Appendix B
Water Quality Evaluation

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1. Introduction

The Tijuana River flows northwestward through the City of Tijuana, Baja California, Mexico, and across the international border into California, USA. It then flows westward, descending to the Pacific Ocean over a distance of about 9,540 m. The last 3,000 m is a tidal estuary, with some salinity intrusion from the sea. The estuary is part of a coastal estuarial wetland that lies parallel to the coast, separated from the coast by a narrow barrier beach. Over time, the course of the tidal portion of the river has meandered considerably, with several relict channels and lakes. The estuarial wetlands lie largely within the Tijuana River National Estuarine Research Reserve.

Flows in the Tijuana River (which can be a combination of natural runoff, potable water leaks, sewer leaks and spills) are intercepted at the border before crossing into the U.S. by pump station PB-CILA. From PB-CILA (see photo), flows are directed to the "International" interceptor and combines with sewage flows from the wastewater collection system. Approximately 25 mgd (1,100 L/s) of the flow conveyed by the International Interceptor runs by gravity to the SBIWTP and the rest goes to Pump Station PB1 where it is pumped to the San Antonio de los Buenos (Punta Bandera) WWTP through the parallel line (pressure and gravity flow) and ultimately disposed of in the Pacific Ocean. Figure 2-1 shows the location of PB-CILA, PB-1, and associated conveyance infrastructure. The PB-CILA currently has a capacity of 11 mgd (500 L/s) and stops operating in wet weather when river flows exceed 11 mgd (500 L/s). At these times, water is allowed to flow into the U.S. for discharge into the ocean via the Tijuana River estuary.

The Comisión Estatal de Servicios Públicos de Tijuana (CESPT) has been implementing a number of projects aimed at improving the condition and geographical coverage of the sewer system. The expansion of portions of the sewer system within the Tijuana watershed would reduce the frequency of spills and provide treatment to these flows.

With Tijuana's continued growth in population and upgrading of wastewater facilities, two new advanced secondary wastewater plants are due to come on line within the Tijuana River watershed. The JBIC (named after the Japan Bank for International Cooperation) plants are scheduled to release treated effluent into the river, which will combine with urban dry weather flow and excess wet weather flow. A portion of these flows could cross the border into the U.S. and eventually get discharged through the Tijuana Estuary into the ocean. The California Regional Water Quality Control Board has expressed the concern that the release of flows to the estuary may (a) harm fish species that are sensitive to changes in estuarine salinity, and (b) allow excessive levels of pathogenic bacteria and viruses to escape to sea and contaminate nearby bathing beaches.

The purpose of this appendix is to evaluate the incremental and cumulative water quality impacts of the alternatives being considered. The action alternatives propose connecting three colonias, Lomas del Valle, Maclovio Rojas and Ojo de Agua, to the sewer system with wastewater flows going the La Morita JBIC plant for treatment. The alternatives also propose various discharge methods for the JBIC plants' treated effluent: (1) the Tijuana River estuary, and on the Pacific coastal beaches near the mouth of the river in the U.S.; (2) the Pacific ocean on the Mexican side of the border from an increased pumping at PB CILA; and (3) an increase discharge of effluent at the South Bay Ocean Outfall. The flows from the three colonias represent the incremental impacts of the alternatives and the total discharges from the JBIC plants represent cumulative impacts. The computations within this analysis are based on the best information currently available, augmented as needed by conventional assumptions. This appendix supports the water resources analysis and conclusions in Section 4 of the EA.

The following sections discuss three types of potential water quality impacts to the Tijuana River Estuary, each in a different manner:

1. The impact of freshwater discharge on the salinity balance of the Tijuana Estuary. This study will examine the extent to which transboundary flow events over the course of a typical year, as modified under the various alternatives, are expected to alter the salinity in the estuary, compared with the salinity variations presently due to runoff from watersheds in the U.S. and from tidally-driven salinity intrusion from the Pacific Ocean.

2. Annual loadings of conventional wastewater constituents are provided to enable study of the aquatic life in the Tijuana Estuary, and related life such as waterfowl and terrestrial biota. Comparing the loadings predicted under the three alternatives, including the no action alternative, with the present loading (year 2006) on the estuary provides a first, qualitative assessment of impact.

3. The annual number of transboundary flow events expected to occur in a typical year is estimated for each of the alternatives studied, to help assess the impact of fecal coliform and other wastewater pathogens on the recreational Pacific Ocean beaches near the mouth of the Tijuana Estuary.
The appendix also describes potential effects of increasing treated effluent discharges at Punta Bandera and the South Bay Ocean Outfall into the Pacific Ocean.

2. Flows in the Tijuana River

The Tijuana River [see (a), in Figure 1] is typical of rivers in the region: during parts of the year the river flows in spate following heavy rains, but in dry months its flow diminishes greatly, at times approaching zero. In the past, the Tijuana River's base flow has been augmented by untreated sewage from unsewered areas of Tijuana [see (b), in Figure 1].

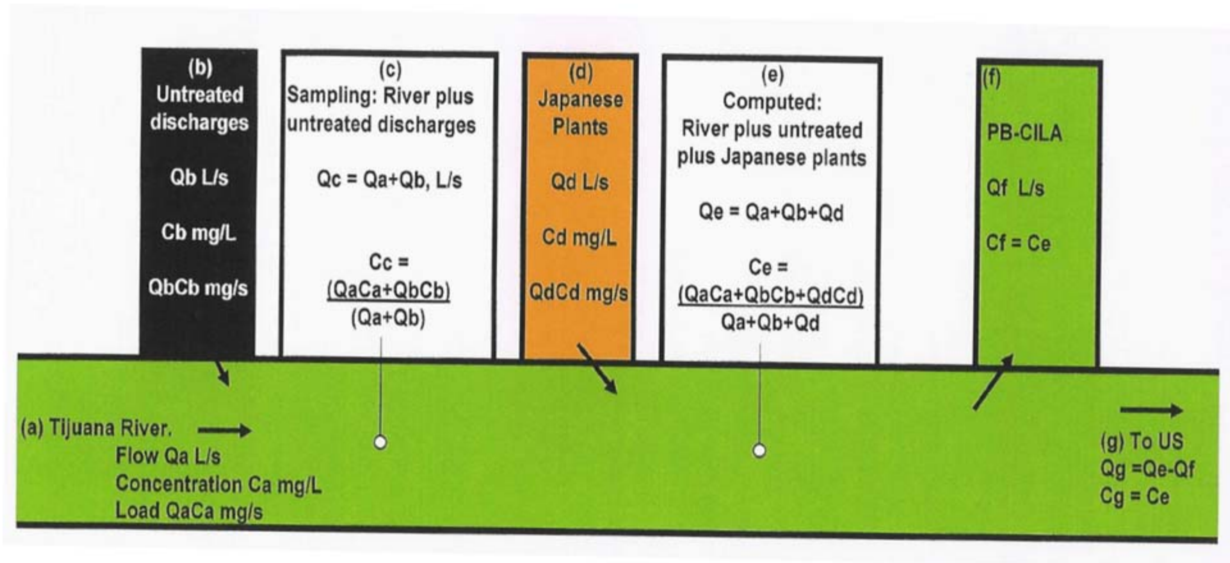


Figure 1. Schematic diagram of the Tijuana River and related flows.

Flow sampling near the international boundary [Point (c) in Figure 1] results in an annual hydrograph such as shown in Figure 2, which includes the untreated discharges (b) as well as the natural river flow (a). The trace in Figure 2, which is for the year 2006, will be used in this document as a typical annual hydrograph, though of course there are variations from year to year.

Flows typified by Figure 2 were carried into the U.S by the Tijuana River on its course through the Tijuana River National Estuarine Research Reserve and the Tijuana Slough National Wildlife Refuge to the recreational beaches of California, USA. Environmental officials in the US were concerned that these flows may be (a) altering the salinity of these coastal wetlands to the detriment of its aquatic life, (b) overloading the wetlands with contaminants, and/or (c) contaminating the ocean beaches with pathogens.

The CESPT installed a pump station (termed PB-CILA) to intercept Tijuana River flows at the international boundary for conveyance to the San Antonio de los Buenos (SAB) secondary wastewater treatment plant on the Pacific coast at Punta Bandera, Mexico, several miles south of the international boundary. The capacity of this pump station is 11 mgd (500 L/s). Figure 2 shows that 11 mgd (500 L/s) would be adequate to intercept the base flow in the river as it approaches the border many times of the year, although not the peak flows (Figure 3).

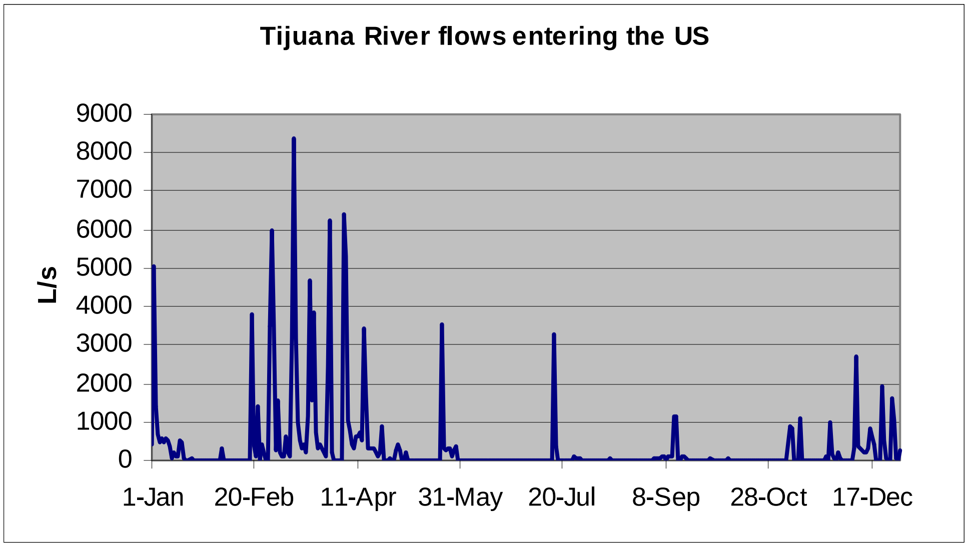


Figure 2. Flow in the Tijuana River, year 2006, including tributary untreated wastewater.

