ATTACHMENT 14

PROPOSED EFFLUENT LIMIT FOR TOTAL RESIDUAL CHLORINE FOR THE SOUTH BAY POWER PLANT

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1. INTRODUCTION

The South Bay Power Plant (SBPP), owned by San Diego Gas and Electric (SDG&E), is located at the southern end of San Diego Bay. This plant, consisting of four independent generating units, utilizes water from the Bay for cooling purposes. As part of routine permitted operation, SBPP utilizes chlorine as a biocide to prevent buildup of bacterial slime and other fouling organisms in the plant's cooling water system. Currently, chlorine is introduced with the intake water to each unit for a duration of 20 minutes every four hours. Without such biocide applications, continued operation of this plant would be economically infeasible.

These biocide applications may result in the release of minute amounts of residual chlorine into San Diego Bay during treatment periods. Chlorine is a non-persistent compound which quickly degrades into relatively non-toxic compounds once released into the Bay. The release of residual chlorine in SBPP's cooling water discharge is regulated under the plant's NPDES Permit as established by the Regional Water Quality Control Board (RWQCB). Historically, the plant has been required to comply with U.S. EPA's technology-based effluent limitation for steam electric plants of 0.2 mg/L and to limit the duration of chlorination to no more than 2 hours per day per unit. Under the previous permit, compliance with the limit was determined at the temperature monitoring buoy located in the discharge channel for the plant. In Order No. 96-05, the RWQCB made two fundamental changes to the permit with respect to chlorine discharges. First, the compliance point was moved upstream to SDG&E's property line. Second, a water quality-based limit will supplant a technology-based limit effective 15 December 1999. Since there is presently no water quality objective for chlorine applicable to San Diego Bay, the RWQCB took the water quality objective for chlorine set forth in the Ocean Plan and applied that objective as the water quality-based chlorine effluent limit for SBPP.

In its appeal of the permit, SDG&E pointed out that this new effluent limit is based upon toxicity results for the most sensitive ocean species, species which do not reside in San Diego Bay. Therefore, SDG&E argued that this objective is not applicable to the Bay. Further, long-term monitoring of the biological communities in the vicinity of SBPP conducted over an 18-year period provides evidence of a healthy ecosystem in this area of the Bay and, thus, no evidence of jeopardy to the beneficial uses of the Bay resulting from compliance with the technology-based limit. Thus, SDG&E argued that the more restrictive limits of the order are unnecessary and, in any event, that the Regional Board failed to follow the appropriate regulatory process in establishing the water quality-based limit.

The purpose of this document is to propose an effluent limit for chlorine for the SBPP that is scientifically sound, economically achievable, and will ensure continued protection of beneficial uses of San Diego Bay. This effluent limit is proposed as a means of settling this dispute and is based on an analysis of chlorine toxicity information conducted in the following three steps:

- Selection of toxicity information relevant to the Bay,
- Establishment of the relationship between toxicity and exposure duration,
- Evaluation of the effects of intermittent chlorination.

The results of these three steps are then integrated to determine an appropriate water quality-based effluent limit for chlorine taking into account the biological communities resident in the Bay and the intermittent nature of releases from the SBPP.

2. ANALYSIS OF RELEVANT CHLORINE TOXICITY INFORMATION

2.1 Selection of Relevant Chlorine Toxicity Data

The purpose of the first step in the analysis is to review available aquatic toxicity data on chlorine and to select that subset of these data that is relevant to the establishment of an effluent limit for SBPP. For this analysis, "relevant" is taken to mean directly applicable to the subsequent analyses and representative of the biological communities inhabiting San Diego Bay which are potentially exposed to SBPP's discharge.

Published chlorine toxicity data for saltwater species were compiled for this analysis from four sources:

- The US EPA's National Water Quality Criteria Document for Chlorine (U.S. EPA 1985a)
- A site-specific evaluation of power plant chlorination (Mattice and Zittel 1976)
- A re-evaluation of the Mattice and Zittel model (Envirosphere 1978)
- The U.S. EPA's AQUIRE database for aquatic toxicity (1998).

These four sources include all the acute chlorine toxicity data used as the basis for the U.S. EPA National Water Criteria for Chlorine, the U.S. EPA Gold Book (which cites the National Criteria), and each of the Ocean Plans which addressed intermittent chlorination (1978 - 1990).

