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Appendix HHH: Relative Salinity Impacts in the Brine Mixing Zone (BMZ) of the Carlsbad Desalination Plant (CDP) for Variable Discharge Rates

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1) Introduction:

This is a supplemental technical note to Appendix-BB (Jenkins, 2016) of Poseidon's NPDES permit application to the Regional Water Quality Control Board, San Diego Region for the Carlsbad Desalination Plant (CDP). Appendix-BB provided an initial dilution analysis for a maximum CDP production scenario of 60 mgd of potable water from 299 mgd of source water intake flow from Agua Hedionda Lagoon, resulting in discharges of 238 mgd of concentrated seawater (brine) at a salinity of 42 ppt. Nearfield dilution curves for salinity vs. distance from the discharge point were developed in Appendix-BB using the EPA certified CORMIX model, with particular attention given to how far a compliance salinity of S_{crit} = 35.52 ppt would extend from the point of discharge, a distance referred to herein as the *critical distance*, X_{crit}. The S_{crit} = 35.52 ppt compliance salinity represents 2 ppt over natural background, and under the Regional Board's interpretation of the Ocean Plan, the CDP discharge salinity must dilute to this level within 656.2 ft. (200 m) from the point of discharge, which is the distance to the outer limit of the BMZ. This calculation is revisited in this technical note using the latest version of the CORMIX mixing model (version-11). This technical note also provides calculations for estimates of relative BMZ salinity impacts for CDP production rates less than 60 mgd, including 50 mgd and 54 mgd of potable water production from 299 mgd of intake flow, with discharges of 249 mgd and 245 mgd of brine at 40.25 ppt and 40.91 ppt, respectively.

2) Relative Emissions Rate Impacts:

As with any dilution problem, the leading order variable in assessing relative impacts of various levels of CDP production is the mass emissions rate of the effluent discharged from the discharge channel. Mass emission rate is quantified by the *flux of R.O. salts* into the BMZ, where *flux* is a term equivalent to the numbers of grams of R.O. salts that are discharged into the BMZ in unit time. The flux of R.O. salts, F_S, scales directly with the brine discharge rate Q_b and the excess salinity of the brine over ambient ocean salinity, $S_b - S_0$, or, $F_s = Q_b(S_b - S_0)$, where S_b is the salinity of the brine and S_0 is the salinity of the ocean receiving water. Note, S_0 is the real-time ambient ocean salinity, which is not necessarily the same as what the Ocean Plan refers to as "*natural background salinity*". *Natural background salinity* is the long-term (20-year) average of S_0, which we shall represent with the symbol $\bar{S}$. Salinity records at the nearby Scripps Pier Shore Station determined that $\bar{S}$ = 33.52 ppt, (SIO, 2018), so that the Ocean Plan salinity compliance limit at the BMZ is $S_{crit} = \bar{S} + 2\,ppt =$ 35.52 ppt. Table -1 compares the salt fluxes for the proposed CDP operating levels under average ocean salinity conditions:

Table 1: Salt Flux Comparisons for Proposed CDP Production Levels

Potable Water Production, mgd	Intake Flow, mgd	Discharge Flow Rate, mgd	Discharge Salinity, ppt	Ocean Salinity, ppt	Flux of R.O. Salts, g/s
50	299	249	40.25	33.52	73,419.9
54	299	245	40.91	33.52	79,324.9
60	299	238	41.97	33.52	88,111.6

Inspection of Table-1 indicates that the amount of R.O. salts entering the BMZ (mass emissions rate) is 20.4% greater when the CDP is producing 60 mgd versus 50 mgd of potable water from 299 mgd of intake flow, (88.4 kg/s vs. 73.4 kg/s) and 11.5 % greater salt flux when producing 60 mgd versus 54 mgd of potable water, (88.4 kg/s vs. 79.3 kg/s). Therefore, the relative salt loading impacts in the BMZ that were originally modeled in Appendix-BB (Jenkins, 2016) were clearly greater than what would otherwise occur at CDP production rates less than 60 mgd.

