The BioWin Advantage

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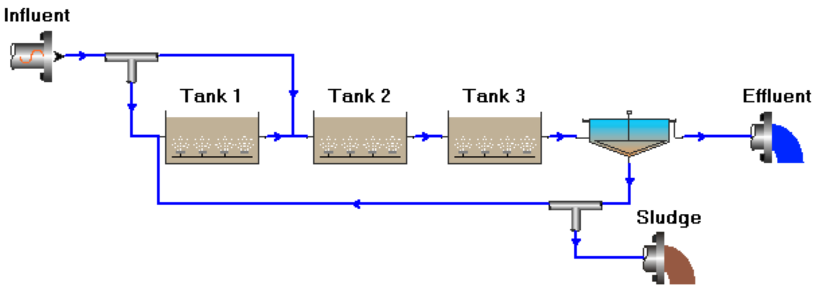
In this edition of **The BioWin Advantage**, we are going to continue exploring ways we can use BW Controller to extend BioWin's functionality by illustrating how to use BW Controller to implement automatic step feeding strategy in a BioWin simulation.

Simulating Step Feed for Storm Events

Background on Simulating Step Feed

In a previous edition of **The BioWin Advantage**, we explored the capabilities of 1-D settling models, and showed how they could simulate the impacts of storm flows entering the plant - specifically with respect to the location of the plant's solids inventory. For example, we saw that if a storm surge was allowed to enter the plant, a portion of the aeration tank solids inventory would be transferred into the secondary clarifier. One aspect that we did not investigate was the implementation of step feed to mitigate this solids transfer. In this edition of **The BioWin Advantage**, we'll illustrate how to set up step feed in a BioWin process layout, and how BW Controller can help to automate its implementation.

In general, to simulate step feed we use a flow splitting element to control where influent flow enters the aeration tank. An example of this is shown in the simple BioWin layout below:



This layout is for a small pilot plant that was used to illustrate the benefits of implementing step feed with respect to secondary clarifier performance. The BioWin charts below show simulation (lines) and experimental (points) results for two storm events. For the first event, all of the storm flow was allowed to enter at the front of the aeration tank (i.e. Tank 1 in the BioWin layout). For the second event, all of the storm flow was directed to a point equivalent to 1/3 of the aeration tank length (i.e. Tank 2 in the BioWin layout).

The charts show that when step feed is not implemented (experiment #1),

Featured Article

Simulating Step Feed for Storm Events

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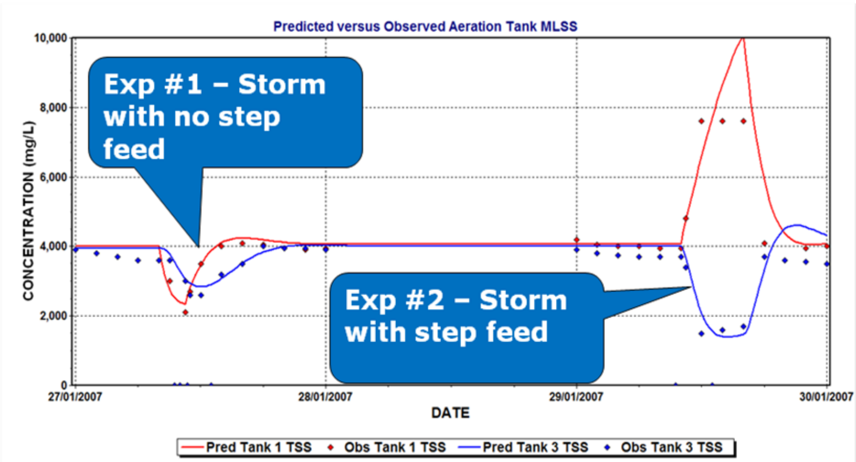
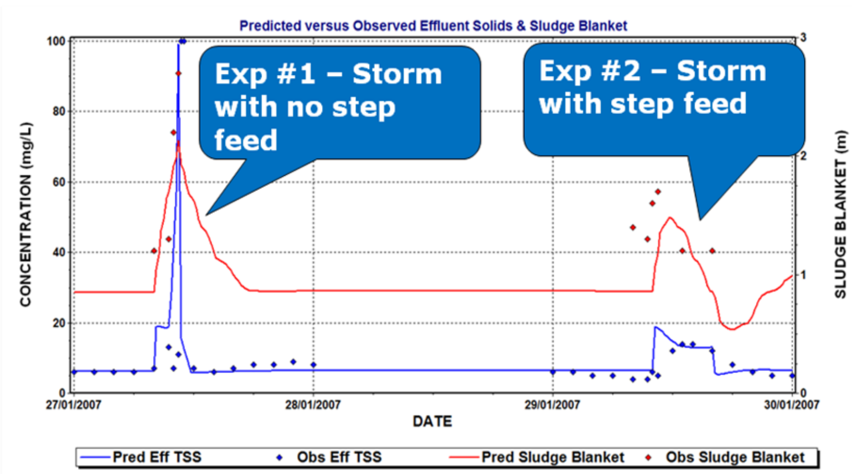
we get transfer of solids out of the aeration tanks and into the secondary clarifier. This is illustrated by two responses: (1) the solids concentration drops in the aeration tanks, and (2) we see an increase in secondary clarifier effluent suspended solids and sludge blanket height. When step feed is implemented (experiment #2), it is apparent that solids only are transferred out of the aeration tank zones downstream of the influent input; solids are actually "stored" in the upstream zone (i.e. we can see that the solids concentration of the first zone approaches that of the return activated sludge). Also, we see less sludge blanket migration and lower effluent suspended solids with the implementation of step feed.

