most sites suggests that current salinity levels are as saline as, or more saline than, previous historical conditions.

No comments

- n/a -

3. Instrumental Observations of the Last 140 Years

Field measurements of rain and snow have far greater accuracy and resolution than the paleoclimate records of precipitation; similarly, field measurements of salinity have far greater accuracy and resolution than the paleosalinity records from sediment cores. These instrumental observations will be used to analyze in more detail the salinity increase identified in the paleoclimate records approximately 100 years ago and determine if the increase in salinity has persisted.

The first sub-section presents observations of precipitation and unimpaired runoff in the upper basin, indicating the natural climatic variability and amount of fresh water available within the Bay-Delta watershed. The second sub-section examines Net Delta Outflow (NDO), which is the amount of water flowing through the Delta into Suisun Bay, directly affecting the level of salinity intrusion into the Delta. NDO is analyzed under both unimpaired (without water diversions and reservoir storage and releases) and historical (actual) conditions; comparison between unimpaired and actual conditions reveals the effect of water management practices. The third sub-section presents field measurements and model-based estimates of salinity at various locations within the Delta and Suisun Bay.

3.1. Precipitation and Unimpaired Flow in the Upper Basin

Precipitation in the Bay-Delta watershed indicates the amount of water available within the system, which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, the timing of runoff to the river channels is often lagged a few months due to snow melt conditions. For this reason, estimates of unimpaired flow (runoff) are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Figure 3-1 illustrates the total annual precipitation at Quincy[7] in the northeastern Sierra, the total annual unimpaired Sacramento River flow[8] and total unimpaired San Joaquin River flow[9]. Figure 3-2 shows the locations of the eight precipitation stations in northern California used to compute the Sacramento eight-station precipitation index (left panel) and the measurement locations of eight flow gages used to calculate the Sacramento and San Joaquin unimpaired flow data (right panel). Additional information on the annual unimpaired flows is provided in Appendix C.

As discussed in Section 2.2, the total annual unimpaired Sacramento River flow exhibits strong variability between years, both in the reconstructed and observed data. Figure 3-1

[7] Precipitation data are from Menne *et al.* (2009)

[8] "Unimpaired Sacramento River flow" is defined as the sum of the "full natural flows" from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

[9] "Unimpaired San Joaquin River flow" is defined as the sum of the full natural flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST)

No comments

- n/a -

indicates that the trends revealed in the total annual unimpaired Sacramento River flow (middle panel) are also evident in the total annual precipitation at Quincy (top panel) and the total annual unimpaired San Joaquin River flow (bottom panel). Alternating periods of wet and dry conditions are evident in both river basins. These data indicate there were wetter than normal conditions in the late 1800's and early 1900's, followed by severe dry conditions in the 1920's and 1930's. These were then followed by generally wetter conditions until the mid-1970's.

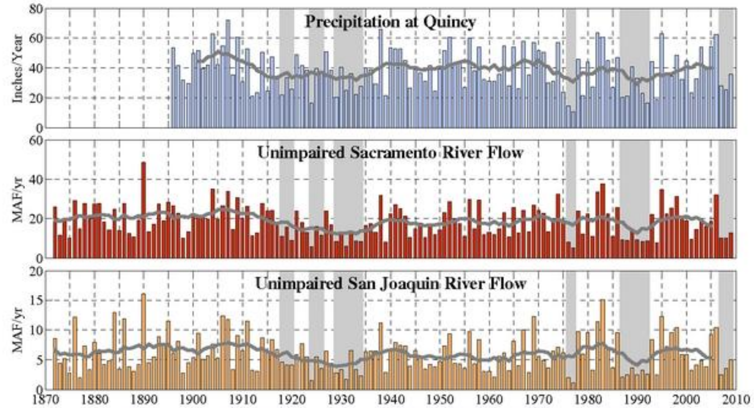

Figure 3-1 – Total annual precipitation and unimpaired flow in the upper Sacramento and San Joaquin River basins (1872-2009)

Total annual precipitation at Quincy in the northeastern Sierra (top panel), total annual unimpaired Sacramento River flow (middle panel), and total annual unimpaired San Joaquin River flow (bottom panel). Bar color on each panel indicates the regional location of the measurements, reflected in the remaining figures of this section (Figure 3-2, Figure 3-3 , and Figure 3-4). Grey line within each panel is the 10-year moving average for each parameter.

No comments

- n/a -

Figure 3-2 – Locations of Precipitation and Runoff Measurements

Location of stations used in the determination of the 8-station precipitation index for northern California (left map), including the location of Quincy (QRD), and the unimpaired Sacramento River flow (red stations, right map) and unimpaired San Joaquin River flow (orange stations, right map).

Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff. For this reason, it is critical to examine the monthly variability in precipitation and unimpaired runoff. Monthly precipitation and unimpaired flow values are available for a shorter time period (generally 1921 to present) than the total annual values (generally 1870's to present).

The monthly distribution of the Sacramento eight-station precipitation index[10] indicates that most of the precipitation in northern California occurs during November through March (Figure 3-3). The variability between years, represented by the vertical bars and '+' marks, shows the distribution is positively skewed, i.e., excessively high precipitation occurs in relatively few years.

Figure 3-4 presents the monthly distribution of unimpaired flow for both the Sacramento and San Joaquin River basins. River flow lags precipitation by about two months because of storage of some precipitation in the form of snow and subsequent snowmelt in the spring. Most of the unimpaired inflow to the Delta originates from the Sacramento Basin, although the contributions from the two basins are approximately the same during the months of late-spring and early-summer snow melt, when unimpaired runoff from the San Joaquin Basin peaks.

[10] Data from 1921 through 2008, downloaded from http://cdec.water.ca.gov/cgi-progs/precip1/8STATIONHIST

No comments

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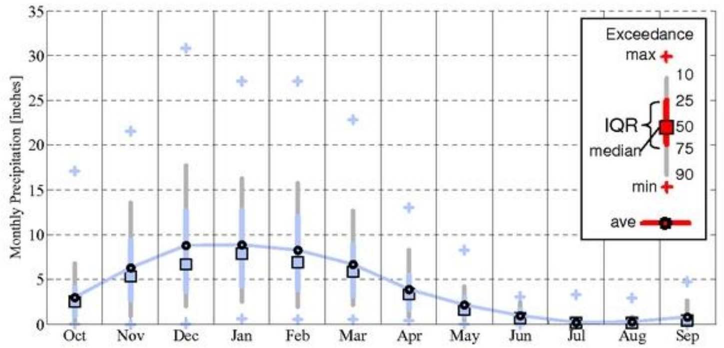

Figure 3-3 – Monthly Distribution of Precipitation in the Sacramento River Basin
Distribution of monthly precipitation for water years 1921 through 2008. Monthly averages are indicated by the blue line with black circles. Monthly median is given by the blue squares, while the interquartile range is indicated by the vertical blue line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

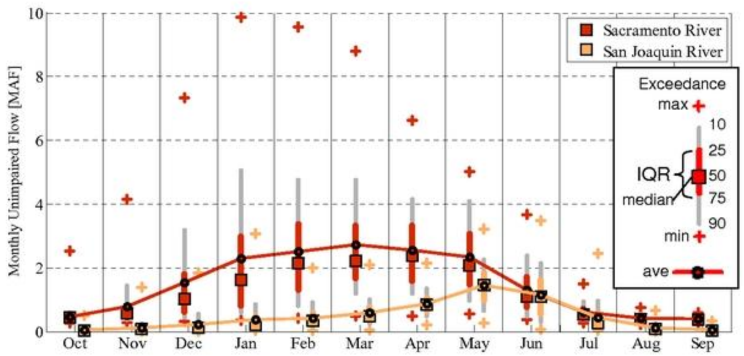

Figure 3-4 – Monthly distribution of unimpaired flow in the Sacramento and San Joaquin River basins
Distribution of monthly unimpaired flows for water years 1921 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

No comments

- n/a -

Conclusions

The long-term observations of precipitation and unimpaired flow indicate:

- Relatively wet conditions occurred in the late 1880's to about 1917 in both the Sacramento and San Joaquin River watersheds prior to large-scale water management operations.
- Unusually dry conditions occurred from about 1918 through the late 1930's; these persistent dry conditions are not representative of the average conditions over the last 130 years.
- Precipitation in Sacramento River watershed peaks between December and March; the unimpaired river flow lags by about 1 to 2 months because of snow melt.

No comments

- n/a -

3.2. Net Delta Outflow

The quantity of water flowing from the Delta into Suisun Bay, defined as Net Delta Outflow (NDO), is the primary factor in determining salinity intrusion in Suisun Bay and the western Delta. Unimpaired NDO is calculated using unimpaired flow in the Sacramento and San Joaquin Rivers (Section 3.1) as well as contributions from other minor tributaries.[11] Unimpaired NDO is the hypothetical Delta outflow that would occur in the absence of any upstream diversion or storage, but with the existing Delta channel and upstream channel configuration.

Because the outflow from the Delta at the wide and deep entrance to Suisun Bay cannot be measured accurately, the parameter of historical (actual) NDO is estimated from a daily mass balance of the measured river inflows to the Delta, measurements of water diversions at major pumping plants in the Delta, and estimates of net within-Delta consumptive use (including Delta precipitation and evaporation).

The effect of anthropogenic water management on NDO is illustrated below by comparing monthly estimates of unimpaired NDO[12] and historical (actual) NDO[13] (Figure 3-5). Since unimpaired flow estimates also assume the existing Central Valley and Delta landscape (reclaimed islands, no natural upstream flood storage, current channel configuration, etc.), this comparison reveals the net effect of water management only. This analysis does not address the change due to physical modification to the landscape or sea level rise.

For the period of joint record, when both unimpaired and historical NDO values are available (water year 1930 through 2003), historical NDO decreased even though unimpaired NDO increased slightly. The long-term (74-year) linear trend in monthly unimpaired NDO (the black dashed line in top panel of Figure 3-5) increased on average 0.49 MAF/month; thus, by 2003, the average annual unimpaired NDO had increased 5.9 MAF/year since 1930. In contrast, the long-term linear trend in monthly historical NDO (the black dashed line in middle panel of Figure 3-5) decreased on average -0.29 MAF/month, totaling a decrease in historical (actual) NDO of -3.5 MAF/year. This corresponds to a net increase in diversion of 9.4 MAF/year of water from the Delta upstream watershed relative to the 1930 level[14].

Increased diversion and export of water have decreased historical NDO (middle panel of Figure 3-5), but this has been partially offset by a natural increase in unimpaired NDO (top panel). The difference between historical and unimpaired NDO (bottom panel) is due to the cumulative effects of upstream diversions, reservoir operations, in-Delta diversions, and

[11] Unimpaired NDO does not include water imported from the Trinity River system, which is outside the Delta watershed.

[12] Unimpaired NDO data was obtained from Ejeta (2009), which is an updated version of DWR (1987).

[13] Historical NDO data was obtained from the IEP's DAYFLOW program (http://www.iep.ca.gov/dayflow/index.html).

[14] This is consistent with current estimates of approximately 15 MAF/year total diversion from the system, which includes the 4-5 MAF/year diversions established prior to 1930 and approximately 1 MAF/year additional water supply imported from the Trinity River system.

No comments

- n/a -

south-of-Delta exports. During most months, water management practices have historically resulted in historical (actual) NDO that is less than unimpaired conditions, indicated by a negative value for the quantity (historical NDO – unimpaired NDO).

Because the difference between monthly historical and unimpaired NDO has become more negative over time, the periods of excess conditions (when historical NDO exceeds unimpaired NDO) have become very infrequent. The only occurrences are now following the wettest years, primarily due to releases from reservoirs in the fall to make room for winter flood control storage.

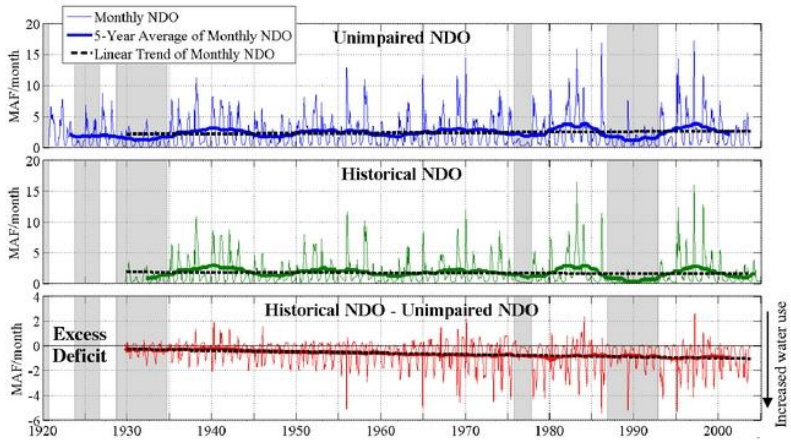

Figure 3-5 – Time series of Monthly Net Delta Outflow under unimpaired conditions and historical (actual) conditions

The thin color line on each panel indicates the monthly NDO, the thick color line indicates a running 5-year average of the monthly NDO, and the dashed black line indicates the linear long-term trend.

The monthly distribution (Figure 3-6) of unimpaired NDO and historical NDO for water years 1930 to 2003 reveals that for all months except September and October (when NDO is low), average unimpaired NDO is greater than average monthly historical NDO. The tendency in the average historical NDO toward greater flow in September and October is influenced strongly by the period prior to about 1975 when reservoir operations resulted in more flow in those months (see Figure 3-7 and related discussion below). On average from 1930-2003, water management practices reduced Delta outflows in the months of November through August (and in all months since about 1975, see Figure 3-7). The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and a portion of the river flow is diverted for direct use.

No comments

- n/a -

As also shown in Figure 3-6, water management practices also shift the peak flow periods to earlier in the year. The unimpaired NDO hydrograph peaks in May when snow melt contributes to high river flows, with at least 4.1 MAF in May in 50% of the years (averaging 4.2 MAF in May over all years). The historical NDO peaks in February with at least 2.9 MAF/month in 50% of the years (averaging 3.7 MAF/month over all years). The variability between years, represented by the vertical bars and '+' marks, indicates the distribution is positively skewed, which means a relatively few years have excessively high flows.

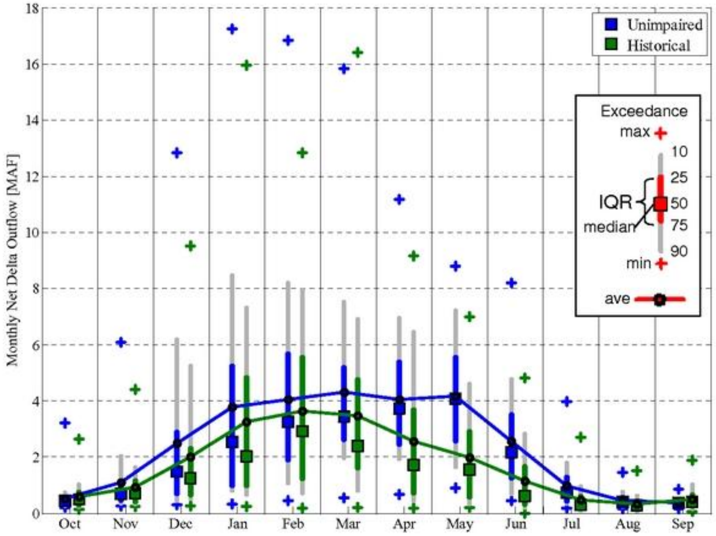

Figure 3-6 – Monthly distribution of Net Delta Outflow

Distribution of monthly NDO for water years 1930 through 2008. Monthly averages are indicated by the lines with black circles. Monthly median is given by the squares, while the interquartile range is indicated by the vertical line for each month and the vertical grey line extends to the 10th and 90th percentiles. Maximum and minimum values are indicated by '+' marks.

Figure 3-7 shows the long-term trends in the difference between historical (actual) monthly NDO and unimpaired monthly NDO. Increased water usage and increased diversion of water to storage has reduced historical NDO relative to unimpaired NDO in most months of the year. In July (and August, not shown in Figure 3-7), the deficit is reduced, likely due to reservoir releases which provide a portion of the water diverted by upstream users prior to reservoir construction. The 1994 Bay-Delta Accord called for higher minimum Delta outflows in July and August to protect Delta fish species, which should also serve to reduce the deficit. However, historical (actual) NDO still remains less than unimpaired NDO.

No comments

- n/a -

In September (and October, not shown in Figure 3-7), historical (actual) NDO exceeded unimpaired NDO from about 1945 to 1975, with an increasing trend in the percent change. Since 1975, the percent change has shown a downward trend with a deficit (historical NDO less than unimpaired NDO) during most years since 1975.

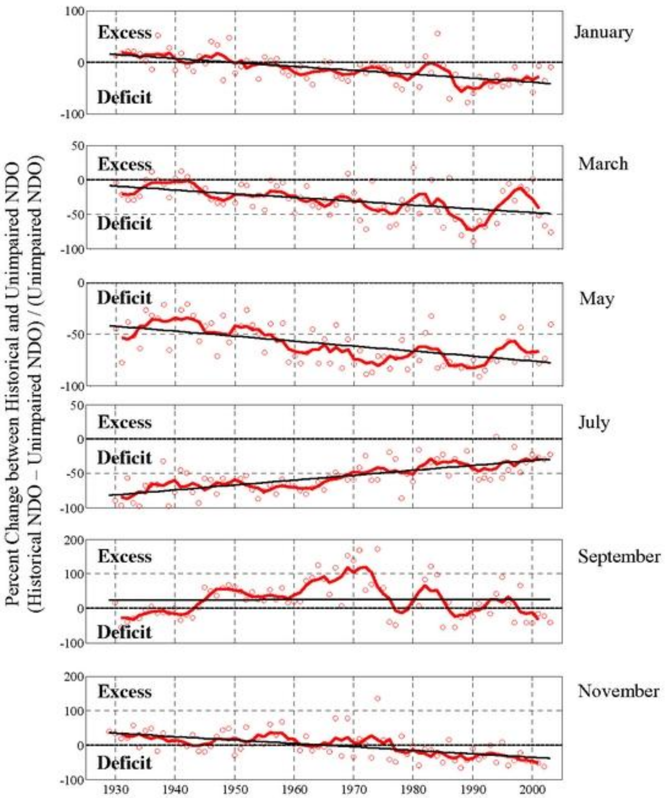

Figure 3-7 – Long-term trends in monthly NDO

Percent change of NDO relative to unimpaired conditions. Circles indicate the percent change for each month of the period of record. The red line indicates a moving 5-year average of the percent change, while the black line indicates the long-term linear trend over the entire period of record.

No comments

- n/a -

Conclusions

Anthropogenic water management practices have altered NDO in the following ways:

- Long-term data demonstrate that the difference between historical (actual) NDO and unimpaired NDO is increasing over time, indicating that water management actions have reduced Delta outflow significantly.
- During most months, water management practices have reduced Delta outflow relative to unimpaired conditions. From the mid-1940's to the mid-1980's, reservoir operations resulted in historical (actual) NDO slightly greater than unimpaired NDO slightly in a number of months, largely in the fall. However, since 1985, reservoir operations have resulted in increased NDO only in the wettest years, and NDO has declined in all other months.
- On average, water management practices have resulted in reduced Delta outflows in all months except September and October. The greatest reduction in Delta outflow relative to unimpaired conditions occurs in the months of March through June, when spring snow melt is captured in reservoirs and some of the remaining river flows are diverted for direct use.

No comments

- n/a -

3.3. Salinity in the Western Delta and Suisun Bay

Observations and model-based estimates can be used to examine historical variations in salinity in the western Delta and Suisun Bay. The observations examined in this section include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and long-term monitoring data published online by the Interagency Ecological Program (IEP). Estimates of salinity intrusion were obtained using the Kimmerer-Monismith equation describing X2 (Kimmerer and Monismith, 1992).

Section 3.3.1 addresses the importance of consistency among salinity comparisons. The spatial variability of a specific salinity level is examined in Section 3.3.2 and Section 3.3.3, while the temporal variability of salinity at specific fixed locations is explored in Section 3.3.4 and Section 3.3.5.

3.3.1. Importance of Consistency among Salinity Comparisons

Water salinity in this report is specified either as electrical conductivity (EC) or as a concentration of chloride in water. EC is a measure of the ability of an aqueous solution to carry an electric current and is expressed in units of microSiemens per centimeter (μS/cm)[15]. Chloride concentration is specified in units of milligrams of chloride per liter of water (mg/L). Conversion between EC and chloride concentration can be accomplished using site-specific empirical relationships such as those developed by Kamyar Guivetchi (DWR, 1986).

Previous studies have evaluated the level of salinity in the Bay and Delta, using a variety of salinity units (e.g. EC, chloride concentration, or concentration of total dissolved solids in water) and various salinity parameters (e.g. annual maximum location 1,000 μS/cm EC, monthly average location of 50 mg/L chloride, or daily average EC at a specific location). Therefore, when comparing studies, it is critical to use consistent salinity units, parameters, and timing, including the phase of tide and time of year. These concepts are discussed further in Appendix D.

3.3.2. Distance to Fresh Water from Crockett

The California & Hawaiian Sugar Refining Corporation (C&H) is located in Crockett, near the western boundary of Suisun Bay (see Figure 3-8). C&H either obtained its freshwater supply in Crockett, or, when fresh water was not available at Crockett, from barges that traveled upstream on the Sacramento and San Joaquin Rivers. The barges generally travelled upstream twice a day beginning in 1908 (DPW, 1931). C&H recorded both the distance traveled by its barges to reach fresh water and the quality of the water they obtained. This provides the most detailed quantitative salinity record available prior to the initiation of salinity monitoring by the State of California in 1920. The distance traveled by the C&H barges serves as a surrogate for the prevailing salinity conditions in the western Delta and

[15] The reported EC values are actually specific conductance, i.e., the electrical conductivity of the water solution at a reference temperature of 25° centigrade, as is standard practice.

No comments

- n/a -

Suisun Bay. Operations by C&H required water with less than 50 mg/L chloride concentration.[16] Additional detail on C&H operations and the detailed barge travel data are included in Appendix D.

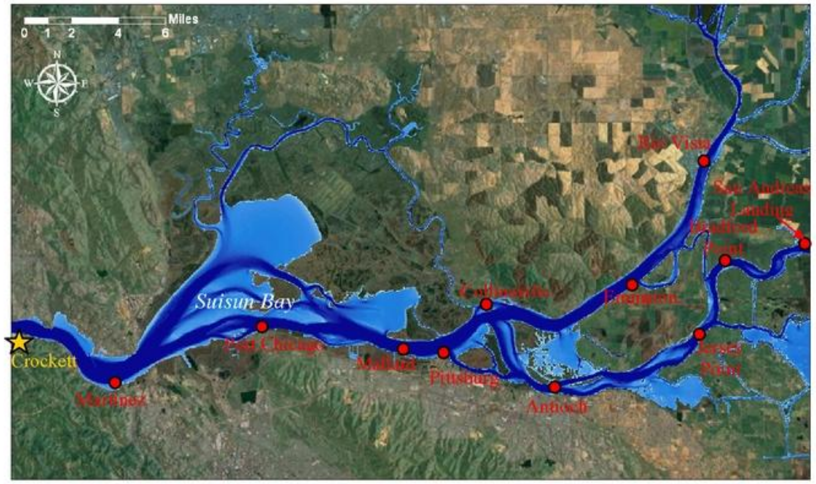

Figure 3-8 – Map of Suisun Bay and Western Delta with locations of continuous monitoring stations

C&H barges traveled up estuary from Crockett (yellow star). Locations of IEP continuous monitoring stations are shown in red. Scale in miles is indicated in the upper left corner of the map.

[16] In comparison, the 50 mg/L concentration required for C&H operations is one-third the concentration of the industrial water quality standard under current conditions in the Delta.

No comments

- n/a -

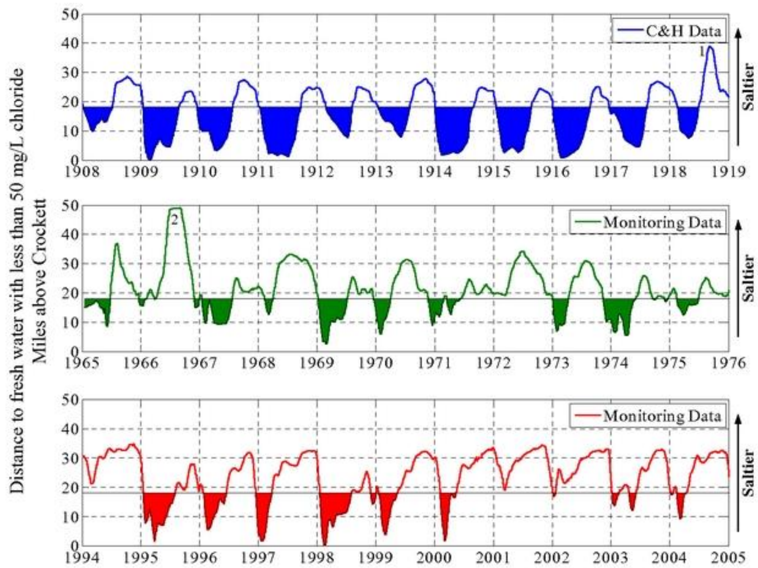

Figure 3-9 – Distance to fresh water from Crockett

"Distance to fresh water" is defined as the distance in miles upstream of Crockett to water with less than 50 mg/L chloride concentration. The horizontal line, at approximately 18 miles, is the distance from Crockett to the Delta. The shading represents the spatial extent and duration of the presence of fresh water within Suisun Bay, downstream of the Delta.

Data notes: (1) During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides; (2) Salinity during 1966 is likely an overestimate due to relatively sparse spatial coverage of IEP monitoring stations. During 1966, salinity at Emmaton (28 miles from Crockett) exceeded 3,000 µS/cm; the nearest station upstream of Emmaton is near Courtland (58 miles from Crockett) and had a salinity of ~ 300 µS/cm. Location of 350 µS/cm isohaline based on data interpolation between these two stations (which are 30 miles apart) is not likely to be representative of the true location.

Figure 3-9 compares surface[17] salinity data from C&H with estimates derived from a network of continuous surface salinity monitoring stations (Figure 3-8) within Suisun Bay and the western Delta dating back to 1964. The monitoring data are published online by the Interagency Ecological Program (IEP, see http://iep.water.ca.gov/dss). The location of the 350 µS/cm EC isohaline, which approximately coincides with the C&H criterion of 50 mg/L chloride concentration, was estimated from the IEP measurements by linear interpolation between the average daily values at IEP monitoring stations.

[17] Due to the method of collection, C&H water samples are assumed to be from near the water surface.

No comments

- n/a -

As a cautionary note, depending on the source of information, the C&H barges are said to have traveled with the tide, indicating they either took water at high tide (moving up river on the flood and down on the ebb) or at low tide (traveling against the tide, but moving a shorter distance). Thus, the C&H records either represent the daily maximum or daily minimum distance traveled. In contrast, the distances to fresh water calculated from recent monitoring data are based on the average daily values of EC measured at fixed locations. The difference between daily average distance and daily minimum or maximum is approximately 2 to 3 miles. However, since the difference between the data from the early 1900's and the more recent time periods exceed this 2 to 3 mile uncertainty, the conclusions of this section remain unchanged regardless of the specific barge travel timing.

From 1908 through 1918, C&H was able to collect fresh water for a large portion of the year within Suisun Bay, without having to travel all the way from Crockett to the Delta. However, as can be seen in Figure 3-9, that would no longer be possible in many years (e.g., 2001-2004).

Figure 3-10 shows the monthly distribution of distance traveled by C&H barges during water years 1908 through 1917, and the equivalent distance from determined from observed data for water years 1966 through 1975 (top panel) and water years 1995 through 2004 (bottom panel). These two latter periods have similar hydrologic characteristics to the period of the C&H data.[18] The monthly distribution for each dataset illustrates the seasonal fluctuations of the salt field as well as the variability between years for each month.

During the early 1900's, the median distance traveled by C&H barges to procure fresh water was less than 8 miles in the spring (March-June) and about 25 miles (between Collinsville and Emmaton) in the fall (September-October). In contrast, due to water management conditions from 1995 to 2005, the equivalent distances would be 13 to 23 miles in the spring and up to 30 miles in the fall. It is worth noting that from 1966 to 1977, the distance to fresh water in the fall and early winter months (September through January) was generally less than the equivalent distance in the early 1900's, indicating that large-scale water management operations circa 1970 tended to reduce salinity in the fall and early winter. However, this trend has reversed in the more recent water management period (1995-2005), with salinity intrusion significantly increased over levels in the early 1900's during all months.

Figure 3-10 also shows that the range of the average annual distance from Crockett to fresh water from 1995 to 2005 was approximately 15 miles (from about 13 to 30 miles), while the range during the early 1900's was approximately 20 miles (from 6 to 25 miles). This analysis indicates that large-scale water management activities limit the fluctuating nature of the salt field by preventing fresh water from reaching as far downstream as it did in the early 1900's.

Finally, Figure 3-10 indicates that salinity intrusion in the Delta occurred later in the year (beginning in July) in the early 1900's than under more recent time period conditions (beginning in March).

[18] This similarity in hydrological characteristics between the periods was established by approximately matching the distribution of annual Sacramento River flow during these periods (see Appendix E).

No comments

- n/a -

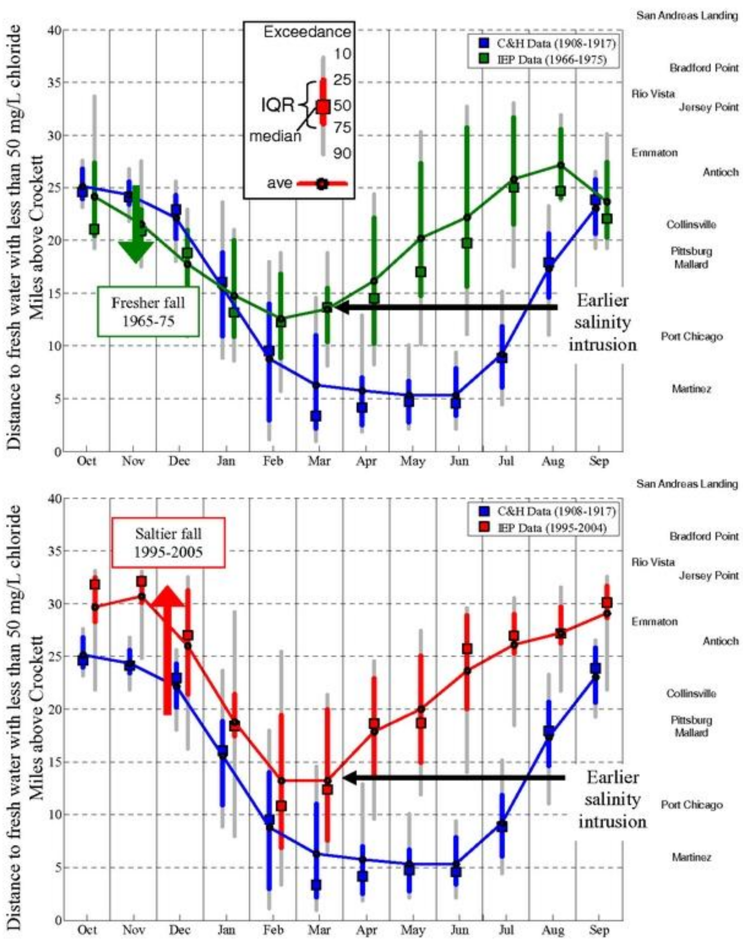

Figure 3-10 – Monthly distribution of distance to fresh water from Crockett

No comments

- n/a -

These comparisons (and other relevant comparisons in Appendix D) show that, on average, C&H barges would have had to travel up to 19 miles farther to procure fresh water under recent large-scale water management conditions than in the early 1900's. These comparisons also indicate that fresh water was present for significantly longer time periods, and over a larger area of the western Delta, in the early 1900's than during similar hydrological periods under current water management conditions. Abrupt changes in salinity just prior to 1920 caused C&H to abandon the Sacramento and San Joaquin Rivers and switch to a water supply contract with Marin County beginning in 1920 (Appendix D).

The distance to fresh water during individual wet years and during individual dry years is presented in Appendix D. The data in Appendix D also show that salinity has been generally higher in recent times than in the early 1900's and that water management has restricted the range in salinity experienced during a water year. The periods when fresh water is present at given locations have been reduced, or, in some cases, eliminated.

Conclusions

The records of the distance traveled upstream from Crockett by C&H barges to procure fresh water and estimates of this distance under large-scale water management conditions (reservoir operations and water diversions) show that:

- Fresh water was present farther downstream and persisted for longer periods of time in the western Delta in the early 1900's than under recent time periods with similar hydrologic conditions;
- Water management practices result in greater salinity intrusion in the western Delta for most months of the year; and,
- Salinity intrusion begins earlier in the year, extends farther upstream, and persists for a longer period each year.

No comments

- n/a -

3.3.3. X2 Variability

An often-used indicator of fresh water availability and fish habitat conditions in the Delta is a metric called X2. X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured near the channel bed along the axis of the San Francisco Estuary. Higher values of X2 indicate greater salinity intrusion. Monthly values of X2 are estimated in this report using the monthly regression equation from Kimmerer and Monismith (1992):

Monthly $X2(t) = 122.2 + 0.3278 * X2(t-1) - 17.65 * \log_{10}(NDO(t))$

The K-M equation expresses X2 (in units of kilometers) in terms of Net Delta Outflow (NDO, see Section 3.2) during the current month and the X2 value from the previous month. The monthly K-M equation was based on a statistical regression of X2 values (interpolated from EC measurements at fixed locations) and estimates of NDO from IEP's DAYFLOW computer program. Hence, the K-M equation is only valid for the existing Delta channel configuration and existing sea level conditions.

The K-M equation can be used to transform unimpaired and historical NDO data into the corresponding X2 values for unimpaired (without reservoir operations or water diversions) and historical (with historical water management) conditions, respectively.

The seasonal and annual variations of X2 are dependent on the corresponding variations of NDO under both historical and unimpaired flow conditions (Figure 3-11). X2 under historical flow conditions is shifted landward relative to unimpaired conditions by approximately 5 km. During the 1930's, historical NDO was often negative, sometimes averaging approximately -3,000 cfs for several months. This was due to relatively low runoff and significant upstream water diversions. Unfortunately, the K-M equation, which includes the logarithm (base 10) of NDO, is unable to account for negative values of NDO. In the case of historical flow conditions, this results in high variability of X2 in the 1930's. The values of X2 under historical flow conditions during 1930's in Figure 3-11 are likely underestimated.

Figure 3-12 compares X2 under unimpaired and historical conditions for the period from 1945-2003, following initiation of the Central Valley Project (i.e., after the completion of the Shasta Reservoir of the CVP). Figure 3-12 shows that, compared to unimpaired conditions, X2 under historical conditions was higher by about 10 km during April-July and by about 5 km during the rest of the year.

Salinity intrusion under historical water management conditions is, therefore, greater (higher X2) than the intrusion that would occur under unimpaired conditions. Moreover, the switch from declining X2 values during fall and winter months to increasing X2 values (increasing salinity intrusion) occurs in March under historical water management conditions and in June under unimpaired conditions. Thus, recent water management practices have resulted in a saltier Delta with earlier occurrence of salinity intrusion in the year.

No comments

- n/a -

Although current water management practices operate to provide salinity control, both the extent and duration of salinity intrusion are greater under current water management practices than under historical conditions. Likewise, current water management practices have changed the overall annual range in salinity (i.e., the difference between the highest and lowest salinity values during the year).

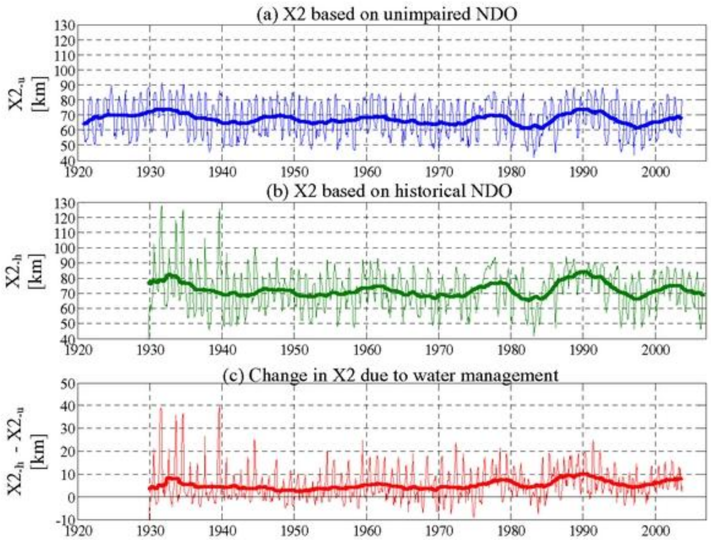

Figure 3-11 – Location of X2 under unimpaired and historical conditions
X2 has a strong seasonal and decadal variability under both unimpaired (top panel) and historical (middle panel) flow conditions reflecting the strong seasonal and decadal variability of NDO. The difference between historical and unimpaired conditions (bottom panel) illustrates the net effect of water management activities.

No comments

- n/a -

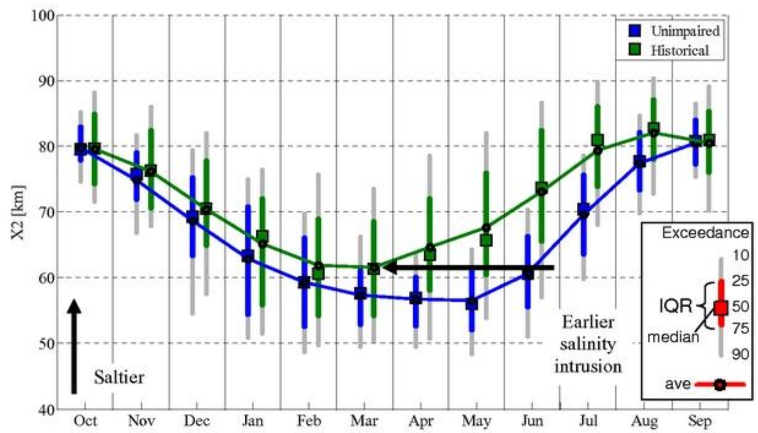

Figure 3-12 – Monthly distribution of X2 from 1945 through 2003

Figure 3-13 presents a comparison of unimpaired X2 and historical X2 during the 10 driest and the 10 wettest years of the CVP period (1945-2006).[19] During dry years (top panel), X2 is substantially greater under historical water management conditions than under unimpaired conditions (i.e., without water management); these effects are less dramatic but still occur during the wet years (bottom panel). Additionally, the annual range in salinity variability is significantly reduced under dry conditions (from approximately 22 km with unimpaired flows to 14 km with historical flows), but not wet conditions. The result of water management practices is a saltier Delta during both wet and dry years, with the greatest amount of salinity intrusion and reduced seasonal variability occurring in dry years.

Conclusions

The analysis of X2 (a measure of salinity intrusion in the Delta) shows that:

- Water management practices (reservoir operations and water diversions) result in a saltier Delta, with earlier salinity intrusion in the year.
- Water management practices result in a saltier Delta during both wet and dry years, but the effect is more pronounced in the dry years when the seasonal variability of salinity is also significantly reduced.

[19] Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

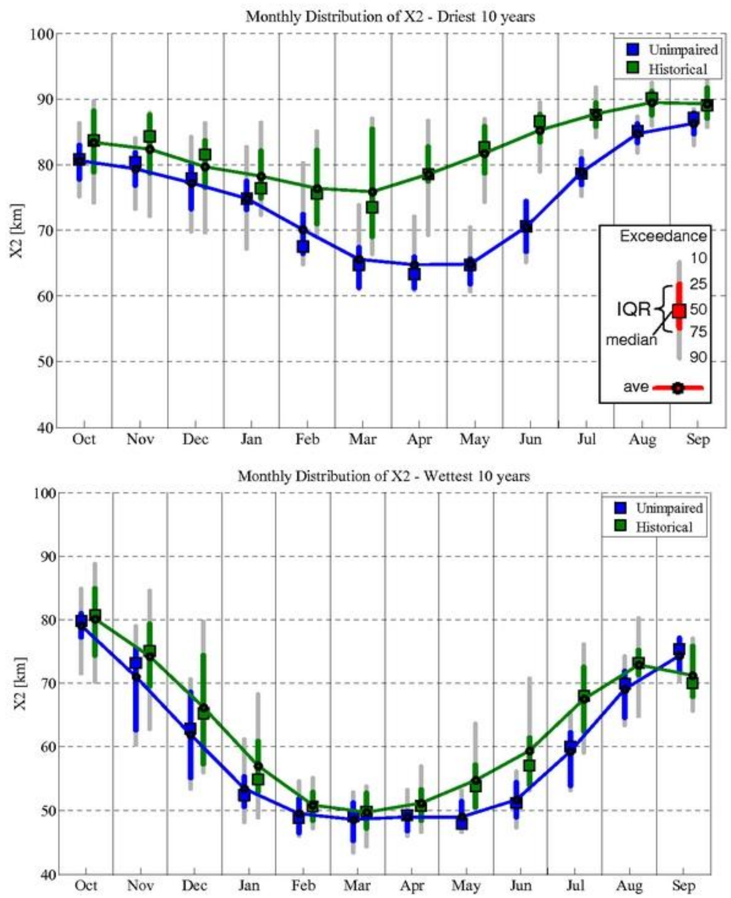

Figure 3-13 – Monthly X2 variability during wet and dry years (1945-2003)

Determination of the ten wettest and driest years is based on the total annual unimpaired Net Delta Outflow. The ten wettest years are 1952, 1956, 1958, 1969, 1974, 1982, 1983, 1986, 1995, and 1998. The ten driest years are 1947, 1976, 1977, 1987, 1988, 1990, 1991, 1992, 1994, and 2001.

No comments

- n/a -

3.3.4. Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[20] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

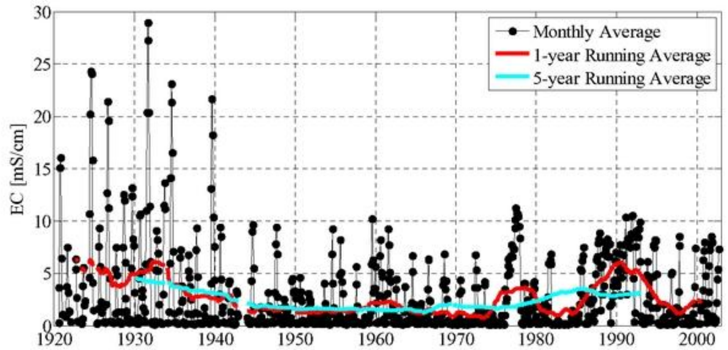

Figure 3-14 – Observed salinity at Collinsville

Monthly average salinity at Collinsville (black dots and black line), with the 12-month running average (red line) and 5-year running average (blue line).

Figure 3-14 shows the monthly average salinity at Collinsville for the period of 1920-2002, and Figure 3-15 shows the long-term trends in monthly salinity at Collinsville. Although the maximum values of salinity in the 1920's and 1930's far exceed subsequent salinity measurements at Collinsville, during the winters and springs of the 1920's and 1930's, the water at Collinsville freshened considerably. During the dry periods of 1920's and 1930's, monthly average salinity was below 350 µS/cm EC (approximately 50 mg/L chloride) for at least one month in every year. The one exception is 1924 which is inconclusive because no data were available from November through March. Monthly average EC data are missing for a portion of the winters and springs prior to 1926, and data for 1943 are missing entirely.

[20] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

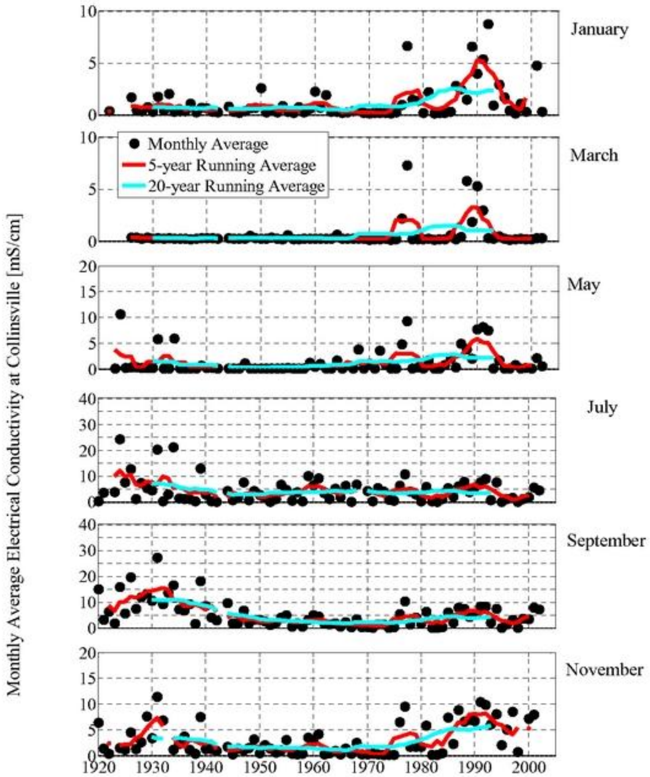

Figure 3-15 – Year-to-year trends in monthly-average salinity at Collinsville, 1920-2002

Monthly average salinity at Collinsville (black dots), with the 12-month running average (red line) and 5-year running average (blue line) for individual months.

Relatively fresh winters and springs during the 1920's are consistent with observations by C&H during that time period. However, monthly EC at Collinsville during the recent droughts (1976-1977 and 1987-1993) was always greater than 350 µS/cm EC, except for one month in both 1989 and 1992. These monthly observations of EC at Collinsville indicate that during the recent dry periods (1976-1977 and 1987-1993), EC at Collinsville was higher than that during similar dry periods in the 1920's and 1930's.

Enright and Culberson (2009) analyzed the trend in salinity variability at Collinsville from 1920-2006. They found increasing salinity variability in eleven of twelve months and

No comments

- n/a -

attributed it to water operations. In seven months (January-May, September-October) the increasing trend was significant ($p<0.05$).

Even in the six-year drought from 1928 to 1934, the Delta still freshened every winter (Figure 3-16). However, as shown in Figure 3-16, the Delta has not freshened during more recent droughts (1976-1977, 1987-1994, and 2007-2009). This indicates that the historical "flushing" of the Delta with fresh water is no longer occurring. This lack of flushing can also allow waste from urban and agricultural developments upstream of and within the Delta to accumulate. Contaminants and toxics have been identified as factors in the decline of the Delta ecosystem (Baxter *et al.* 2007). The data indicate the effect of managing to the X2 standard (implemented in 1995), as the salinity levels attained in the most recent drought are not as high as the 1976-77 and 1987-1992 droughts.

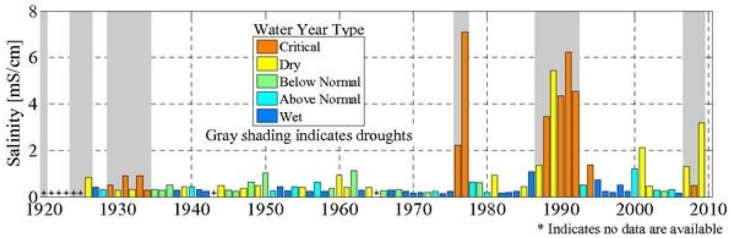

Figure 3-16 – Average Winter salinity at Collinsville

Annual average salinity during the winter (January through March) for water years 1927 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

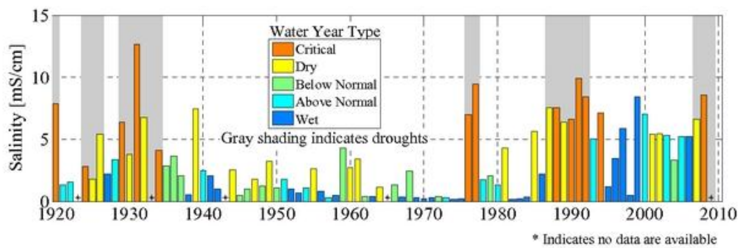

Figure 3-17 – Average Fall salinity at Collinsville

Annual average salinity during the fall months (October through December) for water years 1920 to 2009. Bars are colored by water year type as defined by the Sacramento 40-30-30 index. Grey shading indicates multi-year droughts that include at least one critical water year.

No comments

- n/a -

Figure 3-17 presents the variation in average fall salinity at Collinsville from 1920 to 2008 (October-December). Fall salinity is now high almost every year, while in the past, fall salinity was only high in dry and critical years. High salinity in the fall has been identified as a factor in the decline of the Delta ecosystem. Baxter *et al.* (2008) noted that "fall salinity has been relatively high during the POD years, with X2 positioned further [sic] upstream, despite moderate to high outflow conditions during the previous winter and spring of most years."

Conclusions

- In the 1920's and 1930's, the Delta freshened annually, even during droughts. In recent droughts, the Delta does not always freshen during the winter.
- Prior to 1976, fall salinity was high only in relatively dry years. Recently, fall salinity is high almost every year.

3.3.5. Salinity at Mallard Slough

A 1967 agreement between the Contra Costa Water District (CCWD) and the State of California requires the State to reimburse CCWD for the decrease in availability of usable river water, defined as water with less than 100 mg/L chlorides, at the Mallard Slough intake (CCWD, 1967). The 1967 agreement, and similar agreements between the State and other Delta water users, recognized the State Water Project (SWP) would increase salinity at Mallard Slough. The agreement defined a baseline of 142 days of usable water per year, based on the average number of days of usable water at the Mallard Slough intake from 1926-1967. Since 1967, the average number of days of usable water[21] (for the period 1967-2005) has declined to 122, indicating a 20-day (14%) reduction in the number of days of high quality water at Mallard Slough since the completion of the SWP.

[21] The data are from the USBR-CVO record of EC at Pittsburg, approximately 2 km upstream of Mallard Slough from 1967-2005. Since this station is located upstream of Mallard Slough, the number of days of usable water at Mallard Slough since the SWP was built may be overestimated.

No comments

- n/a -

4. Qualitative Observations of Historical Freshwater Flow and Salinity Conditions

In this section, qualitative observations of salinity conditions in the western Delta and Suisun Bay from the lawsuit filed by the Town of Antioch in 1920 and from various literature reports are discussed to provide a perspective of the salinity conditions prevailing in the late 1800's and early 1900's. Qualitative observations from early explorers and settlers are discussed in Appendix E.

4.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit (hereinafter referred to as the "Antioch Case") against upstream irrigation districts, alleging that upstream water diversions were causing increased salinity intrusion at Antioch. An overview of the Antioch Case is provided in Appendix E. The court decision, legal briefings, and petitions provide qualitative salinity observations from a number of witnesses. Although testimony in the Antioch Case is generally anecdotal, not quantitative, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument.

The upstream interests in the Antioch Case provided information on the operation of pumping plants along the San Joaquin River at Antioch for domestic water supply and the quality of water obtained from the pumping plants, summarized in Table 4-1.

Table 4-1 – Testimony regarding pumping plant operations and water quality in the 1920 Antioch Case

Time period of observation	Relevant information from the testimony
1866-1878	Mr. Dodge ran a pumping/delivery operation at Antioch ▪ Dodge pumped water into a small earthen reservoir at Antioch and then hauled the water to residents in a wagon. ▪ Cary Howard testified that while he was living in Antioch (1867-1876), the water became brackish one or two years in the fall, when they had to drive into the country to get water. This likely occurred during the drought of 1870-71.
1878-1880	Mr. Dahnken bought and operated the Dodge operation ▪ Dahnken testified that the water became brackish at high tide every year in the late summer, and remained brackish at high tide until it rained "in the mountains."

No comments

- n/a -

Time period of observation	Relevant information from the testimony
1880-1903	Belshaw Company provided water ▪ Dahnken testified that Belshaw Company pumped only at low tide.
1903-1920	Municipal Plant ▪ William E. Meek (resident since 1910) testified the water is brackish at high tide every year, for some months in the year. ▪ James P. Taylor testified that for at least the last 5 years, insufficient storage required the plant to pump nearly 24 hours per day, regardless of tidal phase. ▪ Dr. J. W. DeWitt testified that during October of most years between 1897 and 1918, the water was too brackish to drink. Even when the city only pumped at low tide, the water was occasionally so brackish that it would be harmful to irrigate the lawns.

This testimony suggests that, in the late 1800's, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was apparently able to pump fresh water at low tide year-round. A possible exception was the fall season during a few dry years. Water at Antioch was apparently fresh at low tide until at least around 1915. At that time, due to increased demand and inadequate storage, the pumping plants started pumping continuously, regardless of tidal stage. The window of time each year when Antioch is able to pump fresh water from the river has been substantially reduced in the last 125 years.

As shown in Appendix A, DWR (1960) estimated that water with a chloride concentration of 350 mg/L or less would be available about 85% of the time if there were no water management effects. DWR (1960) estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 and about 60% of the time by 1940. DWR also projected further deterioration of water quality by 1960 and beyond but did not include the effects of reservoir releases for salinity control.

Observations of salinity at Antioch during recent years indicate that salinity is strongly dependent on ocean tides, and the diurnal range in salinity can be as much as the seasonal and annual ranges in salinity. This is discussed in more detail in Appendices D and E. For instance, salinity at high tide can be more than five times the salinity at low tide (Figures D-1, D-2, and D-3), and the salinity during the course of a single day may vary up to 6,000 µS/cm EC (Figure D-1). Average daily salinity at low tide during the period of 1983-2002 exceeded 1,000 µS/cm[22] EC for about four and a half months of the year (Figure D-3). During the driest 5 years between 1983 and 2002, salinity at low tide was always greater than 1,000 µS/cm EC (i.e., no fresh water was available at any time of day) for about eight months of the year. Fresh water is currently available at Antioch far less frequently than prior to the 1920's.

[22] The current water quality criterion for municipal and industrial use is 250 mg/L, equivalent to about 1,000 µS/cm EC.

No comments

- n/a -

Available data and observations indicate that, prior to about 1918, fresh water was available at least at low tide during almost the entire year, in all but a few dry years. Around 1918, an abrupt change to higher salinity occurred. Although a prolonged and severe drought also began about this time, salinity conditions at Antioch did not return to pre-drought levels when the drought ended, indicating that water management activities (increased upstream diversions and later storage of water in upstream reservoirs) were the primary causes of this increased salinity.

4.2. Reports on Historical Freshwater Extent

Several literature reports discuss the spatial extent and duration of salinity conditions in the western Delta and Suisun Bay during the late 1800's and early 1900's. Salinity conditions at several key Delta locations are summarized below.

Location: **Western Delta**
Source(s): DPW (1931)
Quotation: "*The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before.*" (DPW, 1931, pg. 22)
Quotation: "*It is particularly important to note that the period 1917-1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time.*" (DPW, 1931, pg. 66)
Summary: Salinity intrusion into the Delta during the period 1917-1929 was much larger than experienced prior to that time.

Location: **Pittsburg, CA**
Source(s): Tolman and Poland (1935) and DPW (1931)
Quotation: "*From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough offshore.*" (DPW, 1931, pg. 60)
Quotation: "*There was an inexhaustible supply of river water available in the New York Slough* [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers], *but in the summer of 1924 this river water showed a startling rise in salinity to 1,400 ppm of chlorine, the first time in many years that it had grown very brackish during the dry summer months.*" (Tolman and Poland, 1935, pg. 27)
Summary: Prior to the 1920's, the water near the City of Pittsburg was sufficiently fresh for the City to obtain all or most of its fresh water directly from the river.

Location: **Antioch, CA**
Source(s): DPW (1931)

No comments

- n/a -

Quotation:	"*From early days, Antioch has obtained all or most of its domestic and municipal water supply from the San Joaquin River immediately offshore from the city. This supply also has always been affected to some extent by saline invasion with the water becoming brackish during certain periods in the late summer and early fall months. However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall.*" (DPW, 1931, pg. 60)
Summary:	Until 1917, the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River. Salinity intrusion has prevented domestic use of water at the Antioch intake in summer and fall after 1917.

Location:	**Benicia, CA (Suisun Bay)**
Source(s):	Dillon (1980) and Cowell (1963)
Quotation:	"*In 1889, an artificial lake was constructed. This reservoir, filled with fresh water from Suisun Bay during the spring runoff of the Sierra snow melt water …*" (Dillon, 1980, pg. 131)
Quotation:	"*…in 1889, construction began on an artificial lake for the* [Benicia] *arsenal which would serve throughout its remaining history as a reservoir, being filled with fresh water pumped from Suisun Bay during spring runoffs of the Sacramento and San Joaquin Rivers which emptied into the bay a short distance north of the installation.*" (Cowell, 1963, pg. 31)
Summary:	In the late 19th Century, fresh water was available in the Suisun Bay and Carquinez Straits for use by the City of Benicia.

The reported presence of relatively fresh water in the western Delta and the Suisun Bay during the late 1800's and early 1900's is consistent with the relatively fresh conditions observed in the paleoclimate records for this time period (Section 2.3) and the relatively wet conditions observed in the Sacramento River runoff and precipitation records (Section 3.1).

Additional observations between 1775 and 1841 are included in Appendix E. These qualitative observations indicated the presence of "*sweet*" water near the confluence of the Sacramento and San Joaquin Rivers in the vicinity of Collinsville in August 1775 (a period of average or above-average Sacramento River flow), and September 1776 (a period of below-average Sacramento River flow). The presence of "*very clear, fresh, sweet, and good*" water was reported in April 1776 (a dry year). Historical observations from 1796 and August 1841 (dry periods) indicated salinity "*far upstream*" at high tide and the presence of brackish (undrinkable) water in Threemile Slough. Current salinity controls and regulations put brackish water (averaged over 14 days) near Jersey Point and Emmaton, each about 2.5 miles below Threemile Slough, on a regular basis annually.

No comments

- n/a -

5. Conclusions

1. Measurements of ancient plant pollen, carbon isotope and tree ring data show that the Delta was predominately a freshwater marsh for the past 2,500 years, and that the Delta has become far more saline in the past 100 years because of human activity. Salinity intrusion during the last 100 years is comparable to the highest levels over the past 2,500 years.
2. Human activities during the last 150 years, including channelization of the Delta, elimination of tidal marsh, construction of deep water ship channels, and diversions of water, have resulted in increased salinity levels in the Delta. Today, salinity typically intrudes 3 to 15 miles farther into the Delta than it did in the early 20th Century.
3. Before the substantial increase in freshwater diversions in the 1940's, the Delta and Suisun Bay would freshen every winter, even during the extreme drought of the 1930's. However, that pattern has changed. During the most recent droughts (1976-1977, 1987-1994, and 2007-2009), the Delta did not always freshen in winter. Without seasonal freshening, contaminants and toxics can accumulate in the system and young aquatic species do not experience the same fresh conditions in the spring that occurred naturally.
4. While half of the past 25 years have been relatively wet, the fall salinity levels in 21 of those 25 years have resembled dry-year conditions. In terms of salinity, the Delta is now in a state of drought almost every fall because of human activity, including water diversions.
5. Seasonal and inter-annual variation in salinity has also been changed; however, this change is the result of reduced freshwater flows into the Delta. At any given location in the western Delta and Suisun Bay, the percentage of the year when fresh water is present has been greatly reduced or even eliminated.
6. The historical record and published studies show the Delta is far saltier now, even after the construction of reservoirs that have been used in part to meet State Water Resources Control Board water quality requirements in the Delta. Operation of reservoirs and water diversions for salinity management somewhat ameliorates the increased salinity intrusion, but the levels still exceed pre-1900 salinities.