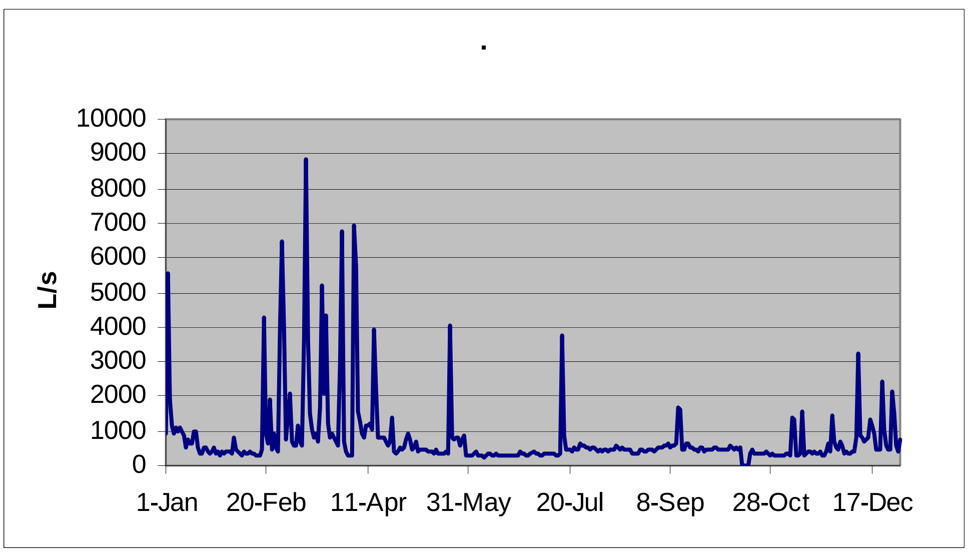


Figure 3. Current situation: Most of the base flow, but not the wet-weather peak flows, are intercepted and removed at the international boundary by the 500-L/s PB-CILA.

CESPT proposes to discharge about 460 L/s in 2008 of treated effluent from the JBIC plants to the river. Although these plants would relieve the river of some 140 L/s of its untreated wastewater, the action would result in a net increase of 320 L/s in base flow by discharging secondary effluent. The existing base flow plus the net increase of 320 L/s would frequently exceed the current 500 L/s capacity of the PB-CILA.

The incremental effects of the alternatives would be the effluent flow contributions of the three colonias. Wastewater flow estimates of the three areas are 72 L/s since 2008, 81 L/s in 2012, and 88 L/s in 2025. Two of the alternatives being considered include upgrading the existing interception, pumping, and conveyance infrastructure or discharge effluent directly to the SBOO to minimize the mixture of secondary effluent, natural runoff, and untreated wastewater flow crossing into the U.S.

Three alternatives are being considered:

Alternative 1: No Action.

1.1 PB-CILA would continue to intercept and divert dry-weather flows in the Tijuana River at the border, up to 500 L/s, for conveyance to the San Antonio de los Buenos WWTP for treatment and ocean disposal.

1.2 JBIC facilities would serve recently sewered districts, thus curtailing 140 L/s of untreated wastewater presently discharged to the river. They would also discharge over 410 L/s of advanced secondary effluent to the Tijuana River.

1.3 There would be no further expansion of the wastewater collection system to the three proposed colonias, whose residents would continue to rely on alternative waste disposal methods, such as latrines or open ditches.

Table 1 shows estimated flows under the No-Action Alternative into the Tijuana River. The capacity of PB-CILA would remain at 500 L/s. Figure 4 shows Tijuana River flows that would enter the U.S., based on 2006 data and the effluent flows in Table 1.

Table 1
Flows under the No-Action Alternative (L/s)

Year	2008	2012	2025
Untreated wastewater flows curtailed	140	140	140
JBIC advanced secondary effluent	399	409	647
Net increase in discharge to the Tijuana River	259	269	507
PB-CILA capacity	500	500	500

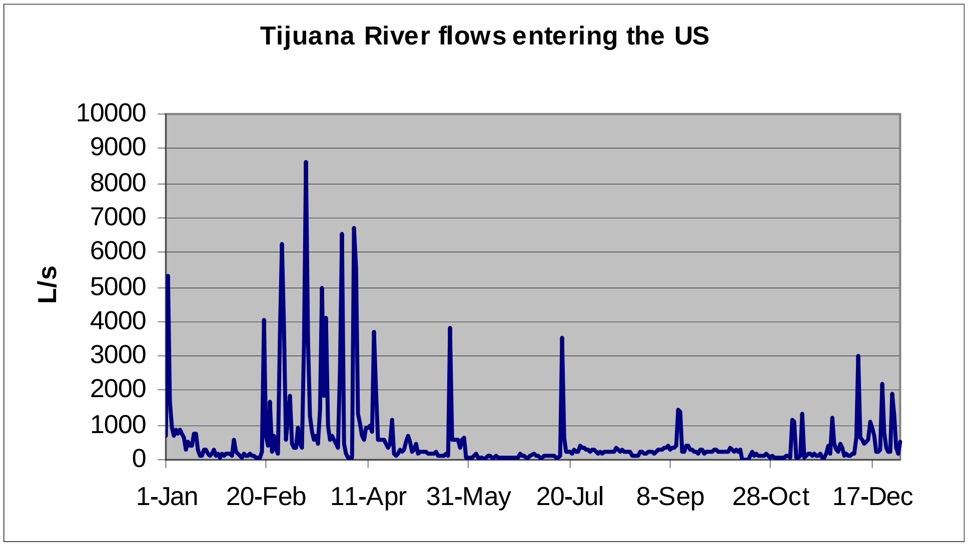


Figure 4. No-Action Alternative. JBIC plants relieve the river of some untreated wastewater but discharge treated wastewater, for a net increase in flow. Under the No-Action Alternative, PB-CILA would no longer be able to capture all the base flow.

Alternative A: Connect Colonias to System and Increase the pumping capacity at PB-CILA from 500 to 1500 L/s (This is the proposed action).

2.1 Alternative A expands the sewer system to connect the three proposed colonias, Lomas del Valle, Maclovio Rojas and Ojo de Agua, to the JBIC facilities for treatment. Untreated wastewater flows curtailed in Table 2 are higher than those identified in Table 1 under the No Action Alternative because of the addition of the proposed colonias, which would be 72 L/s in 2008, 81 L/s in 2012, and 88 L/s in 2025. The JBIC facilities would discharge secondary effluent to the Tijuana River.

2.2 Flows in the river (including secondary effluent from JBIC facilities) would be intercepted at PB-CILA at the border during dry-weather conditions. The PB-CILA would divert up to 1,500 L/s of the river flow for ocean discharge at in Mexico. During wet-weather conditions, flows in the Tijuana River in excess of 1,500 L/s would be allowed to flow into the US.

Table 2 shows estimated flows under the Alternative A into the Tijuana River. The proposed colonias which would generate 72 L/s, 81 L/s and 88 L/s would be 15%, 16% and 12% of the total JBIC effluent in 2008, 2012, and 2025, respectively. The capacity of PB-CILA would increase to 1,500 L/s under Alternative A. Figure 5 shows Tijuana River flows that would enter the U.S., based on 2006 data and the effluent flows in Table 2.

Table 2 Flows under the Proposed Alternative (L/s)			
	2008	2012	2025
Untreated wastewater flows curtailed	211	221	228
JBIC advanced secondary effluent	470	490	733
Net increase in discharge to the Tijuana River	259	269	505
PB-CILA capacity	1500	1500	1500

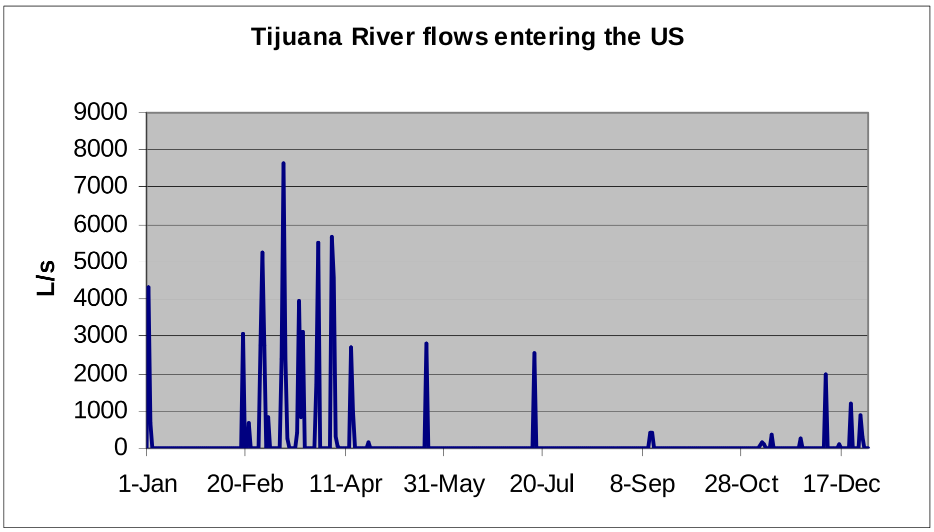


Figure 5. Similar to Figure 4, but now with the capacity of PB-CILA increased to 1,500 L/s. All the base flow and some of the wet-weather flow are diverted to SAB WWTP at Punta Bandera.

Alternative B: Connect colonias to system and construct new pipeline to convey JBIC effluent to SBOO.

3.1 This alternative proposes building a new pipeline from the JBIC wastewater treatment plants to the South Bay Ocean Outfall (SBOO) in the U.S. for the disposal of secondary effluent. The proposed colonias would be connected to the La Morita JBIC plant and hence their treated wastewater contribution would flow to the SBOO.

3.2 The PB-CILA would continue as at present, diverting up to 500 L/s of river flow to San Antonio de los Buenos and allowing wet-weather river flows in excess of 500 L/s to continue into the U.S.

Table 3 shows estimated flows under the Alternative B into the Tijuana River. The capacity of PB-CILA would remain at 500 L/s. Figure 6 shows Tijuana River flows that would enter the U.S., based on 2006 data and the effluent flows in Table 3.

