The Biowin Advantage

Impact of Primary Settling on Wastewater Characteristics

Introduction

In this edition of The BioWin Advantage, we will use some of BioWin's advanced charting features to help us track the change in wastewater characteristics across a primary settling tank.

It's All About Solids Capture

The primary (!) role of a primary settling tank (PST) is to remove solids from the influent wastewater *via* gravity settling under quiescent conditions. For most typical municipal wastewaters, a significant portion of the carbonaceous material (usually quantified by COD and BOD analyses) will be of the particulate form, with the remainder captured in the soluble form. Because of this, an additional benefit of removing solids in the PST is that there will also be COD and BOD removal. The same benefit exists for nutrients (*e.g.* TKN and TP), although to a lesser extent because less of the "total" for these constituents exists in the solid phase.

If we make the assumption that there are minimal transformations taking place in the PST (*e.g.* hydrolysis of particulate material into soluble), then the removal of things like COD, BOD, TKN, and TP across the PST will depend on (a) the overall solids capture achieved by the PST, and (b) the characteristics of the PST influent with respect to the relative division into particulate and soluble phases.

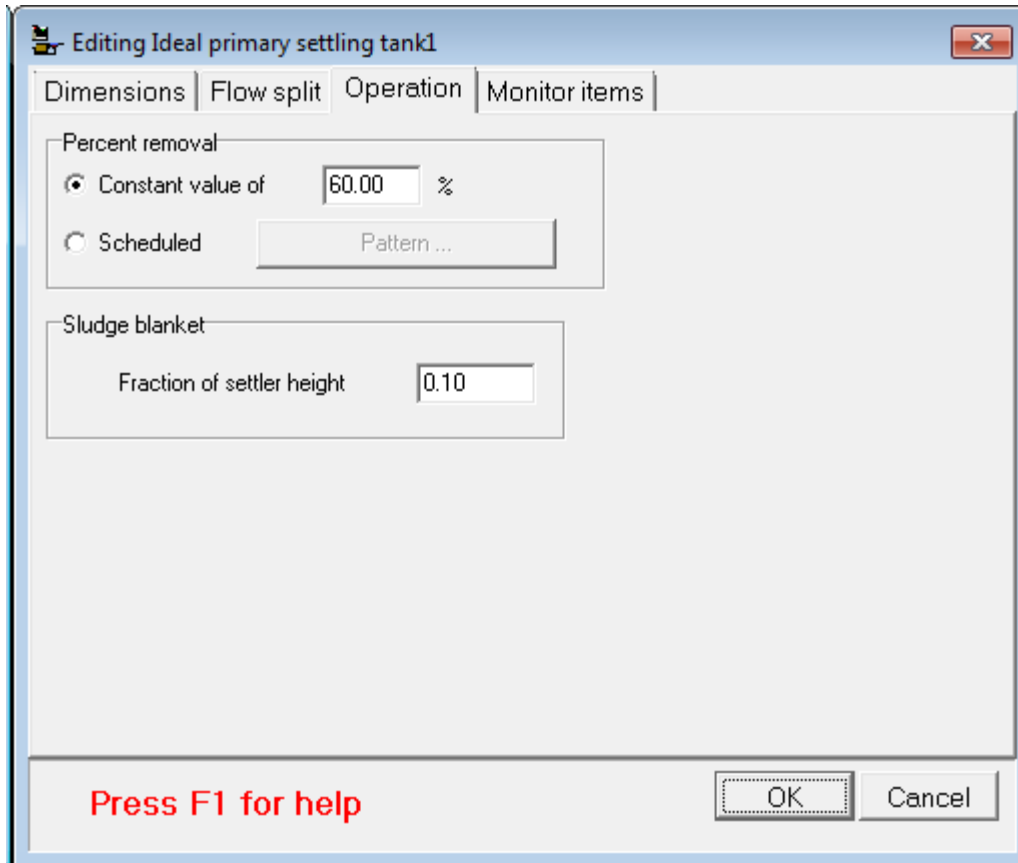## Using BioWin to Show PST Impacts - Mechanics
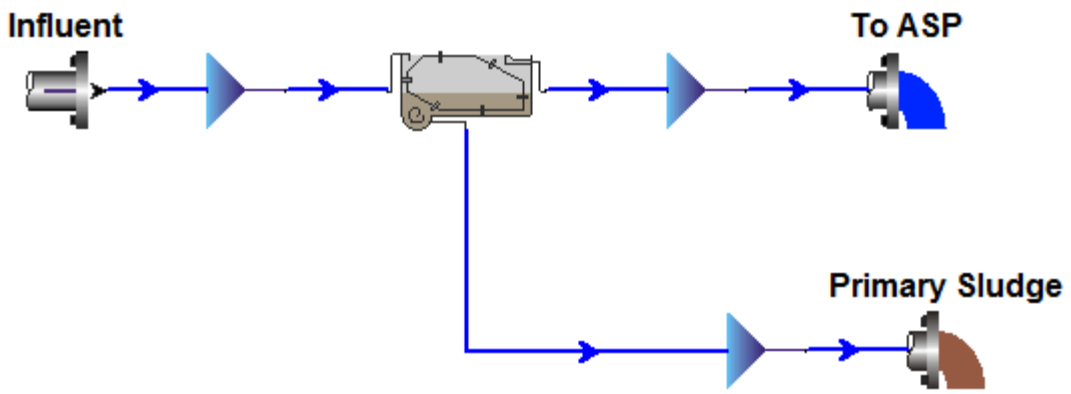
In the previous edition of the BioWin Advantage, we illustrated how we can use a model-based settling tank element to represent a PST. In this edition, we will revert to the simple "ideal" PST element that allows us to specify a constant or time-varying solids capture percentage. However, the same principles apply irrespective of the type of element we use; furthermore, many of the charts that are plotted in the Album of the BioWin file that accompanies this article (**BW 31 Ideal PST #1-Base Case.bwc**) have been generalized such that they rely on the mixing elements on the PST influent, underflow, and effluent streams. This means that it is very easy to modify the file that comes with this article to use a model-based settling tank if you wish because the charts will not be disrupted by replacement of the PST element itself.