3) Sensitivity of Ocean Plan Compliance to Variable CDP Production Rates

The Ocean Plan requires that the compliance salinity S_{crit} = 35.52 ppt is met at the BMZ boundary, i.e., that $X_{crit} \leq$ 656.2 ft (200 m). While the salt flux determines how much R.O salt is loaded into the BMZ in unit time, the compliance salinity is equivalent to 35,520 grams of salt per cubic meter of BMZ, and a sensitivity analysis of CORMIX dilution solutions at variable CDP discharge rates and brine salinity finds that the coefficient of determination for a relation between X_{crit} and salt flux F_s is only r-squared = 0.42.The ultimate question of how far offshore the R.O. salts will travel before diluting to the salinity compliance standard, depends on an additional variable, namely, the available volume of dilution water within the BMZ. Because the CDP has a shoreline discharge, the volume of water inside the BMZ is limited by local water depth, which varies with the stage of the tides and the beach profile according to the stage volume function V_{BMZ}. The previous CORMIX dilution analysis in Appendix-BB assumed the ocean water level was at mean sea level and that the beach profiles around the CDP discharge were defined by the 15 April 2015 beach profile surveys, Cabrillo, (2015). These two assumptions produced an estimate that the volume of water in the BMZ was $V_{BMZ}(2015)$ = 198,953 m^3.

Dividing the flux of R.O. salts by the BMZ storage volume, gives a single *transform* variable which incorporates all the controlling environmental and CDP operating parameters that influence a CORMIX dilution modeling simulation. This transform variable is referred to as the *salt flux density*, γ_S, expressed as:

$$\gamma_s(t_i) = 43.81263 \cdot \frac{Q_b\,(S_b - S_0)}{V_{BMZ}(t_i)} \qquad (1)$$

The constant in equation (1) accommodates brine and ambient ocean salinity inputs, (S_b, S_0), using units of parts per thousand, ppt; the brine discharge rate Q_b using units of millions of gallons per day, mgd; and the brine mixing zone storage volume, V_{BMZ}, using units of cubic meters. The *salt flux density* represents the grams of R.O. salts discharged per cubic meter of BMZ per second, which is equivalent to parts per million per second, ppm/s. With this transform variable, all the possible results from CORMIX dilution simulations at variable discharge flow rates and brine salinity can be estimated from a simple algebraic equation:

$$X_{crit} = a + b\gamma_s + c\gamma_s^2 \qquad (2)$$

where: a = -95.29746603 ft
b = 2396.604213 ft/ppm/s
c = -1646.982471 ft/ppm^2/s^2

The complete range of possible outcomes for X_{crit} from CORMIX v-11 dilution solutions are plotted as the solid black curve in Figure 1 as a function of the salt flux density. Relative comparisons of the BMZ impacts at variable CDP production rates of potable water are also summarized in Table-2. The original solution from Appendix-BB (Jenkins, 2016) is plotted as the black dot in Figure 1, which predicted that the CDP brine would dilute to S_{crit} = 35.52 ppt just inside the BMZ boundary at X_{crit} = 643 ft. (195.9 m) from the discharge point, (for brine discharges of 238 mgd at 42 ppt as a result of 60 mgd of R.O. production from 299 mgd of source water intake flow). As the CDP reduces potable water production from 60 mgd to 54 mgd or 50 mgd, (always using 299 mgd intake flow), the critical distance X_{crit} becomes smaller and the brine dilutes to the compliance salinity S_{crit} = 35.52 ppt closer to the discharge point. At 54 mgd potable water production, the critical distance declines to X_{crit} = 598 ft (182.2 m), cf. blue circle in Figure 1; and at 50 mgd potable water production, the critical distance is reduced further to X_{crit} = 565 ft. (172.2 m), cf. the magenta square in Figure 1.

Table 2: Critical Distance, X_{crit}, Comparisons for Proposed CDP Production Levels

Potable Water Production, mgd	Intake Flow, mgd	Discharge Flow Rate, mgd	Discharge Salinity, ppt	Flux of R.O. Salts, g/s	Salt Flux Density, g/m^3/s (ppm/s)	Critical Distance to 35.52 ppt, X_{crit}, ft.
50	299	249	40.25	73,419.9	0.369 *	565*
54	299	245	40.91	79,324.9	0.399*	598*
60 (App-BB)	299	238	41.97	88,111.6	0.443*	643*

* based on BMZ storage volume = 198,953 m^3 from the 11 October 2017 beach surveys