Table 3
Flows under the SBOO Alternative (L/s)

	2008	2012	2025
Untreated wastewater flows curtailed	211	221	228
JBIC advanced secondary discharge to the Tijuana River	0	0	0
Net increase in discharge to the Tijuana River	-211	-221	-228
PB-CILA capacity	500	500	500

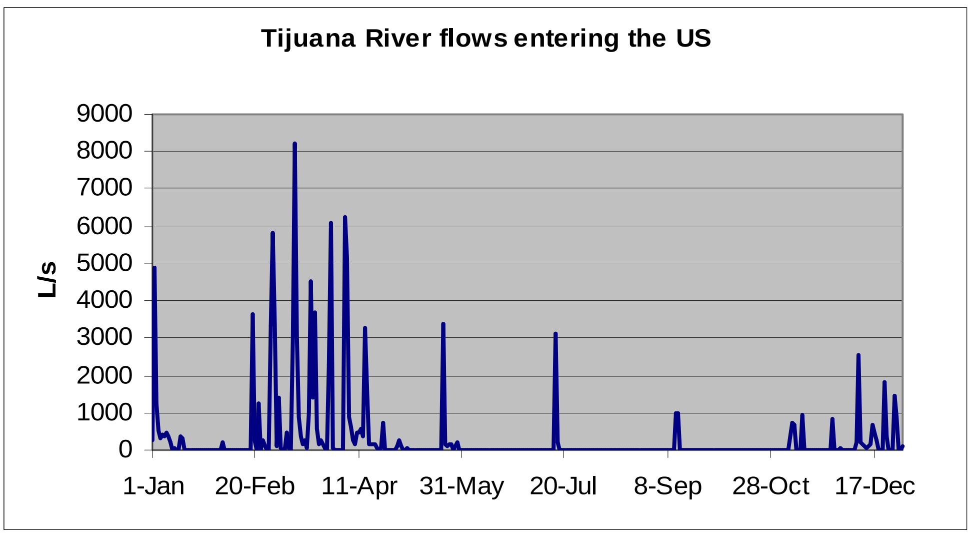


Figure 6. PB-CILA capacity remains at 500 L/s, while all JBIC effluent is piped to the SBOO.

For the conditions illustrated in Figures 3 through 6, Table 4 lists the number of days per year that there are no transboundary flows, as well as the number of days per year in which there are some transboundary flows, of any amount.

Table 4 Frequency of flow entering the U.S. via the Tijuana River			
Alternative	**Year**	**Days/year without transboundary flow**	**Days/year with transboundary flow**
Present Condition	2006	220	145
No Action	2008	4	361
	2012	4	361
	2025	0	365
Alternative A	2008	324	41
	2012	324	41
	2025	315	50
Alternative B	2008	264	101
	2012	275	90
	2025	276	88

Under the No Action Alternative, Tijuana River flows would increase in 2008, 2012 and 2025 relative to present conditions because of the addition of effluent discharges by the JBIC plants. By 2025, there would not be any days without transboundary flows under the No Action Alternative.

Alternative A would reduce the number of days with transboundary flows the most relative to the No Action Alternative. Days without flows under Alternative A would be 324 days in 2008 and 2012 and 315 days in 2025. Alternative B would also increase days without transboundary flow substantially relative to the No Action Alternative.

In 2008 and 2025, the proposed colonias would contribute very little to the total effluent flows from the JBIC plants, approximately 15% and 12%, respectively. Under Alternative A, most of these flows would be intercepted at the enlarged PB-CILA and under Alternative B, all effluent flows would be discharged through the new pipeline to the SBOO.

3. Wastewater Loads in the Tijuana River

Water quality sampling at Point (c) in Figure 1 results in the monthly average values for several standard parameters listed in Table 5. These values reflect not only the quality of the natural river flow but the contributions of the untreated discharges.

Table 5 Monthly Average Water Quality Measurements in the Tijuana River (2002 – 2003)					
Month	**BOD** (mg/L)	**TSS** (mg/L)	**NH3** (mg/L)	**P** (mg/L)	**Fecal Coliform** (MPN/100 mL)
Jan	138	110	22.1	16.6	5.68 E6
Feb	62	74	26.9	8.2	1.02 E4
Mar	68	70	24.6	10.8	9.94 E4
April	66	57	13.6	NA	4.30 E5
May	124	254	9.9	4.9	9.30 E7
June	77	67	7.6	4.3	4.30 E5
July	82	182	NA	2.5	1.40 E7
Aug	50	82	NA	2.5	9.30 E5
Sept	21	38	NA	2	3.00 E6
Oct	19	48	9.8	3.4	2.20 E7
Nov	19	71	8.5	3.2	3.20 E6
Dec	23	50	9.4	3	1.37 E7
Source: CESPT					

Water quality measurements for the raw wastewater flows have not been obtained, so textbook values for medium-strength untreated domestic wastewater (Linsley and Franzini) were used, as listed in Table 6.

Table 6 Assumed wastewater constituent concentrations					
Strength	**BOD** (mg/L)	**TSS** (mg/L)	**NH3** (mg/L)	**P** (mg/L)	**Fecal Coliform** (MPN/100 mL)
Untreated Domestic Wastewater	220	220	25	8	3 E8

Table 7 shows the assumed constituent concentrations for secondary effluent, from plants such as the JBIC facilities.

Table 7 Assumed secondary effluent constituent concentrations					
Strength	**BOD** (mg/L)	**TSS** (mg/L)	**NH3** (mg/L)	**P** (mg/L)	**Fecal Coliform** (MPN/100 mL)
Secondary Effluent	20	20	3.5	5	2.4 E2

The transboundary flows for the present situation (year 2006) and the no action and two action alternatives are represented by the annual hydrographs of daily flows plotted in Figures 2 through 6. Annual loadings of BOD, TSS, NH_3, and P are estimated as a first step to enable assessment of the impact of these constituents on the life in the Estuary.

The annual loading of a constituent, such as BOD, is computed as follows:

1. Use the daily flows rates over the course of a year, as plotted in Figure 2.

2. Multiply the daily flow rates (L/s) by the BOD concentration measured in the river for that month (Table 5; e.g. 138 mg/L for any day in January) to obtain an estimate of the loading rate [Q (L/s) * concentration (mg/L) = load (mg/s)] for each day of the year.

3. Convert the load units from mg/s to tonnes (i.e. metric tons)/day.

4. Sum the daily loads over the 365 days of the year, to obtain the annual load in tonnes/year. *This is the load in the river without yet accounting for the untreated wastewater curtailed by the JBIC plants or the JBIC secondary effluent added.*

5. To estimate the load relief by curtailing untreated discharges, multiply the "Untreated wastewater flow curtailed (L/s)" (from Tables 1, 2, and 3, for each design year) by the BOD concentration (mg/L, Table 6) to obtain a loading being curtailed (mg/s).

6. To estimate the load added by the JBIC secondary plants, multiply the "JBIC advanced secondary discharge to the Tijuana River (L/s)" from Tables 1, 2, and 3, for each design year, by the BOD concentration (mg/L, Table 7) to obtain a load being added (mg/s).

7. Subtract the loading being curtailed from the load being added to obtain a net load being added. Add this net load, day by day, to the load in the river obtained in Step 2.

8. Day by day, divide the combined load obtained in Step 7 by the flow in the river (this is the daily flow graphed in Figure 2, plus the JBIC discharge, less the flow curtailed) to obtain the overall concentration of BOD in the river as it approaches the international boundary—and the intake to the PB-CILA.

9. Day by day, reduce the flow in the river by the capacity of PB-CILA or the flow in the river, whichever is less (and never less than zero). This is the flow diverted from the river by the PB-CILA and sent to SAB for treatment.

10. Day by day, reduce the load in the river by multiplying the flow rate taken by PB-CILA (Step 9) by the overall concentration of BOD in the river that day (Step 8).

11. Day by day, compute the reduced load in the river (Step 7's result minus Step 10's result, but nothing less than zero). As in Step 3, convert the reduced load in the river from mg/s to tonnes/day.

12. Sum the daily loads over the 365 days of the year to obtain the BOD load in tonnes/year that flows into the US.

13. Repeat for TSS, NH_3, and P.

14. Enter the results in Table 8; plot the results in Figure 7.

Table 8 and Figure 7 show that the No Action Alternative would produce a substantial increase of loadings relative to the present situation (year 2006). Alternative A which increases the PB-CILA capacity to 1,500 L/s and Alternative B which discharges through the SBOO both reduce the loads on the Estuary, relative to the present situation. Increasing the PB-CILA capacity under Alternative A is more effective in reducing loadings, cutting the no-action loads in half.

The incremental effects of the proposed alternative would not contribute substantially to the total loads because the flows are only a portion of the total effluent released from the plants. In addition, the secondary treated effluent released would be better quality than the existing quality of the Tijuana River flows.

Table 8
Loads entering the US via the Tijuana River (tonnes/year)

Alternative	Year	BOD	TSS	NH_3	P
Present situation		775	906	211	95
No Action	2008	809	1038	149	131
	2012	778	990	240	123
	2025	928	1217	285	159
Alternative A	2008	401	459	123	56
	2012	377	433	119	55
	2025	400	460	127	60
Alternative B	2008	581	610	170	83
	2012	517	610	170	79
	2025	509	601	169	78

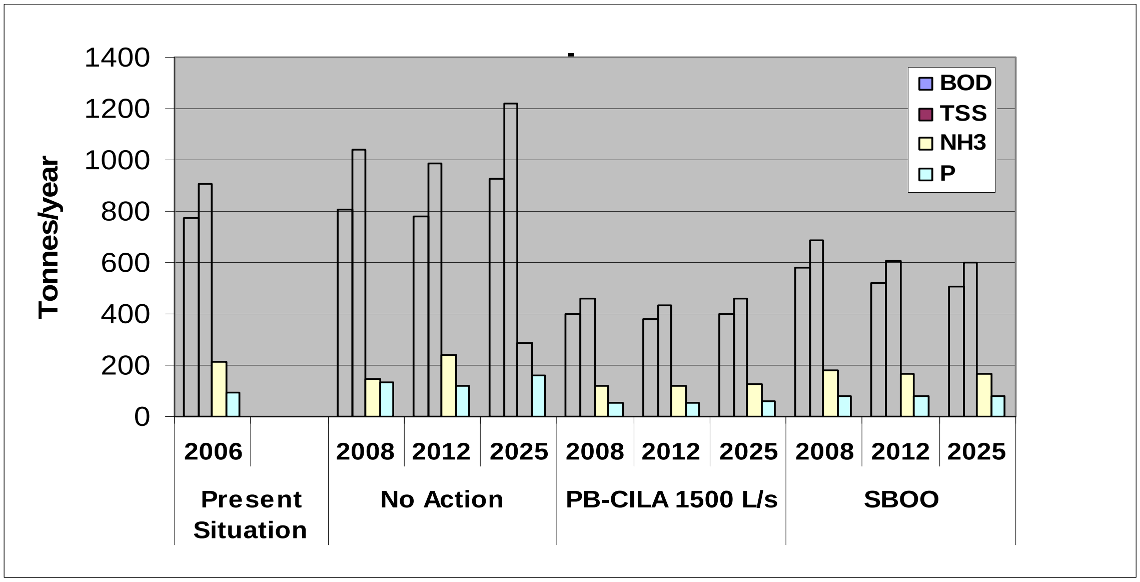


Figure 7. Constituent loads carried to the U.S. by the Tijuana River, Tonnes/year.

