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PONDCALC—A Tool to Estimate Discharge from the Alviso Salt Ponds, South San Francisco Bay, California

Scientific Investigations Report 2007–5005

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

A view of the pond A3W discharge structure from inside the pond showing the opened screw gates and the sled used for velocity measurements.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Abbreviations

ADCP, acoustic Doppler current profiler

ISP, (South Bay Salt Ponds) Initial Stewardship Plan

PONDCALC, pond calculator

USFWS, U.S. Fish and Wildlife Service

USGS, U.S. Geological Survey

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Abstract

Former commercial salt ponds in Alviso, California, now are operated by the U.S. Fish and Wildlife Service (USFWS) to provide habitat for birds. The USFWS has modified the operation of the ponds to prevent exceedingly high salinity. Ponds that were formerly hydraulically isolated from South San Francisco Bay and adjacent sloughs now are managed as flow-through ponds, and some are allowed to discharge to the Bay and sloughs. This discharge is allowed under a permit issued by the Regional Water Quality Control Board. As a requirement of the permit, the USFWS must estimate the amount of discharge from each discharge pond for the period May through November of each year. To facilitate the accurate estimation of pond discharge, a calculation methodology (hereafter referred to as 'calculator' or PONDCALC) for the discharging Alviso ponds has been developed as a Microsoft Excel™ file and is presented in this report. The presence of flap gates on one end of the discharge culverts, which allow only outflow from a pond, complicates the hydraulic analysis of flow through the culverts. The equation typically used for culvert flow contains an energy loss coefficient that had to be determined empirically using measured water discharge and head at the discharge structure of one of the ponds. A standard weir-flow equation is included in PONDCALC for discharge calculation in the ponds having weir box structures in addition to culverts. The resulting methodology is applicable only to the five Alviso ponds (A2W, A3W, A7, A14, and A16) that discharge to South San Francisco Bay or adjacent sloughs under the management practices for 2005.

Introduction

In March 2003, 16,500 acres of salt evaporation ponds owned by the Cargill Corporation in the San Francisco Estuary were purchased using State, Federal, and private funds. Currently (2006), the California Coastal Conservancy is leading a collaborative planning effort with the U.S. Fish and Wildlife Service (USFWS) and the California Department of Fish and Game to restore the ponds to tidal action while providing for flood management, public access, and recreation.

The ponds presently are being operated and maintained according to the South Bay Salt Ponds Initial Stewardship Plan (ISP). The goals of the ISP are to maintain existing habitat and prevent a build-up of salt in the ponds, in a cost-effective manner, until the long-term restoration plan is in effect (Life Science!, Inc., 2003). The Alviso Salt Pond Complex, located in South San Francisco Bay, (fig. 1) is made up of 8,300 acres of salt ponds. Water is discharged from five of the Alviso ponds (A2W, A3W, A7, A14, and A16) into South San Francisco Bay or adjacent sloughs to prevent the build-up of salt in the ponds, as happened in the Napa salt ponds (Lionberger and others, 2004). This discharge is allowed through a permit issued by the Regional Water Quality Control Board. As a requirement of the permit, the USFWS must estimate the amount of discharge from each of the five ponds for the period May through November of each year.

Purpose and Scope

The purpose of this report is to present a pond discharge calculator (PONDCALC) for the Alviso salt ponds. Relevant theory, pond discharge measurements, discharge relations, tidal predictions, input data, calculator output, and assumptions and limitations are described. PONDCALC is applicable to only the five Alviso ponds (A2W, A3W, A7, A14, and A16) that discharged to South San Francisco Bay or to sloughs connected to South San Francisco Bay in 2005. The USFWS must report discharges that occur during the period May though November to the Regional Water Quality Control Board, so calculations are limited to this period. PONDCALC is available as a Microsoft Excel™ file.

Acknowledgements

Neil Ganju of the USGS assisted with discharge measurements. Pat Mapelli of Cargill Corporation provided culvert invert elevations and information about the weir structures. Clyde Morris and Eric Mruz of the Don Edwards San Francisco Bay National Wildlife Refuge provided additional information and access to the ponds. Bassam Younis, Jim Orlando, and Charles Parrett provided thoughtful reviews that greatly improved the manuscript. Funding was provided by the U.S. Fish and Wildlife Service and the U.S. Geological Survey Priority Ecosystem Science Program.

