APPENDIX F

Near-Field Mixing Zone and Dilution Analysis for the
Deep Water Outfall Diffuser in San Pablo Bay

Technical Memorandum

DATE:	1 October 2009
TO:	Dean Allison, City of Pinole Ken Coppo, City of Pinole Erwin Blancaflor, City of Hercules Brent Salmi, City of Hercules
CC:	Denise Conners, Larry Walker Associates
SUBJECT:	Near-field Mixing Zone and Dilution Analysis for the Deep Water Outfall Diffuser in San Pablo Bay

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Overview

The California Regional Water Quality Control Board, San Francisco Bay Region (Regional Water Board) regulates discharges from the Pinole-Hercules Water Pollution Control Plant (Pinole-Hercules WPCP) under an NPDES permit (CA0037796), which was adopted by the Regional Water Board as Order R2-2007-0024 in March 2007. Secondary-treated effluent from Pinole-Hercules WPCP is pumped to the Rodeo Sanitation District's Water Pollution Control Facility (RSD WPCF). The combined effluent is discharged to San Pablo Bay via a single deep-water outfall (Outfall 001). The current permitted average dry-weather flows (ADWF) from the Pinole-Hercules WPCP and RSD WPCF are 4.06 million gallons per day (MGD) and 1.14 MGD, respectively, resulting in a combined ADWF of 5.2 MGD.

The current permitted wet-weather capacity for the Pinole-Hercules WPCP is 10.3 MGD. The Cities of Pinole and Hercules are designing upgrades to the WPCP and will ask the Regional Water Board to increase the permitted wet-weather flow to 14.59 MGD (daily average). Coupled with RSD WPCF's current wet-weather capacity of 2.5 MGD (daily average), this change would result in an increase from 12.8 MGD to 17.09 MGD maximum daily average flow through Outfall 001. No increase in ADWF for either treatment facility is forecast through 2030 (the design period).

Based on conditions assumed in various simulations, the following dilutions are estimated:

Time Frame	Condition	Dilution Credit
Current	Chronic	279
Current	Acute	43
Future	Chronic	279
Future	Acute	33

This memo provides information and analysis to support consideration of these dilution credits for discharges through Outfall 001. This information may be used in the derivation of effluent limitations in the next NPDES permits issued for the Pinole-Hercules WPCP and the RSD WPCF. In addition, diffuser repairs/modifications may occur during the WPCP upgrade, after the next NPDES permit renewal in 2012. Simulation results are also presented for potential future diffuser conditions.

Regulatory Guidance

Guidance on delineating mixing zones and calculating dilution ratios is given in the 1991 USEPA Technical Support Document, or "TSD"[1]. Section 2.2.2 of the TSD suggests that two types of mixing zones may be applied to account for acute and chronic aquatic life criteria. Water quality-based effluent limits would be based on San Francisco Bay Basin Plan objectives specified as annual median[2] and instantaneous maximum concentrations. The Regional Water Board derives effluent limits from both objectives and then selects the lower effluent limits for inclusion in NPDES permits. In accordance with this approach, the following assumptions are considered the most appropriate:

- A dilution credit based on the average dry-weather effluent flow rate and median tidal velocity during moderate Delta outflow conditions is used for calculating average monthly (chronic) effluent ammonia limits;
- A dilution credit based on the maximum design effluent flow rate and average velocity 30 minutes before and after slack tide during moderate Delta outflow conditions is used for calculating maximum daily (acute) effluent ammonia limits.

Modeling Tools

Resource Management Associates, Inc. (RMA) simulated receiving water conditions under a range of Delta outflow conditions[3]. RMA's modeling work used coupled hydrodynamic-water quality models calibrated to velocity, stage, flow and salinity data, as well as drogue and dye studies. The coupled models are RMA-2 for hydrodynamics in two dimensions (vertically averaged) and RMA-11 for water quality. RMA-2 output for time-varying current direction and velocity over the outfall diffuser are applied as input for ambient conditions in the near-field model.

The near-field mixing zone model CORMIX was applied to represent dilution of the effluent plume. CORMIX is a USEPA-approved mixing zone model for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges[4]. Comprehensive models such as CORMIX are effective because they first classify the flow structure in order to determine the appropriate prediction technique. CORMIX Version 5.0GT was applied in this case, including HYDRO2: Version-5.0.2.0 produced in October 2008.

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[1] USEPA (1991). Technical Support Document for Water Quality-based Toxics Control. EPA Number 505290001. 292 pp.

[2] Median is the 50th percentile, which is the value where half the data are below and half are above or equal to this value. Mean and average are synonymous, calculated as the sum of the values divided by the number of values.

[3] Resource Management Associates, Inc. (2009). "Technical Summary Report – Water quality impacts of Pinole-Hercules Water Pollution Control Plant discharge in San Pablo Bay." Prepared for City of Pinole. May. 81 pp.

[4] See http://www.cormix.info/index.php.

Near-field mixing processes accounted for, in this case, are buoyant jet mixing (including ambient current effects and merging of individual port's plumes) and boundary interactions (including density gradient effects). Receiving water depth and velocity, outfall configuration, and discharge flow rate are the most important input parameters. For Outfall 001's submerged, multi-port diffuser, the subprogram CORMIX2 was used. CORMIX2 analyzes uni-directional, staged, and alternating designs of multiport diffusers and allows for arbitrary alignment of the diffuser structure within the ambient water body and for arbitrary arrangement and orientation of the individual ports.