4 The Setting North of the Border

Sections 2 and 3 established the quantity and frequency of flows, and constituent loads that may be expected to cross the international boundary via the Tijuana River, be conveyed to the SAB plant in Mexico, and/or conveyed to the SBOO on the U.S. side of the border. This Section describes the Tijuana River and Estuary on the U.S. side of the boundary.

4.1 Alignment of the River Bed

Figure 8, together with available aerial and satellite photographs, show the Tijuana River north of the U.S.-Mexican border to have meandered considerably over time, with numerous relict channels and isolated ponds in addition to the current flow channel. The tidal portion of the estuary includes not only the current channel and several tributary branches, but also an extensive coastal lagoon called Oneonta Slough, separated from the sea by a barrier beach. There is currently one inlet connecting the estuary with the sea.

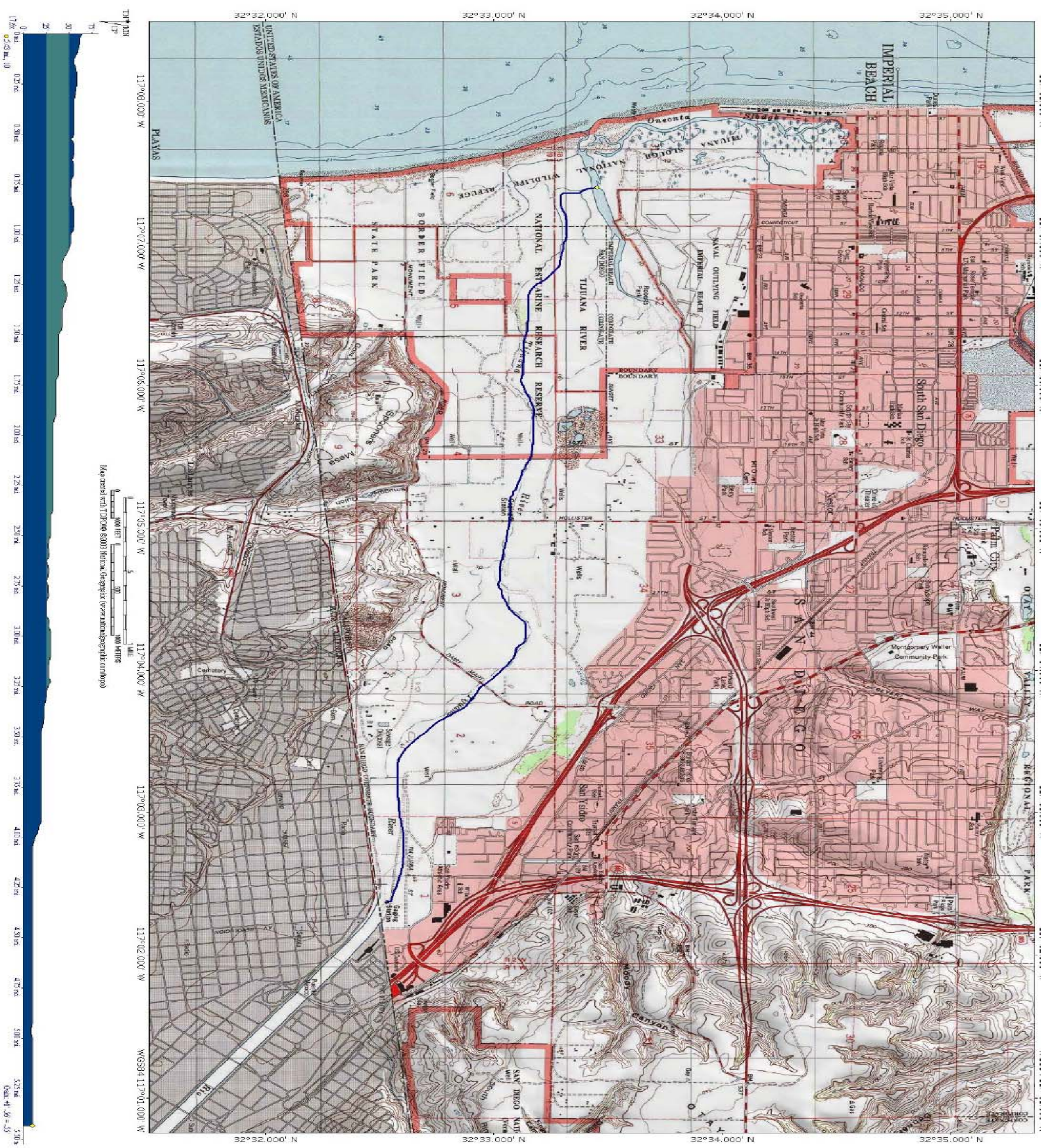
4.2 Flow Characteristics of the River Bed

The profile of the river along its current principal channel, shown in the bottom margin of Figure 8, indicates an elevation of about 60 ft (18.3 m) at the border, dropping over the next 4.05 miles (6,518 m) to an elevation of 10 ft (3.05 m.) For the remaining 3022 m to the sea, the elevation remains essentially unchanged. The first 6,518 m will therefore be termed “above tidewater”, while the final 3,022 m will be termed “tidewater.”

Above tidewater. The flow characteristics above tidewater are estimated in Table 9, assuming (a) a fairly constant slope, (b) a parabolic channel cross-section, and (c) a Manning "n" of 0.05. The final column of the table indicates that the time of travel over the 6,518 m above tidewater ranges from 6 hours at the lower flows of interest down to about 2 hours at the peak flow rates.

Figures 3 through 6 indicate that transboundary flow rates would range from zero to nearly 10,000 L/s. Table 9 indicates that the travel time from the international border to the head of tidewater is estimated to be about 2 hours at peak flows to 10 hours for flow rates of the order of 100 L/s.

Tidewater. The tidewater, or estuary, part of the Tijuana River is complex because of many channels, islands, and branches. It is brackish, with runoff (including baseflow) of fresh water mixing with salt water brought in from the ocean on every flood tide. The ratio of fresh water to sea water at any point in the estuarial system varies, with increasing freshness, as the observer moves inland. At any station, one must expect a certain degree of stratification, with a lower more brackish layer underlying a less brackish upper layer. There are as yet no direct measurements of such stratification available for this estuary.



Plan and Course of the Tijuana River and Estuary
(USGS Imperial Beach quadrangle map, TCA1099)

Table 9
Estimated Flow Characteristics of the Tijuana River above Tidewater

L ength = 6518 m Drop = 15.2 m Manning friction factor = 0.05

Channel depth = 0.03 x width² (Parabolic cross-section assumed)

Width, m	Depth, m	A, m^2	P, m	R, m	Q, m3/s	Q, L/s	V, m/s	Froude Number	Travel Time, sec	Travel Time, hr
0.78591	0.005	0.001	0.786	0.001	0.000	0	0.010	0.139	662099	183.92
1.57182	0.018	0.006	1.572	0.004	0.000	0	0.025	0.175	262795.87	73.00
2.357731	0.042	0.022	2.360	0.009	0.001	1	0.043	0.200	153093.9	42.53
3.143641	0.074	0.052	3.148	0.016	0.003	3	0.062	0.220	104364.62	28.99
3.929551	0.116	0.101	3.938	0.026	0.008	8	0.084	0.237	77548.706	21.54
4.715461	0.167	0.175	4.731	0.037	0.019	19	0.107	0.251	60853.797	16.90
5.501371	0.227	0.277	5.526	0.050	0.036	36	0.131	0.264	49586.818	13.77
6.287282	0.296	0.414	6.324	0.065	0.065	65	0.157	0.276	41537.153	11.54
7.073192	0.375	0.590	7.126	0.083	0.108	108	0.183	0.287	35536.766	9.87
7.859102	0.463	0.809	7.931	0.102	0.171	171	0.211	0.297	30914.566	8.59
8.645012	0.561	1.077	8.741	0.123	0.257	257	0.239	0.306	27259.514	7.57
9.430922	0.667	1.398	9.555	0.146	0.375	375	0.268	0.314	24306.792	6.75
10.21683	0.783	1.777	10.374	0.171	0.530	530	0.298	0.323	21878.66	6.08
11.00274	0.908	2.220	11.199	0.198	0.729	729	0.328	0.330	19851.699	5.51
11.78865	1.042	2.730	12.030	0.227	0.981	981	0.359	0.337	18137.73	5.04
12.57456	1.186	3.314	12.866	0.258	1.296	1296	0.391	0.344	16672.2	4.63
13.36047	1.339	3.975	13.710	0.290	1.682	1682	0.423	0.350	15406.841	4.28
14.14638	1.501	4.718	14.560	0.324	2.150	2150	0.456	0.356	14304.896	3.97
14.93229	1.672	5.549	15.417	0.360	2.712	2712	0.489	0.362	13337.915	3.70
15.7182	1.853	6.472	16.282	0.398	3.379	3379	0.522	0.367	12483.563	3.47
16.50411	2.043	7.492	17.155	0.437	4.165	4165	0.556	0.373	11724.074	3.26
17.29002	2.242	8.615	18.036	0.478	5.084	5084	0.590	0.377	11045.156	3.07
18.07593	2.451	9.844	18.926	0.520	6.148	6148	0.625	0.382	10435.192	2.90
18.86184	2.668	11.184	19.824	0.564	7.375	7375	0.659	0.387	9884.6468	2.75
19.64775	2.895	12.641	20.732	0.610	8.779	8779	0.694	0.391	9385.6278	2.61
20.43366	3.132	14.220	21.649	0.657	10.377	10377	0.730	0.395	8931.5501	2.48
21.21958	3.377	15.924	22.576	0.705	12.187	12187	0.765	0.399	8516.8798	2.37
22.00549	3.632	17.760	23.512	0.755	14.226	14226	0.801	0.403	8136.9346	2.26
22.7914	3.896	19.732	24.459	0.807	16.514	16514	0.837	0.406	7787.7286	2.16
23.57731	4.169	21.844	25.417	0.859	19.071	19071	0.873	0.410	7465.8488	2.07

5 Analysis

5.1 Salinity in the Estuary

Zedler et al. (1992) identified salinity depression as a major impact imposed by the previous wastewater discharges to the Tijuana Estuary. Currently the Regional Water Quality Board is voicing the same concern. Therefore, analysis of the impacts of wastewater discharge on the estuary should include study of the reduction of salinity, as well as conventional wastewater parameters such as BOD, TSS, ammonia, nutrients, and bacteria.

