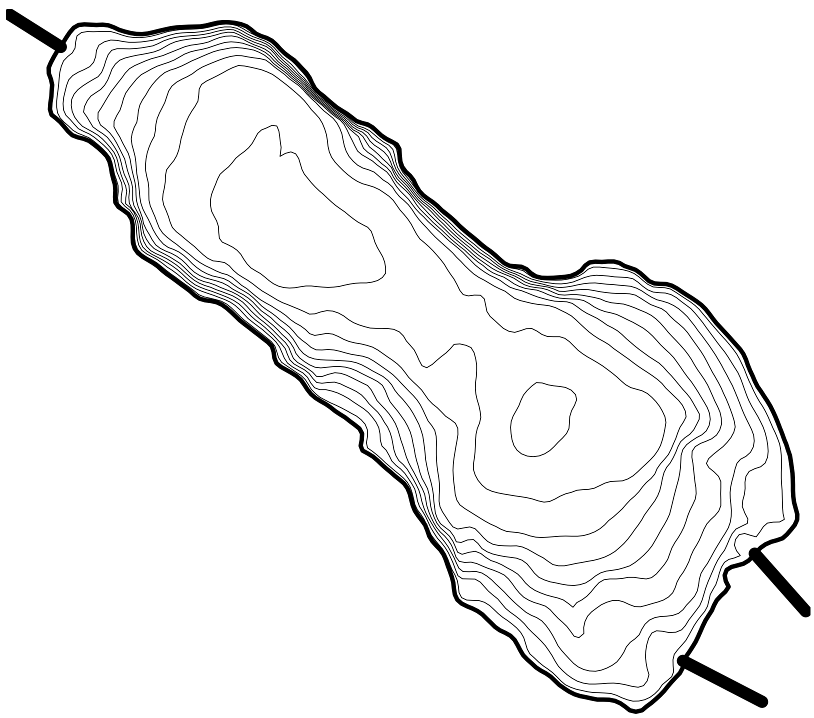
Salton Sea Operational Model

version 1.1



Salton Sea Authority
June 8, 1998

Introduction

This report documents a Salton Sea model developed for use by the Salton Sea Authority. The model is intended to facilitate comparison of several salinity and elevation management alternatives. The model has *not* been calibrated against historic Salton Sea data.

The model is a workbook created in Microsoft Excel version 5.0c for Microsoft Windows version 3.1. For the most part, the model utilizes simple mass balance arithmetic to calculate changes in elevation and salinity in response to annual estimates of inflow, evaporation, pumpin, and pumpout.

Workbook Sheets

The workbook contains the following 15 sheets:

SW - spreadsheet for an impoundment in the southwest region of the Sea (offshore of the old Navy base)
SwGrf - graph for the above spreadsheet

SWSE - spreadsheet for two shoreline impoundments together: the impoundment in sheet **SW** plus an impoundment in the southeast region of the Sea (offshore of the state wildlife area)
SWSEfig - figure showing the location of the two impoundments above
SWSEgrf - graph for the above spreadsheet

Cent - spreadsheet for an impoundment located in the center of the southern portion of the Sea
CentFig - figure showing the location of the above impoundment
CentGrf - graph for the above spreadsheet

SB - spreadsheet for an impoundment located in the central portion of the Sea's south basin extending to shore between the New and Alamo Rivers
SBfig - figure showing the location of the above impoundment
SBgrf - graph for the above spreadsheet

Gen - spreadsheet for an impoundment of variable size
GenGrf - graph for the above spreadsheet

Dam - spreadsheet for a south basin impoundment which has been constructed to withstand head differences, i.e. the elevations of the Sea and the impoundment can fluctuate independently
DamGrf - graph for the above spreadsheet

Xch - spreadsheet for water exchange (pumpin/pumpout) alternatives
XchGrf - graph for the above spreadsheet

Graphs

All graphs in the workbook are linked to their associated spreadsheets. Although the spreadsheets run out to 100 years, the graphs plot only the first 50 years of results. All graphs follow the same format utilizing, in effect, three vertical axes.