No comments

- n/a -

No comments

- n/a -

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No comments

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No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

A summary of historical reviews, reports, analyses and measurements

Appendices

Water Resources Department

Contra Costa Water District

Concord, California

February 2010

Technical Memorandum WR10-001

No comments

- n/a -

No comments

- n/a -

Historical Fresh Water and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay

Appendices
February 2010

No comments

- n/a -

Tables

Figures

No comments

- n/a -

No comments

- n/a -

No comments

- n/a -

Appendix A. Factors Influencing Salinity Intrusion

Salinity intrusion in the Delta is the result of the interaction between tidally-driven saline water from the Pacific Ocean and fresh water from rivers flowing into the Delta. Regional climate change (e.g., sea level rise and change in precipitation regime), physical changes to the Central Valley landscape (e.g., creation of artificial channels and land use changes), and water management practices (e.g., reservoir storage, water diversions for agricultural and municipal and industrial use) affect this interaction between the ocean tides and the freshwater flow, in turn affecting salinity intrusion in the Delta (The Bay Institute (TBI), 1998, Department of Public Works (DPW), 1931, Nichols *et al.*, 1986, Conomos, 1979, and Knowles, 2000).

These factors are grouped into three categories (Table A-1) and discussed individually and qualitatively to provide context for observed salinity variability, which is necessarily due to the cumulative impact of all factors.

Table A-1 – Factors Affecting Salinity Intrusion into the Delta

Natural and artificial factors affect the salinity of the Delta. The factors are grouped into three categories: regional climate change, physical changes to the landscape, and water management practices.

Category	Factors affecting salinity intrusion and specific effect on Delta salinity
Regional Climate Change	• Precipitation regime ○ Long-term reduction of spring (April-July) snowmelt runoff may increase salinity in the spring, summer, and fall. ○ A shift to more intense winter runoff may not decrease salinity in the winter because outflows are typically already high during winter storms. • Ocean conditions ○ Added periodic variability to precipitation (via mechanisms such as the El Niño/Southern Oscillation (ENSO) or Pacific Decadal Oscillation (PDO)) • Sea level rise ○ Expected to increase salinity intrusion (DWR, 2006). Actual salinity response to rising sea level will depend upon actions taken to protect against flooding or overtopping (e.g., new tidal marsh vs. sea walls or dykes).
Physical Changes to the Landscape	• Deepening, widening, and straightening of Delta channels ○ Generally increase salinity, but response will depend upon location within the Delta (DWR, 2006)

No comments

- n/a -

Category	Factors affecting salinity intrusion and specific effect on Delta salinity

	• Separation of natural floodplains from valley rivers
	  ○ Confining peak flows to river channels would reduce salinity during flood events.
	  ○ Preventing floodplains from draining back into the main channel would increase salinity after floods (late spring and summer).
	
	• Reclamation of Delta islands
	  ○ Varies (the effect on salinity depends on marsh vegetation, depth, and location), but marshes generally dampen tides, reducing salinity intrusion
	
	• Creation of canals and channel "cuts"
	  ○ Generally creates more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to native conditions
	
	• Deposition and erosion of sediments in Suisun Bay (Cappiella *et al.*, 1999)
	  ○ Deposition of mining debris (occurred from 1860's to approximately 1887) reduced salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)
	  ○ Erosion (occurring since 1887) increases salinity in Suisun Bay and the western and central Delta (Enright, 2004, Enright and Culberson, 2009)

Water Management Practices (reservoir operations, water diversions, and exports from the Delta)	• Decreasing Net Delta Outflow (NDO) by increasing upstream and in-Delta diversions as well as exports
	  ○ Increases salinity
	
	• Increasing upstream storage capacity
	  ○ Generally increases salinity when reservoirs are filling. Reservoir releases may decrease salinity if they increase outflow. Historically, this occurred when flood control or other releases were required in wetter years. However, as this study shows, this has generally been small and intermittent; salinity measurements indicate it occurred occasionally prior to 1985, and very seldom since. Increased early winter diversion of runoff to storage will maintain or increase high salinities in the winter.

No comments

- n/a -

No comments

- n/a -

A.1. *Climatic Variability*

Changes in precipitation regimes and sea levels, brought about by a changing climate, can affect the spatial and temporal salinity conditions in the Delta. Long-term variations in river runoff, precipitation and sea level are discussed below.

A.1.1. Regional Precipitation and Runoff

Precipitation in the Bay-Delta watershed sets the amount of water available within the system which could ultimately reach the Bay and affect salinity conditions. However, since precipitation falls as both rain and snow, runoff to river channels is spread over more months than the precipitation events themselves; any runoff from rain generally reaches the river channels within days of the precipitation event, but runoff resulting from snow is delayed until the spring snowmelt. For this reason, estimates of unimpaired flow (runoff), rather than precipitation, are generally used to characterize hydrological variability. Unimpaired runoff represents the natural water production of a river basin, unaltered by water diversions, reservoir storage and operation, and export of water to or import of water from other basins.

Knowles (2000) determined that variability in freshwater flows accounts for the majority of the Bay's salinity variability. The spatial distribution, seasonal timing, annual magnitude, decadal variability, and long-term trends of unimpaired flow all affect the hydrology and salinity transport in the Delta. Total annual unimpaired flow in the Sacramento and San Joaquin basins from 1872 through 2009 is presented in Section 3.1, with the seasonal distribution provided for 1921 through 2003.

The total annual unimpaired flow of the upper Sacramento Basin for water years 1906 through 2006 exhibits substantial year-to-year variability with a strong decadal oscillation in the 5-year running average (see Figure 3-1). On average, over the last 100 years, the total annual unimpaired Sacramento River flow is increasing by about 0.06% or 11 thousand-acre feet (TAF) each year. However, increased total annual unimpaired flow does not necessarily reduce salinity intrusion. Knowles (2000) illustrated that the seasonal timing of runoff can significantly alter salinity intrusion without any change to the total annual runoff.

Typically, most precipitation in California occurs during winter in the form of snow in the Sierra Nevada. The subsequent melting of this snow, beginning in the spring, feeds the rivers that flow into the Delta. The four months from April through July approximately span the spring season and represent the period of runoff due to snow melt. The long-term trend in spring (April-July) runoff decreased by approximately 1.3 MAF from 1906 to 2006 (Figure A-1). This effect is believed to be caused by climate change; as temperatures warm, more precipitation falls as rain instead of snow, and what snowpack that does accumulate tends to melt earlier in the year. This leads to higher runoff during winter months, but lower runoff in spring or summer, resulting in the potential for greater salinity intrusion. These observed changes in the magnitude and timing of spring runoff of the Sacramento River watershed are consistent with similar changes in spring runoff observed across river watersheds of the western United States (e.g., Dettinger, 2005; Mote *et al.*, 2005; Stewart *et al.*, 2005). Note that, from 1920 to 2006, the long-term trend in spring runoff actually increased slightly (approximately 0.5 MAF).

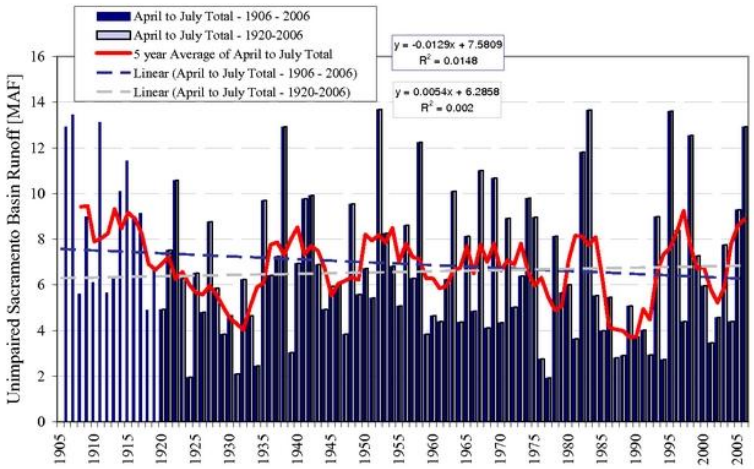

Figure A-1 – Unimpaired runoff from the Sacramento River basins from April to July
Data source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

Precipitation and runoff are influenced by regional events such as the Little Ice Age (about 1300 to 1850 CE) and the Medieval Warm Period (about 800 to about 1300 CE). During the Little Ice Age, the winter snowline in the Sierra was generally at a lower elevation, and spring and summer nighttime temperatures were significantly lower. This temperature pattern would allow the snowmelt to last further into the summer, providing a more uniform seasonal distribution of runoff such that significantly less salinity intrusion than occurs today would be expected. This expectation is borne out by paleosalinity studies (see Section 2.3).

At shorter time scales, oceanic conditions such as the Pacific Decadal Oscillation (PDO) and El Niño/Southern Oscillation (ENSO) also impact precipitation and runoff patterns. Runoff in the upper watershed is the primary factor that determines freshwater outflow from the Delta. Anthropogenic flow management (upstream diversions, reservoir operations, in-Delta diversions, and south-of-Delta exports) alters the amount and timing of flow from the upper watershed (see Section 2.3). Changes to the physical landscape further alter the amount and timing of flow (see Section 2.2).

No comments

- n/a -

A.1.2. Sea Level Rise

Sea level fluctuations resulting from the repeated glacial advance and retreat during the Pleistocene epoch (extending from 2 million years ago to 15,000 years ago) resulted in deposition of alternating layers of marine and alluvial sediments in the Delta (TBI, 1998). A warming trend starting about 15,000 years ago ended the last glacial advance and triggered rapid sea-level rise. At the end of this period (known as the "Holocene Transgression") approximately 6,000 years ago, sea level had risen sufficiently to inundate the Delta at high tide (Atwater *et al*., 1979).

Sea level is estimated to have risen at an average rate of about 5 cm/century during the past 6,000 years and at an average rate of 1-2 cm/century during the past 3,000 years (Cayan *et al.*, 2008). Observations of sea level at the Golden Gate in San Francisco reveal that the mean sea level has risen at an average rate of 2.2 cm/decade (or 0.22 mm/yr) over the past 100 years (Cayan *et al*., 2008). Future increases in sea level are expected to increase salinity intrusion into the Delta (DWR, 2006); actual salinity response to rising sea level will depend upon actions taken to protect against flooding or levee overtopping (e.g. new tidal marsh would generally reduce salinity intrusion, while construction of sea walls or dykes may further increase salinity).

A.2. Physical Changes to the Delta and Central Valley

Creation of artificial channels, reclamation of marshlands, land use changes and other physical changes to the landscape of the Delta and Central Valley have significantly altered water movement through the Delta and the intrusion of salinity into the Delta. Major physical changes to the Delta and Central Valley landscape have occurred over the last 150 years. As many of these physical changes were made prior to flow and salinity monitoring (which began in the 1920's), only a qualitative discussion is presented below.

A.2.1. Deepening, Widening, and Straightening Channels (early 1900's-present)

The lower Sacramento River was widened to 3,500 feet and straightened (creating Decker Island) around 1910 (Lund *et al.,* 2007). Progressive deepening of shipping channels began in the early 1900's. Original channel depths were less than 10 feet; channels were gradually dredged to depths exceeding 30 feet, and maintenance dredging continues today.

These changes to the river channels have increased salinity intrusion. Deepening the river channels increases the propagation speed of tidal waves, leading to increased salinity intrusion. Similarly, straightening the river channels provides a shorter path for the passage of the tidal waves and increases salinity intrusion. Widening of the river channels increases the tidal prism (the volume of water in the channels), resulting in further salinity intrusion. Larger cross-sections reduce velocities, lowering friction losses and maintaining more tidal energy, which is the driving force for dispersing salinity into the Delta.

No comments

- n/a -

A.2.2. Reclamation of Marshland (1850-1920)

In the Central Valley

The original natural floodplains captured large winter flows, gradually releasing the water back into the river channels throughout the spring and summer, resulting in a more uniform flow into the Delta (reduced peak flow and increased low flow) compared to current conditions. The increased surface area of water stored in these natural floodplains increased total evaporation and groundwater recharge, reducing total annual inflow into the Delta.

Even with less Delta inflow, the difference in the seasonal flow pattern may have limited salinity intrusion. The drainage of floodplains back into rivers during the spring and groundwater seepage back to the rivers in the summer and fall provided a delayed increase in river flows during the low flow period. Raising and strengthening natural levees in the Central Valley effectively disconnected the rivers from their floodplains, removing this natural water storage, increasing the peak flood flows and reducing the low flows. The net effect of these changes in the Central Valley was to reduce salinity during floods, when salinity is typically already low, and increase salinity during the following summers and falls, which is likely to have led to increased maximum annual salinity intrusion.

In the Delta

Reclamation of Delta marshland began around 1850. By 1920, almost all land within the legal Delta[1] had been diked and drained for agriculture (DPW, 1931). Before the levees were armored and the marshes were drained, the channels would have been shallower and longer (more sinuous), which would have slowed propagation of the tides into the Delta, reduced tidal energy and reduced salinity intrusion.

The natural marsh surface would have increased the tidal prism. However, the shallow marsh depth and native vegetation would have slowed the tidal wave progression. The combined effect on salinity intrusion depends on the location and depth of the marsh, the native vegetation distribution, and the dendritic channels that were removed from the tidally active system.

Figure A-2 shows the western, central, and southern portions of the Delta in 1869. For comparison, Figure A-3 shows the same area in 1992, with man-made channels highlighted grey.

A.2.3. Mining debris

Hydraulic mining in the Sierra Nevada began in the 1860's and produced large quantities of debris which traveled down the Sacramento River, through the Delta and into the Bay. Mining debris may have contributed to the extensive flooding reported in 1878 and 1881. Cappiella *et al.* (1999) estimate that, from 1867 to 1887, approximately 115 million cubic meters (Mm3) of sediment were deposited in Suisun Bay. This deposition was due to the inflow of hydraulic mining debris.

[1] The legal Delta is defined in California Water Code Section 12220.

No comments

- n/a -

Figure A-2 - Map of the Delta in 1869

Channels of the western, central, and southern Delta in 1869, prior to extensive reclamation efforts (Gibbes, 1869)

No comments

- n/a -

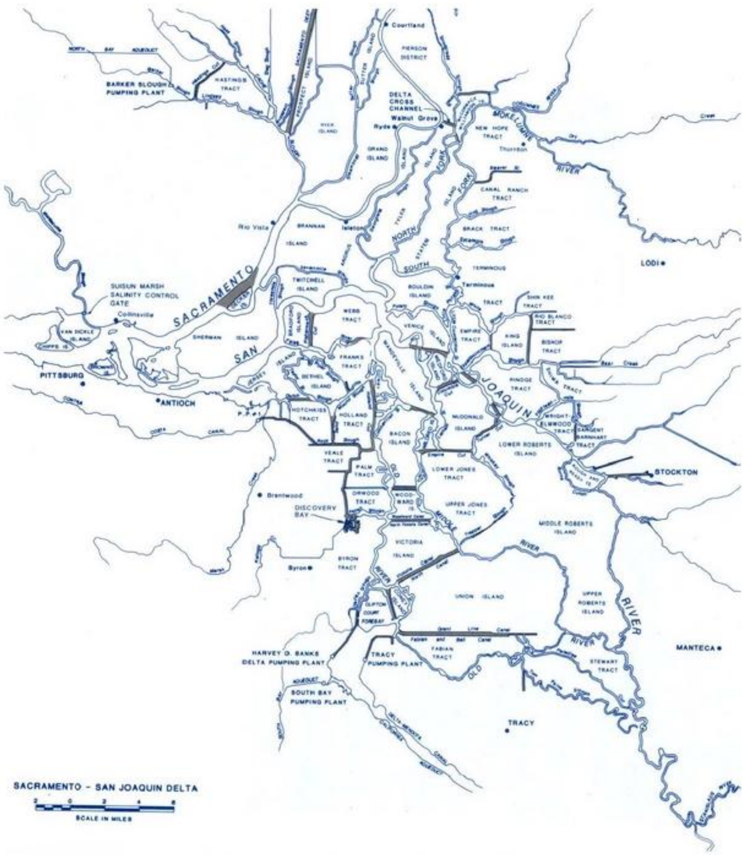

Figure A-3 – Map of the Delta in 1992

Channels of the western, central, and southern Delta from the Delta Atlas (DWR, 1992) Constructed waterways (highlighted in grey) generally create more efficient routes for tidal flows to enter the Delta, thereby increasing salinity intrusion relative to the native tidal marshes.

No comments

- n/a -

Cessation of hydraulic mining around 1884 resulted in erosion of Suisun Bay, which continues to erode even today. From 1887 to 1990, approximately 262 Mm3 of sediment were eroded from Suisun Bay. The net change in volume of sediment during 1867-1887 was 68 Mm3 (net deposition) and during 1887-1990 was -175 Mm3 (net erosion). As a result of these changes, the tidal flat of Suisun Bay increased from about 41 km^2 in 1867 to 52 km^2 in 1887, but decreased to 12 km^2 by 1990 (due to erosion subsequent to the cessation of hydraulic mining). Cappiella *et al.* (1999) attributed the change in the Suisun Bay area from being a largely depositional environment to an erosional environment not only to the hydraulic mining practices of the late 1800's but also to increased upstream water management practices. The Suisun Marsh Branch of the DWR estimated that erosion of Suisun Bay (modeled as a uniform change in depth of 0.75 meters) has increased salinity in Suisun Bay and the western Delta by as much as 20% (Enright, 2004; Enright and Culberson, 2009).

A.3. Water Management Practices

Extensive local, state, and federal projects have been built to move water around the state, altering the natural flow patterns throughout the Delta and in upstream watersheds. For clarity in the discussion that follows, definitions and discussions of actual flow and salinity, unimpaired flow and salinity, and natural flow and salinity, are given below.

Historical (actual) flow and salinity
Historical (or actual) flow and salinity refer to the flow and electrical conductivity, total dissolved solids concentration, or chloride concentration that occurred in the estuary. Historical conditions have been observed, measured, or estimated at various times and locations; they are now measured at monitoring stations throughout the estuary. Historical data are also used to estimate flow and water quality conditions at other locations with the following tools: the DAYFLOW program from IEP, the DSM2 model from the California Department of Water Resources, the X2[2] equation (Kimmerer and Monismith, 1992) and Contra Costa Water District's salinity outflow model (also referred to as the G-model) (Denton, 1993; Denton and Sullivan, 1993). The use of these tools to estimate flow and water quality is necessarily dependent upon the Delta configuration to which they were calibrated. Use of these tools in hypothetical configurations (such as pre-levee conditions, flooding of islands, etc) is subject to un-quantified error.

Unimpaired flow and salinity
Unimpaired flows are hypothetical flows that would have occurred in the absence of upstream diversions and storage, but with the existing Delta and tributary configuration. Unimpaired flows are estimated by the California Department of Water Resources (DWR) for the 24 basins of the Central Valley; the Delta is one of the 24 basins. Additionally, DWR estimates unimpaired in-Delta use and unimpaired net Delta outflow (NDO). Unimpaired NDO estimates can be used to estimate unimpaired water quality using a salinity-outflow relationship such as the X2 or G-model tools discussed above.

[2] X2 is defined as the distance from the Golden Gate to the 2 part-per-thousand isohaline (equivalent to a salinity of 2 grams of salt per kilogram of water), measured along the axis of the San Francisco Estuary. X2 is often used as an indicator of freshwater availability and fish habitat conditions in the Delta (Jassby *et al.*, 1995; Monismith, 1998).

No comments

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Since unimpaired flows assume the existing Delta configuration, the use of these tools should not violate their basic assumptions. However, the results should be taken in context. Water quality based on unimpaired flows compared to water quality based on historical (actual) flows shows how water management activities affect water quality. Water quality based on unimpaired flows cannot be considered natural.

Natural flow and salinity
Natural flow and salinity reflect pre-European settlement conditions, with a virgin landscape in both the Central Valley and the Delta, native vegetation, and no diversions or constructed storage. As discussed above, the natural landscape included natural storage on the floodplains and extensive Delta marsh. Estimation of natural flow requires assumptions regarding the pre-European landscape and vegetation throughout the Central Valley. Estimation of natural salinity requires development of new models to account for pre-European Delta geometry, incorporating the estimates of natural flow. These assumptions induce an unknown level of error. For this reason, no attempt is made in this report to calculate natural flow or the resulting salinity. Instead, paleosalinity studies are examined to provide evidence of salinity in the pre-European era.

Water management practices have continually evolved since the mid-1850's. As discussed in Section 1.1, anthropogenic modification include diversion of water upstream and within the Delta, construction of reservoirs, and system operations to meet regulatory requirements.

The irrigated acreage in the Central Valley has been steadily increasing since 1880 (Figure 1-3), increasing the upstream diversions of water. There were two periods of rapid growth in irrigated acreage: from 1880 to 1920 and from 1940 to 1980. In-Delta diversions (Figure 1-3) began in 1869 with reclamation of Sherman Island; from 1869 to 1930, in-Delta diversions are assumed to have grown in proportion to the area of reclaimed marshland (from Atwater *et al.*, 1979).

Upstream diversions first became an issue with respect to Delta salinity around 1916 with the rapid growth of the rice cultivation industry (Antioch Case, Town of Antioch v. Williams Irrigation District, 1922, 188 Cal. 451; see Appendix E.2). These early "pre-project" diversions for irrigation had particularly large impacts because of the seasonality of water availability and water use. Diversions for agriculture typically start in the spring and continue through the early fall (when river flow is already low). These early irrigation practices, combined with the decrease in spring and summer flow due to the separation of rivers from their natural floodplains, resulted in a significant reduction of the spring and summer river flow, leading to increased salinity intrusion.

Figure A-4 shows the Department of Water Resources' estimates of the effects of upstream diversions and south-of-Delta exports on the salinity in the San Joaquin River at Antioch (DWR, 1960). DWR's 1960 report indicated that water with less than 350 mg/L chlorides would be present at Antioch approximately 88% of the time on average "naturally," and that availability decreased to approximately 62% by 1940 due to upstream diversions. This illustrates that upstream depletions had a significant effect on salinity at Antioch during 1900-1940, prior to the construction of large upstream reservoirs. (For reference, Shasta Dam was completed in 1945.)

No comments

- n/a -

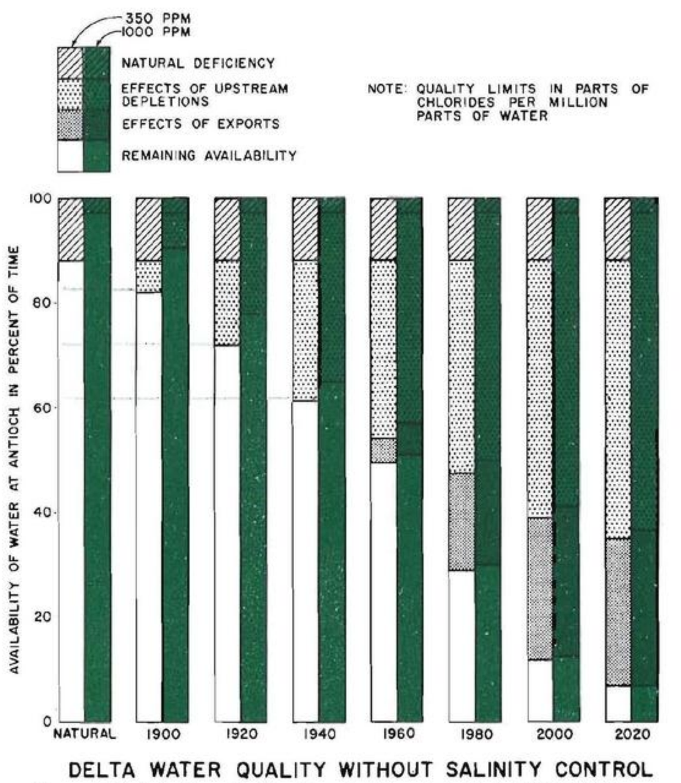

Figure A-4 - Salinity on the San Joaquin River at Antioch (DWR, 1960)

The Department of Water Resources examined the effects of upstream depletions and south-of-Delta exports on salinity in the San Joaquin River at Antioch, estimating the percent of time water that a certain quality of water (with less than 350 mg/L chlorides; or less than 1,000 mg/L chlorides) would be available in the river without reservoir releases to provide salinity control. The estimates for 1960, 1980, 2000, and 2020 assume the reservoirs do not make releases for salinity control and therefore underestimate the actual quality of water during these years.

Figure A-4 also shows estimates of the availability of water in 1960, 1980, 2000, and 2020, without reservoir releases to provide salinity control, demonstrating that upstream depletions and in-Delta exports would have continued to degrade water quality at Antioch.

No comments

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Exports from the south Delta started in 1951 with the completion of the federal Central Valley Project pumping facility near Tracy, California. Exports from the State Water Project Banks Pumping Plant, just to the west of the federal facility, began in 1967. As shown in Figure 1-3, south-of-Delta exports increased rapidly from 1951 through the mid-1970s, and since then the combined exports have averaged more than 4 million acre-feet per year.

Construction of upstream reservoirs also altered natural patterns of flow into the Delta. Figure A-5 and Figure A-6 show the extent and rapid rise of constructed reservoirs in the upstream watersheds of the Delta (DWR, 1993). The location, year of completion and approximate storage capacities (in acre-feet, AF) are shown in Figure A-5. Figure A-6 shows the temporal development of reservoir capacity. Reservoir construction began in 1850. The major reservoirs of the Central Valley Project (CVP) and State Water Project (SWP) are the Shasta (4.5 MAF capacity) and Oroville (3.5 MAF) reservoirs, respectively. These reservoirs capture the flow in the wet season (reducing the flow into the Delta in the wet season) and release water for irrigation and diversions.

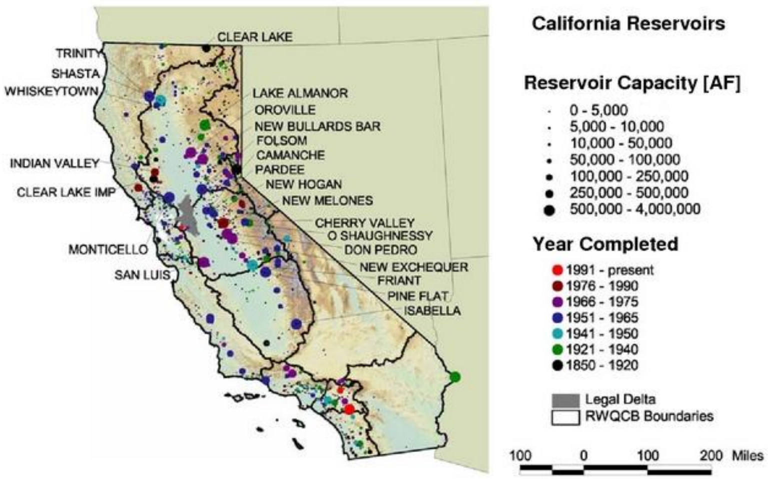

Figure A-5 – Storage reservoirs in California

Location of storage reservoirs within California. Reservoir capacity is indicated by the size of the circle, while the year construction was completed is indicated by color.

No comments

- n/a -

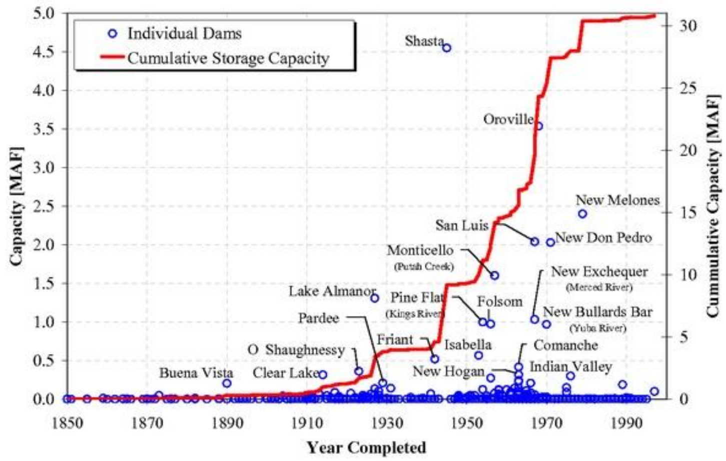

Figure A-6 – Surface Reservoir Capacity

Timeline of reservoir development in California. Individual reservoir capacity is indicated by the blue circles (left axis), while the cumulative capacity is indicated with the red line (right axis).

Water management practices have been altered by regulations that require maintenance of specified flow and salinity conditions at locations in the Bay-Delta region during certain periods of the year. The 1978 Water Quality Control Plan and State Water Resources Control Board (SWRCB) Decision 1485 established water quality standards to manage salinity to protect Delta agriculture and municipal and industrial (M&I) uses. The listing of delta smelt as a threatened species under the Endangered Species Act in 1993, followed by the Bay-Delta Accord in 1994 and the adoption of a new water quality control plan by the State Water Resources Control Board in 1995 changed the amount and timing of reservoir releases and south-of-Delta exports. California's Rice Straw Burning Act was enacted in 1992 to reduce air pollution by phasing out the burning of rice field stubble; by 1999, Sacramento Basin rice farmers were diverting additional water to flood harvested fields to decompose the stubble.

Changes in water diversions and reservoir operations have altered the magnitude and timing of river flows to the Delta, and anthropogenic modifications to the Delta landscape have altered the interaction of fresh water from the rivers with salt water from the ocean, thus changing patterns of salinity intrusion into the Delta.

No comments

- n/a -

No comments

- n/a -

Appendix B. Paleoclimatic Records of Hydrology and Salinity

This section presents paleoclimate records of hydrology (precipitation and unimpaired runoff) and salinity in the Bay-Delta region, in addition to those presented in Section 2 of the main report.

B.1. Methods of Paleoclimatic Reconstruction

The field of paleoclimatology aims to deduce climatological information from natural "archives" in order to reconstruct past global climate. These archives are created by such Earth processes as the formation of ice sheets, sediments, rocks, and forests. Examples of information sampled from such archives include atmospheric temperatures from ice cores and precipitation cycles from tree rings. When samples are dated, through radiometric or other methods, the data preserved therein become proxy indices, establishing a timeline of major events in the local environment of the sample. Multiple samples collected over larger spatial scales can be cross-dated to create regional climate and landscape process chronologies.

The material sampled for paleoclimatic reconstructions has limitations that decrease the resolution and confidence of data going back in time. Although paleoclimatic reconstructions have a coarser temporal resolution than modern measurements, the variations in climate and landscape responses to change are reliably described "in the first person" because the evidence of localized climate change is preserved as a time series *in situ*, absent of human influence.

The San Francisco Bay-Delta has been the focus of several paleoclimatic reconstructions. Surveys have sampled from Browns Island (Goman and Wells, 2000; May, 1999; Malamud-Roam and Ingram, 2004), Roe Island (May, 1999; Malamud-Roam and Ingram, 2004) Rush Ranch (Starratt, 2001; Byrne *et al.*, 2001; Starratt, 2004), and China Camp and Benicia State Parks (Malamud-Roam and Ingram, 2004).

Sediment cores are the predominate archive used to reconstruct Bay-Delta climate. Changes in wetland plant and algae communities are the dominant response in the Bay-Delta to climate change and associated fluctuations in temperature and precipitation. Proxies of plant and algae response to environmental conditions are preserved in the sediment cores and determined by quantification and taxonomic identification of diatom frustules (Byrne *et al.*, 2001; Starratt, 2001; Starratt, 2004), plant seeds and roots (Goman and Wells, 2000) and plant pollen (May, 1999; Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004) and measurement of peat carbon isotope ratios (Byrne *et al.*, 2001; Malamud-Roam and Ingram, 2004).

Plant communities in the Delta are characterized by salt tolerance. Salt-tolerant plant communities are dominated by pickleweed (*Salicornia* spp.) while freshwater plant

No comments

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assemblages are dominated by tule (*Scirpus* spp.) and cattail (*Typha* spp.) (Atwater *et al.*, 1979). Plants contribute pollen, seeds, and vegetative tissue in the form of peat to the sediment archive. Plant material deposited to surface sediments are significantly correlated to the surrounding standing vegetation, and thus plant material preserved in sediment cores are considered autochthonous to the type of wetland existent at the time of sediment deposition, allowing reconstruction of the salinity conditions in the Delta over time.

Diatom taxa are classified according to their salinity preference expressed as the Diatom Salinity Index (DSI) (Eq 1) (Starratt, 2004). Starratt (2001) classified salinity preference as freshwater (F; 0-2‰), freshwater and brackish water (FB; 0-30‰), brackish (B; 2-30‰), brackish and marine (BM; 2-35‰), and marine (M; 30-35‰). Samples dominated by marine taxa have a DSI range of 0.00 to 0.30.

$$DSI = \frac{F + FB + 0.5B}{F + FB + B + BM + M} \tag{1}$$

Carbon-isotope ratios ($^{13}C/^{12}C$) (Eq 2) are measured by spectrometry and the δ notation calculated as

$$\delta^{13}C = \left[\left(\frac{{}^{13}C/{}^{12}C_{sample}}{{}^{13}C/{}^{12}C_{std}}\right) - 1\right] \times 1000 \tag{2}$$

The $\delta^{13}C$ value of peat samples is a proxy for the composition of the plant assemblages contributing vegetation to the formation of the peat. Plants utilizing the C_4 mechanism have higher $\delta^{13}C$ values (~-14‰) than those utilizing the C_3 or CAM (~-27‰) (Table B-1). Using the $\delta^{13}C$ proxy can detect the presence of upland bunchgrasses such as *Spartina* and *Distichlis*.

Pollen can be classified to the taxonomic family level. *Chenopodiaceae (*now *Salicornioideae*) is representative of salt-tolerant *Salicornia*. *Cyperaceae* is representative of freshwater species including *Scirpus*. The ratio of *Chenopodiaceae* to the sum of *Chenopodiaceae* and *Cyperaceae* (Eq. 3) is a proxy of the percent relative abundance of salt-tolerant species (May, 1999).

$$\%ST = \frac{Chenopodiaceae}{Chenopodiaceae + Cyperaceae} \tag{3}$$

To establish chronologies for sediment archives, dates must be established for when material was deposited through the length of the sediment cores. Radiocarbon dating by Accelerator Mass Spectrometry (AMS) determines age by counting the ^{14}C content of plant seeds or carbonate shells calibrated against a northern hemisphere atmospheric carbon calibration curve (Malamud-Roam *et al.*, 2006). Radiocarbon dating is valid to about 40,000 years

No comments

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before present (BP)[3], making it an ideal method for establishing dates through the period of interest for the Bay and Delta. When archived proxies are correlated with the sediment core chronology, a timeline is established reconstructing past climate and landscape response.

Table B-1 – Carbon Isotope Ratios ($\delta^{13}C$) of Plant Species in the San Francisco Estuary
(adapted from Byrne et al. 2001)

Species	Common Name	Photosynthetic Pathway	δ13C (‰)
Distichlis spicata	Saltgrass	C4	-13.5
Spartina foliosa	California cordgrass	C4	-12.7
Cuscuta salina	Salt-marsh dodder	C3	-29.8
Frankenia grandifolia	Alkali heath	C3	-30.2
Grindelia stricta	Gumplant	C3	-26.4
Jaumea carnosa	Marsh jaumea	C3	-27.2
Juncus balticus	Baltic rush	C3	-28.4
Lepidium latifolium	Perennial pepperweed	C3	-26.6
Scirpus californicus	California bulrush	C3	-27.5
Scirpus maritimus	Alkali bulrush	C3	-25.5
Typha latifolia	Cattail	C3	-27.8
Salicornia virginica	Pickleweed	CAM	-27.2

A large number of paleoclimatic reconstructions exist for California and the western U.S., but a complete discussion is beyond the scope of this report. These reconstructions are reviewed by Malamud-Roam *et al.* (2006; 2007) and provide important context to events in the Bay and Delta by recording major non-localized events and larger regional climate shifts. Important examples include: Central Valley oaks, Sierra Nevada giant sequoias, and White Mountain Bristlecone pines used to establish precipitation and temperature from the location of the tree line and tree rings; Mono Lake sediments and submerged tree stump rings for precipitation; and Sacramento and San Joaquin River floodplain deposits for flood events. These studies establish a record of environmental conditions in the Bay and Delta from their formation to the present.

B.2. Major Regional Climatic Events

Formation of the Sacramento-San Joaquin Delta

The Holocene epoch began approximately 8000 BCE at the end of Pleistocene glaciations (Malamud-Roam *et al.*, 2007). In the early Holocene, a general warming and drying period in California accompanied high orbitally driven insolation until insolation reached current values at approximately 6000 BCE. In the Sierra Nevada, western slopes were in the early stages of ecological succession following the retreat of glaciers. The modern river floodplain systems were forming in the Central Valley. Parts of the Delta and Bay were river valleys

[3] Before Present (BP) is a time scale, with the year 1950 as the origin, used in many scientific disciplines. Thus, 100 BP refers to the calendar year 1850.

No comments

- n/a -

prior to approximately 8000 to 6000 BCE, when rapidly rising sea level entered the Golden Gate and formed the early Bay estuary (Atwater *et al.*, 1979). A fringe of tidal marshes retreated from a spreading Bay until approximately 4000 BCE when the rate of submergence slowed to 1 to 2 cm per year, allowing the formation of extensive Delta marshes over the next 2000 years (Atwater *et al.*, 1979). Sedimentation from upstream sources kept up with subsidence from increasing sea-level rise.

2000 – 1 BCE

After 2000 BCE, information from archives indicates climate in the Bay and Delta was cooler with greater freshwater inflows. The Sierra Nevada became more moist and cooler during a period ca. 4000-3500 BP (Malamud-Roam *et al.*, 2006).

1 BCE - Present

The cooler and wetter period ended approximately 1 BCE, replaced by more arid conditions (Malamud-Roam, 2007). Major climatic events, known from other parts of the world, are captured in the regional paleoclimatic reconstructions and help to calibrate or correlate these reconstructions to global events. Unusually dry conditions prevailed during the Medieval Warm Period (approximately 800-1300 CE). Wetter and cooler conditions existed during the Little Ice Age (approximately 1400-1700 CE). These climate variations are reflected in variations in the plant communities.

Droughts

Two extreme droughts occurred in the region from about 900 to 1150 CE and from 1200 to 1350 CE. Low freshwater inflows to the Delta occurred during periods 1230-1150, 1400-1300, 2700-2600, and 3700-3450 B.P.

Flood Events

Periods of increase moisture occurred from 800-730 BP and 650-300 BP. Massive flooding inundated the Central Valley in the winter of 1861 (Malamud-Roam *et al.*, 2006). High periods of inflow occurred during 1180-1100, 2400-2200, 3400-3100, and 5100-3800 BP.

Sampling for paleoclimatic reconstructions captures the modern era, enabling a comparison of current conditions with conditions over the past several thousand years. The erratic nature of precipitation in California observed over the past century have been normal and small compared to natural variations over the past millennia.

Reconstructed River Flow and Precipitation Records

Meko *et al.* (2001a) used tree-ring chronologies in statistical regression models to reconstruct time series of annual unimpaired Sacramento River flow for approximately the past 1,100 years (see Section 2.1). Similarly, Graumlich (1987) used tree ring data from the Pacific Northwest to reconstruct precipitation records for the period of 1675-1975 (Figure B-1). Compared to the average observed precipitation from 1899 to 1975, the reconstructed record has above-average precipitation during the latter half of the nineteenth century (1850-1900) (Figure B-1). These relatively wet conditions during the late 1800's and the severe dry

No comments

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conditions from the 1920's trough the 1930's in the reconstructed precipitation record are consistent with the annual unimpaired Sacramento River flow reconstruction from Meko *et al.* (2001) presented in Section 2.1.

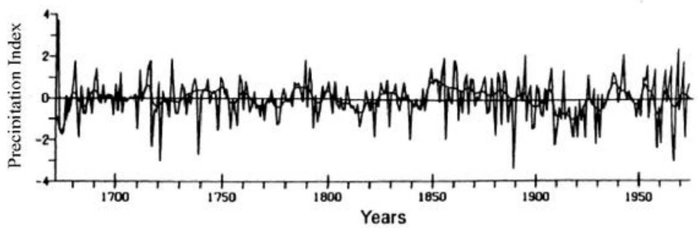

Figure B-1 – Reconstructed annual precipitation, 1675-1975
Data from Graumlich (1987). Precipitation index is presented in units of standard deviation from the 1899-1975 observed mean value.

Estimates of annual precipitation (Graumlich, 1987) and unimpaired runoff (Meko *et al.*, 2001a) from tree ring analysis are used in this study to provide hydrological context, indicating the relative hydrology (e.g. wet or dry) of a specific year and surrounding decade. The reconstructed hydrological data are not used to estimate salinity intrusion for two reasons. First, the seasonal distribution of hydrology is critical in determining salinity variability; two years with the same total annual flow could have significantly different salinity intrusion due to the timing of the flow (Knowles, 2000). Second, since 1850, anthropogenic modifications to the landscape and river flows alter the hydrodynamic response to freshwater flow, somewhat decoupling the unimpaired hydrology from the downstream response (i.e. salinity intrusion).

Malamud-Roam *et al.* (2005) and Goman *et al.* (2008) review paleoclimate as it relates to San Francisco Bay. Generally, they found that paleoclimatic studies showed that a wetter (and fresher) period existed from about 4000 BP to about 2000 BP. In the past 2,000 years, the climate has been cooling and becoming drier, with several extreme periods, including decades-long periods of very wet conditions and century-long periods of drought. As discussed in the next section, the century-long periods of drought are found in paleosalinity records in Suisun Bay and Rush Ranch in Suisun Marsh, but are much less evident in Browns Island, indicating a predominately freshwater marsh throughout the Delta. Citing Meko *et al.* (2001), they note that only one period had a six-year drought more severe than the 1928-1934 period: a seven-year drought ending in 984 CE. They also not the most extreme dry year was in 1580 CE, and state that it was almost certainly drier than 1977. On the whole, however, the last 600 years have been a generally wet period. This is reflected in the salinity records discussed in the next section.

No comments

- n/a -

B.3. Reconstructed Salinity in the Bay-Delta

Starratt (2001) reconstructed historical salinity variability at Rush Ranch, in the northwestern Suisun Marsh, over the last 3,000 years by examining diatoms from sediment cores. The taxa were classified according to their salinity preference: freshwater (< 2‰), freshwater and brackish water (0‰ to 30‰), brackish (2‰ to 30‰), brackish and marine (2‰ to > 30‰), and marine (> 30‰). Based on the composition of the diatom assemblages, Starrat identified centennial-scale salinity cycles (Table B-2).

Table B-2 – Salinity Intervals over the last 3,000 years at Rush Ranch
Salinity intervals determined from the diatom populations in a sediment core in northwestern Suisun Marsh.

Approximate Years	*Type of Interval* [a]
1850 CE – present	[not classified]
1250 CE – 1850 CE	fresh
250 CE – 1250 CE	brackish
500 BCE – 250 CE	fresh
1000 BCE – 500 BCE	brackish

[a] Classification according to Starratt (2001)

These results correspond well to other paleoclimatic reconstructions. The most recent broad-scale freshwater interval roughly corresponds to the Little Ice Age, and the most recent brackish interval corresponds to the Medieval Warm Period.

Starratt notes that the post-1850 interval indicates an increase in the percentage of diatoms that prefer brackish and marine salinities compared to the last freshwater interval, indicating an increase in salinity during the last 150 years, in comparison to the previous 600 years. During the post-1850 period, diatoms that prefer "marine" environments constitute as much as 50% of the total diatom population, a percentage that is at or above that of any other period. During the most recent years, "freshwater" assemblages constitute about 20% of the total population, a percentage that is only about 10% higher than the most recent *brackish* interval from 250 to 1250 CE.

Malamud-Roam *et al.* (2006) compared reconstructed salinity records for the past three thousand years from four locations (three tidal marsh locations and one location in the Bay) in the Bay-Delta region (Figure B-2(a)). Figure B-2(b) shows several periods with higher than average salinity (e.g., 1600-1300 and 1000-800 BP and 1900 CE to present) and several periods with lower than average salinity (e.g., 1300 to 1200 BP and 150 to 100 BP). These paleosalinity records are consistent with each other and with the paleoclimatic records of river flow and salinity presented in Section 2.

No comments

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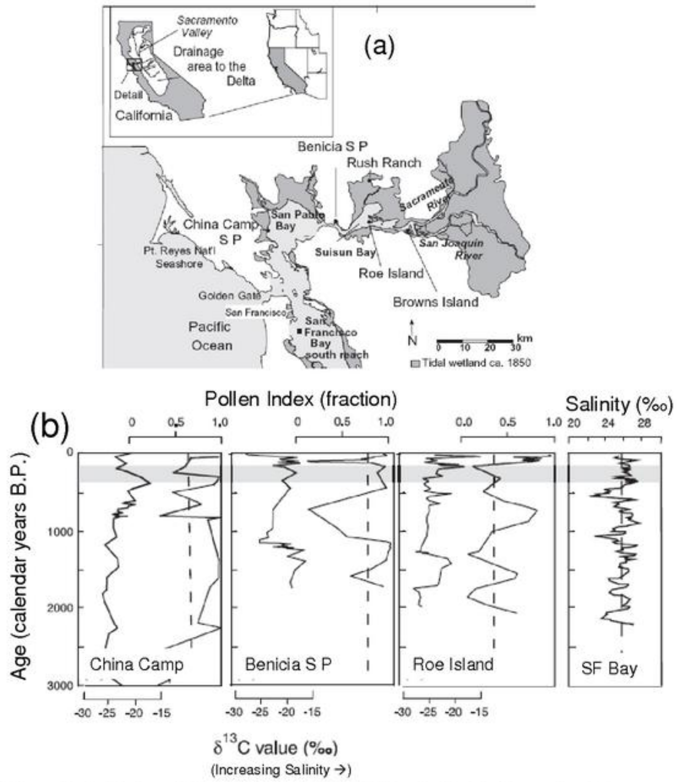

Figure B-2 – Paleosalinity records at selected sites in the San Francisco Estuary

(a) location of the three tidal marsh sites (China Camp, Benicia State Park and Roe Island) and one site in the Estuary (Oyster Point in San Francisco Bay) where sediment cores were obtained.
(b) time series for the pollen index (ranging from 0 to 1, higher values corresponding to higher salinity) and the δ13C values at the tidal marsh sites; salinity at Oyster Point, San Francisco Bay (inferred from δ13O values) is also shown. The broken line shows the estimated mean pollen index prior to European disturbance. (modified from Malamud-Roam and Ingram (2004) and Malamud-Roam et al. (2006))

No comments

- n/a -

No comments

- n/a -

Appendix C. Quantitative Hydrological Observations

Long-term records of river runoff are useful in understanding hydroclimatic variations. Section 3.1 discusses the long-term variations of the unimpaired Sacramento River runoff and unimpaired San Joaquin River runoff. The estimates of these variables from early 1900's to the present are available on the internet . Estimates prior to the early 1900's (late 1800's to early 1900's) were obtained from a 1923 California Department of Public Works report (DPW, 1923). Table C-1 through Table C-4 present estimates of Sacramento River runoff and San Joaquin River runoff for the period of 1872-2008, obtained from DPW (1923) and http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST.

The unimpaired Sacramento River runoff is the sum of the flows from the Sacramento River at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River at Smartville, and the American River inflow to Folsom Lake. The unimpaired San Joaquin River runoff is the sum of the flows from the Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Table C-1 – Annual unimpaired Sacramento River runoff for 1872-1905
Data source: DPW (1923

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
	Acre-feet (AF)				Million acre-feet (MAF)
1872	10,200,000	7,254,000	4,352,000	4,215,600	**26.0**
1873	4,780,000	3,347,000	1,638,400	1,862,200	**11.6**
1874	7,300,000	5,571,000	3,340,800	3,079,800	**19.3**
1875	4,390,000	2,747,000	1,561,600	1,391,600	**10.1**
1876	14,500,000	6,867,000	3,594,000	4,450,900	**29.4**
1877	9,870,000	2,437,000	1,292,800	1,289,200	**14.9**
1878	17,800,000	4,836,000	2,528,000	2,721,700	**27.9**
1879	8,380,000	5,513,000	2,796,800	3,304,900	**20.0**
1880	12,300,000	7,061,000	3,641,600	4,502,100	**27.5**
1881	15,400,000	5,610,000	3,104,000	3,540,300	**27.7**
1882	8,000,000	4,797,000	2,150,400	3,264,000	**18.2**
1883	6,670,000	3,714,000	1,804,800	2,169,200	**14.4**
1884	11,400,000	6,190,000	3,104,000	4,103,000	**24.8**
1885	6,460,000	3,482,000	2,304,000	1,780,400	**14.0**
1886	14,400,000	6,384,000	3,174,400	3,918,900	**27.9**
1887	6,670,000	2,611,000	1,561,600	1,862,200	**12.7**
1888	5,430,000	2,669,000	998,400	1,575,700	**10.7**
1889	10,600,000	5,126,000	1,612,800	1,903,200	**19.2**
1890	22,700,000	12,090,000	6,176,000	7,725,200	**48.7**

No comments

- n/a -

Water Year	Sacramento River @ Bend Bridge	Feather River @ Lake Oroville	Yuba River @ Smartville	American River @ Folsom Lake	Sacramento River Runoff
1891	6,460,000	3,482,000	1,747,200	1,944,100	**13.6**
1892	7,250,000	5,416,000	1,945,600	2,568,200	**17.2**
1893	12,400,000	7,177,000	3,488,000	4,399,800	**27.5**
1894	8,640,000	4,410,000	2,432,000	3,304,900	**18.8**
1895	12,300,000	7,177,000	4,160,000	4,737,400	**28.4**
1896	11,343,200	7,738,000	3,641,600	3,857,500	**26.6**
1897	10,391,400	5,610,000	3,040,000	3,632,400	**22.7**
1898	5,135,800	2,805,000	1,184,000	1,186,900	**10.3**
1899	5,977,400	3,288,000	1,984,000	2,362,600	**13.6**
1900	8,712,500	6,500,000	2,956,800	3,683,500	**21.9**
1901	9,020,900	6,229,000	2,854,400	3,714,200	**21.8**
1902	11,380,600	4,468,000	2,432,000	3,079,800	**21.4**
1903	9,941,800	4,483,500	2,368,000	3,038,900	**19.8**
1904	16,095,800	9,377,000	4,101,800	5,249,000	**34.8**
1905	10,775,200	4,529,200	2,403,500	2,050,000	**19.8**

No comments

- n/a -

Table C-2 – Annual unimpaired Sacramento River runoff for 1906-2009

Data Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST

Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)	Water Year	Sacramento River Runoff (MAF)
1906	26.7	1936	17.4	1966	13.0	1996	22.3
1907	33.7	1937	13.3	1967	24.1	1997	25.4
1908	14.8	1938	31.8	1968	13.6	1998	31.4
1909	30.7	1939	8.2	1969	27.0	1999	21.2
1910	20.1	1940	22.4	1970	24.1	2000	18.9
1911	26.4	1941	27.1	1971	22.6	2001	9.8
1912	11.4	1942	25.2	1972	13.4	2002	14.6
1913	12.9	1943	21.1	1973	20.1	2003	19.3
1914	27.8	1944	10.4	1974	32.5	2004	16.0
1915	23.9	1945	15.1	1975	19.2	2005	18.6
1916	24.1	1946	17.6	1976	8.2	2006	32.1
1917	17.3	1947	10.4	1977	5.1	2007	10.3
1918	11.0	1948	15.8	1978	23.9	2008	10.3
1919	15.7	1949	12.0	1979	12.4	2009	12.9
1920	9.2	1950	14.4	1980	22.3		
1921	23.8	1951	23.0	1981	11.1		
1922	18.0	1952	28.6	1982	33.4		
1923	13.2	1953	20.1	1983	37.7		
1924	5.7	1954	17.4	1984	22.4		
1925	16.0	1955	11.0	1985	11.0		
1926	11.8	1956	29.9	1986	25.8		
1927	23.8	1957	14.9	1987	9.3		
1928	16.8	1958	29.7	1988	9.2		
1929	8.4	1959	12.1	1989	14.8		
1930	13.5	1960	13.1	1990	9.3		
1931	6.1	1961	12.0	1991	8.4		
1932	13.1	1962	15.1	1992	8.9		
1933	8.9	1963	23.0	1993	22.2		
1934	8.6	1964	10.9	1994	7.8		
1935	16.6	1965	25.6	1995	34.6		

No comments

- n/a -

Table C-3 – Annual unimpaired San Joaquin River runoff for 1872-1900
Data source: DPW (1923)

Water Year	Stanislaus River @ New Melones Lake	Tuolumne River @ New Don Pedro Reservoir	Merced River @ Lake McClure	San Joaquin River @ Millerton Lake	San Joaquin River Runoff
	units of acre-feet (AF)				units of million acre-feet (MAF)
1872	1,860,000	2,624,000	1,511,000	2,627,000	**8.6**
1873	959,000	1,543,000	769,000	1,122,000	**4.4**
1874	970,000	1,576,000	791,000	1,862,000	**5.2**
1875	482,000	982,000	439,000	887,000	**2.8**
1876	2,930,000	4,059,000	2,384,000	2,862,000	**12.2**
1877	408,900	561,000	220,000	809,000	**2.0**
1878	1,570,000	2,286,000	1,274,000	2,218,000	**7.3**
1879	823,000	1,353,000	659,000	470,000	**3.3**
1880	1,390,000	2,071,000	1,132,000	3,349,000	**7.9**
1881	970,000	1,576,000	791,000	2,740,000	**6.1**
1882	944,000	1,526,000	764,000	1,000,000	**4.2**
1883	1,020,000	1,600,000	813,000	1,392,000	**4.8**
1884	2,250,000	3,152,000	1,840,000	5,732,000	**13.0**
1885	582,000	1,097,000	505,000	1,218,000	**3.4**
1886	2,070,000	2,929,000	1,692,000	5,211,000	**11.9**
1887	619,000	1,139,000	538,000	1,479,000	**3.8**
1888	540,000	1,048,000	478,000	957,000	**3.0**
1889	718,000	1,262,000	599,000	1,574,000	**4.2**
1890	3,580,000	5,099,000	2,955,000	4,349,000	**16.0**
1891	959,000	1,543,000	769,000	1,227,000	**4.5**
1892	1,050,000	1,650,000	846,000	1,931,000	**5.5**
1893	2,150,000	3,036,000	1,758,000	1,914,000	**8.9**
1894	1,860,000	2,624,000	1,511,000	1,331,000	**7.3**
1895	2,700,000	3,795,000	2,236,000	2,786,700	**11.5**
1896	1,380,000	1,588,100	1,110,000	1,985,700	**6.1**
1897	1,920,000	2,437100	1,566,000	2,219,700	**8.1**
1898	498,000	960,500	450,000	922,300	**2.8**
1899	1,030,000	1,334,700	824,000	1,269,500	**4.5**
1900	1,350,000	1,628,100	1,099,000	1,343,000	**5.4**

No comments

- n/a -

Table C-4 – Annual unimpaired San Joaquin River runoff for 1901-2009

Data Source: *http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST*

Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)	Water Year	San Joaquin River Runoff (MAF)
1901	9.4	1931	1.7	1961	2.1	1991	3.2
1902	5.1	1932	6.6	1962	5.6	1992	2.6
1903	5.7	1933	3.3	1963	6.2	1993	8.4
1904	7.6	1934	2.3	1964	3.1	1994	2.5
1905	5.3	1935	6.4	1965	8.1	1995	12.3
1906	12.4	1936	6.5	1966	4.0	1996	7.2
1907	11.8	1937	6.5	1967	10.0	1997	9.5
1908	3.3	1938	11.2	1968	2.9	1998	10.4
1909	9.0	1939	2.9	1969	12.3	1999	5.9
1910	6.6	1940	6.6	1970	5.6	2000	5.9
1911	11.5	1941	7.9	1971	4.9	2001	3.2
1912	3.2	1942	7.4	1972	3.6	2002	4.1
1913	3.0	1943	7.3	1973	6.5	2003	4.9
1914	8.7	1944	3.9	1974	7.1	2004	3.8
1915	6.4	1945	6.6	1975	6.2	2005	9.2
1916	8.4	1946	5.7	1976	2.0	2006	10.4
1917	6.7	1947	3.4	1977	1.1	2007	2.5
1918	4.6	1948	4.2	1978	9.7	2008	3.5
1919	4.1	1949	3.8	1979	6.0	2009	5.0
1920	4.1	1950	4.7	1980	9.5		
1921	5.9	1951	7.3	1981	3.2		
1922	7.7	1952	9.3	1982	11.4		
1923	5.5	1953	4.4	1983	15.0		
1924	1.5	1954	4.3	1984	7.1		
1925	5.5	1955	3.5	1985	3.6		
1926	3.5	1956	9.7	1986	9.5		
1927	6.5	1957	4.3	1987	2.1		
1928	4.4	1958	8.4	1988	2.5		
1929	2.8	1959	3.0	1989	3.6		
1930	3.3	1960	3.0	1990	2.5		

No comments

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No comments

- n/a -

Appendix D. Instrumental Observations of Salinity

In Section 3, historical variations in the net quantity of water flowing from the Delta to the Suisun Bay (called net Delta outflow or NDO) and salinity in the western Delta were discussed using available observations and a suite of commonly used modeling tools. This section presents additional information on the historical variations of NDO and salinity in the western Delta and Suisun Bay discussed in Section 3.

D.1. Introduction

D.1.1. Salinity Units

Salinity is specified in this report either as electrical conductivity (EC, in units of microSiemens per centimeter, or µS/cm) or as a concentration of chloride in water (in units of milligrams of chloride per liter of water, or mg/L). Conversion between EC and chloride concentration is accomplished using site-specific empirical relationships developed by Kamyar Guivetchi (DWR, 1986). Table D-1 presents a sample of typical EC concentrations and their approximate equivalent chloride concentrations.

Table D-1 – Typical electrical conductivity (EC) and equivalent chloride concentration

Electrical Conductivity (µS/cm)	Chloride (mg/L)
350	50
525	100
1,050	250
1,900	500
2,640	700
3,600	1,000

Qualitative terms such as "fresh" and "brackish" are often used to describe relative salinity. The quantitative thresholds of average chloride concentration that distinguish fresh water from brackish water and the averaging time period vary among studies. For instance, chloride concentrations of 1,000 mg/L, 700 mg/L, and 50 mg/L have been used by different studies (Table D-2).

D.1.2. Temporal and Spatial Variability of Salinity

The main variability in salinity along the length of the Bay-Delta system is due to the gradient from saline Pacific Ocean water (EC of approximately 50,000 µS/cm) to fresh water of the Central Valley rivers (EC of approximately 100 µS/cm). However, the salinity in the Bay-Delta varies both in space and time. It is important to clarify which time scales and measurement locations are being used when comparing and discussing salinity trends.

