RiverWare

Technical Documentation Version 7.3

Water Quality

Center for Advanced Decision Support for
Water and Environmental Systems (CADSWES)
UNIVERSITY OF COLORADO BOULDER

Water Quality Table of Contents

Water Quality

1. Overview and General Features

Water quality may be modeled in RiverWare along with simulated water quantity calculations. Currently water quality modeling is available on reservoirs, reaches, confluences, bifurcations, canal, gages, aggregate reaches, aggregate diversion site, aggregate distribution canals, water users, and groundwater storage objects. Constituents include Salinity (TDS), Temperature, Dissolved Oxygen (DO), and Total Dissolved Gas (TDG).

The development of the water quality methods were initially completed in 1996, but were not used extensively. They were updated in 2012 to better model salinity but still may require some minor modifications with more extensive testing and use.

Note: In previous versions of RiverWare, the constituents and solution approach were chosen on the run control. You had to choose either Layered/Discretized or Simple Well Mixed. Starting in version 6.6, this selection is performed on each object. Now, you can mix and match constituents and/or approach within a single model.Use the multi-object method selector to speed the selection process, **HERE (ObjectDialogs.pdf, Section 4)**.

Following is an overview of the water quality methods available.

1.1 Layered/Discretized for Salinity, Temperature and/or DO

Salinity, Temperature and Dissolved oxygen can be modeled using a layered approach on reservoirs and groundwater objects and a discretized approach on reaches. Other objects pass the constituents along using methods that are indicated with the “propagate” terminology.

The layered/discretized approach models reservoirs as having two layers, an epilimnion and a hypolimnion. Reaches are modeled based on the selected routing method but can be discretized such that 1 dimensional dispersion can be included. In this approach, mass, concentration, and/or heat are calculated and propagate downstream. As a result, the user should link each constituents mass, concentration, and/or heat slots between objects. For salinity modeling, salt concentrations (instead of mass) should be linked between objects.

Features of the Reservoir methods include:

- 2-Layer structure with constant epilimnion thickness. Inflows distributed by the user or based on temperature. Outflows are distributed as a “cone of influence” around the outlet works. The modeling of these distributions are user-selectable methods.

- Segmented 2-Layer method computes flow vertically and longitudinally through the reservoir. The elevation of the thermocline is assumed to be constant. Inflow and Outflow are distributed based on user-selectable methods. Flow between segments and layers is used to model reservoir salinity.
- Methods for surface heat flux (convection, radiation, evaporation, etc.) and diffusion/dispersion across the thermocline. The complex surface heat flux equations may also be used if evaporation is a component of the mass-balance.

Features of the reach water quality methods include:

- Both implicit and explicit control-volume approaches for salinity and temperature, as well as a simple lagged and variable lagging approach.
- Routing methods to support the control-volume methods, including channel characterization schemes and advanced routing algorithms (Muskingum-Cunge, kinematic wave, MacCormack).
- Ability to model the quality of diversions, return flows, local inflows, and seepage.

Features of the Groundwater salinity methods include:

- 2-Layer structure, with a head based flow solution. The upper layer has a constant structure. Methods are available to see the computed salt mass in addition to salt concentrations.

Other objects pass constituents downstream so a complex network can be modeled.

1.2 Well Mixed Salinity

Salinity can be modeled using simple well mixed methods. These assume that water in each of the objects is completely mixed. In this approach, mass and concentration are calculated.Concentrations propagate upstream or downstream. As a result, the user should link each salt concentrations between objects.

Features of the simple well mixed salt approach:

- On reservoirs, there are user selectable methods to specify how the reservoir is mixed, either using a weighting factor or using a predictor-corrector algorithm.
- Reaches are well mixed but can only be modeled using the No Routing method. Reaches can model salt contributed or removed through local inflows, diversions, and return flows.
- Confluences, Bifurcations, and Stream Gages pass the Salt upstream or downstream depending on how the object solves
- Agg Diversion Sites and Water Users allow the modeling of return flow salt pickup, i.e. the amount of salt to add to the return flow.

1.3 Total Dissolved Gas

High Total Dissolved Gas (TDG) concentrations can reduce the population of some fish species. These effects are most pronounced in the tailwater of reservoirs during spill operations. The TDG concentrations are increased by spills; the turbulent nature of the spill creates air bubbles that are then forced deep into the tailwater. The deep water has higher pressure which cause gases in the bubbles to dissolve in the water. Once dissolved, the gas propagates downstream.

To alleviate the problems of high TDG concentrations, certain reservoir operations are constrained by maximum allowable TDG tailwater concentrations. RiverWare models TDG in both simulation and optimization on the following objects:

- Reservoir objects model TDG of the Spill and Turbine Release. The Spill TDG concentration is a function of the tailwater depth.
- Reach objects propagate the TDG concentration upstream to downstream using simple lagging.
- Within Optimization, methods are available to set up constraints based on TDG information. This approach is described in the Reservoir section, HERE (Section 16.4.49).

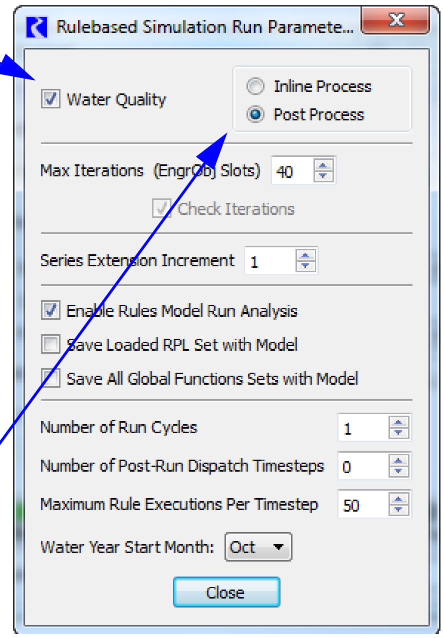
This document describes how to enable and define a water quality simulation. Then the water quality methods and solution approach is presented for each type of object.

2. How to Use WQ

Water quality is modeled by first enabling water quality for the entire system and specifying the timing of the computations, either inline or post process. Select the constituents and methods on each object and populate slots with data. Run the model as usual; the water quality results are stored in slots on the individual objects. Following is a brief description of the steps to set up a water quality model.

2.1 Enable Water Quality Modeling

Enable water quality modeling on the **Run Control** parameters dialog. From the **Run Control**, select either **View ➥ Simulation Run Parameters** or **View ➥ Rulebased Simulation Run Parameters**, depending on the selected controller. Check the **Water Quality** box to enable the methods.



Note: If you later un-check this toggle, no water quality solution will occur and the water quality methods will be hidden. The selections and slot are still there, but they are not visible. Re-check the box to re-enable the water quality solution.

2.2 Specify Process

Select one of the Water Quality processes. The following section gives more information on how each process works.

- **Inline Process:** Water Quality calculations are performed at each timestep inline with the water quantity simulation calculations.
- **Post Process:** Water Quality calculations for all timesteps are performed at the end of the run, i.e., after all the simulation timesteps have been executed.

3. How it Works

When water quality modeling is enabled and the methods are selected, the water quality slots are instantiated. The water mass balance simulation proceeds as usual with objects dispatching when dispatch conditions are met. Similarly, there are separate dispatch methods for the water quality used to solve how the constituents move through the objects. Water quality dispatch methods are described for each of the objects. Each dispatch method calls a number of utility methods that typically do the work.

Like the mass balance dispatch method, water quality dispatch methods have dispatch conditions. Whenever the water quality dispatch conditions are met for a given method, the object is added to the queue. Water quality dispatch conditions also include water quantity slots. For example, for a reservoir to dispatch for water quality it needs to know Inflow, Outflow, and Storage as well as the inflow salt concentrations, temperature, etc (depending on constituents modeled). The water quality dispatch condition are always solved top down, i.e. after the water balance has been executed for that object. It is not possible to specify or “request” a particular salinity at the lower end of the river and have the system solve for the flow with that salinity. It must first solve for the water quantity, before it can solve for water quality.

The water quality dispatch methods are processed based on the selected process, either Inline or Post:

- Inline Process: If the Inline Process is selected, at any time dispatch conditions are met, the water quality controller may dispatch object's water quality dispatch methods. In Inline water quality, there is one dispatch queue that contains both mass balance and water quality dispatch methods. The queue is processed "first in, first out" so mass balance and water quality dispatching may be interspersed.
- Post Process: If the Post Process is selected, water quality dispatching only happens at the end of the run. Two separate queues are maintained, one for mass balance dispatching and one for water quality dispatching. The mass balance queue is processed as usual (at each timestep) while the water quality queue is only processed at the end of the run.

3.1 Execution Order

Following is the order of operations for a water quality calculation as part of a regular simulation.

- Initialization: reset all Output slots to NaN, set Input values, propagate links, and determine first dispatch timestep.
- Execute Beginning of Run behavior on all objects including Water Quality Beginning of Run checks and evaluation of start of run expression slots.
- Execute each timestep:
  - Execute start of timestep expression slots
  - Execute the Beginning of Timestep on all objects.
  - Execute Timestep: process the dispatch queue until it is empty. If water quality is configured to be an **Inline Process**, process the water quality dispatch methods when they are on the queue. The queue is first in, first out order.
  - Execute End of Timestep on all objects.
  - Execute end of timestep expression slots

Advance the timestep and repeat the five steps above.

- Execute End of Run behavior on all objects.
- If water quality is configured to be **Post Process**, process the water quality dispatch queue which contains water quality dispatch methods as necessary.
- Evaluate all end of run expression slots.

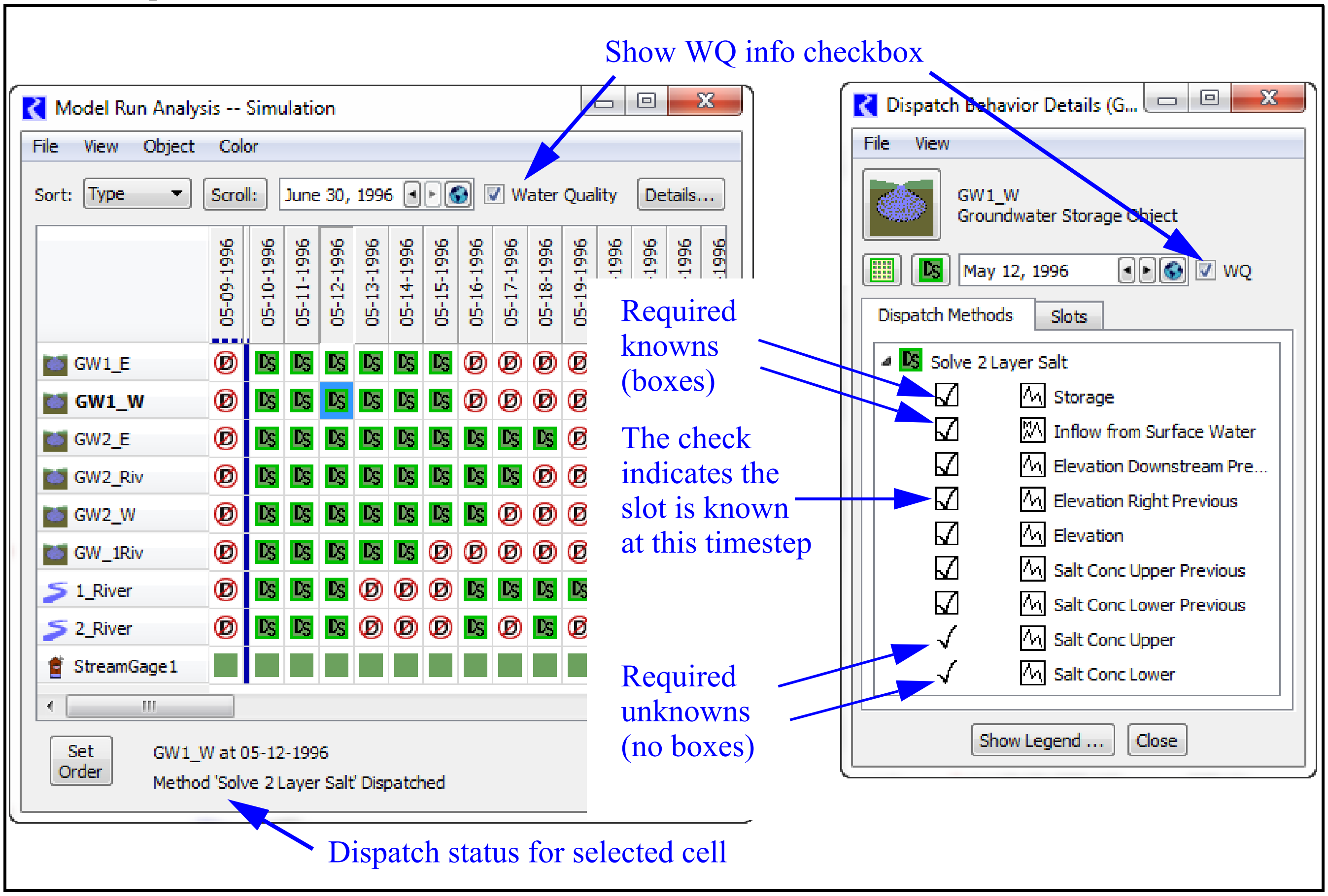
Combining water quality with Rulebased Simulation allows the rules to reference water quality slots in making operational decisions. The Inline Process water quality dispatching happens during the timestep when the required dispatch conditions are met. This means that water quality can dispatch multiple times during a timestep based on the values that the rules set and whether the dispatch slots are reset.

In a rulebased simulation run with the Post Process water quality selected, dispatching happens at the end of the run. Rules cannot reference water quality information as it has not been solved yet.

3.2 Viewing Water Quality Dispatch Information

The **Model Run Analysis** tool is used to show dispatching information. A general description is HERE

(ModelRunAnalysis, Section 1). This utility by default shows object dispatching information for the water quantity solution. When **Water Quality** is enabled as described above, a **Water Quality** checkbox is shown on the main **Model Run Analysis** dialog. When checked, the dialog shows dispatch information for the water quality solution. Double clicking on a cell opens the **Dispatch Behavior Details** dialog. This dialog has an analogous **WQ** toggle. This details dialog shows the required knowns and unknowns for each dispatch method and the known and unknown status of each slot.



Note: You can also show the details dialog docked in the Model Run Analysis using the **Details** button.

The water quality checkboxes represent a single state shared amongst the **Model Run Analysis** and all instances of the **Dispatch Behaviors Detail** dialog; clicking the checkbox in any of these dialogs also changes the checkbox in all open dialogs of either type.

Note: When running rulebased simulation and water quality, the model run analysis for water quality only shows the icons indicating dispatch state. There is no analogous **Rules Grid** for water quality.

3.3 Document Organization

The remainder of this document is organized as follows: for each object, we describe the water quality approach including slots and user methods, then present solution and dispatch methods, then utility methods if defined.

4. Agg Distribution Canal

Agg Distribution Canals have water quality methods to model salt by calculating the total salt mass of the inflow and outflow. The actual water quality work is done on the Distribution Canal elements. Links are automatically created between Distribution Canals within the aggregate.

The Distribution Canal can currently model salt.

4.1 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Agg Distribution Canal. Note that these methods actually control the method on the member elements.

4.1.1 Agg Distribution Canal Water Quality

The methods in this category add the necessary slots to the element. They also control the method selection on the member Distribution Canals.

4.1.1.1 None

No water quality solution is performed. No slots are added.

4.1.1.2 Propagate Salt

Following are the slots added to the

☞ **INFLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the inflow to the Agg Distribution Canal
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ **INFLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the inflow to the Agg Distribution Canal
I/O: Output only
Links: Not Linkable

☞ **OUTFLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the outflow from the Agg Distribution Canal
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ **OUTFLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the outflow from the Agg Distribution Canal
I/O: Output Only
Links: Not Linkable

4.2 Dispatch Methods

Following are the available dispatch method when Propagate Salt is selected.

4.2.1 Solve Salt Mass

This method computes the total inflow and outflow salt mass only. The salt concentrations should come from the linked element objects or from upstream/downstream objects (or via input or rules).

REQUIRED KNOWN SLOTS:

☞ **TOTAL INFLOW**
☞ **INFLOW SALT CONCENTRATION**
☞ **TOTAL OUTFLOW**
☞ **OUTFLOW SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

☞ **INFLOW SALT MASS**
☞ **OUTFLOW SALT MASS**

METHOD DETAILS:

This method does the following:

$$InflowSaltMass = InflowSaltConcentration \times InflowVol \quad (4-1)$$

$$OutflowSaltMass = OutflowSaltConcentration \times OutflowVol \quad (4-2)$$

5. Aggregate Diversion Site

The Agg Diversion Sites has water quality methods to model salt using either the Propagate Salt or Well Mixed Salt method.

For Sequential or No Structure configurations, the actual water quality work is done on the Water User elements. For Lumped configurations, the aggregate does the water quality solution.

Links are automatically created between Water Users within (and to) the aggregate when using the Sequential structure

5.1 User Selectable Methods

Below is a description of each user selectable method on the Agg Diversion Site.

5.1.1 Agg Diversion Site Water Quality

The methods in this category specify the constituents and approach.

5.1.1.1 None

No Water Quality is modeled and no slots are added.

5.1.1.2 Propagate Salt

Salt is propagated to the elements. This method has no slots on the aggregate. When used, it automatically selects the Salinity method on water user elements. This method is described HERE (Section 18.1.1.2).

5.1.1.3 Well Mixed Salt

Salt is modeled using the Well Mixed approach. This method has no slots on the aggregate. When used, it automatically selects the Salinity method on water user elements. This method is described HERE (Section 18.1.1.2).

5.1.2 Return Flow Salt

Following are the user selectable methods in the **Return Flow Salt** category. These methods are used to specify how the Return Flow Salt Mass should be calculated. In other words, how much salt is picked up in the return flow from the diversion site.

5.1.2.1 None

This is the default method in this category. It does no calculations and instantiates no slots. It is the only available method for the No Structure Agg Diversion Site. Each water user element behaves independently, but each automatically uses the Propagate Salt method.

5.1.2.2 Lumped Salt

This method models additional salt added to a lumped Agg Diversion Site. This is the only available method for the lumped Agg Diversion Site when using the Propagate Salt method. It is one of four available methods for the Well Mixed Salt method.

SLOTS ADDED BY THIS METHOD:

☞ **DIVERSION SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **DIVERSION SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Diversion
I/O: Output only
Links: Not Linkable

☞ **SALT LOADING**

Type: Series Slot
Units: MASS
Description: The additional salt that is to be added to the return flow.
I/O: Input or set by a rule. If not specified, no additional salt is added.
Links: Not Linkable

☞ **RETURN FLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable for Well Mixed Salt. The concentration should be linked for Propagate Salt.

☞ **RETURN FLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable for Propagate Salt.

If Salt Loading is valid,

$$ReturnFlowSaltMass = DiversionSaltMass + SaltLoading \tag{5-1}$$

Otherwise:

$$ReturnFlowSaltMass = DiversionSaltMass \tag{5-2}$$

Return Flow Salt Concentration is computed from the Return Flow Salt Mass and Return Flow volume.

5.1.2.3 Sequential Salt

This method models salt on a sequential Agg Diversion Site. This is the only available method for the sequential Agg Diversion Site using Propagate Salt. It does not do any calculations but instantiates slots that can be linked to upstream or downstream objects.

SLOTS ADDED BY THIS METHOD:

☞ **DIVERSION SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Automatically linked to the first element’s Diversion Salt Concentration.

☞ **TOTAL UNUSED SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration of the Total Unused Water
I/O: Output only
Links: Automatically linked to the last element’s Outgoing Salt Concentration. It can also be linked to a downstream object’s salt concentration slot.

5.1.2.4 Variable Salt Pickup

This method is available for Well Mixed Salt on a Lumped Agg Diversion Site. It executes the selected method in the Salt Pickup category: either Salt Pickup Concentration or Salt Pickup Mass. No other calculations are performed.

☞ **Diversion Salt Concentration**

Type: Series Slot
Units: Concentration
Description: Salt concentration associated with the Total Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Diversion Salt Mass**

Type: Series Slot
Units: Mass
Description: Salt mass associated with the Total Diversion
I/O: Output only
Links: Not Linkable

☞ **Return Flow Salt Mass**

Type: Series Slot
Units: Mass
Description: Salt mass associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable, but you should typically link Return Flow Salt Concentration instead.

☞ **Return Flow Salt Concentration**

Type: Series Slot
Units: Concentration
Description: Salt concentration associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable

☞ **Return Flow Salinity Pickup Conc**

Type: Series Slot
Units: Concentration
Description: The additional salinity that is to be added to the return flow.
I/O: Optional input.
Type: Not Linkable

5.1.2.5 Distributed Annual Salt Loading

This method is available for Well Mixed Salt on a Lumped Agg Diversion Site. This method is typically used on a monthly timestep to distribute annual salt loads.

SLOTS ASSOCIATED WITH THIS METHOD

☞ DIVERSION SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ DIVERSION SALT MASS

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Diversion
I/O: Output only
Links: Not Linkable

☞ RETURN FLOW SALT MASS

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable, but you should typically link Return Flow Salt Concentration instead.

☞ RETURN FLOW SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable

☞ PERCENT OF ANNUAL DEMAND

Type: Table Slot
Units: DECIMAL
Description: A 12X1 table of the monthly fraction of annual diversion demand
I/O: Required Input: This slot requires a percentage for each of the 12 months to calculate the equivalent annual shortage.
Links: Not Linkable

☞ Percent of Annual Mass

Type: Table Slot
Units: Decimal
Description: A 12X1 table of the monthly fraction of annual salt mass
I/O: This slot requires a percentage for each of the 12 months to calculate the monthly non-shortage salt mass.
Links: Not Linkable

☞ Return Flow Salinity Pickup Conc

Type: Series Slot
Units: Concentration
Description: The additional salinity that is to be added to the return flow.
I/O: Optional input. If Return Flow Salinity Pickup Mass is input, this slot cannot be input
Links: Not Linkable

☞ Return Flow Salinity Pickup Mass

Type: Series Slot
Units: Mass
Description: The additional salinity that is to be added to the return flow.
I/O: Optional input. If Return Flow Salinity Pickup Conc is input, this slot cannot be input
Links: Not Linkable

Method Details:

The Distributed Annual Salt Loading method calculates the annual mass and monthly non-shortage return flow salt mass.

First, the method determines whether the return flow pickup salinity is specified as a concentration or a mass by looking at the input status of the two slots.

- Return Flow Salinity Pickup Conc
- Return Flow Salinity Pickup Mass

One or the other must be input and it must be input for the entire run. If neither is input or both are input, an error will occur.

The variable “annual salt mass” for the current year is calculated in January by summing each month’s Return Flow Salinity Pickup Mass or each month’s Return Flow Salinity Pickup Conc times the computed Return Flow Volume.

A monthly Non Shortage Salt Mass is calculated each month by multiplying the annual salt mass by the percentage for that month specified in the Percent of Annual Mass table. The monthly value is stored as a local variable, nonShortRFSaltMass, during execution of the method.

The method then converts Total Return Flow, and Total Diversion from a flow to a volume.

Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times diversionVolume}{TotalReturnFlowVol} \quad (5\text{-}3)$$

Note, if Total Return Flow Vol is zero, concentrated is set to zero

$$returnFlowSaltConc = concentrated \quad (5\text{-}4)$$

The method then gets the Return Flow slot from the reach to which this Total Return Flow slot is linked. If Total Return Flow is not linked to a Reach, an error will be issues and the run will be aborted. On this reach, the method gets the Outflow and the minimum value from the Outflow. If Total Return Flow is zero and the reach's outflow is less than the minimum value, Return Flow Salt Mass and Distributed Salinity Pickup Mass are equal to zero and the method exits.

Otherwise, if the Total Diversion Requested or Total Depletion Requested is less than or equal to zero or Total Diversion equals Total Diversion Requested, there is no shortage and Return Flow Salt Mass is set equal to:

$$returnFlowSaltMass = concentrated \times TotalReturnFlowVol + nonShortRFSaltMass \quad (5\text{-}5)$$

And Distributed Salinity Pickup Mass is equal to *nonShortRFSaltMass*.

Otherwise, the method computes the percent short:

$$\%Short = \left(1 - \frac{TotalDiversion \times \left(1 - \frac{totalDiversionRequested - totalDepletionRequested}{totalDiversionRequested}\right)}{totalDepletionRequested}\right) \times 100 \quad (5\text{-}6)$$

If the % Short is greater than 75%, Return Flow Salt Mass is set equal to *concentrated* times Total Return Flow Volume, and Distributed Salinity Pickup Mass is zero. Else, if the Percent of Annual Demand for the given month is zero, the equivalentAnnualShortage is zero. Otherwise, the equivalentAnnualShortage is computed by dividing the percent of shortage in a month's diversion by Percent of Annual Demand (from the table) for the current month.

Finally, the Return Flow Salt Mass is set equal to:

$$returnFlowSaltMass = concentrated \times TotalReturnFlowVol + nonShortRFSaltMass \times (1 - equivalentAnnualShortage) \quad (5\text{-}7)$$

Distributed Salinity Pickup Mass is equal to $nonShortRFSaltMass \times (1 - equivalentAnnualShortage)$.

5.1.2.6 Variable Salt Pickup with Debt

This method is available for Well Mixed Salt on a Lumped Agg Diversion Site. This method calculates Return Flow Salt Mass and Return Flow Salt Concentration based on a salt debt policy if it applies. This can be used to simulate Water Quality Improvement Projects (WQIP's). This method determines if there is sufficient salt in the river to satisfy the WQIP. If not, the amount of salt removal is set equal to the amount available. The Salt Debt slot is used to track the deficiency and the method will attempt to repay the debt in subsequent timesteps.

SLOTS ASSOCIATED WITH THIS METHOD

☞ DIVERSION SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ DIVERSION SALT MASS

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Diversion
I/O: Output only
Links: Not Linkable

☞ RETURN FLOW SALT MASS

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable, but you should typically link Return Flow Salt Concentration instead.

☞ RETURN FLOW SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Total Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable

☞ SALT DEBT

Type: Series Slot
Units: MASS
Description: The debt (of mass) associated with the return flow salt
I/O: Output only, initial value is a required input
Links: Linkable

☞ Return Flow Salinity Pickup

Type: Series Slot
Units: Concentration
Description: The additional salinity that is to be added to the return flow.
I/O: Output only
Links: Not Linkable

Method Details:

If the Total Return Flow is zero, the Return Flow Salt Concentration, Return Flow Salt Mass and Salt Debt are set to zero and the method is exited.

The method then converts Total Return Flow, Total Diversion, Total Diversion Requested, and Total Depletion Requested from a flow to a volume (TotalReturnFlowVol, TotalDiversionVol, TotalDiversionRequestedVol, and TotalDepletionRequesetedVol).

Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times diversionVolume}{TotalReturnFlowVol} \tag{5-8}$$

Then, the method initializes the Return Flow Salt Concentration slot to be equal to concentrated. Set the current timestep's Salt Debt equal to the previous timestep's value. Calculate the local variables unshortReturnFlowVol and massRequested:

$$unshortReturnFlowVol = TotalDiversionRequestedVol - TotalDepletionRequestedVol \tag{5-9}$$

$$massRequested = -(unshortReturnFlowVol \times returnFlowSalinityPickup) \tag{5-10}$$

The method then gets the Return Flow slot from the reach to which this Total Return Flow is linked. If Total Return Flow is not linked to a Reach, an error will be issued and the run will be aborted. On this reach, the method gets the Inflow volume (reachInflowVol) and the minimum value from the slot Outflow Salt Concentration (reachOutSaltMin).

If the Diversion Salt Concentration is less than the reachOutSaltMin, then set Salt Debt equal to the previous timestep's value plus the massRequested. If the new WaterQualitySaltDebt is less than zero, reset it to zero. Then go to Equation 5-17 or Equation 5-18 and finish the method.

Otherwise, the Diversion Salt Concentration is greater than or equal to reachOutSaltMin, the river has some of the salt that the WQIP needs, determine if is all or not. First calculated the estimated outflow volume (estOutVol) as:

$$estOutVol = reachInflowVol + TotalReturnFlowVol - TotalDiversionVol \tag{5-11}$$

Compute the mass than can be returned (massThatCanBe) as:

$$massThatCanBe = reachInflowVol \times DiversionSaltConcentration - estOutVol \times reachOutSaltMin \tag{5-12}$$

If massThatCanBe is greater than massRequested, the river can meet all of the WQIP and any excess can be used to repay the debt. If Salt Debt is positive, set Return Flow Salt Concentration equal to

Return Flow Salinity Pickup and go to Equation 5-17 or Equation 5-18. Otherwise, Salt Debt is set to:

$$SaltDebt = max(SaltDebt[-1] - (massThatCanBe - massRequested),0) \tag{5-13}$$

$$returnFlowSaltConcentration = -\left(\frac{SaltDebt[-1] - SaltDebt + massRequested}{TotalReturnFlowVol}\right) \tag{5-14}$$

Then go to Equation 5-17 or Equation 5-18.

Else, massThatCanBe is less than or equal to massRequested, so meet part of the request and increases the debt.

$$returnFlowSaltConcentration = -\left(\frac{massThatCanBe}{TotalReturnFlowVol}\right) \tag{5-15}$$

$$SaltDebt = SaltDebt[-1] - (massThatCanBe - massRequested) \tag{5-16}$$

If concentrated is greater than zero, then:

$$returnFlowSaltConcentration = returnFlowSaltConcentration + concentrated \tag{5-17}$$

else:

$$returnFlowSaltConcentration = -returnFlowSaltConcentration + concentrated \tag{5-18}$$

Finally, set the salt mass:

$$returnFlowSaltMass = returnFlowSaltConcentration \times TotalReturnFlowVol \tag{5-19}$$

5.1.3 Salt Pickup

This category is dependent on the Variable Salt Pickup method being selected in the **Return Flow Salt** category.

5.1.3.1 Salt Pickup Concentration

This method determines the Return Flow Salt Mass as a function of Diversion Salt Concentration, Return Flow Pickup and Return Flow Volume.

METHOD DETAILS:

The method first converts Total Return Flow, and Total Diversion from a flow to a volume (*TotalReturnFlowVol* and *TotalDiversionVol*).

Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times TotalDiversionVolume}{TotalReturnFlowVol} \tag{5-20}$$

Note, if *TotalReturnFlowVol* is zero, concentrated is set to zero

If both of the local variables *concentrated* and TotalReturnFlowVol are less than zero, then Return Flow

Salt Concentration equals:

$$returnFlowSaltConc = concentrated - ReturnFlowSalinityPickupConc \quad (5\text{-}21)$$

Else, Return Flow Salt Concentration equals:.

$$returnFlowSaltConc = concentrated + ReturnFlowSalinityPickupConc \quad (5\text{-}22)$$

At the end of this method, Return Flow Salt Mass is calculated as:

$$ReturnFlowSaltMass = returnFlowSaltConc \times TotalReturnFlowVol \quad (5\text{-}23)$$

5.1.3.2 Salt Pickup Mass

This method determines the Return Flow Salt Mass as a function of Diversion Salt Concentration, Return Flow Pickup and Return Flow Volume. The user specified salt mass can be negative or positive and can add salt even when Return Flow equals zero.

SLOTS ASSOCIATED WITH THIS METHOD

☞ ANNUAL SALINITY PICKUP MASS

Type: Table Slot
Units: MASS
Description: A table holding the Salinity Pickup mass for the year
Information: Note, this slot is not used in any calculations. It is strictly for user comparison purposes.
I/O: Input only
Links: Not Linkable

☞ ANNUAL RETURN FLOW VOLUME

Type: Table Slot
Units: VOLUME
Description: A table holding the return flow volume for the year
Information: Note, this slot is not used in any calculations. It is strictly for user comparison purposes.
I/O: Input only
Links: Not Linkable

☞ RETURN FLOW SALINITY PICKUP MASS

Type: SeriesSlot
Units: MASS
Description: slot for salinity pickup mass
Information: user specified salinity pickup mass is entered in the slot.
I/O: Required Input
Links: Not Linkable

The method first converts Total Return Flow and Total Diversion from a flow to a volume (TotalReturnFlowVol and TotalDiversionVol). Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times TotalDiversionVolume}{TotalReturnFlowVol} \tag{5-24}$$

Note, if TotalReturnFlowVol is zero, concentrated is set to zero

The Salt Pickup Mass method first checks if Return Flow Salinity Pickup Mass is valid. If it is not valid, the run will abort and an error will be posted. If Total Return Flow equals zero, Return Flow Salinity Pickup and Return Flow Salt Concentration is set equal to zero and Return Flow Salt Mass is calculated as:

$$ReturnFlowSaltMass = concentrated \times TotalReturnFlowVol + ReturnFlowSalinityPickupMass \tag{5-25}$$

If Total Return Flow does not equal zero, Return Flow Salinity Pickup is calculated as:

$$ReturnFlowSalinityPickup = \frac{returnFlowSalinityPickupMass}{TotalReturnFlowVol} \tag{5-26}$$

Then, Return Flow Salt Mass is calculated as:

$$ReturnFlowSaltMass = concentrated \times TotalReturnFlowVol + ReturnFlowSalinityPickupMass \tag{5-27}$$

Return Flow Salt Concentration is calculated as:

$$ReturnFlowSaltConc = \frac{ReturnFlowSaltMass}{TotalReturnFlowVol} \tag{5-28}$$

5.1.4 Salt Removal Category

This category is available when Well Mixed Salt is used. The methods in this category model salt removed directly from a linked Reach.

5.1.4.1 None

This is the default method. No slots are instantiated and no calculations are performed.

5.1.4.2 Salt Mass Removal

This method allows you to specify a mass of salt to remove. Two links are required between the Agg Diversion Site and Reach. The Salt Mass Removal slots on both objects should be linked to each other, and the Salt Available For Removal slots should be linked.

SLOTS ASSOCIATED WITH THIS METHOD:

☞ Salt Mass Removal

Type: Series Slot
Units: Mass
Description: The amount of salt that is removed from the linked reach
I/O: Output only
Links: Linked to the Salt Mass Removal on a reach.

☞ Salt Mass Removal Request

Type: Series Slot with Periodic Input
Units: Mass
Description: The mass of salt you would like to remove.
I/O: Required input
Links: Not linked

☞ Salt Available For Removal

Type: Series
Units: Mass
Description: The maximum salt mass that can be removed from the linked reach without dropping below the specified minimum salt concentration (if solving downstream) or exceeding the specified maximum salt concentration (if solving upstream). The value in this linked slot will be solved for by the linked reach.
I/O: Output only
Links: Linked to Salt Available For Removal on a reach

The method checks that both Salt Mass Removal and Salt Available For Removal are linked to a Reach. If they are not linked to a Reach, an error will be issued, and the run will be aborted.

Next, the method checks if Salt Available For Removal is less than zero and if so, sets it to zero.

$$massThatCanBeRemoved = max(\text{Salt Available For Removal}, 0) \tag{5-29}$$

If massThatCanBeRemoved is greater than Salt Mass Removal Request, the river can meet all of the salt mass request. The Salt Mass Removal is set to:

$$\text{Salt Mass Removal} = min(massThatCanBeRemoved, \text{Salt Mass Removal Request}) \tag{5-30}$$

5.1.4.3 Salt Mass Removal with Debt

This method allows you to specify a mass of salt you would like to remove. If it cannot remove all the salt, the debt is tracked and met at later timesteps. Two links are required between the Agg Diversion Site and Reach. The Salt Mass Removal slots on both objects should be linked to each other, and the Salt Available For Removal slots should be linked.

Slots associated with this method:

☞ Salt Mass Removal

Type: Series Slot
Units: Mass
Description: The amount of salt that is removed from the linked reach
I/O: Output only
Links: Linked to the Salt Mass Removal on a reach.

☞ Salt Mass Removal Request

Type: Series Slot with Periodic Input
Units: Mass
Description: The mass of salt you would like to remove.
I/O: Required input
Links: Not linked

☞ Salt Available For Removal

Type: Series
Units: Mass
Description: The maximum salt mass that can be removed from the linked reach without dropping below the specified minimum salt concentration (if solving downstream) or exceeding the specified maximum salt concentration (if solving upstream). The value in this linked slot will be solved for by the linked reach.
I/O: Output only
Links: Linked to Salt Available For Removal on a reach

☞ Salt Debt

Type: Series Slot
Units: Mass
Description: The cumulative mass of salt that was intended to be removed but could not because it was not available.
I/O: Output only, initial value is an optional input or it is assumed to be zero
Links: Linkable

The method checks that both Salt Mass Removal and Salt Available For Removal are linked to a Reach. If they are not linked to a Reach, an error will be issued, and the run will be aborted.

Next, the method checks if Salt Available For Removal is less than zero and if so, sets it to zero.

$$massThatCanBeRemoved = max(\text{Salt Available For Removal}, 0) \tag{5-31}$$

If massThatCanBeRemoved is greater than Salt Mass Removal Request, the river can meet all of the salt mass request, and any excess can be used to meet the debt. The slots are set as follows:

$$\text{Salt Mass Removal} = min(massThatCanBeRemoved, \text{Salt Mass Removal Request} + SaltDebt[-1]) \tag{5-32}$$

$$SaltDebt = max(SaltDebt[-1] - (massThatCanBeRemoved - \text{Salt Mass Removal Request}), 0) \tag{5-33}$$

5.2 Dispatch Methods

Following is the available dispatch method for an Agg Diversion Site that uses the Lumped structure. No structure and sequential Agg Diversion Sites do not have dispatch methods.

5.2.1 Solve Lumped Salt Removal

If either the Salt Mass Removal method or the Salt Mass Removal with Debt method is selected in the **Salt Removal** category, then the following dispatch conditions apply:

REQUIRED KNOWN SLOTS:

- ☞ SALT AVAILABLE FOR REMOVAL,
- ☞ SALT MASS REMOVAL REQUEST

REQUIRED UNKNOWN SLOTS:

- ☞ SALT MASS REMOVAL

The dispatch method executes the selected method(s) in the **Return Flow Salt** category and **Salt Removal** category where the work is done and the unknown slots are set**.**

5.2.2 Solve Lumped Return Flow Salt

This dispatch method is available for Lumped Agg Diversion Sites

REQUIRED KNOWN SLOTS:

- ☞ DIVERSION SALT CONCENTRATION
- ☞ TOTAL DIVERSION
- ☞ TOTAL RETURN FLOW

REQUIRED UNKNOWN SLOTS:

- ☞ RETURN FLOW SALT MASS,
- ☞ RETURN FLOW SALT CONCENTRATION

METHOD DETAILS:

The Diversion Salt Mass is set by multiplying the Total Diversion volume by the Diversion Salt Concentration.

Then, the dispatch method executes the selected method(s) in the **Return Flow Salt** category and **Salt Removal** category where the work is done and the unknown slots are set**.**

Agg Reach Water Quality

6. Agg Reach

Agg Reaches have water quality methods to model salt by calculating the total salt mass of the inflow and outflow. The actual water quality work is done on the reach elements. Links are automatically created between reaches within the aggregate and to the aggregate.

6.1 Slots

Below is a description of each of the slots (on the aggregate) associated with Salinity.

☞ **INFLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the inflow to the Agg Reach
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ **INFLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the inflow to the Agg Reach
I/O: Output only
Links: Not Linkable

☞ **OUTFLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the outflow from the Agg Reach
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ **OUTFLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the outflow from the Agg Reach
I/O: Output Only
Links: Not Linkable

6.2 User Selectable Methods

Following are the user selectable methods on the agg reach.

6.2.1 Agg Reach Water Quality

Methods in this category specify how you wish to model water quality parameters.

6.2.1.1 None

This is the default, no-action method for this category. No slots are instantiated by this method. When this method is selected, all of the member elements are configured to also not model water quality. That is, the None method, described **HERE (Section 15.2.2.1)**, is selected on each reach.

6.2.1.2 Discretized Salt

The aggregate controls whether the member elements model salinity. Reach elements of the aggregate either model salt or doesn’t. But they all perform the same. Also, the Water Quality Routing category is made invisible on the reach.

6.2.1.3 Well Mixed Salt

The aggregate controls whether the member elements model salinity. Reach elements of the aggregate either model salt or doesn’t. But they all perform the same. Also, the Water Quality Routing category is made invisible on the reach.

6.2.2 WQ on Reach Elements

The **WQ on Reach Elements** category allows you to choose whether to model salinity on the member elements.

6.2.2.1 None

This is the default, no-action method for this category. No slots are instantiated by this method. When this method is selected, all of the member elements are configured to not model salt. That is, the None method, described **HERE (Section 15.2.2.1)**, is selected on each reach.

6.2.2.2 Salinity

When this method is selected, all of the member elements are configured to model salt. That is, the Salinity method, described **HERE (Section 15.2.2.9)**, is selected on each reach. Also, concentration links are created between the aggregate and the first and last element and between successive reach elements. For example Element1.Salt Concentration Outflow is linked to element2.Salt Concentration Inflow. These links are made automatically.

Note: The reach element must have No Routing selected, or an error will be issued.

6.2.2.3 Mass Balance Salinity

When this method is selected, all of the member elements are configured to model salt. That is, the Mass Balance Salinity method, described HERE (Section 15.2.2.19), is selected on each reach. Also, concentration links are created between the aggregate and the first and last element and between successive reach elements. For example Element1.Salt Concentration Outflow is linked to element2.Salt Concentration Inflow. These links are made automatically.

Note: The reach element must have noRouting selected, or an error will be issued.

6.3 Dispatch Methods

Following is the available dispatch method when the solution approach is Well Mixed Salt or Discretized Salt:

6.3.1 Solve Salt

This method computes the total inflow and outflow salt mass only. The salt concentrations should come from the linked element objects or from upstream/downstream objects (or via input or rules).

REQUIRED KNOWN SLOTS:

- ☞ INFLOW
- ☞ INFLOW SALT CONCENTRATION
- ☞ OUTFLOW
- ☞ OUTFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- ☞ NONE

METHOD DETAILS:

This method does the following:

$$InflowSaltMass = InflowSaltConcentration \times InflowVol \tag{6-1}$$

$$OutflowSaltMass = OutflowSaltConcentration \times OutflowVol \tag{6-2}$$

Bifurcation Water Quality

7. Bifurcation

The bifurcation has water quality methods simply to pass information upstream or downstream.

7.1 Slots

The following slots are instantiated based on the selected constituents Note that all of the slots on the bifurcation are dispatch slots.

7.1.1 Salinity Slots

☞ **INFLOW SALT CONCENTRATION**

Type: Multi Slot
Units: CONCENTRATION
Description: holds the values of inflow salinity for the bifurcation
Information: There should be one link/column per column in the Inflow slot (or an error is posted at run start). The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Input, output, propagated, or rules
Links: Can be linked to a salt concentration on any other object.

☞ **INFLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow salt mass for the bifurcation
I/O: Output only
Links: Should not be linked; link concentrations instead.

☞ **OUTFLOW1 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of Outflow1 salt mass for the bifurcation
I/O: Output only
Links: Can be linked to a salt concentration on any other object.

☞ Outflow1 Salt Mass
Type: Series Slot
Units: Mass
Description: holds the values of Outflow1 salt mass for the bifurcation
I/O: Output only
Links: Should not be linked; link concentrations instead.

☞ Outflow2 Salt Concentration
Type: Series Slot
Units: Concentration
Description: salinity of Outflow2 from the bifurcation
I/O: Output only
Links: Can be linked to a salt concentration on any other object.

☞ Outflow2 Salt Mass
Type: Series Slot
Units: Mass
Description: salinity of Outflow2 from the bifurcation
I/O: Output only
Links: Should not be linked; link concentrations instead.

7.1.2 Temperature Slots

☞ Inflow Heat
Type: Series Slot
Units: Heat
Description: holds the values of heat for the inflow
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Outflow1 Heat
Type: Series Slot
Units: Heat
Description: holds the values of Ouflow1 heat
I/O: Output only
Links: Linkable

☞ Outflow2 Heat
Type: Series Slot
Units: Heat
Description: holds the values of Ouflow2 heat
I/O: Output only
Links: Linkable

7.1.3 Dissolved Oxygen Slots

☞ **INFLOW DETRITUS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow detritus mass
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW DISSOLVED ORGANICS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow dissolved organics mass
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW AMMONIA MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow ammonia mass
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW DISSOLVED OXYGEN MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow dissolved oxygen mass
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **OUTFLOW1 DETRITUS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of Outflow1 detritus mass
I/O: Output only
Links: Linkable

☞ **OUTFLOW1 DISSOLVED ORGANICS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of Outflow1 dissolved organics mass
I/O: Output only
Links: Linkable

☞ Outflow1 Ammonia Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow1 ammonia mass
I/O: Output only
Links: Linkable

☞ Outflow1 Dissolved Oxygen Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow1 dissolved oxygen mass
I/O: Output only
Links: Linkable

☞ Outflow2 Detritus Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow2 detritus mass
I/O: Output only
Links: Linkable

☞ Outflow2 Dissolved Organics Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow2 dissolved organics mass
I/O: Output only
Links: Linkable

☞ Outflow2 Ammonia Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow2 ammonia mass
I/O: Output only
Links: Linkable

☞ Outflow2 Dissolved Oxygen Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow2 dissolved oxygen mass
I/O: Output only
Links: Linkable

7.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Bifurcation.

7.2.1 Bifurcation Water Quality

Methods in this category are used to select the constituent and approach.

7.2.1.1 None

No water quality solution is performed. No slots are added.

7.2.1.2 Propagate Salt

All of the salt slots are added and the **Solve Salt** dispatch method is made available.

7.2.1.3 Propagate Temperature

All of the temperature slots are added and the **Solve Temp** dispatch method is made available.

7.2.1.4 Propagate Temp and Salt

All of the temperature and salt slots are added. This method makes the Solve Temp and Salt dispatch method available.

7.2.1.5 Propagate Temp and DO

All of the temperature and DO slots are added. This method makes the Solve Temp and DO dispatch method available.

7.2.1.6 Propagate Temp Salt and DO

All of the temperature, salt and DO slots are added. This method makes the Solve Temp Salt and DO dispatch method available.

7.3 Dispatch Methods

Following are the dispatch methods.

7.3.1 Solve Temp

This dispatch method is available for the Propagate Temperature method

Required Known slots:

- ☞ Inflow
- ☞ Inflow Heat
- ☞ Outflow1
- ☞ Outflow2

Required Unknown slots:

- ☞ Outflow1 Heat
- ☞ Outflow2 Heat

Method Details:

This method simply distributes heat associated with Inflow to the two outflows. If Inflow is 0, the two outflow heats are zero. Otherwise:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \tag{7-1}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \tag{7-2}$$

7.3.2 Solve Salt

This dispatch method is available for the Propagate Salt method.

Required Known slots:

- ☞ Inflow
- ☞ Inflow Salt Concentration
- ☞ Outflow1
- ☞ Outflow2

Required Unknown slots:

- ☞ Outflow1 Salt Concentration
- ☞ Outflow2 Salt Concentration

Method Details:

This method simply distributes salt associated with Inflow to the two outflows. If Inflow is 0, the two outflow salt masses are zero. Otherwise:

$$Outflow1SaltMass = \frac{Outflow1}{inflow} \times InflowSaltMass \tag{7-3}$$

$$Outflow2SaltMass = \frac{Outflow2}{inflow} \times InflowSaltMass \tag{7-4}$$

Outflow 1 and Outflow 2 Salt Concentrations are set to Inflow Salt Concentration (unless the flow is 0, then the concentration is 0 as well).

7.3.3 Solve Temp and Salt

This dispatch method is available for the Propagate Temp and Salt method.

Required Known slots:

- ☞ Inflow
- ☞ Outflow1

- Inflow Heat
- Inflow Salt Concentration
- Outflow2

Required Unknown slots:

- Outflow1 Heat
- Outflow1 Salt Concentration
- Outflow2 Heat
- Outflow2 Salt Concentration

Method Details:

This method simply distributes heat and salt associated with Inflow to the two outflows. If Inflow is 0, the two outflow heats and salt masses are zero. Otherwise:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \tag{7-5}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \tag{7-6}$$

$$Outflow1SaltMass = \frac{Outflow1}{inflow} \times InflowSaltMass \tag{7-7}$$

$$Outflow2SaltMass = \frac{Outflow2}{inflow} \times InflowSaltMass \tag{7-8}$$

Outflow 1 and Outflow 2 Salt Concentrations are set to Inflow Salt Concentration (unless the flow is 0, then the concentration is 0 as well).

7.3.4 Solve Temp and DO

This dispatch method is available for the Propagate Temp and DO method

Required Known slots:

- Inflow
- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Oxygen Mass
- Inflow Heat
- Outflow1
- Outflow2

Required Unknown slots:

- Outflow1 Detritus Mass
- Outflow1 Heat
- Outflow1 Ammonia Mass
- Outflow1 Dissolved Organics Mass
- Outflow1 Dissolved Oxygen Mass
- Outflow2 Detritus Mass
- Outflow2 Heat
- Outflow2 Ammonia Mass
- Outflow2 Dissolved Organics Mass
- Outflow2 Dissolved Oxygen Mass

Method Details:

This method simply distributes heat and DO masses associated with Inflow to the two outflows. If Inflow is 0, the two outflow heats and DO masses are zero. Otherwise:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \tag{7-9}$$

$$Outflow1DetritusMass = \frac{Outflow1}{inflow} \times InflowDetritusMass \tag{7-10}$$

$$Outflow1DissolvedOrganicsMass = \frac{Outflow1}{inflow} \times InflowDissolvedOrganics \tag{7-11}$$

$$Outflow1AmmoniaMass = \frac{Outflow1}{inflow} \times InflowAmmonia \tag{7-12}$$

$$Outflow1DissolvedOxygenMass = \frac{Outflow1}{inflow} \times InflowDissolvedOxygen \tag{7-13}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \tag{7-14}$$

$$Outflow2DetritusMass = \frac{Outflow2}{inflow} \times InflowDetritusMass \tag{7-15}$$

$$Outflow2DissolvedOrganicsMass = \frac{Outflow2}{inflow} \times InflowDissolvedOrganics \tag{7-16}$$

$$Outflow2AmmoniaMass = \frac{Outflow2}{inflow} \times InflowAmmonia \tag{7-17}$$

$$Outflow2DissolvedOxygenMass = \frac{Outflow2}{inflow} \times InflowDissolvedOxygen \tag{7-18}$$

7.3.5 Solve Temp Salt and DO

This dispatch method is available for the Propagate Temp Salt and DO method

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW AMMONIA MASS**
- ☞ **INFLOW DISSOLVED OXYGEN MASS**
- ☞ **INFLOW DETRITUS MASS**
- ☞ **INFLOW DISSOLVED ORGANICS MASS**
- ☞ **INFLOW HEAT**
- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW1**
- ☞ **OUTFLOW2**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW1 AMMONIA MASS**
- ☞ **OUTFLOW1 DETRITUS MASS**
- ☞ **OUTFLOW1 DISSOLVED ORGANICS MASS**
- ☞ **OUTFLOW1 DISSOLVED OXYGEN MASS**
- ☞ **OUTFLOW1 HEAT**
- ☞ **OUTFLOW1 SALT CONCENTRATION**
- ☞ **OUTFLOW2 AMMONIA MASS**
- ☞ **OUTFLOW2 DETRITUS MASS**
- ☞ **OUTFLOW2 DISSOLVED ORGANICS MASS**
- ☞ **OUTFLOW2 DISSOLVED OXYGEN MASS**
- ☞ **OUTFLOW2 HEAT**
- ☞ **OUTFLOW2 SALT CONCENTRATION**

Method Details:

This method simply distributes heat, salt, and DO masses associated with Inflow to the two outflows. If Inflow is 0, the two outflow heats, salt mass, and DO masses are zero. Otherwise:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \tag{7-19}$$

$$Outflow1SaltMass = \frac{Outflow1}{inflow} \times InflowSaltMass \tag{7-20}$$

$$Outflow1DetritusMass = \frac{Outflow1}{inflow} \times InflowDetritusMass \tag{7-21}$$

$$Outflow1DissolvedOrganicsMass = \frac{Outflow1}{inflow} \times InflowDissolvedOrganics \tag{7-22}$$

$$Outflow1AmmoniaMass = \frac{Outflow1}{inflow} \times InflowAmmonia \tag{7-23}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \tag{7-24}$$

$$Outflow2SaltMass = \frac{Outflow2}{inflow} \times InflowSaltMass \tag{7-25}$$

$$Outflow1DissolvedOxygenMass = \frac{Outflow1}{inflow} \times InflowDissolvedOxygen \tag{7-26}$$

$$Outflow2DetritusMass = \frac{Outflow2}{inflow} \times InflowDetritusMass \tag{7-27}$$

$$Outflow2DissolvedOrganicsMass = \frac{Outflow2}{inflow} \times InflowDissolvedOrganics \tag{7-28}$$

$$Outflow2AmmoniaMass = \frac{Outflow2}{inflow} \times InflowAmmonia \tag{7-29}$$

$$Outflow2DissolvedOxygenMass = \frac{Outflow2}{inflow} \times InflowDissolvedOxygen \tag{7-30}$$

Outflow 1 and Outflow 2 Salt Concentrations are set to Inflow Salt Concentration (unless the flow is 0, then the concentration is 0 as well).

Canal Water Quality

8. Canal

Currently, water quality values will be propagated through the Canal object.

The current method passes a concentration through the canal in the direction of water flow. In order to dispatch, the canal must have an flow concentration which has been passed through the link of an adjoining reservoir's Canal Flow constituent concentration.

8.1 Slots

Following is a list of slots associated with each constituent.