Half-hourly salinity measurements have been taken over the past 5 years at a site in the estuary about one mile inshore of the coastline. The sampling station appears not to be on the present main channel of the Tijuana River, but on a side channel.

For this report, the half-hourly data were averaged to yield daily average values. Figure 9 shows these daily average salinity values, along with daily total precipitation, plotted for each day of 2003. Of note is that:

- The salinity value is seen to oscillate between near-zero and 27 parts per thousand;
- The periods of low salinity coincide with the periods of heavy rainfall;
- Following a springtime period of near-zero salinity, the salinity increases gradually over the summer;
- The oscillations in salinity have a period of about 15 days.

One may consider three regimes in this record: a) following heavy rainfall (salinity = 0 to 2 parts per thousand [ppt]); b) with moderate baseflow (salinity = 2 to 20 ppt), and c) with low baseflow (17 to 27 ppt).

Figure 10 for 2004 shows a generally similar pattern, except that the salinity record stops at October 18, shortly following an extremely heavy (6-inch) rainfall.

The daily average salinity value oscillations with a period of 15 days leads one to hypothesize that the value is dependent on the rate of tidal flushing. Ocean tide oscillations predicted for nearby Imperial Beach for a typical month (May 2006) are shown in Figure 11. The tide pattern is mixed, in that for some parts of the month the tide pattern is largely semidiurnal, while for other parts of the month it is nearly diurnal (i.e. one tide flood and ebb per day, except for a minor “kink” in the record showing a small semidiurnal component.) All such tidal movement promotes the exchange of water, and salt, between the sea and the estuary.

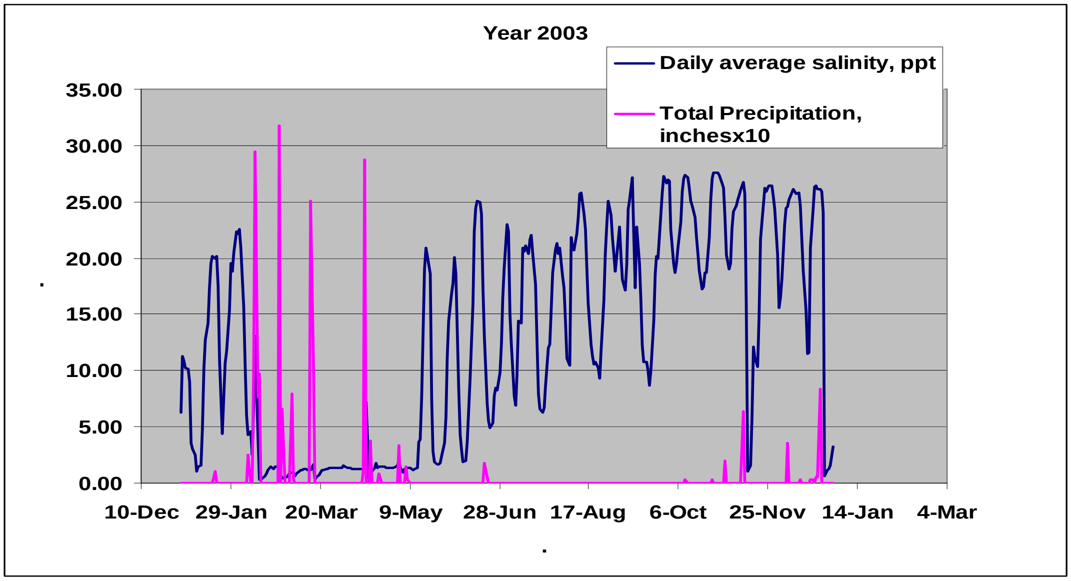


Figure 9. Daily average salinity at Zedler et al.'s "E-W monitoring station" in the estuary, and local precipitation, 2003

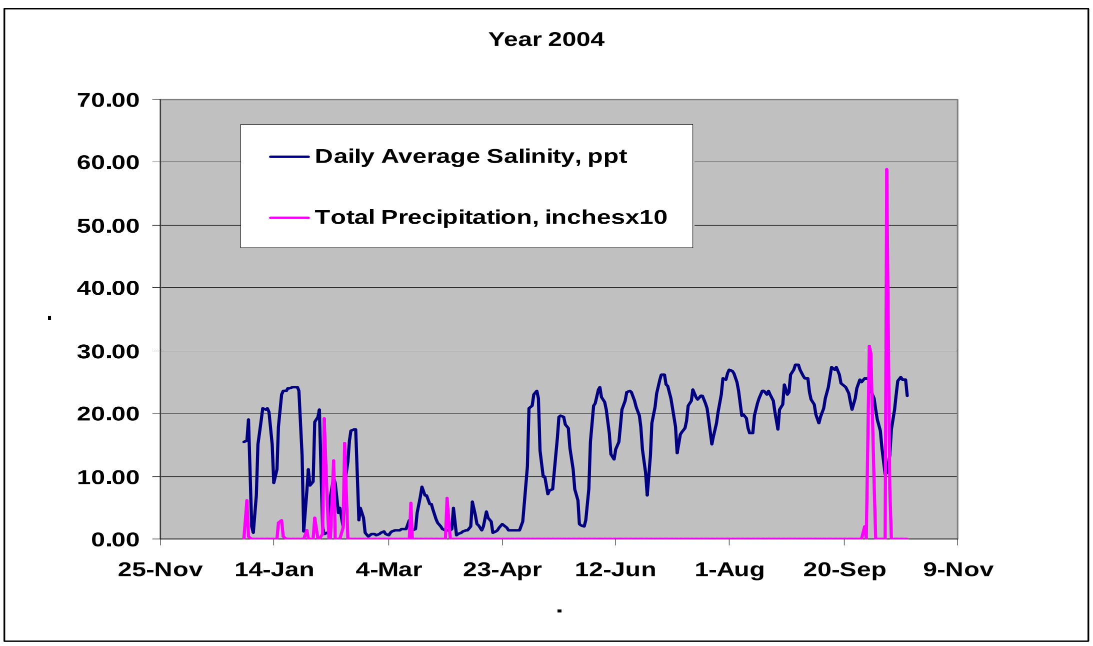


Figure 10. Daily average salinity at Zedler et al.'s "E-W monitoring station" in the estuary, and local precipitation, 2004

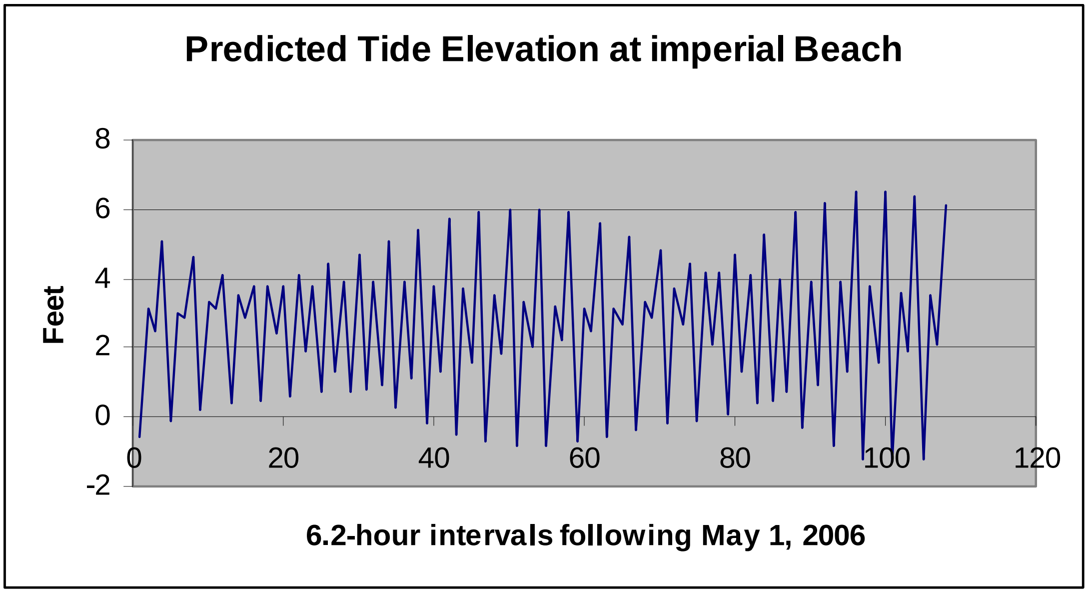


Figure 11. Predicted tide elevation at Imperial Beach (www.saltwatertides.com)

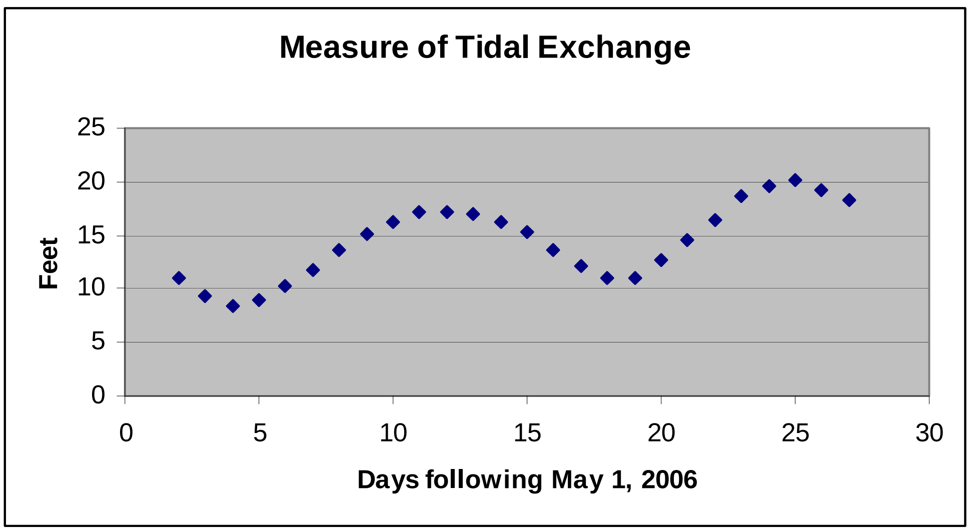


Figure 12. Measure of tidal exchange

Figure 12 is a plot of the sum of the tidal movements (two daily high-tide-to-low-tide ranges plus two daily low-tide-to-high-tide ranges) for the 28-day period. It shows the characteristic fortnightly oscillation similar to that of the estuarine salinity data.

