RiverWare

Technical Documentation Version 6.2

Water Quality

CADSWES

Center for Advanced Decision Support for Water and Environmental Systems

Water Quality Table of Contents

Water Quality

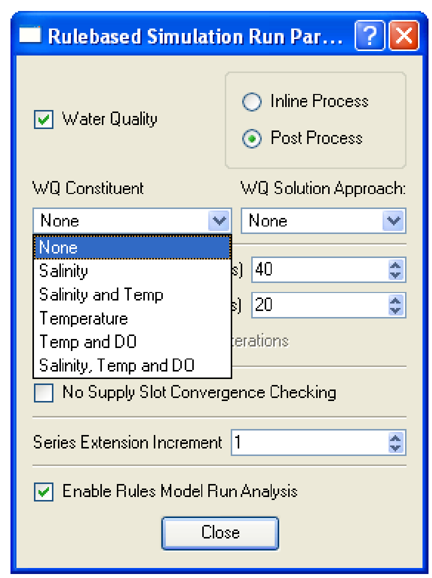
1. Overview and General Features

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, and aggregate diversion site objects. Although the development of the water quality methods were initially completed in 1996, they have not been used extensively and may require some minor modifications with more extensive testing and use.

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. Then, the user specifies the constituents to model and the type of process and approach to use. Additional methods are then selected on the individual objects and slots are populated with data. The model is then run as usual; the water quality results are stored in slots on the individual objects. Following is a brief description of the process used to set up a water quality model.



2.1 Enable Water Quality Modeling

Water quality modeling is enabled 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.

2.2 Specify Process

Two options for Water Quality modeling are presented of which one must be selected, either Inline Process or Post Process:

- **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.

2.3 Select Constituents and Solution Approach

On the parameters dialog, the user is able to select the water quality constituents and solution approach. The following options are available:

WQ Constituent	Available WQ Solution Approach
None	None
Salinity	Simple Well-Mixed
Salinity and Temperature	Layered/Discretized
Temperature	Layered/Discretized
Temperature and Dissolved Oxygen	Layered/Discretized
Salinity, Temperature, and Dissolved Oxygen	Layered/Discretized

After the water quality constituents and solution approach are selected, the simulation objects may have methods that need to be selected. The methods available and their physical process algorithms are described below. Following is a description of the two approaches.

2.3.1 Layered/Discretized

The two 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 dimension dispersion can be included. In this approach, mass and heat are calculated and propagate downstream. As a result, the user should link each constituents mass and/or heat slots between objects.

Features of the Reservoir Water Quality methods include:

- 2-Layer structure, with inflows distributed by temperature and outflows distributed as a “cone of influence” around the outlet works. The modeling of these distributions are user-selectable methods.
- 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 approach.
- Routing methods to support the control-volume methods, including channel characterization schemes and advanced routing algorithms (Muskingum-Cunge, kinematic wave, MacCormack).

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

2.3.2 Simple Well-Mixed

The Simple Well-Mixed salinity methods assume that water in each of the objects is completely mixed. In this approach, mass and concentration are calculated but concentrations propagate up or downstream. As a result, the user should link each salt concentrations between objects.

Features of the Simple Well-Mixed 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 allow the modeling of return flow salt pickup, i.e. the amount of salt to add to a reach.

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, after the water balance has been executed for that object; i.e., it is not possible to “request” a particular salinity at the lower end of the river and have the system solve upstream.

The water quality dispatch methods are processed differently 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.

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
- Evaluate 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.

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.

Agg Diversion Site Water Quality

4. Aggregate Diversion Site

Agg Diversion Sites have water quality methods to model Simple Well-Mixed salt. These methods were designed to work with the Lumped Structure on the AggDiversionSite. Typically, the Total Return Flow is then linked to the Return Flow slot on a reach. Note that the water quality work is done on the aggregate object not on the elements.

4.1 Layered/Discretized Approach

Layered/Discretized is not a valid water quality solution approach for an Aggregate Diversion Site; an error will be issued. Contact CADSWES if you wish to use Layered/Discretized with Agg Diversion Sites.

4.2 Simple Well-Mixed Approach

Following is a description of the Simple Well-Mixed approach to water quality on the agg reach including the slots, and dispatch methods.

4.2.1 General Slots

Below is a description of each of the slots associated with Salinity and the Simple Well-Mixed approach.

☞ **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

☞ **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

☞ **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

☞ **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: Not Linkable

4.2.2 User Methods

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

4.2.2.1 aggDivSiteSalinityCategory

Following are the user selectable methods in the aggDivSiteSalinityCategory. 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.

4.2.2.1.1 No Salinity Calculation

This is the default method in this category and does not perform any calculations.

4.2.2.1.2 Variable Salt Pickup

This method executes the selected method in the Salt Pickup Category: either Salt Pickup Concentration or Salt Pickup Mass. No other calculations are performed.

4.2.2.1.3 Distributed Annual Salt Loading

This method is typically used on a monthly timestep to distribute annual salt loads.

Slots associated with this method

☞ **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

Method Details:

The Distributed Annual Salt Loading method calculates the annual mass and monthly non-shortage return flow salt mass. The variable “annual salt mass” for the current year is calculated in January by summing the products of each month’s Return Flow volume and Return Flow Salinity Pickup.

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:

$$concentrated = \frac{DiversionSaltConcentration \times diversionVolume}{TotalReturnFlowVol} \quad \text{(EQ 4-1)}$$

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

$$returnFlowSaltConc = concentrated \quad \text{(EQ 4-2)}$$

The method then gets the Return Flow slot from the reach that this Total Return Flow 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, we get 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 is 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:

$$returnFlowSaltMass = concentrated \times TotalReturnFlowVol + nonShortRFSaltMass \quad \text{(EQ 4-3)}$$

Otherwise, the method computes the percent short:

$$\%Short = \left(1 - \frac{TotalDiversion \times \left(1 - \frac{totalDiversionRequested - totalDepletionRequested}{totalDiversionRequested}\right)}{totalDepletionRequested}\right) \times 100 \quad \text{(EQ 4-4)}$$

If the %Short is greater than 75%, Return Flow Salt Mass is set equal to *concentrated* times Total Return Flow Volume. Else, if the Percent of Annual Demand for the given month is zero, the equivalent annual shortage is zero. Otherwise, the equivalent annual shortage 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:

$$returnFlowSaltMass = concentrated \times TotalReturnFlowVol + nonShortRFSaltMass \times (1 - equivalentAnnualShortage) \quad \text{(EQ 4-5)}$$

4.2.2.1.4 Variable Salt Pickup with Debting

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 Water Quality 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

☞ **WATER QUALITY 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

METHOD DETAILS:

If the Total Return Flow is zero, the Return Flow Salt Concentration, Return Flow Salt Mass and Water Quality 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:

$$concentrated = \frac{DiversionSaltConcentration \times diversionVolume}{TotalReturnFlowVol} \quad \text{(EQ 4-6)}$$

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

$$unshortReturnFlowVol = TotalDiversionRequestedVol - TotalDepletionRequestedVol \quad \text{(EQ 4-7)}$$

$$massRequested = -(unshortReturnFlowVol \times returnFlowSalinityPickup) \quad \text{(EQ 4-8)}$$

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 Water Quality 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 4-15 or Equation 4-16 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:

$$estOutVol = reachInflowVol + TotalReturnFlowVol - TotalDiversionVol \quad \text{(EQ 4-9)}$$

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

$$massThatCanBe = reachInflowVol \times DiversionSaltConcentration - estOutVol \times reachOutSaltMin \quad \text{(EQ 4-10)}$$

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 Water Quality Salt Debt is positive, set Return Flow Salt Concentration equal to Return Flow Salinity Pickup and go to Equation 4-15 or Equation 4-16. Otherwise, Water Quality Salt Debt is set to:

$$WaterQualitySaltDebt = max(WaterQualitySaltDebt[-1] - (massThatCanBe - massRequested), 0) \quad \text{(EQ 4-11)}$$

$$returnFlowSaltConcentration = -\left(\frac{WaterQualitySaltDebt[-1] - WaterQualitySaltDebt + massRequested}{TotalReturnFlowVol}\right) \quad \text{(EQ 4-12)}$$

Then go to Equation 4-15 or Equation 4-16.

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

$$returnFlowSaltConcentration = -\left(\frac{massThatCanBe}{TotalReturnFlowVol}\right) \quad \text{(EQ 4-13)}$$

$$WaterQualitySaltDebt = WaterQualitySaltDebt[-1] - (massThatCanBe - massRequested) \quad \text{(EQ 4-14)}$$

If concentrated is greater than zero, then:

$$returnFlowSaltConcentration = returnFlowSaltConcentration + concentrated \quad \text{(EQ 4-15)}$$

else:

$$returnFlowSaltConcentration = -returnFlowSaltConcentration + concentrated \quad \text{(EQ 4-16)}$$

Finally, set the salt mass:

$$returnFlowSaltMass = returnFlowSaltConcentration \times TotalReturnFlowVol \quad \text{(EQ 4-17)}$$

4.2.2.2 Salt Pickup Category

This category is dependent on the Variable Salt Pickup method being selected in the aggDivSiteSalinityCategory.

4.2.2.2.1 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:

$$concentrated = \frac{DiversionSaltConcentration \times TotalDiversionVolume}{TotalReturnFlowVol} \quad \text{(EQ 4-18)}$$

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

If the local variable concentrated is greater than or equal to 0.0. Then, Return Flow Salt Concentration equals:.

$$returnFlowSaltConc = concentrated + returnFlowSalinityPickup \quad \text{(EQ 4-19)}$$

Else, Return Flow Salt Concentration equals:.

$$returnFlowSaltConc = concentrated - returnFlowSalinityPickup \quad \text{(EQ 4-20)}$$

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

$$returnFlowSaltMass = returnFlowSaltConc \times TotalReturnFlowVol \quad \text{(EQ 4-21)}$$

4.2.2.2.2 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 (TotalReturn-FlowVol and TotalDiversionVol). Next, the local variable *concentrated* is computed as:

$$concentrated = \frac{DiversionSaltConcentration \times TotalDiversionVolume}{TotalReturnFlowVol} \quad \text{(EQ 4-22)}$$

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:

$$ReturnFlowSaltMass = concentrated \times TotalReturnFlowVol + ReturnFlowSalinityPickupMass \quad \text{(EQ 4-23)}$$

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

$$ReturnFlowSalinityPickup = \frac{returnFlowSalinityPickupMass}{TotalReturnFlowVol} \quad \text{(EQ 4-24)}$$

Then, Return Flow Salt Mass is calculated as:

$$ReturnFlowSaltMass = concentrated \times TotalReturnFlowVol + ReturnFlowSalinityPickupMass \quad \text{(EQ 4-25)}$$

Return Flow Salt Concentration is calculated as:

$$ReturnFlowSaltConc = \frac{ReturnFlowSaltMass}{TotalReturnFlowVol} \quad \text{(EQ 4-26)}$$

4.2.3 Dispatch Methods

Following is the available dispatch method when the solution approach is Simple Well-Mixed.

4.2.3.1 solveSaltModel

This dispatch method is available if the solution approach is Simple Well-Mixed and the constituent is Salinity. This method computes the total inflow and outflow salt mass only. The Diversion Salt Concentration, Total Diversion, and Total Return Flow should come from the linked reach object (or via input or rules).

REQUIRED KNOWN SLOTS:

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

REQUIRED UNKNOWN SLOTS:

- ☞ RETURN FLOW SALT MASS

METHOD DETAILS:

If Return Flow Salinity Pickup is not valid, it is set to zero. Then, the dispatch method executes the selected method in the aggDivSiteSalinityCategory where the work is done and slots are set.