In the next section, we'll explore a more realistic storm event, and use BW Controller to implement a step feed strategy for us.





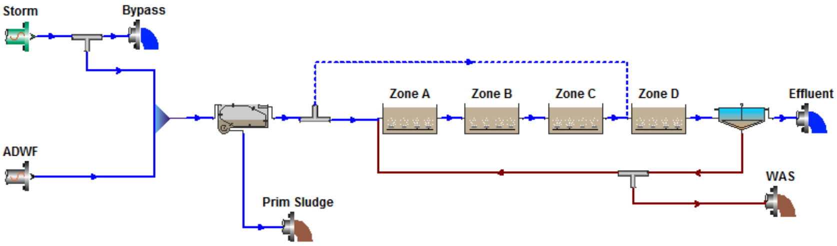
The Base Plant for Control Example

[please refer to **BioWin Advantage #5 - One Dimensional Settling Models** for details on strategies for simulating the input of storm events and other pertinent background. It is available for download at **http://www.envirosim.com/support/bwa.php**]

The basis for the BioWin layout is very similar to the one we used to illustrate sludge inventory shift, and is based on an actual plant in the Asia-Pacific region.

The files used in this example can be found **here** (*Sludge Mass Shift (US Units - with DE Model)-With Step Feed.bwc*) and **here** (*Step Feed Controller.bcf*)

A process flowsheet is shown below:



Some pertinent design features of the system are listed in the following table:

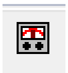
ATTRIBUTE	VALUE
Average Influent Flow	3.97 mgd
Maximum Daily Flow	5.95 mgd
Average Influent BOD Load	6914 lb/d
Average Influent TSS Load	6168 lb/d
Average Influent TKN Load	1555 lb/d
Minimum Design Temp	20°C
Total Aeration Volume	2.35 mil. gal.
Average Zone D MLSS	2,771 mg/L
Average WAS Flow	31,700 gpd
Secondary Clarifier Volume	1.585 mil. gal.
Secondary Clarifier Area	16,146 ft^2
Secondary Clarifier Depth	13.1 ft
Average Clarifier SLR	8.4 $lb/ft^2/d$
Average Clarifier SOR	239 $gal/ft^2/d$
RAS Flow	1.98 mgd (50%)
Average Effluent Ammonia	0.10 mgN/L

Other details of interest include:

- The layout incorporates a **Storm input**; a flow splitter is used to control whether or not the storm flow enters the treatment plant (for scenario simulation purposes). A state variable input is used to simplify the addition of water plus some additional inerts (25 mg ISS/L).
- Step feed of primary effluent may be implemented by directing a portion of the primary effluent to the last ¼ of the aeration tank length (i.e. the beginning of Zone D on the BioWin flowsheet layout). Because flow to this zone may not occur all the time, it is represented by a dashed line in BioWin.
- The secondary clarifier is big! For average conditions, the SLR and SOR are below Metcalf and Eddy suggested ranges. However, the size is large due to two main factors:
    - The storm event is brief (6 hours) but significant (see the chart below).
    - The sludge settleability is de-rated from the BioWin defaults (which represent a well-settling sludge).