Using this master set of available chlorine toxicity data, an initial subset was selected for subsequent analysis using three criteria. First, toxicity information was limited to estimates based on free or total residual chlorine. Second, toxicity information was limited to the single end-point of mortality. Third, the chlorine toxicity information selected for this evaluation were further limited to the single measurement end-point - LC50. This selection process provides for consistency and direct comparability within the data set and is consistent with the approach used in U.S. EPA (1985a) for development of the national water quality criteria for chlorine.

Following this initial data selection, the data were further subsetted to focus on chlorine toxicity information most relevant to the biotic communities actually residing in the Bay. To achieve this goal, two additional biological criteria were applied: one, that the species tested are known residents of San Diego Bay, or, two, that other members of the genus of the species tested are resident in the Bay. The rationale for the first criterion is self-explanatory. The second criterion is based on the presumption that species of the same genus would have similar life history and physiological/biochemical characteristics and, thus, should respond to chemicals like chlorine in a similar manner. This is consistent with U.S. EPA's methodology for derivation of water quality criteria in that the U.S EPA aggregates data for calculation of geometric mean values up to the genus level and to no higher taxonomic level to generate final concentration guidelines.

Species and/or genera know to inhabit San Diego Bay were identified based on the results of the following ecological studies of the Bay:

Allen (1994)
Allen (1995)
California Regional Water Quality Control Board, San Diego Region (1996)
Department of Biology San Diego State College and Ford (1968)
Ford (1994)
Merkel and Associates, Inc. and Science Applications International Corporation (1995)
Merkel and Associates, Inc. (1997)
Michael Brandman Associates, Inc. (1990)
San Diego Unified Port District (1979).

Based on the spatial and temporal coverage provided by these studies, the overall list of species inhabiting the Bay used for this analysis is reasonably inclusive of the aquatic communities potentially exposed to the discharge from the SBPP.

Following application of the above five selection criteria, a total of 41 individual aquatic toxicity measurements across 10 species were deemed relevant for this analysis (Table 1). Chlorine concentrations listed on this table are the concentrations associated with an LC50 for that species and exposure interval. In other words, the concentrations listed on that table are those which caused mortality in 50 percent of the test organisms in each experiment. However in order to be protective of beneficial uses in San Diego Bay, we must consider any mortality on indigenous species, not just the loss of 50 percent. Therefore, in the subsequent analysis the focus was more on chlorine concentrations that prevent any mortality in the species representative of the Bay's ecological communities. To estimate these "threshold" concentrations of chlorine, we multiplied each LC50 concentration by an adjustment factor. Although U.S. EPA universally applies an adjustment factor of 0.5 for converting a concentration based on LC50 data to a threshold or "safe" concentration for calculating water quality criteria for all pollutants, this is presumably based on the approximate relationship between LC50 concentrations and threshold concentrations found in bioassay testing across many species in both freshwater and saltwater. A more relevant adjustment factor (0.52) has been used in this evaluation that reflects the mean ratio of LC50 concentrations to threshold concentrations in 33 saltwater toxicity tests where both endpoints were measured at constant exposure durations (Envirosphere 1978). The value of 0.52 was used to convert the concentration which caused median lethal effects to the concentration that would begin to cause any mortality for the same exposure time. The calculated threshold concentrations, which are listed on Table 1, were used to define the relationship between exposure time and toxicity described in the next section.

2.2 Relationship between exposure duration and toxic effects.

It is a well-established fact that the toxicity induced in aquatic organisms by any pollutant is a function of both the concentration of that pollutant and the temporal duration of exposure. Typically, water quality criteria are calculated presuming continuous exposure as this is the most conservative scenario and appropriate for relatively persistent pollutants. However, chlorine is commonly used on an intermittent basis and is not persistent. Thus, water quality criteria for chlorine based on continuous exposures would be considerably more protective than necessary for intermittent releases such as occur at SBPP.

Recognizing this fact, the Ocean Plan provides an equation to adjust water quality objectives for chlorine for ocean species to account for shorter chlorine discharges (SWRCB 1990). The nature of this adjustment was based on earlier analysis of toxicity data for marine species conducted by Mattice and Zittel (1976). In developing the 1990 Ocean Plan revision, the SWRCB adjusted the original Mattice and Zittel model to be protective of the most sensitive species found in the State's ocean waters, neither of which reside in San Diego Bay. Therefore, the purpose of this second step in our analysis is to estimate the relationship between exposure time and threshold mortality for species that are representative of the Bay's aquatic communities.

