TECHNICAL MEMORANDUM **LCRA**

Off-Channel Reservoirs Water Availability & Environmental Assessment

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Summary

Water Supply

Water availability was assessed for potential off-channel reservoirs in Colorado, Wharton, or Matagorda counties. The locations of the reservoirs are not specified, but are assumed to be near the Colorado River, but not on a recognizable tributary of the river. The reservoirs would operate to capture river flows not needed by any other water user and supply that water for irrigation and municipal purposes. Water diverted from the river was assumed to be part of the underutilized irrigation water right at the LCRA irrigation districts. However, no senior priority date was assumed to be imposed on the diversion.

A spreadsheet model was prepared to simulate daily reservoir operation, including diversions, for the 1941-1965 period. Each reservoir was assumed to have storage capacity of 25,000 acre-feet and divert directly from the Colorado River at a maximum instantaneous rate of either 200 or 500 cubic feet per second (cfs), depending on the water demand distribution applied. Two alternative daily water demand distributions were considered: (1) irrigation use within the region; and (2) uniform use for municipal export. For modeling purposes, a single composite reservoir was assumed to have the combined storage and diversion capacities of any specific number of individual reservoirs considered. This single reservoir was assumed to be located in southern Wharton or northern Matagorda County upstream of Bay City.

The river flows available for diversion were assumed to be the daily flows remaining at Bay City after all upstream diversions under the year 2050 condition LCRA RESPONSE model simulated operation, subject to restrictions on minimum flows to pass by the diversion point. These minimum flows are considered in two categories: (1) stored water released

from the Highland Lakes for estuarine inflows; and (2) Consensus Water Planning Environmental Criteria (CWPEC). The latter is applied for new reservoirs operated under new or substantially changed water rights. Given that existing irrigation water rights are used to divert and store water in the off-channel reservoirs, it is not clear as which of the two restrictions would apply in the implementation of this strategy. Hence, each was applied separately to restrict diversions in determining water supply.

The CWPEC may be applied in this case since there is no site specific environmental flow criteria for Matagorda Bay freshwater inflows. There are site specific inflow criteria for operation of the LCRA Highland Lakes, but these do not apply to any other water users in the basin.

Based on these assumptions and scenarios, the dependable water supplies from a number of potential reservoirs were determined. Using an irrigation demand distribution and up to eight reservoirs, the annual dependable water supply varied from 69,000 (one reservoir) to 203,000 (eight reservoirs) acre-feet without application of the CWPEC. Applying the CWPEC, the dependable supply was from 56,000 to 124,000 acre-feet annually, for one and eight reservoirs, respectively.

Similarly, based on a uniform demand distribution, the water supply from one to eight reservoirs varied from 140,000 to 247,000 acre-feet annually without the CWPEC applied. Using this criteria, the supply ranged from 100,000 to 157,000 acre-feet annually.

Environmental Impacts

Development of off-channel reservoirs along the lower Colorado River to storage excess river flows will have impacts on terrestrial and aquatic environments. Aquatic ecosystem changes are assessed in this report, while terrestrial impacts are examined in the South Central Regional Water Plan.

For purposes of illustration, the aquatic impacts were evaluated for the operation of four off-channel reservoirs supplying a uniform demand distribution. The CWPEC was applied to restrict diversions to the composite reservoir.

The water supply for the reservoirs was determined to be about 131,000 acre-feet annually during a repetition of the critical drought-of-record period. In providing this additional supply, there would be a reduction in flows in the Colorado River downstream of their diversion points. Since the reservoirs will be located near the mouth of the river downstream of the most important riverine habitats and downstream of the locations were instream flows are specified in the LCRA Water Management Plan, the impacts on the river ecosystem are not expected to be significant. However, further study is needed once specific reservoir sites have been identified.

The four reservoirs will have more significant impacts on the inflows to and ecology of Matagorda Bay, than on the Colorado River itself. When compared to the year 2050 conditions with no new water supply or conservation development (“Status Quo” alternative), the operation of the reservoirs is projected to reduce average bay inflows from the Colorado River by 147,000 acre-feet annually, or a reduction of 12 percent. During the

critical drought-of-record (1947-1956), the average annual inflows from the Colorado River would be reduced by 28 percent or 134,000 acre-feet.

The reduction in freshwater inflows due to the reservoirs cannot be related to quantitative measures of biological impacts on the Matagorda Bay ecosystem. However, the changes in freshwater inflows can be evaluated based on estimated changes to salinity conditions near the mouth of the Colorado River. Salinity is considered a key indicator of estuarine conditions.

Using available inflow-salinity relationships, the average bay salinity near the Colorado River mouth during the critical drought-of-record is expected to increase from 23 ppt (under the "Status Quo" alternative) to 25 ppt under operation of the four reservoirs. For the full 25-year hydrologic simulation period, the average salinity is estimated to increase from 20 ppt for the "Status Quo" option to 22 ppt with the reservoirs. These changes represent approximately a ten percent increase in average salinity.

Clearly there is an identifiable change in salinity conditions with the off-channel reservoirs. Generally, high salinity over extended periods of time is detrimental of the biological diversity of the bay. However, the estuarine ecosystem suffers stress during extended drought conditions presently without the reservoirs in operation. It is not clear how much worse the environmental stress would be with the modest increase in average salinity. The extent of environmental damage cannot be quantified and further study is needed before implementing this alternative.