Near field re-entrainment is a process where previously discharged fluid from the far field is advected into the vicinity of the outfall and is dynamically re-entrained into the turbulent jet, reducing jet dilution. Because the dilution from turbulent jet mixing, buoyant spreading or ambient diffusion is a cumulative effect which fractionally reduces concentrations in a fluid parcel, any reduction in initial mixing from re-entrainment is carried through the entire plume and results in increased concentrations in the final plume.

Steady-state ambient current is assumed for chronic conditions. However, information on the tidal cycle can be input to account for re-entrainment in an unsteady ambient flow field for acute conditions. Input in the case of modeling conditions around slack tide includes tidal period, maximum tidal velocity, and velocity at any time relative to slack tide. The plume shape is conservatively delineated by the surface area containing one standard deviation (i.e., 68%) of the plume in a Gaussian distribution-shaped cross-section. Initial dilution is assumed to be complete when the plume's discharge momentum and buoyancy dissipate. Although turbulent diffusion subsequently dilutes the effluent plume even more, initial dilution is commonly applied for calculating effluent limitations.

Model results delineate the effluent plume defining the edge of the mixing zone. Dilution in CORMIX is presented as the ratio of initial concentration to concentration at a given location (S), which is the inverse of 'fraction of effluent.' Dilution credit, as applied in Bay Area NPDES permits, is calculated from CORMIX output as S-1.

Simulation Conditions

The study area is in the vicinity of Outfall 001 in San Pablo Bay (**Figure 1**). The outfall diffuser is described in this section, along with effluent and ambient receiving water conditions that affect mixing characteristics of the effluent plume.

Figure 1. Pinole-Hercules and Rodeo's Outfall 001 study area. Nearby DWR metering stations and RMP monitoring stations are shown.

Diffuser Geometry

The Outfall 001 diffuser cross-section design is shown in **Figure 2**. The diffuser is located in San Pablo Bay about 3,775 feet from the shoreline, aligned at 25^{o} counter-clockwise from North. The original diffuser design consisted of 15 pairs of diffuser ports (30 ports total) placed 8 feet on center. The ports are sharp-edged and 2.5 inches in diameter. An underwater inspection conducted in Fall 2005 found no damage to the portholes, outfall or diffuser pipeline; however, four ports were partially or totally blocked by sediment or corrosive buildup (Underwater Resources, 2005).

The modeled diffuser in its <u>current</u> condition consists of 26 ports with a diameter of 2.5 inches (0.06 m), 5 inches (0.013 m) from the Bay floor. Ports are set as pairs on either side at 27.5^{o} from horizontal. The total length of the diffuser is 120 feet. The total water depth is 16.7 feet (5.1 m) below Mean Sea Level. Future conditions assume that all 30 ports are open, each fit with 3-inch duckbill valves. The modeled diffuser is visualized using the CORMIX visualization tool CorSpy as shown in **Figure 3**.

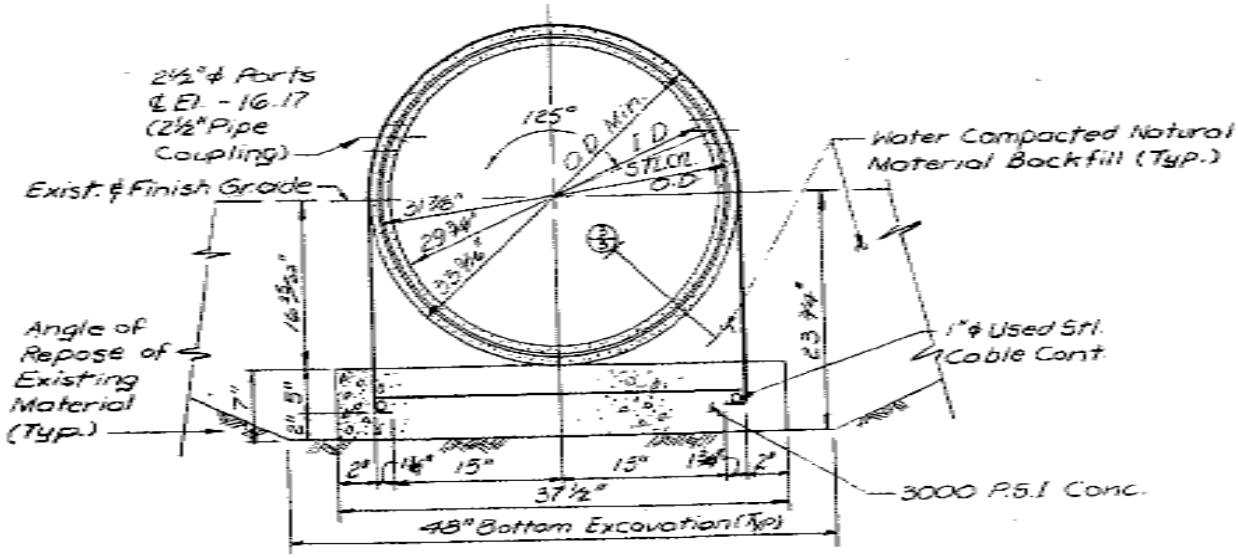

Figure 2. Outfall 001 diffuser cross-section drawing. Source: CDM (1979). "Drawing M-3, Effluent Outfall Diffuser Section Details and Trench Sections".