Previous studies have demonstrated that the relationship between exposure time and specific toxicity endpoints for aquatic species can be described by a power function

(Mattice and Zittel 1976, Envirosphere 1978). This functional relationship predicts that toxicity increases at an increasing rate at longer exposure times and, conversely, threshold concentrations at shorter exposure times can be relatively high compared to longer exposures. By transforming the measurements of exposure time and threshold concentrations using logarithms, this power function algebraically converts to a linear relationship. It is this log-transformed linear relationship which is most commonly used to quantify the relationship between exposure time and toxicity for chlorine.

For this analysis, we used well-accepted regression techniques (Snedecor and Cochran 1967) to statistically estimate the linear relationship between the log of the chlorine concentration for threshold mortality (mg/L) and the log of exposure time (minutes) using the data listed in Table 1. Using traditional least-squares techniques, we fit the following model to the chlorine toxicity data set most representative of San Diego Bay biotic communities:

$$\log_{10}(Concentration) = -0.404\log_{10}(ExposureTime) + 0.383(R^2 = 0.47). \quad (1)$$

This model can be used to predict the median threshold concentration at any specific exposure time for biological communities in San Diego Bay. However use of median threshold concentrations as a water quality criterion will not provide sufficient protection to the biotic resources of the Bay, since one would expect threshold concentrations of chlorine for half of the species to fall below the regression line.

In order to provide sufficient protection to the beneficial uses of San Diego Bay, the water quality criterion for chlorine must be sufficiently low to be protective of 95 percent of the species found in the Bay. This level of protection is consistent with U.S. EPA's methods for establishing both national and site-specific water quality criteria, which are designed to protect 95 percent of the species in the aquatic community (U.S. EPA 1985b). To estimate chlorine concentrations at specific exposure times affording such a level of protection, we used the variance around the regression model to define the lower 90 percent confidence bound for individual predicted values as follows:

$$Log(LCB) = (aX + b) - t_{0.90} S_{Y \bullet X}\sqrt{1 + \frac{1}{n} + \frac{(X - \bar{X})^2}{\sum (X - \bar{X})^2}}$$

$$and \quad (2)$$

$$LCB = 10^{Log(LCB)}$$

where:

LCB	=	lower 90 percent confidence limit
X	=	log of the exposure time of interest

a	=	slope of the linear regression line = -0.404
b	=	intercept of the linear regression line = 0.383
$t_{0.90}$	=	"t" statistic (alpha = 0.10, n-2 degrees of freedom) = 1.685
$S_{Y \cdot X}$	=	standard deviation about regression line = 0.393
n	=	number of toxicity measures for regression = 41
$\overline{X}$	=	mean log exposure time = 3.058
$\sum (X - \overline{X})^2$	=	sum of squares about mean of X = 33.947.

Based on the data contained in Table 1, this lower confidence bound should be lower than 95 percent of the individual measurements of threshold toxicity.

The estimated regression line, the lower 90 percent confidence bound and the original toxicity data are presented on Figure 1. As can be seen in this figure the lower 90 percent confidence bound is not linear. The distance between the mean concentration, as estimated from the regression, and the lower 90 percent confidence bound increases with increasing distance higher and lower than the mean exposure time used to develop this regression.

2.3 Effects of Intermittent Chlorination

The majority of bioassay studies, such as those used in the derivation of the site-specific effluent guideline model presented above, use a constant exposure condition. That is, the test organisms are exposed to a constant toxic concentration throughout a given test duration. Test durations ranging from minutes to 96 hours are generally considered to provide measures of toxicity for short-term (or acute) exposure. Test durations typically ranging from 14 to 60+ days provide measures of toxic response to long-term (or chronic) exposure. However, chlorine is applied intermittently at SBPP, as at many power plants, to minimize the daily chlorine loading while controlling condenser biofouling. For example, at SBPP chlorine is currently introduced with the intake water to each unit for a duration of 20 minutes every four hours.

A study by Brooks et. al. (1989) demonstrates the magnitude of reduction in toxicity effected by intermittent chlorination. Four of the ten most sensitive freshwater organisms ranked by EPA *(Daphnia magna, Goniobasis livescens, Notropis cornutus, and Salmo gairdneri)* were exposed to monochloramine continuously and intermittently (2 hours per day) in parallel tests. All four species were tested over periods ranging from 48 hours to 120 hours. Chronic (20 to 60 day) tests were also conducted on two of the species (Daphnia and rainbow trout). Based on the results, Brooks concluded:

> *". . . the acute test ratios indicate that [two-hour] intermittent exposures are approximately 3 to 7 times less toxic to aquatic organisms than are continuous exposures [48 to 120 hours] . . ."*

". . . the results of chronic tests in this study indicate that intermittent exposures of monochloramine applied over a period of 21 to 60 days are approximately 5 to 8 times less toxic . . . than are continuous exposures."

