Flow Science Incorporated
723 E. Green St., Pasadena, CA 91101
(626) 304-1134 • FAX (626) 304-9427

FISCHER DELTA MODEL STUDY
FATE OF A CONSERVATIVE TRACER DURING WATER YEARS 2000-2001

Prepared
for

San Joaquin River Group Authority

Reviewed By

E. John List, Ph.D., P.E.
Principal Consultant

Prepared by

Susan Paulsen, Ph.D., P.E.
Vice President, Senior Scientist

Alex Anderson
Nami Tanaka
Associate Engineers

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INTRODUCTION

Flow Science Incorporated (Flow Science) has been retained to model the Sacramento-San Joaquin River Delta during water years 2000 and 2001. The objective of this study is to determine the fate of a neutrally buoyant, conservative tracer[1] released in the San Joaquin River near Mossdale Landing. Modeled tracer release dates correspond to fish release dates, and were simulated as 24-hour tracer releases occurring on April 17, 18, and 28, 2000, and on April 30 and May 1, 7, and 8, 2001. Simulations were conducted using the historical, measured tide at the downstream model boundary and using historical inflows, exports, and diversions. A second set of simulations was conducted using the same input data but shifting the tides forward by one week, in essence trading spring and neap tides, to determine if the fate of releases is tied to tidal conditions.

FISCHER DELTA MODEL

The Fischer Delta Model (FDM)[2] consists of two linked models: a hydrodynamic model and a water quality model. The hydrodynamic model (DELFLO) utilizes the fixed grid method of characteristics to simulate the hydrodynamics of the Delta. The water quality model (DELSAL) uses the Lagrangian method, in which the motions of parcels of water are followed through the Delta. The Lagrangian method uses no grid points, but the computational effort required is equivalent to the use of approximately 2,500 grid points in a finite element numerical model.

The model extends from the downstream boundary in Carquinez Strait, upstream to Sacramento on the Sacramento River, and to Vernalis on the San Joaquin River. It also includes all tidally influenced sloughs and accounts for inflows from all major tributaries, state and federal project exports, riparian diversions, channel depletion, and agricultural returns.

These models describe hydrodynamics and changes in water quality in the Delta as affected by changes in geometry, hydrology, and Delta operations. Changes in hydrology include changes in river flows and diversions and exports within and to the south of the Delta. The models are also designed to allow prediction of the effect of levee breaks, channel gate operations, changes in agricultural discharges, and changes in municipal discharges and withdrawals. The model is capable of simulating a partial year, a full year, or multiple years of hydrology.

DELFLO was initially calibrated by comparing model output at 40 stations to observations in the field and to the physical hydraulic model operated by the U. S. Army Corps of Engineers at Sausalito, California. Two conditions were studied: the tide of August 27-28, 1968, with a net Delta

[1] A conservative tracer is a tracer that does not experience decay. The total mass of tracer does not increase or decrease within the Delta.
[2] The model is operated by Flow Science Incorporated for Hugo B. Fischer, Inc.

outflow of 2,500 cfs, and the tide of September 14-15, 1968, with a net Delta outflow of 17,200 cfs. The values of Manning's "n" for each channel were varied until a satisfactory agreement was obtained between the numerical model and physical model water surface elevations. In most cases, the field and physical model elevations agree within 0.2-feet water surface elevation. DELFLO has also been recalibrated and verified using both extensive flow and stage measurements made by the USGS within the Delta in 1988 and in 1996-1999.

DELSAL, the water quality model, has been calibrated by comparing model output for salinity to field data and verified using measured elemental tracer concentrations in the Delta. The Lagrangian method adopted in the model eliminates numerical dispersion, which is inherent in finite difference and finite element models and is difficult to reconcile with actual dispersion processes in the Delta. The model was designed to simulate salinity changes in the Delta, as affected by physical and hydrologic changes in the Delta, but it can also be used to determine the movement and dispersion of pollutants (or any mass conserving, neutrally buoyant particles) released from point sources. The FDM has also been verified by comparing FDM-computed "source fractions" (computations of the source of water located at specific interior Delta locations) to measured source fractions. Measured source fractions were determined using elemental concentrations measured at specific points in the Delta over a one-year period beginning in March 1996.

The FDM has been successfully applied to the transport of total dissolved solids (TDS) and other neutral buoyant tracers in the Sacramento-San Joaquin Delta for over twenty years. The model has undergone continuous improvement over the years.

Modeled Scenarios

Two scenarios were modeled for this study. The first scenario was a historical simulation. Historical simulations, as the name implies, involve modeling of systems based on historical data. The second modeled scenario was similar to the historical simulation, except that the tidal boundary condition was shifted one week forward in time. In other words, a high tide that historically occurred on April 15 would be modeled as occurring on April 22, with the entire record of measured tides shifted accordingly. Modeling these two scenarios, the historical scenario and the shifted-tide scenario, allows exploration of the effects of the spring-neap tidal cycle on the fate of a tracer.

Input Data

The numerical model uses a network of 163 channels and 125 nodes for the Sacramento-San Joaquin Delta. In addition to the basic channel geometry data and some model control parameters for the Fischer Delta Model (FDM), this study required the following data:

(a) hourly tidal elevation at the downstream boundary of the model;

(b) daily inflow data (flow rate and salinity) for Sacramento River, Yolo Bypass, San Joaquin

River, Mokelumne River, and Calaveras River at the upstream boundaries of the model;

(c) daily export or diversion rates at Tracy Pumping Plant, Banks Pumping Plant, Contra Costa Canal, Los Vaqueros Intake, and North Bay Aqueduct; and

(d) gate operation schedules at the Delta Cross Channel, the south Delta barriers, and Clifton Court Forebay.

Historical hydrodynamic data were downloaded from publicly available sources on the internet[3]. Initial tracer concentrations within the Delta and for inflows at all model boundaries, including rivers and the downstream boundary at Martinez, were set to zero. A tracer was injected at a flow rate of 10 ft^3/sec and a concentration of 1,000,000 mg/L south of Mossdale Landing for 24 hours on each day that fish were released. Each day's injected tracer was tracked separately as it moved through the Delta.

Gates and barriers in the Delta were modeled according to historical record. These operations are summarized below in Table 1.

Table 1: Water Year 2000 and 2001 South Delta barrier operation schedules

		Head of Old River Barrier	Grant Line Canal Barrier	Middle River Barrier	Old River Barrier near Tracy
Water year 2000	Barrier Installation	4/5/2000-4/15/2000	5/19/2000-5/31/2000	4/4/2000-4/5/2000	4/4/2000-4/15/2000
	Barrier In Place and Fully Operational	4/16/2000-5/18/2000	6/1/2000-9/30/2000	4/6/2000-9/30/2000	4/16/2000-9/30/2000
	Barrier Removal	5/19/2000-6/1/2000	Remained in place through remainder of study	Remained in place through remainder of study	Remained in place through remainder of study
Water year 2001	Barrier Installation	4/17/2001-4/25/2001	5/2/2001-5/5/2001	4/20/2001-4/22/2001	4/23/2001-4/25/2001
	Barrier In Place and Fully Operational	4/26/2001-5/22/2001	5/6/2001-9/30/2001	4/23/2001-9/30/2001	4/26/2001-9/30/2001
	Barrier Removal	5/23/2001-5/28/2001	Remained in place through remainder of study	Remained in place through remainder of study	Remained in place through remainder of study

Note: Culverts were installed and removed along with each barrier.
HORB: Six culverts, each two feet in diameter, bottom elevation -3.22 ft (NGVD29), allow flow in both directions.

3 Tide and river flow rate data were downloaded from: www.iep.ca.gov. South Delta barrier operations are available at: http://sdelta.water.ca.gov/web_pg/tempmesr.html. Delta Cross Channel barrier operations are available at: http://www.usbr.gov/mp/cvo/.

GLCB: Six culverts, each two feet in diameter, bottom elevation -0.72 ft (NGVD29), allow flow in landward direction only.
MRB: Six culverts, each two feet in diameter, bottom elevation -3.22 ft (NGVD29), allow flow in landward direction only.
ORB: Nine culverts, each two feet in diameter, bottom elevation 0.28 ft (NGVD29), allow flow in landward direction only.

PRESENTATION OF RESULTS

Results for the releases that occurred during historical tide simulations of water years 2000 and 2001 are presented in graphical format in Appendices A and C, and in Table 2. Results for releases that occurred during shifted-tide simulations of water years 2000 and 2001 are presented in Appendices B and D, and in Table 3. Results are presented for the locations shown in Figure 1. Figures 2 through 5 show tides at Martinez during April and May of each water year, with tracer release dates indicated in red. Figures 6 and 7 show State Water and Central Valley Projects flow rates for water years 2000 and 2001.

Figure 1: Locations of model output stations

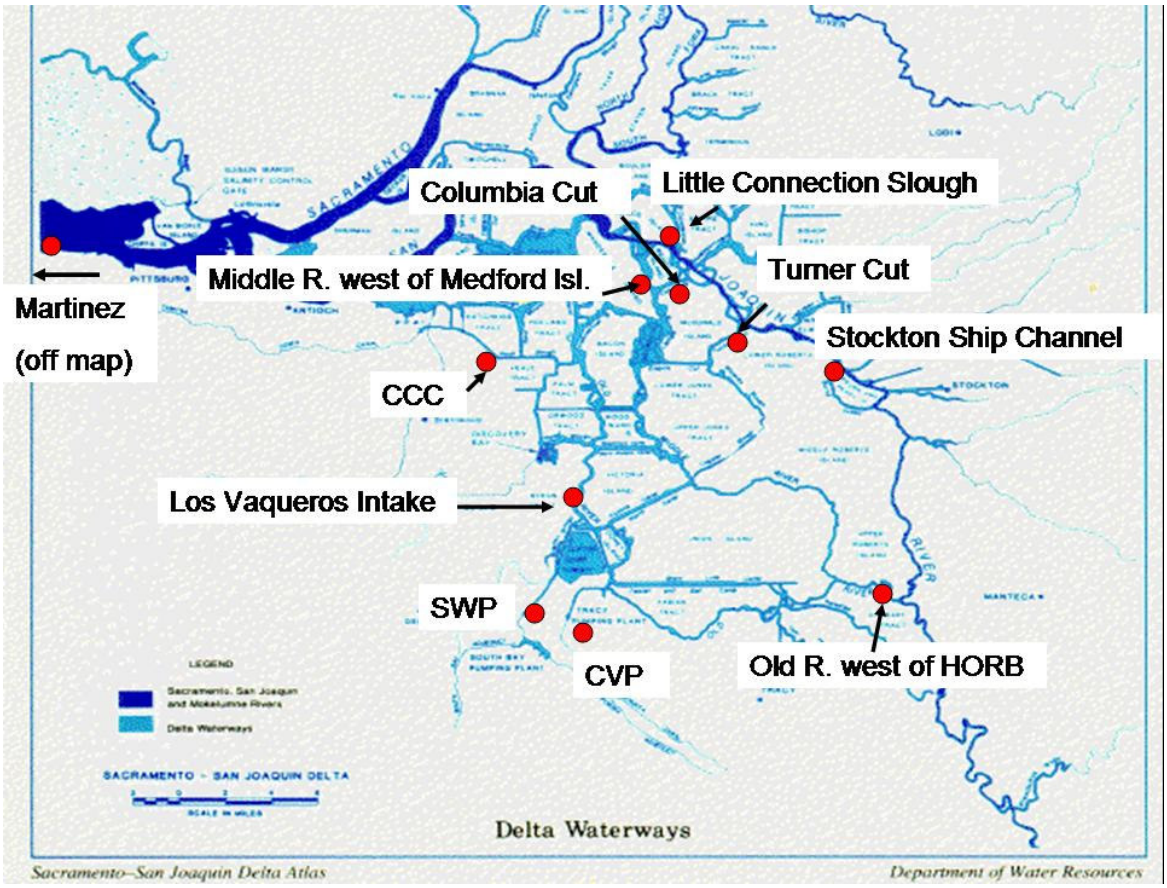

Figure 2: Tide at Martinez April 1- May 30, 2000, with tracer release dates shown in red

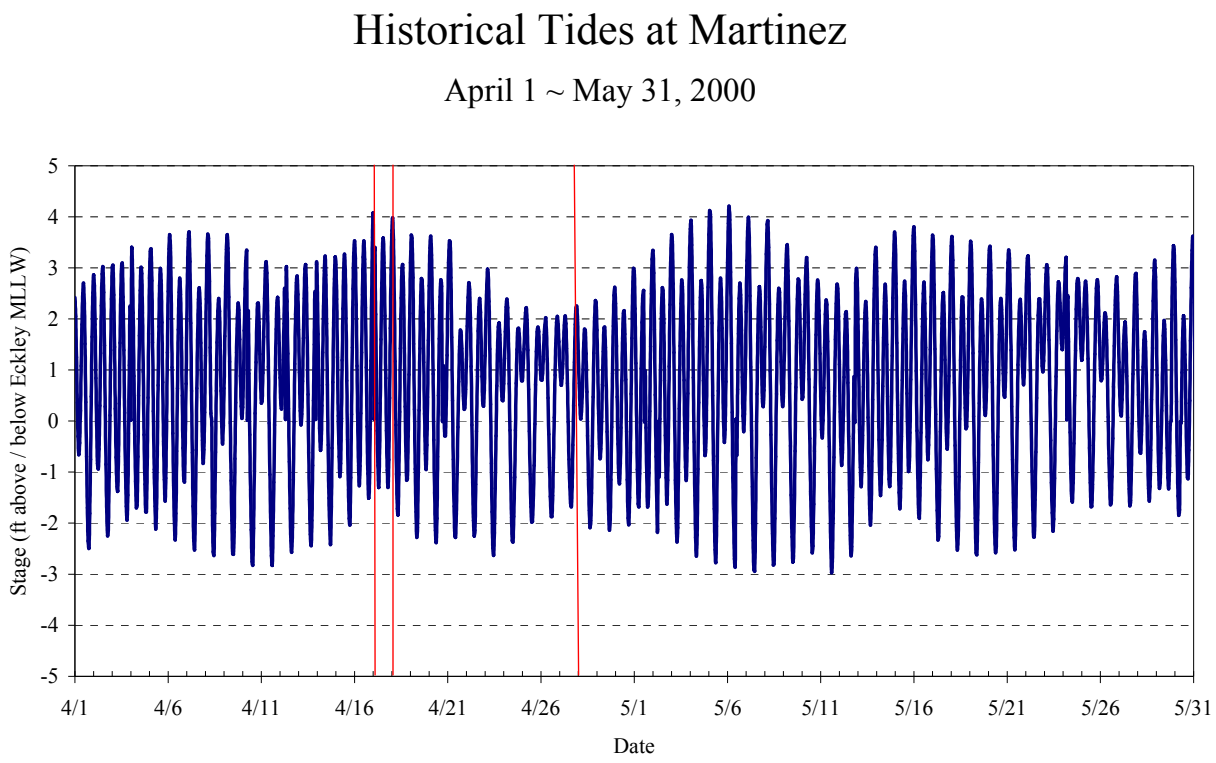

Figure 3: Tide at Martinez April 1- May 30, 2001, with tracer release dates shown in red

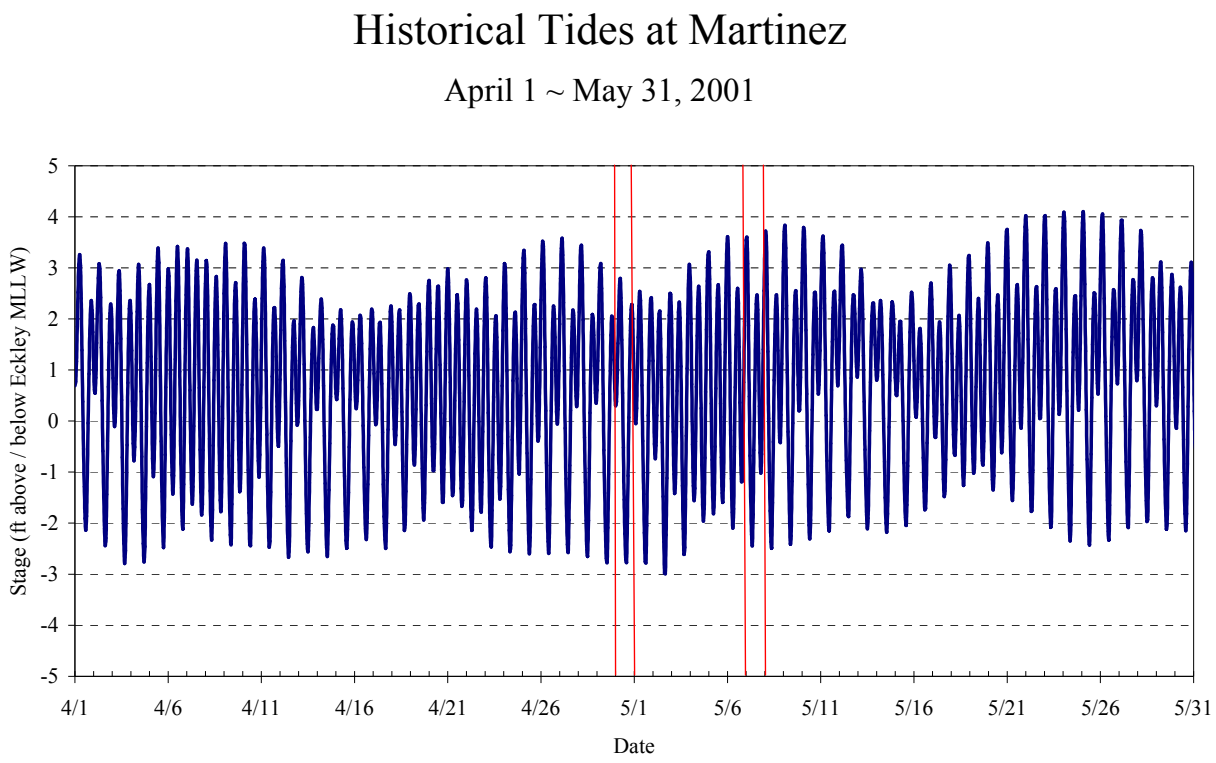

Figure 4: Shifted Tide at Martinez, April 1-May 30 2000, with tracer release dates shown in red

