The Biowin Advantage

## SRT Control Under Dynamic Conditions Using BW Controller

Introduction

In this issue we will compare the performance of an anoxic-aerobic activated sludge system under steady state and dynamic loading conditions. The BW Controller will be used to simulate two modes of operation: a) periodic wasting to keep the aeration tank MLSS between upper and lower bounds; and b) varying the wastage rate to maintain a target SRT.

Steady State Design Information

The process flowsheet is shown below:
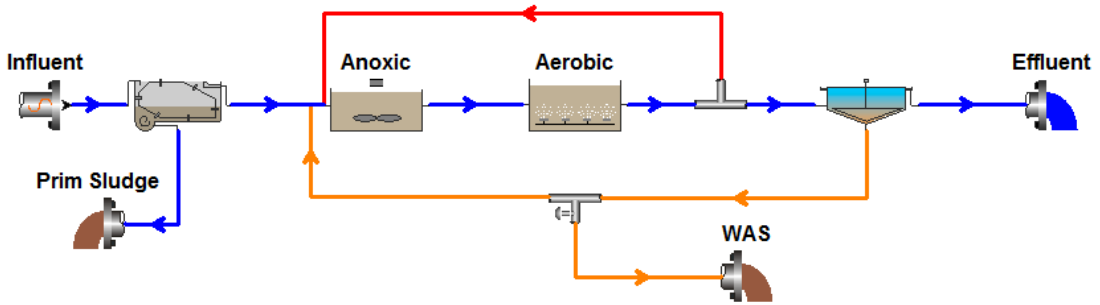
Some pertinent design features of the system are listed in the table below.

| ATTRIBUTE	VALUE
Average Influent Flow	33.9 mgd
Maximum Peak Hour Flow	77 mgd
Average Influent BOD Load	96,135 lb/d
Average Influent TSS Load	97,352 lb/d
Average Influent VSS Load	77,346 lb/d
Average Influent TKN Load	13,511 lb/d
Minimum Design Temp	14°C
Aerobic Volume	11 MG
Anoxic Volume	5 MG
Steady State Design SRT	15 days
Steady State Aerobic MLSS	3,607 mg/L
Steady State WAS Flow	0.5764 mgd
Steady State Clarifier SLR	26.7 lb/ft^2/d
Steady State Clarifier SOR	437.5 gal/ft^2/d
RAS Flow	33.9 mgd
NRCY Flow	135.5 mgd (4Q)

Steady State Effluent Ammonia	0.81 mgN/L

To achieve the steady state design SRT of 15 days, BioWin's built-in steady state SRT controller was used. The following figures show the flowsheet elements used to define the total mass and the mass removal points for the SRT calculation:
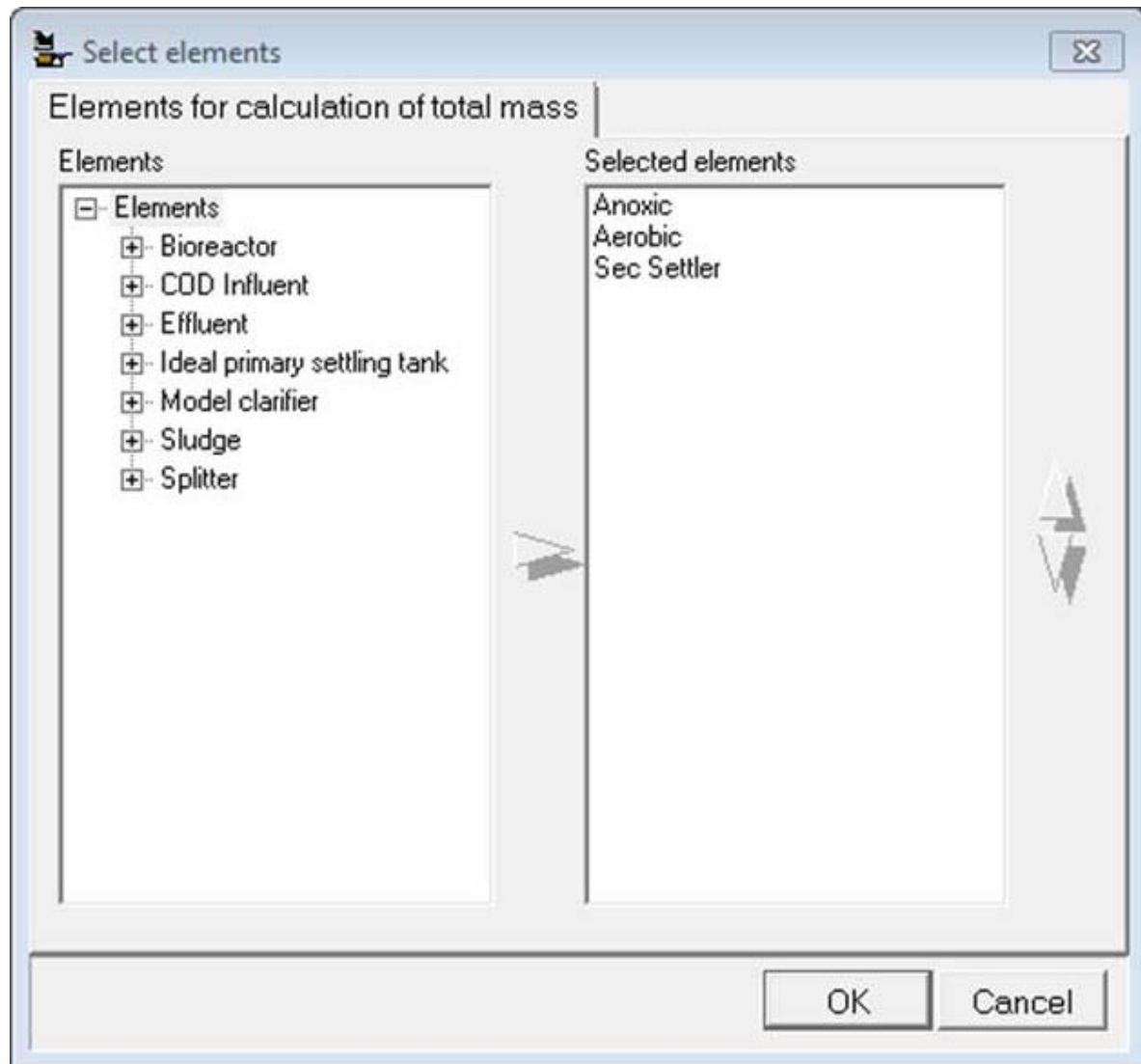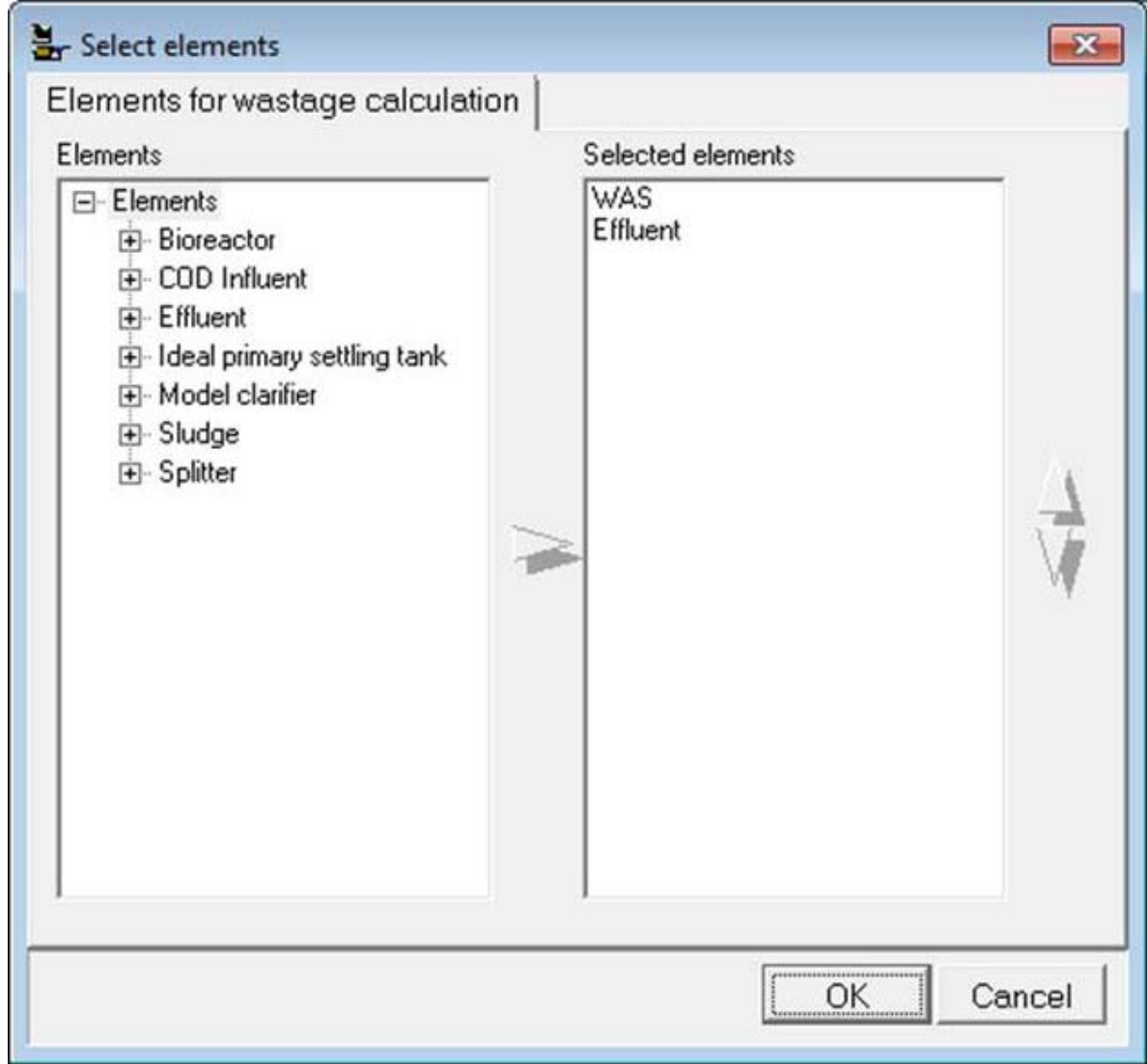
Using the built-in steady state SRT controller, we can tell BioWin to set the waste activated sludge splitter flow so that the target steady state SRT of 15 days is achieved:
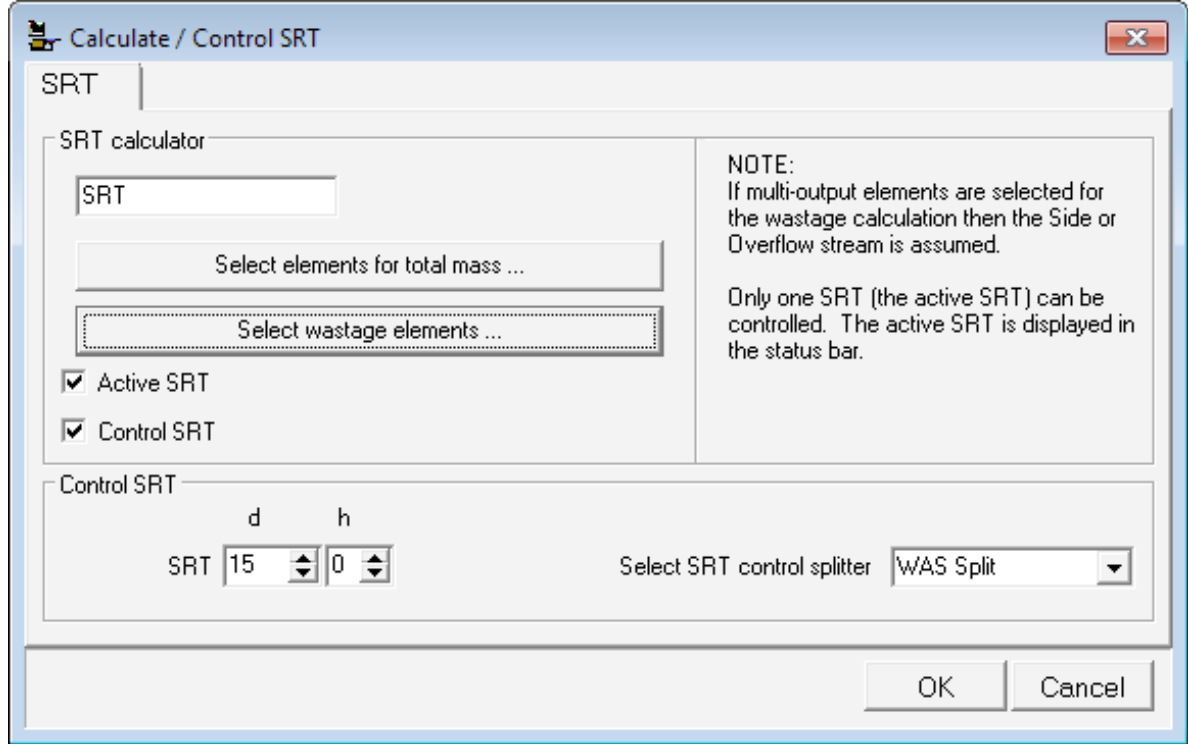
Once BioWin has solved the system with the waste activated sludge flow necessary to achieve the target SRT, the waste flow is set at this constant value. That is, if a dynamic simulation is performed, the waste flow will stay at the steady state value. The SRT will not be "controlled" for a dynamic simulation. For that, we need to use the BW Controller. In this edition of the BioWin Advantage, we will explore how to do that!
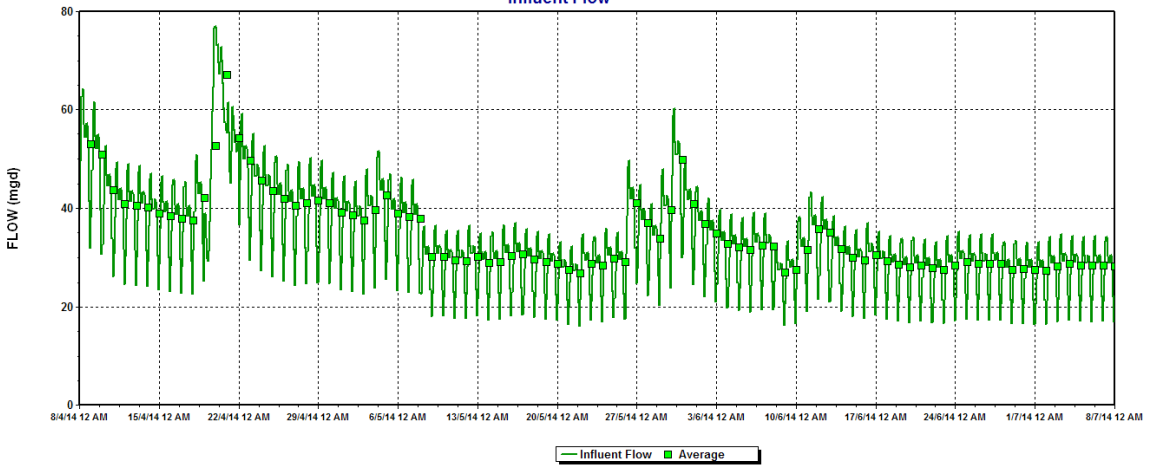
Using BW Controller to Explore Operation Modes