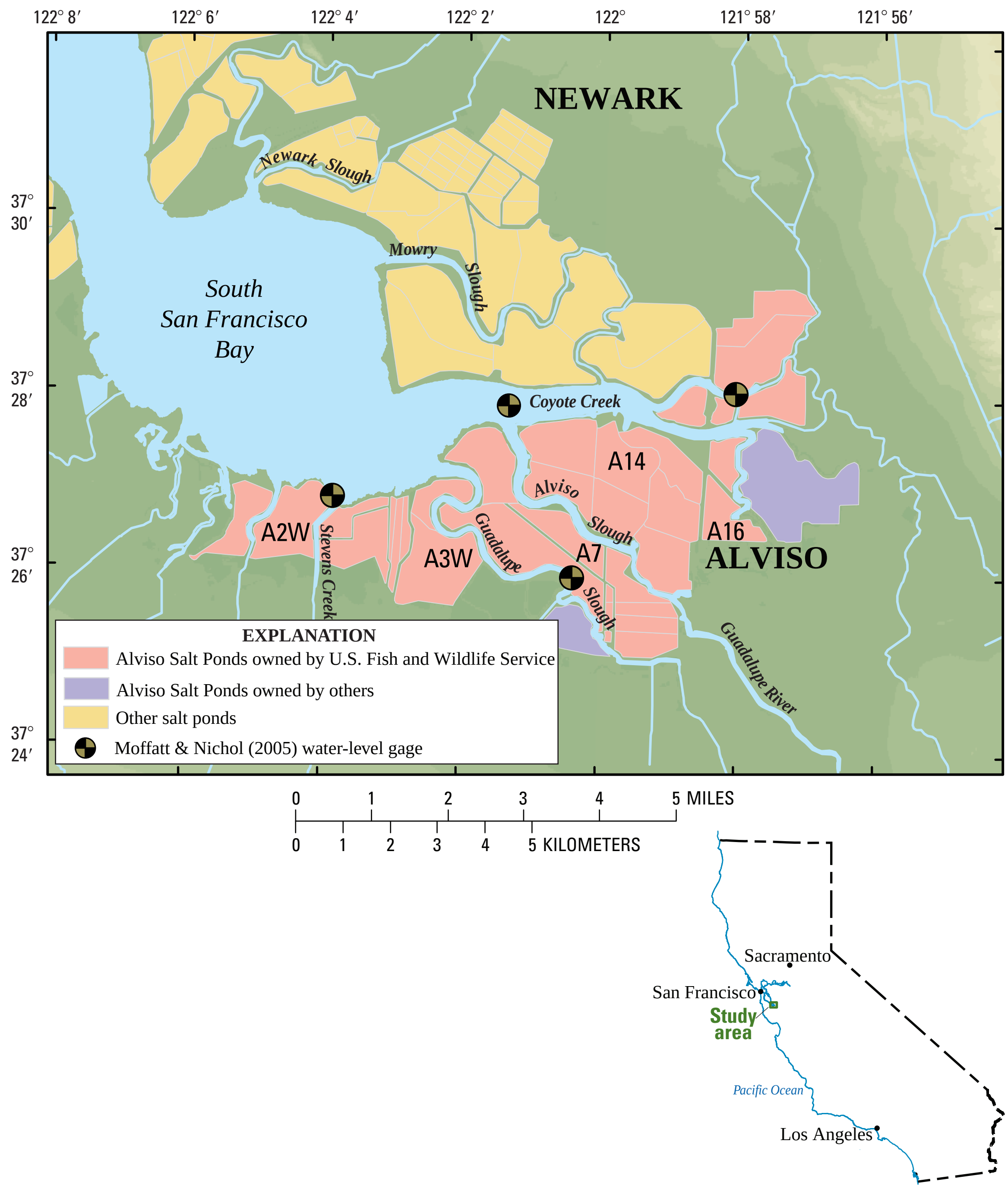

Figure 1. Alviso salt pond study area as part of the Alviso Salt Pond Complex, South San Francisco Bay, California. Discharge ponds relevant to this report are labeled.

Pond Discharge Equations

The structures used to control discharge from the ponds are culverts and weir boxes. Each pond has different structures (table 1).

Table 1. Discharge structures for the study salt ponds in the Alviso Salt Pond Complex, South San Francisco Bay, California.

[See figure 1 for pond locations]

Pond	Number of culverts	Number of weir boxes
A2W	1	1
A3W	3	0
A7	2	2
A14	2	1
A16	1	1

A culvert is a conduit that allows water to flow between two bodies of water. All culverts in this study are round, 48-in. diameter, poly-coated, corrugated, metal pipes installed with no slope (that is, level) (fig. 2). Each culvert is inside a levee that separates the two water bodies. A discharge structure may include several culverts. Because the slough is tidal, its water level rises and falls by 3–10 ft during a tidal cycle. Flow is from the pond to the tidal slough when the water-surface elevation in the pond is higher than in the slough. A hinged flap gate on the slough side of each culvert prevents flow from entering the pond by closing when the water level in the slough rises above that in the pond. The flap gate is pushed open when the water level in the pond is greater than that in the slough and also can be raised or lowered manually to allow water to flow in both directions. A screw gate on the pond side of each culvert can be raised or lowered to an open position, partially open, or closed. A trash rack surrounds the discharge structure at the slough side of the culvert to prevent debris from clogging the culvert.

The other type of discharge structure present for some Alviso ponds is a weir box (fig. 3). The weir boxes are roughly 9 ft × 9 ft × 6 ft and made of cast concrete with six bays of removable wooden weir boards. Each bay functions as a sharp-crested, rectangular weir, and water discharges over the boards and enters a 48-in. culvert, which carries the water to the slough. Culverts associated with the weirs are the same as the culverts described above. For our calculations, we assume that the weir box typically controls discharge unless it is submerged or all of the weir boards are removed. The culvert will control discharge under these conditions.

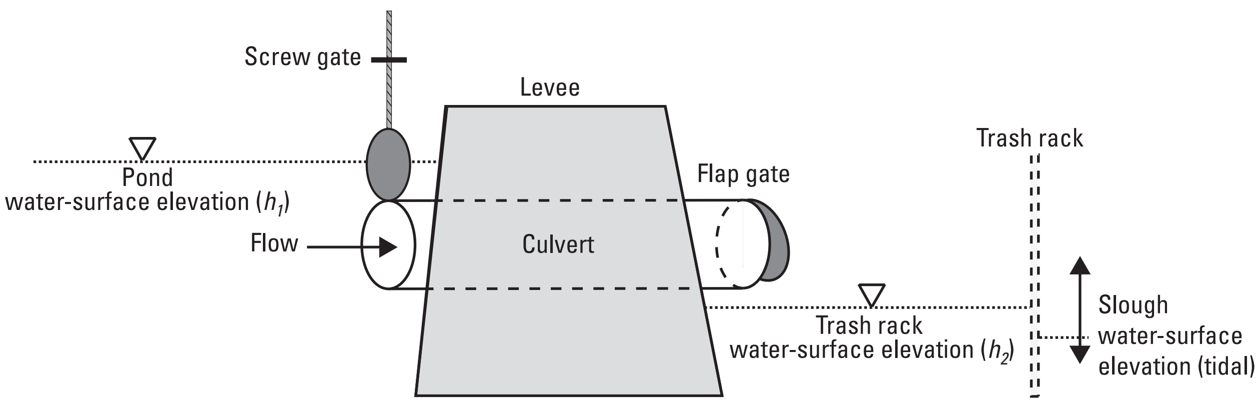

Figure 2. Schematic diagram of culvert discharge structure used in the Alviso salt ponds, California.

