Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 2: Sacramento Deep Water Ship Channel Flow Monitoring

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2 Sacramento Deep Water Ship Channel Flow Monitoring

2.1 Introduction

Flow measurement work was performed in the Sacramento Deep Water Ship Channel near the William G. Stone boat lock in West Sacramento in support of the CALFED Sacramento Deep Water Ship Channel Fish Passage Facilities Project. The purpose of the project is to test fish passage concepts that may be applied near Hood, California for a proposed fish screened Thru-Delta Water Facility. Figure 2.1 is a USGS map of the project area showing the launching areas and sampling area located downstream of the boat lock. Closer views of the gates are shown in Figures 2.2 and 2.3. The primary objective was to measure the flow leaking through the closed boat lock.

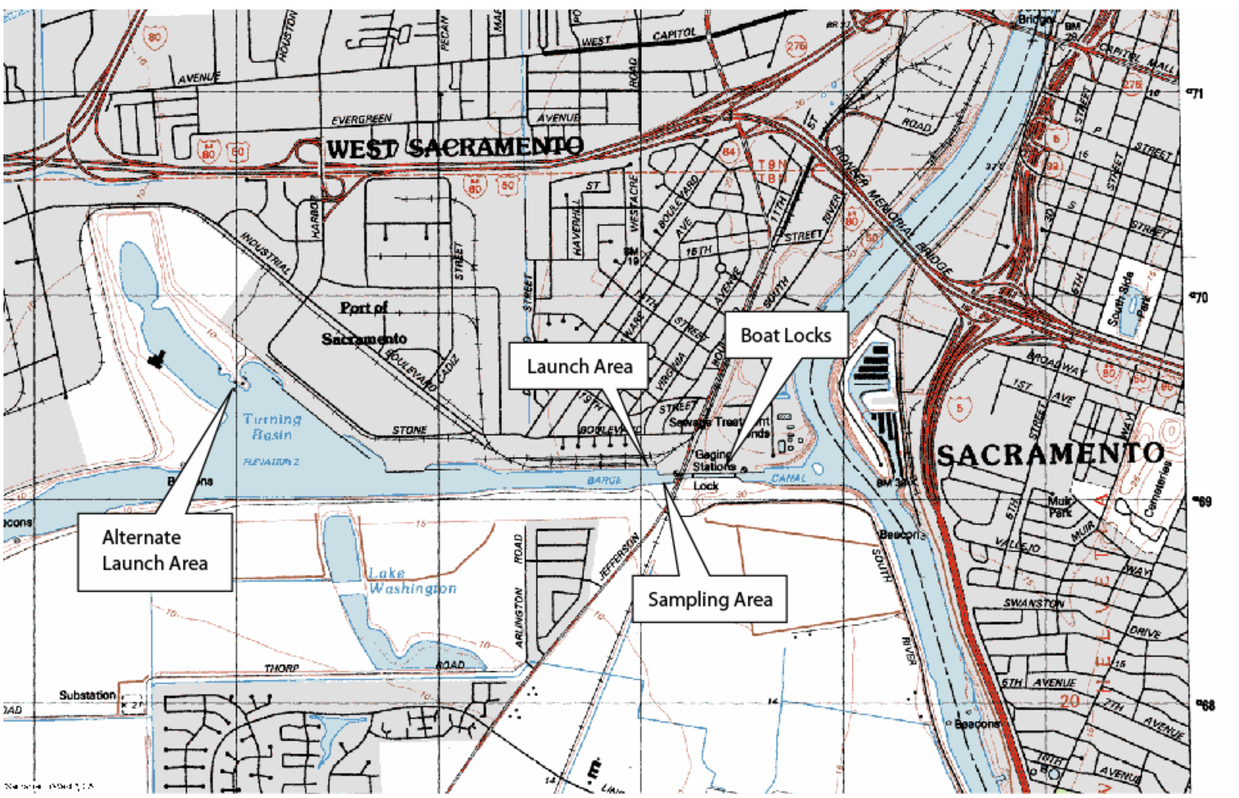
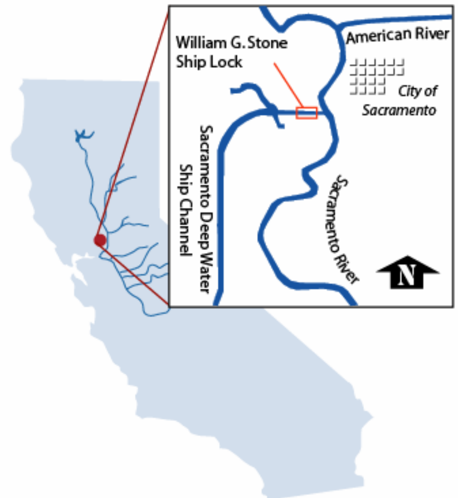


Figure 2.1: USGS quad map of the Sacramento Deep Water Ship Channel study area.