We will use BW Controller to analyze the response of the steady state design to dynamic loading under two operating modes: a) periodic wasting to keep the MLSS between defined upper and lower bounds; and b) controlling the SRT such that it is maintained at 15 days.

Note: Please ensure you have **downloaded the latest version of BioWin and BW Controller** to ensure proper results when following these examples. When you select Help > About in BW Controller you should see the version number is at least 4.0.14.21.

To perform the dynamic simulations, the following 3-month flow and concentration patterns were defined and input. Note that there is a diurnal flow and concentration variation for each day.
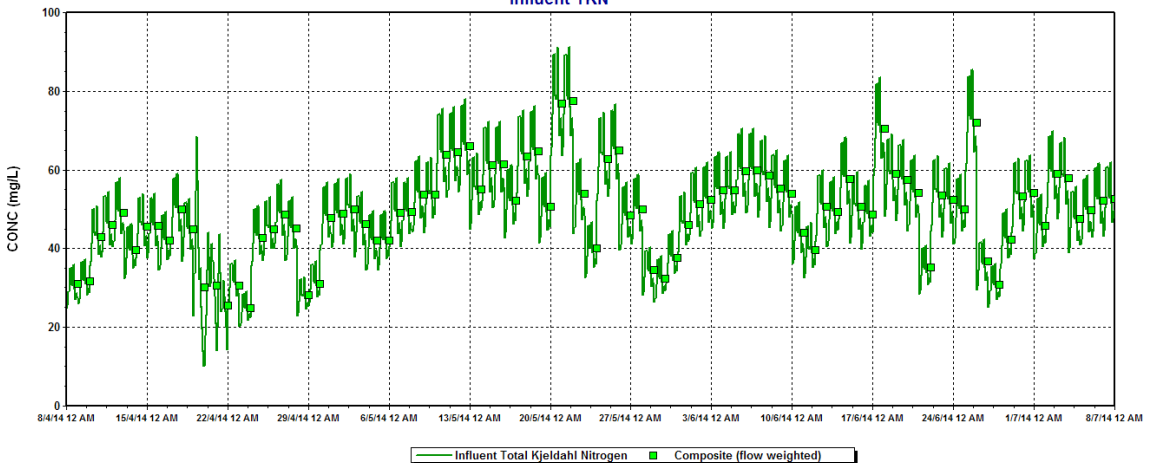
Influent Flow

Influent Total Carbonaceous BOD
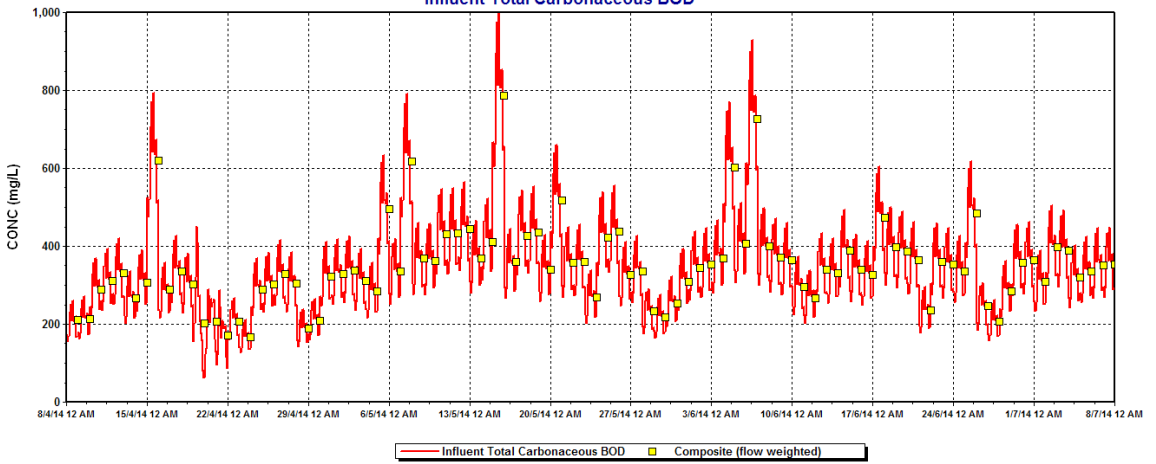
Influent TKN

Using BW Controller to Explore On-Off Wasting

In a **previous BioWin Advantage** we used BW Controller to explore a few different wasting strategies. The most simple of these was to simply turn the waste flow on when the MLSS

reached an upper limit (e.g. 3,500 mg/L) and turn it off when it was reduced to a lower limit (e.g. 2,500 mg/L). As a basis for comparison, the anoxic-aerobic system outlined above was run using this approach. First, the control strategy was defined:

Note that the controller is an "on/off" type, with the measured variable defined as the total suspended solids concentration in the aerobic reactor:

Select Measured Variable

BioWin and controller variables

Variable type: Combined ▼

Location: Output ▼

◉ Concentration
○ Mass rate

Elements and controllers:

Elements:
Influent
Anoxic
Aerobic
Sec Settler
Effluent
WAS
WAS Split
NRCY
Ideal primary settling tank7
Prim Sludge

Variables:

ISS Cellular
Nitrite + Nitrate
Particulate COD
Particulate TKN
pH
Soluble PO4-P
Total Carbonaceous BOD
Total COD
Total inorganic N
Total inorganic suspended solids
Total Kjeldahl Nitrogen
Total N
Total P
Total precipitated solids
Total suspended solids
Volatile fatty acids

User defined variables

Add...
Edit...
Remove

OK   Cancel

The manipulated variable is the sidestream flow rate of the WAS splitter:

Select Manipulated Variable

BioWin and controller variables

Variable type: |Operating ▾|

Elements and controllers:

Elements:
Influent
Anoxic
Aerobic
Sec Settler
WAS Split
NRCY
Ideal primary settling tank7

Variables:

Sidestream flow rate

User defined variables

[Add...]
[Edit...]
[Remove]

[OK]   [Cancel]
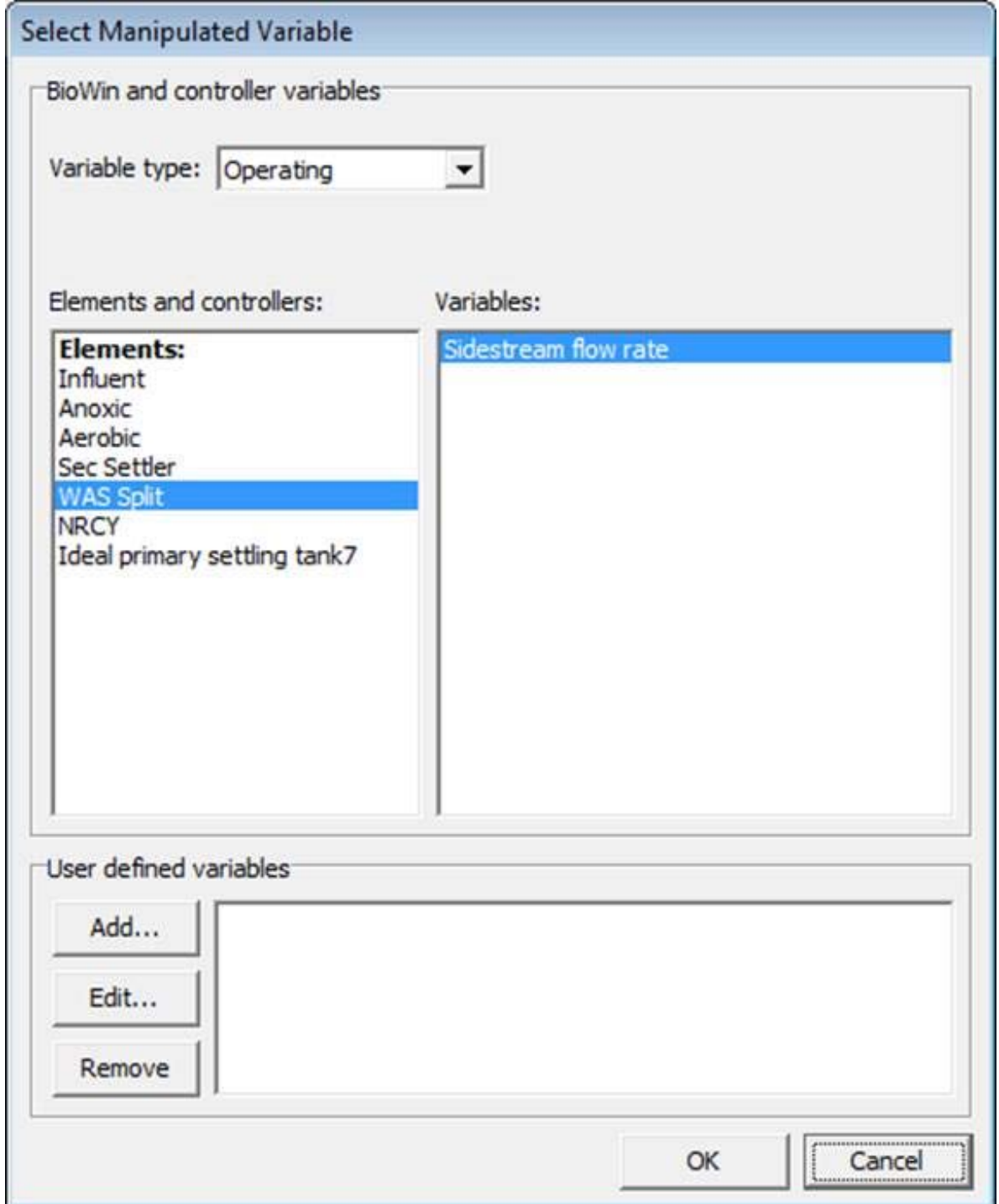
The on/off control strategy is defined as:

1. If the TSS concentration in the aerobic reactor exceeds 3,500 mg/L, turn the sidestream flow rate of the WAS splitter to 1.5 mgd.
2. If the TSS concentration in the aerobic reactor drops below 2,500 mg/L, turn the sidestream flow rate of the WAS splitter to 0 mgd.
3. The control interval is 10 minutes; that is, every 10 minutes the controller will check to see if it needs to take action.