Agg Reach Water Quality

5. Agg Reach

Agg Reaches have water quality methods to model Simple Well-Mixed salt by calculating the total salt mass of the inflow and outflow. The actual water quality work is done on the reach elements. Note, unlike the flow slots on the agg reach, there are no automatic links created between the agg and the elements or between elements and other elements. It is up to the user to create the appropriate links.

5.1 Layered/Discretized Approach

Layered/Discretized is not a valid water quality solution approach for an Aggregate Reach; an error will be issued when the object tries to dispatch. Contact CADSWES if you wish to use Layered/Discretized with Agg Reaches.

5.2 Simple Well-Mixed Approach

Following is a description of the Simple Well-Mixed approach to water quality on the agg reach including the slots, and dispatch methods.

5.2.1 Slots

Below is a description of each of the slots associated with Salinity and the Simple Well-Mixed approach.

☞ **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

5.2.2 Dispatch Methods

Following is the available dispatch method when the solution approach is Simple Well-Mixed.

5.2.2.1 solveSaltModel

This dispatch method is available if the solution approach is Simple Well-Mixed and the constituent is Salinity. 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:

$$InflowSaltMass = InflowSaltConcentration \times InflowVol \qquad \text{(EQ 5-1)}$$

$$OutflowSaltMass = OutflowSaltConcentration \times OutflowVol \qquad \text{(EQ 5-2)}$$

Bifurcation Water Quality

6. Bifurcation

The bifurcation has water quality methods simply for the purpose of passing information up or down stream.

6.1 Layered/Discretized Approach

The Layered/Discretized solution approach uses a simple weighted balance of heat and mass.

6.1.1 Slots

The following slots are instantiated if the approach is Layered/Discretized. Note that all of the water quality slots on the bifurcation are dispatch 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

☞ **INFLOW SALT MASS**

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

☞ **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 Heat

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

☞ Outflow1 Salt Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow1 salinity mass
I/O: Output only
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 Heat

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

☞ Outflow2 Salt Mass

Type: Series Slot
Units: Mass
Description: holds the values of Outflow2 salinity 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

6.1.2 Dispatch Methods

The following dispatch methods are available if the approach is Layered/Discretized.

6.1.2.1 solveTempModel

This dispatch method is available for the Layered/Discretized approach when the constituent is only Temperature.

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:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \quad \text{(EQ 6-1)}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \quad \text{(EQ 6-2)}$$

6.1.2.2 solveTempandSaltModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Salt.

REQUIRED KNOWN SLOTS:

- INFLOW
- INFLOW HEAT
- INFLOW SALT MASS
- OUTFLOW1
- OUTFLOW2

REQUIRED UNKNOWN SLOTS:

- OUTFLOW1 HEAT
- OUTFLOW1 SALT MASS
- OUTFLOW2 HEAT
- OUTFLOW2 SALT MASS

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:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \quad \text{(EQ 6-3)}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \quad \text{(EQ 6-4)}$$

$$Outflow1SaltMass = \frac{Outflow1}{inflow} \times InflowSaltMass \quad \text{(EQ 6-5)}$$

$$Outflow2SaltMass = \frac{Outflow2}{inflow} \times InflowSaltMass \quad \text{(EQ 6-6)}$$

6.1.2.3 solveTempandDOModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Dissolved Oxygen.

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
- OUTFLOW2 DETRITUS MASS
- OUTFLOW2 HEAT

- ☞ **OUTFLOW1 AMMONIA MASS**
- ☞ **OUTFLOW1 DISSOLVED ORGANICS MASS**
- ☞ **OUTFLOW1 DISSOLVED OXYGEN MASS**
- ☞ **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:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \quad \text{(EQ 6-7)}$$

$$Outflow1DetritusMass = \frac{Outflow1}{inflow} \times InflowDetritusMass \quad \text{(EQ 6-8)}$$

$$Outflow1DissolvedOrganicsMass = \frac{Outflow1}{inflow} \times InflowDissolvedOrganics \quad \text{(EQ 6-9)}$$

$$Outflow1AmmoniaMass = \frac{Outflow1}{inflow} \times InflowAmmonia \quad \text{(EQ 6-10)}$$

$$Outflow1DissolvedOxygenMass = \frac{Outflow1}{inflow} \times InflowDissolvedOxygen \quad \text{(EQ 6-11)}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \quad \text{(EQ 6-12)}$$

$$Outflow2DetritusMass = \frac{Outflow2}{inflow} \times InflowDetritusMass \quad \text{(EQ 6-13)}$$

$$Outflow2DissolvedOrganicsMass = \frac{Outflow2}{inflow} \times InflowDissolvedOrganics \quad \text{(EQ 6-14)}$$

$$Outflow2AmmoniaMass = \frac{Outflow2}{inflow} \times InflowAmmonia \quad \text{(EQ 6-15)}$$

$$Outflow2DissolvedOxygenMass = \frac{Outflow2}{inflow} \times InflowDissolvedOxygen \quad \text{(EQ 6-16)}$$

6.1.2.4 solveTempSaltandDOModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature, Salt and Dissolved Oxygen.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW AMMONIA MASS**
- ☞ **INFLOW DISSOLVED OXYGEN MASS**
- ☞ **INFLOW HEAT**
- ☞ **INFLOW SALT MASS**
- ☞ **OUTFLOW1**

- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Outflow2

Required Unknown slots:

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

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:

$$Outflow1Heat = \frac{Outflow1}{inflow} \times InflowHeat \quad \text{(EQ 6-17)}$$

$$Outflow1SaltMass = \frac{Outflow1}{inflow} \times InflowSaltMass \quad \text{(EQ 6-18)}$$

$$Outflow1DetritusMass = \frac{Outflow1}{inflow} \times InflowDetritusMass \quad \text{(EQ 6-19)}$$

$$Outflow1DissolvedOrganicsMass = \frac{Outflow1}{inflow} \times InflowDissolvedOrganics \quad \text{(EQ 6-20)}$$

$$Outflow1AmmoniaMass = \frac{Outflow1}{inflow} \times InflowAmmonia \quad \text{(EQ 6-21)}$$

$$Outflow2Heat = \frac{Outflow2}{inflow} \times InflowHeat \quad \text{(EQ 6-22)}$$

$$Outflow2SaltMass = \frac{Outflow2}{inflow} \times InflowSaltMass \quad \text{(EQ 6-23)}$$

$$Outflow1DissolvedOxygenMass = \frac{Outflow1}{inflow} \times InflowDissolvedOxygen \quad \text{(EQ 6-24)}$$

$$Outflow2DetritusMass = \frac{Outflow2}{inflow} \times InflowDetritusMass \quad \text{(EQ 6-25)}$$

$$Outflow2DissolvedOrganicsMass = \frac{Outflow2}{inflow} \times InflowDissolvedOrganics \quad \text{(EQ 6-26)}$$

$$Outflow2AmmoniaMass = \frac{Outflow2}{inflow} \times InflowAmmonia \quad \text{(EQ 6-27)}$$

$$Outflow2DissolvedOxygenMass = \frac{Outflow2}{inflow} \times InflowDissolvedOxygen \qquad \text{(EQ 6-28)}$$

6.2 Simple Well-Mixed

The simple/well-mixed approach uses a simple weighted balance of temperature and concentration.

6.2.1 Slots

The following slots are instantiated if the approach is Simple Well-Mixed. Note that all of the slots on the bifurcation are dispatch slots.

☞ **INFLOW SALT CONCENTRATION**

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

☞ **OUTFLOW1 SALT CONCENTRATION**

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

☞ **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.

6.2.2 Dispatch Methods

Following is the available dispatch methods when the Simple Well-Mixed approach is used.

6.2.2.1 solveSaltModel

This dispatch method is available if the constituent is salinity and the process is Simple Well-Mixed.

REQUIRED KNOWN SLOTS:

- ☞ **INFLOW**
- ☞ **INFLOW SALT CONCENTRATION**
- ☞ **OUTFLOW1**
- ☞ **OUTFLOW2**

REQUIRED UNKNOWN SLOTS:

☞ **OUTFLOW1 SALT CONCENTRATION**

☞ **OUTFLOW2 SALT CONCENTRATION**

METHOD DETAILS:

This method simply sets the two outflow salt concentrations equal to the inflow salt concentration:

$$outflow1SaltConc = Outflow2SaltConc = inflowSaltConc \quad \text{(EQ 6-29)}$$

Canal Water Quality

7. Canal

Currently, water quality for Canal object can only be modeled using the Layered/Discretized approach. If the Simple/ Well-Mixed approach is selected, an error will result if the user attempts to model a canal.

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.

7.1 Layered/Discretized approach

The layered/discretized solution approaches transfers temperature and concentrations across the canal.

7.1.1 Slots

Following is a list of slots associated with the Layered/Discretized approach and the selected constituent.

☞ **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 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 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 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

☞ 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

☞ **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

7.1.2 Dispatch Methods

Following are the dispatch methods available (depending on constituent) when the Layered/Discretized approach is used.

7.1.2.1 solveTempModelFlow2

This dispatch method is available for the Layered/Discretized approach when the constituent is Temperature.

Required Knowns

☞ **Flow 1 Temperature**

Required Unknowns

☞ **Flow 2 Temperature**

Method Details:

This method does the following:

$$Flow2Temperature = Flow1Temperature \quad \text{(EQ 7-1)}$$

7.1.2.2 solveTempModelFlow1

This dispatch method is available for the Layered/Discretized approach when the constituent is Temperature.

Required Knowns

☞ Flow 2 Temperature

Required Unknowns

☞ Flow 1 Temperature

Method Details:

This method does the following:

$$Flow1Temperature = Flow2Temperature \quad \text{(EQ 7-2)}$$

7.1.2.3 solveTempandSaltModelFlow2

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Salt.

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:

$$Flow2Temperature = Flow1Temperature \quad \text{(EQ 7-3)}$$

$$Flow2SaltConc = Flow1SaltConc \quad \text{(EQ 7-4)}$$

7.1.2.4 solveTempandSaltModelFlow1

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Salt.

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:

$$Flow1Temperature = Flow2Temperature \quad \text{(EQ 7-5)}$$

$$Flow1SaltConc = Flow2SaltConc \quad \text{(EQ 7-6)}$$

7.1.2.5 solveTempandDOModelFlow2

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Dissolved Oxygen.

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:

$$Flow2Temperature = Flow1Temperature \quad \text{(EQ 7-7)}$$

$$Flow2DetritusMass = Flow1DetritusMass \quad \text{(EQ 7-8)}$$

$$Flow2AmmoniaMass = Flow1AmmoniaMass \quad \text{(EQ 7-9)}$$

$$Flow2DissolvedOrganicsMass = Flow1DissolvedOrganicsMass \quad \text{(EQ 7-10)}$$

$$Flow2DissolvedOxygenMass = Flow1DissolvedOxygenMass \quad \text{(EQ 7-11)}$$

7.1.2.6 solveTempandDOModelFlow1

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Dissolved Oxygen.

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:

$$Flow1Temperature = Flow2Temperature \quad \text{(EQ 7-12)}$$

$$Flow1DetritusMass = Flow2DetritusMass \quad \text{(EQ 7-13)}$$

$$Flow1AmmoniaMass = Flow2AmmoniaMass \quad \text{(EQ 7-14)}$$

$$Flow1DissolvedOrganicsMass = Flow2DissolvedOrganicsMass \quad \text{(EQ 7-15)}$$

$$Flow1DissolvedOxygenMass = Flow2DissolvedOxygenMass \quad \text{(EQ 7-16)}$$

7.1.2.7 solveTempSaltandDOModelFlow2

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature, Salt and Dissolved Oxygen.