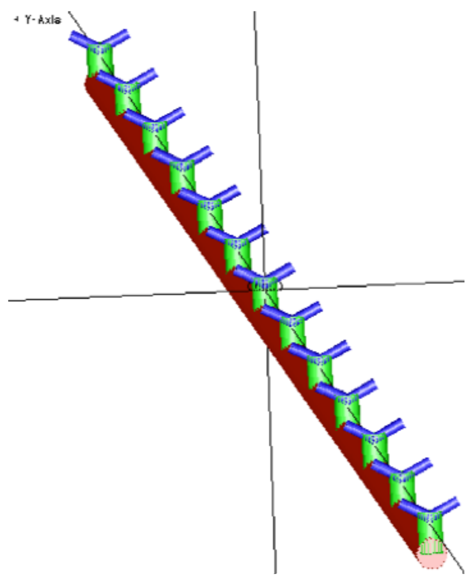

Figure 3. Visualization of Outfall 001 diffuser (current condition) by the CORMIX visualization tool CorSpy.

Effluent Conditions

The combined effluent flow rates for the available period of record (10/1/2003 – 5/31/2008) is shown in **Figure 4** along with the design flows underlined in the following paragraphs. Effluent conditions assumed for CORMIX simulations are based on facility design information.

The current permitted average dry-weather flows (ADWF) from the Pinole-Hercules WPCP and RSD WPCF are 4.06 million gallons per day (MGD) and 1.14 MGD, respectively, resulting in a combined ADWF of 5.2 MGD. No increase in dry-weather flows for the two treatment facilities is forecast through 2030 (the design period); therefore this flow rate applies to both current and future conditions.

The current permitted wet-weather capacity for the Pinole-Hercules WPCP is 10.3 MGD. Based on planned improvements to the WPCP, the Cities of Pinole and Hercules will request that the Regional Water Board increase the permitted wet-weather flow for Pinole-Hercules to 14.59 MGD (daily average). Coupled with RSD WPCF's current wet-weather capacity of 2.5 MGD (daily average), the maximum daily average flow through Outfall 001 is currently 12.8 MGD, increasing in the future to 17.09 MGD.

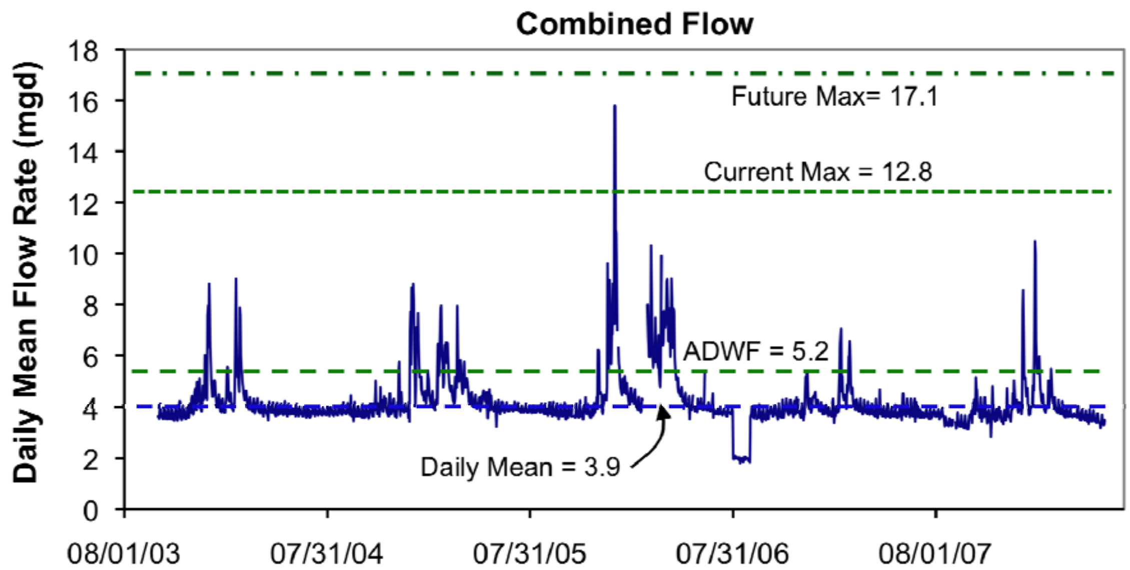

Figure 4. Combined daily mean effluent flow rates for period 10/1/2003 – 5/31/2008, with current daily mean and simulated values indicated.

Temperature affects the effluent density. The daily flow data for the Pinole-Hercules WPCP and RSD WPCF were added, and temperature data combined as a flow-weighted value for the available period of record (10/1/2003 – 5/31/2008). Paired flow and temperature values are shown in **Figure 5**. Temperature values input to CORMIX for calculating density are 19 ^{o}C chronic (current and future), 17 ^{o}C acute current, and 16 ^{o}C acute future.

