BROWN AND CALDWELL

201 North Civic Drive
Walnut Creek, California, 94596
Tel: 925.210.2384
Fax: 925.937.9026

Technical Memorandum

FINAL

Prepared for: City of Santa Cruz/Soquel Creek Water District

Project Title: Dilution Analysis for Brine Disposal via Ocean Outfall

Project No: 137197

Technical Memorandum

Date: August 9, 2011

To: Heidi R. Luckenbach, Desalination Program Coordinator
City of Santa Cruz, Santa Cruz, CA

From: William K. Faisst, Ph.D., PE, Brown and Caldwell

Copy to: File

Prepared by: ______________________________

Soumya Kini, Ph.D., Brown and Caldwell

Reviewed by: ______________________________

Tom Birmingham, PE, Brown and Caldwell
California, License No. 67405 exp. 12/2010

REVIEWED BY: William K Faisst ______________________________

WILLIAM KARL FAISST
No. C 29146
Exp. 03-31-11

WILLIAM K. FAISST, PH.D., PE BROWN AND CALDWELL
CALIFORNIA, LICENSE NO. 29146 EXP. 03/2011

Limitations:

This document was prepared solely for City of Santa Cruz in accordance with professional standards at the time the services were performed and in accordance with the contract between Santa Cruz and Brown and Caldwell dated March 6, 2009. This document is governed by the specific scope of work authorized by City of Santa Cruz; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by City of Santa Cruz and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

EXECUTIVE SUMMARY

The City of Santa Cruz (City) and Soquel Creek Water District (District) are evaluating a jointly constructed reverse osmosis facility to desalt seawater and produce potable water to supplement existing water supplies for both agencies. The desalination plant, as described in the program-level Environmental Impact Report, would proceed with an initial production flow of 2.5 million gallons per day (mgd) with a potential to expand to 3.5 and 4.5 mgd in the future, if required. The City and the District plan to dispose of brine through the City's existing ocean outfall after combining brine with the effluent from the City's Water Pollution Control Facility (WPCF). Two prior studies were conducted as follows: 2002 with operating conditions of 2/4/6 mgd flow with City's National Pollution Discharge Elimination System (NPDES) discharge permit minimum initial dilution ratio (seawater to effluent) (MIDR) of 114:1; 2004 with operating conditions of 2.5/3.5 mgd flow with a NPDES discharge permit MIDR of 114:1. In this Technical Memorandum, we present an updated evaluation to determine how such a combined discharge with operating conditions of 2.5/3.5/4.5 mgd flow would achieve a modified MIDR of 139:1 required by the City's NPDES permit (CA 0048194) for the WPCF, how brine discharge must be modulated to achieve continual permit compliance, and how the brine/effluent discharge would never exceed ambient salinity of the receiving waters.

Outfall and Diffuser Hydraulics: We evaluated flow distribution along the outfall using Brown and Caldwell's proprietary diffuser hydraulics program DIFF$$ for effluent flows ranging from 3 to 100 mgd. We assumed that each port was covered by a Red Valve©. We also examined how the diffuser could perform in its "as installed" configuration.

Installation of Red Valves© over existing ports is recommended because Red Valves© would provide significant advantages over existing diffuser ports as summarized below:

a) Installing Red Valves© over existing ports would allow the City to open all diffuser ports and have all ports available at low flows, thus spreading the effluent flow along the entire diffuser length. Currently, about 60 percent of the diffuser ports are plugged to maintain minimum flow from open ports at low flows. This configuration operates to meet all discharge requirements with an effluent-only discharge; the wastewater effluent is more buoyant and achieves better initial dilution than a denser brine/effluent mixture. The revised configuration would open all ports when discharging a denser brine/effluent mixture regardless of flow rate.

b) Unlike existing diffuser ports, Red Valves© would expand and contract depending on the flow, resulting in better jet velocities at low flows. Therefore addition of Red Valves© would improve dilution at low brine/effluent flows. At higher flows, Red Valves© would expand to fully open, ensuring availability of full diffuser capacity.

c) At low flows, a risk exists that seawater and/or sediment could intrude through existing ports with all ports open. Because Red Valves© are specially fabricated to allow flow only in one direction; reverse flow of seawater or sediment into the outfall is prevented. Red Valves© can be fabricated to be more or less flexible. The Red Valves© could be fabricated to be less flexible closer to the shore to facilitate more even flows across all ports on the diffuser as total flow changes.

We compared MIDRs during summer/fall and in winter conditions between Red Valves® retrofitted over existing ports and existing ports at various combined effluent flows and with various brine to effluent ratios. Our analysis showed that MIDRs were lower with existing ports than with Red Valves© under all combined effluent flows, seasons, and brine to effluent ratios evaluated. At flows less than or equal to 3 mgd, flow weighted MIDRs with existing ports were lower than 139:1, whereas MIDR was greater than 139:1 with Red Valves©. Red Valves© allowed diffuser operation with all ports open, whereas only 41 percent of existing ports could be opened at combined effluent flows less than or equal to 3 mgd. Based on this analysis, and other benefits discussed above, we recommend installation of Red Valves© on existing diffuser ports.

The analysis showed that all diffuser ports were open under all flow rates evaluated, but the effective Red Valve© diameter was 1 to 2 inches for effluent flows under 15 mgd, and equivalent to existing port diameters for effluent flows greater than or equal to 15 mgd. At lower flows the Red Valves would open partially, acting as continuously variable nozzles. This property of the Red Valves would help spread flow along the diffuser more uniformly and would also enhance jet mixing at lower flows. At higher flows, the Red Valves would open fully and the underlying original ports in the concrete diffuser pipe would govern flow distribution and jet velocity.

Dilution Factor, Discharged Salinity, and Brine Storage Requirements: Addition of brine to effluent caused a significant decrease in dilution achieved at the diffuser. With no brine discharge, MIDR ranged from 400:1 to 600:1 at flow rates ranging from 4 to 15 mgd. However, as the ratio of brine to effluent increased, MIDRs dropped dramatically under both summer/fall and winter scenarios. Table E-1 below summarizes minimum effluent flows required to maintain a MIDR of 139:1 for desalination plant production flows of 2.5, 3.5 and 4.5 mgd. If effluent flow drops below these values, then brine flow would need to be shut-off or reduced and sent to storage, so its subsequent discharge would maintain a MIDR of 139:1. Similarly, at lower effluent flow rates, brine flow would need to be reduced or shut-off and sent to storage to ensure that brine/effluent discharge salinity would not exceed the salinity of the receiving water. Table E-1 also shows an initial calculation of brine storage requirements for the three desalination plant production flows. The values presented in Table E-1 are those required for meeting MIDRs consistently. To prevent the end-of-pipe salinity of the effluent/brine mixture from exceeding average ambient receiving water salinity (about 33. 8 parts per thousand based on historical data) the storage would need to be increased slightly and the rate of brine discharge decreased slightly early each day, when the effluent flow rate would be lower. However, in no case would the effluent be insufficient to achieve the overall maximum discharged salinity required to not exceed ambient seawater salinities. When the City selects a final recovery rate for the desalination plant, then the calculations presented herein should be updated to set the final required storage size. In summary with properly sized brine storage and appropriate discharge controls, the combined effluent/brine discharge will:

- Not exceed the average salinity of the receiving seawater. The reader should note that the current effluent discharge never exceeds ambient salinity.
- Always be buoyant so that it never forms an effluent field spreading across the ocean floor.
- Always achieves the minimum initial dilution as now required for the current effluent-only discharge.

Trace Metal and Other Ocean Plan Table B Constituent Concentrations: Brine concentrations of most trace metals (copper, mercury, silver and zinc) except arsenic were less than effluent concentrations. Trace metal concentration in the composite effluent will remain below the effluent limits required by the City's NPDES permit (CA 0048194). Similarly, the concentrations for other Table B constituents in the discharge would comply with Ocean Plan requirements as occurs now for the effluent discharge.

Locations for Brine Addition to Effluent: We identified two locations where brine could be added to the effluent, which included the tunnel portal box close to the WPCF and the tunnel gate box close to the outfall at the beach. Brine introduction at the tunnel gate box resulted in the least headloss increase between existing conditions and new conditions, thereby making it the better option. Combining brine with effluent will expose a number of structures to high salinity water. As a result, the structures could be more susceptible to corrosion. Of particular concern are the 36-inch and 72-inch sluice gates in the tunnel gate box. Therefore conceptually, brine addition is recommended downstream of the sluice gates through the pre-cast concrete slab at the pig launching station. A 12-inch diameter nozzle located at the slab top could inject brine into the effluent at sufficient velocities to ensure complete mixing at all flows. This approach should receive more detailed review during facilities design.

Table E-1. Summary of Minimum Effluent Flows and Brine Storage Requirements to Maintain a Dilution Factor of 139 or Higher

Desalination Plant Production Flow (mgd)	Brine Flow Based on 45 Percent Recovery (mgd)	Minimum WPCF Effluent Flow Required During Summer/Fall Months (mgd)[1]	Brine Storage Volume During Summer/Fall Months (mg)[2]	Minimum Effluent Flow Required During Winter Months (mgd)	Brine Storage Volume During Winter Months (mg)[2]
2.5	3.1	2.1	0.6	2.1	0.6
3.5	4.3	4.1	1.3	4.8	1.6
4.5	5.5	5.3	2.0	6.3	2.0

Notes:

[1] If WPCF effluent flow falls below these values, then brine flow would need to be stopped and sent to storage.

[2] Brine storage volume includes additional 20 percent safety factor to account for reduction in WPCF flows due to water conservation measures, drought-time water use restrictions, and lower rates of infiltration and inflow.

Assumptions and Conclusions: This study required a number of assumptions to be made about the efficiency and operation of a full scale SWRO desalination facility. These assumptions are stated below. As a result, it is recommended that the City update the analysis based on information being gathered during facility design including actual brine recovery, most recent WPCF flows, location of mixing, etc.

1. INTRODUCTION

This Technical Memorandum describes outfall and diffuser hydraulics and dilution predictions in the ocean outfall after combining brine from the proposed seawater desalination facility with the effluent from the Water Pollution Control Facility located in the City of Santa Cruz, CA. We also describe operational considerations that control storage and release of brine.

1.1 Scope of Work

The City of Santa Cruz (City) and Soquel Creek Water District (District) are evaluating a jointly constructed reverse osmosis (RO) facility to desalt seawater to supplement existing water supplies for both agencies. Based on the program-level Environmental Impact Report, the desalination plant likely would proceed with initial production flows of 2.5 million gallons per day (mgd) with the potential to expand to 3.5 and 4.5 mgd in the future, if required. The production flow would range from 0.5 mgd to 2.5 mgd, 0.5 mgd to 3.5 mgd, and 0.5 mgd to 4.5 mgd. The City and the District plan to dispose of brine through the City's existing ocean outfall after combining brine with the effluent from the City's Water Pollution Control Facility (WPCF). An updated evaluation is needed to determine how such a combined discharge will still achieve minimum initial dilution ratio (seawater to effluent) (MIDR) of 139:1 required by the City's National Pollution Discharge Elimination System (NPDES) permit for the WPCF and how the brine discharge must be modulated to achieve continual permit compliance. Note that the MIDR of 139:1 is significantly greater than 114:1 used in the previous analyses. This change in MIDR makes brine addition more challenging while meeting NPDES permit limitations.

1.2 Objectives

The objectives of this study were to:

- Examine WPCF effluent flow to establish a reasonable diurnal pattern to base subsequent dilution analyses. This rejection rate implies brine flows of 3.1 4.3, and 5.5 mgd corresponding to desalination plant production flows of 2.5, 3.5, and 4.5 mgd respectively and an assumed recovery of 45 percent.
- Update previously conducted diffuser hydraulics and effluent dilution analyses (Brown and Caldwell, 2002, 2004) that evaluated the effect of ocean disposal of brine from the proposed joint seawater desalination facility. The updated evaluation re-assesses outfall hydraulics, diffuser hydraulics, and initial dilution.
- Estimate brine-flow equalization requirements under various brine disposal scenarios.
- Identify any other issues of concern regarding brine addition such as end-of-pipe salinity of the combined discharge remaining at or below average receiving water salinity.

2. ASSUMPTIONS

The following assumptions for diffuser hydraulics and dilution analysis were used.