The water-surface elevation in the slough changes with the tide. The trash rack prevents debris in the sloughs from blocking the hinged flap gate.

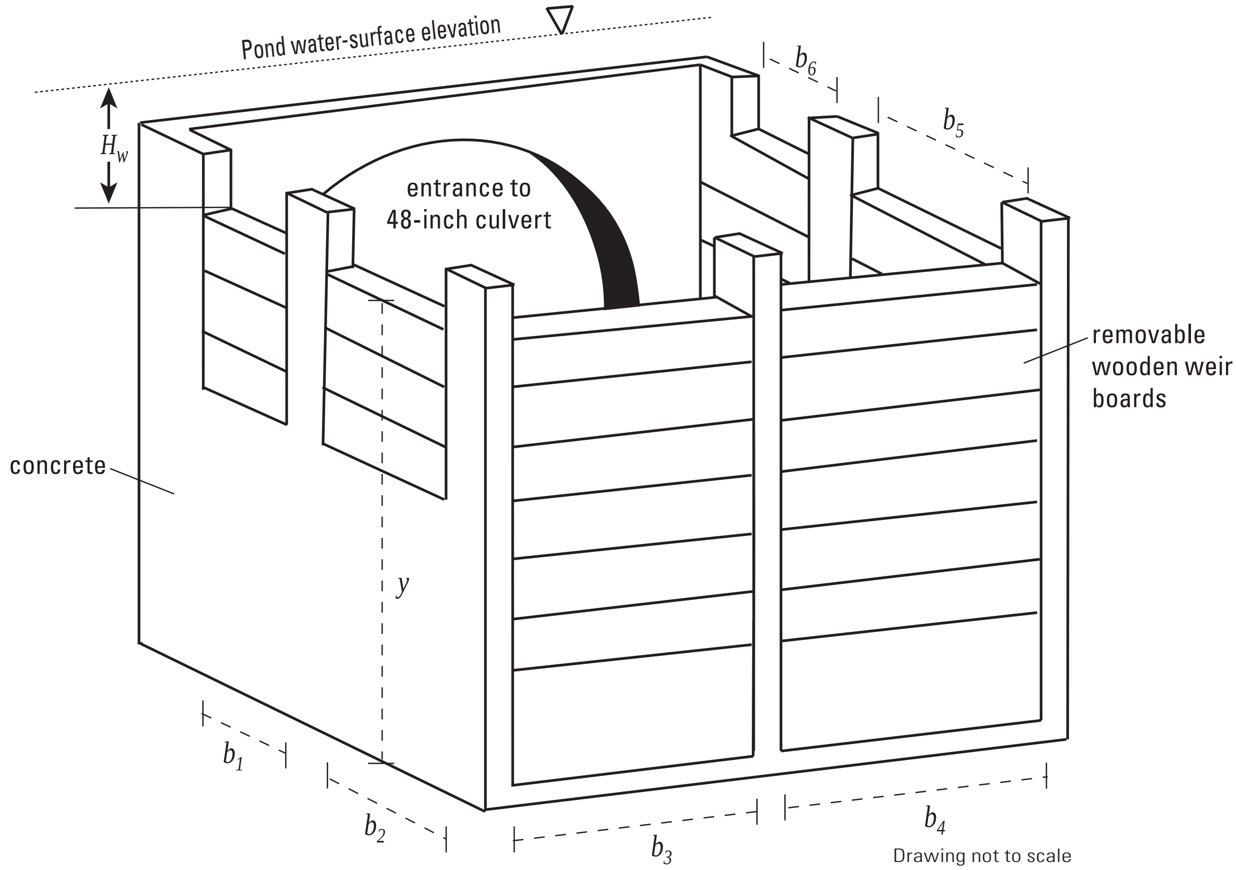

Figure 3. Schematic diagram of weir box structure used in Alviso salt ponds, California.

H_W represents the height of the pond water surface above the weir boards, b is the width of the weir boards, and y is the height of the weir boards above the pond bottom.

Theory

A simple culvert discharge equation can be derived by applying Bernoulli's equation between the pond and slough sides of the culvert, by assuming that the water velocity at the trash rack is the same as the velocity in the culvert, and that the culvert is flowing full (Jobson and Froehlich, 1988). One form of the derived equation can be expressed as

$$Q = A\sqrt{\frac{2gH_C}{1+K_L}} \tag{1}$$

where

Q is the culvert discharge,

H_C is the head (the distance between the water-surface elevation in the pond and that in the trash rack, that is, $h_1 - h_2$ in figure 2),

A is the cross-sectional area of the culvert,

g is gravitational acceleration, and

K_L is a coefficient intended to account for all energy losses, including entrance, friction, contraction, and exit as well as unquantifiable losses associated with the flap gates.

The assumption that the culvert is flowing full is key to use of equation 1. During site investigations, pond culverts were observed to be flowing nearly full on the upstream ends (there was a gap of several inches below the crown of the culvert and the water surface), while the flap gates on the culvert outlets tended to create backwater in the culvert. The screw gates were fully opened. However, these conditions are not sufficient to maintain a full flowing culvert, so this assumption may not be valid. For this study, the loss coefficient, K_L, was determined empirically from measurements of discharge from pond A3W, as is discussed in the next section of this report.

Weir discharge can be determined from a standard weir equation (Sturm, 2001) as

$$Q = \left(\frac{2}{3}\right) C_W\, b\sqrt{2g}\, H_W^{3/2} \quad (2)$$

where

Q is the discharge,

b is the length of the weir perpendicular to the flow (figure 3, where $b = b_1 + b_2 + b_3 + \ldots b_6$),

H_W is the depth of water above the weir crest (head),

and

$$C_W = 0.602 + 0.075\left(\frac{H_W}{y}\right) \quad (3)$$

where

y is the height of the weir above the pond bottom (fig. 3), and

C_W is the discharge coefficient that incorporates the effects on discharge of the approach velocity, head loss, and contraction.

