Using 3D Hydrodynamic and Particle-Tracking Models to Explore Fish Movements and Distributions

CWEMF Annual Workshop Tuesday, February 24, 2009 Asilomar Conference Center Peter E. Smith (retired) USGS CA Water Science Center Sacramento, California

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<u>What I'll Talk About Tonight</u>

Some project history 3D hydrodynamic modeling Graphics and animation Recent Si3D Model Studies Delta Cross Channel South Delta

Future directions in modeling



Many Thanks!

Interagency Ecological Program for the San Francisco Bay-Delta Estuary

Federal Agencies:

- U.S. Bureau of Reclamation
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- U.S. Army Corps of Engineers
- U.S. Environmental Protection Agency
- NOAA Fisheries Service
- State Agencies:
 - California Dept. of Water Resources
 - California Dept. of Fish and Game
 - California State Water Resources Control Board









Nat'l USGS Surface Water Research Conference – Hood River, Oregon, 1991

Modeling Team (1980s)



Modeling Team Assignments (1984)

Pete Smith, San Pablo Bay

Mike Ford, DWR, Northern Reach of Bay

Larry Smith, Suisun Bay Jon Burau, Full Bay, Spectral Model



Henry Wong, USBR, Delta Model

In the early days, we had a field hydrodynamic program that started with Rick Oltmann and Mike Simpson...



Rick Oltmann Jon Burau Mike Simpson Ralph Cheng Jeff Gartner Pete Smith Larry Smith Purchased first commercially available, shallow water Acoustic Doppler Current Profiler (ADCP) in 1985 for measuring velocity profiles in SF Bay...





A discharge measuring system was later developed in 1987 and 1988 by Mike Simpson and Rick Oltmann First measurement of Delta Outflow into San Francisco Bay using a vessel-mounted ADCP measuring system was successfully done in Spring 1988





The first hydroacoustic flow-monitoring stations in the Delta began operating in January 1987 on on Old and Middle Rivers



The network has grown to 29 stations in 2009



Cathy Ruhl



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Cathy Ruhl



First deployment of an upward-looking ADCP was done in Carquinez Strait in March 1988







We also did dye studies...



3D Modeling

3D modeling in 1986 was not very practical. A course-grid model of San Pablo Bay could barely run faster than real time...





Despite the challenges, some interesting results were achieved showing the non-tidal, densitydriven (gravitational) circulation in the bay.



Semi-implicit 3D Model (Si3D)



 Semi-implicit numerical method
 Leapfrog-trapezoidal, finitevolume scheme
 Second-order accuracy
 No mode-splitting
 Fortran 90/95 language
 No coordinate transformations





In cooperation with the Interagency Ecological Program for the San Francisco Bay–Delta Estuary

A Semi-Implicit, Three-Dimensional Model for Estuarine Circulation



Open-File Report 2006–1004

U.S. Department of the Interior U.S. Geological Survey

http://pubs.usgs.gov/of/2006/1004/

Model Pre-and Post-Processing



http://ca.water.usgs.gov/program/sfbay/gr/

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John Donovan



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3D Numerical Grid for San Francisco Bay (2007)



San Francisco Bay

Graphic by John Donovan

3D Particle Tracking Model







3D Models in Progress

San Francisco Bay

Delta Cross Channel

 Stockton Deep-Water Ship Channel

South Delta



Delta Cross Channel







Measured and Simulated Velocity Profiles during Maximum Flood Flow





A)

B)

A)

B)



-75

Cross section locations

0

Maximum Ebb Flow



Maximum Ebb Flow



Late-Fall Chinook Salmon Smolt



 $Drag = C_d \frac{1}{2}\rho U^2 A$

Juvenile Salmon Distribution in Channel Cross Section near DCC







Zone of Entrainments for various Phases of the Tidal Flow



South Delta Project

Delta Smelt



Hypomesus transpacificus

CONTRACTOR CONTRACTOR



Compare ZOEs







Water entrained at export pumps
Water exiting the northern boundaries
Water flowing past Chipps Island
Water remaining in Delta

45 days of particle tracking

Percent of Particles Entrained at Pumps within 45 days



<u>Future Directions and Needs</u>

- More flexible gridding in the 3D model is needed and the model needs to be extended to the full bay and delta with 1D and 2D capabilities added
- Need capability to simulate salinity intrusion into the Delta
- Numerical Fish Surrogate Model (or some fish behavior model)
- More applications to explore fish movements

A Final Comment: Don't forget Verification and Validation

3D Free-Surface Flow Models

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Thanks!