8.1.1 Salt Slots

☞ **FLOW 1 SALT CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Salt Concentration associated with Flow 1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 2 SALT CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

8.1.2 Temperature Slots

☞ **FLOW 1 TEMPERATURE**

Type: Series Slot
Units: TEMPERATURE
Description: Temperature of Flow 1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 2 TEMPERATURE**

Type: Series Slot
Units: TEMPERATURE
Description: Temperature of Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

8.1.3 Dissolved Oxygen Slots

☞ **FLOW 1 DETRITUS CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Detritus concentration associated with Flow1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 1 DISSOLVED ORGANICS CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Dissolved organics concentration associated with Flow1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 1 AMMONIA CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Ammonia concentration associated with Flow1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 1 DISSOLVED OXYGEN CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Dissolved oxygen concentration associated with Flow1
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **FLOW 2 DETRITUS CONC**

Type: Series Slot
Units: CONCENTRATION
Description: Detritus concentration associated with Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **Flow 2 Dissolved Organics Conc**

Type: Series Slot
Units: CONCENTRATION
Description: Dissolved organics concentration associated with Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **Flow 2 Ammonia Conc**

Type: Series Slot
Units: CONCENTRATION
Description: Ammonia concentration associated with Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

☞ **Flow 2 Dissolved Oxygen Conc**

Type: Series Slot
Units: CONCENTRATION
Description: Dissolved oxygen concentration associated with Flow 2
I/O: Input, set by a rule, propagated, or solved for by dispatch method
Links: Linkable

8.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Canal.

8.2.1 Canal Water Quality

Methods in this category are used to select the constituent and approach.

8.2.1.1 None

No water quality solution is performed. No slots are added.

8.2.1.2 Propagate Temperature

All of the temperature slots are added and the **solveTempModelFlow2** and **solveTempModelFlow1** dispatch methods are made available.

8.2.1.3 Propagate Temp and Salt

All of the temperature and salt slots are added. This method makes the **solveTempandSaltModelFlow2** and **solveTempandSaltModelFlow1** dispatch methods available.

8.2.1.4 Propagate Temp and DO

All of the temperature and DO slots are added. This method makes the **solveTempandDOModelFlow2** and **solveTempandDOModelFlow2** dispatch methods available.

8.2.1.5 Propagate Temp Salt and DO

All of the temperature, salt and DO slots are added. This method makes the **solveTempandSaltModelFlow1** and **solveTempandSaltModelFlow2** dispatch methods available.

8.3 Dispatch Methods

Following are the dispatch methods available (depending on constituent).

8.3.1 solveTempModelFlow2

This dispatch method is available for the **Propagate Temperature** method.

REQUIRED KNOWNS

☞ **FLOW 1 TEMPERATURE**

REQUIRED UNKNOWNS

☞ **FLOW 2 TEMPERATURE**

METHOD DETAILS:

This method does the following:

$$Flow2Temperature = Flow1Temperature \tag{8-1}$$

8.3.2 solveTempModelFlow1

This dispatch method is available for the **Propagate Temperature** method.

REQUIRED KNOWNS

☞ **FLOW 2 TEMPERATURE**

REQUIRED UNKNOWNS

☞ **FLOW 1 TEMPERATURE**

METHOD DETAILS:

This method does the following:

$$Flow1Temperature = Flow2Temperature \tag{8-2}$$

8.3.3 solveTempandSaltModelFlow2

This dispatch method is available for the **Propagate Temp and Salt** method.

REQUIRED KNOWNS

- FLOW 1 SALT CONC
- FLOW 1 TEMPERATURE

REQUIRED UNKNOWNS

- FLOW 2 SALT CONC
- FLOW 2 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow2Temperature = Flow1Temperature \tag{8-3}$$

$$Flow2SaltConc = Flow1SaltConc \tag{8-4}$$

8.3.4 solveTempandSaltModelFlow1

This dispatch method is available for the **Propagate Temp and Salt** method.

REQUIRED KNOWNS

- FLOW 2 SALT CONC
- FLOW 2 TEMPERATURE

REQUIRED UNKNOWNS

- FLOW 1 SALT CONC
- FLOW 1 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow1Temperature = Flow2Temperature \tag{8-5}$$

$$Flow1SaltConc = Flow2SaltConc \tag{8-6}$$

8.3.5 solveTempandDOModelFlow2

This dispatch method is available for the **Propagate Temp and DO** method.

REQUIRED KNOWNS

- FLOW 1 AMMONIA CONC
- FLOW 1 DETRITUS CONC
- FLOW 1 DISSOLVED ORGANICS CONC
- FLOW 1 DISSOLVED OXYGEN CONC
- FLOW 1 TEMPERATURE

REQUIRED UNKNOWNS

- FLOW 2 AMMONIA CONC
- FLOW 2 DETRITUS CONC
- FLOW 2 DISSOLVED ORGANICS CONC
- FLOW 2 DISSOLVED OXYGEN CONC
- FLOW 2 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow2Temperature = Flow1Temperature \tag{8-7}$$

$$Flow2DetritusMass = Flow1DetritusMass \quad (8\text{-}8)$$

$$Flow2AmmoniaMass = Flow1AmmoniaMass \quad (8\text{-}9)$$

$$Flow2DissolvedOrganicsMass = Flow1DissolvedOrganicsMass \quad (8\text{-}10)$$

$$Flow2DissolvedOxygenMass = Flow1DissolvedOxygenMass \quad (8\text{-}11)$$

8.3.6 solveTempandDOModelFlow1

This dispatch method is available for the **Propagate Temp and DO** method.

REQUIRED KNOWNS

- ☞ FLOW 2 AMMONIA CONC
- ☞ FLOW 2 DETRITUS CONC
- ☞ FLOW 2 DISSOLVED ORGANICS CONC
- ☞ FLOW 2 DISSOLVED OXYGEN CONC
- ☞ FLOW 2 TEMPERATURE

REQUIRED UNKNOWNS

- ☞ FLOW 1 AMMONIA CONC
- ☞ FLOW 1 DETRITUS CONC
- ☞ FLOW 1 DISSOLVED ORGANICS CONC
- ☞ FLOW 1 DISSOLVED OXYGEN CONC
- ☞ FLOW 1 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow1Temperature = Flow2Temperature \quad (8\text{-}12)$$

$$Flow1DetritusMass = Flow2DetritusMass \quad (8\text{-}13)$$

$$Flow1AmmoniaMass = Flow2AmmoniaMass \quad (8\text{-}14)$$

$$Flow1DissolvedOrganicsMass = Flow2DissolvedOrganicsMass \quad (8\text{-}15)$$

$$Flow1DissolvedOxygenMass = Flow2DissolvedOxygenMass \quad (8\text{-}16)$$

8.3.7 solveTempSaltandDOModelFlow2

This dispatch method is available for the **Propagate Temp Salt and DO** method.

REQUIRED KNOWNS

- ☞ FLOW 1 AMMONIA CONC
- ☞ FLOW 1 DETRITUS CONC
- ☞ FLOW 1 DISSOLVED ORGANICS CONC
- ☞ FLOW 1 DISSOLVED OXYGEN CONC
- ☞ FLOW 1 SALT CONC
- ☞ FLOW 1 TEMPERATURE

REQUIRED UNKNOWNS

- ☞ FLOW 2 AMMONIA CONC
- ☞ FLOW 2 DETRITUS CONC
- ☞ FLOW 2 DISSOLVED ORGANICS CONC
- ☞ FLOW 2 DISSOLVED OXYGEN CONC
- ☞ FLOW 2 SALT CONC
- ☞ FLOW 2 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow2Temperature = Flow1Temperature \tag{8-17}$$

$$Flow2SaltConc = Flow1SaltConc \tag{8-18}$$

$$Flow2DetritusMass = Flow1DetritusMass \tag{8-19}$$

$$Flow2AmmoniaMass = Flow1AmmoniaMass \tag{8-20}$$

$$Flow2DissolvedOrganicsMass = Flow1DissolvedOrganicsMass \tag{8-21}$$

$$Flow2DissolvedOxygenMass = Flow1DissolvedOxygenMass \tag{8-22}$$

8.3.8 solveTempSaltandDOModelFlow1

This dispatch method is available for the **Propagate Temp Salt and DO** method.

REQUIRED KNOWNS

- FLOW 2 AMMONIA CONC
- FLOW 2 DETRITUS CONC
- FLOW 2 DISSOLVED ORGANICS CONC
- FLOW 2 DISSOLVED OXYGEN CONC
- FLOW 2 SALT CONC
- FLOW 2 TEMPERATURE

REQUIRED UNKNOWNS

- FLOW 1 AMMONIA CONC
- FLOW 1 DETRITUS CONC
- FLOW 1 DISSOLVED ORGANICS CONC
- FLOW 1 DISSOLVED OXYGEN CONC
- FLOW 1 SALT CONC
- FLOW 1 TEMPERATURE

METHOD DETAILS:

This method does the following:

$$Flow1Temperature = Flow2Temperature \tag{8-23}$$

$$Flow1SaltConc = Flow2SaltConc \tag{8-24}$$

$$Flow1DetritusMass = Flow2DetritusMass \tag{8-25}$$

$$Flow1AmmoniaMass = Flow2AmmoniaMass \tag{8-26}$$

$$Flow1DissolvedOrganicsMass = Flow2DissolvedOrganicsMass \tag{8-27}$$

$$Flow1DissolvedOxygenMass = Flow2DissolvedOxygenMass \tag{8-28}$$

Confluence Water Quality

9. Confluence

The confluence has water quality methods simply for the purpose of passing constituent information upstream or downstream.

9.1 Slots

The following slots are instantiated based on the selected constituents Note that all of the slots on the confluence are dispatch slots.

9.1.1 Salinity Slots

☞ **INFLOW1 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of inflow salinity for the first inflow to the confluence
I/O: Input, output, rules or solved for in the dispatch method.
Links: Can be linked a salt concentration on any other object.

☞ **INFLOW2 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of inflow salinity for the second inflow to the confluence
I/O: Input, output, rules or solved for in the dispatch method.
Links: Can be linked a salt concentration on any other object.

☞ **OUTFLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: salinity of outflow from the confluence
I/O: Input, output, rules or solved for in the dispatch method.
Links: Can be linked a salt concentration on any other object.

☞ Inflow1 Salt Mass

Type: Series Slot
Units: Mass
Description: holds the values of salt mass for the first inflow to the confluence
I/O: Output
Links: Linkable, but you should probably link the concentration slot instead.

☞ Inflow2 Salt Mass

Type: Series Slot
Units: Mass
Description: holds the values salt mass for the second inflow to the confluence
I/O: Output
Links: Linkable, but you should probably link the concentration slot instead.

☞ Outflow Salt Mass

Type: Series Slot
Units: Mass
Description: outflow salt mass from the confluence
I/O: Output
Links: Linkable, but you should probably link the concentration slot instead.

9.1.2 Temperature Slots

☞ Inflow1 Heat

Type: Series Slot
Units: Heat
Description: holds the values of inflow heat for the first inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Inflow2 Heat

Type: Series Slot
Units: Heat
Description: holds the values of inflow heat for the second inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Outflow Heat

Type: Series Slot
Units: Heat
Description: outflow heat from the confluence
I/O: Output only
Links: Linkable

9.1.3 Dissolved Oxygen Slots

☞ **INFLOW1 DETRITUS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow detritus mass for the first inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW1 DISSOLVED ORGANICS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow dissolved organics mass for the first inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW1 AMMONIA MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow ammonia for the first inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW1 DISSOLVED OXYGEN MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow dissolved oxygen for the first inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ **INFLOW2 DETRITUS MASS**

Type: Series Slot
Units: MASS
Description: holds the values of inflow detritus mass for the second inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Inflow2 Dissolved Organics Mass

Type: Series Slot
Units: Mass
Description: holds the values of inflow dissolved organics mass for the second inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Inflow2 Ammonia Mass

Type: Series Slot
Units: Mass
Description: holds the values of inflow ammonia for the second inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Inflow2 Dissolved Oxygen Mass

Type: Series Slot
Units: Mass
Description: holds the values of inflow dissolved oxygen for the second inflow to the confluence
I/O: Required Known via input, rules, or propagated
Links: Linkable

☞ Outflow Detritus Mass

Type: Series Slot
Units: Mass
Description: outflow detritus mass from the confluence
I/O: Output only
Links: Linkable

☞ Outflow Dissolved Organics Mass

Type: Series Slot
Units: Mass
Description: outflow dissolved organics mass from the confluence
I/O: Output only
Links: Linkable

☞ Outflow Ammonia Mass

Type: Series Slot
Units: Mass
Description: outflow ammonia mass for the confluence
I/O: Output only
Links: Linkable

☞ **OUTFLOW DISSOLVED OXYGEN MASS**

Type: Series Slot
Units: MASS
Description: outflow dissolved oxygen from the confluence
I/O: Output only
Links: Linkable

9.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Confluence.

9.2.1 Confluence Water Quality

Methods in this category are used to select the constituent and approach.

9.2.1.1 None

No water quality solution is performed. No slots are added.

9.2.1.2 Solve Outflow Salt

All of the salt slots are added and the **Solve Salt Given In 1 and 2** dispatch method is made available.

9.2.1.3 Solve Outflow Temperature

All of the temperature slots are added and the **Solve Temperature** dispatch method is made available.

9.2.1.4 Solve Outflow Temp and Salt

All of the temperature and salt slots are added. This method makes the **Solve Temp and Salt** dispatch method available.

9.2.1.5 Solve Outflow Temp and DO

All of the temperature and DO slots are added. This method makes the **Solve Temp and DO** dispatch method available.

9.2.1.6 Solve Outflow Temp Salt and DO

All of the temperature, salt and DO slots are added. This method makes the **Solve Temp Salt and DO** dispatch method available.

9.2.1.7 Solve Outflow of Inflow Salt

This (well mixed) approach uses a simple weighted balance of concentration. This method adds all of the salinity slots. This method makes the **Solve Salt Given In 1 and 2, Solve Salt Given In 1 and Out,** and **Solve Salt Given In 2 and Out** dispatch methods available.

9.3 Dispatch Methods

Following are the dispatch methods.

9.3.1 Solve Temperature

This dispatch method is available for the Solve Outflow Temperature method.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW1**
- ☞ **INFLOW2**
- ☞ **INFLOW1 HEAT**
- ☞ **INFLOW2 HEAT**
- ☞ **OUTFLOW**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW HEAT**

Method Details:

This method simply adds heat associated with Inflow 1 and Inflow 2. It then sets the outflow heat equal to this sum. For example:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \tag{9-1}$$

9.3.2 Solve Salt Given In 1 and 2

This dispatch method is available for the Solve Outflow Salt method.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW1**
- ☞ **INFLOW1 SALT CONCENTRATION**
- ☞ **INFLOW2**
- ☞ **INFLOW2 SALT CONCENTRATION**
- ☞ **OUTFLOW**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW SALT CONCENTRATION**

METHOD DETAILS:

This method computes the Salt Mass for each Inflow (based on concentration and flow). Then the method simply adds the salt mass associated with Inflow 1 and Inflow 2. It then sets the salt mass equal to this sum. For example:

$$OutflowSaltMass = Inflow1SaltMass + Inflow2SaltMass \tag{9-2}$$

Outflow Salt Concentration is computed based on the Outflow Salt Mass and Outflow.

9.3.3 Solve Temp and Salt

This dispatch method is available for the Solve Outflow Temp and Salt.

Required Known slots:

- Inflow1
- Inflow1 Heat
- Inflow1 Salt Concentration
- Inflow2
- Inflow2 Heat
- Inflow2 Salt Concentration
- Outflow

Required Unknown slots:

- Outflow Heat
- Outflow Salt Concentration

Method Details:

This method computes the Salt Mass for each Inflow (based on concentration and flow). Then the method simply adds heat and salt mass associated with Inflow 1 and Inflow 2. It then sets the outflow heat and salt mass equal to this sum. For example:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \tag{9-3}$$

$$OutflowSaltMass = Inflow1SaltMass + Inflow2SaltMass \tag{9-4}$$

Outflow Salt Concentration is computed based on the Outflow Salt Mass and Outflow.

9.3.4 Solve Temp and DO

This dispatch method is available for the Solve Outflow Temp and DO.

Required Known slots:

- Inflow1
- Inflow1 Ammonia Mass
- Inflow1 Detritus Mass
- Inflow1 Dissolved Organics Mass
- Inflow1 Dissolved Oxygen Mass
- Inflow1 Heat
- Inflow2
- Inflow2 Ammonia Mass
- Inflow2 Detritus Mass
- Inflow2 Dissolved Organics Mass
- Inflow2 Dissolved Oxygen Mass
- Inflow2 Heat
- Outflow

Required Unknown slots:

- Outflow Ammonia Mass
- Outflow Detritus Mass
- Outflow Dissolved Organics Mass
- Outflow Dissolved Oxygen Mass
- Outflow Heat

Method Details:

This method simply adds heat and mass associated with Inflow 1 and Inflow 2. It then sets the outflow heat and mass equal to this sum. For example:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \tag{9-5}$$

$$OutflowDetritusMass = Inflow1DetritusMass + Inflow2DetritusMass \tag{9-6}$$

$$OutflowDissolvedOranicsMass = Inflow1DissolvedOranicsMass + Inflow2DissolvedOranicsMass \tag{9-7}$$

$$OutflowAmmoniaMass = Inflow1AmmoniaMass + Inflow2AmmoniaMass \tag{9-8}$$

$$OutflowDissolvedOxygenMass = Inflow1DissolvedOxygenMass + Inflow2DissolvedOxygenMass \tag{9-9}$$

9.3.5 Solve Temp Salt and DO

This dispatch method is available for the Solve Outflow Temp Salt and DO.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW1**
- ☞ **INFLOW1 AMMONIA MASS**
- ☞ **INFLOW1 DETRITUS MASS**
- ☞ **INFLOW1 DISSOLVED ORGANICS MASS**
- ☞ **INFLOW1 DISSOLVED OXYGEN MASS**
- ☞ **INFLOW1 HEAT**
- ☞ **INFLOW1 SALT CONCENTRATION**
- ☞ **INFLOW2**
- ☞ **INFLOW2 AMMONIA MASS**
- ☞ **INFLOW2 DETRITUS MASS**
- ☞ **INFLOW2 DISSOLVED ORGANICS MASS**
- ☞ **INFLOW2 DISSOLVED OXYGEN MASS**
- ☞ **INFLOW2 HEAT**
- ☞ **INFLOW2 SALT CONCENTRATION**
- ☞ **OUTFLOW**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW AMMONIA MASS**
- ☞ **OUTFLOW DETRITUS MASS,**
- ☞ **OUTFLOW DISSOLVED ORGANICS MASS**
- ☞ **OUTFLOW DISSOLVED OXYGEN MASS**
- ☞ **OUTFLOW HEAT**
- ☞ **OUTFLOW SALT CONCENTRATION**

METHOD DETAILS:

This method computes the Salt Mass for each Inflow (based on concentration and flow). Then, the method simply adds heat and mass associated with Inflow 1 and Inflow 2. It then sets the outflow heat and mass equal to this sum:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \tag{9-10}$$

$$OutflowSaltMass = Inflow1SaltMass + Inflow2SaltMass \tag{9-11}$$

$$OutflowDetritusMass = Inflow1DetritusMass + Inflow2DetritusMass \tag{9-12}$$

$$OutflowDissolvedOranicsMass = Inflow1DissolvedOranicsMass + Inflow2DissolvedOranicsMass \tag{9-13}$$

$$OutflowAmmoniaMass = Inflow1AmmoniaMass + Inflow2AmmoniaMass \tag{9-14}$$

$$OutflowDissolvedOxygenMass = Inflow1DissolvedOxygenMass + Inflow2DissolvedOxygenMass \tag{9-15}$$

Finally, Outflow Salt Concentration is computed based on the Outflow Salt Mass and Outflow.

9.3.6 Solve Salt Given In 1 and 2

This dispatch method is available for the Solve Outflow or Inflow Salt method.

REQUIRED KNOWN SLOTS:

- INFLOW1
- INFLOW1 SALT CONCENTRATION
- NFLOW2
- INFLOW2 SALT CONCENTRATION
- OUTFLOW

REQUIRED UNKNOWN SLOTS:

- OUTFLOW SALT CONCENTRATION

METHOD DETAILS:

This method simply takes a weighted average of the inflows, and their respective salt concentrations, and sets the outflow salt concentration accordingly.

$$outflowSaltConc = \frac{\left(\begin{array}{l} inflow1SaltConc \times Inflow1VOL \\ + inflow2SaltConc \times Inflow2VOL \end{array}\right)}{OutflowVOL} \tag{9-16}$$

If Outflow is zero, Outflow Salt Concentration is set to 0. Finally, Inflow1 Salt Mass, Inflow2 Salt Mass, and Outflow Salt Mass are set as the product of the concentration and the volume.

9.3.7 Solve Salt Given In 1 and Out

This dispatch method is available for the Solve Outflow or Inflow Salt method.

REQUIRED KNOWN SLOTS:

- INFLOW1
- INFLOW1 SALT CONCENTRATION
- INFLOW2
- OUTFLOW
- OUTFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- INFLOW2 SALT CONCENTRATION

METHOD DETAILS:

This method simply takes a weighted average of inflow1 and outflow salt concentrations, and sets the Inflow2 salt concentration accordingly.

$$inflow2SaltConc = \frac{\left(\begin{array}{l} outflowSaltConc \times outflowVOL \\ - inflow1SaltConc \times Inflow1VOL \end{array}\right)}{inflow2VOL} \tag{9-17}$$

If Inflow2 is zero, Inflow2 Salt Concentration is set to 0. Finally, Inflow1 Salt Mass, Inflow2 Salt Mass, and Outflow Salt Mass are set as the product of the concentration and the volume.

9.3.8 Solve Salt Given In 2 and Out

This dispatch method is available for the Solve Outflow or Inflow Salt method.

Required Known slots:

- ☞ **Inflow1**
- ☞ **Inflow2**
- ☞ **Inflow2 Salt Concentration**
- ☞ **Outflow**
- ☞ **Outflow Salt Concentration**

Required Unknown slots:

- ☞ **Inflow1 Salt Concentration**

Method Details:

This method simply takes a weighted average of the Inflow2 and Outflow salt concentrations, and sets the Inflow1 salt concentration accordingly.

$$inflow1SaltConc = \frac{\begin{pmatrix} outflowSaltConc \times outflowVOL \\ - inflow2SaltConc \times Inflow2VOL \end{pmatrix}}{inflow1VOL} \tag{9-18}$$

If Inflow1 is zero, Inflow1 Salt Concentration is set to 0. Finally, Inflow1 Salt Mass, Inflow2 Salt Mass, and Outflow Salt Mass are set as the product of the concentration and the volume.

Computational Subbasin WQ

10. Computational Subbasin

The Computational Subbasin has water quality methods for computing system wide summary information for Total Dissolved Gas methods

10.1 User Selectable Methods

10.1.1 Subbasin Total Dissolved Gas.

This category will only be available when water quality is enabled. In this category there will be two methods: **None** and **TDG Max Deltas**.

10.1.1.1 None

The **None** method is the no-action method and is not described further.

10.1.1.2 TDG Max Deltas

The **TDG Max Deltas** method computes maximum deltas through the subbasin and throughout the run.

SLOTS ASSOCIATED WITH THIS METHOD:

☞ **MAX DELTA TURBINE RELEASE**

Type: Scalar
Units: FLOW
Description: The maximum Delta Turbine Release throughout the basin and throughout the run.
I/O: Output Only
Links: Not Linkable

☞ **MAX DELTA SPILL**

Type: Scalar
Units: FLOW
Description: The maximum Delta Spill throughout the basin and throughout the run.
I/O: Output Only
Links: Not Linkable

This method is executed at the end of the run. The following computations are made:

$$\text{Max Delta Spill} = MAX(\forall\text{Reservoir in Subbasin}[\forall\text{Timestep in Run}[|\text{Delta Spill}|]]) \quad (10\text{-}1)$$

Conceptually, this equation says that the Max Delta Spill is the largest **absolute value** of Delta Spill on any reservoir in the subbasin at any timestep in the run.

Also:

$$\text{Max Delta Turbine Release} = MAX(\forall\text{Reservoir in Subbasin}[\forall\text{Timestep in Run}[\text{Delta Turbine Release}]]) \quad (10\text{-}2)$$

Similarly, this equation says that the Max Delta Turbine Release is the largest **absolute value** of Delta Turbine Release on any reservoir in the subbasin at any timestep in the run.

For more information on the Reservoir TDG computations, see HERE (Section 16.4.49).

Distribution Canal Water Quality

11. Distribution Canal

Distribution Canals have water quality methods to model salt by calculating the total salt mass of the inflow, diversion, return flow, and outflow. Routing methods (No Routing and Time Lag) are provided to route the salt through the canal.

The Water User can currently only model salt.

Note, there are no user selectable methods on the Distribution Canal. The water quality methods are specified on the aggregate and is performed identically on all member elements. Automatic links are created between the aggregate and elements.

11.1 Slots

Below is a description of each of the slots associated with salt.

☞ Inflow Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration associated with the inflow to the Distribution Canal
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ Inflow Salt Mass

Type: Series Slot
Units: Mass
Description: Salt mass associated with the inflow to the Distribution Canal
I/O: Output only
Links: Not Linkable

☞ Outflow Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration associated with the outflow from the Distribution Canal
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable

☞ Outflow Salt Mass

Type: Series Slot
Units: Mass
Description: Salt mass associated with the outflow from the Distribution Canal
I/O: Output Only
Links: Not Linkable

☞ Delivered Flow Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration associated with the delivered flow from the Distribution Canal
I/O: Typically output and set to the routed inflows salt concentration. But, it could be input or set by a rule.
Links: Linkable

☞ Delivered Flow Salt Mass

Type: Series Slot
Units: Mass
Description: Salt mass associated with the delivered flow from the Distribution Canal
I/O: Output Only
Links: Not Linkable

☞ Return Flow Salt Concentration

Type: Multi Slot
Units: Concentration
Description: Salt concentration associated with the return flow to the Distribution Canal
Information: When there are multiple links to this slot, the subslots will be shown. The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Typically propagated from the linked object. If not linked, it can be input, set by a rule or it will default to zero.
Links: Linkable

☞ **RETURN FLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the return flow to the Distribution Canal
Information: Output Only
I/O: Not Linkable

☞ **SEEPAGE SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration of the Seepage
I/O: Input, set by a rule, or propagated across a link.
Links: Linkable

☞ **SEEPAGE SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt Mass of the Seepage
I/O: Output only
Links: Not linkable

11.2 User Selectable Methods

There are no water quality user methods on the Distribution Canal.

Note: There is not a separate water quality routing method. The selected flow routing method is used to determine the water quality routing dispatch method.

11.3 Dispatch Methods

Following are the available dispatch method.

Note: If the Flow Routing method is Storage Time or Variable Storage Time, an error is issued as these are not supported.

11.3.1 Solve No Routing Salt

This method is available when the **Flow Routing** method is **No Routing**. This method computes the Outflow salt given the Inflow Salt Concentration.

REQUIRED KNOWN SLOTS:

- ☞ INFLOW
- ☞ OUTFLOW
- ☞ INFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- ☞ OUTFLOW SALT CONCENTRATION

METHOD DETAILS:

Inflow Salt Mass is set at the current timestep by multiplying the Inflow volume by the Inflow Salt Concentration.

If Delivered Flow Salt Concentration is not input or set by a rule, then it is set to the Inflow Salt Concentration.

When a non-default Seepage method is selected and the water quality approach is Propagate Salt (on the aggregate), Seepage Salt Concentration and Seepage Salt Mass slots are available. If Seepage is positive, the Seepage Salt Concentration is set to the Inflow Salt Concentration. If Seepage is negative, the Seepage Salt Concentration must be specified possibly by a link to a slot on another object. If Seepage Salt Concentration is linked but not valid, the reach exits the dispatch method and waits until the seepage Salt Concentration is available from that object. Seepage Salt Mass is computed from the Seepage Salt Concentration and the Seepage.

Note: Although there are Seepage Routing methods, these only serve to compute the Seepage at the current timestep. In general, Outflow = Inflow - Seepage. Thus, the Seepage Salt concentration does not need to be routed; it is just the value at that timestep.

Then, for each constituent, if the concentration and the flow is valid, the mass is computed. Otherwise the mass is considered zero, but not set.

Finally:

$$outflowSaltMass = InflowSaltMass - SeepageSaltMass - DeliveredFlowSaltMass + returnFlowSaltMass \tag{11-3}$$

Finally, Outflow Salt Concentration is computed from the Outflow and Outflow Salt Mass.

11.3.2 Solve TimeLag Salt

This method is available when the **Flow Routing** method is **Time Lag**.

This method computes the outflow salt at the current timestep based on inflow salt from previous timesteps and diversion and return flow salt at the current timestep. Lagging on this object is required to be an integer number of timesteps.

REQUIRED KNOWN SLOTS:

- ☞ INFLOW
- ☞ OUTFLOW
- ☞ INFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

☞ Outflow Salt Concentration

Method Details:

Inflow Salt Mass is set at the current timestep by multiplying the Inflow volume by the Inflow Salt Concentration.

Next, the inflow at the previous timesteps is checked. If either the Inflow(-Lag) or the Inflow Salt Concentration(-Lag) are not valid, the method is exited to wait until they become valid. If they are both valid, then the routedSaltMass is computed using the Inflow(-Lag) and Inflow Salt Concentration(-Lag).

If Diversion Salt Concentration is not input or set by a rule, Diversion Salt Concentration is set equal to the lagged Inflow Salt Concentration, i.e. Inflow Salt Concentration(-Lag)

Then, for each constituent, if the concentration and the flow is valid, the mass is computed. Otherwise the mass is considered zero, but not set.

Finally:

$$\begin{aligned} outflowSaltMass &= routedSaltMass - \\ &\quad DeliveredFlowSaltMass + returnFlowSaltMass \end{aligned} \tag{11-4}$$

Finally, Outflow Salt Concentration is computed from the Outflow and Outflow Salt Mass.

Note: No Seepage Salt is modeled for the Time Lag method.

Diversion Object Water Quality

12. Diversion Object

The Diversion Object has water quality methods simply to pass values from the source to the destination. There are no dispatch methods; water quality constituent values are transferred via links. You should link the constituent slot to slots on both the source and destination objects.

12.1 Slots

12.1.1 Salt Slots

☞ **SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable, typically to Diversion Salt Concentration on a reach or reservoir.

12.1.2 Temperature Slots

☞ **HEAT**

Type: Series Slot
Units: HEAT
Description: Heat associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

12.1.3 Dissolved Oxygen Slots

☞ **AMMONIA MASS**

Type: Series Slot
Units: MASS
Description: Ammonia mass associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Detritus Mass**

Type: Series Slot
Units: Mass
Description: Detritus mass associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Dissolved Organics Mass**

Type: Series Slot
Units: Mass
Description: Dissolved organics mass associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Dissolved Oxygen Mass**

Type: Series Slot
Units: Mass
Description: Dissolved oxygen mass associated with the flow diverted.
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

12.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Bifurcation.

12.2.1 Diversion Object Water Quality

Methods in this category are used to select the constituent and approach.

12.2.1.1 None

No water quality solution is performed. No slots are added.

12.2.1.2 Propagate Salt

All of the salt slots are added.

12.2.1.3 Propagate Temperature

All of the temperature slots are added.

12.2.1.4 Propagate Temp and Salt

All of the temperature and salt slots are added.

12.2.1.5 Propagate Temp and DO

All of the temperature and DO slots are added.

12.2.1.6 Propagate Temp Salt and DO

All of the temperature, salt and DO slots are added.

12.3 Dispatch Methods

There are no dispatch methods for the Diversion Object. This object propagates information via links.You should link the constituent slot to slots on both the source and destination objects.

Groundwater Water Quality

13. Groundwater

The groundwater object allows you to model **Salinity** with a layered approach (Layered Salt) when the groundwater object is using the **Head Based Groundwater Grid** method in the **Solution Type** category.

Following is a brief description of the groundwater solution equations when using a head based solution. Flows to/from the groundwater object are either input, provided across a link or computed. When computed based on head, the computation uses previous timestep information. Following is the mass balance equation for connected groundwater objects:

$$\begin{aligned}\text{Storage(t)} = {} & \text{Storage(t-1)} + \text{Flow Upstream} + \text{Flow Downstream} \\ & + \text{Flow Left} + \text{Flow Right} + \text{Inflow From Surface Water} \\ & - \text{ET Volume} - \text{Percolation} - \text{Pumped Flow} - \text{Evaporation}\end{aligned} \tag{13-1}$$

$$\text{Elevation (t)} = \text{Elevation (t-1)} + \frac{\text{Storage (t)} - \text{Storage (t-1)}}{\text{Specific Yield} \times \text{Aquifer Area}} \tag{13-2}$$

The figure HERE (Objects.pdf, Section 14.2.2) shows a diagram of the existing groundwater object including all of these mass balance components and typical links that are created.

13.1 Conceptual Overview of Salinity Modeling

The shallow groundwater is not always well mixed in terms of salinity. In some areas, the upper portion of the aquifer interacts quickly with the surface, but further down, the interaction is slower. This process can be modeled as two fully mixed layers within the groundwater object.

The current implementation of the ground water quality model allows you to model salinity with the Layered Salt method.

Figure 13-1 shows a diagram of the groundwater object with two layers in terms of flow and volume slots. Figure 13-2 shows the two layers in terms of salinity slots. All of the slots and links shown in the figure HERE (Objects.pdf, Section 14.2.2) are still there; the object just has additional slots and links for salinity modeling.

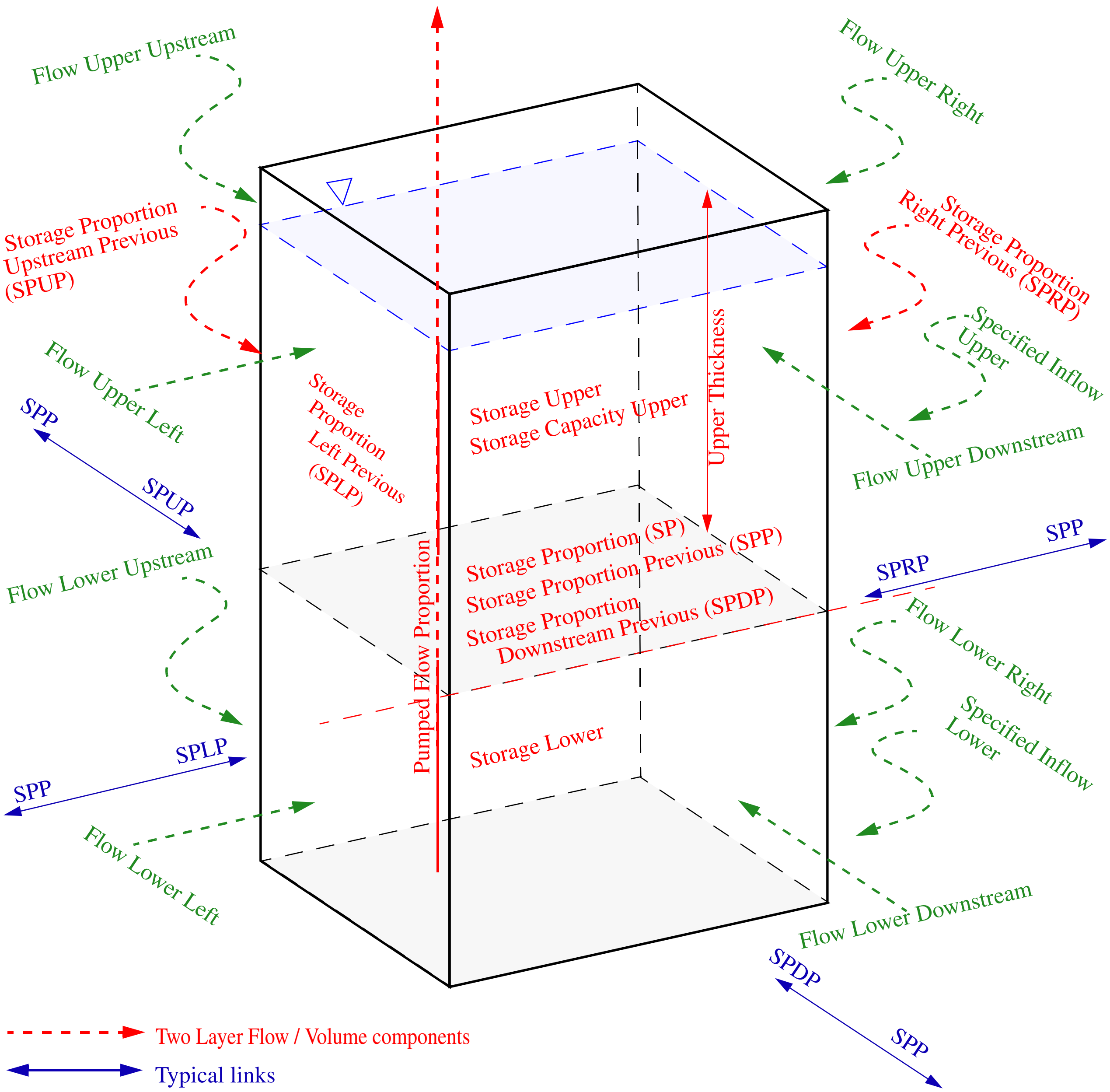


Figure 13-1: Diagram of the slots to model two layers in terms of flow and storage. All slots and links shown **HERE (Objects.pdf, p337)** are also on the two layer water quality groundwater object.

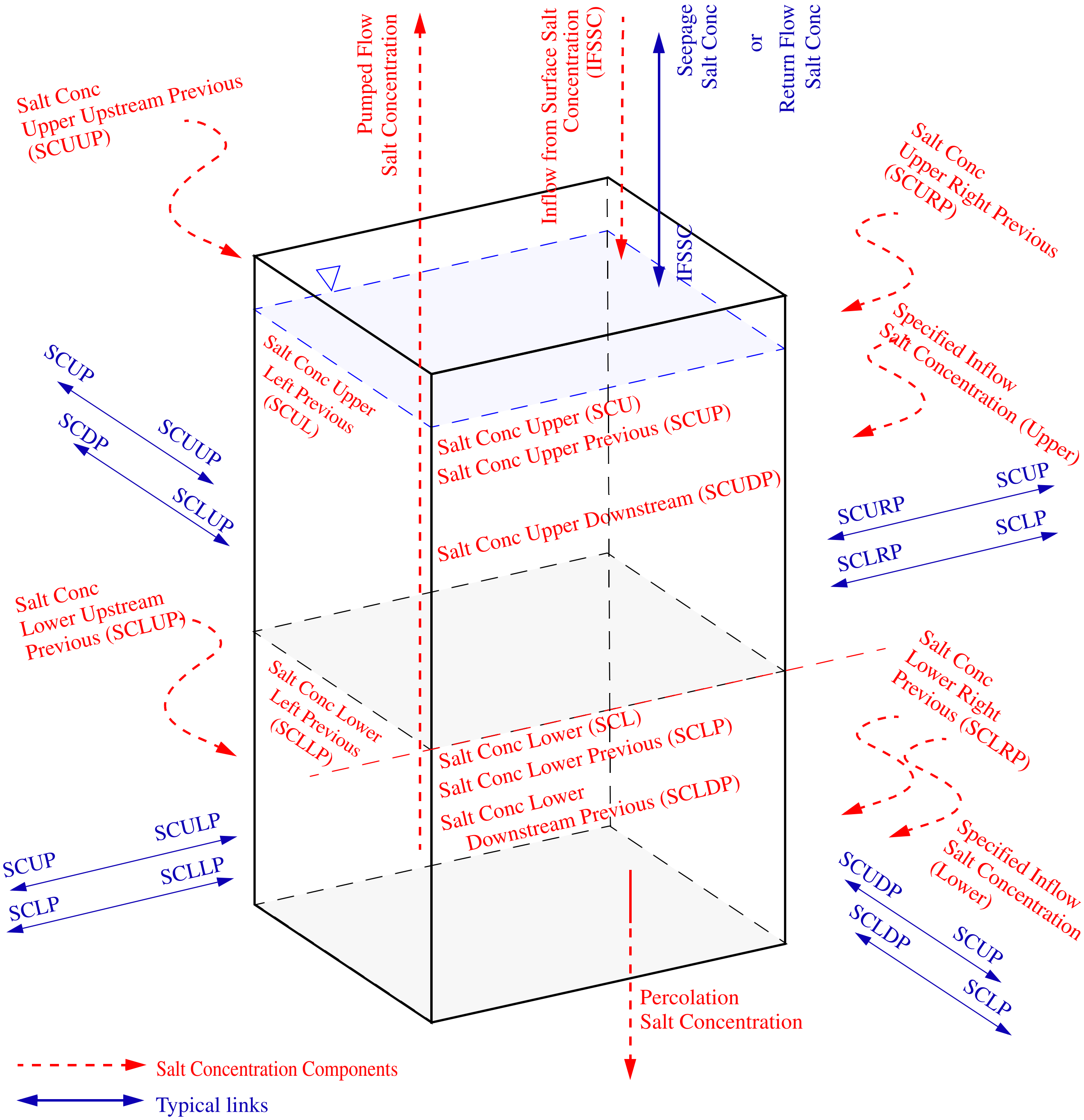


Figure 13-2: Diagram of the slots on the groundwater object to model salinity with two layers. All slots and links shown HERE (Objects.pdf, p337) and in Figure 13-1 still exist on the water quality groundwater object.

In this approach, the thickness of the upper layer is constant. Each mass balance component except Evaporation and Evapotranspiration have an equivalent Salt Concentration component. They are shown in red in Figure 13-1. On the groundwater object, the Flow Upstream/Downstream/Left/Right, Inflow From Surface Water, Pumped Flow and Percolation could be either negative or positive.When the flow is coming into the groundwater object, the salt concentration comes from the linked slot or be specified (input or rules). If the flow is out of the groundwater object, the concentration is computed by the groundwater object. When the groundwater object is defining the concentration, the previous values are used to avoid iteration problems.

Following are assumptions used in this computation:

- Inflow from Surface Water is added to (or removed from) the **upper** layer.
- Specified Inflow is added to either layer based on a user specified proportion.
- Evaporation is removed from the **upper** layer and no salt is removed.
- Evapotranspiration is removed from the **upper** layer and no salt is removed.
- Percolation is removed from (or added to) the **lower** layer.
- Pumped Flow is removed from (or added to) **either** layer as specified by the user.

Following is a conceptual overview of the computation to determine storage and salt concentration in each layer. This computation is described in detail **HERE (Section 13.3.2)**.

1. Determine the layer storages and the proportion based on the capacity of the upper layer.

2. Compute the lateral flow and salt flux from each layer based on the storage proportion on the given object or adjacent objects.

3. Compute pumped flow proportion and salt flux.

4. Compute inflow from surface water salt flux.

5. Compute specified inflow salt flux.

6. Compute percolation salt flux.

7. Compute the intermediate layer storage and concentration based on the computed incoming and outgoing components.

8. By comparing the intermediate and final storage and salt concentration, transfer water and salt between the two layers.

9. Compute the salt concentration of each layer.

10. Set salt mass slots if method is selected.

Note: This conceptual design is for two layers. It can be reduced to one layer by specifying a large Upper Thickness.

13.2 User Selectable Methods

Following are the user selectable methods on the Groundwater object that model water quality.

13.2.1 Groundwater Water Quality

This category is used to specify the constituents and approach for water quality modeling

13.2.1.1 None

No water quality is modeled and no slots are added.

13.2.1.2 Layered Salt

The following slots are added based on the selected method in the **Lateral Link Direction** category. These slots represent salt and flow in each linked direction for both the upper and lower layer.

13.2.1.2.1 Storage Slots

The following storage slots are added for all methods in the Lateral Link Direction category:

☞ **STORAGE UPPER**

Type: Series Slot
Units: VOLUME
Description: Storage in the upper layer.
Information:
I/O: Output only
Links: Not linkable

☞ **STORAGE LOWER**

Type: Series Slot
Units: VOLUME
Description: Storage in the lower layer.
Information:
I/O: Output only
Links: Not linkable

☞ **STORAGE CAPACITY UPPER**

Type: Scalar
Units: VOLUME
Description: The volume of water that can be stored in the upper layer when full
Information: This value is computed at beginning of run (read-only) as:

$$\text{Storage Capacity Upper} = UpperThickness \times AquiferArea \times SpecificYield$$

I/O: Output only
Links: Not Linkable

☞ Storage Proportion

Type: Series Slot
Units: No Units
Description: The proportion of the total storage that is in the upper layer
Information:

$$\text{Storage Proportion}(t) = \frac{\text{Storage Upper(t)}}{\text{Storage(t)}}$$

I/O: Output only
Links: Typically not linked.

☞ Storage Proportion Previous

Type: Series Slot
Units: No Units
Description: The proportion of the total storage that is in the upper layer
Information: The Storage Proportion of the previous timestep.
I/O: Output only
Links: Linkable to adjacent objects' Storage Proportion Upstream, Downstream, Left or Right Previous slot.

☞ Storage Proportion Upstream, Downstream, Left and/or Right Previous

Type: Series Slot
Units: No Units
Description: The proportion of storage in the upper layer on the adjacent objects
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only
Links: Linkable to adjacent objects' Storage Proportion Previous slot

☞ Upper Thickness

Type: Scalar
Units: Length
Description: The thickness of the upper layer
Information:
I/O: Required Input
Links: Not Linkable

13.2.1.2.2 Flow Slots

The following slots are added based on the Lateral Link Direction:

☞ **FLOW UPPER UPSTREAM, DOWNSTREAM, RIGHT, AND/OR LEFT**

Type: Series
Units: FLOW
Description: Lateral flow out of the object from the upper layer.
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only
Type: Not linkable

☞ **FLOW LOWER UPSTREAM, DOWNSTREAM RIGHT, AND/OR LEFT**

Type: Series
Units: FLOW
Description: Lateral flow out of the object from the lower layer.
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only
Links: Not linkable

13.2.1.2.3 Storage and Lateral Flow Salt Slots

Following are salt mass and concentration slots associated with storage in the upper and lower layers and lateral flows.

☞ **SALT CONC UPPER**

Type: Series
Units: CONCENTRATION
Description: Concentration of the well mixed upper layer
Information: Initial value is required
I/O: Output only
Links: Typically not linked

☞ **SALT CONC UPPER PREVIOUS**

Type: Series
Units: CONCENTRATION
Description: The Salt Conc of the upper layer at the previous timestep
Information:
I/O: Output only
Links: Linkable to adjacent objects' Salt Conc Upper Upstream, Downstream, Left and/or Right Previous

☞ Salt Conc Upper Upstream, Downstream, Left and/or Right Previous

Type: Series Slot
Units: CONCENTRATION
Description: The salt concentration in the upper layer on adjacent objects
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only
Links: Linkable to adjacent objects’ Salt Conc Upper Previous slot

☞ Salt Conc Lower

Type: Series
Units: CONCENTRATION
Description: Concentration of the well mixed Lower layer
Information: Initial value is required
I/O: Output only
Links: Typically not linked

☞ Salt Conc Lower Previous

Type: Series
Units: CONCENTRATION
Description: Concentration of the well mixed Lower layer at the previous timestep
Information:
I/O: Output only
Links: Linkable to adjacent objects’ Salt Conc Lower Upstream, Downstream, Left and/or Right Previous

☞ Salt Conc Lower Upstream, Downstream, Left and/or Right Previous

Type: Series Slot
Units: CONCENTRATION
Description: The salt concentration in the Lower layer on adjacent objects
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only
Links: Linkable to adjacent objects’ Salt Conc Lower Previous slot

13.2.1.2.4 Specified Inflow Slots

Following are salt slots associated with the Specified Inflow:

☞ **SPECIFIED INFLOW SALT CONCENTRATION**

Type: Series
Units: CONCENTRATION
Description: The salt concentration of the specified inflow slot.
I/O: Specified or output. If the Specified Inflow is negative or zero (out of the object), the salt concentration must be output. If the Specified Inflow is positive (into the object), then the salt concentration must be input or set by a rule.
Links: Not Linkable

☞ **SPECIFIED INFLOW SALT MASS**

Type: Agg Series
Units: MASS
Description: The salt mass associated with the specified inflow slot.
Information: There are three columns for: Total, Upper, and Lower salt mass into the object.
I/O: Output only
Links: Not Linkable

☞ **SPECIFIED INFLOW PROPORTION**

Type: Series Slot with Periodic Input
Units: NO UNITS
Description: The proportion of the Specified Inflow that enters the upper layer.
Information: This value must be specified.
I/O: Input or Rules
Links: Not Linkable

13.2.1.2.5 Inflow from Surface Water Slots

Following are salt slots associated with Inflow from Surface Water. Surface water always enters/leaves the upper layer.

☞ **INFLOW FROM SURFACE SALT CONCENTRATION**

Type: Multi
Units: CONCENTRATION
Description: This slot transfers the salt concentration to connected surface sources.
Information: There should be one link/column per column in the Inflow from Surface Water slot (or an error is posted at run start). The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Output typically
Links: Can be linked to salt concentration on surface objects

☞ Inflow From Surface Salt Mass

Type: Series
Units: Mass
Description: This slot tracks the total mass (through all surface water links) that is transferred into (+) or out (-) of the surface of the groundwater object.
Information:
I/O: Output only
Links: Not linkable

13.2.1.2.6 Percolation Slots

Percolation always enters/leaves the lower layer. Following are salt slots associated with Deep Percolation. They are automatically added when the **Head Based Percolation** method (**Deep Percolation** category) and **Layered Salt** is selected.

☞ Percolation Salt Concentration

Type: Series
Units: Concentration
Description: This slot transfers the salt concentration to the deep aquifer.
Information:
I/O: Output only
Links: Not linkable

☞ Percolation Salt Mass

Type: Series
Units: Mass
Description: This slot displays the salt flus to the deep aquifer.
Information:
I/O: Output only
Links: Not linkable

☞ Deep Aquifer Salt Conc

Type: Scalar
Units: Concentration
Description: This slot represents the deep aquifer salt concentration
Information: If Percolation Salt Concentration is not linked, this slot must have a value.
I/O: Required Input
Links: Not linkable

13.2.1.2.7 Pumped Flow Slots

Following are salt slots associated with pumped flow. They are automatically added when the **Input Pumped Flow** method (**Groundwater Pumping** category) and **Layered Salt** is selected. Pumped flow can come out of either or both layers.

☞ PUMPED FLOW PROPORTION

Type: Series
Units: NO UNITS
Description: The proportion of pumped flow that comes out of the upper layer:
Information:

$$\text{Pumped Flow Proportion}(t) = \frac{\text{Pumped Flow Upper(t)}}{\text{Pumped Flow(t)}}$$

I/O: Input, Rules, or Output
Links: Not linkable

☞ PUMPED FLOW SALT CONCENTRATION

Type: Multi Slot
Units: CONCENTRATION
Description: The well mixed salt concentration of the water coming out of both upper and lower layer
Information: When there are multiple links to this slot, the subslots will be shown. The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Output only
Links: Linkable to surface salt concentrations

☞ PUMPED FLOW SALT MASS

Type: Series
Units: CONCENTRATION
Description: The well mixed salt mass of the water coming out of both upper and lower layer
Information:
I/O: Output only
Links: Not linkable

13.2.2 Show Salt Mass and Flux Category

The category, **SHOW SALT MASS AND FLUX,** has methods that are used to show salt mass values when desired.

For each **Lateral Link Direction**, there are two methods available:

13.2.2.1 None

No salt mass slots are shown

13.2.2.2 Salt Mass Slots (No Linked Objects), Upstream, Downstrea, Right and Left Slots

Note: Method selection in this category is optional and does NOT affect the final salt concentrations. The purpose of these methods is for debugging and viewing salt mass values. Select a new method when you want to see mass values during debugging. Select the **None** method when you are finished. This saves some space in terms of model files size.

The following slots are added:

☞ **SALT MASS**

Type: Agg Series Slot
Units: MASS
Description: Salt Mass on this groundwater object. The Agg Series has four columns: Total salt mass, Upper layer salt mass, lower layer salt mass, and salt mass flux upper to lower layer.
Information:
I/O: Output only
Links: Not linkable

☞ **SALT MASS FLUX UPSTREAM, DOWNSTREAM, LEFT AND/OR RIGHT**

Type: Agg Series Slot
Units: MASS
Description: Salt mass flux out of this groundwater object in the direction specified. The Agg Series has three columns: Total flux, upper layer flux, and lower layer flux.
Information: These are actually 4 separate slots as specified by the selected method in the Lateral Link Direction category. There is a slot for each connected object.
I/O: Output only

13.3 Solution / Dispatching

Following is a description of the beginning of run and dispatching behavior when **Layered Salt** is selected.

13.3.1 Beginning of Water Quality Run

At the beginning of run, the scalar value for the Storage Capacity Upper is computed as:

$$\text{StorageCapacityUpper} = UpperThickness \times AquiferArea \times SpecificYield \tag{13-3}$$

On the initial timestep, the upper and lower storage, and proportion are computed as shown in Equations 13-4 - 13-9, below. Also, the Salt Conc Upper and Salt Conc Lower are checked for valid values on the initial timestep.

13.3.2 Dispatch Method - Solve 2 Layer Salt

The required knowns are:

Required Knowns

- Storage
- Inflow From Surface Water
- Elevation
- Elevation Previous Left/Right/Upstream/Downstream (depending on linked directions)
- Salt Conc Upper Previous
- Salt Conc Lower Previous

Required Unknowns

- Salt Conc Upper
- Salt Conc Lower

In addition, the method require any salt concentrations that are provided across links to be known or the dispatch method exits and waits for them to be known. When not provided across links, the previous values of many slots must be known.

At each water quality dispatch, the following computations are performed. Note, the object has already solved for flows, storages, and elevations so all mass balance values are known.