- Complete mixing of brine and effluent prior to discharge into the outfall.
- Rejection rate of brine from reverse osmosis is 55 percent (45 percent recovery), which represents the most extreme scenario (high recovery rate).
- Red Valves© were retrofitted over existing outfall ports (see section "Diffuser Hydraulics" elsewhere in this document).
- Conservatively, effluent salinity is 0.5 parts per thousand (ppt).
- No change in brine temperature through the treatment process, i.e., brine temperature equals ambient seawater temperature.
- Required minimum dilution for discharge is 139:1 as per NPDES permit number CA 0048194.
- The average daily effluent flow from the WPCF is 9.8 mgd under low-flow conditions. The minimum future dry weather flow would not drop below this level; for example, possible reductions in effluent flow associated with improved water efficiency in potable water use would be offset by growth in the number of connections.

3. FACTORS AFFECTING DILUTION

Diffuser hydraulics and dilution are a function of several variables including outfall and diffuser characteristics, effluent density, effluent flow rate, and the density, velocity, and depth of ambient water. Density in turn is a function of temperature and salinity. High dilution rates are achieved:

- When effluent is much more buoyant than the ambient fluid (e.g., fresh water is discharged into seawater; warm water is discharged into cooler water) and is discharged below the surface.
- When ambient fluid is not density stratified (e.g., winter versus summer conditions).

Therefore, addition of cool, high-salinity brine to the effluent is expected to lower dilution by increasing density (and salinity), lowering the temperature, and increasing the flow rate of the composite effluent.

3.1 Composite Effluent

In order to evaluate the impact of brine addition on diffuser performance, we estimated salinity and temperature of brine and WPCF effluent. Brine salinity and temperature were estimated using coastal water quality data from Brown and Caldwell's Oceanographic Predesign Phase Report (1978), assuming that the intake for the desalination plant was 39 feet deep (Table 3-1). This assumption was consistent with Brown and Caldwell (2002) letter report. Winter conditions were based on the average of four profiles collected in February, 1977. Summer/fall conditions are the average of four profiles collected in September, 1976. These profiles were measured in 45 and 60 feet of water, roughly one-third of a mile off Terrance Point in Santa Cruz. Effluent temperature was based on 2001 effluent data in February (winter condition) and October (summer/fall condition), similar to Brown and Caldwell (2002, 2004) report (Table 3-1).

Analyses comparing combined effluent density in 1978 and 2009 are shown in Appendix E. Data indicated that the density difference in combined effluent between 1978 conditions and 2009 conditions was at most 0.3 percent. This is consistent with our hypothesis that the relative difference between brine temperature and salinity, and effluent temperature and salinity between 1978 conditions and 2009 conditions will likely not change and will not change our conclusions (e.g., if brine temperature increased, it is likely that effluent temperature also increased making relative difference in density between 2009 and 1978, similar to 1978 conditions).

Table 3-1. Brine and Effluent Water Quality[1]

	Brine		WPCF Effluent	
Condition	Temperature (°C)	Salinity (ppt)	Temperature (°C)	Salinity (ppt)
Winter	12.3	61.4	18.0	0.5
Summer/Fall	12.8	61.4	23.0	0.5

Notes:

[1] Temperature and salinity values are consistent with that used in Brown and Caldwell (2002, 2004) report. Sensitivity analysis at salinities less than 0.5 ppt for WPCF effluent did not make a significant difference to the dilution analysis.

[2] Brine temperature based on typical intake at 39 feet deep.

3.2 Ambient Water Quality

Density stratification in the receiving (ambient) water due to seasonal changes can affect dilution. Thermal stratification during summer/fall can reduce dilution by preventing upward momentum of the buoyant plume, hindering mixing of the rising plume with the ambient water. In winter, ambient coastal waters are essentially isothermal (i.e., no temperature gradient). Effluent in the summer is substantially warmer than in the winter as shown in Table 3-1 making it more buoyant than the receiving waters; the high effluent temperature enhances dilution. Two ambient water seasonal scenarios were examined – summer/fall ambient and winter ambient water conditions. These scenarios were obtained from temperature and salinity profiles collected in February 1976 and September 1977 and are consistent with the profiles used in Brown and Caldwell (2002, 2004) report (Table 3-2).

Table 3-2. Summer/Fall and Winter Ambient Water Profile

Depth from Surface (feet)	Summer/Fall Profile		Winter Profile	
	Temperature (°C)	Salinity (ppt)	Temperature (°C)	Salinity (ppt)
0	14.87	33.69	12.48	33.76
13	14.13	33.70	12.47	33.77
26	13.70	33.73	12.44	33.78
39	12.70	33.76	12.38	33.78
53	12.52	33.78	12.31	33.78
66	12.32	33.78	12.18	33.78
79	12.16	33.81	11.98	33.79
92	12.07	33.80	11.79	33.77
105	11.94	33.80	11.56	33.79

3.3 Effluent Flow

Given the need for a buoyant discharge to achieve MIDR of 139:1, analyses showed an upper limit to the amount of brine that can be added to the outfall. This amount of brine is a function of the effluent flow rate. When effluent flows are low, the outfall capacity to accept brine and still meet MIDR of 139:1 is limited. Therefore, the worst-case effluent flow scenario was based on minimum observed flow rates. Daily flow data available for the City's WPCF were examined to develop a worst-case 24-hour flow pattern. Flow pattern during a low flow period in April 2003 was plotted against time and a best fit fourth order quadratic curve was used to predict this pattern (Figure 3-1). By using the predicted effluent flow data, the total daily flow under the worst-case scenario was 9.8 mgd, in agreement with typical dry weather WPCF daily flows.

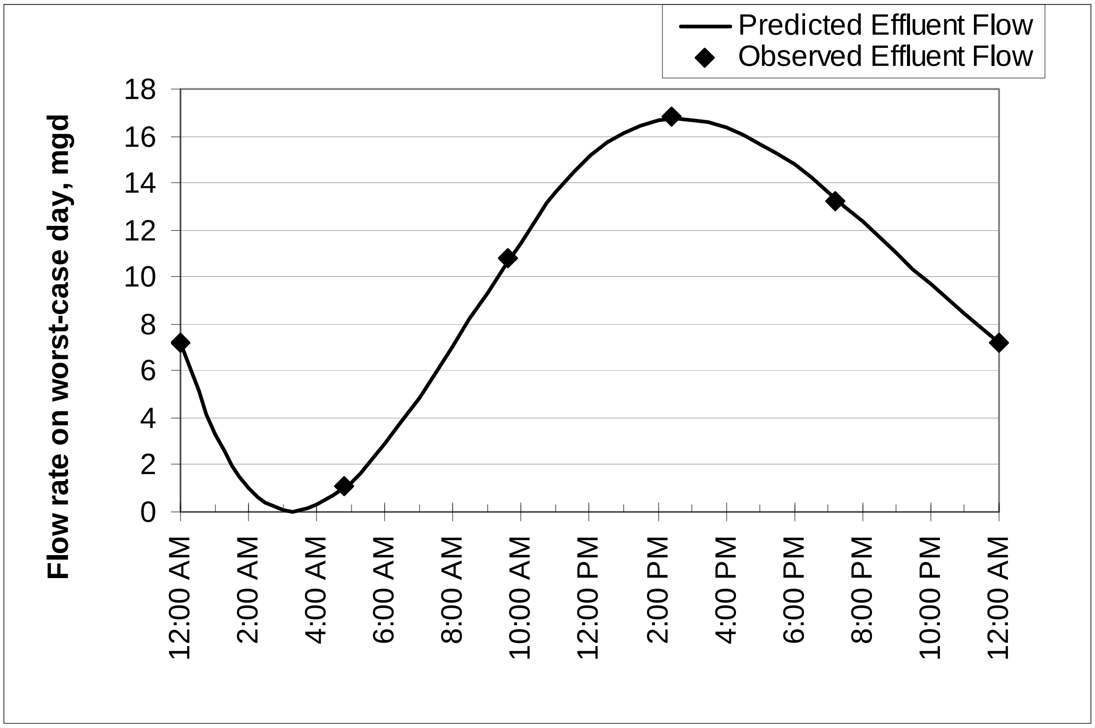


Figure 3-1. Worst-Case 24-hour Effluent Flow Pattern

Note: During Early Morning Hours, the actual WPCF Effluent Flow May Drop to Zero for Several Hours Owing to low WPCF Influent Flows and Necessary Process Recirculation.

4. METHODS

4.1 Diffuser Hydraulics

Flow distribution along the outfall was evaluated using Brown and Caldwell's proprietary diffuser hydraulics program DIFF$$. Model inputs included outfall and diffuser characteristics, flow rate, density of the composite effluent, and density of the ambient fluid. The outfall consists of a 72-inch diameter pipe with a 72-inch diameter diffuser of length 2048 feet, three major diffuser sections and an end gate structure (Table 4-1). The average downward slope is 0.0076 feet per foot. The number and diameter of ports were designed to maintain fairly constant discharge velocity along the length of the diffuser under a wide variety of flow conditions. Over half the ports are now closed since the outfall is currently operating at less than the design hydraulic capacity.

In this analysis, we assumed that each port was replaced by a Red Valve©. By retrofitting Red Valve© on existing ports, effective diameter of the Red Valve© and the number of ports open would depend on the flow rate of combined effluent through the outfall. We also examined how the diffuser could perform in its "as installed" configuration. Installation of Red Valves© over existing ports is recommended because Red Valves© would provide significant advantages over existing diffuser ports as summarized below:

a) Installing Red Valves© over existing ports would allow the City to open all diffuser ports and have all ports available at low flows, thus spreading the effluent flow along the entire diffuser length. Currently, about 60 percent of the diffuser ports are plugged to maintain minimum flow from open ports at low flows. This configuration is acceptable with an effluent only discharge because the wastewater effluent is more buoyant and achieves better initial dilution than a denser brine/effluent mixture would.

b) Unlike existing diffuser ports, Red Valves© would expand and contract depending on the flow, resulting in better jet velocities at low flows. Therefore addition of Red Valves© would improve dilution at low brine/effluent flows. At higher flows, Red Valves© would expand to fully open, ensuring availability of full diffuser capacity.

c) At low flows with traditional diffuser ports, a risk exists that seawater and/or sediment could intrude through existing ports with all ports open. Because Red Valves© are specially fabricated to allow flow only in one direction; reverse flow of seawater or sediment into the outfall is prevented. Red Valves© can be fabricated to be more or less flexible. The Red Valves© could be fabricated to be less flexible closer to the shore to facilitate more even flows across all ports on the diffuser as total flow changes.

Table 4-2 presents results from the analyses when all ports were open. At lower flows, the Red Valves would only open partially. At combined effluent flows of 15 mgd or more, the effective Red Valve© would open completely and existing port shown in Table 4-1 would govern flow distribution and jet velocity.

Table 4-1. Diffuser Characteristics

Diffuser Section	Port Diameter[1] (inches)	Number of Ports	Section Length (feet)
End Gate	4.25	2	NA
Offshore	3.7	50	606
Middle	2.5	64	706
Nearshore	2.0	60	714

Notes:

[1] Indicates existing port diameter. Effective diameter and number of ports open will depend on flow rate if Red Valve© is used (see Table below)

Table 4-2. Percentage of Ports Open for Various Flow Rates and Effective Red Valve© Diameters

Effective Diameter of all ports (inches)	Flow Rate (mgd)								
	3	5	10	15	20	50	80	90	100
1"/port	100% ports open	100% ports open							
2"/port			100% ports open						
Port diameters from Table 4-1				100% ports open	100% ports open	100% ports open	100% ports open	100% ports open	100% ports open

Notes:

Results obtained by running DIFF$$ program. Blank cells indicate that a scenario was not evaluated

4.2 Minimum Initial Dilution Ratio Calculation

MIDR was estimated using VISUAL PLUMES, a Windows-based mixing zone modeling application developed by Frick et al. (2001). The single-port Windows version of the Updated Merge (UM) model in the VISUAL PLUMES package, used by Brown and Caldwell (2002) report has now been upgraded to a three-dimensional flow model and renamed as UM3 to differentiate it from the previous version. The UM3 model was used in this report for dilution calculation. Dilution model inputs included flow rate through each diffuser section (estimated using DIFF$$ model), diffuser section characteristics, temperature and salinity of the composite effluent (Table 3-1), and temperature and salinity of the ambient water (Table 3-2).