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:

$$Flow2Temperature = Flow1Temperature \quad \text{(EQ 7-17)}$$

$$Flow2SaltConc = Flow1SaltConc \quad \text{(EQ 7-18)}$$

$$Flow2DetritusMass = Flow1DetritusMass \quad \text{(EQ 7-19)}$$

$$Flow2AmmoniaMass = Flow1AmmoniaMass \quad \text{(EQ 7-20)}$$

$$Flow2DissolvedOrganicsMass = Flow1DissolvedOrganicsMass \quad \text{(EQ 7-21)}$$

$$Flow2DissolvedOxygenMass = Flow1DissolvedOxygenMass \quad \text{(EQ 7-22)}$$

7.1.2.8 solveTempSaltandDOModelFlow1

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature, Salt and Dissolved Oxygen.

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:

$$Flow1Temperature = Flow2Temperature \quad \text{(EQ 7-23)}$$

$$Flow1SaltConc = Flow2SaltConc \quad \text{(EQ 7-24)}$$

$$Flow1DetritusMass = Flow2DetritusMass \quad \text{(EQ 7-25)}$$

$$Flow1AmmoniaMass = Flow2AmmoniaMass \quad \text{(EQ 7-26)}$$

$$Flow1DissolvedOrganicsMass = Flow2DissolvedOrganicsMass \quad \text{(EQ 7-27)}$$

$$Flow1DissolvedOxygenMass = Flow2DissolvedOxygenMass \quad \text{(EQ 7-28)}$$

7.2 Simple Well-Mixed Approach

If Simple Well-Mixed is selected and the canal attempts to dispatch, an error will be issued and the run will be stopped. Please contact CADSWES if you wish to use a canal with the Simple Well-Mixed approach.

Confluence Water Quality

8. Confluence

The confluence has water quality methods simply for the purpose of passing constituent information up or down stream.

8.1 Layered/Discretized Approach

The layered discretized solution approaches use is a simple weighted balance of heat and mass. Using this approach, the confluence can only solve in the downstream direction, i.e. for Outflow.

8.1.1 Slots

The following slots are instantiated if the approach is Layered/Discretized. Note that all of the slots on the confluence are dispatch 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

☞ **INFLOW1 SALT MASS**

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

☞ **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 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

☞ Inflow2 Salt Mass

Type: Series Slot
Units: Mass
Description: holds the values of inflow salinity for the second 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 Heat

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

☞ Outflow Salt Mass

Type: Series Slot
Units: Mass
Description: outflow salinity from the confluence
I/O: Output only
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

8.1.2 Dispatch Methods

The following dispatch methods are available if the approach is Layered/Discretized.

8.1.2.1 solveTempModel

This dispatch method is available for the Layered/Discretized approach when the constituent is only Temperature.

Required Known slots:

- ☞ Inflow1
- ☞ Inflow2
- ☞ Inflow1 Heat
- ☞ Inflow2
- ☞ HeatOutflow

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:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \quad \text{(EQ 8-1)}$$

8.1.2.2 solveTempandSaltModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Salt.

REQUIRED KNOWN SLOTS:

- ☞ INFLOW1
- ☞ INFLOW1 HEAT
- ☞ INFLOW1 SALT MASS
- ☞ INFLOW2
- ☞ INFLOW2 HEAT
- ☞ INFLOW2 SALT MASS
- ☞ OUTFLOW

REQUIRED UNKNOWN SLOTS:

- ☞ OUTFLOW HEAT
- ☞ OUTFLOW SALT MASS

METHOD DETAILS:

This 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:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \quad \text{(EQ 8-2)}$$

$$OutflowSaltMass = Inflow1SaltMass + Inflow2SaltMass \quad \text{(EQ 8-3)}$$

8.1.2.3 solveTempandDOModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Dissolved Oxygen.

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:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \quad \text{(EQ 8-4)}$$

$$OutflowDetritusMass = Inflow1DetritusMass + Inflow2DetritusMass \quad \text{(EQ 8-5)}$$

$$OutflowDissolvedOranicsMass = Inflow1DissolvedOranicsMass + Inflow2DissolvedOranicsMass \quad \text{(EQ 8-6)}$$

$$OutflowAmmoniaMass = Inflow1AmmoniaMass + Inflow2AmmoniaMass \quad \text{(EQ 8-7)}$$

$$OutflowDissolvedOxygenMass = Inflow1DissolvedOxygenMass + Inflow2DissolvedOxygenMass \quad \text{(EQ 8-8)}$$

8.1.2.4 solveTempSaltandDOModel

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature, Salt and Dissolved Oxygen.

REQUIRED KNOWN SLOTS:

- ☞ INFLOW1
- ☞ INFLOW1 AMMONIA MASS
- ☞ INFLOW1 DETRITUS MASS
- ☞ INFLOW1 DISSOLVED ORGANICS MASS
- ☞ INFLOW1 DISSOLVED OXYGEN MASS
- ☞ INFLOW1 HEAT
- ☞ INFLOW1 SALT MASS
- ☞ INFLOW2
- ☞ INFLOW2 AMMONIA MASS
- ☞ INFLOW2 DETRITUS MASS
- ☞ INFLOW2 DISSOLVED ORGANICS MASS
- ☞ INFLOW2 DISSOLVED OXYGEN MASS
- ☞ INFLOW2 HEAT
- ☞ INFLOW2 SALT MASS
- ☞ 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 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:

$$OutflowHeat = Inflow1Heat + Inflow2Heat \quad \text{(EQ 8-9)}$$

$$OutflowSaltMass = Inflow1SaltMass + Inflow2SaltMass \quad \text{(EQ 8-10)}$$

$$OutflowDetritusMass = Inflow1DetritusMass + Inflow2DetritusMass \quad \text{(EQ 8-11)}$$

$$OutflowDissolvedOranicsMass = Inflow1DissolvedOranicsMass + Inflow2DissolvedOranicsMass \quad \text{(EQ 8-12)}$$

$$OutflowAmmoniaMass = Inflow1AmmoniaMass + Inflow2AmmoniaMass \quad \text{(EQ 8-13)}$$

$$OutflowDissolvedOxygenMass = Inflow1DissolvedOxygenMass + Inflow2DissolvedOxygenMass \quad \text{(EQ 8-14)}$$

8.2 Simple Well-Mixed

The simple/well-mixed approach uses a simple weighted balance of temperature and concentration.

8.2.1 Slots

The following slots are instantiated if the approach is Simple Well-Mixed. Note that all of the slots on the confluence are dispatch 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.

8.2.2 Dispatch Methods

Following are the available dispatch methods when the Simple Well-Mixed approach is used.

8.2.2.1 solveSaltModelGivenIn1andIn2

This dispatch method is available if the constituent is salinity and the process is Simple Well-Mixed.

REQUIRED KNOWN SLOTS:

☞ **INFLOW1**
☞ **INFLOW1 SALT CONCENTRATIONI**
☞ **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. For example:

$$outflowSaltConc = \frac{\begin{pmatrix} inflow1SaltConc \times Inflow1VOL \\ + inflow2SaltConc \times Inflow2VOL \end{pmatrix}}{OutflowVOL} \tag{EQ 8-15}$$

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.

8.2.2.2 solveSaltModelGivenIn1andOut

This dispatch method is available if the constituent is salinity and the process is Simple Well-Mixed.

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 the inflows, and their respective salt concentrations, and sets the outflow salt concentration accordingly. For example:

$$inflow2SaltConc = \frac{\begin{pmatrix} outflowSaltConc \times outflowVOL \\ - inflow1SaltConc \times Inflow1VOL \end{pmatrix}}{inflow2VOL} \tag{EQ 8-16}$$

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.

8.2.2.3 solveSaltModelGivenIn2andOut

This dispatch method is available if the constituent is salinity and the process is Simple Well-Mixed.

REQUIRED KNOWN SLOTS:

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

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. For example:

$$inflow1SaltConc = \frac{\left(\begin{array}{c} outflowSaltConc \times outflowVOL \\ -inflow2SaltConc \times Inflow2VOL \end{array}\right)}{inflow1VOL} \quad \text{(EQ 8-17)}$$

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.

Reach Water Quality

9. Reach

The current implementation of the reach water quality model allows the user to model salinity with a Simple Well-Mixed approach, and temperature along with any combination of dissolved oxygen and salinity with a Layered/Discretized approach.

The basic structure of slots and methods on the reach is slightly different than the reservoir and the documentation is organized as such. On the reservoir, slots are instantiated when the user chooses a constituent and selects the approach. On the reach, slots are instantiated when the user selects a method from the waterQualSolutionType category; the available waterQualSolutionType methods depend on the constituent, approach, and 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 Simple Well-Mixed or Layered/Discretized approach.

9.1 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 waterQualSolutionType category. Each of those methods list the slots that are instantiated.

9.1.1 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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
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
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
Links: Not Linkable

9.1.2 Salinity Slots

☞ Inflow Salt Mass

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

☞ Outflow Salt Mass

Type: Series Slot
Units: Mass
Description: salt mass in outflow from the reservoir
I/O: Output only
Links: This slot can be linked to the Inflow Salt Mass slot of a downstream object. This slot is used by Layered/Discretized solution approach.

☞ 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: Series Slot
Units: Concentration
Description: salt concentration of Return Flow.
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.

☞ 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
Links: Not Linkable

☞ Inflow Salt Concentration

Type: Multi 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. This slot is used by Simple Well-Mixed solution approach.

☞ 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.

☞ Return Flow Salt Mass

Type: Series Slot
Units: MASS
Description: salt mass of Return Flow.
I/O: Optional known
Links: If Return Flow is not linked and is not valid, Return Flow Salt Mass is set to zero.

☞ 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. This slot is used by Simple Well-Mixed solution approach.

9.1.3 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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.

9.2 User Selectable Methods

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

9.2.1 waterQualSolutionType category

On the reach, the appropriate water quality slots are added when a method is selected in the waterQualSolutionType 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, and are also called the “water quality routing methods”. Each method describes when it is available and the slots that are instantiated. The slots are described above.

9.2.1.1 noWQ

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.

9.2.1.2 TimeLagTempModel

This method is available if the constituent is Temperature, the approach is Layered/Discretized and the reach is configured to use timeLagRouting.

Slots Associated with this Method:

☞ **Inflow Heat**
☞ **Lag Time**
☞ **Outflow Heat**
☞ **Specific Heat**

Method Details:

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

9.2.1.3 TimeLagSaltTempModel

This method is available if the constituents are Salinity and Temperature, the approach is Layered/Discretized and the reach is configured to use timeLagRouting.

Slots Associated with this Method:

☞ **Inflow Heat**
☞ **Outflow Heat**

- Inflow Salt Mass
- Outflow Salt Mass
- Specific Heat of Water

Method Details:

This method calls the utility methods:

- solveTimeLagSalt
- solveTimeLagTemp

9.2.1.4 TimeLagTempDOModel

This method is available if the constituents are Temp and DO, the approach is Layered/Discretized and the reach is configured to use timeLagRouting.

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

9.2.1.5 TimeLagSaltTempDOModel

This method is available if the constituents are Salinity, Temperature, and DO, the approach is Layered/Discretized and the reach is configured to use timeLagRouting.

Slots Associated with this Method:

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

Method Details:

This method calls the utility methods:

- solveTimeLagSalt
- solveTimeLagTemp

- **solveTimeLagDO**

9.2.1.6 NoRoutingTempModel

This method is available if the constituent is Temperature, the approach is Layered/Discretized and the reach is configured to use noRouting.

SLOTS ASSOCIATED WITH THIS METHOD:

- DIVERSION TEMPERATURE
- INFLOW HEAT
- LOCAL INFLOW TEMPERATURE
- OUTFLOW HEAT
- RETURN FLOW TEMPERATURE
- SPECIFIC HEAT OF WATER

METHOD DETAILS:

This method calls the utility methods

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

9.2.1.7 NoRoutingSaltTempModel

This method is available if the constituents are Salinity and Temp, the approach is Layered/Discretized and the reach is configured to use noRouting.