Figure 2.2: Sacramento Deep Water Ship Channel Boat Lock from upstream end near Sacramento River.

Figure 2.3: Water leaking through the closed boat lock.

WILLIAM G. STONE SHIP LOCK



LOCATION: West Sacramento, Yolo County California

WATERWAY(S): Sacramento Deep Water Ship Channel & Sacramento River

COORDINATES: 38°33′40″ N - 121°31′36″ W

DATE OF CONSTRUCTION: 1963

CONSTRUCTED BY: US Army Corps of Engineers

OWNER: City of West Sacramento

STATUS: Decommissioned in mid 1980s, Deauthorized by Federal Govt. in 2000

STRUCTURE TYPE: Gated boat lock

SIZE: 640′ long x 86′ wide x 13′ deep

CONCERNS: Possible impediment to upstream salmon migration

2.2 Methods

The first attempt to measure flow was by the velocity indexing method, considered the state of the art method for monitoring flow in tidal areas. It uses a velocity meter that is permanently anchored at mid depth on one side of a channel. A series of boat-based flow measurements are used to develop a relationship between measured velocity and flow, and this relationship is subsequently used to calculate discharges from the measured velocity. See Ruhl (2005) for more details on this method. Two brands of side-looking Acoustic Doppler Current Profiling (ADCP) velocity meters were installed at three different positions in the channel. Due to the very low velocities at the site, persistently high noise levels, and the non-uniform nature of the flow field, this method was abandoned.

Fortunately, boat-based, downward looking Acoustic Doppler flow measurements proved successful even though some noise or natural fluctuations were present. A series of five separate flow measurements from 2003 to 2005 were used to calibrate a simple water surface level-based model to determine flow. The measured flow location was just downstream (west) of the boat locks, as shown in the sampling area in Figure 2.1. The best fit of observed flow rates proved to be a combination of an orifice flow equation (Equation 2.1) and a vertical slot flow equation (Equation 2.2) developed by Rajaratnam (1992). The ratio of the combination of the orifice flow to vertical slot flow equations was 3:1 (Equation 2.3).

$$Q_{orifice} = AK\sqrt{2g\Delta h} \qquad \text{[Eqn. 2.1]}$$

Where,

A = Area (in ft^2),
K = empirical constant (unitless),
g = gravity (in ft/s^2),
Δh = head difference, $y_0 - y_1$ (in ft),
y_0 = stage upstream of the gate at I Street Bridge (in ft), and
y_1 = stage downstream of the gate (in ft).

$$Q_{vertical\ slot} = \alpha\left(y_0/b_0\right) - \gamma \qquad \text{[Eqn. 2.2]}$$

Where,

α = empirical constant (in cfs),
γ = empirical constant (in cfs), and
b_0 = vertical slot width (in ft).

$$Q = 0.75\ Q_{orifice} + 0.25\ Q_{vertical\ slot} \qquad \text{[Eqn. 2.3]}$$

Equations 2.1 and 2.3 require stage data for the project area, which unfortunately is not currently recorded. Consequently, a relationship for y_1 (Equation 2.4) was created between recorded stage at the Rio Vista Bridge (RVB) site and just downstream of the boat lock to generate the needed stage.

$$y_1 = 1.22x - 0.4438 - 1.75 \qquad \text{[Eqn. 2.4]}$$

Where,

x = stage at RVB (in ft), and
1.75 = empirical number for stage equalization.

An empirical number was used to force the computed stage downstream of the boat lock to equal the I Street Bridge (IST) stage when the measured flow was zero, because it was assumed that at a zero stage difference there is zero flow past the gates.

Water surfaces upstream and downstream of the lock, RVB, and IST sites were used to compute flow rates from May 21, 2003 to June 1, 2004. The flow model combines equations 2.3 and 2.4 to calculate the flow when both gates are closed. In the event one gate is opened, as during a typical operation of the boat lock, the flow rate calculated by the model is increased by a factor of 2. This multiplication factor is based on flow measurements collected when the gates were operated.