MIDRs for all four diffuser sections (see Table 4-1) were calculated in the analysis, unlike previous report (Brown and Caldwell, 2002) that calculated MIDR only in the offshore section – the poorest performing section of the diffuser. Note that previous analyses did not consider adding Red Valves© to the ports to enhance flow distribution along the diffuser. MIDRs in individual diffuser sections are shown in Appendix B. Of the four sections, Section 1 had the lowest MIDRs at all combined effluent flows; furthermore, the predicted MIDRs were lower than the NPDES permit requirement of 139:1. However, as shown in Table 4-1, Section 1 is an end gate section and contains only two ports. Less than 4 percent of total flow through the diffuser discharges through Section 1. Therefore we have shown that flow through Section 1 will not have a significant impact on the overall dilution provided by the diffuser. If MIDR at Section 1 becomes a concern in the future, then the City would plug the two ports in Section 1 and operate the diffuser with 174 ports. Note that without discharge through Section 1, MIDR through the other three sections individually meet initial dilution requirements.

Comparison of MIDRs during summer/fall and in winter conditions between Red Valves© retrofitted over existing ports and existing ports at various combined effluent flows and at various brine to effluent ratios are also presented in Appendix B. The analysis showed that MIDRs were lower with existing ports than with Red Valves© under all combined effluent flows, seasons, and brine to effluent ratios evaluated. At flows less than or equal to 3 mgd, flow weighted MIDRs with existing ports were lower than 139:1, whereas MIDR was greater than 139:1 with Red Valves©. Red Valves© allowed diffuser operation with all ports open, whereas only 41 percent of existing ports could be opened at combined effluent flows less than or equal to 3 mgd. Based on this analysis, and other benefits discussed in Section 4.1, we recommend installation of Red Valves© on existing diffuser ports.

5. RESULTS

5.1 Outfall Hydraulics

Outfall hydraulics for various flow rates and effective Red Valve© diameters (Table 4-2) were evaluated using the DIFF$$ model with the results presented in Table 5-1.

Table 5-1. Outfall Hydraulics

Effluent Flow Rate (mgd)	Effective Diameter when 100 Percent Ports are Open (inches)	Port Velocity[1] (ft/s)	Total Head Loss for all Ports (feet)
3	1	4.9	3.1
5	1	8.1	3.7
10	2	4.1	3.1
15	Port diameters from Table4-1	3.7	3.2
20	Port diameters from Table 4-1	4.6	3.6
50	Port diameters from Table 4-1	10.7	8.3
80	Port diameters from Table 4-1	16.9	17.0
90	Port diameters from Table 4-1	19.0	20.8
100	Port diameters from Table 4-1	21.1	25.0

Notes:

[1] Average velocity

5.2 Factors Controlling Dilution Factor

The addition of brine to the effluent had a substantial effect on the MIDR achieved at the diffuser (Figures 5-1a and 5-1b). With no brine discharge, MIDR ranged from 400:1 to 600:1 at flow rates ranging from 4 to 15 mgd. However, as the ratio of brine to effluent increased, MIDR dropped dramatically. Depending on the capacity of the desalination facility, MIDR ranged from 150:1 to 250:1 at ratios of approximately one part brine to one part effluent. A minimum effluent flow of 2.1 mgd was required to maintain a MIDR of 139:1 with a 2.5 mgd desalination plant for summer/fall conditions. Similarly, for 3.5 and 4.5 mgd desalination plants, the minimum effluent flow required was 4.1 mgd and 5.3 mgd respectively for summer/fall conditions. These results indicate that brine storage will be necessary when flows drop below the minimum levels. Note that higher jet velocities at higher wastewater effluent flow rates resulted in higher MIDRs.

Winter conditions resulted in lower MIDRs than summer/fall conditions at effluent flows greater than 4 mgd. When effluent flows were less than 4 mgd, the MIDRs were nearly equal for summer/fall and winter conditions. The minimum effluent flows required to meet the MIDR of 139:1 were 2.1, 4.8, and 6.3 mgd for 2.5, 3.5 and 4.5 mgd desalination plants respectively during winter conditions. See Appendix A for a summary of MIDR calculations.

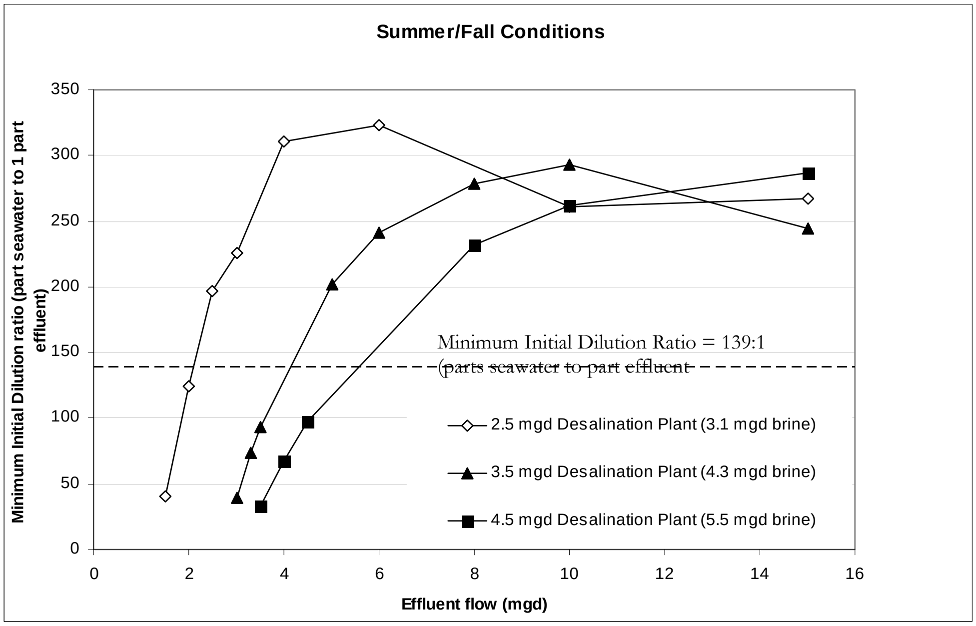


Figure 5-1(a). Dilution Factors Under Three Desalination Alternatives as a Function of Increasing Wastewater Effluent Flow Rates during Summer/fall Conditions

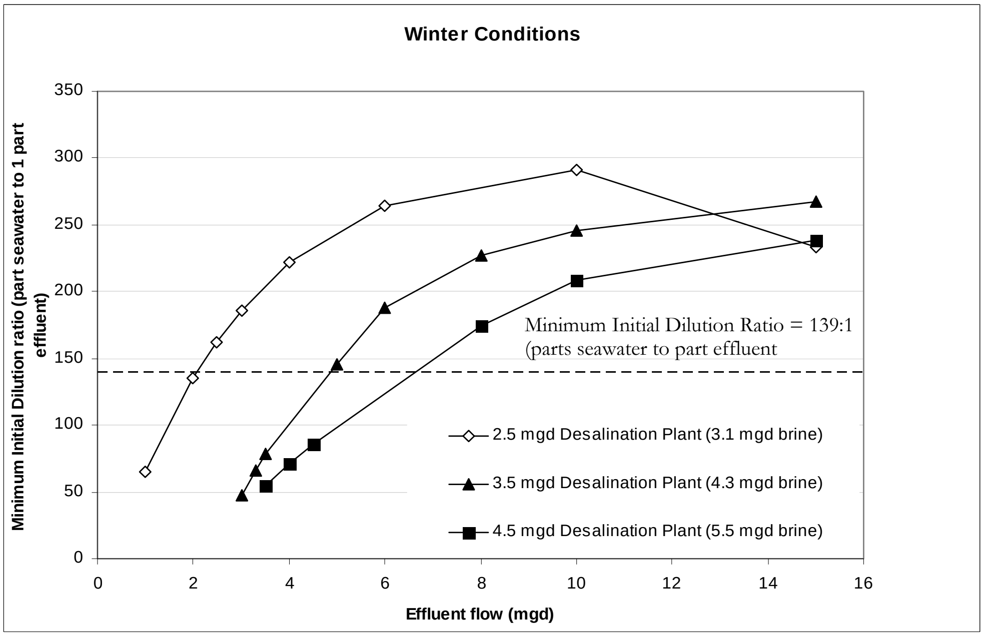


Figure 5-1(b). Dilution Factors under Three Desalination Alternatives as a Function of Increasing Wastewater Effluent Flow Rates during Winter Conditions

5.3 Acceptable Brine Flows

Based on extensive hydraulic and dilution modeling, a relationship between effluent flow and maximum brine flow that can be added to effluent to meet a MIDR of 139:1 or greater was developed (Figure 5-2). A relationship was developed for both winter (cool combined effluent and isothermal conditions in receiving waters) and summer/fall (warmer combined effluent and thermal stratification in receiving waters) conditions. The best-fit, quadratic curves of maximum brine flow (Q_b) as a function of effluent flow (Q_e) are:

$$Q_b \text{ (summer/fall)} = -0.023\ Q_e^2 + 1.025\ Q_e + 0.172$$

$$Q_b \text{ (winter)} = -0.028\ Q_e^2 + 0.972\ Q_e + 0.099$$

The magnitude of maximum brine flow is roughly equivalent to the effluent flow. Slightly higher brine flows are permitted during summer/fall conditions versus winter conditions because a higher MIDR is achieved in the summer. Combined effluent is warmer in the summer/fall (18°C) compared to winter (15°C). Warmer, more buoyant water enhances dilution upon discharge even though the ambient water column is stratified. Typically, a stratified water column will inhibit dilution. See Appendix B for summary of acceptable brine flow calculation. Note that the focus of this section was to determine the acceptable brine flow to achieve MIDR. Subsequently, an additional criterion, discharged effluent/brine mixture with a salinity never exceeding for the average ambient salinity of the receiving waters, that is, salinity slightly less than ambient--33.4 ppt (see Section 3.2 above) was added. Based on a review of data summaries presented in Appendix A (e.g., on p. A-2, Summer/Fall Scenario 2.5 mgd of desalted water produced, salinity of predicted 34.1-ppt salinity with an initial dilution of 196:1) , the discharge salinity could slightly exceed 33.4 ppt with the storage identified herein. However, with slightly greater storage and slightly lower brine discharge flow rates, this situation would not occur.

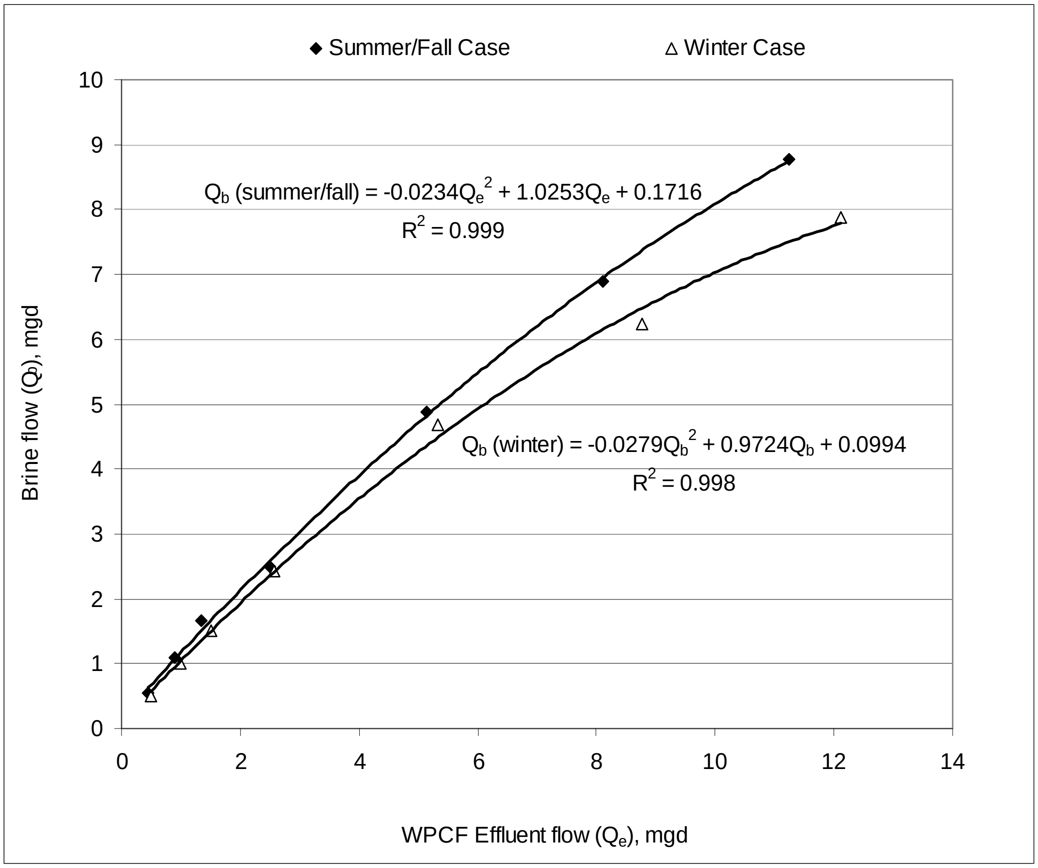


Figure 5-2. Maximum Brine Flow as a Function of Wastewater Effluent Flow to Maintain a Dilution Factor of 139
Line through Points Shows Best-fit Second Order Quadratic

5.4 Brine Storage Requirements

Brine storage will be required when actual brine flow exceeds the maximum brine flow permitted to meet a MIDR of 139:1. This condition will occur when effluent flows from the WPCF fall below the minimum effluent flows established in Section 5.2. We determined that minimum effluent flows of 2.1, 4.1 and 5.3 mgd were required to maintain a MIDR of 139:1 for 2.5, 3.5 and 4.5 mgd desalination plants respectively in summer/fall conditions. During winter conditions, the minimum effluent flows required to meet a MIDR of 139:1 were 2.1, 4.8, and 6.3 mgd for 2.5, 3.5 and 4.5 mgd desalination plants, respectively.