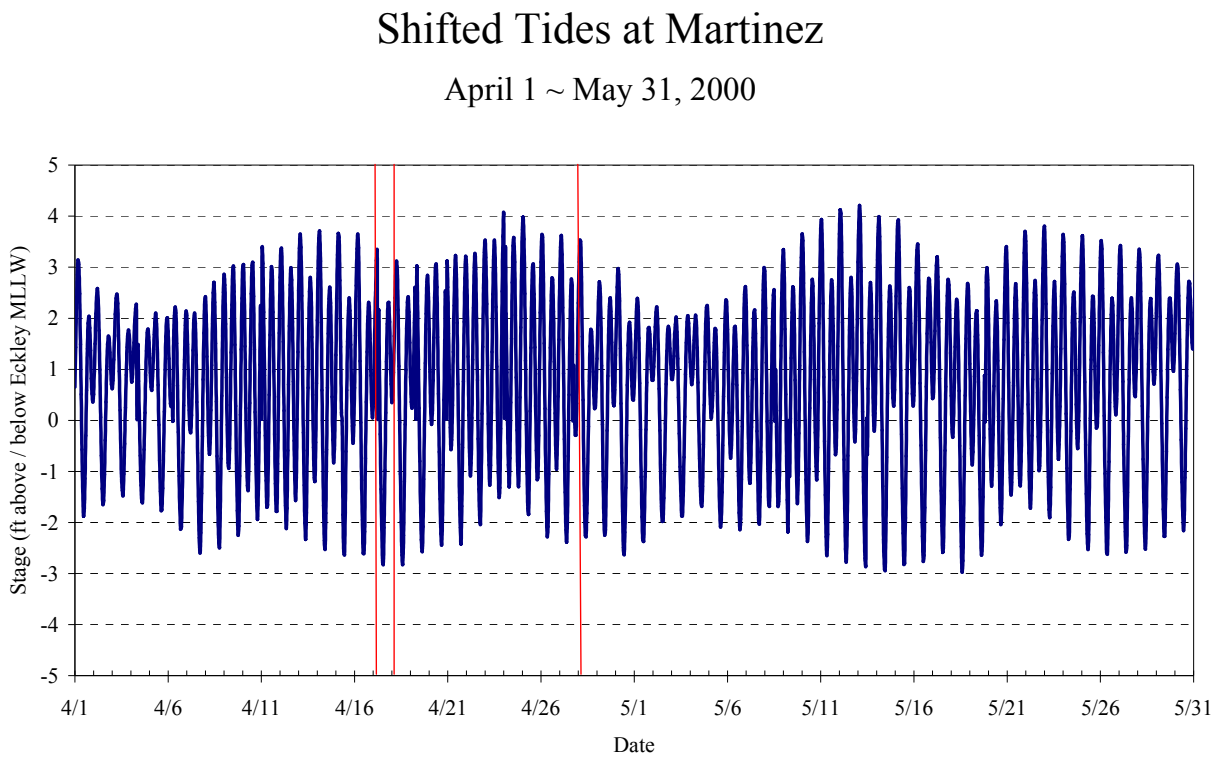

Figure 5: Shifted Tide at Martinez, April 1-May 30 2001, with tracer release dates shown in red

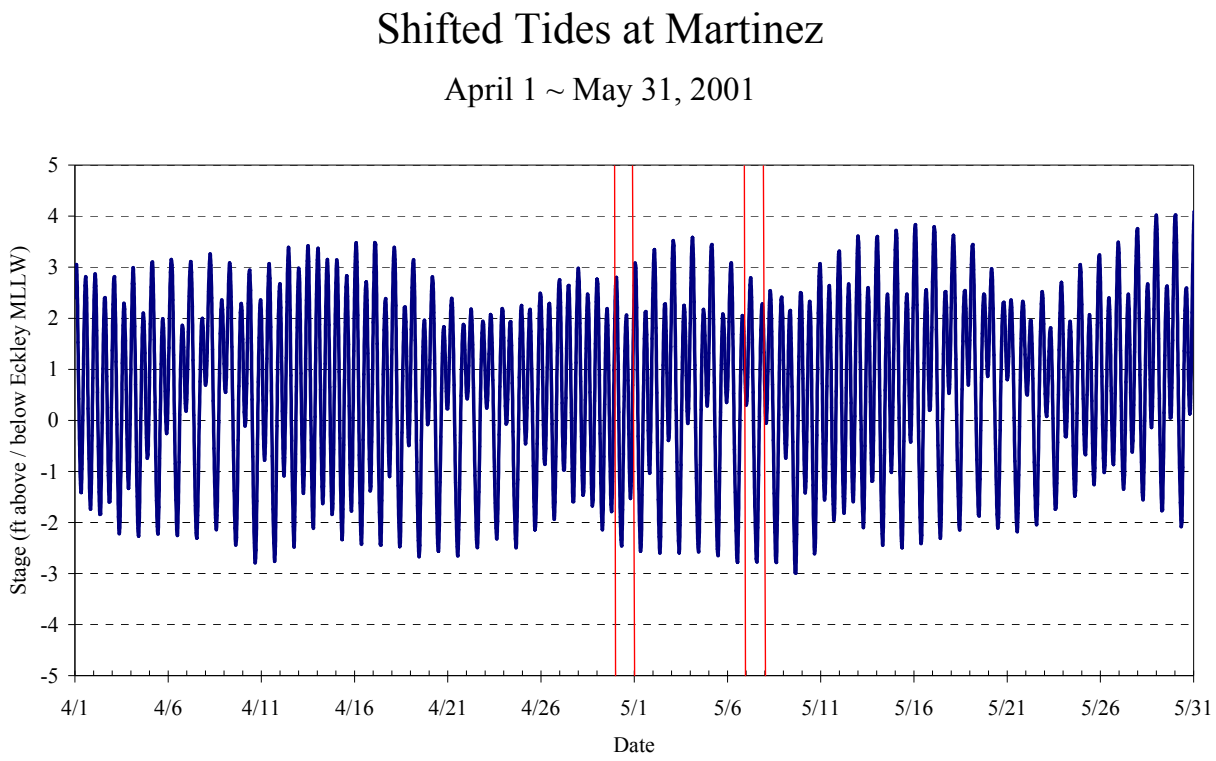

Figure 6: State Water and Central Valley Projects flow rates, water year 2000

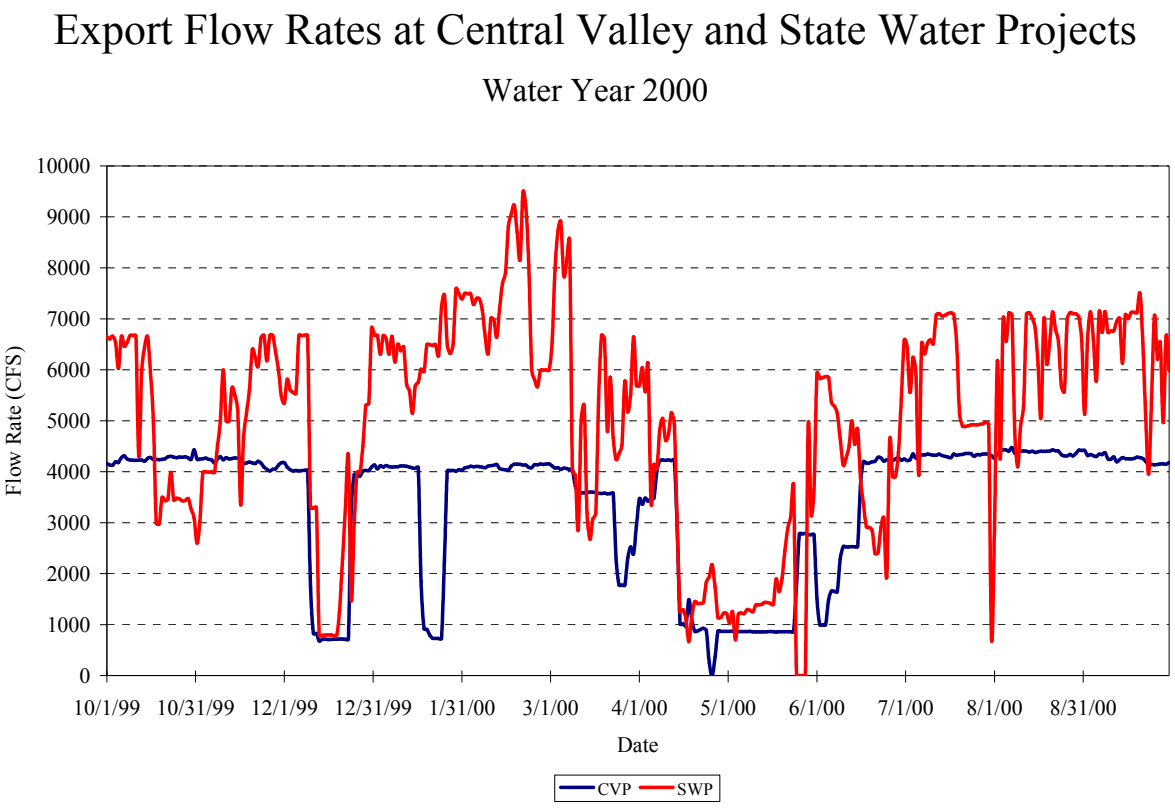

Figure 7: State Water and Central Valley Projects flow rates, water year 2001

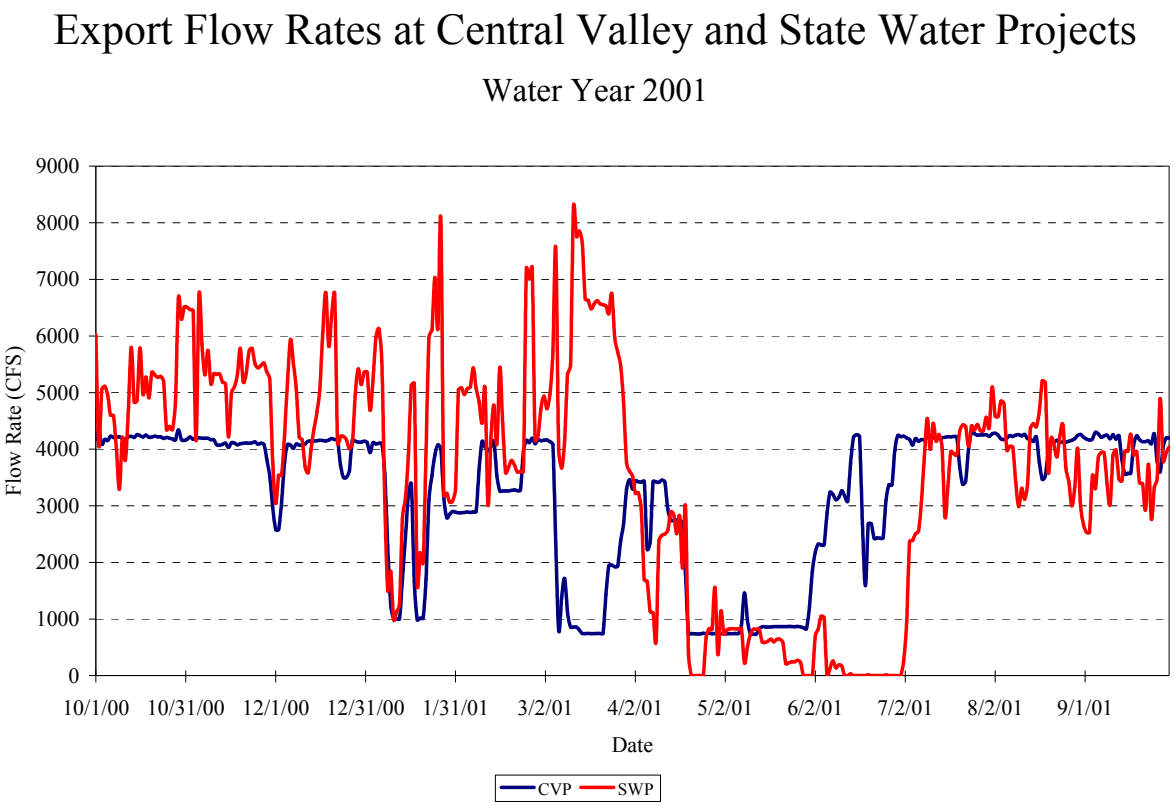

Table 2: Percent of Total Tracer that is exported from or flows past various locations, Historical Water Years 2000 and 2001

	Release Date	Exported: Central Valley Project	Exported: State Water Project	Diverted: Los Vaqueros Intake	Diverted: Contra Costa Canal	Old R. west of HORB [Flow to NW]	Stockton Ship Channel [Flow toward Bay]	Turner Cut [Flow to SW]	Columbia Cut [Flow to SW]	Little Connection Slough [Flow to NW]	Middle R. west of Medford Island [Positive flow NW]	Martinez [Flow west]
WY 2000	**4/17/00**	8.7	15.0	0.8	0.2	5.1	89.5	13.0	22.3	11.1	0.2	48.7
	4/18/00	9.2	15.6	0.8	0.2	5.0	90.4	12.8	22.0	12.7	0.4	47.4
	4/28/00	13.3	22.4	0.7	0.3	6.5	84.3	18.4	28.3	9.2	4.7	33.9
WY 2001	**4/30/01**	28.6	9.4	1.6	0.9	8.7	89.5	20.7	33.9	10.3	2.2	22.4
	5/1/01	29.4	9.3	1.7	0.9	8.6	89.6	22.5	31.0	11.7	1.4	21.8
	5/7/01	28.7	7.6	3.0	1.4	9.1	90.5	21.1	28.8	11.4	-0.2	19.2
	5/8/01	29.5	7.4	3.0	1.4	9.0	90.9	20.1	28.6	10.0	-1.0	18.9

Table 3: Percent of Total Tracer that is exported from or flows by various locations, Shifted Tide, Water Years 2000 and 2001

	Release Date	Exported: Central Valley Project	Exported: State Water Project	Diverted: Los Vaqueros Intake	Diverted: Contra Costa Canal	Old R. west of HORB [Flow to NW]	Stockton Ship Channel [Flow to NW]	Turner Cut [Flow to SW]	Columbia Cut [Flow to SW]	Little Connection Slough [Flow to NW]	Middle R. west of Medford Island [Positive flow to NW]	Martinez [Flow west]
WY00	**4/17/00**	9.1	15.4	0.8	0.2	5.3	88.2	11.3	24.2	9.1	2.4	48.0
	4/18/00	9.9	16.6	0.9	0.2	5.2	90.0	13.3	25.3	10.1	3.2	45.7
	4/28/00	12.5	21.4	0.6	0.3	6.3	84.9	14.2	26.3	10.3	3.3	36.5
WY01	**4/30/01**	27.9	9.4	1.6	0.9	9.2	90.8	20.7	28.1	11.5	1.4	23.2
	5/1/01	28.3	9.1	1.7	0.9	9.4	90.3	19.8	28.7	10.5	0.9	23.3
	5/7/01	29.8	7.8	3.3	1.4	8.3	90.4	21.7	33.3	11.4	0.8	19.0
	5/8/01	30.7	7.6	3.3	1.4	8.3	89.9	23.0	30.9	11.8	-0.4	18.2

It is evident from Tables 2 and 3 that the period of the tidal cycle in which the tracer is released does not have a substantial impact on the fraction of tracer (or San Joaquin River flow) that is ultimately exported. For all seven tracer release dates, the percent of tracer ultimately exported/diverted in the South Delta varied only ~1% between historical tides and shifted-tide scenarios. Differences between the scenarios were up to ~6% in other portions of the Delta.