In the previous BioWin Advantage where this operation strategy was employed, the system did not respond favorably with respect to the effluent ammonia. Let's see if the same pattern holds

with this system!

The BioWin file "**Long Term SRT Control-after on-off WAS.bwc**" contains many charts that are useful for interpreting the response of the system. First, let's look at the solids concentration in the aerobic reactor to ensure that the control strategy accomplished what we expected it to:
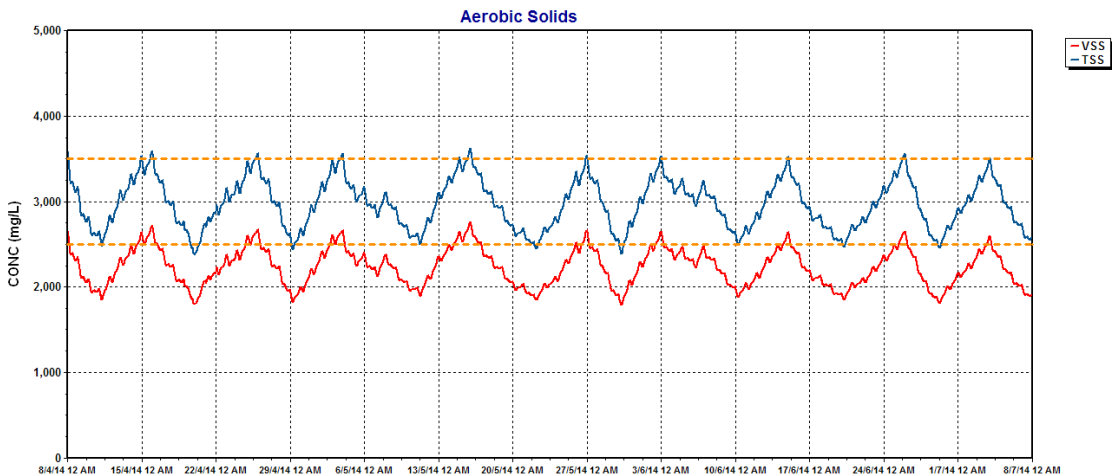

Next, let's take a look at the effluent ammonia response (recalling that the steady state design achieved an effluent ammonia concentration of 0.81 mg/L):

Effluent Ammonia
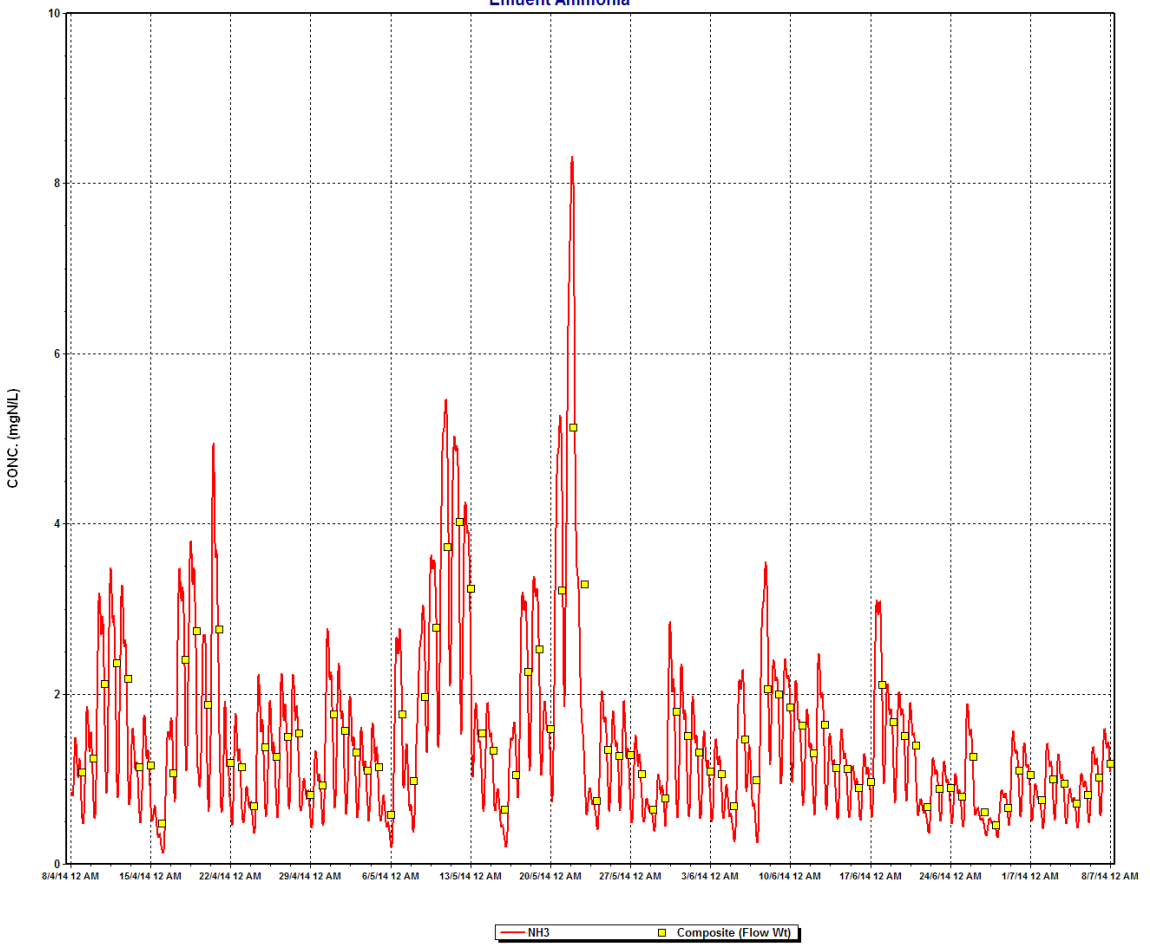
It is apparent from looking at the effluent response that this strategy is less than ideal. The large degree of variability in the effluent ammonia stems from the variability in the plant sludge mass (and consequently nitrifier mass) imposed by limiting the MLSS concentration as the plant load increases. This strategy effectively requires that the SRT be reduced, leading to ammonia breakthrough. Perhaps imposing a higher value for the lower MLSS limit (e.g. 3,000 mg/L as opposed to 2,500 mg/L) would result in less ammonia variability. This will be easy for you to explore using the controller and BioWin files that accompany this edition of the BioWin Advantage!


WAS Flow, Concentration and Mass Rate

Dynamic Solids Inventory

Aerobic Reactor Nitrifying Organisms (as cell COD)
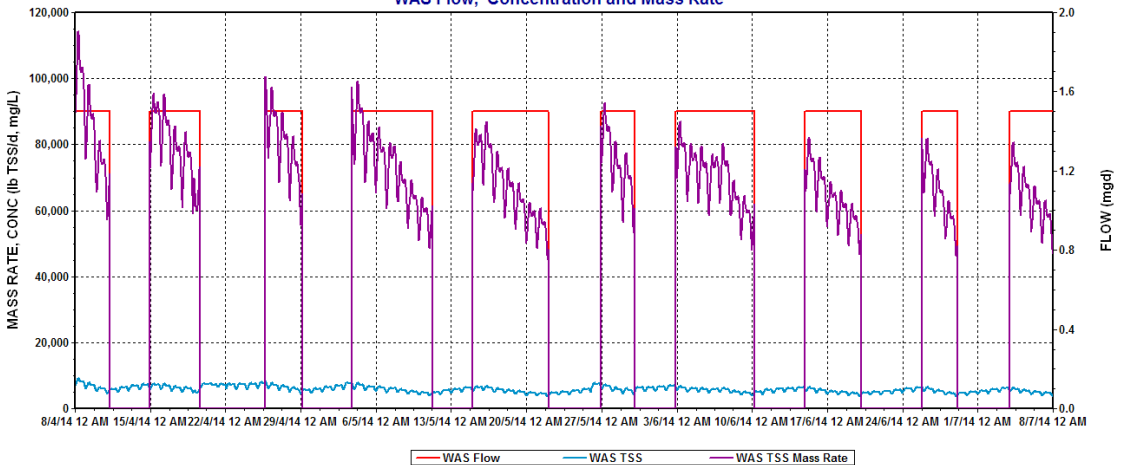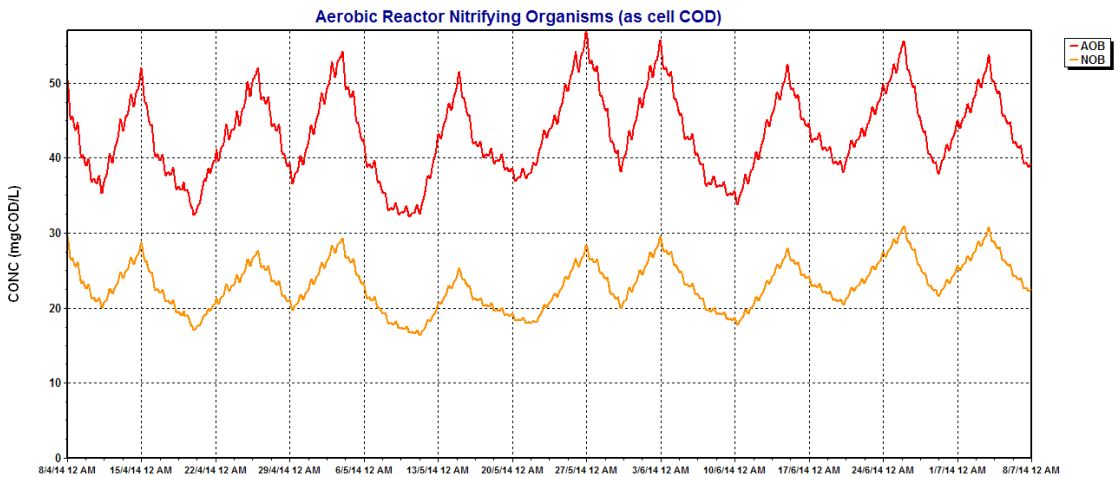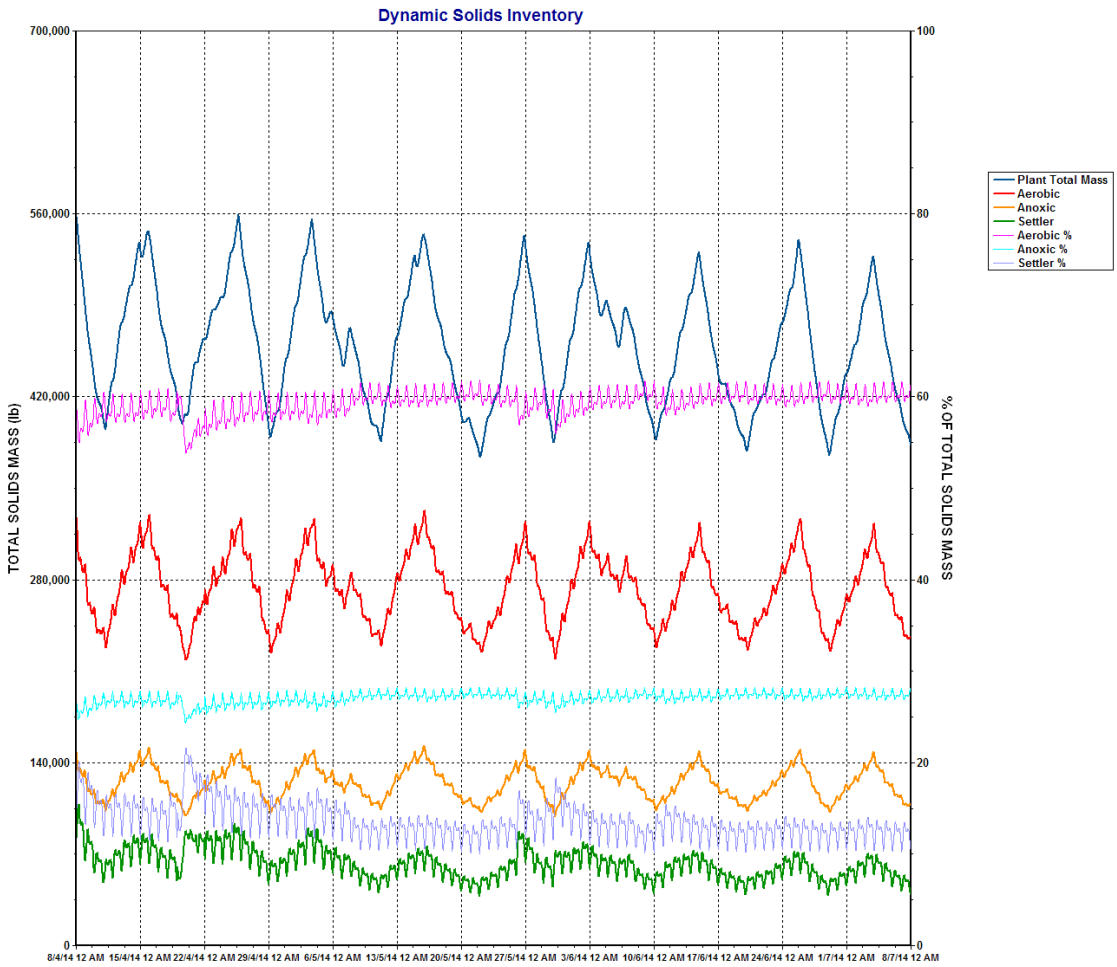
Using BW Controller to Explore SRT Control