The amount of brine that can be discharged is proportional to the effluent flow; therefore, the worst case scenario from a brine disposal perspective is when daily average effluent flows are the lowest. The storage requirement to equalize brine flow to maintain a MIDR of 139:1 was estimated using WPCF effluent flow developed for a 24-hour period from 2003 data (see Section 3.3). Results are shown in Figures 5-3a through 5-3c for summer/fall conditions.

Based on this analysis, brine storage would be required during the low effluent flow periods of 1:00 a.m. to 7:00 a.m. Equalization basin capacity will range from 0.6 mgd for the 2.5 mgd plant to 2.0 mgd for the largest desalination plant capacity of 4.5 mgd. These calculations include an additional 20 percent safety factor to account for possible reductions in WPCF flows due to conservation measures, drought-time water use restrictions, and lower rates of infiltration and inflow. Infiltration and inflow are non-wastewater flows that enter sewer through pipe defects and leaky manholes, increasing total flow to the WPCF. During winter conditions (figures not shown), brine would need to be stored from 1:00 a.m. to 7:00 a.m., similar to summer/fall conditions. The equalization basin capacity was similar to that required during summer/fall conditions. See Appendix C for a summary of brine storage requirement calculations. Note that the shaded areas in the figures below show additional effluent flow available for brine dilution. The amount of additional effluent available for dilution more than exceeds the amount necessary to ensure that the discharged salinity never exceeds average ambient receiving water salinity.

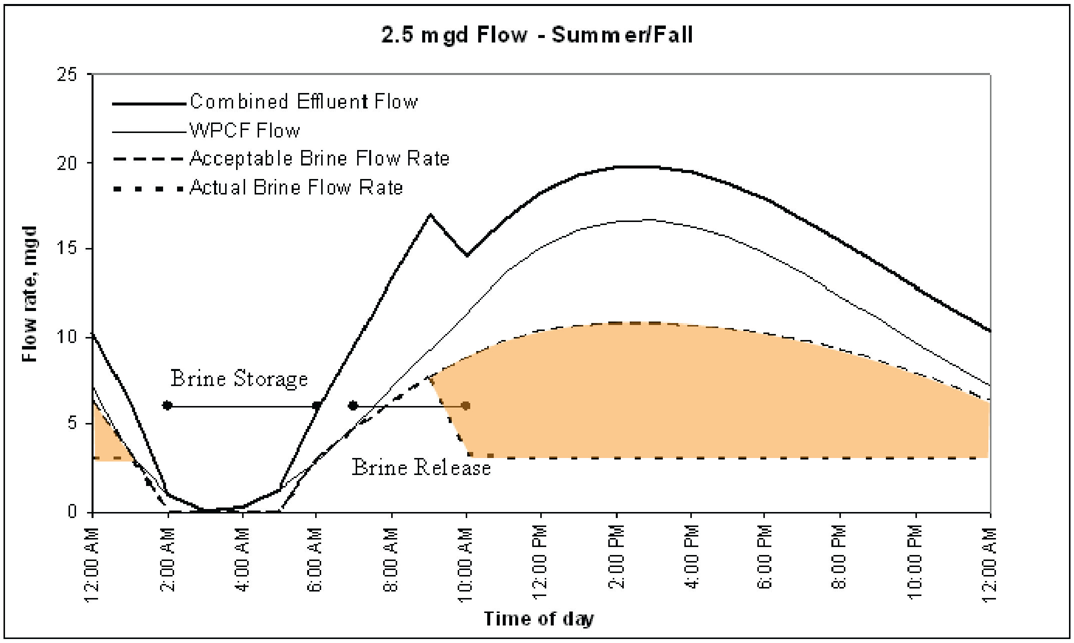


Figure 5-3(a). Brine Storage Requirements under Desalination Plant Production Flow of 2.5 mgd

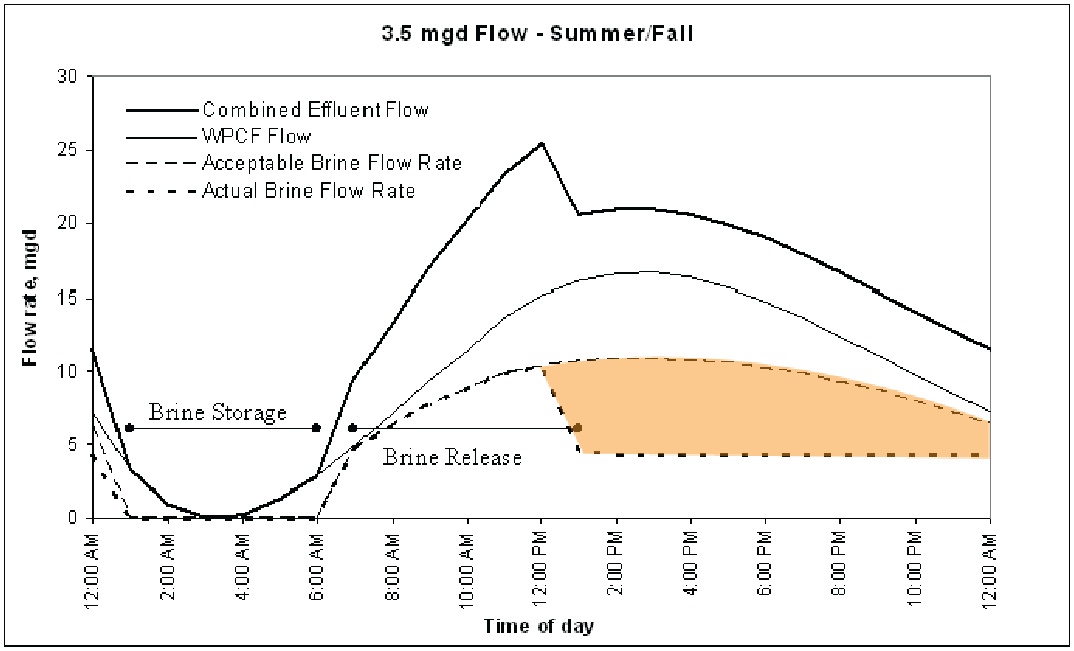


Figure 5-3(b). Brine Storage Requirements under Desalination Plant Production flow of 3.5 mgd

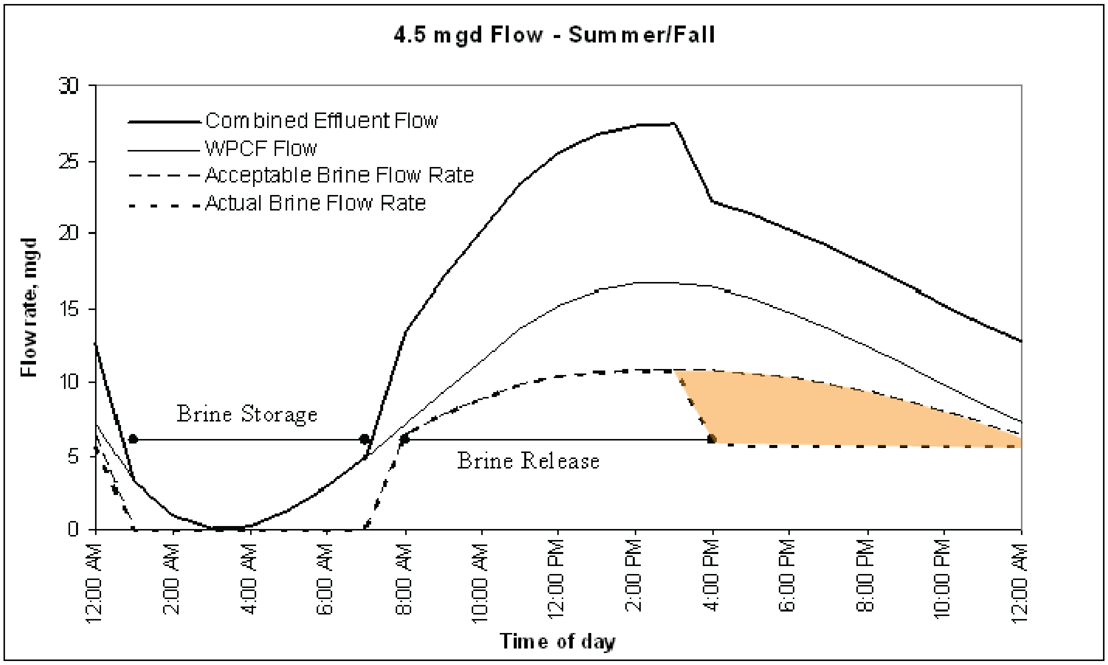


Figure 5-3(c). Brine Storage Requirements under Desalination Plant Production Flow of 4.5 mgd

5.5 Trace Metal and Other Ocean Plan Table B Constituent Concentrations

The concentration of trace metals in the brine can be estimated by multiplying ocean levels by a concentration factor of 1.82. This factor is based on an RO membrane rejection rate of 55 percent. As shown in Table 5-2, trace metal concentrations in brine are expected to be less than the effluent trace metal concentrations except arsenic. Therefore, the addition of brine to the effluent will result in lower concentrations of trace metals discharged to the ocean in the effluent flow. The concentration of the composite effluent will remain far below the effluent limits. For other Ocean Plan Table B constituents, the Ocean Plan allows one to assume that the concentrations are zero. Hence, it is easier to achieve that required initial dilution. The existing effluent discharge complies with dilution requirements for all Table B constituents. With brine added to the effluent, the discharge would continue to meet Ocean Plan requirements.

Table 5-2. Trace Metal Concentrations Analysis

Parameter	Effluent[1] (μg/L)	Brine[2] (μg/L)	Effluent limit[3] (μg/L)
Arsenic	1.6	5.5	703
Copper	12	3.7	140
Mercury	0.016	0.0009	5.53
Silver	<4	0.3	98
Zinc	33	14.6	1688

Notes:

[1] Effluent concentration based on highest reported value or, if never detected, on the highest reported detection limit for 2007 and 2008.

[2]Trace metal concentration in brine based on background seawater concentrations cited in the California State Water Resources Control Board's California Ocean Plan (2005) multiplied by a concentration factor of 1.82.

[3]Reported effluent limit is 6-month median reported in the City's NPDES permit (CA 0048194).

5.6 Locations for Brine Addition to Effluent

We identified two locations were brine can be added to the effluent. They include:

- Tunnel portal box located roughly 40 feet southeast of the WPCF administration building
- Tunnel gate box located near the beach just south of West Cliff Drive.

In both cases above, brine must be added in a way that promotes complete mixing of brine and effluent to avoid two-phase, stratified flow. Two-phase flow is the phenomena in which a distinct layer of low-density freshwater (effluent) flows on top of heavier more saline water (brine). If this was to occur, heavier brine could potentially fill the outfall and limit the flow out of the diffusers and the predicted dilution. To ensure adequate mixing of the brine and the effluent, the brine will need to be discharged into the portal or gate box using a nominal 12-inch diameter nozzle to promote rapid and complete mixing. We conducted a hydraulic analysis to evaluate headloss when brine is added at the above two locations and at two different effluent flow rates. Results are presented in Table 5-3.