Determine Upper and Lower Storage: The storage in each layer is computed as follows:

```
If Storage(t) < Storage Capacity Upper
```

$$\text{Storage Upper(t)} = \text{Storage(t)} \tag{13-4}$$

$$\text{Storage Lower(t)} = 0 \tag{13-5}$$

```
Else
```

$$\text{Storage Upper(t)} = \text{Storage Capacity Upper} \tag{13-6}$$

$$\text{Storage Lower(t)} = \text{Storage(t)} - \text{Storage Capacity Upper} \tag{13-7}$$

Then the storage proportion is computed as:

$$\text{Storage Proportion}(t) = \frac{\text{Storage Upper(t)}}{\text{Storage(t)}} \tag{13-8}$$

The same value is set on the **Storage Proportion Previous** slot at the **next** timestep (note, the current timestep value was set during a previous timestep's solution). It is not the Storage Proportion at a previous timestep, but a separate slot called **Storage Proportion Previous**. This is done to enable the object to consider solving at the next timestep.

$$\text{Storage Proportion Previous}(t+1) = \text{Storage Proportion}(t) \tag{13-9}$$

Compute Lateral Upper and Lower Flow and Salt Flux: The flow in/out of each layer is proportional to the relative proportion of storage in each layer. Each side of the object is computed similarly, for example, the **right** side would be:

```
If Groundwater Flow Right(t) <= 0 (flow is out of this object, use this object's values)
```

$$\text{Flow Upper Right}(t) = \mathit{FlowRight}(t) \times \text{Storage Proportion Previous}(t) \tag{13-10}$$

$$\text{Salt Mass Flux Upper Right}(t) = \text{Flow Upper Right}(t) \times \text{Salt Conc Upper Previous}(t) \times \Delta t \tag{13-11}$$

$$\text{Flow Lower Right}(t) = \text{Flow Right(t)} - \text{Flow Upper Right}(t) \tag{13-12}$$

$$\text{Salt Mass Flux Lower Right}(t) = \text{Flow Lower Right}(t) \times \text{Salt Conc Lower Previous}(t) \times \Delta t \tag{13-13}$$

```
Else (Flow is into this object, use adjacent object's values)
```

$$\text{Flow Upper Right}(t) = \mathit{FlowRight}(t) \times \text{Storage Proportion Right Previous}(t) \tag{13-14}$$

$$\text{Salt Mass Flux Upper Right}(t) = \text{Flow Upper Right}(t) \times \text{Salt Conc Upper Right Previous}(t) \times \Delta t \tag{13-15}$$

$$\text{Flow Lower Right}(t) = \text{Flow Right(t)} - \text{Flow Upper Right}(t) \tag{13-16}$$

$$\text{Salt Mass Flux Lower Right}(t) = \text{Flow Lower Right}(t) \times \text{Salt Conc Lower Right Previous}(t) \times \Delta t \tag{13-17}$$

Repeat this for each direction: Left, Upstream, and Downstream.

Compute Upper and Lower Pumped Flow and Salt Flux: Next, compute the amount of pumped flow that is coming out of each layer.

If Pumped Flow Proportion is input or set by a rule, its value is used. Otherwise, the Pumped Flow Proportion is set to the Storage Proportion Previous value. Note, other methods could be developed to specify this proportion.

$$\text{Pumped Flow Upper}(t) = \text{Pumped Flow}(t) \times \text{Pumped Flow Proportion}(t) \tag{13-18}$$

$$\text{Pumped Flow Lower}(t) = \text{Pumped Flow}(t) - \text{Pumped Flow Upper}(t) \tag{13-19}$$

Compute the mass coming out of each layer:

$$\text{Pumped Flow Salt Mass Upper}(t) = \text{Pumped Flow Upper}(t) \times \text{Salt Conc Upper Previous} \times \Delta \tag{13-20}$$

$$\text{Pumped Flow Salt Mass Lower}(t) = \text{Pumped Flow Lower}(t) \times \text{Salt Conc Lower Previous} \times \Delta \tag{13-21}$$

Assuming the pumped flow is fully mixed, then the concentration can be computed as:

$$\text{Pumped Flow Salt Conc}(t) = \frac{\text{Pumped Flow Salt Mass Upper}(t) + \text{Pumped Flow Salt Mass Lower}(t)}{\text{Pumped Flow}(t) \times \Delta t} \tag{13-22}$$

This value is necessary to link to other objects.

Compute Upper and Lower Specified Inflows: Compute the amount of Specified Inflow flow that is entering each layer:

$$\text{Specified Inflow Upper}(t) = \text{Specified Inflow}(t) \times \text{Specified Inflow Proportion}(t) \tag{13-23}$$

$$\text{Specified Inflow Lower}(t) = \text{Specified Inflow}(t) - \text{Specified Inflow Upper}(t) \tag{13-24}$$

```
If the flow is into this object (Specified Inflow is positive), use the specified
Salt Concentration value:
```

$$\text{Specified Inflow Salt Mass Upper}(t) = \text{Specified Inflow Upper}(t) \times \text{Specified Inflow Salt Concentration} \times \Delta t \tag{13-25}$$

$$\text{Specified Inflow Salt Mass Lower}(t) = \text{Specified Inflow Lower}(t) \times \text{Specified Inflow Salt Concentration} \times \Delta t \tag{13-26}$$

```
Otherwise, flow is out of this object (negative or zero Specified Inflow) use the
previous timestep salt concentrations:
```

$$\text{Specified Inflow Salt Mass Upper}(t) = \text{Specified Inflow Upper}(t) \times \text{Salt Conc Upper Previous}(t) \times \Delta t \tag{13-27}$$

$$\text{Specified Inflow Salt Mass Lower}(t) = \text{Specified Inflow Lower}(t) \times \text{Salt Conc Lower Previous}(t) \times \Delta t \tag{13-28}$$

In this case, also set the Specified Inflow Salt Concentration to the weighted average of the upper/lower mass and flows.

Compute Inflow from Surface Water Salt Flux: Inflow from Surface Water enters or leaves the upper layer. Inflow from Surface Water is a multi-slot and each column can be either negative or positive. Thus, the following computation must be performed on each column, i, of the slot. There must be an associated linked salt concentration for each flow:

tempSaltMass = 0 (this is a local variable used to track the sum) **(13-29)**

```
For Each column, i, of the Inflow From Surface Water multi slot
```

If Inflow From Surface Water$_i$(t) <= 0 (flow is out of this object, use this object's upper layer)

$$\text{Salt Mass for This Column} = \text{Inflow From Surface Water}_i(t) \times \text{Salt Conc Upper Previous}(t) \times \Delta t \tag{13-30}$$

$$\text{Inflow from Surface Salt Conc}_i(t) = \text{Salt Conc Upper Previous}(t) \tag{13-31}$$

```
Else (Flow is into this object, use linked object's values)
```

$$\text{Salt Mass for This Column} = \text{Inflow From Surface Water}_i(t) \times \text{Inflow from Surface Salt Conc}_i(t) \times \Delta t \tag{13-32}$$

```
End IF
```

tempSaltMass = tempSaltMass + Salt Mass For This Column **(13-33)**

```
End FOR
```

Inflow From Surface Salt Mass (t) = tempSaltMass **(13-34)**

Compute Percolation Salt Flux: Deep percolation enters or leaves the lower layer.

```
If Percolation(t) > 0 (flow is out of this object, use this object's
lower layer)
```

$$\text{Percolation Salt Mass}(t) = \text{Percolation}(t) \times \text{Salt Conc Lower Previous}(t) \times \Delta t \quad (13\text{-}35)$$

$$\text{Percolation Salt Conc}(t) = \text{Salt Conc Lower Previous}(t) \quad (13\text{-}36)$$

```
Else (Flow is into this object, use specified concentrations.
   A value for deep aquifer salt conc must be given)
```

$$\text{Percolation Salt Mass}(t) = \text{Percolation}(t) \times \text{Deep Aquifer Salt Conc} \times \Delta t \quad (13\text{-}37)$$

```
End if
```

Compute Temporary Storage and Concentration: Although the final storage from the groundwater mass balance solution is known, it is not known how flows in and out of the upper and lower layer are included. A temporary storage and concentration is computed for each layer which are then used to compute the flux between layers. First, compute the upper layer intermediate storage and salt concentration:

$$\begin{aligned} \text{Storage Upper Intermediate(t)} = {} & \text{Storage Upper Previous(t)} \\ & + (\text{Flow Upper Right}(t) \\ & + \text{Flow Upper Left}(t) \\ & + \text{Flow Upper Downstream}(t) \\ & + \text{Flow Upper Upstream}(t) \\ & - \text{Pumped Flow Upper}(t) \\ & + \text{Inflow From Surface Flow(t)} \\ & + \text{Specified Inflow Upper(t)})\Delta t \\ & - \text{ET Volume}(t) \\ & - \text{Evaporation}(t) \end{aligned} \quad (13\text{-}38)$$

$$\begin{aligned} \text{Salt Conc Upper Intermediate(t)} = {} & [\text{Salt Concentration Upper Previous(t)} \times \text{Storage Upper Previous}(t) \\ & + \text{Salt Mass Flux Upper Right}(t) \\ & + \text{Salt Mass Flux Upper Left}(t) \\ & + \text{Salt Mass Flux Upper Downstream}(t) \\ & + \text{Salt Mass Flux Upper Upstream}(t) \\ & + \text{Inflow from Surface Salt Mass}(t) \\ & + \text{Specified Inflow Salt Mass Upper(t)} \\ & - \mathit{Pumped}\ \text{Flow Salt Mass Upper}(t)] / \text{Storage Upper Intermediate(t)} \end{aligned} \quad (13\text{-}39)$$

Then, compute the lower layer intermediate storage and salt concentration:

$$\begin{aligned}\text{Storage Lower Intermediate(t)} = \ & \text{StorageLower Previous(t)} \\ & + (\text{Flow Lower Right}(t) \\ & + \text{Flow Lower Left}(t) \\ & + \text{Flow Lower Downstream}(t) \\ & + \text{Flow Lower Upstream}(t) \\ & + \text{Specified Inflow Lower(t)} \\ & - \text{Pumped Flow Lower}(t) \\ & - \text{Percolation}(t))\Delta t\end{aligned} \tag{13-40}$$

$$\begin{aligned}\text{Salt Conc Lower Intermediate(t)} = \ & [\text{Salt Concentration Lower Previous(t)} \times \text{Storage Lower Previous}(t) \\ & + (\text{Salt Mass Flux Lower Right}(t) \\ & + \text{Salt Mass Flux Lower Left}(t) \\ & + \text{Salt Mass Flux Lower Downstream}(t) \\ & + \text{Salt Mass Flux Lower Upstream}(t) \\ & + \text{Specified Inflow Salt Mass Lower(t)} \\ & - Pumped\ \text{Flow Salt Mass Lower}(t) \\ & - \text{Percolation Salt Mass})(t)] / \text{Storage Lower Intermediate(t)}\end{aligned} \tag{13-41}$$

Transfer Water and Salt Up or Down and Compute Layer Concentration: Now that the intermediate storage and salt concentrations have been computed, the method computes how the water and salt transfers between the two layers to maintain a constant thickness of the upper layer. This computation uses the actual storage in each layer and the intermediate values computed above.

```
If Storage Upper Intermediate(t) >= Storage Upper(t)
   Transfer water from the upper to the lower layer
```

$$\text{Storage Transfer Upper to Lower(t)} = \text{Storage Upper Intermediate(t)} - \text{Storage Upper}(t) \tag{13-42}$$

$$\begin{aligned}\text{Salt Mass Flux Upper to Lower(t)} = \ & \text{Salt Conc Upper Intermediate(t)} \times \\ & \text{Storage Transfer Upper to Lower(t)}\end{aligned} \tag{13-43}$$

$$\text{Salt Conc Upper(t)} = \text{Salt Conc Upper Intermediate(t)} \tag{13-44}$$

$$\begin{aligned}\text{Salt Conc Lower(t)} = \ & [\text{Salt Conc Lower Intermediate(t)} \times \text{Storage Lower Intermediate(t)} \\ & + \text{Salt Mass Flux Upper to Lower(t)}] / \text{Storage Lower(t)}\end{aligned} \tag{13-45}$$

```
Else If Storage Upper Intermediate(t) < Storage Upper(t) and
           Storage Lower Intermediate(t) > 0
   If Storage Lower Intermediate(t) >=
    Storage Upper(t) - Storage Upper Intermediate(t)
```

$$\text{Storage Transfer Upper to Lower(t)} = -(\text{Storage Upper(t)} - \text{Storage Upper Intermediate}(t)) \tag{13-46}$$

```
   Else
```

$$\text{Storage Transfer Upper to Lower(t)} = -\text{Storage Lower Intermediate}(t) \tag{13-47}$$

```
   End If
```

$$\begin{aligned}\text{Salt Mass Flux Upper to Lower(t)} = \ & \text{Salt Conc Lower Intermediate(t)} \times \\ & \text{Storage Transfer Upper to Lower(t)}\end{aligned} \tag{13-48}$$

$$\text{Salt Conc Upper(t)} = [\text{Salt Conc Upper Intermediate(t)} \times \text{Storage Upper Intermediate(t)} \\ - \text{Salt Mass Flux Upper to Lower(t)}] / \text{Storage Upper(t)} \tag{13-49}$$

$$\text{Salt Conc Lower(t)} = \text{Salt Conc Lower Intermediate(t)} \tag{13-50}$$

```
End If
```

Finally, as preparation for the next timestep's dispatch, the previous salt concentrations are set at t plus one.

$$\text{Salt Conc Upper Previous}(t+1) = \text{Salt Conc Upper}(t) \tag{13-51}$$

$$\text{Salt Conc Lower Previous}(t+1) = \text{Salt Conc Lower}(t) \tag{13-52}$$

Set Salt Mass and Flux: If the None method is selected in the Show Salt Mass and Flux category, the dispatch method is complete.

Otherwise, when a **Show Salt Mass and Flux** method is selected, then the salt mass slots are set. There is one agg series slot for each **Lateral Link Direction**. Each agg series mass slot contains a column for the **Total**, **Upper**, and **Lower** layers. There is also one agg series slot for the object itself. In addition, to **Total**, **Upper**, and **Lower** columns for Salt Mass, it also shows the Salt Mass **Flux Upper to Lower**. Each column of these agg series slots is set to the appropriate value as computed above.

The Solve 2 Layer Salt dispatch method is complete.

Pipe Junction Water Quality

14. Pipe Junction

The Pipe Junction has water quality methods that pass salt information upstream or downstream by combining the salt mass and performing a flow weighted average for salt concentration.

14.1 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Pipe Junction.

14.1.1 Pipe Junction Water Quality

14.1.1.1 None

No water quality solution is performed. No slots are added.

14.1.1.2 Propagate Salt

All of the following salt slots are added and the **Solve Salt**... dispatch methods are made available.

☞ **FLOW 1 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of Flow 1 Salinity
Information:
I/O: Input, output, propagated, or rules
Links: Can be linked to a salt concentration on any other object.

☞ **FLOW 1 SALT MASS**

Type: Series Slot
Units: MASS
Description: holds the values of flow 1 salt mass
I/O: Output only
Links: Should not be linked; link concentrations instead.

☞ **FLOW 2 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of Flow 2 salt Conc
I/O: Input, output, propagated, or rules
Links: Can be linked to a salt concentration on any other object.

☞ **FLOW 2 SALT MASS**

Type: Series Slot
Units: MASS
Description: holds the values of Flow 2 salt mass
I/O: Output only
Links: Should not be linked; link concentrations instead.

☞ **FLOW 3 SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: salinity of Flow 3
I/O: Input, output, propagated, or rules
Links: Can be linked to a salt concentration on any other object.

☞ **FLOW 3 SALT MASS**

Type: Series Slot
Units: MASS
Description: salinity of Flow 3
I/O: Output only
Links: Should not be linked; link concentrations instead.

14.2 Dispatch Methods

14.2.1 Solve Salt Given 1 and 2

This dispatch method is available when **Propagate Salt** is selected:

REQUIRED KNOWN SLOTS:

☞ **FLOW 1**
☞ **FLOW 1 SALT CONCENTRATION**
☞ **NFLOW2**
☞ **FLOW 2 SALT CONCENTRATION**
☞ **FLOW 3**

REQUIRED UNKNOWN SLOTS:

☞ **FLOW 3 SALT CONCENTRATION**

METHOD DETAILS:

This method simply takes a weighted average of Flow 1 and Flow 2 salt concentrations, and sets the

Flow 3 Salt Concentration accordingly.

$$Flow3SaltConc = \frac{\begin{pmatrix} Flow1SaltConc \times Flow1VOL \\ + Flow2SaltConc \times Flow2VOL \end{pmatrix}}{Flow3VOL} \quad \text{(14-53)}$$

If Flow 3 is zero, Flow 3 Salt Concentration is set to 0.

Finally, Flow 1 Salt Mass, Flow 2 Salt Mass, and Flow 3 Salt Mass are set as the product of the concentration and the volume.

14.2.2 Solve Salt Given 1 and 3

This dispatch method is available when **Propagate Salt** is selected:

REQUIRED KNOWN SLOTS:

- ☞ **FLOW 1**
- ☞ **FLOW 1 SALT CONCENTRATION**
- ☞ **FLOW 2**
- ☞ **FLOW 3**
- ☞ **FLOW 3 SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

- ☞ **FLOW 2 SALT CONCENTRATION**

METHOD DETAILS:

This method simply takes a weighted average of Flow 1 and Flow 3 salt concentrations, and sets the Flow 2 salt concentration accordingly.

$$Flow2SaltConc = \frac{\begin{pmatrix} Flow3SaltConc \times Flow3VOL \\ - Flow1SaltConc \times Flow1VOL \end{pmatrix}}{Flow2VOL} \quad \text{(14-54)}$$

If Flow 2 is zero, Flow 2 Salt Concentration is set to 0.

Finally, Flow 1 Salt Mass, Flow 2 Salt Mass, and Flow 3 Salt Mass are set as the product of the concentration and the volume.

14.2.3 Solve Salt Given 2 and 3

This dispatch method is available when **Propagate Salt** is selected:

REQUIRED KNOWN SLOTS:

- ☞ **FLOW 1**
- ☞ **FLOW 2**
- ☞ **FLOW 2 SALT CONCENTRATION**
- ☞ **FLOW 3**
- ☞ **FLOW 3 SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

- ☞ **FLOW 1 SALT CONCENTRATION**

METHOD DETAILS:

This method simply takes a weighted average of the Flow 2 and Flow 3 salt concentrations, and sets the

Flow 1 salt concentration accordingly.

$$Flow1SaltConc = \frac{\begin{pmatrix} Flow3SaltConc \times Flow3VOL \\ - Flow2SaltConc \times Flow2VOL \end{pmatrix}}{Flow1VOL} \tag{14-55}$$

If Flow 1 is zero, Flow 1 Salt Concentration is set to 0.

Finally, Flow 1 Salt Mass, Flow 2 Salt Mass, and Flow 3 Salt Mass are set as the product of the concentration and the volume.

Reach Water Quality

15. Reach

The current implementation of the reach allows the user to model salinity with a simple well-mixed method or a discretized method. Temperature along with any combination of dissolved oxygen and salinity can also be modeled with the discretized methods.

On the reach, slots are added when a method from the **Water Quality Routing** category is selected (usually automatically based on the **Reach Water Quality** method); the available **Water Quality Routing** methods depend on the selected **Reach Water Quality** method and physical routing method. As a result, the documentation is organized by first listing all the slots, then the user selectable methods, beginning of run behavior, dispatch slots and finally dispatch methods. Each method specifies whether it is valid for the well mixed or discretized set of methods.

15.1 Slots

Following is a list of all of the water quality slots used by the Reach. The slots are instantiated by the selected method in the **Water Quality Routing** category. Each of those methods list the slots that are instantiated.

15.1.1 Temperature Slots

☞ **INFLOW HEAT**

Type: Multi Slot
Units: HEAT
Description: holds the values of inflow heat for each inflow to the reservoir
I/O: Required Known
Links: This slot can be linked to the Outflow Heat slot of an upstream object.

☞ **DIVERSION TEMPERATURE**

Type: Series Slot
Units: TEMPERATURE
Description: temperature of Diversion
I/O: Optional input
Links: If Diversion is not linked and is not valid, Diversion Temperature is set to zero. Otherwise, it is set to the previous epilimnion temperature during calculations.

☞ Return Flow Temperature

Type: Series Slot
Units: TEMPERATURE
Description: temperature of Return Flow.
I/O: Optional input
Links: If Return Flow is not linked and is not valid, Return Flow Temperature is set to zero.

☞ Local Inflow Temperature

Type: Series Slot
Units: TEMPERATURE
Description: temperature of Local Inflow.
I/O: Optional input
Links: If Local Inflow is not linked and is not valid, Local Inflow Temperature is set to zero.

☞ Maximum Flow Rate for WQ Stability

Type: Table Slot
Units: FLOW
Description: Input a flow rate which is greater then or equal to any anticipated for the simulation to keep the explicit solution stable. It should be noted that extremely large values will significantly increase computational cost.
I/O: Input only
Links: Not Linkable

☞ Outflow Heat

Type: Series Slot
Units: HEAT
Description: temperature of releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Heat slot of a downstream object.

☞ Dispersion Coefficient

Type: Table Slot
Units: NONE
Description: longitudinal dispersion coefficient in units of L^2/T
Information: used in temperature calculation
I/O: input only
Links: Not Linkable

☞ Specific Heat of Water

Type: Table Slot
Units: SpecificHeat
Description: specific heat of water. Used for heat / temperature conversions.
I/O: optional input
Links: Not Linkable

☞ Distributed Temperature Output

Type: Table Series Slot
Units: Various
Description: Table which displays the discretized values Water temperature with respect to distance within the Reach.
I/O: Output only - This is a temporary slot that is not saved in the model file.
Links: Not Linkable

☞ Distributed Total Surface Flux Output

Type: Table Series Slot
Units: Various
Description: Table which displays the discretized values of the main components of surface heat exchange as well as the total surface flux with respect to distance.
I/O: Output only - This is a temporary slot that is not saved in the model file.
Links: Not Linkable

☞ Air Temperature

Type: Series Slot
Units: Temperature
Description: air temperature at the reservoir surface
I/O: Input only
Links: Not Linkable

☞ Dewpoint Temperature

Type: Series Slot
Units: Temperature
Description: dewpoint temperature at the reservoir surface
I/O: Required input
Links: Not Linkable

☞ Incoming Solar Radiation

Type: Series Slot
Units: HeatFlux
Description: incoming solar radiation received by the reservoir
I/O: Required Input
Links: Not Linkable

☞ Wind Velocity

Type: Series Slot
Units: VELOCITY
Description: wind velocity at reservoir surface
Information: This slot is assumed to be zero if not a user input.
I/O: Optional input
Links: Not Linkable

☞ Distributed Temperature Output

Type: Table Series Slot
Units: VARIOUS
Description: Table which displays the discretized values Water temperature with respect to distance within the Reach.
I/O: Output only - This is a temporary slot that is not saved in the model file.
Links: Not Linkable

15.1.2 Salinity Slots

☞ Inflow Salt Mass

Type: Series Slot
Units: MASS
Description: holds the values of inflow salinity for each inflow to the reach
I/O: Required known
Links: Linkable, but the Inflow Salt Concentration should be linked instead.

☞ Outflow Salt Mass

Type: Series Slot
Units: MASS
Description: salt mass in outflow from the reservoir
I/O: Output only
Links: Linkable, but the Outflow Salt Concentration should be linked instead.

☞ Seepage Salt Concentration

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration of the Seepage
I/O: Input, set by a rule, or propagated across a link.
Links: Linkable

☞ Diversion Salt Concentration

Type: Series Slot
Units: CONCENTRATION
Description: salt concentration of Diversion.
I/O: Typically output
Links: If Diversion is not linked and is not valid, Diversion Salt Concentration is set to zero. Otherwise, it is set to the previous epilimnion salt concentration during calculations.

☞ Return Flow Salt Concentration

Type: Multi Slot
Units: CONCENTRATION
Description: salt concentration of Return Flow.
Information: When there are multiple links to this slot, the subslots will be shown. The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Input, rules, or propagated from another object
Links: If Return Flow is not linked and is not valid, Return Flow Salt Concentration is set to zero. For Well Mixed Salt, this slot should NOT be linked. Link Return Flow Salt Mass instead.

☞ Local Inflow Salt Concentration

Type: Series Slot
Units: CONCENTRATION
Description: salt concentration of Local Inflow.
I/O: Input, rules, solved for by dispatch method, or propagated from another object
Links: If Local Inflow is not linked and is not valid, Local Inflow Salt Concentration is set to zero.

☞ Distributed Salt Concentration Output

Type: Table Series Slot
Units: VARIOUS
Description: Table which displays the discretized values of Salt Concentration with respect to distance within the Reach.
I/O: Output only - This is a temporary slot that is not saved in the model file.
Links: Not Linkable

☞ Inflow Salt Concentration

Type: Series Slot
Units: CONCENTRATION
Description: holds the values of inflow salinity for inflow to the reach
I/O: Required known
Links: This slot can be linked to the Outflow Salt Concentration of an upstream object.

☞ Diversion Salt Concentration

Type: Series Slot
Units: Concentration
Description: salt concentration of Diversion.
I/O: Optional known
Links: If Diversion is not linked and is not valid, Diversion Salt Concentration is set to zero. Otherwise, it is set to the previous epilimnion salt concentration during calculations.

☞ Seepage Salt Mass

Type: Series Slot
Units: Mass
Description: Salt Mass of the Seepage
I/O: Output only
Links: Not linkable

☞ Return Flow Salt Mass

Type: Multi Slot
Units: Mass
Description: salt mass of Return Flow.
I/O: Optional known
Links: Yes, for Well Mixed Salt. If Return Flow is not linked and is not valid, Return Flow Salt Mass is set to zero. Do not link Return Flow Salt Mass if using the discretized methods, link the concentration instead.

☞ Diversion Salt Mass

Type: Series Slot
Units: Mass
Description: The salt mass value of the Diversion from the reach
I/O: Output only
Links: Not linkable

☞ Local Inflow Salt Mass

Type: Series Slot
Units: Mass
Description: The salt mass value of the Local Inflow
I/O: Output Only
Links: Not Linkable

☞ Outflow Salt Concentration

Type: Series Slot
Units: CONCENTRATION
Description: salinity of releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Salt Concentration of a downstream object.

☞ Salt Mass Removal

Type: Series Slot
Units: Mass
Description: The mass of salt removed from the reach, typically by a linked Agg Diversion Site. This is included into the reach's salinity mass balance. A positive Salt Mass Removal represents salt removed from (subtracted from) the Outflow Salt Mass.
I/O: Optional input, if not linked and not input, defaults to zero
Links: Can be linked to Salt Mass Removal on an Agg Diversion Site

☞ Salt Available For Removal

Type: Series Slot
Units: Mass
Description: The maximum salt mass that can be removed without dropping below the specified Minimum Salt Concentration (if solving downstream) or exceeding the specified Maximum Salt Concentration (if solving upstream). If this slot is not linked, it is not used.
I/O: Output only
Links: Can be linked to Salt Available For Removal on an Agg Diversion Site

☞ Salt Storage

Type: Series Slot
Units: Mass
Description: The mass of salt stored on the reach due to low flows
I/O: Initial timestep can be input, otherwise Output only.
Links: Not Linkable

☞ Maximum Salt Concentration

Type: Periodic Slot
Units: Concentration
Description: The maximum possible salt concentration; i.e. the concentration at saturation
I/O: Required Input
Links: Not Linkable

☞ Minimum Salt Concentration

Type: Periodic Slot
Units: Concentration
Description: The minimum possible salt concentration. There is no restriction on the value in this slot. It can be negative.
I/O: If the Salt Mass Removal slot is linked, this slot is required input. Otherwise it is an optional input.
Links: Not Linkable

15.1.3 Dissolved Oxygen Slots

☞ Inflow Dissolved Oxygen Mass

Type: Multi Slot
Units: Mass
Description: holds the values of inflow dissolved oxygen for each inflow to the reservoir
I/O: Input, rules, or propagated across a link
Links: This slot can be linked to the Outflow Dissolved Oxygen Mass slot of an upstream object.

☞ Inflow Detritus Mass

Type: Multi Slot
Units: Mass
Description: holds the values of inflow detritus for each inflow to the reservoir
I/O: Input, rules, or propagated across a link
Links: This slot can be linked to the Outflow Detritus Mass slot of an upstream object.

☞ Inflow Dissolved Organics Mass

Type: Multi Slot
Units: Mass
Description: holds the values of inflow dissolved oxygen for each inflow to the reservoir
I/O: Input, rules, or propagated across a link
Links: This slot can be linked to the Outflow Dissolved Organics Mass slot of an upstream object.

☞ Inflow Ammonia Mass

Type: Multi Slot
Units: Mass
Description: holds the values of inflow ammonia for each inflow to the reservoir
I/O: Input, rules, or propagated across a link
Links: This slot can be linked to the Outflow Ammonia Mass slot of an upstream object.

☞ Outflow Dissolved Oxygen Mass

Type: Series Slot
Units: Mass
Description: dissolved oxygen mass in Outflow from the reach
I/O: Output only
Links: This slot can be linked to the Inflow Dissolved Oxygen Mass slot of a downstream object.

☞ Outflow Detritus Mass

Type: Series Slot
Units: Mass
Description: detritus mass in Outflow from the reach
I/O: Output only
Links: This slot can be linked to the Inflow Detritus Mass slot of a downstream object.

☞ Outflow Dissolved Organics Mass

Type: Series Slot
Units: Mass
Description: dissolved oxygen mass in releases from the reach\
I/O: Output only
Links: This slot can be linked to the Inflow Dissolved Organics Mass slot of a downstream object.

☞ Outflow Ammonia Mass

Type: Series Slot
Units: Mass
Description: ammonia mass in the outflow from the reach
I/O: Output only
Links: This slot can be linked to the Inflow Ammonia Mass slot of a downstream object.

☞ Diversion Detritus Concentration

Type: Series Slot
Units: Concentration
Description: detritus concentration of Diversion.
Information:
I/O: Output only
Links: If Diversion is not linked and is not valid, Diversion Detritus Concentration is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Return Flow Detritus Concentration

Type: Series Slot
Units: CONCENTRATION
Description: detritus concentration of Return Flow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Return Flow is not linked and is not valid, Return Flow Detritus Concentration is set to zero.

☞ Local Inflow Detritus Concentration

Type: Series Slot
Units: CONCENTRATION
Description: detritus concentration of Local Inflow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Local Inflow is not linked and is not valid, Local Inflow Detritus Concentration is set to zero.

☞ Diversion Diss Org Concentration

Type: Series Slot
Units: CONCENTRATION
Description: dissolved organics concentration of Diversion.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Diversion is not linked and is not valid, Diversion Diss Org Concentration is set to zero. Otherwise, it is set to the previous epilimnion dissolved organics concentration during calculations.

☞ Return Flow Diss Org Conc

Type: Series Slot
Units: CONCENTRATION
Description: dissolved organics concentration of Return Flow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Return Flow is not linked and is not valid, Return Flow Diss Org Concentration is set to zero.

☞ Local Inflow Diss Org Concentration

Type: Series Slot
Units: CONCENTRATION
Description: dissolved organics concentration of Local Inflow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Local Inflow is not linked and is not valid, Local Inflow Diss Org Concentration is set to zero.

☞ Diversion Ammonia Concentration

Type: Series Slot
Units: Concentration
Description: detritus concentration of Diversion.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Diversion is not linked and is not valid, Diversion Ammonia Concentration is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Return Flow Ammonia Concentration

Type: Series Slot
Units: Concentration
Description: detritus concentration of Return Flow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Return Flow is not linked and is not valid, Return Flow Ammonia Concentration is set to zero.

☞ Local Inflow Ammonia Concentration

Type: Series Slot
Units: Concentration
Description: ammonia concentration of Local Inflow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Local Inflow is not linked and is not valid, Local Inflow Ammonia Concentration is set to zero.

☞ Diversion DO Concentration

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of Diversion.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Diversion is not linked and is not valid, Diversion DO Concentration is set to zero. Otherwise, it is set to the previous epilimnion dissolved oxygen concentration during calculations.

☞ Return Flow DO Concentration

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of Return Flow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Return Flow is not linked and is not valid, Return Flow DO Concentration is set to zero.

☞ Local Inflow DO Concentration

Type: Series Slot
Units: CONCENTRATION
Description: dissolved oxygen concentration of Local Inflow.
I/O: Input, rules, solved for, or propagated across a link.
Links: If Local Inflow is not linked and is not valid, Local Inflow DO Concentration is set to zero.

15.1.4 Total Dissolved Gas Slots

☞ Inflow TDG Concentration

Type: Series
Units: FRACTION
Description: TDG concentration of the Inflow
I/O: Input or output
Links: Linked to upstream TDG concentration slot

☞ Outflow TDG Concentration

Type: Series
Units: FRACTION
Description: TDG concentration of the Outflow
I/O: Output only
Links: Linked to downstream TDG concentration slot

☞ TDG Lag Time

Type: Scalar
Units: TIME
Description: The amount of time the TDG concentration should be lagged from the Inflow to the Outflow
I/O: Required Input
Links: Not Linkable

☞ Delta Inflow

Type: Series
Units: FLOW
Description: This slot represents the optimization variable for Delta Inflow
Links: Linkable

☞ Delta Outflow

Type: Series
Units: FLOW
Description: This slot represents the optimization variable for Delta Outflow.
Links: Linkable

DELTA INFLOW TDG CONCENTRATION

Type: Series
Units: FRACTION
Description: This slot represents the optimization variable for Delta Inflow TDG Concentration.
Links: Linkable

DELTA OUTFLOW TDG CONCENTRATION

Type: Series
Units: FRACTION
Description: This slot represents the optimization variable for Delta Inflow TDG Concentration.
Links: Linkable

15.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the reach. These methods are necessary to choose the constituents and whether it is discretized or well mixed.

15.2.1 Reach Water Quality

Methods in this category are used to select the constituent and approach.

15.2.1.1 None

No water quality solution is performed. No slots are added.

15.2.1.2 Discretized Salt

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.3 Discretized Temperature

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.4 Discretized Temp and Salt

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.5 Discretized Temp and DO

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.6 Discretized Temp Salt and DO

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.7 Well Mixed Salt

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.1.8 Propagate TDG

No slots are added directly as the Water Quality Routing method adds the slots.

15.2.2 Water Quality Routing

On the reach, the appropriate water quality slots are added when a method is selected in the Water Quality Routing category. In this category, there are methods that are dependent on the selected constituents, solution approach, and routing method. They are used to represent how the constituents are routed through the reach.

Note: For Discretized Salt and Propagate TDG, the method will be automatically selected based on these factors. For other approaches, you must select the method.

Each method describes when it is available and the slots that are instantiated. The slots are described above.

When the reach is an element of an Agg Reach, the aggregate controls the method selection on the elements and the element category is not shown (it is invisible). For Well Mixed Salt, the reaches can either model **None** or **Mass Balance Salinity**. For Discretized Salt, the reaches can either model **None** or **Salinity**.

15.2.2.1 None

This is the default, no-action method for this category. It is available for any set of constituents, solution approach and routing methods. No slots are instantiated by this method.

15.2.2.2 Time Lag; Temperature

This method is available for Discretized Temperature and the reach is configured to use Time Lag routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ INFLOW HEAT
- ☞ LAG TIME
- ☞ OUTFLOW HEAT
- ☞ SPECIFIC HEAT

METHOD DETAILS:

This method calls the utility methods **solveTimeLagTemp**.

15.2.2.3 Time Lag Salt

This method is available for Discretized Salt and the reach is configured to use Time Lag routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ INFLOW SALT
- ☞ INFLOW SALT CONCENTRATION
- ☞ LAG TIME
- ☞ OUTFLOW SALT CONCENTRATION

METHOD DETAILS:

This method calls the utility methods **solveTimeLagOutSalt**.

Note: In the associated flow routing method Time Lag Routing, you can select methods to specify/compute Local Inflow and Gain Loss. Neither of these are allowed in the WQ methods and will give an error if selected or specified. You will need to add another (no routing) reach to model these parameters.

15.2.2.4 Time Lag; Salt and Temperature

This method is available for Discretized Temp and Salt and the reach is configured to use Time Lag routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ INFLOW HEAT
- ☞ INFLOW SALT MASS
- ☞ INFLOW SALT CONCENTRATION
- ☞ OUTFLOW SALT MASS
- ☞ OUTFLOW HEAT
- ☞ OUTFLOW SALT CONCENTRATION
- ☞ SPECIFIC HEAT OF WATER

METHOD DETAILS:

This method calls the utility methods:

- **solveTimeLagOutSalt**
- **solveTimeLagTemp**

15.2.2.5 Time Lag; Temperature and DO

This method is available for Discretized Temp and DO and the reach is configured to use Time Lag routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ INFLOW AMMONIA MASS
- ☞ INFLOW DETRITUS MASS
- ☞ INFLOW DISSOLVED ORGANICS MASS
- ☞ INFLOW DISSOLVED ORGANICS MASS
- ☞ INFLOW HEAT
- ☞ OUTFLOW AMMONIA MASS
- ☞ OUTFLOW DETRITUS MASS
- ☞ OUTFLOW DISSOLVED ORGANICS MASS
- ☞ OUTFLOW DISSOLVED ORGANICS MASS
- ☞ OUTFLOW HEAT
- ☞ SPECIFIC HEAT OF WATER

METHOD DETAILS:

This method calls the utility methods:

- **solveTimeLagTemp**
- **solveTimeLagDO**

15.2.2.6 Time Lag; Salt, Temperature and DO

This method is available for Discretized Temp Salt and DO and the reach is configured to use Time Lag routing.

Slots Associated with this Method:

- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Organics Mass
- Inflow Heat
- Inflow Salt Mass
- Inflow Salt Concentration
- Outflow Ammonia Mass
- Outflow Detritus Mass
- Outflow Dissolved Organics Mass
- Outflow Dissolved Organics Mass
- Outflow Heat
- Outflow Salt Mass
- Outflow Salt Concentration
- Specific Heat of Water

Method Details:

This method calls the utility methods:

- **solveTimeLagOutSalt**
- **solveTimeLagTemp**
- **solveTimeLagDO**

15.2.2.7 Variable Time Lag Salt

This method is available for Discretized Salt and the reach is configured to use Variable Time Lag routing.

Slots Associated with this Method:

- Inflow Salt
- Inflow Salt Concentration
- Variable Lag Time
-
- Outflow Salt Concentration
-

Method Details:

This method calls the utility methods **solveVarTimeLagOutSalt**.

Note: In the associated flow routing method Variable Time Lag, you can select methods to specify/compute Evaporation and Precipitation, Local Inflow, Return Flow, and Gain Loss. None of these are allowed in the WQ methods and will give an error if selected or specified. You will need to add another (no routing) reach to model these parameters.

15.2.2.8 No Routing; Temperature

This method is available for Discretized Temp and the reach is configured to use No Routing.

Slots Associated with this Method:

- Diversion Temperature
- Outflow Heat

- Inflow Heat
- Local Inflow Temperature
- Return Flow Temperature
- Specific Heat of Water

Method Details:

This method calls the utility methods

- **checkSideFlowTemp**
- **solveNoRoutingTemp**

15.2.2.9 Salinity

This method is available for Discretized Salt and the reach is configured to use No Routing.

Slots Associated with this Method:

- Diversion Salt Concentration
- Inflow Salt Mass
- Inflow Salt Concentration
- Local Inflow Salt Concentration
- Outflow Salt Mass
- Outflow Salt Concentration
- Return Flow Salt Concentrations

Method Details:

This method calls the utility methods

- **checkSideFlowConcSalt**
- **solveNoRoutingOutSalt**

15.2.2.10 No Routing; Salt and Temperature

This method is available for Discretized Temp and Salt and the reach is configured to use No Routing.

Slots Associated with this Method:

- Diversion Salt Concentration
- Diversion Temperature
- Inflow Heat
- Inflow Salt Mass
- Inflow Salt Concentration
- Local Inflow Salt Concentration
- Local Inflow Temperature
- Outflow Heat
- Outflow Salt Mass
- Outflow Salt Concentration
- Return Flow Salt Concentrations
- Return Flow Temperature
- Specific Heat of Water

Method Details:

This method calls the utility methods

- **checkSideFlowConcSalt**
- **solveNoRoutingOutSalt**
- **checkSideFlowTemp**
- **solveNoRoutingTemp**

15.2.2.11 No Routing; Temperature and DO

This method is available for Discretized Temp and DO and the reach is configured to use No Routing.

Slots Associated with this Method:

- Diversion Detritus Concentration
- Diversion Diss Org Concentration
- Diversion DO Conc
- Diversion Temperature
- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Organics Mass
- Inflow Heat
- Local Inflow Ammonia Concentration
- Local Inflow Detritus Concentration
- Local Inflow Diss Org Concentration
- Local Inflow DO Concentration
- Local Inflow Temperature
- Outflow Ammonia Mass
- Outflow Detritus Mass
- Outflow Dissolved Organics Mass
- Outflow Dissolved Organics Mass
- Outflow Heat
- Return Flow Ammonia Concentration
- Return Flow Detritus Concentration
- Return Flow Diss Org Concentration
- Return Flow DO Concentration
- Return Flow Temperature
- Specific Heat of Water

Method Details:

This method calls the utility methods:

- checkSideFlowTemp
- solveNoRoutingTemp
- checkSideFlowConcDO
- solveNoRoutingDO.

15.2.2.12 No Routing; Salt, Temperature and DO

This method is available for Discretized Temp Salt and DO and the reach is configured to use No Routing.

Slots Associated with this Method:

- Diversion Ammonia Concentration
- Diversion Detritus Concentration
- Diversion Diss Org Concentration
- Diversion DO Concentration
- Diversion Salt Concentration
- Diversion Temperature
- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Oxygen Mass
- Inflow Heat
- Inflow Salt Mass
- Inflow Salt Concentration
- Local Inflow Ammonia Concentration
- Local Inflow Salt Concentration
- Local Inflow Temperature
- Outflow Ammonia Mass
- Outflow Detritus Mass
- Outflow Dissolved Organics Mass
- Outflow Dissolved Oxygen Mass
- Outflow Heat
- Outflow Salt Mass
- Outflow Salt Concentration
- Return Flow Ammonia Concentration
- Return Flow Detritus Concentration
- Return Flow Diss Org Concentration
- Return Flow DO Concentration
- Return Flow Salt Concentrations

- Local Inflow Detritus Concentration
- Local Inflow Diss Org Concentration
- Local Inflow DO Concentration
- Return Flow Temperature
- Specific Heat of Water

Method Details:

This method calls the utility methods:

- **checkSideFlowConcSalt**
- **solveNoRoutingOutSalt**
- **checkSideFlowTemp**
- **solveNoRoutingTemp**
- **checkSideFlowConcDO**
- **solveNoRoutingDO**

15.2.2.13 Control Volume Explicit; Temperature

This method is available for Discretized Temperature and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge or Muskingum Cunge Improved routing.

Slots Associated with this Method:

- Air Temperature
- Dewpoint Temperature
- Dispersion Coefficient
- Distributed Salt Concentrations Output
- Distributed Temperature Output
- Distributed Total Surface Flux Output
- Diversion Temperature
- Incoming Solar Radiation
- Inflow Heat
- Local Inflow Temperature
- Maximum Flow Rate for WQ Stability
- Outflow Heat
- Return Flow Temperature
- Wind Velocity

Method Details:

This method calls the utility methods:

- **checkSideFlowTemp**
- **solveTempWQcontrolVolumeExplicit**.

This method solves for water temperature based on control volume mass balances. The numerical solution to the convection-diffusion equation is an explicit backward difference. To prevent instabilities, a user input maximum flow rate is required so that the water quality algorithm will maintain stability regardless of the simulation time step. This is accomplished by calculating the time step required for numerical stability based on a conservative substance. Although the mass balance for water temperature includes transformation it is assumed negligible for the stability of the solution. If the required time step for stability is less than the simulation time step, the algorithm is executed multiple times at a time step less than or equal to the required time step. The total time of these steps will cumulatively equal the simulation time step. If the user defined maximum flow is not exceeded in the simulation, the solution will remain stable.

15.2.2.14 Control Volume Implicit; Temperature

This method is available for Discretized Temperature and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge, or Muskingum Cunge Improved routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- AIR TEMPERATURE
- DEWPOINT TEMPERATURE
- DISTRIBUTED SALT CONCENTRATIONS OUTPUT
- DISTRIBUTED TEMPERATURE OUTPUT
- DISTRIBUTED TOTAL SURFACE FLUX OUTPUT
- DIVERSION TEMPERATURE
- INCOMING SOLAR RADIATION
- INFLOW HEAT
- LOCAL INFLOW TEMPERATURE
- OUTFLOW HEAT
- RETURN FLOW TEMPERATURE
- WIND VELOCITY

METHOD DETAILS:

This method calls the utility methods:

- **checkSideFlowTemp**
- **solveTempWQcontrolVolumeImplicit**.

The basic methodology of the controlVolumeImplicit method is no different than the controlVolumeExplicit method, with the exception of the solution technique being an implicit backward difference approximation to the convection equation. Longitudinal dispersion is not included in this method to decrease to computational effort in obtaining a solution. This numerical solution is unconditionally stable and does not require that a maximum flow rate be input by the user.

15.2.2.15 Control Volume Explicit; Salt

This method is available for Discretized Salt, and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge, or Muskingum Cunge Improved routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- DISTRIBUTED SALT CONCENTRATIONS OUTPUT
- DIVERSION SALT CONCENTRATION
- DIVERSION SALT MASS
- INFLOW SALT CONCENTRATION
- INFLOW SALT MASS
- LOCAL INFLOW SAL T CONCENTRATION
- LOCAL INFLOW SALT MASS
- OUTFLOW SALT MASS
- OUTFLOW SALT CONCENTRATION
- RETURN FLOW SALT CONCENTRATION
- RETURN FLOW SALT MASS

METHOD DETAILS:

This method calls the utility methods:

- **checkSideFlowConcSalt**
- **solveSaltWQcontrolVolumeExplicit**

This method solves for salt concentration based on control volume mass balances.

15.2.2.16 Control Volume Implicit; Salt

This method is available for Discretized Salt, and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge, or Muskingum Cunge Improved routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ DISTRIBUTED SALT CONCENTRATION OUTPUT
- ☞ DIVERSION SALT CONCENTRATION
- ☞ INFLOW SALT CONCENTRATION
- ☞ INFLOW SALT MASS
- ☞ LOCAL INFLOW SALT CONCENTRATION
- ☞ OUTFLOW SALT CONCENTRATION
- ☞ OUTFLOW SALT MASS
- ☞ RETURN FLOW SALT CONCENTRATION

METHOD DETAILS:

This method calls the utility methods:

- **checkSideFlowConcSalt**
- **solveSaltWQcontrolVolumeImplicit**

The basic methodology of the controlVolumeImplicit method is no different than the controlVolumeExplicit method, with the exception of the solution technique being an implicit backward difference approximation to the convection equation.

15.2.2.17 Control Volume Explicit; Salt and Temp

This method is available for Discretized Temp and Salt and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge, or Muskingum Cunge Improved routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ AIR TEMPERATURE
- ☞ DEWPOINT TEMPERATURE
- ☞ DISPERSION COEFFICIENT
- ☞ DISTRIBUTED SALT CONCENTRATIONS OUTPUT
- ☞ DISTRIBUTED TEMPERATURE OUTPUT
- ☞ DISTRIBUTED TOTAL SURFACE FLUX OUTPUT
- ☞ DIVERSION SALT CONCENTRATION
- ☞ DIVERSION TEMPERATURE
- ☞ INCOMING SOLAR RADIATION
- ☞ INFLOW HEAT
- ☞ INFLOW SALT CONCENTRATION
- ☞ INFLOW SALT MASS
- ☞ LOCAL INFLOW SALT CONCENTRATION
- ☞ LOCAL INFLOW TEMPERATURE
- ☞ MAXIMUM FLOW RATE FOR WQ STABILITY
- ☞ OUTFLOW HEAT
- ☞ OUTFLOW SALT MASS
- ☞ OUTFLOW SALT CONCENTRATION
- ☞ RETURN FLOW SALT CONCENTRATIONS
- ☞ RETURN FLOW TEMPERATURE
- ☞ WIND VELOCITY

METHOD DETAILS:

This method calls the utility methods:

- **checkSideFlowConcSalt**
- **solveSaltWQcontrolVolumeExplicit**
- **checkSideFlowTemp**
- **solveTempWQcontrolVolumeExplicit**.

This method solves for salt concentration and water temperature based on control volume mass balances. The numerical solution to the convection-diffusion equation is an explicit backward difference. To prevent instabilities, a user input maximum flow rate is required so that the water quality algorithm will maintain stability regardless of the simulation time step. This is accomplished by calculating the time step required for numerical stability based on a conservative substance. Although the mass balance for water temperature includes transformation it is assumed negligible for the stability of the solution. If the required time step for stability is less than the simulation time step, the algorithm is executed multiple times at a time step less than or equal to the required time step. The total time of these steps will cumulatively equal the simulation time step. If the user defined maximum flow is not exceeded in the simulation, the solution will remain stable.

15.2.2.18 Control Volume Implicit; Salt and Temp

This method is available for Discretized Temp and Salt and the reach is configured to use MacCormack, Kinematic, Kinematic Improved, Muskingum Cunge, or Muskingum Cunge Improved routing.

Slots Associated with this Method:

- ☞ Air Temperature
- ☞ Dewpoint Temperature
- ☞ Distributed Salt Concentrations Output
- ☞ Distributed Temperature Output
- ☞ Distributed Total Surface Flux Output
- ☞ Diversion Salt Concentration
- ☞ Diversion Temperature
- ☞ Incoming Solar Radiation
- ☞ Inflow Salt Concentration
- ☞ Inflow Heat
- ☞ Inflow Salt Mass
- ☞ Local Inflow Salt Concentration
- ☞ Local Inflow Temperature
- ☞ Outflow Heat
- ☞ Outflow Salt Mass
- ☞ Outflow Salt Concentration
- ☞ Return Flow Salt Concentrations
- ☞ Return Flow Temperature
- ☞ Wind Velocity

Method Details:

This method calls the utility methods:

- **checkSideFlowConcSalt**
- **solveSaltWQcontrolVolumeImplicit**
- **checkSideFlowTemp**
- **solveTempWQcontrolVolumeImplicit**.

The basic methodology of the controlVolumeImplicit method is no different than the controlVolumeExplicit method, with the exception of the solution technique being an implicit backward difference approximation to the convection equation. Longitudinal dispersion is not included in this method to decrease the computational effort in obtaining a solution. This numerical solution is unconditionally stable and does not require that a maximum flow rate be input by the user.

15.2.2.19 Mass Balance Salinity

This method is available for Well Mixed Salt and the reach is configured to use No Routing.

Slots Associated with this Method:

- ☞ Diversion Salt Concentration
- ☞ Diversion Salt Mass
- ☞ Inflow Salt Concentration
- ☞ Outflow Salt Mass
- ☞ Return Flow Salt Mass
- ☞ Salt Available For Removal

- ☞ **INFLOW SALT MASS**
- ☞ **LOCAL INFLOW SALT CONCENTRATION**
- ☞ **LOCAL INFLOW SALT MASS**
- ☞ **OUTFLOW SALT CONCENTRATION**
- ☞ **SALT MASS REMOVAL**
- ☞ **SALT STORAGE**
- ☞ **MAXIMUM SALT CONCENTRATION**
- ☞ **MINIMUM SALT CONCENTRATION**

METHOD DETAILS:

This method exists to instantiate the appropriate slots. All of the calculations are performed in the dispatch method. The following dispatch methods are available when Mass Balance Salinity is selected:

- Solve Out Salt Given In Salt **HERE (Section 15.3.2.6)**
- Solve In Salt Given Out Salt **HERE (Section 15.3.2.7)**
- Solve Local In Salt Given In and Out **HERE (Section 15.3.2.8)**

When the reach is an element of an Agg Reach, the aggregate controls the method selection on the elements. For Well Mixed Salt, the reaches can either model None or Mass Balance Salinity. When Mass Balance Salinity is selected on the aggregate, then this method is selected on the reach but is invisible. The routing method must be No Routing or an error will be issued.

15.2.2.20 No Routing, TDG

This method is available for Propagate TDG method and the reach is configured to use No Routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ **INFLOW TDG CONCENTRATION**
- ☞ **OUTFLOW TDG CONCENTRATION**

The reach will route the TDG concentration:

$$TDG_O = TDG_I \tag{15-56}$$

TDG_O = **Outflow TDG Concentration**

TDG_I = **Inflow TDG Concentration**

15.2.2.21 Time Lag, TDG

This method is available for Propagate TDG method and the reach is configured to use No Routing.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ **INFLOW TDG CONCENTRATION**
- ☞ **OUTFLOW TDG CONCENTRATION**
- ☞ **TDG LAG TIME**
- ☞

The reach will route the TDG concentration using a simple lag:

$$TDG_O = TDG_I[t - TDGlag] \tag{15-57}$$

TDG_O = **Outflow TDG Concentration**

TDG_I = **Inflow TDG Concentration**

TDGlag = **TDG Lag Time**

15.2.3 Reach Optimization Total Dissolved Gas

This category is only available if **Propagate TDG** method is selected for the Reach Water Quality category. It contains two methods, the default no-action **None** method and the **Propagate TDG Deltas**.

15.2.3.1 None

This is the default no-action method.

15.2.3.2 Propagate TDG Deltas

This is the optimization component of TDG modeling. See also the simulation model described above. This method instantiates the slots and then sets up the data necessary for the Optimization problem. The defining constraints are also described below.