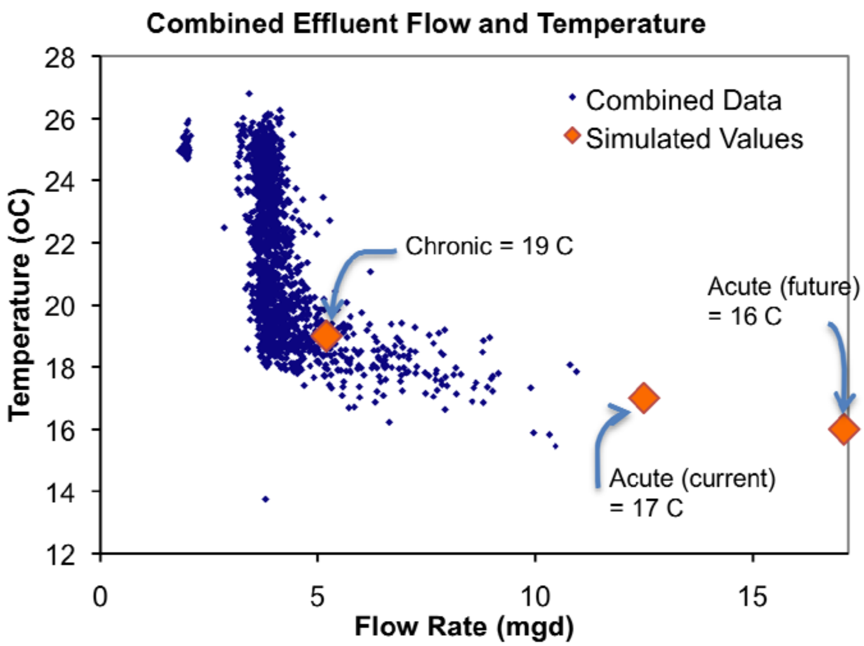

Figure 5. Daily mean effluent flow rates and volume-weighted temperatures during period 10/1/2003 – 5/31/2008, with simulated values indicated.

Ambient Conditions

San Pablo Bay is a shallow, tidal estuary spanning 68,349 acres. It is defined by the mouth of Carquinez Strait to the east and a border drawn between Point San Pablo and Santa Venicia to the southwest. San Pablo Bay is primarily a flat, mud-bottom bay, reflecting its characteristic as a catchment for fine sediments. Tides typically follow a pattern of episodic Delta outflows to San Pablo Bay in December-March, declining flows in April-May, and low freshwater inflows in July-October. The majority of freshwater inflow to San Pablo Bay is from the Central Valley through the Delta and Suisun Bay, although local rivers and creeks such as the Napa River also provide freshwater inflow. Because the majority of freshwater comes from the Delta, the amount and timing of precipitation events in the Delta watershed can have a major impact on freshwater inflows to and circulation patterns in San Pablo Bay.

Mixing conditions in the vicinity of Outfall 001 are highly dependent on the Delta's hydrodynamics (e.g., San Joaquin and Sacramento River flows, neap/spring tides, upstream dam releases, and water exports). Ambient velocity is driven by Delta outflows from the east and ocean tides from the west.

Ambient Current Velocity

Hydrodynamic simulations were performed by RMA to provide velocity results for input to the CORMIX plume model. Hydrodynamic simulations were performed for the 29-day period of April 8 through May 6, 2002, which has been identified as representative of moderate Delta outflow[5].

[5] For years 2000 – 2006, the 29-day running average net Delta outflow is lower than this period approximately 50% of the time.

Velocities at the midpoint of the rectangular outfall element in the RMA model were computed at 7.5-minute intervals and saved at 15-minute intervals. Although velocities fluctuate according to net Delta outflows, median velocities during low and high net Delta outflows are within 4% of the "moderate outflow" period's average. For simulating conditions in CORMIX:

- The median velocity was selected to represent chronic conditions and for use in deriving average monthly effluent limitations. The median of flood and ebb tides velocities during moderate Delta outflows is 1.1 ft/s (0.34 m/s).
- The average tidal-period maximum velocity and average velocity 30 minutes after slack tide were selected to represent acute conditions[6] and for use in deriving maximum daily effluent limitations. The average tidal-period maximum ambient velocity is 1.3 ft/s (0.41 m/s) and the average ambient velocity 30 minutes after slack tide during moderate Delta outflows is 0.41 ft/s (0.12 m/s).

Ambient Current Direction

RMA-2 output includes current velocity vectors at 15-minute intervals. The velocity data were first parsed into ebb and flood tide components. The average ebb and flood tides' velocity directions were then calculated. For the dominant ebb tide (i.e., net Delta outflow means that the current is more often directed westward), the average angle is 114^o counter-clockwise from North. As noted previously in section "Diffuser Geometry", Outfall 001 is aligned at 25^o counter-clockwise from North with ports directing effluent at 90^o from the pipe. Thus, the diffuser is aligned approximately 90^o (114^o-25^o=89^o) relative to the dominant current direction.

Ambient Stratification

Salinity data from Department of Water Resources metering stations near the outfall indicates that minor stratification occurs near the Mare Island Jetty (Station C316) under moderate net Delta outflow conditions. The C316 meter is located close to the depth of Outfall 001; however, water circulation at this station probably results in a different salinity response than actually occurs near the outfall. The flood tide waters at C316 have a flow component from the northwest (the shallower northern portion of San Pablo Bay) that would not be present at the outfall. Salinity data from a meter located near the west opening to Carquinez Straits (Station C24) indicates some stratification following high net Delta outflow and during transitional tidal conditions. However, this is a deep-water station with the upper meter placed at approximately 20 ft below Mean Lower Low Water. Outfall 001 is located 17 ft below MLLW, so the C24 results are difficult to extrapolate to the shallower outfall diffuser.

In summary, it is difficult to quantify the density profile at the diffuser site based on the available data. However, any stratification at Outfall 001 will be small and will have only a minor impact on near-field or far-field plume fate. Consequently, ambient temperature and salinity values of 20.0 ^oC and 20.8 parts per thousand, respectively, constant with water depth are assumed for all simulations. These values are the averages of measurements reported at the nearest Regional Monitoring Program stations in summers of years 2002-2003 and 2005-2007[7].

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[6] This format represents the minimum dilution owing to re-entrainment. See Nash, J.D., "Buoyant Discharges into Reversing Ambient Currents", MS Thesis, DeFrees Hydraulics Laboratory, Cornell University, Ithaca, NY. 1995.

[7] Results generated by the RMP Web Query [http://www.sfei.org/rmp/rmp_data_access.html], for stations annually closest to Outfall 001.

