

**CARLSBAD SEAWATER DESALINATION PROJECT**

**SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD**

**REGION 9, SAN DIEGO REGION**

**ORDER NO. R-9-2006-0065**

**NPDES NO. CA0109223**

**FLOW, ENTRAINMENT AND IMPINGEMENT MINIMIZATION PLAN**

**ATTACHMENT 9 - IMPINGEMENT ESTIMATION ANALYSIS BASED ON DRS.  
CHANG'S AND JENKINS'S STATEMENTS REGARDING OUTLIERS IN 2004-2005**

**EPS SAMPLING DATA**

**March 26, 2009**

**IMPINGEMENT ESTIMATION ANALYSIS BASED ON DRS. CHANG'S AND  
JENKINS'S STATEMENTS REGARDING OUTLIERS IN 2004-2005 EPS SAMPLING  
DATA**

(March 26, 2009)

**I. INTRODUCTION AND SUMMARY**

This analysis complements Attachment 5 to the Flow, Entrainment and Impingement Minimization Plan, which analyzes various approaches to estimating the impingement should the CDP operate in stand-alone mode. Attachment 5 indicates that the CDP's projected impingement when operating in stand-alone mode ranges from 1.57 to 7.1 kilograms per day ("kg/day") based on the 2004-2005 sampling data for the EPS intake system.

The highest of these values assumes that impingement associated with the CDP's stand-alone operations will be identical to impingement observed at the EPS intake over the 2004-2005 sampling period, even though the CDP will require substantially less seawater than was withdrawn for cooling purposes during the sampling period. The other values adjust the 2004-2005 data in various ways to account for the reduced flow volume of the CDP relative to historical EPS cooling water withdrawals. These values are not adjusted to account for other technological or design measures that may be implemented if the CDP operates in stand-alone mode, which measures would be expected to further reduce impingement.

The 2004-2005 EPS sampling data includes 52 samples events. During two of the sample events, January 12 and February 23, the recorded impingement was observed to be relatively higher than on the other fifty days. Importantly, these two sample days immediately follow storm events. Subsequent analysis completed by experts for Poseidon since Attachment 5 was submitted indicates that the storm events preceding the January 12 and February 23 samples have a low probability of recurrence, each likely to occur no more than once every quarter century. The likelihood that *both* such events will occur in any given year, as they did during the 2004-2005 sample year, is even more remote.

These findings indicate that several of the impingement estimates presented in Attachment 5 ascribe too much weight to the two outlier sample days and overstate the impingement likely to be associated with the CDP's stand-alone operations. For project planning purposes, the impingement values at the lower end of the range from 1.57 to 7.1 are the most relevant, as the lower values reflect estimated impingement based on conditions that are expected to prevail over the project lifetime, whereas the relevance of the impingement values at the higher end is suspect as they presume annual recurrence of rare storm events.

**II. THE STORMS PRECEDING THE JANUARY 12 AND FEBRUARY 23 SAMPLING EVENTS WERE VERY RARE**

Drs. Jenkins<sup>1</sup> and Chang<sup>2</sup> presented the results of their hydrologic analyses in two short

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<sup>1</sup> See "Statement Addressing Regional Board Staff Concerns regarding the Biological Data," Dr.

reports submitted to the Regional Board on March 19, 2009 and included as part of this attachment. Dr. Jenkins explains that the impingement samples taken on January 12 and February 23, 2005 were preceded by at least five days of rainfall totaling 4.01 inches and 3.24 inches, respectively. These rainfall amounts correspond to periods of extreme rain that rank among the highest on record. According to Dr. Jenkins, both storms set rainfall records: precipitation preceding the January 12 sample constituted the highest 5-day rain total in the period of record of the Agua Hedionda Creek watershed, while the storm preceding the February 23 sample was the eighth wettest on record.<sup>3</sup>

Doctors Chang and Jenkins each used a different method to calculate the occurrence probabilities of storms of comparable magnitudes. Dr. Jenkins compared rainfall totals with four decades of rainfall data.<sup>4</sup> He noted the frequency with which storms of equal or greater magnitude to the January 12 or February 23 occurred in the database. He plotted the two storms on a log-scale and determined that the January 12 and February 23 storms have probabilities of occurrence of 0.025% and 0.17%, respectively.<sup>5</sup>

Dr. Chang created a hydrological simulation to generate stream flow estimates at selected points of concentration along the Agua Hedionda Creek. His simulation incorporated rainfall data obtained from the County of San Diego and drainage basin characteristics of the Agua Hedionda Creek watershed.<sup>6</sup> Applying the stream flow hydrological model, Dr. Chang estimated that the storms preceding the January 12 and February 23 collections produced stream flow discharges just before the Calavera Creek confluence of 2,715 and 3,609 cfs, respectively.<sup>7</sup> When compared with peak discharge volume and frequency data for Agua Hedionda Creek that are used by the Federal Emergency Management Agency (FEMA) to evaluate flood hazards in a community, these values represent rare events.<sup>8</sup> Specifically, Dr. Chang concluded that, in any given year, there is only a 4.2% chance that stream flows will occur that are large enough to produce discharge volumes equal to or greater than those resulting from the storms that preceded the January 12 sampling event.<sup>9</sup> Based on this observation, he concluded that the probability that a storm will occur in a year that equals or exceeds that which preceded the January 12 and

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Scott Jenkins, March 19, 2004 (Attachment 9-B, page 4).

<sup>2</sup> See “Frequencies for Storm Events of January and February 2005,” Dr. Howard Chang, March 19, 2009 (Attachment 9-A, page 2).

<sup>3</sup> *Id.*

<sup>4</sup> Daily rainfall measured by NOAA/NCDC rain gage #03177 at Carlsbad Airport (cf. NWS, 2009) at Carlsbad Airport (cf. NWS, 2009). *Id.* at 3.

<sup>5</sup> *Id.* at 4.

<sup>6</sup> *Id.*

<sup>7</sup> *Id.* at 4.

<sup>8</sup> *Id.* at 5.

<sup>9</sup> *Id.*

February 23 sampling events is only 4.8% and 2.8% respectively.<sup>10</sup> For every 100 years, in other words, Dr. Chang concludes that these storms will occur approximately 4 and 3 times, respectively. That is, they were about 25- and 35-year storms.<sup>11</sup> The likelihood that *both* such storms will occur in the same year again is 0.12% (4.2% x 2.8%). Therefore, such an event would be expected to occur approximately once in a 1,000 years.<sup>12</sup>

### III. RELATIVELY HIGHER IMPINGEMENT WAS ASSOCIATED WITH THE JANUARY 12 AND FEBRUARY 23 STORMS

The samples collected after the extraordinary rain events consisted of relatively higher impingement than that observed on the other sampling days. The impingement on the January 12 sampling day was 23.5 times greater than the impingement on the 50 normal sampling days, and the impingement on the February 23 sampling day was 6.3 times greater. The following table shows the extent to which impingement following the record storms exceeded average impingement totals for the rest of the year.

<b>Table 2: outliers compared with typical events</b>				
	<b><u>Number of Fishes</u></b>		<b><u>Weight of Impinged Fish</u></b>	
<b><u>Average for the 50 typical sampling events</u></b>	263		4.67 kg/day	
<b>January 12, 2005</b>	5,001	<u>19 times</u> greater than the average of the 50 normal events	109,526 (grams)	<u>23.5 times</u> greater than the average
<b>February 23, 2005</b>	1,274	<u>4.8 times</u> greater than the average of the 50 normal events	29,531 (grams)	<u>6.3 times</u> greater than the average
<b>Average for the 2 outlier sampling events</b>	3,138	<u>11.9 times</u> greater than the average of the 50 normal events	69,528 (grams)	<u>15 times</u> greater than the average

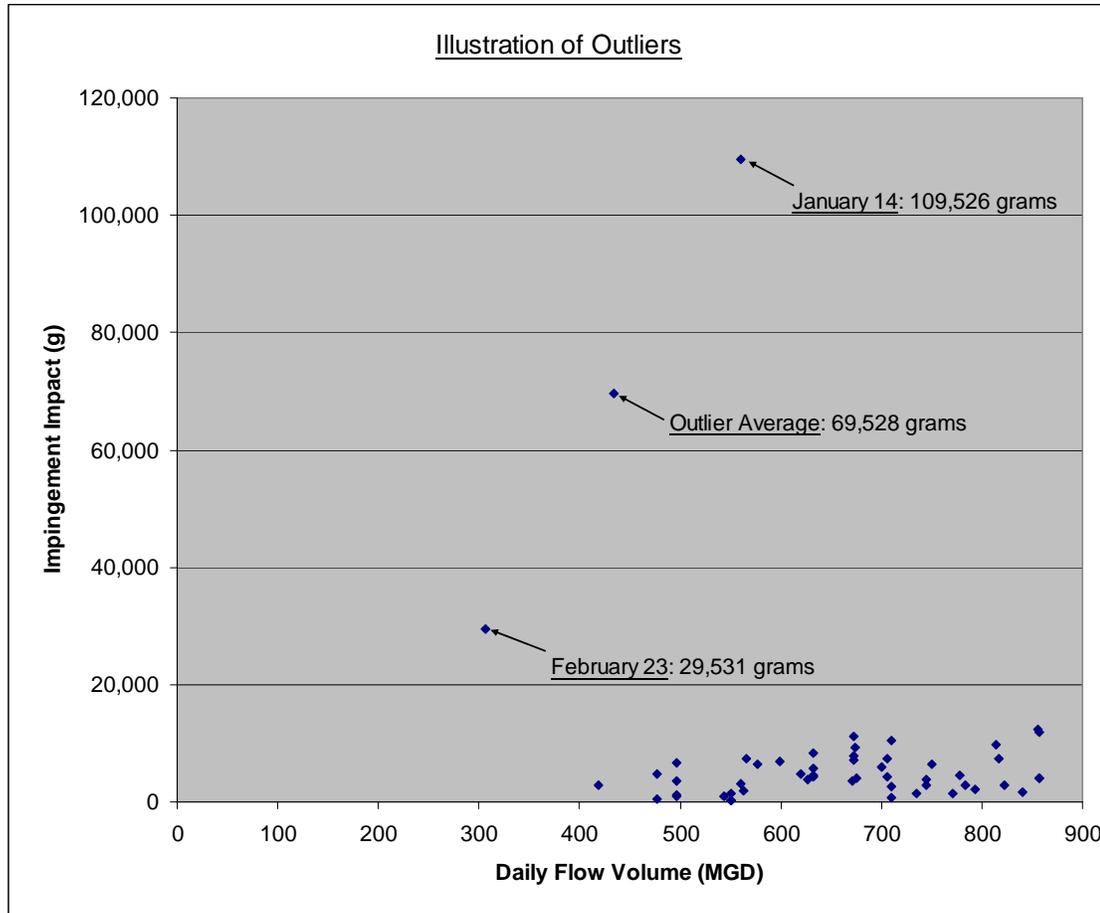
The following figure illustrates the same point graphically.