SLOTS SPECIFIC TO THIS METHOD:

☞ **DELTA INFLOW**

Type: Series
Units: FLOW
Description: This slot represents the optimization variable for Delta Inflow
Links: Linkable

☞ **DELTA OUTFLOW**

Type: Series
Units: FLOW
Description: This slot represents the optimization variable for Delta Outflow.
Links: Linkable

☞ **DELTA INFLOW TDG CONCENTRATION**

Type: Series
Units: FRACTION
Description: This slot represents the optimization variable for Delta Inflow TDG Concentration.
Links: Linkable

☞ **DELTA OUTFLOW TDG CONCENTRATION**

Type: Series
Units: FRACTION
Description: This slot represents the optimization variable for Delta Inflow TDG Concentration.
Links: Linkable

For the this method, the deltas and concentrations must also be routed. A constraint is added to define the outflows as a lag from the inflow, for both delta concentration, delta flows and concentrations. NOTE flows and TDG deltas are lagged by separate slots which may or may not contain the same lag value.

$$\Delta TDG_O = \Delta TDG_I[t - TDGlag] \tag{15-58}$$

$$\Delta Q_O = \Delta Q_I[t - lagTime] \tag{15-59}$$

$$TDG_O = TDG_I[t - TDGlag] \tag{15-60}$$

This method is also available when No Routing is used. In that case, the lag is assumed to be zero (and is not shown) and outflow values equal inflow values. Click **HERE (Section 16.4.49.2)** for more information on the optimization solution for TDG on the Reservoir.

15.3 Solution/Dispatching

15.3.1 Beginning of Water Quality Run

The function following behavior is executed one time at the beginning of the run. It is called from within beginning of run behavior on the Reach object.

- If Diversion is not linked and not valid, set relevant Diversion parameter concentrations to zero.
- If Return Flow is not linked and not valid, set relevant Return Flow parameter concentrations to zero.
- If Return Flow Temperature is in use but not linked, issue an error if any values are missing.
- If Local Inflow is not linked and not valid, set relevant Local Inflow parameter concentrations to zero.
- If Specific Heat is not input, set it to 4.186 J/gC.
- If Control Volume Explicit or Control Volume Implicit are selected water quality routing methods
    - If modeling Temperature
        - Check for Air Temperature, Dewpoint Temperature, and Solar Radiation data. If data is incomplete, then flag error and exit.
        - If Wind Velocity data is incomplete, set is to zero.
        - If Thermo Diffusion Coefficient Adjust data is incomplete, then fill values to 1.0.
    - If Control Volume Explicit is selected water quality routing method, check for valid maximum flow value.
    - If MacCormack or Muskingum Cunge routing, check for valid routing timestep.
        - Check for initial heat and salt mass values. Flag error if not given.
        - Call **setWQInitConds**.
- If modeling Total Dissolved Gas with time lag routing, check that the TDG Lag Time slot is valid.

15.3.2 Dispatch Methods

The following water quality dispatch methods exist on all reaches. In order for the method to be executed the first time for each timestep, both the known and unknown slot lists must be satisfied. Once a dispatch method has been invoked in normal simulation, the same method is executed again if any slot value is reset; this normally is caused by a value propagating across a link. Each dispatch method represents a possible combination of constituent and solution approach choices made at the global level.

15.3.2.1 Solve Discretized Temp

This dispatch methods executes the selected method in the Water Quality Routing category (**HERE (Section 15.2.2)**):

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW HEAT**
- ☞ **OUTFLOW**

UNKNOWN SLOTS:

- ☞ **OUTFLOW HEAT**

15.3.2.2 Solve Discretized Salt

This dispatch methods executes the selected method in the Water Quality Routing category (**HERE (Section 15.2.2)**):

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **OUTFLOW**
- ☞ **INFLOW SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW SALT MASS**

15.3.2.3 Solve Discretized Temp and Salt

This dispatch methods executes the selected method in the Water Quality Routing category (**HERE (Section 15.2.2)**):

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW HEAT**
- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW HEAT**
- ☞ **OUTFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW SALT MASS**

15.3.2.4 Solve Discretized Temp and DO

This dispatch methods executes the selected method in the Water Quality Routing category (**HERE (Section 15.2.2)**):

Required Known slots:

- ☞ Inflow
- ☞ Inflow Ammonia Mass
- ☞ Inflow Detritus Mass
- ☞ Inflow Dissolved Organics Mass
- ☞ Inflow Dissolved Oxygen Mass
- ☞ Inflow Heat
- ☞ Outflow

Required Unknown slots:

- ☞ Outflow Ammonia Mass
- ☞ Outflow Detritus Mass
- ☞ Outflow Dissolved Organics Mass
- ☞ Outflow Dissolved Oxygen Mass
- ☞ Outflow Heat

15.3.2.5 Solve Discretized Temp Salt and DO

This dispatch methods executes the selected method in the Water Quality Routing category (HERE (Section 15.2.2)):

Required Known slots:

- ☞ Inflow
- ☞ Inflow Ammonia Mass
- ☞ Inflow Detritus Mass
- ☞ Inflow Dissolved Organics Mass
- ☞ Inflow Dissolved Oxygen Mass
- ☞ Inflow Heat
- ☞ Inflow Salt Concentration
- ☞ Outflow

Required Unknown slots:

- ☞ Outflow Ammonia Mass
- ☞ Outflow Detritus Mass
- ☞ Outflow Dissolved Organics Mass
- ☞ Outflow Salt Concentration
- ☞ Outflow Dissolved Oxygen Mass
- ☞ Outflow Heat
- ☞ Outflow Salt Mass

15.3.2.6 Solve Out Salt Given In Salt

This dispatch method is called when the Inflow, Outflow, and Inflow Salt Concentration slots are known and the Outflow Salt Concentration slot is unknown.

Required Known slots:

- ☞ Inflow
- ☞ Inflow Salt Concentration
- ☞ Local Inflow (if instantiated)
- ☞ Local Inflow Salt Concentration (if instantiated)
- ☞ Outflow

Required Unknown slots:

- ☞ Outflow Salt Concentration

Method Details:

If Maximum Salt Concentration does not contain a valid value, the run will abort.

Equivalent volumes over the timestep are calculated for the following flows: Inflow, Outflow, Diversion, Local Inflow (plus Local Inflow Adjust), Return Flow.

Inflow Salt Mass and Local Inflow Salt Mass are calculated by multiplying each concentration by the corresponding flow volume. If Local Inflow is zero and Local Inflow Salt Concentration is not specified, Local Inflow Salt Concentration and Local Inflow Salt Mass are set equal to zero.

Next calculate the diversion salt. If Diversion Salt Concentration is not specified (input or set by a rule), the local variable *tempDivSaltConc* is set equal to the Inflow Salt Concentration (or zero if Diversion is either zero or unused). If it is specified, *tempDivSaltConc* is set to the specified value. If Diversion Salt Concentration is specified, then Return Flow must be zero (the “Special Export” condition). If Diversion Salt Concentration is specified and Return Flow is non-zero, the run will abort with an error message.

Then a check is made to see if the corresponding salt mass is available to be diverted. It will not allow more salt to be diverted than is in the inflow.

$$tempDivSaltMass = DiversionVol \times tempDivSaltConc$$

IF $tempDivSaltMass > \text{Inflow Salt Mass}$

IF $\text{Inflow Salt Mass} > 0$

All of the Inflow Salt Mass will be diverted.

$$\text{Diversion Salt Mass} = \text{Inflow Salt Mass}$$

ELSE (Inflow Salt Mass is negative)

$$\text{Diversion Salt Mass} = 0$$

END IF

ELSE (There is sufficient salt mass in the inflow to meet the calculated diversion mass.)

$$\text{Diversion Salt Mass} = tempDivSaltMass$$

END IF

If the Diversion Salt Concentration is not specified, then the slot value will be calculated based on the final Diversion Salt Mass.

IF $isNotInput(\text{Diversion Salt Concentration})$

$$\text{Diversion Salt Concentration} = \frac{\text{Diversion Salt Mass}}{DiversionVol}$$

If Diversion is zero or is unused, Diversion Salt Concentration will be set to zero.

END IF

Note that a specified Diversion Salt Concentration value will not be changed even when the Diversion Salt Mass is reduced, but a warning message will be issued to notify the user that the Diversion Salt Mass does not correspond to the specified Diversion Salt Concentration. The appropriate mass balance will be maintained.

If Return Flow Salt Mass is linked but not valid, the method will exit and wait for the linked Agg Diversion Site to solve for Return Flow Salt Mass. If Return Flow Salt Mass is not linked and does not contain a value, it will default to zero.

If Salt Storage at the previous timestep is invalid (NaN) or negative, the local variable *prevSaltStorage* is set equal to 0. Otherwise it is set equal to Salt Storage at the previous timestep.

If Salt Available For Removal is linked, a check is made that Minimum Salt Concentration contains a valid value (otherwise Minimum Salt Concentration is an optional input). If Minimum Salt Concentration does not contain a valid value, the run will abort and an error message will be posted. Then Salt Available For Removal is calculated as:

IF $Outflow \geq 0$

$$\text{Salt Available For Removal} = \text{Inflow Salt Mass} + \text{Local Inflow Salt Mass} - \text{Diversion Salt Mass} + \text{Return Flow Salt Mass} + prevSaltStorage - (OutflowVol \times \text{Minimum Salt Concentration})$$

ELSE (negative Outflow)

For negative Outflow, removing salt will raise the concentration, so the maximum available for removal is based on the Maximum Salt Concentration.

$$\text{Salt Available For Removal} = \text{Inflow Salt Mass} + \text{Local Inflow Salt Mass} - \text{Diversion Salt Mass} + \text{Return Flow Salt Mass} + prevSaltStorage - (OutflowVol \times \text{Maximum Salt Concentration})$$

END IF

If Salt Mass Removal is linked, it will check for a value in the slot. If there is no value, the method will exit and wait for the linked Agg Diversion Site to solve. If the slot is not linked and it does not contain an input value, it is set to zero.

Then the initial salinity mass balance solves for the local variable *tempOutSaltMass*:

$$tempOutSaltMass = \text{Inflow Salt Mass} - \text{Diversion Salt Mass} + \text{Return Flow Salt Mass} + \text{Local Inflow Salt Mass} - \text{Salt Mass Removal}$$

After setting tempOutSaltMass it then carries out the following logic to check if the Outflow Salt Mass should be adjusted:

IF $Outflow = 0$

IF $tempOutSaltMass \geq 0$

$$\text{Outflow Salt Mass} = 0$$

$$\text{Outflow Salt Concentration} = 0$$

If there is no Outflow, and positive tempOutSaltMass will get added to Salt Storage.

ELSE (tempOutSaltMass is negative)

IF $prevSaltStorage > -tempOutSaltMass$

$$\text{Outflow Salt Mass} = 0$$

$\text{Outflow Salt Concentration} = 0$

Any available Salt Storage will be used to bring the Outflow Salt Mass up to 0.

ELSE (There is not enough Salt Storage to make up the negative tempOutSaltMass.

Run aborts. There cannot be a negative Outflow Salt Mass with zero Outflow.

END IF

END IF

ELSE (Outflow is non-zero.)

Solve for the initial outflow concentration

$$tempOutSaltConc = \frac{tempOutSaltMass}{OutflowVol}$$

IF $tempOutSaltConc > \text{Maximum Salt Concentration}$

Set the concentration to the maximum. Any excess salt will get added to Salt Storage.

$$\text{Outflow Salt Concentration} = \text{Maximum Salt Concentration}$$

$$\text{Outflow Salt Mass} = \text{Outflow Salt Concentraiton} \times OutflowVol$$

ELSE

Use up any existing Salt Storage up to the maximum concentration.

First calculate the maximum amount of salt that could be added to the Outflow without exceeding the maximum concentration.

IF $Outflow \geq 0$

$$maxOutSaltMass = \text{Maximum Salt Concentration} \times OutflowVol$$

ELSE

For a negative Outflow, adding to the Outflow Salt Mass will lower the concentration, so the maximum that can be added is based on the Minimum Salt Concentration if it is specified, otherwise all Salt Storage will be added.

IF $isValid(\text{Minimum Salt Concentraiton})$

$$maxOutSaltMass = \text{Minimum Salt Concentration} \times OutflowVol$$

ELSE

$$maxOutSaltMass = tempOutSaltMass + prevSaltStorage$$

END IF

END IF

$$maxAddOutSaltMass = maxOutSaltMass - tempOutSaltMass$$

IF $maxAddOutSaltMass > prevSaltStorage$

Add all of the stored salt to the Outflow.

$$\text{Outflow Salt Mass} = tempOutSaltMass + prevSaltStorage$$

ELSE (Stored salt is more than the maximum that can be added.)

Only increase outflow salt up to the maximum.

$$\text{Outflow Salt Mass} = maxOutSaltMass$$

END IF

$$\text{Outflow Salt Concentration} = \frac{\text{Outflow Salt Mass}}{OutflowVol}$$

END IF

END IF

Finally calculate the new Salt Storage.

$$deltaSaltStorage = tempOutSaltMass - \text{Outflow Salt Mass}$$

$$\text{Salt Storage} = prevSaltStorage + deltaSaltStorage$$

15.3.2.7 Solve In Salt Given Out Salt

This dispatch method is called when the Inflow, Outflow, and Outflow Salt Concentration slots are known and the Inflow Salt Concentration slot is unknown.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **LOCAL INFLOW (IF INSTANTIATED)**
- ☞ **LOCAL INFLOW SALT CONCENTRATION (IF INSTANTIATED)**
- ☞ **OUTFLOW**
- ☞ **OUTFLOW SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

- ☞ **INFLOW SALT CONCENTRATION**

METHOD DETAILS:

If Maximum Salt Concentration does not contain a valid value, the run will abort.

Equivalent volumes over the timestep are calculated for the following flows: Inflow, Outflow, Diversion, Local Inflow (plus Local Inflow Adjust), Return Flow.

If Local Inflow is zero and Local Inflow Salt Concentration is not specified, Local Inflow Salt Concentration and Local Inflow Salt Mass are set equal to zero.

In order for the Reach to solve for inflow salt and diversion salt, it must know the return flow salt, which is solved for by the linked object or must be specified. If Return Flow Salt Mass is linked, and it is not linked to the same object as the Diversion Salt Concentration, then the Return Flow Salt Mass must be valid, or the method will exit and wait for more information.

If Return Flow Salt Mass and Diversion Salt Concentration are linked to the same Agg Diversion Site, the Return Flow Salt Mass from the Agg Diversion Site is calculated as:

$$\text{Return Flow Salt Mass} = \text{Diversion Salt Mass} + saltPickupMass$$

Or if Return Flow is zero, then $\text{Return Flow Salt Mass} = saltPickupMass$.

Therefore if the Reach knows the value for *saltPickupMass*, it can solve for inflow salt and diversion salt. The Reach retrieves the value for *saltPickupMass* from one of four slots on the Agg Diversion Site, depending on which Return Flow Salt method is selected on the Agg Diversion Site, as described in the table below.

Note: Return Flow Salt Mass can only be linked to a single slot.

Agg Diversion Site Return Flow Salt Method/Salinity Pickup Method (If Applicable)	*saltPickupMass*
None	0
Variable Salt Pickup/Salt Pickup Concentration	$\text{Return Flow Salinity Pickup Conc} \times ReturnFlowVol$
Variable Salt Pickup/Salt Pickup Mass	Return Flow Salinity Pickup Mass
Distributed Annual Salt Loading	Distributed Salinity Pickup Mass
Lumped Salt	Salt Loading

If Salt Storage at the previous timestep is invalid (NaN) or negative, the local variable *prevSaltStorage* is set equal to 0. Otherwise it is set equal to Salt Storage at the previous timestep.

Outflow Salt Mass and Local Inflow Salt Mass are calculated by multiplying each concentration by the corresponding flow volume.

If Salt Available For Removal is linked, its value is calculated as:

IF $\text{Return Flow} = 0$

IF $isSpecified(\text{Diversion Salt Concentration})$

IF $Inflow \geq 0$

$$\begin{aligned}\text{Salt Available For Removal} &= (InflowVol \times \text{Maximum Salt Concentration}) \\ &- \text{Diversion Salt Concentration} \times \text{DiversionVol} + saltPickupMass \\ &+ \text{Local Inflow Salt Mass} + prevSaltStorage - \text{Outflow Salt Mass}\end{aligned}$$

ELSE (negative Inflow)

$$\text{Salt Available For Removal} = (InflowVol \times \text{Minimum Salt Concentration}) - \text{Diversion Salt Concentration} \times \text{DiversionVol} + saltPickupMass + \text{Local Inflow Salt Mass} + prevSaltStorage - \text{Outflow Salt Mass}$$

END IF

ELSE (Diversion Salt Concentration will be equal to Inflow Salt Concentration)

IF $Inflow \geq 0$

$$\text{Salt Available For Removal} = (InflowVol - DiverstionVol) \times \text{Maximum Salt Concentration} + saltPickupMass + \text{Local Inflow Salt Mass} + prevSaltStorage - \text{Outflow Salt Mass}$$

ELSE (negative Inflow)

$$\text{Salt Available For Removal} = (InflowVol - DiverstionVol) \times \text{Minimum Salt Concentration} + saltPickupMass + \text{Local Inflow Salt Mass} + prevSaltStorage - \text{Outflow Salt Mass}$$

END IF

END IF

ELSE (Return Flow is non-zero, so diversion salt cancels from the mass balance)

IF $Inflow \geq 0$

$$\text{Salt Available For Removal} = (InflowVol \times \text{Maximum Salt Concentration}) + saltPickupMass + \text{Local Inflow Salt Concentration} + prevSaltStorage - \text{Outflow Salt Mass}$$

ELSE (negative Inflow)

$$\text{Salt Available For Removal} = (InflowVol \times \text{Minimum Salt Concentration}) + saltPickupMass + \text{Local Inflow Salt Concentration} + prevSaltStorage - \text{Outflow Salt Mass}$$

END IF

END IF

If Salt Mass Removal is linked, the method will check for a value in the slot. If there is no value, the method will exit and wait for the linked Agg Diversion Site to solve. If the slot is not linked and it does not contain an input value, it is set to zero.

Then the initial salinity mass balance solves for the local variable *tempInSaltMass*. The form of the mass balance depends on whether there is a non-zero Return Flow and whether or not Diversion Salt Concentration is specified (input or set by a rule).

IF $\text{Return Flow} \neq 0$

If Return Flow is non-zero, all diverted salt mass gets returned and thus cancels from the mass balance.

$$tempInSaltMass = \text{Outflow Salt Mass} - saltPickupMass - \text{Local Inflow Salt Mass} + \text{Salt Mass Removal}$$

IF $Inflow = 0$

There cannot be a non-zero salt mass if there is no Inflow.

IF $tempInSaltMass > 0$

IF $prevSaltStorage \geq tempInSaltMass$

Use any Salt Storage to make up the difference, so that Inflow Salt Mass will be zero. The change in Salt Storage will be accounted for at the end of the method.

$$\text{Inflow Salt Mass} = 0$$

$$\text{Inflow Salt Concentration} = 0$$

ELSE

There is not enough Salt Storage to make up the difference. This would result in positive salt with no flow, so the run will abort with an error message.

END IF

ELSE (*tempInSaltMass* is negative or zero)

$$\text{Inflow Salt Mass} = 0$$

$$\text{Inflow Salt Concentration} = 0$$

Any change will be added to Salt Storage.

END IF

ELSE (Inflow is non-zero)

Incorporate salt from storage if there is any.

IF $InflowVol \geq 0$

IF $isValid(\text{Minimum Salt Concentration})$

If the Minimum Salt Concentration is specified, calculate the corresponding minimum mass. Minimum Salt Concentration is generally an optional input, but it is a required input if using one of the Salt Removal methods on a linked Agg Diversion Site.

$$minInSaltMass = \text{Minimum Salt Concentratoin} \times InflowVol$$

ELSE

If the minimum is not specified, all Salt Storage will be incorporated.

$$minInSaltMass = tempInSaltMass - prevSaltStorage$$

END IF

ELSE

For a negative Inflow, incorporating more salt from storage will lower the Inflow

Salt Mass but will raise the Inflow Salt Concentration, so the minimum inflow mass is based on the Maximum Salt Concentration.

$$minInSaltMass = \text{Maximum Salt Concentration} \times InflowVol$$

END IF

$$maxSaltFromStorage = tempInSaltMass - minInSaltMass$$

IF $maxSaltFromStorage \geq prevSaltStorage$

Use up all of the salt from storage.

$$\text{Inflow Salt Mass} = tempInSaltMass - prevSaltStorage$$

ELSE

Using up all Salt Storage would take Inflow Salt Concentration below the minimum, so only take it down to the minimum.

$$\text{Inflow Salt Mass} = minInSaltMass$$

This also takes care of the case when *tempInSaltMass* is already less than the minimum. It will bring the inflow salt up to the minimum, and the difference will get added to Salt Storage.

END IF

$$\text{Inflow Salt Concentration} = \frac{\text{Inflow Salt Mass}}{InflowVol}$$

END IF

Calculate the change in Salt Storage.

$$deltaSaltStorage = \text{Inflow Salt Mass} - tempInSaltMass$$

ELSE (Return Flow is zero. It is either the “Special Export” condition or there is no Diversion.)

The mass balance calculation depends on whether or not Diversion Salt Concentration is an specified (input or set by a rule)

IF $isSpecified(\text{Diversion Salt Concentration})$

$$\text{Diversion Salt Mass} = \text{Diversion Salt Concentration} \times DiversionVol$$

$$tempInSaltMass = \text{Outflow Salt Mass} + \text{Diversion Salt Mass} - saltPickupMass - \text{Local Inflow Salt Mass} + \text{Salt Mass Removal}$$

IF $Inflow = 0$

There cannot be a non-zero salt mass if there is no Inflow.

IF $tempInSaltMass > 0$

IF $prevSaltStorage \geq tempInSaltMass$

Use any Salt Storage to make up the difference, so that Inflow Salt Mass will be zero. The change in Salt Storage will be accounted for at the end of the method.

$$\text{Inflow Salt Mass} = 0$$

$$\text{Inflow Salt Concentration} = 0$$

ELSE

There is not enough Salt Storage to make up the difference. This would result in positive salt with no flow, so the run will abort.

END IF

ELSE (*tempInSaltMass* is negative or zero)

$$\text{Inflow Salt Mass} = 0$$

$$\text{Inflow Salt Concentration} = 0$$

Any change will be added to Salt Storage.

END IF

ELSE (Inflow is non-zero)

Incorporate salt from storage if there is any.

IF $InflowVol \geq 0$

IF $isValid(\text{Minimum Salt Concentration})$

If the Minimum Salt Concentration is specified, calculate the corresponding minimum mass. Minimum Salt Concentration is generally an optional input, but it is a required input if using one of the Salt Removal methods on a linked Agg Diversion Site.

$$minInSaltMass = \text{Minimum Salt Concentratoin} \times InflowVol$$

ELSE

If the minimum is not specified, all Salt Storage will be incorporated.

$$minInSaltMass = tempInSaltMass - prevSaltStorage$$

END IF

ELSE

For a negative Inflow, incorporating more salt from storage will lower the Inflow Salt Mass but will raise the Inflow Salt Concentration, so the minimum inflow mass is based on the Maximum Salt Concentration.

$$minInSaltMass = \text{Maximum Salt Concentration} \times InflowVol$$

END IF

$maxSaltFromStorage = tempInSaltMass - minInSaltMass$

IF $maxSaltFromStorage \geq prevSaltStorage$

Use up all of the salt from storage.

$\text{Inflow Salt Mass} = tempInSaltMass - prevSaltStorage$

ELSE

Using up all Salt Storage would take Inflow Salt Concentration below the minimum, so only take it down to the minimum.

$\text{Inflow Salt Mass} = minInSaltMass$

This also takes care of the case when *tempInSaltMass* is already less than the minimum. It will bring the inflow salt up to the minimum, and the difference will get added to Salt Storage.

END IF

$$\text{Inflow Salt Concentration} = \frac{\text{Inflow Salt Mass}}{InflowVol}$$

END IF

Calculate the change in Salt Storage.

$deltaSaltStorage = \text{Inflow Salt Mass} - tempInSaltMass$

ELSE (Return Flow is zero, and Diversion Salt Concentration is not specified.)

Diversion Salt Concentration will either be zero (if there is no Diversion), or it will be equal to the Inflow Salt Concentration.

First calculate the initial net in salt mass. This is the Inflow Salt Mass minus the Diversion Salt Mass.

$$tempNetInSaltMass = \text{Outflow Salt Mass} + saltPickupMass \\ - \text{Local Inflow Salt Mass} + \text{Salt Mass Removal}$$

$netInVol = InflowVol - DiversionVol$

IF $netInVol = 0$

There cannot be a non-zero salt mass if there is no net flow.

IF $tempNetInSaltMass > 0$

IF $prevSaltStorage \geq tempNetInSaltMass$

Use any Salt Storage to make up the difference, so that *netInSaltMass* will be zero. The change in Salt Storage will be accounted for at the end of the method.

$$netInSaltMass = 0$$

$$\text{Inflow Salt Concentration} = 0$$

ELSE

There is not enough Salt Storage to make up the difference. This would result in positive salt with no flow, so the run will abort.

END IF

ELSE (*tempNetInSaltMass* is negative or zero)

$$netInSaltMass = 0$$

$$\text{Inflow Salt Concentration} = 0$$

Any change will be added to Salt Storage.

END IF

ELSE (*netInVol* is non-zero)

Incorporate salt from storage if there is any.

IF $netInVol \geq 0$

IF $isValid(\text{Minimum Salt Concentration})$

If the Minimum Salt Concentration is specified, calculate the corresponding minimum mass. Minimum Salt Concentration is generally an optional input, but it is a required input if using one of the Salt Removal methods on a linked Agg Diversion Site.

$$minNetInSaltMass = \text{Minimum Salt Concentratoin} \times netInflowVol$$

ELSE

If the minimum is not specified, all Salt Storage will be incorporated.

$$minNetInSaltMass = tempNetInSaltMass - prevSaltStorage$$

END IF

ELSE

For a negative *netInVol*, incorporating more salt from storage will lower the *netInSaltMass* but will raise the concentration, so the minimum mass is based on the Maximum Salt Concentration.

$$minNetInSaltMass = \text{Maximum Salt Concentration} \times netInflowVol$$

END IF

$$maxSaltFromStorage = tempNetInSaltMass - minNetInSaltMass$$

IF $maxSaltFromStorage \geq prevSaltStorage$

Use up all of the salt from storage.

$$netInSaltMass = tempNetInSaltMass - prevSaltStorage$$

ELSE

Using up all Salt Storage would take Inflow Salt Concentration below the minimum, so only take it down to the minimum.

$$netInSaltMass = minNetInSaltMass$$

This also takes care of the case when *tempInSaltMass* is already less than the minimum. It will bring the inflow salt up to the minimum, and the difference will get added to Salt Storage.

END IF

$$\text{Inflow Salt Concentration} = \frac{netInSaltMass}{netInVol}$$

END IF

Calculate the Inflow Salt Mass and the change in Salt Storage.

$$\text{Inflow Salt Mass} = \text{Inflow Salt Concentration} \times InflowVol$$

$$deltaSaltStorage = netInSaltMass - tempNetInSaltMass$$

END IF

END IF

Set the final Diversion Salt Concentration if it is not specified, and calculate the Diversion Salt Mass.

IF $isNotSpecified(\text{Diversion Salt Concentration})$

IF $Diversion = 0$

$$\text{Diversion Salt Concentration} = 0$$

ELSE

$$\text{Diversion Salt Concentration} = \text{Inflow Salt Concentration}$$

END IF

END IF

$$\text{Diversion Salt Mass} = \text{Diversion Salt Concentration} \times DiversionVol$$

Finally calculate the new Salt Storage.

$$\text{Salt Storage} = prevSaltStorage + deltaSaltStorage$$

15.3.2.8 Solve Local In Salt Given In and Out

This dispatch method is called when the Inflow, Outflow, Local Inflow, Inflow Salt Concentration and Outflow Salt Concentration slots are known and the Local Inflow Salt Concentration slot is unknown.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **LOCAL INFLOW**
- ☞ **OUTFLOW**
- ☞ **OUTFLOW SALT CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

- ☞ **LOCAL INFLOW SALT CONCENTRATION**

METHOD DETAILS:

If Maximum Salt Concentration does not contain a valid value, the run will abort.

Equivalent volumes over the timestep are calculated for the following flows: Inflow, Outflow, Diversion, Local Inflow (plus Local Inflow Adjust), Return Flow.

Inflow Salt Mass and Local Inflow Salt Mass are calculated by multiplying each concentration by the corresponding flow volume. If Local Inflow is zero and Local Inflow Salt Concentration is not specified, Local Inflow Salt Concentration and Local Inflow Salt Mass are set equal to zero.

Next calculate the diversion salt. If Diversion Salt Concentration is not specified (input or set by a rule), the local variable *tempDivSaltConc* is set equal to the Inflow Salt Concentration (or zero if Diversion is either zero or unused). If it is specified, *tempDivSaltConc* is set to the value. If Diversion Salt Concentration is specified, then Return Flow must be zero (the “Special Export” condition). If Diversion Salt Concentration is specified and Return Flow is non-zero, the run will abort with an error message.

Then a check is made to see if the corresponding salt mass is available to be diverted. It will not allow more salt to be diverted than is in the inflow.

$$tempDivSaltMass = DiversionVol \times tempDivSaltConc$$

IF $tempDivSaltMass > \text{Inflow Salt Mass}$

IF $\text{Inflow Salt Mass} > 0$

All of the Inflow Salt Mass will be diverted.

$$\text{Diversion Salt Mass} = \text{Inflow Salt Mass}$$

ELSE (Inflow Salt Mass is negative)

$$\text{Diversion Salt Mass} = 0$$

END IF

ELSE (There is sufficient salt mass in the inflow to meet the calculated diversion mass.)

$$\text{Diversion Salt Mass} = tempDivSaltMass$$

END IF

If the Diversion Salt Concentration is not specified, then the slot value will be calculated based on the final Diversion Salt Mass.

IF $isNotSpecified(\text{Diversion Salt Concentration})$

$$\text{Diversion Salt Concentration} = \frac{\text{Diversion Salt Mass}}{DiversionVol}$$

If Diversion is zero or is unused, Diversion Salt Concentration will be set to zero.

END IF

Note that a specified Diversion Salt Concentration value will not be changed even when the Diversion Salt Mass is reduced, but a warning message will be issued to notify the user that the Diversion Salt Mass does not correspond to the specified Diversion Salt Concentration. The appropriate mass balance will be maintained.

If Return Flow Salt Mass is linked but not valid, the method will exit and wait for the linked Agg Diversion Site to solve for Return Flow Salt Mass. If Return Flow Salt Mass is not linked and does not contain a value, it will default to zero.

If Salt Storage at the previous timestep is invalid (NaN) or negative, the local variable *prevSaltStorage* is set equal to 0. Otherwise it is set equal to Salt Storage at the previous timestep.

Inflow Salt Mass, Outflow Salt Mass and Diversion Salt Mass are calculated by multiplying each concentration by the corresponding flow volume.

If Salt Available For Removal is linked, its value is calculated as:

IF $LocalInflowVol \geq 0$

$$\text{Salt Available For Removal} = (LocalInflowVol \times \text{Maximum Salt Concentration}) + \\ \text{Inflow Salt Mass} - \text{Diversion Salt Mass} + \text{Return Flow Salt Mass} + prevSaltStorage - \text{OutflowSaltMass}$$

ELSE (negative Local Inflow)

For negative Outflow, removing salt will lower the concentration, so the maximum available for removal is based on the Minimum Salt Concentration.

$$\text{Salt Available For Removal} = (LocalInflowVol \times \text{Minimum Salt Concentration}) + \\ \text{Inflow Salt Mass} - \text{Diversion Salt Mass} + \text{Return Flow Salt Mass} + prevSaltStorage - \text{OutflowSaltMass}$$

END IF

If Salt Mass Removal is linked, it will check for a value in the slot. If there is no value, the method will exit and wait for the linked Agg Diversion Site to solve. If the slot is not linked and it does not contain an input value, it is set to zero.

Then the initial salinity mass balance solves for the local variable *tempOutSaltMass*:

$$tempLocInSaltMass = \text{Outflow Salt Mass} - \text{Inflow Salt Mass} \\ + \text{Diversion Salt Mass} - \text{Return Flow Salt Mass} + \text{Salt Mass Removal}$$

After setting *tempLocInSaltMass* it then carries out the following logic to check if the Local Inflow Salt Mass should be adjusted:

IF $\text{Local Inflow} = 0$

IF $tempLocInSaltMass \geq 0$

IF $prevSaltStorage \geq tempLocInSaltMass$

Use any Salt Storage to make up the difference, so that Local Inflow Salt Mass will be zero. The change in Salt Storage will be accounted for at the end of the method

$$\text{Local Inflow Salt Mass} = 0$$

$$\text{Local Inflow Salt Concentration} = 0$$

ELSE

There is not enough Salt Storage to make up the difference. This would result in positive salt with no flow, so the run will abort.

END IF

ELSE (*tempLocInSaltMass* is negative or zero)

$$\text{Local Inflow Salt Mass} = 0$$

$$\text{Local Inflow Salt Concentration} = 0$$

Any change will be added to Salt Storage.

END IF

ELSE (Local Inflow is non-zero)

Incorporate salt from storage if there is any.

IF $LocalInflowVol \geq 0$

IF $isValid(\text{Minimum Salt Concentration})$

If the Minimum Salt Concentration is specified, calculate the corresponding minimum mass. Minimum Salt Concentration is generally an optional input, but it is a required input if using one of the Salt Removal methods on a linked Agg Diversion Site.

$$minLocalInSaltMass = \text{Minimum Salt Concentratoin} \times LocalInflowVol$$

ELSE

If the minimum is not specified, all Salt Storage will be incorporated.

$$minLocalInSaltMass = tempLocalInSaltMass - prevSaltStorage$$

END IF

ELSE

For a negative Local Inflow, incorporating more salt from storage will lower the Local

Inflow Salt Mass but will raise the Local Inflow Salt Concentration, so the minimum local inflow mass is based on the Maximum Salt Concentration.

$$minLocalInSaltMass = \text{Maximum Salt Concentration} \times LocalInflowVol$$

END IF

$$maxSaltFromStorage = tempLocalInSaltMass - minLocalInSaltMass$$

IF $maxSaltFromStorage \geq prevSaltStorage$

Use up all of the salt from storage.

$$\text{Local Inflow Salt Mass} = tempLocalInSaltMass - prevSaltStorage$$

ELSE

Using up all Salt Storage would take Local Inflow Salt Concentration below the minimum, so only take it down to the minimum.

$$\text{Local Inflow Salt Mass} = minLocalInSaltMass$$

This also takes care of the case when *tempLocalInSaltMass* is already less than the minimum. It will bring the local inflow salt up to the minimum, and the difference will get added to Salt Storage.

END IF

$$\text{Local Inflow Salt Concentration} = \frac{\text{Local Inflow Salt Mass}}{LocalInflowVol}$$

END IF

Calculate the change in Salt Storage.

$$deltaSaltStorage = \text{Local Inflow Salt Mass} - tempLocalInSaltMass$$

$$\text{Salt Storage} = prevSaltStorage + deltaSaltStorage$$

15.3.2.9 Solve Outflow TDG

This dispatch method is called when the Inflow, Outflow, Local Inflow, Inflow Salt Concentration and Outflow Salt Concentration slots are known and the Local Inflow Salt Concentration slot is unknown.

REQUIRED KNOWN SLOTS:

☞ **INFLOW TDG CONCENTRATION**

REQUIRED UNKNOWN SLOTS:

☞ **NONE**

This method executes the Water Quality Routing method, either **No Routing, TDG** or **Time Lag, TDG** **HERE (Section 15.2.2.20)**.

15.4 Utility Methods

Utility Methods are methods (subroutines, or functions) which do not belong to a user-selectable method type. Each of the utility methods outlined below is used by one or more of the methods above. Note that some of these methods set slots directly, while others, return values but do not set slots explicitly.

15.4.1 calcHar

This method returns Har (J/(m^2*day), the surface heat flux due to incoming solar radiation, using the following equation (Thomann and Mueller, 1987):

$$Har = \phi(T_a + 273)^4(A + 0.031\sqrt{\varepsilon_a}) \tag{15-61}$$

where

ϕ = Stefan-Boltzmann Constant (0.0049 J/(m^2*day*K))

Ta = air temperature (C)

ε_a = air vapor pressure

A = coefficient ralted to air temperature and ratio of measured radiation to clear sky radiation (0.5-0.7)

The values of the Stefan-Boltzmann constant and A are constants or internally set variables. Ta is user input through the Air Temperature slot, and air vapor pressure is returned by the getAirVaporPressure method (see below).

15.4.2 calcHbr

This method returns Hbr (J/(m^2*day), the longwave radiation emitted by the reach, using the Stefan-Boltzmann law for a (nearly perfect) black-body emitter:

$$Hbr = \varepsilon\phi(T_s + 273)^4 \tag{15-62}$$

where

ϕ = Stefan-Boltzmann Constant (0.0049 J/(m^2*day*K))

Ts = water surface(temperature (C))

ε = emissivity (0.97)

The values of the Stefan-Boltzmann constant and emissivity are static variables. Ts is the value of the reach segment temperature from the previous timestep (Distributed Temperature Output(-1)).

15.4.3 calcHc

This method returns Hc (J/(m^2*day), the heat flux at the reach surface due to conduction. The form of the equation is:

$$Hc = c_1(getWindEffect())(T_e - T_a)(41860) \quad \text{(15-63)}$$

where:

$$c_1 = \text{Bowen's Coefficient}(0.47 \text{ mmHG/ C})$$
$$T_e = Surface \text{ Temperature}$$
$$T_a = Air \text{ Temperature}$$

getWindEffect is a utility method (see below) and 41860 is the conversion rate from cal/cm^2 to J/m^2.

15.4.4 calcHe

This method returns He (J/(m^2*day)), the heat flux at the surface due to evaporative heat loss. The form of the equation is:

$$He = (\text{getWindEffect()})(VP_s - VP_a)(41860) \quad \text{(15-64)}$$

where

VP_s = value of surface vapor pressure returned from getSurfaceVaporPressure() utility method

VP_{sa} = value of air vapor pressure returned from getAirVaporPressure() utility method

getWindEffect is a utility method and 41860 is the conversion rate from cal/cm^2 to J/m^2.

15.4.5 checkSideFlowConcDO

The function checkSideFlowConcDO checks detritus, ammonia, dissolved organics, and dissolved oxygen concentrations associated with side flows and sets them if appropriate.

METHOD DETAILS:

First, if Local Inflow is not in use, issue an error.

Next, if Diversion concentration for each DO component is not valid, set it to the respective inflow concentrations. If the respective return flow concentrations or local inflow concentrations are linked but are not valid, the method is exited so that the other object can solve first and propagate a concentration across the link.

15.4.6 checkSideFlowConcSalt

The function checkSideFlowConcSalt checks salt concentrations associated with side flows.

First, if Local Inflow Salt Concentration is linked but not valid, exit the method and wait for it to become valid. If it is not linked, but Local Inflow is linked and Local Inflow Salt Concentration is not valid, issue an error that you should specify the value.

If Return Flow Salt Concentration is linked but not valid, exit the method and wait for it to become valid. If it is not linked, but Return Flow is linked and Return Flow Salt Concentration is not valid, issue an error that you should specify the value.

15.4.7 checkSideFlowTemp

The function, checkSideFlowTemp, checks temperatures associated with side flows and sets them if appropriate.

METHOD DETAILS:

First, if the previous Diversion Temperature is not valid, set a local variable *temp* to 10deg Celsius. Otherwise, set *temp* to the previous Diversion Temperature. This value is used to compute the density of the water. If the current Diversion Temperature is not valid, set it to:

$$diversionTemperature = \frac{inflowHeat}{density(temp) \times specificHeat \times InflowVol} \tag{15-65}$$

If Local Inflow is in use but Local Inflow Temperature is linked but not valid, exit the method and wait for it to become valid.

If Return Flow Temperature is linked but not valid, exit the method and wait for it to become valid.

15.4.8 defaultCalcSurfaceFlux

This method is called from solveTempWQcontrolVolume Explicit and solveTempControlVolumeImplcit. This method calls several subroutines, each of which calculate a specific flux type. The total flux is recorded in the Surface Heat Flux slot. It is the sum of incoming solar radiation (input variable), long and short wave back radiation (calcHar and calcHbr), conductive/convective (calcHc), and evaporative (calcHe) heat fluxes.

15.4.9 getAirVaporPressure

This method returns Air Vapor Pressure, the vapor pressure of the air mass overlying the reach

$$P_a = 4.596e^{\left(\frac{17.27T_d}{237.3 + T_d}\right)} \tag{15-66}$$

where

P_a = Vapor Pressure of Air

T_d = Dewpoint Temperature

15.4.10 getDensity

This method returns water density for a given temperature, temp. Calculations are based on the following polynomial relationship with temperature:

$$\rho = 1000(6.14x10^{-8}T^3 - 9.5x10^{-6}T^2 + 8.93x10^{-5}T + 0.999812) \tag{15-67}$$

If this value evaluates to a density greater than $1x10^6$ g/m^3, the method returns $1x10^6$ g/m^3.

15.4.11 getQualStep

The function getQualStep is called if one of the control volume explicit methods is selected. It looks at Maximum Flow Rate for WQ Stability provided by the user and sets an internal water quality timestep, Water Quality Timestep Computed, in order to satisfy stability. It also sets Num WQ Steps per Sim Timestep.

15.4.12 getSurfaceVaporPressure

This method returns Surface Vapor Pressure, the vapor pressure at the surface of the reach:

$$P_s = 4.596e^{\left(\frac{17.27T_s}{237.3 + T_s}\right)} \tag{15-68}$$

where

$$P_s = \text{Vapor Pressure at Reservoir Surface}$$
$$T_s = \text{Surface Temperature}$$

15.4.13 getWindEffect

This method returns Coefficient of Wind Effect, the effect of wind on the surface heat flux equations.

$$W = 19.0 + 0.95U^2 \tag{15-69}$$

where

$$W = \text{Wind Effect Coefficient}$$
$$U = \text{Wind Velocity}$$

15.4.14 solveNoRoutingDO

This method calculates Outflow Detritus Mass, Outflow Dissolved Organics Mass, Outflow Ammonia Mass, and Outflow Dissolved Oxygen Mass based on Inflow Detritus Mass, Inflow Diss Org Mass, Inflow Ammonia Mass, Inflow Diss Oxygen Mass and the associated side flow concentrations. Each constituent is calculated with the same basic equation where Constituent is DO variable.

$$\begin{aligned} outflowConstituentMass = {} & inflowConstituentMass \\ & + returnFlowVol \times returnFlowConstituentConc \\ & - diversionVol \times diversionConstituentConc \\ & + localInflowVol \times localInflowConstituentConc \end{aligned} \tag{15-70}$$

15.4.15 solveNoRoutingOutSalt

This method calculates Outflow Salt Mass and Concentration based on Inflow Salt Conc, Return Flow Salt Concentration, Diversion Salt Concentration, Local Inflow Salt Concentration, Seepage Salt Concentration (if modeled) and the respective flows as follows:

If Diversion Salt Concentration is not input or set by a rule, then it is set to the Inflow Salt Concentration.

When a non-default Seepage method is selected and the water quality approach is Discretized Salt, Seepage Salt Concentration and Seepage Salt Mass slots are available. If Seepage is positive, the Seepage Salt Concentration is set to the Inflow Salt Concentration. If Seepage is negative, the Seepage Salt Concentration must be specified possibly by a link to a slot on another object. If Seepage Salt Concentration is linked but not valid, the reach exits the dispatch method and waits until the seepage Salt Concentration is available from that object. Seepage Salt Mass is computed from the Seepage Salt Concentration and the Seepage.

Note: Although there are Seepage Routing methods, these only serve to compute the Seepage at the current timestep. In general, Outflow = Inflow - Seepage. Thus, the Seepage Salt concentration does not need to be routed; it is just the value at that timestep.

Then, for each constituent, if the concentration and the flow is valid, the mass is computed. Otherwise the mass is considered zero, but not set.

Finally:

$$\begin{aligned} outflowSaltMass = {} & InflowSaltMass - SeepageSaltMass - DiversionSaltMass + \\ & LocalInflowSaltMass + returnFlowSaltMass \end{aligned} \tag{15-71}$$

Finally, Outflow Salt Concentration is computed from the Outflow and Outflow Salt Mass.

15.4.16 solveNoRoutingTemp

This method calculates Outflow Heat based on Inflow Heat, Return Flow Temperature, Diversion Temperature, and Local Inflow Salt Temperature.

$$\begin{aligned} outflowHeat = {} & inflowHeat \\ & + returnFlowVol \times returnFlowTemp \times \rho \times H \\ & - diversionVol \times diversionTemp \times \rho \times H \\ & + localInflowVol \times localInflowTemp \times \rho \times H \end{aligned} \tag{15-72}$$

where ρ is water density and H is Specific Heat of Water.

15.4.17 solveSaltWQcontrolVolumeExplicit

There are two control volume water quality methods: `controlVolumeExplicit` and `controlVolumeImplicit`. Both of these methods utilize the discretized hydraulic variables generated from the hydraulic routing methods. Therefore a hydraulic routing method must be used with the control volume water quality methods. The difference between controlVolumeExplicit and controlVolumeImplicit is simply in the solution technique described in the following sections

This method uses the following mass balance equation for a conservative substance to Calculate Distributed Salt Concentration Output, the salt concentrations of each discretized segment of the reach.

This function also sets Outflow Salt Mass for the reach.

$$\frac{M_i^{t+1} - M_i^t}{\Delta t} = c_{i-1}^t\left(Q_{(i-1),i}^t + E\frac{A_{(i-1),i}^t}{\Delta x}\right) + c_i^t\left(-Q^t{}_{(i+1),i} - E\frac{A_{(i+1),i}^t}{\Delta x} - E\frac{A_{(i-1),i}^t}{\Delta x}\right) + c_{i+1}^t\left(E\frac{A_{(i+1),i}^t}{\Delta x}\right) \tag{15-73}$$

where M = salt mass [M], c = salt concentration [M/L^3], E = longitudinal dispersion coefficient [L^2/T], and A = cross sectional area [L^2].

15.4.18 solveSaltWQcontrolVolumeImplicit

This method uses the following mass balance equation for a conservative substance to calculate Distributed Salt Concentration Output, the salt concentrations of each discretized segment of the reach. This function also sets Outflow Salt Mass for the reach.

$$\frac{M_i^{t+1} - M_i^t}{\Delta t} = c_{i-1}^{t+1}(Q_{(i-1),i}^t) + c_i^{t+1}(-Q^t{}_{(i+1),i}) \tag{15-74}$$

15.4.19 solveTempWQcontrolVolumeExplicit

This method uses the following mass balance equation to calculate Distributed Temperature Output, the temperature of each discretized segment of the reach. This function also sets Outflow Heat for the reach.

$$\frac{(TV)_i^{t+1} - (TV)_i^t}{\Delta t} = T_{i-1}^t\left(Q_{(i-1),i}^t + E\frac{A_{(i-1),i}^t}{\Delta x}\right) + T_i^t\left(-Q^t{}_{(i+1),i} - E\frac{A_{(i+1),i}^t}{\Delta x} - E\frac{A_{(i-1),i}^t}{\Delta x}\right) + T_{i+1}^t\left(E\frac{A_{(i+1),i}^t}{\Delta x}\right) + \frac{\Delta HA_{si}^t}{\rho c} \tag{15-75}$$

where T = water temperature, V = elemental volume [L^3], ΔH = flux of thermal energy across the system boundaries [H/L^2/T], A_{si} = water surface area [L^2], ρ = water density [M/L^3], and c = specific heat of water [H/M/Temp.]

15.4.20 solveTempWQcontrolVolumeImplicit

This method uses the following mass balance equation to calculate Distributed Temperature Output, the temperature of each discretized segment of the reach. This function also sets Outflow Heat for the reach.

$$\frac{(TV)_i^{t+1} - (TV)_i^t}{\Delta t} = T_{i-1}^{t+1}(Q_{(i-1),i}^t) + T_i^{t+1}(-Q^t{}_{(i+1),i}) + \frac{\Delta HA_{si}^t}{\rho c} \tag{15-76}$$

15.4.21 solveTimeLagDO

This method calculates Outflow Detritus Mass, Outflow Diss Org Mass, Outflow Ammonia Mass, and Outflow Diss Oxygen Mass at future timesteps based on Inflow Detritus Mass, Inflow Diss Org Mass, Inflow Ammonia Mass, Inflow Diss Oxygen Mass at the current timestep and Lag Time of the reach.

15.4.22 solveTimeLagOutSalt

This method calculates Outflow Salt Concentration and Mass at future timesteps based on Inflow Salt Concentration at the current timestep and Lag Time of the reach.

15.4.23 solveVarTimeLagOutSalt

This method calculates Outflow Salt Concentration and Mass at future timesteps based on Inflow Salt Concentration at the current timestep (and previous timesteps) and Variable Lag Time of the reach.

This method executes when the Inflow Salt Concentration is known for the current timestep. The resulting Inflow Salt Mass is computed using the Inflow. Outflow Salt Concentration (and Mass) values are solved for at the timesteps corresponding to the Variable Lag Time. A sample calculation is given below:

$$\text{OutflowSaltMass(intger value of Variable Lag Time)} = \text{flowFrac1} \bullet (\text{InflowSaltMass})$$

$$\text{Outflow(integer value of Variable Lag Time + 1)} = \text{flowFrac2} \bullet (\text{InflowSaltMass})$$

where flowFrac1 and flowFrac2 to are calculated by the following equations:

$$\text{flowFrac1} = 1 - \left(\frac{\text{Variable Lag Time}}{\text{timestep}} - (integerValueOf)\frac{\text{Variable Lag Time}}{\text{timestep}}\right)$$

$$\text{flowFrac2} = 1 - \text{flowFrac1}$$

In the equations given above, the integer value of a number means that the number is truncated after the decimal point with no rounding.

Since the lag time can vary with every timestep, it possible that more the one Inflow Salt Mass can contribute to a particular Outflow Salt Mass/Concentration. This method may set multiple Outflow Salt Mass/Concentrations (up to the max lag) based on a range of previous and future Inflow Salt Mass values.

15.4.24 solveTimeLagTemp

This method calculates Outflow Heat based at future timesteps based on Inflow Heat at the current timestep and Lag Time of the reach.

15.4.25 setWQInitConds

The function getQualStep is called if one of the control volume methods (either explicit or implicit) is selected. It sets initial salt concentrations and temperatures in each internal reach segment by setting previous values on Distributed Salt Concentration Output, and Distributed Temperature Output.

Reservoir Water Quality

16. Reservoirs

The description of water quality for all reservoirs is contained in this section. There are no fundamental differences in the water quality methods between the Storage, Level Power, Slope Power, and Pumped Storage Reservoirs. Slope Power Reservoirs differ from the others slightly because they account for concentrations transported by an additional side flow, Inflow 2.

The current implementation of the reservoir water quality model allows the user to model:

- Salinity with a simple well-mixed approach or layered approach.
- Temperature along with any combination of dissolved oxygen and salinity with a layered approach.
- TDG Outflow Concentration based on the Tailwater Depth.

The algorithms employed are explicit, which allows for ease of implementation and eliminates the need to iterate between objects or between water quality and water quantity calculations (which would be necessary if evaporation was based on heat flux).

16.1 Slots

Following is a description of each of the slots for the various constituents. They are organized by water quality constituents: Temperature Slots, Salinity Slots, and Dissolved Oxygen Slots. The appropriate slots are instantiated when the user selects a Reservoir Water Quality method. Note, TDG related slots are included in the TDG section, HERE (Section 16.4.49.1).

16.1.1 Temperature Slots

The following slots are instantiated if temperature is one of the constituents.

☞ **RESERVOIR BOTTOM ELEVATION**

Type: Table Slot
UNITS: LENGTH
Description: 1X1 table slot representing the elevation (above some common datum) of the bottom of the reservoir at the dam
Information: Used to calculate a mean depth at the dam.
Links: Not Linkable

☞ Thickness of Epilimnion
Type: Table Slot
Units: Length
Description: 1X1 table slot representing the thickness of the epilimnion layer
I/O: Must be input by user.
Links: Not Linkable

☞ Thickness of Metalimnion
Type: Table Slot
Units: Length
Description: 1X1 table slot representing the thickness of the metalimnion layer (also known as the thermocline)
I/O: Must be input by user.
Links: Not Linkable

☞ Elevation of Thermocline
Type: Series Slot
Units: Length
Description: elevation of the thermocline.
Information: Pool Elevation minus the Epilimnion Thickness
I/O: Output only
Links: Not Linkable

☞ Inflow to Epilimnion
Type: Series Slot
Units: Flow
Description: inflow contribution to the epilimnion layer
Information: Inflow to Hypolimnion + Inflow to Epilimnion = Inflow.
I/O: Output only
Links: Not Linkable

☞ Outflow from Epilimnion
Type: Series Slot
Units: Flow
Description: portion of release coming from the epilimnion
I/O: Output only
Links: Not Linkable

☞ Epilimnion Volume
Type: Series Slot
Units: Volume
Description: amount of water in the epilimnion
I/O: Output only
Links: Not Linkable

☞ Inflow to Hypolimnion
Type: Series Slot
Units: Flow
Description: inflow contribution to the hypolimnion layer
Information: Hypolimnion inflow + epilimnion inflow = inflow.
I/O: Output only
Links: Not Linkable

☞ Outflow from Hypolimnion
Type: Series Slot
Units: Flow
Description: portion of release coming from the hypolimnion
I/O: Output only
Links: Not Linkable

☞ Hypolimnion Volume
Type: Series Slot
Units: Volume
Description: amount of water in the hypolimnion
Information: Output only
I/O: Not Linkable

☞ Thermocline Diffusion Coefficient
Type: Series Slot
Units: AreaPerTime
Description: diffusion rate through thermocline
I/O: Output only
Links: Not Linkable

☞ Thermocline Diffusion Coefficient Adjustment
Type: Series Slot
Units: NoUnits
Description: scaling factor used to adjust diffusion depending on the Julian date
I/O: This slot is equal to 1.0 if not user input.
Links: Not Linkable

☞ Surface Area
Type: Series Slot
Units: Area
Description: The surface area of the reservoir
I/O: Output only
Links: Not Linkable

☞ ELEVATION AREA TABLE
Type: Table
UNITS: LENGTH VS AREA
Description: A table relating pool elevation to surface area
I/O: Required Input
Links: Not Linkable

☞ INFLOW HEAT
Type: Multi Slot
UNITS: HEAT
Description: holds the values of inflow heat for each inflow to the reservoir
I/O: Input, set by a rule, output or propagated via a link
Links: This slot can be linked to the Outflow Heat slot of an upstream object.