A simple tidal-flushing box model was built to try to emulate the salinity oscillations observed in the estuary. For any day, the estuarine salinity, $S_{estuary}$, is:

$$S_{estuary} = (Q_{ocean} * S_{ocean})/(Q_{ocean} + Q_{freshwater} + Q_{tijuana})$$

Where Q_{ocean} is the daily flux of ocean water into the inlet through the coastal inlet, S_{ocean} is the salinity of the ocean, $Q_{freshwater}$ is the flow of runoff and baseflow out through the estuary, and $Q_{tijuana}$ is the additional flow that crosses the border from the City of Tijuana. It is assumed that $Q_{freshwater}$ and $Q_{tijuana}$ have negligible salt content compared with the assumed ocean water salinity of 34 parts per thousand (ppt).

Q_{ocean} and the water level within the estuary are computed in tandem for each day using estimated values for the size of the tidal prism in the estuary (the volume of water taken in and driven out with each tide cycle). $Q_{tijuana}$ varies daily according to Figure 2 for present conditions, or Figures 3 through 5 for the various discharge options and hence flow management alternatives being considered for Tijuana.

$Q_{freshwater}$ was estimated based on the rationale that it would include a baseflow plus runoff from storm systems precipitating on tributary watersheds on both the Mexican and U.S. sides of the border. The U.S.-generated runoff was therefore assumed to be directly proportional to the flow in the Tijuana River approaching the border, but not yet reaching the PB-CILA.

For the tidal signal, the 28-day prediction for May 2006 was simply repeated 12 times, to represent the 12 months of the year.

The result of this simulation is shown in Figure 13 for the Present Situation, where there is transboundary flow only during wet-weather flows exceeding the present 500 L/s capacity of the PB-CILA. The ranges of salinity predicted for the 2006 flows used are comparable with those measured in 2003 (Figure 9) and 2004 (Figure 10). In times of wet weather the salinity is depressed to less than 5 ppt, and in dry weather the tide signal is visibly letting the salinity oscillate between 20 and 24 ppt.

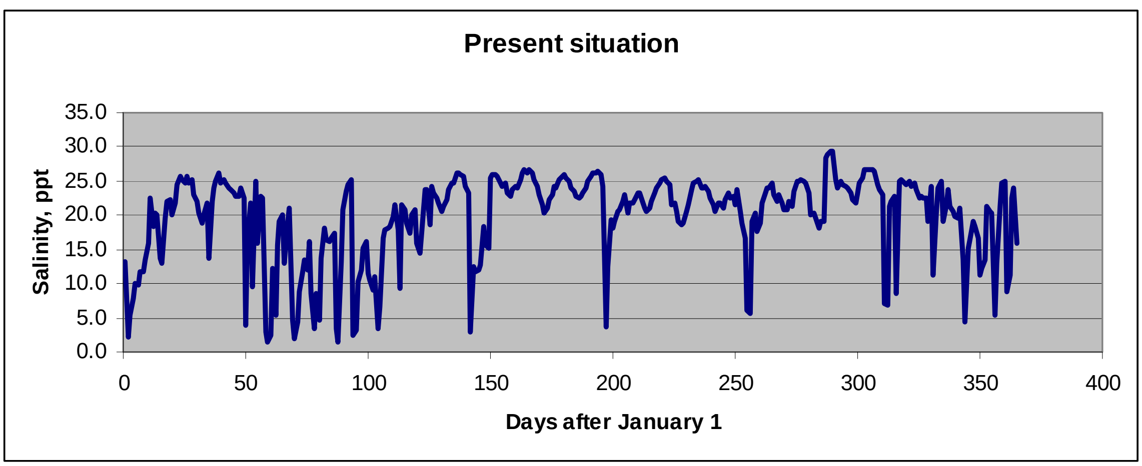


Figure 13. Estuary salinity for the present situation (PB-CILA @ 500 L/s capacity)

In Figures 14 through 16 this salinity signal for the present situation is compared with the signals that are predicted to result in 2025 from the three alternatives. In Figure 14 for the No Action Alternative, the net addition of flow sends a continuous dry-weather flow across the border, significantly depressing the salinity, though not below the range experienced in the present situation.

In Figure 15 for the Preferred Alternative discharging at Punta Bandera, and in Figure 16 for Alternative B using the SBOO, there is essentially no alteration of the salinity signal from the present situation. In both these alternatives the dry-weather flow is intercepted and curtailed as well as, or better, than at present, and the only transboundary flows occur in wet weather. The incremental loads from the three colonias would not have any effects on salinity in the river.

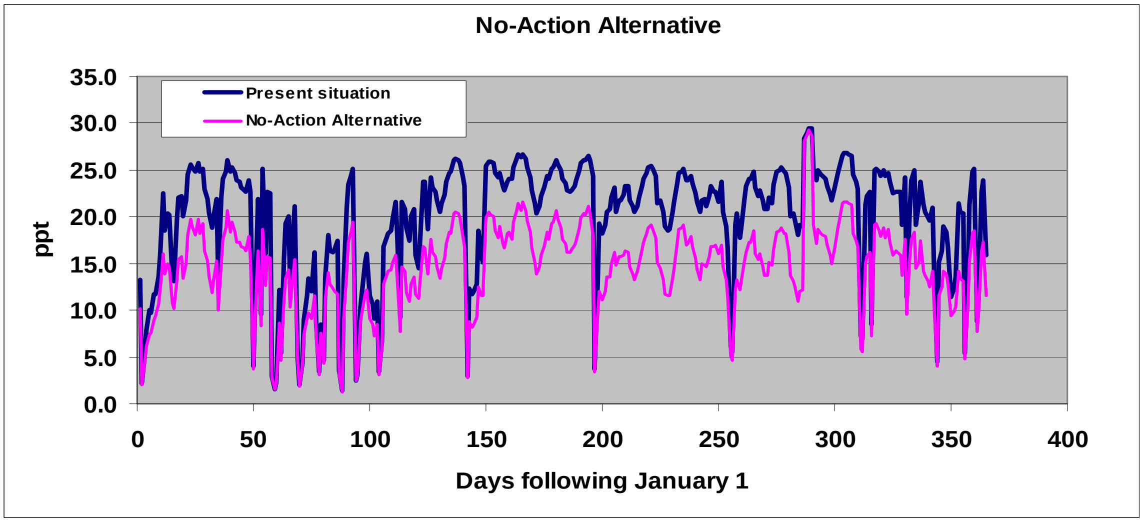


Figure 14. Salinity depression for the No-Action Alternative

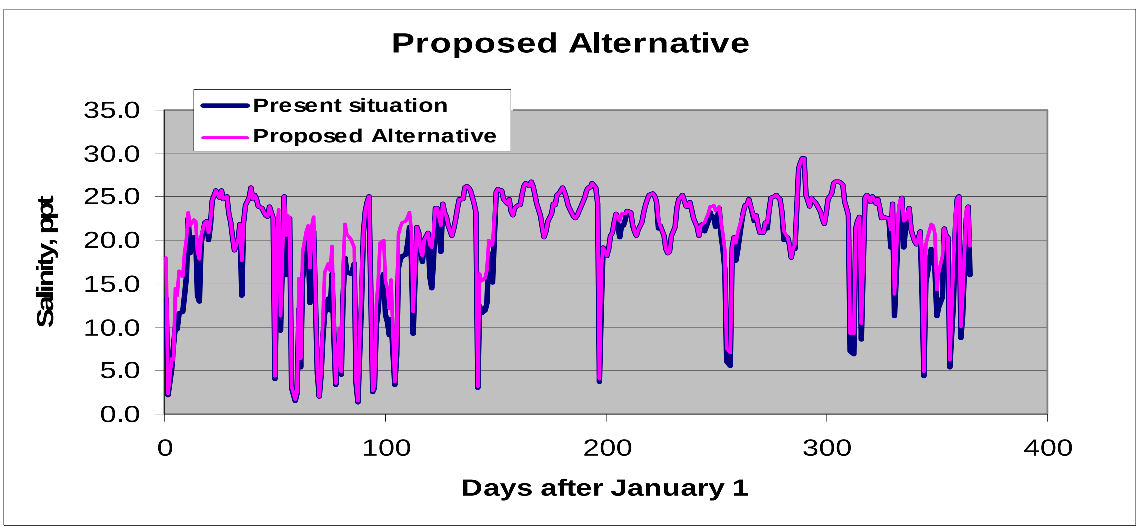


Figure 15. Salinity depression for the Preferred Action Alternative A

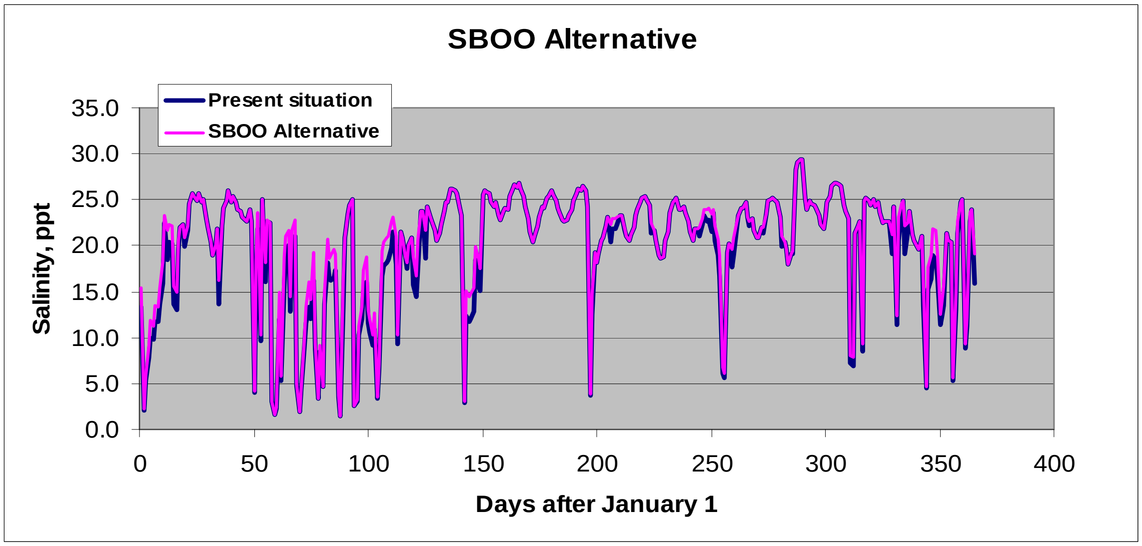


Figure 16. Salinity depression for Alternative B using the SBOO

5.2 BOD, TSS, and DO; Nutrients

As shown in Table 9, the travel time from the international border to the head of tide—and, effectively, the upstream limit of saline water—is only on the order of 6 hours. A typical Streeter-Phelps analysis would show that only a small fraction of the BOD in the river would be reduced in that time.