As part of future evaluations, there should be an examination of mitigation options to minimize whatever adverse impact the reservoirs may have on the Matagorda Bay ecosystem. One possible mitigation could involve operation of the off-channel reservoirs to reduce the highest salinity by timely releases of stored water. Such mitigation would require reduction in the water supply available for human uses, but would not necessarily make the reservoirs economically infeasible.

Introduction

The Highland Lakes provide highly efficient management and control of Colorado River flows upstream of Mansfield Dam. However, the lower part of the river has no significant regulation. Runoff in the Austin area and further downstream is largely uncontrolled and passes on to Matagorda Bay as natural inflow sources. Further, some reservoir releases cannot be diverted for their intended use and join the natural runoff as freshwater inflows to the Bay.

One method to control a portion of these river flows is to divert and stored them in off-channel reservoirs. Four such major artificial, off-channel lakes presently operate along the Colorado River. They are all used as cooling water ponds for major power plants. These are lakes Decker, Bastrop, and Fayette; and the South Texas Project (STP) Reservoir.

Except for the STP Reservoir, all of the lakes are formed by dams constructed across tributaries of the Colorado River. The STP reservoir is a ringed embankment structure, where the water body is fully enclosed by an artificial dike or levee.

To develop new surface water supplies, additional off-channel lakes could be constructed. The typical off-channel project envisioned in this analysis would be similar to the reservoir at the STP, but about one-tenth the volume.

Construction of off-channel reservoirs would provide additional water, but would have impacts on the terrestrial and aquatic habitats in the area of the reservoir sites and in the Colorado River and Matagorda Bay. The purpose of this report is to evaluate the water supplies available and the environmental impacts of various off-channel reservoirs.

Water Availability Analysis

The estimation of surface water availability from multiple off-channel reservoirs was determined using a daily flow simulation of the actual reservoir operation. A variety of assumptions were made in this analysis and these are listed below.

Assumptions

- Daily river flows available for diversion were assumed to be the simulated flows passing Bay City over the period 1941-1965 under the year 2050 SB1 water demand conditions from the LCRA Water Management Plan strategy; coupled with the use of return flows from the City of Austin. These daily flows were derived from the LCRA RESPONSE hydrologic simulation model (LCRA, 1998). The computer program simulates the daily hydrologic conditions on the river and estimates the water supply available to the major run-of-river water rights, all of which are senior to the water rights for the Highland Lakes System. The model also calculates the water available from storage in the Highland Lakes and operates them on a monthly basis to meet water needs that are not satisfied by the natural river flow, including environmental needs.
- Water diverted from the Colorado River is assumed to be withdrawn under existing, underutilized water rights held by the LCRA for the Gulf Coast, Garwood, Pierce Ranch, and Lakeside irrigation systems. The use of these rights may require environmental flow restrictions, subject to TNRCC decisions.
- Two alternative daily water demand distributions were assumed: irrigation and uniform demands.
  - The irrigation demand distribution is the historical daily usage fraction of the annual demand for the existing four major irrigation districts: Lakeside, Gulf Coast, Pierce Ranch, and Garwood (LCRA Water Management Plan, 1999, page 104).
  - For the uniform demand distribution, the annual water need was distributed equally each day. This distribution represents the likely demand for water if its use were for municipal purposes, including those outside the Colorado River basin.
- A maximum daily diversion capacity of 200 cfs was assumed in the operation of each reservoir when operated to meet the irrigation demand distribution. When a uniform demand distribution is assumed, each reservoir would have a maximum diversion capacity of 500 cfs.

- The consideration of flow pass-through for environmental needs was considered in two alternative ways: with and without Consensus Water Planning Environmental Criteria (CWPEC). The CWPEC may be applied in this case since there are no site-specific environmental flow criteria for Matagorda Bay freshwater inflows. There are site-specific inflow criteria for operation of the LCRA Highland Lakes, but these do not apply to any other water users in the basin.
  - Since the water would be diverted under existing irrigation water rights and may not be subject to additional flow restrictions, the water supply was computed assuming that only the flow releases required under the LCRA Water Management Plan for the Highland Lakes were passed. This flow is equivalent to a minimum flow of 18 cfs and represents stored water released for the Highland Lakes to meet freshwater inflow needs in Matagorda Bay.
  - The second scenario required that the diversions exclude river flows that must pass according to the CWPEC.
- The location of each reservoir was assumed to be in close proximity of the river somewhere in southern Wharton or northern Matagorda counties. The specific locations of the projects will depend on land availability.
- Each reservoir was assumed to have a capacity of 25,000 acre-feet and a surface area of 1,340 acres.
- The annual evaporation rate from each lake was assumed to be the average of the historical rates from 1947-1956, with the monthly rates distributed according to the monthly average during that period.
- The daily flows potentially available for diversion to the off-channel reservoirs are the flows passing Bay City calculated by the RESPONSE model, plus the year 2050 surface water demands at Bay City. These demands consists of: (1) the portion of the Gulf Coast Irrigation District's demand at Bay City (56% of the total district demand based on total diversion capacity); and (2) the manufacturing, mining, and stream electric demands.