☞ OUTFLOW HEAT
Type: Series Slot
UNITS: HEAT
Description: temperature of releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Heat slot of a downstream object.

☞ TEMPERATURE
Type: Agg Series Slot
UNITS: TEMPERATURE
Description: contains the inflow temperature, outflow temperature, total inflow temperature, hydrologic inflow temperature, epilimnion temperature, and hypolimnion temperature.
I/O: Most values of this slot are calculated; however, hydrologic inflow temperature may be input and initial epilimnion and hypolimnion temperatures must be input.
Links: Not Linkable

☞ DIVERSION TEMP
Type: Series Slot
UNITS: TEMPERATURE
Description: temperature of Diversion.
I/O: Input, set by a rule, output or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Temp is set to zero. Otherwise, it is set to the previous epilimnion temperature during calculations.

☞ Return Flow Temp

Type: Series Slot
UNITS: TEMPERATURE
Description: temperature of Return Flow.
I/O: Input, set by a rule, output or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Temp is set to zero.

☞ Canal Flow Temp

Type: Series Slot
UNITS: TEMPERATURE
Description: temperature of Canal Flow.
I/O: Input, set by a rule, output or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Temp is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Temp is set to the previous epilimnion temperature. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Temp

Type: Series Slot
UNITS: TEMPERATURE
Description: temperature of inflow from Pumped Storage Reservoir.
I/O: Input, set by a rule, output or propagated via a link
Links: If Flow FROM Pumped Storage and not linked or is not valid, Pump Storage Inflow Temp is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Temp

Type: Series Slot
UNITS: TEMPERATURE
Description: temperature of outflow to Pumped Storage Reservoir.
I/O: Input, set by a rule, output or propagated via a link
Links: If Flow TO Pumped Storage and not linked or is not valid, Pump Storage Outflow Temp is set to zero. Otherwise, it is set to the previous epilimnion temperature during calculations.

☞ Specific Heat of Water

Type: Table Slot
UNITS: SPECIFICHEAT
Description: specific heat of water. Used for heat / temperature conversions.
I/O: Input or defaults to standard value
Links: Not Linkable

☞ **Heat of Evaporation**
Type: Series Slot
Units: EnergyFlux
Description: heat used in evaporation during the timestep
Information: Calculated by the calcHe function.
I/O:
Links:

☞ **Surface Heat Flux**
Type: Series Slot
Units: EnergyFlux
Description: total gain or loss from evaporation, incoming solar, convection, back radiation, etc. at the reservoir surface
Information: Output only
I/O: Not Linkable

☞ **Air Temperature**
Type: Series Slot
Units: Temperature
Description: air temperature at the reservoir surface
I/O: Input only
Links: Not Linkable

☞ **Dewpoint Temperature**
Type: Series Slot
Units: Temperature
Description: dewpoint temperature at the reservoir surface
I/O: Input only
Links: Not Linkable

☞ **Incoming Solar Radiation**
Type: Series Slot
Units: HeatFlux
Description: incoming solar radiation received by the reservoir
I/O: Input only
Links: Not Linkable

☞ **Wind Velocity**
Type: Series Slot
Units: Velocity
Description: wind velocity at reservoir surface
I/O: This slot is assumed to be zero if not a user input.
Links: Not Linkable

16.1.2 Salinity Slots

The following three sections describe the salt slots.

16.1.2.1 Well Mixed Salt Slots

The following water quality slots are instantiated:

☞ **INFLOW SALT CONCENTRATION**
Type: Multi Slot
UNITS: CONCENTRATION
Description: holds the values of inflow salinity for each inflow to the reservoir
Information: Because this slot is a multi-slot, more than one link can be created to this slot which will add columns to the slot. The first column is the sum of the other columns but does not represent the inflow concentration. The dispatch methods do a weighted average to determine the weighted concentration, but this is not displayed in the slot.
I/O: Input, set by a rule, output or propagated via a link
Links: This slot can be linked to the Outflow Salt Concentration of an upstream object.

☞ **INFLOW SALT MASS**
Type: Multi Slot
UNITS: MASS
Description: holds the values of inflow salinity for each inflow to the reservoir
I/O: Output only
Links: This slot can be linked to the Outflow Salt Mass of an upstream object.

☞ **HYDROLOGIC INFLOW SALT CONC**
Type: Series Slot
UNITS: CONCENTRATION
Description: salt concentration of hydrologic inflows.
I/O: Input, set by a rule, output or propagated via a link
Links: This slot can be linked to a slot representing the Outflow Salt Concentration from an upstream object.

☞ **HYDROLOGIC INFLOW SALT MASS**
Type: Series Slot
UNITS: MASS
Description: holds the values of inflow salinity for each hydrologic inflow to the reservoir
I/O: Output only
Links: Not linkable

☞ Diversion Salt Concentration
Type: Series Slot
Units: Concentration
Description: salt concentration of Diversion.
I/O: Input, set by a rule, output or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Salt Concentration is set to zero. Otherwise, it is set to the previous epilimnion salt concentration during calculations.

☞ Diversion Salt Mass
Type: Series Slot
Units: Mass
Description: The mass values of salt that is diverted from the reservoir
I/O: Output only
Links: Not Linkable

☞ Return Flow Salt Mass
Type: Multi Slot
Units: Mass
Description: The mass values of salt in each return flow to the reservoir.
I/O: Input, set by a rule, output or propagated via a link
Links: Linkable to return flow salt mass on another object

☞ Return Flow Salt Conc
Type: Series Slot
Units: Concentration
Description: The salt concentration for the return flow to the reservoir.
I/O: Output only
Links: This slot should not be linked for Well Mixed Salt. Instead, link Return Flow Salt Mass.

☞ Outflow Salt Concentration
Type: Series Slot
Units: Concentration
Description: salinity of releases from the reservoir
I/O: Input, set by a rule, output or propagated via a link
Links: This slot can be linked to the Inflow Salt Concentration of a downstream object.

☞ Outflow Salt Mass
Type: Series Slot
Units: Mass
Description: salt mass in releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Salt Mass slot of a downstream object.

☞ **RESERVOIR SALT CONCENTRATION**

Type: Series Slot
UNITS: CONCENTRATION
Description: salt concentration of reservoir
Information: If not input at the initial timestep, this will default to zero.
I/O: Output only
Links: Not Linkable

☞ **RESERVOIR SALT MASS**

Type: Series Slot
UNITS: MASS
Description: Mass of salt in the reservoir
Information: $\text{Reservoir Salt Mass} = (\text{Reservoir Salt Concentration} \times (\text{Storage} + \text{Dead Storage}))$
I/O: Output only
Links: Not Linkable

☞ **DEAD STORAGE**

Type: Table Slot
UNITS: VOLUME
Description: dead storage volume.
I/O: Input, if not valid at initial timestep, this will default to zero.
Links: Not Linkable

16.1.2.2 Layered salt slots

The following slots are added for the **Layered Salt**, **Layered Temp and Salt**, and **Layered Temp Salt and DO**:

☞ **INFLOW SALT MASS**

Type: Multi Slot
UNITS: MASS
Description: holds the values of inflow salinity for each inflow to the reservoir
I/O: Input, rules, output, or propagated via a link
Links: Linkable, but instead the Salt Concentration should be linked.

☞ **INFLOW SALT CONCENTRATION**

Type: Multi Slot
UNITS: CONCENTRATION
Description: holds the values of inflow salinity for each inflow to the reservoir
Information: Because this slot is a multi-slot, more than one link can be created to this slot which will add columns to the slot. The first column is the sum of the other columns but does not correctly represent the inflow concentration. The dispatch methods do a

weighted average to determine the weighted concentration, but this is not displayed in the slot.
I/O: Input, rules, output, or propagated via a link.
Links: This slot can be linked to the Outflow Salt Concentration of an upstream object.

☞ Outflow Salt Mass

Type: Series Slot
Units: Mass
Description: salt mass in releases from the reservoir
I/O: Output only
Links: Linkable, but instead the Salt Concentration should be linked.

☞ Outflow Salt Concentration

Type: Series Slot
Units: Concentration
Description: holds the values of outflow salinity from the reservoir
I/O: Output
Links: This slot can be linked to the Outflow Salt Concentration of a downstream object.

☞ Salt Concentrations

Type: Agg Series Slot
Units: Concentration
Description: contains the inflow salt concentration, outflow salt concentration, total inflow salt concentration, hydrologic inflow salt concentration, epilimnion salt concentration, and hypolimnion salt concentration.
I/O: Most values of this slot are calculated; however, hydrologic inflow salt concentration may be input and initial epilimnion and hypolimnion salt concentrations must be input.
Links: Not Linkable

☞ Diversion Salt Concentration

Type: Series Slot
Units: Concentration
Description: salt concentration of Diversion.
I/O: Input, rules, output, or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Salt Concentration is set to zero. Otherwise, it is set to the previous epilimnion salt concentration during calculations.

☞ Return Flow Salt Conc

Type: Multi Slot
Units: Concentration
Description: salt concentration of Return Flow.
Information: When there are multiple links to this slot, the subslots will be shown. The first column is the sum column, which is not relevant as these are concentrations not mass.
I/O: Input, rules, output, or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Salt Conc is set to zero.

☞ Canal Flow Salt Conc

Type: Series Slot
Units: Concentration
Description: salt concentration of Canal Flow.
I/O: Input, rules, output, or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Salt Conc is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Salt Conc is set to the previous epilimnion salt concentration. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Salt

Type: Series Slot
Units: Concentration
Description: salt concentration of inflow from Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow FROM Pumped Storage and not linked or is not valid, Pump Storage Inflow Salt is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Salt

Type: Series Slot
Units: Concentration
Description: salt concentration of outflow to Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow TO Pumped Storage and not linked or is not valid, Pump Storage Outflow Salt is set to zero. Otherwise, it is set to the previous epilimnion salt concentration during calculations.

☞ **INFLOW2 SALT CONCENTRATION**

Type: Series Slot
UNITS: CONCENTRATION
Description: holds the values of Inflow 2 salinity to the reservoir
Information: This slot is on a Sloped Power Reservoir only.
I/O: Input, propagated, or set by a rule.
Links: Linkable

☞ **INFLOW2 SALT MASS**

Type: Series Slot
UNITS: MASS
Description: holds the values of Inflow 2 salt mass entering the reservoir
Information: This slot is on a Sloped Power Reservoir only.
I/O: Output only
Links: Not linkable

16.1.2.3 Segmented 2 Layer Salt slots

The following slots are added for the **Segmented 2 Layer Salt** method:

16.1.2.3.1 Flow and Volume Slots

☞ **EPILIMNION INFLOW BY SEGMENT**

Type: Agg Series Slot
UNITS: FLOW
Description: Flow into the epilimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ **HYPOLIMNION INFLOW BY SEGMENT**

Type: Agg Series Slot
UNITS: FLOW
Description: Flow into hypolimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Epilimnion Outflow By Segment

Type: Agg Series Slot
Units: Flow
Description: Flow out of the epilimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Hypolimnion Outflow By Segment

Type: Agg Series Slot
Units: Flow
Description: Flow out of hypolimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Epilimnion Volume By Segment

Type: Agg Series Slot
Units: Volume
Description: Volume in the epilimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Hypolimnion Volume By Segment

Type: Agg Series Slot
Units: Volume
Description: Volume in the hypolimnion for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Vertical Flow By Segment

Type: Agg Series Slot
Units: Flow
Description: Flow from the epilimnion to hypolimnion in the reservoir.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output Only
Links: Not linkable

☞ Bank Storage By Segment

Type: Agg Series Slot
UNITS: VOLUME
Description: Volume in the bank storage for each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Diversion By Segment

Type: Agg Series Slot
UNITS: FLOW
Description: Diversions from each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Return Flow By Segment

Type: Agg Series Slot
UNITS: FLOW
Description: Return flow to each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Hydrologic Inflow By Segment

Type: Agg Series Slot
UNITS: FLOW
Description: Hydrologic inflows to each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Evaporation By Segment

Type: Agg Series Slot
UNITS: VOLUME
Description: Volume of evaporation from each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ **PRECIPITATION BY SEGMENT**
Type: Agg Series Slot
UNITS: VOLUME
Description: Volume of precipitation into each reservoir segment.
Information: There is one column for each reservoir segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

16.1.2.3.2 Salt Concentration and Mass Slots

☞ **INFLOW SALT MASS**
Type: Series Slot
UNITS: MASS
Description: Mass of salt entering the reservoir in the inflow.
Information:
I/O: Input or Output
Links: Maybe linked

☞ **INFLOW SALT CONCENTRATION**
Type: Series Slot
UNITS: CONCENTRATION
Description: Salt concentration entering in the inflow.
Information:
I/O: Input or Output
Links: Maybe linked to outflow salt concentration slots.

☞ **OUTFLOW SALT MASS**
Type: Series Slot
UNITS: MASS
Description: Mass of salt leaving the reservoir in the outflow.
Information:
I/O: Output only
Links: Maybe linked to the inflow of other objects.

☞ **OUTFLOW SALT CONCENTRATION**
Type: Series Slot
UNITS: CONCENTRATION
Description: Salt concentration leaving the reservoir.
Information:
I/O: Output only
Links: Maybe linked to the inflow of other objects.

☞ Diversion Salt Mass

Type: Series Slot
Units: Mass
Description: Mass leaving the reservoir in diversions.
Information:
I/O: Output only
Links: Not Linkable

☞ Diversion Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration in the diversions from the reservoir.
Information:
I/O: Output only
Links: Linkable

☞ Return Flow Salt Mass

Type: Series Slot
Units: Mass
Description: Mass entering the reservoir in return flows.
Information:
I/O: Output only
Links: Not Linkable

☞ Return Flow Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration reentering the reservoir in the return flow.
Information:
I/O: Output only
Links: Linkable

☞ Hydrologic inflow Salt Mass

Type: Series Slot
Units: Mass
Description: Mass entering the reservoir in hydrologic inflows.
Information:
I/O: Output only
Links: Not Linkable

☞ Hydrologic Inflow Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration entering the reservoir in the hydrologic inflows.
Information:
I/O: Input or output
Links: Linkable

☞ Bank Storage Salt Concentration

Type: Series Slot
Units: Concentration
Description: Salt concentration in the bank storage.
Information:
I/O: Output only
Links: Not Linkable

☞ Epilimnion Salt Concentration By Segment

Type: Agg Series Slot
Units: Concentration
Description: The salt concentration in the epilimnion of each segment.
Information: One column for each segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Epilimnion Salt Mass By Segment

Type: Agg Series Slot
Units: Mass
Description: The salt mass in the epilimnion of each segment.
Information: One column for each segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ Hypolimnion Salt Concentration By Segment

Type: Agg Series Slot
Units: Concentration
Description: The salt concentration in the hypolimnion of each segment.
Information: One column for each segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ **Hypolimnion Salt Mass By Segment**

Type: Agg Series Slot
Units: Mass
Description: The salt mass in the hypolimnion of each segment.
Information: One column for each segment. The model must be initialized to update the number of segments in this aggregate series slot.
I/O: Output only
Links: Not linkable

☞ **Reservoir Salt Mass**

Type: Series Slot
Units: Mass
Description: The salt mass in the entire volume of the reservoir.
Information:
I/O: Output only
Links: Not linkable

16.1.2.3.3 Method Parameter Slots

☞ **Thermocline Elevation**

Type: Scalar
Units: Length
Description: The elevation where the hypolimnion and epilimnion are separated. This elevation is constant.
Information:
I/O: Input only
Links: Not linkable

☞ **Thermocline Thickness**

Type: Series with periodic input
Units: Length
Description: The thickness of the thermocline; used to calculate diffusion between the epilimnion and hypolimnion.
Information:
I/O: Input only
Links: Not Linkable

☞ THERMOCLINE DIFFUSIVITY

Type: Series with periodic input
UNITS: AREA PER TIME
Description: The diffusivity of the thermocline; used to calculate the diffusion of salt across the thermocline.
Information:
I/O: Input only
Links: Not Linkable

☞ NUMBER OF SEGMENTS

Type: Scalar
UNITS: NONE
Description: This slot specifies the total number of segments, N, in the reservoir.
Information: This slot is used to update other Agg Series and Table slots with the correct number of segments. The model must be initialized to update the number of segments in the other slots slot.
I/O: Input only
Links: Not linkable

☞ SEGMENT PARAMETER TABLE

Type: Table Slot
UNITS: NONE
Description: This slot holds segment parameters, including the Segment Bank Storage Proportion, the Segment Diversion Proportion, the Segment Return Flow Proportion, and the Segment Hydrologic Inflow Proportion.
Information: There will be 4 columns: Segment Bank Storage Proportion, Segment Diversion Proportion, Segment Return Flow Proportion, and Segment Hydrologic Inflow Proportion. The values in each column must add to 1.
I/O: Input only
Links: Not linkable

☞ DEAD STORAGE

Type: Table
UNITS: VOLUME
Description: The reservoir volume not accessible to outflow from the reservoir, and therefore not included in the Elevation Volume Table. This volume will be included in concentration and interior flow calculations for the reservoir.
Information: There is a row for each segment.
I/O: Input only
Links: Not linkable

☞ **Elevation Volume Table By Segment**

Type: Table Slot
Units: Length, Volume
Description: The Elevation Volume table for each segment will be input by the user. All the Elevation Volume Segment tables should add up to the reservoir Elevation Volume table plus the dead storage. The Dead Storage should not be added into the Elevation Storage Segment Table.
Information: The first column will be elevation. The second will be the first segment, and each additional column added to the table will be for any additional segments.
I/O: Input only
Links: Not linkable

☞ **Elevation Area Table By Segment**

Type: Table Slot
Units: Length, Area
Description: The Elevation Area table for each segment will be input by the user. All the Elevation Area Segment tables should add up to the reservoir Elevation Surface Area table.
Information: The first column will be elevation. The second will be the first segment, and each additional column added to the table will be for any additional segments.
I/O: Input only
Links: Not linkable

16.1.3 Dissolved Oxygen Slots

The following slots are instantiated for the **Layered Temp and DO** and **Layered Temp Salt and DO**.

☞ **Inflow Detritus Mass**

Type: Multi Slot
Units: Mass
Description: holds the values of inflow detritus for each inflow to the reservoir
I/O: Typically a Required Known when simulating DO. Input, rules, or propagated via a link.
Links: This slot can be linked to the Outflow Detritus Mass slot of an upstream object.

☞ **Outflow Detritus Mass**

Type: Series Slot
Units: Mass
Description: detritus mass in releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Detritus Mass slot of a downstream object.

☞ **Detritus Concentrations**

Type: Agg Series Slot
Units: Concentration
Description: contains the inflow detritus concentration, outflow detritus concentration, total inflow detritus concentration, hydrologic inflow detritus concentration, epilimnion detritus concentration, and hypolimnion detritus concentration.
I/O: Most values of this slot are calculated; however, hydrologic inflow detritus concentration may be input and initial epilimnion and hypolimnion detritus concentrations must be input.
Links: Not Linkable

☞ **Inflow Dissolved Organics Mass**

Type: Multi Slot
Units: Mass
Description: holds the values of inflow dissolved oxygen for each inflow to the reservoir
I/O: Input, rules, or propagated via a link
Links: This slot can be linked to the Outflow Dissolved Organics Mass slot of an upstream object.

☞ **Outflow Dissolved Organics Mass**

Type: Series Slot
Units: Mass
Description: dissolved oxygen mass in releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Dissolved Organics Mass slot of a downstream object.

☞ **Inflow Dissolved Oxygen Mass**

Type: Multi Slot
Units: Mass
Description: holds the values of inflow dissolved oxygen for each inflow to the reservoir
I/O: Input, rules, or propagated via a link
Links: This slot can be linked to the Outflow Dissolved Oxygen Mass slot of an upstream object.

☞ **Diversion Detritus Conc**

Type: Series Slot
Units: Concentration
Description: detritus concentration of Diversion.
I/O: Input, rules, or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Detritus Conc is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Return Flow Detritus Conc
Type: Series Slot
Units: Concentration
Description: detritus concentration of Return Flow.
I/O: Input, rules, output, or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Detritus Conc is set to zero.

☞ Canal Flow Detritus Conc
Type: Series Slot
Units: Concentration
Description: detritus concentration of Canal Flow.
I/O: Input, rules, or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Detritus Conc is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Detritus Conc is set to the previous epilimnion detritus concentration. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Detritus
Type: Series Slot
Units: Concentration
Description: detritus concentration of inflow from Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow FROM Pumped Storage and not linked or is not valid, Pump Storage Inflow Detritus is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Detritus
Type: Series Slot
Units: Concentration
Description: detritus concentration of outflow to Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow TO Pumped Storage and not linked or is not valid, Pump Storage Outflow Detritus is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Dissolved Organics Concentrations
Type: Agg Series Slot
Units: Concentration
Description: contains the inflow dissolved organics concentration, outflow dissolved organics concentration, total inflow dissolved organics concentration, hydrologic inflow

dissolved organics concentration, epilimnion dissolved organics concentration, and hypolimnion dissolved organics concentration.

I/O: Most values of this slot are calculated; however, hydrologic inflow dissolved organics concentration may be input and initial epilimnion and hypolimnion dissolved organics concentrations must be input.

Links: Not Linkable

☞ Diversion Dissolved Organics Conc

Type: Series Slot
Units: Concentration
Description: dissolved organics concentration of Diversion.
I/O: Input, rules, or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Dissolved Organics Conc is set to zero. Otherwise, it is set to the previous epilimnion dissolved organics concentration during calculations.

☞ Return Flow Dissolved Organics Conc

Type: Series Slot
Units: Concentration
Description: dissolved organics concentration of Return Flow.
I/O: Input, rules, or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Dissolved Organics Conc is set to zero.

☞ Canal Flow Dissolved Organics Conc

Type: Series Slot
Units: Concentration
Description: dissolved organics concentration of Canal Flow.
I/O: Input, rules, or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Dissolved Organics Conc is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Dissolved Organics Conc is set to the previous epilimnion dissolved organics concentration. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Organics

Type: Series Slot
Units: Concentration
Description: dissolved organics concentration of inflow from Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow FROM Pumped Storage and not linked or is not valid, Pump Storage Inflow Organics is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Organics

Type: Series Slot
Units: Concentration
Description: dissolved organics concentration of outflow to Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow TO Pumped Storage and not linked or is not valid, Pump Storage Outflow Organics is set to zero. Otherwise, it is set to the previous epilimnion dissolved organics concentration during calculations.

☞ Inflow Ammonia Mass

Type: Multi Slot
Units: Mass
Description: holds the values of inflow ammonia for each inflow to the reservoir
I/O: Typically a Required Known when simulating DO; Input, rules, or propagated via a link
Links: This slot can be linked to the Outflow Ammonia Mass slot of an upstream object.

☞ Outflow Ammonia Mass

Type: Series Slot
Units: Mass
Description: ammonia mass in releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Ammonia Mass slot of a downstream object.

☞ Ammonia Concentrations

Type: Agg Series Slot
Units: Concentration
Description: contains the inflow detritus concentration, outflow detritus concentration, total inflow detritus concentration, hydrologic inflow detritus concentration, epilimnion detritus concentration, and hypolimnion detritus concentration.
I/O: Most values of this slot are calculated; however, hydrologic inflow detritus concentration may be input and initial epilimnion and hypolimnion detritus concentrations must be input.
Links: Not Linkable

☞ Diversion Ammonia Conc

Type: Series Slot
Units: Concentration
Description: detritus concentration of Diversion.
I/O: Input, rules, or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Ammonia Conc is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Return Flow Ammonia Conc

Type: Series Slot
Units: Concentration
Description: detritus concentration of Return Flow.
I/O: Input, rules, or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Ammonia Conc is set to zero.

☞ Canal Flow Ammonia Conc

Type: Series Slot
Units: Concentration
Description: detritus concentration of Canal Flow.
I/O: Input, rules, or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Ammonia Conc is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Ammonia Conc is set to the previous epilimnion detritus concentration. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Ammonia

Type: Series Slot
Units: Concentration
Description: detritus concentration of inflow from Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow FROM Pumped Storage and not linked or is not valid, Pump Storage Inflow Ammonia is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Ammonia

Type: Series Slot
Units: Concentration
Description: detritus concentration of outflow to Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: If Flow TO Pumped Storage and not linked or is not valid, Pump Storage Outflow Ammonia is set to zero. Otherwise, it is set to the previous epilimnion detritus concentration during calculations.

☞ Outflow Dissolved Oxygen Mass

Type: Series Slot
Units: Mass
Description: dissolved oxygen mass in releases from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Dissolved Oxygen Mass slot of a downstream object.

☞ Dissolved Oxygen Concentrations

Type: Agg Series Slot
Units: Concentration
Description: contains the inflow dissolved oxygen concentration, outflow dissolved oxygen concentration, total inflow dissolved oxygen concentration, hydrologic inflow dissolved oxygen concentration, epilimnion dissolved oxygen concentration, and hypolimnion dissolved oxygen concentration.
I/O: Most values of this slot are calculated; however, hydrologic inflow dissolved oxygen concentration may be input and initial epilimnion and hypolimnion dissolved oxygen concentrations must be input.
Links: Not Linkable

☞ Diversion Dissolved Oxygen Conc

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of Diversion.
I/O: Input, rules, or propagated via a link
Links: If Diversion is not linked and is not valid, Diversion Dissolved Oxygen Conc is set to zero. Otherwise, it is set to the previous epilimnion dissolved oxygen concentration during calculations.

☞ Return Flow Dissolved Oxygen Conc

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of Return Flow.
I/O: Input, rules, or propagated via a link
Links: If Return Flow is not linked and is not valid, Return Flow Dissolved Oxygen Conc is set to zero.

☞ Canal Flow Dissolved Oxygen Conc

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of Canal Flow.
I/O: Input, rules, or propagated via a link
Links: If Canal Flow is not linked and is not valid, Canal Flow Dissolved Oxygen Conc is set to zero. If Canal Flow is negative (out of the reservoir), Canal Flow Dissolved Oxygen Conc is set to the previous epilimnion dissolved oxygen concentration. Otherwise, it is propagated through the canal link.

☞ Pump Storage Inflow Dissolved Oxygen

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of inflow from Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: Link to Pump Storage Outflow Dissolved Oxygen on another reservoir. If Flow FROM Pumped Storage is not linked or is not valid, Pump Storage Inflow Oxygen is set to zero. Otherwise, it is propagated through the Pumped Storage reservoir link.

☞ Pump Storage Outflow Dissolved Oxygen

Type: Series Slot
Units: Concentration
Description: dissolved oxygen concentration of outflow to Pumped Storage Reservoir.
I/O: Input, rules, or propagated via a link
Links: Link to Pump Storage Inflow Dissolved Oxygen on another reservoir. If Flow TO Pumped Storage is not linked or is not valid, Pump Storage Outflow Oxygen is set to zero. Otherwise, it is set to the previous epilimnion dissolved oxygen concentration during calculations.

☞ Detritus Parameters

Type: Table Slot
Units: Various
Description: Parameter data for detritus calculations.
Information: Contains the maximum detritus decay rate (KmaxDet [1/T]), a detritus settling rate (Kset [L/T]), an oxygen stoichiometric coefficient for detritus (rDet [M/M]), and S-curve temperature correction data (K1, K2 [1/T], and T1, T2 [degC]).
I/O: Input only
Links: Not Linkable

☞ Ammonia Parameters

Type: Table Slot
Units: Various
Description: Parameter data for ammonia calculations.
Information: Contains the maximum ammonia decay rate (KmaxAmm [1/T]), an oxygen stoichiometric coefficient for ammonia (rAmm [M/M]), and S-curve temperature correction data (K1, K2 [1/T], T1, T2 [degC]).
I/O: Input only
Links: Not Linkable

☞ Dissolved Organics Parameters

Type: Table Slot
Units: Various
Description: Parameter data for dissolved organics calculations.
Information: Contains the maximum dissolved organics decay rate (KmaxOrg [1/T]), an oxygen stoichiometric coefficient for dissolved organics (rOrg [M/M]), and S-curve temperature correction data (K1, K2 [1/T], T1, T2 [degC]).
I/O: Input only
Links: Not Linkable

☞ SOD Parameters

Type: Table Slot
Units: Various
Description: Contains parameter data for sediment oxygen demand calculations.
Information: Contains the maximum sediment oxygen demand (KmaxSOD [M/L^2 T]), a calibration coefficient for sediment oxygen demand (fSOD [None]), and S-curve temperature correction data (K1, K2 [1/T], T1, T2 [degC]).
I/O: Input only
Links: Not Linkable

☞ Photosynthesis Parameters

Type: Table Slot
Units: Various
Description: Contains parameter data for photosynthesis calculations.
Information: Contains the maximum photosynthesis rate at 20 degrees C (Pmax20 [M/L^2 T]), a temperature correction coefficient for Pmax20 (thetaP [None]), a calibration coefficient for respiration (fPhoto [None]), maximum possible solar radiation (Emax [$kcal/L^2$ T]), fraction of solar radiation absorbed at surface (beta [None]), and the extinction coefficient for solar radiation (eta [1/L]).
I/O: Input only
Links: Not Linkable

☞ Respiration Parameters

Type: Table Slot
Units: Various
Description: Contains parameter data for respiration calculations.
Information: Contains the maximum respiration rate at 20 degrees C (KmaxResp [M/L^3 T]), a temperature correction coefficient for KmaxResp (thetaR [None]), a calibration coefficient for respiration (fResp [None]), and double S-curve temperature correction data (K1, K2, K3, K4 [1/T], T1, T2, T3, T4 [degC]).
I/O: Input only
Links: Not Linkable

16.2 User Selectable Methods

The following categories and methods are available:

16.2.1 Reservoir Water Quality

Methods in this category are used to select the constituent and approach.

16.2.1.1 None

No water quality solution is performed. No slots are added.

16.2.1.2 Layered Salt

The layered salt slots described HERE (Section 16.1.2.2) are added. The **Solve 2 Layer Salt** dispatch method is made available.

16.2.1.3 Layered Temp

All of the temperature slots are added. The **Solve 2 Layer Temperature** dispatch method is made available.

16.2.1.4 Layered Temp and Salt

All of the temperature and the layered salt slots described HERE (Section 16.1.2.2) slots are added. This method makes the **Solve 2 Layer Temp and Salt** dispatch method available.

16.2.1.5 Layered Temp and DO

All of the temperature and DO slots are added. This method makes the **Solve 2 Layer Temp and DO** dispatch method available.

16.2.1.6 Layered Temp Salt and DO

All of the temperature and DO slots are added. The layered salt slots described HERE (Section 16.1.2.2) are also added. This method makes the **Solve 2 Layer Temp Salt and DO** dispatch method available.

16.2.1.7 Well Mixed Salt

The well mixed salt slots described HERE (Section 16.1.2.1) are added. This method makes the **Solve Weight Factor Salt** and **Solve Pred-Corr Salt** sets of dispatch methods available.

16.2.1.8 Segmented 2 Layer Salt

The segmented salt slots described HERE (Section 16.1.2.3) are added. This method makes the **Solve Segmented 2 Layer Salt** dispatch method available.

16.2.1.9 Outflow TDG using Tailwater Depth

This method models the spill, turbine release and mixed outflow TDG concentration based on the depth of the tailwater. The method and all the slots are documented HERE (Section 16.4.49).

16.2.2 WQ Distribute Inflow

This category of methods is only applicable to the layered methods. These methods define how the incoming water from the Inflow and side flows (e.g., canal flow, hydrologic inflow, etc.) is distributed into the reservoir. For example, it may be a function of density, temperature, etc., and may be "allocated" into one or more of the reservoir layers.

16.2.2.1 None

This is the default method and is not a valid method for calculation. An error is flagged if this method executes. This method does not instantiate any water quality slots.

16.2.2.2 By Temperature

No slots are explicitly instantiated by this method but the following slots are used as a part of the calculation:

Slots with Required Known Data

☞ **Total Inflows**
☞ **Temperature**

This method requires a current total inflow temperature, a previous epilimnion temperature, and a previous hypolimnion temperature, all are columns of the Temperature Agg Series Slot.

Slots with Output Data

☞ **Inflow to Epilimnion**
☞ **Inflow to Hypolimnion**

Method Details:

The method, distributeInflowbyTemp, compares the average total inflow temperature and distributes the total inflow based on a simple linear weighting scheme. In general, if the temperature is between the temperatures of the epilimnion and hypolimnion, the total inflow is split by a linear ratio of the total inflow temperature to the temperature difference between the two layers. If the total inflow temperature is greater or less than both layer's temperatures, the total inflow is totally allocated to the layer with the more similar temperature.

Following is more detail on the algorithm; note, only one bullet is selected:

- If previous epilimnion and hypolimnion temperatures are very close (within 0.1C) distribute the total inflow to each layer based on previous layer volumes.
- If the Total Inflow Temperature is greater than the previous epilimnion temperature, distribute all of the Total Inflow to the top layer, the epilimnion.

- If Total Inflow Temperature is less than the previous hypolimnion temp, distribute all of the Total Inflow to the bottom layer, the hypolimnion.
- If Total Inflow Temperature is between the previous epilimnion and hypolimnion temperatures, distribute the Total Inflow using a weighted ratio based on previous layer temperatures and the current Total Inflow Temperature.

16.2.2.3 Specify Distribution

No slots are explicitly instantiated by this method but the following slots are used as a part of the calculation:

☞ **TOTAL INFLOWS**
☞ **INFLOW TO HYPOLIMNION**
☞ **INFLOW TO EPILIMNION**

The method distributes the Total Inflow based on the values in either the Inflow to Hypolimnion or Epilimnion slots. One or the other of these must be specified but not both or an error will occur.

16.2.2.4 Specify Fraction

This method allows you to distribute the inflows using a series of fractions. The following slot is added by this method:

☞ **INFLOW TO HYPOLIMNION FRACTION**

Type:	Series with Periodic Input
UNITS:	FRACTION
Description:	The fraction of the total inflow that enters the Hypolimnion
Information:	The value must be specified and the value must be between 0 and 1, inclusive.
I/O:	Required via input or Rules
Links:	Not Linkable

The distribution is computed as follows:

$$\text{Inflow to Hypolimnion} = \text{Inflow to Hypolimnion Fraction} * \text{Total Inflows} \quad (16\text{-}77)$$

$$\text{Inflow to Epilimnion} = \text{Total Inflows} - \text{Inflow to Hypolimnion}; \quad (16\text{-}78)$$

16.2.3 WQ Distribute Outflow

This category of methods is only applicable to the layered methods. These methods allow the user to model the physical character of the outlet works of the reservoir. This is crucial for accurate tracking of release temperatures, DO levels, etc.

16.2.3.1 None

This is the default method and is not a valid method for calculation. An error is flagged if this method executes. This method does not instantiate any water quality slots.

16.2.3.2 Zone of Influence

No slots are explicitly instantiated by this method but the following slots are used as a part of the calculation:

☞ **RESERVOIR LENGTH**

Type: Table Slot
UNITS: LENGTH
Description: 1X1 table slot representing the length of the reservoir
I/O: Required Input
Links: Not Linkable

☞ **RESERVOIR BOTTOM ELEVATION**

Type: Table Slot
UNITS: LENGTH
Description: 1X1 table slot representing the elevation (above some common datum) of the bottom of the reservoir at the dam
Information: Used to calculate a mean depth at the dam.
Links: Not Linkable

☞ **RELEASE ELEVATION**

Type: Table Slot
UNITS: LENGTH
Description: 1X1 table slot representing the elevation (above some common datum) of the outlet works.
I/O: Required Input
Links: Not Linkable

☞ **THICKNESS OF EPILIMNION**

Type: Table Slot
UNITS: LENGTH
Description: 1X1 table slot representing the thickness of the epilimnion layer
I/O: Must be input by user.
Links: Not Linkable

☞ **RESERVOIR GEOMETRY COEFFICIENTS**

Type: Table Slot
UNITS: NOUNITS
Description: table of coefficients which represent the a1, a2, a3, a4 coefficients.
I/O: If not input, they are generated by the function `cubicFit`.
Links: Not Linkable

☞ **Withdrawal Zone Coefficient**

Type: Table Slot
Units: NoUnits
Description: 1x1 table of a single coefficient to represent cone of influence around outlet works.
I/O: If not input, it is set to 1.0.
Links: Not Linkable

Slots with Required Known Data

- ☞ **Outflow**
- ☞ **Reservoir Bottom Elevation**
- ☞ **Release Elevation**
- ☞ **Reservoir Geometry Coefficients Table**
- ☞ **Reservoir Length**
- ☞ **Thickness of Epilimnion**
- ☞ **Withdrawal Zone Coefficient**

Slots with Output Data

- ☞ **Outflow from Epilimnion**
- ☞ **Outflow from Hypolimnion**

Method Details:

The method, Zone of Influence, uses a cubic function (user input coefficients or calculated from the elevation-volume table), the magnitude of the outflow, and the release elevation to define a "zone of influence" from which the outflow is taken. The fraction of total outflow attributed to the epilimnion and hypolimnion is reflected by the values set in the Outflow from Hypolimnion and Outflow from Epilimnion slots.

NOTE: Zone of Influence is based on algorithms developed for use in the TVA system by Gary Hauser.

16.2.3.3 Specify Outflow Fraction

This method allows you to distribute the outflows using a series of fractions with a periodic input. The following slot is added by this method:

☞ **Outflow from Hypolimnion Fraction**

Type: Series with Periodic Input
Units: Fraction
Description: The fraction of the total outflow that leaves the Hypolimnion
Information: The value must be specified and the value must be between 0 and 1, inclusive.
I/O: Required via input or Rules
Links: Not Linkable

The distribution is computed as follows:

$$\text{Outflow from Hypolimnion} = \text{Outflow from Hypolimnion Fraction} * \text{Total Outflows} \quad (16\text{-}79)$$

$$\text{Outflow from Epilimnion} = \text{Total Inflows} - \text{Outflow from Hypolimnion}; \quad (16\text{-}80)$$

16.2.4 Surface Heat Flux

These methods represent the flux of heat across the reservoir surface. It is used as a heat source or sink for the upper layer(s) of the reservoir model.

16.2.4.1 None

This is the default method, and is not a valid method for calculation. An error is flagged if this method is executed.

16.2.4.2 Energy Balance

The flux method determines the flux from incoming solar radiation, incoming longwave radiation, outgoing radiation from the reservoir, outgoing heat due to conduction, and outgoing heat due to evaporation.

SLOTS WITH REQUIRED INPUT DATA

- ☞ **AIR TEMPERATURE**
- ☞ **DEWPOINT TEMPERATURE**
- ☞ **INCOMING SOLAR RADIATION**
- ☞ **TEMPERATURE**
- ☞ **WIND VELOCITY**

This method requires a current epilimnion temperature which is a column of the Temperature Agg Series Slot.

SLOTS WITH OUTPUT DATA

- ☞ **HEAT OF EVAPORATION**
- ☞ **SURFACE HEAT FLUX**

METHOD DETAILS:

The method calculates the surface flux as (each variable represents a utility method described below):

$$\mathrm{HeatFlux} = \mathrm{IncomingSolarRadiation} + \mathrm{calcHar}(\ ) - \mathrm{calcHbr}(\ ) - \mathrm{calcHc}(\ ) - \mathrm{calcHe}(\ ) \qquad \text{(EQ 16-1)}$$

16.2.5 Bank Storage Salt

If the reservoir considers bank storage and has either the “Input Bank Storage” or “CRSS Bank Storage” user method selected, salinity in the bank storage can be considered. The Bank Storage Salt category becomes visible with the following two method options:

16.2.5.1 None

This default method does not consider salinity of bank storage water.

16.2.5.2 Bank Storage Salt

If the “Bank Storage Salt” method is selected in the Bank Storage Salt category, the following water quality slot is instantiated:

☞ **BANK STORAGE SALT CONCENTRATION**

Type: Series Slot
UNITS: CONCENTRATION
Description: salt concentration of bank storage water.
Information: If the initial timestep's value is not known, it defaults to the Reservoir Salt Concentration at the initial timestep
I/O: Output only
Links: Not Linkable

METHOD DETAILS:

If this method is selected, the dispatch method will consider the salt concentration of the bank storage flows as follows:

If the flow is from the bank to the reservoir (Delta Bank Storage is negative), then the in-bound salt mass is calculated from the Delta Bank Storage and the previous Bank Storage Salt Concentration. Bank Storage Salt Concentration is the set to the previous timestep's value. There is no out-bound salt mass.

If the flow is from the reservoir to the bank (Delta Bank Storage is positive), then the Bank Storage Salt Concentration is a weighted average of the incoming water and the existing bank storage:

$$\text{BankStorageSaltConcentration} = \frac{\text{DeltaBankStorage} \times \text{ReservoirSaltConcentration}[-1] + \text{BankStorage}[-1] \times \text{BankStorageSaltConcentration}[-1]}{\text{BankStorage}} \quad \textbf{(16-2)}$$

16.2.6 WQ Reservoir Routing

The WQ Reservoir Routing category is used to specify how salinity routes through a reservoir. It is available for Well Mixed Salt. Two methods exist, the default Predictor-Corrector Salt and the Weighting Factors Salt method. The method currently in RiverWare uses a weighting factor to release salt over multiple time steps in a manner that prevents numerical instability, which occurs when reservoir storage is small in relation to the salt routed through the reservoir over a single time step

16.2.6.1 Predictor-Corrector Salt

The Predictor-Corrector Salt method uses a Huen numerical method to compute reservoir salinity concentration that treats reservoirs as "true" fully mixed systems. This method requires that the reservoir salinity and reservoir outflow salinity are the same for a given timestep.

METHOD DETAILS:

This method is used to limit the available dispatch methods. When this method is selected, the available dispatch methods are:

- Solve Pred-Corr Salt Given In
- Solve Pred-Corr Salt Given Out

16.2.6.2 Weighting Factor Salt

The Weighting Factor Salt method uses a weighting factor to release salt over multiple time steps in a manner that prevents numerical instability, which occurs when reservoir storage is small in relation to the salt routed through the reservoir over a single time step.

☞ **WEIGHTING FACTOR**

Type: Series Slot
UNITS: NO UNITS
Description: This slot holds the weighting factor as calculated by the dispatch method.
I/O: Output Only
Links: Not Linkable

METHOD DETAILS:

This method is used to limit the available dispatch methods. When this method is selected, the available dispatch methods are:

- Solve Weight Factor Salt Given In
- Solve Weight Factor Salt Given Out

16.2.7 Optimization Total Dissolved Gas

This category is only shown if the **Outflow TDG Tailwater Depth** method is selected in the **Reservoir Water Quality** category. It contains two methods, the default no-action **None** method and the **Opt Outflow TDG Tailwater Depth** method.

16.2.7.1 None

This method does not do any computations.

16.2.7.2 Opt Outflow TDG Tailwater Depth

The **Opt Outflow TDG Tailwater Depth** method is the optimization component of TDG modeling. The method and all the slots associated with it are documented HERE (Section 16.4.49.2).

16.3 Solution / Dispatching

16.3.1 Beginning of Water Quality Run

The function following functionality is executed one time at the beginning of the run. It is called from within beginning of run behavior on the Reservoir object.

- If using layered methods
    - If modeling Temperature

        - Check for initial epilimnion and hypolimnion temperatures. If not input, then flag an error and exit
        - Check Specific Heat slot for input. If not input, then set to standard value of 4.186 KJ/g C.
        - Check Reservoir Geometry Coefficients for data. If not input, then execute utility method `cubicFit`.
        - Check Release Elevation, Reservoir Length, Thickness of Epilimnion, and Thickness of Metalimnion for input. If not input, then flag an error and exit.
        - If the Withdrawal Zone Coefficient is not valid, set it to 1.0.
        - Check for Air Temperature, Dewpoint Temperature, and Solar Radiation data. If data is incomplete, then flag error and exit.
        - If Wind Velocity data is incomplete, set is to zero
        - If Thermo Diffusion Coefficient Adjust data is incomplete, then fill values to 1.0.
        - If Diversion, Return Flow, or Inflow are not linked and not valid, set corresponding temperatures to zero.
        - For a Slope Power Reservoir, if Inflow2 is not linked and not valid, set corresponding temperatures to zero.
    - If modeling Salinity
        - Check for initial epilimnion and hypolimnion salt concentrations. If not valid, then flag an error and exit.
        - If Diversion, Return Flow, or Inflow are not linked and not valid, set corresponding salt concentrations to zero.
        - For a Slope Power Reservoir, if Inflow2 is not linked and not valid, set corresponding salt mass to zero.
    - If modeling Dissolved Oxygen,
        - check for initial epilimnion and hypolimnion detritus, dissolved organics, ammonia, and dissolved oxygen concentrations. If not input, then flag and error.
        - If Diversion, Return Flow, or Inflow are not linked and not valid, set corresponding detritus, dissolved organics, ammonia, and dissolved oxygen concentrations to zero.
        - Check for data in following slots: Detritus Parameters, Dissolved Organics Parameters, Ammonia Parameters, SOD Parameters, Photosynthesis Parameters, Respiration Parameters. If any data is missing, flag error and exit.
        - For a Slope Power Reservoir, if Inflow2 is not linked and not valid, set Inflow 2 detritus, dissolved organics, ammonia, and dissolved oxygen concentrations to zero.
- If using Well Mixed Salt method
    - Check for initial Reservoir Salt Concentration, initial Bank Storage Salt Concentration, and Dead Storage. If not input, then set to zero.
        - If Hydrologic Inflow Salt Concentration, Return Flow Salt Mass, or Diversion Salt Concentration are not linked and not input, then set to zero.
- If using Segmented 2 Layer method

- Check the Agg Series Slots and Table slots to ensure they contain the number of rows or columns which correspond to the number of segments.
- Check for initial Epilimnion Salt Concentration by Segment, Hypolimnion Salt Concentration by Segment, and initial Bank Storage Salt Concentration. If not input, then set to zero.
- If Hydrologic Inflow Salt Concentration, Return Flow Salt Mass, or Diversion Salt Concentration are not linked and not input, then set to zero.
- Check the Segment Parameters Table to ensure all proportions sum to 1.
- Calculate initial values for Epilimnion Volume by Segment, Hypolimnion Volume by Segment, Bank Storage by Segment and Reservoir Salt Mass.

- If modeling TDG
  - Check for valid values in the slots: Tailwater Bottom Elevation, TDG c1, TDG Entrainment b1, TDG Entrainment b3, TDG Spill b2, TDG Spill and Turbine Release Limits.
  - If the Opt Outflow TDG Tailwater Depth is selected, make sure a valid Tailwater method is selected. These are shown in the method descriptionHERE (Section 16.4.49.2).

16.3.2 Dispatch Slots

Dispatch slots either appear in the dispatch conditions of the Dispatch Methods, or they are linked to another object, or both. Thus, the existence of a value in these slots determines when the object dispatches and which Dispatch Method is executed. The following water quality slots are dispatch slots for the Layered methods (depending on the selected constituents):

- ☞ Canal Flow Ammonia Conc
- ☞ Canal Flow Detritus Conc
- ☞ Canal Flow Dissolved Organics Conc
- ☞ Canal Flow Dissolved Oxygen Conc
- ☞ Canal Flow Salt Conc
- ☞ Canal Flow Temp
- ☞ Diversion Ammonia Conc
- ☞ Diversion Detritus Conc
- ☞ Diversion Dissolved Organics Conc
- ☞ Diversion Dissolved Oxygen Conc
- ☞ Diversion Salt Concentration
- ☞ Diversion Temp
- ☞ Inflow Ammonia Mass
- ☞ Inflow Detritus Mass
- ☞ Inflow Dissolved Organics Mass
- ☞ Inflow Dissolved Oxygen Mass
- ☞ Inflow Heat
- ☞ Inflow Salt Mass
- ☞ Outflow Ammonia Mass
- ☞ Outflow Detritus Mass
- ☞ Outflow Dissolved Organics Mass
- ☞ Outflow Dissolved Oxygen Mass
- ☞ Outflow Heat
- ☞ Outflow Salt Mass
- ☞ Pump Storage Inflow Ammonia
- ☞ Pump Storage Inflow Detritus
- ☞ Pump Storage Inflow Dissolved Oxygen
- ☞ Pump Storage Inflow Organics
- ☞ Pump Storage Inflow Salt
- ☞ Pump Storage Inflow Temp
- ☞ Pump Storage Outflow Ammonia
- ☞ Pump Storage Outflow Detritus
- ☞ Pump Storage Outflow Dissolved Oxygen
- ☞ Pump Storage Outflow Organics
- ☞ Pump Storage Outflow Salt
- ☞ Pump Storage Outflow Temp
- ☞ Return Flow Ammonia Conc
- ☞ Return Flow Detritus Conc
- ☞ Return Flow Dissolved Organics Conc
- ☞ Return Flow Dissolved Oxygen Conc
- ☞ Return Flow Salt Conc
- ☞ Return Flow Temp

If using Well Mixed Salt. the dispatch slots are:

- DIVERSION SALT CONCENTRATION
- HYDROLOGIC INFLOW SALT CONC
- INFLOW SALT CONCENTRATION
- INFLOW SALT MASS
- OUTFLOW SALT CONCENTRATION
- OUTFLOW SALT MASS
- RESERVOIR SALT CONCENTRATION
- RETURN FLOW SALT MASS

If using Segmented 2 Layer Salt, the dispatch slots are:

- DIVERSION SALT CONCENTRATION
- HYDROLOGIC INFLOW SALT CONC
- INFLOW SALT CONCENTRATION
- INFLOW SALT MASS
- OUTFLOW SALT CONCENTRATION
- OUTFLOW SALT MASS
- RETURN FLOW SALT CONCENTRATION

If using TDG method, the dispatch slots are:

- INFLOW TDG CONCENTRATION
- SPILL TDG CONCENTRATION
- DELTA OUTFLOW
- DELTA INFLOW TDG CONCENTRATION
- OUTFLOW TDG CONCENTRATION
- DELTA INFLOW
- DELTA OUTFLOW TDG CONCENTRATION

16.3.3 Dispatch Methods

The controller for water quality currently has a dispatch method for each constituent and solution approach combination. They assume the mass balance has already solved and therefore mass balance slots are also required slots.

The following water quality dispatch methods exist on all reservoirs. In order for the method to be executed for each timestep, both the known and unknown slot lists must be satisfied. Each dispatch method represents a possible combination of constituent and solution approach choices made at the global level.

16.3.3.1 Solve 2 Layer Temperature

This dispatch method is available for the **Layered Temp** method.

REQUIRED KNOWN SLOTS:

- DIVERSION
- HYDROLOGIC INFLOW
- INFLOW
- INFLOW HEAT
- OUTFLOW
- RETURN FLOW
- STORAGE

REQUIRED UNKNOWN SLOTS:

- OUTFLOW HEAT

METHOD DETAILS:

This method calls the following utility methods:

- checkSideFlowTemp
- WQ_2_Layer

16.3.3.2 Solve 2 Layer Salt

This dispatch method is available for the **Layered Salt** method.

REQUIRED KNOWN SLOTS:

- ☞ DIVERSION
- ☞ HYDROLOGIC INFLOW
- ☞ INFLOW
- ☞ INFLOW SALT CONCENTRATION
- ☞ OUTFLOW
- ☞ RETURN FLOW
- ☞ STORAGE

REQUIRED UNKNOWN SLOTS:

- ☞ INFLOW SALT MASS
- ☞ OUTFLOW SALT MASS,
- ☞ OUTFLOW SALT CONCENTRATION

METHOD DETAILS:

This method calls the following utility methods:

- checkSideFlowConcSalt
- WQ_2_Layer

16.3.3.3 Solve 2 Layer Temp and Salt

This dispatch method is available for the **Layered Temp and Salt** method.

REQUIRED KNOWN SLOTS:

- ☞ DIVERSION
- ☞ HYDROLOGIC INFLOW
- ☞ INFLOW
- ☞ INFLOW HEAT
- ☞ INFLOW SALT MASS
- ☞ OUTFLOW
- ☞ RETURN FLOW
- ☞ STORAGE

REQUIRED UNKNOWN SLOTS:

- ☞ OUTFLOW HEAT
- ☞ OUTFLOW SALT MASS

METHOD DETAILS:

This method calls the following utility methods:

- checkSideFlowTemp
- checkSideFlowConcSalt
- WQ_2_Layer

16.3.3.4 Solve 2 Layer Temp and DO

This dispatch method is available for the **Layered Temp and DO** method.

REQUIRED KNOWN SLOTS:

- ☞ DIVERSION
- ☞ HYDROLOGIC INFLOW
- ☞ INFLOW DISSOLVED OXYGEN MASS
- ☞ INFLOW HEAT

- ☞ **Inflow**
- ☞ **Inflow Ammonia Mass**
- ☞ **Inflow Detritus Mass**
- ☞ **Inflow Dissolved Organics Mass**
- ☞ **Outflow**
- ☞ **Return Flow**
- ☞ **Storage**
- ☞

Required Unknown slots:

- ☞ **Outflow Ammonia Mass**
- ☞ **Outflow Detritus Mass,**
- ☞ **Outflow Dissolved Organics Mass**
- ☞ **Outflow Dissolved Oxygen Mass**
- ☞ **Outflow Heat**

Method Details:

This method calls the following utility methods:

- checkSideFlowTemp
- checkSideFlowConcDO
- WQ_2_Layer

16.3.3.5 Solve 2 Layer Temp Salt and DO

This dispatch method is available for the **Layered Temp Salt and DO** method.