Table 5-3. Expected Headloss at the Two locations where Brine can be Added to the Effluent

Case	Description	Effluent Flow Rate (mgd)	Brine Flow rate (mgd)	Combined Effluent Flow Rate (mgd)	Total Headloss [1,2] (feet)
1	No brine introduction, effluent flow rate is maximum design capacity	105	0.0	105	40.4
2	5.5 mgd brine introduction at tunnel portal box, effluent flow rate is maximum design capacity	105	5.5	110.5	44.2
3	5.5 mgd brine introduction at tunnel gate box, effluent flow rate is maximum design capacity	105	5.5	110.5	43.5
4	No brine introduction, effluent flow rate is representative of peak wet-weather flow	85	0.0	85	27.4
5	5.5 mgd brine introduction at tunnel portal box, effluent flow rate is representative of peak wet-weather flow	85	5.5	90.5	30.4
6	5.5 mgd brine introduction at tunnel gate box, effluent flow rate is representative of peak wet-weather flow	85	5.5	90.5	29.9

Notes:

[1]Following loss coefficients were assumed in calculations:

sluice gate entry loss is 0.5, sluice gate exit loss is 0.6, and tunnel portal box entry loss is 0.5.

Inflow and outflow were assumed to be equal at any section.

Pipe friction factor was assumed to be 0.014.

[2]Total Headloss was the sum of headlosses across the tunnel portal box section, tunnel section, tunnel gate box section and outfall section.

If brine is added to the tunnel portal box, modification in the City's effluent monitoring may be required since they currently monitor effluent through a sampling port just upstream of the box. Additionally, combining brine with effluent would expose a number of structures to high salinity water. As a result, the structures would be more susceptible to corrosion. Of particular concern are the 36-inch and 72-inch sluice gates in the tunnel gate box. Therefore conceptually, brine addition is recommended downstream of the sluice gates through the pre-cast concrete slab (see drawing in Appendix D). A 12-inch diameter nozzle would inject brine into the WPCF effluent at sufficient velocities to ensure complete mixing at all flows. This approach should receive more detailed review during facilities design.

6. CONCLUSIONS

We draw the following conclusions from the analysis presented in this report:

- The addition of brine to the effluent had a substantial effect on MIDR achieved at the diffuser. With no brine addition, the MIDR ranged from 400:1 to 600:1 at flow rates ranging from 4 to 15 mgd. However, as the relative amount of brine to effluent increased, the MIDR dropped dramatically. The analysis indicated that brine storage was necessary to maintain a MIDR of 139:1 or greater when effluent flows dropped below 2.1, 4.8, and 6.3 mgd for 2.5, 3.5 and 4.5 mgd desalination plants respectively in the winter. Minimum effluent flows were slightly higher during summer/fall conditions.
- Based on extensive hydraulic and dilution modeling, a relationship between effluent flow and maximum brine flow that can be added to effluent for meeting a MIDR of 139:1 or greater was developed. The best-fit curves were quadratic representing maximum brine flow (Q_b) as a function of effluent flow. Slightly higher brine flows were permitted during summer/fall conditions versus winter conditions because warmer, more buoyant water in the summer/fall enhanced dilution even though the stratified ambient water column inhibited dilution.
- Brine storage was required during the low effluent flow periods of 1:00AM to 7:00AM. Equalization basin capacity for brine storage ranged from 0.6 mgd for 2.5 mgd plant to 2.0 mgd for the largest desalination plant capacity of 4.5 mgd. Brine storage volumes include an additional 20 percent safety factor to account for reduction in WPCF flows due to water conservation measures, drought-time water use restrictions and lower rates of infiltration and inflow.
- With properly sized brine storage and appropriate discharge controls, the combined effluent/brine discharge will:
    - Maintain a salinity level that will always be equal to or less than for the average ambient salinity of the receiving waters.
    - Always be buoyant so that it never forms an effluent field spreading across the ocean floor.
    - Always achieves the minimum initial dilution as now required for the current effluent only discharge.
- The amount of additional effluent available for dilution more than exceeds the amount necessary to ensure that the discharged salinity never exceeds average ambient receiving water salinity.
- The addition of brine to effluent diluted the concentrations of trace metals in the effluent and the concentrations of most trace metals (copper, mercury, silver and zinc) in the combined effluent remained below the trace metal effluent limits specified in the NPDES permit.
- We identified two locations where brine can be added to the effluent. They include tunnel portal box located roughly 40 feet southeast of the WPCF administration building and tunnel gate box located near the beach just south of West Cliff Drive at Mitchell's Cove.

7. RECOMMENDATIONS

We provide the following recommendations from the analysis presented in this report:

- The analysis assumed brine recovery of 45 percent (55 percent rejection) from reverse osmosis. However actual recoveries may vary. It is recommended that the City update the analysis based on actual brine recovery when data becomes available and size brine storage accordingly to achieve both MIDR and targeted end-of-pipe salinity concentrations.
- The analysis assumed a 20 percent safety factor in brine storage volume to account for conservation measures, drought-time water use restrictions and lower rates of infiltration and inflow. It is recommended that the City update this analysis with most recent WPCF flows during drought conditions when it becomes available.
- Combining brine with effluent will expose a number of structures to high salinity water and as a result, the structures will be more susceptible to corrosion. Of particular concern are the 36-inch and 72-inch sluice gates in the tunnel gate box. Therefore conceptually, brine addition is recommended downstream of the sluice gates through the precast concrete slab. A 12-inch diameter nozzle will inject brine into the WPCF effluent at sufficient velocities to ensure complete mixing at all flows. It is recommended that this approach receive more detailed review during facilities design.

8. REFERENCES

Brown and Caldwell (2002) Soquel Creek Water District Alternative Water Supply Project – Brine Disposal. Letter report submitted to the City of Santa Cruz in February 2002.

Brown and Caldwell (2004) Soquel Creek Water District Alternative Water Supply Project – Brine Storage Requirements for 2.5 mgd and 3.5 mgd Desalination Plant. Letter report submitted to the City of Santa Cruz in June 2004.

Brown and Caldwell (1978) Oceanographic Predesign Phase Report – Santa Cruz Wastewater Facilities Planning Study. August 1978.

Frick, W.E., Roberts, P.J.W., Davis, L.R., Keyes, J., Baumgartner, D.J. and George, K.P (2001) Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes). Prepared for Environmental Research Division, U.S. Environmental Protection Agency, Athens, Georgia.

California State Water Resources Control Board (2005) California Ocean Plan – Water Quality Control Plan Ocean Waters of California. Sacramento, CA.

APPENDIX A: BRINE DISCHARGE DILUTIONS AT VARIOUS EFFLUENT FLOWS

Summer/Fall Scenario

Parameter	INPUT
Ambient Temp (C)[1]	11.98
Ambient Density (g/ml)[1]	1.02567
Desal Intake Temp (C)[2]	12.8
Desal Intake Salinity (ppt)[2]	33.78
WWTP Temp (C)[3]	23
WWTP TDS (ppt)[3]	0.5

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
0	0.00	0	0	4	0.5	23	4.00	1.00	1.50	0.50	23.00	0.99798	0.02700	557
0	0.00	0	0	6	0.5	23	6.00	1.00	2.14	0.50	23.00	0.99798	0.02700	499
0	0.00	0	0	10	0.5	23	10.00	2.00	4.27	0.50	23.00	0.99798	0.02700	368
0	0.00	0	0	15	0.5	23	15.00	2.00	4.04	0.50	23.00	0.99798	0.02700	385

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
2.5	3.06	61.42	12.8	1.5	0.5	23	4.56	1.00	1.70	41.36	16.16	1.03060	-0.00481	41
2.5	3.06	61.42	12.8	2	0.5	23	5.06	1.00	1.80	37.32	16.83	1.02740	-0.00169	124
2.5	3.06	61.42	12.8	2.5	0.5	23	5.56	1.00	1.90	34.01	17.39	1.02468	0.00096	196
2.5	3.06	61.42	12.8	3	0.5	23	6.06	1.00	2.10	31.24	17.85	1.01975	0.00577	226
2.5	3.06	61.42	12.8	4	0.5	23	7.06	1.00	2.40	26.89	18.58	1.01636	0.00907	310
2.5	3.06	61.42	12.8	6	0.5	23	9.06	2.00	3.10	21.06	19.56	1.01200	0.01333	323
2.5	3.06	61.42	12.8	10	0.5	23	13.06	2.00	4.90	14.76	20.61	1.00749	0.01772	261
2.5	3.06	61.42	12.8	15	0.5	23	18.06	2.00	6.60	10.81	21.27	1.00476	0.02038	267

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
3.5	4.28	61.42	12.8	3	0.5	23	7.28	1.00	2.70	36.31	17.00	1.02468	0.00096	39
3.5	4.28	61.42	12.8	3.3	0.5	23	7.58	1.00	2.70	34.89	17.24	1.02468	0.00096	73
3.5	4.28	61.42	12.8	3.5	0.5	23	7.78	1.00	2.70	34.01	17.39	1.02468	0.00096	94
3.5	4.28	61.42	12.8	5	0.5	23	9.28	2.00	3.80	28.59	18.30	1.02195	0.00363	202
3.5	4.28	61.42	12.8	6	0.5	23	10.28	2.00	3.70	25.86	18.75	1.01975	0.00577	241
3.5	4.28	61.42	12.8	8	0.5	23	12.28	2.00	4.40	21.73	19.45	1.01636	0.00907	278
3.5	4.28	61.42	12.8	10	0.5	23	14.28	2.00	5.20	18.75	19.94	1.01389	0.01149	293
3.5	4.28	61.42	12.8	15	0.5	23	19.28	2.00	6.90	14.02	20.74	1.00988	0.01539	244

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
4.5	5.50	61.42	12.8	3.5	0.5	23	9.00	2.00	3.40	37.73	16.77	1.02468	0.00096	33
4.5	5.50	61.42	12.8	4	0.5	23	9.50	2.00	3.40	35.77	17.09	1.02468	0.00096	67
4.5	5.50	61.42	12.8	4.5	0.5	23	10.00	2.00	3.40	34.01	17.39	1.02468	0.00096	98
4.5	5.50	61.42	12.8	8	0.5	23	13.50	2.00	4.70	25.32	18.84	1.02118	0.00438	232
4.5	5.50	61.42	12.8	10	0.5	23	15.50	2.00	5.40	22.12	19.38	1.01848	0.00701	263
4.5	5.50	61.42	12.8	15	0.5	23	20.50	2.00	7.20	16.85	20.26	1.01389	0.01149	287

Winter Scenario

Parameter	INPUT
Ambient Temp (C)[1]	11.68
Ambient Density (g/ml)[1]	1.02572
Desal Intake Temp (C)[2]	12.32
Desal Intake Salinity (ppt)[2]	33.76
WWTP Temp (C)[3]	18
WWTP TDS (ppt)[3]	0.5

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
0	0.00	0	0	4	0.5	18	4.00	1.00	1.50	0.50	18.00	0.99798	0.02700	617
0	0.00	0	0	6	0.5	18	6.00	1.00	2.14	0.50	18.00	0.99798	0.02700	546
0	0.00	0	0	10	0.5	18	10.00	2.00	4.27	0.50	18.00	0.99798	0.02700	439
0	0.00	0	0	15	0.5	18	15.00	2.00	4.04	0.50	18.00	0.99798	0.02700	446

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
2.5	3.06	61.38	12.32	1	0.5	18	4.06	1.00	1.70	46.37	13.72	1.03060	-0.00481	65
2.5	3.06	61.38	12.32	2	0.5	18	5.06	1.00	1.80	37.30	14.56	1.02740	-0.00169	135
2.5	3.06	61.38	12.32	2.5	0.5	18	5.56	1.00	1.90	33.98	14.87	1.02468	0.00096	162
2.5	3.06	61.38	12.32	3	0.5	18	6.06	1.00	2.10	31.22	15.13	1.01975	0.00577	186
2.5	3.06	61.38	12.32	4	0.5	18	7.06	1.00	2.40	26.87	15.54	1.01636	0.00907	222
2.5	3.06	61.38	12.32	6	0.5	18	9.06	2.00	3.10	21.04	16.08	1.01200	0.01333	264
2.5	3.06	61.38	12.32	10	0.5	18	13.06	2.00	4.90	14.75	16.67	1.00749	0.01772	291
2.5	3.06	61.38	12.32	15	0.5	18	18.06	2.00	6.60	10.80	17.04	1.00476	0.02038	234

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
3.5	4.28	61.38	12.32	3	0.5	18	7.28	1.00	2.70	36.29	14.66	1.02468	0.00096	48
3.5	4.28	61.38	12.32	3.3	0.5	18	7.58	1.00	2.70	34.87	14.79	1.02468	0.00096	66
3.5	4.28	61.38	12.32	3.5	0.5	18	7.78	1.00	2.70	33.98	14.87	1.02468	0.00096	79
3.5	4.28	61.38	12.32	5	0.5	18	9.28	2.00	3.80	28.57	15.38	1.02195	0.00363	146
3.5	4.28	61.38	12.32	6	0.5	18	10.28	2.00	3.70	25.84	15.63	1.01975	0.00577	187
3.5	4.28	61.38	12.32	8	0.5	18	12.28	2.00	4.40	21.71	16.02	1.01636	0.00907	227
3.5	4.28	61.38	12.32	10	0.5	18	14.28	2.00	5.20	18.74	16.30	1.01389	0.01149	246
3.5	4.28	61.38	12.32	15	0.5	18	19.28	2.00	6.90	14.01	16.74	1.00988	0.01539	267