In reality, intermittent chlorination lowers chlorine toxicity even more than revealed by these bioassay test results. This is because real world exposure is reduced by both active and passive mechanisms that can operate when chlorine is not continuously present in the effluent. For example, Brooks et. al (1989) found that intermittent exposure was more than 100 times less toxic than continuous exposure to the snail *Goniobasis livescens*, reflecting the ability of the species to avoid chlorine exposure by temporarily retreating into their shells. Thus, even species with limited mobility are able to actively avoid exposure under intermittent chlorination regimes. More mobile forms will actively avoid chlorine concentrations in the discharge vicinity that are well below their toxicity threshold but can still be able to utilize all habitat during the unchlorinated periods. The flushing of planktonic organisms from the plant vicinity by tidal action and unchlorinated plant flow in the intervals between chlorination periods also reduces exposure of free-floating forms. Therefore, movement of mobile forms throughout the bay, flushing and exchange of planktonic forms, and protective retreating of immobile invertebrates likely preclude repeated exposures of individual organisms in the vicinity of the discharge.

Consistent with these factors, the Ocean Plan specifies that a water quality objective for intermittent chlorine sources shall be determined by a concentration-exposure time relationship based on the duration of uninterrupted chlorine discharge (not exceeding 2 hours).

3. PROPOSED EFFLUENT LIMIT FOR SBPP

Based on the information presented above, we propose an effluent limitation for residual chlorine at SBPP based on the curve presented in Figure 1 and the equation described in Section 2.2 (Equation 2) for the lower 90 percent confidence bound based on the regression model. The limit is expressed as an instantaneous maximum limit which based on the duration of the uninterrupted period of chlorine discharge. Examples of instantaneous maximum limits for total residual chlorine at SBPP, calculated using this approach, for uninterupted discharge durations ranging from 10 to 120 minutes are listed in Table 2. For example, based on an uninterrupted exposure time of 80 minutes, the instantaneous limit for residual chlorine would be 0.085 mg/L at the SDG&E property line during chlorination.

We believe that this approach to establishing an effluent limit for chlorine for the SBPP is more scientifically defensible than use of either the current or any previous Ocean Plan. The equation for intermittent chlorination included in the current Ocean Plan is based entirely on chronic toxicity data using the two most sensitive species in the data set, neither of which resides in San Diego Bay. The equation for intermittent chlorination included in all previous Ocean Plans (1978 - 1988) was based on the results of Mattice and Zittel (1976) as the basis for defining the relationship between threshold chlorine concentration and exposure time. The approach presented in this report corrects several shortcomings of the Mattice and Zittel approach for establishing a chlorine effluent limit at SBPP. These are detailed below:

- Mattice and Zittel recognized that "placing reasonable limits on chlorine releases to the environment ideally would involve knowledge of the effects . . . on the animal populations at the specific site . . ." Because this knowledge was not available, Mattice and Zittel attempted to formulate a generalized model based on the limited chlorine toxicity data available at the time. Our approach uses data on the toxicity of chlorine to genera resident in San Diego Bay to achieve this desired site-specificity. Most of the information on site-specific taxa (34 of the 41 data points used in our regression model) was not included in the Mattice and Zittel paper.

- The Mattice and Zittel model also converted median response data to threshold response levels using a conversion factor. However, the Mattice and Zittel conversion factor was based on a mix of freshwater and saltwater data. The chemistry of chlorine and the associated physiological stresses are markedly different in freshwater and saltwater. Developing a conversion factor based on freshwater and saltwater organisms and applying it to marine organisms is of questionable validity. Our approach, based on the conversion factor from Envirosphere (1978), is more appropriate in that it uses data on marine organisms only to derive the factor for converting LC50 concentrations to threshold concentrations.

- The accuracy and precision of the chemical methods used to measure chlorine concentrations in the data set for our regression model is superior to that in the data set available to Mattice and Zittel. Preferred chemical methods (amperometric and DPD-ferrous) were used in the bioassays that generated 78 percent of the our data points, but only 23 percent of the data points used by Mattice and Zittel.

- Mattice and Zittel established the slope of their duration/concentration line arbitrarily, with a focus on only 3 data points. There is no reason why other lines of different slope could not have been drawn as well. (In fact, the Mattice and Zittel data set could be used in this arbitrary manner to derive an effluent limit very similar to that calculated by our model). Our approach derives the slope of the line objectively with a statistical method that uses all the data and provides a method to assign specific probabilities associated with any exposure time-threshold concentration point.