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<sup>10</sup> *Id.*

<sup>11</sup> Dr. Chang explains “that the storm events preceding January 12, 2005 have been determined to have the return period of 23.8 years, the storm events preceding February 23, 2005 have been determined to have the return period of 35.7 years.” (*Id.*)

<sup>12</sup> *Id.*



Note that the EPS flows for these days were significantly below the sampling period average of 657 MGD. In fact, the 307 MG flow value on February 23 represents the lowest volume recorded during the entire 52-week survey. Attachment 5 describes how these facts indicate that, at least for these two days, impingement was most likely the product of non-flow-related factors.

**IV. RECORD RAINFALL PRECEDING JANUARY 12 AND FEBRUARY 23 APPEARS TO BE AN IMPORTANT FACTOR RELATED TO THE RELATIVELY HIGHER IMPINGEMENT ON THOSE DAYS**

The association between (a) the extreme rainfall preceding the January 12 and February 23 sampling events, and (b) the atypical impingement values recorded on those days suggests that the increased impingement is related to the heavy rains. This apparent relationship is supported by the fact that a number of freshwater fishes were collected on those days—and on those days only. Freshwater runoff from Agua Hedionda Creek may have transported these freshwater fish into the lagoon, where they may have become susceptible to impingement, possibly because of pre-impingement mortality.

The precise extent and nature of this relationship between record rainfall and atypical impingement remains unclear. The heavy rains may have increased impingement in several different ways. For instance, the rains may have affected water quality and/or salinity levels at

or near the intake. They may have washed pollutants into the lagoon in the form of urban runoff. And/or they may have flushed freshwater species into the saltwater lagoon. There is insufficient scientific evidence upon which to draw any definitive conclusions with respect to the exact nature of the relationship.

**V. ASSUMING THAT THE EXTRAORDINARY RAIN EVENTS WILL RECUR EVERY YEAR OVERESTATES THE POTENTIAL FOR IMPINGEMENT**

**A. Four of the Previously Submitted Impingement Estimates Assume that the Outlier Events Will Occur 14 Days Per Year, Every Year**

Attachment 5 introduces five estimation approaches, all except one of which (i.e., Regression Approach 1-A) include the outlier data. The following table shows algebraically how these approaches treat the outliers to calculate the CDP’s daily impingement estimates.

<b><u>Approaches</u></b>	<b><u>Expression:</u></b> CDP’s Daily Impingement = ...
Regression (1-A)	<i>Regression value for typical events [excludes outliers]</i>
Regression (1-B)	<i>((regression value for typical events x 50) + (average for outliers x 2))/52</i>
Equivalence (2)	<i>((average for typical events x 50) + (average for outliers x 2))/52</i>
Proportional (3-A)	<i>((flow-proportioned average for typical events x 50) + (flow-proportioned average for outliers x 2))/52</i>
Proportional (3-B)	<i>((flow-proportioned average for typical events x 50) + (average for outliers x 2))/52</i>

Thus, the four approaches that account for outliers each assumes that that the 2004/2005 sample properly represents the incidence and extent of the non-flow-related events. Except for Regression Approach 1-A, all approaches assume that there is a 100% probability that every year will include fourteen days (i.e., 2/52 x 365) when impingement will equal the average of the impingement values recorded on the two outlier days (i.e., 69 kg/day).<sup>13</sup> The following table identifies the probability assumption for each of the four approaches:

<b><u>Approaches</u></b>	<b><u>Expression:</u></b> CDP’s Daily Impingement = ...
Regression (1-B)	<i>((regression value for normal events) x (52 – 2 x P<sub>outliers</sub>) + ((average for outliers) x (2 x P<sub>outliers</sub>)))/52</i>
Equivalence (2)	<i>((average for normal events) x (52 – 2 x P<sub>outliers</sub>) + ((average for outliers) x (2 x P<sub>outliers</sub>)))/52</i>
Proportional (3-A)	<i>((flow-proportioned average for normal events) x (52 – 2 x P<sub>outliers</sub>) + ((flow-proportioned average for outliers) x (2 x P<sub>outliers</sub>)))/52</i>

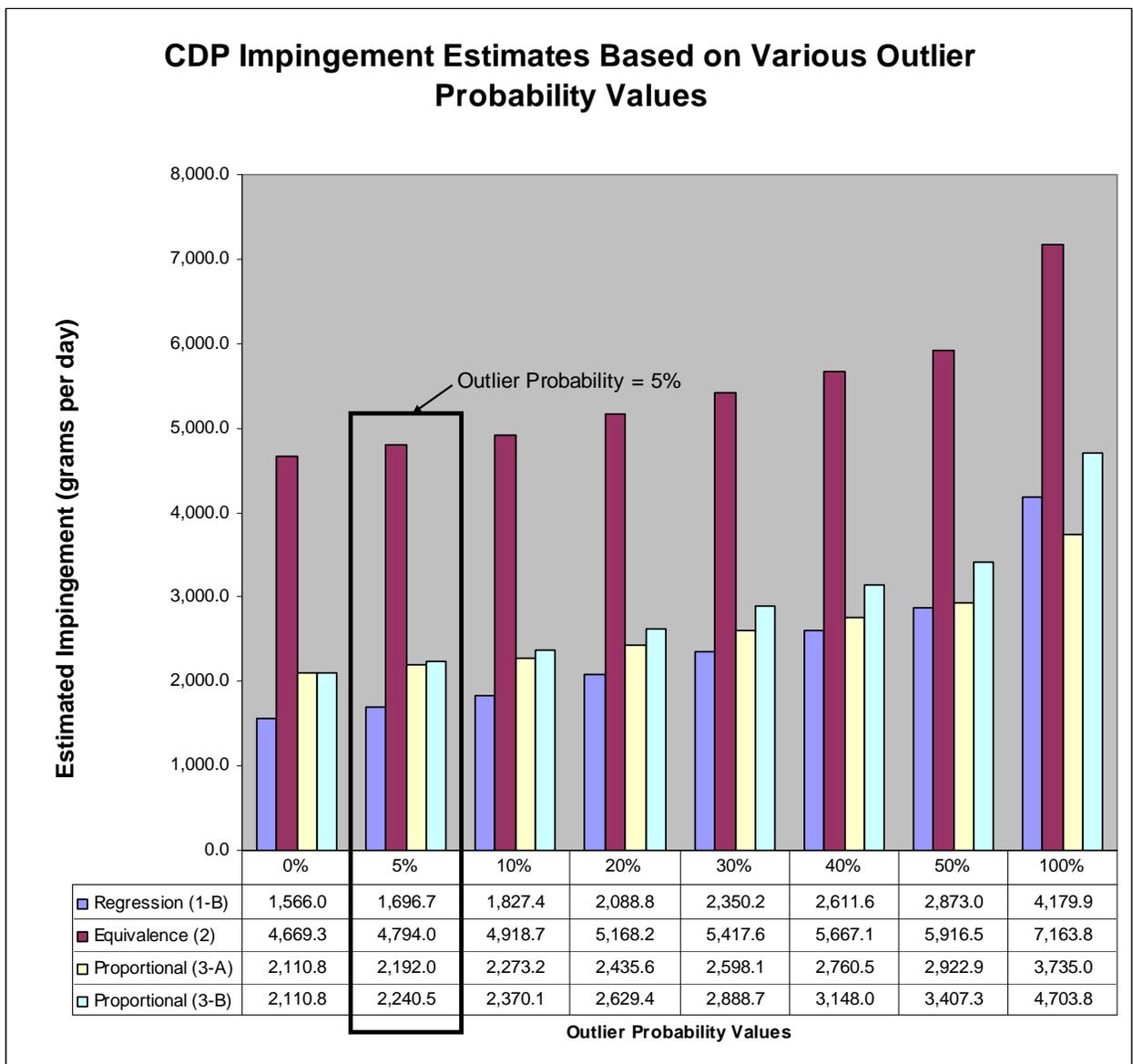
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<sup>13</sup> Proportional Approach 3-A would discount this value by the CDP’s reduced flow volume.