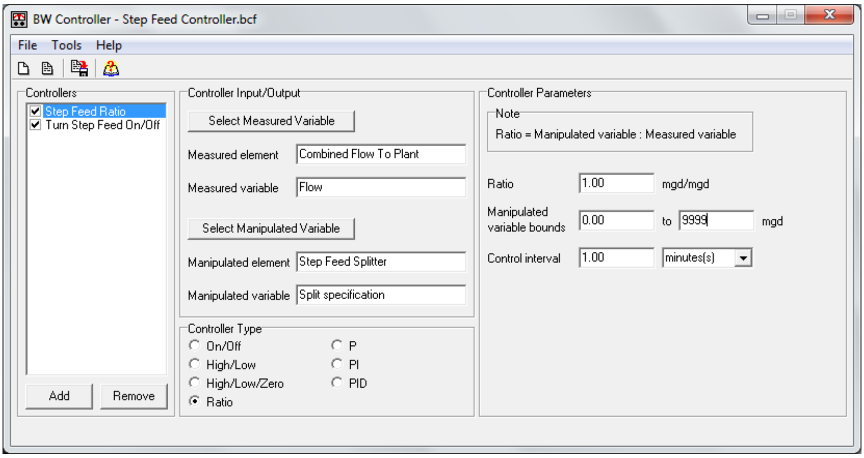
Using BW Controller to Automatically Implement Step Feed

Before we run our simulations, we'll set up BW Controller to implement the step feed strategy for us. In fact, we'll use two controllers - one to control the ratio of flow that is directed to Zone D, and another that will control whether the first controller is active or not.



First, we launch BW Controller from our base system by clicking the BW Controller button located on the **Main** toolbar. When we do this, we'll see the BW Controller interface, which will allow us to set up the control strategy we want to investigate.

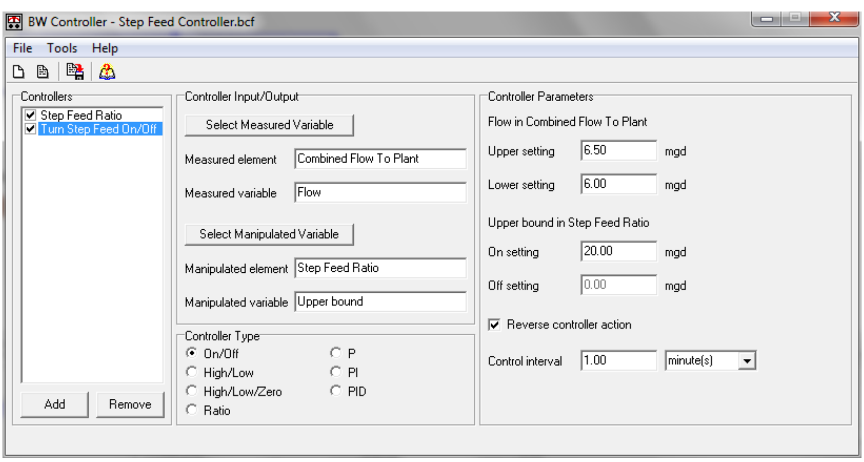
First, we'll set up our step feed ratio, as shown below :



Pertinent details are as follows:

- This first controller is called **Step Feed Ratio**.
- The measured variable is the flow in the element named **Combined Flow To Plant**, which is the general mixer just upstream of the primary clarifier.
- The manipulated variable is the "split specification" of the **Step Feed Splitter**, which is the flow-splitting element just downstream of the primary clarifier. Note that the controller automatically switches the split specification to flow rate in the side stream. This means that at a selected ratio of 1, all incoming flow is directed to Zone D. A ratio of 0.5 would split the flow in half.
- The controller type is a Ratio controller.
- The **ratio** in this example has been set to 1.0; that is, the flow in the side stream of the splitter (to Zone D) would be equal to the combined flow to plant. The other way of thinking of this is that all of the combined flow to the plant will be routed to Zone D. We could (and will!) specify alternate values for the ratio to explore different strategies.
- The bounds of the flow rate in the side stream (the manipulated variable) are set such that the lower and upper values are 0 and 9999 mgd (unlimited), respectively.

Next, we'll set up the controller that turns the step feed on or off, as shown below :



Pertinent details are as follows:

This second controller is called **Turn Step Feed On/Off**.