Next, BW Controller will be used to control the SRT to a target of 15 days. To do this, we will need to use a more advanced feature that involves defining variables within the control setup. The completed controller is shown below (details of the PI controller parameters will be discussed later):
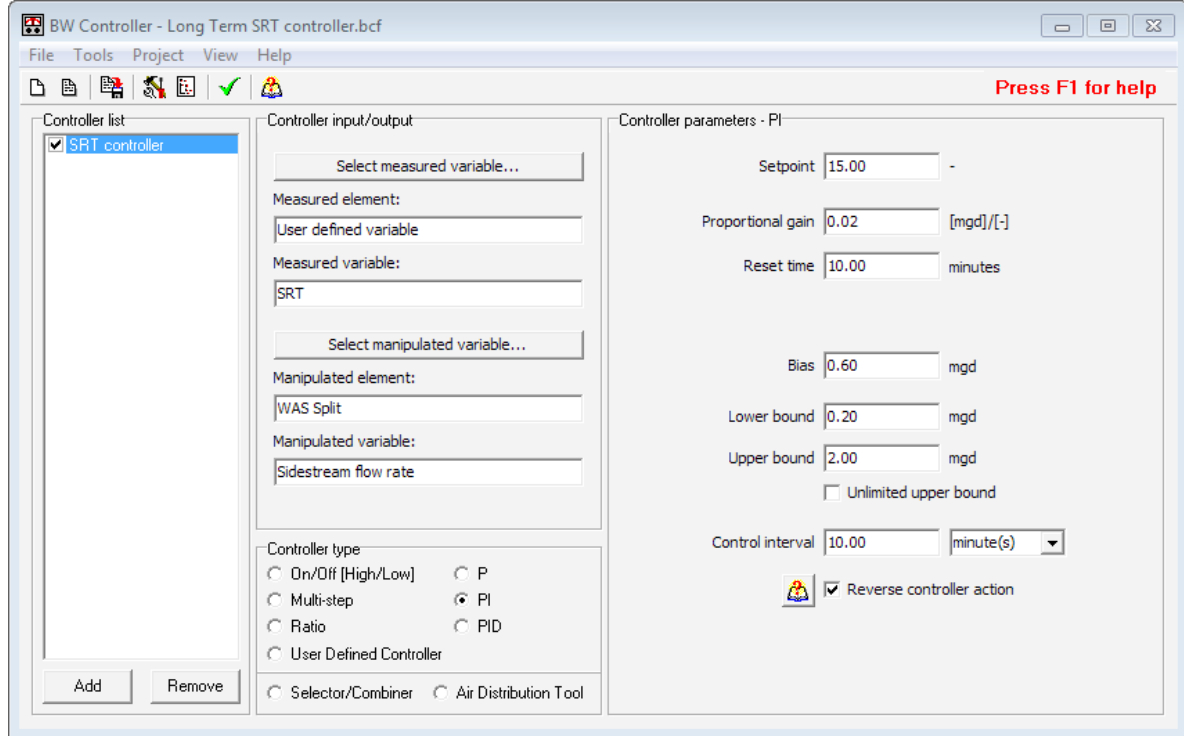
Defining the Measured Variable

Note that the measured element is a "User defined variable" and that the measured variable is "SRT". Let's examine this in more detail. If the "Select measured variable" button is clicked, we see the following interface:

In addition to the list of BioWin elements that define the process flowsheet, the SRT controller has three additional user defined variables: 1) SRT Mass, 2) SRT WAS, and 3) SRT. User defined variables can be added to this list by either clicking the Add... button, or by selecting the menu option Project > Variables, to obtain the following dialogue box:
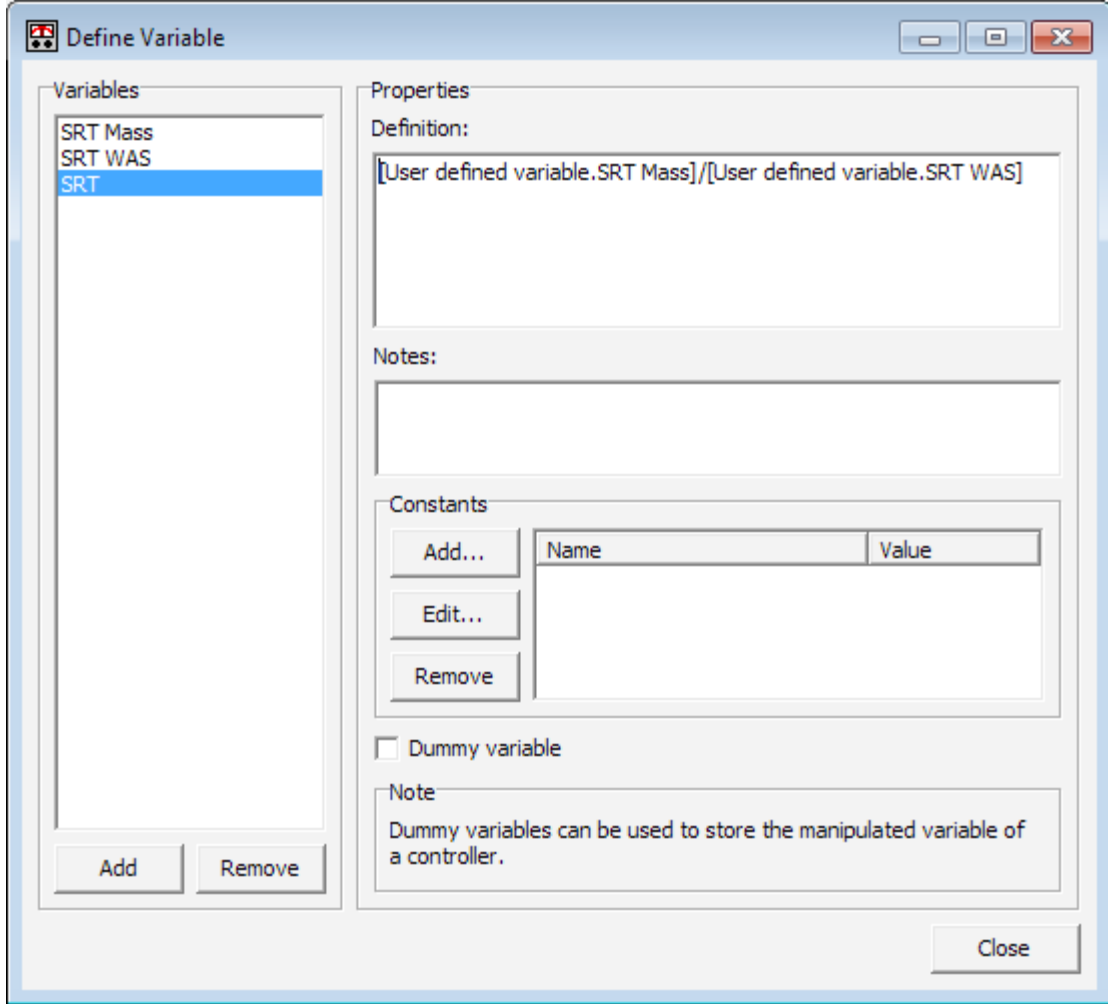
It is possible for one user defined variable to operate on one or more other user-defined variables. For example, in the screen shot above it is apparent that the "SRT" user defined variable is defined as the "SRT Mass" user defined variable divided by the "SRT WAS" user defined variable. Let's look at how the "SRT Mass" and "SRT WAS" variables are defined.

SRT MASS VARIABLE

The "SRT Mass" variable is defined as the sum of the TSS mass in the aerobic, anoxic, and secondary settler elements. Note that the "SRT Mass" as defined in the BW Controller matches the definition of the "total mass" used for BioWin's internal SRT calculation that we used in the steady state setup. While this is not strictly required, it allows us to use BioWin's feature of plotting an SRT so that we can check to ensure our controller is working properly. The "SRT Mass" variable was added via the following steps:

1. Select the menu option Project > Variables.
2. Click the Add button at the bottom left of the Define Variable dialogue box.
3. The variable name "SRT Mass" is input to the provided field:

4. Right-click in the "Definition" field, and select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box, which allows you to first select the Aerobic element, change the "Variable type" field to "Element specific", and then select the "Total solids mass":
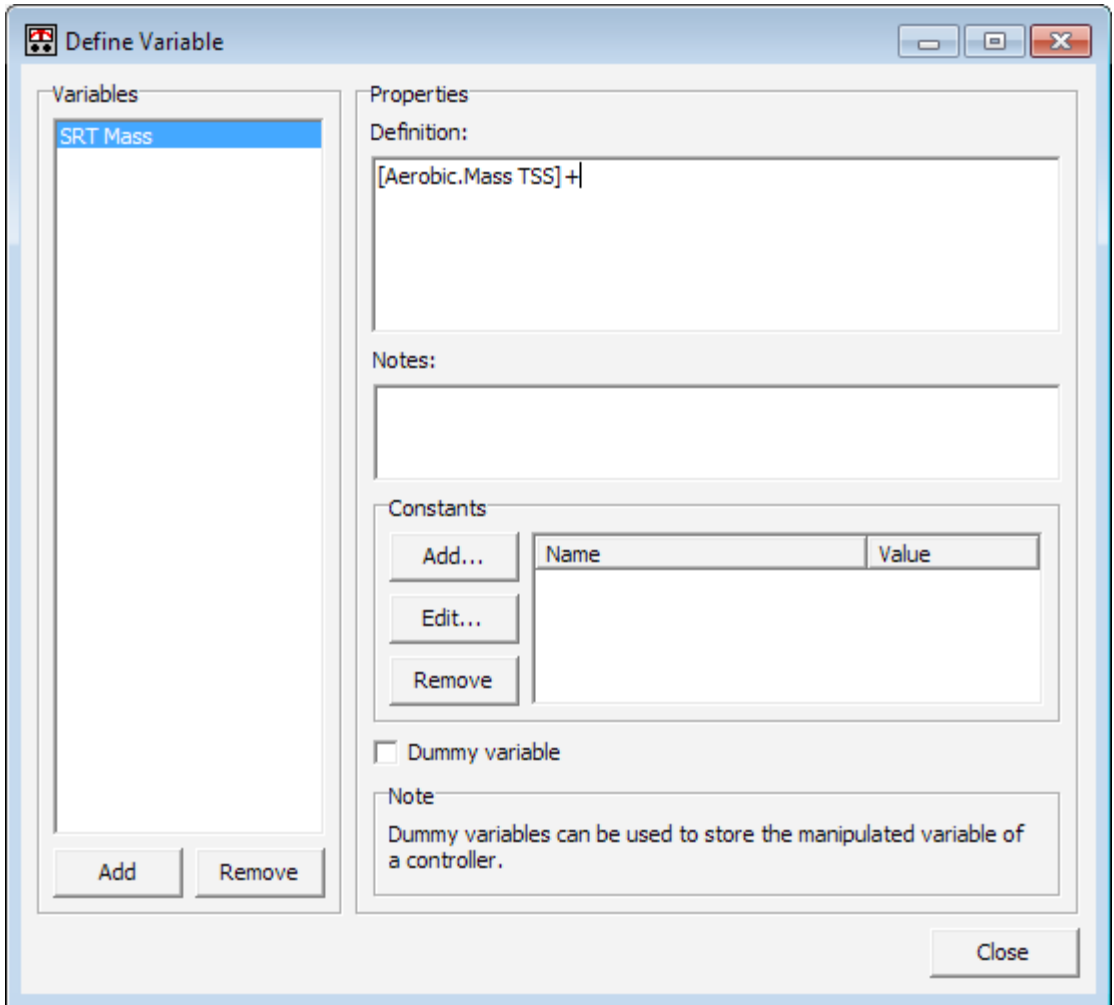
5. When you click OK, the first part of the "SRT Mass" variable has been input to the definition field. To continue, you can either manually type in a "+" sign, or right click, select "Operator" from the pop-up menu, and select a "+" sign.