The sum of exports, diversions, and Delta outflow at Martinez ranged from ~60-73% for the scenarios, indicating that ~27-40% of the San Joaquin River water that entered the Delta on the various fish release days remained in the Delta September 30, the end of the modeling period, was pumped out for agricultural use, or was diluted by other flows to concentrations below the level that can be resolved by the model.

Appendix A-Historical Tides, Water Year 2000

Normalized Tracer Concentrations in Clifton Court

Model Period: April ~ September 2000

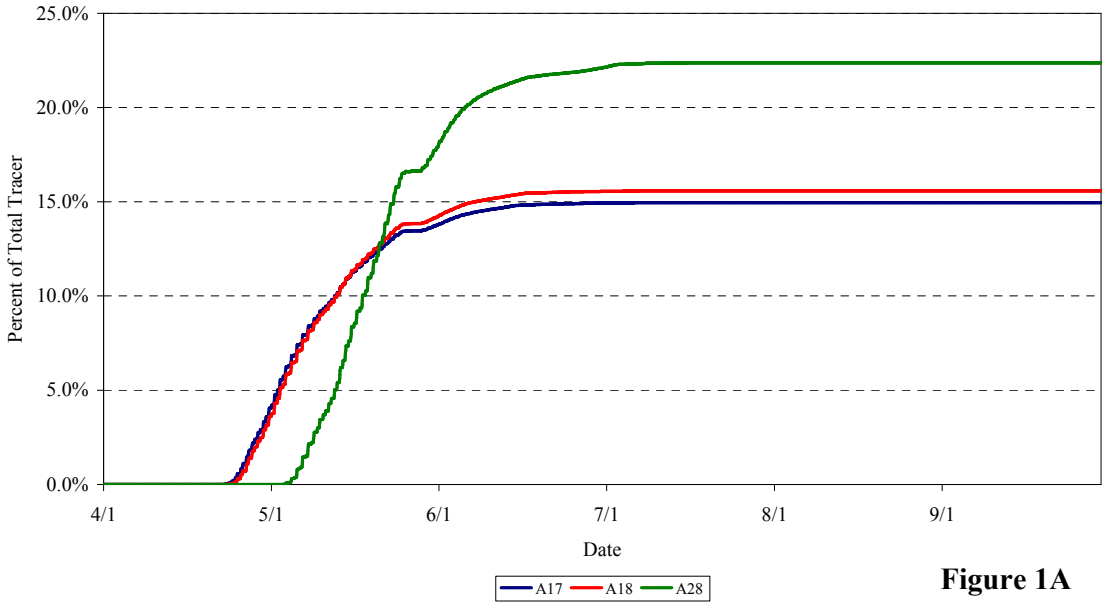

Figure 1A

Normalized Tracer Concentrations at Tracy Pumping Station

Model Period: April ~ September 2000

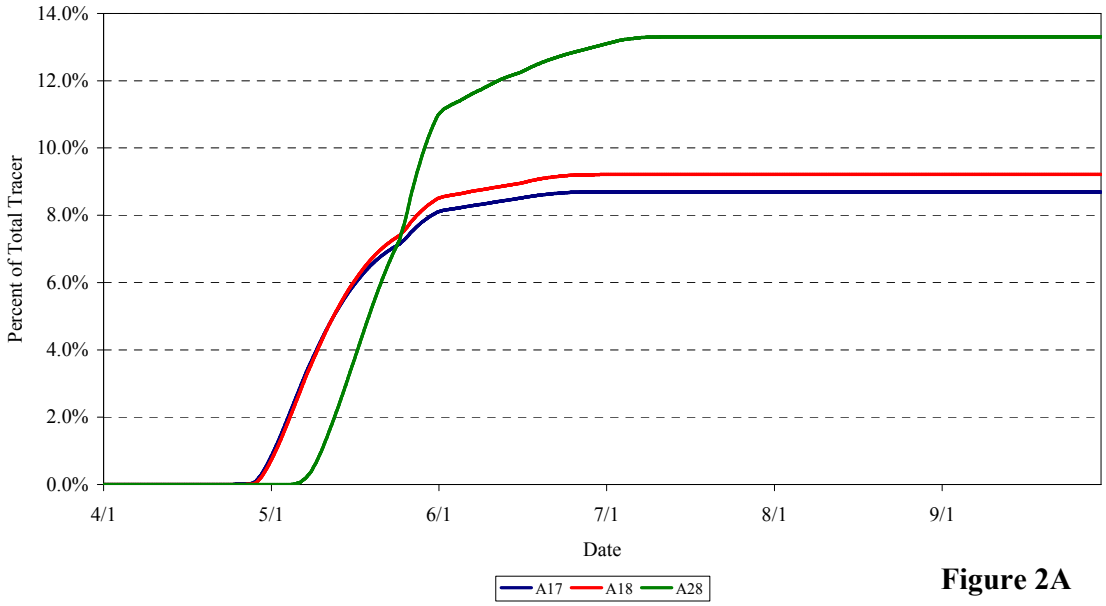

Figure 2A

Normalized Tracer Concentrations at Los Vaqueros Intake

Model Period: April ~ September 2000

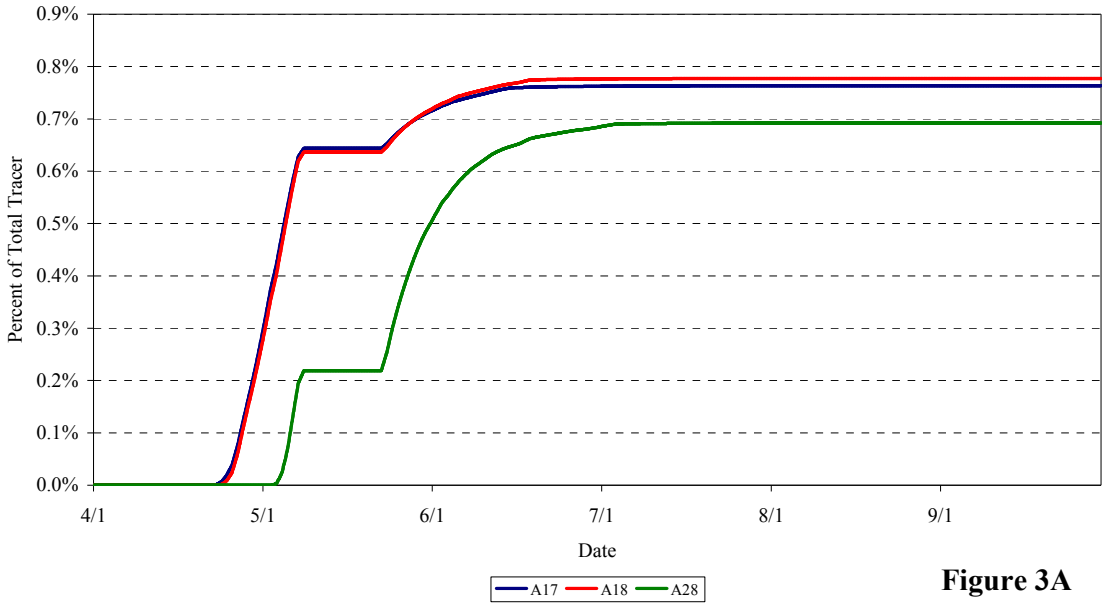

Figure 3A

Normalized Tracer Concentrations at Contra Costa Canal Intake

Model Period: April ~ September 2000

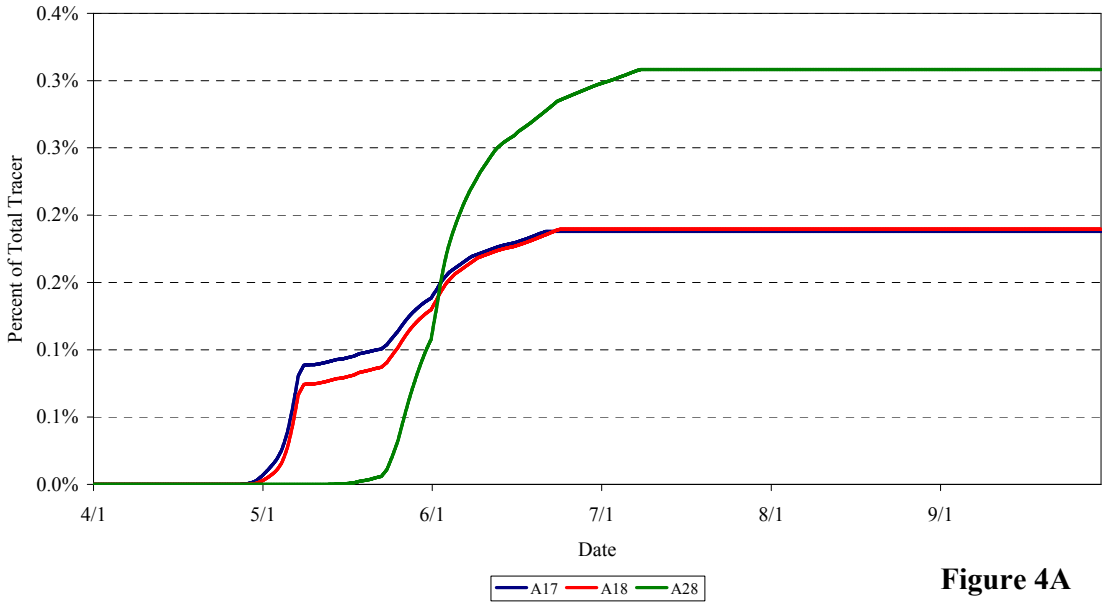

Figure 4A

Normalized Tracer Concentrations in Turner Cut

Model Period: April ~ September 2000

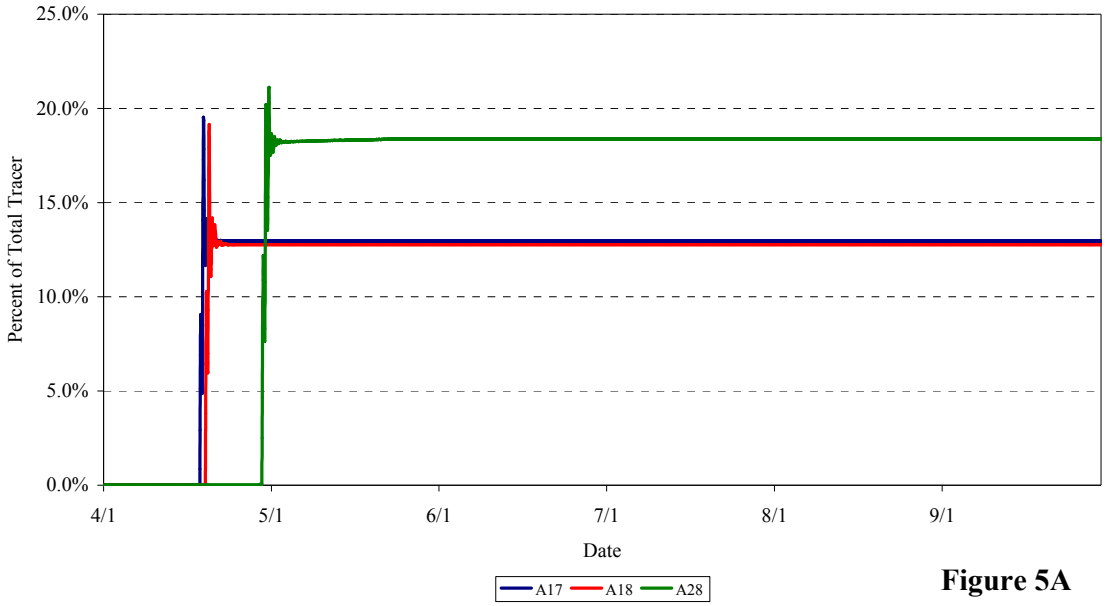