Since the focus of this article is on the impact of primary settling on the influent wastewater characteristics, the example configuration will be kept quite simple and it does not include downstream processes such as activated sludge and solids digestion. Some pertinent features of the system are listed in the following table:

ATTRIBUTE	VALUE
Average Influent Flow	10 mgd
Average Influent TSS Load	24,165 lb/d
Average Influent BOD Load	24,598 lb/d
Primary Settling Tank Volume	0.83 mil. gal.
Primary Settling Tank Area	7,957 ft^2
Primary Settling Tank Depth	14 ft
Primary Settling Tank Underflow	0.10 mgd
Average SOR	1,244 gal/ft^2/d
Average HRT	2 hours

The ideal primary settling tank is set up with a 60% solids capture and a fixed sludge blanket height of 10% of the total depth, as shown below:

Editing Ideal primary settling tank1

Dimensions | Flow split | Operation | Monitor items

Percent removal
- ⦿ Constant value of [60.00] %
- ○ Scheduled [Pattern ...]

Sludge blanket

Fraction of settler height [0.10]

Press F1 for help   [OK] [Cancel]

Important influent characteristics, in terms of both totals and fractions, are listed in the following table:

| PARAMETER	VALUE
COD	600 mg/L
BOD	295 mg/L
TSS	290 mg/L
VSS	235 mg/L
TKN	50 mg/L
TP	8 mg/L
Unbiodegradable particulate COD fraction (F_{UP})	0.13 mgCOD/mgCOD
Readily biodegradable soluble COD fraction (F_{BS})	0.16 mgCOD/mgCOD
Unbiodegradable soluble COD fraction (F_{US})	0.05 mgCOD/mgCOD
Ammonia fraction of TKN (F_{NA})	0.66 mgN/mgN
Soluble PO_4 fraction of TP (F_{PO4})	0.50 mgP/mgP

The various wastewater fractions listed above, as well as others listed on the wastewater characteristics tab of the influent element in the accompanying BioWin file, represent default BioWin values which are representative of typical North American wastewaters. As such, several ratios for "total" parameters fall within expected ranges, *e.g.*:

- The COD/BOD ratio is 2.04 mgCOD/mgBOD
- The TSS/BOD ratio is 0.98 mgTSS/mgBOD
- The VSS/TSS ratio is 0.81 mgVSS/mgTSS

To calculate ratios of interest such as those listed above, we can get BioWin to do the work for us. This way, if we make a change to the influent wastewater, we will be able to see the impact on our ratios of interest right away. The best way to do this in BioWin is through the use of charts that employ "function series".

For example, if we open up the Album of the accompanying BioWin file and navigate to the tab called "**TKN / Organics Ratios**", the top chart is a plot of the COD/BOD ratio:
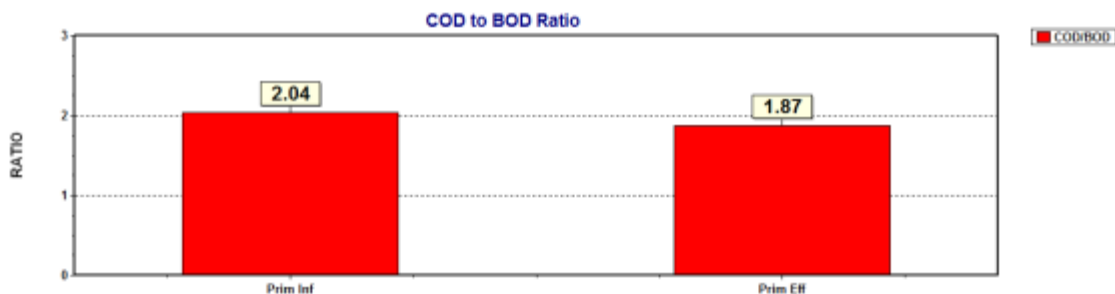

Function series allow us to perform a mathematical operation on one or more series that are plotted in a BioWin chart. If we're only interested in the function series itself, we can hide the underlying source series. In fact, that's precisely what's been done in the above plot. First, a **Current Value** bar chart was added for the parameters COD and BOD at the primary influent and effluent locations; the result would look something like the plot below:
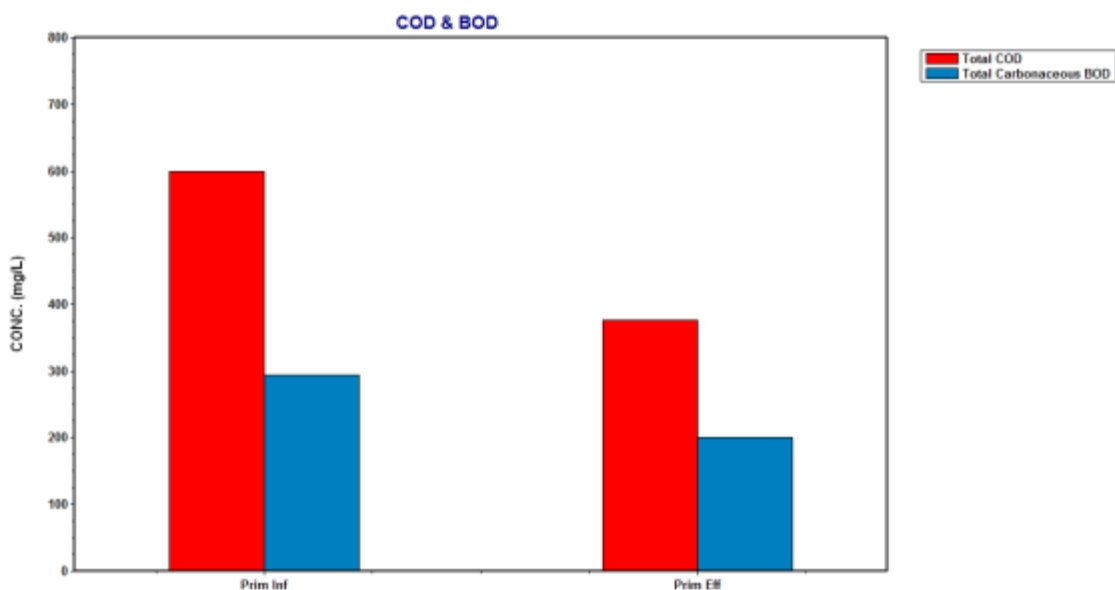