Proportional (3-B)	$\frac{((\text{flow-proportioned average for normal events}) \times (52 - 2 \times P_{\text{outliers}}) + ((\text{average for outliers}) \times (2 \times P_{\text{outliers}})))}{52}$
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**B. It Would Be Reasonable for Each of the Four Approaches to Discount the Outlier Events in Accordance with Their Likelihood of Recurrence**

A reasonable estimate of the CDP’s stand-alone impingement would discount the non-flow-related events by their probability of occurrence ( $P_{\text{outliers}}$ ). Theoretically, the outlier probability value could range from between 0% and 100%. Depending on the value that is assigned to  $P_{\text{outliers}}$ , the various approaches produce the following grams per day estimation ranges for impingement:



In the graph and table above, the overall impingement estimate contained in the March 9 submittal is equivalent to the far-right column, in which it is assumed that the outliers have a probability of recurrence of 100%. In other words, the outlier events were treated as having the same probability of recurrence as typical, routine events, which in fact are highly likely to recur annually. This approach fails to reflect that the sampling data set consists of two subpopulations of events – the rare events corresponding to January 12 and February 23, and the other 50 events.

The graph and table above demonstrate how the impingement estimates are a strong function of how the outlier events are treated. The estimated range of impingement is 3.7 to 7.2 kg/day when the outliers are treated like typical events, and 1.6 to 4.7 kg/day if the outliers are ignored altogether. Note how the outlier events contribute very little to long-term, projected impingement if their probability of recurrence is in the 5% to 10% range. This is because, under such scenarios, their influence in essence is spread over many years. This may be a sound approach for project planning purposes, as it enables unusual events to be taken into account when assessing project mitigation, but not allowing an overstatement of rare events to disproportionately influence mitigation obligations.

**C. It Is Reasonable to Assume that the Outlier Probability Is Less than 5%**

The analyses of Drs. Chang and Jenkins suggest that the various estimation approaches overstate the influence of the outlier events by assuming that similar rain events will occur every year (i.e.,  $P_{\text{outliers}} = 100\%$ ). The obvious problem with this assumption is that twenty-five and thirty-five year storms do not occur every year.

Given that: (a) the survey outliers were apparently influenced by the extreme storms, and (b) the likelihood of comparable storms occurring in any given year is less than 5% according to experts Dr. Chang and Dr. Jenkins, it is reasonable to assume that the outlier probability value is less than 5%. If we assume that the outlier impingement values were associated with the record rainfall and that said rainfall has a probability of occurrence of no more than 5% (i.e., occurs less than once every 20 years), the outlier average should be discounted by its probability. This results in the following stand-alone, upper bound impingement estimates:

<u>Approaches</u>	$P_{\text{outliers}} = 5\%$
Regression (1-B)	Less than 1.70 kg/day
Equivalence (2)	Less than 4.80 kg/day
Proportional (3-A)	Less than 2.20 kg/day
Proportional (3-B)	Less than 2.24 kg/day

**VI. CONCLUSION**

Attachment 5 concluded that the weighted-average flow-proportioned approach (i.e., Proportional (3-B)) provides a reasonable basis for estimating the CDP's stand-alone

impingement because it (a) treats the flow-independent outliers separately, (b) accounts for the relationship between flow and impingement, and (c) discounts for the fact that the intake flow velocities during stand-alone operations will be lower than the velocities that occurred during the sampling period. For these reasons, the data and analyses of Drs. Chang and Jenkins support Proportional Approach 3-B as an appropriate estimation model.

The hydrologic research of Drs. Chang and Jenkins add depth to the prior analysis by placing the outlier events in context. They establish that the extreme storms that preceded the January 12 and February 23 samples were very rare.

These conclusions inform the estimation models. Because the rains preceding the two outlier collection events can be expected to occur less than once every 20 years (i.e., less than 5%), the weight of the outliers should be discounted accordingly. When the weighted-average flow-proportioned approach (3-B) incorporates an outlier probability value of less than 5%, the approach calculates an impingement estimate of less than 2.24 kg/day, with 2.24 providing a reasonable upper bound. This value provides a reasonable approximation of the CDP's potential impingement.

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**FLOW, ENTRAINMENT AND IMPINGEMENT MINIMIZATION PLAN**

**ATTACHMENT 9-A - FREQUENCIES FOR STORM EVENTS**

**OF JANUARY AND FEBRUARY 2005, submitted by Dr. Howard H. Chang, Ph.D., P.E.**

**(March 19, 2009)**

**March 26, 2009**

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## FREQUENCIES FOR STORM EVENTS OF JANUARY AND FEBRUARY 2005

Prepared for Poseidon

Prepared by  
Howard H. Chang, Ph.D., P.E.



March 19, 2009

### EXECUTIVE SUMMARY

A hydrology study has been made to determine the discharges of Agua Hedionda Creek on January 12 and February 23, 2005. The discharges were determined by hydrologic simulation of stream flows using rainfall data and the Agua Hedionda Creek watershed model. The January 12<sup>th</sup> stream flow has been determined to have a return period of 25.8 years; and the February 23<sup>rd</sup> flow has a return period of 35.7 years. Such stream flows with long recurrence intervals are very rare events. Two such rare events occurred in early 2005. The probability of surpassing two such large events in any particular year is only 0.12%, or 1.2 times in 1,000 years. It was an extremely rare combination of stream flows.

Total rainfall for 2004-5 was about 26 inches for the area, far exceeding the long-term average of about 13 inches. The stream flows on January 12 and February 23 are far outliers. After discarding the two outliers, the weekly impingement sampling events captured a sufficient number of storm runoff events to reflect typical wet weather conditions for the watershed. Since the remaining rainfall amount still far exceeds the annual average, there was a sufficient number of storms to be representative of a typical, twelve-month period.

### QUALIFICATIONS

I am a registered civil engineer with a specialty in hydrology. I have practiced hydrology in this region for over 40 years. I prepared the hydrology study covering northeastern Carlsbad in 1989 (Chang, 1989). This study has since been used by the City as the standard for stream flows of Agua Hedionda Creek and Calavera Creek. My curriculum vitae is attached.

## INTRODUCTION

Certain questions have been raised by the staff of the Regional Water Quality Control Board regarding the data used to support Poseidon's Impingement and Entrainment Assessment for the Agua Hedionda Lagoon. The staff questioned whether the sampling set is skewed because the data were collected during a year that was atypical with regard to rainfall.

The purpose of this study is to determine the frequencies of two unusually large storm events that occurred prior to January 12 and February 23 of 2005. Relatively higher impingement on these two dates may have been related to the fresh water flow in Agua Hedionda Lagoon, which receives freshwater inflows primarily from Agua Hedionda Creek and Calavera Creek.

## METHOD OF STUDY

In a natural stream without stream gages, hydrological simulation is the standard, and generally accepted, method for determining the stream flow. Hydrologic simulation uses the rainfall data and the drainage basin characteristics to generate the stream flow at selected points of concentration. More details of using this method as applied to the Agua Hedionda Creek basin are described below:

Rainfall Records of 2005 - I contacted the County of San Diego for the 2005 rainfall data. For the Agua Hedionda watershed, rainfall data for the periods of January and February 2005 were obtained from the following gaging stations:

- Oceanside Pumping Plant, Thomas Guide p.1086, D5, corner of Jones Rd and San Luis Rey Rd.
- Agua Hedionda, Thomas Guide p.1107, B7, SW corner of El Camino Real and Cannon Rd. Station installed Feb 4, 2005
- Carlsbad AP, Thomas Guide p.1127, D2, central N side of McClellan Palomar AP
- Deer Springs, Thomas Guide p.1089, C7, Mesa Rock Rd at the Deer Springs Fire Station

These are the County stations that are inside and immediately surrounding the Agua Hedionda watershed. The records in the attached spreadsheet represent individual bucket tips (0.04" resolution) that were received by a radio at the County office. The rainfall data have been analyzed to determine the 24-hr total rainfall for the time period immediately before January 12 and February 23. The results for these two dates are tabulated in Tables 1 and 2. The rainfall collected at the reference stations for the period beginning July 1, 2004 and ending June 30, 2005 is tabulated in Table 3. As noted in Table 3, total rainfall for 2004-5 was about 26 inches for the area, far exceeding the long-term average for the Agua Hedionda watershed of about 13 inches.

Table 1. 24-hr Rainfall Immediately Before January 12, 2005

<u>Gaging station</u>	<u>Rainfall depths, inches</u>
Agua Hedionda	---
Carlsbad AP	1.12
Deer Springs	2.20
Oceanside Pumping Station	1.40
Average of three readings	1.57

Table 2. 24-hr Rainfall Immediately Before February 23, 2005

<u>Gaging station</u>	<u>Rainfall depths, inches</u>
Agua Hedionda	2.12
Carlsbad AP	2.08
Deer Springs	2.04
Oceanside Pumping Station	2.00
Average of four readings	2.06

Table 3. Total Rainfall 2004-2005<sup>1</sup>

<u>Gaging station</u>	<u>Rainfall depths, inches</u>
Agua Hedionda	---
Carlsbad AP	24.95
Deer Springs	27.81
Oceanside Pumping Station	26.39
Average of three readings	26.39

Antecedent Moisture Conditions (AMC) – The stream flows of January 12 and February 23 were both preceded by at least five days of heavy rainfall. It is easy to see from the rainfall tabulations that unusual amounts of rainfall occurred preceding these two dates. For this reason, we had very wet antecedent moisture conditions, for which the AMC number is 3.

Hydrological Simulation - This hydrology study is guided by, and consistent with, the Hydrology Manual of the County of San Diego. As specified in the manual, the SCS method for hydrology is applied to drainage basin that is larger than 0.5 square miles in surface area. For this study, the HEC-1 computer model developed by the U. S. Army Corps of Engineers that applies the SCS method was used.

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<sup>1</sup> The rainfall collected at the Agua Hedionda and Oceanside stations is for the period beginning July 1, 2004 and ending June 30, 2005; data for the Deer Springs Station is for the period beginning November 1, 2004 and ending June 30, 2005.