Desal Plant				WWTP			Outfall Effluent							
Prod. Water (mgd)	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Diffuser diameter inches	Flow through Diffuser section (mgd)	Salinity (ppt)	Temp (C)	Final density (g/ml)	Density ratio	Resulting MIDR (part effluent to 1 part seawater)
4.5	5.50	61.38	12.32	3.5	0.5	18	9.00	2.00	3.40	37.70	14.53	1.02468	0.00096	55
4.5	5.50	61.38	12.32	4	0.5	18	9.50	2.00	3.40	35.75	14.71	1.02468	0.00096	71
4.5	5.50	61.38	12.32	4.5	0.5	18	10.00	2.00	3.40	33.98	14.87	1.02468	0.00096	856
4.5	5.50	61.38	12.32	8	0.5	18	13.50	2.00	4.70	25.30	15.68	1.02118	0.00438	175
4.5	5.50	61.38	12.32	10	0.5	18	15.50	2.00	5.40	22.10	15.98	1.01848	0.00701	209
4.5	5.50	61.38	12.32	15	0.5	18	20.50	2.00	7.20	16.84	16.48	1.01389	0.01149	239

APPENDIX B: ACCEPTABLE BRINE FLOWS

Summer/Fall Outfall Modeling

Parameter	INPUT
Ambient Temp (C)	11.98
Ambient Density (g/ml)	1.02567
Desal Intake Temp (C)	12.8
Desal Intake Salinity (ppt)	33.78
WWTP Temp (C)	23
WWTP TDS (ppt)	0.5
Min brine flow rate (MGD)	0.6
Max brine flow rate (MGD)	5.5

Section	No. of ports	Distance between ports (ft)
1	2	1
2	50	11.9
3	64	12
4	60	11.9

Total flow (mgd)	Diffuser Section Diameter			
	1	2	3	4
1	1	1	1	1
2	1	1	1	1
3	1	1	1	1
5	1	1	1	1
10	2	2	2	2
15	4.25	3.7	2.5	2
20	4.25	3.7	2.5	2

Total Flow (mgd)	Diffuser Section 1 Flow MGD	Diffuser Section 2 Flow MGD	Diffuser Section 3 Flow MGD	Diffuser Section 4 Flow MGD	Brine Flow: WWTP Flow	Desal Plant			WWTP			Outfall Effluent					
						Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Salinity (ppt)	Temp (C)	Final density (kg/m^3)	Final density (g/mL)	Density ratio
1	0.01	0.26	0.36	0.37	1.19	0.54	61.42	12.8	0.46	0.5	23	1.00	33.60	17.46	1024.4	1.0244	0.0012
2	0.02	0.56	0.73	0.69	1.21	1.10	61.42	12.8	0.90	0.5	23	2.00	33.85	17.42	1024.6	1.0246	0.0010
3	0.03	0.85	1.09	1.00	1.23	1.65	61.42	12.8	1.35	0.5	23	3.00	34.10	17.37	1024.8	1.0248	0.0009
5	0.06	1.40	1.82	1.70	1.00	2.50	61.42	12.8	2.50	0.5	23	5.00	30.96	17.90	1022.2	1.0222	0.0034
10	0.11	2.71	3.63	3.60	0.95	4.87	61.42	12.8	5.13	0.5	23	10.00	30.18	18.03	1021.6	1.0216	0.0040
15	0.36	7.07	4.54	3.00	0.85	6.89	61.42	12.8	8.11	0.5	23	15.00	28.49	18.31	1020.3	1.0203	0.0052
20	0.49	9.6	6.01	3.90	0.78	8.76	61.42	12.8	11.24	0.5	23	20.00	27.19	18.53	1019.2	1.0192	0.0063

Total Flow (mgd)	Brine Flow: WWTP Flow	Resulting MIDR from RedValves© retrofitted over existing ports				
		Diffuser Section 1	Diffuser Section 2	Diffuser Section 3	Diffuser Section 4	Flow weighted Average MIDR (part effluent to 1 part seawater)
1	1.19	77.94	142.7	141.6	140.7	140.9
2	1.21	67.17	140.6	141.4	141.7	140.5
3	1.23	69.58	162.2	162.5	160.8	160.9
5	1	99.9	230.7	231.1	230.5	229.2
10	0.95	68.98	184.1	182.2	179.2	180.4
15	0.85	35.64	141.9	188.8	218.4	169.0
20	0.78	34.39	141.8	189.8	220.8	169.0
80	0.5	30.1	131.1	177.7	209.4	156.5

Total Flow (mgd)	Brine Flow: WWTP Flow	Resulting MIDR from existing ports				
		Diffuser Section 1	Diffuser Section 2	Diffuser Section 3	Diffuser Section 4	Flow Weighted Average MIDR
1	1.19	61.5	119.8	116	121.4	118.0[1]
2	1.21	30	82	90	96.4	84.6[1]
3	1.23	24.1	64	74	82	67.9[1]
5	1	65.7	182.1	204.5	222.1	200.4
10	0.95	37.25	140.7	183.9	211.8	167.0
15	Same dilution as RedValves©. See Table above for MIDR.					
20	Same dilution as RedValves©. See Table above for MIDR.					
80	Same dilution as RedValves©. See Table above for MIDR.					

[1] *MIDR based on 41 percent of existing ports open.*

Winter Outfall Modeling

Parameter	INPUT
Ambient Temp (C)[1]	11.68
Ambient Density (g/ml)[1]	1.02572
Desal Intake Temp (C)[2]	12.32
Desal Intake Salinity (ppt)[2]	33.76
WWTP Temp (C)[3]	18
WWTP TDS (ppt)[3]	0.5

Total	Diffuser	Diffuser	Diffuser	Diffuser	Brine	Desal Plant			WWTP			Outfall Effluent					
Flow (mgd)	Section 1 Flow MGD	Section 2 Flow MGD	Section 3 Flow MGD	Section 4 Flow MGD	Flow: WWTP Flow	Brine Flow (mgd)	Brine Salinity (ppt)	Brine Temp (C)	Flow (mgd)	TDS (ppt)	Temp (C)	Flow (mgd)	Salinity (ppt)	Temp (C)	Final density (kg/m^3)	Final density (g/mL)	Density ratio
1	0.01	0.26	0.36	0.37	1.05	0.51	61.38	12.32	0.49	0.5	18	1.00	31.68	15.09	1024.5	1.0245	0.0011
2	0.02	0.56	0.73	0.69	1.03	1.01	61.38	12.32	0.99	0.5	18	2.00	31.39	15.12	1024.7	1.0247	0.0009
3	0.03	0.85	1.09	1.00	1.00	1.50	61.38	12.32	1.50	0.5	18	3.00	30.94	15.16	1024.8	1.0248	0.0009
5	0.06	1.40	1.82	1.70	0.95	2.44	61.38	12.32	2.56	0.5	18	5.00	30.16	15.23	1022.2	1.0222	0.0034
10	0.11	2.71	3.62	3.6	0.88	4.68	61.38	12.32	5.32	0.5	18	10.00	29.00	15.34	1021.3	1.0213	0.0043
15	0.35	6.96	4.59	3.1	0.71	6.23	61.38	12.32	8.77	0.5	18	15.00	25.78	15.64	1018.8	1.0188	0.0070
20	0.49	9.51	6.03	4.0	0.65	7.88	61.38	12.32	12.12	0.5	18	20.00	24.48	15.76	1017.8	1.0178	0.0077

Total Flow (mgd)	Brine Flow: WWTP Flow	**Resulting MIDR from RedValves® retrofitted over existing ports**				
		Diffuser Section 1	Diffuser Section 2	Diffuser Section 3	Diffuser Section 4	Flow weighted Average MIDR (part effluent to 1 part seawater)
1	1.05	51.3	146.2	143.5	142.7	143.0
2	1.03	45.31	144	144.1	144.1	143.1
3	1	46.2	157.6	157.7	157.1	156.4
5	0.95	85.9	183.2	184.1	183.6	182.5
10	0.88	63.39	144.7	143.4	140.8	141.9
15	0.71	48.56	142.2	178.7	199.5	163.0
20	0.65	43.8	140.6	178.5	200.6	161.6
80	0.20	25	135.2	166.3	235.9	163.5

Total Flow (mgd)	Brine Flow: WWTP Flow	**Resulting MIDR from existing ports**				
		Diffuser Section 1	Diffuser Section 2	Diffuser Section 3	Diffuser Section 4	Flow Weighted Average MIDR
1	1.05	64.2	122	120.3	125.1	120.8[1]
2	1.03	42.5	107	119	120.6	109.8[1]
3	1	36.8	107.2	123	124	109.0[1]
5	0.95	56.4	142	146.3	151.2	145.4
10	0.88	50	122.3	152	163	138.8
15	Same dilution as RedValves©. See Table above for MIDR.					
20	Same dilution as RedValves©. See Table above for MIDR.					
80	Same dilution as RedValves©. See Table above for MIDR					

[1] *MIDR based on 41 percent of existing ports open.*

APPENDIX C: BRINE STORAGE REQUIREMENTS

	2.5 mgd Desalination Plant, Summer/Fall												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	Brine Flow After Releasing Stored Brine (mgd)	Actual Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00 AM	7.20	6.34	13.54	0.88	3.10	0.43	0	0	0.13	0	3.10	10.30	0.43
1:00 AM	3.27	3.27	6.54	1.00	3.10	0.95	0	0	0.01	0	3.10	6.37	0.95
2:00 AM	1.00	0.00	1.00	0.00	3.10	3.10	0.13	0.13	0	0.13	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.10	0.00	3.10	32.16	0.13	0.26	0	0.26	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.27	0.00	3.10	11.28	0.13	0.39	0	0.39	0.00	0.27	0.00
5:00 AM	1.28	0.00	1.28	0.00	3.10	2.42	0.13	0.52	0	0.52	0.00	1.28	0.00
6:00 AM	2.88	2.93	5.82	1.02	3.10	1.07	0.01	0.52	0	0.52	2.93	5.82	1.02
7:00 AM	4.88	4.62	9.49	0.95	3.10	0.64	0	0	0.06	0.46	4.62	9.49	0.95
8:00 AM	7.08	6.26	13.33	0.88	3.10	0.44	0	0	0.13	0.33	6.26	13.33	0.88
9:00 AM	9.32	7.70	17.02	0.83	3.10	0.33	0	0	0.19	0.14	7.70	17.02	0.83
10:00 AM	11.40	8.82	20.22	0.77	3.10	0.27	0	0	0.24	0.00	3.24	14.64	0.28
11:00 AM	13.59	9.78	23.38	0.72	3.10	0.23	0	0	0.28	0	3.10	16.69	0.23
12:00 PM	15.16	10.34	25.49	0.68	3.10	0.20	0	0	0.30	0	3.10	18.26	0.20
1:00 PM	16.15	10.63	26.78	0.66	3.10	0.19	0	0	0.31	0	3.10	19.25	0.19
2:00 PM	16.64	10.75	27.39	0.65	3.10	0.19	0	0	0.32	0	3.10	19.74	0.19
3:00 PM	16.68	10.76	27.44	0.65	3.10	0.19	0	0	0.32	0	3.10	19.78	0.19
4:00 PM	16.34	10.68	27.02	0.65	3.10	0.19	0	0	0.32	0	3.10	19.44	0.19
5:00 PM	15.68	10.49	26.17	0.67	3.10	0.20	0	0	0.31	0	3.10	18.78	0.20
6:00 PM	14.76	10.21	24.96	0.69	3.10	0.21	0	0	0.30	0	3.10	17.86	0.21

	2.5 mgd Desalination Plant, Summer/Fall												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	Brine Flow After Releasing Stored Brine (mgd)	Actual Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
7:00 PM	13.64	9.80	23.44	0.72	3.10	0.23	0	0	0.28	0	3.10	16.74	0.23
8:00 PM	12.38	9.28	21.66	0.75	3.10	0.25	0	0	0.26	0	3.10	15.48	0.25
9:00 PM	11.05	8.64	19.69	0.78	3.10	0.28	0	0	0.23	0	3.10	14.15	0.28
10:00 PM	9.71	7.92	17.63	0.82	3.10	0.32	0	0	0.20	0	3.10	12.81	0.32
11:00 PM	8.42	7.14	15.56	0.85	3.10	0.37	0	0	0.17	0	3.10	11.52	0.37
12:00 AM	7.23	6.36	13.60	0.88	3.10	0.43	0	0	0.14	0	3.10	10.33	0.43
Average daily flow	**9.44**												
Maximum Storage Required (mg)								**0.52**					