6. After the addition operator has been input, then you can right-click, select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box, which allows you to select the Anoxic element, change the "Variable type" field to "Element specific", and then select the "Total solids mass":
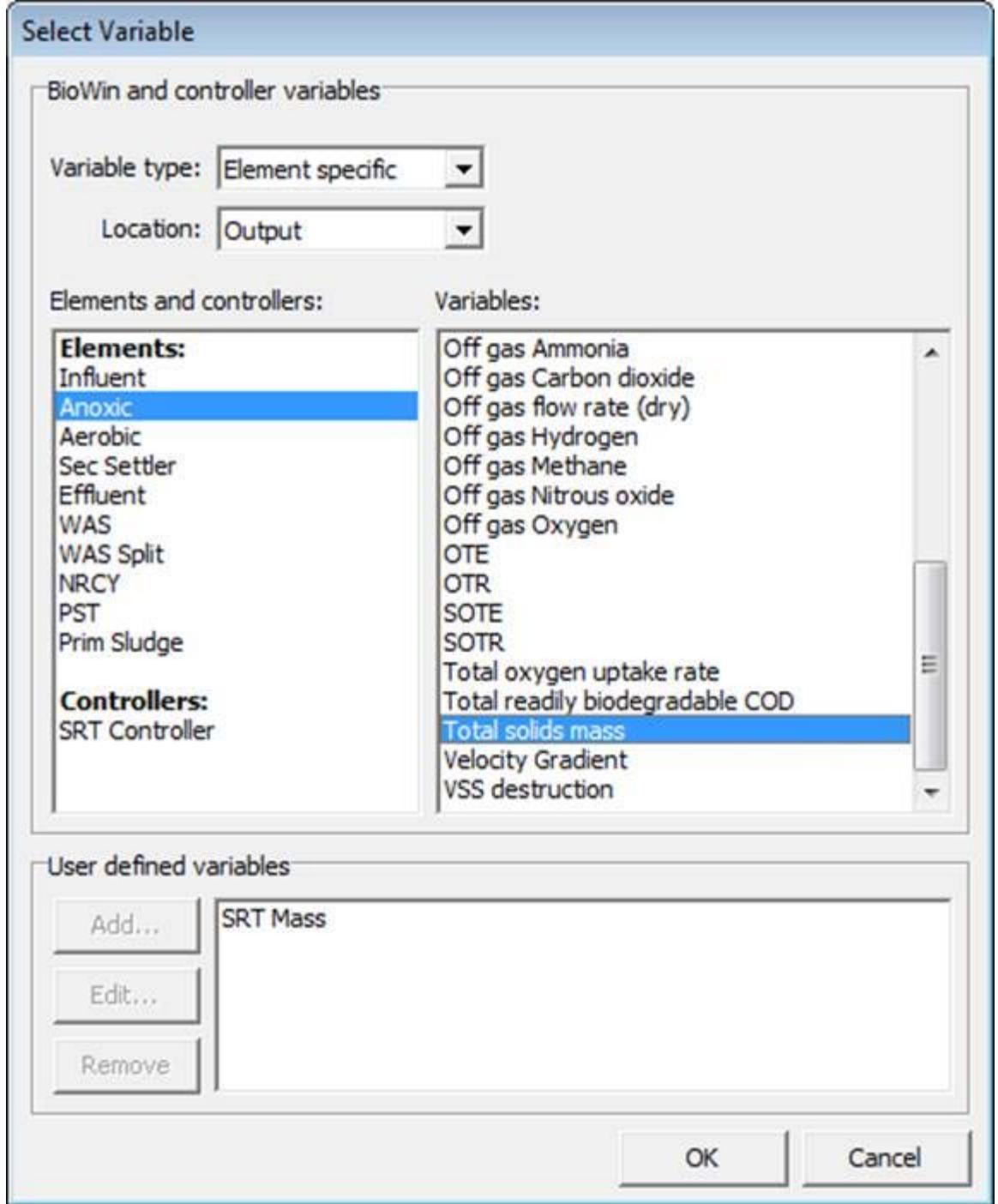
7. Repeating the above steps for the secondary clarifier will give the final definition for the "SRT Mass" variable:
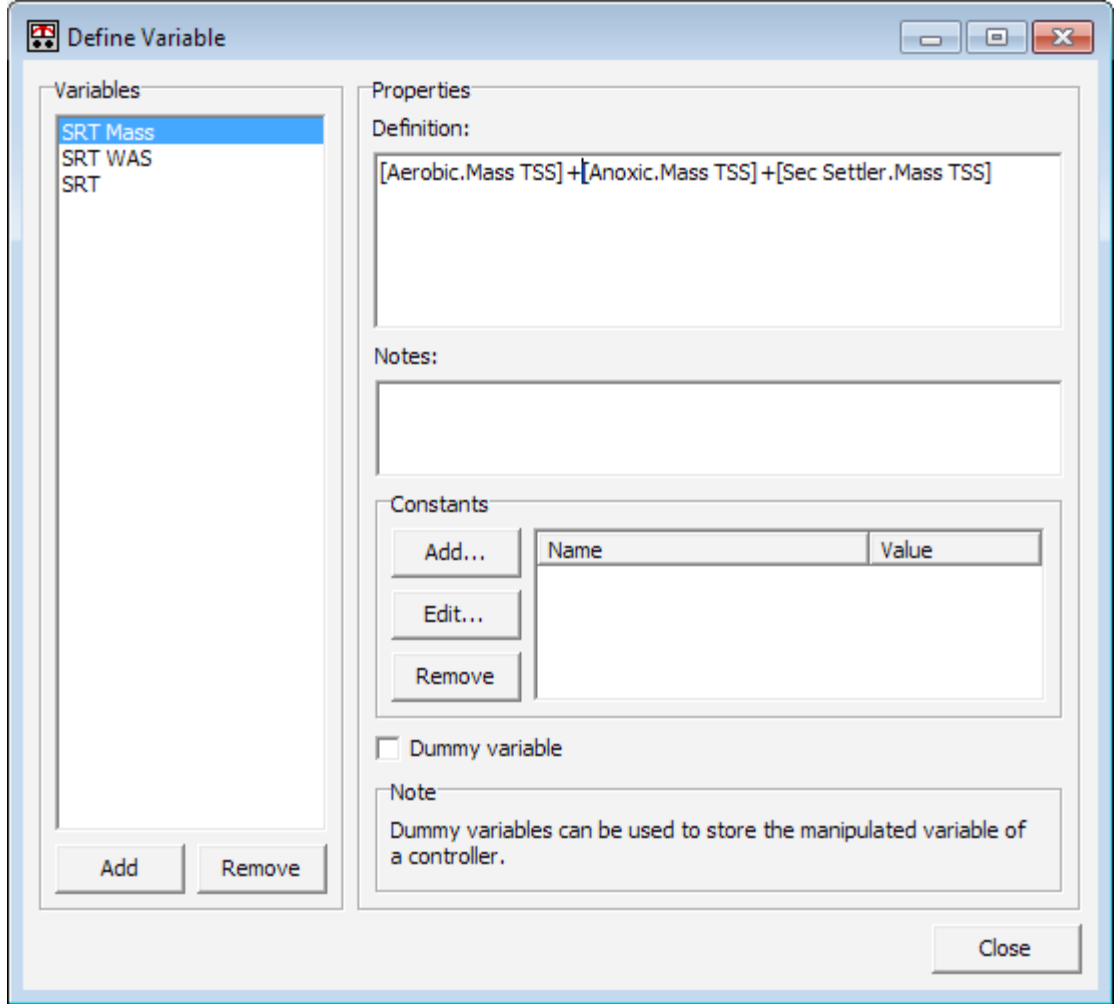
Now that the creation of the "SRT Mass" variable has been discussed, let's explore the other component that we need to define the measured variable – the "SRT WAS".

SRT WAS VARIABLE

The "SRT WAS" variable is defined as the sum of the TSS mass in waste splitter side stream and the effluent. Note that once again, the "SRT WAS" as defined in the BW Controller matches the definition of the "mass removed each day" used for BioWin's internal SRT calculation that we used in the steady state setup. The "SRT WAS" variable was added via the following steps:

1. Select the menu option Project > Variables.
2. Click the Add button at the bottom left of the Define Variable dialogue box.
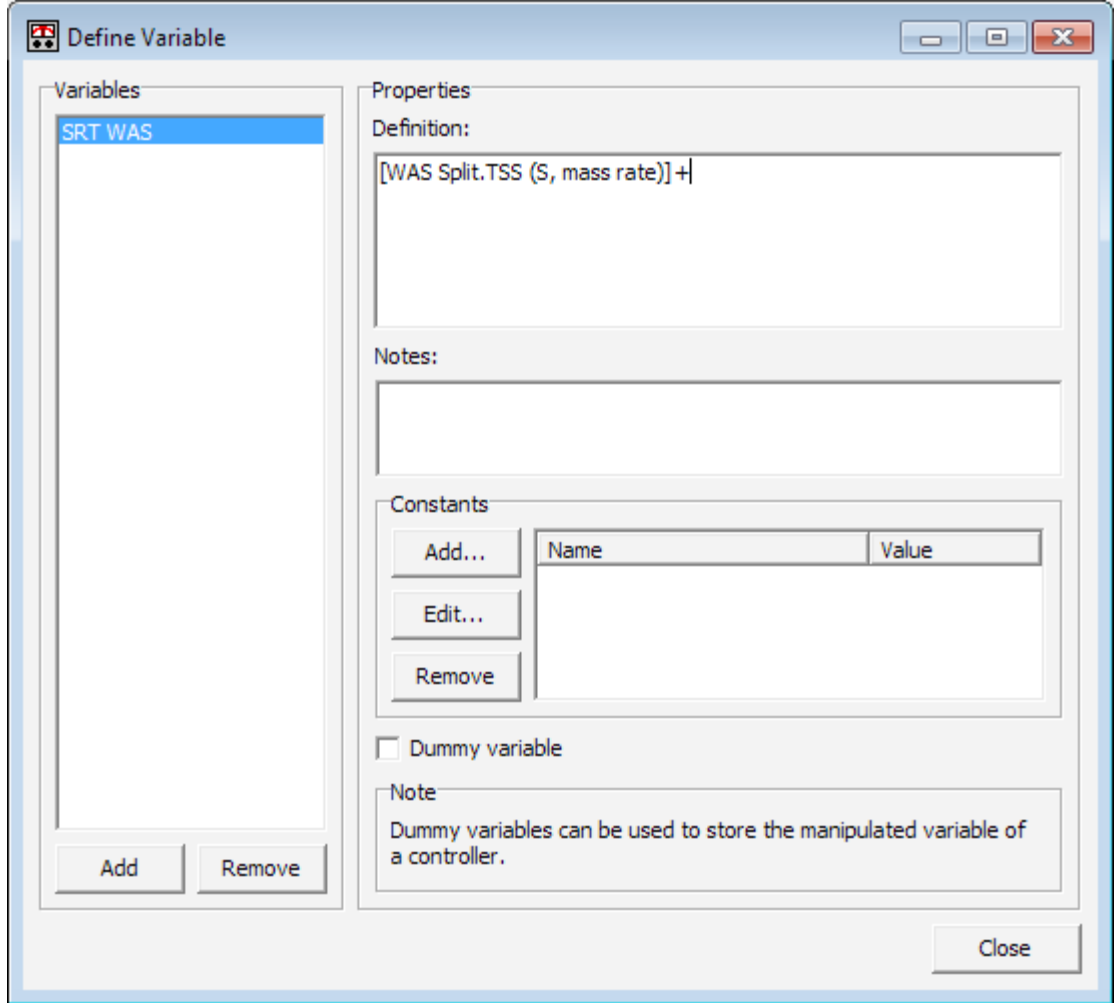3. The variable name "SRT WAS" is input to the provided field:
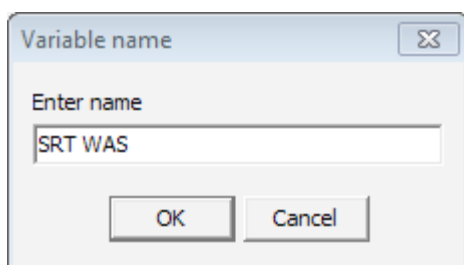
4. Right-click in the "Definition" field, and select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box, which allows you to first select the WAS split element, change the "Variable type" field to "Combined", change the "Location" to "Sidestream", pick "Mass rate" rather than Concentration, and then select the "Total suspended solids" variable:

5. When you click OK, the first part of the "SRT WAS" variable has been input to the definition field. To continue, you can either manually type in a "+" sign, or right click, select "Operator" from the pop-up menu, and select a "+" sign.