Consensus Water Planning Environmental Criteria

The CWPEC uses three zones of daily flow ranges to determine the amount of diversion allowed to off-channel reservoirs. Their ranges are defined by three flows: (1) the lowest seven-day consecutive flow expected every two years (7Q2); (2) the monthly 25th percentile; and, (3) the monthly median. HDR Engineering has developed the values for these flows as part of its work for the SB1 South Central Regional Water Plan (Volume III, Option SCTN-20, page 3.6-6). The specific flow limits used in the CWPEC are indicated in Table 1.

The CWPEC requires daily flows to be passed at rates equal to the threshold levels for each zone. For example, if the flow is greater than the 25th percentile but less than the median then the 25th percentile flow must be passed and not diverted to off-channel storage.

Simulated Operation

The simulated operation of the potential off-channel reservoirs used a daily time step. For each day, the river flow was evaluated to see if there was sufficient water to divert. Flows going to downstream irrigation, manufacturing, mining, and stream electric demands were automatically passed; as was an additional 18 cfs, which represents the average annual stored water release from the Highland Lakes for estuarine inflows. Additional minimum flows were passed as required under the CWPWC. The off-channel diversion was limited to the daily maximum diversion pumping capacity applied. Further, the actual diversion would be limited by the sum of the storage available (if reservoir was not full), water demand, and evaporation losses. For example, if the reservoir was full at the beginning of the day and river flow was available for diversion, then the only diversion was the water needed to meet the daily water demand from the reservoirs and evaporation losses.

Results

The dependable yield of various reservoir combinations depends on the assumptions regarding demand distribution and minimum river flows required to pass by the diversion point. The amounts of these supplies will be described separately for each demand distribution.

Irrigation Demand

As shown in Figure 1, the water supply developed for irrigation use varies from about 50,000 to slightly over 200,000 acre-feet annually. The available supply is significantly influenced by the application of the CWPEC, particularly for more than two reservoirs. For example, with four reservoirs, a dependable supply of about 150,000 acre-feet is reduced to 100,000 acre-feet, when the CWPEC is used to determine the flows required to pass the reservoir.

Uniform Demand

Figure 2 shows similar dependable supply curves for a uniform water demand. The dependable supply for four reservoirs is about 131,000 acre-feet annually with the CWPEC; and 211,000 acre-feet per annum without the CWPEC.

Environmental Impacts

The purpose of this section is to evaluate the impact of off-channel reservoirs on the aquatic ecosystems in the Colorado River and in Matagorda Bay. Terrestrial impacts will not be presented, since they have already been identified in analyses preformed as part of the regional water plan prepared by the South Central Regional Water Planning Group.

Operation of new off-channel reservoirs would reduce the flow in the Colorado River downstream of the diversion points and the inflow of freshwater into Matagorda Bay. Each of these impacts will be assessed separately. Additionally, if the new water supply is used for irrigation then more acres of second-crop rice would be cultivated, thereby providing important food sources and habitat for winter migratory waterfowl in the irrigated rice fields. Further, the off-channel lakes would also provide open water habitat for these waterfowl.

For purposes of illustration, the aquatic impacts were evaluated for the operation of four off-channel reservoirs supplying a uniform demand distribution. The CWPEC was applied to the reservoirs' diversions. As given in the earlier section, the water supply for the reservoirs was determined to be about 131,000 acre-feet annually during a repetition of the critical drought-of-record period.

Impacts on Instream Flows

According to the model, the diversion of river flow into the off-channel reservoirs will result in lower flows in the Colorado River downstream of the reservoirs. However, because the composite off-channel project is assumed located near Bay City, there would be little impact on instream flows below Bay City since the river becomes tidally influenced at this point; and the existing in-channel dam at Bay City creates a small lake for many miles upstream of Bay City.

In actual implementation, there will be more impacts on river flows since it is likely that several reservoirs would be developed at different points upstream of Bay City. Thus, more of the river channel would actually be subject to change due to diversions into the off-channel reservoirs.

However, studies by the LCRA indicate that the key habitat areas for important fishery species in the lower Colorado River are upstream of the City of Columbus, and all off-channel reservoir sites are assumed to be downstream of Columbus.

A complete evaluation of the impact on the riverine ecosystem will require identification of specific sites for the off-channel reservoirs.

Impacts on Estuarine Inflows

The most extensive environmental impact due to the off-channel projects is likely to be on the volume and timing of freshwater inflows to Matagorda Bay. This impact can be assessed by looking at the Bay City river flows, which is the last downstream point for flow measurement in the Colorado River.

In evaluating the impacts, comparisons will be made between the conditions expected with and without the reservoirs in operation under year 2050 water demands with no additional water supply development or irrigation water conservation. The alternative without the reservoirs is termed the "Status Quo" alternative. This alternative assumes continuation of the LCRA Water Management Plan and the current amount of discharge from the City of Austin's return flows.

For the 1941-1965 period, the average annual inflow at Bay City under the "Status Quo" alternative is approximately 1.23 million acre-feet. Operation of the four reservoirs is projected to reduce the estimated annual inflows to Matagorda Bay by approximately 147,000 acre-feet, or about 12 percent of the average annual inflows without the reservoirs.