	3.5 mgd Desalination Plant (Summer/Fall)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00 AM	7.20	6.34	13.54	0.88	4.30	0.60	0	0	0.08	0	4.30	11.50	0.60
1:00 AM	3.27	0.00	3.27	0.00	4.30	1.32	0.18	0.18	0.00	0.18	0.00	3.27	0.00
2:00 AM	1.00	0.00	1.00	0.00	4.30	4.30	0.18	0.36	0	0.36	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.10	0.00	4.30	44.61	0.18	0.54	0	0.54	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.27	0.00	4.30	15.65	0.18	0.72	0	0.72	0.00	0.27	0.00
5:00 AM	1.28	0.00	1.28	0.00	4.30	3.36	0.18	0.90	0	0.90	0.00	1.28	0.00
6:00 AM	2.88	0.00	2.88	0.00	4.30	1.49	0.18	1.08	0	1.08	0.00	2.88	0.00
7:00 AM	4.88	4.62	9.49	0.95	4.30	0.88	0	0	0.01	1.06	4.62	9.49	0.95

	3.5 mgd Desalination Plant (Summer/Fall)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
8:00 AM	7.08	6.26	13.33	0.88	4.30	0.61	0	0	0.08	0.98	6.26	13.33	0.88
9:00 AM	9.32	7.70	17.02	0.83	4.30	0.46	0	0	0.14	0.84	7.70	17.02	0.83
10:00 AM	11.40	8.82	20.22	0.77	4.30	0.38	0	0	0.19	0.65	8.82	20.22	0.77
11:00 AM	13.59	9.78	23.38	0.72	4.30	0.32	0	0	0.23	0.42	9.78	23.38	0.72
12:00 PM	15.16	10.34	25.49	0.68	4.30	0.28	0	0	0.25	0.17	10.34	25.49	0.68
1:00 PM	16.15	10.63	26.78	0.66	4.30	0.27	0	0	0.26	0	4.47	20.62	0.28
2:00 PM	16.64	10.75	27.39	0.65	4.30	0.26	0	0	0.27	0	4.30	20.94	0.26
3:00 PM	16.68	10.76	27.44	0.65	4.30	0.26	0	0	0.27	0	4.30	20.98	0.26
4:00 PM	16.34	10.68	27.02	0.65	4.30	0.26	0	0	0.27	0	4.30	20.64	0.26
5:00 PM	15.68	10.49	26.17	0.67	4.30	0.27	0	0	0.26	0	4.30	19.98	0.27

Time	3.5 mgd Desalination Plant (Summer/Fall)												
	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
6:00 PM	14.76	10.21	24.96	0.69	4.30	0.29	0	0	0.25	0	4.30	19.06	0.29
7:00 PM	13.64	9.80	23.44	0.72	4.30	0.32	0	0	0.23	0	4.30	17.94	0.32
8:00 PM	12.38	9.28	21.66	0.75	4.30	0.35	0	0	0.21	0	4.30	16.68	0.35
9:00 PM	11.05	8.64	19.69	0.78	4.30	0.39	0	0	0.18	0	4.30	15.35	0.39
10:00 PM	9.71	7.92	17.63	0.82	4.30	0.44	0	0	0.15	0	4.30	14.01	0.44
11:00 PM	8.42	7.14	15.56	0.85	4.30	0.51	0	0	0.12	0	4.30	12.72	0.51
12:00 AM	7.23	6.36	13.60	0.88	4.30	0.59	0	0	0.09	0	4.30	11.53	0.59
Average daily flow	**9.44**												
Maximum Storage Required (million gallons)								**1.08**					

	4.5 mgd Desalination Plant (Summer/Fall)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00 AM	7.20	6.34	13.54	0.88	5.50	0.76	0	0	0.03	0	5.50	12.70	0.76
1:00 AM	3.27	0.00	0.00	0.00	5.50	1.68	0.23	0.23	0.0	0.23	0.00	3.27	0.00
2:00 AM	1.00	0.00	0.00	0.00	5.50	5.50	0.23	0.46	0	0.46	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.00	0.00	5.50	57.05	0.23	0.69	0	0.69	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.00	0.00	5.50	20.01	0.23	0.92	0	0.92	0.00	0.27	0.00
5:00 AM	1.28	0.00	0.00	0.00	5.50	4.29	0.23	1.15	0	1.15	0.00	1.28	0.00
6:00 AM	2.88	0.00	0.00	0.00	5.50	1.91	0.23	1.38	0	1.38	0.00	2.88	0.00
7:00 AM	4.88	0.00	0.00	0.00	5.50	1.13	0.23	1.60	0	1.60	0.00	4.88	0.00
8:00 AM	7.08	6.26	13.33	0.88	5.50	0.78	0	0	0.03	1.57	6.26	13.33	0.88
9:00 AM	9.32	7.70	17.02	0.83	5.50	0.59	0	0	0.09	1.48	7.70	17.02	0.83
10:00 AM	11.40	8.82	20.22	0.77	5.50	0.48	0	0	0.14	1.34	8.82	20.22	0.77
11:00 AM	13.59	9.78	23.38	0.72	5.50	0.40	0	0	0.18	1.16	9.78	23.38	0.72
12:00 PM	15.16	10.34	25.49	0.68	5.50	0.36	0	0	0.20	0.96	10.34	25.49	0.68
1:00 PM	16.15	10.63	26.78	0.66	5.50	0.34	0	0	0.21	0.75	10.63	26.78	0.66

	4.5 mgd Desalination Plant (Summer/Fall)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
2:00 PM	16.64	10.75	27.39	0.65	5.50	0.33	0	0	0.22	0.53	10.75	27.39	0.65
3:00 PM	16.68	10.76	27.44	0.65	5.50	0.33	0	0	0.22	0.31	10.76	27.44	0.65
4:00 PM	16.34	10.68	27.02	0.65	5.50	0.34	0	0	0.22	0.10	5.81	22.15	0.36
5:00 PM	15.68	10.49	26.17	0.67	5.50	0.35	0	0	0.21	0	5.60	21.27	0.36
6:00 PM	14.76	10.21	24.96	0.69	5.50	0.37	0	0	0.20	0	5.50	20.26	0.37
7:00 PM	13.64	9.80	23.44	0.72	5.50	0.40	0	0	0.18	0	5.50	19.14	0.40
8:00 PM	12.38	9.28	21.66	0.75	5.50	0.44	0	0	0.16	0	5.50	17.88	0.44
9:00 PM	11.05	8.64	19.69	0.78	5.50	0.50	0	0	0.13	0	5.50	16.55	0.50
10:00 PM	9.71	7.92	17.63	0.82	5.50	0.57	0	0	0.10	0	5.50	15.21	0.57
11:00 PM	8.42	7.14	15.56	0.85	5.50	0.65	0	0	0.07	0	5.50	13.92	0.65
12:00 AM	7.23	6.36	13.60	0.88	5.50	0.76	0	0	0.04	0	5.50	12.73	0.76
Average daily flow	**9.44**												
Maximum Storage Required (million gallons)								**1.60**					

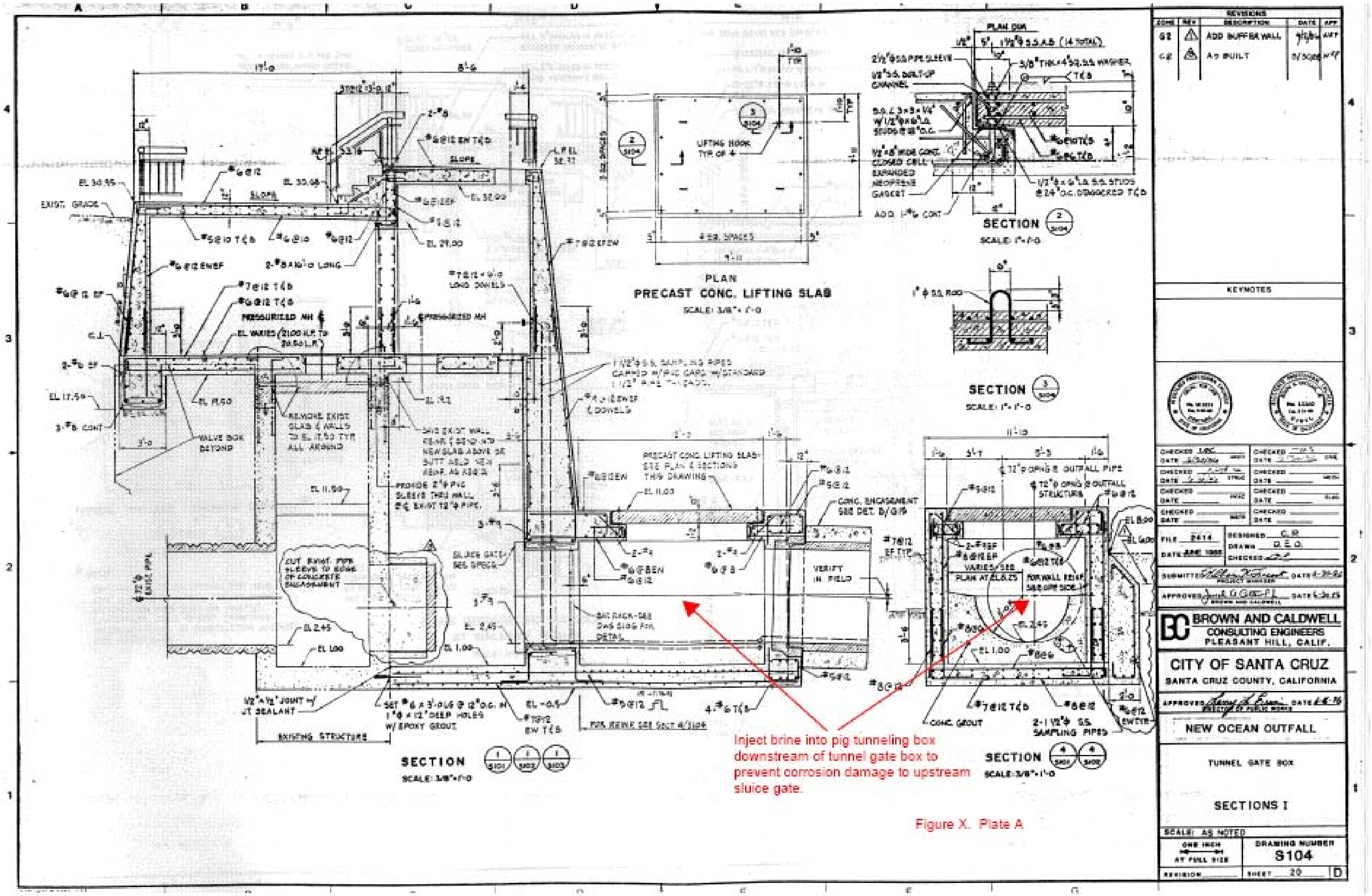
	2.5 mgd Desalination Plant (Winter)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	Brine Flow After Releasing Stored Brine (mgd)	Actual Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00AM	7.20	5.65	12.85	0.79	3.10	0.43	0	0	0.11	0	3.10	10.30	0.43
1:00 AM	3.27	2.98	6.25	0.91	3.10	0.95	0.005	0.005	0.00	0	3.10	6.37	0.95
2:00 AM	1.00	0.00	1.00	0.00	3.10	3.10	0.13	0.13	0	0.13	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.10	0.00	3.10	32.16	0.13	0.26	0	0.26	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.27	0.00	3.10	11.28	0.13	0.39	0	0.39	0.00	0.27	0.00
5:00 AM	1.28	0.00	1.28	0.00	3.10	2.42	0.13	0.52	0	0.52	0.00	1.28	0.00
6:00 AM	2.88	2.67	5.56	0.93	3.10	1.07	0.02	0.54	0	0.54	2.67	5.56	0.93
7:00 AM	4.88	4.18	9.05	0.86	3.10	0.64	0	0	0.04	0.49	4.18	9.05	0.86
8:00 AM	7.08	5.58	12.66	0.79	3.10	0.44	0	0	0.10	0.39	5.58	12.66	0.79
9:00 AM	9.32	6.74	16.06	0.72	3.10	0.33	0	0	0.15	0.24	6.74	16.06	0.72
10:00 AM	11.40	7.56	18.96	0.66	3.10	0.27	0	0	0.19	0.05	7.56	18.96	0.66
11:00 AM	13.59	8.16	21.76	0.60	3.10	0.23	0	0	0.21	0	3.15	16.75	0.23
12:00 PM	15.16	8.43	23.58	0.56	3.10	0.20	0	0	0.22	0	3.10	18.26	0.20
1:00 PM	16.15	8.53	24.68	0.53	3.10	0.19	0	0	0.23	0	3.10	19.25	0.19
2:00 PM	16.64	8.55	25.19	0.51	3.10	0.19	0	0	0.23	0	3.10	19.74	0.19