Table 8 and Figure 7 show that the No Action Alternative would somewhat increase the loads of BOD, TSS, and nutrients to the estuary, by about 30 percent. The other two alternatives would actually reduce the loads on the estuary somewhat, compared with the present situation. No undue stress on the ecology of the estuary is anticipated as a result of Alternatives A and B. Further, the incremental loads from the three colonias would not have any effects on BOD, TSS, and nutrients to the estuary.

5.3 Coliform Bacteria

Table 5 indicates that fecal coliform counts in the anticipated flow have a range of 10^4 to 10^8 MPN per 100 mL. These concentrations exceed bathing water criteria values by factors of 10^2 to 10^6.

Factors known to reduce coliform concentrations include exposure to sunlight and contact with seawater. However, the travel time is so short from the international border to the head of the tide that little reduction in fecal coliform levels can be counted upon, particularly at night. At most, two orders of magnitude reduction might be expected during daylight hours. Contact with seawater can reduce coliform levels by an order of magnitude.

A very rough estimate of the reduction in fecal coliform counts between the international border and the sea is therefore at best about 3 orders of magnitude, much less than the 6 orders of magnitude reduction that at times would be needed to meet bathing criteria in seawater.

The parameter of importance concerning coliform bacteria (and other wastewater pathogens, for which fecal coliform are used as a surrogate parameter) then becomes the frequency with which there is a transboundary flow. These frequencies were presented for the no action and two action alternatives in Table 4.

At present, the 500 L/s capacity of the PB-CILA keeps the estuary free of effluent for about 60% of the year. Under the No-Action Alternative, this would degrade to essentially no days free of effluent. The preferred Alternative A, increasing the PB-CILA capacity to 1500 L/s, would keep the estuary free of effluent for about 320 days per year. Alternative B using the SBOO would keep the estuary free of effluent for 270 days per year. Both alternatives would improve the coliform levels in the estuary relative to the No Action Alternative. The incremental loads from the three colonias would not substantially affect coliform levels in the estuary because the wastewater flows would be treated at the JBIC plants and represent only a small portion of total effluent discharges.

5.4 Increased flows and loads to the SAB plant

The present capacity of the SAB wastewater treatment plant is 25 mgd = (1100 L/s). At present the flows sent its way are of the order of 35 mgd (1530 L/s). The plant accepts only the 25 mgd for which it has capacity; any excess is bypassed, as indicated, and recombined with the treated effluent for discharge at the coastline at nearby Punta Bandera. The No Action Alternative and Alternative B would not change this situation with respect to flow rate, as the PB-CILA capacity remains at 500 L/s.

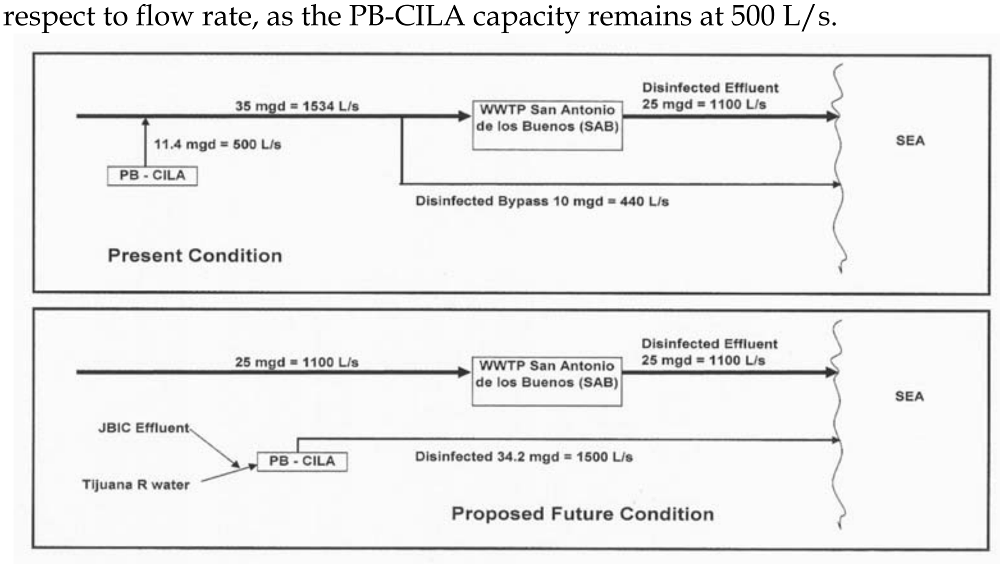


Figure 17. Schematic diagram of flow paths to SAB WWTP and the sea

The preferred alternative (Alternative A) would increase the flow rate from the PB-CILA by up to 1000 L/s which would go through a parallel pipeline towards the SAB Plant for distribution and ultimate discharge to the ocean. The flow for discharge in the ocean now would be nearly 2,600 L/s, with 1,100 L/s from the SAB Plant and 1,500 L/s from PB-CILA. Figure 17 shows schematic flow diagrams for the present condition and under the preferred Alternative A.

Pathogenic contamination of beach areas due to the increased effluent flow rate is not expected to be a problem, since both the PB-CILA flow and the SAB effluent are to be disinfected. Whatever coliform concentrations remain after the disinfection process would be reduced by roughly an order of magnitude upon contact with the sea water. A further reduction of at least 1.5 log cycles (roughly a factor of 30) is attained through physical dilution as the effluent plume is advected northward along the coast. There would also be die-off due to solar radiation, during the daylight hours.

Conventional wastewater parameters. According to recent available data, the quality of the Tijuana River water conveyed by the PB-CILA (Table 10, Row 1) is comparable to, or even better than, the quality of the effluent from the SAB plant (Rows 3), and much better than the quality that has been pumped at PB-1 (Row 2), as shown in Table 10. It should be noted that the June 2007 data marks only a single water quality check at one point in the river and may not be representative of consistent water quality in the river.

Table 10
Concentrations of key conventional wastewater parameters in Tijuana River and effluent discharged from the SAB wastewater plant (mg/L)

	BOD	TSS	NH_3	Total P
1. Tijuana River/PB-CILA, June 2007	59	84	1.1	2.0
2. PB-1, average values 1996-2001	420	327	32	22.6
3a. SAB, June 2005	108	123	38.8	11.1
3b. SAB, June 2006	70	340	<0.1	83.0
3c. SAB, June 2007	84	184	49.2	6.3
3. Geometric mean of SAB values	86	197	5.8	18
4. Weighted average of 440 L/s (10 mgd) bypass flow and 1,100 L/s (25 mgd) SAB effluent	181	234	13	19
5. Weighted average of 1,500 L/s PB-CILA flow and 1,100 L/s SAB effluent	70	132	3.1	8.8

However, the water quality in the Tijuana River may be expected to be better than the historical values, as untreated discharges are to be curtailed and replaced in part by advanced secondary effluent from the JBIC plants.

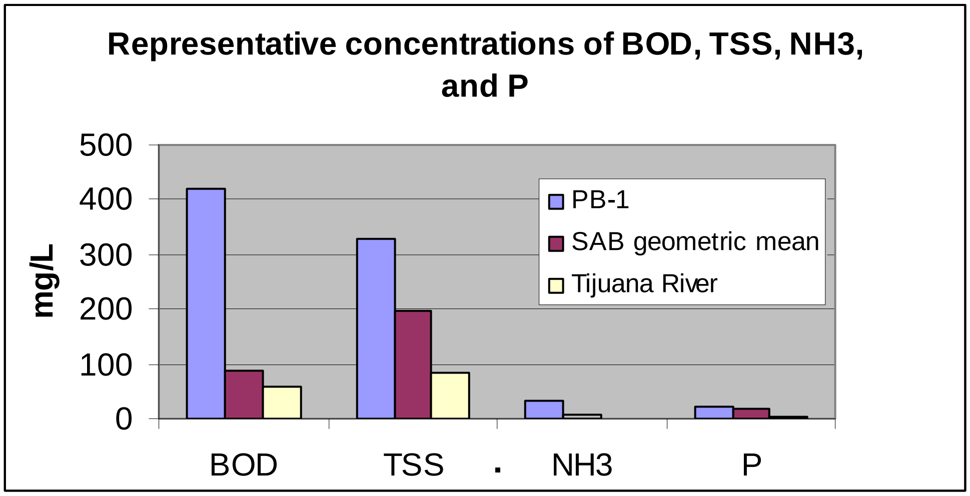


Figure 18. Representative water quality values from PB-1, SAB, and the Tijuana River, from Table 10.

Weighted Average concentrations in discharges to sea. Row 4 of Table 10 presents weighted average concentrations for the 1,100 L/s SAB discharge combined with the 440 L/s bypassing the SAB plant, assuming that the flow bypassing the plant is characterized by the PB-1 quality shown in Row 2, for the four parameters shown.

Row 5 presents weighted average concentrations for the 1,100 L/s SAB discharge combined with the 1500 L/s capacity of the enlarged PB-CILA, which under the preferred Alternative A would all bypass the SAB plant, but be disinfected and combined with the SAB effluent before discharge to sea. It is assumed that the flow bypassing the plant is characterized by the PB-CILA quality shown in Row 1, for the four parameters shown.