Figure 5A

Normalized Tracer Concentrations in Columbia Cut

Model Period: April ~ September 2000

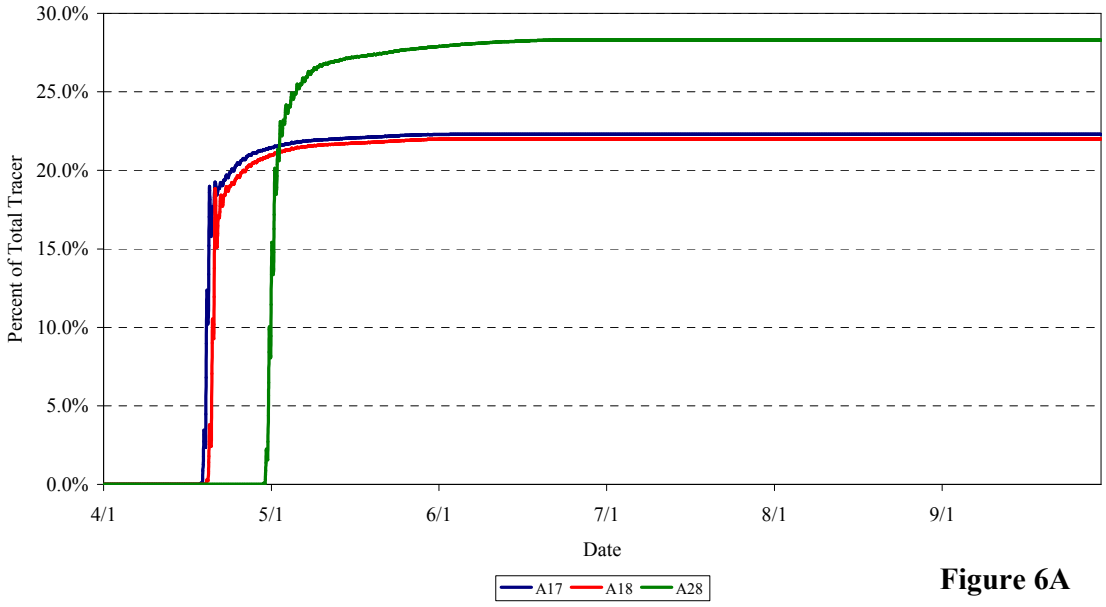

Figure 6A

Normalized Tracer Concentrations in Stockton Ship Channel

Model Period: April ~ September 2000

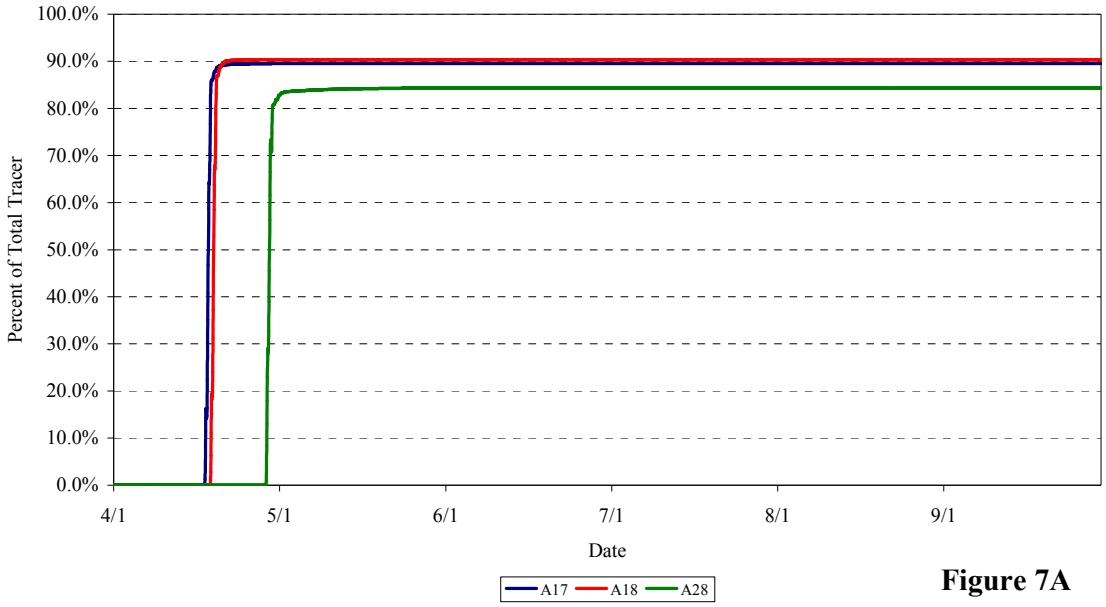

Figure 7A

Normalized Tracer Concentrations in Old River West of HORB

Model Period: April ~ September 2000

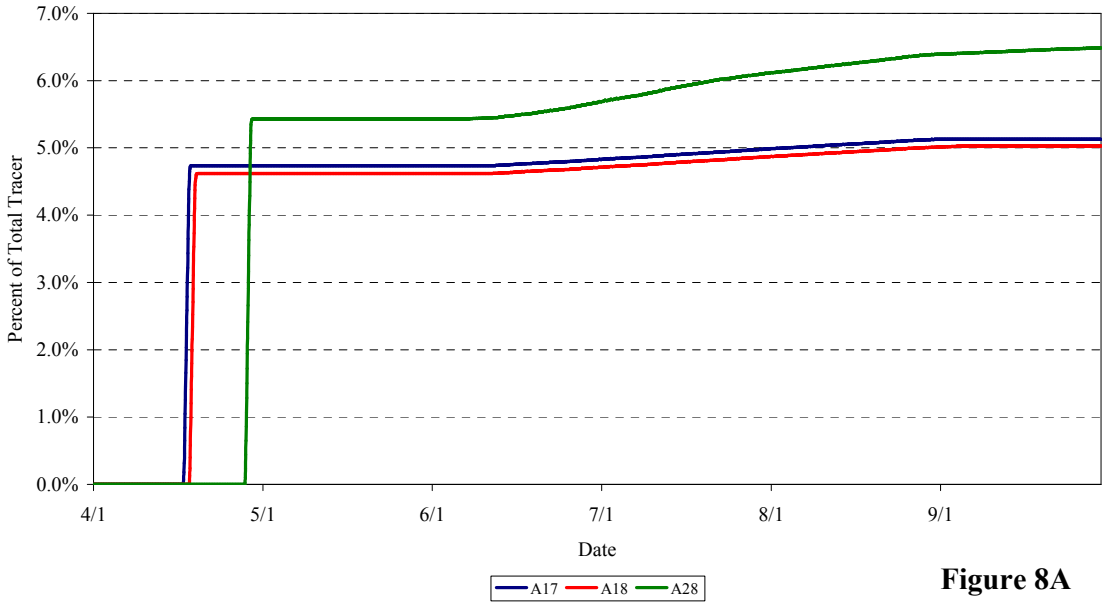

Figure 8A

Normalized Tracer Concentrations in Middle River W. of Medford Is

Model Period: April ~ September 2000

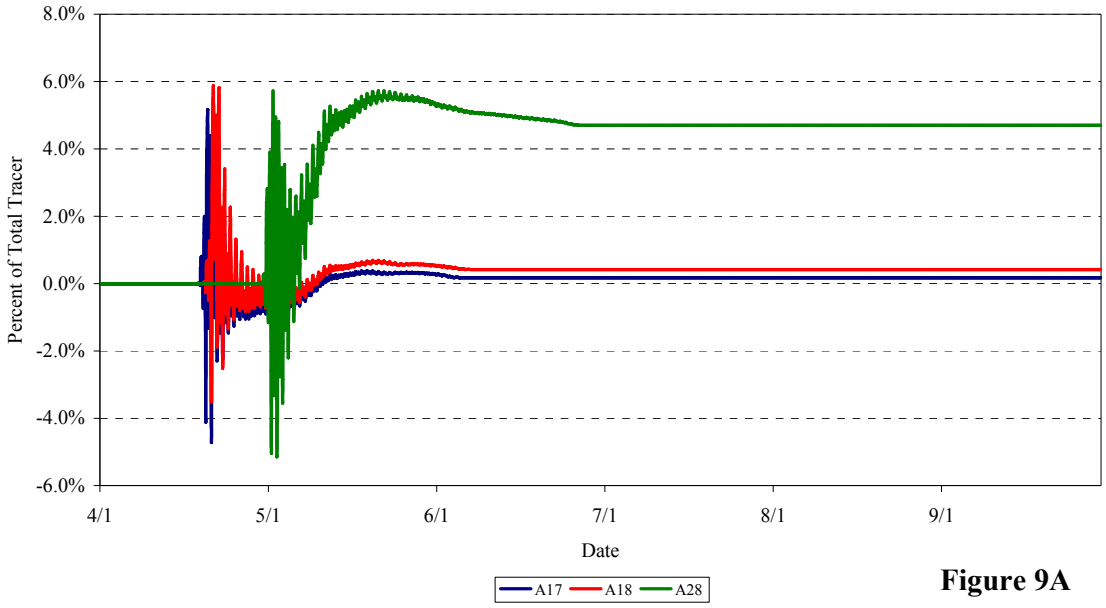

Figure 9A

Normalized Tracer Concentrations in Little Connection Slough

Model Period: April ~ September 2000

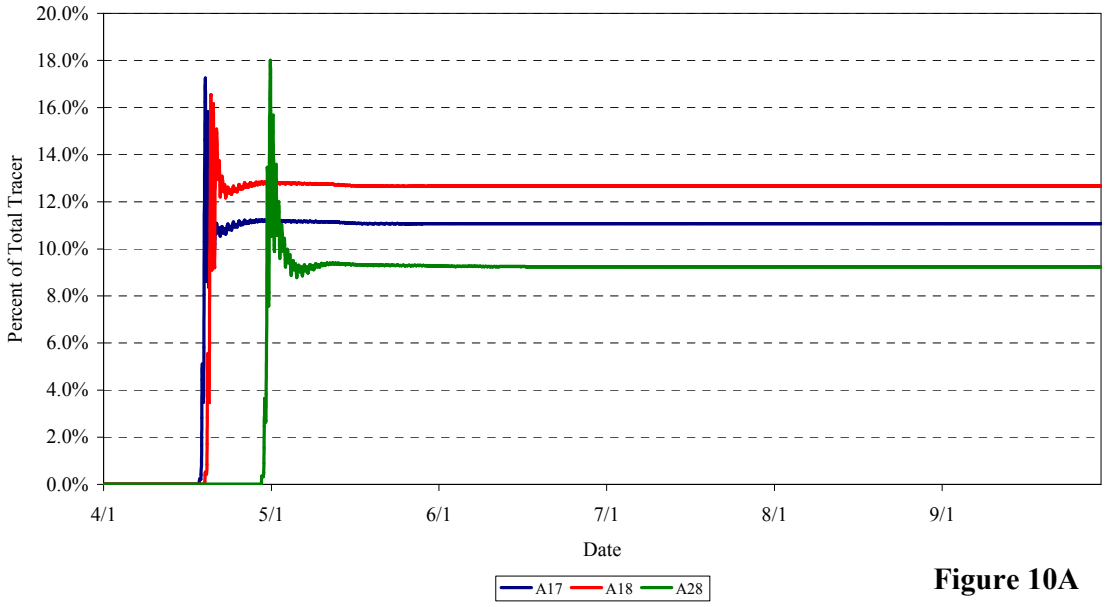

Figure 10A

Normalized Tracer Concentrations in Martinez

Model Period: April ~ September 2000

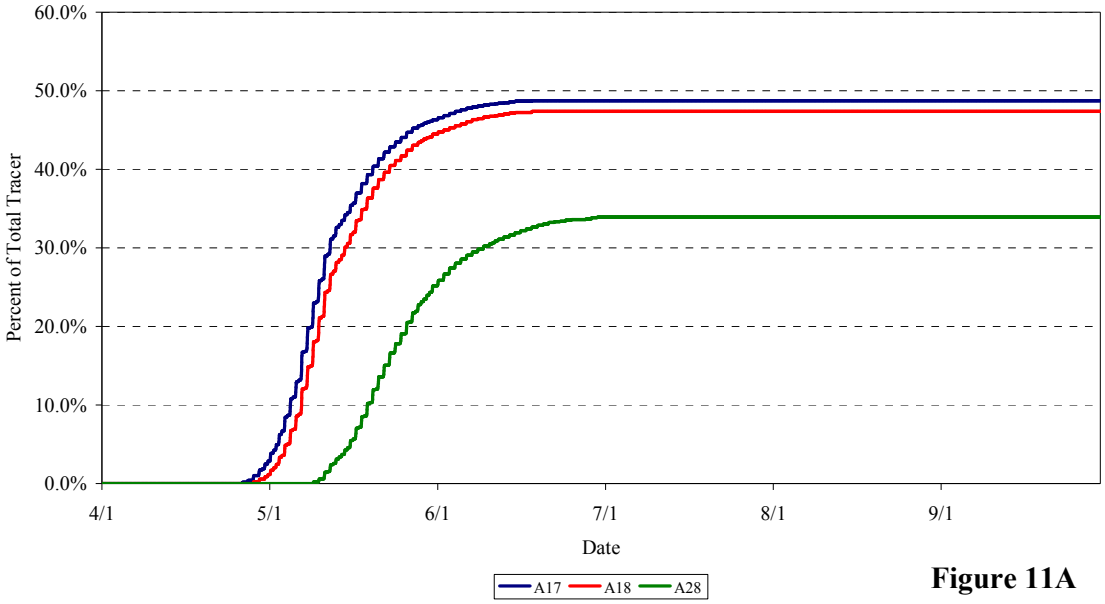

Figure 11A

Appendix B-Shifted Tides, Water Year 2000

Normalized Tracer Concentrations in Clifton Court

Model Period: April ~ September 2000

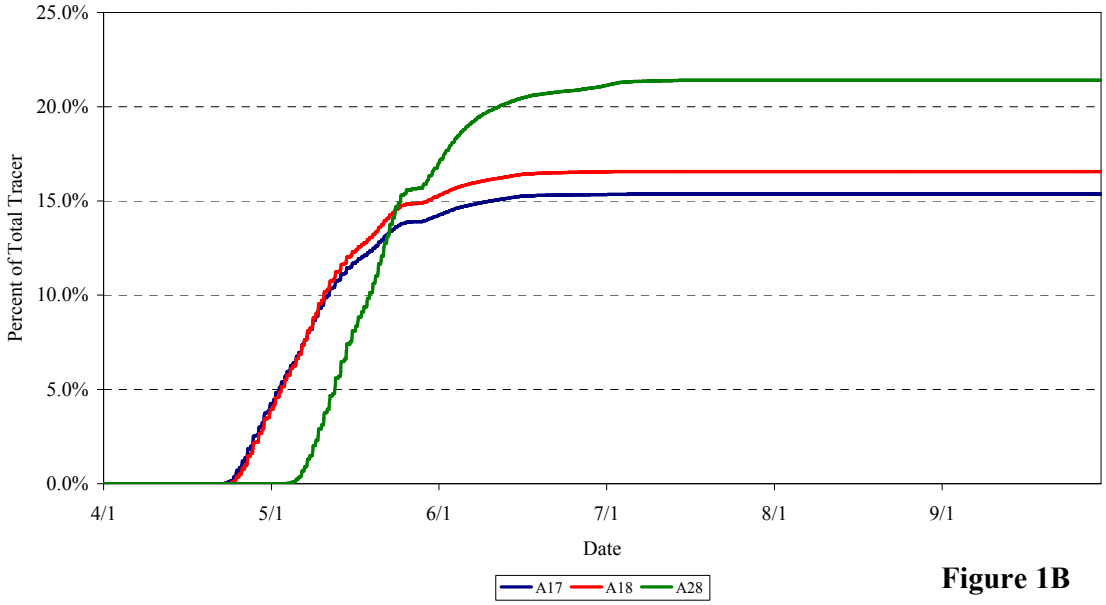

Figure 1B

Normalized Tracer Concentrations at Tracy Pumping Station

Model Period: April ~ September 2000