No comments

- n/a -

Table D-2 – Metrics used to distinguish between "fresh" and "brackish" water

Description	Sample timing or averaging	Salinity Value	
		Chloride (mg/L)	EC (µS/cm)
Isohalines in Delta Atlas (DWR, 1995)	Annual maximum of the daily maximum	1,000 mg/L	3,700 µS/cm
X2 position (Jassby *et al*., 1995)	Daily average (or a 14-day average)	700 mg/L	2,640 µS/cm
Barge travel by C&H[4]	Monthly average of the daily maximum	50 mg/L	350 µS/cm

Salinity in the western Delta is strongly influenced by tides. The hourly or daily variability of salinity can be much larger than the seasonal or annual variability. For instance, during the fall of 1999 (following a relatively wet year[5]), hourly EC in the San Joaquin River at Antioch varied by about 6,000 µS/cm (from about 3,000 µS/cm to 9,000 µS/cm) while the daily-averaged EC for all of 1999 ranged from about 100 µS/cm to 6,000 µS/cm (Figure D-1).

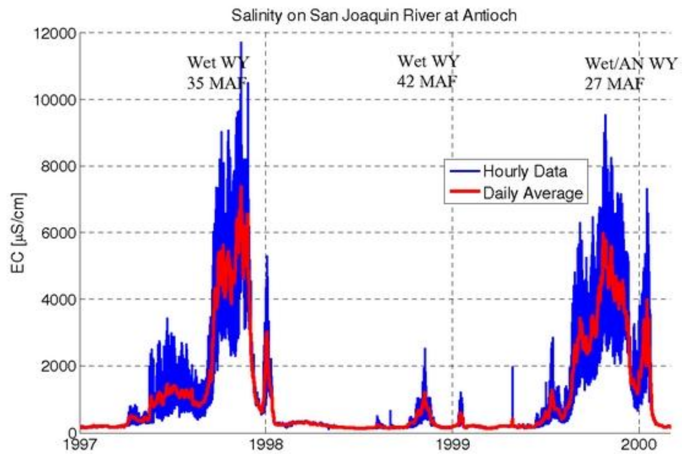

Figure D-1 – Hourly and daily salinity variability in the San Joaquin River at Antioch
Total annual unimpaired Sacramento River flow and water year type is indicated for each water year.
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

[4] The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1908 (DPW, 1931).
[5] Water year 1999 was classified as wet using the Sacramento Valley 40-30-30 index and above-normal using the San Joaquin Valley 60-20-20 index; indices are defined in D-1641.

No comments

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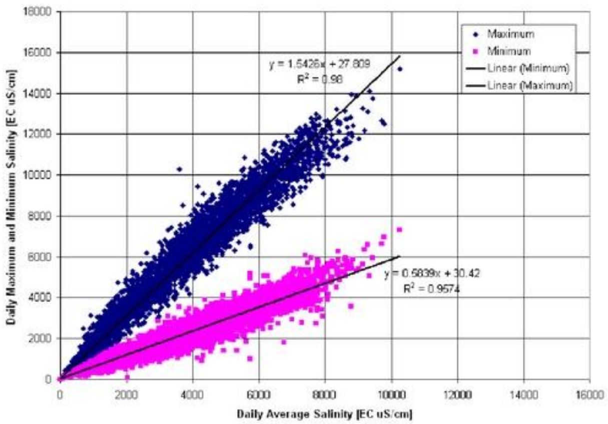


Figure D-2 – Tidal Variability in Salinity at Antioch (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

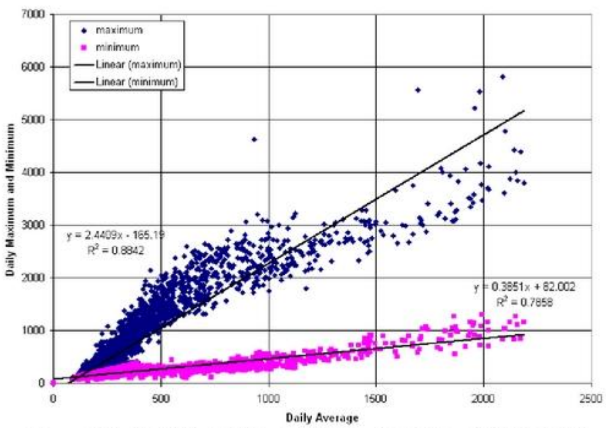


Figure D-3 – Tidal Variability in Salinity at Rio Vista (1967 to 1992)
Data Source: IEP Data Vaults (http://www.iep.ca.gov/dss/)

No comments

- n/a -

The high tide maximum, low tide minimum, and daily-averaged salinity at a given location are very different. As shown in Figure D-2, the daily maximum salinity in the San Joaquin River at Antioch can be double the daily-averaged salinity. Because of the large tidal variability in salinity, any comparisons of salinity observations should be at the same phase of the tide, or at least take into account tidal variability.

Similarly, as shown in Figure D-3, the daily maximum salinity in the Sacramento River at Rio Vista can be 170-400% of the daily average salinity. The daily minimum at Rio Vista may be 10-65% of the daily average.

D.2. Variations in the Spatial Salinity Distribution

Observations examined in this section and Section 3.3 include records from the early 1900's from the California & Hawaiian Sugar Refining Corporation in Crockett (C&H) and the long-term monitoring data from the Interagency Ecological Program (IEP). Estimates of salinity at specific locations of interest were obtained from DWR's DSM2 model and Contra Costa Water District's salinity-outflow model (also known as the G-model) (Denton, 1993). Estimates of salinity intrusion were obtained using the K-M equation (Kimmerer and Monismith, 1992).

D.2.1. Distance to Freshwater from Crockett

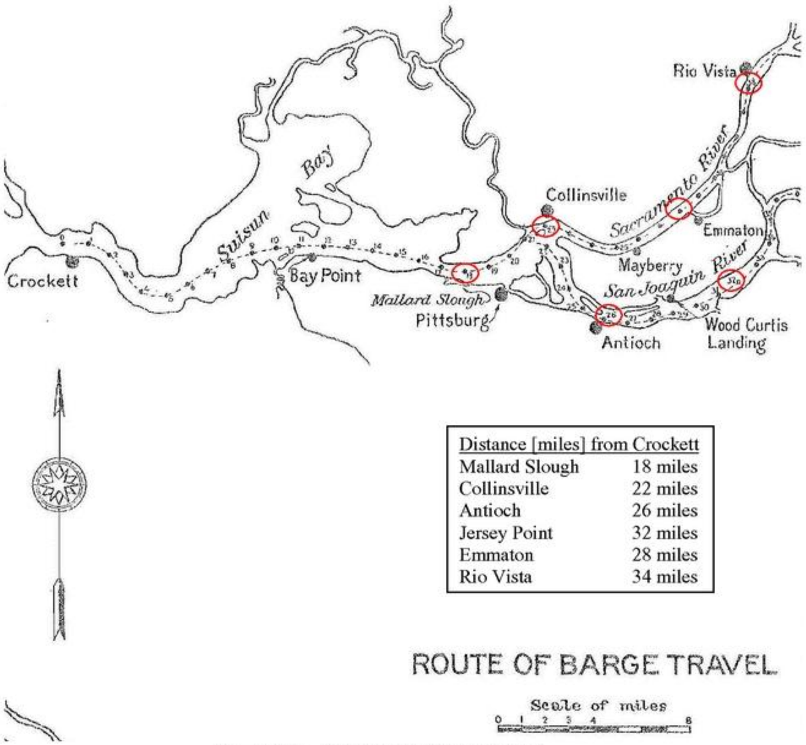
The California & Hawaiian Sugar Refining Corporation in Crockett (C&H) obtained its freshwater supply from barges traveling up the Sacramento and San Joaquin Rivers, generally twice a day beginning in 1905 through 1929 or later (DPW, 1931). The salinity information recorded by C&H is the most detailed salinity record available prior to the intensive salinity monitoring by the State of California, which started in 1920. This section presents a comparison of the salinity observations of C&H with recent monitoring data and modeling results to determine how the managed salinity regime of the late 20th Century compares to the salinity regime of the early 1900's.

Data Sources and Methods

C&H data: C&H operations required water with less than 50 mg/L chloride concentration. According to DPW (1931), the C&H barges typically traveled up the river on flood tide and returned downstream on ebb tide. Since the maximum daily salinity for a given location in the river channel typically occurs about one to two hours after high slack tide, the distance traveled by the C&H barges represents approximately the daily maximum distance to 50 mg/L water from Crockett. The monthly minimum, average, and maximum distance traveled by C&H barges are shown in Figure D-4 and Figure D-5. For the following analysis, monthly averages of the C&H daily maximum distances were extracted from Figure D-5 for the period of 1908-1918 (after 1917, extensive salinity intrusion was reported and agricultural diversions reportedly started affecting flows into the Delta).

No comments

- n/a -



Distance [miles] from Crockett	
Mallard Slough	18 miles
Collinsville	22 miles
Antioch	26 miles
Jersey Point	32 miles
Emmaton	28 miles
Rio Vista	34 miles

Figure D-4 – C&H Barge Travel Routes

Map adapted from DPW (1931). Red circles indicate locations of landmarks, with distance from Crockett listed in the inset box.

No comments

- n/a -

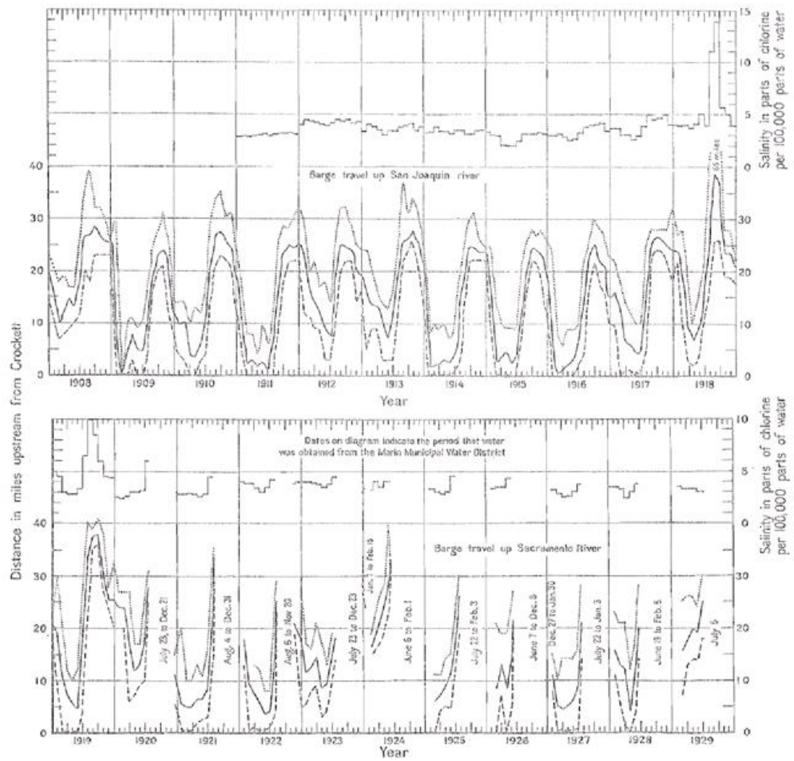


Figure D-5 – C&H Barge Travel and Quality of Water obtained

C&H barge travel up the San Joaquin River (1908 through 1918, top panel) and Sacramento River (1919 through 1929, bottom panel). The lower three lines on each panel (reference to the left axes) indicate the monthly minimum (dashed line), monthly maximum (dotted line), and monthly average (solid line) distance traveled by C&H barges to obtain their fresh water supply. The uppermost solid line on each panel (reference to the right axes) indicates the average monthly salinity of the water obtained by the barges. Figure adapted from DPW (1931)

From 1908 through 1917, C&H was able to obtain water with less than 50 mg/L chlorides within 30 miles of Crockett on average (below Jersey Point on the San Joaquin River). In 1918, the salinity of the water obtained by C&H barges had increased due to a combination of a lack of precipitation and upstream diversions (especially for newly introduced rice cultivation) (DPW, 1931). During August and September 1918, salinity exceeded 60 mg/L chloride, and the C&H barges traveled farther upstream than any time previously recorded.

No comments

- n/a -

In 1919, a wetter year than 1918, salinity was high for an even longer period of time, most likely due to increased upstream diversions for irrigation. Salinity exceeded 60 mg/L chloride during July, August, and September. Beginning in 1920, C&H abandoned the Sacramento and San Joaquin Rivers during the summer and fall seasons, replacing the water supply with a contract from Marin County. However, even during the driest years of the 1920's, C&H obtained water with less than 50 mg/L chloride below the confluence of the Sacramento and San Joaquin Rivers during a portion of every year.

Salinity observations from the Interagency Ecological Program (IEP): Long-term monitoring of electrical conductivity (EC) at multiple stations within the Bay and Delta began around 1964. Publicly-available daily-averaged data were obtained for this analysis from the Interagency Ecological Program (IEP) data vaults (Table D-3).

Table D-3 – Overview of long-term salinity observation records from IEP
(see http://www.iep.ca.gov/dss/)

Location	*Station*	*Source*	*Data*
Selby	RSAC045	USGS-BAY	Historical
Martinez	RSAC054	CDEC	Real-time
Benicia Bridge	RSAC056	USBR-CVO	Historical
Port Chicago	RSAC064	USBR-CVO	Historical
Mallard	RSAC075	CDEC	Real-time
Pittsburg	RSAC077	USBR-CVO	Historical
Collinsville	RSAC081	USBR-CVO	Historical
Emmaton	RSAC092	USBR-CVO	Historical
Rio Vista	RSAC101	USBR-CVO	Historical
		DWR-ESO-D1485C	Historical
Georgiana Slough	RSAC123	DWR-CD-SURFWATER	Historical
Greens Landing	RSAC139	USBR-CVO	Historical
Antioch	RSAN008	USBR-CVO	Historical
Jersey Pont	RSAN018	USBR-CVO	Historical
Bradford Point	RSAN024	USBR-CVO	Historical
San Andreas Landing	RSAN032	USBR-CVO	Historical

Delta Simulation Model (DSM2) Historical Simulation: The DSM2 historical simulation (1989-2006) was used to provide estimates of water quality to complement the limited field data from IEP. Because DSM2 has a very detailed spatial computational network covering the Delta and Suisun Bay, DSM2 can output much more detailed spatial and temporal salinity information than just the water quality at the IEP monitoring stations. DSM2 results include the daily-averaged EC at each model node along the lower Sacramento and San Joaquin Rivers. The location of the 350 μS/cm EC isohaline (corresponding to 50 mg/L chloride) was identified from the DSM2 results and compared with the equivalent C&H and IEP data.

No comments

- n/a -

Analysis time frame: The first decade of C&H barge travel (1908-1917) was a relatively wet period compared to the entire period of record (1906-2006) (Figure D-6). To compare conditions under similar hydrological conditions, specific recent decades (Figure D-6(a)) and select recent years (Figure D-6(b)) were selected that have comparable or slightly wetter hydrology than the C&H years. The periods 1966-1975 and 1995-2004 have similar annual unimpaired Sacramento River flow to the C&H data period (1908-1917) (see Figure D-6(a)). In addition, two wet years (1911 and 1916) and two dry years (1913 and 1918) selected from the C&H time period were compared with two wet years (1969 and 1998) and two dry years (1968 and 2002) from the IEP record.

Limitations of the analysis: The C&H data approximately represent the maximum daily salinity at a given location, whereas recent conditions (IEP or DSM2 data) are represented by the daily-averaged salinity. The estimates of the distance that must be traveled to reach fresh water under current conditions are, therefore, underestimated.

In addition, the C&H barges traveled up the San Joaquin River from 1908 through 1917, yet the equivalent travel distance for C&H barges under current conditions are estimated for the Sacramento River, and not the San Joaquin River. Under present-day conditions, the upstream distance to fresh water on the San Joaquin River is greater than for the Sacramento River, so this approach will also serve to underestimate the actual distance that C&H barges would have to travel under present-day conditions.

No comments

- n/a -

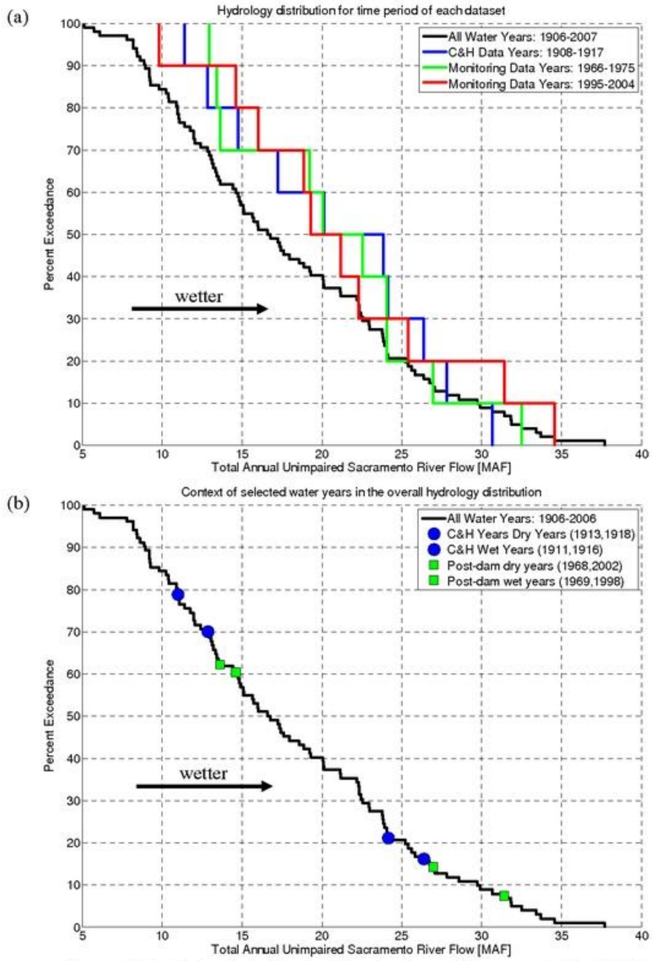


Figure D-6 – Hydrologic Context for Analysis of Distance to Fresh Water

(a) Hydrology distribution for water years 1906 to 2007, and select decades.

(b) Hydrology distribution for water years 1906 to 2007, with select water years shown for context.

No comments

- n/a -

Results and Discussion

Selected Wet Years

As shown in Figure D-7, the salinity patterns during the two selected C&H-era wet years, 1911 and 1916, are similar to each other. During these wet years, the location of 50 mg/L chloride water is west of Martinez for about 4-5 months (late February to early August in 1911 and from early February to late June in 1916). In contrast, during recent wet years 1969 and 1998, water with 50 mg/L chlorides or less was west of Martinez for only about 6 weeks in February and March. This comparison shows that in 1969 and 1998 the western Delta was saltier in the fall and spring than it was in 1911 and 1916, and salinity intrusion occurred much earlier in 1969 and 1998.

If barges were still traveling up the Sacramento River today to find fresh water, they would have to travel farther during the fall, spring, and summer than the C&H barges traveled during similar wet years. In 1916, fresh water retreated upstream about one month earlier than in 1911, possibly influenced by the increasing upstream diversions during 1911-1916 (see Figure 1-3). In recent years with even greater unimpaired runoff, fresh water retreats two to three months earlier than in 1916. Additionally, fresh water reaches Martinez for a much shorter period of time, about less than one month in recent years compared to four and five months during 1916 and 1911, respectively.

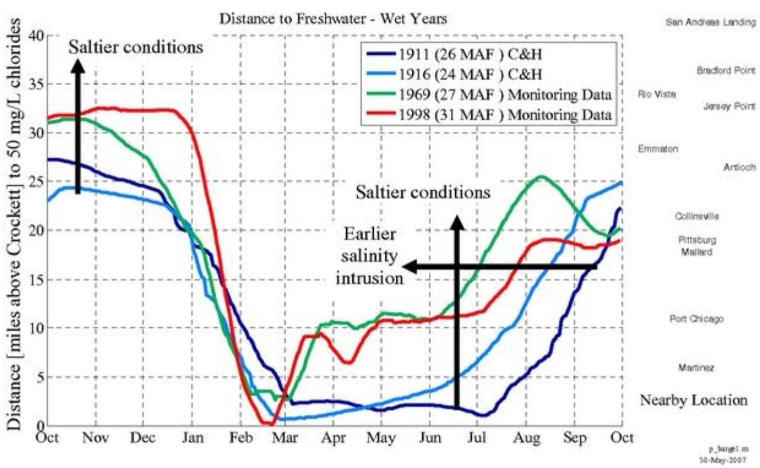


Figure D-7 – Distance to Fresh Water in Select Wet Years

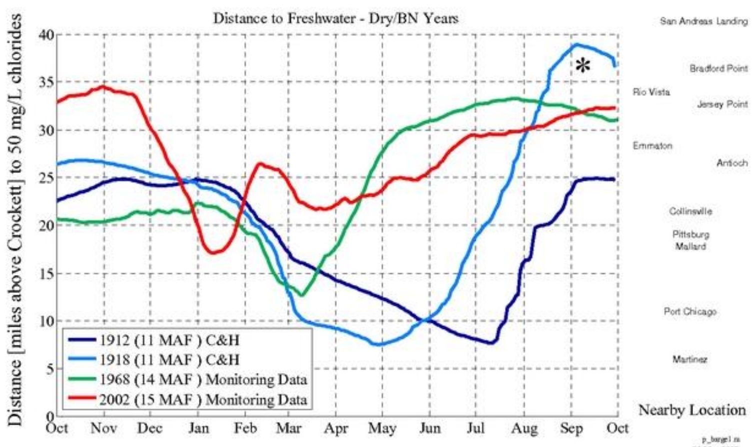
No comments

- n/a -

Selected Dry Years

Figure D-8 shows that the most visible difference between the distance to fresh water in dry years of the early 1900's and more recent dry years is the substantial increase in distance to fresh water, particularly from April through June. This indicates the spring was much fresher during the dry years of the early 1900's, before large upstream reservoirs were built to capture the spring runoff. In dry and below-normal water years under today's conditions, barges would have to travel farther during spring, summer and fall than they traveled in the early 20th Century.

The C&H barge travel distance in the dry years of 1913 and 1918 are quite different, especially the additional 10 miles of distance to fresh water traveled in August and September of 1918. C&H recorded relatively high salinity (greater than 110 mg/L chlorides) above Bradford Point on the San Joaquin in 1918, which is greater than observed salinity on the Sacramento River near Rio Vista in similar water years. This may be partially explained by the development of the rice cultivation industry around 1912 (DPW, 1931) and increased upstream diversions when seasonal river flows were already low.



* During August and September 1918, average water quality obtained by C&H exceeded 110 mg/L chlorides

Figure D-8 – Distance to Fresh water in Select Dry or Below Normal Years

Figure D-9 shows the exceedance probabilities for distance traveled up the Sacramento River for different salinity levels. During 1908-1917, on a monthly-averaged basis, C&H barges had to travel above the confluence of the Sacramento and San Joaquin Rivers (approximately 22 miles above Crockett) about 26% of this time period to reach water with salinity less than

No comments

- n/a -

350 μS/cm EC (about 50 mg/L chlorides). In contrast, from 1995-2006, DSM2 simulations suggest that barges would have to travel above the confluence approximately 56% of the time to reach water with salinity of 350 μS/cm EC.

The location of the 50 mg/L chloride isohaline during 1908-1917 approximately corresponds to the location of X2 (2,640 μS/cm EC, or 700 mg/L chlorides) during 1995-2006 (Figure D-9). This is equivalent to more than a 7-fold increase in salinity from the early 1900's to the present day.

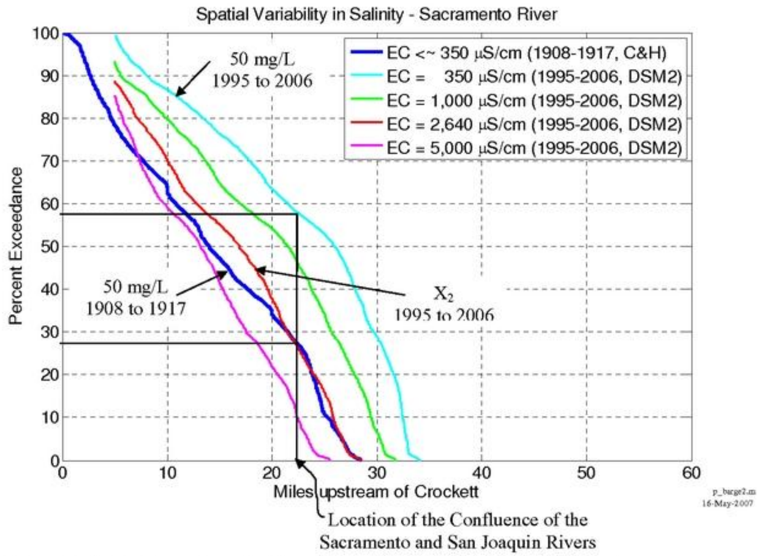


Figure D-9 – Distance along the Sacramento River to Specific Salinity Values

No comments

- n/a -

D.2.2. Maximum Annual Salinity Intrusion Before and After Large-scale Reservoir Construction

Figure D-10 shows maximum salinity intrusion during 1921-1943 (pre-CVP period), prior to the completion of the Shasta Dam of the Central Valley Project in 1945. Salinity intrusion is presented in terms of contours of 1,000 mg/L chlorides. Figure D-11 shows the maximum salinity intrusion during the post-CVP period of 1944-1990. These figures indicate the pre-CVP period experienced greater salinity intrusion than the post-CVP period, with seawater intruding farther into the Delta during 6 of the 24 pre-CVP years (1920, 1924, 1926, 1931, 1934, and 1939) than in any of the 47 years in the post-CVP period (1944-1990).

The extreme salinity intrusion during the pre-CVP period was due, in part, to relatively low runoff during these years. Meko *et al.* (2001a) determined that the period from 1917 through 1936 was the driest 20-year period in the past 400 years; this long-term drought encompassed 16 of the 24 years in the pre-CVP period. In addition, estimates of unimpaired runoff from the Sacramento River (obtained from http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST) indicate that the Sacramento River had 6 critical water years during the 24-year period of 1920-1943, whereas, the Sacramento River had only 4 critical water years during the 47-year period of 1944-1990.

Figure D-12 shows that the peak salinity intrusion during the pre-CVP period occurred between mid-August and mid-September, while peak salinity intrusion during the first portion of the the post-CVP period (1944-1960) occurred between late-July and late-August. Salinity intrusion during the pre-CVP period was not only affected by relatively low runoff, but also by extensive upstream diversions (DPW, 1931).

The salinity investigations of the pre-CVP era found that the extreme salinity intrusion was larger than any previous intrusions known to local residents and concluded the intrusion was due, in part, to the extensive upstream diversions. As observed in DPW (1931):

> "Under conditions of natural stream flow before upstream irrigation and storage developments occurred, the extent of saline invasion and the degree of salinity reached was much smaller than during the last ten to fifteen years." (DPW, 1931, page 15)
>
> "Beginning in 1917, there has been an almost unbroken succession of subnormal years of precipitation and stream flow which, in combination with increased irrigation and storage diversions from the upper Sacramento and San Joaquin River systems, has resulted in a degree and extent of saline invasion greater than has occurred ever before as far as known." (DPW, 1931, page 15)
>
> "The abnormal degree and extent of saline invasion into the delta during recent years since 1917 have been due chiefly to: first, subnormal precipitation and run-off with a subnormal amount of stream flow naturally available to the delta, and second, increased upstream diversions

No comments

- n/a -

for irrigation and storage on the Sacramento and San Joaquin River systems, reducing the inflow naturally available to the delta. It is probable that the degree of salinity in the lower channels of the delta and the extent of saline invasion above the confluence of the Sacramento and San Joaquin rivers have been about doubled by reason of the second factor." (DPW, 1931, page 42)

Conclusions from DPW (1931) and similar investigations have been corroborated by paleosalinty studies (see Section 2.3), which indicate that Browns Island in the western Delta was a freshwater marsh for approximately 2,500 years until salinity intruded in the early 20^{th} Century.

No comments

- n/a -

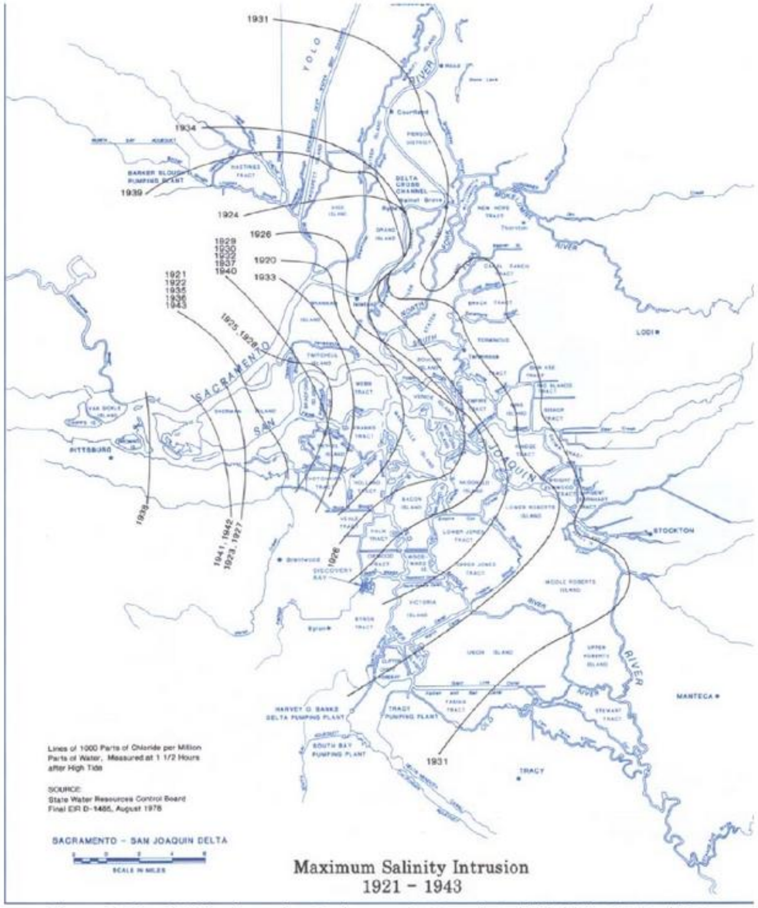


Figure D-10 – Salinity intrusion during pre-CVP period, 1921-1943 (DWR, 1995)

No comments

- n/a -

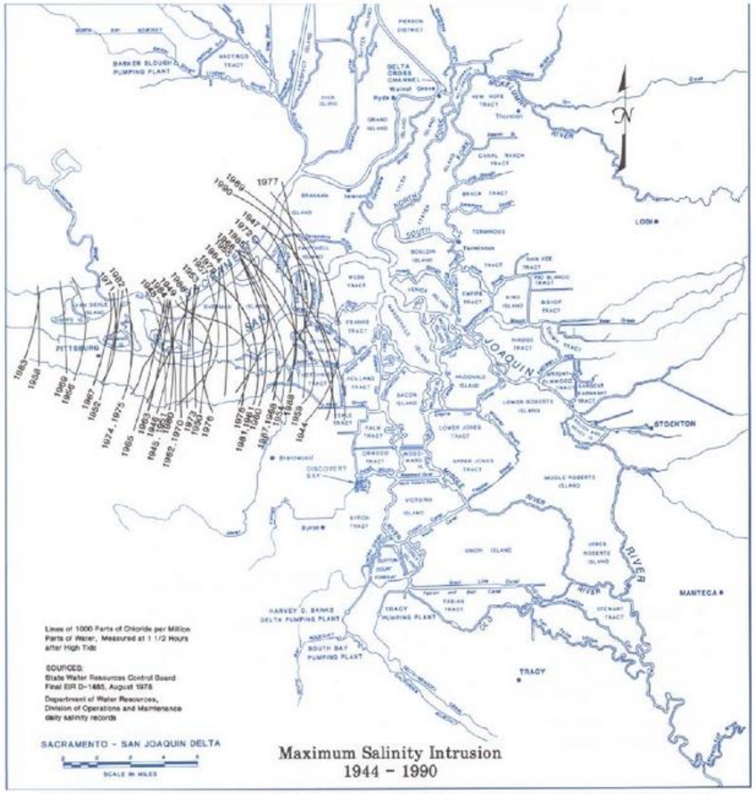


Figure D-11 – Salinity intrusion during post-CVP period, 1944-1990 (DWR, 1995)

No comments

- n/a -

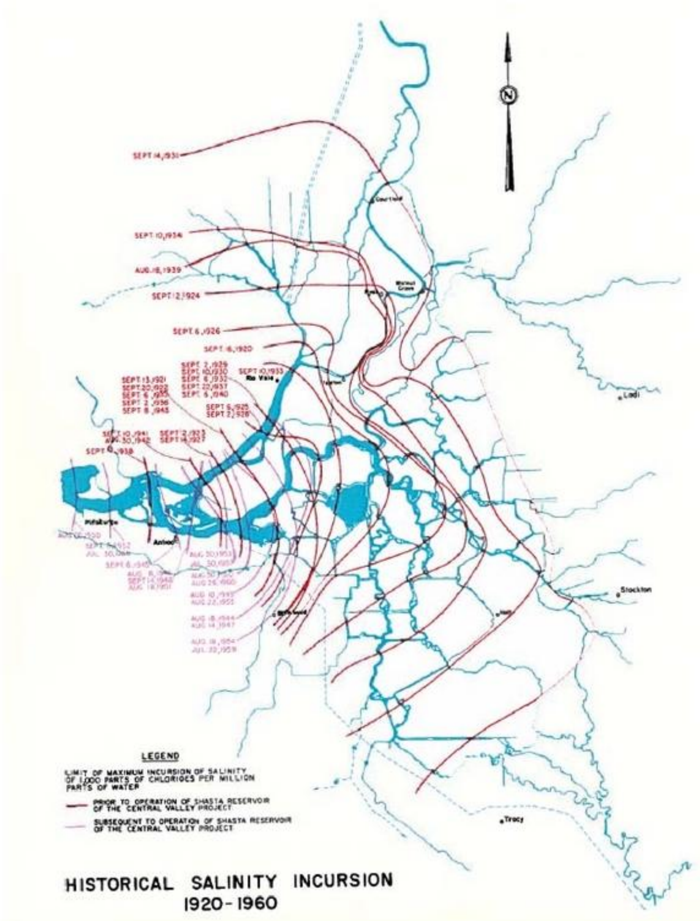


Figure D-12 – Salinity intrusion during 1920-1960 (DWR, 1960)

No comments

- n/a -

Figure D-13 illustrates the maximum annual salinity intrusion for comparable dry years[6]. Water year 1913 experienced the least extent of intrusion, most likely because upstream diversions were significantly less than in later years. Water years 1926 and 1932 were subject to extensive upstream agricultural diversions, while water years 1979 and 2002 had the benefit of the CVP and SWP to provide "salinity control". The CVP and SWP operations now regulate the amount of freshwater flowing through the Delta in order to prevent extreme salinity intrusions such as those observed during the 1920's and 1930's.

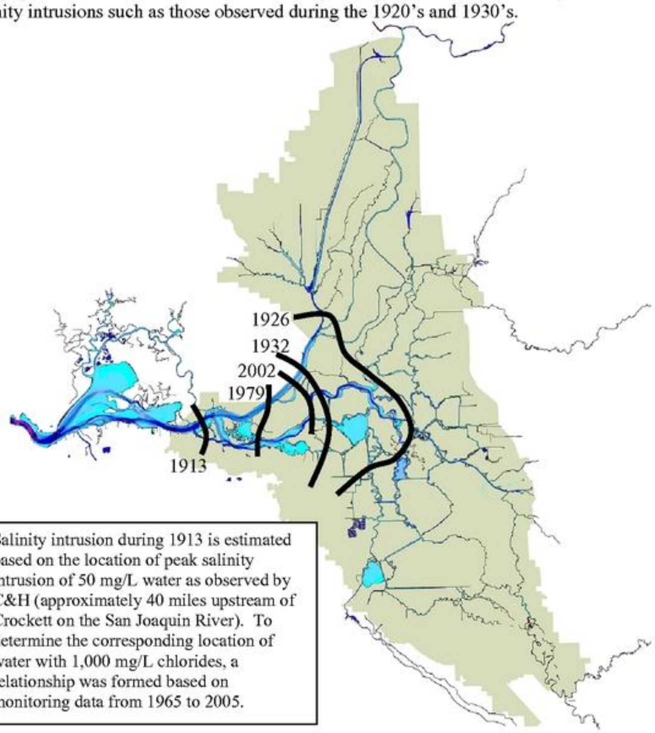


Figure D-13 – Annual Maximum Salinity Intrusion for relatively dry years

Salinity intrusion for <u>relatively dry water years</u> with similar total annual unimpaired runoff, using 1,000 mg/L chloride concentration to distinguish the extent of intrusion.

---

[6] Hydrological metrics from http://cdec.water.ca.gov/cgi-progs/iodir/wsihist for comparison: total unimpaired Sacramento River and San Joaquin River flow for water years 1913, 1926, 1932, 1979, and 2002 was 15.9 MAF, 15.3 MAF, 19.8 MAF, 18.4 MAF, and 18.7 MAF, respectively; Sacramento River water year type index for water years 1913, 1926, 1932, 1979, and 2002 was 6.24, 5.75, 5.48, 6.67, and 6.35, respectively; and San Joaquin River water year type index for water years 1913, 1979, and 2002 was 2.00, 2.30, 3.41, 3.67, and 2.34, respectively.

No comments

- n/a -

D.3. *Temporal Variability of Salinity in the Western Delta*

D.3.1. Seasonal Salinity at Collinsville

Collinsville, near the confluence of the Sacramento and San Joaquin Rivers, was one of the first long-term sampling locations implemented by the State of California. The Suisun Marsh Branch[7] of the DWR estimated monthly average salinity at Collinsville for the period 1920-2002, using a combination of 4-day TDS (total dissolved solids) grab samples from 1920-1971 and EC measurements from 1966-2002. Data from the overlap period of 5 years between the TDS grab samples and EC measurements were used in a statistical regression model, and the monthly averaged 4-day TDS samples were converted to monthly average EC (Enright, 2004). The result of this regression analysis was a time series of monthly EC values at Collinsville for the period of 1920-2002.

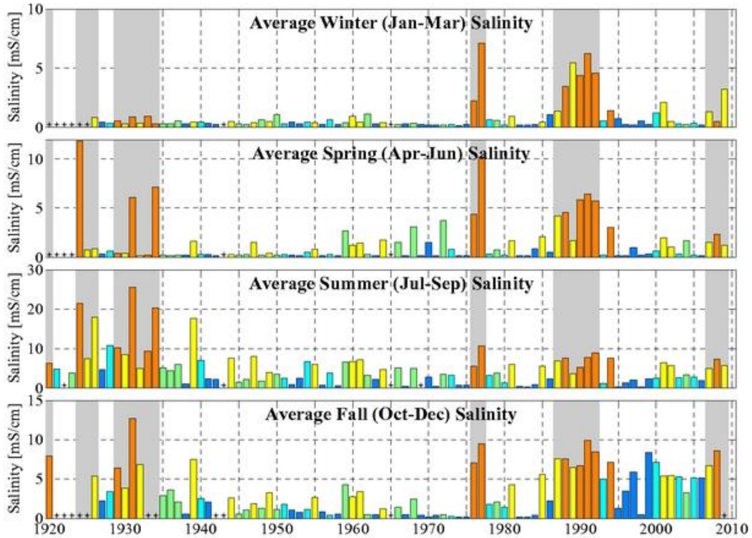


Figure D-14 – Average Seasonal Salinity at Collinsville

[7] Data provided by Chris Enright (DWR), personal communication, 2007.

No comments

- n/a -

D.3.2. Effects of Water Management on Salinity at Collinsville

In order to compare the effects of water management on salinity at Collinsville, an empirical model of salinity transport (Denton (1993), Denton and Sullivan (1993)) was used in the following analyses. Contra Costa Water District's salinity-outflow model (also known as the G-model) estimates salinity in the western Delta as a function of NDO. Estimates of salinity at Collinsville were derived for both actual historical flow (1930-2008) and unimpaired flow (1922-2003) conditions.

Figure D-15 shows the estimated monthly-averaged salinity at Collinsville under unimpaired and actual historical flow conditions. The predicted seasonal and annual variations of EC at Collinsville are dependent on corresponding variations of NDO under both unimpaired and actual flow conditions. Water management practices have a significant effect on the seasonal variability of salinity at Collinsville, particularly during dry years (1930's, 1976-1977 and 1987-1993), when Collinsville experiences a much greater range of monthly-averaged salinity under actual historical conditions than would be the case under unimpaired conditions.

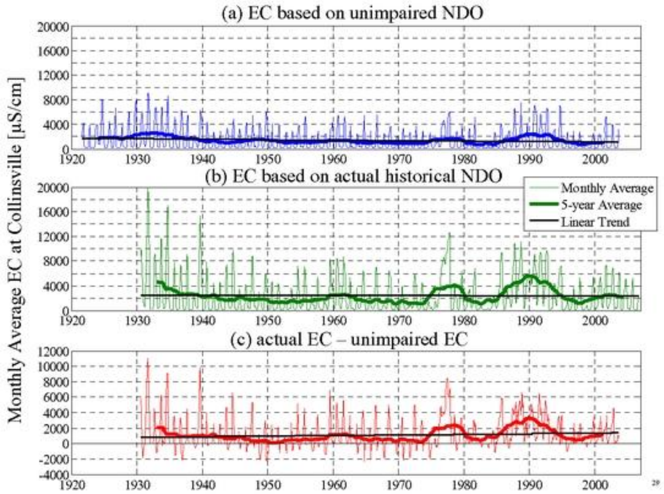


Figure D-15 – Estimates of Collinsville salinity using the G-model for unimpaired and actual historical flow conditions

Historical (actual) NDO during the 1930's was relatively low, sometimes averaging about -3,000 cfs for several months under actual conditions. The low values of NDO result in the high variability of estimated salinity in the 1930's under actual historical conditions.

No comments

- n/a -

The effects of water management on salinity at Collinsville are highlighted in Figure D-16, which shows the estimated salinity under actual historical conditions as a percent change from the unimpaired conditions. The data in Figure D-16 are the change in G-model estimates of salinity at Collinsville for the period of 1956-2003, computed as the difference between actual and unimpaired salinity as a percent change from the unimpaired salinity. Positive values indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity (freshening).

From April through August, estimated median salinity under actual historical conditions is substantially greater (more than a 100% increase) than median salinity under unimpaired conditions (Figure D-16). For the remainder of the year, there are no substantial differences between the estimates of median salinity under unimpaired and actual conditions. These distributions of estimated salinity indicate that water management practices result in significant increase in salinity throughout the year at Collinsville.

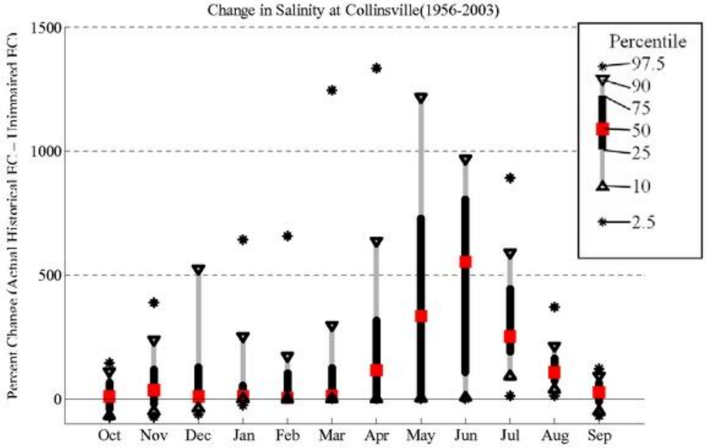


Figure D-16 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1956-2003

Figure D-17 shows the estimated salinities at Collinsville under actual historical and unimpaired conditions for just the more recent years (1994-2003). Positive values again indicate an increase in salinity under actual conditions and negative values indicate a decrease in salinity. The effects of water management on fall salinity are greater during this recent period 1994-2003 than during the longer period (1956-2003), but the effects during the recent period in the spring and early summer are smaller. This response reflects implementation of the X2 regulatory requirements agreed upon in the 1994 Bay-Delta Accord and regulated by the subsequent 1995 Water Quality Control Plan.

No comments

- n/a -

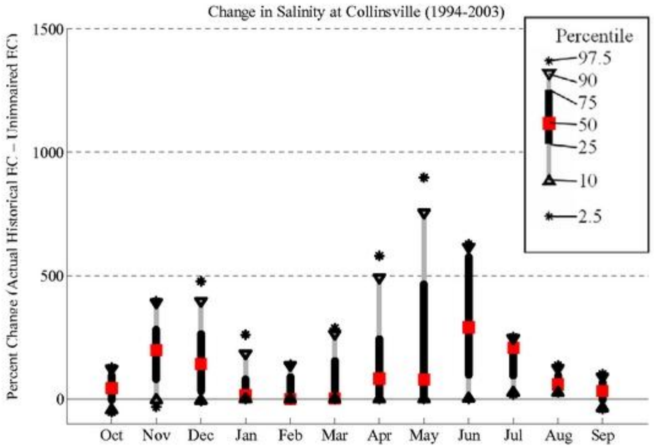


Figure D-17 – Estimated change in salinity at Collinsville under actual historical conditions, as a percent change from unimpaired conditions, 1994-2003

D.3.3. Fall Salinity in the Western Delta

Figure D-18 shows the average fall salinity (October-December) at three stations in Suisun Bay and the western Delta (Chipps Island, Collinsville, and Jersey Point). The fall salinity data categorized according to the pre-Endangered Species Act (ESA) period of 1964-1992 and the post-ESA period (1993-2006)[8]. Figure D-18 illustrates that there has been a noticeable increase in fall salinity since the release of the ESA biological opinions for winter-run salmon and Delta smelt in 1993. These increases occur during normal water years, when total annual runoff ranges from 15 to 30 MAF. During very wet years, there are large Delta outflows and the ESA limits do not affect water operations. Similarly, during very dry years, the biological opinions do not have a large effect on water operations because upstream reservoir storage is low and exports from the south Delta are already small.

[8] In 1993, delta smelt and winter-run salmon were listed under the California ESA, triggering new water management regulations.

No comments

- n/a -

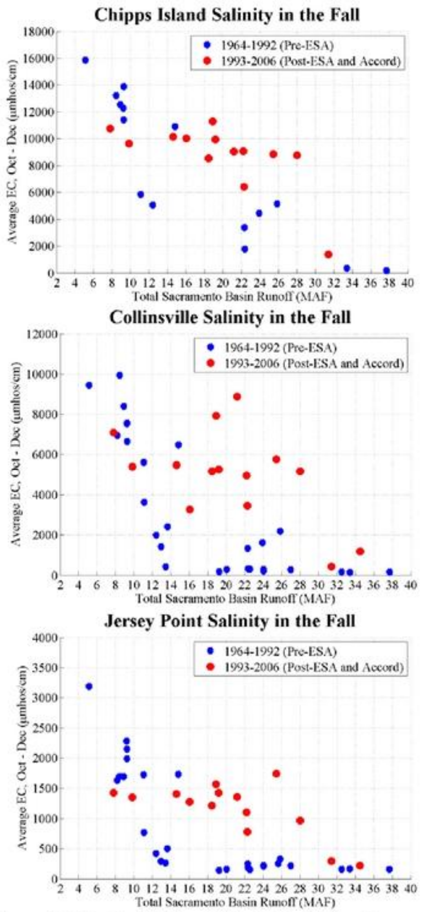


Figure D-18 – Post-ESA salinity in the Suisun Bay and western Delta

Figure D-19 shows the observed salinity at Chipps Island during the fall (October-December) for the period of 1976-1992 (pre-ESA) and 1993-2005 (post-ESA). Fall salinity at Chipps

No comments

- n/a -

Island during normal years is now comparable to fall salinity during dry and critical years prior to 1994.

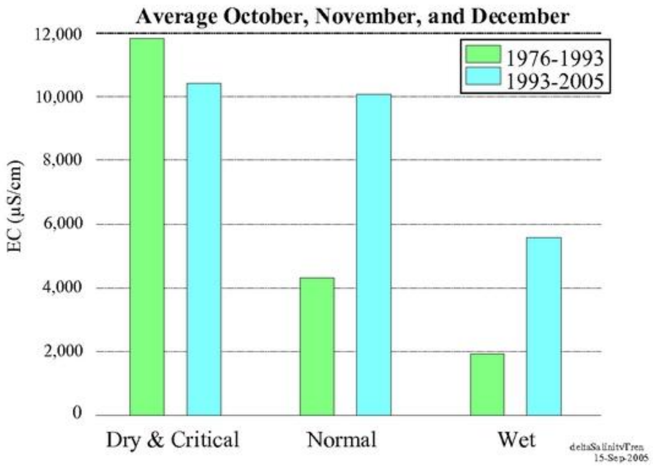


Figure D-19 – Increase in Fall Salinity at Chipps Island

D.4. General conceptual overview of salinity changes

Observed changes in seasonal salinity with time

The salinity regime in the western Delta has changed as the level of development has increased and water project operations have changed due to regulatory requirements. The comparison of three decades with similar hydrology in Figure D-20 presents a conceptual illustration of the changing salinity regime in Suisun Bay and the western Delta.

Monthly-averaged salinity in the spring and summer was substantially greater from 1966 through 1975 than during the early 1900's. However, fall and early winter salinity was lower than the early 1900's. This reduction in salinity in the fall and early winter was likely due in part to CVP and SWP reservoir releases for flood control purposes in the fall, which freshened the Delta. Flood control releases during this period were large because CVP and SWP diversions and exports were not fully developed and upstream reservoirs were often above flood control maximum storage levels in the fall, entering the wet season.

Salinity during 1995 through 2004, however, exceeded the salinities in the early 1900's during all months, for years with similar hydrologic conditions. The dramatic increase in fall

No comments

- n/a -

salinity relative to observed levels from 1966 to 1975 is accompanied by a slight decrease in spring and summer salinity. This is likely due to minimum flow and X2 requirements imposed by the State Water Resources Board in 1995. However, spring and summer salinities remain much greater relative to salinity in the early 1900's.

The range of seasonal variability during 1966-1975 was greatly reduced because the Delta did not get as fresh as it did in the early 1900's. During the last decade, seasonal variability has increased such that the range of salinity observed in the Delta over the course of a year is similar to that in the early 1900's. However, salinity intrusion has moved inland relative to the early 1900's, resulting in saltier conditions in the Suisun Bay and western Delta and a reduction in the period when fresher water is available.

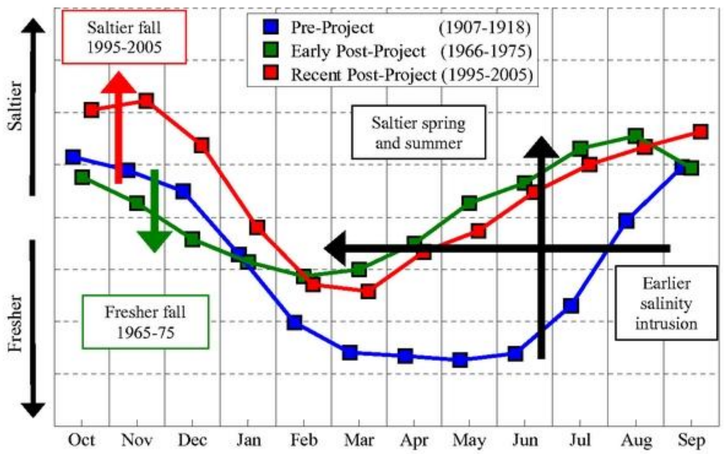


Figure D-20 – Conceptual plot of seasonal variability of salinity in Suisun Bay and the western Delta during different water management eras

The effect of water management for wet and dry years

Water management has the largest effect during dry years when the Delta stays relatively salty throughout the year with limited seasonal variability compared to unimpaired conditions. As shown conceptually in Figure D-21, during wet years the Delta freshens as much as it would under unimpaired conditions, but the Delta does not stay fresh for as long.

No comments

- n/a -

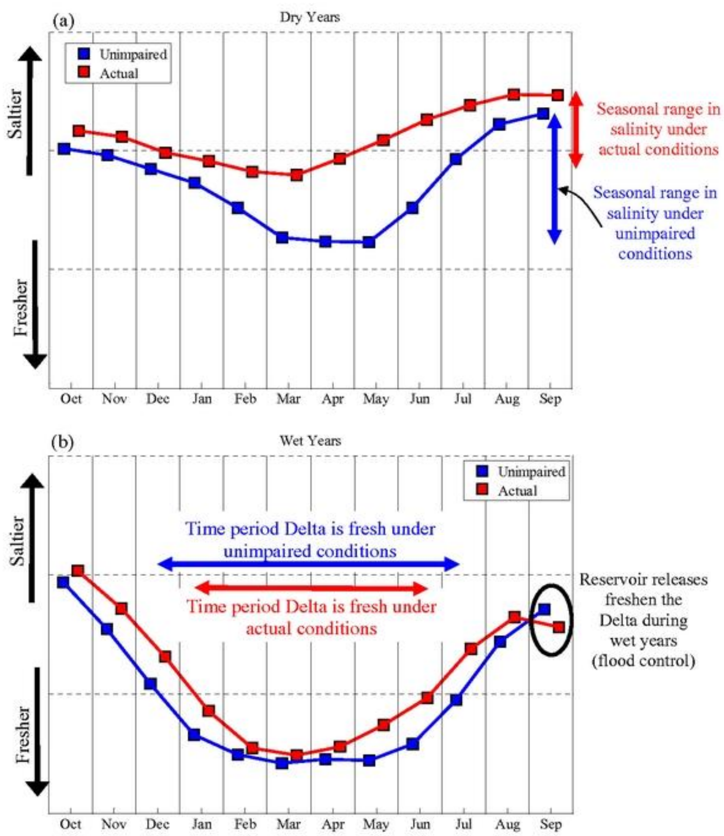


Figure D-21 – Conceptual plot of seasonal salinity variations in the Delta under actual historical conditions compared to unimpaired conditions in (a) dry years and (b) wet years

No comments

- n/a -

Appendix E. Qualitative Salinity Observations

The earliest written accounts of explorers were often concerned with adequate drinking water, and salinity was generally described in qualitative terms, such as "brackish," "fresh," or "sweet." For the purposes of comparing the present-day water quality with the historical conditions, these qualitative observations need to be quantified.

Testimony from Antioch Case (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) indicated early settlers required water with less than 100 mg/L of chloride (approximately 525 µS/cm EC) for municipal use.[9] Similarly, DPW (1931) indicated that a "noticeable" level of salinity was 100 mg/L chloride. The current secondary water quality standard for municipal and industrial use is 250 mg/L chloride (1,000 µS/cm EC) (SWRCB 2006; US EPA 2003). This report assumes a value of 250 mg/L chloride (equivalent to 1000 µS/cm EC) to be the demarcation between "fresh" (or "sweet") water and "brackish" water.

E.1. Observations from Early Explorers

Table E-1 summarizes some reported observations of water quality made by early explorers and settlers. These observations were qualitative and were most likely only a glimpse of the ambient conditions and may not completely represent true historical water quality conditions. Moreover, these observations were from a time period when anthropogenic effects on this region were minimal and this region was close to natural conditions.

Table E-1 also lists the reconstructed Sacramento River annual flow (MAF) from Meko *et al.* (2001b) for the year of observation and for the previous year. For reference, the average Sacramento River flow from Meko *et al.* (2001b) for the period 1860-1977 is 18 MAF/yr.

Table E-1 – Qualitative salinity observations from early explorers

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1775 August	near the Sacramento-San Joaquin confluence	sweet, the same as in a lake	1774 / 25 1775 / 19	Canizares	Britton, 1987 in Fox, 1987b
1776 April	near Antioch (San Joaquin River)	very clear, fresh, sweet, and good	1775 / 19 1776 / 9	Font	Britton, 1987 in Fox, 1987b
1776 September	near the Sacramento-San Joaquin confluence	sweet	1775 / 19 1776 / 9	Canizares	Britton, 1987 in Fox, 1987b

9 Supplement to Respondent's Answering Brief, p. 10.

No comments

- n/a -

Date	Location	Description	Year / Reconstructed Flow [MAF]	Observer	Reference
1796	unknown	salinity "far upstream" at high tide	1795 / 6 1796 / 10	Hermengildo Sal	Cook, 1960 in TBI, 1998
1811 October	near the Sacramento-San Joaquin confluence	sweet	1810 / 19 1811 / 23	Abella	Britton, 1987 in Fox, 1987b
1841 August	Three Mile Slough north of Emmaton	brackish (undrinkable)	1840 / 16 1841 / 6	Wilkes	Britton, 1987 in Fox 1987b

E.1.1. Fresh Conditions

Table E-1 indicates that some early explorers observed "sweet" water near the confluence of the Sacramento and San Joaquin Rivers both in relatively wet years (August of 1775 and October of 1811, reconstructed runoff about 19 MAF/yr) and in relatively dry years (September of 1776, reconstructed runoff about 9 MAF/yr). Except as noted, it is unknown whether these observations were made at high tide or low tide.

In order to provide a context for these anecdotal observations, present-day observed monthly salinity (EC) conditions at Collinsville (located near the confluence of Sacramento and San Joaquin Rivers) are plotted against unimpaired annual Sacramento River flow in Figure E-1. The observed data are monthly-averaged salinity (µS/cm) during August-October for the period 1965-2005. The data for the post-ESA years (1994-2005) are shown as shaded circles. Note that the anecdotal observations in Table E-1 are likely "one-time" observations, while those shown in Figure E-1 are average monthly values.

No comments

- n/a -

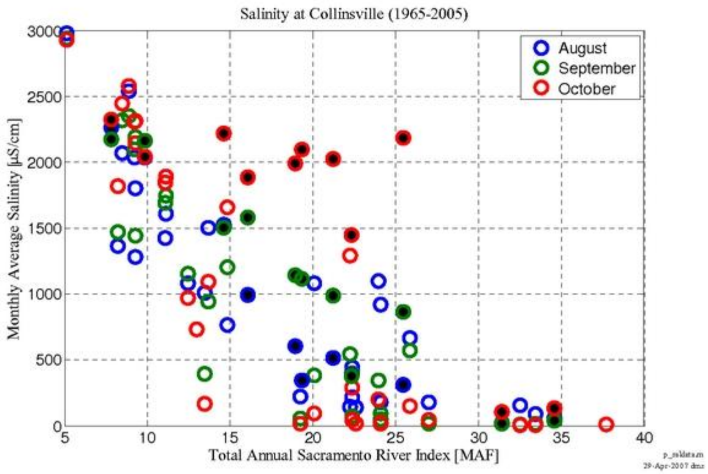


Figure E-1 – Observed salinity at Collinsville, 1965-2005

Under current management conditions, the monthly average salinity at Collinsville from August through October is only less than 1,000 µS/cm EC (the interpretation of the "sweet" threshold for drinking water) when the unimpaired runoff is greater than about 20 to 25 MAF/yr (Figure E-1). This suggests either the "sweet" threshold used in this report is too small, or salinity at Collinsville is higher today than it was in the late 18th and early 19th centuries.