CORMIX Input Values

The complete set of CORMIX input data is shown in **Table 1**. These values were used to simulate the current and future, chronic and acute dilution conditions described previously.

Table 1. CORMIX Input Data Summary

Term	Value	Units	Notes	Ref's
			Effluent Data	
Pollutant type	Conservative			
Pollutant concentration	100	mg/L	level above background, use 100 to represent %	1
Flow rate	0.23	m^3/s	Chronic (current and future conditions): ADWF = 5.2 mgd	
	0.56	m^3/s	Acute (current): 12.8 MGD maximum daily-average flow	
	0.75	m^3/s	Acute (future): 17.09 MGD maximum daily-average flow	
Temperature	19	°C	chronic at ADWF (current and future)	2
	17	°C	acute at current maximum daily average flow	2
	16	°C	acute at future maximum daily average flow	2
			Ambient Parameters	
Bounded?	Unbounded		Assume no side boundary effects in near field	
Average depth (HA)	5.1	m	16.7 ft below MSL (chronic)	3
Depth at discharge (HD)	5.1	m	uniform within outfall zone: same as avg depth	1
Wind speed	0	m/s	conservatively assume zero	
Ambient velocity	0.34	m/s	chronic: median, moderate Delta outflow (April 8 – May 9, 2002)	4
	12.4	hr	tidal period	4
	0.41	m/s	average of tidal-cycle maximum velocities	4
	0.12	m/s	acute: avg. 30-min after slack tides, moderate Delta outflow (April 8 – May 9, 2002)	4
Manning's n	0.025	–	Earthen bottom with some stones and weeds	1,5
Stratification Type	Non-freshwater, Uniform	–	Generally shallow and fully-mixed vertically	4
Density	20.0	°C	Average temperature, 2002-2003 and 2005-2007 summers	6
	20.8	ppt	Average salinity, 2002-2003 and 2005-2007 summers	6
			Discharge Geometry Data	
Submodel	CORMIX2	–	for multi-port diffuser	
Nearest bank	left	–	looking downstream from East	
Diffuser length	120	ft	total length, not adjusted for blocked ports	3
Dist to 1st endpoint	3775	ft	distance from shoreline to nearest port	3
Dist to 2nd endpoint	3895	ft	add length to endpoint 1	3
Port Height	0.127	m	5 inches, per diver inspection	5
Port Diameter	0.06	m	Current: 2.5" diameter	3,5
	0.08	m	Future: 3" diameter	7
Contraction ratio	1	–	Current: well-rounded ports, flush with pipe wall	1
	0.7	–	Future: 3" duckbill valves	1
Number of openings	26	–	Current: 4 closed per diver inspection	3,5
	30	–	Future: All ports open	7
Alignment angle (GAMMA)	90	degrees	Perpendicular to downstream current	3
Port configuration	2 ports/riser, opposing	–	pairs, flush with pipe, 62.5 deg from vertical	3
Vertical angle (THETA)	27.5	degrees	angle from horizontal	3

REFERENCES:

1 = Doneker, R.L., and G.H. Jirka (2007). "CORMIX User Manual – A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters." EPA-823-K-07-001, 236 pp.

2 = Pinole-Hercules NPDES self-monitoring data

3 = CDM (1979). Drawing M-2 "Rodeo, Pinole, and Hercules Effluent Outfall Plan & Profile"; Drawing M-3 "Effluent Outfall Diffuser Section Details and Trench Sections".

4 = Resource Management Associates, Inc. (2009). "Technical Summary Report – Water quality impacts of Pinole-Hercules Water Pollution Control Plant discharge in San Pablo Bay." Prepared for City of Pinole. May. 81 pp.

5 = Underwater Resources Inc. (2005). Letter Report for Underwater Inspection of Outfall Diffuser Pipeline. October 27. 5

6 = RMP Web Query [http://www.sfei.org/rmp/rmp_data_access.html]

7 = Email from Nancy Ku [mailto:nancy.ku@psomas.com] to Denise Conners; sent Monday, August 24, 2009 11:08 AM

Model Results and Dilution Credits

Session reports for the CORMIX simulations of chronic and acute discharge conditions under the simulated current conditions are provided in **Appendix A**. Values referenced in this section are highlighted in the session reports. In each case, the plume flow class (MU8 in the session report) and flow configuration apply to a layer corresponding to the full water depth at the discharge site. The effluent density is less than the surrounding ambient water density at the discharge level. Therefore, the effluent is positively buoyant and tends to rise towards the surface.

Under both chronic and acute conditions (current and future), the plume becomes vertically fully-mixed over the diffuser, but re-stratifies later and is not mixed in the far-field. Depending on the flow scenario, near-field mixing is complete at a distance of 170-210 ft (50-65 m) from the diffuser centerline. The travel time for the discharge to reach this distance is approximately 2-3 minutes. At that point, the plume covers a surface area of 0.5-0.9 acres and fills a volume of 8-15 acre-ft.

The TSD recommends—but does not require—a minimum exit velocity of 3 m/s (10 ft/s) to provide sufficiently rapid mixing that would minimize organism exposure time to toxic material. Current and future acute conditions, which are of interest for short-term exposure, produce exit velocities greater than 7 m/s. The exposure concern can in many instances also be met by other characteristics, such as high ambient velocity. Median currents of 1.1 ft/sec (0.34 m/s) pass drifting organisms through the mixing zone in approximately 5 minutes.

Initial dilutions estimated by CORMIX are summarized in **Table 2**, showing only the characteristics that vary among the simulated conditions.