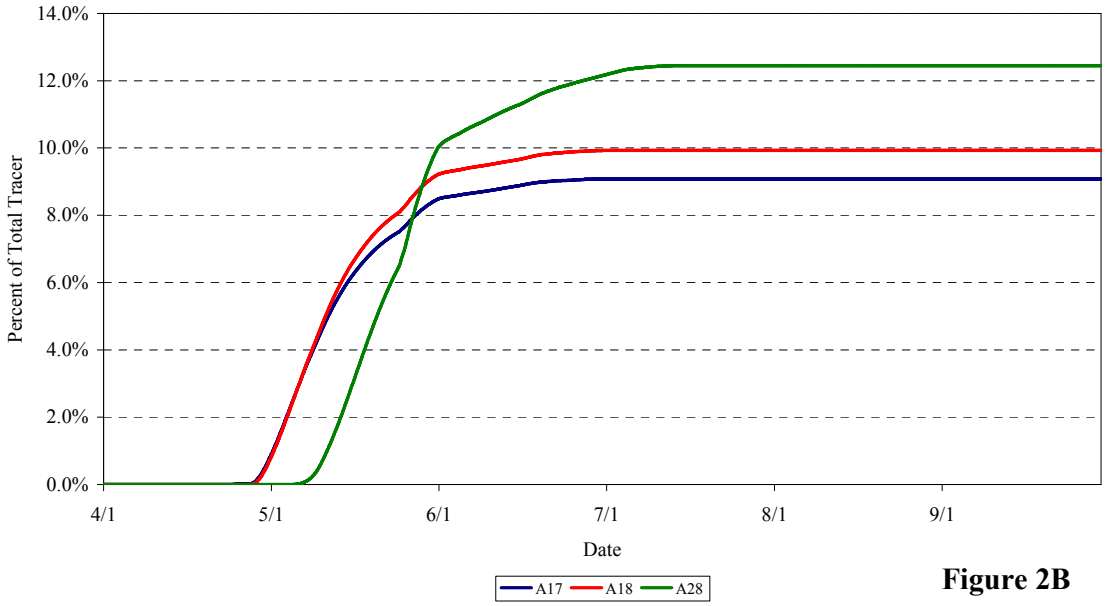

Figure 2B

Normalized Tracer Concentrations at Los Vaqueros Intake

Model Period: April ~ September 2000

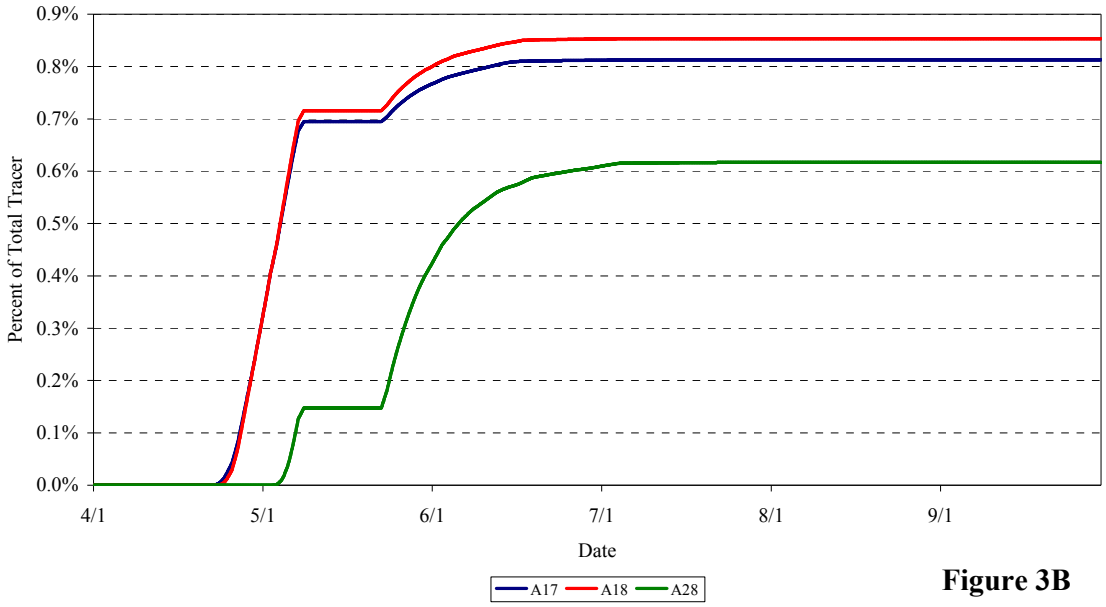

Figure 3B

Normalized Tracer Concentrations at Contra Costa Canal Intake

Model Period: April ~ September 2000

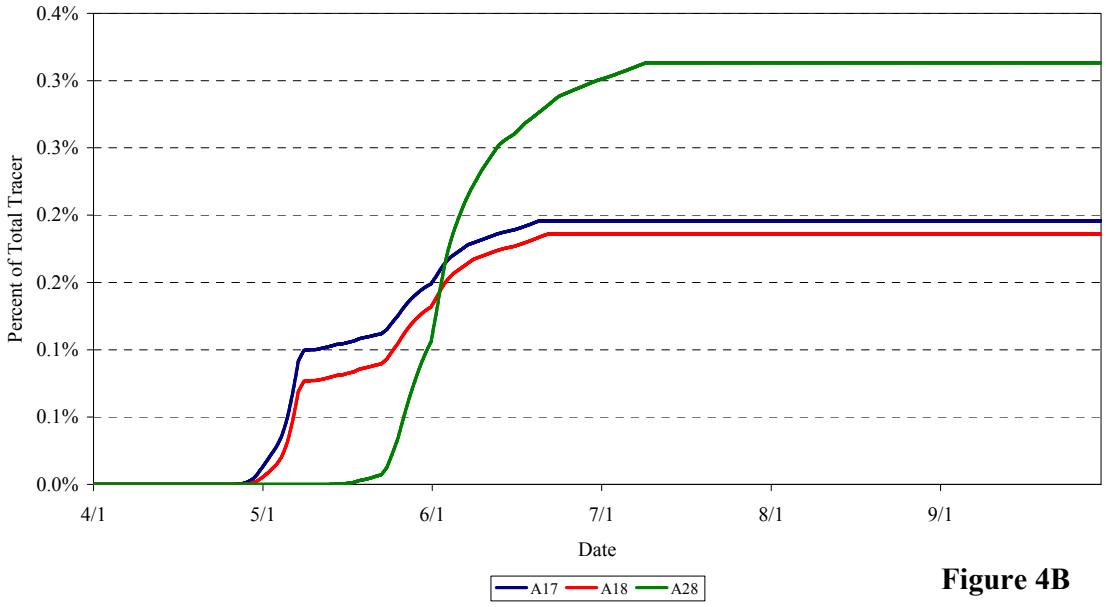

Figure 4B

Normalized Tracer Concentrations in Turner Cut

Model Period: April ~ September 2000

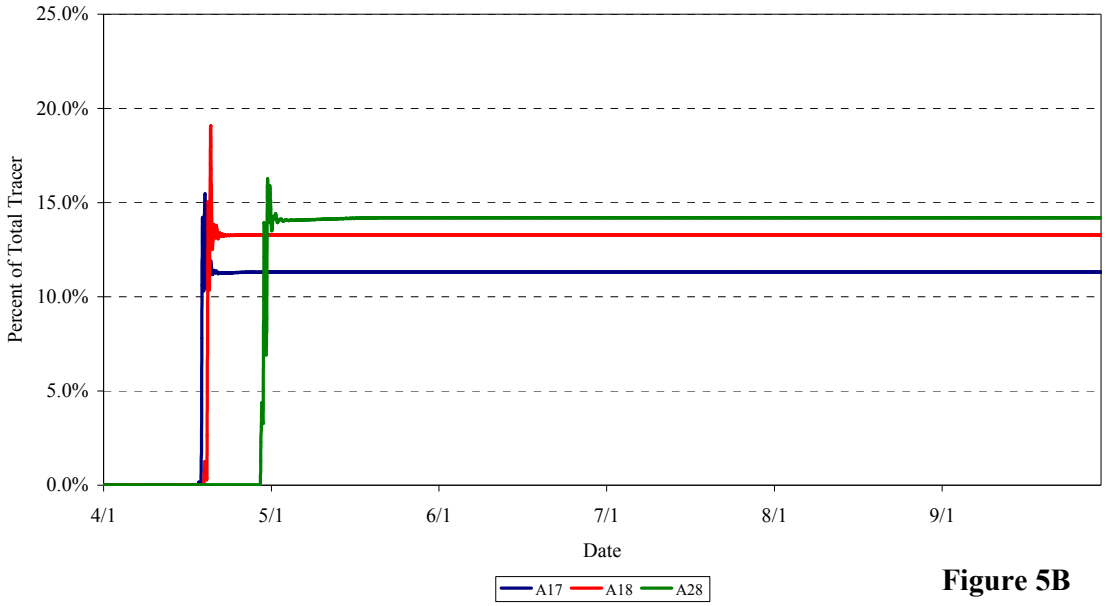

Figure 5B

Normalized Tracer Concentrations in Columbia Cut

Model Period: April ~ September 2000

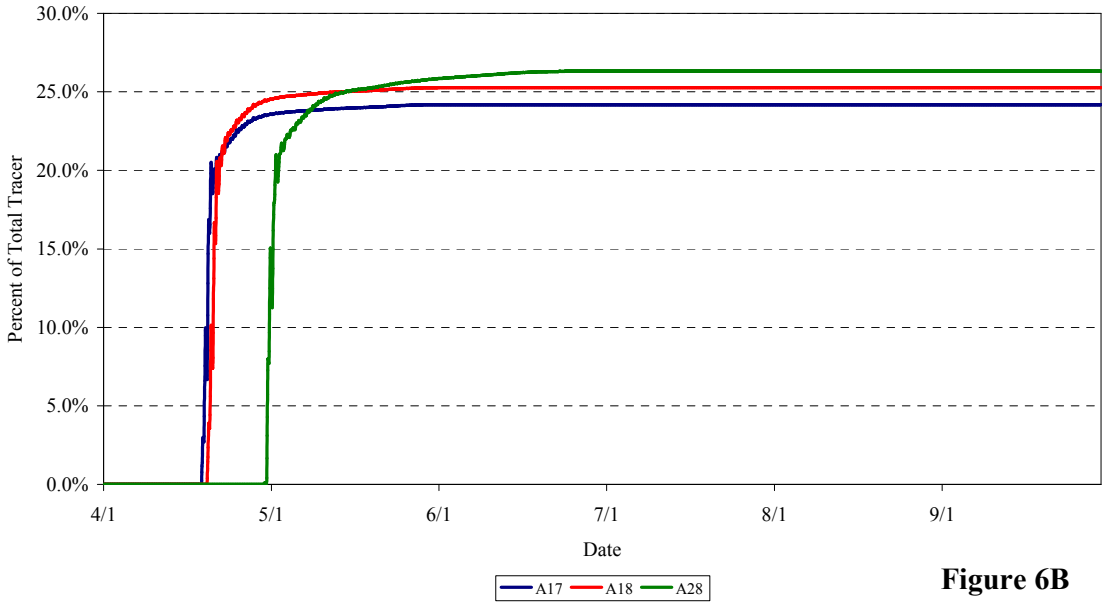

Figure 6B

Normalized Tracer Concentrations in Stockton Ship Channel

Model Period: April ~ September 2000

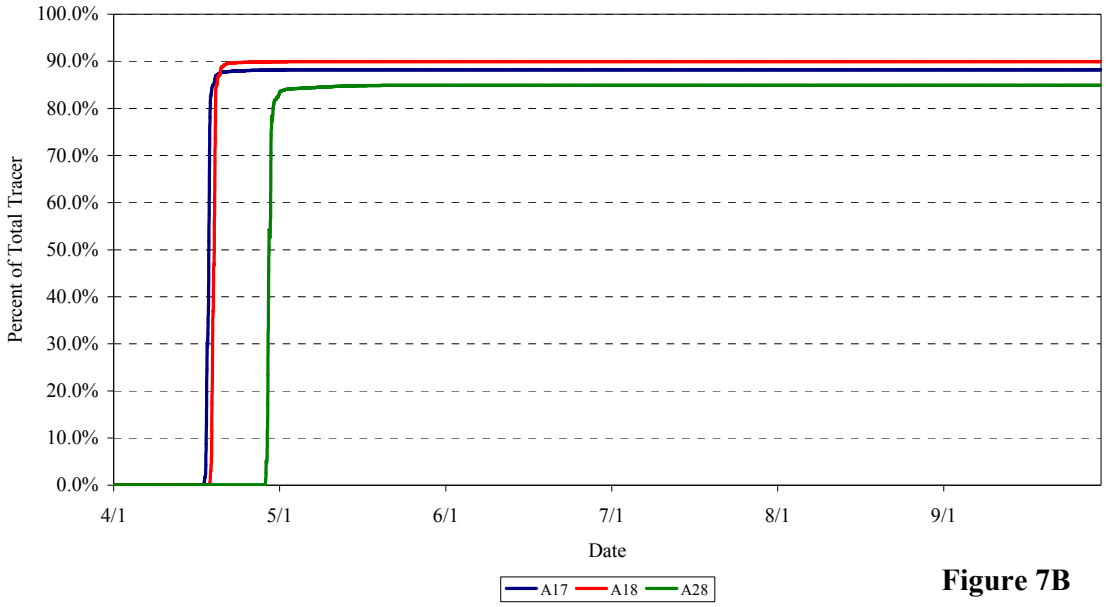

Figure 7B

Normalized Tracer Concentrations in Old River West of HORB

Model Period: April ~ September 2000

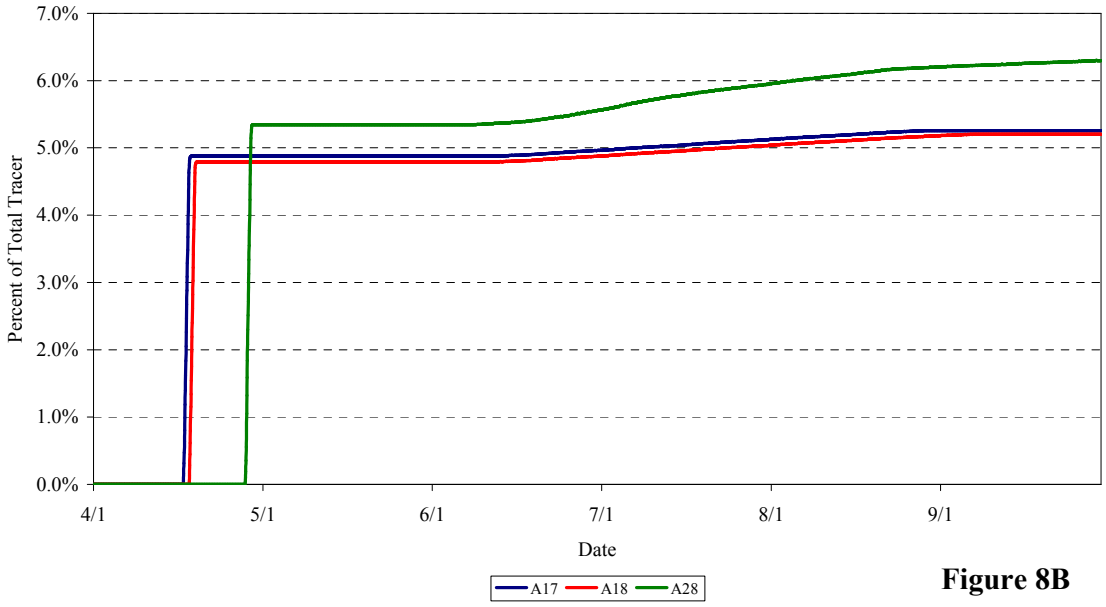

Figure 8B

Normalized Tracer Concentrations in Middle River W. of Medford Is

Model Period: April ~ September 2000

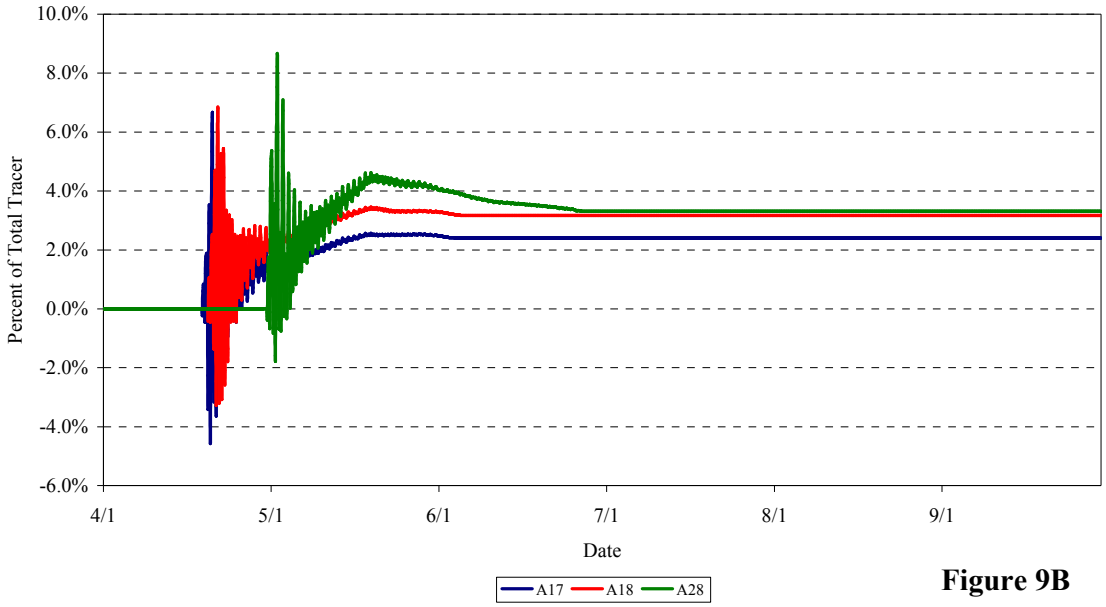

Figure 9B

Normalized Tracer Concentrations in Little Connection Slough

Model Period: April ~ September 2000