Hydrological simulation for the storm events that preceded the January 12 and February 23 sampling events have been made using the HEC-1 model.<sup>2</sup> This model is used extensively by engineers for hydrologic simulation of watersheds, and is a generally accepted method for this purpose. This model was used in the 1989 Chang study for northeastern Carlsbad, and is considered to provide an appropriate means by which to simulate rainfall/runoff in the subject watershed.

The hydrologic simulation is based on the rainfall, delineation of the drainage basin and hydrologic parameters for the selected subbasins. For the purpose of hydrological computation, certain basin characteristics are required. Such characteristics include the basin and subbasin areas, precipitation zone number (PZN), antecedent moisture condition (AMC), precipitation amounts for the 24-hr. storms, SCS curve number (CN), lag time, etc. Since the drainage basin of the Agua Hedionda Creek is large, the 24-hour storm produces greater flows than the 6-hour storm. For this study, we used the same hydrologic parameters that were used in the 1989 hydrology study for Agua Hedionda Creek. The rainfall depths and AMC values were changed according to the 2005 storm conditions.

Summary of Results – The peak discharges for Agua Hedionda Creek just before the Calavera Creek confluence have been obtained to be 2,715 cfs for the storm events leading up to January 12, and 3,609 cfs for the storm events leading up to February 23. At this point of concentration, the drainage basin area for Agua Hedionda Creek is 17.3 square miles. Input/output listings for the HEC-1 runs are attached to this report.

In order to determine the occurrence frequency of these two storm events, their peak discharges were compared with the FEMA-adopted peak discharges for Agua Hedionda Creek taken from the FEMA publication “Flood Insurance Study”, 1999. Table 4 lists the FEMA-adopted discharges at two points of concentration along Agua Hedionda Creek. The FEMA-adopted discharges are for the developed, or ultimate, conditions of the watershed. The table also has the discharge for the current (existing) conditions of the watershed.

Table 4. FEMA-Adopted Peak Discharges along Agua Hedionda Creek

Point of Concentration	Basin Area	Peak Discharge in cfs		
		10-yr	50-yr	100-yr
At confluence with Buena Creek (ultimate)	6.3	1,600	4,800	7,000
Upstream of Calavera Creek (ultimate)	17.3	---	---	8,080
Upstream of Calavera Creek (existing)	17.3			6,366

From this study, the stream flow resulting from the storm events prior to January 12<sup>th</sup> has the peak discharge of 2,715 cfs. The peak discharge for the stream flow from the storm events prior to February 23 has the value of 3,609 cfs. The return periods of these events may be determined from the log-probability paper shown in Fig. 1. The peak discharge versus frequency relation for stream flows in this region follows the long-normal distribution. The return period is

<sup>2</sup> See <http://www.hec.usace.army.mil/software/legacysoftware/hecl/hecl.htm> for documentation and software.

the reciprocal of the frequency. The storm return period is plotted against the peak discharge as a straight line on the log-probability paper. Fig. 1 shows one straight line for the concentration point at the confluence with Buena Creek and two straight lines for the concentration point just upstream of Calavera Creek.

The discharges of the stream flows from the storm events preceding January 12 and February 23 are plotted on line 3 in Fig. 1 as Point A and Point B, respectively. Point A has the frequency of 4.2. In other words, the January 12<sup>th</sup> flow occurs 4.2 times in 100 years. The return period, as the reciprocal of the frequency, is therefore 23.8 years. Point B for the February 23<sup>rd</sup> flow has the frequency 2.8, for which the return period is 35.7 years.

In summary, the probability to have a storm with the peak discharge greater than 2,715 cfs in a year is 4.2 %. The probability that a storm discharge of 3,607 cfs would be exceeded in any given year is 2.8%. Both events have low probabilities of occurrence; they are rare events. Two such rare events occurred in early 2005. The probability for two events to be exceeded in a year is the product of the two probabilities. In this case, the probability of having two such events in any given year =  $0.042 \times 0.028 = 0.0012$ , or 0.12 %

In conclusion, the storm events preceding January 12, 2005 have been determined to have the return period of 23.8 years, the storm events preceding February 23, 2005 have been determined to have the return period of 35.7 years. Such storms are very rare events. The probability of surpassing two such large events in year is only 0.12%, or 1.2 times in 1,000 years.

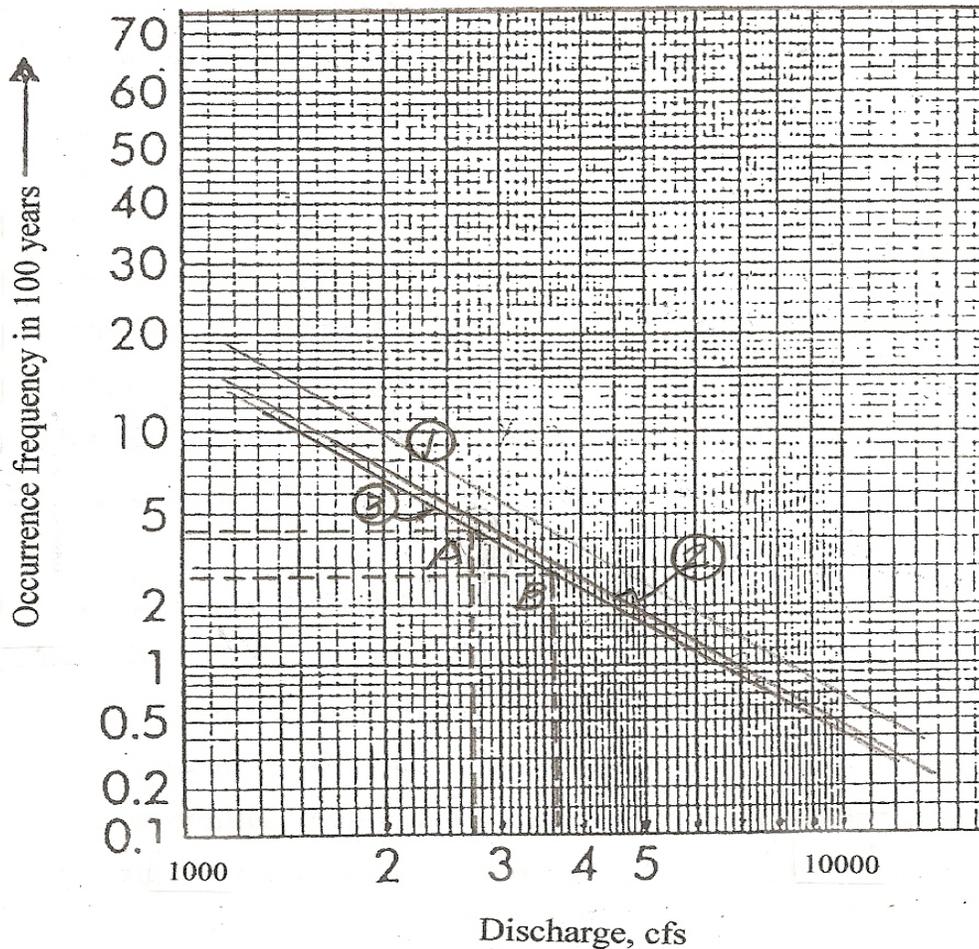


Fig. 1. Log-probability relations of frequency-discharge for Agua Hedionda Creek  
 Line 1: At confluence with Buena Creek (ultimate)  
 Line 2: Upstream of Calavera Creek (ultimate)  
 Line 3: Upstream of Calavera Creek (existing)  
 Point A: Storm of January 12, 2005  
 Point B: Storm of February 23, 2005

The distribution of mean annual rainfall in San Diego County is shown in Fig. 2. The mean annual rainfall for the Agua Hedionda Creek watershed varies from 11.5 inches at the coast to 15 inches at the eastern boundary. The total rainfall for 2004-5 was about 26 inches for the area, far exceeding the long-term average of about 13 inches. The storms of January 12 and February 23 are far outliers. After discarding the two outliers, the weekly impingement sampling events captured a sufficient number of storm runoff events to reflect typical wet weather conditions for the watershed. Since the remaining rainfall amount still far exceeds the annual average, there was sufficient number of storms to be representative of a normal twelve month period.



## REFERENCES

Chang, Howard H., “Hydrological Study for Northeastern Carlsbad – Basins of Calavera Lake Creek and Agua Hedionda Creek”, July 1989.

FEMA, “Flood Insurance Study – San Diego County”, Volume 1 of 7, 1999.

## ATTACHMENTS

This report has the following attachments:

JAN12.OUT: Hydrologic simulation for the Agua Hedionda watershed model  
based on the January 12, 2005 storm

FEB23.OUT: Hydrologic simulation for the Agua Hedionda watershed model  
based on the February 23, 2005 storm

## 2005 RAINFALL DATA

CHANGCV.DOC: Curriculum vitae of Howard H. Chang

**CARLSBAD SEAWATER DESALINATION PROJECT**

**SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD**

**REGION 9, SAN DIEGO REGION**

**ORDER NO. R-9-2006-0065**

**NPDES NO. CA0109223**

**FLOW, ENTRAINMENT AND IMPINGEMENT MINIMIZATION PLAN**

**ATTACHMENT 9-B - STATEMENT ADDRESSING REGIONAL BOARD STAFF  
CONCERNS REGARDING THE BIOLOGICAL DATA USED TO SUPPORT  
POSEIDON'S IMPINGEMENT AND ENTRAINMENT ASSESSMENT, submitted by Dr.**

**Scott A. Jenkins, Ph.D. (March 19, 2009)**

**March 26, 2009**

# **Statement Addressing Regional Board Staff Concerns regarding the Biological Data Used to Support Poseidon's Impingement and Entrainment Assessment**

**Prepared by Scott A. Jenkins, Ph.D.**

3/19/09

## **PURPOSE OF STATEMENT**

Poseidon asked me to address certain questions raised by staff in staff's April 4, 2008 technical report. Specifically, staff state therein:

“This sampling set is likely to be skewed because it does not account for annual variability and the data were collected during a year that was atypical with regards to rainfall.”

