Chapter 17

M3: Salinity Penetration into Channel

Contents

17.1 Problem Specification

M3 Salinity penetration into channel

Focus diffusion algorithm, coupled models, initial transients.

Channel geometry, friction and hydrodynamic open boundary conditions as in schematic application H3. Also, same fixed Δx and Δt as application H3. Use final predicted solution at $t = 2T$ from H3 as hydrodynamic initial conditions at $t = 0$ here.

Contaminant initial conditions are $C(x, 0) = 0$ throughout. The upstream contaminant open boundary condition at L is no contaminant inflow and unconstrained contaminant outflow. The downstream contaminant open boundary condition is

$$C(x_F, t) = \begin{cases} 0 & \text{for } Q(x_F, t) \leq 0 \\ 1 & \text{for } Q(x_F, t) > 0 \end{cases} \tag{17.1.1}$$

The longitudinal dispersion coefficient is $E_x = 10^3$ ft^2/s.

Compute and write to file in the STANDARD FORMAT the initial conditions at $t = 0$ and the model predictions for every time step to $t = 2T$.

17.2 Background

Salinity transport in a tidal channel is driven by the hydrodynamics, Equations 2.4.1 and 2.4.2, which provides predictions of $\eta(x,t)$ and $Q(x,t)$.

Knowing the channel geometry $A(x,t)$ (from $\eta(x,t)$) and the flow $Q(x,t)$, salinity transport follows Equation 2.4.4. Salinity transport and the hydrodynamics are coupled problems, though there is no feedback to the hydrodynamics. The interaction is nonetheless complex. The hydrodynamics is a hyperbolic initial boundary value problem that is boundary driven, there being no internal forcing. The salinity transport is a parabolic initial boundary value problem that is mostly internally forced by the coupled hydrodynamics. Boundary conditions on the salinity transport remains a concern, and are further complicated by the parabolic nature of the transport equation. In most situations, the salinity transport is advection-dominated, and there can be an advective flux into the solution field only when there is a flow into the solution field. In this Problem M3, there is an advective salinity flux into the solution field on the flood tide and from the solution field on the ebb tide.

Salinity transport into the San Francisco Bay-Delta system is a major issue in the on-going water debate. The major transport influences are tidal transport and fresh water throughflow. Problem M3 directly address these issues in a very schematic form.

17.3 Contra Costa Water District

No response.

17.4 Department of Water Resources

The files provided did not have sufficient information to permit any analysis.

The DWR model provides excellent predictions for advective transport (see the M1 and M2 discussions), but does not reach the same perfection in the representation of dispersive transport, the term $\partial/\partial x\,(E_x A \partial C/\partial x)$ in Equation 2.4.4. Dispersive transport is not represented directly, but through a "dispersion factor" approximation[1]. While advective transport will mostly be the dominant transport process (, and this part is done well), it is unfortunate that a potentially

[1] The following commentary was provided by DWR (2 February 2001): "Problem M3 and M4: These problems were designed to examine dispersion through specification of the dispersion coefficient. As communicated with Dr. Sobey early in the peer-review process, DSM2 uses a non-dimensional value called the "dispersion factor". There is no one-to-one relationship between the dispersion coefficient and the dispersion factor; therefore, the problem as stated was not solvable by DSM2. Because the test problems were not re-designed to account for DSM2's specific formulation, they were conducted assuming typical dispersion factor values. As expected, the solution computed by DSM2 did not match what Dr. Sobey expected. Short of re-formulating DSM2, there is little that DWR can do except to rerun test problems M3 and M4 with dispersion factor values that are higher than were originally specified. This may help Dr. Sobey look for trends, but we are not sure how much value this would have."

excellent model for contaminant transport has been compromised by a numerical approximation to dispersive transport that lacks physical fidelity[2].

17.5 Resource Management Associates

Figure 17.1a shows the RMA-predicted[3] salinity penetration into a tidal channel. The figure is truncated to the range $0 \leq x \leq 50{,}000$ ft near the ocean boundary. The expected salinity advance into the solution field on the flood tide and retreat on the ebb tide is clearly seen. The smaller influence of dispersion can be seen in the advancing penetration during the second tide cycle. This is the expected response.

Figure 17.1b shows the contaminant mass balance at $x = 3{,}000$ ft. Contaminant mass is conserved. Also evident is the approach to the steady state cycling of terms in the balance during each tidal cycle. Again, this is the expected response.

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[2]The following additional commentary was provided by DWR (13 August 2001): "Basically we are concerned with the language you have used in response to the M3 and M4 test problems. Here are some examples of the statements you wrote:

- Sect. 17.4 -Dispersive transport is not represented directly, but through a "dispersive factor" approximation .... It is unfortunate that a potentially excellent model for contaminant transport has been compromised by a numerical approximation to dispersive transport that lacks physical fidelity.
- Sect.20.4- ...However, the DWR dispersive transport did not have the physical credibility to successfully complete the M3 and M4 tests.

We think these are super-strong statements. I am wondering whether:

i) Are these statements based on the few E-mails we have had on this issue, or

ii) Are these statements based on you personal first hand knowledge of the actual mathematical formulation and derivation of the dispersive term that is currently being used in the model.