If the definition of the "sweet" threshold is changed to 1,300 µS/cm EC and the post-ESA years (1994-2005) are excluded, then the monthly-averaged salinity at Collinsville during August-October is "fresh" (less than 1,300 µS/cm EC) when runoff is greater than 16 MAF/yr. This corresponds better to the anecdotal observations, discussed above, but suggests a recent increase in salinity at Collinsville during moderately wet years (with runoff between 14 and 26 MAF/yr). In 5 of the 12 post-ESA years (1997, 1999, 2000, 2003 and 2004), the water at Collinsville in October would not be considered "sweet" even under the relaxed criterion of 1,300 µS/cm EC, suggesting that October salinity under present conditions could be greater than it was in 1811.

E.1.2. Brackish Conditions

The qualitative observations of high salinity intrusion in Table E-1 are less specific about location. However, some of these observations have been interpreted by others (Cook, 1960, in TBI, 1998; Fox, 1987b) to indicate intrusion as far upstream as Rio Vista. The drought periods of 1976-1977 and 1987-1992 are similar to these periods when these qualitative

No comments

- n/a -

observations were made. During 1976-1977, daily average salinity at Rio Vista exceeded 1,000 µS/cm for approximately six months of the year. During 1987-1992, salinity at Rio Vista at high tide often exceeded 2,000 µS/cm, particularly during the fall. This is consistent with the anecdotal observations made in 1796 and 1841, which report salt water extending into the western Delta.

Summary: Interpretation of the above observations in the context of the reconstructed Sacramento River flows shows that the Delta is generally saltier than the historical levels for equivalent runoff conditions and does not support the hypothesis that the present-day Delta is managed as a freshwater system in comparison with its historical salinity regime. Moreover, this analysis indicates that salinity in the western Delta has increased during September and October in the recent years (post-1994 period).

E.2. Observations from early settlers in the Western Delta

Observations from early settlers in the western Delta provide a more complete description of salinity in the late 1800's and early 1900's than the observations from early explorers discussed earlier. Assuming the early settlers inhabited a particular region for longer time periods than the early explorers, observations from the early settlers capture the temporal variability better than those from the early explorers.

E.2.1. Town of Antioch Injunction on Upstream Diverters

In 1920, the Town of Antioch filed a lawsuit against upstream irrigation districts alleging that the upstream diversions were causing increased salinity intrusion at Antioch. The court decision, legal briefings, and petitions provide salinity observations from a variety of witnesses. Although anecdotal testimony summarized in these legal briefs is far from scientific evidence, it provides a perspective of the salinity conditions prevailing in the early 1900's. Because the proceedings were adversarial in nature, this report focuses on the testimony of the upstream interests, who were trying to demonstrate that salinity intrusion was common near Antioch prior to their diverting water (prior to 1920). Consequently, the testimony may be biased in support of this "more saline" argument. Nonetheless, these anecdotal testimonies indicate that the western Delta was less salty in the past than it is today. Analyses of some of the testimonies are presented below.

Case History

On July 2, 1920, the Town of Antioch filed suit in the Superior Court of the State of California (hereinafter referred to as the "Antioch Case") against upstream diverters on the Sacramento River and Yuba River. A hearing for a temporary injunction began on July 26, 1920, and lasted approximately three months. On January 7, 1921, Judge A. F. St. Sure granted a temporary injunction, restraining the defendants "from diverting so much water from the said Sacramento River and its tributaries, to non-riparian lands, that the amount of water flowing past the City of Sacramento, in the County of Sacramento, State of California, shall be less than 3500 cubic feet per second" (Town of Antioch v. Williams Irrigation District, Supplement to Appellants' Opening Brief, p. 13).

No comments

- n/a -

The defendants appealed to the Supreme Court of the State of California, which issued its opinion on March 23, 1922. The Supreme Court reversed the lower court and withdrew the injunction, declaring "[i]t is evident from all these considerations that to allow an appropriator of fresh water near the outlet of these two rivers to stop diversions above so as to maintain sufficient volume in the stream to hold the tide water below his place of diversion and secure him fresh water from the stream at that point, under the circumstances existing in this state, would be extremely unreasonable and unjust to the inhabitants of the valleys above and highly detrimental to the public interests besides."

The Supreme Court did not make any comment whatsoever on the evidence of salinity intrusion prior to the upstream diversions in question. The Court indicated that their decision was based on a "policy of our law, which undoubtedly favors in every possible manner the use of the waters of the streams for the purpose of irrigating the lands of the state to render them fertile and productive, and discourages and forbids every kind of unnecessary waste thereof." (Town of Antioch v. Williams Irrigation District (1922) 188 Cal. 451). The Court concluded that allowing 3,500 cubic feet per second (cfs) to "waste" into the Bay to provide less than 1 cfs of adequate quality water for the Town of Antioch would constitute unreasonable use of California's limited supply of water.

The court did not base their decision on historical salinity observations at Antioch, which indicate that Antioch was able to divert freshwater at low tide at all times from 1866 to 1918, except possibly for some fall months during some dry years (Section 3.1).

E.2.2. Salinity at Antioch – then and now

In the present day, the City of Antioch maintains a municipal water intake on the San Joaquin River at Antioch. As a general operating rule, the City of Antioch pumps water from the river when salinity at the intake is less than 1,000 µS/cm EC. Salinity varies substantially with the tide; generally the greatest salinity is observed near high tide and the lowest salinity is observed at low tide. Figure E-2 shows that salinity in the San Joaquin River at Antioch is highly variable and is dependent on tidal conditions and season. Figure E-2 indicates that for water year 2000 (an above-normal water year) the City of Antioch could pump water all day for about four and half months (early February through mid-June) and could pump for a portion of the day at low tide for another three and half months (mid-June through September). For the remaining four months (October-January), water at Antioch's intakes exceeded 1,000 µS/cm EC for the entire day, regardless of tidal phase.

Testimony from multiple witnesses in the Antioch Case indicates that fresh water was always available in the San Joaquin River at Antioch at low tide until just prior to 1920. Antioch's legal position was that fresh water was always available before upstream development. In cross-examination of Antioch's witnesses, the upstream irrigators demonstrated that brackish conditions did occasionally exist at high tide.

No comments

- n/a -

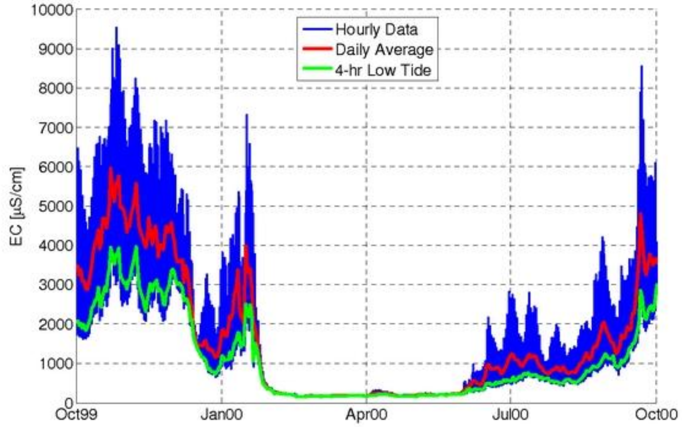


Figure E-2 – Salinity variations in the San Joaquin River at Antioch, water year 2000

Figure E-3 shows the distribution of low tide salinity (salinity during the freshest 4 hours of each day) for the period of May 1, 1983 through September 30, 2002.[10] These data indicate that, on average (in 50% of the water years), low tide salinity exceeds 1,000 µS/cm EC from late-August through December. The data in Figure E-3 provide context for the qualitative observations from the Antioch Case. During the driest 25% of the years (5 out of 20 years), low tide salinity exceeds 1,000 µS/cm EC from June through January, leaving the Antioch intake with no fresh water for eight months of the year.

Under average conditions corresponding to the period 1983-2002, Antioch would have to stop pumping from late August to late December in 10 of the 20 years; i.e., they would have an average of eight months of low-tide pumping per year, compared to the pre-1915 average of twelve months per year (based on the anecdotal information filed by the Appellants (upstream diverters) in the Antioch Case).

[10] Data Source: Interagency Ecological Program, HEC-DSS Time-Series Databases. Station RSAN007. Agency: DWR-ESO-D1485C. Measurement: 1-hour EC. Time Range: May 1, 1983 through September 30, 2002

No comments

- n/a -

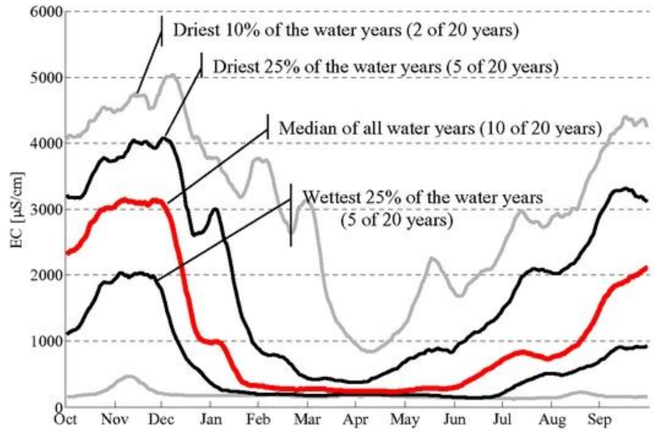


Figure E-3 – Seasonal Distribution of low-tide salinity at Antioch, 1983-2002

Conclusions

- The window, when Antioch is able to pump water with salinity less than 1,000 µS/cm EC, has substantially narrowed in the last 125 years.
- Antioch was apparently able to pump fresh water at low tide year-round in the late 1800's, with the possible exception of the fall season during one or two dry years.
- During 10 of the 20 years between 1983 and 2002, salinity was less than 1,000 µS/cm EC at low tide for only about eight months of the year.
- During the driest 5 years between 1983 and 2002, salinity was less than 1,000 µS/cm for only about four months per year; i.e., no fresh water was available at any time of the day for about eight months of the year.

E.2.3. Salinity at Kentucky Point on Twitchell Island – then and now

The appellants in the Antioch Case, representing the upstream diverters, identified one resident of Twitchell Island who reported the water at Kentucky Landing was brackish on "one or two occasions" between 1870 and 1875 during August and September. During this time, he had to travel up the San Joaquin River to Seven Mile Slough (the eastern boundary of Twitchell Island) and sailed as far as the mouth of the Mokelumne River (approximately 2

No comments

- n/a -

miles further up the San Joaquin River than the Seven Mile Slough junction) to obtain fresh drinking water.

For comparison, we look at salinity monitoring data in that region for 1981 and 2002 to see the location of potable water.[11] The source document (Town of Antioch v. Williams Irrigation District, 188 Cal. 451) for the 1870's drought uses up to 100 mg/L chloride concentration as the threshold for a potable water supply. Monitoring data from 1981 shows similar salinity intrusion as described by the Twitchell Island resident; salinity along the San Joaquin River at Bradford Island (about 1.5 miles upstream of Three Mile Slough) exceeded 1,000 µS/cm EC (about 250 mg/L Cl) during August and September. During the same time period, salinity was around 400 µS/cm EC (about 64 mg/L Cl) approximately 5 miles upstream on the San Joaquin River between Seven Mile Slough and the Mokelumne River. This comparison indicates that the extent of salinity intrusion in 1981 is similar to that which occurred in 1870 and 1871.

Similarly, in September 2002, the salinity in the San Joaquin River at San Andreas landing (less than 2 miles downstream of the Mokelumne River mouth) peaked at 977 µS/cm EC, which corresponds to approximately 225 mg/L chloride concentration. Therefore, if the observer was to travel upriver for potable water in 2002, they would have likely traveled up to the mouth of the Mokelumne River as they did in 1870. Salinity intrusion in critically dry years is even farther into the Delta than was found in 2002.

In conclusion, salinity intrusion up the San Joaquin River during the dry years of 1870 and 1871 as described by a Twitchell Island resident is consistent with salinity intrusion in 1981 and 2002 under similar hydrological conditions. There is no evidence that salinity intrusion during the drought of 1870-71 was more extensive than salinity intrusion during similar water years in the current salinity regime.

[11] 1981 and 2002 were both dry water years in the Sacramento River basin as defined in D-1641 with similar annual unimpaired Sacramento River flow to the years 1870 and 1871. Annual unimpaired Sacramento River flow in 1870, 1871, 1981, and 2002 was 11 MAF, 10 MAF, 11 MAF, and 14 MAF, respectively.

No comments

- n/a -

February 16, 2010

Division of Water Rights
State Water Resources Control Board
Attn: Phillip Crader
P. O. Box 2000
Sacramento, CA 95812-2000

Re: Delta Flow Criteria Informational Proceeding

Dear Mr. Crader:

The City of Antioch has been diverting Sacramento River water for drinking water use from the western Delta since the 1860s, and as such, has information and data directly relevant to the SWRCB's current proceedings to establish Delta flow criteria. The City, because of its position in the western Delta, is also concerned with the ecological health of the Delta and the long-term viability of the City's historic freshwater fishing and recreational opportunities.

Please find attached the City of Antioch's exhibits and supporting documents describing the historical salinity conditions at Antioch. The City of Antioch believes that it is vitally important to consider historical salinity and flow conditions when establishing flow criteria and water quality standards that will affect the future biological and ecological integrity of the Delta, and we believe that the SWRCB should not allow flow to be reduced below, or salinity to be increased above, levels currently allowed by both D-1641 and X2 requirements. In fact, the City asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition.

We appreciate your consideration in this matter. Please feel free to contact me with any questions.

Sincerely,

P. Harrington

Phil Harrington
Director of Capital Improvements and Water Rights
City of Antioch

No comments

- n/a -

Attachments:

- City of Antioch's Witness List
- City of Antioch's Exhibit Identification List
- City of Antioch's Response to Key Questions
- City of Antioch's Written Summary
- City of Antioch's supporting document – a powerpoint presentation on historical salinity conditions
- City of Antioch's supporting document – A report by Thomas Means (1928): "Salt Water Problem"
- City of Antioch's supporting document – Excerpts from the DWR (1931) Report: "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay"
- City of Antioch's supporting document – DWR (1960) Report: "Delta Water Facilities"

No comments

- n/a -

Testimony by City of Antioch: Witness List
SWRCB Delta Flow Criteria Informational Proceeding
March 22 2010

WITNESS IDENTIFICATION LIST (Revised January 29, 2010)
(Due 12 Noon, Tuesday, February 16, 2010)

Delta Flow Criteria Informational Proceeding

Scheduled to Commence
Monday, March 22, 2010

______ The City of Antioch ______ plans to call the following witnesses: (name of individual participant or group of participants)

NAME	PROPOSES PARTICIPATION ON THE FOLLOWING PANEL(S) note panel number)	WILL THE WITNESS SUBMIT TESTIMONY (no if only responding to questions)
Susan C. Paulsen, Ph.D., P.E., Vice President, Flow Science Incorporated	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	Yes
E. John List, Ph.D., P.E., Principal Consultant, Flow Science Incorporated	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No
Phil Harrington, Director of Capital Improvements and Water Rights, City of Antioch	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No
Matthew L. Emrick, Special Water Counsel to the City of Antioch	Hydrology (Panel 1) and Hydrodynamics (Panel 5)	No

No comments

- n/a -

EXHIBIT IDENTIFICATION LIST
(Due 12 Noon, Tuesday, February 16, 2010)

Delta Flow Criteria Informational Proceeding

Scheduled to Commence
Monday, March 22, 2010

PARTICIPANT: **The City of Antioch**

Exhibit Identification Number	Exhibit Description
Antioch Doc #1	City of Antioch's Cover Letter
Antioch Doc #2	City of Antioch's Witness Identification List
Antioch Doc #3	City of Antioch's Exhibit Identification List
Antioch Doc #4	City of Antioch's Response to Key Questions
Antioch Doc #5	City of Antioch's Written Summary
Antioch Doc #6	City of Antioch's supporting document – a powerpoint presentation on historical salinity conditions
Antioch Doc #7	City of Antioch's supporting document – A report by Thomas Means (1928): "Salt Water Problem"
Antioch Doc #8	City of Antioch's supporting document – Excerpts from the DWR (1931) Report: "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay"
Antioch Doc #9	City of Antioch's supporting document – DWR (1960) Report: "Delta Water Facilities"

No comments

- n/a -

Response to Key Questions

Delta Flow Criteria Informational Proceeding
March 22, 2010

The following are brief "bullet-point style" responses to the five questions posed by the State Water Board in its original notice. The written testimony and the supporting documents submitted by the City of Antioch elaborate on these responses.

Key Question #1

What key information, in particular scientific information or portions of scientific information, should the State Water Board rely upon when determining the volume, quantity, and timing of water needed for the Delta ecosystem pursuant to the board's public trust obligations?

- The current Delta ecosystem is very different than the historical Delta – both flow and salinity are altered compared to historical conditions. For example:
  - since European settlement in the 1850s, dramatic changes to the Delta landscape have occurred, including removal of tidal marsh and building of permanent river channels
  - water management operations (reservoir storage and diversions) since the early 1900s have increased reservoir storage in the upstream watersheds to more than 30 million acre-feet (MAF)
  - water exports from the Delta have been steadily increasing since the 1950s to the present, from about 0.5 MAF/yr to about 5 MAF/yr
- Before 1918 (i.e., before large-scale diversions for upstream agricultural operations), freshwater conditions were pervasive in the western Delta as indicated by literature and technical reports (e.g., testimony from the Antioch lawsuit in 1920, DPW 1931 and DWR 1960)
- Salinity monitoring data indicate that salinity at Antioch has increased from 1965 to present; the increase in salinity continues in recent years.
- Salinity intrusion under current management conditions occurs earlier in the year (currently beginning in about March, as compared to June-July historically). Salinity intrusion also persists longer; currently, the period of high salinity persists for about 10 months on average, compared to about 5 months on average for unimpaired flow conditions (i.e., without any current management operations but with the current Delta channel configuration).

For large reports or documents, what pages or chapters should be considered?

- Specific page number references have been provided in the detailed exhibit and supporting documents.

What does this scientific information indicate regarding the minimum and maximum volume, quality, and timing of flows needed under the existing physical conditions, various hydrologic conditions, and biological conditions?

No comments

- n/a -

- Historic Delta was significantly fresher than the current Delta.
- Characterization of the Delta as "historically saline" is false and is not based on scientific evidence.
- Salinity intrusion under current management conditions occurs earlier (timing) and persists longer (duration) compared to unimpaired flow conditions (i.e., without any current management operations but with the current Delta channel configuration).
- Salinity has continued to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 µS/cm EC) has declined significantly.
- Historical fresh conditions must be considered in any effort to restore ecological conditions in the Delta.

With respect to biological conditions, what does the scientific information indicate regarding appropriateness of flow to control non native species?

- This question is not addressed in the City's submittal.

What is the level of scientific certainty regarding the foregoing information?

- Salinity and flow monitoring data were collected using scientific techniques which are universal and reliable.
- Testimony and historical evidence presented is consistent with historical literature reports, measurements made by the California & Hawaiian Sugar Refining Corporation (C&H) during the early 20th century, and also with paleo records constructed from tree rings and sediment cores (presented by others and in CCWD salinity report).

Key Question #2

What methodology should the State Water Board use to develop flow criteria for the Delta? What does that methodology indicate the needed minimum and maximum volume, quality, and timing of flows are for different hydrologic conditions under the current physical conditions of the Delta?

- The City suggests that, given historical conditions, salinity should not be allowed to rise (and flows should not be allowed to decline) beyond existing levels as required by D-1641 and X2 operations criteria.
- The City requests that compliance points should not be moved land-ward.
- The SWRCB should consider using the gauging station at Antioch as a point of interest for monitoring of both salinity and flow conditions in the western Delta.

No comments

- n/a -

Key Question #3

When determining Delta outflows necessary to protect public trust resources, how important is the source of those flows?

- Even though Antioch is on the San Joaquin River, the Sacramento River was historically and continues to be the main source of water at Antioch. Thus, the Sacramento River has historically been the main source of water in the western Delta, and the source of water to which Delta species have been historically exposed and to which they may have adapted.
- In the context of flushing of the South Delta, baseline residence times should be established based on current conditions, and to be used as a measure by which future actions (e.g., BDCP) can be assessed.

How should the State Water Board address this issue when developing Delta outflow criteria?

- This question is not addressed in the City's submittal.

Key Question #4

How should the State Water Board address scientific uncertainty when developing the Delta outflow criteria?

- The City of Antioch respectfully suggests, in light of the information provided, that the SWRCB should err on the side of not allowing greater salinity intrusion.

Specifically, what kind of adaptive management, monitoring, and special studies programs should the State Water Board consider as part of the Delta outflow criteria, if any?

- This question is not addressed in the City's submittal.

Key Question #5

What can the State Water Board reasonably be expected to accomplish with respect to flow criteria within the nine months following enactment of SB 1? What issues should the State Water Board focus on in order to develop meaningful criteria during this short period of time?

- This question is not addressed in the City's submittal.

No comments

- n/a -

State Water Resources Control Board
Delta Flow Criteria Informational Proceeding
March 22, 2010

Exhibit by City of Antioch
Summary of Historical Freshwater Availability at Antioch

Summary

The historic (pre-1918) Delta was significantly fresher than the current Delta. The characterization of the Delta as "historically saline" is false and is not based on scientific evidence. Historical salinity and flow conditions must be considered when: (i) establishing Delta outflows and inflows to protect public trust values which adapted to these conditions, (ii) establishing the criteria (volume, timing and quality) required by Senate Bill 7X 1, and (iii) establishing drinking water quality standards for the Delta.

1. Introduction

The City of Antioch (Antioch), located along the San Joaquin River in the western portion of the Sacramento and San Joaquin River Delta (Delta), is one of the oldest towns in California. Since the 1860s, Antioch has obtained all or part of its freshwater supply directly from the San Joaquin River.[1] The City, because of its position in the western Delta, is also concerned with the ecological health of the Delta and its long-term viability as a recreational destination.

As part of the informational proceeding on establishing flow criteria in the Delta, this document summarizes the historical salinity and flow conditions near Antioch and contrasts them with the largely saline conditions prevailing today. The supporting document to this summary is a "powerpoint style" document containing text and figures relevant to the material presented in this summary.

2. Systemic changes have reduced freshwater flows and increased salinity in the western Delta, including at Antioch

Salinity in the western Delta (including at Antioch) is influenced both by natural factors, including ocean tides and hydrology of the upstream watersheds, and by artificial factors, including channelization of the Delta, elimination of tidal marsh, reservoir storage and release operations, and water diversions.

Major anthropogenic modifications to the Delta that affect salinity intrusion began with the European settlement of the region around 1850. Tidal marsh acreage in the Delta decreased from over 250,000 acres in the 1870s to less than 30,000 acres in the 1920s and

[1] Much of the water in the western Delta (including the City's water supply) comes from the Sacramento River. Historically, significant amounts of Sacramento River water flowed into the San Joaquin River east of Antioch at Three Mile and Georgiana Sloughs. Sacramento River water also reaches Antioch where the river merges with the San Joaquin River just west of the City. Town of Antioch v. Williams Irrigation District et al. (1922) 188 Cal. 451, 455

No comments

- n/a -

has since continued to decrease (CCWD 2010), producing significant changes in the Delta landscape (Att. at pg. 7). For example, dredging of the Delta river channels to create the Stockton and Sacramento Deep Water Ship Channels affected the salt transport and distribution in the Delta (CCWD 2010). Construction of reservoirs for storage purposes started in the early 1900s and the largest reservoirs of the Central Valley Project (CVP, Lake Shasta) and the State Water Project (SWP, Lake Oroville) were completed in 1945 and 1968, respectively (CCWD 2010). Total upstream reservoir storage capacity increased from 1 million acre-feet (MAF) in 1920 to more than 30 MAF by 1979 (CCWD 2010). Water exports from the Delta have been steadily increasing since the 1950s, and the combined annual exports from CVP and SWP have increased, on average, from about 0.5 MAF/yr in the late 1950s to about 5 MAF/yr during the recent period (Att. at pg. 8).

3. Historical extent of freshwater

Testimony from the lawsuit filed by the Town of Antioch in 1920 and from various literature reports demonstrates that freshwater (low salinity conditions) prevailed in the western Delta in the late 1800s and early 1900s.

3.1 Testimony from Antioch's lawsuit in 1920

In 1920, the Town of Antioch filed a lawsuit against upstream irrigation districts alleging that the upstream diversions were causing increased salinity intrusion at Antioch (Town of Antioch [plaintiff] v. Williams Irrigation District et al. [defendants] (1922, 188 Cal. 451)). The testimony from the Antioch lawsuit provides a perspective of the salinity conditions prevailing in the early 1900s.

3.1.1 Pre-1918: Freshwater was available at Antioch year-round

Testimony from the defendants in the Antioch lawsuit indicated that in the late 1800s, water at Antioch was known to be brackish at high tide during certain time periods, but Antioch was able to pump freshwater at low tide throughout the year, with the possible exception of the fall season during one or two dry years. Water at Antioch was fresh at low tide at least until around 1915 (when the pumping plants started pumping continuously, regardless of tidal stage) (Att. at pg. 11).

Testimony from the plaintiff in the Antioch lawsuit indicated that Antioch's freshwater supply was obtained directly from the San Joaquin River (see footnote 1 above) from about 1866 to 1918, first by private water companies and then by the municipality after 1903 (when the City acquired pre-existing water rights) (Att. at pg. 12). Plaintiff's testimony included salinity measurements taken at Antioch (1913-1917) that indicated that prior to 1918, freshwater was available at Antioch even during dry years and in the fall (Att. at pg. 12).

No comments

- n/a -

3.1.2 Post-1918: Increased upstream diversions drastically increased salinity intrusion

Testimony and measurements from the Delta (1918-1920) presented by the plaintiff in the Antioch lawsuit indicated that after 1918, salinity abruptly increased during the irrigation (rice cultivation) season, but returned to a potable level after irrigation ceased (Att. at pg. 13). The effect of upstream diversions was also confirmed by records in the plaintiff's testimony from California & Hawaiian Sugar Refining Corporation (C&H) (CCWD 2010). Plaintiff's testimony indicated that although Antioch is located along the San Joaquin River, the source of much of the water at Antioch was the Sacramento River, which flowed to Antioch via Georgiana and Three Mile Sloughs (Att. at pg. 14-15); this was confirmed by the California Supreme Court (Att. at p. 15).

Information from the Antioch lawsuit is consistent with literature reports (see the following discussion) and with paleo records of salinity and river flow obtained from tree rings and sediment cores (CCWD 2010).

3.2 Literature reports

Several literature reports confirm that freshwater was available year-round in the western Delta (including Antioch) and Suisun Bay during the late 1800s and early 1900s. For instance, DPW (1931), the precursor to the Department of Water Resources, indicated that the City of Antioch obtained all or most of its freshwater supplies directly from the San Joaquin River until 1917, and that salinity intrusion prevented domestic use of water at the Antioch intake in summer and fall after 1917 (Att. at pg. 9). DPW (1931) and Tolman and Poland (1935) indicated that prior to the 1920s, water near the City of Pittsburg was sufficiently fresh for that City to directly obtain all or most of its freshwater (Att. at pg. 10). Dillon (1980) and Cowell (1963) indicated that prior to the 1920s, freshwater was available in the Suisun Bay and Carquinez Straits for use by the City of Benicia (Att. at pg. 10). Means (1928) indicated that Carquinez Strait (near Martinez in the western Delta) is the approximate boundary between salt water and freshwater under natural conditions. Moreover, Means (1928) also indicated that during the wet season freshwater extended up to the Golden Gate (Att. at pg. 9).

The California Department of Water Resources (DWR, 1960) estimated that water with a chloride concentration of 350 mg/L or less would be available at San Joaquin at Antioch about 85% of the time under "natural" conditions (Att. at pg. 16). DWR (1960) also estimated that chloride concentrations at Antioch would be less than 350 mg/L about 80% of the time in 1900 and about 60% of the time by 1940, with decreasing freshwater availability due to upstream diversions; DWR also projected further deterioration of water quality in 1960 and later, but did not include the effects of reservoir releases for salinity control (Att. at pg. 16).

4. Current Salinity Conditions at Antioch

Salinity data compiled by the Interagency Ecological Program (IEP) and California Data Exchange Center (CDEC) were used to analyze the present availability of freshwater at Antioch. These quantitative measurements from the present were compared to the

No comments

- n/a -

testimony from the Antioch lawsuit and to observation recorded by C&H to establish how salinity at Antioch and in the western Delta has increased over time compared to historical conditions.

4.1 Freshwater availability continues to decline

Availability of freshwater at Antioch continues to decline. Antioch may take water at its intake when salinity is less than 250 mg/L chlorides (equivalent to about 1000 µS/cm EC)[2]. The number of days per year, expressed as a percentage, when daily average salinity at Antioch was below 1000 µS/cm EC declined from about 70% in the late 1960s to about 40% during the recent period (Att. at pg. 19).

Even in years with above normal runoff in the Sacramento River watershed, freshwater at Antioch is less available than historically (Att. at pg. 20). For instance, during the above normal water year 2000, water at the City of Antioch's intake was below 1000 µS/cm EC for the entire day for about four-and-a-half months (early February through mid-June) and for a portion of the day at low tide for another three-and-a-half months (mid-June through September). For the remaining four months (October-January), water at the City's intakes exceeded 1,000 µS/cm EC for the entire day, regardless of tidal stage. Testimony from the Antioch lawsuit indicates that prior to 1918, water at the City of Antioch's intake was below 1000 µS/cm EC for the entire day during above-normal years and in all but dry fall months.

Salinity at low tide at Antioch during the present is higher than historical conditions (Att. pg. 21). For instance, during the period 1985 to 2009, the tenth percentile low tide daily salinity was below 1,000 µS/cm EC for about one-and-a-half months, and the 25th percentile low tide daily salinity was below 1,000 µS/cm EC for about nine months. However, testimony from the Antioch lawsuit indicates that during the driest years prior to 1918, low tide salinity at the City of Antioch's intake was below 1000 µS/cm EC for about nine months; for all but the driest years, salinity at low tide was below 1,000 µS/cm EC throughout the year. These data establish that salinity is higher at Antioch for a wider range of hydrologic conditions and for a longer duration of the year than under historic conditions.

4.2 Salinity intrusion occurs earlier and extends farther

Since the early 1900s the California & Hawaiian Sugar Refining Corporation (C&H), located in Crockett near the western edge of Suisun Bay, obtained its freshwater supply in Crockett. When freshwater was not available at Crockett, C&H used barges that traveled upstream on the Sacramento and San Joaquin Rivers to procure freshwater. The measurements of distance to freshwater from Crockett, recorded during these barge operations, serve as a surrogate for the historical extent of freshwater in the western

[2] The freshwater salinity threshold of 250 mg/L chlorides at the San Joaquin River at Antioch is based on the 1968 agreement between the City of Antioch and DWR. This threshold is approximately equivalent to 1000 µS/cm EC, based on the site-specific empirical relationships between chloride concentration and EC (K. Guivetchi, DWR Memorandum dated June 24, 1986).

No comments

- n/a -

Delta. A comparison of C&H data during 1908-1917 and estimates[3] of distance to freshwater from Crockett during the post-SWP construction period (1966-1975) indicates that salinity intrusion into the Delta occurs on average about 4 months earlier (in March instead of July) during the post-SWP construction period of 1966-1975 (Att. at pg. 17). Comparison of C&H data from 1908-1917 to estimates of distance to freshwater from Crockett during the period 1995-2004 indicates that salinity intrusion during the recent period not only occurs earlier (by 4 months) but also extends farther in to the Delta (by about 5 to 20 miles) (Att. at pg. 18).

5. Conclusions

- Prior to 1918, freshwater was almost always available at Antioch at least at low tide. Only during dry years and during high tide conditions did salinity at Antioch become brackish.
- Between 1918 and the late 1930s, drought conditions, upstream water diversions, and channelization increased the salinity of water at Antioch.
- By 1940 the drought receded, but salinity at Antioch remained elevated.
- Salinity has continued to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 µS/cm EC) has declined significantly.
- "Historic" Delta was significantly fresher than the current Delta.

6. Request

The City of Antioch requests that the State Water Resources Control Board review and incorporate historic salinity data into its analyses when considering Delta outflow requirements to protect public trust resources in the Western Delta and the flow requirements of SB X7 1 (e. g., volume, timing and quality), and that the Board use historic data to establish and to adjust its "baseline" of water quality for both fisheries health and drinking water quality standards. In fact, the City asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition. The City also requests that the SWRCB consider using the gauging station at Antioch as a point of interest to ensure that flow criteria and salinity objectives are met.

References

[CCWD] Contra Costa Water District. 2010. Report titled "Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay".
Cowell, J. W. 1963. History of Benicia Arsenal: Benicia, California: January 1851 – December 1962. Berkeley, Howell-North Books.
[DPW] Department of Public Works. 1931. *Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay*. Bulletin No. 27. State of California, Department of Public Works, Division of Engineering and Irrigation. [DWR] Department of Water Resources. 1960. *Delta Water Facilities*. Bulletin No. 76. State of California.
Dillon, R. 1980. Great Expectations: The Story of Benicia, California, Fresno, California. 241 pp.
Means, T. 1928. Salt Water Problem: San Francisco Bay and Delta of Sacramento and San Joaquin Rivers, San Francisco, California, April 1928. Report prepared for the Association of Industrial Water Users of Contra Costa and Solano Counties.
Tolman, C. F. and J. F. Poland. 1935. *Investigation of the Ground-Water Supply of the Columbia Steel Company Pittsburg, California*. Stanford University, California, May 30, 1935.
Town of Antioch v. Williams Irrigation District (1922, 188 Cal. 451).

[3] These estimates were made using IEP data in CCWD (2010), which will be presented by the Contra Costa Water District during this informational proceeding.

No comments

- n/a -

Testimony by City of Antioch

For SWRCB Delta Flow Criteria Informational Proceeding

Submitted February 16, 2010

For hearings beginning March 22, 2010

No comments

- n/a -

Overview

- Antioch has taken fresh drinking water from the Delta since the 1860s
- Infrastructure and flow diversions have changed distribution and timing of freshwater flows
- Historic conditions were far fresher than current conditions
- Quality of water at Antioch has declined markedly

No comments

- n/a -

Why Is This Important ?

- Characterizations of the Delta as "historically saline" are false
- Native species are adapted to historical conditions, so historic salinity and flow patterns must be considered in establishing appropriate flow and salinity standards

No comments

- n/a -

What Should Happen ?

- SWRCB should review and incorporate historic salinity data into its analyses
- SWRCB should use historic data to establish an historic baseline of water quality and flows for both fisheries and drinking water quality standards

No comments

- n/a -

What Should Happen ?

- SWRCB should ensure that flows are not reduced, nor salinity increased, beyond levels assured by D-1641 and current X2 requirements
- In fact, the City of Antioch asks the SWRCB to establish flow and salinity standards in line with the Delta's historic fresh condition
- SWRCB should state that characterizations of the Delta as "historically saline" are false
- SWRCB should consider using Antioch's gauging station as a 'point of interest' to gauge flow and salinity conditions

No comments

- n/a -

Systemic Changes Have Influenced Flows and Salinity

Factors Influencing Salinity

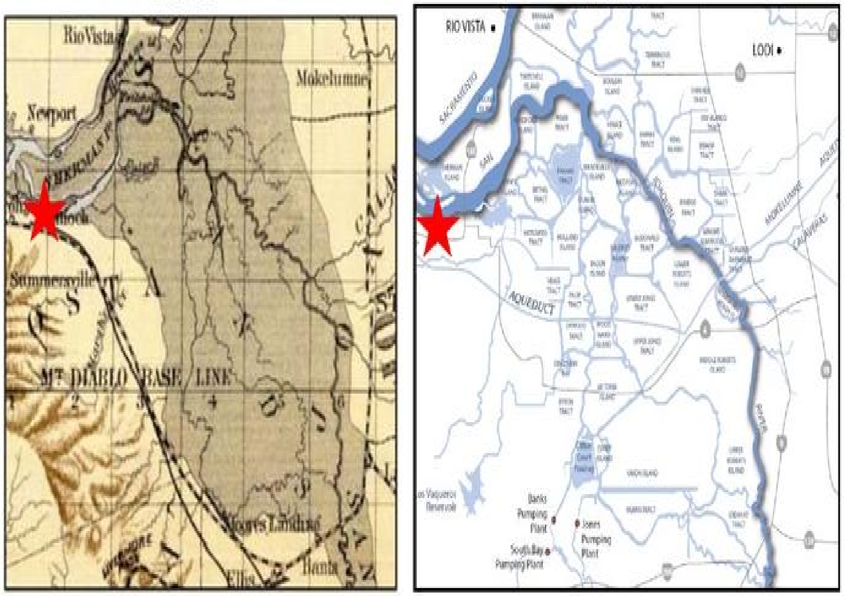
- Hydrology
- Changes to the Delta landscape
- Water Management
  - Exports
  - Diversions
  - Reservoir Storage

No comments

- n/a -

The Delta Landscape is Dramatically Different

1873 2010



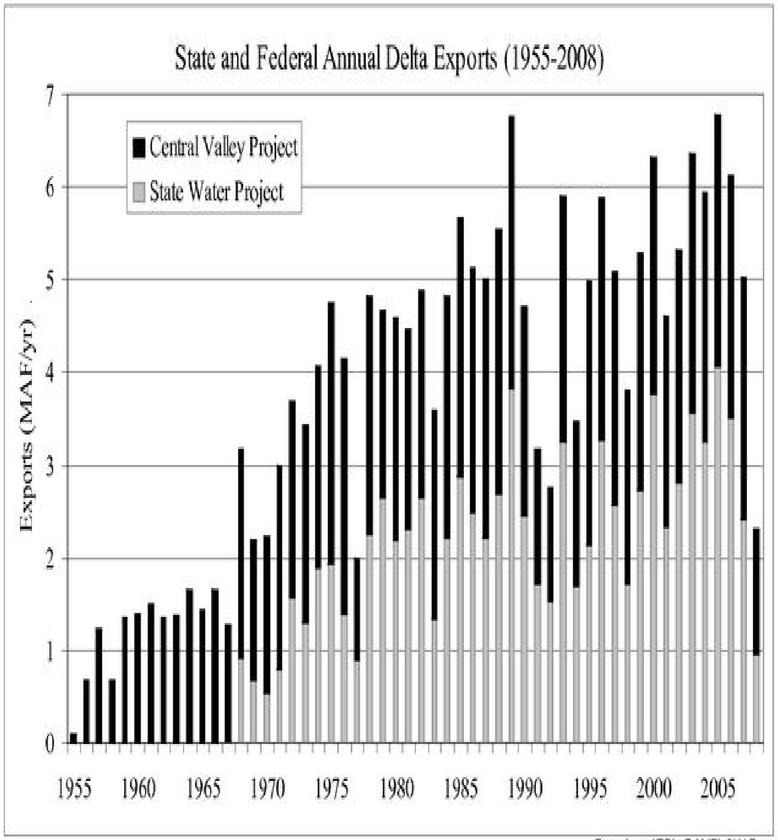
★ Approximate location of City of Antioch's water intake

Source: left panel: DWR archives presented to Delta Vision (2008) final report; right panel: Delta Vision (2008)

No comments

- n/a -

Water Exports Have Increased and Remove Fresh Water from Delta



Data from IEP's DAYFLOW Program

No comments

- n/a -

Pre-1918, Fresh Water was Available in Western Delta Nearly Year-round

Location	Quotation
Antioch, CA	*"From early days, Antioch has obtained all or most of its domestic and municipal water supply from the San Joaquin River immediately offshore from the city… However, conditions were fairly satisfactory in this respect until 1917, when the increased degree and duration of saline invasion began to result in the water becoming too brackish for domestic use during considerable periods in the summer and fall."* (DPW, 1931, pg. 60)
Western Delta	*"The dry years of 1917 to 1919, combined with increased upstream irrigation diversions, especially for rice culture in the Sacramento Valley, had already given rise to invasions of salinity into the upper bay and lower delta channels of greater extent and magnitude than had ever been known before."* (DPW, 1931, pg. 22) *"It is particularly important to note that the period 1917-1929 has been one of unusual dryness and subnormal stream flow and that this condition has been a most important contributing factor to the abnormal extent of saline invasion which has occurred during this same time."* (DPW, 1931, pg. 66)
Carquinez Strait (Western Delta)	*"Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region…"* (Means, 1928, pg. 9) *"For short intervals in late summer of years of minimum flow, salt water penetrated at lower river and delta region, and in wet seasons the upper bay was fresh, part of the time, to the Golden Gate."* (Means, 1928, pg. 9 & pg. 57)

DPW (1931). Bulletin No. 27. State of California, Department of Public Works, See http://www.archive.org/details/variationcontrol27calirich
Means, T. (1928). Salt Water Problem: San Francisco Bay and Delta of Sacramento and San Joaquin Rivers, San Francisco, California, April 1928. A report prepared for the Association of Industrial Water Users of Contra Costa and Solano Counties.

No comments

- n/a -

Pre-1918, Fresh Water was Available in Western Delta Nearly Year-round

Location	Quotation
Benicia, CA (Suisun Bay)	"*In 1889, an artificial lake was constructed. This reservoir, filled with fresh water from Suisun Bay during the spring runoff of the Sierra snow melt water* ..." (Dillon, 1980, pg. 131) "*...in 1889, construction began on an artificial lake for the* [Benicia] *arsenal which would serve throughout its remaining history as a reservoir, being filled with fresh water pumped from Suisun Bay during spring runoffs of the Sacramento and San Joaquin Rivers which emptied into the bay a short distance north of the installation.*" (Cowell, 1963, pg. 31)
Pittsburg, CA	"*From 1880 to 1920, Pittsburg (formerly Black Diamond) obtained all or most of its domestic and municipal water supply from New York Slough [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers] offshore.*" (DPW, 1931, pg. 60) "*There was an inexhaustible supply of river water available in the New York Slough* [near Pittsburg at the confluence of the Sacramento and San Joaquin Rivers], *but in the summer of 1924 this river water showed a startling rise in salinity to 1,400 ppm of chlorine, the first time in many years that it had grown very brackish during the dry summer months.*" (Tolman and Poland, 1935, pg. 27)

Cowell, J. W. 1963. History of Benicia Arsenal: Benicia, California: January 1851 – December 1962. Berkeley, Howell-North Books
Dillon, R. 1980. Great Expectations: The Story of Benicia, California, Fresno, California. 241 pp.
Tolman, C. F. and J. F. Poland. 1935. *Investigation of the Ground-Water Supply of the Columbia Steel Company Pittsburg, California*. Stanford University, California, May 30, 1935

No comments

- n/a -

Testimony from Antioch Lawsuit: Pre-1918, Fresh Water was Available at Antioch Year-round

•Antioch lawsuit in 1920: Town of Antioch [plaintiff] v. Williams Irrigation District et al. [defendants] (1922, 188 Cal. 451)

•Plaintiff alleged that the upstream diversions were causing increased salinity intrusion at Antioch

•Testimony from defendants in the Antioch lawsuit (from the supporting Supreme Court record on file at the State Archives) (CCWD, 2010)

- •In the late 1800s, water at Antioch was known to be brackish at high tide during certain time periods.
- •Antioch was able to pump fresh water at low tide throughout the year, with the possible exception of the fall season during one or two dry years.
- •Water at Antioch was apparently fresh at low tide at least until around 1915 (when the pumping plants started pumping continuously, regardless of tidal stage).

No comments

- n/a -

Testimony from Antioch Lawsuit: Pre-1918, Fresh Water was Available at Antioch in Fall

Testimony from plaintiff in the Antioch lawsuit (from the supporting Supreme Court record on file at the State Archives)

- Antioch's freshwater supply was obtained directly from the western Delta from about 1866 to 1918 (pg. 47-48).

- Prior to 1918, freshwater was available at Antioch even during dry years and in the fall (pg. 23-24).

Date	Location	Salinity (ppm)
1913 (Sept; a dry year)	Antioch	66
1916 (Aug. 5th; wet year)	Antioch	22.3
1916 (Aug. 9th; wet year)	Antioch	12.3
1916 (Sept. 19th; wet year)	Antioch	101.3
1917 (Sept. 14th; wet year)	Antioch	141.6

No comments

- n/a -

Testimony from Antioch Lawsuit: Post-1918, Upstream Diversions Drastically Increased Salinity Intrusion

Testimony from plaintiff in the Antioch lawsuit (continued)

- After 1918, salinity abruptly increased during irrigation (rice cultivation) season, and returned to a potable level after irrigation ceased (pg. 18-20)

Date	Location	Salinity (ppm)
1918 (Sept. 25th; dry year)	Antioch	1360
1920 (mid-July; critical year)	Pittsburg, CA	4500
1920 (end-July; critical year)	Pittsburg, CA	6000
1920 (mid-Aug.; critical year)	Pittsburg, CA	9500
1920 (end-Sept.; critical year)	Pittsburg, CA	2500
1920 (during rice irrigation; critical year)	Antioch	12,500
1920 (end-Oct, after irrigation; critical year)	Pittsburg, CA	fresh

Measurements at Pittsburg, CA, are from the Great Western Electro Chemical Co.

- Information on the effect of upstream diversions is also confirmed by records in the plaintiff's testimony from C&H Sugar (see CCWD 2010).

No comments

- n/a -

Testimony from Antioch Lawsuit: Water at Antioch is from Sacramento River

- Testimony from plaintiff in the Antioch lawsuit (continued)

  - Plaintiff testimony asserted that in 1920 "the amount of water which the San Joaquin carried was dependent entirely upon the amount of water in the Sacramento," and that "the San Joaquin itself carried practically no water at all. In other words, it was demonstrated that the amount of fresh water which came into the San Joaquin and down as far as the Town of Antioch was practically all Sacramento River water." (pg. 15)

  - Water was delivered to the San Joaquin River from the Sacramento River via two main conduits: Georgiana Slough and Three Mile Slough. 1920 flow rates in these sloughs were the basis of the assertion quoted above.

No comments

- n/a -

Testimony from Antioch Lawsuit: Water at Antioch is from Sacramento River

- "It is necessary here to state some additional facts to explain how this pollution comes about and why diversions from the Sacramento River may or do affect the volume and quality of the water flowing down the San Joaquin River . . . From the Sacramento River at two points, one about eight [Three Mile] and the other about twenty - three miles [Georgiana] above its mouth, sloughs diverge, into which parts of its waters escape and flow through the said sloughs and into the San Joaquin River at points several miles above the place of the diversion by the city of Antioch." Town of Antioch v. Williams Irrigation District et al. (1922) 188 Cal. 451, 455

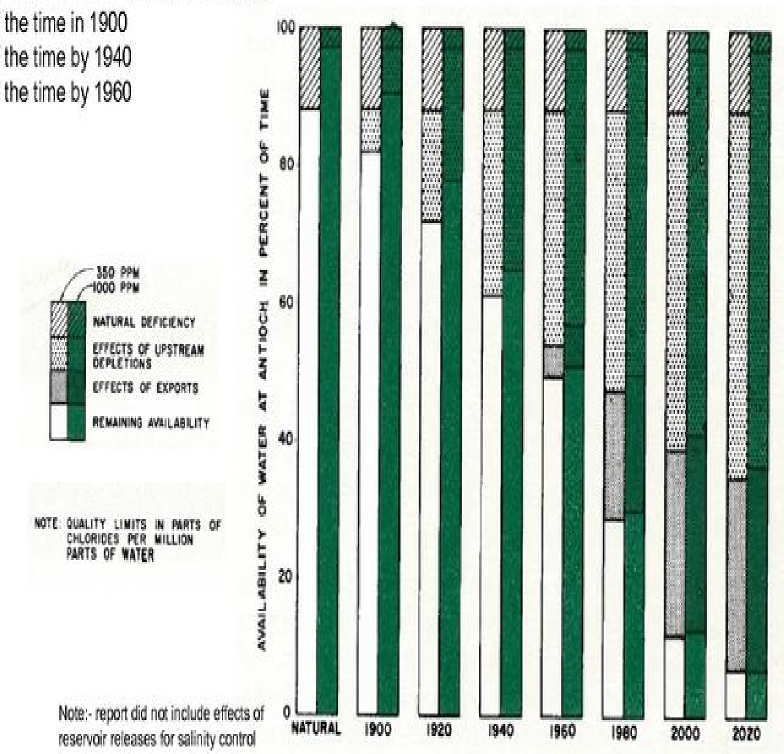
No comments

- n/a -

Freshwater Availability has Declined

DWR (1960, pg. 13) found that freshwater was available at San Joaquin River at Antioch:

- 85% of the time under "natural" conditions
- 80% of the time in 1900
- 60% of the time by 1940
- 50% of the time by 1960



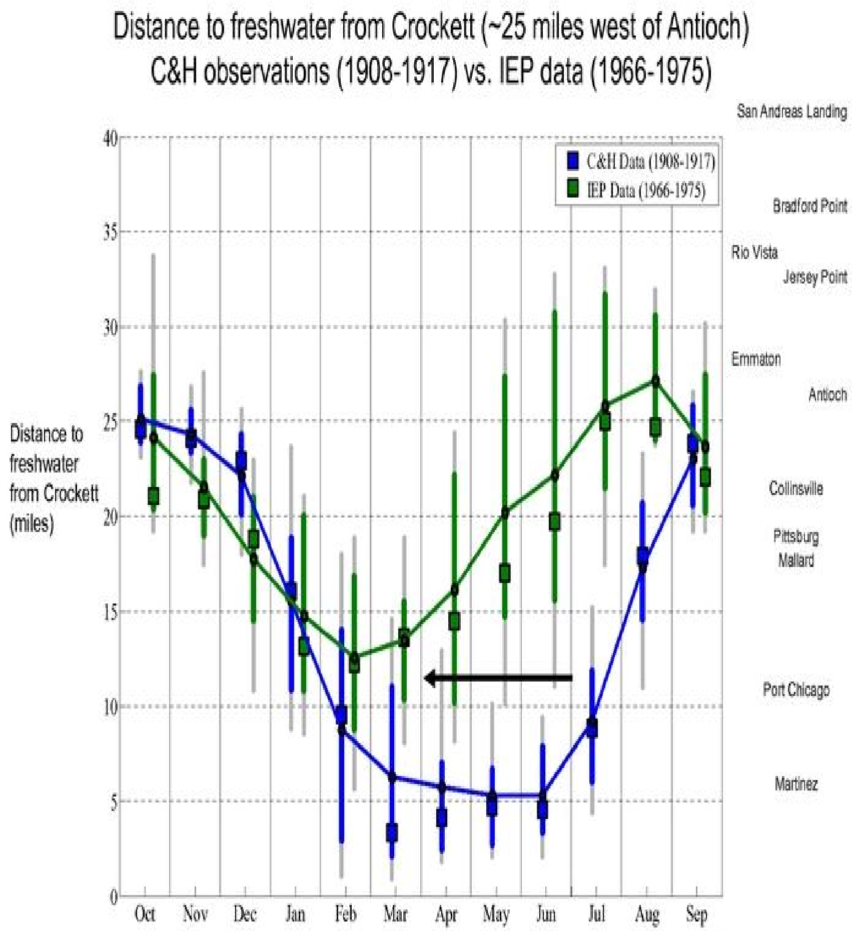
DELTA WATER QUALITY WITHOUT SALINITY CONTROL

DWR (1960). Bulletin No. 76. State of California. See http://www.deltacorridors.com/uploads/Bulletin_No._76_Delta_Water_Facilities-Color.pdf

No comments

- n/a -

Salinity Intrusion Occurred Earlier by 1975

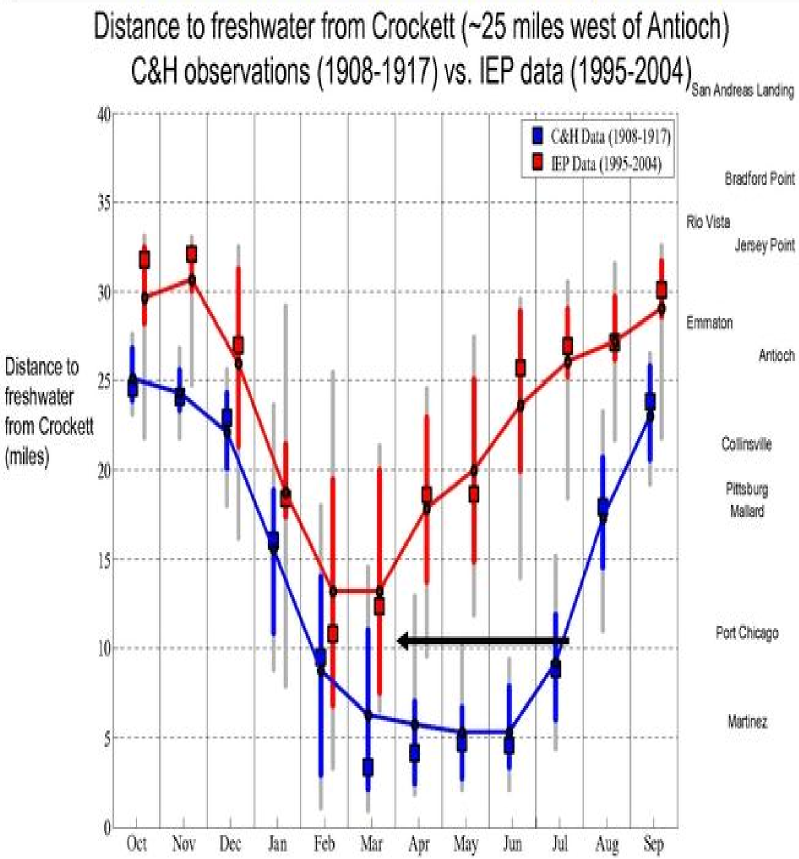


Source: CCWD Salinity Report (2010)

No comments

- n/a -

Salinity Intrusion Occurred Even Earlier and Extended Farther by 2004



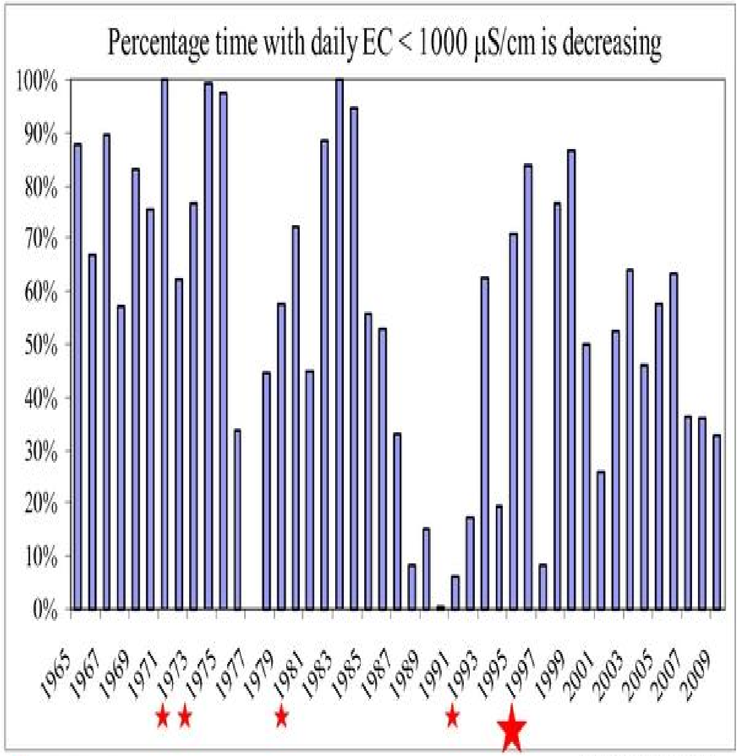
Source: CCWD Salinity Report (2010)

No comments

- n/a -

City of Antioch: Document #6 City of Antioch – Supporting Document - Page 19

Freshwater Availability at Antioch Continues to Decline



★ 10%-20% data missing

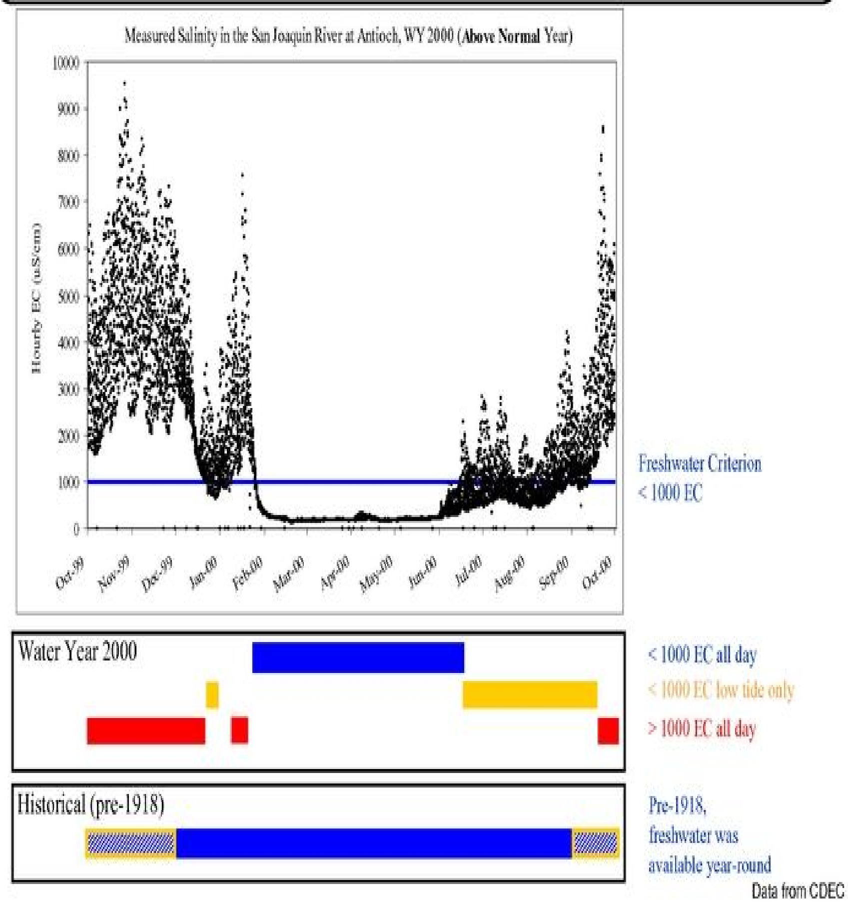
★ 80% data missing

Data from IEP & CDEC

No comments

- n/a -

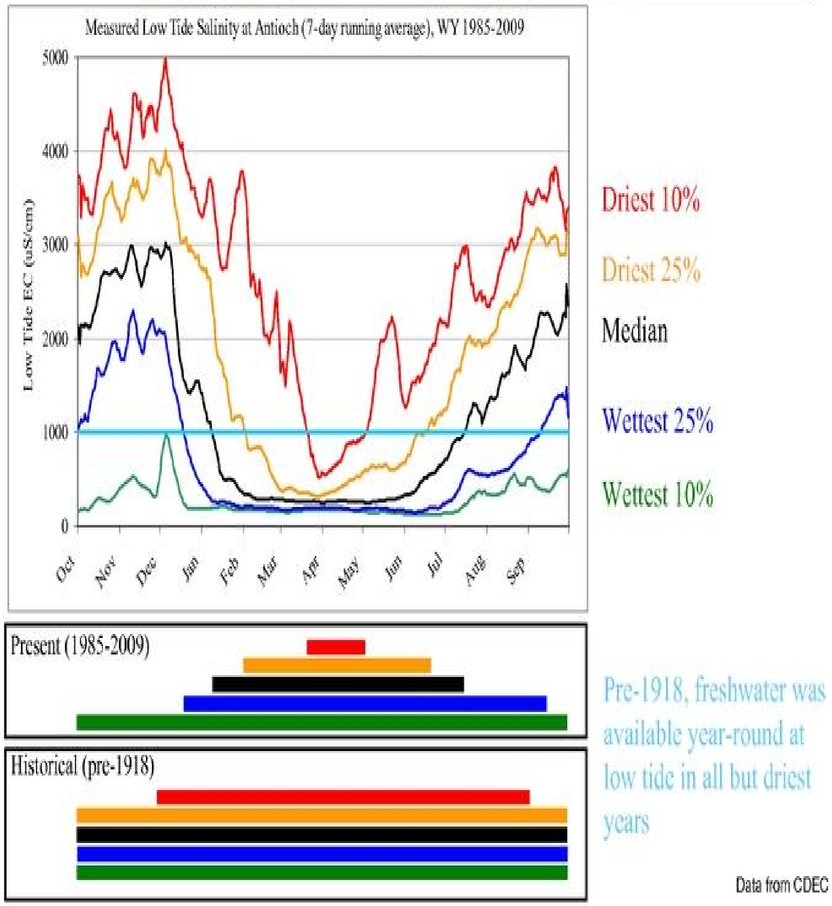
Even in Above Normal Years, Freshwater is Now Unavailable in Summer/Fall



No comments

- n/a -

Freshwater is Now Available at Antioch Far Less Often



No comments

- n/a -

Summary: The Western Delta was Historically Fresher

- Pre-1918, freshwater was almost always available at least at low tide.
- Between 1918 and the late 1930s, drought conditions, upstream water diversions, and channelization increased the salinity of water at Antioch.
- By 1940 the drought receded, but salinity at Antioch remained elevated.
- Salinity continues to increase in recent years at Antioch.
- The fraction of time that water at Antioch is suitable for use (when salinity is < 250 mg/L chlorides or 1000 µS/cm EC) has declined significantly.
- "Historic" Delta was significantly fresher than the current Delta.