Measurements of Culvert Discharge

The culvert loss term, K_L, was determined empirically from measurements of discharge from pond A3W. An acoustic Doppler current profiler (ADCP) (R.D. Instruments, 1,200 kHz, water mode five with 5 pings per second) was used to measure the discharge as described by Simpson (2002) and Oberg and others (2005). The ADCP emits an acoustic pulse, measures the return signal, then applies the principles of the Doppler shift to determine the velocity profile. The ADCP was mounted on a sled that floats on the water surface (fig. 4). A bottom-tracking feature allows the ADCP to determine its relative position as it moves along a path in the water. The discharge through the cross-sectional flow area below the path of the ADCP can be calculated using the measured velocity profile, bottom tracking, and water-surface elevation data.

The sled in this study was towed with ropes from shore in a straight path on the pond side of the discharge structure about 12 ft upstream from the culvert intake. This location was chosen to ensure that water velocities would be large enough for reliable measurement, and the sled would be upstream and clear of the rapidly accelerating flow at the culvert intake (fig. 4). Measurements were collected upstream from the culvert because flow downstream from the culvert is highly non-uniform and is likely to introduce greater uncertainty in the measured discharge.

Measurements were collected at the pond A3W discharge structure on May 10, 2005. Pond A3W was selected for measurements because low dissolved oxygen concentrations in this pond dictated estimates of discharge as a requirement of the discharge permit granted to USFWS. Discharge and water-surface elevations were measured at intervals of 2–10 minutes from 07:59 to 08:39 a.m. and from 10:12 a.m. to 12:47 p.m. (all times given are in Pacific Standard Time). The measurement gap between 08:40 and 10:11 a.m. is due to equipment failure. The tide in the receiving water in Guadalupe Slough varied slightly from the water-surface elevation measured at the trash rack. Because the discharge point and trash rack are at a higher elevation than the bottom of the slough, during low tide the water surface in the trash rack is perched above the water surface in the slough. Therefore, the tide in the slough could be rising while the water-surface elevation in the trash rack is falling. Tidal predictions indicate that the tide was falling until roughly 08:30 a.m., while the water-surface elevation measured in the trash rack continued to drop until after 08:40 a.m. Water-surface elevations in the pond and the trash rack were measured from staff plates with marked elevations referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). The measured total discharge was divided by three to determine the discharge through a single culvert. Discharge through a single culvert, as a function of head (H_C, the water-surface elevation difference), is shown in figure 5.

Empirical Discharge Relations

Given measured pairs of head and discharge, equation 1 was solved to estimate K_L. Ordinary least squares regression analysis was used to determine the best-fit relation between K_L and head. The results indicate that the behavior of the culvert loss term is best described by two separate equations (fig. 6). At low heads (H_C<0.63 ft), K_L decreases exponentially with increasing head,

$$K_L = 49.7e^{-6.47 H_C} \quad (4)$$

The rapid decrease in K_L probably is due to opening of the flap gate as head increases. At greater heads (H_C<0.63 ft), K_L increases linearly with an increase in head.

$$K_L = 1.90 H_C - 0.32 \quad (5)$$

Figure 4. Sled holding the acoustic Doppler current profiler used to measure discharge from pond A3W, Alviso salt ponds, California. Note culvert discharge structures with the red screw gates in the background.

The exponential function defined by equation 4 and the line defined by equation 5 intersect at H_C = 0.63 ft. Equations 1, 4, and 5 provide the discharge-head relations for culverts used in PONDCALC. The measured and predicted single culvert discharges for pond A3W are compared in figure 5. Figure 5 indicates that the measured discharges closely match the predicted discharges for low heads (H_C <0.63 ft), but measured discharges for high heads (H_C >0.63 ft) have considerable scatter around the predicted discharges. The simple culvert discharge equation 1 evidently does not account fully for the more complex energy losses when heads are high. Nevertheless, the comparison shown in figure 5 indicates that PONDCALC estimates for culvert discharge are reasonable, overall. The discharge relation calculated from measured data obtained at pond A3W is assumed valid for the other discharge ponds in the Alviso Salt Pond Complex because their discharge structures are similar to that of pond A3W.

PONDCALC uses a standard weir equation (eq. 2) to estimate discharge through the weir box discharge structures. The head term in equation 2 does not include the water-surface elevation downstream from the weir; therefore, the reduction of discharge as the weir is submerged at higher tides is not simulated by the equation. To overcome this limitation with the weir equation, the culvert discharge also is calculated by PONDCALC. The calculated culvert discharge, which is based on the difference between pond and trash rack water-surface elevations (culvert head, H_C) is dependant on tidal stage. The discharges calculated from the weir and culvert equations are compared, and the lower of the two values is the estimated discharge provided by PONDCALC. The lower value is used on the basis of the assumption that the weir box controls discharge when downstream water-surface elevations are low (low tide), and the culvert controls discharge when downstream water-surface elevations are high (high tide) and the weir is submerged.