There are plenty of papers available on this topic. In fact, you may have a copy from the first package we sent you. The "Users Manual For a Branched Lagrangian Transport Model (USGS 1987)" has a discussion on this subject and refers to a number of papers going over more details. The main point is that this is not an "Approximate Method", and this model certainly is believed to have the physical credibility in the modeling community.

Basically dispersion is included as an inter-parcel discharge. Schoellhamer and Jobson (1986) show that for steady flow:

$$\text{DQQ} = \frac{D_x}{U^2 \Delta t}$$

Where DQQ is the ratio of the inter-parcel discharge, D_x is the dispersion coefficient, U is the average velocity and Δt is the time-step. The user instead of specifying D_x, specifies DQQ, which is a non-dimensionalized parameter called the dispersion factor.

The model has been used with a great degree of success to simulate water quality transport in a number of major estuaries in the United States.

I am hoping that we would be able to resolve this issue. We will be happy to help you locate the relevant published papers, should you need them."

[3]The RMA data file provided seems to have a read error just beyond $t = 84{,}500$ s. Data beyond this time could not be accessed.

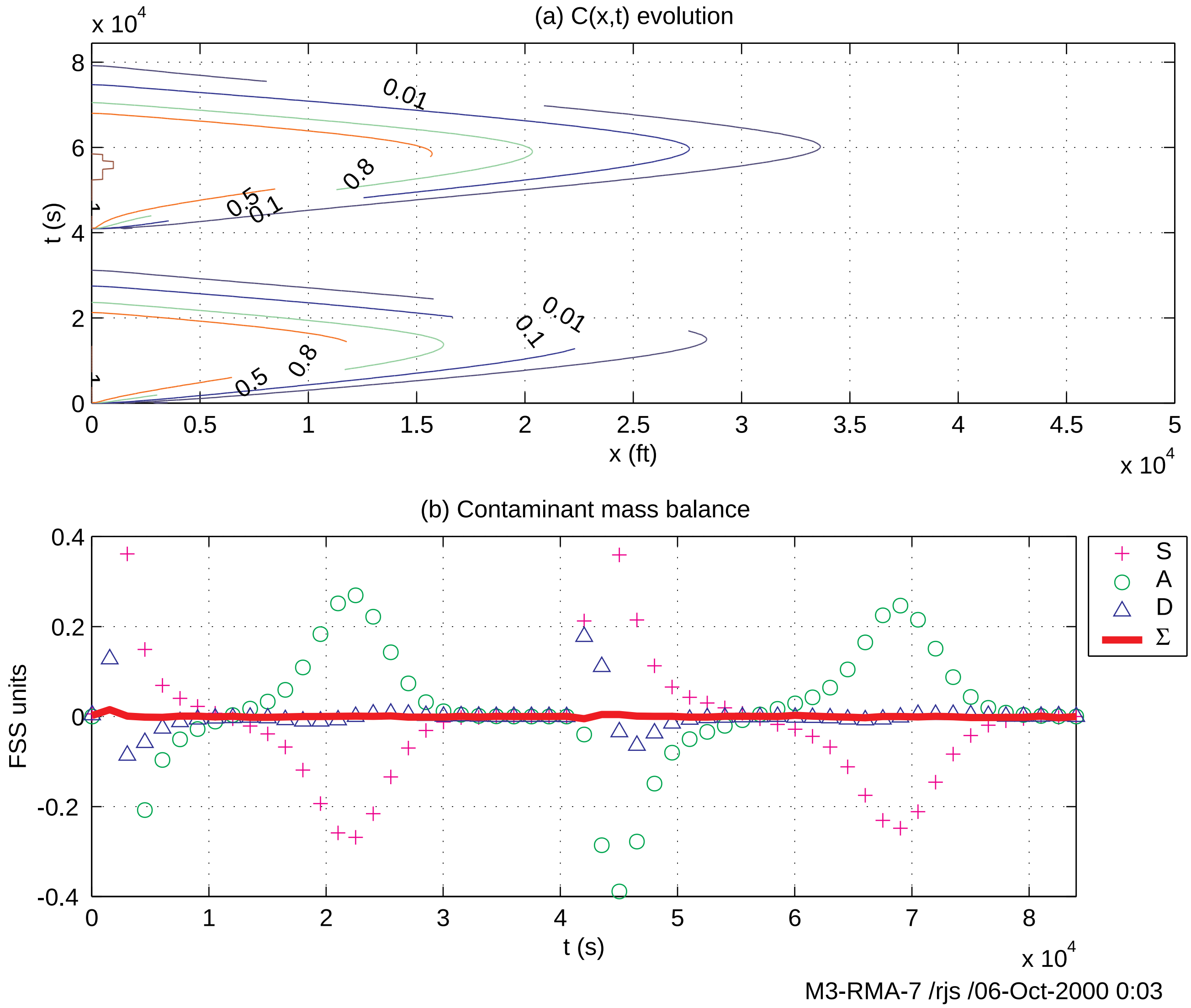

Figure 17.1: M3 RMA-predicted Salinity Penetration into Channel, and Contaminant Mass Balance at $x = 3{,}000$ ft. Contour levels in part (a) are 0.01, 0.1, 0.5, 0.8, 1.0.