Changes in the Sea's surface elevation are depicted as a sequence of red dots whose values are given along the right axis. The range of the right axis, -226 to -278 feet, approximates the current maximum depth of the Sea, i.e. an elevation line which declines vertically halfway down the graph indicates a halving of the Sea's maximum depth.

The left axis of the graphs serves double duty as a direct scale (in acre-feet) for water flows (various black lines) and a relative scale for salinity (solid blue line). The actual salinity value can be calculated by dividing the values along the left axis by 10. Ocean salinity (35,000 ppm) is represented as a dashed blue line.

Figures

The three figures depict the approximate impoundment locations and sizes modeled in the associated spreadsheets. The impoundments are shown with the Sea at a surface elevation of -227 feet. The contour lines indicate five foot intervals from -230 to -275 feet elevation.

Spreadsheets

Equations

Equations were fitted using TableCurve 2.0 (Jandel Scientific, now SPSS). The equations selected to represent a relationship were not always the best-fitting equations because better fitting equations sometimes produced nonsensical results just beyond the data range. For example, the equation used to estimate the entire Sea's area from volume was not the best-fitting equation: better fitting equations became inverse (greater volume producing less area) at volumes only slightly greater than that at -227 feet. To ensure that the model would produce reasonable results in case the elevation rose, a curve with a monotonic positive form for some distance past the existing data range was selected. The difference in fit (as measured by r^2) was trivial.

Evaporation Rate

The influence of salinity on evaporation rate was estimated by fitting a curve to normalized (against fresh water) evaporation rates from Crow (1974) and Salhotra et al. (1985). Since a simple fitted curve (a curve with only one inflection point) did not indicate 100% evaporation in freshwater, the curve was, in effect, elevated so that proportional evaporation was 1.0 at zero salinity. For example, using the fitted curve, the proportional evaporation at 44 ppt [f(44)] is estimated to be 96.06% of the maximum (freshwater) evaporation rate. If the actual evaporation rate at 44 ppt is then set at 68 inches per year, the actual rate at another salinity = the proportional rate at that salinity [f(s)] x (68 / 0.9606).

Volumes & Areas

Areas and volumes for diked impoundment projects were based on a recent bathymetry survey of the Sea by the U.S. Bureau of Reclamation (Ferrari and Weghorst 1997) and generated with Surfer 5.0 (Golden Software) by blanking out contour grid nodes along the -255 foot contour for the shoreline (SW and SW+SE) impoundment options and the -250 foot contour for the south basin impoundment alternative. Blanking a grid node in the program gives it an infinite elevation, in effect producing a vertically-cliffed plateau in the blanked area. Volumes and areas for the Sea with and without the impoundment(s) were then calculated at one foot elevation increments up to -227 feet and the impoundment volumes/areas calculated by subtraction. This method was imperfect in three ways:

1) nodes were not always situated close to the desired contour and the impoundment boundary therefore, follows a somewhat irregular path;

2) no allowance was made for the volume of the dike structure creating the impoundment; and

3) the method produced artifacts at elevations close to the foot of the impoundment dike, i.e. the volume of the Sea with an impoundment was calculated to be greater than the volume without an impoundment. This probably occurs because the volume estimating algorithm is optimized for smooth contours rather than vertical cliffs. The calculated volumes in these cases were replaced with linearly

interpolated estimates and areas and volumes were set to zero at elevations below -255 feet for the shoreline impoundments and -250 for the south basin impoundment..

In actuality for curve fitting purposes, all zero values for both volume and area were deleted from the data sets because the fitted curves were sometimes distorted at the upper elevations. Greater accuracy at upper elevations was judged more important than that at lower elevations.

For the south central impoundment option, the impoundment volume from the dike toe to the deepest point and the impoundment surface area were generated with Autocad by the CVWD drafting department along the -260 foot contour directly utilizing USBR's bathymetry data. Again, the dike structure was assumed to be a vertical dimensionless structure so the area was fixed for all elevations above -260 feet and the volume was simply this area x the depth above -260 feet plus the volume below the dike toe. For elevations below -260 feet, Surfer was used to generate volumes and areas at one foot increments as described above.