SLOTS ASSOCIATED WITH THIS METHOD:

- DIVERSION SALT CONCENTRATION
- DIVERSION TEMPERATURE
- INFLOW HEAT
- INFLOW SALT MASS
- LOCAL INFLOW SALT CONCENTRATION
- LOCAL INFLOW TEMPERATURE
- OUTFLOW HEAT
- OUTFLOW SALT MASS
- RETURN FLOW SALT CONCENTRATIONS
- RETURN FLOW TEMPERATURE
- SPECIFIC HEAT OF WATER

METHOD DETAILS:

This method calls the utility methods

- **checkSideFlowConcSalt**
- **solveNoRoutingSalt**
- **checkSideFlowTemp**
- **solveNoRoutingTemp**

9.2.1.8 NoRoutingTempDOModel

This method is available if the constituents are Temperature and DO, the approach is Layered/Discretized and the reach is configured to use noRouting.

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**.

9.2.1.9 NoRoutingSaltTempDOModel

This method is available if the constituents are salinity, temperature and DO, the approach is Layered/Discretized and the reach is configured to use noRouting.

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
- 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
- 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**
- **solveNoRoutingSalt**
- **checkSideFlowTemp**
- **solveNoRoutingTemp**
- **checkSideFlowConcDO**
- **solveNoRoutingDO**

9.2.1.10 ControlVolumeExplicitTemp

This method is available if the constituent is Temperature, the approach is Layered/Discretized and the reach is configured to use macCormackRouting, kinematicRouting, or muskingumCungeRouting.

☞ **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.

9.2.1.11 ControlVolumeImplicitTemp

This method is available if the constituent is Temperature, the approach is Layered/Discretized and the reach is configured to use macCormackRouting, kinematicRouting, or muskingumCungeRouting.

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.

9.2.1.12 ControlVolumeExplicitSaltTemp

This method is available if the constituents are salinity and temperature, the approach is Layered/Discretized and the reach is configured to use macCormackRouting, kinematicRouting, or muskingumCungeRouting.

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 Mass
- Local Inflow Salt Concentration
- Local Inflow Temperature
- Maximum Flow Rate for WQ Stability
- Outflow Heat
- Outflow Salt Mass
- 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.

9.2.1.13 ControlVolumeImplicitSaltTemp

This method is available if the constituents are salinity and temperature, the approach is Layered/Discretized and the reach is configured to use macCormackRouting, kinematicRouting, or muskingumCungeRouting.

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 HEAT
- ☞ INFLOW SALT MASS
- ☞ LOCAL INFLOW SALT CONCENTRATION
- ☞ LOCAL INFLOW TEMPERATURE
- ☞ OUTFLOW HEAT
- ☞ OUTFLOW SALT MASS
- ☞ 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.

9.2.1.14 Mass Balance Salinity

This method is available if the constituent is salinity, the approach is sSimple Well-Mixed and the reach is configured to use noRouting.

SLOTS ASSOCIATED WITH THIS METHOD:

- ☞ DIVERSION SALT CONCENTRATION
- ☞ DIVERSION SALT MASS
- ☞ INFLOW SALT CONCENTRATION
- ☞ INFLOW SALT MASS
- ☞ LOCAL INFLOW SALT CONCENTRATION
- ☞ LOCAL INFLOW SALT MASS
- ☞ OUTFLOW SALT CONCENTRATION
- ☞ OUTFLOW SALT MASS
- ☞ RETURN FLOW SALT MASS

METHOD DETAILS:

This method exists to instantiate the appropriate slots. All of the calculations are performed in the dispatch method.

9.3 Solution/Dispatching

9.3.1 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**.

9.3.2 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.

9.3.2.1 solve2LayerTemp

This dispatch methods executes the selected method in the waterQualSolutionType category (i.e the water quality routing method (HERE (Section 9.2.1)).

REQUIRED KNOWN SLOTS:

- INFLOW
- INFLOW HEAT
- OUTFLOW

UNKNOWN SLOTS:

- OUTFLOW HEAT

9.3.2.2 solve2LayerTempandSalt

This dispatch methods executes the selected method in the waterQualSolutionType category (i.e the water quality routing method (HERE (Section 9.2.1)).

REQUIRED KNOWN SLOTS:

- INFLOW
- INFLOW HEAT
- INFLOW SALT MASS
- OUTFLOW

REQUIRED UNKNOWN SLOTS:

- OUTFLOW HEAT
- OUTFLOW SALT MASS

9.3.2.3 solve2LayerTempandDO

This dispatch methods executes the selected method in the waterQualSolutionType category (i.e the water quality routing method (HERE (Section 9.2.1)).

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

9.3.2.4 solve2LayerTempSaltandDO

This dispatch methods executes the selected method in the waterQualSolutionType category (i.e the water quality routing method (HERE (Section 9.2.1)).

REQUIRED KNOWN SLOTS:

- INFLOW
- INFLOW AMMONIA MASS
- INFLOW DETRITUS MASS
- INFLOW DISSOLVED ORGANICS MASS
- INFLOW DISSOLVED OXYGEN MASS
- INFLOW HEAT
- INFLOW SALT MASS
- OUTFLOW

REQUIRED UNKNOWN SLOTS:

- OUTFLOW AMMONIA MASS
- OUTFLOW DETRITUS MASS
- OUTFLOW DISSOLVED ORGANICS MASS
- OUTFLOW DISSOLVED OXYGEN MASS
- OUTFLOW HEAT
- OUTFLOW SALT MASS

9.3.2.5 solveOutSaltGivenInSalt

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:

Declare the local variables inflowVol, diversionVol, outflowVol, and returnFlowVol. Set the variables by multiplying the flow rate for each by the timestep length.

If Diversion is not valid or Diversion is equal to 0.0, then if Diversion Salt Concentration is not valid, set Diversion Salt Concentration equal to 0.0. Otherwise, Diversion Salt Concentration is set equal to the Inflow Salt Concentration.

If Return Flow is not valid or Return Flow is equal to 0.0, there is a special export where the reach is exporting salt but there is no return flow. If the diversion salt mass is greater than the inflow salt mass or outflow is zero, set Outflow Salt Concentration equal to Inflow Salt Concentration. Otherwise, set Outflow Salt Concentration as:

$$OutflowSaltConc = \frac{inflowVol \times inflowSaltConc - diversionVol \times diversionSaltConcentration}{outflowVol} \quad \text{(EQ 9-1)}$$

If Return Flow Salt Mass is linked to another object and not valid then exit the method and return to dispatch manager waiting for it to become valid. If Return Flow Salt Mass is not linked but not valid, assume it is zero.

If Local Inflow is not valid or equal to 0.0 and Local Inflow Salt Concentration is not valid, set Local Inflow Salt Concentration equal to 0.0.

If Outflow is equal to 0.0 and Outflow Salt Concentration is not valid, set Outflow Salt Concentration equal to Inflow Salt Concentration.

Finally, Outflow Salt Concentration is calculated as:

$$outflowSaltConc = (inflowVol \times inflowSaltConc + returnFlowSaltMass - diversionVol \times diversionSaltConc + localInflowVol \times localnflowSaltConc) / outflowVol \quad \text{(EQ 9-2)}$$

Set Local Inflow Salt Mass, Inflow Salt Mass, Outflow Salt Mass, and Diversion Salt Mass by multiplying the respective volume times the respective concentration.

9.3.2.6 solveInSaltGivenOutSalt

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:

Declare the local variables inflowVol, diversionVol, outflowVol, and returnFlowVol. Set the variables by multiplying the flow rate for each by the timestep length.

This method first checks if the Return Flow slot is valid or equals 0.0. If Return Flow is not valid the method exits and waits until Return Flow is valid. If Return Flow is valid the method checks if diversion is not valid or equals 0.0. If these requirements are all met, Diversion Salt Concentration is set equal to 0.0. Otherwise, Diversion Salt Concentration is set equal to the Outflow Salt Concentration.

If the Return Flow exists, is valid and does not equal zero, the method gets the value in the Return Flow Salinity Pickup from the linked Agg Diversion Site object linked to the Reach object. If not linked to an Agg Diversions Site or of Return Flow Salinity Pickup is not valid, set it to 0.0.

Next, the reach volume is calculated as outflow volume minus return flow volume.

$$reachVol = outflowVol - returnFlowVol \quad \text{(EQ 9-3)}$$

Diversion Salt Concentration is calculated as:

$$diversionSaltConc = \frac{outflowVol \times outflowSaltConc - returnFlowVol \times salinityPickupConc}{reachVol + diversionVol} \quad \text{(EQ 9-4)}$$

If Return Flow Salt Mass is linked to another object and not valid then exit the method and return to dispatch manager. Otherwise, if Local Inflow is not valid or equal to 0.0 and Local Inflow Salt Concentration is not valid, set Local Inflow Salt Concentration equal to 0.0.

If Inflow is equal to 0.0 and Inflow Salt Concentration is not valid, set Inflow Salt Concentration equal to Outflow Salt Concentration. Set the local variables inflowVol, outflowVol, if Diversion is valid, diversionVol, if Local Inflow is valid, localInflowVol, and if Local Adjusted Inflow is valid, localInflowAdjustVol by multiplying their flow rate by the current timestep. Also:

$$localInflowVol = localInflowVol + localInflowAdjustVol \quad \text{(EQ 9-5)}$$

If Diversion, Local Inflow, or Local Adjusted Inflow, or Return Flow Salt Mass are not valid respectively set them equal to 0.0. Finally, Inflow Salt Concentration is calculated as:

$$\begin{aligned} inflowSaltConc = (&outflowVol \times outflowSaltConc - returnFlowSaltMass \\ &+ diversionVol \times diversionSaltConc - localInflowVol \times locaInflowSaltConc) / inflowVol \end{aligned} \quad \text{(EQ 9-6)}$$

Set Local Inflow Salt Mass, Inflow Salt Mass, Outflow Salt Mass, and Diversion Salt Mass by multiplying the respective volume times the respective concentration.

9.3.2.7 solveLocalInSaltGivenInAndOut

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:

Declare the local variables inflowVol, diversionVol, outflowVol, and returnFlowVol. Set the variables by multiplying the flow rate for each by the timestep length. Calculate total local inflow volume:

$$localInflowVol = localInflowVol + localInflowAdjustVol \quad \text{(EQ 9-7)}$$

This method then: if the Diversion slot is not valid or it equals 0.0 and if Diversion Salt Concentration is valid Diversion Salt Concentration is set equal to 0.0. Otherwise, if Diversion Salt Concentration is not valid it is set equal to the Inflow Salt Concentration.

If Diversion Salt Concentration is valid but Return Flow is not valid or Return Flow is equal to 0.0 then this reach has a a Special Export and has it’s own concentration. A check is made to see how much mass is available in the river. If Diversion Salt Concentration times diversionVolume is greater than Inflow Salt Concentration times Inflow Volume, or Outflow equals 0.0, set Outflow Salt Concentration equal to Inflow Salt Concentration. Otherwise, Outflow Salt Concentration is calculated as:

$$outflowSaltConc = \frac{inflowVol \times inflowSaltConc - diversionVol \times diversionSaltConc}{outflowVol} \quad \text{(EQ 9-8)}$$

Next, if Return Flow Salt Mass is linked to any object and not valid, the method is exited and control returns to the dispatch controller to wait.

If Local Inflow is not valid or equal to 0.0 and Local Inflow Salt Concentration is not valid set Local Inflow Salt Concentration equal to 0.0.