I examined these concerns prior to my testimony before the Board at the April 9, 2008 meeting. I submitted a written statement to the Board on 26 January 2009 that memorializes that testimony. Since that time, new information has come to my attention that allows me to perform a more in-depth analysis of these concerns. The statement below presents that new analysis and elaborates on relevant sections of my 26 January 2009 statement.

## **QUALIFICATIONS**

I earned a B.S. in Chemistry at Yale University and a Ph.D. in Physical Oceanography at University of California, Scripps Institution of Oceanography. I am presently a Principal Engineer at the Scripps Institution of Oceanography where I have been employed since the age 16. I have 30 years experience in coastal process and have published research in the *Journal of Geology* that is specifically relevant to this statement (see, Inman, D. L. & S. A. Jenkins, 1999, “Climate change and the episodicity of sediment flux of small California rivers,” *Jour. Geology*, v. 107, p. 251–270). That research discovered a relation between climate cycles and rainfall, stream flow and sediment flux of small California rivers. In addition, I have provided consulting services in wetlands tidal hydraulics and restoration, beach erosion, as well as more generally hydrodynamics, aerodynamics and pollution dispersion in nearshore waters, harbors and estuaries (services include field measurements and numerical modeling). I have authored 23 peer reviewed publications, 47 conference proceedings and technical publications and 60 technical reports. A true and correct copy of my Curriculum Vitae is attached. The opinions expressed here are based on my education and experience including 29 years of studying tidal exchange and sediment transport in the Agua Hedionda Lagoon.

## **ROLE ON THIS PROJECT**

I performed hydrodynamic modeling for Poseidon Resources of the brine dispersion and dilution from the Carlsbad Desalination Plant and tidal transport analysis of the effect the

CDP might have on Agua Hedionda Lagoon water quality, sand influx into the Lagoon and historic variations of water levels in the Lagoon over multi-decadal climate cycles.

## **SUMMARY STATEMENT**

Staff is correct that the year in which the Impingement & Entrainment data were collected was an above-average year for rainfall in the relevant vicinity. This turns out to be a benefit of the field program – not a problem. The field program captured not only typical lagoon conditions and variability, but also two events that were atypical and which have a very low probability of occurring in any given year. This enabled me to examine whether such events skewed the results of the overall program. Such was not the case. The lagoon rebounds quickly from depressed salinities associated with extreme events. Lagoon salinity does not appear to have been depressed on a persistent basis by these extreme events. While infrequent extreme events depress salinity more than typical rainfall-runoff conditions, the effect is transient.

I have examined the relevant characteristics of rainfall-runoff affecting Agua Hedionda Lagoon during the period of the field studies, June 2004-May 2005. The timing of this study was ideal (even fortuitous) because it spanned the full range of natural hydrologic variability, and yet average, long-term water quality properties in the lagoon remained normal during the June 2004-May 2005 study period. The lagoon recovers rapidly from extreme hydrologic impacts associated with rainfall and runoff because it holds a large volume of seawater to dilute the storm water, and, has excellent tidal flushing that limits the residence time of storm water. Over the year-long period of sampling, the rainfall and runoff were neither intense enough nor persistent enough to alter the predominately salt water environment of Agua Hedionda Lagoon on other than a transient and short-term basis. I have concluded that the rainfall-runoff did not skew the results as staff were concerned, but rather provided a comprehensive data base that captured a range of conditions, including some that are not likely to re-occur in most years.

## **DISCUSSION**

The sampling set used for Poseidon's Impingement and Entrainment Assessment is not likely to be skewed because the data were collected during a year that was atypical with regards to rainfall. While two extreme events appear to present a different condition than typically occurs in the lagoon, the effects are isolated to those events, and do not affect the utility of the remaining data set for long-range planning, and characterization of typical conditions. As discussed more fully below, the 2004-2005 rainy season provided a robust picture of impacts arising from hydrologic variability without upsetting the predominately salt water environment of Agua Hedionda Lagoon that is representative of its long-term state. The Regional Board can be confident that the sample set was robust and comprehensive and included extreme hydrologic events.

**1. The physical data indicate that the 2005 rainy season altered the predominantly salt water environment of Agua Hedionda Lagoon only on a transient basis. Ninety-**

**five percent of the time during this period, lagoon salinity exceeded 32 parts per thousand (ppt), whereas average ocean salinity is 33.5 ppt.**

Agua Hedionda Lagoon is a salt water environment populated by salt water tolerant species. The watershed draining to Agua Hedionda Lagoon consists of 18,800 acres upstream from the lagoon, which drains to the lagoon principally via the Agua Hedionda Creek. (See Figure 1). The physical data show that this watershed is too small for runoff from it to persistently alter the predominantly salt water environment of Agua Hedionda Lagoon, even in a relatively wet year such as the period from June 2004 to June 2005 when the sampling for the impingement and entrainment study was done. (See Figure 2). As a point of reference, annual rainfall totals in the Agua Hedionda Creek watershed (as measured by the NOAA/NCDC rain gage #03177 at Carlsbad Airport) average 9.05 inches. In contrast, 19.19 inches of rain fell during the Impingement & Entrainment Study according to the same gage.<sup>1</sup>

Tetra Tech (2007) prepared a comprehensive report on the Agua Hedionda Watershed water quality for the City of Vista, and Table 3 and Figure 7 of that report provide flow rate measurements for Agua Hedionda Creek for 2005-2007. Unfortunately, Tetra Tech (2007) provides no flow rate data during the first half of the impingement and entrainment study in 2004, and there were some heavy rainfall events occurring in October 2004. (See Figure 2). The missing flow rate data can be estimated from rainfall data by establishing a quantitative relationship (hydrographic rating function) between rainfall and creek discharge using the body of data that does exist for 2005-2007. Figure 3a compares the Tetra Tech (2007) daily discharge rates for Agua Hedionda Creek (shown as black crosses) against the daily rainfall (red bars) measured by NOAA/NCDC rain gage #03177 at Carlsbad Airport (cf. NWS, 2009). Note each rainfall event produces a corresponding peak discharge event in the creek, except during a portion of the winter of 2006 when no flow data was collected. Figure 3b indicates that the relation between rainfall and creek discharge rate can be expressed as a second order polynomial (hydrographic rating curve) having a coefficient of determination, R-squared = 0.80, (indicating a reasonably good fit). The polynomial can then be applied to the rainfall during the first half of the impingement/entrainment to fill in the missing creek discharge data, as shown in Figure 4. Here, the creek discharge calculated from the hydrographic rating curve (red) tends to over estimate measured creek discharge rates (black), and consequently errs on the side of caution with respect to not underestimating storm water impacts on the lagoon water quality.

Now, consider how the storm water discharge from Figure 4 is diluted in the volume of sea water in the lagoon. On average, the lagoon exchanges 1,700 acre ft. of seawater with the ocean each day through tidal flushing, and stores an average of 3,450 acre ft. of seawater. (Elwany, 2005; Jenkins and Wasyl, 2006.) Because of tidal flushing, storm water would remain in the lagoon for only 2.6 days, based on the residence time of the lagoon water mass as determined by Elwany, (2005) and Jenkins and Wasyl, (2006) using two independent methods. Applying these dilution volumes and residence times to

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<sup>1</sup> The NOAA/NCDC rain gage #03177 at the Carlsbad Airport is the closest gage to the project site that is located inside Agua Hedionda Creek watershed.

the creek discharges in Figure 4 (using the tidal hydraulics model detailed in Jenkins and Wasyl, 2006), produces the time series of lagoon salinity throughout the impingement and entrainment study shown by the green/red/cyan trace in Figure 5. Although the dilution analysis in Figure 5 is based on the assumption of a well mixed lagoon, the predicted lagoon salinity in green/red/cyan compares closely with unpublished near-surface salinity measurements (Tenera Environmental, 2009) shown as blue triangles. The lowest predicted salinity (red) in Figure 5 is 20.4 ppt and the lowest measured salinity (blue) is 20.1 ppt. However the green portions of the curve predict a number of other events of salinity depression in the lagoon when salinity measurements were not taken. Regardless, a histogram analysis in Figure 6 of the salinity variation in Figure 5 indicates that 95 % of the time, lagoon salinity exceeded 32 ppt throughout the year-long impingement and entrainment study, while average ocean salinity is 33.52 ppt (Jenkins and Wasyl, 2001, 2006). From this, I conclude that rainfall events during 2004-2005 were neither intense enough nor persistent enough to significantly alter the predominantly salt water environment of Agua Hedionda Lagoon.