Further, the 41 individual toxicity measurements for species directly representative of San Diego Bay used in this analysis is considerably higher that the 15 acute toxicity measurements used as the basis for the 6-month median chlorine objective of 0.002 mg/L in the 1978, 1983, and 1988 Ocean Plans. Of these 15 acute values used as the basis for this Ocean Plan objective, 10 are for species which are exclusively freshwater, 4 are on species which are freshwater inhabitants at the time of testing, and only 1 is an exclusively saltwater species (spot), a species which is not even found in the Pacific Ocean.

The effluent limit proposed in this report addresses the need to protect species specific to the community of South San Diego Bay and provides a reasonable level of protection consistent with the intermittent nature of the discharge in a scientifically sound and defensible manner. This effluent limit for residual chlorine discharges from SBPP was developed in a manner consistent with the "uninterrupted discharge" concept as presented in the Ocean Plan for applying concentration-exposure time curves.

This proposed limit will continue to assure the protection of the beneficial uses of South San Diego Bay for the following reasons:

- It provides reasonable protection to the biological communities of San Diego Bay consistent with established U.S. EPA procedures (U.S. EPA 1985b);
- It is substantially lower than the previous technology-based limit of 0.2 mg/L, which has been shown in numerous scientific studies to be protective of beneficial uses of South San Diego Bay;
- Compliance monitoring has been shifted from the buoy to the property line, providing an even higher level of protection;
- There will be continued rapid dilution and decay of chlorine beyond the property boundary from unchlorinated plant flow and bay waters; and
- Actual organism concentration-time exposures will be less than that used to establish the proposed limit due to active avoidance mechanisms exhibited by many species.

This proposed effluent limit for chlorine is consistent with the California Porter Cologne Water Quality Control Act's objective of maintaining the highest water quality that is reasonable, considering all factors, consistent with the protection of beneficial uses of the Bay.

4. REFERENCES

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TABLE 1. CHLORINE TOXICITY DATA REPRESENTATIVE OF THE BIOLOGICAL COMMUNITIES IN SAN DIEGO BAY.

Species	Common Name	Continuous Exposure Duration (min)	LC50 Concentration (mg/L)[1]	Threshold Concentration (mg/L)[2]
Clupea harengus	Atlantic herring	5,760	0.065	0.034
Cymatogaster agregata	Shiner surfperch	5,760	0.071	0.037
		1,980	0.112	0.058
		1,320	0.120	0.062
		1,260	0.150	0.078
		1,140	0.190	0.099
		60	0.230	0.120
		60	0.330	0.172
		60	0.300	0.156
Hemigrapsus sp	shore crabs	5,760	1.418	0.737
Morone saxatilis	Striped bass	1,440	0.360	0.187
		1,440	0.200	0.104
		1,440	0.190	0.099
		2,880	0.200	0.104
		2,880	0.220	0.114
		5,760	0.040	0.021
		5,760	0.040	0.021
		5,760	0.070	0.036
Acartia tonsa	copepods	0.7	10.000	5.200
		30	0.820	0.426
		120	1.000	0.520

		1,440	0.050	0.026
		1,440	0.403	0.210
		2,880	0.050	0.026
		5,760	1.000	0.520
Cynoscion nebulosus	Spotted sea trout	2,880	0.210	0.109
		2,880	0.210	0.109
		2,880	0.170	0.088
Morone americana	White perch	1,440	0.310	0.161
		5,760	0.210	0.109
		5,760	0.150	0.078
		4,560	0.270	0.140
Pontogeneia sp	amphipods	5,760	0.687	0.357
Pseudodiaptomus coronatus	copepods	5	10.000	5.200
		45	2.500	1.300
Sygnathus sp	pipefishes	1,440	0.280	0.146
		2,880	0.270	0.140
		1,440	0.280	0.146
		2,880	0.270	0.140
		5,760	0.270	0.140
		5,760	0.270	0.140

[1] LC50 concentration refers to the estimated concentration associated with 50 percent mortality at the set exposure time as calculated in the original study.
[2] Threshold concentration refers to the adjusted value used to estimate the concentration where increased mortality to the population just begins to occur as described in Section 2.1