If the Return Flow is not valid, assume Return Flow Salt Mass is zero. Finally, Local Inflow Salt Concentration is calculated as:

$$localInflowSaltConc = (outflowVol \times outflowSaltConc - retrunFlowSaltMass + diversionVol \times diversionSaltConc - localInflowVol \times locaInflowSaltConc) / localInflowVol \quad \text{(EQ 9-9)}$$

Set Local Inflow Salt Mass, Inflow Salt Mass, Outflow Salt Mass, and Diversion Salt Mass by multiplying the respective volume times the respective concentration.

9.4 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.

9.4.1 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):

$$Har = \phi(T_a + 273)^4(A + 0.031\sqrt{\varepsilon_a}) \quad \text{(EQ 9-10)}$$

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).

9.4.2 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:

$$Hbr = \varepsilon\phi(T_s + 273)^4 \qquad \text{(EQ 9-11)}$$

where

$$\phi = \text{Stefan-Boltzmann Constant } (0.0049 \text{ J/(m}^2\text{*day*K))}$$
$$Ts = \text{water surface(temperature (C))}$$
$$\varepsilon = \text{emissivity } (0.97)$$

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)).

9.4.3 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:

$$Hc = c_1(getWindEffect())(T_e - T_a)(41860) \qquad \text{(EQ 9-12)}$$

where:

$$c_1 = \text{Bowen's Coefficient(0.47 mmHG/ C)}$$
$$T_e = Surface \text{ Temperature}$$
$$T_a = Air \text{ Temperature}$$

getWindEffect is a utility method (see below) and 41860 is the conversion rate from cal/cm^2 to J/m^2.

9.4.4 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:

$$He = (\text{getWindEffect()})(VP_s - VP_a)(41860) \qquad \text{(EQ 9-13)}$$

where

$$VP_s = \text{value of surface vapor pressure returned from getSurfaceVaporPressure() utility method}$$
$$VP_{sa} = \text{value of air vapor pressure returned from getAirVaporPressure() utility method}$$

getWindEffect is a utility method and 41860 is the conversion rate from cal/cm^2 to J/m^2.

9.4.5 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.

9.4.6 checkSideFlowConcSalt

The function checkSideFlowConcSalt checks salt 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 Salt Concentration is not valid, set it to inflow salt concentration. If Return Flow Salt Concentration or Local 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.

9.4.7 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 Celcius. Otherwise, set *temp* to the previous Diversion Temperature. This value is used to compute the denisty of the water. If the current Diversion Temperature is not valid, set it to:

$$diversionTemperature = \frac{inflowHeat}{density(temp) \times specificHeat \times InflowVol} \quad \text{(EQ 9-14)}$$

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.

9.4.8 defaultCalcSurfaceFlux

This method is called from solveTempWQcontrolVolume Explicit and solveTempControlVolumeIm-plcit. 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.

9.4.9 getAirVaporPressure

This method returns Air Vapor Pressure, the vapor pressure of the air mass overlying the reach

$$P_a = 4.596e^{\left(\frac{17.27T_d}{237.3 + T_d}\right)} \quad \text{(EQ 9-15)}$$

where

P_a = Vapor Pressure of Air

T_d = Dewpoint Temperature

9.4.10 getDensity

This method returns water density for a given temperature, temp. Calculations are based on the following polynomial relationship with temperature:

$$\rho = 1000(6.14x10^{-8}T^3 - 9.5x10^{-6}T^2 + 8.93x10^{-5}T + 0.999812) \quad \text{(EQ 9-16)}$$

If this value evaluates to a density greater than $1x10^6$ g/m^3, the method returns $1x10^6$ g/m^3.

9.4.11 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.

9.4.12 getSurfaceVaporPressure

This method returns Surface Vapor Pressure, the vapor pressure at the surface of the reach:

$$P_s = 4.596e^{\left(\frac{17.27T_s}{237.3 + T_s}\right)} \quad \text{(EQ 9-17)}$$

where

P_s = Vapor Pressure at Reservoir Surface

T_s = Surface Temperature

9.4.13 getWindEffect

This method returns Coefficient of Wind Effect, the effect of wind on the surface heat flux equations.

$$W = 19.0 + 0.95U^2 \quad \text{(EQ 9-18)}$$

where

$$W = \text{Wind Effect Coefficient}$$
$$U = \text{Wind Velocity}$$

9.4.14 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 Constitutent is DO variable.

$$\begin{aligned} outflowConstituentMass = {} & inflowConstituentMass \\ & + returnFlowVol \times returnFlowConstituentConc \\ & - diversionVol \times diversionConstituentConc \\ & + localInflowVol \times localInflowConstituentConc \end{aligned} \quad \text{(EQ 9-19)}$$

9.4.15 solveNoRoutingSalt

This method calculates Outflow Salt Mass based on Inflow Salt Mass, Return Flow Salt Concentration, Diversion Salt Concentration, and Local Inflow Salt Concentration.

$$\begin{aligned} outflowSaltMass = {} & inflowSaltMass \\ & + returnFlowVol \times returnFlowSaltConc \\ & - diversionVol \times diversionSaltConc \\ & + localInflowVol \times localInflowSaltConc \end{aligned} \quad \text{(EQ 9-20)}$$

9.4.16 solveNoRoutingTemp

This method calculates Outflow Heat based on Inflow Heat, Return Flow Temperature, Diversion Temperature, and Local Inflow Salt Temperature.

$$\begin{aligned} outflowHeat = {} & inflowHeat \\ & + returnFlowVol \times returnFlowTemp \times \rho \times H \\ & - diversionVol \times diversionTemp \times \rho \times H \\ & + localInflowVol \times localInflowTemp \times \rho \times H \end{aligned} \quad \text{(EQ 9-21)}$$

where ρ is water density and H is Specific Heat of Water.

9.4.17 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.

$$\frac{M_i^{t+1} - M_i^t}{\Delta t} = c_{i-1}^t\left(Q_{(i-1),i}^t + E\frac{A_{(i-1),i}^t}{\Delta x}\right) + c_i^t\left(-Q^t_{(i+1),i} - E\frac{A_{(i+1),i}^t}{\Delta x} - E\frac{A_{(i-1),i}^t}{\Delta x}\right) + c_{i+1}^t\left(E\frac{A_{(i+1),i}^t}{\Delta x}\right) \quad \text{(EQ 9-22)}$$

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].

9.4.18 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.

$$\frac{M_i^{t+1} - M_i^t}{\Delta t} = c_{i-1}^{t+1}(Q_{(i-1),i}^t) + c_i^{t+1}(-Q^t_{(i+1),i}) \quad \text{(EQ 9-23)}$$

9.4.19 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.

$$\frac{(TV)_i^{t+1} - (TV)_i^t}{\Delta t} = T_{i-1}^t\left(Q_{(i-1),i}^t + E\frac{A_{(i-1),i}^t}{\Delta x}\right) + T_i^t\left(-Q^t_{(i+1),i} - E\frac{A_{(i+1),i}^t}{\Delta x} - E\frac{A_{(i-1),i}^t}{\Delta x}\right) + T_{i+1}^t\left(E\frac{A_{(i+1),i}^t}{\Delta x}\right) + \frac{\Delta H A_{si}^t}{\rho c} \quad \text{(EQ 9-24)}$$

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.]

9.4.20 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.

$$\frac{(TV)_i^{t+1} - (TV)_i^t}{\Delta t} = T_{i-1}^{t+1}(Q_{(i-1),i}^t) + T_i^{t+1}(-Q^t_{(i+1),i}) + \frac{\Delta H A_{si}^t}{\rho c} \quad \text{(EQ 9-25)}$$

9.4.21 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 timetstep and Lag Time of the reach.

9.4.22 solveTimeLagSalt

This method calculates Outflow Salt Mass at future timesteps based on Inflow Salt Mass at the current timestep and Lag Time of the reach.

9.4.23 solveTimeLagTemp

This method calculates Outflow Heat based at future timesteps based on Inflow Heat at the current timestep and Lag Time of the reach.

9.4.24 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

10. 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 only with a simple well-mixed approach, and temperature along with any combination of dissolved oxygen and salinity with a Layered/Discretized approach. The algorithms employed are explicit, which allows for ease of implementation and eliminates the need to iterate between objects or even between dispatch controllers (as is the case if evaporation fluxes are implicitly modeled).

10.1 Layered/Discretized Approach

Following is a description of the Layered/Discretized approach to water quality on the reservoir including the slots, user methods, and dispatch methods. In this approach, the methods solve for the Outflow heat or Outflow mass of the each constituent. Therefore, water quality can only solve in a downstream direction.

10.1.1 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 the Layered/Discretized approach and the constituents from the Run Parameters.

10.1.1.1 Temperature Slots

The following slots are instantiated if temperature is one of the constituents in the Layered/Discretized approach.

☞ **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

☞ 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

☞ 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

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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

10.1.1.2 Salinity Slots

The following slots are instantiated if salinity is one of the constituents in the Layered/Discretized approach.

☞ **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: This slot can be linked to the Outflow Salt Mass 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: This slot can be linked to the Inflow Salt Mass slot of a downstream object. This slot is used by Layered/Discretized solution approach.

☞ **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: Series Slot
UNITS: CONCENTRATION
Description: salt 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 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.

10.1.1.3 Dissolved Oxygen Slots

The following slots are instantiated if dissolved oxygen is one of the constituents in the Layered/Discretized approach.

☞ **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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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. This slot is used by Layered/Discretized solution approach.

☞ 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

10.1.2 User Selectable Methods

The following categories and methods are available when the selected approach is Layered/Discretized:

10.1.2.1 DistributeInflowCategory

This category of methods is only applicable of the Layered/Discretized solution approach. 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.

10.1.2.1.1 noDistributeInflow

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.

10.1.2.1.2 distributeInflowbyTemp

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.

10.1.2.2 DistributeOutflowCategory Methods

This category of methods is only applicable of the Layered/Discretized solution approach. 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.

10.1.2.2.1 noDistributeOutflow

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.

10.1.2.2.2 distributeOutflowbyFlow

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

- ☞ 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, distributeOutflowbyFlow, 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: distributeOutflowbyFlow is based on algorithms developed for use in the TVA system by Gary Hauser.

10.1.2.3 surfaceFluxCalculationCategory Methods

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.

10.1.2.3.1 noCalcSurfaceFlux

This is the default method, and is not a valid method for calculation. An error is flagged if this method is executed.

10.1.2.3.2 defaultCalcSurfaceFlux

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):

$$HeatFlux = IncomingSolarRadiation + calcHar(\ ) - calcHbr(\ ) - calcHc(\ ) - calcHe(\ ) \quad \text{(EQ 10-1)}$$

10.1.3 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 / Discretized Approach
  - 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.

10.1.4 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 Layer/Discretized approach (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

10.1.5 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 Layered/Discretized dispatch methods calls utility methods to check for necessary data. Then, these dispatch methods call the utility method **AdjKDet** which is general for all constituent combinations and does the bulk of the work

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.

10.1.5.1 solve2LayerTemp

This dispatch method is available for the Layered/Discretized approach when the constituent is only Temperature.

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

10.1.5.2 solve2LayerTempandSalt

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Salt.

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

10.1.5.3 solve2LayerTempandDO

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature and Dissolved Oxygen.

Required Known slots:

- Diversion
- Hydrologic Inflow
- Inflow
- Inflow Ammonia Mass
- Inflow Detritus Mass
- Inflow Dissolved Organics Mass
- Inflow Dissolved Oxygen Mass
- Inflow Heat
- 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

10.1.5.4 solve2LayerTempSaltandDO

This dispatch method is available for the Layered/Discretized approach when the constituents are Temperature, Salt and Dissolved Oxygen.

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

10.2 Simple Well-Mixed Approach

Following is a description of the Simple Well-Mixed approach to simulating salinity on the reservoir including the slots and user methods. In this approach, the methods solve for inflow or outflow salt concentration.