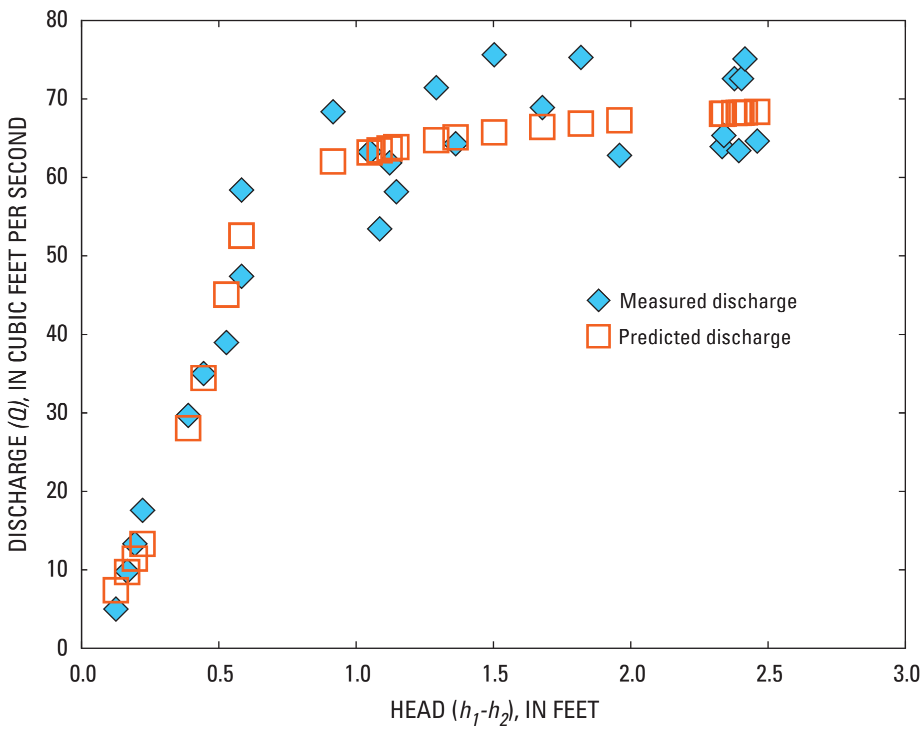

Figure 5. Measured and predicted discharge from pond A3W compared to head (h_1-h_2), Alviso salt ponds, California.

Predicted discharge is calculated from equation 1 with the energy loss term, K_L, calculated from equations 4 and 5.

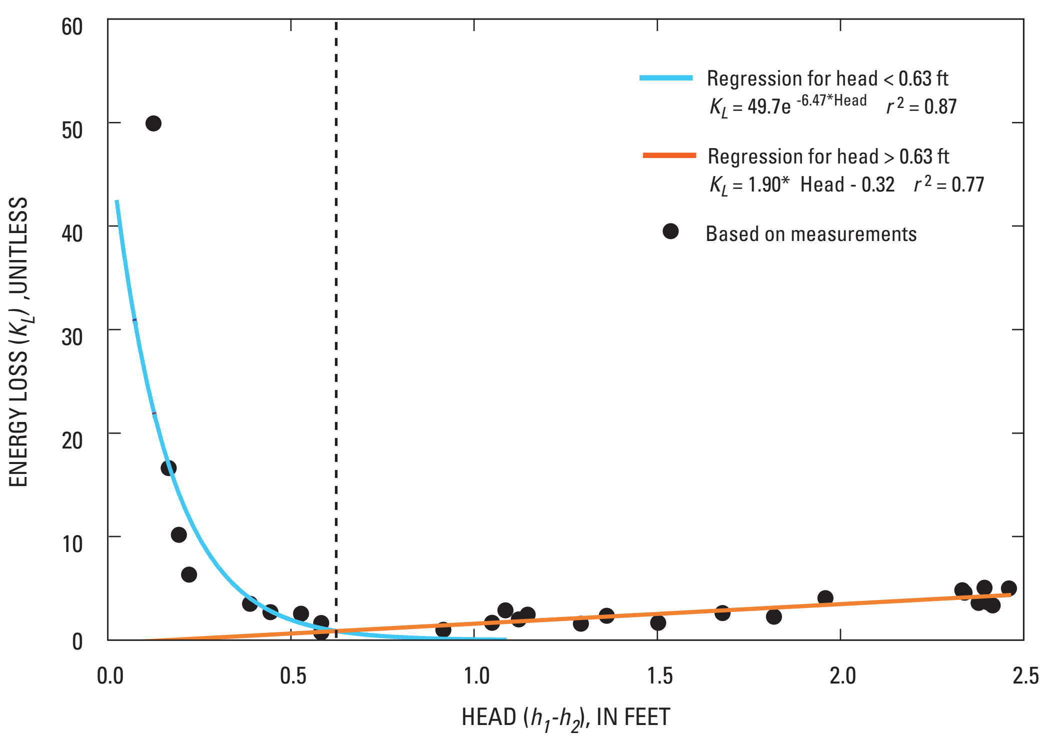

Figure 6. Culvert loss coefficient, K_L, related to head in pond A3W, Alviso salt ponds, California.

The two curve fits were determined by least squares regression. The dotted vertical line shows the transition between the two regressions.

Pond Discharge Calculator PONDCALC

The pond discharge calculator PONDCALC is contained in a Microsoft Excel™ file named “PONDCALC”. The worksheet entitled “Inputs” displays the input data specifications and the PONDCALC simulation results. The other visible worksheet, “Weir Values”, contains the heights and elevations for all the weir structures with varying weir boards installed. Two other worksheets (“Dropdown Values” and “Date Time Tide”) are hidden. These worksheets are required only for calculations contained in the model and are not needed by the model users. Discharge calculations are performed by the model code, which is written in Visual Basic.

Input Data

The left side of the “Inputs” worksheet displays the six user inputs available: five inputs have limited selections in drop-down boxes (three are in blue, and two are for the dates), and one input must be entered manually by the user (in yellow). The inputs are as follows:

Year—This drop-down box allows a user to select either 2005, 2006, 2007, or 2008 as the year of interest.

Pond—User can select any one of the five previously mentioned ponds. “A2Wweir”, “A7weir”, “A14weir”, and “A16weir” should not be selected for culvert flow calculations because they are only for weir flow.

Pond WSE—This is the surface elevation of the water in a given pond, as measured on the elevation gage in the pond (input must be given in feet NGVD 29). The value placed in this cell must be entered before the calculator will work.