Dilution in the littoral drift. Parsons (2004) modeled the shoreline discharge from Punta Bandera, and obtained predictions of the concentration the diluted effluent would have once it had drifted north along the coast to the International Boundary and beyond. Excerpts of their predictions are presented in Table 13, for the month of August (when recreational beach usage is near its annual peak), presented as a function of discharge rate from Punta Bandera (SAB plant effluent plus flows in excess of 1,100 L/s that bypass the plant). The data in Table 11 are plotted in Figure 21.

The third column of Table 11 establishes the trend of concentration vs. discharge rate. For just the SAB plant effluent, for example, the concentration is 0.0184, i.e. the concentration of a conservative constituent measured in the surf at the international border is 0.0184 times as strong as at the discharge point. For an effluent discharge rate of 2,200 L/s, the concentration in the surf at the border is 0.0354 times as strong as at the point of discharge.

Table 11
Model predictions of the average concentration of conservative constituents at the international boundary, 8 km north of the discharge point, for the month of August.

Discharge Q, m^3/s	Discharge Q, mgd	Parsons Model predictions	For 25 mgd + 10 mgd (present condition)	For 25 mgd + 1500 L/s (Proposed future condition)
1.10	25	0.0184		
1.36	31	0.0221		
2.19	50	0.0354		
2.46	56	0.0404		
2.59	59	0.0426		
2.85	65	0.047		
1.53	35		0.0247	
2.54	58			0.0425

The fourth column is for the 25 mgd SAB discharge plus an increase of 440 L/s (10 mgd) to represent the 440 L/s flow that typically bypasses the SAB plant at present, for a total of 1,540 L/s (35 mgd). By visual interpolation, the resulting concentration at the border would be 0.0247, relative to that at the discharge point. Similarly, the fifth column indicates that if the 1,500 L/s (34 mgd) proposed to be pumped from PB-CILA is added to the 1,100 L/s (25 mgd) flow discharged from the SAB plant at the present time, the concentration at the border would be about 0.0425 times that at the discharge point. The values in Table 11 are plotted in Figure 19.

Concentrations at the International Border. One may now multiply the present effluent concentrations at the point of discharge (Table 10, Row 4) by the factor 0.0247 for the 35-mgd discharge to obtain the concentrations at the international boundary (blue columns, Figure 20. Similarly, one may multiply the proposed effluent concentrations at the point of discharge (Table 10, Row 5) by the factor 0.0425 to obtain the concentrations at the international boundary for the proposed conditions (purple columns, Figure 22).

Figure 20 shows that the concentrations are nearly unchanged from present conditions to the proposed future conditions under the preferred Alternative A. Compensating for the increase in discharge flow rate is a decrease in constituent concentrations. The figure suggests a slight net decrease in border concentrations, but due to uncertainties in the data and the methods of estimation, it may be best to conclude that the concentrations remain essentially unchanged.

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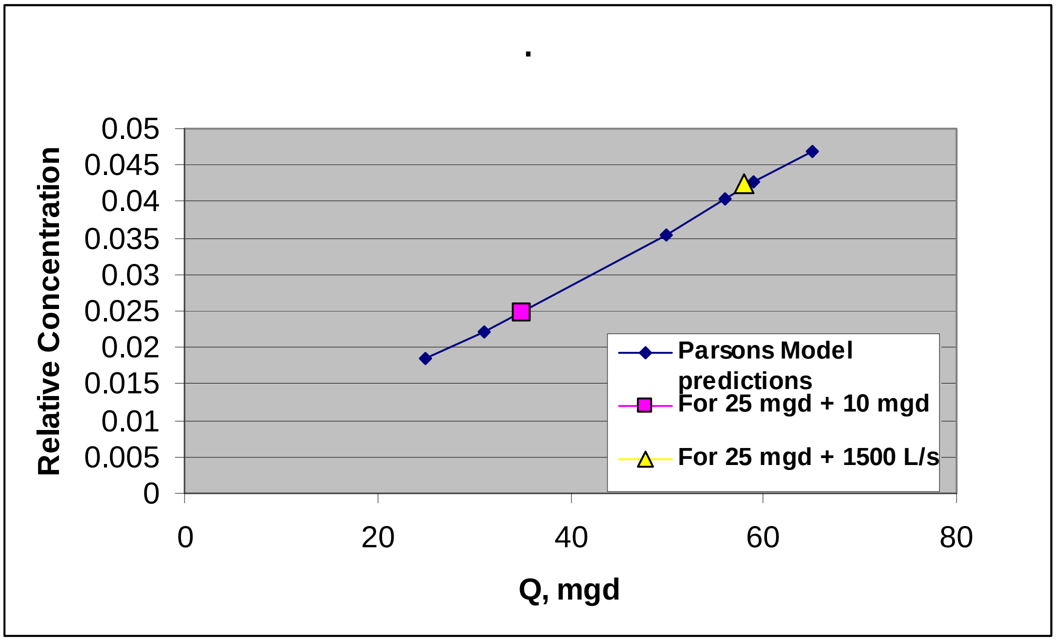

Figure 19. Interpolations into predictions by Parsons (2004) for average concentrations in Punta Bandera effluent measured at the international border.

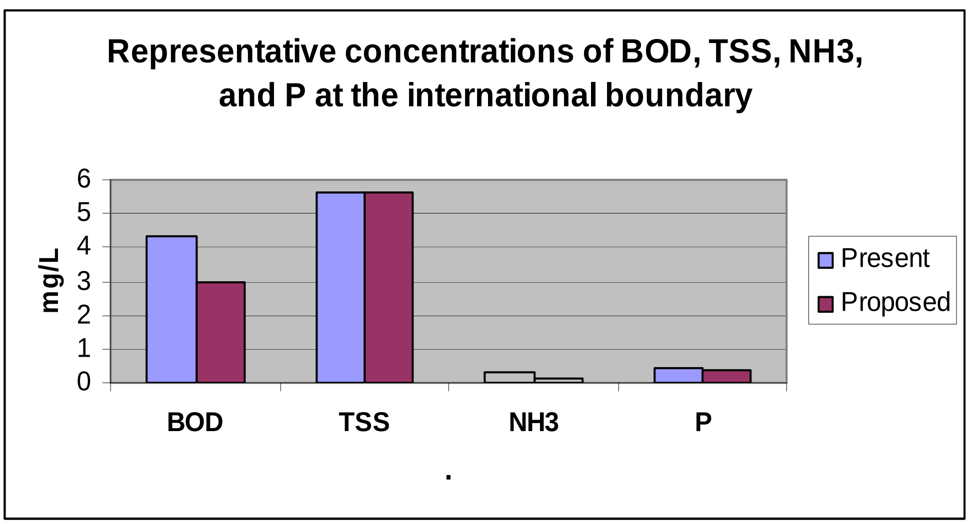

Figure 20. Concentrations of several wastewater parameters at the international boundary, due to present and proposed discharges at Punta Bandera

5.5 Additional flows and loads to the SBOO

For Alternative B, Table 12 and Figure 21 summarize the loads (tonnes/year) that would be added to the present discharge through the South Bay Ocean Outfall. Provided that the operation and maintenance at the JBIC advanced secondary plants are comparable to that at the South Bay International Wastewater Treatment Plant, the quality of the effluent should not change significantly. Under Alternative B using the SBOO, the additional flows to the South Bay Ocean Outfall, projected to be about 17 mgd or 733 L/s in 2025, would represent a 67% increase in flow rate over the SBOO's existing (2006) flow rate of about 25 mgd, or 1,100 L/s. Essentially all of this additional flow would be advanced secondary effluent from the JBIC plants, i.e. of a quality comparable to that produced by the South Bay International Wastewater Treatment Plant, discharging through the same outfall.

Table 12
Summary of loads (tonnes/year) to the South Bay Ocean Outfall (Alternative B only).

	BOD	**TSS**	**NH_3**	**P**
Present Situation	**--None--**			
2008	445	445	89	74
2012	464	464	93	77
2025	693	693	139	116

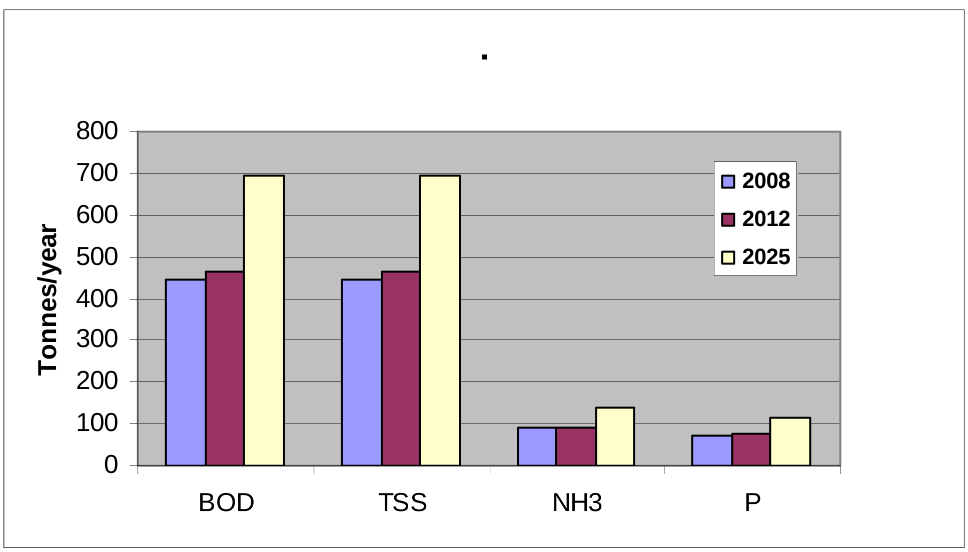

Figure 21. Additional loads conveyed to the South Bay Ocean Outfall under Alternative B.

5.6 Discussion and Conclusions

Of the three alternatives examined, both the Alternative A and the Alternative B would greatly decrease the impacts that would otherwise occur under the No Action Alternative. Alternative A, the main feature of which is to triple the pumping capacity of the PB-CILA, is the more successful at reducing both the flows and the contaminant loads crossing the international boundary.

None of the alternatives studied appears to greatly affect the salinity regime in the estuary. Once again, Alternative A imposes less impact than either the No Action Alternative or Action Alternative B.

The impact of coliform loads on the Pacific Ocean beaches in the U. S., near the mouth of the river, is best assessed by the number of days per year that transboundary flows occur. The No-Action Alternative condemns the system to essentially daily transboundary flows. Alternative B provides about 270 days per year free of such flows. Once again, Alternative A is best, in providing about 320 days per year free of transboundary flows.

6 References

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