No comments

- n/a -

Conclusions

Consider historic fresh conditions to:

Establish Delta outflows and inflows to protect species adapted to these conditions.

Establish the criteria (volume, timing, quality) required by SB 7X 1.

Establish drinking water quality standards for the Delta.

No comments

- n/a -

Flow Science Incorporated
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FLOW SCIENCE®

April 14, 2010

Division of Water Rights
State Water Resources Control Board
Attention: Phillip Crader
P.O. Box 2000
Sacramento, CA 95812-2000

Re: Delta Flow Criteria Closing Comments

Dear Mr. Crader:

Flow Science, on behalf of the City of Antioch, appreciates this opportunity to submit closing comments to the SWRCB regarding its development of Delta Flow criteria for the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan.

Our closing comments include key points and recommendations for SWRCB consideration, supported by our written testimony and exhibits and the oral testimony provided at the hearings on March 22-24, 2010. Because we do not have the biological expertise to recommend specific flow rates and flow volumes, we are not providing specific quantitative recommendations with this submittal.

At the March 2010 hearing, we suggested that it may be useful for the SWRCB to consider a process of simultaneously working from the "bottom up"—identifying the flow needs of fish—and working from the "top down"—analyzing flows that can be provided by the current system and systems operations, in the context of other beneficial uses, including upstream flow and temperature requirements, and water supply needs. On behalf of the City of Antioch, I would be happy to work with SWRCB Staff to explore the advantages of such a process and to participate in such a process.

Key Points for SWRCB consideration

As discussed in our February 16, 2010, written submittal, the City of Antioch has been diverting water for drinking water use from the western Delta since the 1860s. In its written testimony, the City of Antioch has provided the SWRCB with information and data on historical flows and salinity conditions in the western Delta (testimony submitted by the City of Antioch on February 16, 2010, and incorporated here by reference in its entirety; see http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/antioch.shtml). Key points in the City's oral and written testimony include the following:

No comments

- n/a -

FLOW SCIENCE

1. Historical fresh conditions must be considered in any effort to restore ecological conditions in the Delta.

We believe that it is essential for the SWRCB and its Independent Science Team to consider the historical salinity and flow conditions within which the Delta fisheries thrived, to ensure that the Delta flow criteria and other standards will ensure the protection of public trust resources, i.e. the future biological and ecological integrity of the Delta.

Systemic changes in the Delta over the years have reduced freshwater flows and dramatically increased salinity (Antioch testimony, Document #5, p. 1). Infrastructure and flow diversions have changed distribution and timing of freshwater flows, and historic conditions were far fresher than current conditions (Antioch testimony, Document #5, p. 2-4 & Document #6, p. 16-21).

It has sometimes been contended that the Delta was historically saline. As mentioned in our oral testimony (and as documented in the City's written testimony at p. 4-5 of Document #5), while the system experienced variability in flows and salinity in the past, the variability existed in a significantly fresher Delta, especially in the fall, spring and early summer months. As shown in Contra Costa Water District's submittal "Historical Freshwater and Salinity Conditions in the Western Sacramento-San Joaquin Delta and Suisun Bay" (at p. v and p. 47), while variability occurred historically, the levels of salinity were much lower than current conditions.

2. Native species are adapted to historical conditions, so historic salinity and flow patterns must be considered in establishing appropriate flow and salinity standards.

Our oral testimony during the March 2010 Informational Proceeding outlined the changes that have occurred to alter the flow and salinity environment in the Delta. This testimony on such changes was supported by other panelists. These changes include, in approximate chronological order:

- Alterations to Delta channels and loss of marshlands (Antioch testimony, Document #5, p. 1-2 & Document #6, p. 7)
- Alterations to sedimentation and transport patterns (Antioch testimony, Document #6, p. 7)
- Diversions of flows upstream of the Delta including the dewatering of significant portions of the San Joaquin River (Antioch testimony, Document #5, p. 2 & Document #6, p. 14-15)
- Diversions/exports of flows from the Delta and from Delta channels themselves (Antioch testimony, Document #6, p. 8 & p. 16)

No comments

- n/a -

FLOW SCIENCE®

3. Because of these changes to the Delta, flow now plays a more crucial role than in the past, in order to maintain or improve physical habitat and water quality in the Delta.

We encourage the SWRCB to explore and document the biological significance of the historical changes in flow and salinity regimes, and to consider this information in its recommendations. It is critical to keep in mind the significance of Sacramento River flows on the health of the public trust resources in the Delta.

Closing Recommendations

1. SWRCB should review, consider, and incorporate historic salinity data into its Flow Criteria analyses. The City of Antioch and Contra Costa Water District have provided valuable data regarding historic Delta flow and lower salinity conditions.
2. SWRCB should use historic flow and salinity data to establish a baseline of water quality and flows sufficient to restore public trust resources in the Delta.
3. SWRCB should ensure that flows are not reduced, nor salinity increased, beyond levels assured by D-1641 and current X2 requirements. Ideally, the SWRCB should increase flows to more proximate historic conditions of outflow and low salinity. The City is not recommending that historic flows be completely restored as this is not practical and could potentially impact other beneficial uses. However, historic flows and historic low salinity levels supported native species and must be considered in making any determinations on restoring Delta flows.
4. Compliance points for outflow and salinity should not be moved land-ward (easterly) and should likely be established more westerly than present as supported by the historical data.
5. Due to the loss of historic San Joaquin River flows, it is critical that Sacramento River flows be maintained in and through the Delta – and that the SWRCB recognizes that such Sacramento River flows included significant flows into the Central and Western Delta through Georgiana and Three Mile Sloughs.
6. SWRCB should consider using Antioch's gauging station as a 'point of interest' to gauge flow and salinity conditions, given Antioch's historical diversion of fresh drinking water dating back to the 1860s.

Please feel free to contact me or Phil Harrington with any questions.

Sincerely,

Susan C. Paulsen

Susan C. Paulsen, Ph.D., P.E.
Vice President and Senior Scientist

cc: Phil Harrington

No comments

- n/a -

SALT WATER PROBLEM

SAN FRANCISCO BAY *and*
DELTA *of* SACRAMENTO
and SAN JOAQUIN RIVERS

APRIL, 1928

THOMAS H. MEANS, *Consulting Engineer*
216 PINE STREET SAN FRANCISCO, CALIFORNIA

No comments

- n/a -

THOS. H. MEANS
CONSULTING ENGINEER
216 PINE STREET
SAN FRANCISCO
TELEPHONE SUTTER 76

June 15, [illegible]

Association of Industrial Water Users of Contra Costa and Solano Counties.

Dear Sirs:

Statements in this report on pages 39, 51, 56, 63 and 69 concerning the proposed Southern Pacific Railroad's Suisun Bay Bridge, located near Army Point, were published before the plans of that company were made public. The information now available shows that the site selected for the railroad bridge lies from 800 to 1800 feet above the location for the Salt Water Barrier selected by Mr. Young. The plans for the bridge provide for piers founded on rock over both the waterway and marsh areas. The experiences of the railroad do not favor the location of the tracks upon rock fill dikes, as proposed by Mr. Young, but would require piers to rock throughout the length of the structure. According to estimates by the railroad company's engineer, the saving in cost by combining the railroad bridge with the barrier under these conditions would be small and the disadvantage of having the lift span located close to locks, where the movement of vessels is slow, serves to offset any saving in cost

The railroad bridge as planned provides for a bridge giving a clearance of 70 feet (as compared with 50 feet in Young's plans), a height great enough to permit the free passage of river boats. The lift span will be used for ocean-going vessels. Piers are spaced 413 feet on centers and foundations in all cases will be carried to bedrock. The construction of the barrier as proposed by Young will not be interfered with if this site is selected.

The estimated cost of the bridge now proposed is about $6,400,000, exclusive of approaches, track, etc.

There is no advantage to be gained by a combined structure unless the result is in decreased cost to both barrier and railroad. Since there is apparently no such advantage to be gained and the bridge will not interfere with the barrier if the Army Point site is selected, I suggest that this letter be attached to my report in correction of the statements made therein.

Very truly yours,

THOS. H. MEANS.

No comments

- n/a -

SALT WATER PROBLEM

SAN FRANCISCO BAY *and*
DELTA *of* SACRAMENTO
and SAN JOAQUIN RIVERS

APRIL, 1928

THOMAS H. MEANS, *Consulting Engineer*
216 PINE STREET · SAN FRANCISCO, CALIFORNIA

No comments

- n/a -

City of Antioch
Supporting Document
March 22, 2010

MARTINEZ:
MARTINEZ DAILY STANDARD

No comments

- n/a -

TABLE OF CONTENTS

No comments

- n/a -

Preface

The following report by Engineer Thos. H. Means was financed by the Association of Industrial Water Users of Contra Costa and Solano Counties.

The only instructions given Mr. Means in preparing this report were to get the facts, and it is hoped that this document will be of benefit in establishing some of the facts relating to the proposed Salt Water Barrier as designed by Engineer Walker R. Young.

The following firms are members of the Association:

American Smelting & Refining Co.
Associated Oil Company
Atchison, Topeka & Santa Fe Railway Co.
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San Francisco & Sacramento R. R.
Shell Company of California
Southern Pacific Company
Union Oil Company

ASSOCIATION OF INDUSTRIAL WATER USERS
OF CONTRA COSTA AND SOLANO COUNTIES
C. W. Schedler, *Chairman.*

No comments

- n/a -

PENETRATION OF SALT WATER IN UPPER BAY AND LOWER RIVER REGION

Under natural conditions, Carquinez Straits marked, approximately, the boundary between salt and fresh water in the upper San Francisco Bay and delta region of the two tributary rivers—the Sacramento and San Joaquin. Ordinarily salt water was present below the straits and fresh water was present above. Native vegetation in the tide marshes was predominantly of salt water types around San Pablo Bay and of fresh water types around Suisun Bay.

In tidal waters, into which run fresh water streams of variable flow, there is an ebb and flow of salt water and the zone of mixing will move up and down stream as the fresh water flow increases and decreases. For short intervals in late summer of years of minimum flow, salt water penetrated the lower river and delta region, and in wet seasons the upper bay was fresh, part of the time, to the Golden Gate. This variation in quality of water was not, however, of sufficient duration to affect the characteristic vegetation growth of the regions on each side of the straits, nor to change the designation of Suisun Bay as ordinarily a fresh water body and San Francisco Bay as salt water.

The works of man have changed conditions in many ways. The most important changes have been brought about gradually,—so slowly as to be hardly noticeable. The dry season of 1918,—when large summer diversions for irrigation in the Sacramento Valley resulted in the sudden penetration of salt water farther upstream than ever known before, at such an early period in summer,—first brought the salt water problem to public notice. The slow effects of increasing diversions in previous years had escaped notice, but were brought prominently to the attention of the inhabitants of the upper bay and delta regions in this year. Since 1918, the dry years of 1920, 1924 and 1926 have more convincingly demonstrated the importance of the salt water problem.

An accurate picture of natural conditions is not possible, because no records have been collected on which such a picture can be based, but very close approximations can be made. The log of the distance traveled by the water barge of the California Hawaiian Sugar Company in going upstream to obtain fresh water has been kept since 1908. These figures give the means of determining approximately the conditions during that period. In 1908 irrigation had been extensively developed in both valleys and conditions then were not natural. For an estimate of earlier conditions we must go to the stream flow records of the tributary streams before important diversions are taken out.

It is the practice of the Sugar Company to send the barge upstream until water of approximately 50 to 70 parts per million chlorine is reached. The crew of the barge are equipped with apparatus by which water is analyzed until this degree of purity is reached. Since trips are made nearly every day during the summer months, the record is a very good indication of the point reached by salt water. A summary of the complete records shows the fluctuation of the line between fresh and salt water. Records of the Sugar Company are attached. (Table 1.)

The Sugar Company requires water of great purity. For irrigation, domestic or ordinary industrial uses, water of a lesser degree of purity may be used. A comparison of the point where the Sugar Company's barge is filled with the point where the remaining uses could be satisfied, indicates that from five to ten miles downstream from the place where the barge turns, water could be obtained satisfactory for domestic supply. Making an allowance of 7½ miles in the average records, we find

No comments

- n/a -

that an average flow of 5,000 second feet in both streams will maintain fresh water at Collinsville; 7,000 second feet will maintain fresh water at the San Francisco-Sacramento ferry.

If we sum up the flow of the important tributaries of the Sacramento and San Joaquin rivers at the points where these streams leave the mountains and assume that this flow under natural conditions would have reached the head of the Suisun Bay, we will find that at no time in the past ten years would the average monthly flow have been less than 5,100 second feet. It is probable, should all streams be running in a natural way, that salt water would have penetrated no farther in this extremely dry period than Antioch, and then only for a few days at a time.

It is not possible to make a more detailed study of this condition without making a number of assumptions as to speed of flow from the gaging stations to the head of the bay, and there is little accurate information on which the assumptions may be made. The definite statement that salt water under natural conditions did not penetrate higher upstream than the mouth of the river, except in the driest years and then only for a few days at a time, is warranted. (See Table 2 for monthly flow of tributary streams.)

At present salt water reaches Antioch every year, in two-thirds of the years running further upstream. It is to be expected that it will continue to do so in future, even in years of greatest runoff. In other words, the penetration of salt water has become a permanent phenomenon in the lower river region.

CAUSE OF CHANGE IN SALT WATER CONDITIONS

The cause of this change in the salt water condition is due almost entirely to the works of man. If natural changes have had any effect, it is too small to be measured. The most important natural condition is the sequence of dry and wet periods. Since 1917 the State has experienced dry years with low runoff in nearly all streams. During this period two years have exceeded normal stream flow in some streams (1921 and 1927). In each of these years excessive salinity (over 100 parts chlorine per 100,000) was present at Antioch about two months.

Irrigation

Storage and diversion of water have been the principal causes of salinity increase in the upper bay country. The area irrigated varies from year to year; in 1926 the acreage of lands on the floor of the valley was approximately as follows:

Estimate of Diversions and Area Irrigated 1926—Sacramento and San Joaquin Valleys, Not Including Mountain Areas

	Acre Feet Diverted	Acres Irrigated
Sacramento and tributaries above Sacramento, including rice, 128,439 acres	1,644,973	235,995
Delta uplands	146,906	53,649
Delta area		264,479
San Joaquin Valley estimated	2,100,000	700,000
	3,891,879	1,254,123

In addition to this area on the valley floor, there is a large acreage in the mountains which uses water from the streams tributary to the rivers that drain through Suisun Bay. The acreage irrigated in the mountains is not so accurately known as the area on the valley floor, but it is large and, particularly in low flow season, very

No comments

- n/a -

effectively uses up the water in the streams. The use of water in the mountains is usually more economical than in the valley and the return seepage is less. The net effect is to consume all of the water diverted. The effect upon the flow is pronounced.

The latest accurate determination of area irrigated is that made by the United States Census.

IRRIGATION IN CALIFORNIA

Census of 1920

	1902	1919	1920 Area in Enterprises	1920 Area Capable of Irrigation
Sacramento River and Tributaries	206,312	640,950	1,204,769	864,605
Sacramento River direct	10,942	194,397	439,169	296,748
Pit River	72,072	89,984	129,984	107,478
Cow Creek	2,321	6,068	12,488	7,446
Cottonwood Creek	1,858	2,972	21,016	4,112
Battle Creek	2,642	2,966	6,590	5,108
Stony Creek	4,110	23,559	45,143	36,191
Feather River	67,111	142,841	186,756	167,463
Yuba River	Not Rep.	19,473	69,074	23,492
Cache Creek	3,756	24,541	56,498	31,212
American River	10,112	47,156	82,695	52,842
Other Tributaries	31,388	86,993	155,356	132,513
San Joaquin River and Tributaries	220,651	1,069,161	2,072,739	1,497,661
San Joaquin River direct	129,647	642,261	1,083,862	873,300
Fresno River	10,729	12,412	30,004	14,016
Merced River	19,636	65,151	222,715	71,709
Tuolumne River	Not Rep.	165,533	298,418	250,425
Stanislaus River	13,840	75,359	155,453	111,192
Calaveras River	Not Rep.	13,323	21,598	16,489
Mokelumne River	5,558	36,848	155,480	72,144
Cosumnes River	Not Rep.	3,259	9,011	6,405
Other Tributaries	41,241	55,015	96,198	81,981

The above includes springs and wells.

Where area in watershed is not reported (not rep.) it is included in other watersheds. Records for other census periods have not been tabulated so as to be comparable.

This table shows that in the 18 years between 1902 and 1920 the area irrigated in the Sacramento Valley trebled, while in the San Joaquin Valley the increase was nearly five times as great. The area included in irrigation enterprises was only half watered in 1920, while the area capable of being irrigated was only about two-thirds watered. The total area irrigated in both watersheds was 1,710,000 acres in 1920.

No accurate records have been collected since 1920. It is known, however, that the growth of irrigation has continued, though at a slower rate than prior to 1920. Since 1920 the growth in area has been proportionally larger in the San Joaquin than in the Sacramento Valley. In the latter valley grain production (seldom irrigated) is still profitable and much land within irrigation projects goes into grain. Other crops, such as rice, vary in area with the price of rice.

No comments

- n/a -

United States Department of Agriculture tabulation of area in rice in California is shown below:

ACRES IN RICE IN CALIFORNIA

1920	162,000
1921	135,000
1922	140,000
1923	106,000
1924	90,000
1925	103,000
1926	149,000

Storage reservoirs, both for irrigation and power, have been built on many streams in the past fifteen years. Many others are planned and their construction will be undertaken within a short time. The following list of reservoirs is as complete as it is possible to make it. Small reservoirs—less than 1,000 acre feet capacity—have been omitted.

STORAGE RESERVOIRS
GOLDEN GATE DRAINAGE WATERSHED

SACRAMENTO BASIN		Height of Dam	Reservoir Capacity Acre-Feet
Cottonwood Creek	Misselbeck Reservoir	105	5,460
Pit River	Darris Reservoir	......	12,500
Pit River	Big Sage Reservoir	......	....
Pit River	Mt. Shasta Power Co. No. 3	112	36,000
Stony Creek	East Park	139	51,000
	Stoney Gorge	120	50,000
Paradise Creek	Paradise Reservoir	......	....
Battle Creek	2 Reservoirs	......	3,000
Feather River	Lake Almanor	125	1,317,000
	Bucks Creek	128	103,000
	Butte Valley	115	106,000
Yuba River	Bullards Bar	183	11,000
	Lake Francis	70	2,400
	Spalding	......	74,000
	25 Reservoirs, small	......	54,000
	Bowman being enlarged	......	....
American	4 Reservoirs	......	12,800
Mokelumne	Pardee under construction	350	200,000
	Electra System, 7 Res.	......	24,800
Stanislaus	Salt Springs, under construction	300	130,000
	Relief	140	15,000
	Strawberry	135	18,000
	Utica, 3 Reservoirs	......	8,900
	Woodward	......	36,000
	Melones	191	112,500

No comments

- n/a -

Tuolumne	Hetch Hetchy	-----	----------
	O'Shaughnessy Dam	344	206,000
	Dom Pedro	284	290,000
	Lake Eleanor	-----	25,300
	Dallas Warner	-----	28,000
	Davis	-----	48,000
Merced	Exchequer	330	278,000
San Joaquin	Florence Lake	-----	64,500
	Huntington	165	88,700
	Shaver Lake	183	138,500
	Crane Valley	150	38,000
Cache Creek	Clear Lake	-----	400,000
Suisun Creek	Gordon Valley	104	10,000
Total Constructed Reservoirs			3,998,360

Projected Reservoirs (Partial List)

Sacramento	Kennett	420	2,838,000
	Iron Canyon	-----	709,000
American	Folsom	220	300,000
Mokelumne	Dry Creek	140	1,200,000
Tuolumne	O'Shaughnessy, increased to	430	350,000
Total Projected Reservoirs			5,397,000

In round numbers, reservoirs of a capacity of 4,000,000 acre feet are in use on streams tributary to San Francisco Bay above Carquinez Strait. Reservoirs of much larger capacity are being considered for future construction.

Mining Debris. Mining debris and sediment in the rivers and by-pass channels have probably changed the tidal flow to a small extent, and may have affected salt water movements. The effect has been too small to measure, but it has been generally in the direction of reducing tidal prism and tidal flow where the deposits are laid down in bay waters, and of increasing tidal flow through the Golden Gate where deposited in the rivers. The net change has probably been very small. Gilbert, in his report upon Hydraulic Mining Debris (U. S. G. S. Prof. Paper 105, page 87) estimates the reduction in tidal currents in Golden Gate caused by deposition of debris as 2.49 per cent.

Land Reclamation. Reclamation of land by building levees has affected tidal flow and movement of salt water in two ways: first, by decreasing the tidal prism in the delta and, second, by changing the time of arrival of floods and of low water.

First, Reduction of Tidal Prism: The reduction in tidal prism by the construction of levees in the delta region and around the upper end of San Pablo Bay and around Suisun Bay has probably had the effect of slightly reducing the tidal flow through Golden Gate. As has been shown by Gilbert in the publication above referred to, the effect of leveeing in the lower river has had the tendency of increasing Golden Gate flow, while the same work in Suisun and San Pablo Bays has had the opposite effect. The net effect, however, is small and results in decreased flow. Gilbert (U. S. Geologic Survey Professional Paper 105, page 79) estimates the average percentage of the flow through Golden Gate as follows, when all marshes are leveed:

MARSH LAND AREAS—AVERAGE VOLUME FLOWING THROUGH GOLDEN GATE EXPRESSED IN PERCENTAGE

	Per Cent
San Pablo Bay marshes and Napa River	*1.95
Suisun Bay	*1.18
Sacramento Delta	†1.04
San Joaquin Delta	†3.35
Net effect on Golden Gate flow	†1.26

* Means decrease in tidal flow through Golden Gate.
† Means increase in tidal flow through Golden Gate.

Second, Change in Time of Arrival of Floods: The effect of leveeing upstream from tide lands has been to decrease the storage in basins and to increase the rate of travel of floods toward tide water. Under natural conditions the basin areas filled with water in flood time and slowly released this water in late summer, maintaining the flow well into the period of low water.

Most of these up-river basins have been leveed and floods run through the river channel and by-passes to the ocean with very little retardation by storage. There is no stored water from these basins to maintain low flow, consequently the low flow reaches the tidal channels earlier in the year than under natural conditions.

The effect of this reclamation work upon salt water conditions has been very pronounced. In the period just prior to 1918, some of the largest reclamation districts were leveed, Sutter Basin being a notable example. Prior to this closing off from flood flows these basins retained large volumes of water, sometimes until the middle of summer, the water slowly draining back into the channel. Nowadays instead of delivering water to the channel, water is taken from the channels for irrigation during summer months. Drainage returns a small part of the irrigation water directly to the river.

Return seepage from irrigation has had the effect of increasing the low water flow in the Sacramento. Stafford, in publications of the Division of Water Rights (Biennial Report November, 1924, page 133; Sacramento-San Joaquin Water Supervisor's Report 1926, page 85) estimates the water returned to the Sacramento River as follows:

WATER RETURNED TO SACRAMENTO RIVER
(INCLUDING ALL ACCRETIONS)

Flow in Second Feet

	1924	1925	1926
June	879	....	2280
July	734	1624	1573
August	785	1320	1240
September	634	1310	1077
October	......	460	......
Mean	763	1179	1543

Dredging, particularly in the Sacramento River, near its mouth, has had the effect of increasing the water prism, but the probable effect upon tides through Golden Gate is to decrease them. The dredging work is so far upstream as to be on the tidal movement opposite to that in the Golden Gate.

No comments

- n/a -

The deepening of the channel has, further, the effect of permitting the deep flowing salt water to pass upstream with more ease through the deep channel. A like effect will probably result from deepening of Suisun Bay and the San Joaquin River to Stockton, a navigation project authorized by Congress.

It is not possible to measure these effects, but it is well established that salt water being heavier moves along the bottom of deep channels with greater ease than over shallow ones. Any deepening of channels or straightening of approach through dredger cuts has the tendency to facilitate the movement of the deeper waters.

Irrigation and Storage of Water in the San Joaquin Valley. Irrigation in the San Joaquin Valley has had an effect upon tidal conditions and the movement of salt water in two ways: first, by diverting and storing water during flood period, and second, by increasing the flow in late summer and fall months through return seepage.

A much larger utilization of water resources has taken place in the San Joaquin than in the Sacramento Valley. Rainfall is lighter on the floor of the valley, so dry farming has been less profitable and there is greater necessity of irrigation. All streams tributary to the bay are now completely diverted during the low flow period and no water enters the tidal channels except return flow. This condition has been true for over ten years.

The following brief description of the streams and the irrigated area will show the extent to which the water supply has been put to use.

Upper San Joaquin. The upper San Joaquin enters the valley floor at Friant. The mean annual flow of the stream at the valley's edge averages 2,050,000 acre feet. Storage above this point, built by the San Joaquin Light and Power Corporation and the Southern California Edison Power Company under contract with riparian owners and appropriative users of water, amounts to 330,000 acre feet. Other storage reservoirs have been planned. Lands irrigated from the stream lie on both sides of the river and aggregate 400,000 acres. The diversion capacity of the ditches, sloughs and canals in use is very large.

Above the Merced River, canals, ditches and sloughs with control gates have a capacity in excess of 7,000 second feet. Sloughs and channels used for wild flooding increase this diversion capacity to in excess of 10,000 second feet. Below the Merced, a number of pumps take water from the river to West Side slope. Down to Paradise Dam, about the head of tide water, these diversions total in excess of 500 second feet.

All water entering the valley is diverted in late summer. The San Joaquin is dried above the Merced for three or four months a year. Return seepage commences to "make" about the mouth of the Merced. Below that point there is always water in the channel, except for short periods of time, just below some of the larger pumping plants.

Fresno River. This stream has a small watershed area of low mountains with a mean annual flow of 68,000 acre feet. The entire low flow is utilized around Madera and toward the San Joaquin. No return seepage makes from this area, as pumping plants have lowered the ground water plane and probably intercept nearly the entire ground water flow.

Chowchilla River. This stream has about the same area and topographic conditions in its watershed as has the Fresno. Its mean flow approximates 68,000

No comments

- n/a -

acre feet. All low flow is utilized. Pumping has been heavy on its lower course. No return seepage makes from this area.

Merced River. The Merced Irrigation District and riparian lands lying above the junction with the San Joaquin utilize all low flow. The Exchequer Reservoir of the Merced District, with a storage capacity of 278,000 acre feet, controls the stream except in wet years. The power plant at the dam delivers water into the river, when water is plentiful, in excess of the district's diverting capacity. Water always passes the district's headgate for use of lands lower down on the Merced. The mean flow of the stream is 1,330,000 acre feet. Return seepage maintains a continuous flow at the mouth of the Merced, the water coming from both the Turlock and Merced sides of the river. This return flow now amounts to 80 to 100 second feet in summer months and there are indications that it is increasing. Pumps along the Merced utilize a part of this return flow.

Tuolumne River. The Tuolumne drains a high mountain area and has a mean annual flow of 2,055,000 acre feet. Three irrigation districts—the Waterford, Modesto and Turlock, with a total area of 276,783 acres—divert water at the LaGrange Dam. Three storage reservoirs with capacity of 366,000 acre feet are operated by these districts. The City of San Francisco has rights on the upper watershed for water for domestic uses and has built reservoirs of capacity of 231,000 acre feet. A conduit of capacity of 620 second feet is under construction. San Francisco has control of other reservoir sites and proposes, ultimately, to divert 400 million gallons daily (620 second feet) from the watershed. To do this, storage of about 850,000 acre feet will be required.

Return seepage in the Tuolumne, at its mouth, resulting from irrigation now amounts to from 250 to 350 second feet constant flow. Additional seepage from these irrigated areas appears in the Merced, the Stanislaus and San Joaquin rivers.

Stanislaus River. The Stanislaus River—mean annual flow 1,376,000 acre feet—is under storage control for both power and irrigation. Power reservoirs with capacity built or being built of 172,000 acre feet, high on the stream, increase the low flow, but this water is re-stored in reservoirs or diverted by the South San Joaquin and Oakdale irrigation districts. These districts, with an area of 145,348 acres, have in Melones and Woodward reservoirs a storage capacity of 148,000 acre feet. All low flow is diverted. Return seepage in the Stanislaus River at its mouth (coming in part from the Modesto District) now varies from 100 to 160 second feet constant flow. An additional amount enters the San Joaquin River.

Return Flow in the San Joaquin River. Return seepage in the San Joaquin River from the mouth of the Merced to Durham Ferry (just above tide water) now amounts to a continuous flow of from 600 to 1,000 second feet. About 300 second feet of this water is diverted above tide water by pumps irrigating West Side lands. Additional pumps recently installed or in process of installation and pumps diverting from the tidal portion of the stream have a combined capacity of between 750 and 800 second feet. In the peak of the irrigating season these West Side pumps divert practically all of the visible flow in the San Joaquin River. The delta lands and islands are dependent upon ground water flow and such water as flows down the Calaveras, Mokelumne and connecting sloughs from the Sacramento River.

No comments

- n/a -

NET RESULT OF IRRIGATION AND STORAGE ON SALT WATER PROBLEM

Summarizing former statements upon the effect of irrigation and storage upon the flow of salt water in the lower river and upper bay region, the following may be said:

1. Under natural conditions the boundary between salt and fresh water was Carquinez Straits. In late summer, Suisun Bay became brackish but salt water penetrated as far as Antioch only rarely and then for but a few days' time.

2. The combined effects of irrigation and diversion in the Sacramento Valley have been to reduce the flow entering tidal waters to a small fraction of the flow under natural conditions. In 1924 the flow at Sacramento was about 720 second feet and was below 1,000 second feet for in excess of a month. In 1925 the flow at Sacramento reached a minimum of 2750 second feet and was below 3,000 for nearly a month. In 1926 the flow of the Sacramento reached a minimum of 1200 second feet and was below 2,000 for over a month.

3. The late summer flow of the San Joaquin—all return seepage—has been below 1,000 second feet in all years except 1927. The capacity of pumping plants irrigating West Side lands exceeds the inflow nearly every summer, so that, so far as visible flow in the San Joaquin is concerned, all of the late summer inflow into tidal channels is used on West Side area. The delta lands now must obtain their supply from the water stored in channels or which flows underground, or from the Calaveras, Mokelumne, and sloughs connecting with the Sacramento River.

4. The use of water by the delta lands on both San Joaquin and Sacramento rivers has not been accurately determined. The area irrigated amounts to 360,000 acres. If this area consumes 1¾ acre feet of water per annum, of which 20 per cent is used in a month, the consumptive draft will be at the rate of 2100 second feet. This quantity exceeds the low flow in years of light rain.

PRESENT CONDITIONS OF SALT WATER IN UPPER BAY AND LOWER RIVER REGIONS

Salt water conditions have been under observation by the Division of Water Rights of the Department of Public Works since 1917. Results have been published in the annual reports of this Division. Earlier records of much value in the study of the problem are those of the California-Hawaiian Sugar Company, referred to earlier in this report, covering the period from 1908 to 1920. In 1920 the Sugar Company obtained a supply from the Marin Municipal Water District at San Quentin Point, approximately 15 miles from Crockett. Since then, when the distance traveled upstream to fresh water is less than 15 miles, the water is taken from the river; when the distance exceeds 15 miles, the Marin County water is used.

A number of other investigations of salt water conditions have been collected at various places and are of help in the determination of the changes which have taken place in recent years. Among these records are those collected by Mr. William Pierce north of Suisun Slough, on the north side of Suisun Bay; records for a short period by the Pacific Portland Cement Company at Suisun, showing salinity of Suisun Slough; records by the Great Western Electro Chemical Company at Pittsburg, extending from 1916 to date, giving total solids and chlorine in the river water; and information collected at various times in the investigation of water supplies by the City of San Francisco, the City of Richmond, and the East Bay Water Company. A large amount of information from these various sources has

No comments

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been obtained and is helpful in interpreting the changes which have taken place and in formulating a fairly accurate conception of conditions in the past and what may be expected in the future.

Attached to this report is a chart of the region, the base being photographed from the Annual Report of the Division of Water Rights. On this chart red lines have been placed showing the penetration of salt water during the months of June and September, 1924. Similar charts for other years show that in every year, salt water has penetrated to a point beyond Antioch on the San Joaquin River and Collinsville on the Sacramento, and that in years of low flow, such as 1918, 1920, 1924 and 1926, the extreme limit of salt water penetration has been well into the delta region.

The year 1927 is one of approximately 100 per cent runoff in the streams tributary to San Francisco Bay. In this year salt water reached the middle of Suisun Bay in June, was approximately at Collinsville and Antioch in July, and during August and September had reached approximately to Emmaton on the Sacramento and the lower end of Jersey Island on the San Joaquin River.

Stream flow records show that approximately one-third of the years are in excess of 100 per cent runoff and two-thirds of the years below that figure. This gives, roughly, an approximation of the period of time in which salt water conditions will be worse than in 1927 and the period in which better results can be expected.

For practical purposes, a period of thirty days or more would be detrimental to either irrigation, domestic use or supply for industrial purposes. An examination of records in more detail indicates that, under the conditions now existing, in practically all dry years salt water will reach the lower end of the delta for at least a month's time, and that in two-thirds of the years water will be in the lower delta region in excess of a month's time or as much as three to four months.

The areas of delta land within the salt water flow are shown in the following table:

	Approximate Stream Flow in Per Cent, Normal	Area of Delta Penetrated by Salt Water
1924	24	169,000
1926	53	58,000
1925	74	8,500
1927	100	5,000

PROSPECTIVE CHANGES IN THE FUTURE

Storage of water for power purposes and diversion for irrigation and domestic uses in the watersheds tributary to the bay are steadily increasing. The rate of increase of the irrigated area is not so rapid as during the decade 1910 to 1920, but there is a steady, continuous growth and plans are on foot for large increases in the use of water through new projects and through the extension of irrigation on old projects.

As illustrating the extent to which conditions are changing, reference may be made to the growth of the San Joaquin River basin since the year 1920, a period ordinarily regarded as one of stagnation in irrigation development in California. Since 1920, the Southern California Edison Power Company has constructed and placed in operation the Florence Lake and Shaver Lake Reservoirs on the San Joaquin River with a storage capacity of 203,000 acre feet. This stored water will be

No comments

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diverted and used as fast as it is released for power purposes by the agricultural lands above the mouth of the Merced.

On the next stream, the Merced Irrigation District has built a storage reservoir of 278,000 acre foot capacity and has approximately trebled the area in irrigation in 1920. The district is rapidly growing and the entire irrigable acreage in the total of 189,000 acres will be all in cultivation within a few years.

On the Tuolumne River, since 1920, the Modesto and Turlock Irrigation Districts have built the Dom Pedro Reservoir of 290,000 acre foot capacity, and both districts have extensively increased their irrigated area. The growth is steady.

The Waterford District has acquired rights to use the water of the Yosemite Power Company, which formerly delivered approximately 60 cubic feet per second into the Tuolumne River below LaGrange Dam, further reducing the stream flow.

Since 1920 the City of San Francisco has built Lake Eleanor and the O'Shaughnessy Dam, storing 231,000 acre feet. The water released from these reservoirs has not yet been diverted from the watershed but it has been picked up, at least during the summer period, by the irrigation districts, and no water except return seepage has flowed into the Tuolumne River during the summer and early fall months.

On the Stanislaus River, the Melones Dam has been built by two irrigation districts in cooperation with the Pacific Gas and Electric Company, and the late summer use of water has been very much increased.

In addition the Power Companies have now under construction Salt Springs Reservoir on the headwaters of the Stanislaus, with the intention of ultimately raising this to storage capacity of 130,000 acre feet. This water when released will be caught by the Melones and Woodward reservoirs lower on the stream and utilized during the late summer.

The East Bay Utility District has now under construction the Lancha Plana Reservoir site on the Mokelumne River, a reservoir of 200,000 acre foot capacity, and has completed a pipe line from the Mokelumne to the East Bay district of a capacity of 60 million gallons daily (90 second feet). The water to be diverted by this Utility District will be taken out of the watershed and there will be no return flow from it.

In addition to the reservoirs and increased irrigated area on the east side of the San Joaquin, several pumping plants have been built lifting water up the West Side slope for the irrigation of high lands. Important among these are the Banta-Carbona Irrigation District, approximately at the head of tide water, which commenced irrigating in 1925 and now has a pumping capacity of 220 cubic feet per second.

The Burkhart Ranch further south has installed a pumping capacity of about 50 cubic feet per second since 1920, and a number of other districts and appropriators of water have increased either the size of their pumping equipment or the extent of their use, so that at the present time the capacity of the pumping plants irrigating West Side lands exceeds the flow in the San Joaquin River at the place where tide water is reached.

Further extension of this irrigated area is in progress and one new district is now engaged in preparation of plans which will result in the pumping of approximately 300 second feet from the river.

Extension of area supplied by pumping from wells has been going on at the same time. In Fresno, Madera, Merced, Stanislaus and San Joaquin counties, hundreds of pumping plants have been installed since 1920, all drawing from water

No comments

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which, under natural conditions, would have its outlet to the sea through the San Joaquin River. It is impossible to accurately estimate the effect of this withdrawal of water upon the stream flow or the underflow to delta areas, but, if it has not already done so, it will at some time affect the flow by reducing the quantity of water which reaches the stream from underground sources and affecting to that extent the late summer discharge into tidal waters.

Irrigation development has not been so pronounced in the Sacramento watershed since 1920. There are a large number of irrigation and reclamation enterprises in the Sacramento Valley which have irrigation systems of a capacity larger than the irrigated area. There is, in addition, a large area of land still devoted to grain, rice, sugar beets and other general farm crops, which goes in and out of cultivation as economic conditions vary. The years when grain prices are high, large areas of grain go into cultivation, a portion of which is irrigated. With prospects of low prices for grain other crops are planted, some of which use more water than does grain. The most noticeable effect on the water supply, however, is the increase and decrease in the rice crop. The area irrigated in rice since the industry became stabilized varies from 130,000 to in excess of 200,000 acres a year, and in years of large crop the effect upon the water supply is very noticeable.

Although no large new enterprises have been built in the Sacramento Valley in recent years, the increase in irrigation in the older districts has been steady. The area devoted to orchards, to alfalfa, and to general farm crops requiring irrigation, steadily increases. The result has been continued drafts upon the supply from the river and to gradual reduction in the total flow downstream from the main cultivated section. The reduction in flow, to some extent, has been controlled by the operations of the Division of Water Rights through the Commissioner appointed to superintend the diversions from the Sacramento and San Joaquin rivers. The principal effect of the work of the Commissioner has been to reduce the waste of water, to encourage economy and to endeavor to keep the flow at Sacramento as high as possible, both for purposes of navigation and the use of delta lands.

Return seepage and waste from the lower ends of the rice irrigation canals have to some extent ameliorated the extreme low flow conditions experienced in 1920 and 1924, but the steady increase in irrigated area goes on each year. The total quantity of water which passes out of the valley in late summer is slowly but surely decreasing.

There is nothing to indicate any change of conditions in the immediate future. Irrigation has reached nearly stable conditions on the upland areas of the San Joaquin Valley, largely because the streams are nearly developed to their full capacities. On the Sacramento River, however, large areas of fertile land under irrigation systems built to supply them with water are certain to be placed in crop and increase the use of water. The result will be a steady depletion of the stream and an increase of the salt water menace.

Salt water conditions such as have occurred in the lower delta since 1918 have become permanent and will not be improved until some additional water supply is turned into the river during the low flow period, or unless a barrier is built to prevent the approach of salt water from the ocean. It is difficult to conceive a set of natural conditions that would change this situation. We have reason to expect years of heavy runoff to follow the long period of dry years since 1917, but a review of the past does not lead to the belief that summer water supply can be increased to such a point that any appreciable effect will be experienced by the delta region and industrial area.

No comments

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EFFECT OF SALT WATER ON DEVELOPMENT

The industrial and agricultural areas along the upper bay and lower river region came into being before there was any serious thought of the salt water problem, in other words prior to 1918, for that was the first year in which the encroachment of salt water was serious and over a long period of the year. Since 1918 there has been no large increase of cultivated land in the delta region and few new industries of importance have been established in the industrial area. There has been, however, a steady growth in the industries already established.

The effect of salt water upon the various users of water will be discussed in the following paragraphs.

Agriculture. Water to be supplied for agricultural purposes must be free from large quantities of soluble matter. The upper limit of concentration safe for use depends upon the soil, crop, rate at which it has been used, drainage facilities, and to some extent upon whether fresh water is available at other times in the year for leaching purposes. The determination of the safe limit is, therefore, a matter of considerable difficulty, as it will vary as these factors differ.

For the purposes of this report, however, it is fair to assume that water containing 100 parts of chlorine per 100,000, equivalent to 160 parts of sodium chloride or common salt per 100,000, is the upper limit of safety; since the water contains other salts the total salinity of water containing 100 parts of chlorine will vary from 175 to 200 parts per 100,000. Water of this degree of salinity is not safe for use, except where precautions are taken to provide good drainage and to continue leaching the water through the soil so that there is no accumulation of salty matter. Such water may be used with safety on light soils where drainage is good and the use excessive, and is not harmful where used occasionally during late summer. One-half of this quantity, or 50 parts per 100,000, is much safer for use and waters of this degree of salinity could be used with comparative safety.

The records quoted above show that in years of extreme low flow, waters of 100 parts of chlorine per 100,000 will penetrate into the delta region to points beyond Rio Vista on the Sacramento, and to Stockton and beyond the mouth of Middle River on the San Joaquin. During some part of the summer approximately one-half of the delta area will be surrounded by salt water.

This condition has several results: First, it renders questionable the irrigation of permanent crops, particularly such crops as are sensitive to salt; second, it has a tendency through the percolation beneath the levees of sub-irrigating the adjoining land with saline water; third, it reduces the value of lands through the fear of salinity; and fourth, it adds expense and uncertainty to the question of domestic supply, for on most of the delta the river is a source of domestic water.

The net effect of this condition is to render agriculture uncertain in the delta, to reduce the value of land, and to create a menace which will result in the destruction of the land by the accumulation of salts.

AREA OF AGRICULTURAL LAND AFFECTED BY SALT WATER BARRIER

The area of agricultural land affected by the salt water barrier is taken as:

1st—The area of marsh land lying practically at sea level.

2nd—The area of land up to elevation 150 above sea level; an elevation to which pumping has been carried with success.

No comments

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These areas may be subdivided into geographic regions as follows:

1st—The area around San Pablo Bay, between Carquinez Strait and the site of the San Pablo barrier.

2nd—The area around Suisun Bay, that is, from the mouth of the river at Collinsville to Benicia.

3rd—The delta area or region upstream from the mouth of the river.

4th—Irrigated or irrigable lands above the delta.

San Pablo Bay Area. A large area of marsh land lies along the west and north shores of San Pablo Bay. At present a large part of this area is in process of reclamation. Much of it is growing grain crops or pasture, but little of it is irrigated. The surrounding waters are salty at nearly all times of the year. Fresh water fills the sloughs and bay during flood time, a period becoming shorter each year. Ground water of good quality has not been found and there is little likelihood of its ever being obtained, as deep wells have been drilled in many places.

Much of the land is yet salt and all of it is influenced to some extent by the salt in the bay, and the reclamation by using rainfall alone to wash out the salt is slow. The presence of fresh water surrounding the area would permit much more rapid reclamation and would make it possible to bring into profitable agriculture nearly this entire area.

Surrounding the marsh area is an area of high ground nearly as large, all of which is now unirrigated. This marginal area could be all watered and made available for many different crops by fresh water from San Pablo Bay and tributaries if this bay were kept full of fresh water. Novato, Petaluma and Sonoma Creeks and Napa River all penetrate the marsh lands and extend to high land; they would make fresh water available for the adjoining high ground and enable pumps to supply small units or large, depending upon the physical conditions.

It is to be expected that at some future time all agricultural lands in California will make use to some extent of irrigation water where such is available. Irrigation in the coastal belt has not advanced as rapidly as in the interior valleys, because owners of such land can grow profitable crops without artificial watering. Maximum results can be obtained only by irrigation and it is but natural to expect water to be in demand at some future time.

The San Pablo Bay areas which may at some time become interested in irrigation are all areas where climate and soil are acceptable to agricultural pursuits. The region is close to centers of population; transportation facilities are usually good or easily improved; it is one where increased population is certain. The availability of fresh water in the bay and tidal sloughs will serve to stimulate this growth.

Lands so situated, close to tidal waters and centers of population, are likewise attractive to industries. As the San Francisco Bay region grows, more and more of the territory adjoining the bay will change from agriculture to industrial or residential property. With a water supply attached to it, the change in use becomes easier, for the amount of water required for agriculture supplies the needs of residential or industrial occupation.

Carquinez Strait. Carquinez Strait—7½ miles long—extends from Suisun Bay to San Pablo Bay. High hills with only small areas of flat land bound the strait. The opportunities for extensive developments for use of water in this territory are limited by the topographic conditions. Industries already occupy much of the available territory and the small valleys, particularly in Contra Costa County, are now filled by towns, the population resulting from industrial, transportation and commercial enterprises along the waterfront.

No comments

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If the strait is filled with fresh water and tidal fluctuations and currents are decreased, the more complete occupation of all available ground will be possible. At the present time growth is restricted by water supply. Martinez, Port Costa and adjoining territory obtain a part of their water from wells at Concord, 12 miles away. The supply from ground water is limited. Large additions to this supply are impractical. The Sugar Refinery at Crockett has barged water from the river or the Marin County shore at great cost for many years.

On the north side of the strait, the town of Benicia has a small water supply but cannot increase this supply very much without great expense.

Suisun Bay Area. Marsh lands adjoining Suisun Bay total 70,000 acres. Immediately adjacent to these marshes is an area of 93,000 acres of higher land suitable for agriculture but not now irrigated. Fresh water in Suisun Bay would make it possible to convert this area of dry land to irrigated areas of high value.

The marsh area of Suisun Bay is all practically at sea level. Much of it is salt marsh or at least contains enough salt to interfere with some kinds of agriculture. A large part has been leveed and utilized for pasture, but with unsatisfactory drainage, and salt has accumulated.

Fresh water in the surrounding tidal channels and freedom from daily tidal fluctuations will permit the leaching of this land and make the reclamation of it practical. The land is inherently fertile and will become very productive when leached of salt. The works to accomplish this are simple in character and the operation is simple and certain of success.

If fresh water is made available, there is little question but that these marsh lands can eventually be made as productive as the delta lands of the Sacramento and San Joaquin rivers further upstream.

The high ground above these marsh areas and which may be watered by practical lifts out of tidal channels includes the lower parts of Green Valley around Cordelia, the lower part of Suisun Valley, now highly developed to deciduous fruits, and the region from Suisun to Denverton.

South of the bay the lower parts of Walnut Creek and Ignacio and Seal Creek valleys may be reached with low pumping lifts. These valley lands are now in part planted to fruits and the agricultural possibilities of the region have been demonstrated. Irrigation water cannot be obtained for these areas from any other source known at this time. Wells are of small yield and uncertain life. Storage reservoirs on these streams may be possible but none is known except small ones, and these will serve only small local areas.

The most important difficulty is the extremely erratic nature of the runoff from this area. In wet years floods are heavy, but in years below normal precipitation the runoff may be very limited, often negligible. Storage to be dependable must hold water over two or three dry years, an impracticable condition for agriculture except in very limited areas. The greater part of the area will remain unirrigated unless some cheaper, more dependable supply of water is made available. A salt water barrier will place fresh water at points where it can be readily obtained by practical developments.

The Delta Region. The delta region, affected by tide levels, extends as far up the San Joaquin River as Duncans Ferry (6 miles below the mouth of the Stanislaus River) and up the Sacramento a short distance above the City of Sacramento. The distance from the mouth of the San Joaquin to the head of tide water by river is 77 miles; to the head of tide water on the Sacramento is 56 miles. Between these extremes are many miles of tidal channels and sloughs affording

No comments

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access by boat to nearly all parts of the region, and by relatively short dredger cuts, making it possible to deliver tidal water at the edge of high ground.

This region includes 367,000 acres of land, either marsh or swamp and overflow, and 91,000 acres of high ground immediately adjacent to the marsh on the west side of the valleys. These total 458,000 acres.

The entire area is irrigated or irrigable from waters at tide level. The most recent information indicates that of this area 360,000 acres are now irrigated in both deltas. In both deltas an area of 98,000 acres remain to be irrigated, parts of which are irrigated and farmed irregularly. The economic status of the farmer has much to do with the area under cultivation.

The Up River Country. The entire irrigated area tributary to Suisun Bay is to some extent interested in the salt water problem. At the present time a suit is before the Superior Court of San Joaquin Valley, between riparian users and appropriators in the delta region and 443 defendants on the streams above the delta. This suit involves nearly all of the large users of water, both for irrigation and power, on the stream. Much other litigation is in prospect. The outcome of this controversy cannot be foreseen but it is impossible to predict anything but serious complications and nearly endless difficulties no matter which turn the courts may take.

Should the outcome of the present suit be that tide water lands have no riparian rights upon waters of the streams, in excess of one-half of the present delta area will be periodically surrounded by salt water. The agricultural industry will be affected and the salt water menace to these lands will become permanent. The final result will be disastrous to a very large area of land which has been the most uniformly productive land in the state. The continued storage and use of water above tide level and the increase in pumping to high lands around the tidal area will cause salt water to enter the rivers in all years, and at times the greater part of the tidal waters will be contaminated with salt from the ocean.

Should the courts take the view that owners on tidal waters have riparian rights to the flow of the stream, a great deal of very valuable land now using water must release the water which has heretofore been used and a tremendous damage to higher areas will result. The release of waters may affect salt water conditions to some extent but it is impossible to conceive a condition in which enough water will be released to push back salt in years of light runoff.

As is shown later in this report in the chapter on "Storage and Release for Control of Salinity," the plan under which this proposal has been made does not look practical as a means of taking care of the irrigation problem of the delta. Furthermore, it leaves out of consideration the entire industrial area that lies just below the delta.

Power Companies. Two power companies supply the industrial region—the Great Western Power Company and the Pacific Gas and Electric Company. Both companies have an interest in the salt problem in two ways: The market for power is the first and most apparent interest the power companies have in this problem in that the maintenance of the present industries and their growth in the future affect the income of the distributing companies.

In a later chapter a statement of the approximate use of power for industrial and domestic purposes is included. The rate of growth of power sales indicates a steady increase in industrial activities. The more rapidly these factories grow and the more new factories there are installed, the better will be the power companies' incomes. A potential industrial territory offers opportunity for a very large increase

No comments

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in use of power and the encouragement of these industries is a legitimate function of power companies.

The second way in which these companies are interested is the question of litigation mentioned above. The Great Western Power Company and the Pacific Gas and Electric Company and subsidiary companies, such as the Sierra and San Francisco Power Company and Mount Shasta Power Corporation, are parties to the suit previously mentioned. In addition to them the San Joaquin Light and Power Company and Southern California Edison Company, both developers of power on the San Joaquin River, are included, and the Modesto and Turlock, South San Joaquin and Merced irrigation districts are included on account of their storage and use of water on tributary streams. The interests of these concerns, therefore, are created by the direct attack upon their storage and use of water in the higher watersheds.

Should the outcome of this suit establish the riparian right of the delta land owners, the power companies will suffer very seriously in consequence, by the necessity of either releasing water now stored or condemning the right to continue the practice of controlling the flows.

Fishing Industry. Under present conditions, with the Sacramento and San Joaquin rivers open to the flow of tides, fish have free access from the ocean to the fresh water streams draining the Sierra Nevada Mountains. Several types of commercial fish are caught in these waters and other fish are important as food for the commercial varieties. There has developed a considerable fishing and fish-canning industry along the bay and lower river shore. The catch in river and upper bay approximates 5,000,000 to 6,000,000 pounds a year—largely salmon, shad and striped bass. (See table.)

The Fish and Game Commission has in charge the maintenance of fishing and the preservation and control of natural fish life, together with the propagation of existing species and the introduction of new forms suitable to these conditions.

Plans for the salt water barrier provide for fishways so that fish may travel upstream. Fish will have free travel at such times as gates are opened and will no doubt pass through the ship locks at all times.

THE FUTURE OF THIS REGION

The future of the industrial region on Carquinez Straits and Suisun Bay depends upon the growth of population. California and other Pacific Coast states are growing more rapidly than any other section of the United States. There has been for many years a constant inflow of people from the East and an increase in population along the whole Pacific shore. The cities of Los Angeles, Oakland, San Francisco, Seattle and Portland have grown much more rapidly than is the average growth of American cities.

There is no such rapid development anywhere in the country except the industrial growth in the cities around the Great Lakes, where large manufacturing interests have centered. Aside from the City of Los Angeles, the rapid-growing cities of the country have been the industrial centers. In the case of Los Angeles, the industrial growth has been large but the great increase in population arises, to a large extent, from the attractive climate of this southern city.

Estimates of future population of the San Francisco Bay region have been made by several organizations in studies concerning public utility matters. The results of three such studies are shown in the table following. The first, Column I, is the estimate of the population of San Francisco and East Bay cities made in connec-

No comments

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tion with studies of Trans-bay bridge; Column II is an estimate of the metropolitan district, taken as San Francisco, Alameda, Contra Costa and San Mateo counties, by the Telephone Company; and Column III the estimate of population of the East Bay Municipal Utility District by that organization. Each of these estimates indicates that the population will double in about 25 years.

ESTIMATES OF GROWTH OF POPULATION

YEAR	I. San Francisco and Trans-bay Cities	II. San Francisco Metropolitan District	III. East Bay Municipal Utility District
1910		686,873	229,404
1915	760,000		
1920	850,850	891,477	330,348
1925	976,000		
1930	1,100,000	1,329,200	501,000
1935	1,250,000		
1940	1,400,000	1,856,700	702,000
1945	1,577,000	2,172,000	
1950	1,750,000		948,000
1960			1,230,000

I. Estimate of population San Francisco and East Bay cities by Board of Engineers Trans-Bay Bridge, San Francisco, May, 1927.

II. Pacific Telephone & Telegraph Company—estimate by Robert W. Bachelor, includes San Francisco, Alameda, Contra Costa and San Mateo counties, April, 1925. Published in "San Francisco Business" April 17, 1925.

III. East Bay Municipal Utility District, Annual Report 1925, page 7.

Contra Costa County has grown at a more rapid rate than the Bay region as a whole. Census figures for the counties around the bay are shown in Table 4. Contra Costa's growth as compared with other bay counties is shown below:

Subdivision of State	Population 1920	Increase 1910 to 1920 Per Cent	Increase 1900 to 1920 Per Cent
State	3,426,861	44	130
Alameda County	344,171	40	164
Contra Costa	53,889	70	198
Marin	27,342	9	74
Napa	20,678	4	26
Sacramento	91,029	34	98
San Francisco	506,676	22	48
San Joaquin	79,905	58	125
San Mateo	36,781	38	204
Solano	40,602	47	69

Recent figures to show increase in population are shown in Table 5, in which are given the school enrollments for years 1915, 1921 and 1927. These are summarized below:

No comments

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SCHOOL ENROLLMENT
BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

	1915	1921	1927	Per Cent Increase 1915-21	Per Cent Increase 1915-27
Elementary Schools	5020	7262	9118	45	82
High Schools	510	1037	1586	103	210
Totals	5530	8299	10,704	50	94
Increase		50%	30%		

Population Growth and Its Cycles. California, in common with other states, is going through a readjustment of population distribution and kind of occupation. A comparatively few years ago the greater part of our population was engaged in agriculture; today manufacturing and mechanical industries occupy more people than agriculture. In 1920 agricultural pursuits (including forestry) occupied 18 per cent of the wage earners of the state as compared with 28½ per cent engaged in manufacturing and mechanical industries. Today the percentage engaged in manufacturing is higher and increasing all the time.

Students of population growth recognize cycles of growth which, for certain reasons, start slowly, grow rapidly and decline slowly. California has gone through two cycles of growth—mining and agricultural—and is now entering upon a third cycle—industrial.

The gold rush commencing in 1848 caused the first rapid increase of population after California became a part of the United States. As mining gradually declined in importance, agriculture attracted many people and a great increase in population occurred. Agriculture ceased to make rapid growth in 1912 and since that period manufacturing and mechanical trades have been the principal source of increase in population.

There are several reasons for present conditions:

1. Agriculture has been depressed since the deflation period of 1921. Costs are still high and the sale price of products has not entirely recovered. Profits have been low.

2. Land values in California are high. There is no more chance for cheap land. The incentive which caused many to enter agricultural pursuits in the great period of agricultural growth does not now exist.

3. Farming is more and more becoming purely mechanical; the same area of land can be farmed now with fewer men. This releases men for other occupations and reduces the number of men trained in farming operations—the potential buyers of farms.

4. Freight rates increased during the war and added greatly to cost of placing agricultural products in eastern market centers. At the same time the increase in freight has made it practical and necessary for many manufacturers to establish branches on the Pacific Coast.

5. Since 1900, hydroelectric power and long distance transmission of energy to manufacturing centers have been made practical and cheap, and dependable power for manufacturing has resulted.

6. California, since 1900, has become a large producer of oil. The cheap oil has encouraged manufacturing in many ways.

7. The Panama Canal and better shipping facilities have made raw materials

No comments

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for manufacturing more easily available, and have made it easier to ship products of manufacture to other markets.