6. After the addition operator has been input, right-click in the "Definition" field, and select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box, which allows you to first select the Effluent element, change the "Variable type" field to "Combined", change the "Location" to "Output", select the "Total suspended solids" variable, and then pick "Mass rate" rather than Concentration :

7. Repeating the above steps for the secondary clarifier will give the final definition for the "SRT WAS" variable:

USING THE SRT MASS AND SRT WAS VARIABLES

The third step of defining the "SRT" variable is to use the "SRT Mass" and "SRT WAS" variables. The "SRT" is defined as the "SRT Mass" divided by the "SRT WAS" variables. The "SRT" variable was added via the following steps:

1. Select the menu option Project > Variables.
2. Click the Add button at the bottom left of the Define Variable dialogue box.
3. The variable name "SRT" is input to the provided field:
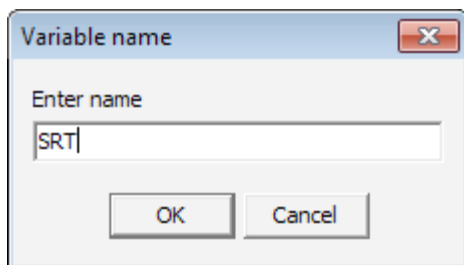
4. Right-click in the "Definition" field, and select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box. The "SRT Mass" variable can be selected from the "User defined variables" list:

Select Variable

BioWin and controller variables

Variable type: State variables ▼

Location: Output ▼

○ Concentration
○ Mass rate

Elements and controllers:

Elements:
Influent
Anoxic
Aerobic
Sec Settler
Effluent
WAS
WAS Split
NRCY
PST
Prim Sludge

Variables:

Acetate
Acetoclastic methanogens
Ammonia N
Ammonia oxidizing biomass
Anaerobic ammonia oxidizers
Anoxic methanol utilizers
Calcium
Dissolved H2
Dissolved methane
Dissolved nitrogen gas
Dissolved oxygen
Endogenous products
Fixed stored polyP
Flow
Hydrogenotrophic methanogens
Hydroxy-apatite

User defined variables

Add...
Edit...
Remove

SRT WAS
SRT Mass
SRT

OK   Cancel

5. When you click OK, the first part of the "SRT" variable has been input to the definition field. To continue, you can either manually type in a "/" sign, or right click, select "Operator" from the pop-up menu, and select a "/" sign.
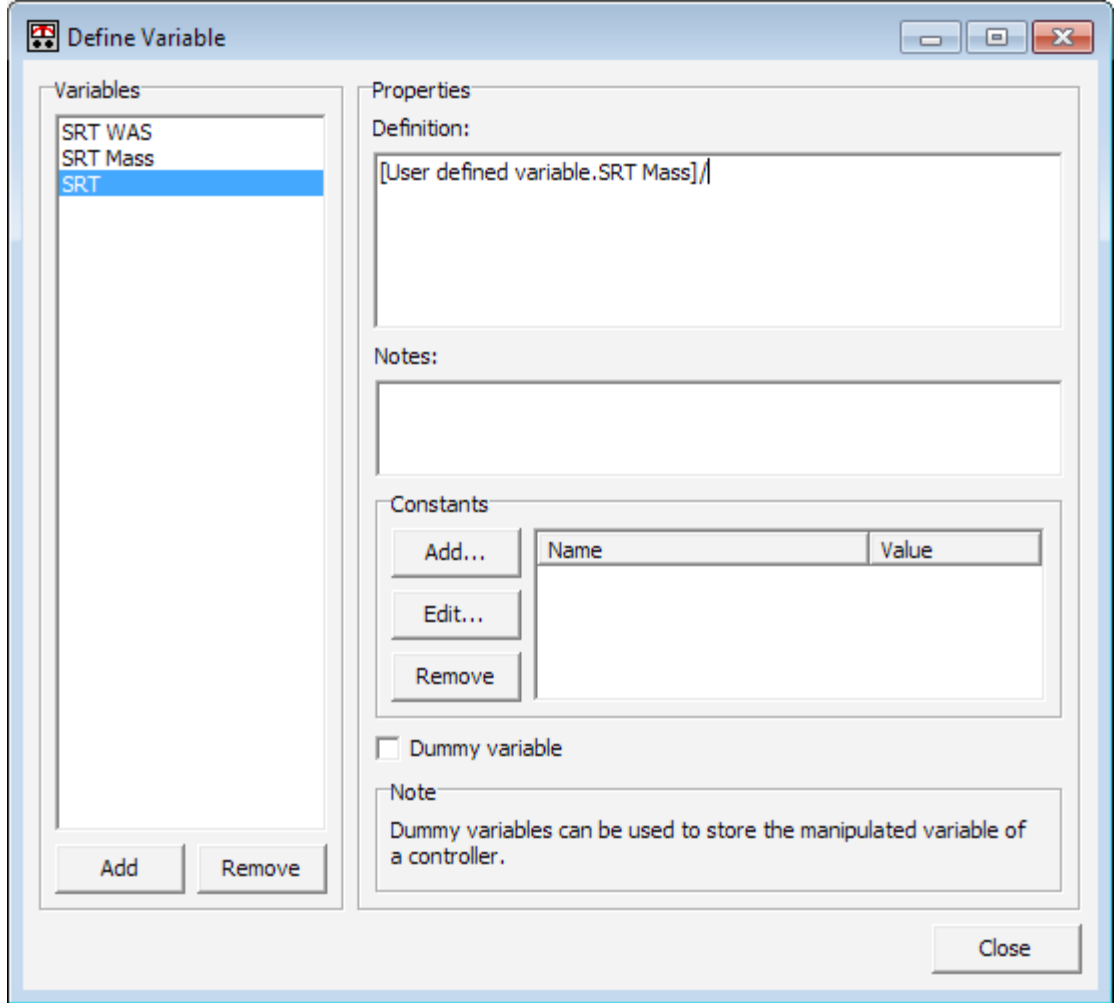
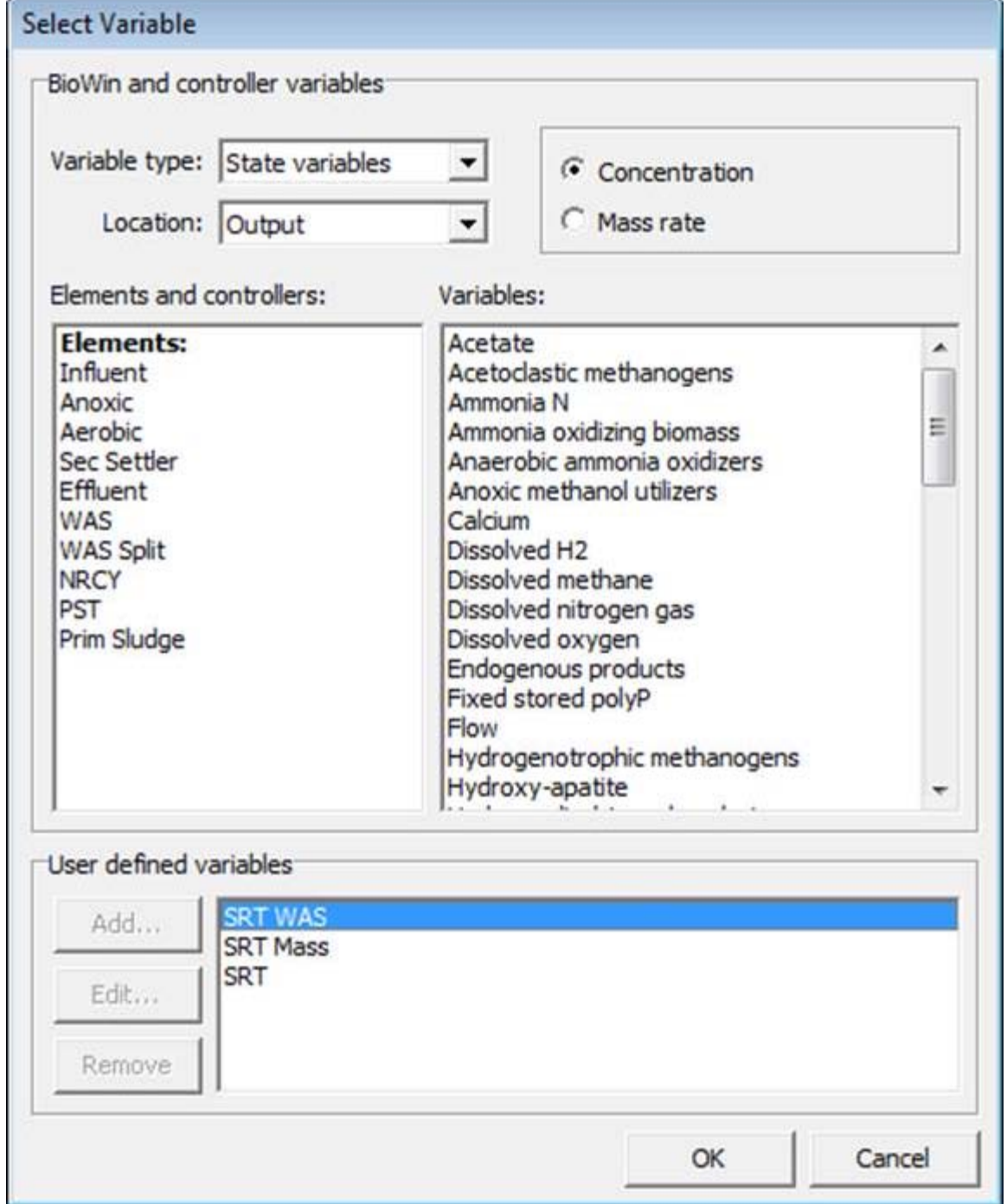6. After the division operator has been input, right-click in the "Definition" field, and select "Variable..." from the pop-up menu to obtain the "Select variable" dialogue box. The "SRT WAS" variable can be selected from the "User defined variables" list:
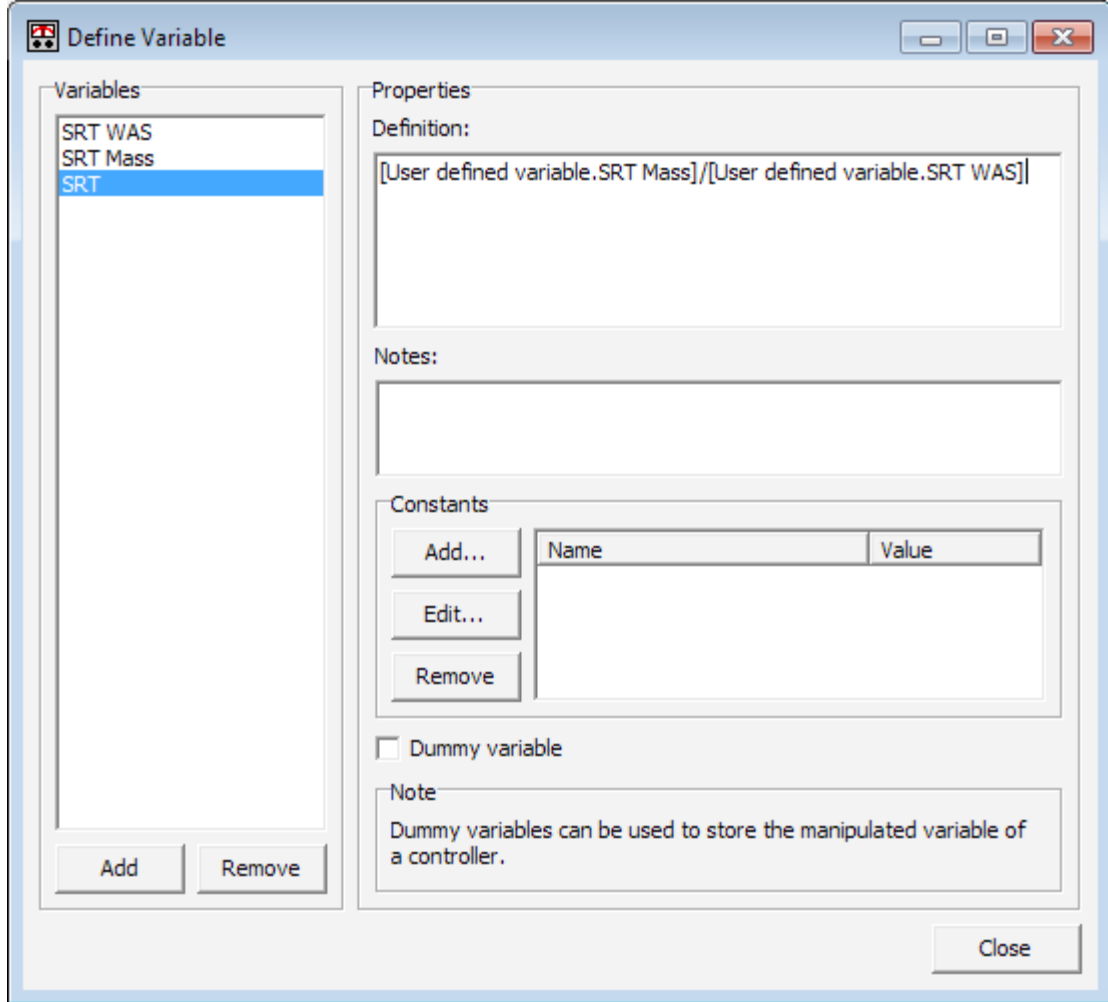
7. Now we have the final definition of the "SRT" variable:

### Defining the Manipulated Variable

The manipulated variable definition is more straightforward since what the controller will be manipulating is the WAS splitter sidestream flow rate. If we click the "Select manipulated variable..." dialog box, the controller allows us to select the Sidestream flow rate of the WAS split element:
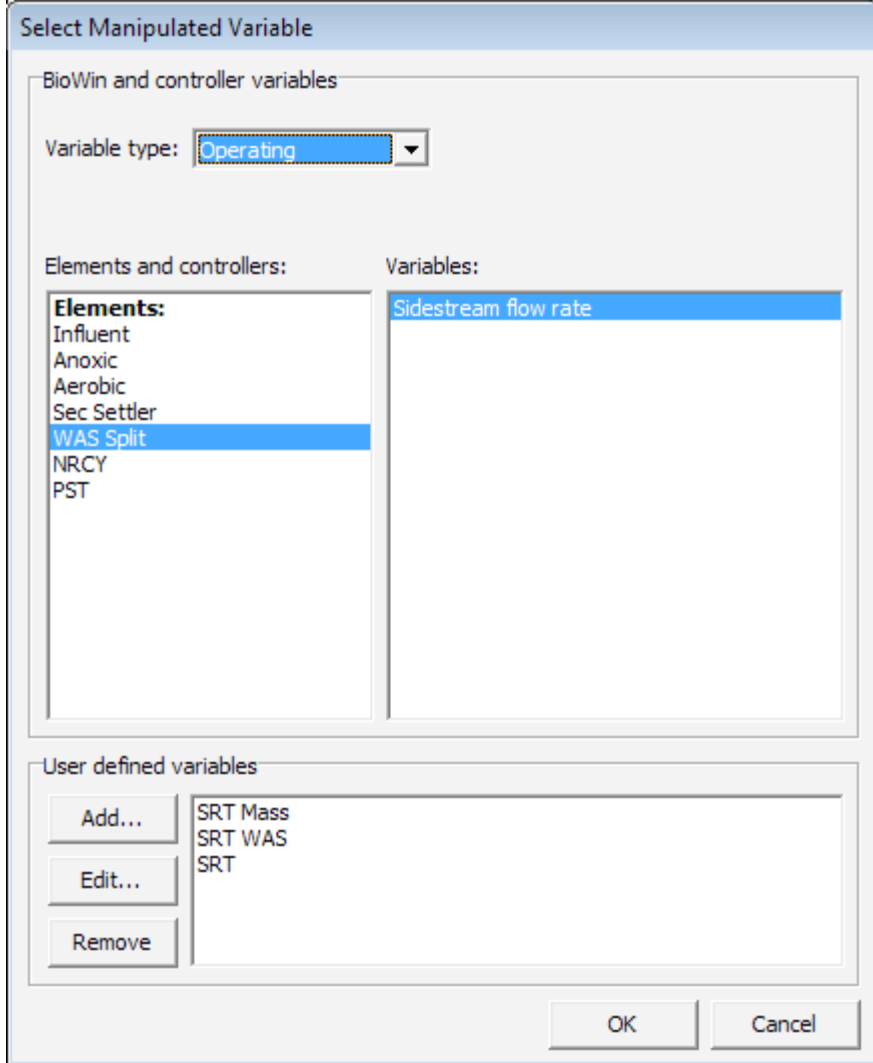
Defining Other Control Parameters
Recall the final controller setup:
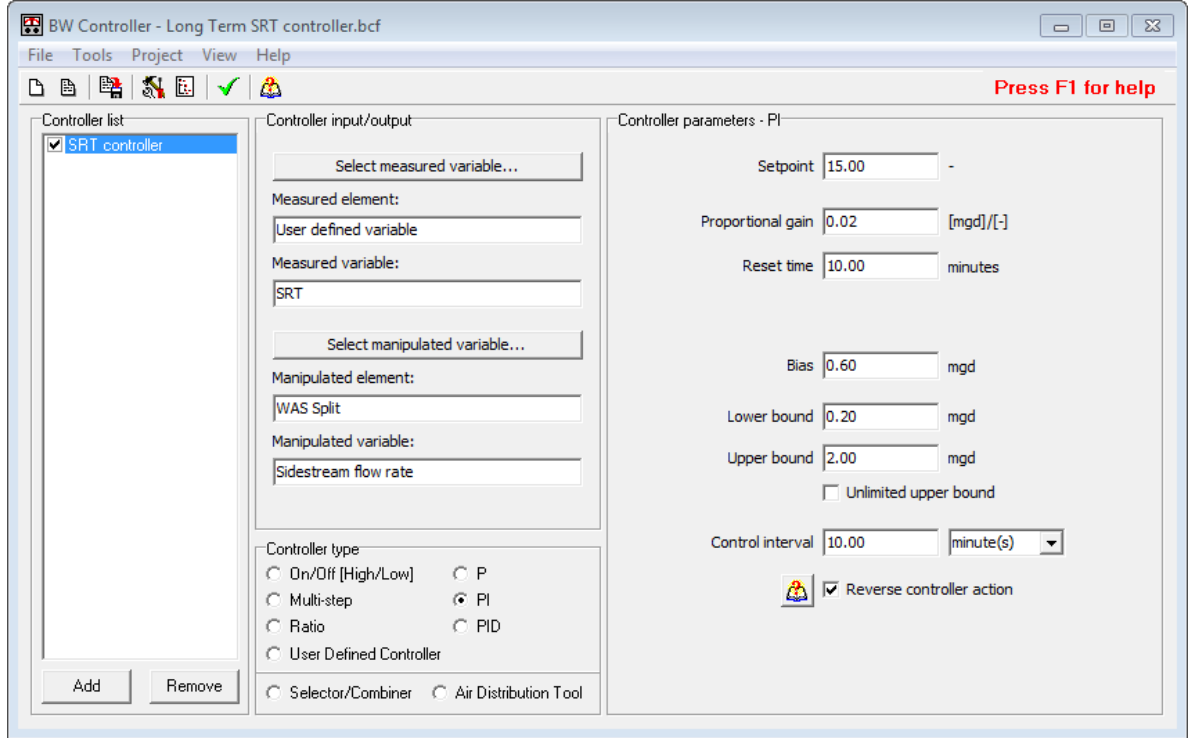
The following parameters have been input as part of the controller setup:

- **Controller type**: PI (Proportional Integral)
- **Setpoint**: 15 d (This is the target SRT that we want the controller to maintain.)
- **Proportional gain**: 0.02 mgd/d (The proportional gain is used to multiply the sum of the error [i.e. the difference between the desired setpoint and the measured variable at a given time] and the integral of the error divided by the reset time as part of the control rule. In general terms, a larger value for the proportional gain parameter will result in larger adjustments to the manipulated variable. If the value for the proportional gain is too low, the controller may not be suitably responsive. On the other hand, if the value for the proportional gain is too high, the controller may exhibit instability.)
- **Reset time**: 10 minutes (The integral term considers the "history" of the error, or how long and how far the measured process variable has been from the set point over time. The integral term of the PI controller is multiplied by the inverse of the reset time. Therefore, larger values for this parameter will decrease the impact of the integral term in the PI controller, and vice versa.)
- **Bias**: 0.60 mgd (This will serve as the starting WAS splitter sidestream flow rate when we begin simulating the control strategy.)
- **Lower bound**: 0.20 mgd (This is the minimum flow that can be achieved in the WAS splitter sidestream.)
- **Upper bound**: 2.00 mgd (This is the maximum flow that can be achieved in the WAS splitter sidestream.)
- **Control interval**: 10 minutes (This is the frequency at which the measured variable is monitored, and the manipulated variable is changed. In this case it means that the SRT will be estimated and the WAS splitter sidestream flow varied 6 times per hour).
- **Reverse controller action**: checked (This option is checked because if we increase the WAS splitter sidestream flow, the system SRT will decrease, and vice versa. If an

increase of the manipulated variable results in a decrease of the measured variable (or vice versa), then this option should be checked.)

Applying the Control Strategy

The BioWin file "**Long Term SRT Control-after 15d SRT Control.bwc"** contains many charts that are useful for interpreting the response of the system. First, if we look at the SRT plot to ensure that the control strategy accomplished what we expected it to, it is apparent that the system SRT was generally held quite close to the target of 15 days:
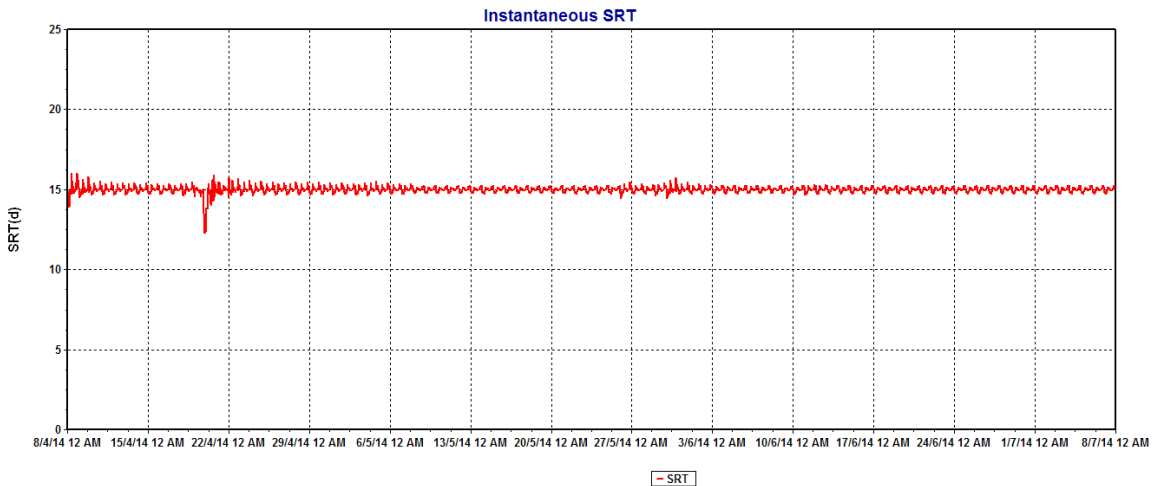

Recall that the first control strategy of maintaining the MLSS between upper and lower setpoints using on/off wasting resulted in a fairly erratic effluent ammonia response for our system. The effluent ammonia response for the system with SRT control is greatly improved, with the daily composite ammonia never exceeding 2 mg/L and an overall average of 0.95 mg/L:

Effluent Ammonia
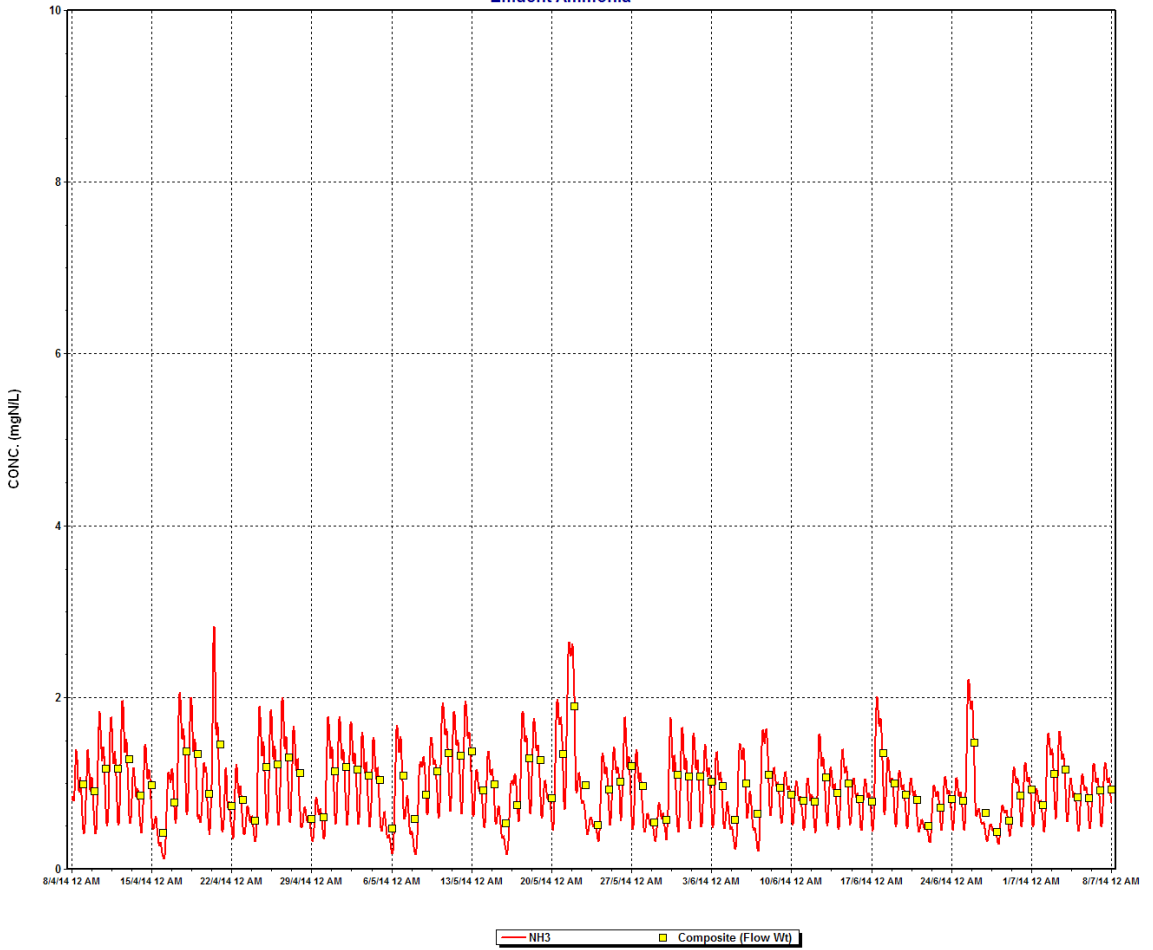
The key to this performance improvement is improved stability in the system mass and the nitrifier concentrations:

Dynamic Solids Inventory

Aerobic Reactor Nitrifying Organisms (as cell COD)
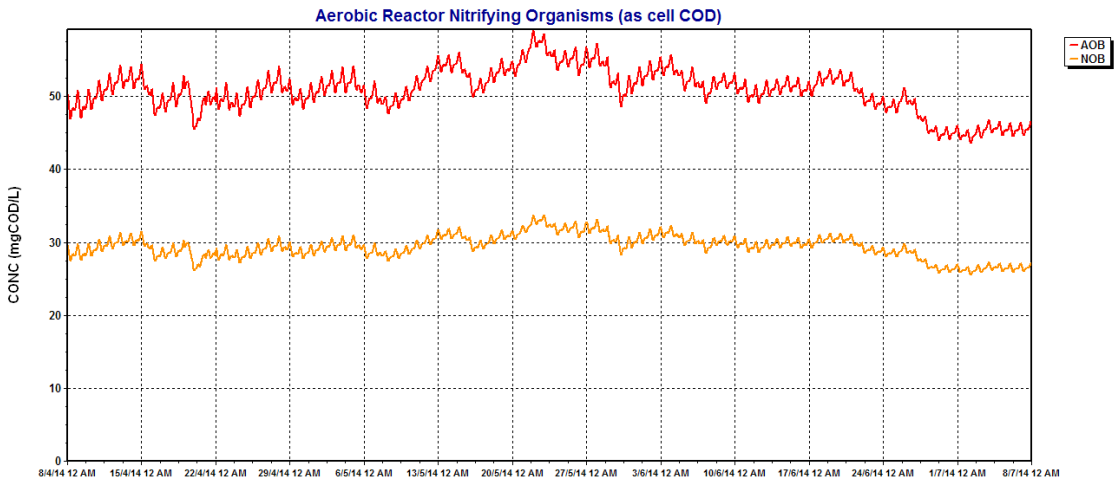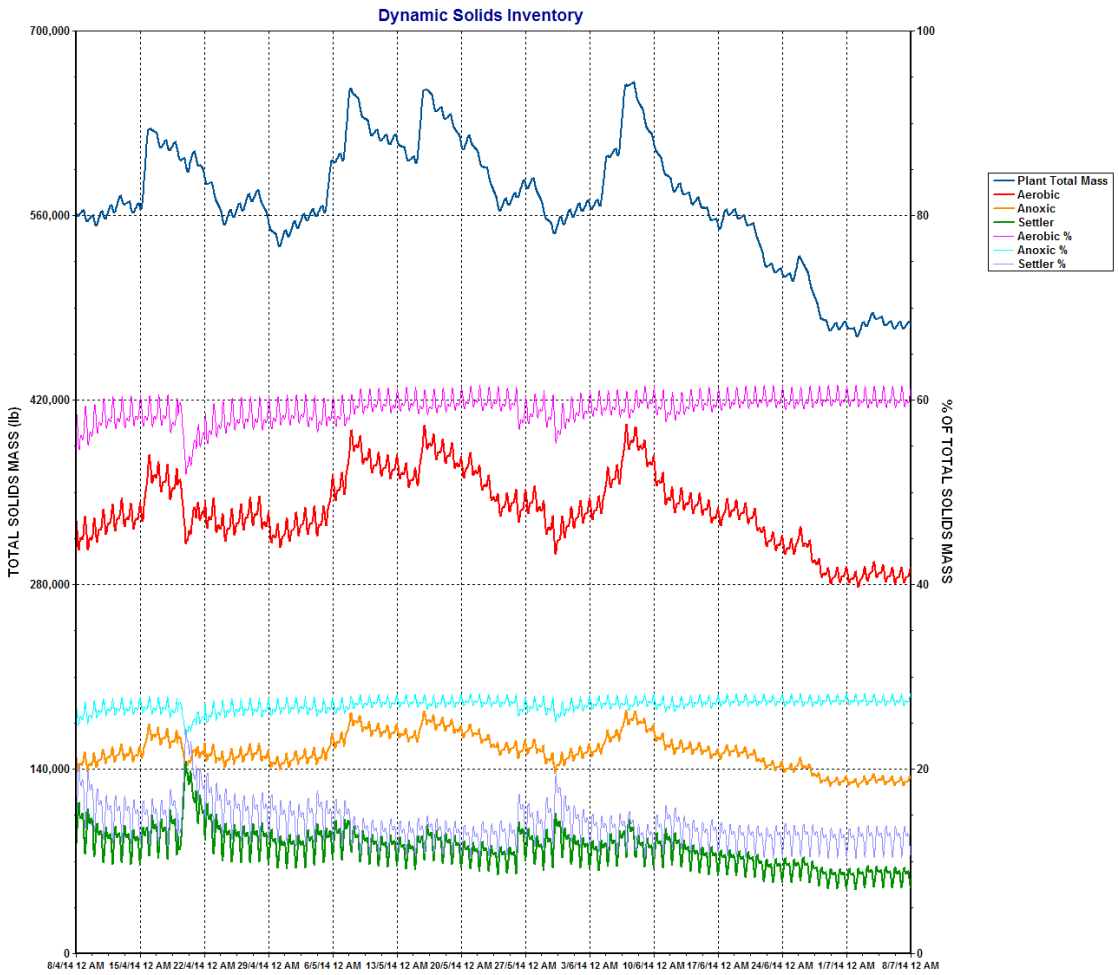
Note however, that because the SRT was maintained at a constant value, when the plant load increased the overall solids mass increased accordingly. This translates to the reactor MLSS increasing for some periods of the year, with an associated increase in settling tank solids loading rate:

Aerobic Solids

Settler Solids Loading Rate
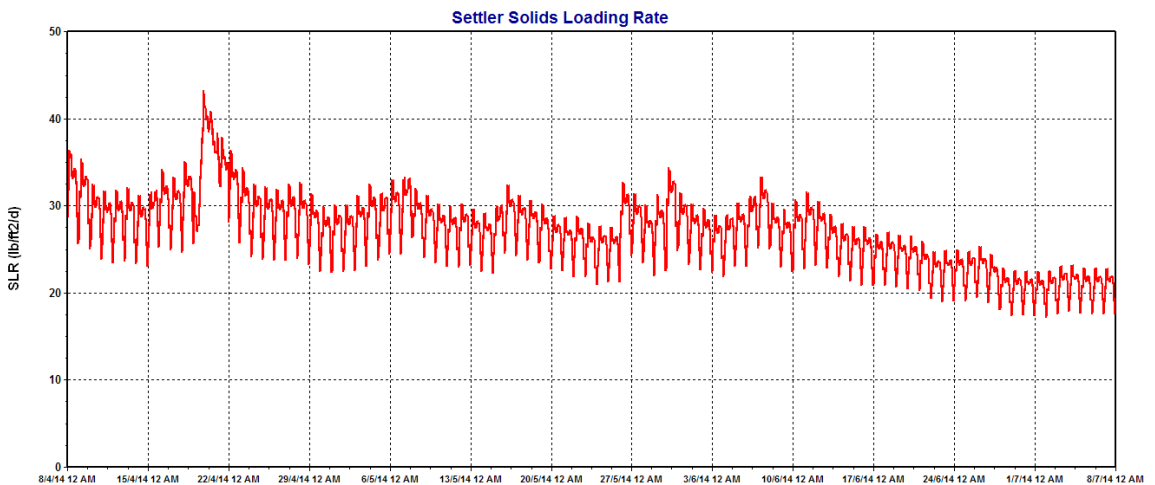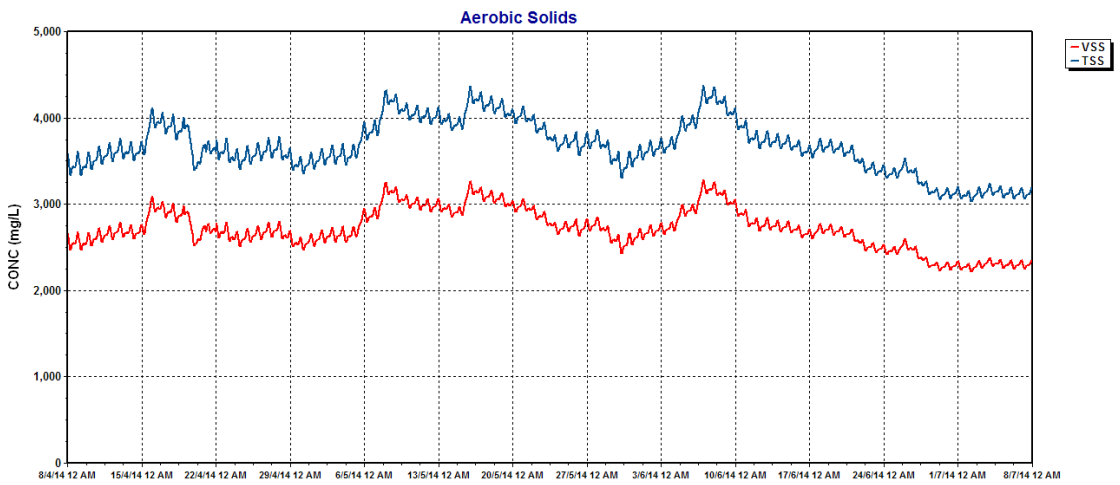
Conclusion

In this edition of the BioWin Advantage, we used BW Controller to investigate different wasting strategies and to implement SRT control for dynamic simulations. In future editions, we'll look at more complex control applications, and also continue to explore other features of BioWin.

We trust that you found this technical topic both interesting and informative. Please feel free to contact us at **info@envirosim.com** (**Subject**: **The BioWin Advantage**) with your comments on this article or suggestions for future articles.

Thank you, and good modeling.

The EnviroSim Team

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