During the 1947-1956 critical drought-of-record period, the inflows at Bay City with the reservoirs in place are reduced by approximately 135,000 acre-feet annually, or 28 percent of the average 476,000 acre-feet of inflow without the reservoirs.

Not only will the annual flow be reduced by operation of the reservoirs, but there will also be changes in the monthly inflows. The average monthly inflows over the 1941-1965 period are compared in Figure 3 for the "Status Quo" alternative and four-reservoir alternative. Note that the reduction in average monthly inflows is relatively constant.

Figure 4 compares average monthly inflows during the critical drought-of-record period for the two alternatives. All months show reduced inflows, but the greatest reductions occur in the fall and winter months when the off-channel reservoirs are refilling.

Estuarine Ecosystem Impacts

There is not sufficient scientific information to fully quantify the biological impacts on the estuarine ecosystem due to operation of the potential reservoirs. However, salinity is considered an important indicator of estuarine conditions and salinity changes can be evaluated. It is possible to estimate salinity near the mouth of the Colorado River using predictive salinity relationships developed as part of the LCRA study of the freshwater inflow needs of Matagorda Bay (LCRA, 1999, page IV-7). Changes in salinity resulting from operation of the off-channel reservoirs can thus be evaluated.

The inflow sets noted in the previous section for the "Status Quo" and four off-channel reservoirs alternative were used to develop expected monthly salinity in Matagorda Bay in the vicinity of the Colorado River mouth over the 1941-1965 period.

Using available inflow-salinity relationships, the average bay salinity near the Colorado River mouth during the critical drought-of-record is expected to increase from 23 parts per thousand or ppt (under the "Status Quo" alternative) to 25 ppt under operation of the four reservoirs. For the full 25-year hydrologic period, the average salinity is estimated to increase from 20 ppt for the "Status Quo" option to 22 ppt with the four off-channel reservoirs.

Figures 5 and 6 give the average monthly salinity near the mouth of the Colorado River for the two alternatives in all years and during critical drought-of-record years. In both figures, it is evident that salinity changes are relatively constant over all months.

The exceedance frequencies for monthly salinity in all simulated years are shown in Figure 7, and higher salinities clearly have a greater probability of occurring with the reservoirs in operation. For example, a monthly salinity of 25 ppt would only be exceeded about 15 percent of the time under the "Status Quo" alternative; compared with an exceedance rate of approximately 35 percent of the time for the four reservoirs option.

Clearly there is a significant change in salinity conditions with the existence of the off-channel reservoirs during critical drought-of-record periods. Generally, high salinity over extended periods of time is detrimental of the biological diversity of the bay. However, the estuarine ecosystem suffers stress during extended drought conditions presently without the reservoirs in operation. It is not clear how much worse the environmental stress would be with the increased salinity. The extent of environmental damage cannot be quantified and further study is needed before implementing the four reservoir alternative.

As part of further studies, there should also be an examination of mitigation options to minimize whatever adverse impact the reservoirs may have on the Matagorda Bay ecosystem. One possible mitigation could involve operation of the off-channel reservoirs to reduce the highest salinity by timely releases of stored water. Such mitigation would require reduction in the water supply available for human uses, but would not necessarily make the reservoirs economically infeasible.

References

LCRA, "System Response Model Description", Open File Report, Austin, Texas, 1998.

LCRA, Water Management Plan, Austin, Texas, 1999.

LCRA, Freshwater Inflow Needs of the Matagorda Bay System, Austin, Texas, 1997.