8. The climate of the coast region of California has become recognized as being well adapted to manufacturing. The cool weather, uniformity of seasons, freedom from freezing or destructive storms, have attracted workmen and capitalists.

The result of all this is that at present the growth of California lies around industrial centers. We are now living in an industrial age. The future of the state depends largely upon the rate and quality of this manufacturing and industrial growth.

This does not mean that there is to be expected a decline in agricultural activity. On the contrary the growth of cities and centers of industrial enterprises will stimulate the growth in agriculture. Markets for more farm produce will result from increases in industrial population, there will be a better market for the raw products of manufacture which originate on the farm and the improvements in transportation that will result from manufacturing will benefit agriculture. We may expect the growth in agriculture to continue, but at a rate lower than during the years prior to 1912.

Agricultural Extension Possible and to Be Expected. In the chapter in which the region lying tributary to the upper end of the bay and lower river is described, the statement is made as to the area of land which could be irrigated from fresh water basin above the proposed salt water barrier. These areas are as follows:

AREAS IRRIGABLE FROM FRESH WATER BASIN
ABOVE BARRIER

	Marsh	Upland	Total
San Pablo Barrier			
San Pablo Bay	51,000	48,000	99,000
Army Point Barrier			
Suisun Bay	70,000	93,000	163,000
Totals above San Pablo	121,000	141,000	262,000
Delta Region above mouth of river:			
San Joaquin	257,000	58,000	315,000
Sacramento	110,000	33,000	143,000
Grand Total	488,000	232,000	720,000
Of this area, that above Army Point is	437,000	184,000	621,000

Of this area, approximately 360,000 acres are irrigated in the delta region. The areas around Suisun Bay and on San Pablo Bay are surrounded by salt water for so much of the summer that pasture crops alone are grown to a considerable extent.

Following the history of growth of the country, it is reasonable to expect that all of the areas which can be irrigated from this fresh water basin will be irrigated and cultivated as rapidly as the population and increase in markets warrant. The region is close to markets, well supplied with transportation facilities, which will be both by rail and water, has a climate suitable to a great variety of crops, and it would be only natural that such areas would be put to use.

No comments

- n/a -

Industrial Growth to be Expected. There is no possible way of predicting what increase there will be in the industrial development except that it will be large and substantial in character. There are many basic industrial activities not represented in this part of the Pacific Coast—industries that will unquestionably settle in this region when a fresh water supply is assured—and there will be a continued and more rapid growth of the ones already on the ground.

Every large industrial region of the world has developed at points where fresh water is abundant and cheap, and where facilities for handling of raw products to factories and carrying the finished products to markets are well established, and the rates to markets are reasonable. San Francisco Bay, being in the geographical center of the Pacific Coast, is the natural point where large factories will locate. The fact that large cities are close at hand, that transportation facilities are established, that power is abundant and cheap where oil pipe lines bring oil from the fields further south, and that the climate is an unusually good one for a manufacturing business, are all important. If there is added to these essential conditions a large fresh water reservoir, there will be no more favorable location for manufacturing. It can be expected that the growth here will be as rapid as in any other part of the country and more rapid than has been true at any time in the past history of the state or Pacific Coast.

WATER REQUIREMENTS OF THE REGION

The present water requirements of the region are supplied from many sources. Richmond, on the upper end of San Pablo Bay, is within the East Bay Municipal Utility District, a public organization engaged in the construction of a water supply system from the Mokelumne River. It is to be expected that this district will purchase the distribution system of the East Bay Water Company now serving the territory, and that it will construct such additional facilities as may be required to supply industrial and domestic requirements of the territory. Water from this system will be costly. The charges of the East Bay Water Company average nearly 30 cents per 1,000 gallons. Little if any reduction in cost can be expected from the Utility District unless a part of the expense is raised as taxes.

The smaller towns, such as Martinez, Port Costa, Benicia, Bay Point, Antioch and Pittsburg, obtain water either from wells or by pumping from the river at fresh water times, or by small storage reservoirs filled during flood or fresh water season. In all of these towns water is high-priced (the average price of water from the Port Costa Water Company is about 27 cents per 1,000 gallons), usually of inferior quality at least some time of the year, and there is no great supply in sight to take care of rapid increase in growth of population. In fact the growth of the territory outside of the Utility District mentioned is to a large extent restricted by its water supply. The Utility District cannot serve the industrial plants on account of the high cost of water.

The construction of a salt water barrier will effectively remove this deterrent to growth, for it will place fresh water of good chemical quality alongside of all of these towns, and with the modern methods of filtration and purification the water will be suitable for domestic or any industrial use. The cost of pumping will be a small part of the cost of water from any other known source.

The industries now established between Oleum and Antioch, on both sides of the straits, use 10 million gallons daily and the use is increasing at the rate of a million gallons daily per year. Enlargements and extensions to these plants will probably increase this rate of growth.

No comments

- n/a -

Prediction as to the future is hazardous, as much depends upon whether or not a salt water barrier is built. This structure will greatly stimulate growth of present industries and will encourage the establishment of new ones. It is within the bounds of reason to expect 100 million gallons daily to be used by industries within the next 25 years.

Domestic Supply for Cities and Towns. Water for domestic purposes is higher priced in San Francisco and the East Bay cities than in any other large cities of America. This high price results from the difficulty of securing water in quantities sufficient to take care of the rapid growth of these communities. The same thing may be said of smaller cities along Carquinez Straits. Water for domestic use has been difficult to secure, the price is high, the quality is not good at all times. There is no known way by which small communities can satisfactorily grow unless the water supply is ample for the needs of their growing population.

As an example of this condition, the history of the Benicia Water Company may be cited. This company has made a careful investigation of the possibilities of securing water, has drilled wells for underground investigation, has considered storage possibilities in the hills back of the town, and has finally been required to use river water at such times as this water is available, and to supplement this supply with pumps. During much of the year the community is unable to supply water of a good quality without great difficulty.

On the south side of the straits the water supply for towns of Crockett, Martinez and surrounding territory is provided by the Port Costa Water Company, largely from wells in the neighborhood of Concord. Litigation has restricted the extent to which these wells can be utilized and this community will be faced with the very large expense of going to distant points for a water supply if the growth of the towns continues.

The town of Pittsburg is supplied from wells and, at seasons of the year when the water is fresh, from the San Joaquin River. The limit to the availability of underground waters is in sight and Pittsburg will be placed to great expense to secure a water supply if the growth continues to be as rapid as it has been in the past. Similar conditions prevail at Antioch, where protracted litigation called the attention of the state to the difficulties of this community carrying out its plan of pumping water from the river. Since 1920 Antioch has built a storage reservoir on the slopes to the south of the city, into which fresh water is pumped during the early summer, and stored and used in late summer. The result is that water is more costly and of poor quality for domestic purposes, largely on account of the taste of stored water in open reservoirs in bright sunlight.

The entire industrial areas along Suisun Bay and Carquinez Straits may be said to be restricted in growth on account of the fact that there is no easily obtainable supply of fresh water. The result has been a restricted rate of growth of population and an increase in cost of water to those who are already in the community.

The salt water barrier, to a large extent, will remove these difficulties. If the barrier is located at the San Pablo site, the entire area will be cared for. If it is placed at the Army Point site, the entire region upstream will be on a fresh water lake. The industrial area below the upper end of the straits can then be supplied from a relatively short pipe line heading above the barrier.

The reversal of flow, caused by tides at Sacramento, has endangered the cities' water supply by causing sewage to back upstream. The barrier will prevent this from occurring, as it will raise low water at Sacramento and prevent upstream flow.

No comments

- n/a -

SURVEY OF REGION AFFECTED BY SALT WATER

The region affected by salt water includes the area from the lower end of Carquinez Straits upstream to Isleton on the Sacramento River, Wakefield Landing on the San Joaquin, and Mansion House on Old River. It includes Carquinez Straits, Suisun Bay, and approximately one-half of the delta on the San Joaquin and Sacramento rivers. San Pablo Bay is of course affected but salt water is more nearly a natural condition in that body of water. Indirect effects are experienced in all parts of the watershed draining through Carquinez Straits and the Bay region and cities which have commerce with these industrial and agricultural areas. The problem, in fact, is one which interests all of California, for the prosperity of this industrial region and the prospective growth of this country in some measure affect the entire area engaged in agriculture or trade in this part of the Pacific Coast.

The region directly affected by the recent invasion of salt water includes the cities and towns of Oleum, Crockett, Port Costa, Martinez, Bay Point, Pittsburg and Antioch on the south side of the straits and Suisun Bay, and Vallejo and Benicia on the north side. Salt water extends as far upstream as Rio Vista.

The estimated population of these towns and outlying territory is in excess of 30,000.

Industries. The important industries located along the Straits af Carquinez and Suisun Bay are as follows:

INDUSTRIES

CARQUINEZ STRAITS

	Town
Left Bank:	
1—Union Oil Company	Oleum
Refining, casing and shipping petroleum products.	
2—Selby Smelting & Lead Company	Selby
Branch of American Smelting & Refining Co. Smelting and refining non-ferrous metals.	
3—California-Hawaiian Sugar Company	Crockett
Sugar refineries, largest in world, 5,000,000 lbs. a day.	
4—Port Costa Brick Company	Port Costa
Makers of brick, etc.	
5—Grain Warehouses	Port Costa
Storing, cleaning, shipping—principally barley.	
6—Petroleum Products Company	Martinez
Petroleum products.	
7—Mountain Copper Company	Martinez
Copper smelting and refining, fertilizers.	
8—Shell Oil Company	Martinez
Refining and shipping petroleum products.	
9—Southern Pacific Company	——
Operating railroad and ferries.	
Right Bank:	
10—Mare Island Navy Yard	Vallejo
Repairs and construction of naval ships.	
11—Sperry Flour Company	Vallejo
Milling of wheat and other grains.	
12—Benicia Barracks and Arsenal	Benicia
U. S. Army stores.	
13—Kullman-Salz Tannery	Benicia
Leather.	

No comments

\- n/a -

Suisun Bay

Left Bank: *Town*

1—Associated Oil Company........ Avon
Refining and packing for shipment petroleum products.
2—Coos Bay Lumber Company........ Bay Point
Manufacturing and wholesale lumber; large storage 75,000,000 F. B. M.
3—Pacific Coast Shipbuilding Company........ Bay Point
Ship building—steel and iron products.
4—General Chemical Company........ Nichols
Large manufacturers of heavy chemicals.
5—San Francisco & Sacramento Railroad Company........ ——

Most Important From Pittsburg to Antioch:

6—Booth Cannery Company........ Pittsburg
Canners of fish, fruit and vegetables.
7—Hickmott Cannery Company........ Pittsburg
Fish, fruit and vegetables.
8—Paraffine Company........ Pittsburg
Paper board.
9—Great Western Electro Chemical Company........ Pittsburg
Diversified heavy chemicals.
10—Redwood Manufacturing Company........ Pittsburg
Redwood pipes and tanks and other products of redwood.
11—Columbia Steel Company........ Pittsburg
Steel products.
12—Pioneer Rubber Company........ Pittsburg
General rubber products.
13—H. W. Johns-Manville Company........ Pittsburg
Magnesium and asbestos building specialties.
14—Santa Fe Railroad Company........ ——

Industries in Richmond and along the shores of San Pablo Bay are as follows:

Left Bank—Below Carquinez Straits: *Town*

1—California Cap Company........ Stege
Caps for detonating high explosives.
2—Stauffer Chemical Company........ Stege
Bulk chemicals from crude ores.
3—Metropolitan Match Company........ Stege
Matches.
4—Pullman Manufacturing Company........ Richmond
General shops, repairs and construction of cars.
5—Santa Fe Railroad Company........ Richmond
General shops, repairs and construction of cars.
6—Standard Sanitary Mfg. Company........ Richmond
Porcelain and enamel plumbing fixtures.
Distribution of other porcelain and enamel ware.
7—Certainteed Products Company........ Richmond
Roofing and paints.
8—Republic Steel Package Company........ Richmond
Metal containers, principally drums for oil and gasoline.

No comments

- n/a -

9—Standard Oil Company..........Richmond Point
Refining and shipping of petroleum products.
10—Philippine Refining Corporation..........Richmond Point
Refining copra and other vegetable oils.
11—California Wine Association..........Winehaven, Richmond Point
Formerly largest winery in world; industrial alcohol.
12—Giant Powder Company..........Giant
Dynamite and other explosives.
13—Hercules Powder Company..........Hercules
Dynamite, T.N.T. and other explosives.

The majority of these establishments along the Straits and Suisun Bay produce large outputs of material and are in the class ordinarily called "heavy" industries. They produce products essential to modern life both in peace and war times. Steel, iron, petroleum products of all kinds, chemicals, fertilizers, powder and fuse, leather, brick and tile, flour and feed, lumber and lumber products, ships and boats, sugar, fish and canned goods are produced in very large quantities.

A survey of the plants between Oleum and Antioch shows an annual production in 1927 of products valued at $250,000,000. The increase in annual output is large and the growth has been regular. The first large factory to establish in this territory was the Sugar Company in 1907. The period up to 1920 was an active one in growth, but since salt water troubles became so prominent only one new plant of large size has located here.

Freight in and out of this district by rail and water, directly attributable to these plants, approximated 14,000,000 tons in 1927. Three railroad systems serve the territory. Vessels, both river and ocean-going, handle much freight. Oil pipe lines from the fields in the San Joaquin Valley deliver oil to the refineries, to large tank farms for storage, and to vessels.

Expenditure for electric power by these industries was $800,000 in 1927. Electric power is furnished by the Pacific Gas and Electric Company and the Great Western Power Company. The use of power increases every year. Power rates are the same as in the Bay cities.

In 1927 these plants employed on an average of 8500 persons, the annual payroll amounting to $15,000,000. Comparatively little seasonal employment is found—most of the factories run fairly constantly through the year. The population dependent upon the factories, using a ratio of 4 to 1, is 34,000.

The industrial territory on San Pablo Bay below Oleum, in Contra Costa County, is nearly as large as the district described above. If the entire waterfront area in Contra Costa County is considered, we find the annual products to be $515,000,000; the number of employees to be 17,000; the annual payroll $29,000,000.

The industries between Oleum and Antioch now use 10,000,000 gallons of water a day. The annual increase is 10 per cent or a million gallons a day. All of this water is pumped from tide water level when there is fresh water in the stream, but some of the factories use wells during the salt water period. Draft upon the ground water is causing a change in the quality of many wells by drawing in salt water. There is a definite limit to the amount of water which may be drawn from underground sources, and it is apparent that this limit has been reached.

Factories engaged in the production of large quantities of "heavy" products ordinarily locate where fresh water is abundant and can be had at the cost of pumping. New plants seldom locate under any other conditions and when there is a

No comments

- n/a -

City of Antioch
Supporting Document
March 22, 2010

choice between localities, the one where water is abundant and cheap is selected, providing the other factors which control locations are the same. There is only one place on the coast of California where such conditions existed in the past—the upper bay and lower river country. Industries now located there expected to obtain water by pumping direct from tide levels, and the change brought about by the invasion of salt water has added to expense of operation and has discouraged increase in plants which involve increased use of water.

There is great need of restoration of the favorable conditions of fresh water which formerly existed in this region. New industrial establishments will be attracted by abundant fresh water. If California does not provide such facilities, northern cities will offer greater inducements and many industries will locate Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure, fresh water is abundant and may be had for the cost of pumping from permanent lakes or streams.

Rates for water in California cities are higher than in the north, as is shown in the following table:

COST OF 500,000 GALLONS OF WATER PER MONTH

San Francisco	$157.56
Oakland	161.71
Los Angeles	72.16
Stockton	54.50
Portland	44.11
Seattle	32.94

The recent disaster to Los Angeles' St. Francis Dam will probably result in an increase in water rates in that city. Proposals have been made to increase the base rate from 5 cents per 100 cubic feet to 18 cents. If this proposal is carried into effect, the rate for 500,000 gallons in the above table will be nearly $120.

Hardness of water is another factor in which northern cities have an advantage over the public supplies in California cities. Hardness is undesirable in water for either domestic or industrial uses—in some classes of industries hard water must be treated before use.

The comparison below will show the relative hardness of public water supplies of Pacific Coast cities:

HARDNESS IN CITY WATER SUPPLIES

Hardness as Calcium Carbonate, Parts Per Million.

(From Water Supply Paper 496)

	Maximum	Minimum	Average	
San Francisco	166	83		
Oakland			181	Reservoir and wells
Stockton			560	Wells.
Sacramento			60	River.
Los Angeles			163	Owens River.
			251	Los Angeles River.
Portland, Oregon	22	6	9	
Seattle, Washington	33	14	23	

No comments

- n/a -

The supply of Sacramento approximates the hardness of water that will be retained above a salt water barrier. The quality of water reservoired above the barrier will be better than any other city supply in California shown.

Hardness may be partly removed from water in modern purification plants. At Columbus, Ohio, water with average hardness of 272 parts per million was reduced to 97 parts at a cost of treatment of 2.45 cents per 1,000 gallons. (Proceedings of American Society of Civil Engineers, February, 1928.)

One of the needs of California today is a fresh water reservoir around which factories can be located with assurance of a permanent supply of pure water. Probably no single accomplishment in the construction program now under discussion will do more toward the general progress of the state. More factories mean greater population and more local markets for agricultural produce and amelioration of the general level of prosperity of the state.

A salt water barrier at San Pablo or Army Point will remove the obstacle now deterring the location of new industries in this region. It will remove the cause of added expense to the present plants and will encourage their more rapid growth.

Besides great quantities of water, large industries require cheap power, efficient transportation facilities, both by rail and water, and a good climate attractive to labor. The lower river and upper bay region lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

Shipping Interests. San Francisco Bay and the rivers drained through Carquinez Strait are used by boats engaged in river and bay traffic as well as ocean-going vessels. At the present time there is a large amount of river and bay traffic between Stockton, Sacramento and numerous delta landings and the cities around the bay. During parts of the year the river traffic extends beyond Sacramento and upstream from Stockton. Ocean-going vessels land at Carquinez Straits' points, Bay Point, Pittsburg and intermediate ports. Traffic by water is on the increase.

Tables 6, 7 and 8, in this report, give the tonnage and value of freight carried by water.

Projects for the improvement of navigation above Carquinez Strait have been approved by Congress and the work of acquiring rights-of-way in preparation for dredging is nearly completed. Two projects have been approved: First, the dredging of the channel through Suisun Bay to provide 26 feet of water for navigation purposes through this bay, and second, the Stockton deep channel which will provide 26 feet of water to Stockton.

Projects for deepening and regulating water depths for Sacramento River navigation are under consideration. A system of dams for controlling levels at low flow has been proposed, though not yet adopted by act of Congress. The present project provides 7 feet of water to Sacramento, 4 feet to Colusa, and with provision for 3 feet as far upstream as Chico Landing. Practical navigation upon the upper San Joaquin is now limited to the head of tide water, though if the project of the state for canalization of the San Joaquin under the "Coordinated Plan for Development of Water Resources" is carried out, navigation will be practical to points far above any places recently reached by boats.

Water transportation is available to all of the islands and reclaimed lands in the delta region, and nearly all of the agricultural produce grown in this country is shipped to market by boat.

Tides, currents and salt water phenomena in the upper bay and lower river region are important to shipping interests for several reasons: First and foremost

No comments

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is the fact that the presence of salt water has retarded growth and, if continued, will decrease the agricultural productivity of this region. Second, and no less important to shipping interests, is the fact that the industrial region along Suisun Bay and Carquinez Strait is held back in its natural growth by the menace of salt water. The water-carried tonnage in and out of this industrial area is large and is on the increase. The completion of the deep water channel will give a stimulus to commerce by water.

The natural result of a salt water barrier would be to increase very rapidly the industrial territory and there would be, in consequence, much more freight to be moved, a larger population to be served, and a tremendous increase in shipping. The effect will be noticeable on both bay and river boats and upon ocean-going traffic.

The plans for a salt water barrier provide for locks so that vessels may have uninterrupted access to the fresh water basin above the barrier. As discussed later, the Young report considers thoroughly the shipping business and the plans provide for locks of at least two sizes—one for small vessels and the second for large vessels. Locks are designed to provide for future increase in traffic, both in size and amount of traffic and depth of drafts.

Tides and currents now cause a loss of time to the shipping interests and necessitate special provisions and greater care in the handling of vessels, particularly in the rapid currents in the Carquinez Strait region. A barrier will provide for a constant water level above the structure except during periods of flood, which will reduce the currents to one direction only, and that downstream, and will facilitate the movement of vessels by reducing the time now consumed by bucking adverse currents. The ability to dock without currents is an additional value to ships.

It is generally agreed by navigation interests that there is some benefit in sea-going vessels docking in fresh water, in the destruction of growths of salt water which cling to the bottoms of the vessels and reduce their speed. Ocean-going shipping entering the fresh water basin above the barrier will have the benefit of this condition.

Sediment carried by the river waters into Suisun and San Pablo Bays adds to the difficulties of navigation and causes annual expenses in its removal. Debris from hydraulic mining is one of the principal sources of such hindrances to navigation. The rivers which enter Suisun Bay bring to salt water each year a portion of the debris deposited in stream channels in years of unrestricted mining. From the best information available, it is probable that the peak of movement of debris has passed out of the rivers and is moving through Suisun and San Pablo bays en route to the ocean.

What effect the salt water barrier will have on the movement is important from the standpoint of navigation interests. Studies which furnish information on the problem have been made several times in the past twenty-five years. The brief statement below discusses these investigations.

In 1906 the writer, then in the employ of the United States Reclamation Service, made a study of the sediment carried by many important streams in the West. The results are in part published in Water Supply Papers Nos. 274 and 237. The investigation had in part the determination of the amount of sediment carried in streams that might be lodged in storage reservoirs. At the time this study was undertaken, experimental work was carried on to determine methods of field and laboratory work. Sampling apparatus was designed and tested to permit the collection of samples at any depth. The use of this apparatus indicated that the problem

No comments

- n/a -

resolved itself into two phases—suspended silt and sand rolled along the bottom. The suspended silt was found to be very fine and to remain in suspension a long time. It is moved as the water moves and in the tidal portions of the stream remains in suspension during the tidal movements.

Samples collected daily during 1906, a 125 per cent runoff year with heavy floods, gave an average silt content (weighted for flow) of 64.5 parts per million by weight or, for silt weighing 80 pounds per cubic foot, 0.081 cubic yards per acre foot. In 1908, a 67 per cent runoff year, the average silt content was 85 parts per million by weight or 0.106 cubic yards per acre foot. The total suspended silt in 1906 was 2,300,000 cubic yards; in 1908 it was 1,550,000 cubic yards.

The greater part of this material continues in suspension until the bay is reached, where slow currents permit a part of it to drop to the bottom. Flocculation from salt water to some extent encourages the deposition.

A salt water barrier will have the effect of improving conditions as affected by the deposition of the suspended silt. Fresh water above the barrier will remove the effect of salt water flocculation above the structure and there will be a greater tendency for the silt to be carried lower than under present conditions. As it is now, the flocculation commences in Suisun Bay or at the first point where fresh water and salt water mix. Eighty per cent of the sediment is carried in the flood months, at times when the barrier gates will be opened and the current above the barrier is highest. In these periods the tendency will be for sediment to be carried through the barrier with less deposition in Suisun Bay than under natural conditions.

Below the barrier, where fresh and salt water mix, there will be the same tendency for deposition and flocculation that now exists, the only important difference being the decreased tidal movements due to the barrier. There is no reason to expect any great change in conditions from those now found. Sediment moves to a large extent in flood periods, so that any accumulations which are deposited in low flow periods or in years of light runoff are swept away in flood years. Fine sediment which enters the streams probably will not greatly change in amount in future years, as the fine materials originating in former hydraulic mining operations are on the decrease. Storage reservoirs on the headwaters will tend to trap sediment and further reduce the load that will arrive at tide waters. On the whole, the barrier will probably benefit rather than harm the navigation interests so far as it affects suspended silt.

Sand and coarse debris rolled along the stream bottom make up an important but unknown part of the total stream load of sediment. Estimates by the writer, made in 1905, indicated that the equivalent of from 10 to 20 per cent of the suspended load was carried along the bottom. In a recent study of silt in the Colorado River (U. S. Dept. of Agriculture Technical Bulletin No. 67), the estimate is made that in that stream 80 per cent of the silt is in suspension and 20 per cent carried as bed load. Though the actual quantity may be in doubt, there is no question but that the stream bed at Sacramento and below has been lowering in recent years—an indication that the burden of debris from the old hydraulic mines is decreasing.

Sand and gravel along the stream bed do not move at ordinary flows but only when the stream is in flood. The barrier, therefore, will have little or no retarding effect upon the movement of sediment carried along the bed, for in times of flood the flow in all practical consideration will be unobstructed and the downstream velocity will be practically the same as without the barrier. The bed load will move as it now does, or at least will move as it would do if the barrier were not present.

No comments

- n/a -

Structures in Water. The teredo and other varieties of marine life which destroy wood have been noticeably active in San Francisco Bay and adjoining waters since about 1914. Prior to that time all wharves, docks and other structures in water in the upper bay country were built of untreated piles and the lives of the structures were very long. About 1914 the teredo became active and in the dry years which followed 1917 practically all wood structures in water below Antioch were destroyed. The Marine Piling Committee estimates that $25,000,000 damage was done in this period. Of this sum several million dollars represent damages in the territory upstream from Richmond. Here the invasion of the teredo is encouraged on account of the encroachment of salt water. In earlier periods fresh water was present each year long enough to prevent wood-destroying animals establishing themselves.

Many of these structures have not yet been replaced. Those which have been replaced have been largely of creosote or other treated piling at an additional cost over untreated timber. No form of treatment gives permanent protection but reduces the activities of boring animals and lengthens the life of timber.

The cost of structures built of timber is, therefore, greatly increased over what it was prior to the invasion of salt water in the upper bay. Where concrete is used an additional increase in cost also occurs, for concrete to be placed in sea water has to be of much better quality than concrete suitable for fresh water conditions. The ordinary mix of concrete for sea water contains approximately two-thirds of a barrel of cement per cubic yard in excess of that considered good quality for fresh water conditions. On this account alone concrete work costs at least $2.00 a yard more, due to the salt water invasion.

Under the present conditions, all future structures to be erected in this region must be built to resist teredo and other boring animals and salt water. The increased cost of wharves, docks, bulkheads, and all similar structures in water, will approximate 20 to 25 per cent more than if fresh water were present. The construction of a barrier to prevent the encroachment of salt water will greatly simplify such construction work and will reduce the cost under present conditions.

Corrosion of Pumps, Piping and Equipment from Salt Water. Steel and iron are corroded more rapidly in brackish or salt water than in fresh water. Experiments indicate that unpainted steel or iron lasts from two to ten times as long in fresh water as in brackish or salt water. This means that all gates, pipes, pumps and other parts of structures in water, or in industrial establishments where water is used, must be painted frequently or they will corrode more rapidly, require more frequent replacement, and cost more to operate than where fresh water is present. In the large industries, such as oil refineries, steel mills and plants where large amounts of cooling water are used, this becomes a very important factor.

Accurate estimates of the cost of salt water due to corrosion alone are difficult to make. Mr. C. W. Schedler, of the Great Western Electro Chemical Company of Pittsburg, California, estimates that there is a minimum of three million dollars' worth of equipment located in the plants between Crockett and Antioch being seriously depreciated by the presence of salt water. The normal life of this equipment is twenty years, or a depreciation of $150,000 a year. Mr. Schedler estimates that the salt water conditions of 1924 caused a depreciation twice as fast as ordinarily. The loss between Crockett and Antioch in that year is a cash loss of $150,000.

Conditions nearly as bad as 1924, so far as these industries are concerned, occurred in 1920 and again in 1926, and in each of the years between there is some

No comments

- n/a -

increase in corrosion from salt water. Conditions in the future offer little promise of improvement, and the probability is that unless a barrier is constructed the present industrial plants alone, without consideration of future extensions or new plants, will suffer an annual loss from salt water in excess of that experienced in the past.

Estimates by the writer in the territory from Oleum to Antioch, on both sides of the channel, indicate a loss from salt water corrosion in excess of that made by Mr. Schedler. The writer is of the opinion that the average annual loss approximates $300,000 a year in the plants now operating.

Railroads. The natural and most feasible direction of travel north to south is across Carquinez Strait for both vehicular and rail traffic. At the present time all railroad transportation is handled by boats. Four lines of boats carry freight and passengers across this waterway. A year ago the first bridge was built—that across Carquinez Strait—for vehicular traffic only.

The Southern Pacific Company, the greatest railroad system in California, has studied a plan of bridging Carquinez Strait for many years. It is understood that a more active study of this problem is now going on than in any time in the past, and that prospects are good for the railroad to carry out such a development.

The San Francisco-Sacramento Railroad, which crosses the channel near the upper end of Suisun Bay, at one time acquired a permit to build a bridge at this point. The traffic carried by the company did not warrant such a heavy expenditure at that time, but recently the control of this road has been acquired by the Western Pacific Railroad Company, and it is likely that a large development of this transportation company will take place in the near future.

Any barrier built to hold back tide water can be easily arranged to act as a bridge for rail and vehicular traffic. In the Young report, a part of which is quoted later, estimates of the cost of providing such a barrier with a bridge are given.

Two applications have been recently filed with the County Board of Supervisors of Contra Costa County for a bridge permit across the bay region in the neighborhood of Richmond, the estimated costs being from $9,000,000 to nearly $20,000,000.

Should the barrier be built at San Pablo Point, it can serve there all present and probably future transportation needs. A barrier in Carquinez Straits, either at Army Point or Dillon Point, will be available for rail transportation and when the present bridge facilities are outgrown it may be used for vehicular traffic.

Mr. Herbert Benjamin, of the Southern Pacific Company, stated before the Joint Legislative Committee on April 16, 1928, that his company had made plans for a bridge between Bulls Head and Army Point, and that the cost, including approaches, was estimated to be less than $10,000,000. The bridge was designed to give clearance of 70 feet. Application for permit had not been formally made to the War Department.

The site selected for this bridge is one of the sites investigated by Young, and any bridge built for the railroad would prevent its use as a site for a salt water barrier. It is highly advisable that full consideration be given of the barrier problem before any bridge permit is let for this location. The barrier can be made to serve as a bridge and the advantages of the double use are apparent. If the barrier is built to accommodate both rail and vehicular traffic and a proper allowance made for this service, the net cost to other interests can be lowered. This phase of the question is discussed later in this report.

Ferries. The ferry from Benicia to Port Costa, now operated to care for

No comments

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vehicles, could be replaced by a barrier at Army Point or Dillon Point. The ferry now operating from Richmond to Point San Quentin could readily be replaced by a barrier at San Pablo Point. This slow method of crossing the water barrier can be replaced by a modern bridge, with little delay in traffic and with cost not greater than the present ferry charges. The automobile registration in California is on the increase and travel across the straits will be greatly stimulated by a bridge. There is no certain method of determining this quantity.

Local Shipping. The tonnage and value of local shipping on the Sacramento and San Joaquin rivers are given in attached tables. It will be seen that there has been a nearly constant increase in freight, except during the period of, and following, the World War. At present 2,100,000 tons of a value of $140,000,000 are carried yearly.

The increase in shipping which will follow the construction of a barrier against salt water will benefit local shipping. As shown elsewhere, the advantages of the barrier will offset the disadvantages, and on the whole greatly benefit shipping.

Ocean-borne Traffic. Ocean-borne traffic is varied, though lumber and petroleum products make up the greater part of the business. The tables attached show the volume of business in Suisun Bay to be about 2½ million tons, valued at over $40,000,000; for Carquinez Straits 4 to 5 million tons valued at $100,000,000 to $150,000,000; San Pablo Bay 4 million tons valued at over $60,000,000.

Increases in ocean-borne traffic will follow the building of a barrier and completion of a deep water channel to Stockton. The stimulation to industrial production will greatly increase traffic for all classes of vessels. Ocean shipping will benefit by the ability to dock in fresh water without the menace now caused by tidal currents. Fresh water tends to cleanse ocean vessels of growths which retard movement.

The menace to shipping in passing through locks is so small that no additional insurance is charged to vessels which use locks. The safeguards to navigation, now provided around locks, greatly reduce the danger in using them. Periods of fog are the times of greatest difficulty. The removal of ferry traffic across the straits at Benicia will probably offset the dangers due to navigating through locks in foggy weather.

SOLUTIONS OF THE SALT WATER PROBLEM

Several solutions of the salt water problems may be suggested:

1. Salt water barrier.
2. Storage and release.
3. Fresh water brought in by conduits or pipes.

The first is the only complete and the most satisfactory method of solving the problem. The Young report best describes the barrier and its effects upon the territory.

The Young Report. Mr. Walker R. Young, Construction Engineer, U. S. Bureau of Reclamation, has written a "Report on Salt Water Barrier—California, Below the Confluence of Sacramento and San Joaquin Rivers." This report is dated August 27, 1927, and was made by the U. S. Bureau of Reclamation in cooperation with the California State Department of Public Works, Division of Engineering and Irrigation, and Sacramento Development Association.

The report consists of a volume of 405 pages of discussion and descriptive

No comments

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matter, a volume of 592 pages of exhibits and tabulations, a portfolio volume of drawings and diagrams, and three volumes giving records of borings at various sites. The work described in these volumes extended over a period in excess of three years, or from January, 1924, to the date of completion.

A large amount of field work was done as a basis for office studies. The investigations include all problems that affect the construction or operation of the structure.

In his report Mr. Young describes in detail the various investigations he has made concerning the salt water problem. He presents sixteen preliminary designs and estimates with three alternatives "in order that they may be readily available in the economic study which is considered necessary in the final determination of the feasibility of the barrier." He made "no attempt to study the economic aspect of the problem other than to enumerate the advantages and disadvantages, as such a study was not considered within the scope of this (his) report." The report, therefore, is an engineering study of the barrier so far as concerns its physical feasibility.

The report determines what kind of a barrier should be built to accomplish its purpose, and presents a large amount of data to show its bearing upon various activities which will be affected by it. Four sites were investigated and the merits and objections to each are set forth in detail, but no final recommendation as to a site is made.

The following quotation from this report gives in condensed form the essentials included therein:

"SUMMARY OF RESULTS

"*General*. The studies made lead to the conclusion that it is physically feasible to construct a salt water barrier at any one of the sites investigated, but at great expense; and that it will be effective in controlling the salinity of the reservoir impounded above it. Not only will it protect the delta and industrial plants along the shores of the bays, but its construction will result in the conservation of a large part of the fresh water required to act as a natural barrier against invasion of water under present conditions.

"Without the barrier, salinity conditions will become more acute unless mountain storage is provided to be released during periods of low river discharge to act as a natural barrier against invasion of salt water. The amount estimated as necessary to act as a natural barrier was in excess of the flow in the Sacramento River above Red Bluff in 1924, and Red Bluff is located above the points of diversion of water used in irrigating the Sacramento Valley.

"The sites selected for development by drilling are considered geologically satisfactory for the type of structure proposed. Although preliminary designs and estimates are presented for four sites, there are only two general plans involved. A barrier, if constructed at the Army Point, Benicia, or Dillon Point site, would create a body of fresh water in Suisun Bay and in the delta channels, while a barrier at the Point San Pablo site would include San Pablo Bay as well.

"*Type of Dam Proposed*. The type of structure to which principal consideration is given is one in which the ship locks and flood gates are located at one side upon rock foundations, the closure of the present waterway being effected by means of an earth and rock fill dam to be brought up to its designed

No comments

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height after completion of the ship locks and flood gate structure. In another type studied the flood gates form the closure between concrete piers sunk to bed rock foundations in the present waterway by the open caisson method. Both types have been designed with and without provision for carrying a railroad and highway.

"The passage of floods is probably the most important problem since it involves the safety of the delta levee system. It would be desirable, if practicable, to provide gate area equivalent to, or slightly in excess of, the present waterway area in order that conditions of flow might remain unchanged, but the accomplishment of this plan would be very costly, if not altogether infeasible.

"In the design of the structure, advantage is taken of the difference in the elevation of water surface which it is possible to create above and below the barrier to discharge flood water. On account of the fluctuating head, resulting from tides on the downstream side, the discharge through the flood gates will vary from a maximum at low tide to a minimum at high tide. The reservoir above the barrier, therefore, will function as a basin in which the river discharge in excess of the flow through the flood gates at high tide is stored to be discharged at a rate in excess of the river discharge during low tide.

"The flood gates are of the Stoney roller type with sills depressed to 50 or 70 feet below sea level in order better to control the salinity of the water behind the barrier as explained in Chapter IX. In operation, the gates would be raised clear of the water surface as required to allow free passage of the floods. As the flood receded the gates would be lowered, one at a time, as necessary to maintain the water surface above the barrier at any predetermined elevation.

"The requirements for passing vessels through the barrier is an important consideration irrespective of where it might be located, but particularly, if located below Mare Island Navy Yard. In the designs proposed, ship locks have been provided in number to care for considerable growth in water-borne commerce, and in size to pass the largest ships likely to navigate the waters above the barrier.

"In some of the designs for the Army Point site, the ship locks would be constructed away from the flood gates, which, of course, would be advantageous for shipping during the passage of great floods from the rivers, but these are rare and considerable study would be required before it could be determined whether the advantage thus gained would offset the advantage of having the large salt water sump adjacent to the ship locks where the salt water entering the fresh water reservoir through the locks could be caught and returned to the salt water side. It is possible that the design with the ship locks and flood gates separated would be even more efficient in controlling salinity, but this is doubtful. The plan at the Army Point site in which the structures are separated interferes least with the plant of the Mountain Copper Company and results in economy otherwise.

"In the designs including a railroad and highway bridge across the locks these have been placed at an elevation to permit a large proportion of vessels using the locks to pass underneath without opening or lifting the bridges. In one design at the Dillon Point site, the clearance is made sufficient to pass

No comments

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"It is probable that the rise in water surface at Collinsville, due to a barrier at the Point San Pablo site with equivalent gate area, would be less than if located at the Army Point site, but it would not be safe to reduce the gate area at Point San Pablo for the reason that extreme tides through the Golden Gate are more effective near the gate as evidenced by the fact that the tide of November 18, 1918, at Presidio, was 0.7 feet higher than that of January 25, 1914, at which time the maximum elevation of water surface at Suisun City was reached.

"At the Army Point and Dillon Point sites the ship locks are considered effective in passing extremely large floods but they are not considered available at the Point San Pablo site because of the greater necessity for keeping the locks open to navigation at that site, even during great floods.

"The effect of a barrier at the Army Point site would be to reduce the tidal volume passing the Golden Gate by less than 8% in comparison with about 35% if it were built at the Point San Pablo site. The occurrence of frequent high tides in the bays due to piling up of water in them as a result of storms on the ocean would be to eliminate through construction of a barrier at any one of the sites investigated. The effect on the elevations of tides below the structure would be to raise them slightly according to the U. S. Coast & Geodetic Survey.

"*Navigation and Bridge Traffic.* Any plan for the control of salinity involving the construction of a dam across the bay or river channels must be coordinated with the requirements of navigation.

"Ship locks are provided in number and size to meet the requirements of the present and immediate future. Provision for ultimate traffic at the time the barrier is constructed does not seem necessary since flood control on the upper rivers will improve to permit the replacement of flood gates by ship locks as the need for them develops. A summary of the operation as it would have occurred on July 6 and 7, 1925, is shown in Table 6-33.

"Although railroad and highway bridges are contemplated in most of the designs they are not regarded as indispensable and are omitted in some in anticipation of indifference on the part of railroad and highway interests toward the opportunities afforded by the barrier. In the studies made it is considered that traffic over them is subject at all times to the convenience to navigation. The bridges are designed to give a vertical channel of 50 feet above high water when in the lowered position and 135 feet when raised. The interruptions to bridge traffic, as they would have been on July 6 and 7, 1925, are summarized in Table 6-40.

"An examination of Plates 2-3 and 2-4, showing depths in San Pablo and Suisun Bays, will indicate the limitations placed upon commerce under present tidal conditions. If the elevation of the water surface above the barrier were maintained at about 2½ feet above mean sea level, a constant depth equivalent to that at mean high tide under present conditions, would be obtained. Uncertain and varying tidal currents would be eliminated above the barrier and they would be reduced in velocity below. The maintenance of a permanent water level would not only be convenient for navigators but would be a material benefit to owners of wharf property above the barrier.

"The farther downstream the barrier is located the more it will interfere with shipping. Locking requirements can be satisfied with least expense at the Army Point site and conditions are most unfavorable at the Point San Pablo site.

No comments

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"The construction of a barrier at the Point San Pablo site probably would be looked upon with disfavor by the Navy Department for the reason that it would restrict free navigation through San Pablo Bay to the Mare Island Navy Yard by the necessity of passing war vessels through ship locks. This objection does not apply to the Dillon Point, Benicia or Army Point sites.

"*Storage in the Delta Channels and Bays.* For convenience the calculated storage in the tidal prism above each barrier site, between elevations —3.6 and +6.4 U. S. G. S. Datum (0 and 10, U. S. Engineer Datum) has been summarized in Table 7-2, Volume II.

"*Silt.* The problem has been attacked with the idea that any structure that would be detrimental to San Francisco Harbor would be looked upon with disfavor by those in jurisdiction. The investigation has not definitely determined the effect of a barrier upon silting. Conclusions must, therefore, take the form of conjecture until studies more comprehensive than it was possible to make in this investigation have been completed.

"The construction of a barrier at any one of the sites investigated may possibly have a beneficial effect upon the Golden Gate bar rather than detrimental. The movement of silt toward San Francisco Bay will be checked by the construction of a barrier at Army Point, Benicia, or Dillon Point. A beneficial effect upon the Pinole Shoal will result through the construction of a barrier at Army Point or Point San Pablo. The effect upon Pinole Shoal of a barrier at Dillon Point is at present indeterminate, as is also the effect on silting in San Francisco Bay of a barrier at Point San Pablo.

"Whether the scouring action of the tidal current tends to maintain or destroy fixed channels in the bay system remains to be determined. Should shoaling occur it will be comparatively small in amount and the channels can readily be maintained by dredging, perhaps with less effort and expense than without the barrier. Dredged material pumped into the marshes would build them up and improve their fertility.

"*Salinity.* In years of normal river discharge there is no salinity problem in the delta. It is menacing for a few days in the fall only but, considering the marshes surrounding the upper bays and the towns and industrial plants along their shores, the encroachment of salt water presents a serious problem almost every year.

"Conflict between irrigation interests in the upper valleys and in the delta region never will occur in years of large run-off for the reason that in the development of storage the construction of expensive reservoirs to hold the excessive run-off from the drainage area, occurring only once in a number of years, will not be practicable even though sufficient reservoir sites in which to store all of the run-off were available.

"The introduction of salt water into the fresh water lake through the ship locks can not be prevented but means are provided for drawing off this salt water and thereby controlling the salinity of the water up-stream from the barrier.

"Leakage of salt water past the flood gates, although comparatively small in amount, can be prevented by maintaining the water surface above the barrier at a higher elevation than below.

"Deep gates, opening from the bottom, are essential to the successful operation of the barrier for dependence is placed upon them as a means of drawing

No comments

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off the heavier salt water which seeks the deep holes and channels, and for flushing out the reservoir above the barrier.

"Unless fresh water is available for occasional flushing, the reservoir above the barrier will gradually become salty. Flushing can be accomplished quite readily if water is available for that purpose. The studies of water supply, although based on meager data, indicate that in normal years there will be from eleven to twelve million acre feet available for that purpose. In years of deficient water supply there will be little, if any, fresh water available for flushing and the reservoir above the barrier may have to hold over one or more years without flushing.

"*Return Flow.* Return flow will increase with irrigation development in the upper valleys with the result that the salt menace in the delta will be alleviated; but, even though the return flow should increase to the 3500 second feet estimated to be sufficient to act as a natural barrier against encroachment of salt water, the demand for water will be such that it could not be used for that purpose unless it is replaced by water from mountain storage.

"*Control of Salinity by Storage in Mountain Reservoirs.* Salinity in the delta can be controlled through construction of storage reservoirs in the mountains from which water could be released during the season of low river discharge in the amount necessary to act as a natural barrier against invasions of salt water. Mountain storage would be a temporary expedient for the reason that, ultimately, there will be use for all of the available flow from the rivers, and the discharge into Suisun Bay and thence to the ocean, of water sufficient to act as a natural barrier against salt, would be an economic waste. However, storage created in mountain reservoirs constructed mainly for other purposes might be used for some time to control the salinity in the upper bays and delta channels during development of the requirement for full use of the reservoirs for the purpose for which they were primarily constructed, thus deferring the large investment in the salt water barrier.

"*Teredo.* The factor of salinity is one of fundamental importance in the distribution of teredo. The average lethal salinity for teredo navalis, the species to be feared most in the upper bays, has been determined experimentally as 5 parts per 1000; therefore, if the water above the barrier is maintained at a concentration below the limit for irrigation use teredo can not exist there.

"*Fish.* Fishing industries above the barrier, if constructed, should not suffer for the reason that, even though the fish ladder, which is an integral part of the structure, should fail to function, the fish would not be prevented from entering the fresh water reservoir because they would have free access to it through the ship locks which, under normal conditions, would be operated many times throughout each day and night.

"*Sewage.* No investigation was made of the effect of the barrier upon sewage, but from investigations made elsewhere it appears that fresh water will be better adapted for receiving sewage than either salt or brackish water since, gallon for gallon, fresh water disposed in a normal manner of more sewage than salt water. It will be best, in this respect, to keep the water above the barrier fresh because the intermittent admission of salt water interferes with bacterial, animal and vegetable growths that effectively aid in taking care of and digesting sewage.

"*Use of Water in Operation of the Barrier.* The seven main sources of

No comments

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loss of fresh water accompanying the operation of the barrier are evaporation from the water surface of the reservoir created; water required for the operation of the ship locks; leakage around the flood gates; water used in operating the fish ladder; and water to supply the requirements of industries, municipalities and possibly irrigation. With the exception of losses past the flood gates and through the fish ladder, which are constant for the same type of structure, the losses increase as the barrier is moved downstream and this factor has an important bearing upon the selection of a site.

"Owing to the increasing difficulty of maintaining the reservoir created by the barrier free from salt water as the water surface is permitted to fall, and because of navigation requirements, it probably will not be advisable to allow the water surface to fall below mean sea level. Likewise, because of the nature of the delta levees and the cost of drainage in that region by pumping, the ultimate maximum allowable water surface for periods of several months' duration may be fixed at 4.0 feet above mean sea level, although later developments may show that this maximum storage level can be increased to 5.0 feet.

"It is not necessary to decide at this time at what elevation the water surface above the barrier should be maintained. To begin with, it should be held at, or a little below, ordinary high tide level. As time goes on the elevation may be raised as experience dictates.

"Water drawn from the fresh water lake for irrigation, domestic and industrial uses, as well as that required in the operation of the ship locks, should be replenished from river flow or mountain storage with the idea of maintaining a constant depth of water for the navigable waterways effected by construction of the barrier. In years of extreme low run-off the water surface could be drawn down to the elevation of mean sea level, or possibly, in an emergency, to the elevation of mean lower water.

"As the water surface behind the barrier is lowered, the cost of maintaining the Delta levee—not considering floods—should become less; the cost of pumping water out of the lake for any use becomes greater; the cost of pumping seepage water would become less; the difficulties of keeping the lake fresh would increase; and the depth of navigable channels affected would become less.

"Ship locks are provided in various sizes in order to economize on the use of fresh water and to prevent entrance into the fresh water lake of larger volumes of salt water than necessary by requiring vessels to use the smallest lock which will accommodate them. Intermediate lock gates are added for the same reason.

"Economy in the use of fresh water in the operation of the ship locks can be effected through the adoption of lock gates divided horizontally at a depth to allow a large portion of the vessels having a shallow craft to pass through the locks without opening the lower half of the gates and it is assumed that this type of construction will be adopted. It is estimated that the resulting annual saving of fresh water, based on an average daily traffic as it was on July 6-7, 1925, would be:

Army Point Site	173,000	Acre Feet
Dillon Point Site	146,000	" "
Point San Pablo Site	295,000	" "

it being assumed that the water surface above the barrier would be maintained at an elevation 2½ feet above mean sea level.

No comments

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City of Antioch
Supporting Document
March 22, 2010

"It will be necessary to flush the reservoir, preferably once each year, to rid it of accumulations of brackish water resulting, principally, through the inability to trap all of the salt water finding its way into the fresh water reservoir from one source or another. The amount of fresh water required cannot be predicted with any degree of accuracy but a study was made of the amount of fresh water available for the operation of the barrier, based upon the assumption that storage in the mountains was well developed. The study is based upon meager data but the results are believed to be indicative.

"From Table 10-13, it is evident that if the maximum height of water surface in the reservoir is restricted to 2½ feet above mean sea level, the water stored in the reservoir thus formed will not be sufficient to operate the barrier at any of the three sites studied during the irrigation season, even in years of heavy run-off, and it will be desirable, therefore, to seek the highest practicable elevation at which to maintain the storage level.

"The shortage due to lack of reservoir capacity increases as the barrier is moved downstream, although the capacity of the reservoir is greater. This is principally due to the greater evaporation, and to the larger requirements of navigation, industries and municipalities.

"As the storage elevation above the barrier is raised the amount of water available for flushing in years of low run-off is decreased. According to Table 10-13, no water would be available in the season 1923-24 for flushing out the reservoir created through construction of a barrier at the Point San Pablo site whether water were impounded to elevation +2.5, +4.0 or +5.0. It appears that, in any case, there would be no flushing water available in 1923-24 if water were stored to elevation +5.0, although in a normal year there would be a large amount available for flushing, regardless of where the barrier is constructed or of the elevation at which the water surface above the barrier is maintained.

"If the above analysis is correct, it may be concluded that since one of the principal objects of the salt water barrier is to conserve fresh water, it will be desirable to maintain the largest practicable storage capacity above the structure. Likewise, it is evident that the farther downstream the location for the barrier is chosen the greater will be the quantity of water required for operation, and the greater will be the shortage during seasons of low run-off. Since the shortage must be supplied from mountain storage in order to maintain sufficient depth for navigation, and to hold the water level at an elevation where the reservoir will not be deluged with salt water whenever the ship locks are opened, it is apparent that consideration of the necessity for conservation of water would require the selection of one of the upstream sites—Army Point, Dillon Point or Benicia, if the latter, upon investigation, is found to be suitable structurally."

Discussion of Young's Report. The summary just given of Young's report gives his main engineering conclusions. As will be seen, the engineering conclusions are as follows:

1. The construction of a salt water barrier is feasible at either San Pablo Point or at one of three sites near the upper end of Carquinez Strait.
2. The barrier can be utilized for both rail and automobile traffic.
3. The cost will depend upon the method of construction. A barrier can be built at Army Point with bridge of 50-foot clearance for $49,800,000;

No comments

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at Benicia for $46,200,000; at Dillon Point for $44,700,000; at Point San Pablo for $75,200,000.

4. The barrier will pass a flood of 750,000 second feet (larger than any flood measured into Suisun Bay) with an estimated raising of water surface of 0.7 of a foot at the barrier, at Army Point, and about 0.55 of a foot at Collinsville. Water levels in the delta under extreme conditions are estimated to be below elevations of high water computed by Flood Control Engineer of the state. With a barrier at Point San Pablo, the raise in water level would be slightly less than at Army Point.
5. The barrier would effectively handle both water transportation through locks and bridge transportation.
6. The barrier would store fresh water and prevent the encroachment of salinity now taking place every summer.
7. The barrier will prevent teredo from working above its location.
8. The barrier can be operated so as not to be a detriment to the fishing industry.
9. The elevation at which water is maintained above the barrier in summer has not been determined. To begin with it should be held a little below ordinary high tide. This point is discussed in more detail in the following pages.
10. Young makes no determination of the economic features of the barrier, nor does he recommend a site.

Two things in connection with Young's conclusions may be given further consideration: first, that return seepage will increase in quantity and ameliorate conditions in the delta, and, second, that water from the Sacramento river may be temporarily carried across the delta for use in the San Joaquin valley by releasing stored water and without the construction of the salt water barrier.

With reference to the first matter, it has been shown that return seepage in the San Joaquin Valley is being recaptured by the pumping plants on the west side of the valley and there is now no benefit from the return seepage to delta lands in late summer. There is no prospect for increase in return flow, in fact the increase in pumping from wells all over the valley and new pumps along the river will decrease that flow.

In the Sacramento valley similar conditions prevail. It is not certain that return seepage on this stream has reached a maximum, because a large area of land close to the river is not yet regularly irrigated. When this land becomes more intensively farmed, it is to be expected that it will utilize to a great extent this very return water and decrease the net amount which reaches the tidal waters. Return flow, therefore, cannot be depended upon, in either river, to improve salt water conditions in the delta.

As to the second matter, it may be said that so long as the tide ebbs and flows there will be the opportunity for salt water to penetrate the delta, just as far or farther than was the case in dry years since 1917. In 1920, 1924 and 1926, salt water went beyond Three Mile Slough, the principal connection between the Sacramento and the San Joaquin deltas. If water were drawn up the San Joaquin, there would be a greater tendency for salt water to penetrate the delta and be drawn southward. It should be remembered, too, that in dry years released water from storage reservoirs is going to be very difficult to deliver past the large areas of riparian

No comments

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lands. The flow of the rivers will undoubtedly be so low that tides will carry salt water beyond Three Mile Slough. Certainly no dependence can be placed upon this method of carrying water across the delta. The barrier is essential to prevent tidal movements and the encroachments of salt water.

ELEVATION OF WATER ABOVE BARRIER

Objection, from owners of delta land, has been raised to the proposal by Young that levels above the barrier might eventually be raised above mean high tide in order that more water might be stored for use by the towns, irrigated area and industries around the lake above the barrier.

Mr. G. A. Atherton, who is probably as thoroughly acquainted with the delta region as any other person, is authority for the statement that a level of 6.0 feet U. S. E. D. (or 2.4 U. S. G. S.) continuously maintained in summer months is as high as can be safely held against the delta levees under present conditions. According to him, to carry water higher would endanger the levees, would increase seepage and pumping, and therefore add greater maintenance cost to the delta land owner. It should be understood that Mr. Atherton has reference to the delta lands where peat predominates.

The answer to this argument is that the delta lands will be surrounded by salt water unless the barrier is built, but the barrier can, and should, be operated so as to do no damage to these peat areas.

There is some uncertainty as to the exact difference between the datum of the two surveys (U. S. G. S. and U. S. E. D.) and the level of tide as indicated by tide tables. U. S. G. S. elevations refer to mean sea level and are based upon a number of years of observation. U. S. E. D. levels are based theoretically upon mean lower low water but practically are taken as 3.6 feet lower than the U. S. G. S. levels. Tide gage levels are theoretically based upon mean lower low water but practically are referred to the elevation of a point on the Presidio tide gage staff in San Francisco. As near as can be determined, the U. S. E. D. and tide table datum planes are not the same, but the U. S. E. D. datum is about 0.63 feet lower. This figure is not exact, however, and for practical purposes it may be assumed that the two are the same. In the delta region the tidal range varies more in different parts of the delta than this variation between the two systems of measurement.

If water is held at 6.0 U. S. E. D., it will be at less than high tide in the central delta. Here the tide rises to over 7.0 feet two or three times a year, and in times of southwest storms it has risen to over 8.0. In 1907, during the flood, the elevation exceeded 10.3. With water held at 6.0 there will be no menace to levees and comparatively little increase in pumping out of seepage water. Furthermore, this elevation will permit the efficient operation of the barrier, for salt water is higher than 6.0 at the Golden Gate less than one per cent of the time, excluding storm and flood periods.

Any increase in height should be made only if it can be done without menace to the island levees. In storm periods water will be held lower than would naturally occur except in the most extreme floods. Reservoirs which have been constructed on nearly all tributaries of the Sacramento and San Joaquin rivers will undoubtedly have the effect of reducing the peaks of floods, and there is little likelihood of a repetition of the extremes experienced in 1907, at least such extremes will occur less frequently.

On the whole, the delta lands will be better off with the barrier than without

No comments

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it. The one factor of slightly increased pumping with the summer level held at 6.0 will be more than overbalanced by the freedom from the present menace of salt water.

SELECTION OF SITE FOR BARRIER

Mr. Young in his report sets forth the conditions surrounding the locations investigated as sites for the barrier. The following statement compares the two locations—the three sites investigated near the upper end of Carquinez Strait being treated as one:

Water Supply: Tables attached give the estimated quantities of water required for all uses above the barrier. The quantities here given are estimated uses when all area above the barrier is developed and are liberal figures, with an allowance for flushing to remove salt water let in by ship locks and leakage. The figures show that under these conditions the requirements for the full year are:

Point San Pablo	2,024,000	Acre Feet
Army Point	1,160,000	" "
Difference	864,000	" "

For the irrigation period May to September, inclusive, the requirements are:

Point San Pablo	1,236,000	Acre Feet
Army Point	638,000	" "
Difference	598,000	" "

The large difference comes principally from the quantity of water required to operate locks and the increased evaporation in the lower site. In other words, from six to eight hundred thousand acre feet are required to supply the additional unavoidable losses from evaporation and ship lockages in San Pablo Bay.

In the matter of cost, Young's estimates show for a barrier with 50 feet of clearance the following:

Point San Pablo	$75,200,000
Army Point	49,800,000
Difference	$25,400,000

The convenience to other interests is of great importance. The Mare Island Navy Yard is located above Point San Pablo but below Carquinez Strait, naval officers will object to the barrier. On account of the greater number of vessels which pass San Pablo than through the upper end of Carquinez Strait, there will be less objection to the upper site.

Barriers at both sites will serve as bridges. The San Pablo location will replace a ferry now in operation—the upper site in Carquinez Strait will serve both for rail and vehicular traffic and will replace two ferries.

The opportunity to combine the barrier with the Southern Pacific Railroad at Port Costa should not be overlooked. The Railroad Company is contemplating the construction of a bridge to replace the present ferry. If the Army Point-Suisun Point site is selected by the railroad, the barrier can not be built on this site. In some respects this is the most attractive site and until final determination is made of the location, no permit should be given for a bridge across this place.

No comments

- n/a -

STORAGE AND RELEASE TO CONTROL SALT WATER

This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands. Emmaton on the Sacramento and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of the Sacramento at Sacramento and San Joaquin at Vernalis (both points about the head of tide water in late summer) must exceed the following figures:

For control at	Cubic Feet Per Second
Emmaton and Jersey Island	3500
Antioch	5000
Collinsville	5500
O. & A. Ferry	6000

These quantities will depend to some extent upon the months preceding the period when control is desired and will, of course, vary with the diversions below the points of measurement. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the Oakland & Antioch Ferry and 370,000 at Emmaton and Jersey. In 1926 over 500,000 acre feet would have been required at the Oakland & Antioch Ferry and 200,000 acre feet at Emmaton and Jersey. Storage in large amount would be needed about half the years at Emmaton and Jersey and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys do not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year. Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to the greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent, except through litigation, the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per

No comments

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second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean.

As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of some interest:

Kennett reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13, Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights of way is $55,000,000; of power plant $25,000,000; a total of $80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920, 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bulletin 13 of Department of Public Works.) The recommended capacity is 1,121,900 acre feet; the estimated cost of dam and power plant is estimated as $26,000,000; the canal system to utilize this water is estimated at $30,-000,000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

> "Sacrificing the power features at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lancha Plana Reservoir practically eliminate this reservoir from consideration.