Table 2. Dilution Estimates for Representative Discharge Conditions

	Effluent		Ambient	Discharge			
Condition	Flow Rate (m3/s)	Temp (oC)	Velocity (m/s)	Port Dia. m)	Contraction Ratio	# ports	Dilution (S)
Chronic Current	0.23	19	0.34	0.06	1.0	26	279
Chronic Future				0.08	0.7	30	279
Acute Current	0.56	17	0.41 max; 0.12 at	0.06	1.0	26	43
Acute Future	0.75	16	30-min after slack	0.08	0.7	30	33

Appendix A. CORMIX Session Reports

Session reports for current (chronic and acute) conditions only are shown. Highlighted values are referenced in the text.

Chronic Conditions

```
CORMIX SESSION REPORT:
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                      CORMIX MIXING ZONE EXPERT SYSTEM
                          CORMIX Version 5.0GT
                       HYDRO2:Version-5.0.2.0  October,2008
SITE NAME/LABEL:                Outfall 001
  DESIGN CASE:                  Base Case
  FILE NAME:                    C:\Program Files\CORMIX
5.0\StephenM\Pinole\MZ Analysis - base case.prd
  Using subsystem CORMIX2:     Multiport Diffuser Discharges
  Start of session:             09/16/2009--15:44:31
*****************************************************************************
SUMMARY OF INPUT DATA:
-----------------------------------------------------------------------------
AMBIENT PARAMETERS:
  Cross-section                           = unbounded
  Average depth                   HA      = 5.1 m
  Depth at discharge              HD      = 5.1 m
  Ambient velocity                UA      = 0.34 m/s
  Darcy-Weisbach friction factor  F       = 0.0285
    Calculated from Manning's n           = 0.025
  Wind velocity                   UW      = 0 m/s
  Stratification Type             STRCND = U
  Surface density                 RHOAS  = 1013.97 kg/m^3
  Bottom density                  RHOAB  = 1013.97 kg/m^3
-----------------------------------------------------------------------------
DISCHARGE PARAMETERS:             Submerged Multiport Diffuser Discharge
  Diffuser type                   DITYPE = alternating perpendicular
  Diffuser length                 LD      = 36.58 m
  Nearest bank                            = left
  Diffuser endpoints              YB1     = 1150.62 m;    YB2 = 1187.2 m
  Number of openings              NOPEN  = 26
  Number of Risers                NRISER = 13
  Ports/Nozzles per Riser         NPPERR  = 2
  Spacing between risers/openings SPAC    = 3.05 m
  Port/Nozzle diameter            D0      = 0.06 m
    with contraction ratio                = 1
  Equivalent slot width           B0      = 0.0020 m
  Total area of openings          TA0     = 0.0735 m^2
  Discharge velocity              U0      = 3.13 m/s
  Total discharge flowrate        Q0      = 0.23 m^3/s
  Discharge port height           H0      = 0.13 m
  Nozzle arrangement              BETYPE = alternating without fanning
  Diffuser alignment angle        GAMMA  = 90 deg
  Vertical discharge angle        THETA  = 90 deg
  Actual Vertical discharge angle THEAC  = 27.5 deg
  Horizontal discharge angle      SIGMA  = 0 deg
  Relative orientation angle      BETA    = 90 deg
  Discharge temperature (freshwater)      = 19 degC
```

```
  Corresponding density           RHO0   = 998.4063 kg/m^3
  Density difference              DRHO   = 15.5637 kg/m^3
  Buoyant acceleration            GP0    = 0.1505 m/s^2
  Discharge concentration         C0     = 100 mg/l
  Surface heat exchange coeff.    KS     = 0 m/s
  Coefficient of decay            KD     = 0 /s
-----------------------------------------------------------------------------
FLUX VARIABLES PER UNIT DIFFUSER LENGTH:
  Discharge (volume flux)         q0     = 0.006288 m^2/s
  Momentum flux                   m0     = 0.019674 m^3/s^2
  Buoyancy flux                   j0     = 0.000947 m^3/s^3
-----------------------------------------------------------------------------
DISCHARGE/ENVIRONMENT LENGTH SCALES:
  LQ  = 0.00 m          Lm  = 0.17 m          LM  = 2.04 m
  lm' = 99999 m          Lb' = 99999 m          La  = 99999 m
  (These refer to the actual discharge/environment length scales.)
-----------------------------------------------------------------------------
NON-DIMENSIONAL PARAMETERS:
Slot Froude number              FR0    = 179.88
  Port/nozzle Froude number       FRD0   = 32.92
  Velocity ratio                  R      = 9.20
-----------------------------------------------------------------------------
MIXING ZONE / TOXIC DILUTION ZONE / AREA OF INTEREST PARAMETERS:
  Toxic discharge                        = no
  Water quality standard specified       = no
  Regulatory mixing zone                 = no
  Region of interest                     = 260 m downstream
*****************************************************************************
HYDRODYNAMIC CLASSIFICATION:
  *------------------------*
  | FLOW CLASS   = MU8 |
  *------------------------*
  This flow configuration applies to a layer corresponding to the full water
  depth at the discharge site.
  Applicable layer depth = water depth = 5.1 m
*****************************************************************************
MIXING ZONE EVALUATION (hydrodynamic and regulatory summary):

-----------------------------------------------------------------------------
X-Y-Z Coordinate system:
  Origin is located at the bottom below the port center:
    1168.91 m from the left bank/shore.
  Number of display steps NSTEP = 10 per module.
-----------------------------------------------------------------------------
NEAR-FIELD REGION (NFR) CONDITIONS :
Note: The NFR is the zone of strong initial mixing.  It has no regulatory
  implication.  However, this information may be useful for the discharge
  designer because the mixing in the NFR is usually sensitive to the
  discharge design conditions.
  Pollutant concentration at NFR edge  c = 0.3589 mg/l
  Dilution at edge of NFR              s = 278.6