10.2.1 Salinity Slots

If the selected constituent is “Salinity” and the solution approach is “Simple Well-Mixed”. 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. Because the flows associated with these concentrations may not be equal, the sum column does not truly represent the inflow concentration. The dispatch methods will do a weighted average to determine the weighted concentration, but this will not be displayed in the slot. Also, care should be taken to link the Inflow Salt Concentrations in the same order as the Inflow was linked; make sure the columns of these two multi-slots are in the same order.
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: Concentration
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

☞ **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

☞ **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

10.2.2 User Selectable Methods

The following categories and methods are available when the selected approach is Simple/Well Mixed.

10.2.2.1 Bank Storage Salt Category

If the reservoir considers bank storage and has either the “InputBankStorage” or “CRSSBankStorage-Calc” user method selected, salinity in the bank storage can be considered. The Bank Storage Salt Category becomes visible with the following two method options:

10.2.2.1.1 No Bank Storage Salt

This default method does not consider salinity of bank storage water.

10.2.2.1.2 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:

$$\text{BankStorageSaltConcentration} = \frac{\text{DeltaBankStorage} \times \text{ReservoirSaltConcentration}[-1] + \text{BankStorage}[-1] \times \text{BankStorageSaltConcentration}[-1]}{\text{BankStorage}} \quad \text{(EQ 10-2)}$$

10.2.2.2 Reservoir Water Quality Routing Category

The Reservoir Water Quality Routing category is used to specify how salinity routes through a reservoir. It is available only when the constituent is Salinity and the process is Simple Well-Mixed. 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

10.2.2.2.1 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:

- **solvePredCorrSaltGivenIn**
- **solvePredCorrSaltGivenOut**

10.2.2.2.2 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:

- **solveWeightFactorSaltGivenIn**
- **solveWeightFactorSaltGivenOut**

10.2.3 Beginning of Water Quality Run

The following behavior 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 Simple Well-Mixed approach
  - 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.

10.2.4 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:

- ☞ **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**

10.2.5 Dispatch Methods

The controller for water quality has a dispatch method for each constituent and solution approach combination. It assumes that the mass balance has already run for the given timestep, and has the required slots. The following water quality dispatch methods exist on all reservoirs for the Simple Well-Mixed approach. 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.

10.2.5.1 solveWeightFactorSaltGivenIn

This dispatch method is available for the Simple Well-Mixed approach (salinity) when the Weighting Factor Salt method is selected from the Reservoir Water Quality 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**, HERE (Section 10.3.45), 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:

$$\text{storSum} = \text{storage} + \text{storage}(-1) + 2 \times \text{deadStorage} \tag{EQ 10-3}$$

Calculate the weightingFactor:

$$\text{weightingFactor} = 1 + 0.6\frac{(\text{inflowVol} + \text{returnFlowVol} + \text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{\text{storSum}} \tag{EQ 10-4}$$

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.

$$\text{reservoirSaltConc} = \Big(\text{reservoirSaltConc}(-1) \times (\text{storage} + \text{deadStorage}) + \text{inflowSaltConc} \times \text{inflowVol} + \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \text{returnFlowSaltMass} + \text{inboundBankStorageSaltMass} - \text{reservoirSaltConc}(-1) \times \frac{(\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}\Big) / \text{storSum} \tag{EQ 10-5}$$

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:

$$\text{OutflowSaltConc} = \frac{\text{reservoirSaltConc}(-1) + \text{weightingFactor} \times \text{reservoirSaltConc}}{1 + \text{weightingFactor}} \tag{EQ 10-6}$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

10.2.5.2 solveWeightFactorSaltGivenOut

This dispatch method is available for the Simple Well-Mixed approach (salinity) when the Weighting Factor Salt method is selected from the Reservoir Water Quality 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:

$$storSum = storage + storage(-1) + 2 \times deadStorage \quad \text{(EQ 10-7)}$$

Calculate the weightingFactor:

$$weightingFactor = 1 + 0.6\frac{(inflowVol + returnFlowVol + outflowVol + diversionVol + outboundBankStorage)}{storSum} \quad \text{(EQ 10-8)}$$

StorSum is then recalculated as:

$$storSum = storage + deadStorage + weightingFactor\frac{(ouflowVol + diversionVol + outboundBankStorage)}{1 + weightingFactor}$$

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.

$$reservoirSaltConc = \frac{(outflowSaltConc \times (1 + weightingFactor) - reservoirSaltConc(-1))}{weightingFactor} \quad \text{(EQ 10-9)}$$

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:

$$\text{InflowSaltConc} = \Big[\text{reservoirSaltConc} \times \left(\text{storage} + \text{deadStorage} + \text{weightingFactor}\frac{(\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage})}{1 + \text{weightingFactor}}\right) + \text{reservoirSaltCon}(-1) \times (\text{ouflowVol} + \text{diversionVol} + \text{outboundBankStorage}) / (1 + \text{weightingFactor}) - \text{returnFlowSaltMass} - \text{inboundBankStorageSaltMass} - \text{reservoirSaltConc}(-1) \times (\text{storage}(-1) + \text{deadStorage})\Big] / \text{inflowVol} \quad \text{(EQ 10-10)}$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

10.2.5.3 solvePredCorrSaltGivenIn

This dispatch method is available for the Simple Well-Mixed approach (salinity) when the Predictor-Corrector Salt method is selected from the Reservoir Water Quality 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.

$$\text{storSum} = \text{storage} + \text{deadStorage} \quad \text{(EQ 10-11)}$$

If storSum is equal to 0.0 then set Reservoir Salt Concentration equal to -1.0 (the Reservoir Salt Concentration is recalculated in Equation 10-17. Otherwise, solve for the **predictor** (in units of salt mass):

$$\begin{aligned}\text{predictor} = {} & \text{inflowSaltConc} \times \text{inflowVol} + \\ & \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \\ & \text{returnFlowSaltMass} + \\ & \text{inboundBankStorageSaltMass} - \\ & \text{reservoirSaltConc}(-1) \times (\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage})\end{aligned} \quad \text{(EQ 10-12)}$$

The local variable intermediateReservoirSaltConc is computed as:

$$\text{intermediateReservoirSaltConc} = \frac{\text{reservoirSaltConc}(-1) \times (\text{storage}(-1) + \text{deadStorage}) + \text{predictor}}{\text{storSum}} \quad \text{(EQ 10-13)}$$

Solve for the **corrector** (in units of salt mass):

$$\text{corrector} = \text{inflowSaltConc} \times \text{inflowVol} + \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \text{returnFlowSaltMass} + \text{inboundBankStorageSaltMass} - \text{intermediateReservoirSaltConc} \times (\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage}) \quad \text{(EQ 10-14)}$$

The local variable **slope** is the average of the predictor and the corrector

$$\text{slope} = \frac{\text{predictor} + \text{corrector}}{2} \quad \text{(EQ 10-15)}$$

The Reservoir Salt Concentration is calculated as:

$$\text{reservoitSaltConc} = \frac{\text{reservoirSaltConc}(-1) \times (\text{storage} + \text{deadStorage}) + \text{slope}}{\text{storSum}} \quad \text{(EQ 10-16)}$$

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.

$$\text{reservoirSaltConc} = (\text{inflowSaltConc} \times \text{inflowVol} + \text{hydroInflowSaltConc} \times \text{hydroInflowVol} + \text{inboundBankStorageSaltMass} + \text{returnFlowSaltMass}) / (\text{inflowVol} + \text{hydroInflowVol} + \text{inboundBankStorageVol} + \text{returnFlow}) \quad \text{(EQ 10-17)}$$

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.

10.2.5.4 solvePredCorrSaltGivenOut

This dispatch method is available for the Simple Well-Mixed approach (salinity) when the Predictor-Corrector Salt method is selected from the Reservoir Water Quality 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.

$$\text{storSum} = \text{storage} + \text{deadStorage} \quad \text{(EQ 10-18)}$$

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.

$$\text{reservoirSaltConc} = \text{outflowSaltConc} \quad \text{(EQ 10-19)}$$

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:

$$\begin{aligned}\text{inflowSaltConc} = (&\text{reservoirSaltConc} \times (\text{storage} + \text{deadStorage}) \\ &+ \text{reservoirSaltConc}(-1) \times (\text{outflowVol} + \text{diversionVol} + \text{outboundBankStorage}) - \text{returnFlowSaltMass} \\ &- \text{inboundBankStorageSaltMass} - \text{reservoirSaltConc}(-1) \times (\text{storage}(-1) + \text{deadStorage})) / \text{inVol}\end{aligned} \quad \text{(EQ 10-20)}$$

Finally, Inflow Salt Mass, Outflow Salt Mass, Diversion Salt Mass and Hydrologic Inflow Salt Mass are set by multiplying their respective volumes and concentrations.

10.3 Utility Methods

Utility Methods are methods (or subroutines, or 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 (denoted as), return values but do not set slots explicitly.

10.3.1 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`.

$$\text{AdjKAmm} = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \quad \text{(EQ 10-21)}$$

`AdjKAmm` should return a value between 0.0 and 1.0.

Slots with Required Known Data

Ammonia Parameters

10.3.2 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.

$$\text{AdjKDet} = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \quad \text{(EQ 10-22)}$$

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**

10.3.3 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`.

$$\text{AdjKOrg} = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \quad \text{(EQ 10-23)}$$

`AdjKOrg` should return a value between 0.0 and 1.0.

Slots with Required Data

☞ **Dissolved Organics Parameters**

10.3.4 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.

$$\text{AdjKResp} = \frac{K1 e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 e^{(\gamma \times (T - T1) - 1)})} \quad \text{(EQ 10-24)}$$

Slots with Required Known Data

☞ **Respiration Parameters**

10.3.5 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`.

$$AdjKSOD = \frac{K1 \times e^{(\gamma \times (T - T1) - 1)}}{(1 + K1 \times e^{(\gamma \times (T - T1) - 1)})} \quad \text{(EQ 10-25)}$$

AdjKSOD should return a value between 0.0 and 1.0.

SLOTS WITH REQUIRED KNOWN DATA

- SOD PARAMETERS

10.3.6 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:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \quad \text{(EQ 10-26)}$$

and, the hypolimnion ammonia concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / H_v \quad \text{(EQ 10-27)}$$

where

C_e^i = Epilimnion Ammonia Concentration at time i

C_h^i = Hypolimnion Ammonia Concentration at time i

C_{in} = Inflow Ammonia 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 = Ammonia 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 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.

$$\Delta AmmDecay_e = C_e^i \times AdjK_{Amm}(\ ) \times Kmax_{Amm} \times \Delta t \quad \text{(EQ 10-28)}$$

$$C_e^i = C_e^i - \Delta AmmDecay_e \quad \text{(EQ 10-29)}$$

and

$$\Delta AmmDecay_h = C_h^i \times AdjK_{Amm}(\ ) \times Kmax_{Amm} \times \Delta t \quad \text{(EQ 10-30)}$$

$$C_h^i = C_h^i - \Delta AmmDecay_h \quad \text{(EQ 10-31)}$$

where

$\Delta AmmDecay_e$ = Ammonia Decay in Epilimnion (g/m^3)

$\Delta AmmDecay_h$ = Ammonia Decay in Hypolimnion (g/m^3)

$AdjK_{Amm}(\ )$ = Function Calculating Maximum Decay Rate Scaling Factor

$Kmax_{Amm}$ = Maximum Decay Rate for Ammonia

E_Z = Epilimnion Thickness

H_Z = Hypolimnion Thickness

It then adjusts the layer ammonia concentrations to account for movement of the thermocline during the timestep.