For the variable sized impoundment option, the following equations were artificially contrived to create a variably-sized impoundment whose proportions largely mirror those of the whole Sea, except at the very lowest surface elevations:

Impoundment Surface Area = 245,276 * (*Impoundment Proportion* * (Elevation + 275) ^ 0.6 / 48 ^ 0.6)
Impoundment Volume = 7,640,033 * (*Impoundment Proportion* * (Elevation + 275) ^ 1.5 / 48 ^ 1.5)

This conceptual impoundment can be imagined as a wedge of the Sea extending out nearly, but not quite, to the deepest part of the Sea and which widens along the shoreline as its size is increased.

Details of Calculations

The following notes describe the calculations contained within the attached spreadsheets but do not include control statements for the no project alternative or various conversion factors (e.g. parts per million to tons/af). Initial and manually set conditions are indicated by *italics* in this document and by red color in the spreadsheets.

Diked Impoundment Alternatives (SW, SW+SE, Cent, & SB)

These four spreadsheets are essentially identical. The only differences among them are the equations utilized for calculating impoundment volume and area.

Initial Conditions

Initial Elevation
= the elevation of the Sea at completion of the impoundment, normally set to -227 feet

Base Evaporation Rate
= the estimated evaporation rate of the Sea at its *Initial Salinity*, normally set to 66.0 inches/year

Solid Salt Density
= the density of salt in its solid form; this determines how much salt can be stored in the impoundment. Different salts have different densities but an overall mean of the salts likely to be formed by evaporation of Salton Sea water seems to be near 2,271 g/liter (see attached table).

Pipe Flow Rate
= the linear speed of water within a pumpin or pumpout pipeline, normally set to 7.9 fps

Rainfall
= average annual precipitation, normally 2.8 inches/year

Impoundment Size
= the proportion of the Sea (by both area and volume - see **Equations**) at an elevation of -227 feet that is contained within the impoundment

Initial Salinity
= the salinity of the Sea at completion of the impoundment, normally set to 44,000 ppm

Target Salinity
= the salinity to be maintained by backpumping from the impoundment, normally set to 35,000 ppm

Pumpin Salinity
= the salinity of water imported into the Sea, normally set to 37,000 ppm for Gulf of California water and 800 ppm for Colorado River water

Salt Solubility
= the maximum amount of salt capable of being dissolved in Sea water, i.e. the salinity at which salt begins to precipitate. This cannot actually be a single number because different salts have different solubilities (see attached table) and because solubility varies with temperature. As a somewhat conservative value, 200,000 ppm provides a worst-case estimate of impoundment longevity; it is also the value suggested for use by Dave Butts of Great Salt Lake Mineral and Mining in his pumpout proposal.

Whole Sea

Elevation
Year zero = *Initial Elevation*
Subsequent years = calculated from entire Sea's Total Volume (see **Equations**)

Area
= calculated from entire Sea's Total Volume (see **Equations**)

Fluid Volume
Year zero = entire Sea's Total Volume
Subsequent years = previous year's entire Sea's Fluid Volume plus previous year's main body Inflow plus previous year's Pumpin Volume plus previous year's main body Precipitation plus previous year's impoundment Precipitation minus previous year's main body Evaporation minus previous year's impoundment Evaporation minus previous year's Pumpout Volume

Total Volume
Year zero = calculated from Elevation (see **Equations**)
Subsequent years = entire Sea's Fluid Volume plus impoundment Salt Volume

Main Body

Area
= entire Sea's Area minus the impoundment Area

<u>Volume</u>
= entire Sea's Volume minus the impoundment Total Volume

<u>Impound Backpump</u>
= Salt Deficit divided by (previous year's impoundment salinity minus the previous year's main body salinity) [to allow for the additional flushing of average salinity water from the main body caused by the pumping]

<u>Salt Deficit</u>
Note: this calculation is triggered only when 1) *Target Salinity* is a numeric value, and 2) main body Salinity would otherwise fall below *Target Salinity*. If either condition is not met then the value is set to zero.
= (*Target Salinity* x main body volume) minus (the previous year's main body Total Salt plus the previous year's Inflow Salt minus the previous year's impoundment Inflow Salt)