Required Known slots:

- ☞ **Diversion**
- ☞ **Hydrologic Inflow**
- ☞ **Inflow**
- ☞ **Inflow Ammonia Mass**
- ☞ **Inflow Detritus Mass**
- ☞ **Inflow Dissolved Organics Mass**
- ☞ **Inflow Dissolved Oxygen Mass**
- ☞ **Inflow Heat**
- ☞ **Inflow Salt Mass**
- ☞ **Outflow**
- ☞ **Return Flow**
- ☞ **Storage**

Required Unknown slots:

- ☞ **Outflow Ammonia Mass**
- ☞ **Outflow Detritus Mass,**
- ☞ **Outflow Dissolved Organics Mass**
- ☞ **Outflow Dissolved Oxygen Mass**
- ☞ **Outflow Heat**
- ☞ **Outflow Salt Mass**

Method Details:

This method calls the following utility methods:

- checkSideFlowTemp
- checkSideFlowConcDO
- checkSideFlowConcSalt
- WQ_2_Layer

16.3.3.6 Solve Segmented 2 Layer Salt

This dispatch method is available for the **Segmented 2 Layer Salt** method.

REQUIRED KNOWN SLOTS:

- STORAGE
- INFLOW
- OUTFLOW
- INFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- OUTFLOW SALT CONCENTRATION
- OUTFLOW SALT MASS

METHOD DETAILS:

This method calls the following utility method:

- WQ_Segmented_2_Layer

16.3.3.7 Solve Weight Factor Salt Given In

This dispatch method is available for the Well Mixed Salt method when the Weighting Factor Salt method is selected from the WQ Reservoir Routing category. It solves for Outflow Salt Concentration given Inflow Salt Concentration.

REQUIRED KNOWN SLOTS:

- INFLOW
- OUTFLOW
- INFLOW SALT CONCENTRATION
- STORAGE

REQUIRED UNKNOWN SLOTS:

- OUTFLOW SALT CONCENTRATION
- RESERVOIR SALT CONCENTRATION

METHOD DETAILS:

First, the massBalanceSaltInit, HERE (Section 16.4.45), utility function is called to set up local variables and verify that there are the necessary data. Next, the getAvgSaltConcIn function is called to determine the weighted average inflowSaltConcentration.

If Storage is not valid or the reservoir's previous and current storage are less than or equal to 5.0 acre-feet, set the Reservoir Salt Concentration equal to the Previous Reservoir Concentration and Outflow Salt Concentration to Inflow Salt Concentration then exit the method.

Next, calculate the local variable storSum as:

$$\text{storSum} = \text{storage} + \text{storage}(-1) + 2 \times \text{deadStorage} \tag{16-3}$$

Calculate the weightingFactor:

$$\text{weightingFactor} = 1 + 0.6\frac{(\text{inflowVol} + \text{returnFlowVol} + \text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{\text{storSum}} \tag{16-4}$$

StorSum is then recalculated as:

$$\text{storSum} = \text{storage} + \text{deadStorage} + \text{weightingFactor}\frac{(\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}$$

If storSum is equal to 0.0 then set Reservoir Salt Concentration equal to Previous Reservoir Salt Concentration. Otherwise, Reservoir Salt Concentration equals Outflow Salt Concentration.

$$\begin{aligned} \text{reservoirSaltConc} = \; & \big(\text{reservoirSaltConc}(-1) \times (\text{storage} + \text{deadStorage}) + \\ & \text{inflowSaltConc} \times \text{inflowVol} + \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \\ & \text{returnFlowSaltMass} + \text{inboundBankStorageSaltMass} - \\ & \text{reservoirSaltConc}(-1) \times \frac{(\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}\big) / \text{storSum} \end{aligned} \tag{16-5}$$

The Previous Reservoir Salt Concentration is set one time step forward to put the reservoir on the queue for the next time step. The Reservoir Outflow Salt Concentration is calculated as:

$$\text{OutflowSaltConc} = \frac{\text{reservoirSaltConc}(-1) + \text{weightingFactor} \times \text{reservoirSaltConc}}{1 + \text{weightingFactor}} \tag{16-6}$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

16.3.3.8 Solve Weight Factor Salt Given Out

This dispatch method is available for the Well Mixed Salt method when the Weighting Factor Salt method is selected from the WQ Reservoir Routing category. It solves for Inflow Salt Concentration given Outflow Salt Concentration.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **OUTFLOW**
- ☞ **OUTFLOW SALT CONCENTRATION**
- ☞ **STORAGE**

REQUIRED UNKNOWN SLOTS:

- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **RESERVOIR SALT CONCENTRATION**

METHOD DETAILS:

First, the massBalanceSaltInit, utility function is called to set up local variables and verify that there are the necessary data.

If Storage is not valid or the reservoir’s previous and current storage are less than or equal to 5.0 Acre-feet, set the Reservoir Salt Concentration equal to the Previous Reservoir Concentration and Inflow Salt Concentration to Outflow Salt Concentration then exit the method.

Next, calculate the local variable storSum as:

$$\text{storSum} = \text{storage} + \text{storage}(-1) + 2 \times \text{deadStorage} \tag{16-7}$$

Calculate the weightingFactor:

$$\text{weightingFactor} = 1 + 0.6\frac{(\text{inflowVol} + \text{returnFlowVol} + \text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{\text{storSum}} \quad (16\text{-}8)$$

StorSum is then recalculated as:

$$\text{storSum} = \text{storage} + \text{deadStorage} + \text{weightingFactor}\frac{(\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}$$

If storSum is equal to 0.0 then set Reservoir Salt Concentration equal to Previous Reservoir Salt Concentration. Otherwise, Reservoir Salt Concentration equals Outflow Salt Concentration.

$$\text{reservoirSaltConc} = \frac{(\text{outflowSaltConc} \times (1 + \text{weightingFactor}) - \text{reservoirSaltConc}(-1))}{\text{weightingFactor}} \quad (16\text{-}9)$$

The Previous Reservoir Salt Concentration is set one time step forward to put the reservoir on the queue for the next time step. The Reservoir Inflow Salt Concentration is calculated as:

$$\begin{aligned} \text{InflowSaltConc} = \Big[&\text{reservoirSaltConc} \times \\ &\left(\text{storage} + \text{deadStorage} + \text{weightingFactor}\frac{(\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}\right) + \\ &\text{reservoirSaltCon}(-1) \times (\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage}) / (1 + \text{weightingFactor}) - \\ &\text{returnFlowSaltMass} - \text{inboundBankStorageSaltMass} - \\ &\text{reservoirSaltConc}(-1) \times (\text{storage}(-1) + \text{deadStorage})\Big] / \text{inflowVol} \end{aligned} \quad (16\text{-}10)$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

16.3.3.9 Solve Pred-Corr Salt Given In

This dispatch method is available for the Well Mixed Salt method when the Predictor-Corrector Salt method is selected from the WQ Reservoir Routing category. It solves for Outflow Salt Concentration given Inflow Salt Concentration.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW**
- ☞ **STORAGE**

REQUIRED UNKNOWN SLOTS:

- ☞ **OUTFLOW SALT CONCENTRATION**
- ☞ **RESERVOIR SALT CONCENTRATION**

METHOD DETAILS:

First, the massBalanceSaltInit, utility function is called to set up local variables and verify that there are the necessary data. Next, the getAvgSaltConcIn function is called to determine the weighted average inflowSaltConcentration.

Next, the local variable storSum is calculated as Storage plus Dead Storage.

$$\text{storSum} = \text{storage} + \text{deadStorage} \tag{16-11}$$

If storSum is equal to 0.0 then set Reservoir Salt Concentration equal to -1.0 (the Reservoir Salt Concentration is recalculated in Equation 16-17. Otherwise, solve for the **predictor** (in units of salt mass):

$$\begin{aligned}\text{predictor} = {} & \text{inflowSaltConc} \times \text{inflowVol} + \\ & \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \\ & \text{returnFlowSaltMass} + \\ & \text{inboundBankStorageSaltMass} - \\ & \text{reservoirSaltConc}(-1) \times (\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})\end{aligned} \tag{16-12}$$

The local variable intermediateReservoirSaltConc is computed as:

$$\text{intermediateReservoirSaltConc} = \frac{\text{reservoirSaltConc}(-1) \times (\text{storage}(-1) + \text{deadStorage}) + \text{predictor}}{\text{storSum}} \tag{16-13}$$

Solve for the **corrector** (in units of salt mass):

$$\begin{aligned}\text{corrector} = {} & \text{inflowSaltConc} \times \text{inflowVol} + \\ & \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \text{returnFlowSaltMass} + \\ & \text{inboundBankStorageSaltMass} - \\ & \text{intermediateReservoirSaltConc} \times (\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})\end{aligned} \tag{16-14}$$

The local variable **slope** is the average of the predictor and the corrector

$$\text{slope} = \frac{\text{predictor} + \text{corrector}}{2} \tag{16-15}$$

The Reservoir Salt Concentration is calculated as:

$$\text{reservoitSaltConc} = \frac{\text{reservoirSaltConc}(-1) \times (\text{storage} + \text{deadStorage}) + \text{slope}}{\text{storSum}} \tag{16-16}$$

If the calculated Reservoir Salt Concentration is negative (i.e. the calculation failed to find a valid concentration because there is very little storage in the reservoir) or if storage and previous storage are less than or equal to 5.0 acre-feet, the Reservoir Salt Concentration is reset to the weighted average of the salt concentrations of the inflows.

$$\begin{aligned}\text{reservoirSaltConc} = {} & (\text{inflowSaltConc} \times \text{inflowVol} + \\ & \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \\ & \text{inboundBankStorageSaltMass} + \text{returnFlowSaltMass}) / (\text{inflowVol} + \text{hydroInflowVol} + \\ & \text{inboundBankStorageVol} + \text{returnFlow})\end{aligned} \tag{16-17}$$

The Previous Reservoir Salt Concentration is set one time step forward to put reservoir on the queue for the next time step. Finally, the Outflow Salt Concentration is set equal to the Reservoir Salt Concentration and Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

16.3.3.10 Solve Pred-Corr Salt Given Out

This dispatch method is available for the Well Mixed Salt when the Predictor-Corrector Salt method is selected from the WQ Reservoir Routing category. It solves for Inflow Salt Concentration given Outflow Salt Concentration.

REQUIRED KNOWN SLOTS:

- INFLOW
- OUTFLOW
- OUTFLOW SALT CONCENTRATION
- STORAGE

REQUIRED UNKNOWN SLOTS:

- INFLOW SALT CONCENTRATION
- RESERVOIR SALT CONCENTRATION

METHOD DETAILS:

First, the massBalanceSaltInit, utility function is called to set up local variables and verify that there are the necessary data.

Next, calculate the local variable storSum as Storage plus Dead Storage.

$$\mathrm{storSum} = \mathrm{storage} + \mathrm{deadStorage} \tag{16-18}$$

If Storage is not valid or the reservoir's previous and current storage are less than or equal to 5.0 Acre-feet, set the Reservoir Salt Concentration equal to the Previous Reservoir Concentration and Inflow Salt Concentration to Outflow Salt Concentration then exit the method.

If storSum is equal to 0.0 then set Reservoir Salt Concentration equal to Previous Reservoir Salt Concentration. Otherwise, Reservoir Salt Concentration equals Outflow Salt Concentration.

$$\mathrm{reservoirSaltConc} = \mathrm{outflowSaltConc} \tag{16-19}$$

The Previous Reservoir Salt Concentration is set one time step forward to put the reservoir on the queue for the next time step. If inVol equals zero then inflowSaltConc is set equal to zero, otherwise the Reservoir Inflow Salt Concentration is calculated as:

$$\begin{aligned}\mathrm{inflowSaltConc} = {} & (\mathrm{reservoirSaltConc} \times (\mathrm{storage} + \mathrm{deadStorage}) \\ & + \mathrm{reservoirSaltConc}(-1) \times (\mathrm{outflowVol} + \mathrm{diversionVol} + \mathrm{outboundBankStorage}) - \mathrm{returnFlowSaltMass} \\ & - \mathrm{inboundBankStorageSaltMass} - \mathrm{reservoirSaltConc}(-1) \times (\mathrm{storage}(-1) + \mathrm{deadStorage})) / \mathrm{inVol}\end{aligned} \tag{16-20}$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

16.3.3.11 Solve Reservoir TDG Outflow

This dispatch method computes the physical and optimization slots based on the actual slot values.

REQUIRED KNOWN SLOTS

- REGULATED SPILL
- TAILWATER ELEVATION
- TURBINE RELEASE
- INFLOW TDG CONCENTRATION

REQUIRED UNKNOWN SLOTS

☞ **SPILL TDG CONCENTRATION**
☞ **OUTFLOW TDG CONCENTRATION**

This dispatch method executes the **Outflow TDG using Tailwater Depth** method and then the selected method in the **Optimization Total Dissolved Gas**. These two methods are described in detail HERE (Section 16.4.49)

16.4 Utility Methods

Utility Methods are methods (or subroutines / functions) which do not belong to a user-selectable method type. For example, there is a utility method which calculates the surface area of the reservoir (calcSurfaceArea), and one which fits a cubic function to a set of elevation - volume data (cubicFit). Each of the utility methods outlined below is used by one or more of the user-selected method types above. Note that some of these methods set slots directly, while others return values but do not set slots explicitly.

16.4.1 AdjKAmm

The function, AdjKAmm, returns a unit-less ammonia decay correction factor based on reservoir temperature and S-curve data. Inputs include an ammonia decay rate, and the corresponding temperature. Gamma is calculated with two rates and two temperatures by the function calcGamma. Current layer temperature is passed in through the variable `temp`.

$$\mathrm{AdjKAmm} = \frac{\mathrm{K1} \times e^{(\gamma \times (\mathrm{T} - \mathrm{T1}) - 1)}}{(1 + \mathrm{K1} \times e^{(\gamma \times (\mathrm{T} - \mathrm{T1}) - 1)})} \tag{16-21}$$

`AdjKAmm` should return a value between 0.0 and 1.0.

SLOTS WITH REQUIRED KNOWN DATA

Ammonia Parameters

16.4.2 AdjKDet

The function, AdjKDet, returns a unit-less detritus decay correction factor based on reservoir temperature and S-curve data. Inputs include a detritus decay rate, and the corresponding temperature. Gamma is calculated with two rates and two temperatures by the function calcGamma. Current layer temperature is passed in through the variable T.

$$\mathrm{AdjKDet} = \frac{\mathrm{K1} \times e^{(\gamma \times (\mathrm{T} - \mathrm{T1}) - 1)}}{(1 + \mathrm{K1} \times e^{(\gamma \times (\mathrm{T} - \mathrm{T1}) - 1)})} \tag{16-22}$$

T1 is the value in the Detritus Parameter, Temp 1 column. `AdjKDet` returns a value between 0.0 and 1.0.

SLOTS WITH REQUIRED KNOWN DATA

☞ Detritus Parameters

16.4.3 AdjKOrg

The function, AdjKOrg, returns a unit-less dissolved organics decay correction factor based on reservoir temperature and S-curve data. Inputs include a dissolved organics decay rate, and the corresponding temperature. Gamma is calculated with two rates and two temperatures by the function calcGamma. Current layer temperature is passed in through the variable `temp`.

$$\text{AdjKOrg} = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \tag{16-23}$$

`AdjKOrg` should return a value between 0.0 and 1.0.

Slots with Required Data

☞ Dissolved Organics Parameters

16.4.4 AdjKResp

The function, AdjKResp, returns a respiration rate correction factor based on reservoir temperature and data from a double S-curve. Inputs include four respiration rates (K1, K2, K3, K4), and the corresponding temperatures (T1, T2, T3, T4). Gamma1 and gamm2 are calculated with two rates and two temperatures by the function calcGamma. Current layer temperature is passed in through the variable `temp`. This general function is used to calculate the temperature adjustment factor, AdjK.

$$\text{AdjKResp} = \frac{K1e^{(\gamma \times (T - T1) - 1)}}{(1 + K1e^{(\gamma \times (T - T1) - 1)})} \tag{16-24}$$

Slots with Required Known Data

☞ Respiration Parameters

16.4.5 AdjKSOD

The function, AdjKSOD`,` returns a unit-less sediment oxygen demand correction factor based on reservoir temperature and S-curve data. Inputs include a sediment oxygen demand, and the corresponding temperature. Gamma is calculated with two rates and two temperatures by the function calcGamma. Current layer temperature is passed in through the variable `temp`.

$$\text{AdjKSOD} = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \tag{16-25}$$

AdjKSOD should return a value between 0.0 and 1.0.

Slots with Required Known Data

☞ SOD Parameters

16.4.6 calcAmmonia

The method, calcAmmonia, calculates the ammonia balance for the epilimnion and the hypolimnion, based on explicit one-step method. Slots with Required Known Data

- Ammonia Concentrations
- Epilimnion Volume
- Hypolimnion Volume
- Inflow to Epilimnion
- Inflow to Hypolimnion
- Outflow from Epilimnion
- Outflow from Hypolimnion
- Thermocline Diffusion Coefficient
- Thickness of Epilimnion
- Thickness of Metalimnion

This method requires a previous epilimnion ammonia concentration and a previous hypolimnion ammonia concentration; both are columns on the Ammonia Concentration Agg Series Slot.

Slots with Output Data

- Ammonia Concentrations

This method sets epilimnion ammonia concentration and hypolimnion ammonia concentration; both are columns on the Ammonia Concentration Agg Series Slot.

Method Details:

The epilimnion dissolved organics concentration is calculated as:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \qquad \textbf{(16-26)}$$

and, the hypolimnion ammonia concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / H_v \qquad \textbf{(16-27)}$$

where

$$C_e^i = \text{Epilimnion Ammonia Concentration at time i}$$
$$C_h^i = \text{Hypolimnion Ammonia Concentration at time i}$$
$$C_{in} = \text{Inflow Ammonia Concentration}$$
$$E_{inVOL} = \text{Epilimnion Inflow Volume}$$
$$H_{inVOL} = \text{Hypolimnion Inflow Volume}$$
$$E_{outVOL} = \text{Epilimnion Outflow Volume}$$
$$H_{outVOL} = \text{Hypolimnion Outflow Volume}$$
$$\varepsilon' = \text{Thermocline Diffusion Coefficient } (m^2/sec)$$
$$A_t = \text{Area of Thermocline}$$
$$\Delta C = \text{Ammonia Concentration Gradient between the Epilimnion and Hypolimnion}$$
$$M_z = \text{Metalimnion Thickness}$$
$$E_v = \text{Epilimnion Volume}$$
$$H_v = \text{Hypolimnion Volume}$$
$$\Delta t = \text{Timestep in seconds}$$

This concentration is then adjusted by accounting for ammonia decay. The amount of ammonia decay is used in other functions.These adjustments will be made within a timestep during which the layer volume will be remain constant. Therefore, it is possible to calculate these sources and sinks in terms of concentration instead of mass.

$$\Delta AmmDecay_e = C_e^i \times AdjK_{Amm}(\ ) \times Kmax_{Amm} \times \Delta t \tag{16-28}$$

$$C_e^i = C_e^i - \Delta AmmDecay_e \tag{16-29}$$

and

$$\Delta AmmDecay_h = C_h^i \times AdjK_{Amm}(\ ) \times Kmax_{Amm} \times \Delta t \tag{16-30}$$

$$C_h^i = C_h^i - \Delta AmmDecay_h \tag{16-31}$$

where

$$\Delta AmmDecay_e = \text{Ammonia Decay in Epilimnion } (g/m^3)$$
$$\Delta AmmDecay_h = \text{Ammonia Decay in Hypolimnion } (g/m^3)$$
$$AdjK_{Amm}(\ ) = \text{Function Calculating Maximum Decay Rate Scaling Factor}$$
$$Kmax_{Amm} = \text{Maximum Decay Rate for Ammonia}$$
$$E_Z = \text{Epilimnion Thickness}$$
$$H_Z = \text{Hypolimnion Thickness}$$

It then adjusts the layer ammonia concentrations to account for movement of the thermocline during the timestep.

16.4.7 calcDetritus

The method, calcDetritus, calculates the detritus balance for the epilimnion and the hypolimnion, based on explicit one-step method.

Slots with Required Known Data

- Detritus Concentrations
- Epilimnion Volume
- Hypolimnion Volume
- Inflow to Epilimnion
- Inflow to Hypolimnion
- Outflow from Epilimnion
- Outflow from Hypolimnion
- Thermocline Diffusion Coefficient
- Thickness of Epilimnion
- Thickness of Metalimnion

This method requires a previous epilimnion detritus concentration and a previous hypolimnion detritus concentration; both are columns on the Detritus Concentrations Agg Series Slot.

Slots with Output Data

- Detritus Concentrations

This method sets epilimnion and hypolimnion detritus concentrations; which is a column on the Detritus Concentrations Agg Series Slot.

Method Details:

The epilimnion detritus concentration is calculated as:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \quad \textbf{(16-32)}$$

and, the hypolimnion detritus concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / H_v \quad \textbf{(16-33)}$$

where

C_e^i = Epilimnion Detritus Concentration at time i

C_h^i = Hypolimnion Detritus Concentration at time i

C_{in} = Inflow Detritus Concentration

E_{inVOL} = Epilimnion Inflow Volume

H_{inVOL} = Hypolimnion Inflow Volume

E_{outVOL} = Epilimnion Outflow Volume

H_{outVOL} = Hypolimnion Outflow Volume

ε' = Thermocline Diffusion Coefficient (m^2/sec)

A_t = Area of Thermocline

ΔC = Detritus Concentration Gradient between the Epilimnion and Hypolimnion

M_z = Metalimnion Thickness

E_v = Epilimnion Volume

H_v = Hypolimnion Volume

Δt = Timestep in seconds

This concentration is then adjusted by accounting for detritus decay and settling. The amount of detritus decay is passed out of the function. These adjustments will be made within a timestep during which the layer volume will be remain constant. Therefore, it is possible to calculate these sources and sinks in terms of concentration instead of mass.

$$\Delta DetDecay_e = C_e^i \times AdjKDet(EpiLayerTemp) \times Kmax_{Det} \times \Delta t \quad \textbf{(16-34)}$$

$$ESettle_{out} = (C_e^i \times K_{set} \times \Delta t) \div E_z \quad \textbf{(16-35)}$$

$$C_e^i = C_e^i - \Delta DetDecay_e - ESettle_{out} \quad \textbf{(16-36)}$$

and

$$\Delta DetDecay_h = C_h^i \times AdjKDet(HypoLayerTemp) \times Kmax_{Det} \times \Delta t \quad \textbf{(16-37)}$$

$$HSettle_{out} = (C_h^i \times K_{set} \times \Delta t) \div H_z - ESettle_{out} \quad \textbf{(16-38)}$$

$$C_h^i = C_h^i - \Delta DetDecay_h - HSettle_{out} \quad \textbf{(16-39)}$$

where

$$\Delta DetDecay_e = \text{Detritus Decay in Epilimnion (g/m}^3\text{)}$$

$$\Delta DetDecay_h = \text{Detritus Decay in Hypolimnion (g/m}^3\text{)}$$

$$AdjKDet\ (temp) = \text{Function Calculating Maximum Decay Rate Scaling Factor}$$

$$Kmax_{Det} = \text{Maximum Decay Rate for Detritus}$$

$$ESettle_{out} = \text{Detritus Settled Out of Epilimnion (g/m}^3\text{)}$$

$$HSettle_{out} = \text{Detritus Settled Out of Hypolimnion (g/m}^3\text{)}$$

$$K_{set} = \text{Detritus Settling Rate}$$

$$E_z = \text{Epilimnion Thickness}$$

$$H_z = \text{Hypolimnion Thickness}$$

It then adjusts the layer detritus concentrations to account for movement of the thermocline during the timestep.

16.4.8 calcDO

The method, calcDO, calculates the dissolved oxygen balance for the epilimnion and the hypolimnion, based on explicit one-step method. Slots with Required Known Data

- ☞ **Dissolved Oxygen Concentrations**
- ☞ **Epilimnion Volume**
- ☞ **Hypolimnion Volume**
- ☞ **Inflow to Epilimnion**
- ☞ **Inflow to Hypolimnion**
- ☞ **Outflow from Epilimnion**
- ☞ **Outflow from Hypolimnion**
- ☞ **Thermocline Diffusion Coefficient**
- ☞ **Thickness of Epilimnion**
- ☞ **Thickness of Metalimnion**

This method requires a previous epilimnion dissolved oxygen concentration and a previous hypolimnion dissolved oxygen concentration, both are columns on the Dissolved Oxygen Concentrations Agg Series Slot.

Slots with Output Data

- ☞ **Dissolved Oxygen Concentrations**

This method sets the epilimnion dissolved oxygen concentration and hypolimnion dissolved oxygen concentration, both are columns on the Dissolved Oxygen Concentrations Agg Series Slot.

Method Details:

The epilimnion dissolved oxygen concentration is calculated as:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \quad \textbf{(16-40)}$$

and, the hypolimnion dissolved oxygen concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\right) / H_v \quad \textbf{(16-41)}$$

where

$$C_e^i = \text{Epilimnion Dissolved Oxygen Concentration at time i}$$
$$C_h^i = \text{Hypolimnion Dissolved Oxygen Concentration at time i}$$
$$C_{in} = \text{Inflow Dissolved Oxygen Concentration}$$
$$E_{inVOL} = \text{Epilimnion Inflow Volume}$$
$$H_{inVOL} = \text{Hypolimnion Inflow Volume}$$
$$E_{outVOL} = \text{Epilimnion Outflow Volume}$$
$$H_{outVOL} = \text{Hypolimnion Outflow Volume}$$
$$\varepsilon' = \text{Thermocline Diffusion Coefficient } (m^2/sec)$$
$$A_t = \text{Area of Thermocline}$$
$$\Delta C = \text{DissolvedOxygen Concentration Gradient between the Epilimnion and Hypolimnion}$$
$$M_z = \text{Metalimnion Thickness}$$
$$E_v = \text{Epilimnion Volume}$$
$$H_v = \text{Hypolimnion Volume}$$
$$\Delta t = \text{Timestep in seconds}$$

This concentration is then adjusted by accounting for photosynthesis, re-aeration, respiration, sediment oxygen demand, and consumption from detritus, dissolved organics, and ammonia decay. These adjustments will be made within a timestep during which the layer volume will be remain constant. Therefore, it is possible to calculate these sources and sinks in terms of concentration instead of mass.

$$\begin{aligned} C_e^i = {} & C_e^i + deltaDOPhoto(\ ) - deltaDOChem(\ ) \\ & + deltaDOReaeration(\ ) - deltaDORespiration(\ ) \\ & - deltaDOSOD(\ ) \end{aligned} \tag{16-42}$$

$$\begin{aligned} C_e^i = {} & C_e^i + deltaDOPhoto(\ ) - deltaDOChem(\ ) \\ & - deltaDORespiration(\ ) - deltaDOSOD(\ ) \end{aligned} \tag{16-43}$$

where

$$C_e^i = \text{Epilimnion Dissolved Oxygen Concentration at time i}$$
$$C_h^i = \text{Hypolimnion Dissolved Oxygen Concentration at time i}$$
$$deltaDOPhoto(\ ) = \text{Function Calculating DO Gain from Photosynthesis}$$
$$deltaDOChem(\ ) = \text{Function Calculating DO Loss from Chemical Decay}$$
$$deltaDOSOD(\ ) = \text{Function Calculating DO Loss from Sediment Oxygen Demand}$$
$$deltaDORespiration(\ ) = \text{Function Calculating DO Loss from Respiration}$$
$$deltaDOReaeration(\ ) = \text{Function Calculating DO Gain from Reaeration}$$

It then adjusts the layer dissolved oxygen concentrations to account for movement of the thermocline during the timestep.

16.4.9 calcGamma

The function, calcGamma, returns a unit-less parameter used to calculate temperature correction factors for sediment oxygen demand, respiration, ammonia decay, dissolved organics decay, and detritus decay. Inputs include two rates (k1, k2), and the corresponding temperatures (t1, t2). Gamma is calculated with the following function:

$$\text{gamma} = \frac{\log\left(\frac{k2 \times (1 - k1)}{k1 \times (1 - k2)}\right)}{(t2 - t1)} \qquad \textbf{(16-44)}$$

16.4.10 calcHar

The function, CalcHar, returns Har (J/(m^2*day), the surface heat flux due to incoming solar radiation, using the following equation (Thomann and Mueller, 1987)

SLOTS WITH REQUIRED KNOWN DATA

- ☞ **AIR TEMPERATURE**
- ☞ **DEWPOINT TEMPERATURE**

METHOD DETAILS:

$$\text{Har} = \phi(T_a + 273)^4(A + 0.031\sqrt{\varepsilon_a}) \qquad \textbf{(16-45)}$$

where

ϕ = Stefan-Boltzmann Constant (0.0049 J/(m^2*day*K))

Ta = air temperature (C)

ε_a = air vapor pressure

A = coefficient ralted to air temperature and ratio of measured radiation to clear sky radiation.

Ta is user input through the Air Temperature slot, and air vapor pressure is returned by the getAir-VaporPressure method (see below). The variable, A, is set as follows: if Air Temperature is less than 20(C), A = 0.65, else, A = 0.70.

16.4.11 calcHbr

The function, calcHbr, returns Hbr (J/(m^2*day), the longwave radiation emitted by the reservoir, using the Stefan-Boltzmann law for a (nearly perfect) black-body emitter.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ **TEMPERATURE**

This method requires a previous epilimnion temperature, which is a column on the Temperature Agg Series Slot.

METHOD DETAILS:

$$Hbr = \varepsilon\phi(T_s + 273)^4 \quad (16\text{-}46)$$

where

ϕ = Stefan-Boltzmann Constant (0.0049 $J/(m^2*day*K)$)
Ts = water surface(temperature (C))
ε = emissivity (0.97)

The values of the Stefan-Boltzmann constant and emissivity are static variables. Ts is the value of the epilimnion temperature from the previous timestep (epilimnionTemp(-1)).

16.4.12 calcHc

The function, calcHc, returns Hc (J/(m^2*day), the heat flux at the reservoir surface due to conduction.

SLOTS WITH REQUIRED KNOWN DATA

- AIR TEMPERATURE
- WIND VELOCITY
- TEMPERATURE

This method requires a previous epilimnion temperature, which is a column on the Temperature Agg Series Slot.

METHOD DETAILS:

The form of the equation is:

$$Hc = c_1(getWindEffect())(T_e - T_a)(41860) \quad (16\text{-}47)$$

where:

c_1 = Bowen's Coefficient(0.47 mmHG/ C)
T_e = Epilimnion Temperature
T_a = Air Temperature

getWindEffect is a utility method (see below) and 41860 is the conversion rate from cal/cm^2 to J/m^2.

16.4.13 calcHe

The function, calcHe, returns He (J/(m^2*day)), the heat flux at the surface due to evaporative heat loss.

SLOTS WITH REQUIRED KNOWN DATA

- DEWPOINT TEMPERATURE
- WIND VELOCITY
- TEMPERATURE

This method requires a previous epilimnion temperature, which is a column on the Temperature Agg Series Slot.

SLOTS WITH OUTPUT DATA

☞ **Heat of Evaporation**

Method Details:

The form of the equation is:

$$He = (\text{getWindEffect}())(VP_s - VP_a)(41860) \tag{16-48}$$

where

VP_s = value of surface vapor pressure returned from getSurfaceVaporPressure() utility method

VP_{sa} = value of air vapor pressure returned from getAirVaporPressure() utility method

getWindEffect is a utility method and 41860 is the conversion rate from cal/cm^2 to J/m^2. The function returns He and sets the Heat of Evaporation slot equal to He / 41860.

16.4.14 calcHeat

The method, calcHeat, calculates the new Temperature for both the epilimnion and hypolimnion based on a backwards-time numerical method. Slots with Required Known Data

- ☞ **Epilimnion Volume**
- ☞ **Hypolimnion Volume**
- ☞ **Inflow to Epilimnion**
- ☞ **Inflow to Hypolimnion**
- ☞ **Outflow from Epilimnion**
- ☞ **Outflow from Hypolimnion**
- ☞ **Specific Heat of Water**
- ☞ **Surface Heat Flux**
- ☞ **Temperature**
- ☞ **Thermocline Diffusion Coefficient**
- ☞ **Thickness of Epilimnion**
- ☞ **Thickness of Metalimnion**

This method requires a previous epilimnion temperature and a previous hypolimnion temperature; both are columns on the Temperature Agg Series Slot.

Slots with Output Data

☞ **Temperature**

This method sets current epilimnion temperature and current hypolimnion temperature; both are columns on the Temperature Agg Series Slot.

Method Details:

First, the method calls the selected method in the Surface Heat Flux category to calculate surface flux. The epilimnion temperatures is calculated as:

$$Te^t = Te^{t-1} + \left(\frac{E_{in}}{E_v}T_{in} - \frac{E_{out}}{E_v}Te^{t-1} + \frac{\Delta H}{\rho C_p E_z} + \frac{\varepsilon' A_t \Delta T}{M_z E_v}\right)\Delta t \tag{16-49}$$

and, the hypolimnion temperatures is calculated as:

$$Th^t = Th^{t-1} + \left(\frac{H_{in}}{H_v}T_{in} - \frac{H_{out}}{H_v}Th^{t-1} + \frac{\varepsilon' A_t \Delta T}{M_z H_v}\right)\Delta t \tag{16-50}$$

where

Te^i = Epilimnion Temperature at time i

Th^i = Hypolimnion Temperature at time t

E_{in} = Epilimnion Inflow

H_{in} = Hypolimnion Inflow

E_v = Epilimnion Volume

H_v = Hypolimnion Volume

E_{out} = Epilimnion Outflow

H_{out} = Hypolimnion Outflow

T_{in} = Inflow Temperature

ΔH = Surface Heat Flux (Joules/m^2 sec)

ρ = Density of Water in Epilimnion (from getEpilimnionDensity())

C_p = Specific Heat of Water (J/gC)

E_z = Epilimnion Thickness

ε' = Thermocline Diffusion Coefficient (m^2/sec)

A_t = Area of Thermocline

ΔT = Temperature Gradient between the Epilimnion and Hypolimnion

M_z = Metalimnion Thickness

Δt = Timestep in seconds

It then adjusts the layer temperatures to account for movement of the thermocline during the timestep and sets the slots.

16.4.15 calcInflowAmmConc

The method, calcInflowAmmConc, calculates the inflow ammonia concentration and total inflow ammonia concentration by doing a weighted average of the inflow and side flow ammonia concentrations. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated ammonia contribution is equal to zero.

Slots with Required Known Data

- ☞ Ammonia Concentrations
- ☞ Canal Flow
- ☞ Canal Flow Ammonia Conc
- ☞ Diversion
- ☞ Diversion Ammonia Conc
- ☞ Flow FROM Pumped Storage
- ☞ Flow TO Pumped Storage
- ☞ Hydrologic Inflow
- ☞ Inflow
- ☞ Inflow Ammonia Mass
- ☞ Pump Storage Inflow Ammonia
- ☞ Pump Storage Outflow Ammonia
- ☞ Return Flow
- ☞ Return Flow Ammonia Conc

This method requires hydrologic inflow ammonia concentration, a column on the Ammonia Concentrations Agg Series Slot

Slots with Output Data

- ☞ Ammonia Concentrations

This method sets inflow ammonia concentration and total inflow ammonia concentration, both are column on the Ammonia Concentrations Agg Series Slot. It uses a similar calculations as calcInflowTemp but sums ammonia mass instead of heat.

16.4.16 calcInflowDetConc

The method, calcInflowDetConc, calculates the inflow detritus concentration and total inflow detritus concentration by doing a weighted average of the inflow and side flow detritus concentrations. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated detritus contribution is equal to zero.

Slots with Required Known Data

- ☞ Canal Flow
- ☞ Canal Flow Detritus Conc
- ☞ Detritus Concentrations
- ☞ Diversion
- ☞ Diversion Detritus Conc
- ☞ Flow FROM Pumped Storage
- ☞ Flow TO Pumped Storage
- ☞ Hydrologic Inflow
- ☞ Inflow
- ☞ Inflow Detritus Mass
- ☞ Pump Storage Inflow Detritus
- ☞ Pump Storage Outflow Detritus
- ☞ Return Flow
- ☞ Return Flow Detritus Conc

Slots with Output Data

- ☞ Detritus Concentrations

It uses a similar calculations as calcInflowTemp but sums detritus mass instead of heat.

16.4.17 calcInflowDOConc

The method, calcInflowDOConc, calculates the inflow dissolved oxygen concentration and total inflow dissolved oxygen concentration by doing a weighted average of the inflow and side flow dissolved oxygen concentrations. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated dissolved oxygen contribution is equal to zero.

Slots with Required Known Data

- ☞ Canal Flow
- ☞ Canal Flow Dissolved Oxygen Conc
- ☞ Dissolved Oxygen Concentrations
- ☞ Diversion
- ☞ Diversion Dissolved Oxygen Conc
- ☞ Flow FROM Pumped Storage
- ☞ Flow TO Pumped Storage
- ☞ Hydrologic Inflow
- ☞ Inflow
- ☞ Inflow Dissolved Oxygen Mass
- ☞ Pump Storage Inflow Dissolved Oxygen
- ☞ Pump Storage Outflow Dissolved Oxygen
- ☞ Return Flow
- ☞ Return Flow Dissolved Oxygen Conc

This method requires hydrologic inflow dissolved oxygen concentration, a column on the Dissolved Oxygen Concentrations Agg Series Slot.

Slots with Output Data

- Dissolved Oxygen Concentrations

This method sets inflow dissolved oxygen concentration and total inflow dissolved oxygen concentration, both are column on the Dissolved Oxygen Concentrations Agg Series Slot.

It uses a similar calculations as calcInflowTemp but sums dissolved oxygen mass instead of heat.

16.4.18 calcInflowOrgConc

The method, calcInflowOrgConc, calculates the inflow dissolved organics concentration and total inflow dissolved organics concentration by doing a weighted average of the inflow and side flow dissolved organics concentrations. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated dissolved organics contribution is equal to zero.

Slots with Required Known Data

- Canal Flow
- Canal Flow Dissolved Organics Conc
- Dissolved Organics Concentrations
- Diversion
- Diversion Dissolved Organics Conc
- Flow FROM Pumped Storage
- Flow TO Pumped Storage
- Hydrologic Inflow
- Inflow
- Inflow Dissolved Organics Mass
- Pump Storage Inflow Organics
- Pump Storage Outflow Organics
- Return Flow
- Return Flow Dissolved Organics Conc

Slots with Output Data

- Dissolved Organics Concentrations

It uses a similar calculations as calcInflowTemp but sums dissolved organics mass instead of heat.

16.4.19 calcInflowSaltConc

The method, calcInflowSaltConc, calculates the inflow salt concentration and total inflow salt concentration by doing a weighted average of the inflow and side flow salt concentrations. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated salt contribution is equal to zero.

Slots with Required Known Data

- Canal Flow
- Canal Flow Salt Conc
- Diversion
- Diversion Salt Concentration
- Flow FROM Pumped Storage
- Flow TO Pumped Storage
- Hydrologic Inflow
- Inflow
- Inflow Salt Mass
- Pump Storage Inflow Salt
- Pump Storage Outflow Salt
- Return Flow
- Return Flow Salt Conc
- Salt Concentrations

This method requires hydrologic inflow salt concentration, one of the columns on the Salt Concentrations Agg Series Slot

Slots with Output Data

☞ **SALT CONCENTRATIONS**

This method sets inflow salt concentration and total inflow salt concentration, both are columns on the Salt Concentrations Agg Series Slot. It uses a similar calculations as calcInflowTemp but sums salt mass instead of heat.

16.4.20 calcInflowTemp

This method sets the inflow temperature and total inflow temperature, both columns on the Temperature Agg Series Slot.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ **CANAL FLOW**
- ☞ **CANAL FLOW TEMP**
- ☞ **DIVERSION**
- ☞ **DIVERSION TEMP**
- ☞ **FLOW FROM PUMPED STORAGE**
- ☞ **FLOW TO PUMPED STORAGE**
- ☞ **HYDROLOGIC INFLOW**
- ☞ **INFLOW**
- ☞ **INFLOW HEAT**
- ☞ **PUMP STORAGE INFLOW TEMP**
- ☞ **PUMP STORAGE OUTFLOW TEMP**
- ☞ **RETURN FLOW**
- ☞ **RETURN FLOW TEMP**
- ☞ **SPECIFIC HEAT OF WATER**
- ☞ **TEMPERATURE**

This method requires a hydrologic inflow temperature, a column on the Temperature Agg Series Slot.

SLOTS WITH OUTPUT DATA

- ☞ **TEMPERATURE**

Method Details:

The method, calcInflowTemp, calculates the inflow temperature and total inflow temperature by doing a weighted average of the inflow and side flow temperatures, i.e. the method sums the heat coming in. The following inflows are considered: Inflow, Hydrologic Inflow Net, Canal Flow, Flow TO Pumped Storage, Flow FROM Pumped Storage, Diversion, and Return Flow. If Canal Flow, Flow FROM Pumped Storage, or Flow TO Pumped Storage are not linked, the associated heat contribution is equal to zero.

The heat associated with each component is calculated as:

$$\text{flowHeat} = \text{flowTemp} \times \text{flowVol} \times \text{specificHeat} \times \text{epilimnionDensity} \quad \textbf{(16-51)}$$

The method then sums the heat as:

$$\begin{aligned}\text{TotalInflowTemp} = {} & (\text{inflowHeat} + \text{hydrologicInflowHeat} + \text{returnFlowHeat} - \\ & \text{diversionHeat} + \text{canalFlowHeat} + \text{pumpInHeat} - \text{pumpOutHeat}) / \\ & (\text{totalInflowVol} \times \text{specificHeat} \times \text{epilimnionDensity})\end{aligned} \quad \textbf{(16-52)}$$

And then sets the Inflow Temp and Total Inflow columns on the Temperature slot.

16.4.21 calcLayerVolumes

The method, calcLayerVolumes, calculates the volume of both the epilimnion and hypolimnion.

Slots with Required Known Data

- Inflow to Hypolimnion
- Outflow from Hypolimnion (current and previous)
- Storage

Slots with Output Data

- Epilimnion Volume
- Hypolimnion Volume

Method Details:

Epilimnion and hypolimnion volumes are calculated as:

$$\text{hypolimnionVol} = \text{hypolimnionVol}[-1] + \text{hypolimnionInflowVol} - \text{hypolimnionOutflowVol} \tag{16-53}$$

$$\text{epilimnionVol} = \text{storage} - \text{hypolimnionVolume} \tag{16-54}$$

These values are later adjusted in AdjKDet after calculating thermocline movement during the timestep.

16.4.22 calcOrganics

This method, calcOrganics, calculates the dissolved organics balance for the epilimnion and the hypolimnion, based on explicit one-step method.Slots with Required Known Data

- Dissolved Organics Concentrations
- Epilimnion Volume
- Hypolimnion Volume
- Inflow to Epilimnion
- Inflow to Hypolimnion
- Outflow from Epilimnion
- Outflow from Hypolimnion
- Thermocline Diffusion Coefficient
- Thickness of Epilimnion
- Thickness of Metalimnion

This method requires a previous epilimnion dissolved organics concentration and a previous hypolimnion dissolved organics concentration; both are columns on the Dissolved Organics Concentrations Agg Series Slot.

Slots with Output Data

- Dissolved Organics Concentrations

Method Details:

This method sets epilimnion dissolved organics concentration and hypolimnion dissolved organics concentration; both are columns on the Dissolved Organics Concentrations Agg Series Slot.

The epilimnion dissolved organics concentration is calculated as:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \tag{16-55}$$

and, the hypolimnion dissolved organics concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / H_v \tag{16-56}$$

where

$$C_e^i = \text{Epilimnion Dissolved Organics Concentration at time i}$$

$$C_h^i = \text{Hypolimnion Dissolved Organics Concentration at time i}$$

$$C_{in} = \text{Inflow Dissolved Organics Concentration}$$

$$E_{inVOL} = \text{Epilimnion Inflow Volume}$$

$$H_{inVOL} = \text{Hypolimnion Inflow Volume}$$

$$E_{outVOL} = \text{Epilimnion Outflow Volume}$$

$$H_{outVOL} = \text{Hypolimnion Outflow Volume}$$

$$\varepsilon' = \text{Thermocline Diffusion Coefficient } (m^2/sec)$$

$$A_t = \text{Area of Thermocline}$$

$$\Delta C = \text{Dissolved Organics Concentration Gradient between the Epilimnion and Hypolimnion}$$

$$M_z = \text{Metalimnion Thickness}$$

$$E_v = \text{Epilimnion Volume}$$

$$H_v = \text{Hypolimnion Volume}$$

$$\Delta t = \text{Timestep in seconds}$$

This concentration is then adjusted by accounting for dissolved organics decay. The amount of dissolved organics decay is passed out of the function. These adjustments will be made within a timestep during which the layer volume will be remain constant. Therefore, it is possible to calculate these sources and sinks in terms of concentration instead of mass.

$$\Delta OrgDecay_e = C_e^i \times AdjK_{Org}(\ ) \times Kmax_{Org} \times \Delta t \tag{16-57}$$

$$C_e^i = C_e^i - \Delta DetDecay_e \tag{16-58}$$

and

$$\Delta OrgDecay_h = C_h^i \times AdjK_{Org}(\ ) \times Kmax_{Org} \times \Delta t \tag{16-59}$$

$$C_h^i = C_h^i - \Delta OrgDecay_h \tag{16-60}$$

where

$$\Delta OrgDecay_e = \text{Dissolved Organics Decay in Epilimnion (g/m}^3\text{)}$$
$$\Delta OrgDecay_h = \text{Dissolved Organics Decay in Hypolimnion (g/m}^3\text{)}$$
$$AdjK_{Org}(\ ) = \text{Function Calculating Maximum Decay Rate Scaling Factor}$$
$$Kmax_{Org} = \text{Maximum Decay Rate for Dissolved Organics}$$
$$E_Z = \text{Epilimnion Thickness}$$
$$H_Z = \text{Hypolimnion Thickness}$$

It then adjusts the layer dissolved organics concentrations to account for movement of the thermocline during the timestep.

16.4.23 calcOutflowAmmConc

The method, calcOutflowDetConc, calculates the outflow ammonia concentration and outflow ammonia mass given the epilimnion and hypolimnion outflows, the total outflow, and the epilimnion and hypolimnion concentrations at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot "outflow ammonia concentration" is set by this method, as the weighted average of the epilimnion and Hypolimnion Outflow and ammonia concentrations.

SLOTS WITH REQUIRED KNOWN DATA

- AMMONIA CONCENTRATIONS
- OUTFLOW
- OUTFLOW FROM EPILIMNION
- OUTFLOW FROM HYPOLIMNION

This method requires a previous epilimnion ammonia concentration and a previous hypolimnion ammonia concentration; both are columns on the Ammonia Concentrations Agg Series Slot.

SLOTS WITH OUTPUT DATA

- AMMONIA CONCENTRATIONS

This method sets the outflow ammonia concentration which is a column on the Ammonia Concentrations Agg Series Slot.

Outflow Ammonia Mass

16.4.24 calcOutflowDetConc

The method, calcOutflowDetConc, calculates the outflow detritus concentration and outflow detritus mass given the epilimnion and hypolimnion outflows, the total outflow, and the epilimnion and hypolimnion concentrations at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot "outflow detritus concentration" is set by this method, as the weighted average of the epilimnion and hypolimnion outflows and detritus concentrations.

SLOTS WITH REQUIRED KNOWN DATA

- DETRITUS CONCENTRATIONS
- OUTFLOW
- OUTFLOW FROM EPILIMNION
- OUTFLOW FROM HYPOLIMNION

This method requires a previous epilimnion detritus concentration and a previous hypolimnion detritus concentration; both are columns on the Detritus Concentrations Agg Series Slot.

SLOTS WITH OUTPUT DATA

- ☞ DETRITUS CONCENTRATIONS

This method sets the outflow detritus concentration, which is a column on the Detritus Concentrations Agg Series Slot.

Outflow Detritus Mass

16.4.25 calcOutflowDOConc

The method, calcOutfloOrgConc, calculates the outflow dissolved oxygen concentration and outflow dissolved oxygen mass given the epilimnion and hypolimnion outflows, the total outflow, and the epilimnion and hypolimnion concentrations at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot “outflow detritus concentration” is set by this method, as the weighted average of the epilimnion and hypolimnion outflows and dissolved oxygen concentrations.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ DISSOLVED OXYGEN CONCENTRATIONS
- ☞ OUTFLOW
- ☞ OUTFLOW FROM EPILIMNION
- ☞ OUTFLOW FROM HYPOLIMNION

This method requires a previous epilimnion dissolved oxygen concentration and a previous hypolimnion dissolved oxygen concentration; both are columns on the Dissolved Oxygen Concentrations Agg Series Slot.

SLOTS WITH OUTPUT DATA

- ☞ DISSOLVED OXYGEN CONCENTRATIONS
- ☞ OUTFLOW DISSOLVED OXYGEN MASS

This method sets the outflow dissolved oxygen concentration; which is a column on the Dissolved Oxygen Concentrations Agg Series Slot.

16.4.26 calcOutflowOrgConc

The method, calcOutfloOrgConc, calculates the outflow dissolved organics concentration and outflow dissolved organics mass given the epilimnion and hypolimnion outflows, the total outflow, and the epilimnion and hypolimnion concentrations at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot “outflow detritus concentration” is set by this method, as the weighted average of the epilimnion and hypolimnion outflows and dissolved organics concentrations.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ DISSOLVED ORGANICS CONCENTRATIONS
- ☞ OUTFLOW
- ☞ OUTFLOW FROM EPILIMNION
- ☞ OUTFLOW FROM HYPOLIMNION

This method requires a previous epilimnion dissolved organics concentration and a previous hypolimnion dissolved organics concentration; both are columns on the Detritus Organics Concentrations Agg Series Slot.

Slots with Output Data

☞ Dissolved Organics Concentrations

This method sets the outflow dissolved organics concentration which is a column on the Detritus Concentrations Agg Series Slot.

Outflow Dissolved Organics Mass

16.4.27 calcOutflowSaltConc

The method, calcOutflowSaltConc, calculates the outflow salt concentration and outflow salt mass given the epilimnion and hypolimnion outflows, the total outflow, and the epilimnion and hypolimnion concentrations at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot “outflow salt concentration” is set by this method, as the weighted average of the epilimnion and hypolimnion outflows and salt concentrations.

Slots with Required Known Data

☞ Outflow
☞ Outflow from Epilimnion
☞ Outflow from Hypolimnion
☞ Salt Concentrations

This method requires a previous epilimnion salt concentration and a previous hypolimnion salt concentration; both are columns on the Salt Concentrations Agg Series Slot.

Slots with Output Data

☞ Salt Concentrations

This method sets the outflow salt concentration which is a column on the Salt Concentration Agg Series Slot.

Outflow Salt Mass

16.4.28 calcOutflowTemp

The method, calcOutflowTemp, calculates the outflow temperature and outflow heat given the Outflow from Epilimnion, Outflow from Hypolimnion, the total outflow, and the epilimnion and hypolimnion temperatures at (t-1). Notice that, as described in the NOTE under the AdjKDet description above, this is an explicit solution. The slot “outflow temperature” is set by this method, as the weighted average of the epilimnion and hypolimnion outflows and temperatures.

Slots with Required Known Data

☞ Outflow
☞ Outflow from Epilimnion
☞ Outflow from Hypolimnion
☞ Temperature

This method requires a previous epilimnion temperature and a previous hypolimnion temperature, both are columns on the Temperature Agg Series Slot.

Slots with Output Data

☞ Outflow Heat
☞ Temperature

This method sets the outflow temperature, which is column on the Temperature Agg Series Slot.

16.4.29 calcSalt

The method, calcSalt, calculates the salt balance for the epilimnion and the hypolimnion, based on explicit one-step method. Slots with Required Known Data

- Epilimnion Volume
- Hypolimnion Volume
- Inflow to Epilimnion
- Inflow to Hypolimnion
- Outflow from Epilimnion
- Outflow from Hypolimnion
- Salt Concentrations
- Thermocline Diffusion Coefficient
- Thickness of Epilimnion
- Thickness of Metalimnion

This method requires previous epilimnion and hypolimnion salt concentrations; both are columns on the Salt Concentrations Agg Series Slot.

Slots with Output Data

- Salt Concentrations

This method sets epilimnion and hypolimnion salt concentrations; both are columns on the Salt Concentrations Agg Series Slot.

Method Details:

The epilimnion salt concentration is calculated as:

$$S_e^t = S_e^{t-1} + \left(SC_{in} E_{inVOL} - S_e^{t-1} E_{outVOL} + \left[\frac{\varepsilon' \Delta S A_t}{M_z} \right] \Delta t \right) / E_v \quad \textbf{(16-61)}$$

and, the hypolimnion salt concentration is calculated as:

$$S_h^t = S_h^{t-1} + \left(SC_{in} H_{inVOL} - S_h^{t-1} H_{outVOL} + \left[\frac{\varepsilon' \Delta S A_t}{M_z} \right] \Delta t \right) / H_v \quad \textbf{(16-62)}$$

where

S_e^i = Epilimnion Salt Concentration at time i

S_h^i = Hypolimnion Salt Concentration at time i

SC_{in} = Inflow Salt Concentration

E_{inVOL} = Epilimnion Inflow Volume

H_{inVOL} = Hypolimnion Inflow Volume

E_{outVOL} = Epilimnion Outflow Volume

H_{outVOL} = Hypolimnion Outflow Volume

ε' = Thermocline Diffusion Coefficient (m^2/sec)

A_t = Area of Thermocline

ΔS = Salt Concentration Gradient between the Epilimnion and Hypolimnion

M_z = Metalimnion Thickness

E_v = Epilimnion Volume

H_v = Hypolimnion Volume

Δt = Timestep in seconds

It then adjusts the layer salt concentrations to account for movement of the thermocline during the timestep and sets the slots.