In connection with the proposal for storage and release of water, it should be

No comments

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remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

WATER FROM OUTSIDE SOURCES

Water may be brought in from outside sources to supply the towns and industries along the Straits and Suisun Bay. It is not likely that the agricultural lands can be reclaimed by any outside source of water on account of the high cost. But for the uses of towns and factories it is possible to secure outside water.

Under present conditions water cannot be drawn at any point on tide water without either running the risk of getting salt water or of interfering with rights already vested. It may be possible to pump during the fresh water period into reservoirs and to pipe the water thus stored along the waterfront, supplying both domestic and industrial consumers. Reservoirs of good size are available in the Montezuma hills north of Suisun Bay and a few small reservoirs are found on the south side of the bay. No estimate has been made of the cost of this method. Surveys beyond the scope of this report would be required. It is known that the cost would be large, though cheaper than any other known source.

Other possible outside sources are:

Eel River—a supply which has been suggested for both San Francisco and East Bay cities. The distance to Carquinez Strait is 125 miles. Harroun estimates the cost at $22,000,000 to carry 50,000,000 gallons daily to south sides of Carquinez Straits.

Conn Valley—a small tributary to Napa River with probable yield of 10,000,000 gallons daily. Cost not known but the supply would only furnish a part of present needs and would provide nothing for future growth.

Putah Creek—a tributary of Sacramento north of Dixon. Cost not known. About 50 miles north of Suisun Bay. Complicated with riparian claims. All storage at considerable distance in mountains.

Mokelumne or Cosumnes—draining Sierras north of Stockton. Cost unknown. Early rights conflicting. About 75 miles distant.

Pumped water from San Joaquin Valley—It has been suggested that the irrigation districts in the San Joaquin Valley could deliver pumped drainage water into the river to be pumped out above salt water limit and delivered to industries and towns along the bay through pipe lines.

East Bay Municipal Utility District—The main pipe line of this district parallels the bay shore from Antioch to Bay Point. To secure water from it the area must enter the district. The district has voted $64,000,000 to complete a 60 m.g.d. supply. Water will be costly if the entire cost is collected from rates, and there

No comments

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is little incentive for Contra Costa County and towns to enter this organization. The water is too costly for the heavy industries, such as now are located along the waterfront.

All of these sources are so distant and costly that the supplies are more of the nature of domestic supplies than of cheap industrial water supplies such as are required in any large and growing industrial region. None of them solves the salt water problem as affecting construction along the waterfront and none of them can possibly be made available for agricultural industries on the bay lands.

THE BARRIER AS A UNIT IN THE STATE COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the Legislature by the State Department of Public Works. This plan provides for the storage and utilization of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for water can not be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

GENERAL DEVELOPMENT OF BAY REGION

The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

Many of these factories would be classed as nuisances if located in a large city, on account of the odors. Carquinez Strait and Suisun Bay have regular winds which prevent a serious nuisance in this locality. Other communities are not so fortunately situated.

The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

CALIFORNIA NOW IN THE INDUSTRIAL AGE

California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters.

No comments

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Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the seventies, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1915. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power and there is comparatively little likelihood of any large increase in agricultural population. The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial areas.

DISTRIBUTION OF BARRIER COST

Several interests should share in the cost of this barrier. As has been shown, conditions now existing have been brought about by developments on the higher parts of the watershed, an area covering 32,000 square miles. The Bay cities will be contributing to the salt water problem by diversions which they propose to make out of the watershed. The agricultural interests through both valleys are using fresh water in such a way as to contribute to the salt water troubles of the delta lands and the industrial territory. The power companies through use of water in the watershed also affect the problem, and in addition these companies are interested in the increase and prosperity of the industrial region. Other public utilities in this region have the same interest in its prosperity.

The problem is so large and its interests so widespread that it may be said to be state-wide in scope.

The federal government through its control of navigation, as well as its general interest in the prosperity of the country, is likewise interested in the problem. The California Debris Commission and the River and Harbor work under the Chief of Engineers of the Army already are engaged in river improvement and in control of reclamation work so far as it affects navigation. It would appear reasonable, therefore, to have participation in this construction work by the federal government.

Local interests which will receive direct and tangible benefits from this barrier, such as the towns, cities and lands which can use water directly from the fresh water lake above the barrier, should contribute to the cost of the structure. The delta lands so far as they divert water from tide water levels should also be included in the area contributing because of benefits.

Railroads and vehicular traffic utilizing the barrier as foundation of a bridge should pay the value of this service. It seems reasonable that railroad and vehicular traffic could reasonably contribute a large sum for the use of the bridge.

It appears from examination of Young's estimates that the sum of $45,000,000 will complete a barrier with a bridge at a point near the upper end of Carquinez Strait. A detailed economic study should be made to determine the proportion of the cost that should be borne by each interest involved.

No comments

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SUMMARY

1. Carquinez Strait marked approximately the boundary between salt and fresh water under natural conditions.
2. Prior to diversions for irrigation, Suisun Bay was brackish in late summer and salt water may have penetrated as far as Antioch, but only for a few days at a time in years of lowest run-off.
3. If the water now diverted for irrigation and held in storage were released, natural conditions would again be brought about.
4. The dry year of 1918, in which the urge of war had encouraged heavy plantings of rice and other crops in the Sacramento Valley, resulted in penetration of salt water into the Delta for a longer time and to a greater distance up-stream than ever known before.
5. Examination of available information shows that the yearly increased diversion of water which had been going on since irrigation commenced in the valleys of California, had been gradually affecting the movements of salt water. This slow effect was hardly noticed until 1918.
6. Irrigation and storage are not solely responsible for the influx of salt water. The load of hydraulic mining debris deposited in the streams draining the Sierra Nevadas is a minor factor in the problem. As the sediment moves down-stream the tidal prism is changed and the movement of water is affected.
7. Leveeing and reclamation of marsh lands, around the bays and in the delta region, have had a slight effect upon tidal movements. The net effect of leveeing marsh land has been to decrease the tendency of salt water to flow up-stream.
8. Leveeing of basin lands and diversion of floods through by-pass channels has had an important effect in sending floods rapidly to tide water and in reducing the late summer flow of water which under natural conditions was stored and slowly released from basins.
9. Dredging, particularly in lower portions of the rivers and in the navigation channels of San Pablo Bay, has increased the tendency for salt water to flow up-stream. Dredging in Suisun Bay and in the deep water channels to Stockton may have the same tendency. All increases in channel depth and in straightening of approach have a tendency to increase up-stream flow of salt water, though a quantitative estimate of this tendency cannot be made.
10. Irrigation now diverts the entire low flow of all streams entering the San Joaquin Valley. The only flows reaching tide water in late summer and early fall are return waters—seepage from irrigation.
11. Pumping plants on the west side of the San Joaquin Valley, lifting water to the west side slopes, now divert more water during late summer than enters tide-levels from the river. The San Joaquin delta under present conditions is dependent in late summer of dry years on flow from the Sacramento River. Additional pumping plants are being installed and there will be a greater tendency in the future than in the past for salt water to flow up-stream into the delta channels.
12. Irrigation in the Sacramento Valley in late summer diverts practically all the flow of streams entering the valley floor. The flow of the river at Sacramento, the head of tide water, is now largely return seepage or waste from canals. The low flow at Sacramento was 500 second feet in 1920; 2750 in 1921;

No comments

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3200 in 1922; 3100 in 1923; 705 in 1924; 2760 in 1925; 1330 in 1926; and 3420 in 1927.

13. The area irrigated in the delta of both rivers is now 360,000 acres. The quantity of water used by this land has not been determined with any accuracy. Comparing crops and other conditions affecting use of water, it is probable that the annual consumption approximates 1¾ acre feet per annum. Twenty per cent of the annual amount is used in the summer months of greatest evaporation. At this rate the consumption of water by the delta area is at the rate of 2100 second feet in the summer. This exceeds the flow into tide water by the river in all years of low flow.

14. Records of salt content of the water have been collected by the Division of Water Rights since 1917. The area of delta land surrounded by salt water (100 parts chlorine per 100,000) at high tide is shown in the following table:

Year	Approximate Stream Flow before Diversions in Per Cent of Normal.	Area in Delta Surrounded by Salt Water, Acres.
1924	24	169,000
1926	53	58,000
1925	74	8,500
1927	100	5,000

15. Contrary to popular opinion, the period since 1918 has not been one of stagnation in irrigation development. A number of large storage reservoirs have been built and placed in operation since then. Of approximately 4,000,000 acre feet of storage reservoirs on streams draining through Carquinez Strait, 55 per cent or 2,725,000 acre feet have been built since 1920. Diversions of water, particularly on the lower San Joaquin River, have increased.

The area under irrigation has steadily increased in both valleys. In 1926 it is estimated that 1,250,000 acres were irrigated in the floor of the valley with 3,900,000 acre feet of water by diversions from streams draining toward Carquinez Strait. If mountain valleys and lands irrigated from wells are included, the total area irrigated is probably over 1,750,000 acres.

16. Further extensions of irrigated area are being planned in both valleys. Within the next five years the bay cities will have diverting capacity of about 185 second feet and will control 431,000 acre feet of storage reservoirs. These enterprises will tend to increase the salt water menace. There is reason to expect the same menace of salt water as occurred in 1920, 1924 and 1926 to be present every year.

17. Salt water will penetrate the lower delta region every summer under present conditions. The distance water will flow up-stream will depend less and less upon the flow of streams into the valleys as the increase in use of water continues. About one-half of the delta is likely to be menaced any year. The area may extend beyond this line.

18. There is now no legal control of diversions, other than by the slow and costly process of litigation, except upon a few small tributary streams where the Division of Water Rights has completed adjudications. Litigation between lower users of water in the delta and upper riparian users and appropriators has been in progress for several years. Other litigation may be started. The legal pro-

No comments

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cesses are so slow, cumbersome and costly that little result is to be expected for many years, if ever.

The outcome of present litigation will be disastrous if the courts uphold the contentions of either of the parties to litigation. If the delta lands have riparian rights to the waters, a large area of land will have to release water, and storage reservoirs constructed by power companies will be decreased in efficiency and value. On the other hand, if the courts decide that riparian rights do not attach to lands on tide water, the delta will be further menaced by salt water and there will be grave danger of permanent injury to a large area of land.

19. The engineering study of a salt water barrier made by Walker Young, of the Bureau of Reclamation, in cooperation with the Department of Public Works of the State of California, concludes that the construction of such a barrier is feasible. Investigations were made at three sites—Point San Pablo, Dillon Point and Army Point. The estimated cost of the barrier with and without bridges is given in the table on Page 60.

20. This barrier will maintain a fresh water reservoir free from tidal fluctuations and currents other than those caused by the flow of river water toward the sea. The level of water up-stream of barrier will be maintained at the highest practical level. Young estimates this level at elevation 2.5, U. S. G. S., or 6.0 on tide gage. It is probable that this height of water will be controlled by conditions of levees in the peat areas. As these levees become more stable the level can be increased. Flood levels will not be increased above those of floods in the past, in fact flood conditions will be improved in all but the most severe and protracted floods.

21. The salt water barrier, if built, will affect agriculture and the industries and activities along the bay and lower river as shown in the following statement:

A. AGRICULTURE

(a) A salt water barrier at Point San Pablo will make fresh water available for the irrigation of 51,000 acres of marsh and 48,000 acres of high land around San Pablo Bay. There is no known source of water for this area of land at present. If such lands are increased $50 an acre above cost of irrigation works, the total increase in value will be $4,950,000.

(b) A salt water barrier in Carquinez Strait or at Army Point will make fresh water available for 163,000 acres (marsh 70,000 acres; high lands 93,000 acres) around Suisun Bay. There is no other known source of water for this area. At $50.00 an acre, the increased value above cost of irrigation works will be $8,150,000.

(c) Either location of barrier will solve the irrigation problem for the lands now irrigated from tide waters in the delta and adjoining it. The area now watered is about 360,000 acres. The total area of irrigable lands is estimated as 458,000 acres. The area menaced by salt water is 169,000 acres. The value of this land is $35,000,000. Improvements at 20 per cent of land value add another $7,000,000.

There will be some increment in value to all the delta area from the security which the salt water barrier will bring about.

(d) The salt water barrier will benefit the areas up-stream from tidal lands by removal of litigation which is now a source of expense and annoyance and which is an obstacle to future projects.

No comments

- n/a -

SALT WATER BARRIER

Comparison of Estimated Costs for Alternate Design at Four Sites.

DISTINGUISHING FEATURES OF ASSUMPTIONS OF DESIGN

No.	Estimated Cost	Highway and Railway Bridge			Locks		Flood Control Gates			Pier Width
		Minimum Clearance at Locks	Decks	Piers or Towers	No.	Location	No.	Size	Location	
						ARMY POINT-SUISUN POINT AND ARMY POINT-MARTINEZ				
1	$46,300,000		No Bridge		3	In Suisun Point	14 2	70x80 50x60	Partially in Suisun Pt.	20 Ft.
2	49,800,000	50 Ft.	Single	Concrete	3	In Suisun Point	do	do	Partially in Suisun Pt.	15-20
3	54,100,000	50 Ft.	Single	Concrete	3	In Suisun Point	30	50x60	Partially in Suisun Pt.	15 Ft.
4	55,900,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	15	70x80	Partially in Suisun Pt.	20 Ft.
5	58,500,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	30	50x60	Partially in Suisun Pt.	15 Ft.
6	77,300,000	50 Ft.	Single	Concrete	3	Offshore from Martinez	15	70x80	Offshore from Martinez	20 Ft.
						BENICIA-PORT COSTA				
7	40,200,000		No Bridge		4	In Benicia	30	50x60	Offshore from Benicia	15 Ft.
8	46,200,000	50 Ft.	Single	Concrete	4	In Benicia	30	50x60	Offshore from Benicia	15 Ft.
						DILLON POINT-ECKLEY				
9	38,900,000		No Bridge		4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
10	44,700,000	50 Ft.	Double	Concrete	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
11	44,900,000	50 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
12	47,600,000	135 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
13	50,400,000	50 Ft.	Double	Concrete	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
14	50,600,000	50 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
15	53,300,000	135 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
16	97,100,000	50 Ft.	Single	Concrete	4	In Dillon Point	15	70x80	In Dillon Point	20 Ft.
						POINT SAN PEDRO-POINT SAN PABLO				
17	66,000,000		No Bridge		5	In Point San Pablo	15	70x82	Offshore Pt. San Pablo	20 Ft.
18	75,200,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	Offshore Pt. San Pablo	20 Ft.
19	82,100,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	In Point San Pablo	20 Ft.

One estimate only is given for the Army Point-Martinez Location—Estimate No. 6.

This site was not drilled—Estimates based largely on assumed foundation conditions except for S. P. Co. test pile data.

NOTE—At all sites except Dillon Point-Eckley, conditions are such that flood gates, locks, piers, etc., would be constructed in the dry behind coffer dams. A limiting depth of 90 feet below mean sea level to rock surface is assumed for this method of construction. The depths at Dillon Point-Eckley exceed this, and Estimates 9 to 15, inclusive, are based upon the placing of concrete under water by the tremie method using caisson gates for the final work on the Stoney Roller Gates. Estimate 16 uses construction methods comparable to those at the other sites as the flood gates are placed in Dillon Point.

No comments

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(e) The salt water barrier is a step in the direction of carrying out the state's plan of supplying water to the Southern San Joaquin Valley—a step in the coordinated plan of water development. It is the first portion of the project which should be built.

B. INDUSTRIES

Industries occupy a large area of land along the waterfront of San Francisco and San Pablo bays, Suisun Bay and Carquinez Strait. Between Oleum and Antioch there are seventeen large industrial plants and a number of smaller ones. On the north side of the straits there are two large industries besides the Mare Island Navy Yard and Benicia Arsenal.

These industries are of the "heavy" type, fundamental industries, which produce essential products necessary both in war and peace. Steel and iron, petroleum products, chemicals, fertilizers, powder and fuse works, leather, brick and tile, flour and feed, roofing lumber and wood products, fish, canned goods and sugar are produced in large quantities. The products of these works have an annual value of $250,000,000. Freight in and out of the district approximates 14,000,000 tons a year. Expenditures for electric power average $800,000 a year. The average number of employees is 8500, having an annual payroll of about $15,000,000. The portion of the population of towns and suburban territory dependent on these industries includes 30,000 inhabitants.

The industries are large users of water. At present 10 million gallons a day are used, not including the Navy Yard or Arsenal, and the annual increase in use by the establishments is one million gallons a day.

Immediately adjoining the industrial area above described are other large establishments which could receive benefit from the fresh water reservoir created above the barrier. If the zone along the waterfront to Richmond were included, the annual value of products for the whole territory would be $515,000,000; the number of employees 17,000; the annual payroll $29,000,000. A part of this area is within the East Bay Municipal District.

Since the salt water menace became widely advertised through the Antioch litigation, only one new industry of large size has been established in this territory. The factories already established have continued to grow but the uncertainty about fresh water has discouraged new industries seeking location. Fresh water in large quantities at low prices is essential to the prosperity of such establishments. Water from any existing utility or municipal district is too high in price for these "heavy" industrial plants.

Ordinarily such works locate where water can be had for the cost of pumping, and such manufacturing establishments will not go to any place where practically free water is not available. There is no other location in California suitable for heavy industries where this condition can be created.

The establishment of new basic industries will be attracted to abundant cheap water. If California does not provide the proper location, Seattle or Portland or some other northern locality will offer greater inducements and many industries will establish Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure fresh water is abundant and may be had for the cost of pumping from permanent running streams. Further than this, rates for water in the cities are cheaper than in California. Below are given the costs of 500,000 gallons of water in the principal Pacific Coast cities:

No comments

- n/a -

Cost of 500,000 Gallons of Water Per Month

San Francisco	$157.56
Oakland	161.71
Los Angeles	72.16
Stockton	54.50
Portland	44.11
Seattle	32.94

One of the greatest needs of the state today is a fresh water reservoir around which factories could be located with assurance of a permanent supply of water. Probably no single accomplishment in the construction program now under discussion would do more toward progress. More factories mean greater population and more local markets for agricultural produce, and the general level of prosperity of the state will be raised.

Salt water is detrimental to the piping and more costly to handle in factories of this sort. The increased annual cost to the users of saline water is estimated to be $300,000 a year through deterioration of equipment and piping in the industries now established. This sum capitalized at 6% means the equivalent of an investment of $5,000,000.

Some of the industries, notably the sugar refinery at Crockett and the chemical works at Pittsburg and Nichol, require water free from saline matter. The presence of salt water in the river for long periods of each year has been the cause of much expense and annoyance in these establishments, and brings seriously to consideration the ability of these factories to continue to exist under the trying conditions.

The salt water barrier will remove the cause of additional expense to the plants now located here, will encourage their more rapid growth, and will offer a great incentive to new establishments to locate here. Large industries require, in addition to large quantities of pure water, cheap power, efficient transportation facilities, preferably both by rail and water, and a good climate attractive to labor. The lower river and upper bay regions lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

C. DOMESTIC WATER SUPPLY

The domestic water supply of towns along the straits in Suisun Bay is high in price and limited in quantity. Vallejo, the only exception to this statement, recently has constructed Gordon Valley Reservoir on Suisun Creek, and has a permit to store 10,000 acre feet and to divert 5,000 acre feet annually. Other towns have no large amount of water for future growth. In fact lack of available water has been a deterrent to the location of industries and the resultant increase in population.

A salt water barrier will solve the water difficulties. If the barrier is located at San Pablo Point, the entire area can be supplied with fresh water; if the barrier is located at Army Point or in Carquinez Strait, all towns on Suisun Bay and in the lower river will be on fresh water; towns below the barrier, such as Crockett, can be readily supplied with short pipe lines heading above the barrier.

Either barrier will be of benefit to the city of Sacramento in preventing the up-flow of tide and reducing the menace of sewage water being carried toward the water intake.

No comments

- n/a -

D. TRAFFIC ACROSS STRAIT

Routes of travel between northern and southern parts of the state naturally pass through Carquinez Strait. The Southern Pacific Company maintains ferries for trains between Benicia and Port Costa and for passengers between Vallejo Junction and Vallejo. The Sacramento-San Francisco Railroad maintains a train ferry from Mallard to Chipps Island. A bridge for vehicular traffic now crosses the strait just below Crockett. A ferry for automobiles and passengers is maintained between Martinez and Benicia.

At Richmond an automobile ferry is in operation a short distance below the site of the proposed salt water barrier at Point San Pablo.

A barrier at San Pablo can be made to serve as a bridge. There are now two applications for bridge permits near this place. The estimated cost of these bridges is from $10,000,000 to $20,000,000. The difference between the cost of a barrier with and without bridge is estimated by Young to be $9,000,000.

At Army Point a bridge 50 feet above water increases the cost $3,500,000; at Benicia a bridge 50 feet above water level increases the cost $6,000,000; at Dillon Point a bridge with a clearance of 50 feet increases the cost $3,800,000; a bridge with clearance of 135 feet increases the cost $8,700,000. Approximate figures indicate that a railroad bridge near the location of the present Southern Pacific ferry between Benicia and Port Costa will cost in excess of $10,000,000. Upon this estimate railroad transportation could bear a part of the cost of barrier. Vehicular traffic is growing so rapidly that there will be need for a second bridge across the straits within a few years.

E. POWER COMPANIES

The power companies are interested in the salt water problem because it has decreased their market for power by discouraging new plants from locating here and by reducing the growth of those already established.

The litigation over water rights may seriously affect their plants supplied from storage in the mountains.

F. FISHING INDUSTRY

Fishing in the bay and rivers is important. Salmon, shad and striped bass are important commercial fish. Smelt and smaller fish are important in furnishing food for commercial varieties. Sturgeon are nearly extinct but it is the endeavor of the Fish and Game Commission to prevent complete extinction and to encourage increases in this species.

The salt water barrier will be an obstacle to migrating fish during low water season. Young's plans provide for fishways and it is his belief that fish will use the locks and that on the whole the barrier will not obstruct the migration. Objection to any forms of barrier will be raised by the fishing industry. Wherever the structure is built there will naturally be some obstruction to free migration of the fish. It is probable, however, that the structure can be so designed and operated as to do only a small amount of damage.

G. NAVIGATION

Any barrier is an obstacle to free movement of vessels, and it is to be expected that owners of vessels will object to the project. This objection arises from the delays caused by using locks and the danger of handling vessels in such restricted quarters, particularly in foggy periods.

No comments

- n/a -

As to delays, it may be said that ordinarily the time lost in transit through locks will be regained by the freedom from adverse currents above the locks. While this will depend upon the place to which the vessel is bound, it is believed that for the great bulk of traffic the delay is likely to be small.

The danger to vessels maneuvering in approach to locks is of course real, but with the safeguards now provided for vessels the risk is small and there are compensating advantages. The ability to dock without tidal currents, as would be true above the barrier, is both a saving in time and reduction of risk. The cleansing action of fresh water upon the bottoms of ocean-going vessels is valuable.

The fear that the barrier will cause silting in channels or will create changes in the Golden Gate bar does not seem to be well founded. Sediment moves almost entirely at flood times when the barrier will be open and the current constantly down-stream. The movement of sediment will probably be facilitated rather than retarded.

Owners of shipping facilities are of course interested in the growth and prosperity of the communities served. The industrial area which will grow up around the fresh water reservoir above the barrier will produce freight for vessels at a greatly increased rate. The depth of water through Suisun Bay and to Stockton will be increased to 26 feet under the plan already adopted by Congress. This depth of channel will be ample for from 73 to 88 per cent of the vessels normally entering the Golden Gate during a year.

In considering the location of the barrier, the extent of shipping is important. The farther downstream the greater the traffic through locks, the greater the quantity of water required for lock operation, and the greater will be the objection by the shipping interests. In this regard the upper location of the barrier will meet with the least objection.

The Navy Yard is above San Pablo site and naval officers will probably be impressed with the difficulties presented by the barrier in time of war. Here we have another and important reason for the selection of the upper site.

H. STRUCTURE BUILT IN WATER

Teredos and other wood-destroying animals have caused damage to structures in San Francisco Bay waters in excess of $25,000,000 since 1914, according to estimates made by the San Francisco Bay Marine Piling Committee. In the upper bay region, teredos have gone as far as Antioch. All structures built in water which may become brackish must be constructed of treated piles or of concrete. Brackish water carried up by tides will continue to cause greater expense in all structures built in water and greater maintenance costs. It is difficult to measure this damage in dollars, but it is a very considerable sum annually.

A salt water barrier will reduce the maintenance cost of structures and will make it practical to build structures as economically as was done prior to the invasion of salt water.

I. THE BARRIER AS A UNIT IN THE STATE'S COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the legislature by the State Department of Public Works. This plan provides for the storage and utilization

No comments

- n/a -

of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for fresh water cannot be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

J. GENERAL DEVELOPMENT OF BAY REGION

The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well-being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

Many of these factories would be classed as nuisances if located in a large city on account of the odors. Carquinez Strait and Suisun Bay have regular winds which prevent a serious nuisance in this locality. Other communities are not so fortunately situated.

The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

CALIFORNIA NOW IN THE INDUSTRIAL AGE

22. California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters.

Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the 70's, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1912. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power

No comments

- n/a -

and there is comparatively little likelihood of any large increase in agricultural population.

The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial centers.

SOLUTION OF THE SALT WATER PROBLEM

23. The salt water problem may be partially solved in several ways but completely only in one way. Conditions may be ameliorated by storage and release of water from reservoirs to push back the salt water or water supply from outside sources may be brought in to supply fresh water through conduits or pipes. The only satisfactory solution of the problem is the salt water barrier. These methods are briefly discussed below:

STORAGE AND RELEASE TO PUSH BACK SALT WATER

24. This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands.

Emmaton on the Sacramento River and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of Sacramento River at Sacramento and the San Joaquin at Vernalis (both points about head of tide water in late summer) must exceed the following figures:

For Control at	Cubic Feet Per Second
Emmaton and Jersey Island	3500
Antioch	5000
Collinsville	5500
O. & A. Ferry	6000

These quantities will depend to some extent upon the months preceding the period when control is desired, and will, of course, vary with the diversions below the points of measurements. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the O. & A. Ferry and 200,000 acre feet at Emmaton and Jersey.

Storage in large amount would be needed about half the years at Emmaton and Jersey, and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys does not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year.

No comments

- n/a -

Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent—except through litigation—the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean. As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of interest:

Kennett Reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13 of the Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights-of-way is $55,000,000; of power plant $25,000,000; a total of $80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920; 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bul. 13, Dept. of Public Works.) The recommended capacity is 1,121,900 acre feet; the cost of dam and power plant is estimated as $26,000,000; the canal system to utilize this water is estimated at $30,000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

"Sacrificing the power feature at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding

No comments

- n/a -

its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, and another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lanch Plana Reservoir practically eliminate this reservoir from consideration.

In connection with the proposal for storage and release of water, it should be remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

WATER FROM OUTSIDE SOURCES

25. Under present conditions the towns and industrial area cannot look to any place within tide water level for a source of water. Above tide levels the following are the principal supplies which may be considered:

Eel River,
Conn Valley,
Putah Creek,
Mokelumne or Cosumnes,
Pumped water from irrigation districts, San Joaquin Valley,
East Bay Municipal Utility District.

All of these sources may be considered, but as all are distant, with long pipe lines and other costly works, they will be able to supply water only at relatively high cost, prohibitory to the types of factories now located in Contra Costa and Solano Counties. Piping water across these straits will be a very costly and difficult affair. The barrier removes the necessity of any pipe line crossing.

LOCATION OF BARRIER

26. For the purpose of providing fresh water to cities, industries and agriculture on adjoining land, the lowest location of the barrier accomplishes the most. However, water supply, cost and convenience to other interests must be considered before the location can be selected. The following may be said on these points:

No comments

- n/a -

Water Supply. The attached tables give the requirements for fresh water above the barrier upon the assumption that development is complete. These figures, in part, are taken from the Young report—in part are the results of studies made for this investigation.

Requirements for the full year are:

Army Point	1,160,000 acre feet
Point San Pablo	2,024,000 " "
Difference	864,000 " "

For the irrigation period May to September, inclusive, the requirements are:

Army Point	638,000 acre feet
Point San Pablo	1,236,000 " "

Additional storage on the headwaters will be required to supply the barrier at San Pablo.

Cost. Young's estimate of cost of barrier with bridge of clearance of 50 feet is as follows:

Point San Pablo	$75,200,000
Army Point	49,800,000
Difference	$25,400,000

Convenience of Other Interests. San Pablo site is below the Mare Island Navy Yard, a great obstacle. Navy men will be against the project. Shipping interests will be more inconvenienced with the lower site occupied. At present about two-thirds of the vessels that pass Point San Pablo continue upstream above Army Point. The San Pablo site will be a convenience to vehicular traffic. The Army Point site will be convenient for both vehicular and railroad traffic, though at present vehicular traffic is cared for by the Carquinez Bridge.

FINAL CONCLUSION

27. If the salt water barrier is built at Army Point to carry vehicles and railroads, and the proper part of the cost paid by these interests, the salt water problem can be solved permanently and cheaper than by any other solution that has been suggested.

The cost of a bridge for rail and automobile traffic at Army Point cannot be determined without more work than is possible in an investigation such as this. It can be safely said, however, that the cost will exceed $10,000,000. Automobile traffic over the Carquinez Bridge (which has been in use less than a year) is at the rate of approximately 1,100,000 automobiles a year and is growing rapidly. There will be economic justification for an auto bridge at Benicia before it can be built. Automobile traffic will justify an expenditure of over $10,000,000. The two combined will be over $20,000,000. If this figure is taken as the value to transportation, there will be left, approximately, an equal sum to be paid by other benefits.

Iron Canyon Reservoir, the only definite storage reservoir suggested for temporary control, will cost $26,000,000. The salt water barrier would permanently solve the difficulties for a smaller sum.

No comments

- n/a -

[TABLE 1]

AVERAGE MILES TRAVELED BY WATER BARGE
CALIFORNIA-HAWAIIAN SUGAR COMPANY

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	19.8	11.6	12.5	14.0	12.9	16.7	26.3	26.8	33.2	27.1	24.8	25.7
1909	6.9	0	4.5	7.7	5.0	4.7	10.5	19.4	23.2	24.2	21.0	11.7
1910	9.6	10.0	3.8	3.0	6.4	10.8	20.4	26.7	27.6	25.4	24.6	19.7
1911	11.6	2.3	16.2	1.0	2.1	0.7	5.7	16.4	23.2	24.5	24.7	25.5
1912	22.0	16.1	14.5	12.7	8.8	7.1	17.6	24.7	24.4	24.2	19.0	18.5
1913	16.4	13.6	13.2	9.9	6.9	10.3	21.0	25.7	26.6	27.8	26.1	20.4
1914	2.1	1.2	1.6	2.5	2.2	3.4	10.3	20.0	24.4	24.5	23.9	23.7
1915	16.4	2.3	3.1	4.3	2.6	3.7	12.6	20.8	24.4	24.2	23.0	17.5
1916	4.9	0.5	1.0	2.3	6.4	5.8	13.2	22.6	25.0	21.7	21.2	15.4
1917	16.0	13.1	6.5	6.3	3.5	4.8	15.5	24.9	26.2	26.0	25.1	24.4
1918	24.3	15.1	9.6	6.2	9.2	15.0	27.0	38.5	37.2	23.0	23.1	21.0
1919	20.4	9.4	7.7	5.7	4.3	14.1	35.3	37.7	37.7	26.8	25.7	25.5
1920	23.8	24.0	17.2	12.0	12.9	17.4	26.0					

[TABLE 3]

COMMERCIAL FISHING—SAN PABLO AND SUISUN BAYS AND
SACRAMENTO AND SAN JOAQUIN RIVERS

(Varieties)

Year	Salmon Native	Shad Planted	Striped Bass Planted	Total Pounds
1919	4,529,048	1,573,713	759,733	6,862,494
1920	3,860,312	1,409,322	668,290	5,937,924
1921	2,511,127	797,128	599,698	3,907,953
1922	1,765,066	1,109,445	682,717	3,557,228
1923	2,243,945	1,285,334	906,869	4,436,148
1924	2,640,110	1,538,735	658,244	4,837,089
1925	2,778,846	2,439,441	836,301	6,054,588
1926	1,261,776	902,202	749,573	2,913,551
1927	920,471	4,103,012	644,789	5,668,272
Total, 9 Years	22,510,701	15,158,332	6,506,214	44,175,247
Mean	2,501,189	1,684,259	722,913	4,908,361

The run of fish will vary from year to year in accordance with weather, feed and unknown factors.

A low or high run for one year may not mean absolute evidence of either increase or decrease in the species.

For example, the extremely low run of salmon in 1927 does not necessarily mean still lower run in 1928, and similarly with shad in reverse tendency.

However, there seems to be a general decrease in salmon, probably an increase in shad, and a static condition in striped bass.

No comments

- n/a -

[TABLE 2]

COMBINED FLOW OF SACRAMENTO AND SAN JOAQUIN TRIBUTARIES

(Flow in Second Feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1916	66,670	92,200	99,830	88,621	73,060	55,619	23,990	11,112	9,300	12,261	11,522	19,986
1917	16,712	56,000	34,521	71,153	69,307	63,407	20,082	9,787	8,309	7,875	8,639	11,071
1918	9,180	21,849	50,360	51,091	39,145	32,183	9,563	6,885	8,621	13,041	11,956	12,118
1919	19,653	58,664	44,948	63,700	65,666	18,261	8,975	7,275	7,049	7,733	7,172	11,460
1920	9,075	9,550	26,759	41,822	49,582	27,404	9,931	6,722	6,059	8,557	39,737	48,539
1921	73,000	58,400	69,470	55,291	65,385	50,246	15,606	8,297	7,435	7,589	8,389	19,407
1922	17,560	50,030	41,389	61,190	109,494	82,327	20,879	9,022	7,329	8,334	11,828	35,715
1923	29,742	22,089	23,785	55,290	54,199	31,844	17,138	9,798	8,809	10,004	7,810	7,919
1924	8,617	19,248	10,222	15,623	14,438	7,007	5,981	5,601	5,171	7,056	13,214	15,029
1925	15,018	89,005	34,394	63,127	59,990	32,824	13,486	9,030	8,535	8,626	9,361	11,720
1926	13,056	57,377	26,323	60,494	30,503	13,603	9,732	8,522	7,364	7,730	32,243	31,338
1927	35,293	109,044	54,556	75,100	59,973	45,353	16,984	11,349	10,652			

No allowance for power storage or regulation.

Combination of	and
Sacramento at Red Bluff,	Mokelumne at Clements,
Feather at Oroville,	Stanislaus at Knights Ferry,
Yuba at Smartsville,	Tuolumne at La Grange,
Bear at Van Trent,	Merced at Exchequer,
American at Fair Oaks,	San Joaquin at Friant.

[TABLE 4]

POPULATION OF BAY COUNTIES— U. S. CENSUS

	1920	1910	1900	1890	1880	1870	1860	1850
State	3,426,861	2,377,459	1,485,053	1,213,398	864,694	560,247	379,994	92,597
Alameda	344,171	246,131	130,197	93,864	62,976	24,237	8,927	
Contra Costa	53,889	31,674	18,046	13,515	12,525	8,461	5,328	
Marin	27,342	25,114	15,702	13,072	11,324	6,903	3,334	323
Napa	20,678	19,800	16,451	16,411	13,235	7,163	5,521	405
Sacramento	91,029	67,806	45,915	40,339	34,390	26,830	24,142	9,087
San Francisco	506,676	416,912	342,782	298,997	233,959	149,473	56,802	
San Joaquin	79,905	50,731	35,452	28,629	24,349	21,050	9,435	3,647
San Mateo	36,781	26,585	12,094	10,087	8,669	6,635	3,214	
Solano	40,602	27,559	24,143	20,946	18,475	16,871	7,169	

No comments

- n/a -

City of Antioch
Supporting Document
March 22, 2010

[TABLE 5]

SCHOOL ENROLLMENT

BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

	1915	1921	1927
Elementary Schools:			
Oakley	85	118	158
Antioch	333	454	731
Pittsburg	668	1122	1485
Bay Point	85	------	162
Martinez	403	792	1068
Port Costa	122	108	75
Carquinez (Crockett)	447	572	617
Selby	72	99	128
Rodeo	108	132	198
Pinole Hercules	227	258	217
San Pablo	182	227	282
Richmond	2288	3380	3997
Total Elementary	5020	7262	9118
High Schools:			
Antioch	105 (Antioch and Pittsburg)	142	149
Pittsburg			183
Alhambra, Martinez	77	121	294
John Swett, Crockett	86	119	206
Richmond	242	655	754
Total High School	510	1037	1586
Total both	5530	8299	10,704

[TABLE 6]

WATER-BORNE TRAFFIC

U. S. ENGINEERING DEPARTMENT DATA

(Total Movement, Tonnage and Values in Thousands of Tons and Thousands of Dollars)

	Suisun Bay		Carquinez Strait		San Pablo Bay		Grand Total	
Year	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1917	Do Data		Incl. in San Pablo		11,946	$212,592		
1918	No Data		Incl. in San Pablo		4,330	152,206		
1919	305	$ 7,034	Incl. in San Pablo		4,634	184,476	4,939	191,510
1920	433	13,877	2,079	$97,991	1,696	54,620	4,208	166,488
1921	562	19,670	1,720		2,019	96,177	4,301	
1922	1,329	32,006	No Data		2,652	118,234		
1923	2,659	43,764	No Data		2,466	109,022		
1924	2,341	51,066	No Data		4,200	156,999		
1925	4,204	88,670	7,673	183,000	4,754	234,409	16,631	506,079
1926	4,205	90,687	7,844	135,522	4,667	260,920	16,716	487,129

Totals are only shown where data are complete for all divisions.

In addition to above, in 1926, there was a total of 1,752,000 tons valued at $124,-077,616 to or from the Sacramento and San Joaquin Rivers, most of which passed through Carquinez Strait. However, all of this having origin and destination in the above Bay division, it appears there also.

Railroad ferry freight traffic across Carquinez Strait was, in 1925, 2,706,000 tons; in 1926, 2,650,000 tons.

No comments

- n/a -

[TABLE 7]

OCEAN-GOING WATER-BORNE TRAFFIC
U. S. ENGINEERING DEPARTMENT DATA

(Tonnage in Thousands of Tons and Values in Thousands of Dollars.)

Year	Suisun Bay Tons	Suisun Bay Value	Carquinez Strait Tons	Carquinez Strait Value	San Pablo Bay Tons	San Pablo Bay Value	Grand Total Tons	Grand Total Value
1925	2659	$43,823	5188	$147,485	4011	$66,999	11,858	$258,307
1926	2495	41,173	4264	107,228	3866	58,942	10,625	207,343

Data do not permit a separation of bay business from ocean-going business previous to 1925, and Carquinez Straits' data are entirely lacking for thee years.

The magnitude of the Petroleum Products traffic and the proportion of the total it occupies are obvious when the following tables are compared with the above.

Year	Suisun Bay Tons	Suisun Bay Value	Carquinez Strait Tons	Carquinez Strait Value	San Pablo Bay Tons	San Pablo Bay Value	Grand Total Tons	Grand Total Value
1925	2464	$34,391	4415	$ 49,562	3837	$45,714	10,716	$129,667
1926	2168	33,663	3409	40,454	3708	43,837	9,285	117,954
OUTGOING BAY AND OCEAN WATER-BORNE PETROLEUM PRODUCTS								
1925	547	$20,811	2949	$ 38,217	1019	$19,783	4,515	$ 78,811
1926	615	29,989	2746	35,197	940	23,837	4,301	89,023

Does not include Standard Oil Co. Richmond plants.

[TABLE 8]

SACRAMENTO AND SAN JOAQUIN RIVER TRAFFIC
U. S. ENGINEERING DEPARTMENT DATA

(Tonnage and Values)

Year	Sacramento River Tons	Sacramento River Value	San Joaquin River Tons	San Joaquin River Value
1910	496,147	$ 29,522,151	631,681	$ 32,878,108
1911	505,285	32,139,048	600,128	35,768,215
1912	477,292	27,755,325	632,591	38,854,539
1913	733,594	35,856,791	820,399	38,341,174
1914	721,090	38,211,760	772,156	35,479,741
1915	766,935	38,027,703	831,234	36,358,240
1916	875,780	46,908,093	824,222	42,179,160
1917	947,690	96,820,992	1,890,856	50,367,760
1918	1,053,510	113,991,123	2,114,382	65,204,825
1919	1,666,025	78,601,238	647,156	54,100,043
1920	1,377,700	53,946,146	692,306	42,203,211
1921	976,596	52,092,263	646,657	37,263,122
1922	1,291,135	60,606,728	678,751	34,291,675
1923	1,264,821	62,470,235	697,773	38,027,909
1924	1,796,105	58,662,997	727,499	38,185,313
1925	1,427,230	80,500,145	849,687	47,192,499
1926	1,222,993	85,315,284	934,809	56,455,662

Contains also movements between river points only.

No comments

- n/a -

[TABLE 9]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER WHEN FULLY DEVELOPED

(Quantities in Second Feet)

POINT SAN PABLO

	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc.	322	322	322	322	322	322	322	322	322	322	322	322
Gate Leakage	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks	705	705	705	705	705	705	705	705	705	705	705	705
Evaporation	250	300	450	650	950	1200	1250	1170	1020	800	500	200
Irrigation	.....	.....	.....	.....	610	1680	2290	1910	1150	.....	.....	.....
Flushing	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.	1678	1728	1878	2078	2988	4308	4968	4508	3598	2228	1928	1628

[TABLE 10]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER WHEN FULLY DEVELOPED

(Quantities in Second Feet)

ARMY POINT

	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc.	155	155	155	155	155	155	155	155	155	155	155	155
Gate Leakage	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks	246	246	246	246	246	246	246	246	246	246	246	246
Evaporation	110	146	200	288	422	530	555	522	455	355	222	89
Irrigation	.....	.....	.....	.....	380	1050	1430	1190	710	.....	.....	.....
Flushing	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.	912	948	1002	1090	1604	2382	2787	2514	1967	1157	1024	891

No comments

- n/a -

[TABLE 11]

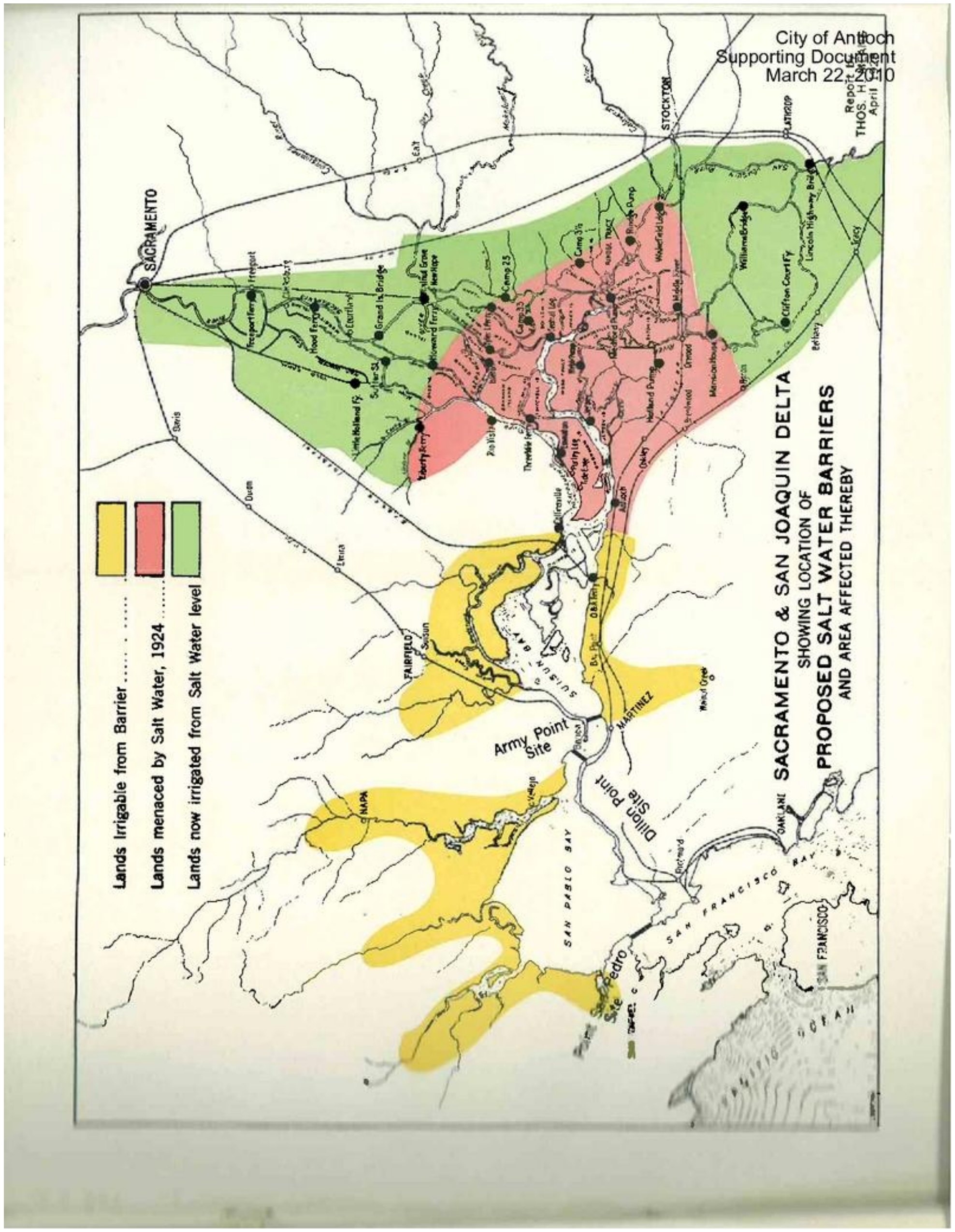
WATER REQUIREMENTS ABOVE SALT WATER BARRIER
WHEN FULLY DEVELOPED

(Quantities in Acre Feet)

	Army Point	Point San Pablo
January	56,000	102,500
February	52,500	95,500
March	62,000	115,000
April	65,000	123,000
May	98,500	184,000
June	147,500	256,000
July	171,000	305,000
August	154,000	277,000
September	117,000	214,000
October	71,000	137,000
November	61,000	115,000
December	54,500	100,000
Totals	1,110,000	2,024,000

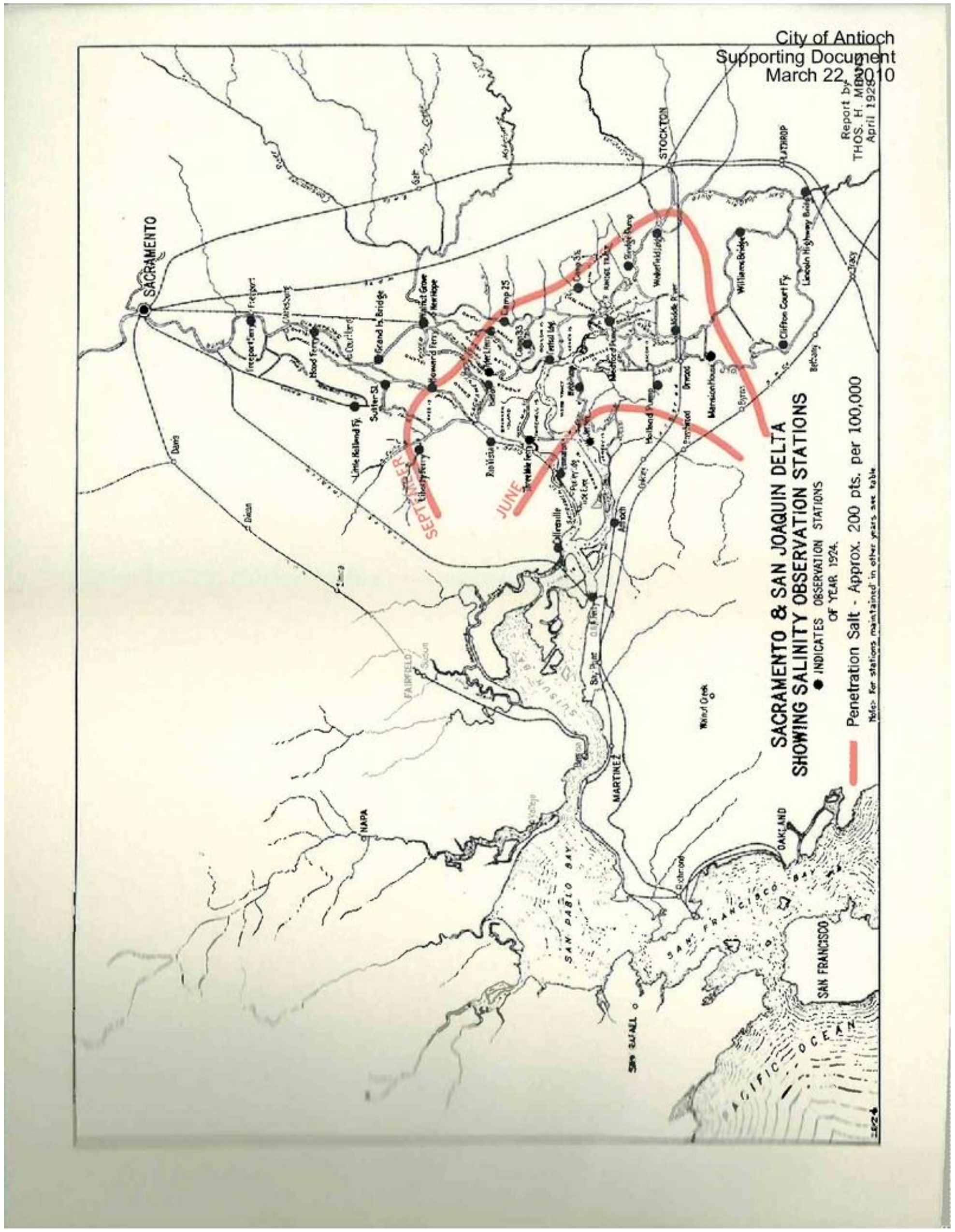
No comments

- n/a -



No comments

- n/a -



No comments

- n/a -

September 30, 2011

Via email to: DeltaPlanComment@deltacouncil.ca.gov

To: Phil Isenberg, Chair and Members of the Delta Stewardship Council (DSC)
Joe Grindstaff, Acting Executive Director, Delta Stewardship Council and DSC Staff

Re: City of Antioch comments on the Fifth Draft Delta Plan

The City of Antioch (Antioch) is pleased to submit its comments regarding the Fifth Draft Delta Plan. Our comments are presented in tabular format, with chapter, page and line references, to make it easier for DSC staff to review.

Included in our comments is an important issue that does not appear to be discussed in the DSC Delta Plan. We bring this to your attention in hopes that you will consider addressing it in the final Delta Plan and EIR. The issue is this: cumulative impacts to the Delta system as a whole are not discussed in the plan, nor is there discussion of creating an oversight or regulatory agency to monitor overall health of the Delta system. For example, who will track the combined impacts of the BDCP, Three Mile Slough and Old and Middle River gates projects on the Delta as a whole?

Different agencies track different Delta indicators, yet there is no scientific body that addresses the viability of the Delta as a whole. As projects come on line, and "adaptive management" is used for both ecosystem restoration and project operations, who will track the cumulative impacts of the combination of projects coming on line? It seems appropriate that the DSC address this in its Delta Plan, even to suggest a scientific body or group of agencies to take this 'system-wide' approach to track changes in/impacts to the overall health of the Delta. Without such oversight, another Delta crash could occur with no way to determine what went wrong, and what factors led to such a crash.

We very much appreciate the work that the DSC is doing and its ongoing efforts to obtain and incorporate public comments and input. We look forward to your review of our comments. Please call me at (925) 779-7025 if you would like more information or if you have additional questions.

Sincerely,

P. Harrington

Phillip Harrington
Director of Capital Improvements/Water Rights
City of Antioch
P.O. Box 5007
Antioch, CA 94531-5007

No comments

- n/a -

Delta Plan Fifth Draft Comment from the City of Antioch 9/30/2011

Chapter	Page number	Line number	Text	Comment
Chapter 1				
	25 26	21-23 1-5	No water rights decisions or water contracts that directly or indirectly impact the Delta are made without consideration of the coequal goals...etc.	Does this indicate that the Delta Plan seeks to replace the current water rights system in California?
Chapter 3				
	54	27-31	Incorporation of Another Plan into the Delta Plan, Updating the Delta Plan	In cover letter to our comments regarding the Fifth Draft, dated 9.30.11--The Delta Plan does not mention nor address cumulative impacts to the Delta system from ongoing + new projects/programs. The effect of not taking a system-wide approach to policy is a Delta ecosystem or water quality/supply crash with no understanding about which event, program, or project caused it. Need a policy or recommendation to create a scientific oversight body to monitor the health of the Delta system-wide.
	55 56	13-14 1-7	...the Delta Reform Act requires the Council to establish and oversee a committee of agencies responsible for implementing the Delta Plan...	Is this committee only responsible for implementing the Delta Plan, or will it meet on an ongoing basis? Who is part of this committee, and will the Delta stakeholders and/or the public have a seat on this committee in addition to agencies?

No comments

- n/a -

	61	16-31	Discretionary Incorporation of Another Plan or Program into the Delta Plan	Again, no discussion of considering the cumulative impacts that an additional plan may add to the Delta System. Need a policy/entity to provide for oversight and monitoring.
	61	32-38	....Upon appeal the Council retains the authority to find the specific project inconsistent with the Delta Plan even if the Council finds that the larger plan is consistent with the Delta Plan.	This seems to indicate that a project under BDCP could be found inconsistent with the Delta Plan. Is this correct?
	62	20-23	...must file a consistency certification indicating only that he covered action is consistent with the BDCP. The Council retains the authority to find the covered action inconsistent with BDCP and therefore the Delta Plan.	This seems to indicate that BDCP only needs consistency with BDCP. The above comment from Page 61, lines 32-38 seems to contradict this. Please clarify.
Chapter 4				
	82	4-8	**WR P1** - A covered action to export water from, transfer water through or use water in the Delta is inconsistent with the Delta Plan if the covered action negatively impacts one or more of the coequal goals and one or more of the water suppliers that receive water from the Delta significantly causes the need for the covered action by failing to comply with one or more of the following	Would this indicate that the BDCP would be inconsistent with the Delta Plan if it significantly impacts one of the water suppliers (such as Antioch) causing the need for a covered action, such as a change in Antioch's diversion point, a water rights transfer or another regional solution driven by the impacts to Antioch's' water supply and quality?
	83	28-40	Evaluation of regional water balance	How are current water rights impacted by the water balance activity? Does this mean that water supply would be curtailed, despite holding pre-1914 water rights?

No comments

- n/a -

	84	34-37	**WR R5 –** SWRCB and/or DWR should require that proponents requesting a new point of diversion, place of use, or purpose of use that results in new or increased use of water from the Delta watershed should demonstrate that the project proponents have evaluated and implemented all other feasible water supply alternatives	Antioch may need to change its point of diversion or place of use, because of the impacts of the BDCP. Does this mean that such a mitigation would have to demonstrate that all other water supply alternatives have been evaluated, even though the change in diversion or place of use were a mitigation for a BDCP project? Also, do pre-1914 water rights holders have to comply with this?
Chapter 5				
	111	Map text	Since the 1960's our water system with upstream reservoirs and "other human-created management" has changed these patterns in two ways:	Insert "such as water exports" after "other human created management." Add a Number "3) Delta outflow was influenced by large outgoing flood flows that are now controlled."
	113	10-12	**ER P1** Prior to the establishment of revised flow objectives criteria identified above, the existing Bay-Delta Water Quality Control Plan objectives shall be used to determine consistency with the Delta Plan.	The current BDCP operation alternatives contain a move of water quality compliance point from Emmaton to Three-Mile Slough. This is will not be in compliance with the existing WQCP.

No comments

- n/a -

	114	1-7	Determine that a covered action that would increase the capacity of any water system to store, divert, move, or export water from or through the Delta would not be consistent with the Delta Plan until the revised flow objectives are implemented. Recommend that the State Water Resources Control Board cease issuing water rights permits in the Delta and the Delta watershed (or, if the absence of flow criteria is specific to one or more of the major tributaries, then the recommendation could be focused on the impacted areas).	Would these apply to any petition for change of use including a petition by BDCP to SWRCB for change of compliance point?
	121	24-26	**ER R3 –** State and Federal fish agencies....should complete "ongoing negotiations" toward a habitat agreement with water supply agencies	To what "ongoing negotiations" is this referring to-- BDCP? If so, state here. If not, clarify the scope of projects you are referring to here.
	122	19-32	Controlling stressors is difficult or impossible.....discussion about the lack of science about cause and effect.	Again, the Delta Plan needs a policy or recommendation for determining the cumulative impacts of stressors and projects in the Delta watershed.

No comments

- n/a -

	124	25-34	**ER R7 –** "…For example, workshops would consider options for varying salinity to reduce impacts of nonnative invasive species while providing overall ecosystem benefits and minimally disrupting water supply."	Suggest deleting "minimally." The Delta Plan discusses options for varying salinity throughout the Plan. Depending upon the location and the conditions, allowing variable salinity could have major impacts on in-Delta M&I water supply/quality. Increased salinity would also impact recreational boating and fishing in the Delta. Recreational boating/fishing are the #1 "recreational" revenue producers for the Delta, according to the Economic Sustainability Plan draft (8.9.11). Boaters use the Delta for its fresh water environment; numerous issues related to boat and marina maintenance would deter this recreational use.
	127	19-37	"Progress toward restoring in-Delta flows to more natural flow patterns to support a healthy estuary. Metrics: results from hydrological monitoring and hydrodynamic modeling …"	This performance measure is very vague; more detail is required, including defining what constitutes a natural flow pattern (which should be tied to pre-1918 conditions).

No comments

- n/a -

Chapter 6				
	133	19-21	To support a more resilient and healthy ecosystem, salinity patterns should be consistent with a more naturally variable hydrograph with high-quality river inflows.	Delta outflow is missing here and is a crucial factor for attainment of the co-equal goals of water quality in the Western Delta as well as for species such as Delta Smelt. Add outflow. Add that the salinity variability historically occurred farther west than it does today (i.e., salinity was more variable historically, but the system was also far fresher than it is today).
	136	35-36	This freshwater-saltwater gradient has changed over the past 150 years because 35 of landscape modification, water management, and climate variability	"Water management" should be changed to "exports, diversions, and other water management." Exports and diversions need to be inserted wherever "water management" occurs in the Delta Plan
	136	41-44	...Even with these measurable shifts in the salinity gradient caused by diversion, storage, and conveyance of water, the primary driver of salinity variability in the western Delta and Suisun Marsh continues to be the amount of precipitation in the watershed.	This is not correct on its face. "Delta outflow" is the major factor for salinity and variability in the western Delta. Historically, fresh water was present in the western Delta even during dry years (see CCWD historic salinity report). Further, the channelization of the Delta has changed the system's response to precipitation, increasing the amount of salinity intrusion (CCWD Historical Salinity Report, 2010).