<u>Total Salt</u>
Year zero = main body Volume x main body Salinity
Subsequent years = previous year's main body Total Salt plus previous year's main body Inflow Salt plus previous year's Pumpin Salt plus Salt Deficit minus previous year's impoundment Inflow Salt minus previous year's Pumpout Salt

<u>Salinity</u>
Year zero = *Initial Salinity*
Subsequent years = main body Total Salt divided by main body Volume

<u>*Inflow Volume*</u>
manually input

<u>*Inflow Salinity*</u>
manually input

<u>Inflow Salt</u>
= *Inflow* x *Inflow Salinity*

<u>Evaporation Rate</u>
= calculated from main body Salinity (see **Equations**)

<u>Evaporation</u>
= main body Area x main body Evaporation Rate

<u>Precipitation</u>
= main body Area x *Rainfall*

<u>*Pumpin Volume*</u>
= manually input

<u>Inflow Rate</u>
= *Pumpin Volume* converted to cfs

Pumpin Rate
= *Pumpin Volume* converted to mgd

Inpipe Diameter
= the diameter of pipe needed to transport the *Pumpin Volume*, with water moving at the rate of *Pipe Flow Rate*

Pumpin Salt
= *Pumpin Salinity* x *Pumpin Volume*

Evaporation Impoundment

Area
= calculated from Elevation (see **Equations**)

Proportional Area
= impoundment Area divided by entire Sea's area

Volume
= calculated from Elevation (see **Equations**)

Proportional Volume
= impoundment Total Volume divided by entire Sea's Total Volume

Total Salt
Year zero = impoundment Total Volume x Overall Salinity
Subsequent years = previous year's impoundment Total Salt plus previous year's impoundment Inflow Salt minus previous year's Salt Deficit

Overall Salinity
Note: this is used to trigger the calculations allocating Total Salt between Dissolved Salt and Solid Salt; values exceeding the *salt solubility* are hypothetical only
Year zero = *Initial Salinity*
Subsequent years = impoundment Total Salt divided by impoundment Total Volume

Solid Salt
= Solid Salt Volume x S*olid Salt Density*

Solid Salt Added
Year zero = Solid Salt
Subsequent years = Solid Salt minus previous year's Solid Salt

Solid Salt Volume
= calculated by an expression derived from simultaneous equations:

equation 1) Vt (Total Volume) = Vs (Solid Salt Volume) + Vf (Fluid Volume)
rearranged: Vf = Vt - Vs
equation 2) St (Total Salt) = *a*Vs + *b*Vf

where a = *Solid Salt Density* and b = *Salt Solubility*
substitute Vf from equation 1 into equation 2:

$$St = aVs + b(Vt - Vs)$$
$$St = aVs + bVt - bVs$$

rearranged: $aVs - bVs = St - bVt$

$$(a - b)Vs = St - bVt$$

therefore: $Vs = (St - bVt) / (a - b)$

<u>Dissolved Salt</u>
= impoundment Total Salt minus Solid Salt

<u>Fluid Volume</u>
= impoundment Total Volume minus Solid Salt Volume

<u>Fluid Salinity</u>
Year zero = *Initial Salinity*
Subsequent years = Dissolved Salt divided by Fluid Volume

<u>Evaporation Rate</u>
= calculated from impoundment Salinity (see **Equations**)

<u>Evaporation</u>
= impoundment Area x impoundment Evaporation Rate

<u>Precipitation</u>
= impoundment Area x *Rainfall*

<u>Inflow</u>
= impoundment Evaporation minus (impoundment Volume minus next year's impoundment Volume) minus impoundment Precipitation

<u>Inflow Salt</u>
= main body Salinity x impoundment Inflow

Variable Size Impoundment (Gen)

This module is identical to the impoundment spreadsheets described above except that the impoundment size can be varied as an additional initial condition. Artificially constructed equations are utilized to portray impoundment area and volume (see **Equations**). The only difference in documentation therefore is:

Initial Conditions

<u>Impoundment Size</u>
= manually input, as a proportion of the Sea's area and volume at -227 feet surface elevation

Elevation Control Impoundment (Dam)

This module utilizes the same impoundment volume and area equations as the South Basin module (spreadsheet **SB**). However, this module assumes that the impoundment has been built to a construction standard sufficient to withstand head differences equal to the depth of the Sea, i.e. the dike walls act as a dam. Therefore, the volumes, areas, and elevations of the main body and the impoundment are calculated independently; the two basins are mathematically connected only by the manually set flow of water from the main body into the impoundment.