# of 48-inch pipes—This drop-down box allows the selection of one to three culverts.

Start Date—This drop-down box allows the selection of a starting date for the discharge calculation from April 30 to November 30 of a given year. The discharge calculation begins at 00:00 (midnight) on this date.

End Date—This drop-down box allows the selection of an ending date for the discharge calculation from May 1 to December 1 of a given year. The discharge calculation ends at 00:00 (midnight) on this date.

The right side of the “Inputs” worksheet displays additional user inputs that are specific to when the weirs are being used to control the discharge. Three of the inputs must be entered manually by the user (in yellow), while the fourth input has limited selections in a drop-down box (in blue). The weir calculations need all of the above-mentioned inputs, except for the “# of 48-inch pipes” input. This input is ignored for weir calculations, because the user selects the number of weirs instead. The following inputs are used only when either a weir is selected in the ‘Pond’ drop-down box on the left side of the worksheet. The weir inputs are as follows:

Total Weir Length—This is the total length of the weir exposed to discharge (*b*, for example, six weir boards at 4 ft long each would result in 24 ft for the length of the weir).

Elevation of Weir Crest—This is the actual elevation of the weir, in ft NGVD 29. This value is used to determine the height of water above the weir crest. If all weir boards are in place, pond A2W has a weir crest at 1.667 ft NGVD 29, pond A7 has a weir crest at 1.067 ft NGVD 29, pond A14 has a weir crest at 1.667 ft NGVD 29, pond A16 has a weir crest at 3.066 ft NGVD 29 (fig. 3). Weir boards are 3 in. high, so if boards are removed, a new weir crest elevation must be calculated and entered (see “Weir Values” worksheet).

Height of Weir Crest—This user input is the weir height above the bottom of the pond, in feet, and is used to calculate the weir coefficient (C_w). If all weir boards are in place, the weir height is 6 ft (*y* in figure 3). Weir boards are 3 in. high, so if boards are removed, a new weir height must be calculated and entered (see “Weir Values” worksheet).

# of Weir Boxes—This drop-down box allows the selection of one or two weir boxes that are used for discharge.

Tide Calculations

The water level varies semidiurnally at the locations where the culverts discharge to the tidal sloughs. At high tide, slough water submerges the culvert outlets, and at low tide the slough water surface is below the bottom of the culverts (but the water-surface elevation in the trash rack never dropped below the bottom of the culvert during measurements at pond A3W). Tidal fluctuations affect the culvert head and thus, culvert discharge.

Tidal harmonic analysis was used to predict the water-surface elevations in the sloughs as a function of time. Tidal fluctuations in water level are composed of many individual components oscillating at known frequencies. Tidal harmonic analysis can be used to determine the amplitude and phase lag of each component (Cheng and Gartner, 1985). Our tidal harmonics analysis was performed using freeware scripts written for Matlab software (t_tide.m and t_predic.m) by Rich Pawlowicz (currently at University of British Columbia). Using water-surface elevation data collected at several South Bay slough locations by Moffatt & Nichol, and Environmental Data Solutions (2005) in winter 2004 (fig. 1), we applied t_tide.m (for Matlab, Pawlowicz and others, 2002) to 12-minute data to obtain local tidal harmonics. Using t_predic.m with the t_tide.m results and specifying a location, we obtained predicted tidal water-surface elevations for the times of interest (April 30–December 1, 2005, 2006, 2007, and 2008) at the different locations. The program was set to output data at 15-minute intervals. The predicted tide from t_predic.m had a zero mean. Mean tidal elevations for each site were obtained from the Moffatt & Nichol, and Environmental Data Solutions (2005) records by averaging tidal water-surface elevations during the period of record, and the mean tidal elevations were added to the predicted tide from t_predict.m to obtain predicted tidal elevations, in NGVD 29. Because the Moffatt & Nichol, and Environmental Data Solutions (2005) data were collected in the wet season, these estimates of mean tidal elevation and tidal water-surface elevation may be high.

The tidal elevation data at the site closest to each discharge structure were assumed to be the tidal elevation at the discharge structure. The average tidal elevation for Guadalupe Slough (A3W) is used for pond A2W (Stevens Creek mouth), because the Stevens Creek tidal data are truncated at about 0 feet NGVD 29 due to the sensor being exposed to air at lower tides. Pond A7 used data from the power tower location. Ponds A14 and A16 use the same tidal harmonics because they both were closest to the same Moffatt & Nichol and Environmental Data Solutions (2005) sampling location (railroad bridge). The distance the tide is below the bottom of the culvert outlet is irrelevant in these calculations, so the minimum slough elevation was set equal to the bottom of each culvert in PONDCALC.

Output

Output is obtained (and updated) by clicking the "Calculate Discharge" button on the "Inputs" worksheet. The output of the estimated total discharge for the user-defined dates is displayed on the bottom of the "Inputs" worksheet as "Total Discharge", which is presented using three different discharge units in the light green box.

In the case where both a weir and a separate culvert may be used for simultaneous discharge from a given pond, two discharge simulations, one for the weir and one for the separate culvert, would need to be performed and added together to get the total discharge. For example, if pond A14 has simultaneous discharge over the weir and through the culvert without a weir, the output from one simulation for the single culvert must be added to the output from another simulation for the single weir to obtain the total pond discharge.

One assumption inherent in these calculations of discharge is that the screw gates are opened fully on each culvert. If the gates are less than fully opened, the discharge can be calculated by multiplying the discharge estimated by the calculator by the percent open area of the pipe. This will scale down the discharge through a given culvert in a proportion equal to the open area of the culvert. However, the assumption that the culvert is running full will be even less valid with a partially closed screw gate, and calculated discharge estimates may be less accurate.