No comments

- n/a -

	137	15-20	..The endangered Delta smelt (*Hypomesus transpacificus*) show a preference for the LSZ. Their distribution during most of the year is centered near X2 (Nobriga et al. 2008). The position of X2 is also correlated with the abundance of several estuarine fish and invertebrates such as the bay shrimp (*Crangon franciscorum*) and longfin smelt (*Spirinchus thaleichthys*). That is, higher outflows (smaller X2 values) are correlated with greater abundance of longfin smelt and bay shrimp (Kimmerer 2004).	Given that Delta Smelt are dependent upon low salinity zone in the western Delta, how will this freshwater zone be preserved, given the BDCP change to outflows, and move of compliance points from Emmaton to Three Mile Slough, which will allow less flow and higher salinity?
	137	21-27	.. The evidence is strong, however, that the Delta was a freshwater ecosystem in the western Delta for 2,500 years before human modification in the nineteenth and twentieth centuries (Malamud-Roam and Ingram 2004).	Antioch agrees with this statement

No comments

- n/a -

	137 138	25-27 1-2	Dredging of channels, reduction in the amount of tidal marsh, and construction of levees have changed the Delta salinity gradient by increasing the strength of tides in the Delta, increasing connections between channels, and reducing the moderating effects of wetlands and floodplains on outflow. Consequently, simply allowing more variability in Delta outflow will not produce the same salinity gradient patterns that existed before development.	Add "water exports" as a cause of salinity gradient change in the first sentence. Exports (since the early 1900s) have dramatically changed the salinity gradient. Note Antioch's comment letter to Isenberg, Grindstaff et al regarding impacts of BDCP, dated 11/15/10 We agree that "simply allowing more variability in Delta outflow will not produce the same salinity gradient patterns that existed before development."
	138	17-21	Water quality at the State Water Project (SWP) and Central Valley Project (CVP) export pumps in the southern Delta, while usually meeting all applicable standards for municipal and agricultural use, is significantly higher in salinity than Sacramento River inflow to the Delta. Allowing salinity to vary in a way that might benefit native fish species could impact agricultural and municipal uses of Delta water at SWP, CVP, and other Delta diversion points. Elevated salinity reduces crop yields (Hoffman 2010) or, if high enough, makes water unusable for agricultural purposes.	The statement implies that salinity variations would benefit native species; however, as noted in CCWD Historical Salinity study report (2010), while the Delta did experience greater variability in the past, it did so within a far fresher environment than currently exists. Thus, it is not clear that greater salinity variation would benefit native species. We concur about allowing salinity to vary could have negative impact on AG and M&I water quality. Please add that recreational boating and fishing would also be impacted.

No comments

- n/a -

	139	26-30	Sources of these drinking water constituents of concern include natural processes, such as tidal mixing of seawater into the Delta, and the flux of water and organic matter from wetlands, as well as urban runoff, agricultural runoff, and municipal wastewater discharge. Pathogenic protozoa, bacteria, and viruses are also present in Delta waters and are a disease risk for both drinking water and body-contact recreation.	Add "water exports" to the non-natural causes listed in this sentence, as increased exports increase salinity in drinking water in the Western Delta. One of the primary factors for tidal mixing of seawater into the Delta has historically been water exports and large diversions from the north (Means Report, 1928 about changing conditions in the 1900s due to increased exports and recent DWR data about exports and salinity increase.)
Chapter 8				
	191	33-34	Boating and water-dependent recreation represent the highest percentage of existing recreation activities in the Delta. In the California Department of Boating and Waterways' 2002 study, annual boating-related visitor days to the Delta were estimated at 6.4 million in 2000, with a 1 projected growth to 8 million visitor days by 2020 (DBW 2002).	Delta Economic Sustainability Plan concurs with this. Increased salinity or increased variability in salinity will impact boaters, species and M&I. Boaters use the Delta for its fresh water environment. Numerous issues related to boat and marina maintenance would deter this #1 recreational economic factor in the Delta.

No comments

- n/a -

	197	28-31	**DP R1** The Economic Sustainability Plan should include, but not be limited to..... • The economic goals, policies, and objectives in local general plans and other local economic efforts, including recommendations on continued socioeconomic sustainability of Delta agriculture and its infrastructure to support the proposed economic strategies and legacy communities in the Delta	Suggest change to read: "The economic goals, policies, and objectives in local general plans and other local economic efforts, including recommendations on continued socioeconomic sustainability of Delta agriculture and its infrastructure, *as well as other beneficial use of public trust resources (such as water quality for M&I, boating and recreation to* support the proposed economic strategies and legacy communities in the Delta"
Chapter 9				
	208	17-23	Urgent expenditures for water reliability and ecosystem protection: Immediate steps should be taken to protect the existing Delta water export system from flood risks, and protect ecosystem improvements being implemented pursuant to existing mitigation commitments of the SWP and the Central Valley Project (CVP). Those immediate needs are discussed in the various chapters of the Delta Plan. These recommendations are in addition to other ongoing efforts that should continue to be funded. Examples include implementing the federal biological opinions, funding levee subventions, funding science, and many more.	This indicates that only water export-system expenditures are considered urgent. What about levees in the Western Delta, that protect the whole system? Suggest change to read: "Immediate steps should be taken to protect the existing Delta "water supply system" ~~export~~ from flood risks, and protect ecosystem improvements being implemented pursuant to existing mitigation commitments of the SWP and the Central Valley Project (CVP).

No comments

- n/a -

	211	20-21	**FP R6** - The Legislature should authorize the Delta Stewardship Council to develop reasonable fees 20 for beneficial uses and reasonable fees for those who stress the Delta ecosystem	Please clarify: What level of and type of stress is indicated by the statement "for those who stress the Delta ecosystem?" Broadly interpreted, this could mean a boater, a fisherman, a hiker, as well as current M&I user.
	212	10-18	**FP R12** - Establish a statewide public goods charge (or broad-based user fee) for water. The Legislature 10 should create a public goods charge (similar to the energy public goods charge created in 1996) 11 on urban water users and agricultural users. This charge could provide for ecosystem costs that were once paid with general obligation bonds, or could be used for State water management costs such as developing the California Water Plan Update or science programs	This indicates that ecosystem restoration mitigation projects required by the BDCP would be paid for by impacted stakeholders in the Delta. This is a "double hit" cost impact to in-Delta agriculture and other in-Delta stakeholders, who would therefore be required to pay for BDCP's mitigation credit projects as well as suffer the impacts of the BDCP project itself.

No comments

- n/a -

No comments

- n/a -

C.7 Conclusions

C.7.1 Summary of Changes in Flow

The preliminary proposal would result in very minimal changes in upstream flows or reservoir operations. As such, there are only a few instances in which changes to the environment and related effects on fish may occur. Flow-related temperature effects on spring-run Chinook salmon and green sturgeon spawning and egg incubation are described in Section C.7.2. In the Delta, flows in and around the San Joaquin River and south Delta would improve, reflecting the reduced use of the south Delta export facilities. However, the flow patterns in the north Delta could be altered by operations of the new north Delta export facilities and the increased inundation of the Yolo Bypass. These operational changes will reduce some Sacramento River flows, resulting in reduced flows in Sutter, Steamboat, and Georgiana Sloughs and the DCC. Similarly, the reduced flows in the Sacramento River would slightly reduce flows in Threemile Slough. These changes in flow patterns in the north Delta can affect the migration and passage of fish through and within the Delta, as described in Section C.7.2. The changes in Delta flows are not expected to result in any substantial changes in turbidity or DO, as described below. However, the changes in Delta operations under the preliminary proposal related primarily to the new north Delta intake could have effects on salinity in some locations, as described below. In most instances, these changes in salinity are compounded by the effects of restoration activities that would occur as part of the preliminary proposal and sea level rise. The following sections provide a discussion of the general trends of changes in flows throughout the Plan Area. More detailed results are provided in Attachment C.A and are the basis for the biological results presented in Section 7.2.

C.7.1.1 Upstream Flows

The CALSIM results indicate that there would be little to no change in how reservoirs are operated. The largest changes to reservoir operations result from changes in runoff and inflow caused by climate change unrelated to the preliminary proposal. Coldwater pool management would be challenging for the CVP facilities. Oroville storage generally would be higher under the PP scenarios and would exhibit greater flexibility to adapt to future changes.

In general, the PP would increase carryover storage (end-of-September storage, often the lowest each year) compared to the EBC scenarios. However, CVP and SWP operations are expected to change operations to address the increased outflow needs caused by sea level rise and climate change. These results suggest that the management of storage for the coldwater pool (May storage is an indicator) would be increasingly difficult in the future, despite the fact that the PP would have increased carryover. The frequency of the end-of-September storage falling below 2,000 thousand acre-feet (taf) would increase by about 10% under both the PP and EBC in the LLT. Considerable adaptation measures would need to be implemented on the upstream operation of the CVP to manage the coldwater pool under the extreme sea level rise and climate change by 2060. Operation of the PP would lessen these challenges, but the effect of climate change and sea level rise would overwhelm these improvements.

These general conclusions are based on the CALSIM data, which are summarized below for each reservoir and river, and the actual operational constraints of the CVP and SWP. Because the CALSIM model uses a monthly time step, it does not necessarily capture the day-to-day operations that would respond to potential adverse effects, such as temperature changes and minimum flow and storage requirements. However, because the preliminary proposal is not expected to require substantial changes in upstream CVP and SWP operations, the CALSIM results indicate considerable monthly changes are not expected to occur in reality. Rather, DWR and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) reservoir operators would continue to operate the reservoirs and associated flows on a daily basis in a manner that meets flow, storage, and temperature requirements.

C.7.1.2 Delta Flows

The primary changes in Delta operations result from the north Delta intakes and the increased flows into the Yolo Bypass at the Fremont Weir. These changes generally divert water from the Sacramento River into either the new intake or the Yolo Bypass, reducing flows in Sutter, Steamboat, Threemile, and Georgiana Sloughs; in the DCC; and at Rio Vista. Reductions in south Delta pumping that are possible with the north Delta intakes increase OMR flows and San Joaquin River flows at Antioch by the amount of the reduced pumping. While climate change may affect flows in the San Joaquin, Mokelumne, and Cosumnes Rivers, no effects of the preliminary proposal are expected in the Delta channels connected to these river inflows. A summary of changes at each Delta location is provided below. However, these changes reflect the general trends and not necessarily the outer bounds of potential changes that could occur across water-year types and months within those water years. The effects analysis used detailed modeling results to determine the biological responses to specific daily, monthly, and water year–type changes. These are reported in the *Results* section above.

C.7.1.2.1 Sacramento River Flows at Freeport

The Sacramento River flow at Freeport provides the largest Delta inflow and represents the water available for diversion at the proposed north Delta intakes. The average annual inflow at Freeport was reduced by about 650 taf (up to 4%), primarily as a result of the increased Fremont Weir spills into the Yolo Bypass that would occur under the preliminary proposal. Similarly, PP_ELT and PP_LLT monthly median flows at Freeport were similar to EBC1 but were shifted in some months as a result of the increased spills at the Fremont Weir and other changes in upstream reservoir releases, as discussed above.

The Freeport median flows were similar in October, November, and December for the EBC1 and PP cases. The Freeport median flows in January, February, and March for the PP cases were about 3,000 cfs less than EBC1 flows, reflecting the increased spills at the Fremont Weir into the Yolo Bypass. The April and May median flows at Freeport were similar for the PP cases and EBC1 conditions. The June median flows were increased for the PP cases. The Freeport median flows for the PP cases in July, August, and September were reduced by about 3,000 cfs compared to EBC1 flows because of changes in upstream reservoir releases. The preliminary proposal north Delta intakes allowed higher exports in April, May, and June and subsequently allowed reduced reservoir releases and reduced exports. The PP cases had inflows and exports that were distributed more evenly during the highest agricultural demand period of April through September.

No comments

- n/a -

C.7.1.2.2 San Joaquin River Flows at Vernalis

The only changes in the San Joaquin River flows are caused by the assumed climate change effects on reduced San Joaquin River (above Friant Dam) inflows and reduced tributary inflows. No changes from preliminary proposal operations were simulated.

C.7.1.2.3 Yolo Bypass Flows to the Delta

The Yolo Bypass flow is nearly identical to the Fremont Weir spills, with the addition of the Cache Creek and Putah Creek flows entering the bypass in months with relatively high runoff. Although the preliminary proposal ELT and LLT cases allow some additional flows into the Yolo Bypass at the Fremont Weir, the monthly sequence of Yolo Bypass flows was very similar. A few more months have flows of 3,000–5,000 cfs (notch capacity), and the high-flow months have slightly more flow (5,000 cfs).

C.7.1.2.4 Mokelumne River and Cosumnes River Flows to the Delta

The monthly inflows from the Mokelumne River near Thornton, just below the Cosumnes River, are very low during the summer months. These flows were nearly identical for all CALSIM cases. Most Cosumnes River runoff enters the Delta, and the Mokelumne River is highly regulated by Pardee and Camanche Reservoirs. The minimum flows below Woodbridge Dam are specified based on runoff, and reservoir spills are rare. There were no effects of the preliminary proposal on these river flows.

C.7.1.2.5 San Joaquin River Diversions to Old River

The preliminary proposal would not result in changes in the San Joaquin River flows at Old River, but some changes are expected as a result of climate change. The median head of Old River flow for December through May was about half of the San Joaquin River flow at Vernalis. The median flows in June through September were about 40% of the San Joaquin River flow at Vernalis because of the effects of the south Delta rock barriers. The annual average head of Old River diversion flow was nearly the same for all six CALSIM cases and was equal to about half of the San Joaquin River flow.

C.7.1.2.6 Old and Middle River Flows

The CALSIM modeling assumed that some OMR reverse flow restrictions would apply for each of the applicable months (December through June). The restrictions were assumed to vary somewhat with runoff conditions. The assumed restrictions were held constant for each of the EBC1 cases, the three EBC2 cases, and the two preliminary proposal cases. Because negative OMR flow is toward the south Delta pumps, the greatest negative values indicate higher pumping. The minimum values indicate the maximum pumping from the central Delta. For example, the October and November minimum flows for EBC1 were -10,000 cfs. The October and November median flows were -8,000 cfs. However, there are no OMR flow restrictions in October and November. The EBC1 December minimum flow was -9,600 cfs, but the median flow was -5,871 cfs (the assumed OMR limit in 30% of the years). This suggests that the OMR limits were reducing the December exports to this level in several of the years. The January through March and June minimum flows were -5,000 cfs because the assumed OMR limits were restricting pumping to this level in many of the years in these months. The minimum flows in April and May were higher than the limit of -5,000 cfs because the NMFS exports/San Joaquin River ratio that applies in April and May was reducing the exports more than the OMR limits. EBC1 flows in July through September were -11,000 to -10,000 cfs, and median flows were -10,000 to -9,000 cfs.

No comments

- n/a -

The preliminary proposal ELT and LLT cases shifted pumping from the south Delta to the north Delta intakes and thereby increased the OMR flows (reduced negative OMR flows). The median OMR flows for the preliminary proposal ELT and LLT cases were about 2,000 cfs higher in October and November; about the same in December; 2,000 cfs higher in January; 5,000 cfs higher in February; 3,500 cfs higher in March; 1,500 cfs higher in June; 6,000 cfs higher in July; 6,500 cfs in August; and 4,500 cfs higher in September.

C.7.1.2.7 Sutter Slough and Steamboat Slough Flows

Sutter and Steamboat Sloughs divert about 40% of the Sacramento River flow. The monthly median diversion flows into Sutter and Steamboat Sloughs were similar for the EBC1 case and the three EBC2 cases because the Sacramento River flows were similar. The median diversions into Sutter and Steamboat Sloughs were lower for the PP_ELT and PP_LLT cases because the north Delta intakes reduce the Sacramento River flow at Sutter and Steamboat Sloughs. The median diversions in October, April, May, and June were about the same for the baseline and the preliminary proposal cases. The median diversions were reduced by 1,000 cfs in November, July, and September; 2,000 cfs in January and August; and 4,000 cfs in February and March. The reductions in the Sutter and Steamboat Slough diversions were about 40% of the simulated north Delta intake diversions. The annual average diversions into Sutter and Steamboat Sloughs were about 6,500 taf (42% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 5,500 taf (36% of the Sacramento River flow at Freeport) for the two preliminary proposal cases.

C.7.1.2.8 Delta Cross Channel and Georgiana Slough Flows

Similar to Steamboat and Sutter Sloughs, the PP_ELT and PP_LLT cases for DCC and Georgiana Slough had reduced monthly median diversion flows because the north Delta intakes reduced the Sacramento River flow. The annual average diversions into the DCC and Georgiana Slough were about 3,750 taf (24% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 3,150 taf (21% of the Sacramento River flow at Freeport) for the two preliminary proposal cases.

C.7.1.2.9 Sacramento River Flows at Rio Vista

The minimum flows in September through December for Rio Vista (3,000–4,500 cfs, depending on water-year type) were generally satisfied. The EBC1 monthly median flows were about 5,500 cfs in October; 7,500 cfs in November; 12,500 cfs in December; 22,000 cfs in January; 29,000 cfs in February; 23,000 cfs in March; 13,000 cfs in April; 10,000 cfs in May; 6,500 cfs in June; 10,500 cfs in July; 8,500 cfs in August; and 6,500 cfs in September. The median flows at Rio Vista for the three EBC2 cases were similar because the Yolo Bypass and Sacramento River inflows were generally the same. The median monthly Rio Vista flows were reduced in the months when the north Delta intake diversions were simulated for the PP_ELT and PP_LLT cases. The reduced Rio Vista flows were generally about the same as the north Delta intake diversions. The annual average Sacramento River flows at Rio Vista were about 14,000 taf for the EBC1 case and three EBC2 cases, and were reduced to about 12,000 taf for the PP_ELT and PP_LLT cases.

No comments

- n/a -

C.7.1.2.10 Threemile Slough Flows

The Threemile Slough flows are about 3% of the Rio Vista flows and were reduced slightly for the preliminary proposal cases because the Rio Vista flows were reduced by the north Delta intake diversions. The annual average Threemile Slough flows were about 1,000 taf for the EBC1 case and the three EBC2 cases, and were reduced to about 750 taf for the two preliminary proposal cases.

C.7.1.2.11 San Joaquin River Flows at Antioch

San Joaquin River flows at Antioch were increased in the PP_ELT and PP_LLT cases because the reduction in south Delta exports will increase OMR and San Joaquin River flows by the same amount. For the preliminary proposal cases, the monthly median flows were about 0 cfs in October and November, and were reversed to -2,000 cfs only in December. The San Joaquin River flows were about 1,500 cfs in January; 8,500 cfs in February; 6,500 cfs in March; 3,000 cfs in April; 2,500 cfs in May and June; 1,000 cfs in July; 500 cfs in August; and 150 cfs in September. The summer periods of reverse San Joaquin River flow were generally eliminated by the preliminary proposal north Delta intake diversions.

C.7.1.2.12 Delta Outflow

The CALSIM-simulated Delta outflow is the sum of all the upstream and Delta operations, and it is the major link with salinity in the Delta and with the X2 position. Delta outflow requirements often limit the Delta exports, so the simulated Delta outflow for many months is equal to the minimum Delta outflow requirement for each month. The EBC1 case did not include the BiOp Fall X2 requirements, so the required Delta outflow was controlled by the D-1641 objectives. The annual average outflow required for EBC1 (D-1641) was 4,250 taf. The three EBC2 cases included the BiOp Fall X2 requirements, and the average annual required outflow was about 5,000 taf for EBC2, about 5,250 taf for EBC2_ELT, and about 5,750 taf for EBC2_LLT. The BiOp Fall X2 requirements (intended for wet and above normal years) raised the annual average required outflow for EBC1 by about 750 taf. The EBC2_ELT and EBC2_LLT cases had even higher required outflows caused by changes in the outflow required to meet X2 because of sea level rise and habitat restoration effects on salinity intrusion.

The monthly median outflows simulated by CALSIM for each modeling scenario are shown in Table C.7-1. About half of the months had excess Delta outflow compared to the outflow requirements, but the outflow in most of these months likely was controlled by the maximum allowed export/inflow (E/I) ratio.

No comments

- n/a -

Table C.7-1. Average Annual and Monthly Mean Outflows for Each of the Six CALSIM Scenarios

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Average Annual Outflow (taf)	15,533	15,743	16,157	16,282	14,875	15,210
Monthly Median Outflow (cfs)						
January	22,361	21,730	21,342	21,903	21,277	22,074
February	36,554	35,578	35,846	37,339	36,181	35,855
March	26,890	26,801	25,701	25,784	24,828	24,486
April	18,921	18,804	18,708	18,283	12,470	13,037
May	15,899	15,655	13,911	12,806	11,352	11,400
June	7,243	7,249	7,243	8,336	8,086	9,290
July	8,000	8,000	8,000	8,520	8,000	8,000
August	4,000	4,000	4,000	4,112	4,000	4,000
September	3,610	3,621	3,659	3,430	3,000	3,000
October	4,000	4,403	5,425	7,813	4,000	9,234
November	5,088	10,313	9,844	10,415	4,500	4,500
December	8,086	7,696	8,666	9,156	8,867	9,219
taf = thousand acre-feet.						

The monthly median outflows for the PP_ELT and PP_LLT cases were similar (within 1,000 cfs) to the EBC1 median outflows in October through February; 2,000 cfs less in March; 6,000 cfs less in April; 4,000 cfs less in May; and similar in June through September. The annual average Delta outflow for the EBC1 case was 15,500 taf. The annual average outflows were 14,875 taf for the PP_ELT case and 15,200 taf for the PP_LLT case.

C.7.1.3 Salinity

Salinity is included in this appendix to assess the potential for changes to habitat as a result of changes in flows that may cause changes in salinity. (Salinity as a drinking water quality parameter is addressed in the BDCP EIR/EIS.) The preliminary proposal allows more salt into the western Delta because of increased tidal mixing associated with the addition of tidal marsh areas and reduced Delta outflow. Substantial increases in salinity at Emmaton and moderate increases at Jersey Point and Rock Slough caused by the preliminary proposal are generally attributable to the reduction in Sacramento River flows in these areas. However, slight reductions in average annual salinity at Threemile Slough are expected as a result of major salinity decreases in July and August caused by higher outflows. As the preliminary proposal is implemented and more tidal marsh is restored, salinity effects at these locations intensify. At Emmaton under PP_LLT, the largest increases in salinity occur from May to September, while there are minimal changes in salinity from October through April. Jersey Point and Rock Slough are also expected to have additional increases in salinity in the LLT as a result of restoration activities. The annual average salinity at Threemile Slough is further reduced in the LLT because of substantial salinity reductions in October and November resulting from higher Sacramento River flow.

Salinity can be controlled somewhat by Delta outflow. Higher Delta outflow moves the salinity gradient west and lowers the X2 (decreases the distance from the Golden Gate). Under the PP scenarios, X2 moves upstream (lower outflow) in some months, with the reduced inflows or higher exports that are allowed with the north Delta intake. However, the PP scenarios will meet the

No comments

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required D-1641 X2 locations from February through June and the minimum Delta outflows, as described above and shown in Table C.7-2.

Table C.7-2. Summary of the Location (km from the Golden Gate Bridge) of X2 under each CALSIM Scenario

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	67.1	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.1	56.2	66.0	63.5
Max	94.7	93.9	92.2	89.7	86.9	83.3	83.2	87.4	90.5	91.2	91.5	92.6
Avg	88.5	86.3	77.9	67.6	60.7	60.7	63.4	67.5	74.6	80.4	85.2	86.4
B. PP_ELT												
Min	72.8	52.2	47.7	47.6	47.6	47.7	47.7	49.3	51.0	62.3	74.7	71.4
Max	93.1	92.6	92.4	90.1	86.8	82.3	83.2	87.1	90.2	90.5	92.1	93.5
Avg	89.0	86.8	78.3	68.3	62.1	62.4	66.7	71.8	77.0	81.6	86.5	88.5
C. PP_LLT												
Min	73.8	54.6	48.8	48.7	48.7	48.7	49.0	51.6	54.8	69.9	83.4	79.3
Max	92.4	94.3	91.6	90.1	85.7	83.5	84.5	89.1	92.1	91.6	91.9	92.7
Avg	85.7	85.1	79.7	68.9	63.2	63.8	68.0	73.7	78.9	83.2	87.5	89.2
D. EBC2												
Min	67.3	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.3	57.1	67.3	65.8
Max	94.6	93.4	92.2	87.2	83.2	82.3	82.5	87.2	90.2	90.9	90.8	92.4
Avg	84.1	82.3	76.3	67.4	60.8	61.0	63.6	67.8	74.7	80.4	85.2	82.5
E. EBC2_ELT												
Min	69.5	52.4	47.8	47.6	47.6	47.7	47.9	49.8	51.5	62.1	73.6	70.9
Max	93.9	94.4	93.6	90.4	87.0	82.7	83.1	87.6	90.2	90.8	90.9	92.6
Avg	84.1	82.3	76.6	67.9	61.7	61.9	64.6	68.9	75.9	80.3	85.1	82.7
F. EBC2_LLT												
Min	72.2	55.4	50.0	49.6	49.6	49.5	50.0	53.1	55.7	71.4	81.2	73.9
Max	94.6	94.7	94.0	90.4	87.3	83.8	84.6	88.7	90.9	90.9	92.1	94.3
Avg	83.7	82.7	78.2	69.4	63.5	63.7	66.5	71.4	77.6	80.8	85.8	83.4

The three EBC2 cases, which included BiOp Fall X2 requirements in September through November of about half of the years (wet and above normal), had corresponding reduced X2 values in the 50–90% cumulative values. The changes in the monthly X2 ranges or in the monthly median values were relatively small because the monthly range in outflows remained similar for each of the EBC1 and EBC2 baseline cases. The preliminary proposal cases allowed some of the X2 positions to move upstream (lower outflow), with the higher exports that were allowed in some months with the north Delta intake. The required D-1641 X2 locations from February through June and the minimum Delta outflows were satisfied by the preliminary proposal cases, although CALSIM results reported above may be based on relaxations of the requirements in certain months.

C.7.1.4 Turbidity

Firm conclusions regarding changes in turbidity in the Plan Area are difficult to make. Uncertainty in sediment supply in the future is high because of factors such as the maturation schedule of habitat restoration within ROAs. In addition, the potential use of fill-in materials or wind breaks in the ROAs

No comments

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to reduce wind-driven sediment resuspension also could greatly affect turbidity. These and other factors limit the feasible scope of the analysis.

The analysis focused on whether the different subregions would become erosional, which would increase turbidity, or depositional, which would decrease turbidity. The analysis also evaluated whether seasonal wind resuspension within ROAs is likely to be greater with the preliminary proposal, thereby increasing turbidity. Factors such as submerged aquatic vegetation (SAV), benthic filter feeders, organic materials, and the potential substantial effects on the critical shear stress of erosion from changes in benthic algae and macrofauna have not been considered in the present analysis of turbidity because of a lack of data, a lack of modeling tools, or both.

The Delta will remain regionally depositional in the LLT time frame, in both EBC and PP scenarios, although the location of the depositional regions will differ. The effects of sea level rise will depend on the balance between sediment supply from the watersheds and the rate of sea level rise, so it is unclear whether sediment supply will be sufficient to maintain the current extent of tidal marsh. The initial effect of the ROAs in the PP is to decrease sediment supply downstream, but the longer-term effects are uncertain as the ROAs reach a dynamic equilibrium.

Under the PP, the North Delta subregion will receive less sediment because of increased flows through the Yolo Bypass, but this may not be a large enough factor to differentiate these effects from the overall effects due to sea level rise and climate change alone in the LLT under existing conditions. The Cache/Yolo Bypass–region ROAs will become depositional with sediment that otherwise would be carried down the Sacramento River. While the ROAs have the potential to increase water clarity in existing open water areas such as Liberty Island at least initially, wind resuspension of unconsolidated sediment during the summer is likely to decrease water clarity in the region seasonally. The West Delta ROA will accrete sediment, resulting in a local increase in water clarity in combination with decreased supply due to sediment deposition in the Cache/Yolo region. However, decreased sediment supply could result in erosion and a decrease in water clarity, leaving a mixed outcome for this region. The East Delta subregion is likely to experience increased water clarity due to the ROAs, both because of decreased flow through Georgiana Slough and because of deposition in the East Delta ROAs of the small amount of sediment originating from the Mokelumne and Cosumnes Rivers. The effect of seasonal winds will be minor because the ROAs are not large in the East Delta. The South Delta ROA consists of large open water areas that (barring establishment of SAV such as *Egeria densa*) likely will experience decreased water clarity due to wind resuspension in the summer. However, deposition in the ROAs also could increase water clarity, resulting in an overall mixed outcome.

The effect of the Suisun Bay subregion ROAs, both locally and due to effects from upstream ROAs, is complicated. Suisun Bay is currently erosional and the opening of ROAs upstream is likely to increase this erosion. If Suisun Bay continues to deepen and intertidal regions are lost, wind waves will become less effective at suspending sediment, so erosion rates may slow even in the presence of reduced sediment supply. The new ROAs may exert a local decrease in water clarity from seasonal resuspension due to wind. However, predicting the balance between the depositional environment in the ROAs and increased regional erosion is very complicated, so the overall result for water clarity is uncertain. The ROAs in Suisun Marsh likely will be depositional because of local sediment supply, resulting in local increases in water clarity. The effects of wind resuspension in decreasing water clarity likely will be limited to the larger ROAs in this region, depending on wind direction.

No comments

- n/a -

The effects of turbidity on fish are not directly linked to survival and are only one component of habitat that may be required for species success. As such, similar to the salinity changes described above, the effects of turbidity on fish and fish habitat will be explored further in Appendices E (*Fish Population Analyses*) and F (*Habitat Restoration*) to better integrate the multiple factors composing fish habitat and the potential effects of the preliminary proposal.

C.7.1.5 Temperature and Dissolved Oxygen

Some temperature changes are expected to occur in some years in some upstream rivers. However, these changes rarely translate to adverse effects on species, as described below. In-Delta water temperature and DO concentrations are not expected to change in response to the preliminary proposal. Water temperatures and DO in the Delta are affected primarily by atmospheric conditions (air temperature, winds, solar radiation, and climate change). Water temperatures are typically in thermal equilibrium with the atmospheric conditions and therefore are not influenced strongly by changes in river flows affected by proposed project operations. Similarly, DO concentrations in the river channels and bays are typically in equilibrium with atmospheric conditions, and proposed project operations are not anticipated to result in biologically significant changes within the Delta. As a result of these factors, it was concluded that proposed project operations would not result in adverse changes in either water temperatures or DO concentrations n the Delta that would affect the target species. Changes in long-term seasonal water temperatures are anticipated to occur within the Delta, however, in response to future climate changes that are independent of proposed project operations, but that also are expected to result in changes in habitat conditions that could potentially adversely affect the population dynamics of the covered species in the future (LLT climate changes).

C.7.2 Flow-Related Biological Effects

The following information is summarized in Table C.1-3, Table C.1-4, and Table C.1-5 above, and describes in detail the conclusions for each species for flow-related parameters in upstream and Delta areas, and for passage, migration, and movement.

C.7.2.1 Upstream Spawning and Egg Incubation

Conclusion 1. Except for Sacramento River spring-run Chinook salmon and Feather River green sturgeon egg incubation, the preliminary proposal would not result in adverse effects on upstream spawning.

Overall, there would be minimal changes to upstream flows and as such, very few effects on spawning and egg incubation. Most of the differences and associated effects on spawning and egg incubation habitat observed among the modeled scenarios were attributable to near-term and long-term climate change effects. In many instances, increased steelhead, winter-run, Pacific lamprey, and river lamprey egg mortality under future conditions is primarily a result of natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on incubating eggs that were largely independent of preliminary proposal operations. Decreased temperatures during egg incubation periods for spring-run Chinook salmon on the Sacramento River and green sturgeon on the Feather River would result in adverse effects on these species.

Steelhead. No adverse effects were detected on steelhead spawning and egg incubation habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted

No comments

- n/a -

magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of spawning and incubation habitat under proposed project and future baseline conditions were comparable. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures during the steelhead spawning and incubation period, but would not affect long-term habitat conditions relative to future baseline conditions.

Winter-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Sacramento River winter-run Chinook salmon based on results from the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Positive and negative changes in instream flows that affect habitat quality and quantity, such as reduced summer and fall flows relative to existing conditions, were detected in the Sacramento River. Differences in flow in the Sacramento River in September of wetter years between existing and preliminary proposal operations reflect, in large part, differences in fall operations for downstream low-salinity habitat that was included as an operating criterion under the EBC2 conditions but was not included in preliminary proposal operations.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from the Reclamation egg mortality model, SALMOD, CALSIM outputs, and other tools. Most spring-run Chinook salmon spawn in tributaries such as the Feather River and Mill, Deer, Butte, and Clear Creeks, in which spring-run egg mortality would not be affected by preliminary proposal operations.

In the Sacramento River, the egg mortality model indicated that there is a 5–10% increase in egg mortality of spring-run Chinook salmon under preliminary proposal operations relative to existing biological conditions in wet, above normal, and below normal water years. This increase was a result of increased water temperatures during fall months, particularly September. Refinements in reservoir operations and coldwater pool management, including real-time management, which CALSIM cannot model, may reduce this effect, but this has not been evaluated using the hydrologic and water temperature simulation models. However, results of the SacEFT and SALMOD models, which account for flow, temperature, and other variables in the upper Sacramento River, predict that spawning habitat conditions will not be different (SALMOD) or will be improved (SacEFT) under the proposed project compared to existing biological conditions, which is in contrast to the egg mortality model results described above.

Fall-run Chinook salmon. No major adverse effects were detected on upstream spawning or egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for fall-run Chinook salmon in the Sacramento River based on results of model analyses using the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Small positive and negative changes were detected in the Sacramento River, such as reduced summer and fall flows relative to existing conditions. No substantive changes in reservoir storage or river flows affecting fall-run Chinook salmon habitat conditions were detected in the Feather, American, San Joaquin, Stanislaus, or Trinity Rivers or Clear Creek. Preliminary proposal operations have no effect on flows or water temperatures in other tributaries, including the Mokelumne, Cosumnes, Merced, and Tuolumne Rivers, or habitats in areas such as Mill, Deer, Butte, and Battle Creeks.

No comments

\- n/a -

Late fall–run Chinook salmon. No major adverse effects were detected on late fall–run Chinook spawning and egg incubation habitat conditions in the Sacramento River based on CALSIM, SacEFT, SALMOD, and other modeling tools. Although most changes in spawning habitat were attributable to climate change, the SacEFT model indicated that preliminary proposal operations would result in a small incremental reduction (5%) in the number of years with "good" spawning habitat conditions for late fall–run Chinook salmon.

White and green sturgeon. Spawning white sturgeon and their eggs would experience similar flow and water temperature conditions under preliminary proposal operations relative to existing biological conditions. There are small beneficial and adverse effects on spawning and egg incubation habitat conditions, but no major or consistent adverse effects were detected in the Sacramento, Feather, or Stanislaus Rivers. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. These major habitat effects were largely independent of differences between existing conditions and preliminary proposal operations. Likewise, no major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., instream flows and water temperatures during egg incubation) in the Sacramento River for green sturgeon based on results from the Reclamation egg mortality model, SacEFT, CALSIM outputs, and other tools. In the Feather River, however, there is a reduction in flows during July and August of 29% on average, but this effect does not translate into a consistent adverse effect on green sturgeon based on water temperature exposure. There were no meaningful differences between existing biological conditions and preliminary proposal operations in exceedance of water temperature tolerances of 63°F and 68°F. The only effect is an increase of exposure to the upper threshold of green sturgeon tolerance of 73°F in up to 8% more months under preliminary proposal operations compared to existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Pacific lamprey and river lamprey based on results from the Reclamation egg mortality model, CALSIM, and other tools.

C.7.2.2 Holding Flows

Holding flows were evaluated for spring- and winter-run Chinook salmon adults. As described below, no adverse effects of the preliminary proposal are expected.

Conclusion 2. The preliminary proposal would have no effects on spring- or winter-run Chinook salmon adult holding flows.

No major or consistent adverse effects were detected on upstream adult holding habitat conditions (e.g., instream flows) in the Sacramento River for spring- and winter-run Chinook salmon or in the Feather and Trinity Rivers or Clear Creek for spring-run Chinook salmon based on results from CALSIM. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflect natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on holding adults that were largely independent of preliminary proposal operations.

No comments

- n/a -

C.7.2.3 Upstream Rearing Habitat

Upstream rearing habitat for covered species would not change substantially, although some increase in Feather River temperature may adversely affect green sturgeon and river lamprey, and a decrease in late fall–run Chinook salmon rearing habitat also may occur. For spring-run Chinook salmon, fall-run Chinook, green sturgeon, white sturgeon, Pacific lamprey, and river lamprey, the greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflects natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on rearing habitat that were largely independent of preliminary proposal operations.

Conclusion 3. Upstream rearing habitat for covered species would not change substantially; however, some adverse effects on late fall–run Sacramento River rearing habitat and on green sturgeon and river lamprey rearing habitat as a result of increases in Feather River temperature, and some benefits to winter-run rearing habitat, are expected.

Steelhead. No major adverse effects were detected on steelhead fry/juvenile rearing habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on steelhead rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures affecting steelhead rearing habitat, but would not affect long-term habitat conditions relative to future baseline conditions. In the Sacramento River between the RBDD and Keswick, the SacEFT model indicated that preliminary proposal operations would result in a small incremental increase (5%) in the number of years with "good" rearing habitat conditions for steelhead.

Winter-run Chinook salmon. The SacEFT model predicted that winter-run Chinook salmon fry/juvenile rearing habitat in the Sacramento River would be classified as *good* in 23–26% more years under preliminary proposal operations relative to existing conditions.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Fall-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for fall-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Late fall–run Chinook salmon. No adverse effects were detected on late fall–run Chinook fry/juvenile rearing habitat conditions in the Sacramento River based on CALSIM, SALMOD, and water temperature modeling. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat in the Sacramento River under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on late fall–run Chinook salmon rearing habitat

No comments

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observed among the modeled scenarios were attributable to near- and long-term climate change effects. Despite these results, the SacEFT model indicated that preliminary proposal operations would result in an incremental reduction of 14–28% in the number of years with "good" rearing habitat conditions for late fall–run Chinook salmon. However, based on the weight of evidence (SALMOD results, flow, and temperature exceedance analyses), there should be no detectable change in rearing habitat conditions for late fall–run Chinook salmon in the upper Sacramento River.

Green and white sturgeon. No major or consistent adverse effects were detected on upstream larvae/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in the Sacramento River or upstream waterways for green or white sturgeon based on results from CALSIM and the Reclamation water temperature model. Additionally, larval and juvenile white sturgeon would experience similar or slightly improved flow and water temperature conditions. Green sturgeon larvae will experience reduced flows in the Feather River from July through September, when flows are reduced by 42% on average in wet, above normal, below normal, and dry water years. However, reduced flows are not expected to translate into water temperature effects in a major or consistent way, except during the LLT implementation period, during which exposure to the upper 73°F water temperature threshold will occur 5–14% more often under preliminary proposal operations than under existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream ammocoete rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for Pacific lamprey or in the Sacramento, Trinity, American, and Stanislaus Rivers for river lamprey based on results from CALSIM and the Reclamation water temperature model. In the Feather River below Thermalito Afterbay, there is a small to moderate increase in exposure to elevated water temperatures, although this effect is not observed farther upstream at the Fish Barrier Dam. This increase in exposure to elevated water temperatures is expected to result in a small to moderate increase in mortality of ammocoetes in the region below the Thermalito Bypass.

C.7.2.4 Passage, Migration, and Movement

Passage, migration, and movement were evaluated for upstream and Delta areas for all species. Overall, the results indicate that there will be some improved and some reduced passage as a result of the preliminary proposal.

Conclusion 4. Overall, flows in upstream areas during migration and transport periods for anadromous fish are not substantially changed under the preliminary proposal, with some exceptions.

The great majority of modeled river flow estimates upstream of the Plan Area suggested that, once effects associated with climate change were factored out, average differences in flow between PP and EBC during covered fish species migration and transport periods would be minor (Table C.1-3). The general pattern was for little change, with minor increases or decreases depending on water-year type. There were essentially no changes in migration flows in Clear Creek, the Stanislaus River, and the San Joaquin River at Vernalis. Analyses were based on the assumption that migration and transport are enhanced with increased flows, although there were few specific thresholds or ranges that could be applied. Summaries of the main patterns are provided below.

No comments

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Steelhead. The Feather River was the only location where migration flows during periods of steelhead occurrence exhibited a number of differences between preliminary proposal and existing conditions: migration flows for juveniles and kelts were somewhat (generally 10% or more) greater under the preliminary proposal in most water-year types, but for adults, preliminary proposal flows were greater (10–20% more) only in dry and critical years.

Winter-run Chinook salmon. The analysis suggested little difference between existing conditions and preliminary proposal average flows during the juvenile downstream migration period in the upper Sacramento River (River Mile [RM] 194 to Keswick).

Spring-run Chinook salmon. As with steelhead, the Feather River was the only location with appreciable differences in migration flows between preliminary proposal and existing conditions, with the former averaging 5–30% greater than the latter in most water-year types.

Fall-run/late fall–run Chinook salmon. Migration flows for fall-run Chinook salmon were generally little different between preliminary proposal and existing conditions at most locations, except the Sacramento River (RM 194 to Keswick), American River, and Feather River. In the upper Sacramento River, adult migration flows were around 10–20% less under the preliminary proposal in wet and above normal water years, and either similar or up to 20% greater under the preliminary proposal in the remaining water-year types. In the American River, appreciably less average adult migration flow (7–26%) occurred under preliminary proposal conditions than under existing conditions in wet and above normal years, whereas in critical years preliminary proposal flows were 13–39% greater. Juvenile migration flows in the Feather River averaged around 10–20% greater than existing biological conditions for above normal, below normal, and dry years and were similar in other years. Adult migration flows were 12–32% less on average under the preliminary proposal in wet, above normal, and below normal years, in contrast to a similar percentage greater under the preliminary proposal in critical years. For late fall–run Chinook salmon adults, there was little difference in migration flows between the preliminary proposal and existing conditions in the Sacramento River (RM 194 to Keswick).

White sturgeon. Analyses for white sturgeon focused on the Sacramento River (North Delta to RM 143 subregion—i.e., Wilkins Slough and Verona CALSIM nodes). For juveniles, average migration flows at Verona were more than 5% lower under the preliminary proposal scenarios in all water-year types, ranging from around 6–11% in critical years to 20% in wet years. Larval transport flows were represented by the average number of months per year that exceeded thresholds of 17,700 cfs (Wilkins Slough) and 31,000 cfs (Verona) and were variable in terms of estimated effects. The results ranged from little change or somewhat more frequent exceedances of flow thresholds (16% greater in above normal years) under the preliminary proposal relative to existing conditions at Wilkins Slough, to reduced flow threshold exceedances at Verona of 9–50%. (The latter value occurred in dry years, when the average number of months exceeding the threshold was low regardless of scenario.)

Green sturgeon. Flows for green sturgeon migration were analyzed in the upper Sacramento River and Feather River and demonstrated contrasting changes for different life stages. Preliminary proposal flows that were lower than flows under the existing conditions were evident for larvae and juveniles in both systems and occurred primarily in wet, above normal, and below normal years, with the preliminary proposal flows in the Feather River falling in the 25–50% reduction category on average and those in the Sacramento River falling in the 5–25% reduction category. In contrast,

No comments

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adult migration flows were either similar or, in the case of the Feather River, somewhat increased in above normal, below normal, and dry water years.

Pacific lamprey. Average flows during Pacific lamprey migration periods were quite similar under the preliminary proposal and existing conditions (or slightly greater, up to 10%, under the preliminary proposal) on the Sacramento River (RM 194 to Keswick), Feather River, American River, Stanislaus River, and San Joaquin River at Vernalis.

River lamprey. Average flows during river lamprey migration periods generally were quite similar under the preliminary proposal and existing conditions for macropthalmia, with differences occurring for adults that typically indicated lower flows under the preliminary proposal than existing conditions. For adults, the difference was less than 5% for the Stanislaus River and San Joaquin River at Vernalis, whereas flows were 6–13% lower under the preliminary proposal for the Sacramento River (RM 194 to Keswick), Feather River, and American River.

Conclusion 5. Attraction flows and olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the preliminary proposal.

Sacramento River flows downstream of the north Delta intakes will be reduced under preliminary proposal operations relative to existing conditions, while reduced exports in the south Delta generally will increase the proportion of water in the west Delta originating from the San Joaquin River. The change in olfactory cues (percentage of Sacramento River or San Joaquin River water at Collinsville predicted using DSM2 modeling within the fingerprint analysis) differed by species (Table C.1-3). Under the preliminary proposal, the average percentage of Sacramento River–origin water was always lower than for the existing conditions, ranging from 2–4% less for steelhead to 8–10% less for fall-run Chinook salmon. Under the preliminary proposal, the percentage of San Joaquin water was generally considerably greater than under existing conditions, at least in relative terms; however, the actual percentages involved were low (single digits) because a very low percentage of San Joaquin River water contributes to the water in the west Delta in any scenario.

Adult attraction/migration flows at Rio Vista under the preliminary proposal were lower than flows under existing conditions for most water-year types. The relative difference between scenarios ranged from 5–9% in all except critical water years (little changed) for winter-run and late fall–run Chinook salmon to more than 20% in some water-year types for steelhead, spring-run Chinook salmon, and fall-run Chinook salmon; the latter species had up to around 50–60% lower average flows under the preliminary proposal in wet and above normal years. In dry and critical years, differences in migration flows between preliminary proposal and existing conditions were often less than 5%, and in some cases preliminary proposal flows were greater (e.g., fall-run Chinook salmon in the LLT).

Conclusion 6. The preliminary proposal improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM 2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species.

The suite of actions proposed to improve adult fish passage as part of CM 2 (Yolo Bypass Fisheries Enhancements) is expected to benefit covered fish species by reducing stranding and delay in the Yolo Bypass. Limited stranding and rescue data indicate that appreciable percentages (10% or more) of the green sturgeon spawning population in particular currently may be negatively affected by the passage impediment caused by the Fremont Weir. The efficacy of the passage improvements

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at the Fremont Weir and other locations in the Yolo Bypass (e.g., Lisbon Weir) cannot be estimated, but will be monitored, and adjustments will be made through adaptive management. Resulting, improvements in migration may vary by year type as a result of differing inundation frequencies and volumes, but overall CM 2 is expected to have a major positive effect on upstream migrating anadromous covered fish species, in particular sturgeons and salmonids.

Conclusion 7. Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management.

The results of the DPM showed that through-Delta survival of Chinook salmon smolts was generally similar or slightly lower under the preliminary proposal than under existing biological conditions. The difference in survival between preliminary proposal scenarios and existing biological conditions in the early and late long-term ranged from averages of considerably less than 1% of the smolts entering the Delta (San Joaquin–origin fall-run Chinook) to 1–2% of smolts for fall-, spring-, and winter-run Chinook from the Sacramento River and fall-run Chinook from the Mokelumne River. The observed patterns represented tradeoffs between positive and negative aspects of the preliminary proposal relative to the existing biological conditions, as assumed in the model. Positive aspects of the preliminary proposal include the increased diversion of fish into the Yolo Bypass for smolts migrating down the Sacramento River that encounter the new notch at the Fremont Weir. The Yolo Bypass migration route is assumed to have survival equal to the maximum survival in the nearby Sacramento River, as well as offering the advantage of avoidance of diversion through Georgiana Slough or the DCC into the low-survival interior Delta. The benefits of increased entry into the Yolo Bypass were greatest for winter-run Chinook, followed by spring-run and finally fall-run, for which there was little benefit because their assumed timing is during a period when Yolo Bypass inundation is generally too low to promote appreciable diversion. The relatively good survival assumed through the Yolo Bypass is based on studies conducted on fish smaller than smolts, and the assumption will require refinement based on monitoring studies of acoustically tagged smolts to be conducted in the future. Reductions in south Delta exports also improve survival of smolts, although as noted in the entrainment appendix (Appendix B), there are situations in drier water years where exports from the south Delta are increased because of bypass requirements at the north Delta intakes. Such situations generally arise during the fall-run migration period and explain the lower survival through the interior Delta of this race.

Negative aspects of the preliminary proposal include an assumed increase in predation of Sacramento River–origin smolts in the vicinity of the north Delta intake structures because of predators holding station in the area; the current modeling assumed around 1% of each run would be lost, but again this number is uncertain and will be refined through targeted studies. The potential benefits of habitat restoration in the Delta also are not captured by the DPM results, which focus on flow-related survival and migration routes through the Delta.

Conclusion 8. Increase in Stockton Deep Water Ship Channel DO levels (CM 14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin.

Preliminary results from the oxygen diffusion system that forms the basis for CM 14 suggest that it can raise DO levels to meet total maximum daily load objectives (at least 6 mg/L of DO from September 1 to November 30, and at least 5 mg/L at all times). The long-term funding for operations and maintenance of this facility, coupled with improvements that would be implemented based on adaptive management and monitoring, will ensure that any passage impediments caused by low DO

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in this area for upstream migrating adult fall-run Chinook salmon and steelhead in the San Joaquin River basin would be minimized. Improvement of DO in the vicinity of the ship channel also will benefit any other covered fish species using that area of the Delta.

Conclusion 9. Modification of the Suisun Marsh Salinity Control Gate operation will improve or maintain passage for adult anadromous fish.

As operations of the SMSCG become less frequent, upstream passage for adult anadromous fish such as Chinook salmon, steelhead, sturgeons, and lampreys will have less potential for delay and subsequent effects on reproduction in natal tributaries. Passage will be improved or maintained at low levels expected from reduced operations under the preliminary proposal.

Conclusion 10. Nonphysical fish barriers (CM 16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research.

Juvenile Chinook salmon and steelhead, and juvenile and adult delta smelt, longfin smelt, and Sacramento splittail are most likely to benefit from nonphysical barriers at important channel divergences such as Sacramento River–Georgiana Slough and San Joaquin River–Old River because these species have hearing abilities that are likely to respond to the main barrier stimulus (i.e., the acoustic signal). As such, these barriers could be an effective tool for precluding these species from entering the interior Delta, where mortality may be higher than in the main channels of the Sacramento and San Joaquin Rivers. There is little potential to inhibit white and green sturgeon or Pacific and river lamprey from entering the interior Delta because these species have little sensitivity to the acoustic deterrence of the nonphysical barriers; further, in the case of deep channels, the barriers are not constructed to include the channel bottom area where benthic-oriented species like sturgeon would be migrating. The effectiveness of nonphysical barriers will depend on the water-velocity characteristics in the vicinity of the barrier and on the extent to which predatory fish congregate along the barrier.

However, nonphysical barriers could be encountered by upstream migrating adult anadromous fishes (e.g., winter- and spring-run Chinook salmon, steelhead, Sacramento splittail, sturgeons, and lampreys). The potential for impedance or delay would be low for fish with poor hearing ability (sturgeons and lampreys), whereas the potential for impedance of the other species would increase as water depth decreases and a greater portion of the water column is occupied by the barrier. Ongoing testing at Georgiana Slough and the head of the Old River will provide more insight into the potential effectiveness of CM 16 under various flow and geomorphic conditions, as will monitoring, research, and adaptive management of the CM.

Conclusion 11. Reduced Sacramento River flows may reduce longfin smelt and delta smelt larval transport, with the potential to reduce survival for longfin smelt.

Decreased transport flows in the lower Sacramento River have been identified as one mechanism that could adversely affect the growth and survival of larval delta and longfin smelt. Compared to existing biological conditions, the preliminary proposal reduces Delta outflows during the winter-spring delta smelt and longfin smelt larval period, potentially reducing downstream longfin larval transport and subsequent survival. Projected reductions assume a direct relationship between outflow (expressed as X2) and longfin smelt abundance. However, the correlation is not understood, and it may not reflect larval transport but may instead be reflective of some other relationship. The longfin smelt analysis estimated that once climate change–related flow effects had been factored

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out, changes in outflow during the larval period have the potential to reduce abundance of older life stages represented in Bay-Delta trawl surveys by 8–24% in the ELT and 1–18% in the LLT on average. Results of particle tracking modeling for longfin smelt estimated that the potential for emigration to the LSZ in Suisun Bay (as represented by the number of particles reaching Martinez) was on average 0–8% lower under the preliminary proposal compared with existing biological conditions when accounting for climate change–related effects.

For delta smelt, larval transport under the preliminary proposal as assessed by particle tracking ranged from little difference from existing conditions up to 20% less, after accounting for flow-related climate change effects. In contrast to longfin smelt, relationships estimating subsequent abundance of older life stages from changes in transport flows are not present, so the estimated changes solely reflect changed potential in larval transport.

C.7.2.5 Delta Area Effects

Conclusion 12. Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.

Results of the analysis of the effects of changes in Sacramento River flow and water surface elevation on channel margin bench habitat showed site-specific differences attributable to site elevation and the interplay of differing flows and other effects such as tidal muting from the preliminary proposal. At the north Delta sites, inundation frequency under the preliminary proposal was on average similar to or lower than under existing conditions, whereas average inundation duration was lower in the early long-term and higher in the late long-term. At the Cache Slough site, considerable increases in inundation frequency and duration under the preliminary proposal may be a result of the site's low elevation combining with tidal dampening because of restoration. Reductions in bench habitat inundation at existing sites may be offset by restoration at other sites within the North Delta and Cache Slough subregions, as described for CM 4 (Tidal Habitat Restoration) and analyzed in Appendix F, *Habitat Restoration*.

Conclusion 13. The reduction in OMR reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying; reverse OMR flows will be greater in certain water-year types.

As a result of preliminary proposal operations, the frequency and magnitude of OMR reverse flows are expected to be reduced significantly during the late winter and spring period for wet, above normal, and critical years, which coincides with the seasonal period of migration of many of the juvenile fish such as Chinook salmon, steelhead, larval and juvenile delta and longfin smelt, and juvenile splittail through the interior Delta channels. The predicted improvements in south Delta flow conditions (significantly reduced OMR reverse flows, improved net positive downstream flows, improved olfactory cues, and attraction flows for the San Joaquin River and its tributaries) are significant benefits of the PP operations on flow conditions affecting habitat, migration, and survival of fish inhabiting the Delta.

Improved hydrologic conditions in the south Delta in response to proposed project operations are expected to contribute to improvement in the flow cues followed by juvenile and adult fish passing upstream and downstream through the Delta and thereby improve migration and survival and reduce straying. Reduction in OMR reverse flows also is expected to reduce the movement of planktonic larval and juvenile fish (e.g., delta and longfin smelt, Chinook salmon) from the

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Sacramento River through the interior Delta to the south Delta and thereby improve their survival and abundance. However, as noted in Appendix B (*Entrainment*), OMR reverse flows may be increased in the late winter/spring in drier water-year types because of export restrictions at the north Delta intakes, which would negatively affect species present there at the time, such as juvenile spring-run Chinook salmon and larval-juvenile delta smelt.

In dry and below normal water years, the reverse OMR flows are increased compared to existing biological conditions, which may translate to adverse effects on Chinook salmon and splittail juveniles, and delta smelt and longfin smelt larvae and juveniles. However, the reverse OMR flows under the preliminary proposal for all water years are still within the requirements of the NMFS and USFWS BiOps for CVP and SWP operations, and the biological response of these species to relatively small OMR reverse flow changes may not result in adverse changes in species survival.

Conclusion 14. Increased Yolo Bypass inundation will create substantial biological benefits to Sacramento splittail spawning and rearing, with other species likely to benefit; stranding risk is generally low.

Based on results of hydrologic models, modification to the Fremont Weir to increase inundation of the Yolo Bypass floodplain during the winter and spring months (CM 2) would create substantial biological benefits to splittail spawning success and rearing; increased benefits to rearing and migration by other juvenile and adult fish also are expected. The benefits of enhanced growth for Chinook salmon fry on the Yolo Bypass are examined in Appendix F, *Ecological Effects*. The benefits of increased inundation to splittail were found to be greatest in wet, above normal, and below normal water years, when seasonal flows in the Sacramento River are greatest. In these water-year types, habitat area for splittail was on average 60–300% greater under the preliminary proposal scenarios compared to existing biological conditions. The anticipated benefits would be greatest for those fish that rear in floodplain habitats as juveniles during downstream migration, including juvenile winter- and fall-run Chinook salmon. Other fish such as steelhead, late fall–run Chinook salmon, green and white sturgeon, and Pacific lamprey would be expected to benefit from using the flooded bypass as a migratory corridor, but would not be expected to rear extensively in the flooded area. Splittail, which spawn on seasonally inundated floodplain habitat, would be expected to benefit from access to spawning and juvenile rearing floodplain habitat. There is little or no change in inundation of the Yolo Bypass floodplain in dry and critically dry years when river flows are low.

Fish species such as splittail and juvenile Chinook salmon that historically used seasonally inundated floodplain habitat for spawning or juvenile rearing have adapted behavior to respond to flow recessions and draining of floodplain habitat. The DRERIP analysis of stranding suggested low magnitude of negative effect for all species examined other than juvenile steelhead, for which the potential for stranding was assessed to be slightly higher. In general, the risk of stranding juvenile fish in the Yolo Bypass has not been identified as a major potential source of mortality but will be informed by monitoring and adaptive management of improvements to the floodplain.

No comments

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Conclusion 15. The delta smelt fall abiotic habitat index is estimated to be similar between the preliminary proposal and existing biological conditions in the drier 40–50% of years and will be lower under the preliminary proposal in the wetter 50–60% of years, with the magnitude of difference depending on existing biological conditions; if occupied by delta smelt, restored habitat may decrease the magnitude of difference in wetter years and result in a greater habitat index in drier years.[5]

The delta smelt fall abiotic habitat index was lower under the preliminary proposal relative to existing biological conditions, particularly for years with higher flow (Table C.1-3). The greatest differences were for years with higher flow under the EBC2 scenarios, which incorporated the USFWS (2008) BiOp requirements for Fall X2 in above normal and wet years. The differences were relatively low between EBC1 and preliminary proposal scenarios because the requirements for Fall X2 were not included under the modeling for EBC1. Under the assumption that restored areas have abiotic characteristics similar to adjacent areas, the magnitude of the reductions under the preliminary proposal may be reduced in wetter years, and there may be a similar or greater habitat index in drier years (Table C.1-3). However, this assumption will depend on the characteristics in the ROAs, a topic explored in more detail in Appendix E (Habitat Restoration). The likely change in the X2–abiotic habitat index relationship under future configurations of the Delta and the potential influence of additional factors such as water temperature add uncertainty to potential effects. Monitoring in restored areas will provide information on physicochemical characteristics of the new habitat to inform the nature of changes in the delta smelt fall habitat index. Fish sampling in these new areas also will reveal the actual extent to which the areas are used by delta smelt.

[5] The scientific value of the abiotic habitat method and its application is currently the subject of Endangered Species Act litigation between USFWS, DWR and the public water agencies, has been under scientific review, and is the subject of ongoing data collection and evaluation. The utility of the results of this method, along with other methods used to evaluate delta smelt habitat, will be reported in Chapter 5.

No comments

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