Figure 1

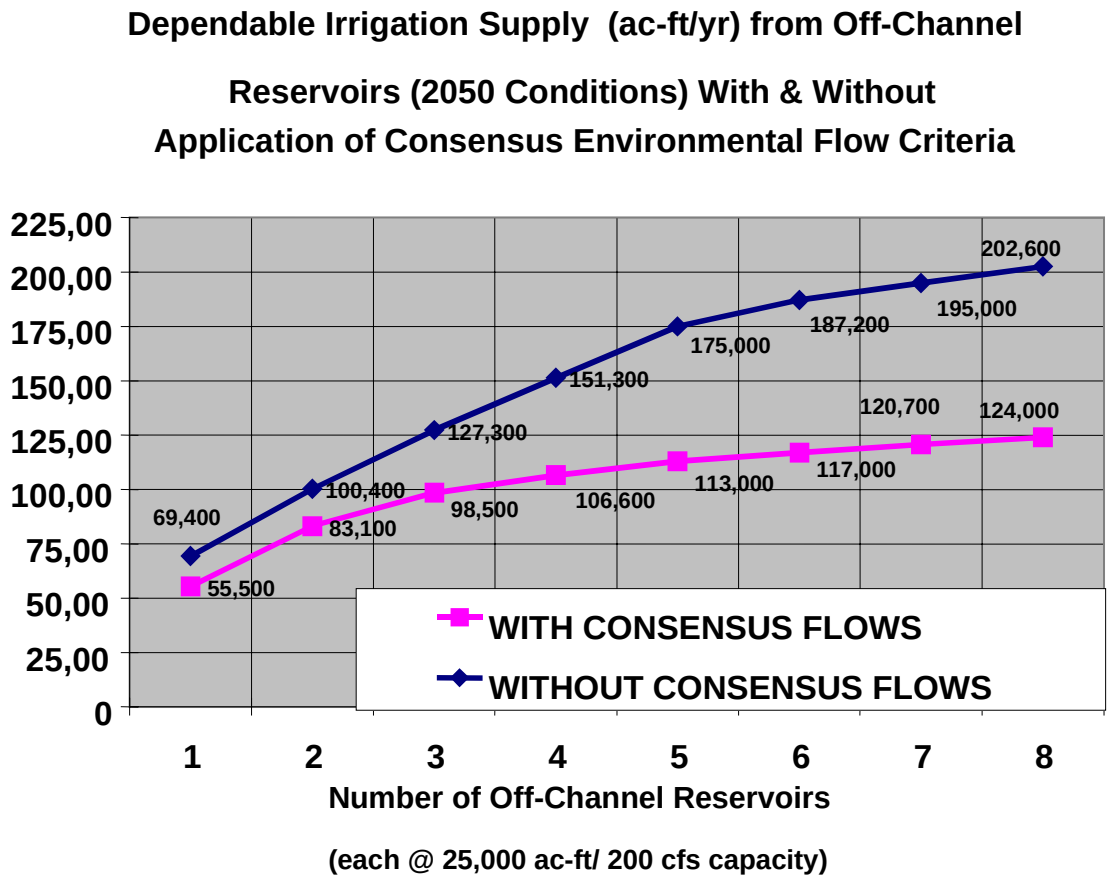
Dependable Irrigation Supply (ac-ft/yr) from Off-Channel Reservoirs (2050 Conditions) With & Without Application of Consensus Environmental Flow Criteria
225,00
200,00
175,00
150,00
125,00
100,00
75,00
50,00
25,00
0
69,400
100,400
127,300
151,300
175,000
187,200
195,000
202,600
55,500
83,100
98,500
106,600
113,000
117,000
120,700
124,000
WITH CONSENSUS FLOWS
WITHOUT CONSENSUS FLOWS
1
2
3
4
5
6
7
8
Number of Off-Channel Reservoirs
(each @ 25,000 ac-ft/ 200 cfs capacity)

Figure 2

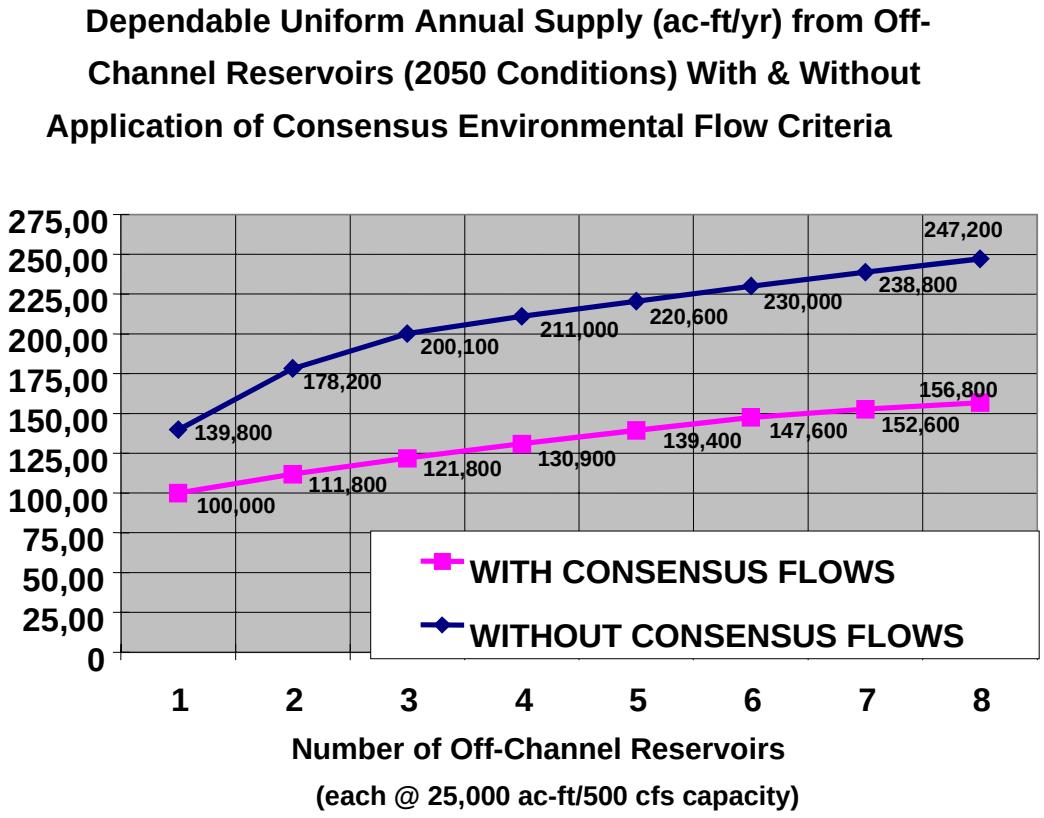
Dependable Uniform Annual Supply (ac-ft/yr) from Off-Channel Reservoirs (2050 Conditions) With & Without Application of Consensus Environmental Flow Criteria
275,00
250,00
225,00
200,00
175,00
150,00
125,00
100,00
75,00
50,00
25,00
0
247,200
238,800
230,000
220,600
211,000
200,100
178,200
139,800
156,800
152,600
147,600
139,400
130,900
121,800
111,800
100,000
WITH CONSENSUS FLOWS
WITHOUT CONSENSUS FLOWS
1
2
3
4
5
6
7
8
Number of Off-Channel Reservoirs
(each @ 25,000 ac-ft/500 cfs capacity)