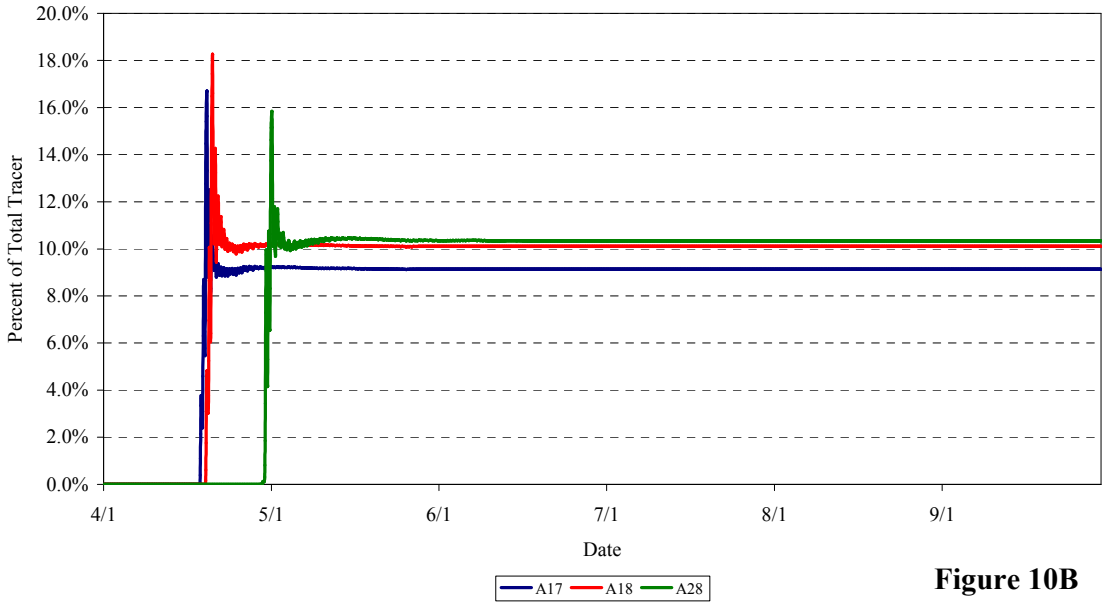

Figure 10B

Normalized Tracer Concentrations in Martinez

Model Period: April ~ September 2000

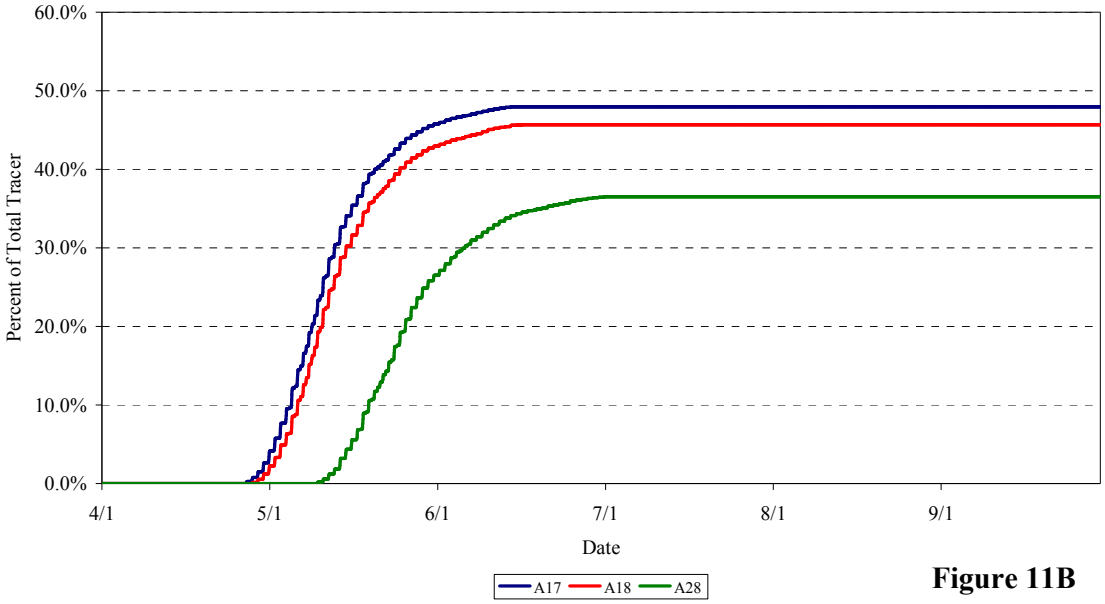

Figure 11B

Appendix C-Historical Tides, Water Year 2001

Normalized Tracer Concentrations in Clifton Court

Model Period: April ~ September 2001

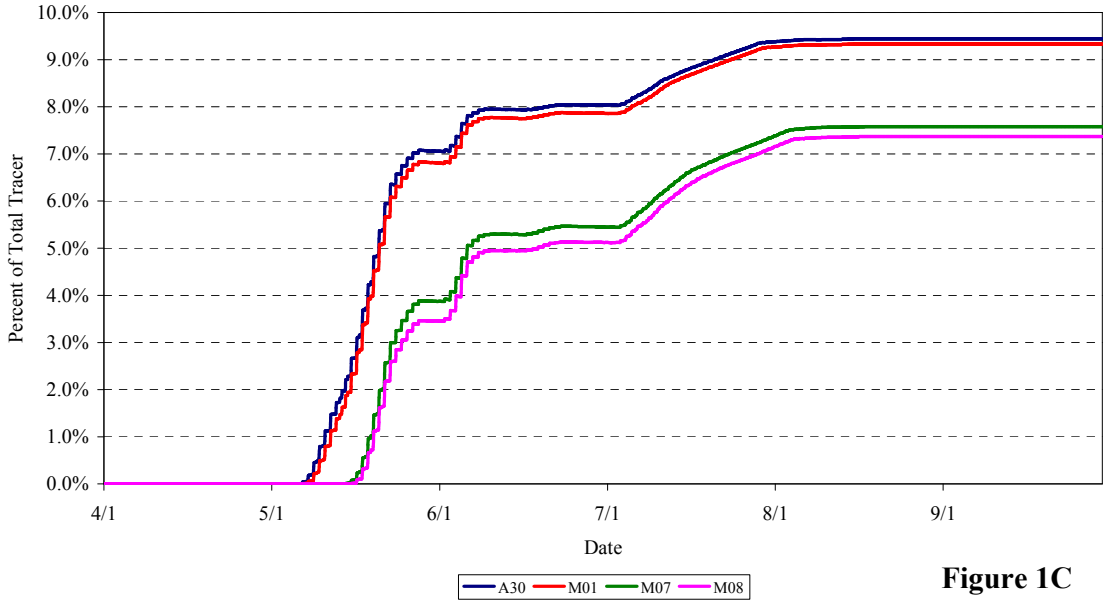

Figure 1C

Normalized Tracer Concentrations at Tracy Pumping Station

Model Period: April ~ September 2001

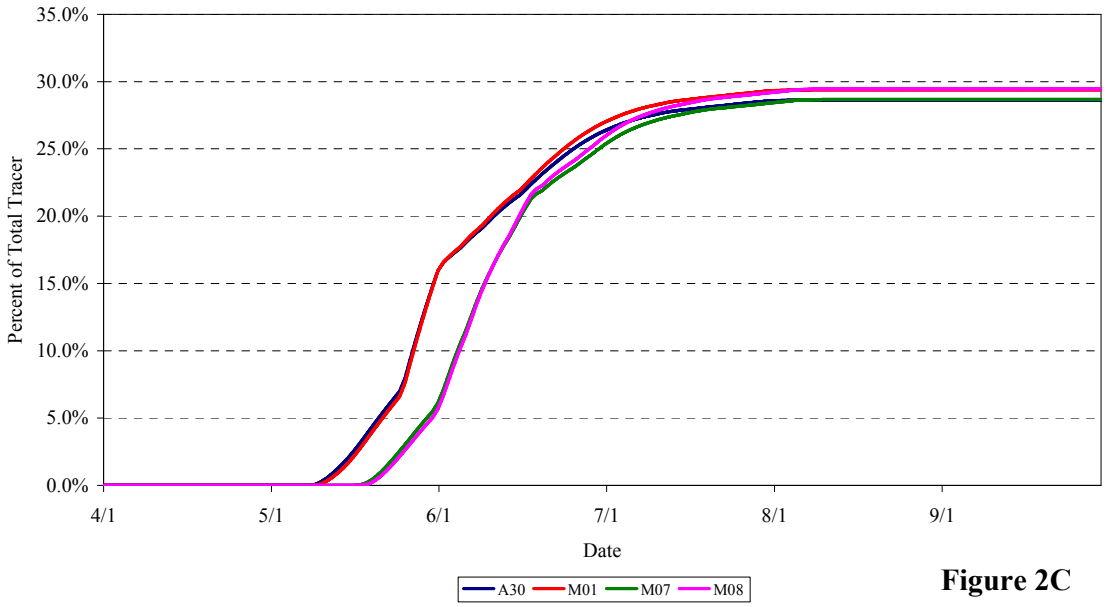

Figure 2C

Normalized Tracer Concentrations at Los Vaqueros Intake

Model Period: April ~ September 2001

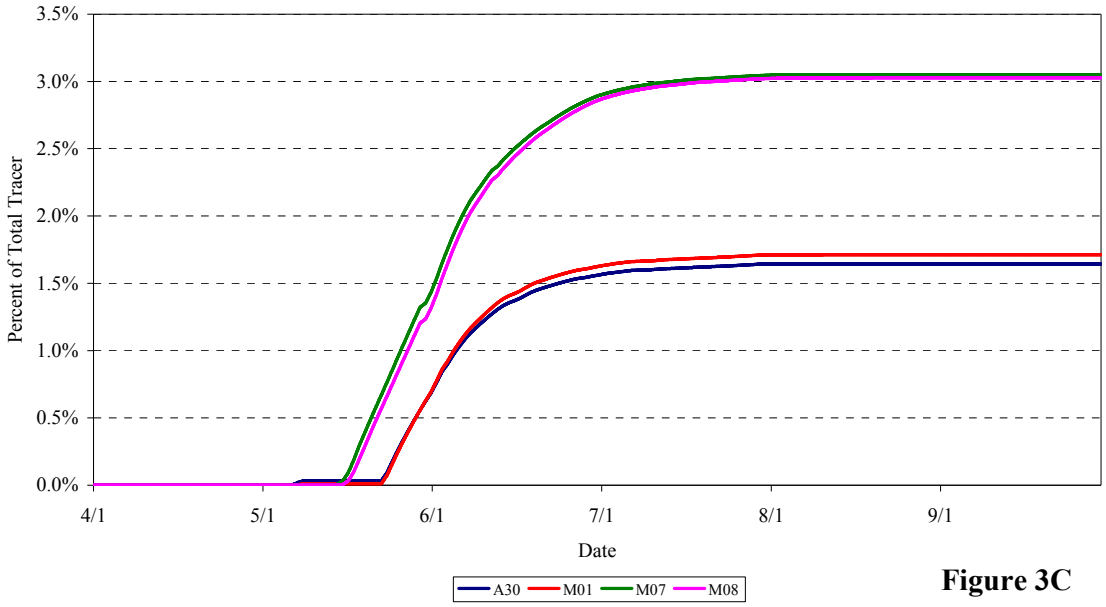

Figure 3C

Normalized Tracer Concentrations at Contra Costa Canal Intake

Model Period: April ~ September 2001

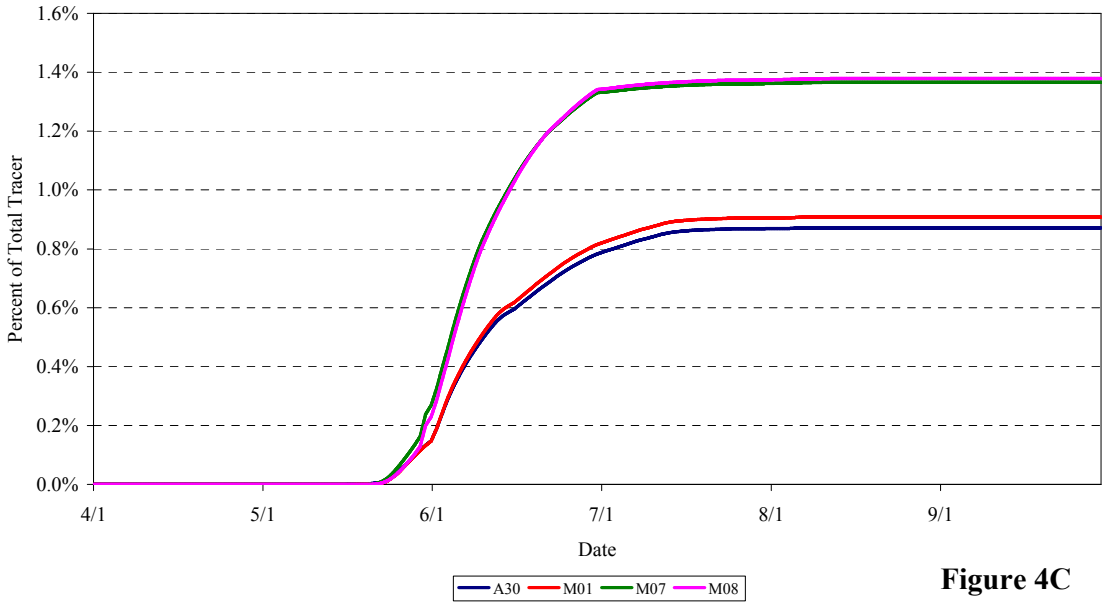

Figure 4C

Normalized Tracer Concentrations in Turner Cut

Model Period: April ~ September 2001

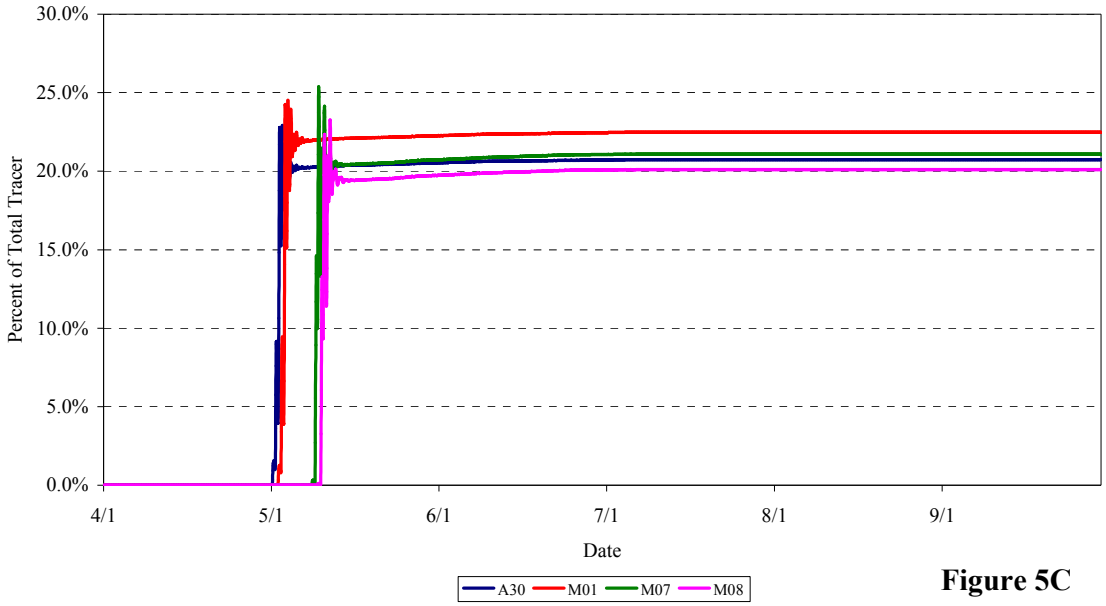

Figure 5C

Normalized Tracer Concentrations in Columbia Cut

Model Period: April ~ September 2001

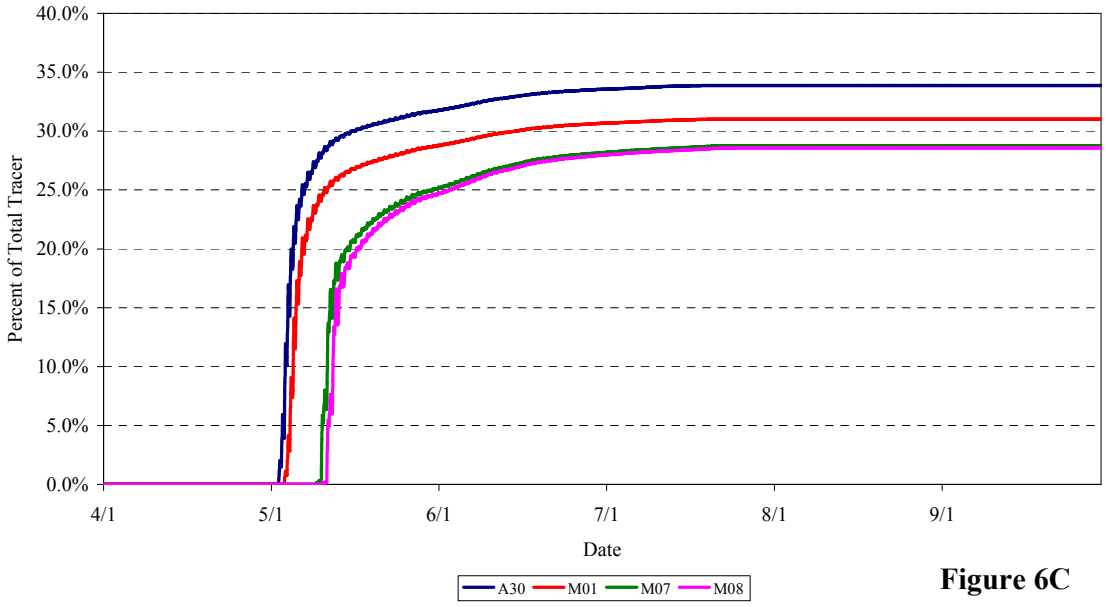

Figure 6C

Normalized Tracer Concentrations in Stockton Ship Channel