If we right-click on the chart, select Add series…, and click the Functions tab, then we're presented with the following dialogue box:
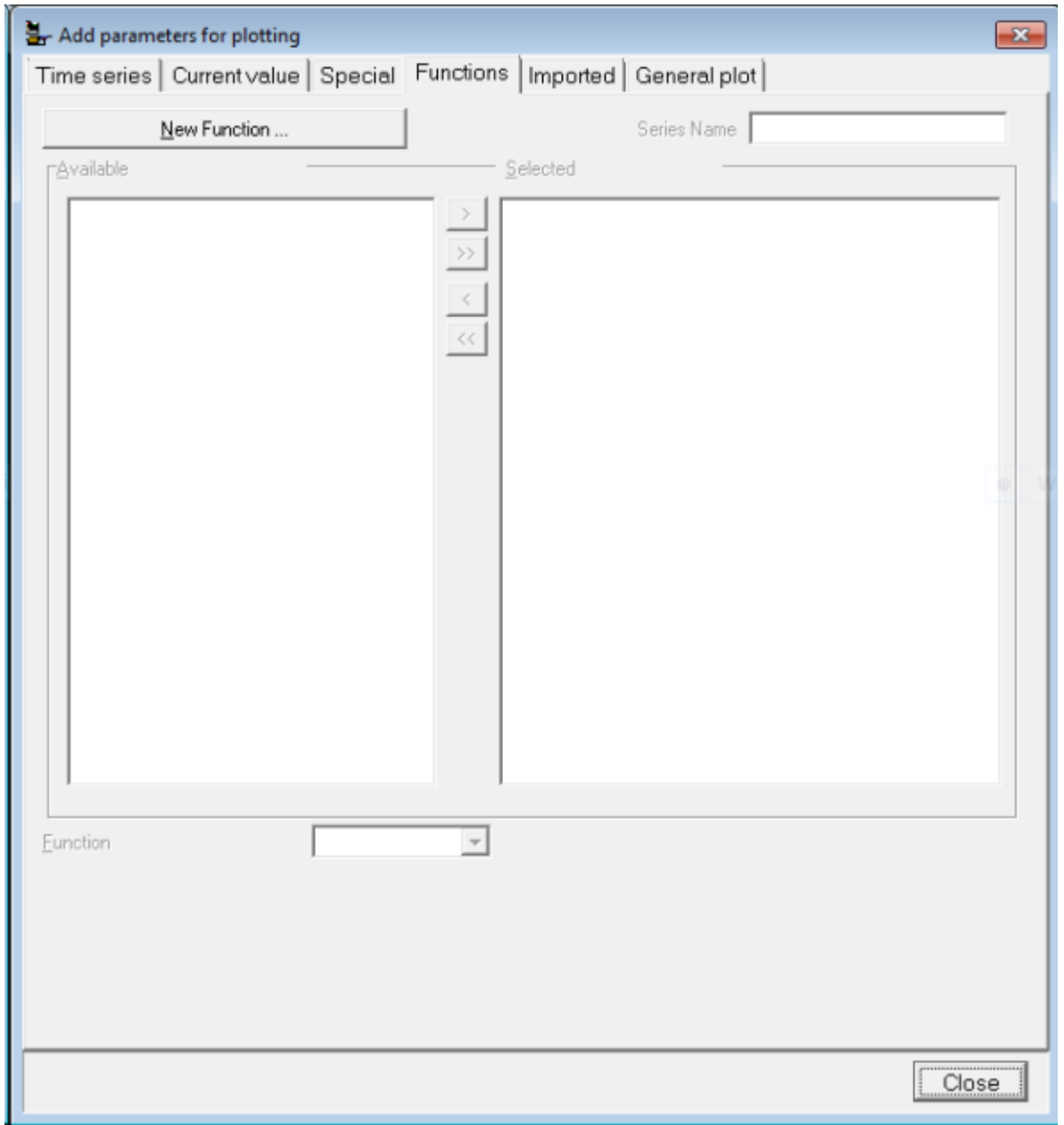
For our COD/BOD ratio plot, we'd like to divide the COD value by the BOD value at each plotting location. Another way to think of this is that we'd like to divide the COD series by the BOD series. If we click the New Function… button, we'll be presented with a range of choices for function operators:
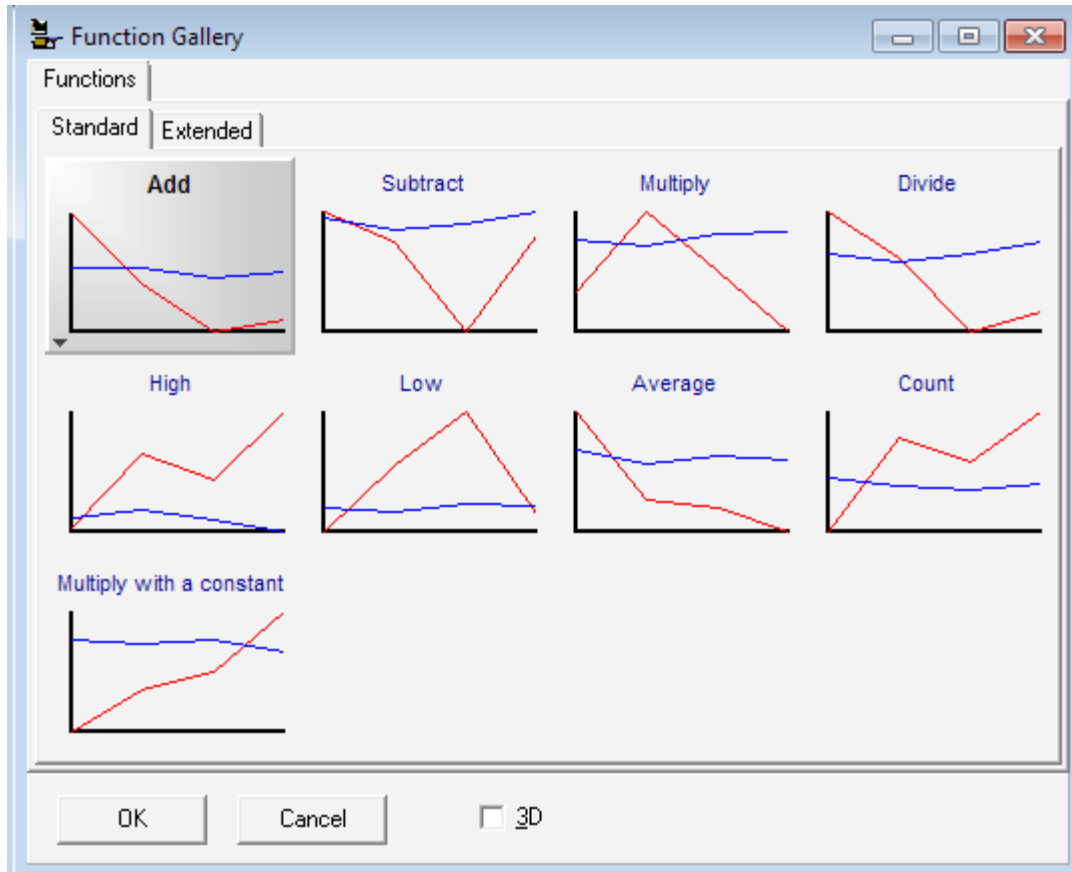
If we click on the **Divide** option, we'll be taken back to the main **Function** series dialogue box, which will have changed slightly to include the currently available series in the left-hand column:
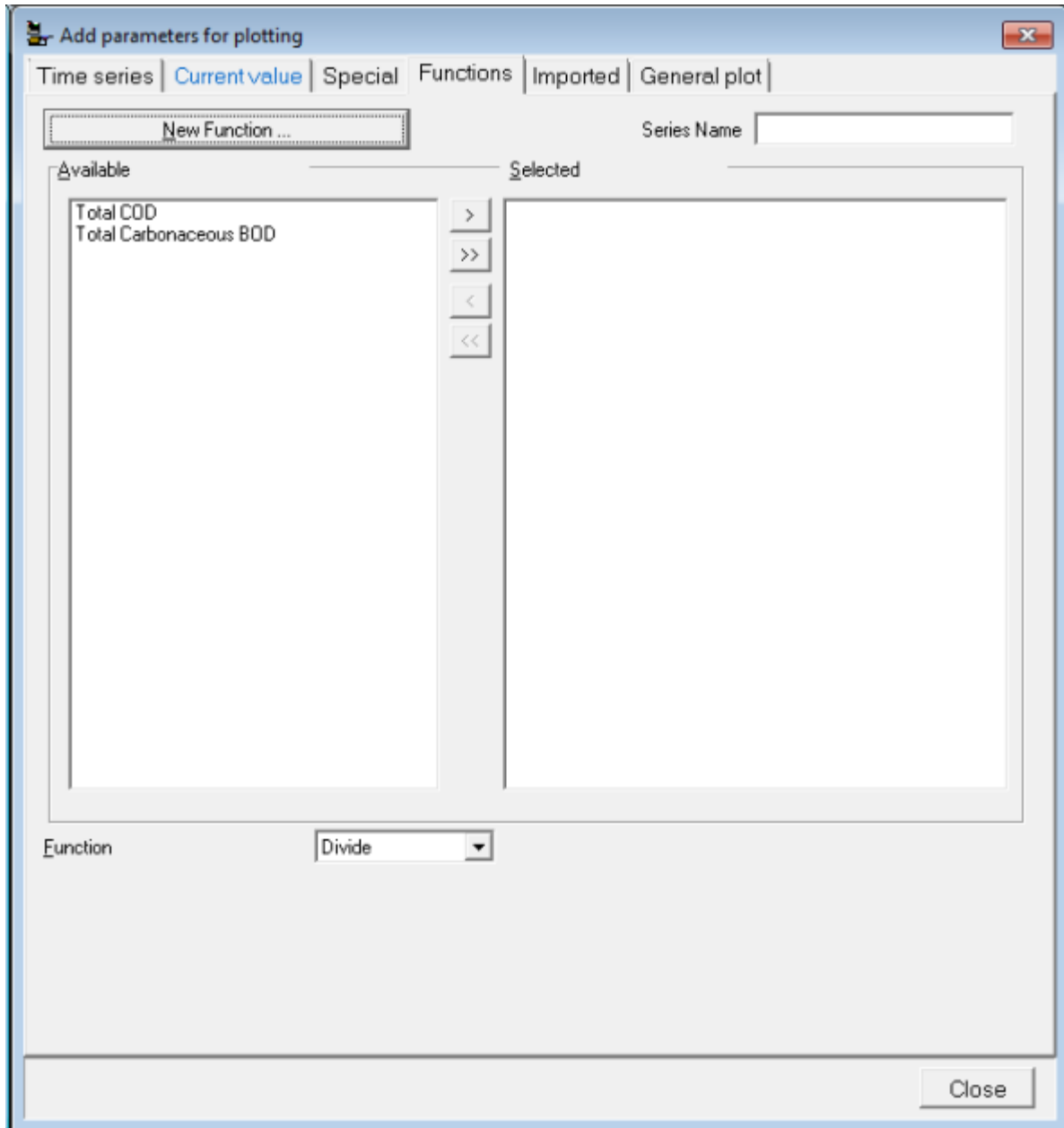
Pushing the right-pointing arrows will move the COD and BOD series over to the Selected column; the first series listed will be the numerator in the division and the second series listed will be the denominator. There will now be a series titled "**Series 1**" added to the chart that we can rename and reformat to suit (*e.g.* by default function series start out as "line" series; we can right-click the chart, select Edit series, and change the type of the series to a different style such as "bar" in order to achieve the look we want). By un-checking the boxes next to the underlying source series, we can hide them so that all the focus is on what we're interested in – in this case, the COD/BOD ratio in the primary influent and effluent:
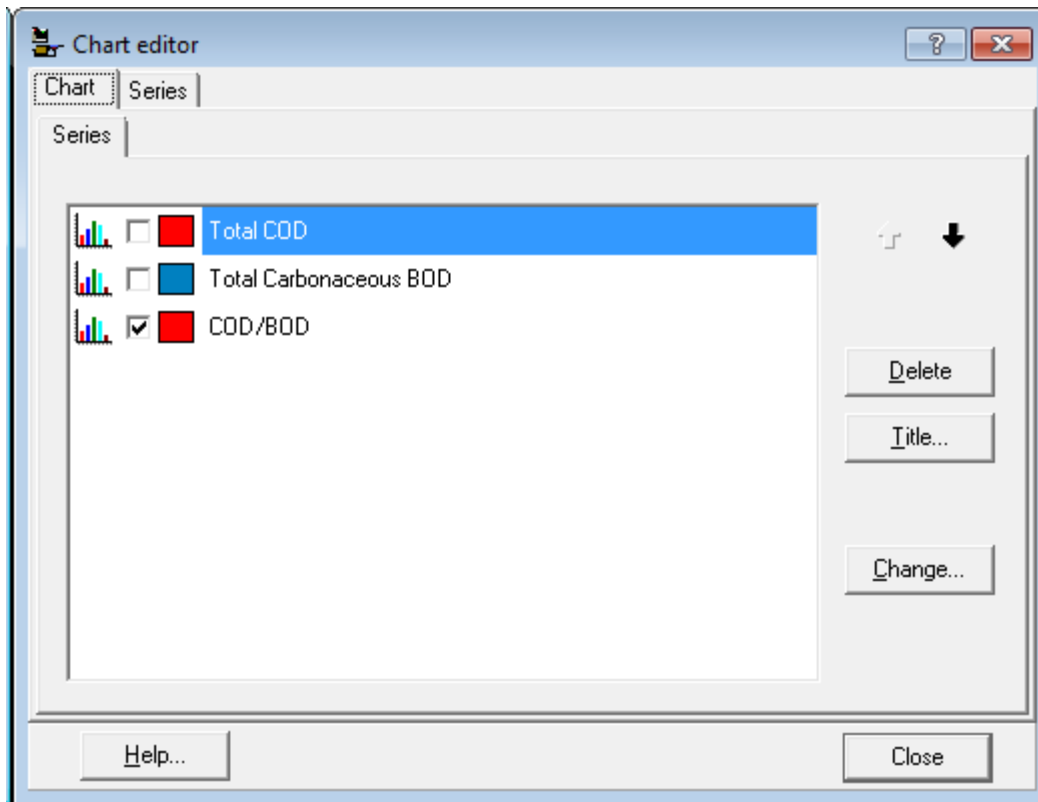
Many of the plots in the accompanying BioWin file rely on the basic steps covered above. Some of them are more complex in that they have function series operating on other function series, but the underlying steps are the same. Take some time to explore the various charts, *e.g.* by right-clicking on a chart and looking for "hidden" source series you can get an idea of how a certain function series has been built up. Also, if you right-click on a chart, select **Edit series**…, and double-click on a series name in the list, you'll be taken to that series' specific formatting options. If that series is a function series, there will be an additional **Data Source** tab; clicking on this tab allows you to see what the source series underlying the function are, and also allows you to make changes to the function operation if you wish.