Initial Conditions

Initial Elevation
= the elevation of the Sea at completion of the impoundment

Target Elevation
not used at this time

Minimum Elevation
not used at this time

Maximum Elevation
not used at this time

Base Evaporation Rate
= the estimated evaporation rate of the Sea at its *Initial Salinity*

Solid Salt Density
= the density of salt in its solid form. This determines how much salt can be stored in the impoundment. Different salts have different densities but an overall mean of the salts likely to be formed by evaporation of Salton Sea water seems to be near 2.3 g/ml (see attached table).

Pipe Flow Rate
= the linear speed of water within a pumpin or pumpout pipeline, normally set to 7.9 fps

Rainfall
= average annual precipitation, normally 2.8 inches/year

Initial Salinity
= the salinity of the Sea at completion of the impoundment

Target Salinity (flow)
= the salinity to be maintained by allocating freshwater inflows between the main body and the impoundment, i.e. keep main body salinity from falling below the specified value . If a non-numeric value is entered then main body Inflow Volume is set equal to whole Sea Inflow Volume, i.e. the allocation process is turned off.

Target Salinity (def)

= the salinity used to calculate *Salt Deficit.* If a non-numeric value is entered then no calculation is performed.

Minimum Salinity
not used at this time

Maximum Salinity
not used at this time

Pumpin Salinity
not used

Salt Solubility
= the maximum amount of salt capable of being dissolved in water, i.e. the salinity at which salt begins to precipitate. This cannot actually be a single number because different salts have different solubilities (see attached table) and because solubility varies with temperature. As a somewhat conservative value, 200 ppt provides a worst-case estimate of impoundment longevity; this is also the value which Dave Butts suggested for use in his pumpout proposal.

Whole Sea

Inflow Volume
manually input

Inflow Salinity
manually input

Inflow Salt
= *Inflow Volume* x *Inflow Salinity*

Main Body

Elevation
Year zero = *Initial Elevation*
Subsequent years = calculated from main body Volume (see **Equations**)

Area
= calculated from main body Volume (see **Equations**)

Volume
Year zero = calculated from main body Elevation (see **Equations**)
Subsequent years = previous year's main body Volume plus previous year's main body *Inflow Volume* plus previous year's *Pumpin Volume* plus previous year's Precipitation minus previous year's main body Evaporation minus previous year's *Transfer Volume*

Salt Deficit
Note: this calculation is triggered only when 1) *Target Salinity (def)* is a numeric value, and 2) main body Salinity would otherwise fall below *Target Salinity (def).* If either condition is not met then the value is set to zero.
= (*Target Salinity (def)* x main body Volume) minus main body Total Salt

Total Salt
Year zero = main body Volume x main body Salinity
Subsequent years = previous year's main body Total Salt plus previous year's main body Inflow Salt plus previous year's Pumpin Salt minus previous year's Transfer Salt

Salinity
Year zero = *Initial Salinity*
Subsequent years = main body Total Salt divided by main body Volume

Inflow Volume
= that portion of whole Sea Inflow Volume which is allocated to the main body in such a way as to ensure that main body Salinity does not fall below *Target Salinity (flow)*
This is calculated by first testing whether allocation of the entire whole Sea Inflow Volume will produce a salinity less than *Target Salinity (flow)*. If this would not happen, then the entire inflow is allocated to the main body. Otherwise the Inflow Volume required to maintain *Target Salinity (flow)* is calculated in the following manner:

Let: SL = *Target Salinity (flow)*
FS = *Inflow Salinity*
CF = conversion factor

IV = inflow volume required to maintain *Target Salinity (flow)*
V = main body Volume
PV = *Pumpin Volume*
E = main body Evaporation
TV = *Transfer Volume*