Figure 3

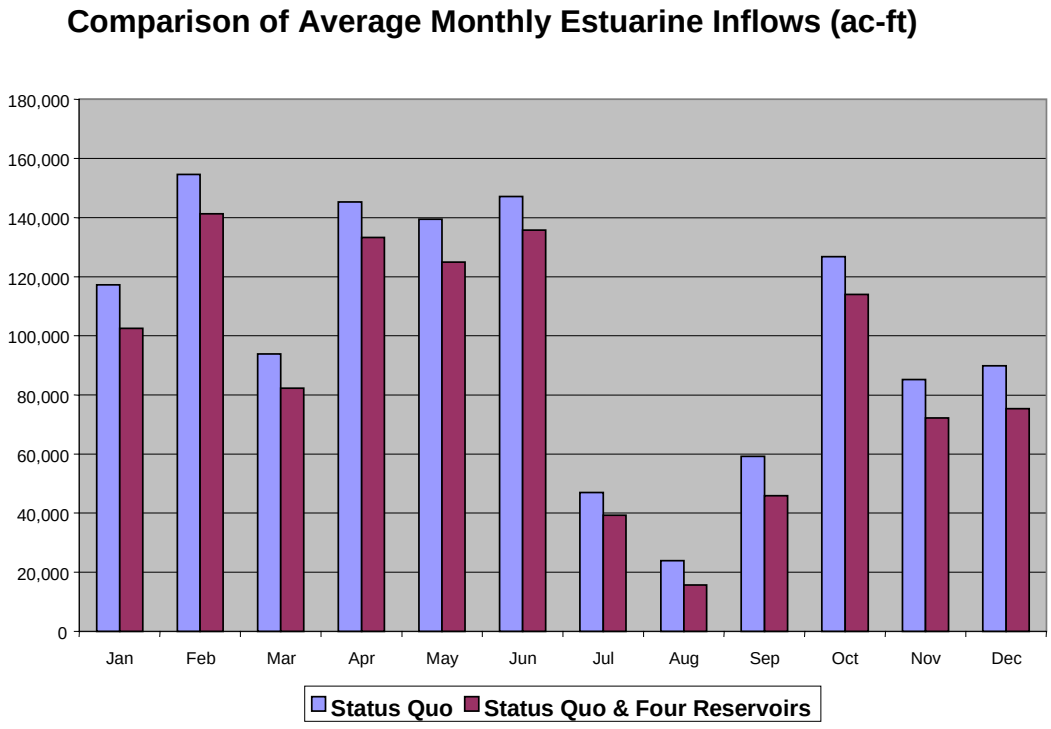
Comparison of Average Monthly Estuarine Inflows (ac-ft)
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Status Quo
Status Quo & Four Reservoirs

Figure 4

Comparison of Average Monthly Estuarine Inflows During Critical Drought-of-Record (ac-ft)