2.3 Results

A combination of the orifice flow equation and vertical slot equation provides a flow calculation that accommodates the complicated flow characteristics at the boat lock since it is an open channel flowing into a vertical slot orifice. The model assumes a constant width of the leakage opening when both gates are closed. After several iterations, empirical constants of K = -2.5 in the orifice flow equation and α = 3.77 cfs, b_0 = 1 ft, and γ = -20 cfs in the vertical slot equation proved to be adequate. On May 25, 2003 the gates were operated and the flow calculated by the flow model was adjusted to fit the open gate condition. In Figure 2.4, the measured flow is compared to the calculated flow to show that, within the limits of noise, the model successfully calculates the average flow rate and flow direction.

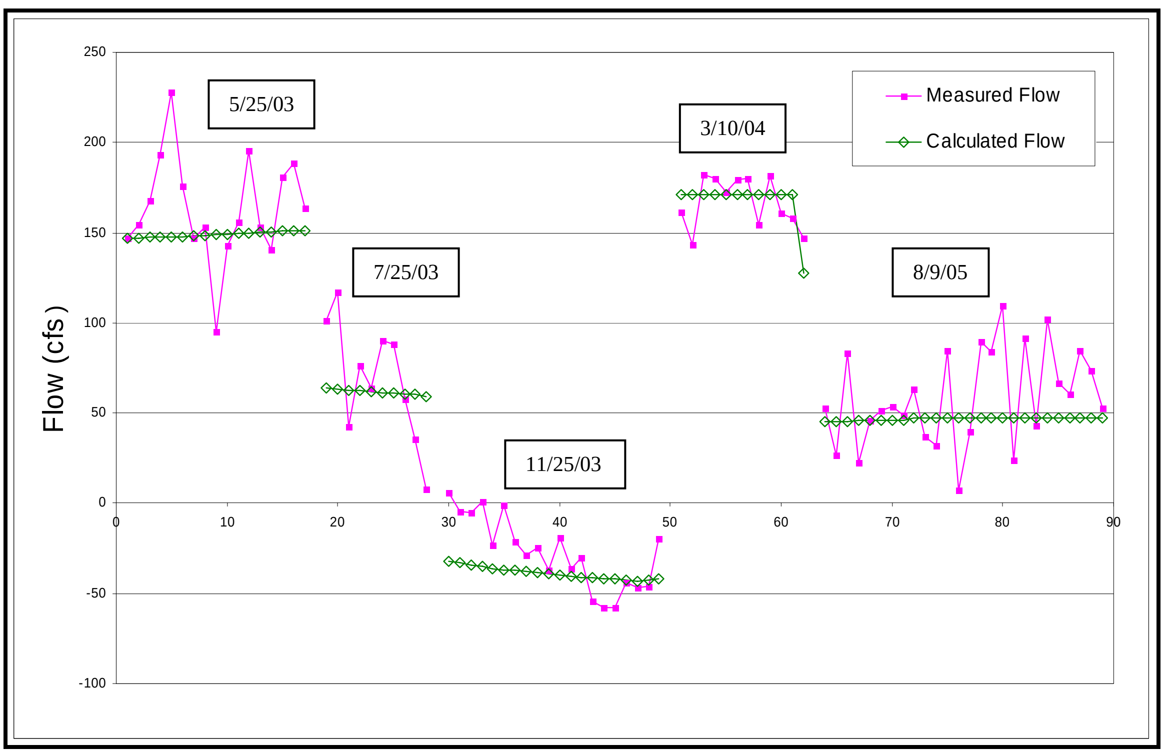


Figure 2.4: Calculated flow vs. measured flow just downstream of the locks.

2.4 Conclusions

The flow model uses a 3:1 ratio of the orifice flow and vertical slot flow equations to generate realistic estimated flow rates for this particular site. The flow rate through the lock can be obtained whether one of the gates at one end of the lock is open or both gates are closed. The described model may be used for flow estimation during any period when the flow producing leaks in the gates are similar to the May 25, 2003 through August 9, 2005 period. Additional measurements can be made to check the condition of the gate's leaks and applicability of the model in the future.

2.5 Reference

Rajaratnam, N., C. Katopodis, and S. Solanki. (1992). *New Designs of Vertical Slot Fishways.* Canadian Journal of Civil Engineering. 19(3): 402-14.

Ruhl, C. A. and M. R. Simpson. (2005). *Computation of Discharge Using the Index-Velocity Method in Tidally Affected Areas.* USGS Scientific Investigations Report 2005-5004. http://pubs.usgs.gov/sir/2005/5004/sir20055004.pdf