For example, if we look at this tab for our COD/BOD ratio example, we will see the tab below which tells us that the COD/BOD series is a division-based function series and allows us to make modifications such as changing the numerator and denominator, *etc*.
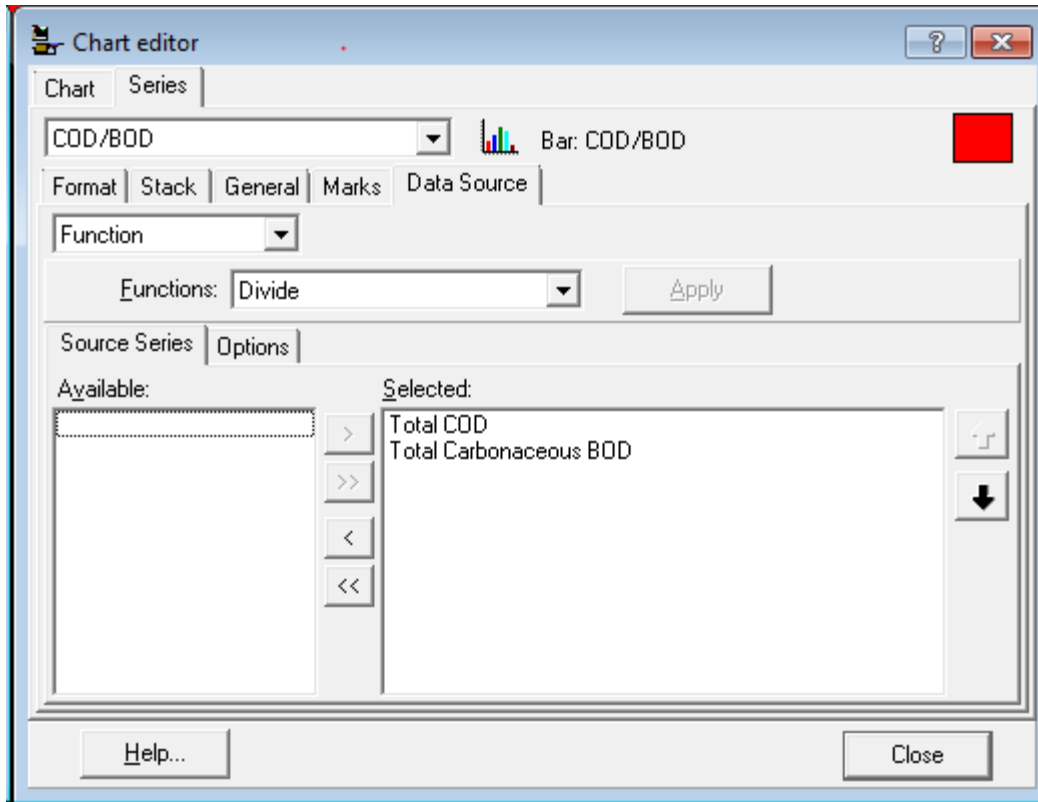
## Using BioWin to Show PST Impacts - Interpretation