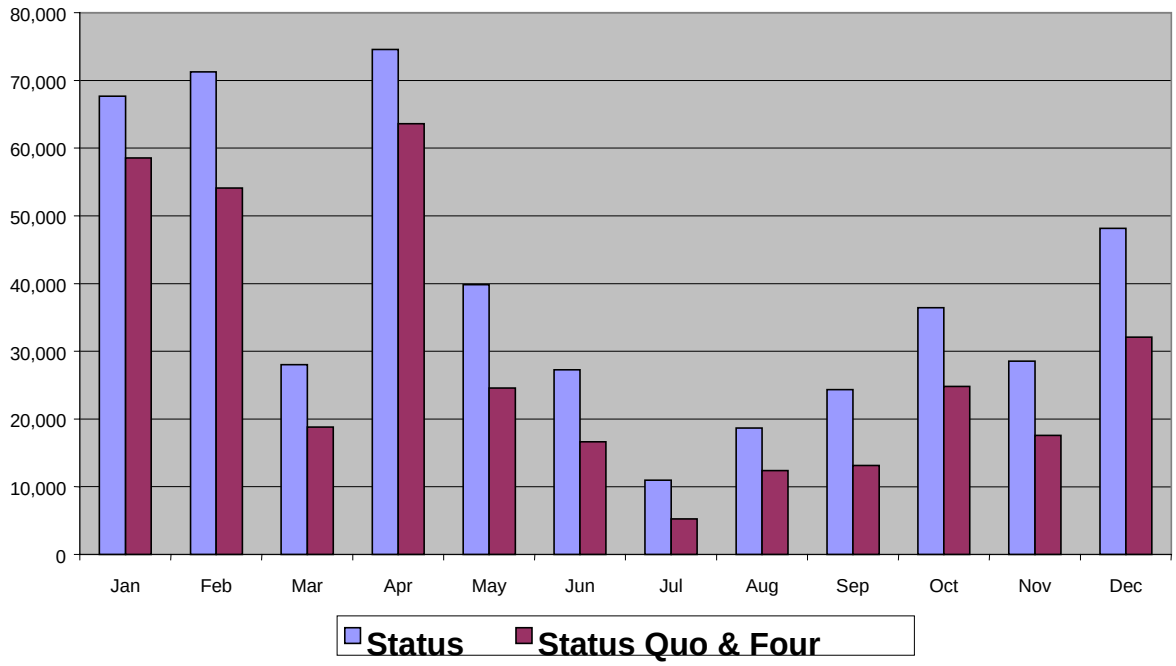

Figure 5

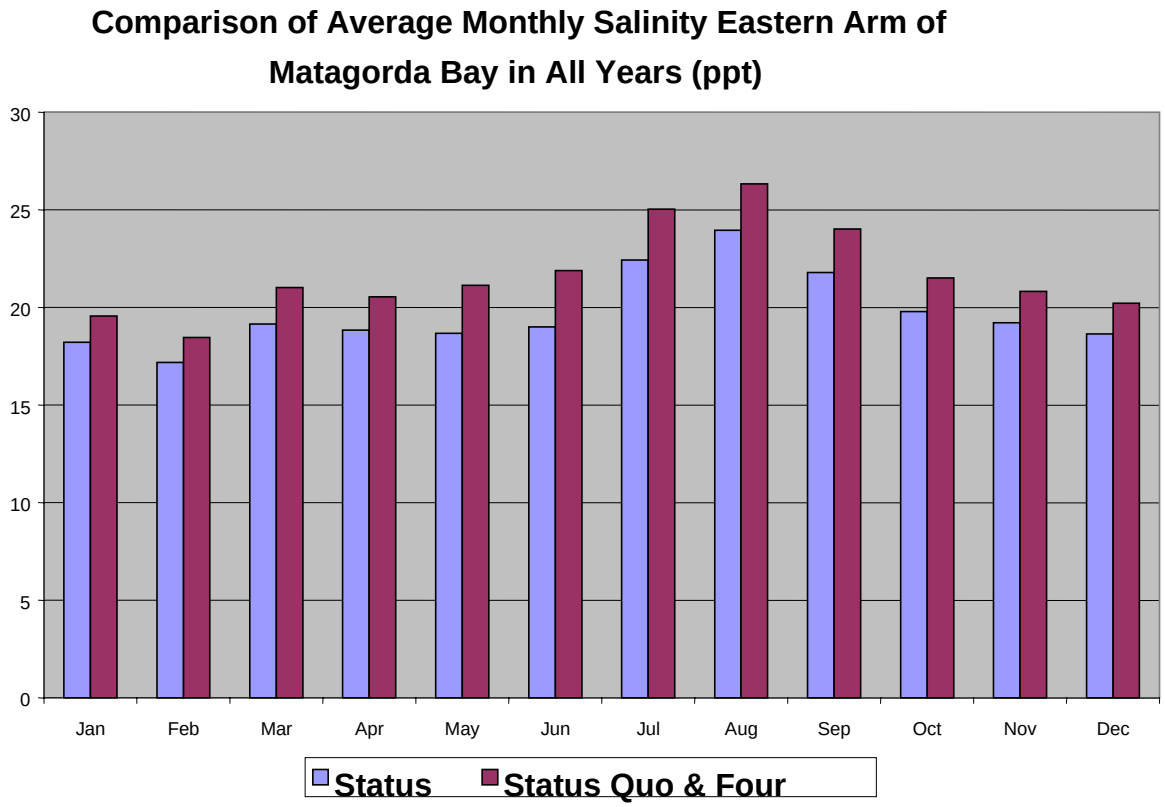
Comparison of Average Monthly Salinity Eastern Arm of Matagorda Bay in All Years (ppt)
30
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Status
Status Quo & Four

Figure 6

Comparison of Average Monthly Salinity Eastern Arm of Matagorda Bay During Critical Drought-of-Record Years (ppt)