  NFR Location:                        x = 25.5 m
    (centerline coordinates)           y = 0 m
                                       z = 5.1 m
  NFR plume dimensions:  half-width (bh) = 18.48 m
                          thickness (bv) = 5.1 m
Cumulative travel time:       148.4593 sec.
-----------------------------------------------------------------------------
```

```
Buoyancy assessment:
  The effluent density is less than the surrounding ambient water
  density at the discharge level.
  Therefore, the effluent is POSITIVELY BUOYANT and will tend to rise towards
  the surface.
-----------------------------------------------------------------------------
Near-field instability behavior:
  The diffuser flow will experience instabilities with full vertical mixing
  in the near-field.
  There may be benthic impact of high pollutant concentrations.
-----------------------------------------------------------------------------
FAR-FIELD MIXING SUMMARY:
  Plume becomes vertically fully mixed WITHIN NEAR-FIELD at 0 m
  downstream, but RE-STRATIFIES LATER and is not mixed in the far-field.
-----------------------------------------------------------------------------
PLUME BANK CONTACT SUMMARY:
  Plume in unbounded section does not contact bank in this simulation.
************************ TOXIC DILUTION ZONE SUMMARY ************************
No TDZ was specified for this simulation.
********************** REGULATORY MIXING ZONE SUMMARY ***********************
No RMZ and no ambient water quality standard have been specified.
********************* FINAL DESIGN ADVICE AND COMMENTS **********************
CORMIX2 uses the TWO-DIMENSIONAL SLOT DIFFUSER CONCEPT to represent
  the actual three-dimensional diffuser geometry.  Thus, it approximates
  the details of the merging process of the individual jets from each
  port/nozzle.
In the present design, the spacing between adjacent ports/nozzles
  (or riser assemblies) is of the order of, or less than, the local
  water depth so that the slot diffuser approximation holds well.

Nevertheless, if this is a final design, the user is advised to use a
  final CORMIX1 (single port discharge) analysis, with discharge data
  for an individual diffuser jet/plume, in order to compare to
  the present near-field prediction.
-----------------------------------------------------------------------------
DIFFUSER DESIGN DETAILS:  Because of the alternating arrangement
  of the opposing nozzles/ports, the AVERAGE VERTICAL ANGLE (THETA)
  has been set to 90 deg.  This represents a ZERO NET HORIZONTAL
  MOMENTUM FLUX for the entire diffuser.
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Acute Conditions

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CORMIX SESSION REPORT:
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
                      CORMIX MIXING ZONE EXPERT SYSTEM
                          CORMIX Version 5.0GT
                       HYDRO2:Version-5.0.2.0  October,2008
SITE NAME/LABEL:                Outfall 001
  DESIGN CASE:                  Base Case
  FILE NAME:                    C:\Program Files\CORMIX
5.0\StephenM\Pinole\MZ Analysis - base case.prd
  Using subsystem CORMIX2:     Multiport Diffuser Discharges
  Start of session:             09/16/2009--15:52:13
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SUMMARY OF INPUT DATA:
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AMBIENT PARAMETERS:
  Cross-section                          = unbounded
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  Average depth                   HA     = 5.1 m
  Depth at discharge              HD     = 5.1 m
  Darcy-Weisbach friction factor  F      = 0.0285
    Calculated from Manning's n          = 0.025
  Wind velocity                   UW     = 0 m/s
TIDAL SIMULATION at time          Tsim   = 0.5 hours
  Instantaneous ambient velocity  UA     = 0.12 m/s
  Maximum tidal velocity          UaMAX  = 0.41 m/s
Rate of tidal reversal          dUA/dt = 0.24 (m/s)/hour
  Period of reversal              T      = 12.4 hours
  Stratification Type             STRCND = U
  Surface density                 RHOAS  = 1013.97 kg/m^3
  Bottom density                  RHOAB  = 1013.97 kg/m^3
-----------------------------------------------------------------------------
DISCHARGE PARAMETERS:             Submerged Multiport Diffuser Discharge
  Diffuser type                   DITYPE = alternating perpendicular
  Diffuser length                 LD     = 36.58 m
  Nearest bank                           = left
  Diffuser endpoints              YB1    = 1150.62 m;    YB2 = 1187.2 m
  Number of openings              NOPEN  = 26
  Number of Risers                NRISER = 13
  Ports/Nozzles per Riser         NPPERR  = 2
  Spacing between risers/openings SPAC   = 3.05 m
  Port/Nozzle diameter            D0     = 0.06 m
    with contraction ratio               = 1
  Equivalent slot width           B0     = 0.0020 m
  Total area of openings          TA0    = 0.0735 m^2
  Discharge velocity              U0     = 7.62 m/s
  Total discharge flowrate        Q0     = 0.56 m^3/s
  Discharge port height           H0     = 0.13 m
  Nozzle arrangement              BETYPE = alternating without fanning
  Diffuser alignment angle        GAMMA  = 90 deg
  Vertical discharge angle        THETA  = 90 deg
  Actual Vertical discharge angle THEAC  = 27.5 deg
  Horizontal discharge angle      SIGMA  = 0 deg
  Relative orientation angle      BETA   = 90 deg
  Discharge temperature (freshwater)     = 17 degC
  Corresponding density           RHO0   = 998.7761 kg/m^3
  Density difference              DRHO   = 15.1939 kg/m^3
  Buoyant acceleration            GP0    = 0.1469 m/s^2
  Discharge concentration         C0     = 100 mg/l
  Surface heat exchange coeff.    KS     = 0 m/s
  Coefficient of decay            KD     = 0 /s
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FLUX VARIABLES PER UNIT DIFFUSER LENGTH:
  Discharge (volume flux)         q0     = 0.015311 m^2/s
  Momentum flux                   m0     = 0.116631 m^3/s^2
  Buoyancy flux                   j0     = 0.002250 m^3/s^3
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DISCHARGE/ENVIRONMENT LENGTH SCALES:
  LQ  = 0.00 m         Lm  = 8.10 m         LM  = 6.78 m
  lm' = 99999 m         Lb' = 99999 m         La  = 99999 m
UNSTEADY TIDAL SCALES:
  Tu  = 0.2152 hours     Lu  = 40.00 m         Lmin= 5.04 m
  (These refer to the actual discharge/environment length scales.)
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NON-DIMENSIONAL PARAMETERS:
Slot Froude number              FR0    = 443.26
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  Port/nozzle Froude number       FRD0    = 81.13
  Velocity ratio                  R       = 63.48
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MIXING ZONE / TOXIC DILUTION ZONE / AREA OF INTEREST PARAMETERS:
  Toxic discharge                         = no
  Water quality standard specified        = no
  Regulatory mixing zone                  = no
  Region of interest                      = 260 m downstream
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HYDRODYNAMIC CLASSIFICATION:
  *-----------------------*
  | FLOW CLASS    = MU8 |
  *-----------------------*
  This flow configuration applies to a layer corresponding to the full water
  depth at the discharge site.
  Applicable layer depth = water depth = 5.1 m
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MIXING ZONE EVALUATION (hydrodynamic and regulatory summary):

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X-Y-Z Coordinate system:
  Origin is located at the bottom below the port center:
    1168.91 m from the left bank/shore.
  Number of display steps NSTEP = 10 per module.
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NEAR-FIELD REGION (NFR) CONDITIONS :
Note: The NFR is the zone of strong initial mixing.  It has no regulatory
  implication.  However, this information may be useful for the discharge
  designer because the mixing in the NFR is usually sensitive to the
  discharge design conditions.
  Pollutant concentration at NFR edge  c = 2.3473 mg/l
  Dilution at edge of NFR              s = 42.6
  NFR Location:                        x = 30.12 m
    (centerline coordinates)           y = 0 m
                                       z = 5.1 m
  NFR plume dimensions:  half-width (bh) = 25.46 m
                          thickness (bv) = 4.39 m
Cumulative travel time:       106.1002 sec.
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Buoyancy assessment:
  The effluent density is less than the surrounding ambient water
  density at the discharge level.
  Therefore, the effluent is POSITIVELY BUOYANT and will tend to rise towards
  the surface.
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Near-field instability behavior:
  The diffuser flow will experience instabilities with full vertical mixing
  in the near-field.
  There may be benthic impact of high pollutant concentrations.
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UPSTREAM INTRUSION SUMMARY:
Plume exhibits upstream intrusion due to low ambient velocity or strong
  discharge buoyancy.
  Intrusion length                        =  4.97 m
  Intrusion stagnation point              =  12.42 m
  Intrusion thickness                     =  4.33 m
  Intrusion half width at impingement     =  25.46 m
  Intrusion half thickness at impingement =  4.39 m
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FAR-FIELD MIXING SUMMARY:
  Plume becomes vertically fully mixed WITHIN NEAR-FIELD at 0 m
  downstream, but RE-STRATIFIES LATER and is not mixed in the far-field.
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PLUME BANK CONTACT SUMMARY:
  Plume in unbounded section does not contact bank in this simulation.
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UNSTEADY TIDAL ASSESSMENT:
 Because of the unsteadiness of the ambient current during the tidal
  reversal, CORMIX predictions have been TERMINATED at:
                                       x = 108 m
                                       y = 0 m
                                       z = 5.1 m.
  For this condition AFTER TIDAL REVERSAL, mixed water from the previous
  half-cycle becomes re-entrained into the near field of the discharge,
  increasing pollutant concentrations compared to steady-state predictions.
  A pool of mixed water formed at slack tide will be advected downstream
  in this phase.
************************ TOXIC DILUTION ZONE SUMMARY ************************
No TDZ was specified for this simulation.
********************** REGULATORY MIXING ZONE SUMMARY **********************
No RMZ and no ambient water quality standard have been specified.
********************* FINAL DESIGN ADVICE AND COMMENTS *********************
CORMIX2 uses the TWO-DIMENSIONAL SLOT DIFFUSER CONCEPT to represent
  the actual three-dimensional diffuser geometry.  Thus, it approximates
  the details of the merging process of the individual jets from each
  port/nozzle.
In the present design, the spacing between adjacent ports/nozzles
  (or riser assemblies) is of the order of, or less than, the local
  water depth so that the slot diffuser approximation holds well.

Nevertheless, if this is a final design, the user is advised to use a
  final CORMIX1 (single port discharge) analysis, with discharge data
  for an individual diffuser jet/plume, in order to compare to
  the present near-field prediction.
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DIFFUSER DESIGN DETAILS:  Because of the alternating arrangement
  of the opposing nozzles/ports, the AVERAGE VERTICAL ANGLE (THETA)
  has been set to 90 deg.  This represents a ZERO NET HORIZONTAL
  MOMENTUM FLUX for the entire diffuser.
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