IS = inflow salt required to maintain *Target Salinity (flow)*
S = main body Total Salt
PS = Pumpin Salt
TS = Transfer Salt

For each year, the main body Salinity is calculated with the previous year's values like this:

$$\frac{S + IS + PS - TS}{\frac{V + IV + PV - E - TV}{CF}}$$

When a specific salinity is desired, this expression can be set equal to that value. The inflow salt can also be expressed as:
IS = IV * FS * CF

Setting the equation and substituting:

$$\frac{S + (IV * FS * CF) + PS - TS}{\frac{V + IV + PV - E - TV}{CF}} = SL$$

Rearranging:

$$\frac{V + IV + PV - E - TV}{S + (IV * FS * CF) + PS - TS} = \frac{1}{SL * CF}$$

Rearranging some more:

$$IV = TV + E - V - PV + \frac{S + (IV * FS * CF) + PS - TS}{SL * CF}$$

Even more rearrangement:

$$IV = TV + E - V - PV + \frac{S + PS - TS}{SL * CF} + \frac{IV * FS}{SL}$$

Getting closer:

$$IV * (1 - FS/SL) = TV + E - V - PV + \frac{S + PS - TS}{SL * CF}$$

And finally:

$$IV = \frac{TV + E - V - PV + \frac{S + PS - TS}{SL * CF}}{1 - FS/SL}$$

<u>Inflow Salt</u>
= main body Inflow Volume x whole Sea *Inflow Salinity*

<u>Evaporation Rate</u>
= calculated from main body Salinity (see **Equations**)

<u>Evaporation</u>
= main body Area x main body Evaporation Rate

<u>Precipitation</u>
= main body Area x *Rainfall*

<u>*Pumpin Volume*</u>
manually input

<u>Inflow Rate</u>
= *Pumpin Volume* converted to cfs

<u>Pumpin Rate</u>
= *Pumpin Volume* converted to mgd

<u>Inpipe Diameter</u>
= the diameter of pipe needed to transport the *Pumpin Volume*, with water moving at the rate of *Pipe Flow Rate*

Pumpin Salt
= *Pumpin Salinity* x *Pumpin Volume*

Evaporation Impoundment

Elevation
Year zero = *Initial Elevation*
Subsequent years = calculated from impoundment Volume (see **Equations**)

Area
= calculated from impoundment Volume (see **Equations**)

Total Volume
Year zero = calculated from *Initial Elevation* (see **Equations**)
Subsequent years = impoundment Solid Salt Volume plus impoundment Fluid Volume

Inflow Volume
= whole Sea *Inflow Volume* minus main body Inflow Volume

Inflow Salt
= impoundment *Inflow Volume* x *Inflow Salinity*

Total Salt
Year zero = impoundment Total Volume x Overall Salinity
Subsequent years = previous year's impoundment Total Salt plus previous year's impoundment Inflow Salt plus previous year's Transfer Salt

Overall Salinity
Note: this is used to trigger the calculations allocating Total Salt between Dissolved Salt and Solid Salt; values exceeding the *Salt Solubility* are hypothetical only
Year zero = *Initial Salinity*
Subsequent years = impoundment Total Salt divided by impoundment Total Volume

Solid Salt
if impoundment Total Salt exceeds Fluid Salt Capacity then = impoundment Total Salt minus Fluid Salt Capacity; otherwise = zero

Solid Salt Volume
= Solid Salt divided by *Solid Salt Density*

Dissolved Salt
= impoundment Total Salt minus Solid Salt

Fluid Salt Capacity
= Fluid Volume x *Salt Solubility*

Fluid Volume
Year zero = calculated from Impoundment Elevation (see **Equations**)

Subsequent years = previous year's impoundment Fluid Volume plus previous year's impoundment Inflow Volume plus previous year's Transfer Volume plus previous year's impoundment Precipitation minus previous year's impoundment Evaporation

Fluid Salinity
Year zero = *Initial Salinity*
Subsequent years = Dissolved Salt divided by Fluid Volume; if Fluid Volume is zero, then Fluid Salinity is set to *Salt Solubility*

Evaporation Rate
= calculated from impoundment Fluid Salinity (see **Equations**)

Evaporation
= impoundment Area x impoundment Evaporation Rate

Precipitation
= impoundment Area x *Rainfall*

Transfer Volume
manually input; this is the volume of water allowed to flow (by gravity) from the main body into the impoundment. Care must be taken to ensure that such large volumes are not transferred that the impoundment Elevation rises higher than the main body Elevation - the model does not check for this possibility.