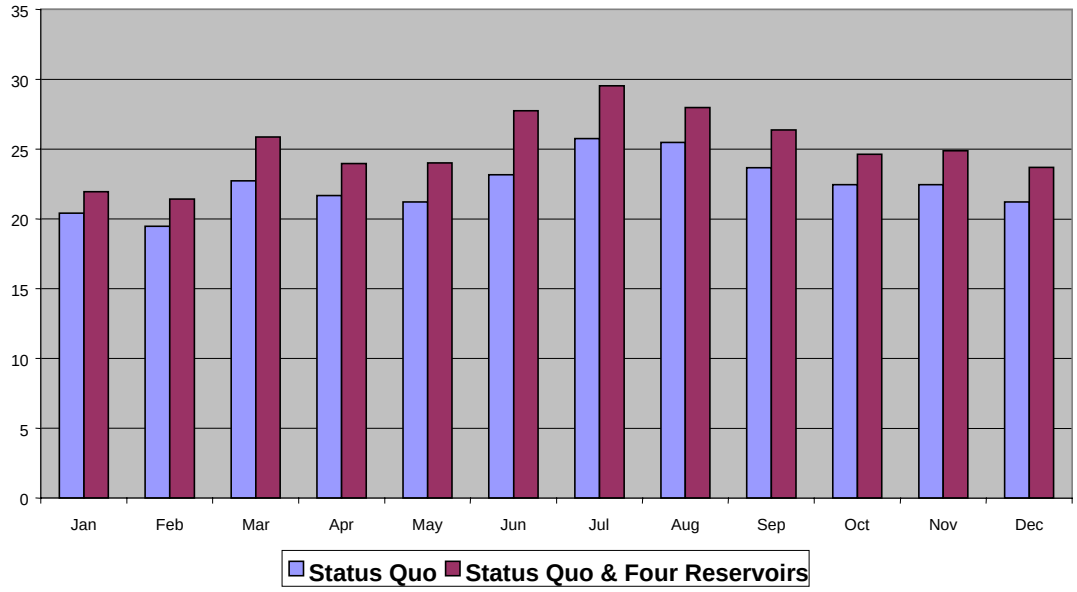

Figure 7

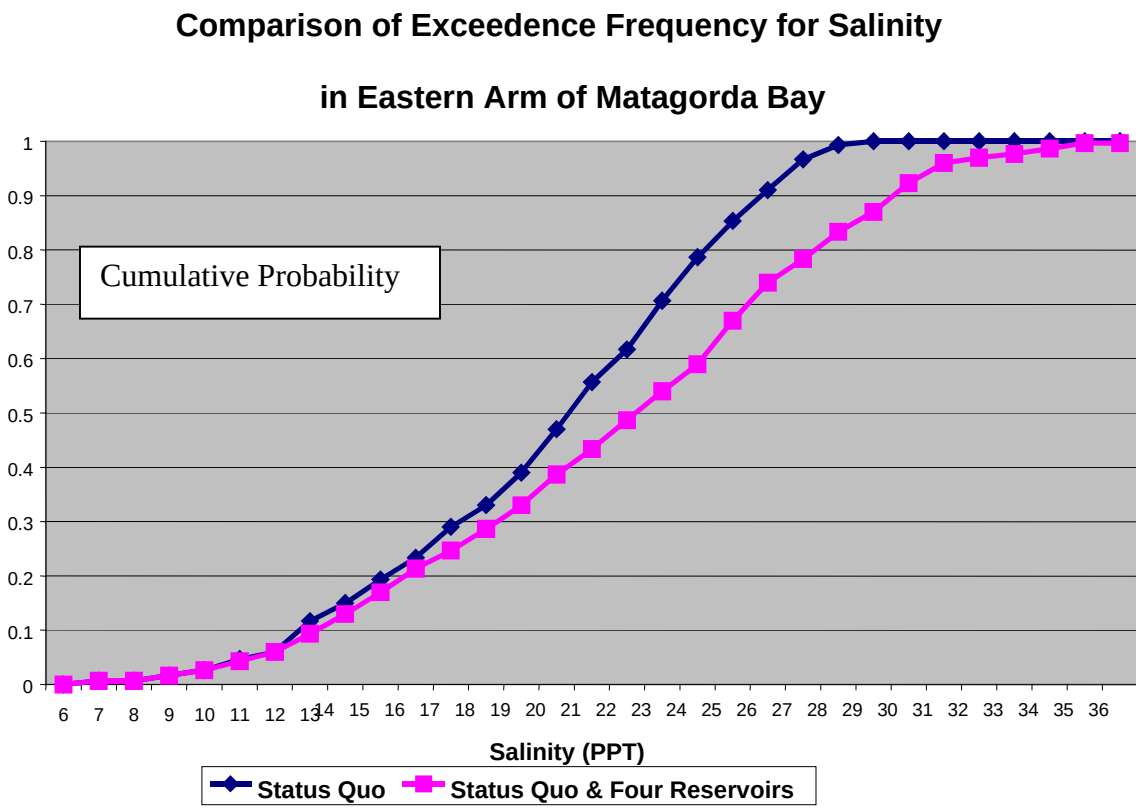
Comparison of Exceedence Frequency for Salinity
in Eastern Arm of Matagorda Bay
Cumulative Probability
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Salinity (PPT)
Status Quo
Status Quo & Four Reservoirs

Table 1

SB 1 Consensus Environmental Flows for Bay City (1)

Month	Bay City Daily Flow Levels (cfs)		
	Level 1 (7Q2)	Level 2 (25 Percentile)	Level 3 (Median)
January	116	367	769
February	116	551	1,239
March	116	412	1,063
April	116	368	1,001
May	116	860	1,763
June	116	520	1,362
July	116	259	605
August	116	209	418
September	116	409	685
October	116	334	830
November	116	348	741
December	116	396	959

(1) The Consensus Flow Levels are considered threshold values for daily diversion.
Level 1 is the 7Q2 naturalized daily flow - the lowest naturalized flow expected for 7 consecutive days every two years.
Level 2 is the 25 percentile monthly naturalized flow expressed as a daily equivalent.
Level 3 is the median monthly naturalized flow expressed as a daily equivalent.