16.4.30 calcSurfaceArea

The function, calcSurfaceArea, returns surface area for a an elevation, based on an approximation of a very small incremental change in the elevation (0.1m) of the reservoir related to the corresponding change in the reservoir volume:

$$A = \frac{\Delta V}{\Delta H} \tag{16-63}$$

This function is only used if the Elevation Area Table is not in used because an evaporation method has not been selected.

Slots with Required Known Data

Elevation Volume Table

16.4.31 checkSideFlowConcDO

The function, checkSideFlowConcDO, checks detritus, ammonia, dissolved organics, and dissolved oxygen concentrations associated with side flows and sets them if appropriate. diversion concentrations, negative canal flow concentrations, and pumped storage outflow concentrations are set to previous epilimnion concentrations. If return flow concentrations, positive canal flow concentrations, or pumped storage inflow concentrations are not valid, the method is exited so that the other object can solve first and propagate a concentration across the link.

16.4.32 checkSideFlowConcSalt

The function, checkSideFlowConcSalt, checks salt concentrations associated with side flows and sets them if appropriate. Diversion Salt Concentration, negative Canal Flow Salt Concentration, and Pumped Storage Outflow Salt Concentration are set to previous epilimnion salt concentration. If Return Flow Salt Concentration, positive Canal Flow Salt Concentration, or Pumped Storage Inflow Salt Concentration are not valid, the method is exited so that the other object can solve first and propagate a concentration across the link.

16.4.33 checkSideFlowTemp

The function, checkSideFlowTemp, checks temperatures associated with side flows and sets them if appropriate. Diversion Temperature, negative Canal Flow Temperature, and Pumped Storage Outflow Temperature are set to previous epilimnion temperature. If Return Flow Temperature, positive Canal Flow Temperature, or Pumped Storage Inflow Temperature are not valid, the method is exited so that the other object can solve first and propagate a temperature across the link.

16.4.34 cubicFit

The method, cubicFit, calculates a cubic fit to the elevation - storage relationship of a reservoir given an elevation volume table. It is currently used by the calcOutflowDistribution method which applies the coefficients in determining a withdrawal cone at the reservoir outlet works.

Slots with Required Known Data

☞ **Elevation Volume Table**

Slots with Output Data

☞ **Reservoir Geometry Coefficients Table**

Method Details:

This method uses a Gauss-Jordan method for fitting cubic function to Elevation Volume table values and places results in Reservoir Geometry Coefficients Table slots.

16.4.35 deltaDOChem

The function, deltaDOChem, returns doChem [g/m3], the amount of dissolved oxygen loss due to detritus, dissolved organics, and ammonia decay during the timestep.

Slots with Required Known Data

☞ **Detritus Parameters**

This method requires an oxygen stoichiometric coefficient for detritus (rDet [M/M]).

☞ **Ammonia Parameters**

This method requires an oxygen stoichiometric coefficient for ammonia (rAmm [M/M]).

☞ **Dissolved Organics Parameters**

This method requires an oxygen stoichiometric coefficient for dissolved organics (rOrg [M/M]).

The values detritusDecay, dissolvedOrganicsDecay, and ammoniaDecay are passed in from the calling function, calcDO and represent the values for either the epilimnion or hypolimnion.

Method Details:

The value, doChem is calculated as:

$$\text{doChem} = \text{detritusDecay} \times \text{rDet} + \text{dissolvedOrganicsDecay} \times \text{rOrg} + \text{ammoniaDecay} \times \text{rAmm} \quad (16\text{-}64)$$

16.4.36 deltaDOPhoto

The function, deltaDOPhoto, returns doPhoto [g/m^3], the amount of dissolved oxygen gained due photosynthesis during the timestep.

Slots with Required Known Data

- Elevation of Thermocline
- Photosynthesis Parameters
- Pool Elevation
- Reservoir Bottom Elevation
- Thickness of Epilimnion

Method Details:

Temperature is the layer's temperature and is passed in to the method. The depthFromSurface is calculated based on Pool Elevation, Elevation of Thermocline, and Thickness of Epilimnion.

The method returns the following values:

$$\text{doPhoto} = \frac{\text{Pmax}\left(\frac{\text{Eave}}{\text{Emax}}\right)\text{fPhoto} \times \Delta t}{\text{layerThickness}} \quad (16\text{-}65)$$

where

$$\text{Pmax} = \text{Pmax20} \times \text{theta}^{(\text{Temperature} - 20)} \quad (16\text{-}66)$$

and

$$\begin{aligned} \text{Eave} &= (\text{Etop} + \text{Ebot})/2 \\ \text{Etop}(\text{Ebot}) &= \text{Emax} \times (1 - \text{beta})e^{(-\text{eta} \times \text{depthFromSurface})} \end{aligned} \quad (16\text{-}67)$$

16.4.37 deltaDOReaeration

The function, deltaDOReaeration, returns doReaer [g/m^3], the amount of dissolved oxygen gained due to re-aeration during the timestep.

Slots with Required Known Data

- Salt Concentrations
- Thickness of Epilimnion
- Wind Velocity

METHOD DETAILS:

The method returns the following:

$$doReaer = \frac{Kreaer \times (C_s - epiConcDO)\Delta t}{layerThickness} \tag{16-68}$$

where K_{reaer} is the surface transfer coefficient

$$Kreaer = 0.5 + 0.05 \times windVelocity \tag{16-69}$$

and C_s is the saturation concentration of dissolved oxygen.

$$C_s = 14.652 - 0.41022T + 0.007991T^2 - 0.7777 \times 10^{-4}T^3 \tag{16-70}$$

Temperature of the layer is passed in through layerTemp. If salinity is modeled, the reduced saturation concentration of dissolved oxygen is calculated with the following equation:

$$\ln C_{ss} = \ln C_s - S\left[1.7674 \times 10^{-2} - \frac{1.0754 \times 10^1}{T} + \frac{2.1407 \times 10^3}{T^2}\right] \tag{16-71}$$

where C_{ss} is the new saturation concentration, and S is the salinity concentration in ppt.

16.4.38 deltaDORespiration

The function, deltaDORespiration, returns doResp [g/m^3], the amount of dissolved oxygen loss due to macrophyte respiration the timestep.

SLOTS WITH REQUIRED KNOWN DATA

☞ **RESPIRATION PARAMETERS**

METHOD DETAILS:

The method returns doResp which is calculated as:

$$\begin{aligned} doResp &= AdjKResp(\ ) \times KmaxResp \times factor \times fResp \\ &\times thetaR^{(Temperature - 20)} \times \Delta t \end{aligned} \tag{16-72}$$

where KmaxResp is the maximum sediment oxygen demand, AdjKResp is a function that calculates a scaling factor to adjust the maximum SOD for the current temperature based on a double S-curve. Factor is a unit-less adjustment ratio for KmaxResp set in calcDO, fResp is an additional calibration knob for sediment oxygen demand. Temperature of the layer is passed into the method.

16.4.39 deltaDOSOD

The function, deltaDOSOD, returns doSOD [g/m^3], the amount of dissolved oxygen loss due sediment oxygen demand during the timestep.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ EPILIMNION VOLUME
- ☞ HYPOLIMNION VOLUME
- ☞ SOD PARAMETERS

METHOD DETAILS:

The method returns doSOD, which is calculated using the following equation:

$$\mathrm{doSOD} = \frac{K_{SODMax} \times \mathrm{sedArea} \times \mathrm{AdjKSOD}(\;) \times \mathrm{Factor} \times F_{SOD} \times \Delta t}{\mathrm{layerVolume}} \qquad \textbf{(16-73)}$$

where K_{SODMax} is the maximum sediment oxygen demand, `AdjKSOD` is a function that calculates a scaling factor to adjust the maximum SOD for the current temperature based on an S-curve. Factor is a unit-less adjustment ratio for K_{SODMax} set in calcDO, F_{SOD} is an additional calibration knob for sediment oxygen demand. For the hypolimnion, the sediment area is the area of the thermocline. For the epilimnion, the sediment area is the surface area minus the thermocline area.

16.4.40 getAirVaporPressure

Returns Air Vapor Pressure, the vapor pressure of the air mass overlying the reservoir.

$$P_a = 4.596e^{\left(\frac{17.27T_d}{237.3 + T_d}\right)} \qquad \textbf{(16-74)}$$

where

P_a = Vapor Pressure of Air

T_d = Dewpoint Temperature

SLOTS WITH REQUIRED KNOWN DATA

Dewpoint Temperature

16.4.41 getAvgSaltConcIn

SLOTS WITH REQUIRED KNOWN DATA

- ☞ INFLOW
- ☞ INFLOW SALT CONCENTRATION

The method, getAvgSaltConcIn, returns a weighted average inflow salt concentration for cases where the Inflow Salt Concentration and Inflow have multiple columns of the multi-slot. The Inflow and Inflow Salt Concentration multi-slots must have the same number of columns.

16.4.42 getEpilimnionDensity

The function, getEpilimnionDensity, returns Epilimnion Water Density.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ TEMPERATURE

This method requires a current or previous epilimnion temperature, a column on the Temperature Agg

Series Slot.

METHOD DETAILS:

The value of density for the epilimnion based on the following polynomial relationship with temperature:

$$\rho = 1000(6.14\text{x}10^{-8}T^3 - 9.5\text{x}10^{-6}T^2 + 8.93\text{x}10^{-5}T + 0.999812) \quad \textbf{(16-75)}$$

If this value evaluates to a density greater than $1\text{x}10^6$ g/m^3, the method returns $1\text{x}10^6$ g/m^3.

16.4.43 getSurfaceVaporPressure

The function getSurfaceVaporPressure, returns Surface Vapor Pressure, the vapor pressure at the surface of the reservoir:

$$P_s = 4.596e^{\left(\frac{17.27T_s}{237.3 + T_s}\right)} \quad \textbf{(16-76)}$$

where

P_s = Vapor Pressure at Reservoir Surface

T_s = Surface (Epilimnion) Temperature

SLOTS WITH REQUIRED KNOWN DATA

☞ **TEMPERATURE**

This method requires a previous epilimnion temperature, a column on the Temperature Agg Series Slot.

16.4.44 getWindEffect

Returns Coefficient of Wind Effect, the effect of wind on the surface heat flux equations.

$$W = 19.0 + 0.95U^2 \quad \textbf{(16-77)}$$

where

W = Wind Effect Coefficient

U = Wind Velocity

SLOTS WITH REQUIRED KNOWN DATA

☞ **WIND VELOCITY**

16.4.45 massBalanceSaltInit

This method first checks if Diversion is not valid or equal to 0.0 and if Diversion Salt Concentration is not valid, Diversion Salt Concentration is set equal to 0.0.

Otherwise, if Diversion is valid or not equal to 0.0. Then, if Diversion Salt Concentration is not valid and Previous Reservoir Salt Concentration is valid set Diversion Salt Concentration equal to the Previous Reservoir Salt Concentration.

Next, the method checks is if Return Flow Salt Mass is linked to any object but not valid. If so, the dispatch method exits successfully and control is returned back to the dispatch controller. The object will go back on the queue if Return Flow Salt Mass gets a value.

If Hydrologic Inflow is not valid or it equals 0.0 and Hydrologic Inflow Salt Concentration is not valid, Hydrologic Inflow Salt Concentration is set equal to 0.0. Otherwise, if Hydrologic Inflow is valid or not equal to 0.0, set Hydrologic Inflow Salt Concentration to 0.0 only if it is not valid.

Next, execute the selected Bank Storage Salt method. If no method is selected, set Inbound Bank Storage Salt Mass and Outbound Bank Storage equal to 0.0.

The method checks if Inflow is valid and if it is not equal to 0.0, it sets inflowVol from the inflow rate times the current time step length. Otherwise, inflowVol is set equal to 0.0.

Otherwise, if Hydrologic Inflow, Return Flow, and Diversion are valid, set their local volume variable and set the local variable returnFlowSaltMass to the Return Flow Salt Mass slot. If they are not valid set each to 0.0 along with returnFlowSaltMass.

Then, the function returns to the calling dispatch method to continue with the method.

16.4.46 setThermoclineDiffusionCoefficient

The method, setThermoclineDiffusionCoefficient, calculates a diffusion coefficient for the thermocline calculations.

SLOTS WITH REQUIRED KNOWN DATA

- ☞ **POOL ELEVATION**
- ☞ **RESERVOIR BOTTOM ELEVATION**
- ☞ **THERMOCLINE DIFFUSION COEFFICIENT ADJUSTMENT**

SLOTS WITH OUTPUT DATA

- ☞ **THERMOCLINE DIFFUSION COEFFICIENT**

METHOD DETAILS:

Typically, this function is called only if the user has NOT supplied a coefficient of their own. The value is set by the following equation:

$$\varepsilon' = 6.10848 \times 10^{-3} \bar{D}^{1.1505} \varepsilon_{adj} \qquad (16\text{-}78)$$

where

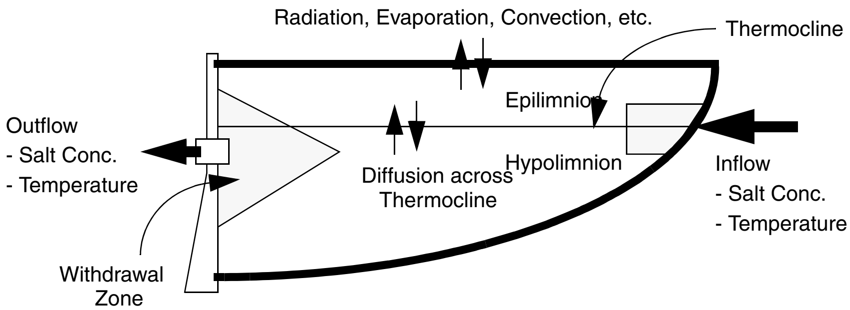
ε' = Thermocline Diffusion Coefficient

$\bar{D}$ = Mean Depth of the Reservoir

ε_{adj} = Thermocline Diffusion Coefficient Adjust

16.4.47 WQ_2_Layer

WQ_2_Layer is the utility method that executes the layered model. It models fluxes of constituents into and out of a reservoir hypolimnion and epilimnion. The general structure is shown in the following figure.



Schematic of 2-layer WQ reservoir structure

NOTE: It is important to mention that the current WQ_2_Layer model uses a purely **explicit** approach to solving the reservoir's water quality balances. That is, all calculations are based (where applicable) on information from the previous timestep. Thus outflow salt concentration is purely a function of the current outflow and the concentrations at the end of the previous timestep (i.e., hypolimnion Salt Concentrations(-1)). This approach eliminates the need for an iterative or simultaneous type of solution, and for larger reservoirs running relatively small timesteps does not compromise the validity of the solution

Slots with Required Known Data (depending on constituents)

- Inflow
- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Oxygen Mass
- Inflow Heat
- Inflow Salt Concentration
- Inflow Salt Mass
- Outflow
- Storage

Slots with Output Data (depending on constituents)

- Ammonia Concentrations
- Detritus Concentrations
- Dissolved Organics Concentrations
- Dissolved Oxygen Concentrations
- Outflow Ammonia Mass
- Outflow Detritus Mass
- Outflow Dissolved Organics Mass
- Outflow Dissolved Oxygen Mass
- Outflow Heat
- Outflow Salt Mass
- Salt Concentrations
- Temperature

Method Details:

The methods associated with this structure are outlined below. The methods are "nested"; that is, many methods rely on sub-methods for pieces of their functionality. For example, the default CalcSurfaceFlux user method relies on output from the calcHar, calcHbr, calcHc, and calcHe utility methods. Description below depict the nested nature of the temperature and salt solver in the water quality controller. The sequence of functions represents the order of execution, and the offset represents the nesting of the methods within "parent" methods. The WQ_2_Layer does the following in order:

Verify that there is a valid previous Hypolimnion Volume and that it does not equal zero. If there is not use the previous pool elevation to calculate the previous Hypolimnion volume using the Epilimnion Thickness. Verify there is a valid previous Epilimnion Volume and Thermocline Elevation. If not, calculate these using the Hypolimnion Volume and Epilimnion Thickness.

Next determine the surface area of the reservoir and surface area of the thermocline using the Elevation Area table (if valid) or the calcSurfaceArea function.

- If modeling temperature, call calcInflowTemp.
- If modeling salinity, call calcInflowSaltConc.
- If modeling dissolved oxygen, call calcInflowDOConc, calcInflowDetConc, calcInflowOrgConc, and calcInflowAmmConc.

Execute the selected DistributeInflowCategory and DistributeOutflowCategory method.

Calculate the outflow concentration for each constituent. This can be done now since the modeling scheme is explicit. If Outflow is zero, set the Outflow Concentration of each constituent to zero.

- If modeling temperature calcOutflowTemp
- If modeling salinity, calcOutflowSaltConc
- If modeling dissolved oxygen, calcOutflowDOConc, calcOutflowDetConc, calcOutflowOrgConc, and calcOutflowAmmConc.

Call calcLayerVolumes to determine the volume in each layer.

Call setThermoclineDiffusionCoefficient.

Find the change in volume between layers due to thermocline movement during timestep. Determine the new HypolimnionVolumne and Epilimnion Volume due to this movement.

Determine the final concentration of the constituent in the reservoir:

- If modeling temperature, calcHeat
- If modeling salinity, calcSalt
- If modeling dissolved oxygen, calcDetritus, calcOrganics, calcDO, calcDO

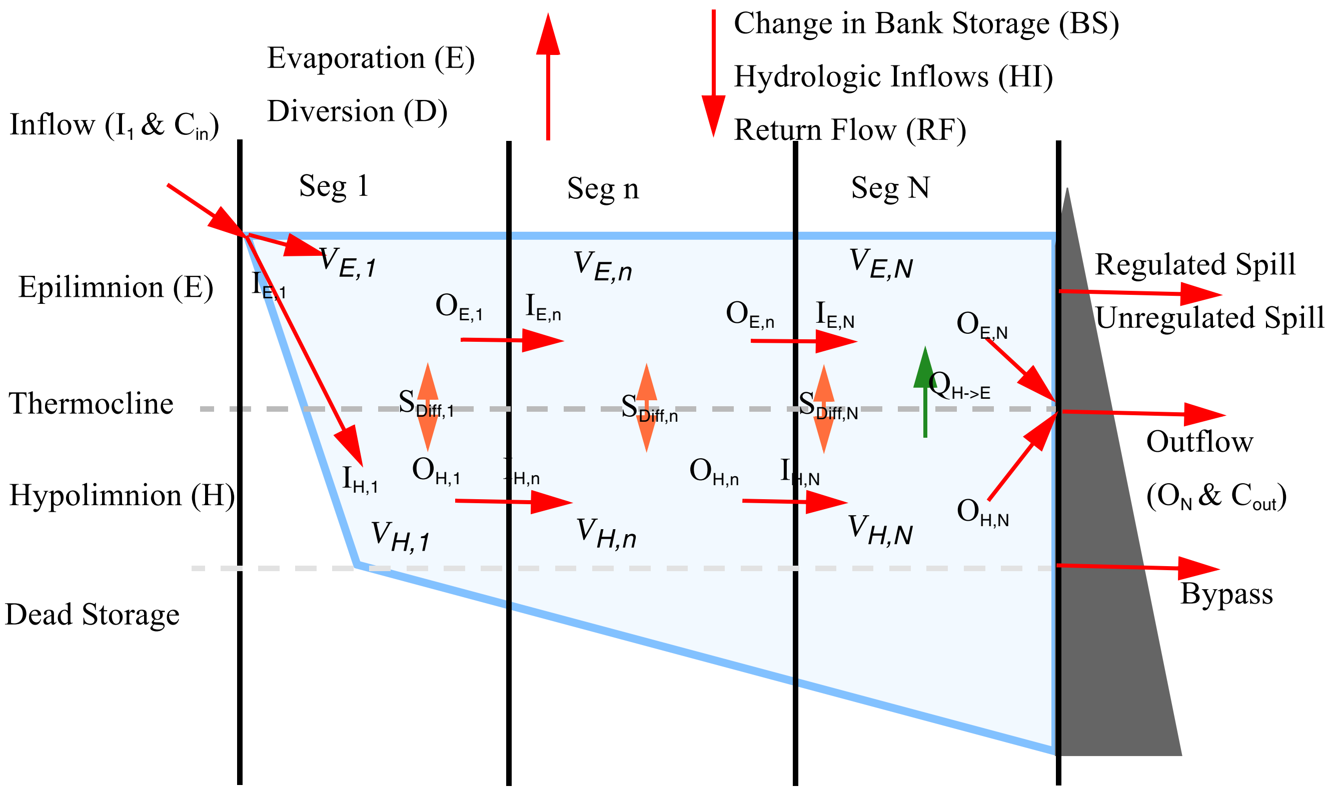
16.4.48 WQ_Segmented_2_Layer

WQ_Segmented_2_Layer is the utility method that executes the segmented 2 layered model. Salt is modeled as it flows through each segment in both the epilimnion and hypolimnion. The general structure is shown in the following figure. The reservoir object has *N* longitudinal segments and two vertical layers, the epilimnion and hypolimnion. Segment 1 represents the segment where water flows into the reservoir; *Segment n* represents zero or more interior segments, and *Segment N* represents the outflow segment. The number of longitudinal segments and the sizes are specified by the user.

When first configuring the method, the user should set the Number of Segments slot and initialize a run. The run will error, but RiverWare will update the Agg Series and Table slots with the correct number of segments. Then, the user can add necessary data to these slots.

In this approach, the thickness of the hypolimnion layer is constant and the elevation of the thermocline is constant, unless the pool elevation drops below the thermocline elevation. Each mass balance component except Evaporation will have an equivalent salt concentration and salt mass component. On the Reservoir object, the Change in Bank Storage and Vertical Flow from Hypolimnion to Epilimnion can be either negative or positive. The salt concentration entering the reservoir comes from a linked slot or is specified (input or rules).

The water mass balance is calculated by existing quantity Dispatch Methods. Once the water quality methods dispatch, this method will calculate a flow balance inside the reservoir now accounting for the layers and segments. The inflow flowing into the hypolimnion and epilimnion and outflow flowing from the hypolimnion and epilimnion is specified with a periodic or series fractional relationship. The salinity balance can then be calculated using the flow balance and a diffusion term to transport salt between the hypolimnion and epilimnion. Concentration in each segment, layer, in the bank storage, diversions, return flow and outflow are calculated each timestep.



NOTE: It is important to mention that the current WQ_Segmented_2_Layer model uses a purely **explicit** approach to solving the reservoir's water quality balances.

Slots with Required Known Data

- ☞ Inflow
- ☞ Outflow
- ☞ Storage
- ☞ Segment Parameters Table
- ☞ Elevation Volume Table by Segment
- ☞ Thermocline Elevation
- ☞ Thermocline Thickness
- ☞ Inflow Salt Concentration
- ☞ Inflow Salt Concentration
- ☞ Number of Segments
- ☞ Dead Storage by Segment
- ☞ Elevation Area Table by Segment
- ☞ Thermocline Diffusivity

Slots with Output Data (depending on constituents)

- ☞ Outflow Salt Concentration
- ☞ Epilimnion Salt Conc by Segment
- ☞ Hypolimnion Salt Conc by Segment
- ☞ Inflow to Hypolimnion
- ☞ Inflow to Epilimnion
- ☞ Epilimnion Volume by Segment
- ☞ Epilimnion Inflow by Segment
- ☞ Hypolimnion Outflow by Segment
- ☞ Vertical Flow
- ☞ Diversion by Segment
- ☞ Hydrologic Inflow by Segment
- ☞ Precipitation by Segment
- ☞ Outflow Salt Mass
- ☞ Epilimnion Salt Mass by Segment
- ☞ Hypolimnion Salt Mass by Segment
- ☞ Outflow from Hypolimnion
- ☞ Outflow from Epilimnion
- ☞ Hypolimnion Volume by Segment
- ☞ Epilimnion Outflow By Segment
- ☞ Hypolimnion Inflow by Segment
- ☞ Bank Storage by Segment
- ☞ Return Flow by Segment
- ☞ Evaporation by Segment

Method Overview:

Following is a conceptual overview of the computation to determine storage, salt concentration, and flow in, out, and between each segment and layer. Once the water balance is calculated by existing RiverWare functions, these steps can be completed. Each step will check if the pool elevation is below the thermocline elevation. When the pool elevation is above the thermocline, the reservoir is composed of two layers, the epilimnion and hypolimnion. If the pool elevation is below than the thermocline elevation, there will only be one layer in the reservoir, the hypolimnion. All inflows and outflows will enter and leave the hypolimnion. There will be no vertical flows, and the evaporation and bank storage will affect the hypolimnion, not the epilimnion.

Following are the conceptual steps taken in a run. These computations are described in detail in the following sections.

- Determine the layer and segment volumes based on the water elevation.
- Determine the inflow into each layer and outflow from each layer using the specified fraction.
- Compute the evaporation from each segment and precipitation entering each segment using the Elevation Area Table by Segment.
- Compute the vertical flow by taking the difference between the outflow and inflow.
- Compute the proportion of bank storage, return flow, diversions, and hydrologic inflow entering and leaving each segment by using values in the Segment Parameters Table.

- Compute the inflow for each epilimnion segment by adding together segment outflows, change in storage, vertical flow, evaporation and subtracting the change in bank storage.
- Compute the inflow for each hypolimnion segment by subtracting the vertical flow from the segment outflow.

The water balance is complete. The following steps describe computations for salinity.

- Compute the salt concentration in the bank storage.
- Compute the salt mass and concentration in the epilimnion and hypolimnion for each segment and layer using the flows calculated from the water balance and an additional diffusion term.
- Compute the outflow salt mass and concentration. Outflow salt concentration is based on current concentration.
- Compute total reservoir salt mass.

The following sections describe these steps in detail.

16.4.48.1 Determine Storage in each Segment and Layer

The storage in each layer and segment is determined at the current timestep using the pool elevation (PE), thermocline elevation (TE), and Elevation Volume Table by Segment. The dead storage is added into the hypolimnion volume.

For each segment *n*,

$$\mathrm{HypolimnionVolume}(t, n) = \mathrm{ElevationVolumeTable}(TE, n) + \mathrm{DeadStorage}(n) \tag{16-79}$$

$$\mathrm{EpilimnionVolume}(t, n) = \mathrm{ElevationVolumeTable}(PE, n) - \mathrm{ElevationVolumeTable}(TE,n) \tag{16-80}$$

16.4.48.2 Compute Inflow to each Layer and Outflow from each Layer

The inflow to the hypolimnion and epilimnion and outflow from the hypolimnion and epilimnion are calculated through the WQ Distribute Outflow and WQ Distribute Inflow methods. The methods calculate flow distribution between the two layers for reservoir inflow and outflow.

16.4.48.3 Compute Evaporation and Precipitation From Each Segment

The evaporation leaving each segment and the precipitation entering each segment is based on the proportion of total surface area in each segment. The proportion of total surface area in each segment is calculated using the Elevation Area Table by Segment. The following equations calculate the evaporation and precipitation in each segment, *n*.

$$\mathrm{EvaporationbySegment}(t,n) = \frac{\mathrm{ElevationAreaTable}(PE,n) \times \mathrm{Evaporation}(t)}{\mathrm{SurfaceArea}(PE)} \tag{16-81}$$

$$\mathrm{PrecipitationbySegment}(t,j) = \frac{\mathrm{ElevationAreaTable}(PE,n) \times \mathrm{Precipitation}(t)}{\mathrm{SurfaceArea}(PE)} \tag{16-82}$$

16.4.48.4 Compute Bank Storage, Hydrologic Inflow, Diversion, and Return Flow for Each Segment

The bank storage, hydrologic inflow, diversion, and return flow entering or leaving each segment is calculated using the Segment Parameters Table. The proportions for each flow component are constant. The following equations calculates the bank storage, hydrologic inflow, diversion, and return flow affecting each segment.

$$\mathrm{BankStoragebySegment(t,n)} = \mathrm{BankStorageProportion}(t, n) \times \mathrm{BankStorage}(t) \tag{16-83}$$

$$\mathrm{HydroInflowbySegment(t,n)} = \mathrm{HydroInflowProportion}(t, n) \times \mathrm{HydrologicInflow}(t) \tag{16-84}$$

$$\mathrm{DiversionbySegment(t,n)} = \mathrm{DiversionProportion}(t, n) \times \mathrm{Diversions}(t) \tag{16-85}$$

$$\mathrm{ReturnFlowbySegment(t,n)} = \mathrm{ReturnFlowProportion}(t, n) \times \mathrm{ReturnFlow}(t) \tag{16-86}$$

16.4.48.5 Compute Vertical Flow From Hypolimnion to Epilimnion

The vertical flow is the difference between the hypolimnion inflow and outflow. The vertical flow moves excess water enter the hypolimnion to the epilimnion to keep the hypolimnion at a constant volume. The vertical flow only occurs in the segment closest to the dam, since there is no physical mechanism for vertical flow in other segments. If the pool elevation is below the thermocline, there is no vertical flow. From the conditions described above, the vertical flow is computed as follows:

```
If PE(t) > Thermocline Elev AND PE(t-1) > Thermocline Elev
```

$$\mathrm{VerticalFlowbySeg(t,N)} = \mathrm{HypolimnionInflow}(t) - \mathrm{HypolimnionOutflow}(t) \tag{16-87}$$

$$\mathrm{VerticalFlowbySeg(t,n)} = 0 \tag{16-88}$$

```
Else
```

$$\mathrm{VerticalFlowbySeg(t,n)} = 0 \tag{16-89}$$

16.4.48.6 Check Inflow and Outflow Layer

The inflow and outflow layer of the reservoir is computed above in WQ Distribute Outflow and WQ Distribute Inflow. The inflow and outflow layer must be checked to ensure water can flow in or out of the epilimnion. All inflows and outflows only enter and leave the hypolimnion if the pool elevation is below the thermocline. If the spillways are in use, the flow through the spillways must be removed from the correct layer. Unregulated and regulated spill outflows from the epilimnion, and bypass outflows from the hypolimnion. The inflows and outflows are checked and reset as follows:

```
If spill(t) < 0
```

$$\mathrm{HypolimnionOutflow}(t) = \mathrm{bypass}(t) + \mathrm{HypolimnionOutflowProp}(t) \times \mathrm{TurbineRelease}(t) \tag{16-90}$$

$$\mathrm{EpilimnionOutflow}(t) = \mathrm{Outflow}(t) - \mathrm{HypolimnionOutflow}(t) \tag{16-91}$$

```
If PE(t) < Thermocline Elev
```

$$\text{EpilimnionInlfow}(t) = 0 \tag{16-92}$$

$$\text{EpilimnionOutflow}(t) = 0 \tag{16-93}$$

$$\text{HypolimnionInflow}(t) = \text{Inflow}(t) \tag{16-94}$$

$$\text{HypolimnionOutflow}(t) = \text{Outflow}(t) \tag{16-95}$$

```
If PE(t) > Thermocline Elev AND PE(t-1) < Thermocline Elev
```

$$\text{HypolimnionInflow}(t) = \Sigma[\text{EpiVolume}(t, n)] - \Sigma[\text{EpiVolume}(t-1, n)] \tag{16-96}$$

$$\text{HypolimnionOutflow}(t) = \text{Outflow}(t) \tag{16-97}$$

$$\text{EpilimnionInflow}(t) = \text{Inflow}(t) - \text{HypolimnionInflow}(t) \tag{16-98}$$

$$\text{EpilimnionOutflow}(t) = 0 \tag{16-99}$$

16.4.48.7 Compute Epilimnion Inflows and Outflows

The epilimnion inflows and outflows for each segment are computed using the water balance calculated by existing RiverWare functions. The water balance calculates outflow using the inflow, volume, vertical flow, evaporation, precipitation, hydrologic inflow, diversion, return flow and bank storage. If the pool elevation (PE) is below the thermocline elevation (TE), there will be no water in the epilimnion. The epilimnion inflows and outflows for each segment are computed as follows:

```
If PE(t) < Thermocline Elev
```

$$\text{EpiInflowbySegment}(t,n) = 0 \tag{16-100}$$

$$\text{EpiOutflowbySegment}(t,n) = 0 \tag{16-101}$$

```
Else (normal scenario)
```

$$\text{EpiInflowbySegment}(t, 1) = \text{EpilimnionInflow}(t) \tag{16-102}$$

$$\begin{aligned}\text{EpiOutflowbySegment}(t,n) = {} & \text{EpiInflowbySegment}(t, n) \\ & - [\text{EpiVolumebySegment}(t, n) - \text{EpiVolumebySegment}(t-1, n)] \\ & + \text{VerticalFlowbySegment}(t, n) - \text{EvapbySegment}(t,n) + \text{PrecipbySegment}(t, n) \\ & - [\text{BSbySegment}(t, n) - \text{BSbySegment}(t-1, n)] - \text{DiversionsbySegment}(t, n) \\ & + \text{ReturnFlowbySegment}(t, n) + \text{HydroInflowbySegment}(t, n)\end{aligned} \tag{16-103}$$

$$\text{EpiInflowbySegment}(t,n) = \text{EpiOutlowbySegment}(t, n-1) \tag{16-104}$$

$$\text{EpiOutflowbySegment}(t, N) = \text{EpilimnionOutflow}(t) \text{ (check mass balance)} \tag{16-105}$$

16.4.48.8 Compute Hypolimnion Inflows and Outflows

The hypolimnion inflows and outflows for each segment are calculated using a vertical flow and outflow, unless the pool elevation is below the thermocline. When the pool elevation is below the thermocline, the hypolimnion inflows and outflows are calculated similar to the epilimnion inflows and outflows. The hypolimnion inflows and outflows for each segment are computed as follows:

```
If PE(t) & PE(t-1) > Thermocline Elev
```

$$\text{HypoInflowbySegment}(t,1) = \text{HypolimnionInflow}(t) \tag{16-106}$$

$$\text{HypoOutflowbySegment}(t,n) = \text{HypoInflowbySegment}(t, n) \tag{16-107}$$

$$\text{HypoOutflowbySegment}(t,N) = \text{HypoInflowbySegment}(t, N) - \text{VerticalFlowbySegment}(t, N) \quad \textit{when } n=N \tag{16-108}$$

$$\text{HypoInflowbySegment}(t,n) = \text{HypoOutflowbySegment}(t, n-1) \tag{16-109}$$

$$\text{HypoOutflowbySegment}(t,N) = \text{HypolimnionOutflow}(t) \text{ (check mass balance)} \tag{16-110}$$

```
If PE(t) < Thermocline Elev & PE(t-1) > Thermocline Elev
```

$$\text{HypoInflowbySegment}(t,1) = \text{HypolimnionInflow}(t) \tag{16-111}$$

$$\begin{aligned}\text{HypoOutflowbySegment}(t,n) = {} & \text{HypoInflowbySegment}(t, n) \\ & - [\text{HypoVolumebySegment}(t, n) - \text{HypoVolumebySegment}(t-1, n)] \\ & - \text{EvapbySeg}(t, n) + \text{PrecipbySegment}(t, n) \\ & - [\text{BSbySegment}(t, n) - \text{BSbySegment}(t-1, n)] \\ & - \text{DiversionbySegment}(t, n) + \text{RFbySegment}(t, n) + \text{HydroInflowbySegment}(t, n) \\ & + \text{EpiVolume}(t-1, n)\end{aligned} \tag{16-112}$$

$$\text{HypoInflowbySegment}(t,n) = \text{HypoOutflowbySegment}(t, n-1) \tag{16-113}$$

$$\text{HypoOutflowbySegment}(t,N) = \text{HypolimnionOutflow}(t) \text{ (check mass balance)} \tag{16-114}$$

```
If PE(t) & PE(t-1) < Thermocline Elev
```

$$\text{HypoInflowbySegment}(t,1) = \text{HypolimnionInflow}(t) \tag{16-115}$$

$$\begin{aligned}\text{HypoOutflowbySegment}(t,n) = {} & \text{HypoInflowbySegment}(t, n) \\ & - [\text{HypoVolumebySegment}(t, n) - \text{HypoVolumebySegment}(t-1, n)] \\ & - \text{EvapbySeg}(t, n) + \text{PrecipbySegment}(t, n) \\ & - [\text{BSbySegment}(t, n) - \text{BSbySegment}(t-1, n)] \\ & - \text{DiversionbySegment}(t, n) + \text{RFbySegment}(t, n) + \text{HydroInflowbySegment}(t, n)\end{aligned} \tag{16-116}$$

$$\text{HypoInflowbySegment}(t,n) = \text{HypoOutflowbySegment}(t, n-1) \tag{16-117}$$

$$\text{HypoOutflowbySegment}(t,N) = \text{HypolimnionOutflow}(t) \text{ (check mass balance)} \tag{16-118}$$

```
If PE(t) > Thermocline Elev & PE(t-1) < Thermocline Elev
```

$$\text{HypoInflowbySegment}(t,1) = \text{HypolimionInflow}(t) \tag{16-119}$$

$$\text{HypoOutflowbySegment}(t,n) = \text{HypoInflowbySegment}(t, n) - [\text{HypoVolume}(t, n) - \text{HypoVolume}(t-1, n)] \tag{16-120}$$

$$\text{HypoInflowbySegment(t,n)} = \text{HypoOutflowbySegment}(t, n-1) \quad (16\text{-}121)$$

$$\text{HypoOutflowbySegment(t,N)} = \text{HypolimnionOutflow}(t) \text{ (check mass balance)} \quad (16\text{-}122)$$

The water mass balance is complete after this step. All the inflows, outflows, changes in storage and vertical flows are now known. The salinity mass balance can be calculated with the above information.

16.4.48.9 Compute Bank Storage Salinity

The bank storage salinity is computed using the previous bank storage salinity and the salinity entering or leaving the bank. When water is entering the bank, salinity mass coming in with the water from the epilimnion affects the concentration in the bank. When water is leaving the bank and entering the reservoir, the salinity mass leaving the bank is added to the epilimnion.

The bank storage salt mass is computed as follows:

```
If Change in Bank Storage(t) < 0
```

$$\text{BankStorageMass}(t) = \text{BankConc}(t-1) \times \text{BankStorage}(t-1) + \text{BankConc}(t-1) \times \text{ChangeinBS}(t) \quad (16\text{-}123)$$

```
If PE(t) > Thermocline Elev & Change in Bank Storage(t) > 0
```

$$\text{BankStorageMass}(t) = \text{BankConc}(t-1) \times \text{BankStorage}(t-1) + \text{ChangeinBS}(t) \times \sum[\text{EpiConcbySegment}(t-1, n) \times \text{BSProp}(n)] \quad (16\text{-}124)$$

```
If PE(t) < Thermocline Elev & Change in Bank Storage(t) > 0
```

$$\text{BankStorageMass}(t) = \text{BankConc}(t-1) \times \text{BankStorage}(t-1) + \text{ChangeinBS}(t) \times \sum[\text{HypoConcbySegment}(t-1, n) \times \text{BSProp}(n)] \quad (16\text{-}125)$$

The bank storage salt concentration is computed as follows:

$$\text{BankStorageSaltConc}(t) = \frac{\text{BankStorageMass}(t)}{\text{BankStorage}(t)} \quad (16\text{-}126)$$

16.4.48.10 Compute Epilimnion and Hypolimnion Salinity

The epilimnion and hypolimnion salt mass and concentration for each segment are computed from a mass balance on salinity. Water and salinity can flow in or out of the bank storage, up or down vertically between the epilimnion and hypolimnion through diffusion and vertical flow, and in and out of each longitudinal segment. The following equations account for the different flow directions of salinity in the mass balance.

The variables *VerticalFlowConc* and *BSFlowConc* must be known before calculating the salinity mass. If an intermediate concentration is computed in the concentration calculations, it will replace the epilimnion or hypolimnion concentrations for the *VerticalFlowConc* and *BSFlowConc* variables.

```
If Vertical Flow(t) > 0
```

$$\text{VerticalFlowConc}(n) = \text{EpiConcbySegment}(t-1, n) \tag{16-127}$$

```
Else
```

$$\text{VerticalFlowConc}(n) = \text{HypoConcbySegment}(t-1, n) \tag{16-128}$$

```
If Change in Bank Storage(t) < 0
```

$$\text{BSFlowConc}(n) = \text{BSConc}(t-1) \tag{16-129}$$

```
If Change in Bank Storage(t) > 0 AND
PE(t) & PE(t-1) > Thermocline Elev
```

$$\text{BSFlowConc}(n) = \text{EpiConcbySegment}(t-1, n) \tag{16-130}$$

```
Else
```

$$\text{BSFlowConc}(n) = \text{HypoConcbySegment}(t-1, n) \tag{16-131}$$

Once the *VerticalFlowConc* and *BSFlowCon* variables are known, the salt mass and concentration are calculated based on the pool elevation and thermocline elevation:

```
If PE(t) < Thermocline Elev & PE(t-1) > Thermocline Elev
```

$$\begin{aligned}\text{IntermediateHypoConcbySeg}(t, n) = {} & [\text{HypoVolumebySeg}(t-1, n) \times \text{HypoConcbySeg}(t-1, n) \\ & + \text{EpiVolumebySeg}(t-1, n) \times \text{EpiConcbySeg}(t-1, n)] \\ & / [\text{HypoVolumebySeg}(t-1, n) + \text{EpiVolumebySeg}(t-1, n)]\end{aligned} \tag{16-132}$$

$$\begin{aligned}\text{HypoConcbySegment}(t, n) = {} & [\text{IntermediateHypoConcbySegment}(t, n) \\ & \times [\text{EpiVolumebySegment}(t-1, n) + \text{HypoVolumebySegment}(t-1, n)] \\ & + \text{HypoInflowbySegment}(t, n) \times \text{HypoConcbySeg}(t, n-1) \\ & - \text{BSConcFlow}(t, n) \times \text{ChangeinBS}(t, n) \\ & + \text{ReturnFlowbySegment}(t, n) \times \text{ReturnFlowConc}(t) \\ & + \text{HydroInflowbySegment}(t, n) \times \text{HydroInflowConc}(t)] \\ & \div [\text{HypoVolumebySegment}(t, n) + \text{HypoOutflowbySeg}(t, n) + \text{DiversionbySeg}(t, n)]\end{aligned} \tag{16-133}$$

$$\text{HypoConcbySegment}(t, n-1) = \text{InflowConc}(t) \ \textit{for } n=1 \tag{16-134}$$

$$\text{HypoMassbySegment}(t, n) = \text{HypoConcbySegment}(t, n) \times \text{HypoVolumebySeg}(t, n) \tag{16-135}$$

$$\text{EpiConcbySegment}(t, n) = 0 \tag{16-136}$$

$$\text{EpiMassbySegment}(t, n) = 0 \tag{16-137}$$

```
If PE(t) < Thermocline Elevation & PE(t-1) < Thermocline Elev
```

$$\begin{aligned}\text{HypoConcbySegment}(t, n) = {} & [\text{HypoConcbySegment}(t-1, n) \times \text{HypoVolumebySegment}(t-1, n) \\ & + \text{HypoInflowbySegment}(t, n) \times \text{HypoConcbySegment}(t, n-1) \\ & - \text{BSConcFlow}(t, n) \times \text{ChangeinBS}(t, n) \\ & + \text{ReturnFlowbySegment}(t, n) \times \text{ReturnFlowConc}(t) \\ & + \text{HydroInflowbySegment}(t, n) \times \text{HydroInflowConc}(t)] \\ & \div [\text{HypoVolumebySegment}(t, n) + \text{HypoOutflowbySeg}(t, n) + \text{DiversionbySeg}(t, n)]\end{aligned} \tag{16-138}$$

$$\text{HypoConcbySegment}(t, n-1) = \text{InflowConc}(t) \ \textit{for } n=1 \tag{16-139}$$

$$\text{HypoMassbySegment}(t, n) = \text{HypoConcbySegment}(t, n) \times \text{HypoVolumebySeg}(t, n) \tag{16-140}$$

$$\text{EpiConcbySegment}(t, n) = 0 \tag{16-141}$$

$$\text{EpiMassbySegment}(t, n) = 0 \tag{16-142}$$

```
If PE(t) > Thermocline Elevation & PE(t-1) > Thermocline Elev
```

$$\begin{aligned}\text{EpiConcbySegment}(t, n) = {} & [\text{EpiVolumebySeg}(t-1, n) \times \text{EpiConcbySegment}(t-1, n) \\ & + \text{EpiInflowbySegment}(t, n) \times \text{EpiConcbySegment}(t, n-1) \\ & + \text{VerticalFlowbySeg}(t, n) \times \text{VerticalFlowConc}(t, n) \\ & - \text{ChangeinBS}(t, n) \times \text{BSConcFlow}(t, n) \\ & + \text{ReturnFlowbySegment}(t, n) \times \text{ReturnFlowConc}(t) \\ & + \text{HydroInflowbySegment}(t, n) \times \text{HydroInflowConc}(t) \\ & + \text{Diffusivity}(t) \times \text{ThermoclineArea}(t, n) \times \Delta t/(\text{ThermoclineThickness}(t)) \\ & \times (\text{EpiConcbySegment}(t-1, n) - \text{HypoConcbySegment}(t-1, n))] \\ & \div [\text{EpiVolumebySeg}(t, n) + \text{EpiOutflowbySeg}(t, n) + \text{DiversionbySeg}(t, n)]\end{aligned} \tag{16-143}$$

$$\begin{aligned}\text{HypoConcbySegment}(t, n) = {} & [\text{HypoVolumebySeg}(t-1, n) \times \text{HypoConcbySegment}(t-1, n) \\ & + \text{HypoInflowbySegment}(t, n) \times \text{HypoConcbySegment}(t, n-1) \\ & - \text{VerticalFlowbySeg}(t, n) \times \text{VerticalFlowConc}(t, n) \\ & + \text{Diffusivity}(t) \times \text{ThermoclineArea}(t, n) \times \Delta t/(\text{ThermoclineThickness}(t)) \\ & \times (\text{HypoConcbySegment}(t-1, n) - \text{EpiConcbySegment}(t-1, n))] \\ & \div [\text{HypoVolumebySeg}(t, n) + \text{HypoOutflowbySeg}(t, n)]\end{aligned} \tag{16-144}$$

$$\text{EpiConcbySegment}(t, n-1) = \text{InflowConc}(t) \textit{ for n=1} \tag{16-145}$$

$$\text{HypoConcbySegment}(t, n-1) = \text{InflowConc}(t) \textit{ for n=1} \tag{16-146}$$

$$\text{EpiMassbySegment}(t, n) = \text{EpiConcbySegment}(t, n) \times \text{EpiVolumebySeg}(t, n) \tag{16-147}$$

$$\text{HypoMassbySegment}(t, n) = \text{HypoConcbySegment}(t, n) \times \text{HypoVolumebySeg}(t, n) \tag{16-148}$$

16.4.48.11 Compute Outflow Salinity

The outflow salt mass and concentration is calculated based on the outflow volume, and the epilimnion and hypolimnion concentration in segment *N*. The following equations calculated the outflow salinity:

$$\begin{aligned}\text{OutflowMass}(t) = {} & \text{EpiConcbySegment}(t, N) \times \text{EpiOutflowbySegment}(t, N) \\ & + \text{HypoConcbySegment}(t, N) \times \text{HypoOutflow}(t, N)\end{aligned} \tag{16-149}$$

$$\text{OutflowConc}(t) = \frac{\text{OutflowMass}(t)}{\text{Outflow}(t)} \tag{16-150}$$

16.4.48.12 Compute Total Reservoir Salt Mass

The reservoir salt mass is calculated based on the concentration and volume in each segment. The following equations calculated the reservoir salt mass:

$$\text{ReservoirSaltMass}(t) = \sum_{j=1}^{N} [\text{EpiMassbySegment}(t, n) + \text{HypoMassbySegment}(t, n)] \tag{16-151}$$

The Segmented Two Layer Salt Reservoir method is complete. The outflow concentration and mass can then be transfered across a link, and water quality in downstream objects can be solved.

16.4.48.13 Notes for Segmented Two Layer Salt Method

The following parameters can be altered to calibrate the salinity model:

- The number of segments.
- The inflow or outflow distribution fraction of the epilimnion and hypolimnion.
- The Elevation Storage Table by Segment. Try to make the volume in each segment relatively equal.
- The diffusion terms. Change the thermocline thickness and diffusivity.
- Segment proportions for the following flows: diversion, return flow, hydrologic inflows, bank storage.

16.4.49 Total Dissolved Gas Methodology

Total Dissolved Gas Modeling consists of two components, A simulation method that computes the TDG concentrations in the reservoir. It also computes partial derivatives that are used in subsequent optimization runs. Within Optimization, constraints are generated and the user can write policy to limit the change in deltas. This section describes the mathematical formulation and the specifics of the methods, but does not outline how to use this approach. That is beyond the scope of this document. Contact CADSWES for more information.

Note, TDG concentration is typically reported as the TDG saturation percentage. So a TDG of 115 is 115% of saturation. Some literature uses a decimal, 1.15, some use a percentage 115%. As a result, in RiverWare, all TDG concentrations use the FRACTION unit type. Then the user can choose to see values in either of the two user units: decimal or percent.

The following sections describe these new methods.

16.4.49.1 Outflow TDG using Tailwater Depth

The method is only available if one of the “Regulated...” spill methods is selected. It is not available for the None method, Monthly Spill or Unregulated Spill methods

SLOTS ASSOCIATED WITH THE OUTFLOW TDG USING TAILWATER DEPTH:

☞ Entrained Flow

Type: Series
Units: FLOW
Description: Entrained Flow is the portion of the Turbine Release that has air from the spillways entrained in it. In the tailrace, there are surface deflectors that attempt to move the spill horizontally and keep it from plunging into the tailrace. These deflectors attract water from the turbine release due to the increased velocity. This portion of the turbine release is then entrained with air from the spillways and has the TDG concentration of the spill. This value is nonnegative.
Information: This slot is computed based on the equation $Q_E = MAX(MIN(Q_T, b_1Q_S + b_3), 0)$.
I/O: Output only.
Links: Not Linkable

☞ Inflow TDG Concentration

Type: Series
Units: Fraction
Description: This slot contains the inflow TDG concentration
I/O: Output or required input
Links: Linkable to upstream object's Outflow TDG Concentration

☞ Outflow TDG Concentration

Type: Series
Units: Fraction
Description: This slot shows the resulting Outflow TDG Concentration. The values can then be compared to the values in the Outflow TDG Concentration Estimate. Once the TDG solution has converged the values in this slot should be equal to the values in the Outflow TDG Concentration Estimate slot at all time steps (within a tolerance)

☞ Spill TDG Concentration

Type: Series
Units: Fraction
Description: This slot shows the resulting Spill TDG Concentration.
Links: Not Linkable

☞ Tailwater Bottom Elevation

Type: Scalar
Units: Length
Description: The elevation at the bottom of the tailrace.
Information: The value in this slot is used in the TDG_S computation to get the depth of tailwater.
I/O: Required Input
Links: Not linkable

☞ TDG c1

Type: Scalar
UNITS: FRACTION
Description: This scalar slot contains the constant in the TDG equation when Spill is zero.
I/O: Required Input
Links: Not Linkable

☞ TDG Entrainment b1

Type: Scalar
UNITS: NONE
Description: The value in this scalar slot represents the fraction of Spill which can be entrained. A portion of the Turbine Release up to this amount will have the same TDG concentration as the Spill.
I/O: Required Input

☞ TDG Entrainment b3

Type: Scalar
UNITS: FLOW
Description: The value in this scalar slot represents the constant of Spill which can be entrained. A portion of the Turbine Release up to this amount will have the same TDG concentration as the Spill.
I/O: Required Input

☞ TDG Spill b2

Type: Scalar
UNITS: PERLENGTHTIME
Description: This scalar slot contains the coefficient in the Spill TDG Concentration equation.
Information: NOTE: This unit type may need to be added.
I/O: Required Input
Links: Not Linkable

☞ Turbine Release TDG Concentration

Type: Series
UNITS: FRACTION
Description: This slot shows the resulting Turbine TDG Concentration. This is sometimes called the forebay concentration or the reservoir concentration.
Links: Not Linkable

☞ **Spill and Turbine Release Limit**

Type: Scalar
Units: Flow
Description: Lower bound for which spill and turbine release will be treated the same as higher flows. Below this flow limit, the computations will be modified.
I/O: Required Input

Method Details: The method is executed by the two water quality dispatch methods:

First, some notation:

TDG_S = **Spill TDG Concentration**

TDG_T = **Turbine Release TDG Concentration**, concentration just above the dam.

TDG_O = **Outflow TDG Concentration**

TDG_I = **Inflow TDG Concentration** (linked to upstream reservoir's TDG_O

Q_{sm} = **Spill and Turbine Release Limit** (calculations are changed for small flows)

Compute the TDG_s:

$$TDG_S = \left(1 + \frac{\rho g(TW - TW_0)}{2p_{atm}}\right)b_2$$

TW is **Tailwater Elevation**.

TW_0 is the elevation at the bottom of the tailrace, a project constant (scalar length).

ρ is the density of water, a global constant. (internal, 999.7kg/m3)

g is the gravitation constant. (internal, 9.81m/s^2)

p_{atm} is the atmospheric pressure. (internal, 101325kg/(m*s)^2)

b2 is a project constant, **TDG Entrainment b2**, (1 / Length-Time).