Troubleshooting

There are four programmed error messages in this calculator. One error message appears if the selected start date is after the selected end date. The calculator will not work until this concern is corrected. If the same date is selected as the 'Start Date' and 'End Date', then zero discharge will be calculated and an error message will appear. Other error messages appear for the culvert and weir calculations if the 'PondWSE' is lower than or equal to the culvert invert elevations or the 'Elevation of the Weir Crest'. There can be no discharge under these conditions. The calculator will not work until this concern is corrected.

A value must be entered into the gold boxes on the 'Inputs' page before the calculator will work. To enter a number, type it into the cell, and then tap the 'Enter' key on the keyboard. Alternatively, using the mouse, click in any cell other than the one in which the number was just entered. Neither the 'Calculate Discharge' button nor any of the drop-down boxes will work until a number is entered.

On occasion when changing the year in the 'Year' drop-down box, the year will not update in the 'Start Date' and 'End Date' boxes. Clicking the 'Calculate Discharge' button at these times will not update the 'Total Discharge' results (and may result in a Visual Basic error message). To correct this problem, restart the calculator. This will reset the program to normal functioning.

Assumptions and Limitations

PONDCALC was developed specifically for use in the Alviso managed ponds listed. The simple culvert discharge equation is applicable to other ponds and culvert configurations, but, to apply it, the energy loss term must be based on discharge measurements specific to the other pond and culvert configurations. A summary of other assumptions inherent in the use of PONDCALC that may limit its applicability, even in the Alviso managed ponds, are as follows:

- The culverts are flowing full.
- The water velocity at the trash rack is the same as in the culvert.
- The screw gates on the pond side of the culverts are opened fully.
- K_L calculated at the pond A3W discharge structure is applicable to the other discharge structures.
- For low heads with culvert flow, K_L decreases exponentially as head increases for every pond, based on equation 4 for A3W.
- For high heads with culvert flow, K_L increases linearly as head increases for every pond, based on equation 5 for A3W.
- Stevens Creek downstream average tide is taken as 0.69 ft (same as A3W), instead of 1.43 ft as calculated from the tide data. This was done because the tidal record at this location shows a clear truncation of tidal elevations below 0 ft NGVD 29.
- Tidal influence on discharge from a weir is accounted for accurately with a combination of the weir flow and culvert flow equations.
- The water-surface elevation in the trash rack is the same as that in the slough.

- The pond water-surface elevation does not change appreciably over the time-period of interest.
- Inflow of slough water to the ponds (if a flap gate is opened) is not considered or calculated.
- Tidal harmonic coefficients and average water-surface elevation from data collected during winter are applicable to summer.
- The selected weir-flow equation is appropriate for the pond weir structures, although this was not verified empirically.
- The tidal harmonics for A14 and A16 are the same (they are derived from the same data set).
- Discharge through one culvert is not affected by flow through adjacent culverts.

Minimum Error Estimate

One method to estimate some of the error associated with the calculated discharge is to compare the measured flow rate, Q_m, with the predicted flow rate, Q_p, obtained from the values of K_L as calculated from equations 4 and 5. The results of this comparison, the percent that Q_p deviates from Q_m plotted against head, are shown in figure 7. For heads above 0.25 ft, the error is always less than 20 percent and generally less than 10 percent. This error also exhibits both signs: that is Q_m is over- and underestimated by Q_p, so the average error for all heads above 0.25 ft is well below 10 percent. At very low heads (less than 0.25 ft), the estimated error increases greatly (up to nearly 50 percent). However, the flow rate at very low heads is very small, so the high error is associated with small numbers. This should have only a minor effect on the estimate of discharge, particularly if the discharge estimate covers several days or more. We refer to the above-discussed error as the minimum error. Other sources of error are associated with the discharge estimates, but they are not calculated here. These errors include instrumental errors associated with the discharge measurement, errors associated with the tidal prediction, and errors related to the application of the discharge-head relationship measured at one pond and applied to other ponds.