Transfer Salt
= *Transfer Volume* x main body Salinity

Water Exchange Alternatives (Xch)

Initial Conditions

Initial Elevation
= the elevation of the Sea at completion of the pipeline(s)

Base Evaporation Rate
= the estimated evaporation rate of the Sea at its *Initial Salinity*

Rainfall
= average annual precipitation, normally 2.8 inches/year

Initial Salinity
= the salinity of the Sea at completion of the pipeline(s)

Pumpin Salinity
= the salinity of water imported into the Sea, normally set to 37,000 ppm for Gulf of California water and 800 ppm for Colorado River water

Pipe Flow Rate
= the linear speed of water within a pumpin or pumpout pipeline, normally set to 7.9 fps

Whole Sea

<u>Elevation</u>
Year zero = *Initial Elevation*
Subsequent years = calculated from Volume (see **Equations**)

<u>Area</u>
= calculated from Volume (see **Equations**)

<u>Volume</u>
Year zero = calculated from *Initial Elevation*
Subsequent years = previous year's Volume plus previous year's *Inflow Volume* plus previous year's *Pumpin Volume* minus previous year's *Pumpout Volume* minus previous year's Evaporation

<u>Salt</u>
Year zero = Volume x *Initial Salinity*
Subsequent years = previous year's Salt plus previous year's Inflow Salt plus previous year's Pumpin Salt minus previous year's Pumpout Salt

<u>Salinity</u>
Year zero = *Initial Salinity*
Subsequent years = Salt divided by Volume

<u>Inflow Volume</u>
manually input

<u>Inflow Salinity</u>
manually input

<u>Inflow Salt</u>
= *Inflow Volume* x *Inflow Salinity*

<u>Evaporation Rate</u>
= calculated from Salinity (see **Equations**)

<u>Evaporation</u>
= Area x Evaporation Rate

<u>Pumpin Volume</u>
manually input

<u>Inflow Rate</u>
= *Pumpin Volume* converted to cfs
<u>Pumpin Rate</u>
= *Pumpin Volume* converted to mgd

<u>Inpipe Diameter</u>

= the diameter of pipe needed to transport the *Pumpin Volume*, with water moving at the rate of *Pipe Flow Rate*

Pumpin Salt
= *Pumpin Volume* x *Pumpin Salinity*

Pumpout Volume
manually input

Outflow Rate
= *Pumpout Volume* converted to cfs

Pumpout Rate
= *Pumpout Volume* converted to mgd

Outpipe Diameter
= the diameter of pipe needed to transport *Pumpout Volume*, with water moving at the rate of *Pipe Flow Rate*

Pumpout Salt
= *Pumpout Volume* x Salinity

Net Salt
= previous year's Salt minus current year's Salt

ASSUMPTIONS & KNOWN INACCURACIES

In addition to items discussed above, this model has the following limitations:

- The relatively fresh inflows are assumed to mix completely and immediately with the saline water already in the Sea.
- The allocation of salt between dissolved and solid phases in impoundment modules causes a slight overestimate of impoundment effectiveness because it is peformed after fluid inflow to the impoundment has been calculated. Since precipitation of salt increases the occupied volume in the impoundment (solid salt has a greater volume than dissolved salt) the volume available for inflow water from the main body is actually about 2% less than calculated once precipitation starts.

LITERATURE CITED

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Version History

version 1.0 - January 7, 1998

version 1.1 - June 8, 1998

- Corrected error in impoundment spreadsheets. Version 1.0 overestimated the speed at which salinity would be reduced when inflows were less than the historical average; the magnitude of the error was proportional to the reduction in inflow but equilibrium conditions were not affected.
- Added direct precipitation as separate input because it is not included in measured inflows to Sea.
- Added Gen impoundment module.

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