Get the TDG_T. This is the same as the TDG_I which may be linked to an upstream reach that lags the TDG concentration by some number of timesteps.

$$TDG_T = TDG_I$$

Compute the **Entrained Flow**, Q_E:

$$Q_E = MAX(MIN(Q_T, b_1 Q_S + b_3), 0)$$

Q_S = **Spill**

Q_T = **Turbine Release**

b_1, **TDG Entrainment b1**, and b_3, **TDG Entrainment b3**, are scalar constants for each project.

The final computation is to compute the TDG_O. This is the mixed outflow concentration which could also be called the tailwater concentration.

If $Q_T + Q_S = 0$

$$TDG_O = TDG_T + c_1$$

c_1 is a constant for each reservoir in fraction units.

Else

$$TDG_O = \frac{TDG_S(Q_S + Q_E) + TDG_T(Q_T - Q_E)}{Q_T + Q_S}$$

To provide continuity with the concentration when outflow is zero, the concentration is adjusted when outflow is small.

If $c_1 >= 0$

$$TDG_O = Max(TDG_O, TDG_T + c_1)$$

Else If $Q_S < Q_{sm}$

$$TDG_O = \frac{TDG_O Q_S + TDG_O, TDG_T + c_1(Q_{sm} - Q_S)}{Q_{sm}}$$

End If

16.4.49.2 Optimization Total Dissolved Gas category

This category will be added when the Outflow TDG using Tailwater Depth method described above is selected.

This category contains two methods, the default no-action **None** method and the **Opt Outflow TDG Tailwater Depth**. Following is a description of the **Opt Outflow TDG Tailwater Depth** method.

This is the optimization component of TDG modeling. See also the simulation model described above. This method instantiates the slots and then sets up the data necessary for the Optimization problem. The defining constraints are also described below.

SLOTS SPECIFIC TO THIS METHOD:

☞ Outflow TDG Concentration

Type: Series
UNITS: FRACTION
Description: This slot represents the optimization variable for Outflow TDG Concentration.
Information:
I/O: Set by a rule
Links: Not Linkable

☞ Outflow TDG Concentration Estimate

Type: Series
UNITS: FRACTION
Information: The total dissolved gas calculations in Optimization require a pre-run estimate of Outflow TDG Concentration at each time step. These values are entered in this series slot, usually by a DMI.
I/O: In the equations, this slot uses the notation: TDG_O*
Links: Not Linkable

☞ Spill Estimate

Type: Series
UNITS: FLOW
Description: The total dissolved gas calculations in Optimization require a pre-run estimate of Spill at each time step. These values are entered in this series slot, usually by a DMI.
Information: In the equations, this slot uses the notation: Q_S*
I/O: Input by the user or through a DMI
Links: Not linkable

☞ Spill TDG Concentration

Type: Series
UNITS: FRACTION
Description: This slot represents the optimization variable for Spill TDG Concentration.
Information:
I/O: Set by a rule
Links: Not Linkable

☞ Tailwater Elevation Estimate

Type: Series
UNITS: LENGTH
Description: This slot operates the same as the Spill Estimate slot but for Tailwater.
Information:
I/O: Input by the user or through a DMI
Links: Not linkable

☞ Turbine Release Estimate

Type: Series
Units: Flow
Description: This slot operates the same as the Spill Estimate slot but for Turbine Release.
Information: Q_T*
I/O: Input by the user or through a DMI
Links: Not linkable

☞ Turbine Release TDG Concentration

Type: Series
Units: Fraction
Description: This series slot is an optimization variable defined based on the lag from the Inflow TDG Concentration.
Information:
Links:

☞ Turbine Release TDG Concentration Estimate

Type: Series
Units: Fraction
Description: This slot operates the same as the Spill Estimate slot but for Turbine Release TDG Concentration.
Information: This value must be input if you wish to write policy constraints on the Turbine Release TDG Concentration.
Links: Not Linkable

☞ dSlot1 dSlot2 Partial Derivative Slots

The following is a list of all of the partial derivative slots. All of the slots are individual series slots that contain the values computed in the simulation portion and are used as input values in the next optimization solution. The name is formed by the partial of Slot 1 with respect to the partial of slot 2: **dSlot1 dSlot2**. The slot names have no spaces and use underscores where appropriate.

Type: Series Slot
Information: The following table shows the information stored in each column
I/O: Input (for use in optimization) or Output (computed by WQ methods)
Links: Not Linkable

TDG Partial Derivatives - Slot Description		
Slot Name	**Units**	**Comment and Equation**
dTDG_Outflow dTDG_Spill	None	Partial derivative of Outflow TDG Concentration with respect to Spill TDG Concentration $\frac{\partial TDG_O}{\partial TDG_S} = \frac{Q_S + Q_E}{Q_O}$
dTDG_Outflow dTDG_TurbineRelease	None	Partial derivative of Outflow TDG Concentration with respect to Turbine Release TDG Concentration. $\frac{\partial TDG_O}{\partial TDG_T} = \frac{Q_T - Q_E}{Q_O}$
dTDG_Outflow dSpill	Fraction PerFlow	Partial derivative of Outflow TDG Concentration with respect to Spill. $\frac{\partial TDG_O}{\partial Q_S} = \frac{TDG_S}{Q_O}$
dTDG_Outflow dTurbineRelease	Fraction PerFlow	Partial derivative of Outflow TDG Concentration with respect to Turbine Release. $\frac{\partial TDG_O}{\partial Q_T} = \frac{TDG_T}{Q_O}$
dTDG_Outflow dEntrainedFlow	Fraction PerFlow	Partial derivative of Outflow TDG Concentration with respect to Entrained Flow. $\frac{\partial TDG_O}{\partial Q_E} = \frac{TDG_S - TDG_T}{Q_O}$
dTDG_Outflow dOutflow	Fraction PerFlow	Partial derivative of Outflow TDG Concentration with respect to Outflow. $\frac{\partial TDG_O}{\partial Q_O} = \frac{TDG_S(Q_S + Q_E) + TDG_T(Q_T - Q_E)}{Q_O^2}$
dTDG_Spill dTailwater	Fraction PerLength	Partial derivative of Spill TDG Concentration with respect to Tailwater. This is only needed if p_{atm} is a series slot. If not, this reduces to a constant. $\frac{\partial TDG_S}{\partial TW} = \left(\frac{\rho g}{2p_{atm}}\right)b_2$
dTailwater dTailwaterBaseValue	None	Partial derivative of Tailwater with respect to Tailwater Base Value. Computed based on the selected Tailwater method.
dTailwater dTailwaterPrevBaseValue	None	Partial derivative of Tailwater with respect to Tailwater Base Value at the previous timestep. Computed based on the selected Tailwater method.
dTailwater dOutflow	Length PerFlow	Partial derivative of Tailwater with respect to Outflow. Computed based on the selected Tailwater method.
dPoolElevation dStorage	Length PerVolume	Partial derivative of Pool Elevation with respect to Storage. This value is computed by finding the slope of the Elevation Volume table for the current Pool Elevation/Storage.

TDG Partial Derivatives - Slot Description		
Slot Name	**Units**	**Comment and Equation**
dEntrainedFlow dSpill	None	Partial derivative of Entrained Flow with respect to Spill. $\frac{\partial Q_E}{\partial Q_S}$
dEntrainedFlow dTurbineRelease	None	Partial derivative of Entrained Flow with respect to Turbine Release. $\frac{\partial Q_E}{\partial Q_T}$

☞ **Delta Entrained Flow**
Type: Series
Units: Flow
Description: This slot is an optimization variable.
I/O: Output Only

☞ **Delta Inflow**
Type: Series
Units: Flow
Description: This series slot is an Optimization Variable.
I/O: Output Only
Links: Linkable to upstream Delta Outflow

☞ **Delta Outflow**
Type: Series
Units: Flow
Information: This series slot is an Optimization Variable.
Links: Linkable to downstream Delta Inflow

☞ **DELTA OUTFLOW TDG CONC**
Type: Series
UNITS: FRACTION
Description: This series slot is an Optimization Variable.

☞ **DELTA POOL ELEVATION**
Type: Series
UNITS: LENGTH
Information: This series slot is an Optimization Variable.

☞ **DELTA STORAGE**
Type: Series
UNITS: VOLUME
Information: This series slot is an Optimization Variable.

☞ **DELTA SPILL TDG CONC**
Type: Series
UNITS: FRACTION
Information: This series slot is an Optimization Variable.

☞ **DELTA TAILWATER**
Type: Series
UNITS: LENGTH
Information: This series slot is an Optimization Variable.

☞ **DELTA TAILWATER BASE VALUE**
Type: Series
UNITS: LENGTH
Description: This series slot is an Optimization Variable.

☞ **DELTA TURBINE RELEASE TDG CONC**
Type: Series
UNITS: FRACTION
Description:
Information: This series slot is an Optimization Variable.

☞ **DELTA TURBINE RELEASE**
Type: Series
UNITS: FRACTION
Description:
Information: This series slot is an Optimization Variable.

METHOD DETAILS

This method is called by the water quality dispatch method and computes the partial derivatives and Taylor expansion equations that will be used in the optimization formulation. This step will only occur when the optimization method is selected, but will occur during water quality dispatching in the simulation runs. In this section, we describe the mathematical formulation, but not the order in which they are computed.

To discuss the partial derivatives, we must write the full mathematical representation. In the following description, we show the equations and note where each one is computed, either in the simulation method (**Sim Calc** or **Sim Input**) or as a defined variable in the optimization (**Defined Variable**). That is, within the WQ dispatching the partial derivatives are computed. Then within the Opt Begin Run, variables are defined, as necessary,

Introduce the following variable to track the difference from the estimated value:

$TDG_O = TDG_O^* + \Delta TDG_O$ Slot: **Outflow TDG Concentration**- **Defined Variable**

TDG_O* is the slot **Outflow TDG Concentration Estimate** - **Sim Input**

ΔTDG_O is the slot **Delta Outflow TDG Concentration** - **Defined Variable**

$\Delta Q_S = Q_S - Q_S^*$ Slot: **Delta Spill**- **Defined Variable**

Q_S is the slot **Spill** - **Defined Variable**

Q_S* is the slot **Spill Estimate** - **Sim Input**

$\Delta Q_T = Q_T - Q_T^*$ Slot: **Delta Turbine Release** - **Defined Variable**

Q_T is the slot **Turbine Release** - **Defined Variable**

Q_T* is the slot **Turbine Release Estimate** - **Sim Input**

To write constraints on the **Turbine Release TDG Conc**, then also track the difference between the estimated concentration and the computed:

$TDG_T = TDG_T^* + \Delta TDG_T$ Slot: **Turbine Release TDG Concentration**- **Defined Variable**

TDG_O* is the slot **Turbine Release TDG Concentration Estimate** - **Sim Input**

ΔTDG_O is the slot **Delta Turbine Release TDG Concentration** - **Defined Variable**

The first-order Taylor series approximation is:

$$\Delta TDG_O = \frac{\partial TDG_O}{\partial TDG_S}\Delta TDG_S + \frac{\partial TDG_O}{\partial TDG_T}\Delta TDG_T + \frac{\partial TDG_O}{\partial Q_S}\Delta Q_S + \frac{\partial TDG_O}{\partial Q_T}\Delta Q_T + \frac{\partial TDG_O}{\partial Q_E}\Delta Q_E + \frac{\partial TDG_O}{\partial Q_O}\Delta Q_O$$

ΔTDG_O is the slot **Delta Outflow TDG Concentration** - **Defined Variable**

The partial derivatives are defined as follows. All of these derivatives are calculated for each timestep and therefore are based on the values computed during the previous rulebased simulation (which used the estimated values, Q_S*, Q_T*, etc...).

$$\frac{\partial TDG_O}{\partial TDG_S} = \frac{Q_S + Q_E}{Q_O}$$ Slot: **dTDG_Outflow dTDG_Spill** - **Sim Calc**

$$\frac{\partial TDG_O}{\partial TDG_T} = \frac{Q_T - Q_E}{Q_O}$$ Slot: **dTDG_Outflow dTDG_TurbineRelease** - **Sim Calc**

$$\frac{\partial TDG_O}{\partial Q_S} = \frac{TDG_S}{Q_O}$$ Slot: **dTDG_Outflow dSpill** - **Sim Calc**

$$\frac{\partial TDG_O}{\partial Q_T} = \frac{TDG_T}{Q_O}$$ Slot: **dTDG_Outflow dTurbineRelease** - **Sim Calc**

$$\frac{\partial TDG_O}{\partial Q_E} = \frac{TDG_S - TDG_T}{Q_O}$$ Slot: **dTDG_Outflow dEntrainedFlow** - **Sim Calc**

$$\frac{\partial TDG_O}{\partial Q_O} = -\frac{TDG_S(Q_S + Q_E) + TDG_T(Q_T - Q_E)}{Q_O^2}$$ Slot: **dTDG_Outflow dOutflow** - **Sim Calc**

$$\Delta TDG_T = \Delta TDG_I$$

ΔQ_O = **Delta Outflow** = **Delta Turbine Release** + **Delta Spill**

For low flow conditions, Q_S and $Q_T < Q_{sm}$, alternative partial derivatives are used to improve convergence. The partial derivatives are set based on the **ratio** = Q_E / Q_T. If $Q_T = 0$ then **ratio** = 0.

$$\frac{\partial TDG_O}{\partial TDG_S} = 0.5 + 0.5\text{ratio}$$

$$\frac{\partial TDG_O}{\partial TDG_T} = 0.5(1 - \text{ratio})$$

$$\frac{\partial TDG_O}{\partial Q_S} = \frac{TDG_S}{Q_{sm}}$$

$$\frac{\partial TDG_O}{\partial Q_T} = \frac{TDG_T}{Q_{sm}}$$

$$\frac{\partial TDG_O}{\partial Q_E} = \frac{TDG_S - TDG_T}{Q_{sm}}$$

$$\frac{\partial TDG_O}{\partial Q_O} = -\frac{TDG_S(1 + \text{ratio}) + TDG_T(1 - \text{ratio})}{2Q_{sm}}$$

If TDG_T is input, then $\Delta TDG_T = 0$. ΔTDG_I is the **Delta Inflow TDG Concentration**, which is linked to an upstream object's ΔTDG_O slot. The slot **Delta Turbine Release TDG Conc** is a **Defined Variable.**

$$\Delta Q_E = \frac{\partial Q_E}{\partial Q_T}\Delta Q_T + \frac{\partial Q_E}{\partial Q_S}\Delta Q_S$$

Slot: **Delta Entrained Flow - Defined Variable**

The partials in this equation depend on the condition of Entrained Flow and Turbine Release.

If $Q_E = Q_T$ and $Q_T > 0$ (using estimated values)

$$\frac{\partial Q_E}{\partial Q_T} = 1$$

$$\frac{\partial Q_E}{\partial Q_S} = 0$$

Else

$$\frac{\partial Q_E}{\partial Q_T} = 0$$

If $b_3 >= 0$ or $Q_E > 0$

$$\frac{\partial Q_E}{\partial Q_S} = b_1$$

Else

$$\frac{\partial Q_E}{\partial Q_S} = 0$$

Next, introduce the variable for the Delta Spill concentration:

$$\Delta TDG_S = \frac{\partial TDG_S}{\partial TW}\Delta TW$$ Slot: **Delta Spill TDG Conc - Defined Variable**

$$\frac{\partial TDG_S}{\partial TW} = \left(\frac{\rho g}{2p_{atm}}\right)b_2$$ Slot: **dTDG_Spill dTailwater - Sim Calc**

To complete the Taylor series expansion:

$$\Delta TW = \frac{\partial TW}{\partial TWBV}\Delta TWBV + \frac{\partial TW}{\partial TWBV_{t-1}}\Delta TWBV_{t-1} + \frac{\partial TW}{\partial Q_O}\Delta Q_O$$

Slot: **Delta Tailwater - Defined Variable**

The tailwater partials are based on the selected Tailwater method. The Tailwater is then based on the selected Tailwater method:

- Tailwater Base Value Method

$\frac{\partial TW}{\partial TWBV} = \frac{1}{2}$ Slot: **dTailwater dTailwaterBaseValue** - **Sim Calc**

$\frac{\partial TW}{\partial TWBV_{t-1}} = \frac{1}{2}$ Slot: **dTailwater dTailwaterPrevBaseValue** - **Sim Calc**

$\frac{\partial TW}{\partial Q_O} = 0$ Slot: **dTailwater dOutflow** - **Sim Calc**

- Base Value Plus Lookup Method

  $\frac{\partial TW}{\partial TWBV} = \frac{1}{2}$ Slot: **dTailwater dTailwaterBaseValue** - **Sim Calc**

  $\frac{\partial TW}{\partial TWBV_{t-1}} = \frac{1}{2}$ Slot: **dTailwater dTailwaterPrevBaseValue** - **Sim Calc**

  $\frac{\partial TW}{\partial Q_O} = \text{Slope from Table}$ Slot: **dTailwater dOutflow** - **Sim Calc**

- Stage Flow Method

  $\frac{\partial TW}{\partial TWBV} = \frac{\text{Slope from Table}}{2}$ Slot: **dTailwater dTailwaterBaseValue - Sim Calc**

  $\frac{\partial TW}{\partial TWBV_{t-1}} = \frac{\text{Slope from Table}}{2}$ Slot: **dTailwater dTailwaterPrevBaseValue** - **Sim Calc**

  $\frac{\partial TW}{\partial Q_O} = \text{Slope from Table}$ Slot: **dTailwater dOutflow** - **Sim Calc**

- Coefficients Table method

  $\frac{\partial TW}{\partial TWBV} = \text{Tailwater Coefficients}[0,2]$ Slot: **dTailwater dTailwaterBaseValue** - **Sim Calc**

  $\frac{\partial TW}{\partial TWBV_{t-1}} = \text{Tailwater Coefficients}[1,2]$ Slot: **dTailwater dTailwaterPrevBaseValue** - **Sim Calc**

  $\frac{\partial TW}{\partial Q_O} = \text{Tailwater Coefficients}[0,1]$ Slot: **dTailwater dOutflow** - **Sim Calc**

If the tailwater base value is input, the partial derivatives are zero. If tailwater base value is set equal to downstream pool elevation then

Res. ΔTWBV = Downstream(Res). ΔPE, Slot: **Delta Tailwater Base Value** - **Defined Variable**

This will require a link, which will create an automatic constraint. The Taylor series equation for pool elevation (aka forebay elevation) depends on reservoir storage.

$\Delta PE = \frac{\partial PE}{\partial S}\Delta S$ Slot: **Delta Pool Elevation** - **Defined Variable**

The partial derivative can be calculated from an elevation-volume table. The **dPoolElevation dStorage** value is stored in a slot.

Storage is defined by the continuity or mass balance equation:

$$\Delta S = \Delta S_{t-1} + \frac{\partial S}{\partial Q_O}(\Delta Q_I - \Delta Q_O)$$ Slot: **Delta Storage - Defined Variable**

The partial derivative $\frac{\partial S}{\partial Q_O}$ is the length of a time step in the model, **dStorage dOutflow.** It will initially be implemented as a constant. If a given S_t is not a variable then $\Delta S_t = 0$. For example, S is typically known at the beginning of a model run.

If inflow is equal to an upstream outflow from a reservoir, reach, or confluence then

Res. ΔQ_I = UpstreamObj. ΔQ_O

Otherwise inflow is an input and as for all inputs, $\Delta Q_I = 0$

TDG_I is the **Inflow TDG Concentration**, which is linked to an upstream object's TDG_O slot.

Stream Gage Water Quality

17. Stream Gage

On the Stream Gage, water quality constituents are transferred through the object. In this approach, there are no dispatch methods. Water quality constituent values are transferred via links. You should link the constituent slot to both the upstream and downstream slots.

17.1 Slots

17.1.1 Temperature Slots

☞ **HEAT**

Type: Series Slot
Units: HEAT
Description: Heat associated with the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

17.1.2 Salinity Slots

☞ **SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the flow at the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

17.1.3 Dissolved Oxygen Slots

☞ **AMMONIA MASS**

Type: Series Slot
Units: MASS
Description: Ammonia mass associated with the flow at the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Detritus Mass**

Type: Series Slot
Units: Mass
Description: Detritus mass associated with the flow at the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Dissolved Organics Mass**

Type: Series Slot
Units: Mass
Description: Dissolved organics mass associated with the flow at the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **Dissolved Oxygen Mass**

Type: Series Slot
Units: Mass
Description: Dissolved oxygen mass associated with the flow at the gage
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

17.2 User Selectable Methods

The following section describes the user selectable methods for water quality modeling on the Stream Gage.

17.2.1 Stream Gage Water Quality

Methods in this category are used to select the constituent and approach.

17.2.1.1 None

No water quality solution is performed. No slots are added.

17.2.1.2 Propagate Salt

All of the salt slots are added.

17.2.1.3 Propagate Temperature

All of the temperature slots are added.

17.2.1.4 Propagate Temp and Salt

All of the temperature and salt slots are added.

17.2.1.5 Propagate Temp and DO

All of the temperature and DO slots are added.

17.2.1.6 Propagate Temp Salt and DO

All of the temperature, salt and DO slots are added.

17.3 Dispatch Methods

There are no dispatch methods for the Diversion Object. This object propagates information via links.You should link the constituent slot to slots on both the source and destination objects.

Water User Water Quality

18. Water User

The Water User currently models only salinity.

Water Users have water quality methods to model salt as either a stand alone water user or as an element of a "No Structure" or "Sequential" Agg Diversion site. Water Users on "Lumped" Agg diversions sites do not model salt as salt is lumped and modeled by the aggregate.

18.1 User Selectable Methods

18.1.1 Water User Water Quality

The following category is available on the stand alone, no structure, or sequential water user.

18.1.1.1 None

No Water Quality is modeled. No slots are added.

18.1.1.2 Salinity

All of the below salinity slots are added. Note, the slots are technically added by a non-visible method that indicates whether the water user is stand alone, lumped or sequential. Therefore, the methods tab on the Open Object dialog does not show the slots, but the Slots tab does.

Note, it is an error if a **Return Flow Routing** method other than "None" is selected and salinity is being model. In other words, you cannot route return flows and model salinity on the same water user.

☞ **DIVERSION SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Diversion
I/O: Input, set by a rule, or propagated via a link
Links: Linkable

☞ **DIVERSION SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Diversion
I/O: Output only
Links: Not Linkable

☞ **RETURN FLOW SALT MASS**

Type: Series Slot
Units: MASS
Description: Salt mass associated with the Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable, but this slot should only be linked to a reach using Well Mixed Salt. Otherwise, link the Return Flow Salt Concentration.

☞ **RETURN FLOW SALT CONCENTRATION**

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the Return Flow
I/O: Output only: solved by dispatch and user methods
Links: Linkable

18.1.2 Salt Storage and Loading

The following category is available on the stand alone, no structure, or sequential water user.

18.1.2.1 None

No salt is stored in the water user. No additional slots are added. This method is available for all **Return Flow** methods.

DIVERSION SALT MASS is set by multiplying the **DIVERSION** volume by the **DIVERSION SALT CONCENTRATION**.

$$ReturnFlowSaltMass = DiversionSaltMass \quad (18\text{-}152)$$

RETURN FLOW SALT CONCENTRATION is computed from the **RETURN FLOW SALT MASS** and **RETURN FLOW** volume.

18.1.2.2 Salt Loading

No salt is stored in the water user. No additional slots are added. This method is available for all **Return Flow** methods.

☞ **SALT LOADING**

Type: Series Slot
Units: MASS
Description: The additional salinity that is to be added to the return flow.
Information: This represents dry salt that is added possibly due to fertilizer or other salt additions.
I/O: Input or set by a rule
Links: Not Linkable

DIVERSION SALT MASS is set by multiplying the **DIVERSION** volume by the **DIVERSION SALT CONCENTRATION**. Then, if **SALT LOADING** is valid,

$$ReturnFlowSaltMass = DiversionSaltMass + SaltLoading \tag{18-153}$$

Otherwise:

$$ReturnFlowSaltMass = DiversionSaltMass \tag{18-154}$$

RETURN FLOW SALT CONCENTRATION is computed from the **RETURN FLOW SALT MASS** and **RETURN FLOW** volume.

18.1.2.3 Salt Pickup Concentration

This method determines the **RETURN FLOW SALT MASS** as a function of **DIVERSION SALT CONCENTRATION**, **RETURN FLOW PICKUP** and **RETURN FLOW VOLUME**. The following slots are added by this method:

☞ **RETURN FLOW SALINITY PICKUP CONC**

Type: Series Slot
Units: CONCENTRATION
Description: The additional salinity that is to be added to the return flow.
Information: Optional input.
I/O: Not Linkable

The method first converts Return Flow and Diversion from a flow to a volume (*ReturnFlowVol* and *DiversionVol*).

Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times DiversionVolume}{ReturnFlowVol} \tag{18-155}$$

Note, if *ReturnFlowVol* is zero, *concentrated* is set to zero

If both of the local variables *concentrated* and ReturnFlowVol are less than zero, then **RETURN FLOW SALT CONCENTRATION** equals:

$$returnFlowSaltConc = concentrated - ReturnFlowSalinityPickupConc \tag{18-156}$$

Else, **Return Flow Salt Concentration** equals:.

$$returnFlowSaltConc = concentrated + ReturnFlowSalinityPickupConc \quad (18\text{-}157)$$

At the end of this method, **Return Flow Salt Mass** is calculated as:

$$ReturnFlowSaltMass = returnFlowSaltConc \times ReturnFlowVol \quad (18\text{-}158)$$

18.1.2.4 Salt Pickup Mass

This method determines the Return Flow Salt Mass as a function of Diversion Salt Concentration, Return Flow Salinity Pickup Mass and Return Flow Volume. The user specified salt mass can be negative or positive and can add salt even when Return Flow equals zero.

Slots associated with this method:

☞ **Return Flow Salinity Pickup Mass**

Type: SeriesSlot
Units: Mass
Description: slot for salinity pickup mass
Information: user specified salinity pickup mass is entered in the slot.
I/O: Required Input
Links: Not Linkable

☞ **Return Flow Salinity Pickup Conc**

Type: Series Slot
Units: Concentration
Description: The additional salinity that is to be added to the return flow.
Information: Output only.
I/O: Not Linkable

Note: In the Agg Diversion Site method of the same name, there are two additional slots: Annual Salinity Pickup Mass and Annual Return Flow Volume. Neither of these slots are used or accessed by the method. These are not added to the Water User by this method. You could add these as custom slots if you want to use them for comparison.

The method first converts **Return Flow** and **Diversion** from a flow to a volume (ReturnFlowVol and DiversionVol). Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times DiversionVolume}{ReturnFlowVol} \quad (18\text{-}159)$$

Note, if ReturnFlowVol is zero, concentrated is set to zero

The Salt Pickup Mass method next checks if **Return Flow Salinity Pickup Mass** is valid. If it is not valid, the run will abort and an error will be posted. If **Return Flow** equals zero, **Return Flow Salinity Pickup** and **Return Flow Salt Concentration** is set equal to zero and **Return Flow Salt Mass** is calculated as:

$$ReturnFlowSaltMass = concentrated \times ReturnFlowVol + ReturnFlowSalinityPickupMass \quad (18\text{-}160)$$

If **RETURN FLOW** does not equal zero, **RETURN FLOW SALINITY PICKUP CONC** is calculated as:

$$ReturnFlowSalinityPickupConc = \frac{returnFlowSalinityPickupMass}{ReturnFlowVol} \quad (18\text{-}161)$$

Then, **RETURN FLOW SALT MASS** is calculated as:

$$ReturnFlowSaltMass = concentrated \times ReturnFlowVol + ReturnFlowSalinityPickupMass \quad (18\text{-}162)$$

RETURN FLOW SALT CONCENTRATION is calculated as:

$$ReturnFlowSaltConc = \frac{ReturnFlowSaltMass}{ReturnFlowVol} \quad (18\text{-}163)$$

18.1.2.5 Soil Moisture Salt Storage

When **Soil Moisture** methods are selected (**HERE (Objects.pdf, Section 27.1.1.5)**), water quality is enabled, the Water User Water Quality method is set to **Salinity,** and the water user is either a Sequential, No Structure, or Stand Alone water user, the **Soil Moisture Salt Storage** is available.

This method selection is necessary on both stand alone water users and on those that are elements of an aggregate diversion site as the method is only valid if soil moisture is being modeled.

SLOTS ASSOCIATED WITH THIS METHOD:

☞ **DELIVERED FLOW SALT CONCENTRATION**

Type: Series
Units: CONCENTRATION
Description: The salinity concentration of the delivered flow. This is the concentration after incidental loss.
Information:
I/O: Output only
Links: Not linkable

☞ **DELIVERED FLOW SALT MASS**

Type: Series
Units: MASS
Description: The salinity mass of the delivered flow. This is the salt mass after incidental loss.
Information:
I/O: Output only
Links: Not linkable.

☞ Incidental Loss Salt Concentration

Type: Series
Units: Concentration
Description: The salt concentration of water lost incidentally.
Information: When this slot is valid, the value is used. For example, the user could set this to zero, indicating the loss is evaporation and the salt remains. Otherwise, Incidental Loss Salt Concentration is assumed to be the same as Diverted Flow Salt Concentration indicating the salt disappears too, as would happen with seepage.
I/O: Optional Input
Links: Not Linkable

☞ Soil Moisture Gain Loss Salt Concentration

Type: Series
Units: Concentration
Description: The concentration of Soil Moisture Gain Loss water.
Information: If the Soil Moisture Gain Loss is positive, water is entering the soil moisture. This slot can be specified via input or rule. If not specified, it defaults to zero. If the Soil Moisture Gain Loss is negative, water is leaving the soil moisture. In this case the concentration is set to the previous Soil Moisture Salt Concentration.
I/O: Optional Input, set by a rule, or computed
Links: Not linkable.

☞ Soil Moisture Gain Loss Salt Mass

Type: Series
Units: Mass
Description: The mass of salt moving with the Soil Moisture Gain Loss
Information:
I/O: Output only
Links: Not linkable

☞ Soil Moisture Salt Concentration

Type: Series
Units: Concentration
Description: The concentration of the entire soil moisture including the portion that is unavailable
Information: It is assume the Soil Moisture is well mixed
I/O: Output only, except initial timestep must be input
Links: Not linkable

☞ Soil Moisture Salt Mass

Type: Series
Units: Mass
Description: The mass of salt in the entire soil moisture.
Information:
I/O: Output only
Links: Not Linkable

☞ Soil Moisture Unavailable to Crops

Type: Scalar
Units: Length
Description: The depth of water that is in the soil that is not available for the crops but contributes to the salinity concentration.
Information:
I/O: Required Input
Links: Not Linkable

☞ Soil Moisture Unavailable Gain Loss

Type: Series
Units: Volume
Description: Miscellaneous gain or loss of unavailable soil moisture volume during the timestep due to irrigated area changes.
Information: This slot represents and gains (positive) or loss (negative) from the unavailable soil moisture. It is used to track the soil moisture volume gained or lost when the irrigated acreage is changed from the previous timestep. It is a computed output, assuming the current unavailable zone is full.
I/O: Output only
Links: Not Linkable

☞ Soil Moisture Unavailable Gain Loss Salt Mass

Type: Series
Units: Mass
Description: The salt mass associated with the Soil Moisture Unavailable Gain Loss
Information:
I/O: Output Only
Links: Not Linkable

☞ Soil Moisture Unavailable Gain Loss Salt Concentration

Type: Series
Units: Concentration
Description: The salt concentration associated with the Soil Moisture Unavailable Gain Loss
Information: If the Soil Moisture Unavailable Gain Loss is positive, water is entering the soil moisture. This slot can be specified via input or rule to indicate the concentration of

gains when the Irrigated Area increases. If not specified, it defaults to the previous timestep's Soil moisture Salt Conc.

I/O: Input, set by a rule, or computed
Links: Not Linkable

☞ SURFACE RUNOFF SALT CONCENTRATION

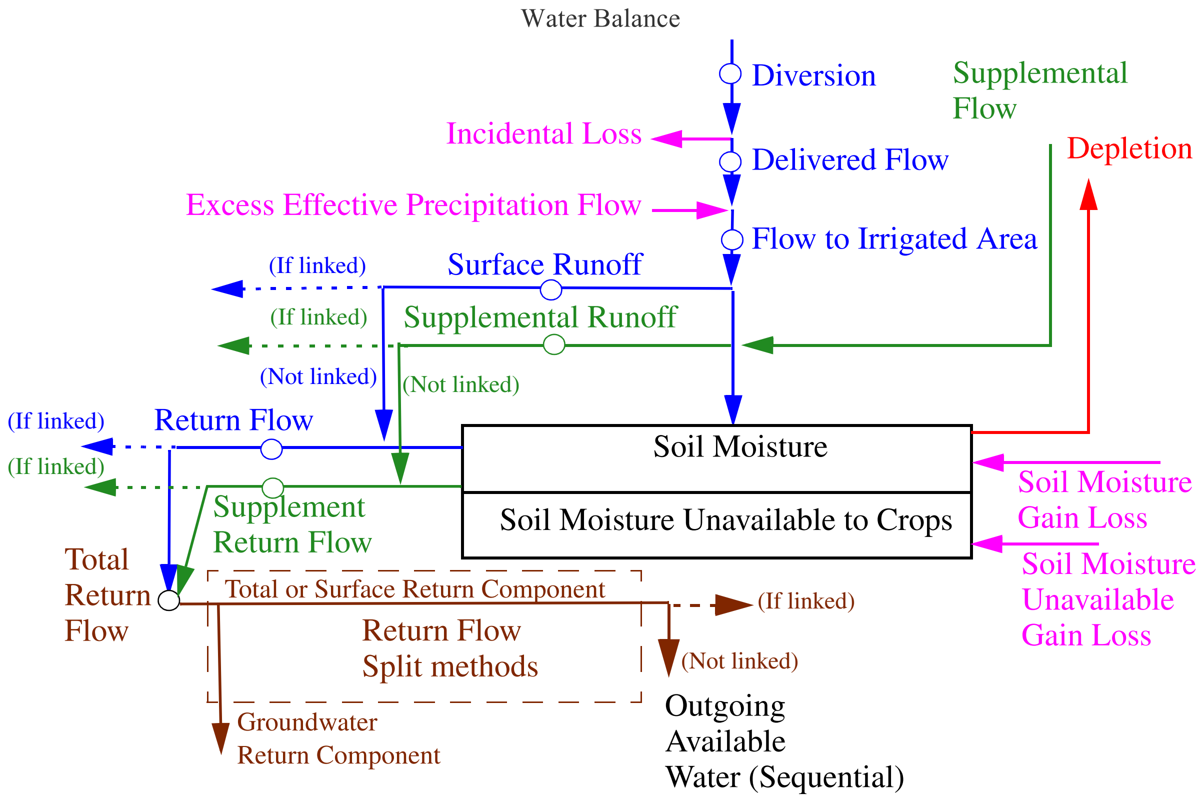
Type: Series
Units: CONCENTRATION
Description: The concentration of the Surface Runoff
Information:
I/O: Output only
Links: Linkable

☞ SURFACE RUNOFF SALT MASS

Type: Series
Units: MASS
Description: The mass of salt associated with the Surface Runoff slot
Information:
I/O: Output only
Links: Not linkable

METHOD DETAILS:

The following figure shows the water balance necessary to model salt on the Water User. Items in blue are default flow values. Pink indicates optional gains/losses. Green is supplemental water (see the method **HERE (Section 18.1.2.6)** for more on supplemental flow). Brown indicates split return flows. Note, not all values shown are separate slot values.

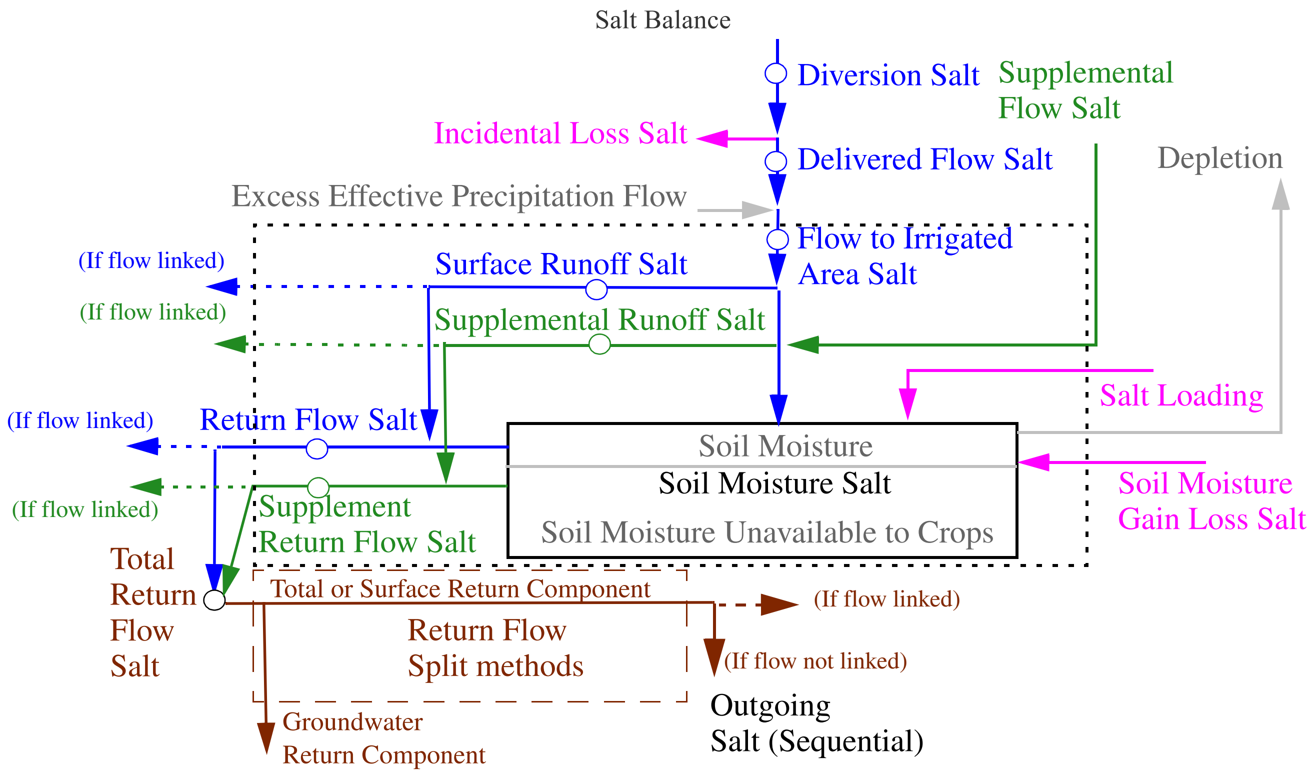


When dealing with salinity concentrations, an additional term is included that is not part of the Soil Moisture. The **Soil Moisture Unavailable to Crops** is a depth of water that contributes to salinity concentrations but does not contribute to soil moisture volume.

If the Irrigated Area changes, the unavailable volume changes, so must be computed. If the current **Irrigated Area** does not equal the **Irrigated Area**(t-1):

$$\text{Soil Moisture Unavailable Gain Loss} = \text{Soil Moisture Unavailable to Crops} \times (\text{Irrigated Area} - \text{Irrigated Area}(t-1)) \qquad \textbf{(18-164)}$$

The following figure shows the salt mass components. Note that **Depletion** and **Excess Effective Precipitation** are grayed out as they do not contribute or remove salt mass. In addition, the **Soil Moisture** and **Soil Moisture Unavailable to Crops** have been combined into one well mixed volume. The dotted line is the boundary used to compute the salt mass balance on the soil, see Equation 18-181.



If **INCIDENTAL LOSS SALT CONCENTRATION** is valid, use that value. For example, the user could set this to zero, indicating the loss is evaporation and the salt remains. Otherwise, **INCIDENTAL LOSS SALT CONCENTRATION** is unknown so set it equal to **DIVERSION SALT CONCENTRATION**:

$$\text{Incidental Loss Salt Concentration} = \text{Diversion Salt Concentration} \quad (18\text{-}165)$$

Next, compute the **DELIVERED FLOW SALT MASS**:

$$\text{Delivered Flow Salt Mass} = \text{Diversion Salt Mass} - \text{Incidental Flow Salt Concentration} \times \text{Incidental Flow}VOL \quad (18\text{-}166)$$

Recompute the temporary variable *flowToIrrigatedArea* from slot values:

$$flowToIrrigatedArea = \text{Delivered Flow} + \text{Excess Effective Precipitation Flow} \quad (18\text{-}167)$$

$$flowToIrrigatedAreaSaltMass = \text{Delivered FlowSaltMass} \quad (18\text{-}168)$$

$$flowToIrrigatedAreaSaltConc = \frac{\text{Delivered FlowSaltMass}}{flowToIrrigatedAreaVOL} \quad (18\text{-}169)$$

Soil Moisture Gain Loss Salt: Next, compute the **SOIL MOISTURE GAIN LOSS SALT MASS**. Remember that **SOIL MOISTURE GAIN LOSS** is a term that can be specified by the user as a miscellaneous addition or subtraction from the soil moisture. In addition, it is used to track the change in **SOIL MOISTURE** volume if the irrigated area changes from one timestep to the next. As a result, the salt calculations must mirror these uses.

If **SOIL MOISTURE GAIN LOSS** is positive, water is entering the soil moisture. The **SOIL MOISTURE GAIN LOSS**

Concentration can be specified or it is assumed to be zero.

Otherwise, the **Soil Moisture Gain Loss** is negative; water is removed from the soil moisture, The **Soil Moisture Gain Loss Concentration** is assumed to be the concentration of the soil moisture at the previous timestep:

$$\text{Soil Moisture Gain Loss Salt Concentration} = \text{Soil Moisture Salt Concentration}[t-1] \quad \textbf{(18-170)}$$

The **Soil Moisture Unavailable Gain Loss Concentration** can be specified via rule or input. Otherwise, the **Soil Moisture Unavailable Gain Loss Concentration** is assumed to be the concentration of the soil moisture at the previous timestep:

$$\text{Soil Moisture Unavail Gain Loss Salt Concentration} = \text{Soil Moisture Salt Concentration}[t-1] \quad \textbf{(18-171)}$$

Compute the **Soil Moisture Gain Loss Salt Mass**. This could be positive or negative depending on the sign of the gains or losses:

$$\begin{aligned}\text{Soil Moisture Gain Loss Salt Mass} = {} & \text{Soil Moisture Gain Loss Salt Concentration} \times \\ & \text{Soil Moisture Gain Loss VOL}\end{aligned} \quad \textbf{(18-172)}$$

$$\begin{aligned}\text{Soil Moisture Unavailable Gain Loss Salt Mass} = {} & (\text{Soil Moisture Unavail Gain Loss Salt Concentration} \times \\ & \text{Soil Moisture Unavailable Gan LossVOL})\end{aligned} \quad \textbf{(18-173)}$$

Return Flow Salt: Next, compute the Return Flow salt mass and concentration. First, the dispatch method will now compute any flows that are greater than the max infiltration rate. This water runs off directly without entering the soil.

$$\text{Surface Runoff} = MAX(flowToIrrigatedArea - \text{Irrigated Area} \times \text{ Max Infiltration Rate,}0cfs) \quad \textbf{(18-174)}$$

We assume this runoff does not pick up any salt, but instead has the concentration of the applied water:

$$\text{Surface Runoff Salt Mass} = \text{Surface Runoff VOL} \times flowToIrrigatedAreaSaltConc \quad \textbf{(18-175)}$$

$$\text{Surface Runoff Salt Concentration} = flowToIrrigatedAreaSaltConc \quad \textbf{(18-176)}$$

If **Surface Runoff** is linked, the **Surface Runoff** is not included in the total Return Flow. Therefore, **Return Flow Salt Concentration** is:

$$\text{Return Flow Salt Mass} = ReturnFlowVOL \times \text{Soil Moisture Salt Concentration}[t-1] \quad \textbf{(18-177)}$$

$$\text{Return Flow Salt Concentration [t]} = \text{Soil Moisture Salt Concentration}[t-1] \quad \textbf{(18-178)}$$

Otherwise, **Surface Runoff** is not linked and it is included in the total Return Flow. Therefore,

$$\begin{aligned}\text{Return Flow Salt Mass} = {} & (ReturnFlowVOL - \text{Surface Runoff VOL}) \\ & \times \text{Soil Moisture Salt Concentration}[t-1] + \\ & \text{Surface Runoff Salt Mass}\end{aligned} \quad \textbf{(18-179)}$$

$$\text{Return Flow Salt Concentration [t]} = \frac{\text{Return Flow Salt Mass}}{ReturnFlowVOL} \quad \textbf{(18-180)}$$

Salt Mass Balance: Compute the mass balance:

$$\begin{aligned}\text{Soil Moisture Salt Mass [t]} = {} & \text{Soil Moisture Salt Mass [t-1]} \\ & + \text{Delivered Flow Salt Mass} \\ & + \text{Salt Loading} \\ & + \text{Soil Moisture Gain Loss Salt Mass} \\ & + \text{Soil Moisture Unavailable Gain Loss Salt Mass} \\ & - \text{Return Flow Salt Mass} \\ & - \text{Surface Runoff Salt Mass (only if linked)}\end{aligned} \tag{18-181}$$

Soil Moisture Salt Concentration is the mass divided by the total volume

$$\text{Soil Moisture Salt Concentration} = \frac{\text{Soil Moisture Salt Mass}}{\text{Soil Moisture} + \text{Soil Moisture Unavailable to Crops} \times \text{Irrigated Area}} \tag{18-182}$$

18.1.2.6 Soil Moisture Salt with Supplemental Flow

This method is the same as the above method "**Soil Moisture Salt Storage**" HERE (Section 18.1.2.5), in terms of slots added and calculations, but also accounts for **Supplemental Flow** and the corresponding salt concentrations.

This method must be selected when using the **Supplemental Diversion including Soil Moisture** and you wish to model salt storage in the soil moisture. It is usually auto-selected but if you select methods out of standard order, it can get into a state where you must select it yourself.

SLOTS ASSOCIATED WITH THIS METHOD

☞ SUPPLEMENTAL FLOW SALT CONCENTRATION

Type: Series
Units: CONCENTRATION
Description: The concentration of Supplemental Flow water
Information:
I/O: Input, set by a rule or more likely linked to a groundwater object
Links: Linkable

☞ SUPPLEMENTAL FLOW SALT MASS

Type: Series
Units: MASS
Description: The salt mass associated with the Supplemental Flow
Information:
I/O: Output only
Links: Not linkable

☞ Supplemental Return Flow Salt Conc

Type: Series
Units: Concentration
Description: The salinity concentration of the Supplemental Return Flow
Information:
I/O: Output only
Links: Linkable

☞ Supplemental Return Flow Salt Mass

Type: Series
Units: Mass
Description: The salt mass of the Supplemental return flow.
Information:
I/O: Output only
Links: not linkable

☞ Supplemental Runoff Salt Conc

Type: Series
Units: Concentration
Description: The salt concentration of supplemental runoff (supplemental water applied that is larger than max infiltration)
Information:
I/O: Output Only
Links: Linkable

☞ Supplemental Runoff Salt Mass

Type: Series
Units: Mass
Description: The salt mass of supplemental runoff.
Information:
I/O: Output only
Links: Not linkable

☞ Total Return Flow Salt Concentration

Type: Series
Units: Concentration
Description: The salinity concentration of the Total Return Flow. This could include both Return Flow Salt and Supplemental Return Flow Salt, depending on the linking.
Information: When this slot is linked, the Outgoing Salt Concentration (on a sequential element) does not include the salt from the Total Return Flow. Because it is linked, it is assumed the flow/salt goes elsewhere and not to the next element.
I/O: Output Only
Links: Linkable to salt concentrations slots on another object.

METHOD DETAILS:

This method is the same as the above method "**Soil Moisture Salt Storage**" HERE (Section 18.1.2.5), in terms of slots added and calculations up through Equation 18-180, where RETURN FLOW SALT CONCENTRATION is computed. This method adds in the supplemental salt as described below:

Supplemental Salt: When Supplemental water is in use, compute Supplemental Salt. SUPPLEMENTAL FLOW SALT CONCENTRATION must be specified or linked, with the value provided by the other object.

$$\text{Supplemental Flow Salt Mass} = \text{Supplemental Flow Salt Concentration} \times \text{Supplemental Use DeliveryVOL} \tag{18-183}$$

Also, compute Supplemental Return Flow salt mass and concentration. First, the water dispatch method will now compute any supplemental flows that are greater than the max infiltration rate.

$$\text{Supplemental Runoff Salt Mass} = \text{Supplemental Runoff VOL} \times \text{Supplemental Flow Salt Concentration} \tag{18-184}$$

$$\text{Supplemental Runoff Salt Concentration} = \text{Supplemental Flow Salt Concentration} \tag{18-185}$$

If SUPPLEMENTAL RUNOFF is linked, the SUPPLEMENTAL RUNOFF is not included in the total Supplemental Return Flow. Therefore, SUPPLEMENTAL RETURN FLOW SALT CONCENTRATION is:

$$\text{Supplemental Return Flow Salt Mass} = SupplementReturnFlowVOL \times \text{Soil Moisture Salt Concentration}[t-1] \tag{18-186}$$

$$\text{Supplemental Return Flow Salt Concentration [t]} = \text{Soil Moisture Salt Concentration}[t-1] \tag{18-187}$$

Otherwise, SUPPLEMENTAL RUNOFF is not linked and it is included in the total Supplemental Return Flow. Therefore,

$$\begin{aligned}&\text{Supplemental Return Flow Salt Mass} = \\ &(SupplementalReturnFlowVOL - \text{Supplemental Runoff VOL}) \times \text{Soil Moisture Salt Concentration}[t-1] + \\ &\text{Supplemental Runoff Salt Mass}\end{aligned} \tag{18-188}$$

$$\text{Supplement Return Flow Salt Concentration [t]} = \frac{\text{Supplement Return Flow Salt Mass}}{SupplementReturnFlowVOL} \tag{18-189}$$

The Total Return Flow Salt Concentration is computed:

$$\text{Total Return Flow Salt Concentration [t]} = \frac{\text{Supplement Return Flow Salt Mass} + \text{Return Flow Salt Mass}}{TotalReturnFlowVOL} \tag{18-190}$$

Salt Mass Balance: Compute the mass balance:

$$\begin{aligned}\text{Soil Moisture Salt Mass [t]} = {} & \text{Soil Moisture Salt Mass [t-1]} + \\ & (\text{Delivered Flow Salt Mass} + \text{Salt Loading} + \text{Supplemental Flow Salt Mass} \\ & + \text{Soil Moisture Gain Loss Salt Mass} \\ & + \text{Soil Moisture Unavailable Gain Loss Salt Mass} \\ & - \text{Return Flow Salt Mass} \\ & - \text{Surface Runoff Salt Mass (only if linked)} \\ & - \text{Supplmental Runoff Salt Mass (only if linked)} \\ & - \text{Supplemental Return Flow Salt Mass})\end{aligned} \tag{18-191}$$

Soil Moisture Salt Concentration is the mass divided by the total volume

$$\text{Soil Moisture Salt Concentration} = \frac{\text{Soil Moisture Salt Mass}}{\text{Soil Moisture} + \text{Soil Moisture Unavailable to Crops} \times \text{Irrigated Area}} \quad (18\text{-}192)$$

18.2 Dispatch Methods

Following are the available dispatch methods for salinity:

18.2.1 Solve Return Flow Salt Conc Sequential

This dispatch method is available for the Salinity method when the water user is on a Sequential Agg Diversion Site. This method computes the **Return Flow Salt Concentration** (and Mass) and **Outgoing Salt Concentration**.

Required Known slots:

- **Diversion Salt Concentration**
- **Diversion**
- **Return Flow**
- **Outgoing Available Water**

Required Unknown slots:

- **Return Flow Salt Concentration**
- **Outgoing Salt Concentration**

Method Details:

First, execute the selected method in the **Salt Storage** category. This computes **Return Flow Salt Mass** and **Concentration**.

Next, the portion of the outgoing water that is from Return Flow is computed, called outgoingFromRF. The purpose is to determine which water has been used and which has not been used as “used” water has the Return Flow Salt Concentration while “unused” water has the Diversion Salt Concentration. This computation depends on the selected Return Flow Split method as described on the Water User documentation and the linking of various slots. Basically, if the return flow slot (Surface Return Flow, Return Flow, or Routed Return Flow) is linked, it is going elsewhere and not available to the next element. If it is not linked, it is considered outgoingFromRF. Thus:

$$unusedFlow = Max(IncomingAvailableWater - Diversion, 0.0) \quad (18\text{-}193)$$

$$\begin{aligned} OutgoingSaltMass = {} & unusedFlowVol \times DiversionSaltConcentration + \\ & outgoingFromRFVol \times ReturnFlowSaltConc \end{aligned} \quad (18\text{-}194)$$

If using Soil Moisture Salt with Supplemental Flow, the equation is:

$$\begin{aligned} OutgoingSaltMass = {} & unusedFlowVol \times DiversionSaltConcentration + \\ & outgoingFromRFVol \times TotalReturnFlowSaltConc \end{aligned} \quad (18\text{-}195)$$

A variable with “Vol” appended is the same variable converted to a volume. Finally, Outgoing Salt Concentration is computed based on the Outgoing Salt Mass and Outgoing Water Available.

18.2.2 Solve Return Flow Salt Conc

This dispatch method is available for the Salinity method when the water user is stand alone or on a "No Structure" Agg Diversion Site. This method computes the RETURN FLOW SALT CONCENTRATION (and MASS).

REQUIRED KNOWN SLOTS:

- ☞ DIVERSION SALT CONCENTRATION
- ☞ DIVERSION
- ☞ RETURN FLOW

REQUIRED UNKNOWN SLOTS:

- ☞ RETURN FLOW SALT CONCENTRATION

METHOD DETAILS:

Execute the selected method in the **Salt Storage** category. This method computes the RETURN FLOW SALT CONCENTRATION (and MASS).

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