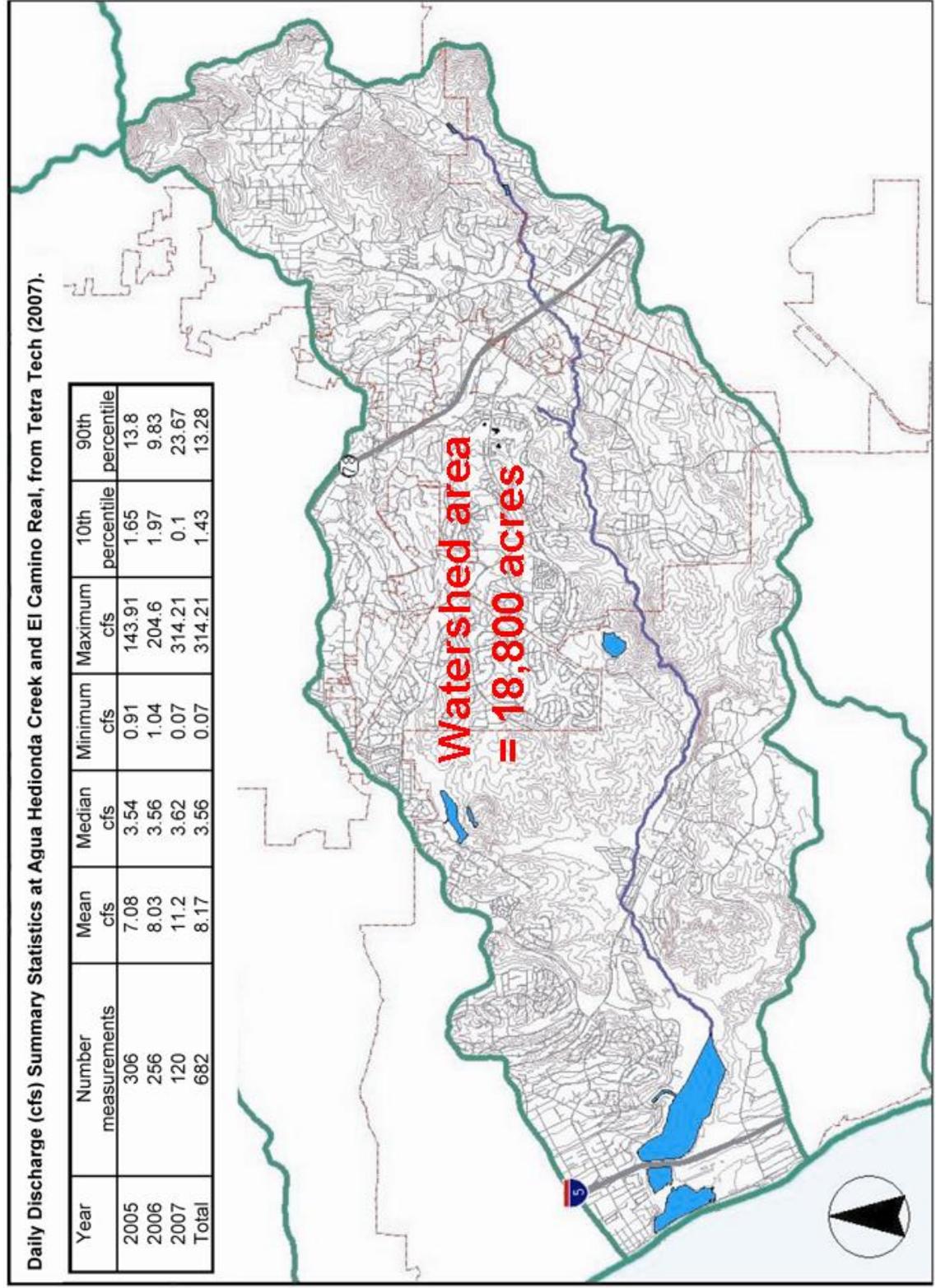
**2. The June 2004-May 2005 impingement study data include two extremely high weekly samples that contained some fresh water species. These samples are statistically anomalous because they were immediately preceded by extreme storms producing 5-day rain totals among the highest found anywhere in the period of record of the Agua Hedionda Creek watershed, with a probability of occurrence of 0.025% to 0.17%. This range compares to a probability of occurrence of 0.12% for these storms that was calculated by Dr. Howard Chang using HEC-1 hydrographic modeling of the Agua Hedionda Cr. watershed.**

The two anomalous weekly impingement samples were taken on 12 January 2005 and 23 February 2005. One sample contained 109.5 kg and the other contained 29.5 kg. In comparison, the average impingement excluding these outliers was only 4.7 kg. Among the fish collected on these dates were catfish and possibly other fresh water species. Both samples were preceded by extreme event storms, each producing five continuous days of rainfall shown as cyan bars in Figure 2. The five-day rain totals preceding the 12 January 2005 samples were the highest 5-day rain totals found anywhere in the period of record of the Agua Hedionda Creek watershed, totaling 4.01 inches with a probability of occurrence of 0.025%. The 23 February 2005 samples were preceded by 5-day rainfall totals that are the eighth highest in the period of record, 3.24 inches with a probability of occurrence of 0.17%. So rare were these two events that a four-decade log-scale was required to render them visible in the histogram of the period of record of the NOAA/NCDC rain gage #03177 at Carlsbad Airport in Figure 7.

The salinity depression in the lagoon caused by these two 5-day storms is shown in cyan in Figure 6. Although these two storms produced the lowest salinity observed during the impingement and entrainment study, these salinity depressions were short-lived. This affirms the value of using the impingement and entrainment study database to identify and quantify both the magnitude and duration of the reaction of the lagoon habitat to the full range of natural hydrologic variability, while still providing a long-term baseline in response to the average hydrologic state.

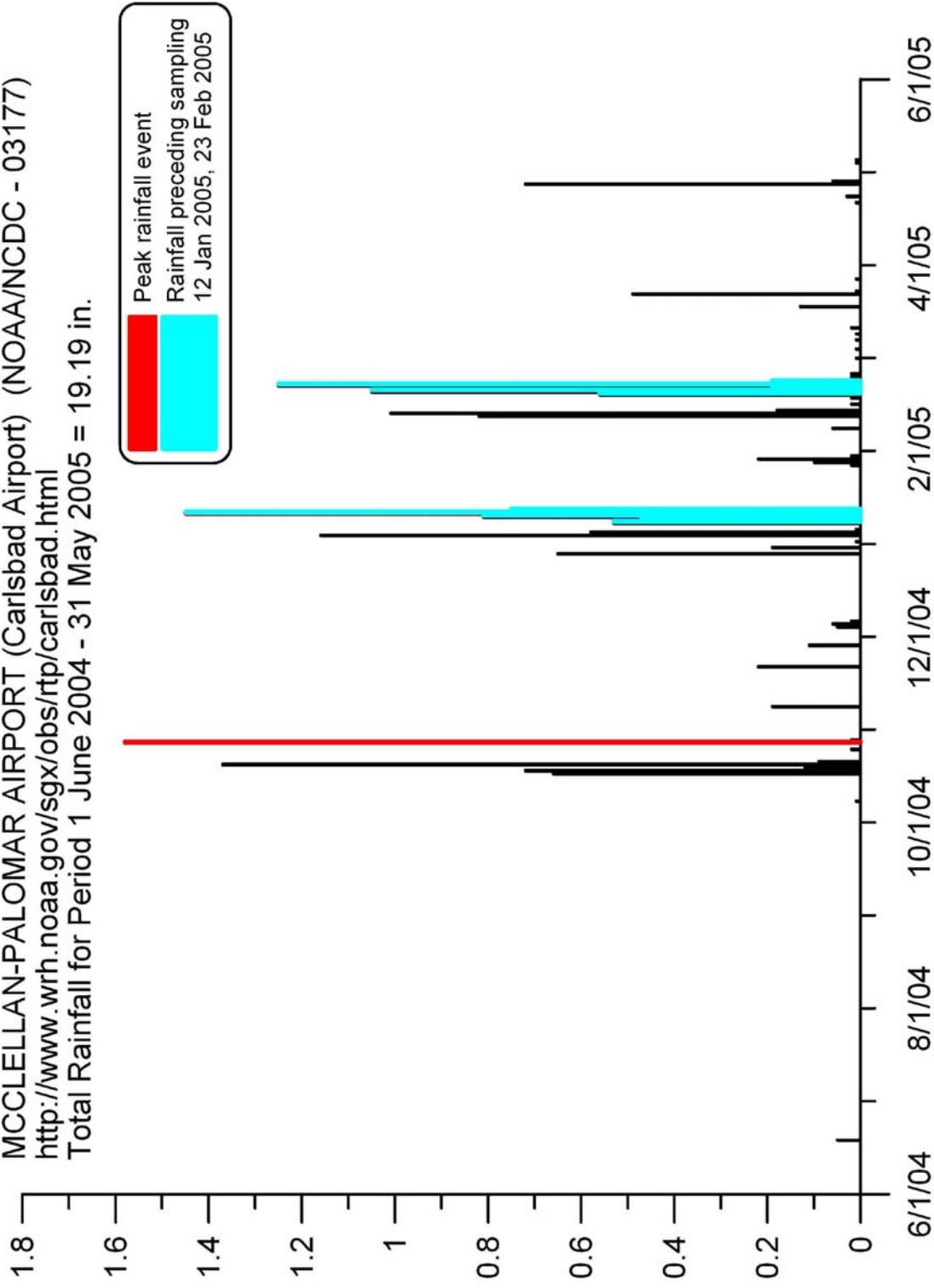
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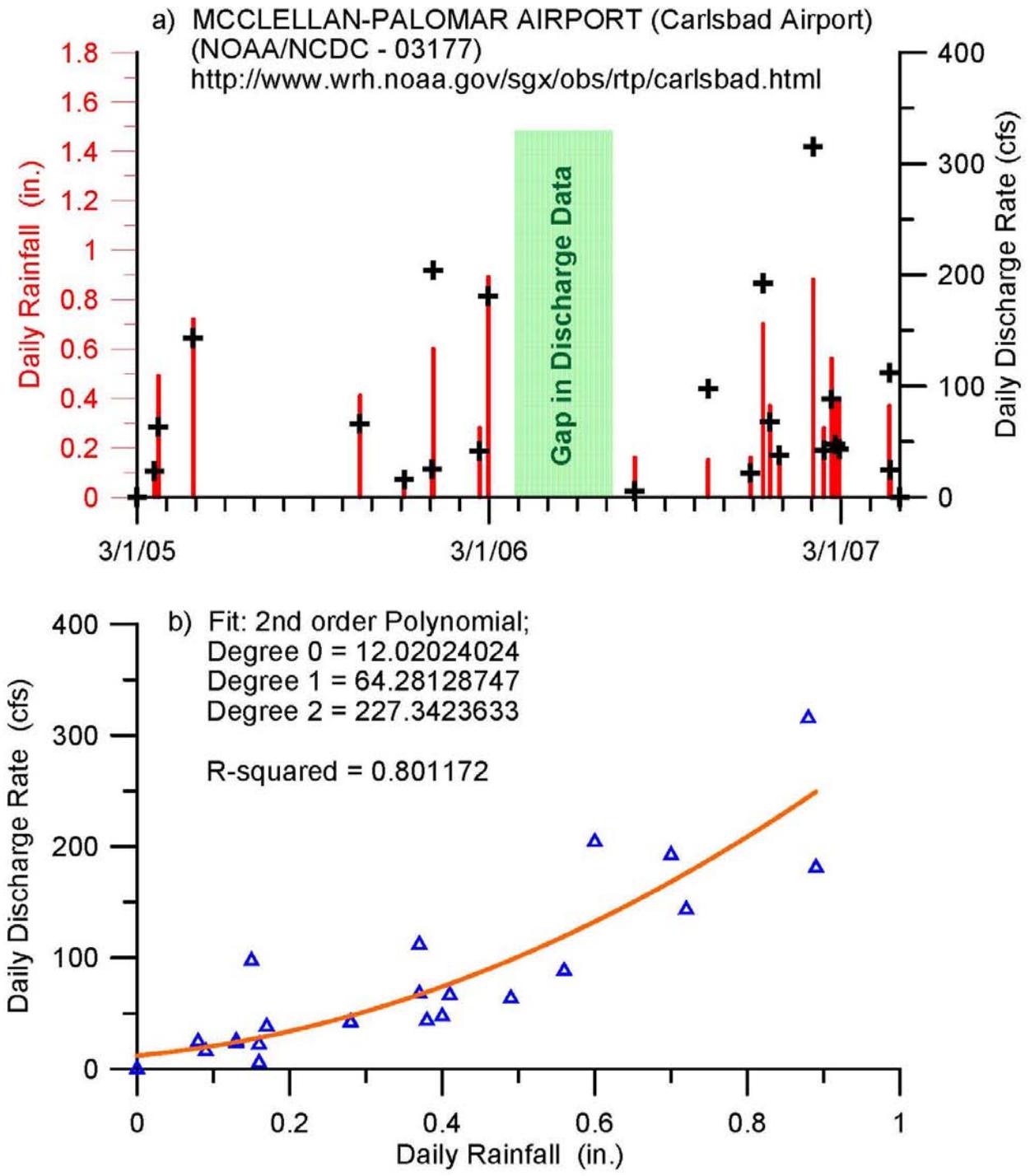