TABLE 2 SELECTED INSTANTANEOUS MAXIMUM TOTAL RESIDUAL CHLORINE LIMITS FOR THE SOUTH BAY POWER PLANT

Uninterrupted Discharge Duration (min)	**Calculated Value(mg/L)**
10	0.186
15	0.160
20	0.144
25	0.132
30	0.124
35	0.117
40	0.111
45	0.106
50	0.102
55	0.098
60	0.095
65	0.092
70	0.090
75	0.087
80	0.085
85	0.083
90	0.082
95	0.080
100	0.078
105	0.077
110	0.076
115	0.074
120	0.073

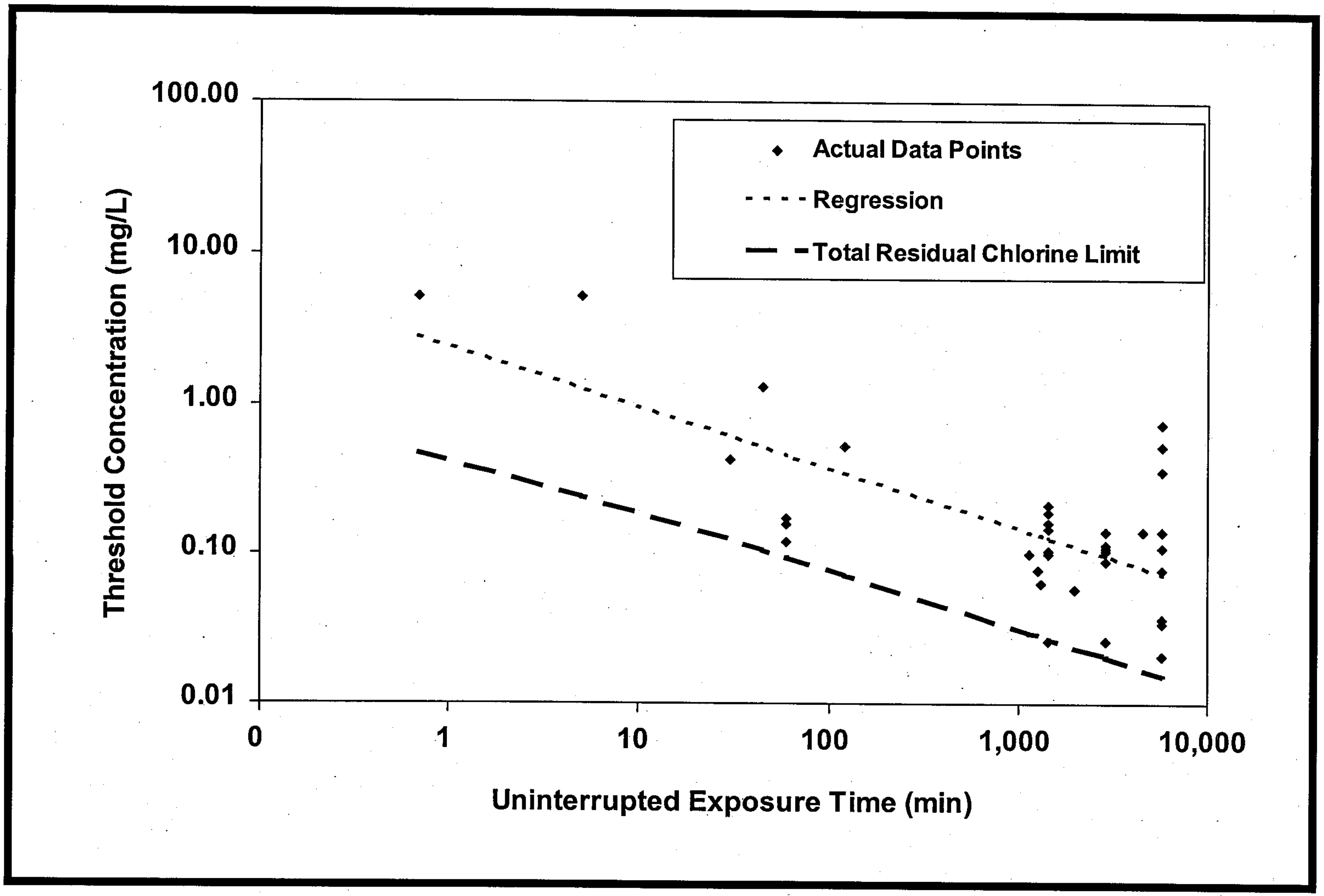

Figure 1. Total residual chlorine limit applicable to the South Bay Power Plant based on regression modeling of available saltwater toxicity data relevant to San Diego Bay.