10.3.7 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

- Deterius 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:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \qquad \text{(EQ 10-32)}$$

and, the hypolimnion detritus concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / H_v \qquad \text{(EQ 10-33)}$$

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.

$$\Delta DetDecay_e = C_e^i \times AdjKDet(EpiLayerTemp) \times Kmax_{Det} \times \Delta t \quad \text{(EQ 10-34)}$$

$$ESettle_{out} = (C_e^i \times K_{set} \times \Delta t) \div E_z \quad \text{(EQ 10-35)}$$

$$C_e^i = C_e^i - \Delta DetDecay_e - ESettle_{out} \quad \text{(EQ 10-36)}$$

and

$$\Delta DetDecay_h = C_h^i \times AdjKDet(HypoLayerTemp) \times Kmax_{Det} \times \Delta t \quad \text{(EQ 10-37)}$$

$$HSettle_{out} = (C_h^i \times K_{set} \times \Delta t) \div H_z - ESettle_{out} \quad \text{(EQ 10-38)}$$

$$C_h^i = C_h^i - \Delta DetDecay_h - HSettle_{out} \quad \text{(EQ 10-39)}$$

where

$$\Delta DetDecay_e = \text{Detritus Decay in Epilimnion } (g/m^3)$$
$$\Delta DetDecay_h = \text{Detritus Decay in Hypolimnion } (g/m^3)$$
$$AdjKDet\ (temp) = \text{Function Calculating Maximum Decay Rate Scaling Factor}$$
$$Kmax_{Det} = \text{Maximum Decay Rate for Detritus}$$
$$ESettle_{out} = \text{Detritus Settled Out of Epilimnion } (g/m^3)$$
$$HSettle_{out} = \text{Detritus Settled Out of Hypolimnion } (g/m^3)$$
$$K_{set} = \text{Detritus Settling Rate}$$
$$E_z = \text{Epilimnion Thickness}$$
$$H_z = \text{Hypolimnion Thickness}$$

It then adjusts the layer detritus concentrations to account for movement of the thermocline during the timestep.

10.3.8 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:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right) / E_v \qquad \text{(EQ 10-40)}$$

and, the hypolimnion dissolved oxygen concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\right) / H_v \qquad \text{(EQ 10-41)}$$

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.

$$C_e^i = C_e^i + deltaDOPhoto(\ ) - deltaDOChem(\ ) + deltaDOReaeration(\ ) - deltaDORespiration(\ ) - deltaDOSOD(\ ) \quad \text{(EQ 10-42)}$$

$$C_e^i = C_e^i + deltaDOPhoto(\ ) - deltaDOChem(\ ) - deltaDORespiration(\ ) - deltaDOSOD(\ ) \quad \text{(EQ 10-43)}$$

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.

10.3.9 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:

$$\text{gamma} = \frac{\log\left(\frac{k2 \times (1 - k1)}{k1 \times (1 - k2)}\right)}{(t2 - t1)} \quad \text{(EQ 10-44)}$$

10.3.10 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:

$$\text{Har} = \phi(T_a + 273)^4 (A + 0.031\sqrt{\varepsilon_a}) \quad \text{(EQ 10-45)}$$

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 getAirVaporPressure 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.

10.3.11 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:

$$Hbr = \varepsilon\phi(T_s + 273)^4 \quad \text{(EQ 10-46)}$$

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)).

10.3.12 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
- TEMPERATURE
- WIND VELOCITY

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:

$$Hc = c_1(\text{getWindEffect()})(T_e - T_a)(41860) \quad \text{(EQ 10-47)}$$

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.

10.3.13 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
- TEMPERATURE
- WIND VELOCITY

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:

$$He = (getWindEffect())(VP_s - VP_a)(41860) \quad \text{(EQ 10-48)}$$

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.

10.3.14 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 surfaceFluxCalculationCategory to calculate surface flux. The epilimnion temperatures is calculated as:

$$Te^t = Te^{t-1} + \left(\frac{E_{in}}{E_v}T_{in} - \frac{E_{out}}{E_v}Te^{t-1} + \frac{\Delta H}{\rho C_p E_z} + \frac{\varepsilon' A_t \Delta T}{M_z E_v}\right)\Delta t \quad \text{(EQ 10-49)}$$

and, the hypolimnion temperatures is calculated as:

$$Th^t = Th^{t-1} + \left(\frac{H_{in}}{H_v}T_{in} - \frac{H_{out}}{H_v}Th^{t-1} + \frac{\varepsilon' A_t \Delta T}{M_z H_v}\right)\Delta t \quad \text{(EQ 10-50)}$$

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 ($\text{Joules/m}^2\text{sec}$)

ρ = Density of Water in Epilimnion (from getEpilimnionDensity())

C_p = Specific Heat of Water (J/gC)

E_z = Epilimnion Thickness

ε' = Thermocline Diffusion Coefficient ($\text{m}^2\text{/sec}$)

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.

10.3.15 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.

10.3.16 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.

10.3.17 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.

10.3.18 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.

10.3.19 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.

10.3.20 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:

$$flowHeat = flowTemp \times flowVol \times specificHeat \times epilimnionDensity \qquad \text{(EQ 10-51)}$$

The method then sums the heat as:

$$TotalInflowTemp = (inflowHeat + hydrologicInflowHeat + returnFlowHeat - diversionHeat + canalFlowHeat + pumpInHeat - pumpOutHeat) / (totalInflowVol \times specificHeat \times epilimnionDensity) \qquad \text{(EQ 10-52)}$$

And then sets the Inflow Temp and Total Inflow columns on the Temperature slot.

10.3.21 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:

$$\text{hypolimnionVol} = \text{hypolimnionVol}[-1] + \text{hypolimnionInflowVol} - \text{hypolimnionOutflowVol} \quad \text{(EQ 10-53)}$$

$$\text{epilimnionVol} = \text{storage} - \text{hypolimnionVolume} \quad \text{(EQ 10-54)}$$

These values are later adjusted in **AdjKDet** after calculating thermocline movement during the timestep.

10.3.22 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:

$$C_e^t = C_e^{t-1} + \left(C_{in}E_{inVOL} - C_e^{t-1}E_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right)/E_v \quad \text{(EQ 10-55)}$$

and, the hypolimnion dissolved organics concentration is calculated as:

$$C_h^t = C_h^{t-1} + \left(C_{in}H_{inVOL} - C_h^{t-1}H_{outVOL} + \left[\frac{\varepsilon'\Delta CA_t}{M_z}\right]\Delta t\right)/H_v \quad \text{(EQ 10-56)}$$

where

C_e^i = Epilimnion Dissolved Organics Concentration at time i

C_h^i = Hypolimnion Dissolved Organics Concentration at time i

C_{in} = Inflow Dissolved Organics 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 = Dissolved Organics 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 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.

$$\Delta OrgDecay_e = C_e^i \times AdjK_{Org}(\ ) \times Kmax_{Org} \times \Delta t \qquad \text{(EQ 10-57)}$$

$$C_e^i = C_e^i - \Delta DetDecay_e \qquad \text{(EQ 10-58)}$$

and

$$\Delta OrgDecay_h = C_h^i \times AdjK_{Org}(\ ) \times Kmax_{Org} \times \Delta t \qquad \text{(EQ 10-59)}$$

$$C_h^i = C_h^i - \Delta OrgDecay_h \qquad \text{(EQ 10-60)}$$

where

$\Delta OrgDecay_e$ = Dissolved Organics Decay in Epilimnion (g/m^3)

$\Delta OrgDecay_h$ = Dissolved Organics Decay in Hypolimnion (g/m^3)

$AdjK_{Org}$ ( ) = Function Calculating Maximum Decay Rate Scaling Factor

$Kmax_{Org}$ = Maximum Decay Rate for Dissolved Organics

E_Z = Epilimnion Thickness

H_Z = Hypolimnion Thickness

It then adjusts the layer dissolved organics concentrations to account for movement of the thermocline during the timestep.

10.3.23 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

10.3.24 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

10.3.25 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.

10.3.26 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

10.3.27 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

10.3.28 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.

10.3.29 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:

$$S_e^t = S_e^{t-1} + \left(SC_{in} E_{inVOL} - S_e^{t-1} E_{outVOL} + \left[\frac{\varepsilon' \Delta S A_t}{M_z} \right] \Delta t \right) / E_v \quad \text{(EQ 10-61)}$$

and, the hypolimnion salt concentration is calculated as:

$$S_h^t = S_h^{t-1} + \left(SC_{in} H_{inVOL} - S_h^{t-1} H_{outVOL} + \left[\frac{\varepsilon' \Delta S A_t}{M_z} \right] \Delta t \right) / H_v \quad \text{(EQ 10-62)}$$

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.

10.3.30 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:

$$A = \frac{\Delta V}{\Delta H} \quad \text{(EQ 10-63)}$$

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

10.3.31 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.

10.3.32 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.

10.3.33 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.

10.3.34 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.

10.3.35 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:

$$\mathrm{doChem} = \mathrm{detritusDecay} \times \mathrm{rDet} + \mathrm{dissolvedOrganicsDecay} \times \mathrm{rOrg} + \mathrm{ammoniaDecay} \times \mathrm{rAmm} \quad \text{(EQ 10-64)}$$

10.3.36 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:

$$\mathrm{doPhoto} = \frac{\mathrm{Pmax}\left(\frac{\mathrm{Eave}}{\mathrm{Emax}}\right)\mathrm{fPhoto} \times \Delta t}{\mathrm{layerThickness}} \quad \text{(EQ 10-65)}$$

where

$$\mathrm{Pmax} = \mathrm{Pmax20} \times \mathrm{theta}^{(\mathrm{Temperature} - 20)} \quad \text{(EQ 10-66)}$$

and

$$\mathrm{Eave} = (\mathrm{Etop} + \mathrm{Ebot})/2$$
$$\mathrm{Etop}(\mathrm{Ebot}) = \mathrm{Emax} \times (1 - \mathrm{beta})e^{(-\mathrm{eta} \times \mathrm{depthFromSurface})} \quad \text{(EQ 10-67)}$$

10.3.37 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:

$$doReaer = \frac{Kreaer \times (C_s - epiConcDO)\Delta t}{layerThickness} \qquad \text{(EQ 10-68)}$$

where K_{reaer} is the surface transfer coefficient

$$Kreaer = 0.5 + 0.05 \times windVelocity \qquad \text{(EQ 10-69)}$$

and C_s is the saturation concentration of dissolved oxygen.

$$C_s = 14.652 - 0.41022T + 0.007991T^2 - 0.7777 \times 10^{-4}T^3 \qquad \text{(EQ 10-70)}$$

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:

$$\ln C_{ss} = \ln C_s - S\left[1.7674 \times 10^{-2} - \frac{1.0754 \times 10^1}{T} + \frac{2.1407 \times 10^3}{T^2}\right] \qquad \text{(EQ 10-71)}$$

where C_{ss} is the new saturation concentration, and S is the salinity concentration in ppt.

10.3.38 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:

$$doResp = AdjKResp(\ ) \times KmaxResp \times factor \times fResp \times thetaR^{(Temperature - 20)} \times \Delta t \qquad \text{(EQ 10-72)}$$

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.

10.3.39 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:

$$doSOD = \frac{K_{SODMax} \times sedArea \times AdjKSOD(\ ) \times Factor \times F_{SOD} \times \Delta t}{layerVolume} \quad \text{(EQ 10-73)}$$

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.

10.3.40 getAirVaporPressure

Returns Air Vapor Pressure, the vapor pressure of the air mass overlying the reservoir.

$$P_a = 4.596e^{\left(\frac{17.27T_d}{237.3 + T_d}\right)} \quad \text{(EQ 10-74)}$$

where

P_a = Vapor Pressure of Air

T_d = Dewpoint Temperature

Slots with Required Known Data

Dewpoint Temperature

10.3.41 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 and the columns must correspond to each other. The order of the columns is determined by the order in which they were linked.