**Figure 1. Flow Statistics of Agua Hedionda Creek Watershed, 2005-2007.**

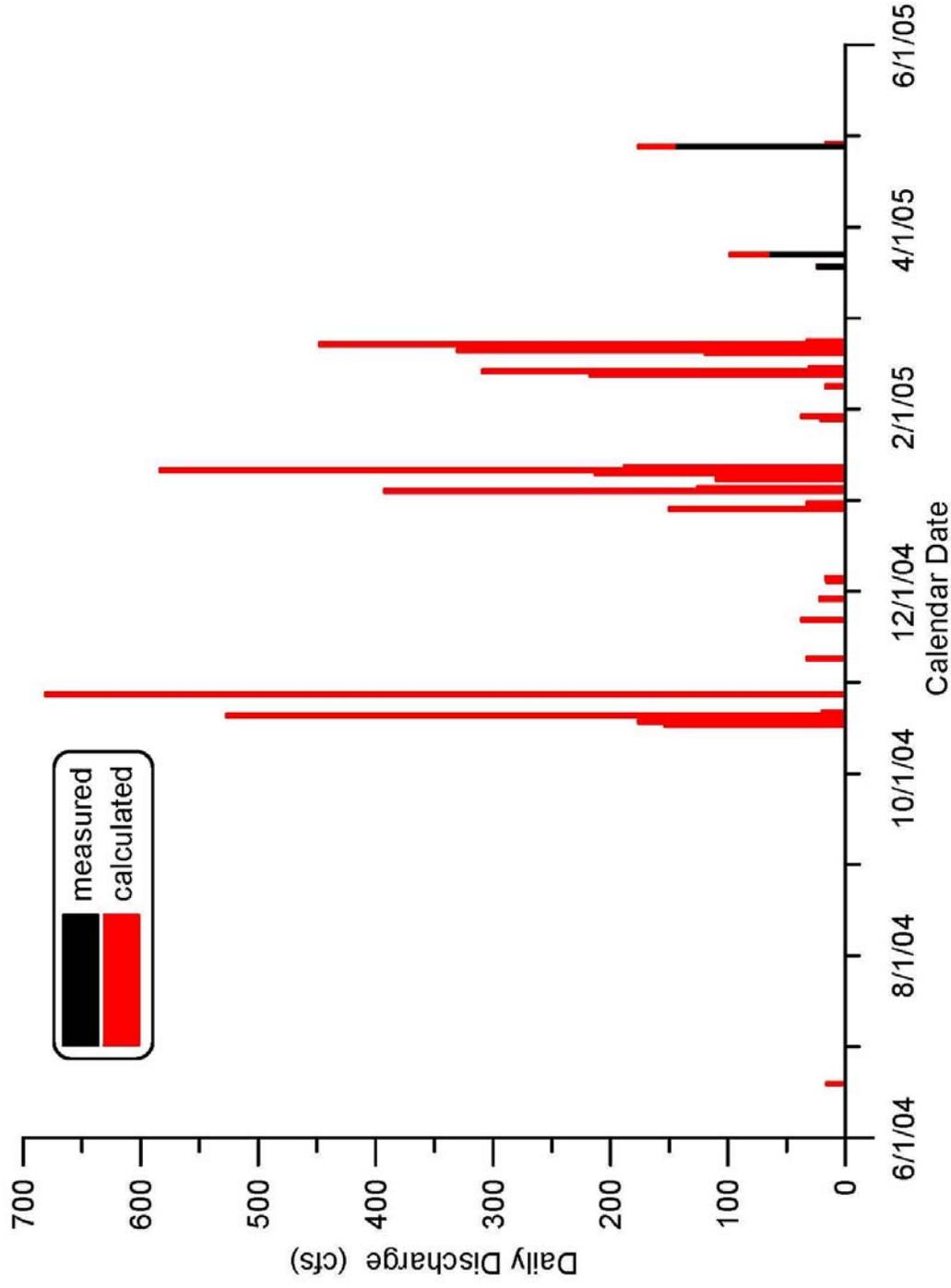
MCCLELLAN-PALOMAR AIRPORT (Carlsbad Airport) (NOAA/NCDC - 03177)  
<http://www.wrh.noaa.gov/sgx/obs/rtp/carlsbad.html>  
 Total Rainfall for Period 1 June 2004 - 31 May 2005 = 19.19 in.



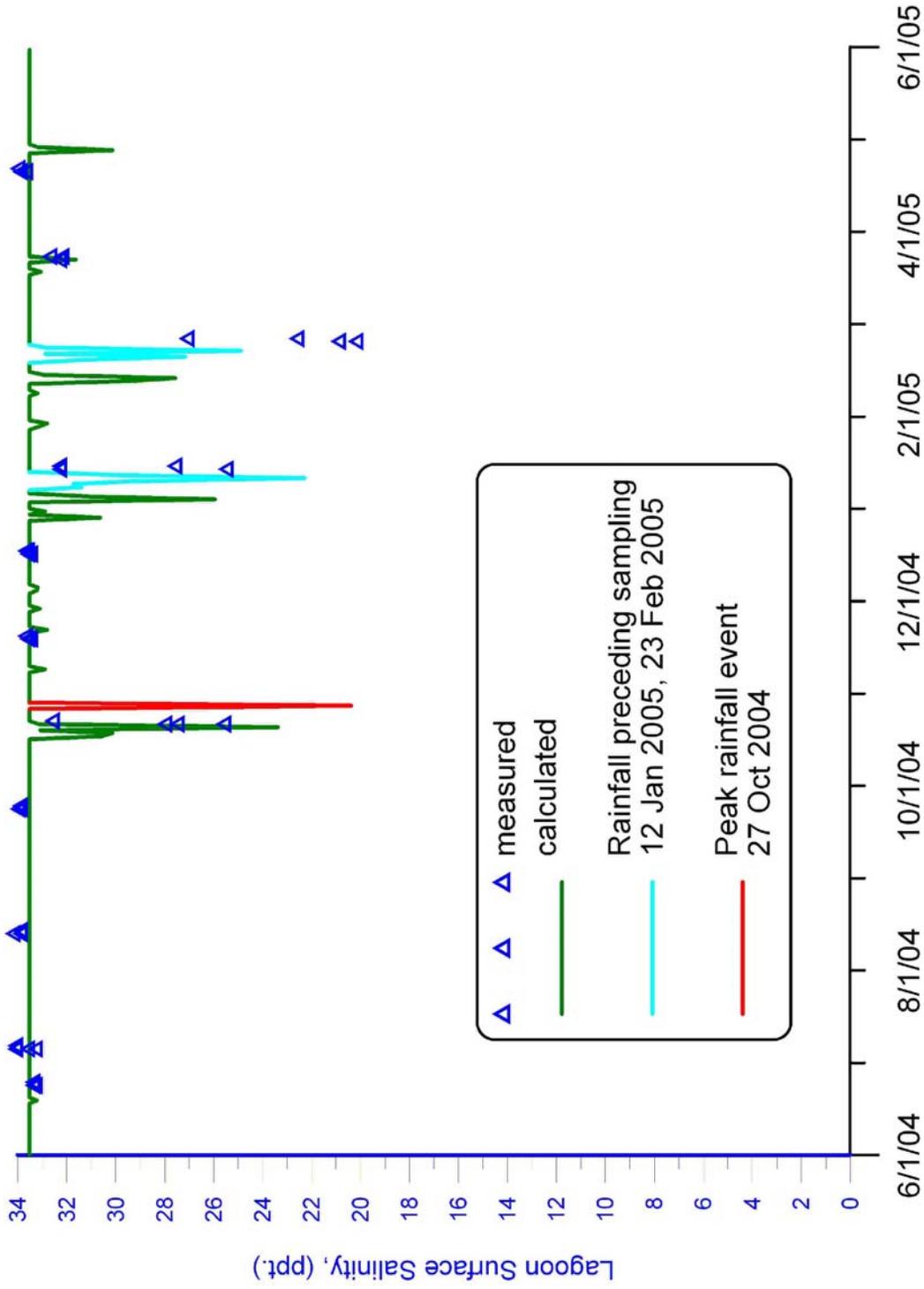
**Figure 2.** Rainfall history during entrainment / impingement study: 1 June 2004 - 31 May 2005. NOAA/NCDC rain gauge #03177, Carlsbad Airport, CA.