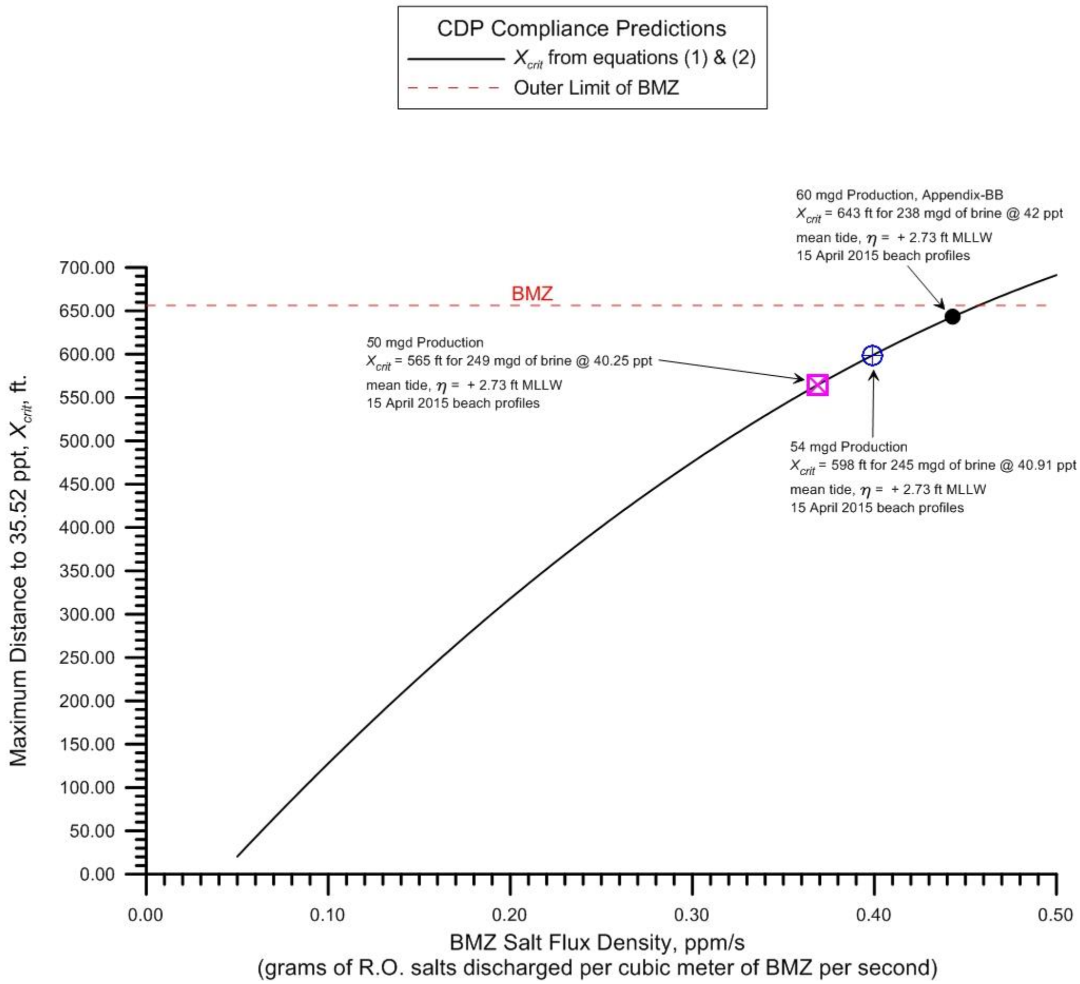

Figure 1: Maximum distance from discharge point to the 35.52 ppt salinity contour, X_{crit}, as a function of the salt flux density. Results calculated from equations (1) & (2) derived from CORMIX-v11 dilution modeling for future CDP stand-alone operations during average ocean conditions with CDP production rates of potable water at 50 mgd, 54 mgd and 60 mgd using 299 mgd of lagoon source water.

4) Conclusions:

In general, every measure of BMZ salinity impacts decline as CDP production rates decline: 1) discharge salinity entering the BMZ declines from 42 ppt at 60 mgd production rates to 40 ppt at 50 mgd production rates; 2) the flux of R.O. salts into the BMZ (emissions rate) declines from 88.1 kg/s at 60 mgd production rates to 73.4 kg/s at 50 mgd production rates; and, 3) the compliance salinity of S_{crit} = 35.52 ppt is reached closer to the discharge point. Hence, Poseidon's original submission of Appendix-BB (Jenkins 2016) with its draft NPDES permit application did indeed capture the worst-case scenario of salinity impacts in the BMZ of the CDP.

References:

Cabrillo Power, 2015, "“Order 96-32: First Quarter 2105, Second Quarter 2015 and Final Monitoring Report for Agua Hedionda Lagoon Dredging", submitted to California Regional Water Quality Control Board, 30 pp.

Jenkins, S. A., 2016, "Note on the Zone of Initial Dilution in a Quiescent Ocean Due to Discharges of Concentrated Seawater from the Carlsbad Desalination Project," submitted to Poseidon Water, LLC, Appendix-BB in Poseidon's NPDES application to the Regional Water Quality Control Board, San Diego Region, 12 July 2016, 39 pp.

SIO, 2018, "SIO shore station, Scripps Pier",

https://scripps.ucsd.edu/programs/shorestations/wp content/uploads/sites/96/2017/07/SIO_SALT_1916-201410.txt