Before looking more in-depth at the impacts of primary settling on wastewater characteristics, it is worth summarizing the primary influent and effluent concentrations of various parameters of interest:
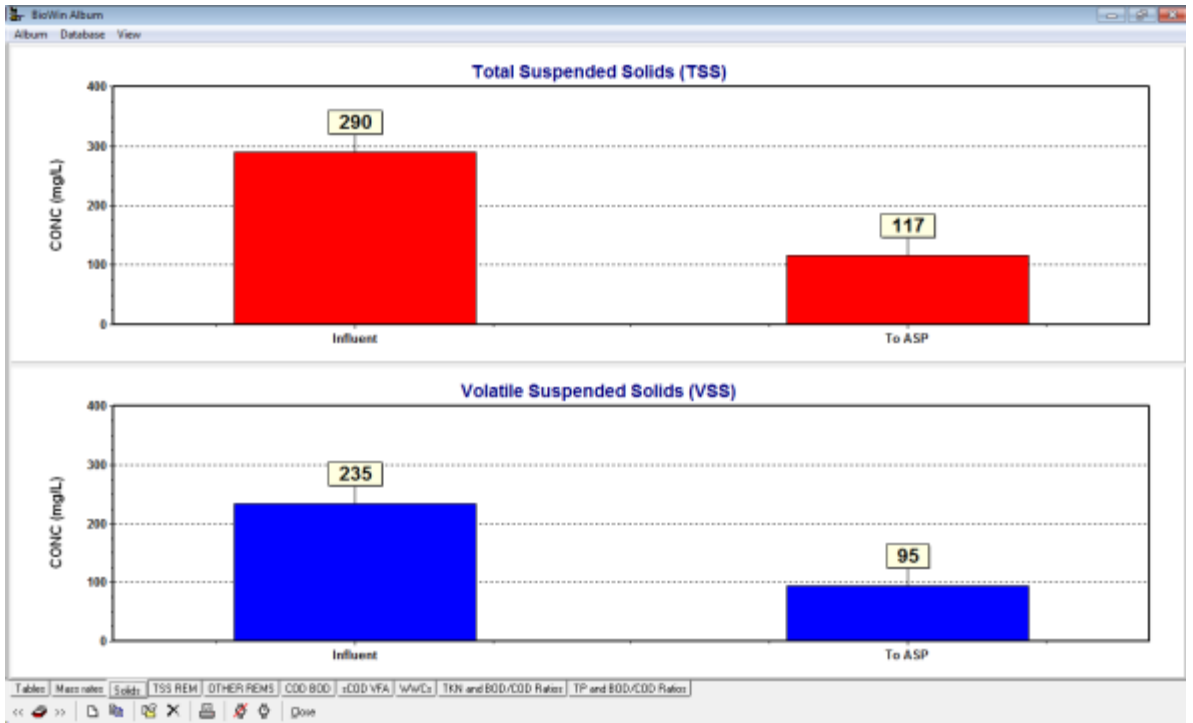
As we expect, we see a reduction in TSS and VSS across the PST. As well, we see a reduction in total COD and BOD across the PST due to a partial removal of the particulate component of each of these parameters. The reduction in TSS corresponds to our removal setting in the ideal PST of 60% (the solids capture plot shown here is generated with a function series but in future versions of BioWin you will be able to directly plot this parameter):