- The measured variable is the flow in the element named **Combined Flow To Plant**, which is the general mixer just upstream of the primary clarifier.
- The manipulated variable is the **Upper bound** of the manipulated variable of the **Step Feed Ratio** controller. That is, we have the situation where one controller is controlling another controller.
- The controller type is **On/Off**.
- The controller action is **Reversed**.
- The upper setting has been set to **6.5 mgd**. Because the controller action is reversed, this is the **Combined Flow To Plant** flow that will turn the step feed on. The lower setting has been set to **6 mgd**; this is the **Combined Flow To Plant** flow that will turn the step feed off. If this controller was to be applied to actual plant flow data (as opposed to the smooth synthetic flow in this example), a larger difference (called a hysteresis) between these flows may need to be specified in order to keep the controller from rapidly cycling on and off under normal flow variations.
- The **On setting** for the **Upper bound** of the first controller has been set to **20 mgd**. This value has been selected such that it is greater than the anticipated **Combined Flow To Plant** flow when storm flow conditions are active, so that all the flow will be routed to Zone D. If the combined flow to the plant were to exceed 20 mgd, any flow in excess of 20 mgd would be routed through Zone A.

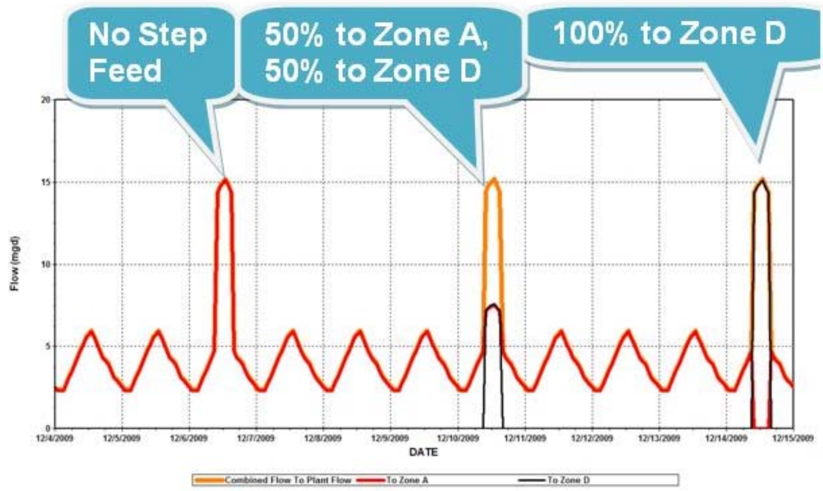
In the next section, we'll run some simulations, see if the controller did what we think it should, and explore the results.

Results and Discussion

The BioWin file that accompanies this edition of **the BioWin Advantage** is a summary of the following steps:

1. First, a steady state was run with no stom input (the **Storm In/Out** splitter was set to a fraction of 0 to direct all flow to the bypass element).
2. With the controller deactivated (we can do this by un-checking the boxes next to the two controllers we set up in the previous steps), a dynamic simulation was run for seven days with no storm flow to establish the base system response.
3. The simulation was re-started and a dynamic simulation was run for two days with no storm input to establish the base system dynamic response.
4. With the simulator paused, the **Storm In/Out** splitter was set to a fraction of 1 to simulate the storm flow entering the plant. Next, the dynamic simulation was continued with no step feed, to establish the worst-case scenario.
5. With the simulator paused, the **Storm In/Out** splitter was set back to a fraction of 0 to simulate no storm flow entering the plant. Next, the dynamic simulation was continued for three days with no storm flow to return to the base system response.
6. With the simulator paused, the **Storm In/Out** splitter was set to a fraction of 1 to simulate the storm flow entering the plant. Also, the BW Controller was switched back on (by checking the boxes next to the two controllers we set up in the previous step), and modified slightly to implement a step feed strategy that directed 50% of the **Combined Flow To Plant** to Zone A and 50% to Zone D (by changing the ratio in the **Step Feed Ratio** controller to 0.5). The dynamic simulation was run for one day
7. With the simulator paused, the **Storm In/Out** splitter was set back to a fraction of 0 to simulate no storm flow entering the plant. The dynamic simulation was then continued for three days with no storm flow, in order to return to the base system response. The BW Controller can remain active since the flow is lower than the "switch on" level.
8. With the simulator paused, the **Storm In/Out** splitter was set to a fraction of 1 to simulate the storm flow entering the plant. Also, the BW Controller was modified to implement a step feed strategy that directed 100% of the **Combined Flow To Plant** to Zone D (by changing the ratio in the **Step Feed Ratio** controller to 1.0). The dynamic simulation was finally run for one day.

When the BioWin Album is opened, the first chart we see shows the total combined flow going to the treatment process. Also, we can see the flow going directly to Zone A, and the flow going directly to Zone D. The large spikes in flow correspond to instances where the storm input was allowed to enter the plant.