Model Period: April ~ September 2001

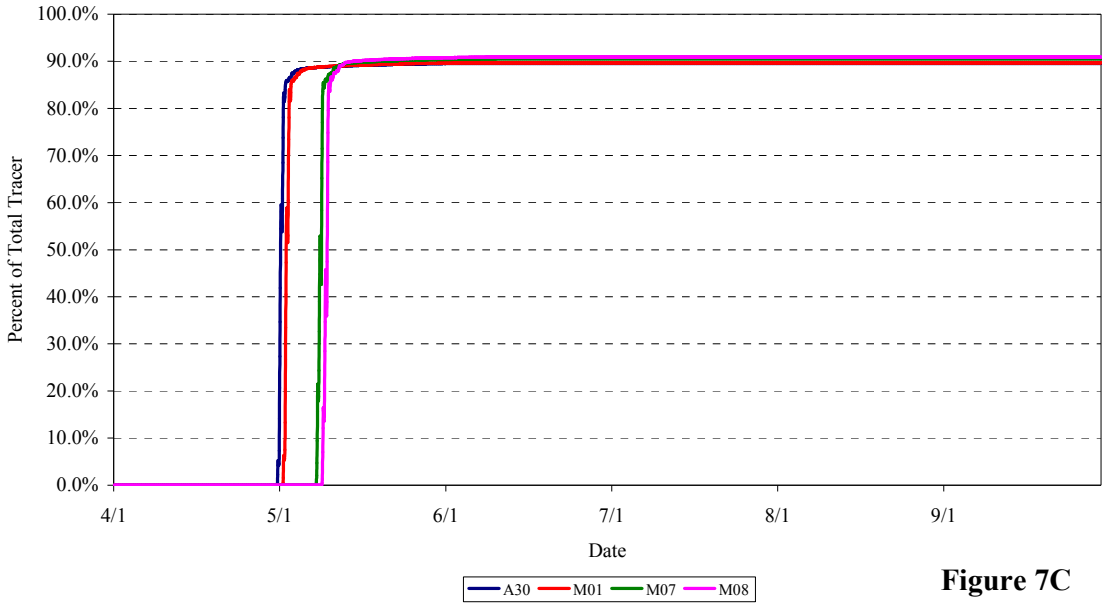

Figure 7C

Normalized Tracer Concentrations in Old River West of HORB

Model Period: April ~ September 2001

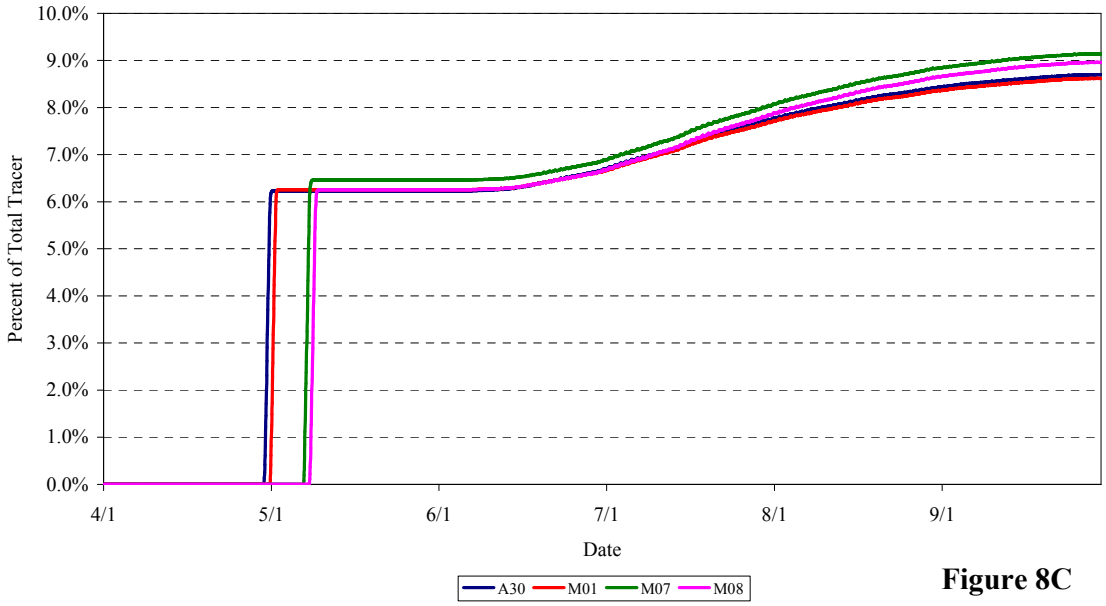

Figure 8C

Normalized Tracer Concentrations in Middle River W. of Medford Is

Model Period: April ~ September 2001

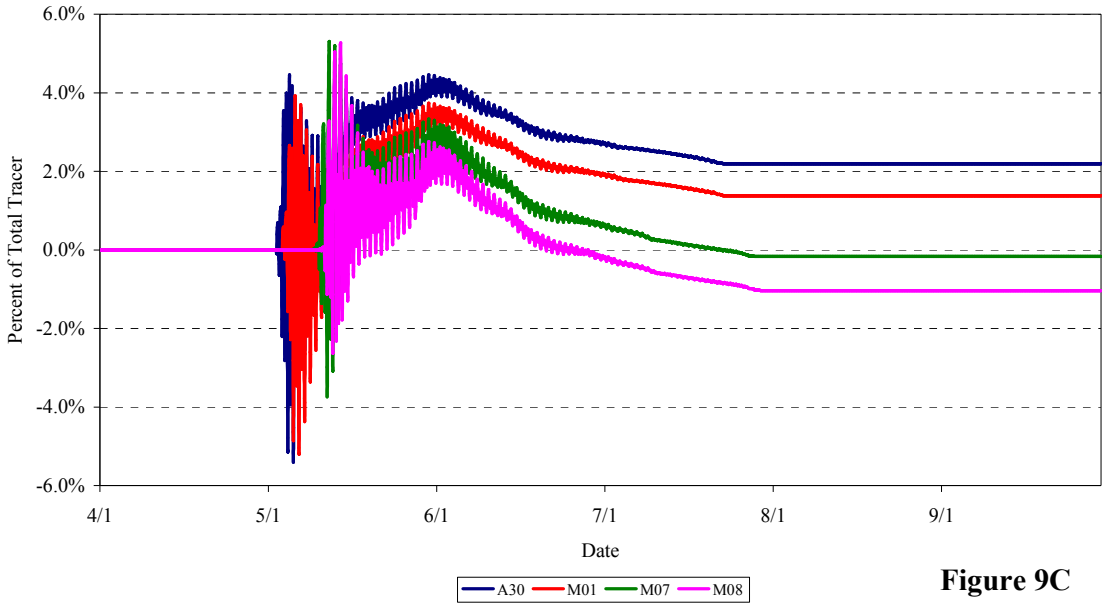

Figure 9C

Normalized Tracer Concentrations in Little Connection Slough

Model Period: April ~ September 2001

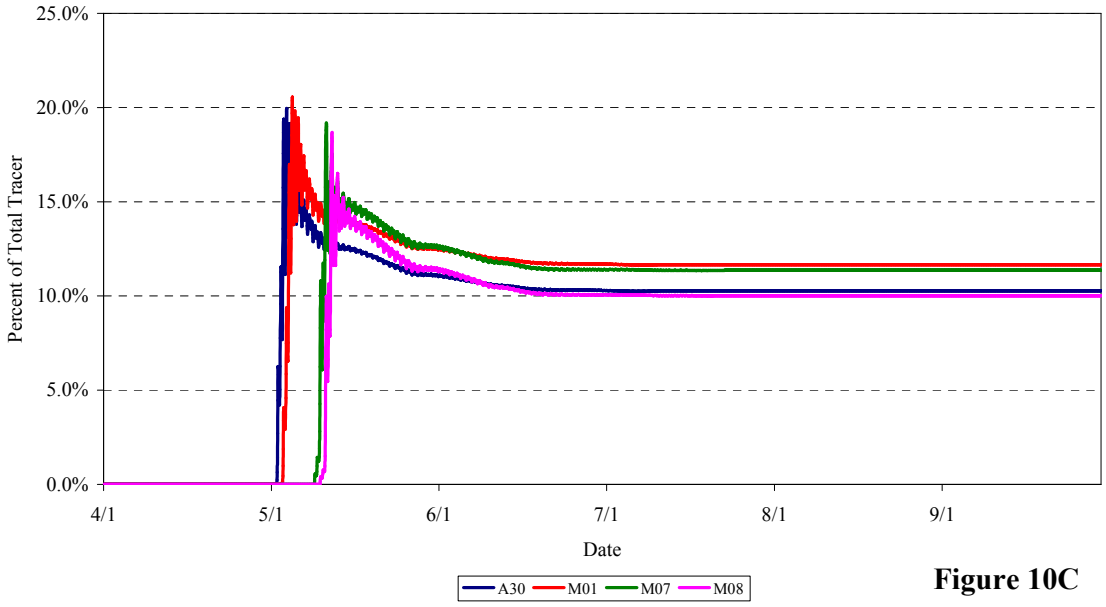

Figure 10C

Normalized Tracer Concentrations in Martinez

Model Period: April ~ September 2001

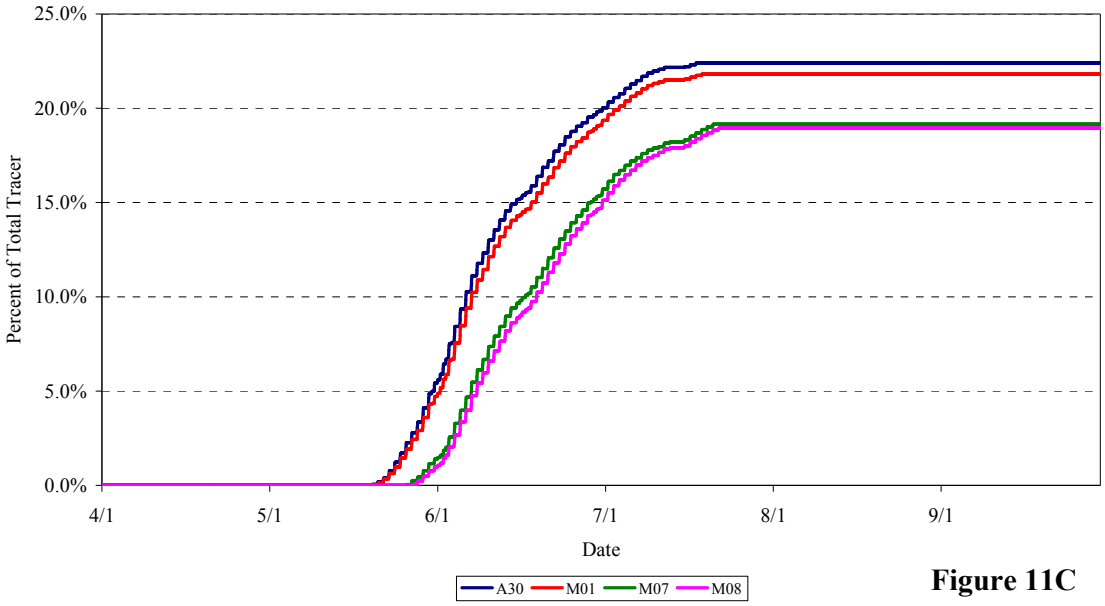

Figure 11C

Appendix D-Shifted Tides, Water Year 2001

Normalized Tracer Concentrations in Clifton Court

Model Period: April ~ September 2001

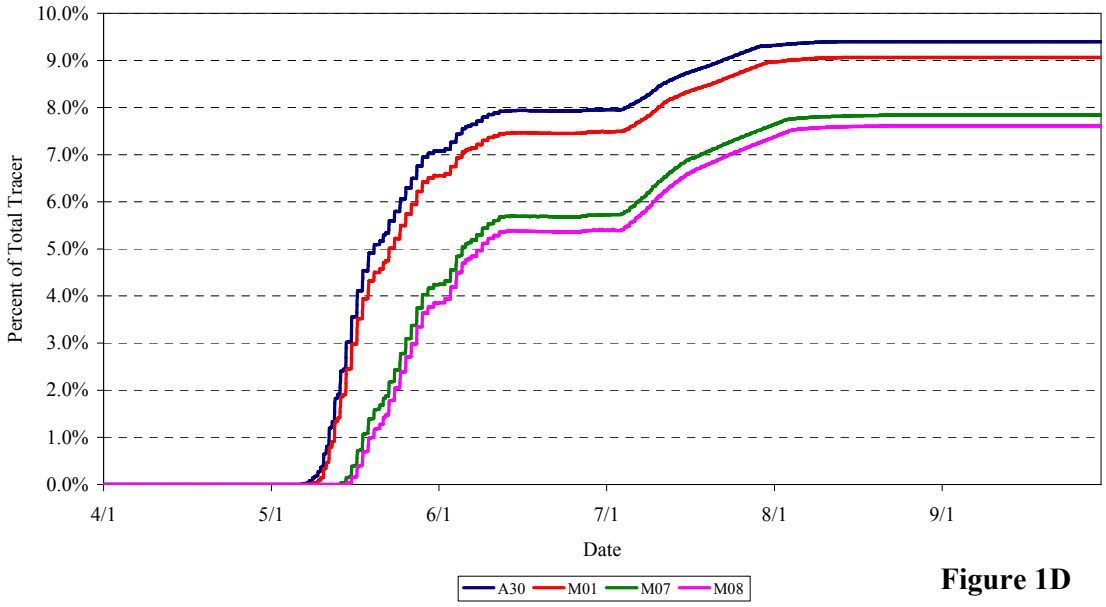

Figure 1D

Normalized Tracer Concentrations at Tracy Pumping Station

Model Period: April ~ September 2001

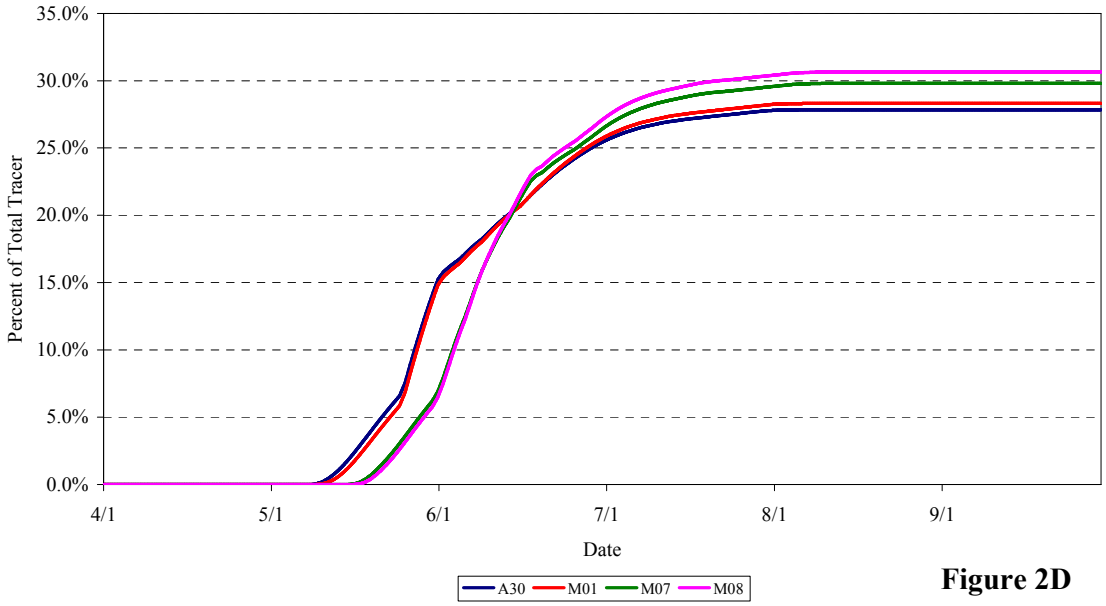

Figure 2D

Normalized Tracer Concentrations at Los Vaqueros Intake

Model Period: April ~ September 2001

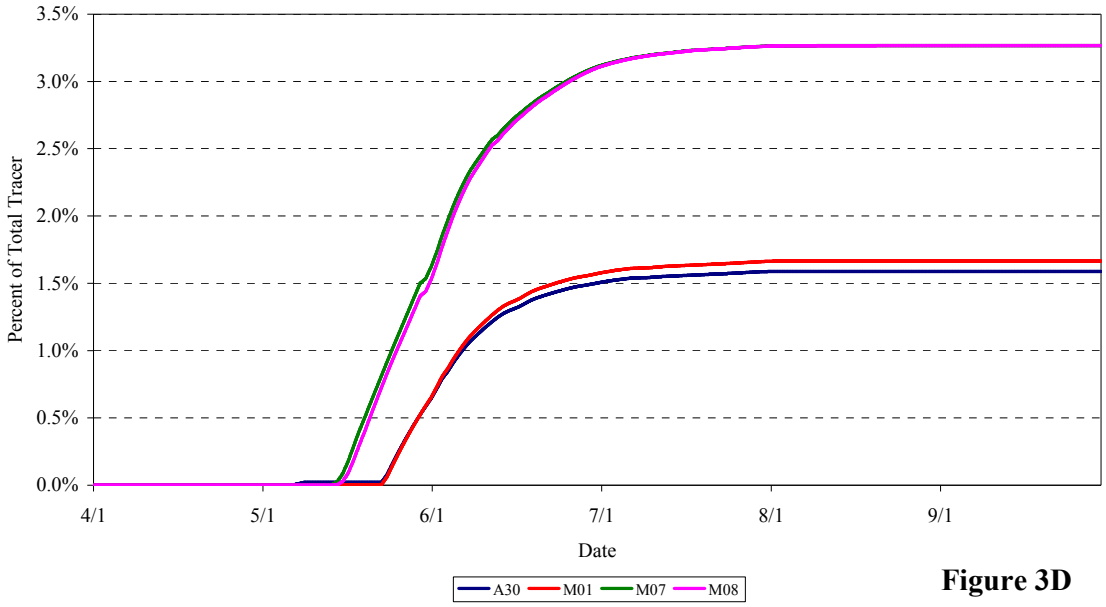

Figure 3D