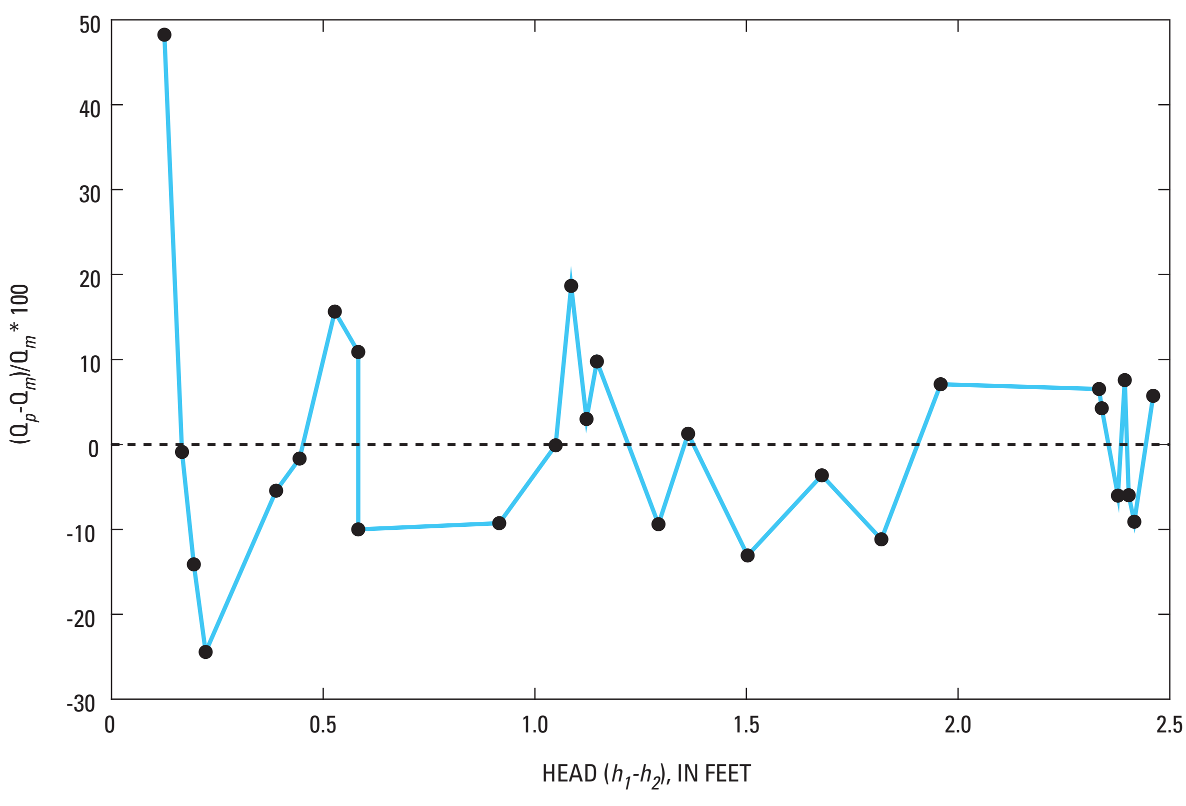

Figure 7. Estimate of the minimum error associated with the prediction of flow rate as compared to head in pond A3W.

The minimum error estimate is the percent error associated with the prediction of Q from the estimates of K_L, where Q_p is the predicted flow rate and Q_m is the measured flow rate. Q is calculated from eq. 1. For heads above 0.25 ft, the predicted flow rate is within 20 percent of the measured flow rate.

The minimum error associated with the discharge estimates provided here could be reduced through additional measurements. Reducing the error would require a longer record of discharge measurements at pond A3W, collection of discharge measurements for the culverts of the other ponds (i.e., A2W, A7, A14, A16), validation of the weir flow equation for ponds A2W, A7, A14, and A16, and measurement of tidal harmonics during the summer as well as the winter. These additional measurements were beyond the scope and funding for this project.

Summary

A pond discharge calculator (PONDCALC) for the Alviso salt ponds (A2W, A3W, A7, A14, and A16) is presented in this report. Flap gates designed to allow only flow out of a pond complicate the hydraulics of flow through the discharge culverts. The conventional culvert flow equation contains an energy loss coefficient. Equations for this coefficient were determined empirically using measured water discharge and head at the pond A3W discharge structure. The resulting equations and several assumptions were used to develop PONDCALC, which is applicable only to the five Alviso salt ponds that discharged to South San Francisco Bay or to its connecting sloughs in 2005. The minimum error is estimated to be less than 20 percent for heads greater than 0.25 ft. During the period May through November, U.S. Fish and Wildlife Service must report discharges to the Regional Water- Quality Control Board: therefore, calculations are limited to this period. PONDCALC is available as a Microsoft Excel™ file.

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Appendix

Below is a screen shot of the interface page for PONDCALC. Descriptions and details of the calculator can be found in the text of this document. PONDCALC is available as a Microsoft Excel™ worksheet (approximately 9 MB) and can be obtained by contacting:

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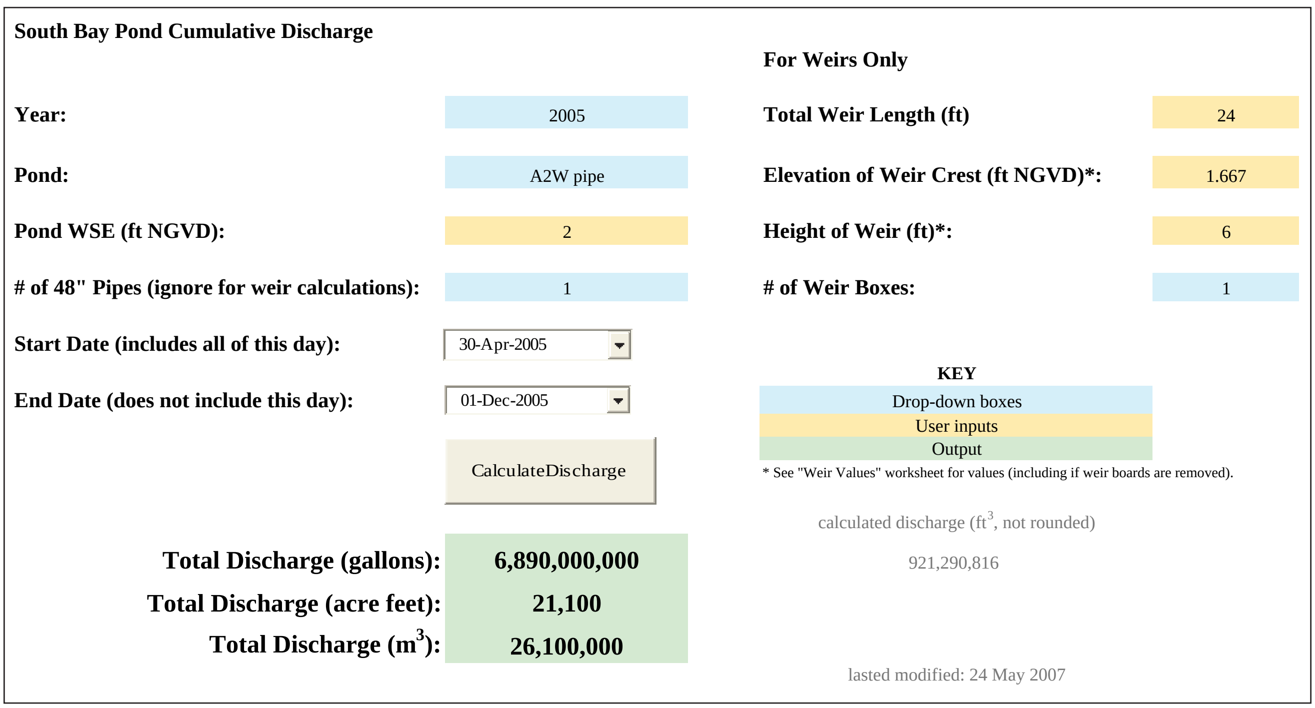

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