10.3.42 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:

$$\rho = 1000(6.14x10^{-8}T^3 - 9.5x10^{-6}T^2 + 8.93x10^{-5}T + 0.999812) \quad \text{(EQ 10-75)}$$

If this value evaluates to a density greater than $1x10^6$ g/m^3, the method returns $1x10^6$ g/m^3.

10.3.43 getSurfaceVaporPressure

The function getSurfaceVaporPressure, returns Surface Vapor Pressure, the vapor pressure at the surface of the reservoir:

$$P_s = 4.596e^{\left(\frac{17.27T_s}{237.3 + T_s}\right)} \quad \text{(EQ 10-76)}$$

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.

10.3.44 getWindEffect

Returns Coefficient of Wind Effect, the effect of wind on the surface heat flux equations.

$$W = 19.0 + 0.95U^2 \quad \text{(EQ 10-77)}$$

where

W = Wind Effect Coefficient

U = Wind Velocity

SLOTS WITH REQUIRED KNOWN DATA

☞ **WIND VELOCITY**

10.3.45 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 Category 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.

10.3.46 setThermoclineDiffusionCoefficient

The method, setThermoclineDiffusionCoefficient, calculates a diffusion coefficient for the thermocline calculations.

SLOTS WITH REQUIRED KNOWN DATA

- POOL ELEVATION
- THERMOCLINE DIFFUSION COEFFICIENT ADJUSTMENT
- RESERVOIR BOTTOM ELEVATION

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:

$$\varepsilon' = 6.10848 \times 10^{-3} \bar{D}^{1.1505} \varepsilon_{adj} \qquad \text{(EQ 10-78)}$$

where

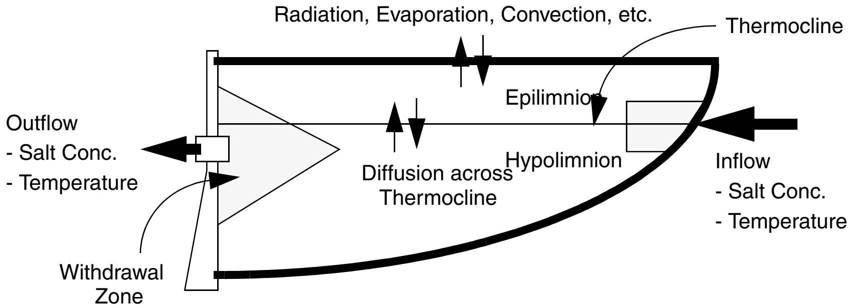
ε' = Thermocline Diffusion Coefficient

$\bar{D}$ = Mean Depth of the Reservoir

ε_{adj} = Thermocline Diffusion Coefficient Adjust

10.3.47 WQ_2_Layer

WQ_2_Layer is the default model for the Layered/Discretized modeling approach. 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**

Stream Gage Water Quality

11. Stream Gage

On the Stream Gage, water quality constituents are transferred through the object by the water quality dispatch methods.

11.1 Layered/Discretized Approach

Following is a description of the Layered/Discretized approach to water quality on the stream gage including the slots and dispatch methods. In this approach, the methods solve for the Outflow heat or Outfow mass of the each constituent. Therefore, water quality can only solve in a downstream direction.

11.1.1 Slots

Below is a list of the slots that are used in the Layered/Discretized approach organized by constituent.

11.1.1.1 Temperature Slots

☞ **INFLOW HEAT**

Type: Series Slot
Units: HEAT
Description: Heat associated with the Inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **OUTFLOW HEAT**

Type: Series Slot
Units: HEAT
Description: Heat associated with the Outflow from the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

11.1.1.2 Salinity Slots

☞ **Inflow Salt Mass**

Type: Series Slot
Units: Mass
Description: Salt mass associated with the inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **Outflow Salt Mass**

Type: Series Slot
Units: Mass
Description: Salt mass associated with the outflow from the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

11.1.1.3 Dissolved Oxygen Slots

☞ **Inflow Ammonia Mass**

Type: Series Slot
Units: Mass
Description: Ammonia mass associated with the inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **Inflow Detritus Mass**

Type: Series Slot
Units: Mass
Description: Detritus mass associated with the inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **Inflow Dissolved Organics Mass**

Type: Series Slot
Units: Mass
Description: Dissolved organics mass associated with the inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **INFLOW DISSOLVED OXYGEN MASS**

Type: Series Slot
Units: MASS
Description: Dissolved oxygen mass associated with the inflow to the gage
I/O: Required known: input, set by a rule, or propagated via a link
Links: Linkable

☞ **OUTFLOW AMMONIA MASS**

Type: Series Slot
Units: MASS
Description: Ammonia mass associated with the outflow from the gage
I/O: Output only: solved for by dispatch method
Links: Linkable

☞ **OUTFLOW DETRITUS MASS**

Type: Series Slot
Units: MASS
Description: Detritus mass associated with the outflow from the gage
I/O: Output only: solved for by dispatch method
Links: Linkable

☞ **OUTFLOW DISSOLVED ORGANICS MASS**

Type: Series Slot
Units: MASS
Description: Dissolved Organics mass associated with the outflow from the gage
I/O: Output only: solved for by dispatch method
Links: Linkable

☞ **OUTFLOW DISSOLVED OXYGEN MASS**

Type: Series Slot
Units: MASS
Description: Dissolved oxygen mass associated with the outflow from the gage
I/O: Output only: solved for by dispatch method
Links: Linkable

11.1.2 Dispatch Methods

Following are the available dispatch methods when the solution approach is Layered/Discretized, depending on constituents.

11.1.2.1 SolveTempModel

This dispatch method is available if the solution approach is Layered/Discretized and the constituent is: Temperature.

REQUIRED KNOWN SLOTS:

- GAGE INFLOW
- GAGE OUTFLOW
- INFLOW HEAT

REQUIRED UNKNOWN SLOTS:

- OUTFLOW HEAT

METHOD DETAILS:

This method the following:

$$OutflowHeat = InflowHeat \quad \text{(EQ 11-1)}$$

11.1.2.2 SolveTempandSaltModel

This dispatch method is available if the solution approach is Layered/Discretized and the constituent is: Temperature and Salinity.

REQUIRED KNOWN SLOTS:

- GAGE INFLOW
- GAGE OUTFLOW
- INFLOW HEAT
- INFLOW SALT MASS

REQUIRED UNKNOWN SLOTS:

- OUTFLOW HEAT
- OUTFLOW SALT MASS

METHOD DETAILS:

This method does the following:

$$OutflowHeat = InflowHeat \quad \text{(EQ 11-2)}$$

$$OutflowSaltMass = InflowSaltMass \quad \text{(EQ 11-3)}$$

11.1.2.3 SolveTempandDOModel

This dispatch method is available if the solution approach is Layered/Discretized and the constituent is: Temperature and Dissolved Oxygen.

REQUIRED KNOWN SLOTS:

- GAGE INFLOW
- GAGE OUTFLOW
- INFLOW AMMONIA MASS
- INFLOW DETRITUS MASS
- INFLOW DISSOLVED ORGANICS MASS
- INFLOW DISSOLVED OXYGEN MASS
- INFLOW HEAT

REQUIRED UNKNOWN SLOTS:

- OUTFLOW AMMONIA MASS
- OUTFLOW DETRITUS MASS
- OUTFLOW DISSOLVED ORGANICS MASS
- OUTFLOW DISSOLVED OXYGEN MASS
- OUTFLOW HEAT

METHOD DETAILS:

This method does the following:

$$OutflowHeat = InflowHeat \quad \text{(EQ 11-4)}$$

$$OutflowDetritusMass = InflowDetritusMass \quad \text{(EQ 11-5)}$$

$$OutflowAmmoniaMass = InflowAmmoniaMass \quad \text{(EQ 11-6)}$$

$$OutflowDissolvedOrganicsMass = InflowDissolvedOrganicsMass \quad \text{(EQ 11-7)}$$

$$OutflowDissolvedOxygenMass = InflowDissolvedOxygenMass \quad \text{(EQ 11-8)}$$

11.1.2.4 SolveTempSaltandDOModel

This dispatch method is available if the solution approach is Layered/Discretized and the constituent is: Temperature, Salt, and Dissolved Oxygen.

REQUIRED KNOWN SLOTS:

- ☞ GAGE INFLOW
- ☞ GAGE OUTFLOW
- ☞ INFLOW AMMONIA MASS
- ☞ INFLOW DETRITUS MASS
- ☞ INFLOW DISSOLVED ORGANICS MASS
- ☞ INFLOW DISSOLVED OXYGEN MASS
- ☞ INFLOW HEAT
- ☞ INFLOW SALT MASS

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 does the following:

$$OutflowHeat = InflowHeat \quad \text{(EQ 11-9)}$$

$$OutflowSaltMass = InflowSaltMass \quad \text{(EQ 11-10)}$$

$$OutflowDetritusMass = InflowDetritusMass \quad \text{(EQ 11-11)}$$

$$OutflowAmmoniaMass = InflowAmmoniaMass \quad \text{(EQ 11-12)}$$

$$OutflowDissolvedOrganicsMass = InflowDissolvedOrganicsMass \quad \text{(EQ 11-13)}$$

$$OutflowDissolvedOxygenMass = InflowDissolvedOxygenMass \quad \text{(EQ 11-14)}$$

11.2 Simple Well-Mixed Salinity

Following is a description of the Simple Well-Mixed approach to water quality on the stream gage including the slots, and dispatch methods. In this approach, the gage can solve either upstream or downstream for the salt concentration.

11.2.1 Slots

Below is a description of each of the slots associated with Salinity and the Simple Well-Mixed approach.

☞ INFLOW SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the inflow to the gage
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 gage
I/O: Output only
Links: Not Linkable

☞ OUTFLOW SALT CONCENTRATION

Type: Series Slot
Units: CONCENTRATION
Description: Salt concentration associated with the outflow from the gage
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 gage
I/O: Output only
Links: Not Linkable

11.2.2 Dispatch Methods

Following are the available dispatch methods when the solution approach is Simple Well-Mixed.

11.2.2.1 SolveSaltGivenInflow

This dispatch method is available if the solution approach is Simple Well-Mixed and the constituent is Salinity.

REQUIRED KNOWN SLOTS:

- GAGE INFLOW
- GAGE OUTFLOW
- INFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- OUTFLOW SALT CONCENTRATION

METHOD DETAILS:

This method does the following: If Inflow is zero, Outflow Salt Concentration is zero. Otherwise,

$$OutflowSaltConcentration = InflowSaltConcentration \quad \text{(EQ 11-15)}$$

$$OutflowSaltMass = OutflowSaltConcentration \times InflowVol \quad \text{(EQ 11-16)}$$

$$InflowSaltMass = InflowSaltConcentration \times InflowVol \quad \text{(EQ 11-17)}$$

11.2.2.2 SolveSaltGivenOutflow

This dispatch method is available if the solution approach is Simple Well-Mixed and the constituent is Salinity.

REQUIRED KNOWN SLOTS:

- GAGE INFLOW
- GAGE OUTFLOW
- OUTFLOW SALT CONCENTRATION

REQUIRED UNKNOWN SLOTS:

- INFLOW SALT CONCENTRATION

METHOD DETAILS:

This method does the following: If Inflow is zero, Inflow Salt Concentration is zero. Otherwise,

$$InflowSaltConcentration = OutflowSaltConcentration \quad \text{(EQ 11-18)}$$

$$OutflowSaltMass = OutflowSaltConcentration \times InflowVol \quad \text{(EQ 11-19)}$$

$$InflowSaltMass = InflowSaltConcentration \times InflowVol \quad \text{(EQ 11-20)}$$