Normalized Tracer Concentrations at Contra Costa Canal Intake

Model Period: April ~ September 2001

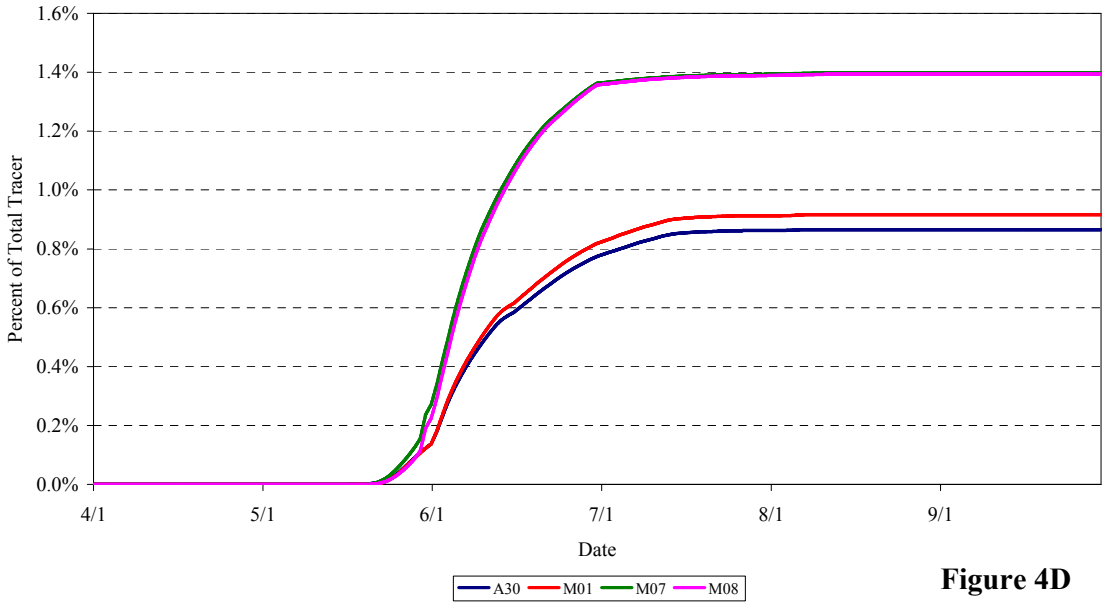

Figure 4D

Normalized Tracer Concentrations in Turner Cut

Model Period: April ~ September 2001

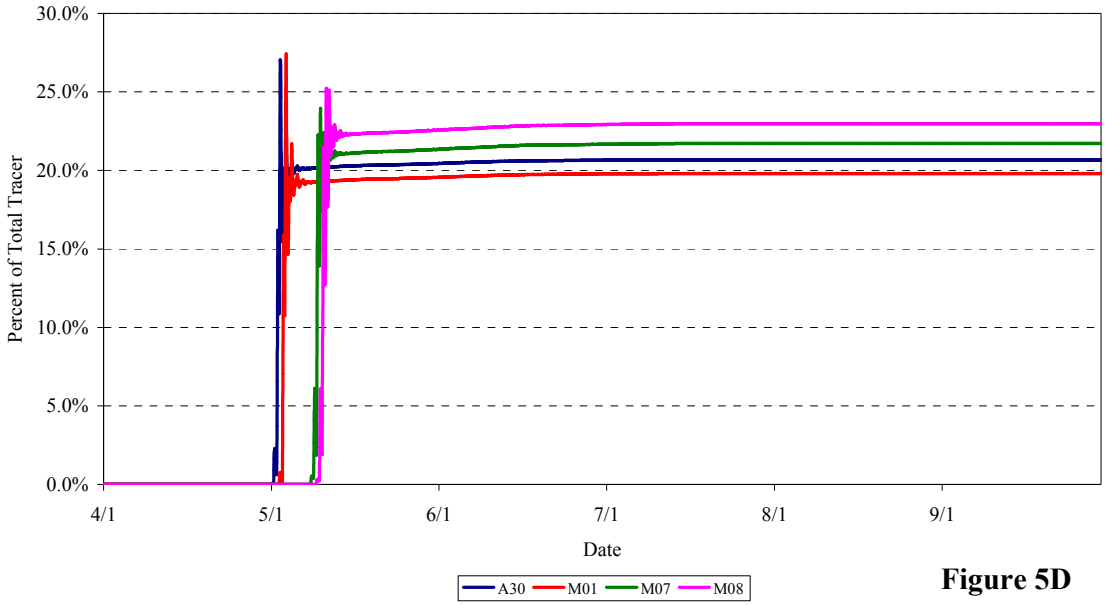

Figure 5D

Normalized Tracer Concentrations in Columbia Cut

Model Period: April ~ September 2001

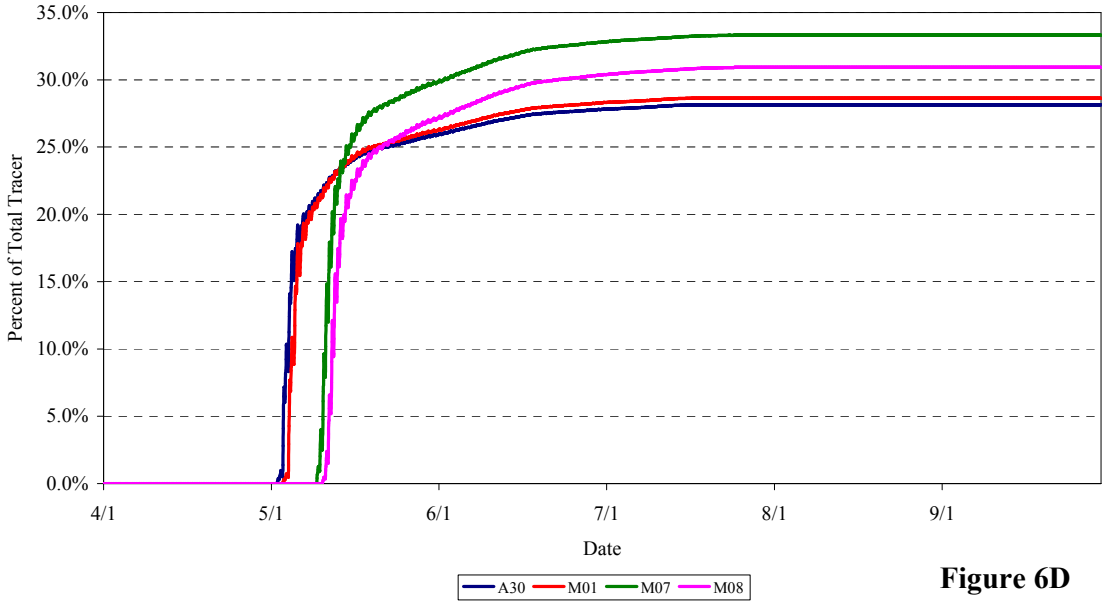

Figure 6D

Normalized Tracer Concentrations in Stockton Ship Channel

Model Period: April ~ September 2001

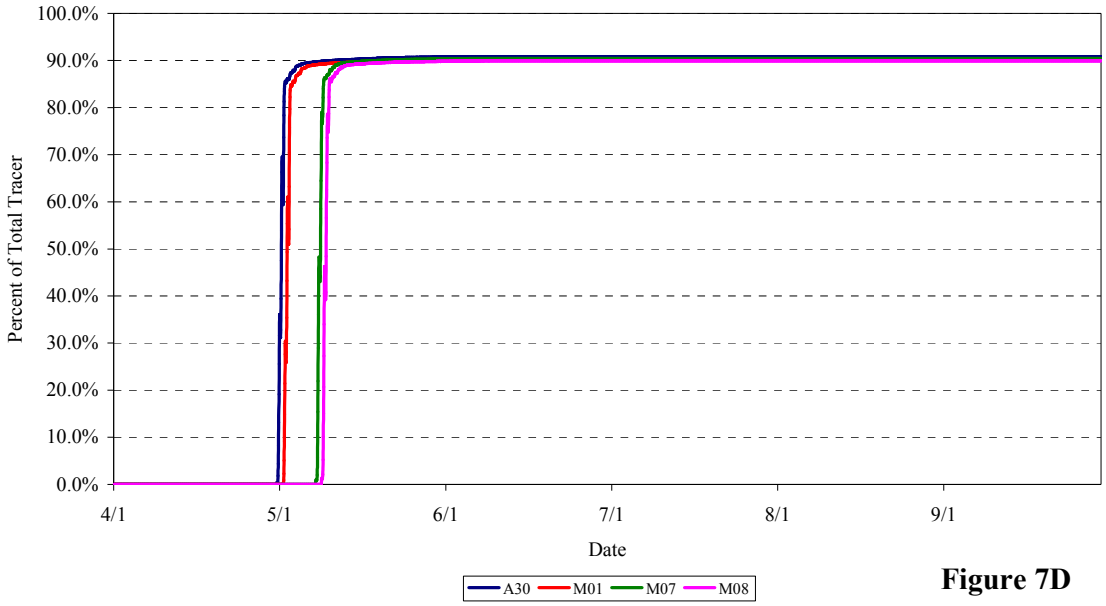

Figure 7D

Normalized Tracer Concentrations in Old River West of HORB

Model Period: April ~ September 2001

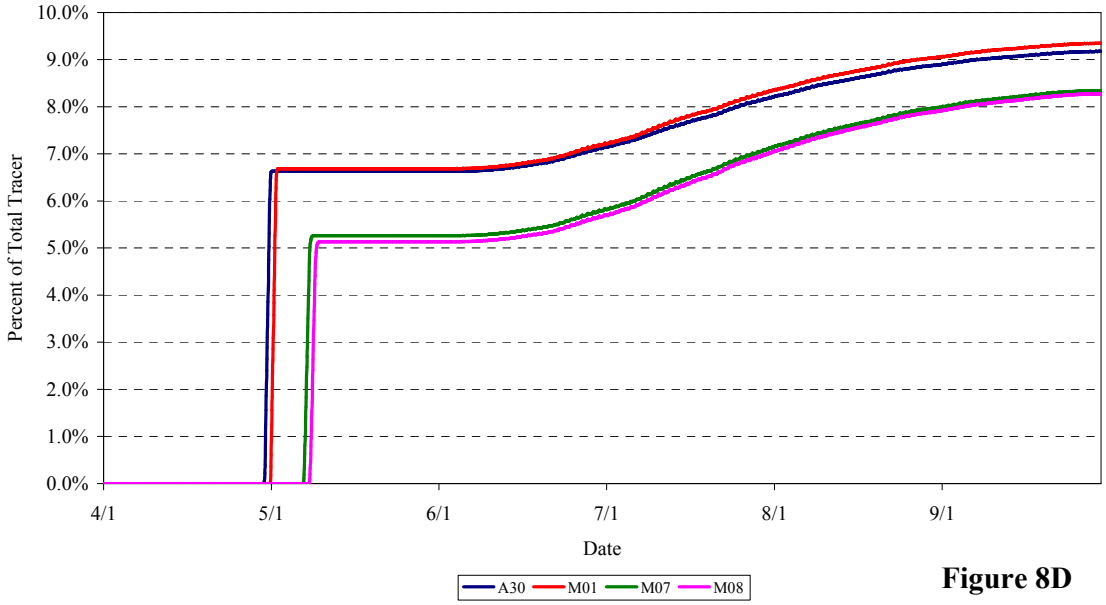

Figure 8D

Normalized Tracer Concentrations in Middle River W. of Medford Is

Model Period: April ~ September 2001

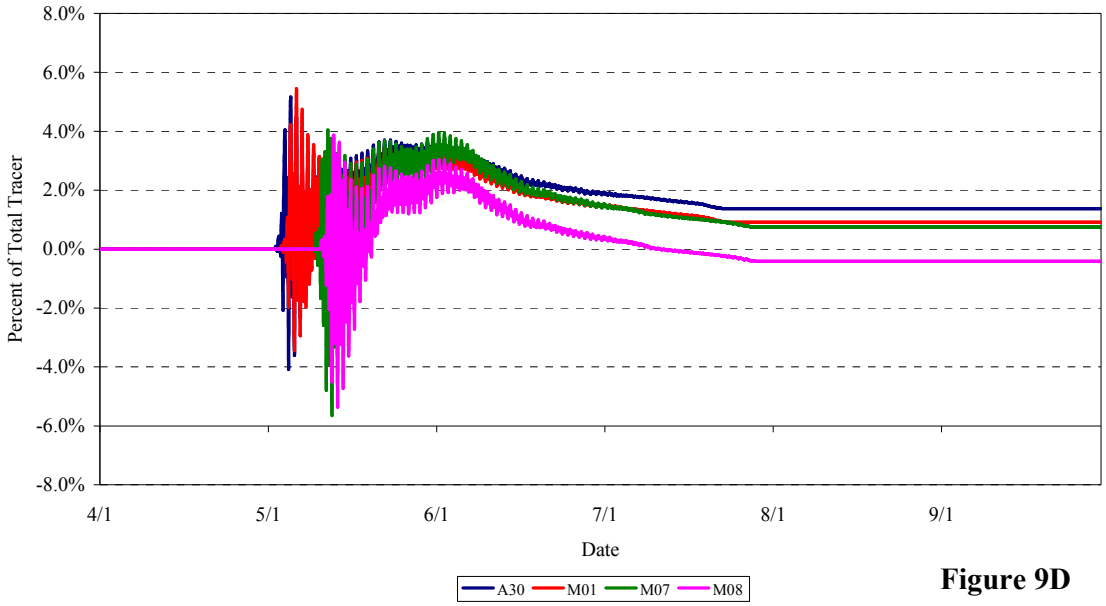

Figure 9D

Normalized Tracer Concentrations in Little Connection Slough

Model Period: April ~ September 2001

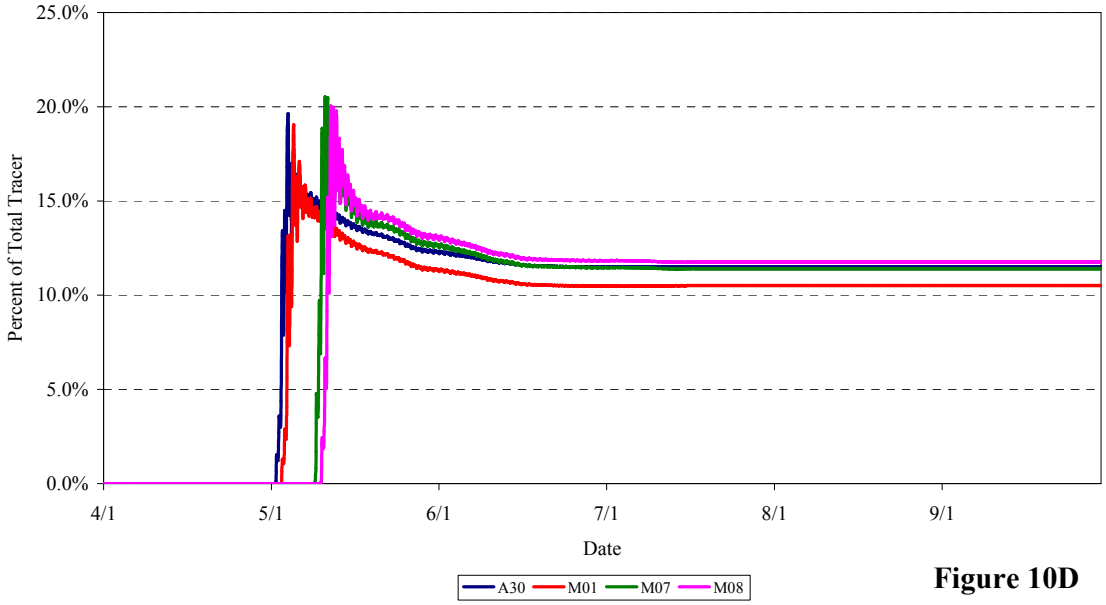

Figure 10D

Normalized Tracer Concentrations in Martinez

Model Period: April ~ September 2001

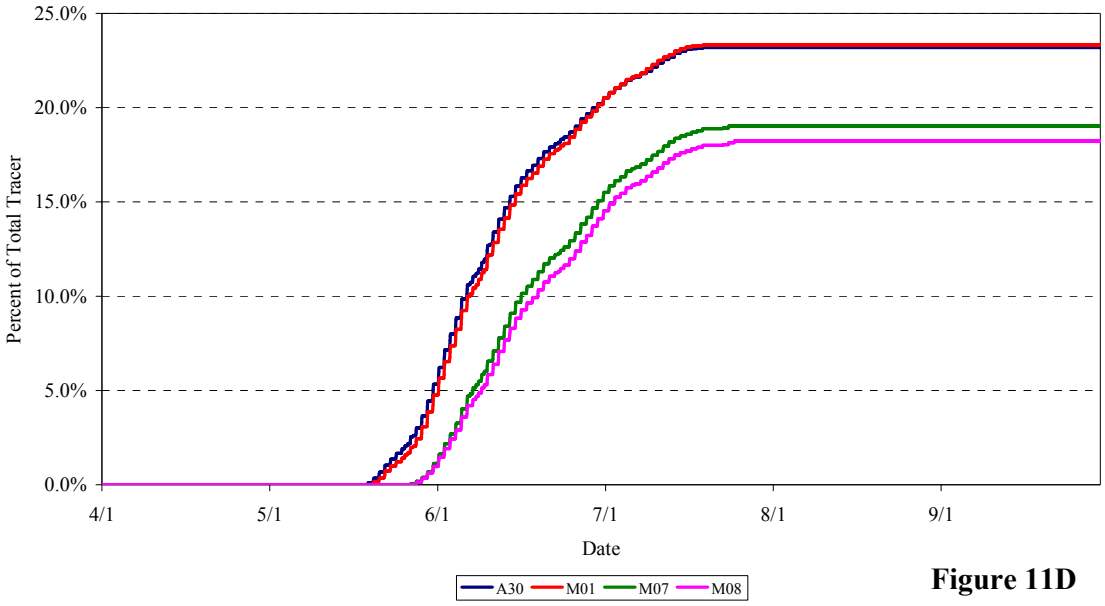

Figure 11D