TSS and TSS Removal Across Primary
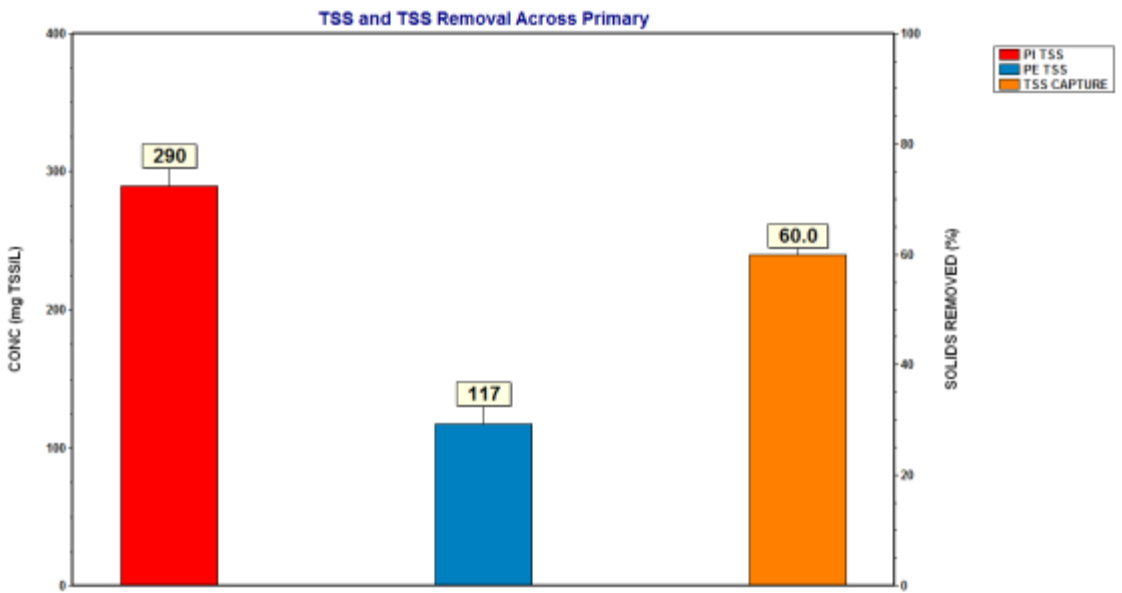
Because the soluble portions of the total COD and BOD pass through the PST unchanged (recall that we are not modelling any biological transformations in this PST), the overall COD and BOD removals will be lower than the solids capture of 60%:


Other Parameter Capture Rates
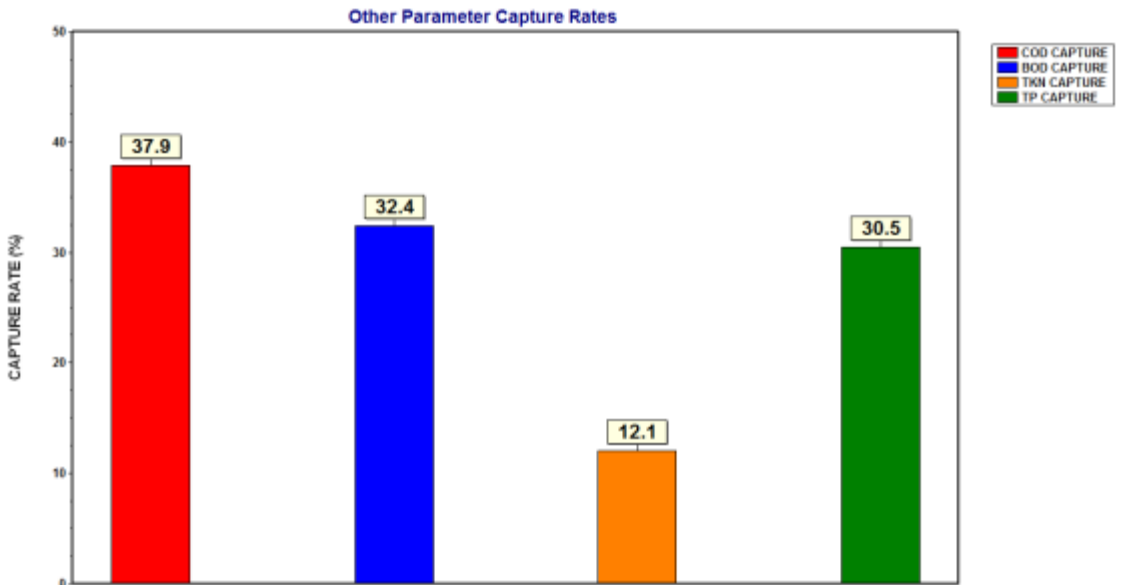
The following points are of interest with respect to the capture rates of these other wastewater components:
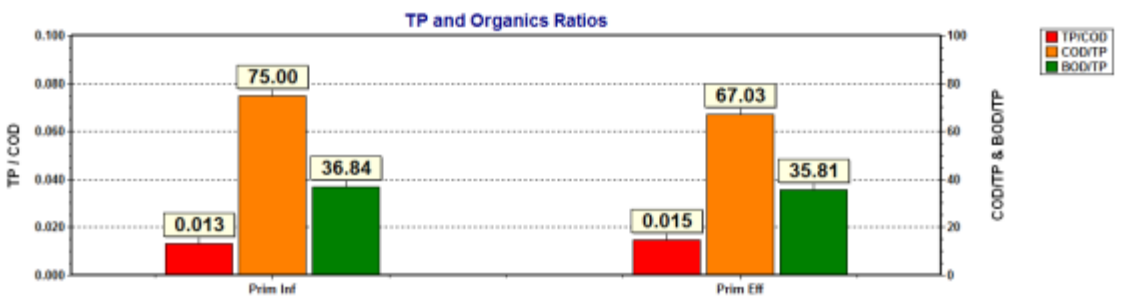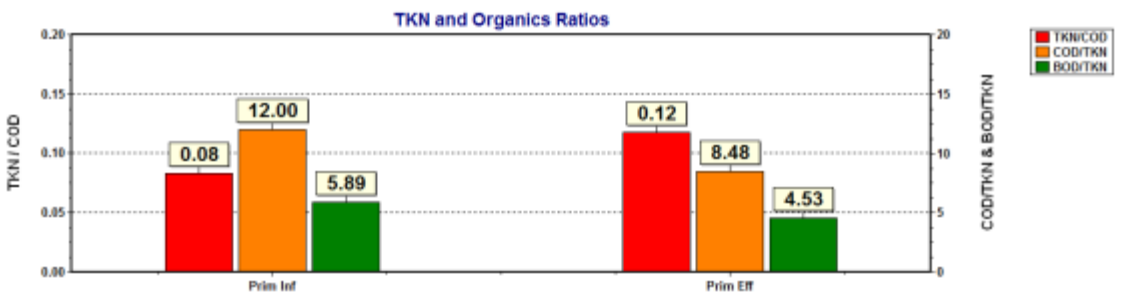
- The COD removal is higher than the BOD capture because the COD measurement captures a portion of the organics (unbiodegradable particulate) that the BOD measurement does not; the unbiodegradable particulate material is partially removed across the PST.
- The TKN removal is quite small, because in this "typical" influent wastewater, 66% of the TKN is in the soluble ammonia form which passes through the PST unchanged (*i.e.* $F_{NA} = 0.66$ mgN/mgN).

- The TP removal is fairly high because the total is evenly divided between soluble PO4 and particulate forms (*i.e.* F_{PO4} = 0.50 mgP/mgP).

These concepts are helpful when interpreting the changes in various design ratios of interest across the PST. For example, we can see that the COD/BOD ratio of the primary effluent is lower than that of the primary influent. This is a direct result of the first point in the list above; the partial removal of unbiodegradable particulate organics which are not captured by the BOD test:

COD to BOD Ratio

	Prim Inf	Prim Eff
COD/BOD	2.04	1.87
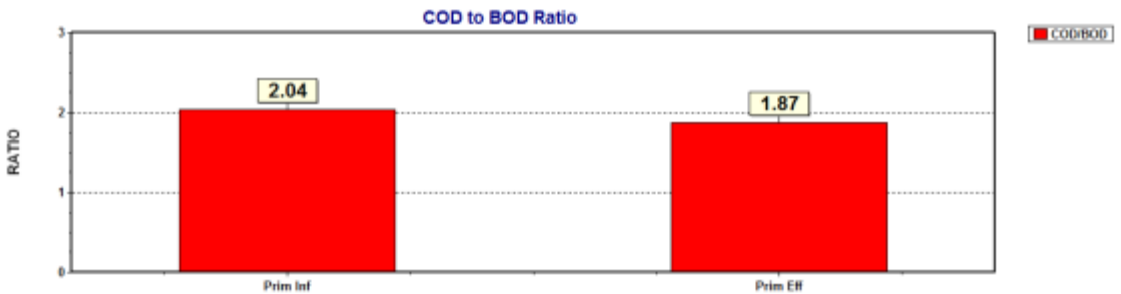
Other ratios that are of interest in the design of biological nutrient removal systems can also be calculated and are shown below:

TKN and Organics Ratios

	Prim Inf	Prim Eff
TKN/COD	0.08	0.12
COD/TKN	12.00	8.48
BOD/TKN	5.89	4.53

TP and Organics Ratios

	Prim Inf	Prim Eff
TP/COD	0.013	0.015
COD/TP	75.00	67.03
BOD/TP	36.84	35.81

Ratios such as those shown above often are of use in engineering design with regards to guiding process selection, *e.g.* whether or not a system that must achieve a TN limit will require one anoxic zone or two; whether or not an external carbon source will be required; whether or not biological phosphorus removal is possible. In some cases, depending on the relative soluble and particulate portions of an influent wastewater, these ratios may become *less* favourable to biological nutrient removal when a PST is included in the process flowsheet. This is where engineering judgment will be required with respect to looking at the

plant performance and requirements holistically – and BioWin can be very helpful in this regard!

In terms of the actual wastewater characteristic fractions, we can use BioWin and its function series capability to look at the impacts of a PST on these as well, as shown below:
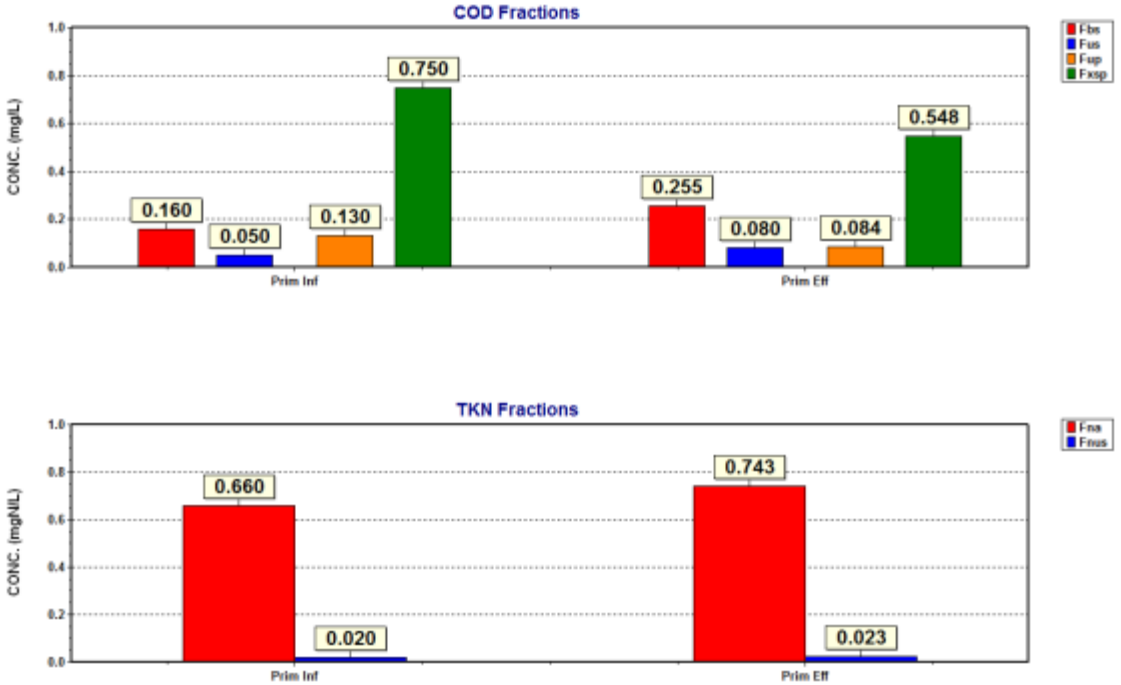
As expected in light of the discussion above, what we see is a wastewater with more of a bias toward the soluble fractions. For example, we can see that the unbiodegradable particulate fraction has been reduced from 13 % to just over 8%; the soluble readily biodegradable fraction has increased from 16% to just over 25%.

Conclusion

In this edition of the BioWin Advantage, we've extended BioWin's charting functionality to look at the impacts of primary settling on wastewater characteristics. The way this file has been set up allows alternate primary settling models to be investigated by simply swapping in the desired PST element to the accompanying BioWin file. For example, the figure below shows how we could investigate a PST operated as a fermenter with elutriation:
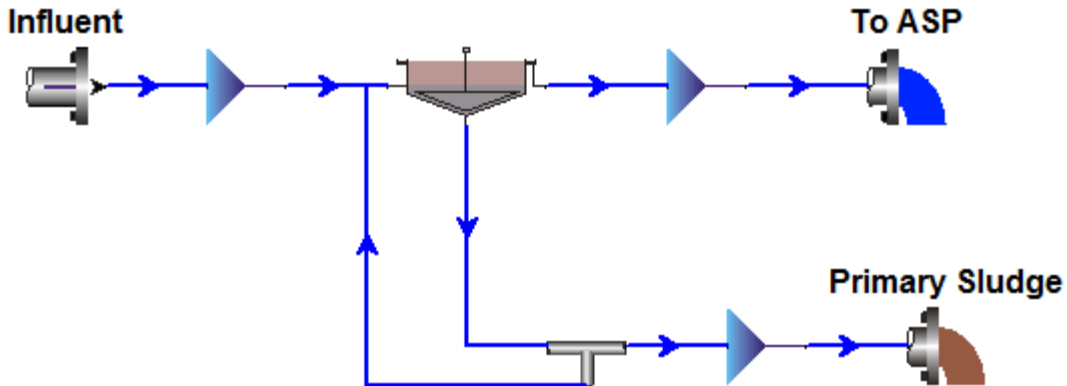
We trust that you found this technical topic both interesting and informative. Please feel free to contact us at **info@envirosim.com** (**Subject**: **The BioWin Advantage**) with your comments on this article or suggestions for future articles.

Thank you, and good modeling.

The EnviroSim Team