The following details are worth noting:

- On the third day of simulation, when storm flow comes to the plant and no step feed action is taken, we see that the combined flow to the plant and the flow to Zone A are equal, and hence the lines lie on top of each other.
- On the seventh day of simulation, we can see that the controller takes the specified 50% to Zone A / 50% to Zone D action. The Zone D line which had been running along at zero flow comes up when the storm flow enters the plant, and is equal to that entering Zone A.
- On the last day of simulation, we can see that the controller takes the specified 100% to Zone D action. The Zone D line comes up and tracks the line representing the total flow to the plant; note also that the flow to Zone A line plummets to zero when the storm enters the plant.

Another chart of interest is a plot of mixed liquor suspended solids concentration in Zones A and D located on the **Dynamic Sludge Shift** tab, shown below:

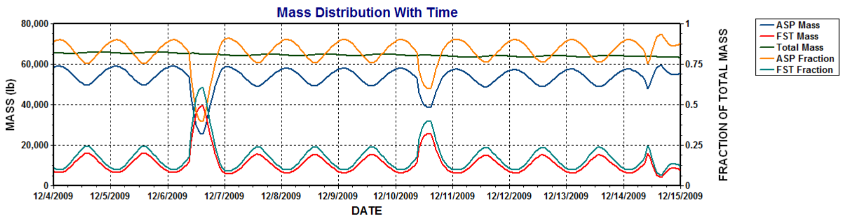
The following details are worth noting:

- On the third day of simulation, when storm flow comes to the plant and no step feed action is taken, we see that the concentration of both Zones A and D drop significantly as solids are pushed into the secondary clarifier.
- On the seventh day of simulation, when the 50% to Zone A / 50% to Zone D step feed action is implemented by the BW Controller, the concentration in Zone A does not drop as much; the concentration drop in Zone D is similar to that when no step feed control was

taken.

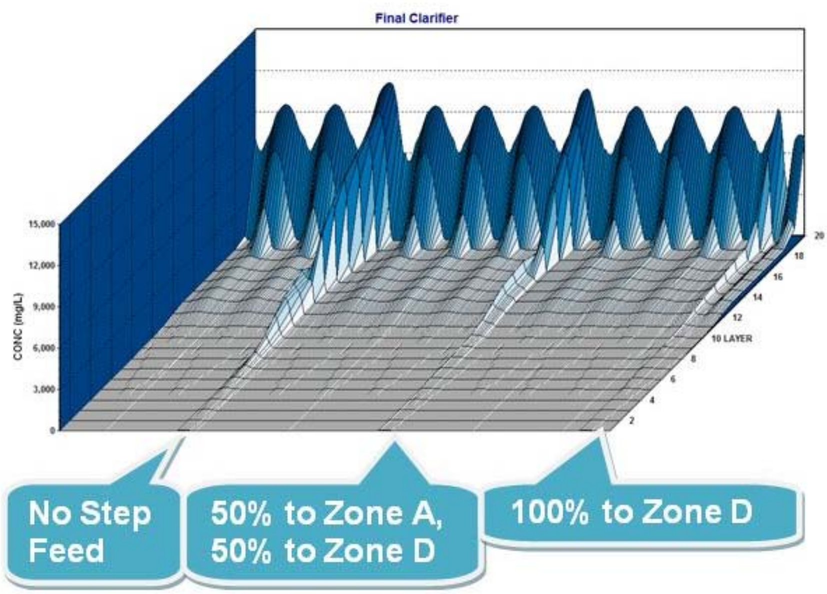
- On the last day of simulation, when the 100% to Zone D step feed action is implemented by the BW Controller, only the concentration in Zone D drops significantly. The concentration in Zone A rises and approaches the RAS concentration as solids are stored there. This response is similar to the pilot plant results discussed earlier.

We can see the concentration changes presented in an alternate form as dynamic sludge mass plots, shown below:



[once again the reader is referred to **BioWin Advantage #5 - One Dimensional Settling Models** for details on creating these more complex charts. It is available for download at http://www.envirosim.com/support/bwa.php]

Finally, if we look at the **FST Time Layers 2** tab, we can see how under normal loading, we don't carry much of a sludge blanket in the secondary clarifier. However, when the storm flow passes through, the concentration in the bottom layer increases and the concentration increases as we move up the clarifier - to the point where we see a slight solids "bulge" extending all the way up to the top layer (layer 1). Looking through the second and third storm events we can see how this sludge blanket migration is mitigated through the implementation of step feed - the "bulge" doesn't come up as high!



In Conclusion

In this edition of the **BioWin Advantage**, we've extended a previous example that explored some of the capability of 1-D secondary clarifier models by using BW Controller to implement step feed once a certain influent flow limit was exceeded.

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 article.

Thank you and good modeling

The EnviroSim Team