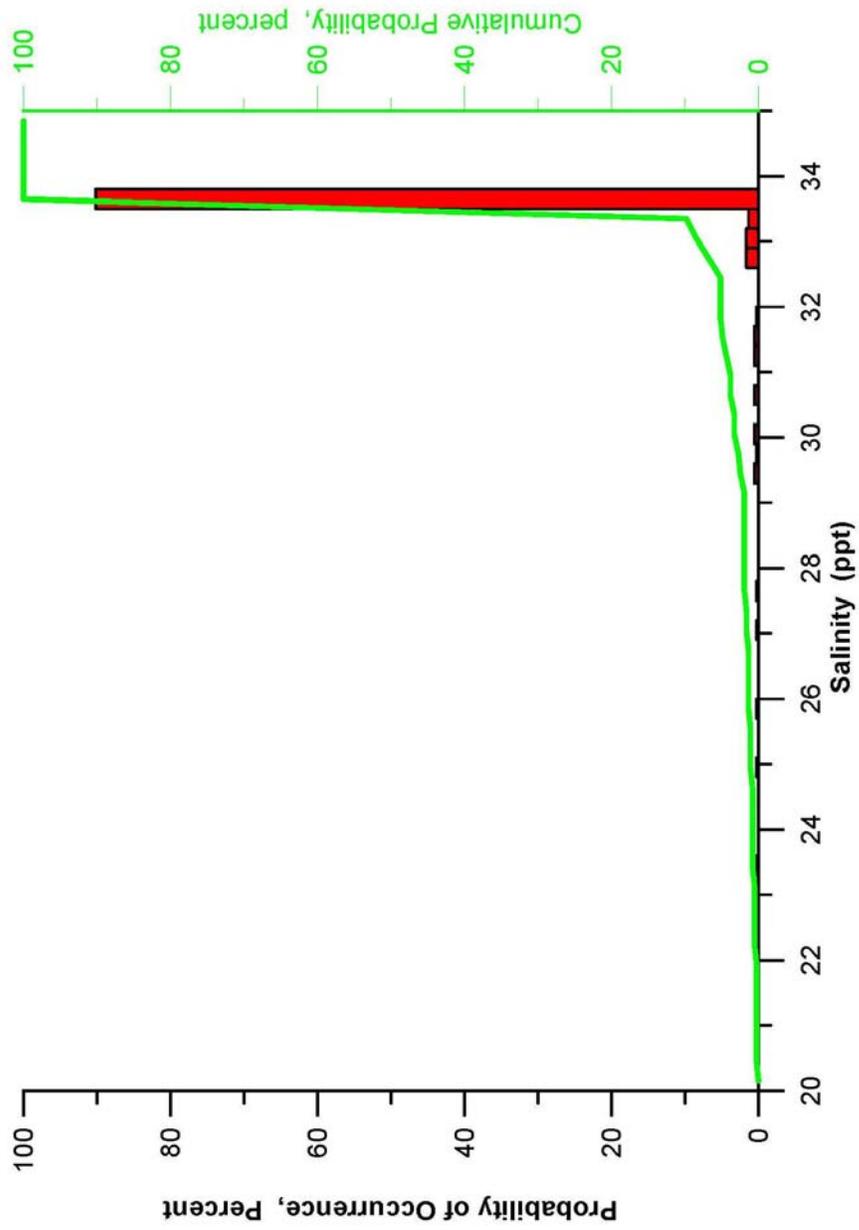
**Figure 3.** Relation between rainfall and discharge rate of Agua Hedionda Creek: a) Rainfall (red bars) & daily discharge Agua Hedionda Cr. (black crosses from Tetra Tech, 2007). b) Hydrographic rating curve (red) from 2nd order polynomial fit to flow rate vs rainfall data (blue diamonds).



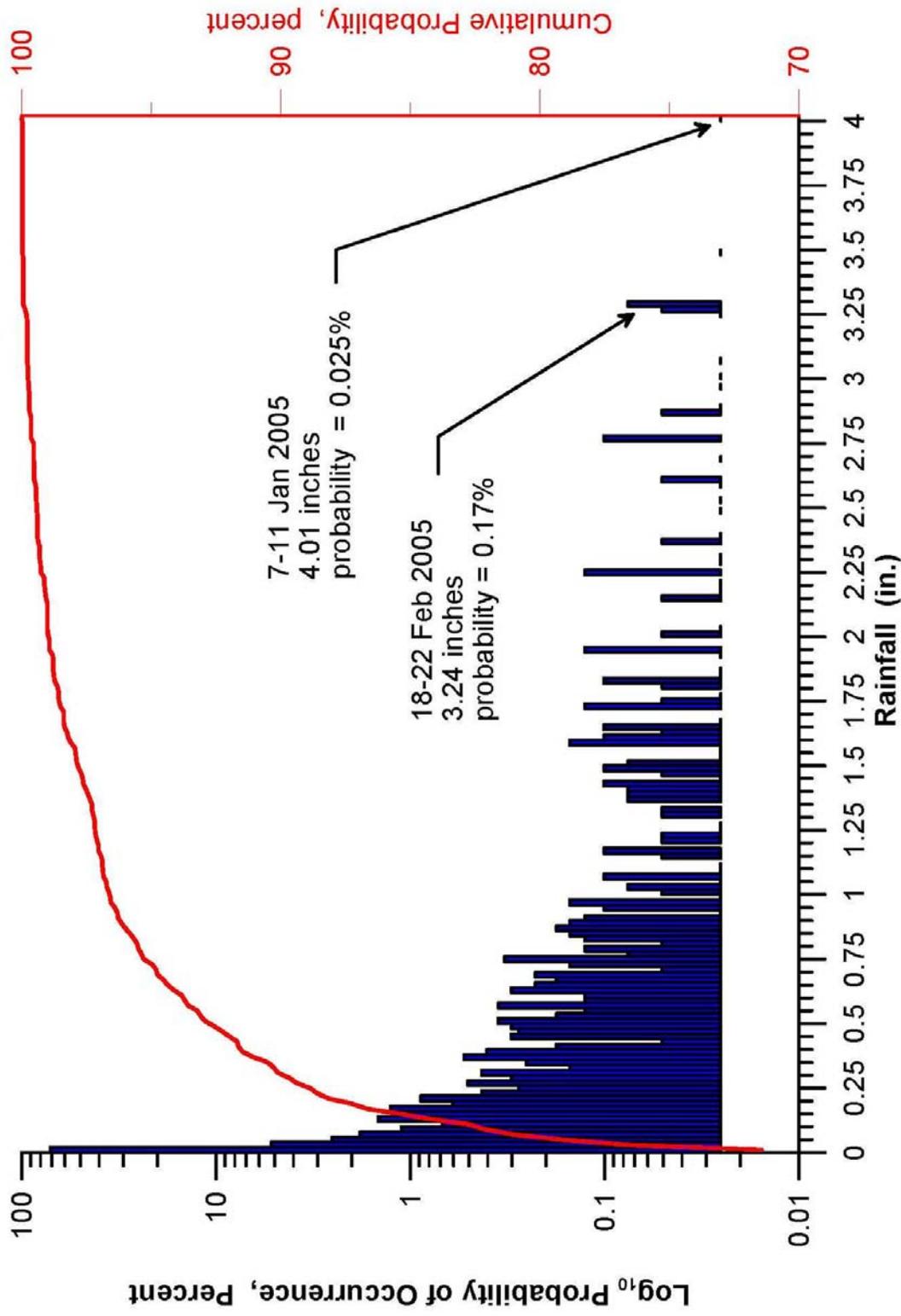
**Figure 4.** Daily discharge flow rates from Agua Hedionda Creek during the entrainment/impingement study: 1 June 04 - 1 June 05; measured data (black), from Tetra Tech, (2007), values calculated from hydrographic rating curve (red) .



**Figure 5.** Salinity in Agua Hedionda Lagoon during entrainment/impingement study: 1 June 04 - 1 June 05. Measured values (blue diamonds), from unpublished data due to Tenera Environmental vs. calculated salinity (green, red, cyan) from hydrographic rating curve applied to measurements of tidal prism and storage volume after Elwany et al., [2005], and Jenkins and Wasy [2006].



**Figure 6.** Histogram of salinity in Agua Hedionda Lagoon during the entrainment impingement study, 1 June 2004 - 31 May 2005. Probabilities of occurrence based on the red curve in Figure 5.



**Figure 7.** Histogram of 5-day rainfall totals measured in Agua Hedionda Cr. watershed during the period of record, 23 May 1998 - 8 Mar 2009. <http://www.wrh.noaa.gov/sgx/obs/rtp/carlsbad.html>