	2.5 mgd Desalination Plant (Winter)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	Brine Flow After Releasing Stored Brine (mgd)	Actual Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
3:00 PM	16.68	8.56	25.24	0.51	3.10	0.19	0	0	0.23	0	3.10	19.78	0.19
4:00 PM	16.34	8.54	24.88	0.52	3.10	0.19	0	0	0.23	0	3.10	19.44	0.19
5:00 PM	15.68	8.49	24.16	0.54	3.10	0.20	0	0	0.22	0	3.10	18.78	0.20
6:00 PM	14.76	8.37	23.13	0.57	3.10	0.21	0	0	0.22	0	3.10	17.86	0.21
7:00 PM	13.64	8.17	21.81	0.60	3.10	0.23	0	0	0.21	0	3.10	16.74	0.23
8:00 PM	12.38	7.86	20.24	0.64	3.10	0.25	0	0	0.20	0	3.10	15.48	0.25
9:00 PM	11.05	7.44	18.49	0.67	3.10	0.28	0	0	0.18	0	3.10	14.15	0.28
10:00 PM	9.71	6.91	16.62	0.71	3.10	0.32	0	0	0.16	0	3.10	12.81	0.32
11:00 PM	8.42	6.31	14.72	0.75	3.10	0.37	0	0	0.13	0	3.10	11.52	0.37
12:00AM	7.23	5.67	12.91	0.78	3.10	0.43	0	0	0.11	0	3.10	10.33	0.43
Average daily flow	**9.44**												
Maximum Storage Required (million gallons)								**0.54**					

	3.5 mgd Desalination Plant (Winter)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00 AM	7.20	5.65	12.85	0.79	4.30	0.60	0	0	0.06	0	4.30	11.50	0.60
1:00 AM	3.27	0.00	3.27	0.00	4.30	1.32	0.18	0.18	0	0.18	0.00	3.27	0.00
2:00 AM	1.00	0.00	1.00	0.00	4.30	4.30	0.18	0.36	0	0.36	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.10	0.00	4.30	44.61	0.18	0.54	0	0.54	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.27	0.00	4.30	15.65	0.18	0.72	0	0.72	0.00	0.27	0.00
5:00 AM	1.28	0.00	1.28	0.00	4.30	3.36	0.18	0.90	0	0.90	0.00	1.28	0.00
6:00 AM	2.88	0.00	2.88	0.00	4.30	1.49	0.18	1.08	0	1.08	0.00	2.88	0.00
7:00 AM	4.88	0.00	4.88	0.00	4.30	0.88	0.18	1.25	0	1.25	0.00	4.88	0.00
8:00 AM	7.08	5.58	12.66	0.79	4.30	0.61	0	0	0.05	1.20	5.58	12.66	0.79
9:00 AM	9.32	6.74	16.06	0.72	4.30	0.46	0	0	0.10	1.10	6.74	16.06	0.72
10:00 AM	11.40	7.56	18.96	0.66	4.30	0.38	0	0	0.14	0.96	7.56	18.96	0.66
11:00 AM	13.59	8.16	21.76	0.60	4.30	0.32	0	0	0.16	0.80	8.16	21.76	0.60
12:00 PM	15.16	8.43	23.58	0.56	4.30	0.28	0	0	0.17	0.63	8.43	23.58	0.56
1:00 PM	16.15	8.53	24.68	0.53	4.30	0.27	0	0	0.18	0.45	8.53	24.68	0.53
2:00 PM	16.64	8.55	25.19	0.51	4.30	0.26	0	0	0.18	0.28	8.55	25.19	0.51
3:00 PM	16.68	8.56	25.24	0.51	4.30	0.26	0	0	0.18	0.10	8.56	25.24	0.51
4:00 PM	16.34	8.54	24.88	0.52	4.30	0.26	0	0	0.18	0	4.40	20.74	0.27
5:00 PM	15.68	8.49	24.16	0.54	4.30	0.27	0	0	0.17	0	4.30	19.98	0.27
6:00 PM	14.76	8.37	23.13	0.57	4.30	0.29	0	0	0.17	0	4.30	19.06	0.29
7:00 PM	13.64	8.17	21.81	0.60	4.30	0.32	0	0	0.16	0	4.30	17.94	0.32
8:00 PM	12.38	7.86	20.24	0.64	4.30	0.35	0	0	0.15	0	4.30	16.68	0.35
9:00 PM	11.05	7.44	18.49	0.67	4.30	0.39	0	0	0.13	0	4.30	15.35	0.39
10:00 PM	9.71	6.91	16.62	0.71	4.30	0.44	0	0	0.11	0	4.30	14.01	0.44
11:00 PM	8.42	6.31	14.72	0.75	4.30	0.51	0	0	0.08	0	4.30	12.72	0.51
12:00 AM	7.23	5.67	12.91	0.78	4.30	0.59	0	0	0.06	0	4.30	11.53	0.59
Average daily flow	**9.44**												
Maximum Storage Required (million gallons)								**1.25**					

	4.5 mgd Desalination Plant (Winter)												
Time	WW Flow (mgd)	Accept. Brine Flow (mgd)	Theoretical Combined Effluent Flow (mgd)	Theoretical Brine to Effluent Ratio	Actual Brine Flow (mgd)	Actual Brine to Effluent Ratio	Required Brine Storage (mg)	Cumulative Brine Storage (S/F) (mg)	Required Brine Release (mg)	Brine Storage Tank Level	New Brine Flow After Releasing Stored Brine (mgd)	New Combined Effluent Flow (mgd)	New Brine to Effluent Ratio
Initial storage							0	0		0			
12:00 AM	7.20	5.65	12.85	0.79	5.50	0.76	0	0	0.01	0	5.50	12.70	0.76
1:00 AM	3.27	0.00	0.00	0.00	5.50	1.68	0.23	0.23	0.0	0.23	0.00	3.27	0.00
2:00 AM	1.00	0.00	0.00	0.00	5.50	5.50	0.23	0.46	0	0.46	0.00	1.00	0.00
3:00 AM	0.10	0.00	0.00	0.00	5.50	57.05	0.23	0.69	0	0.69	0.00	0.10	0.00
4:00 AM	0.27	0.00	0.00	0.00	5.50	20.01	0.23	0.92	0	0.92	0.00	0.27	0.00
5:00 AM	1.28	0.00	0.00	0.00	5.50	4.29	0.23	1.15	0	1.15	0.00	1.28	0.00
6:00 AM	2.88	0.00	0.00	0.00	5.50	1.91	0.23	1.38	0	1.38	0.00	2.88	0.00
7:00 AM	4.88	0.00	0.00	0.00	5.50	1.13	0.23	1.60	0	1.60	0.00	4.88	0.00
8:00 AM	7.08	5.58	12.66	0.79	5.50	0.78	0	0	0.003	1.60	5.58	12.66	0.79
9:00 AM	9.32	6.74	16.06	0.72	5.50	0.59	0	0	0.05	1.55	6.74	16.06	0.72
10:00 AM	11.40	7.56	18.96	0.66	5.50	0.48	0	0	0.09	1.46	7.56	18.96	0.66
11:00 AM	13.59	8.16	21.76	0.60	5.50	0.40	0	0	0.11	1.35	8.16	21.76	0.60
12:00 PM	15.16	8.43	23.58	0.56	5.50	0.36	0	0	0.12	1.23	8.43	23.58	0.56
1:00 PM	16.15	8.53	24.68	0.53	5.50	0.34	0	0	0.13	1.10	8.53	24.68	0.53
2:00 PM	16.64	8.55	25.19	0.51	5.50	0.33	0	0	0.13	0.98	8.55	25.19	0.51
3:00 PM	16.68	8.56	25.24	0.51	5.50	0.33	0	0	0.13	0.85	8.56	25.24	0.51
4:00 PM	16.34	8.54	24.88	0.52	5.50	0.34	0	0	0.13	0.72	8.54	24.88	0.52
5:00 PM	15.68	8.49	24.16	0.54	5.50	0.35	0	0	0.12	0.60	8.49	24.16	0.54
6:00 PM	14.76	8.37	23.13	0.57	5.50	0.37	0	0	0.12	0.48	8.37	23.13	0.57
7:00 PM	13.64	8.17	21.81	0.60	5.50	0.40	0	0	0.11	0.37	8.17	21.81	0.60
8:00 PM	12.38	7.86	20.24	0.64	5.50	0.44	0	0	0.10	0.27	7.86	20.24	0.64
9:00 PM	11.05	7.44	18.49	0.67	5.50	0.50	0	0	0.08	0.19	7.44	18.49	0.67
10:00 PM	9.71	6.91	16.62	0.71	5.50	0.57	0	0	0.06	0.13	6.91	16.62	0.71
11:00 PM	8.42	6.31	14.72	0.75	5.50	0.65	0	0	0.03	0.10	6.31	14.72	0.75
12:00 AM	7.23	5.67	12.91	0.78	5.50	0.76	0	0	0.01	0.09	5.67	12.91	0.78
Average daily flow	**9.44**												
Maximum Storage Required (million gallons)								**1.60**					

APPENDIX D: BRINE ADDITION TO THE EFFLUENT



Inject brine into pig tunneling box downstream of tunnel gate box to prevent corrosion damage to upstream sluice gate.

Figure X. Plate A

APPENDIX E: COMPARISON OF 2009 AND 1978 COMBINED EFFLUENT DENSITIES

Table E1. Comparison of density difference during summer/Fall conditions at various combined effluent flows

1977-1978[1]			2008-2009[2]			Density difference (kg/m^3)	% Density difference
Salinity (ppt)	Temperature (°C)	Density (kg/m^3)	Salinity (ppt)	Temperature (°C)	Density (kg/m^3)		
33.6	17.5	1024.4	33.3	19.0	1023.7	0.7	0.1
33.9	17.4	1024.6	33.6	19.0	1024.0	0.6	0.1
34.1	17.4	1024.8	33.8	18.9	1024.2	0.6	0.1
31.0	17.9	1022.2	30.7	19.5	1021.6	0.6	0.1
30.2	18.0	1021.6	29.9	19.6	1021.0	0.6	0.1
28.5	18.3	1020.3	28.3	19.9	1019.7	0.6	0.1
27.2	18.5	1019.2	27.0	20.1	1018.7	0.5	0.0

[1] *Data based on Brown and Caldwell's Oceanographic Predesign Phase Report (1978)*

[2] *Data based on 2008-2009 bottom Sonde monitoring location at an ocean depth of 35 feet close to 36-inch diameter abandoned outfall. Data provided to Brown and Caldwell by the City of Santa Cruz in August 2009.*

Table E2. Comparison of density difference during winter conditions at various combined effluent flows

1977-1978[1]			2008-2009[2]			Density difference (kg/m^3)	% Density difference
Salinity (ppt)	Temperature (°C)	Density (kg/m^3)	Salinity (ppt)	Temperature (°C)	Density (kg/m^3)		
31.7	15.1	1024.5	30.4	14.8	1022.5	2.0	0.2
31.4	15.1	1024.7	30.1	14.8	1022.3	2.4	0.2
30.9	15.2	1024.8	29.7	14.9	1021.9	2.9	0.3
30.2	15.2	1022.2	29.0	14.9	1021.4	0.8	0.1
29.0	15.3	1021.3	27.8	15.0	1020.5	0.8	0.1
25.8	15.6	1018.8	24.8	15.4	1018.1	0.7	0.1
24.5	15.8	1017.8	23.5	15.5	1017.1	0.7	0.1

[1] *Data based on Brown and Caldwell's Oceanographic Predesign Phase Report (1978)*

[2] *Data based on 2008-2009 bottom Sonde monitoring location at an ocean depth of 35 feet close to 36-inch diameter abandoned outfall. Data provided to Brown and Caldwell by the City of Santa Cruz in August 2009.*