GPS-X Lite Exercises





Copyright ©1992-2018 Hydromantis Environmental Software Solutions, Inc. All rights reserved.

No part of this work covered by copyright may be reproduced in any form or by any means - graphic, electronic or mechanical, including photocopying, recording, taping, or storage in an information retrieval system - without the prior written permission of the copyright owner.

The information contained within this document is subject to change without notice. Hydromantis Environmental Software Solutions, Inc. makes no warranty of any kind with regard to this material, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose. Hydromantis Environmental Software Solutions, Inc. shall not be liable for errors contained herein or for incidental consequential damages in connection with the furnishing, performance, or use of this material.

Trademarks

GPS-X and all other Hydromantis trademarks and logos mentioned and/or displayed are trademarks or registered trademarks of Hydromantis Environmental Software Solutions, Inc. in Canada and in other countries.

ACSL is a registered trademark of AEgis Research Corporation

Adobe and Acrobat are trademarks of Adobe Systems Incorporated

MATLAB is a registered trademark of The MathWorks, Inc.

JAVA is a trademark of Oracle Corporation.

Microsoft, Windows, Windows Server, Windows XP, Windows Vista, Windows 7, Windows 8, and Windows 10 are trademarks of Microsoft Corporation.

GPS-X uses selected Free and Open Source licensed components. Please see the readme.txt file in the installation directory for details.



Hydromantis ESS, Inc. 407 King Street West Hamilton, ON L9H6Y1, Canada

Table of Contents

GPS-X Lite Exercises	4
Exercise 1 – Configuration of the Starting Point Layout	5
Exercise 2 – Influent Advisor	
Exercise 3 – Comparing the Performance of Alternative Bioreactor Configurations	
Exercise 4 – Plug-Flow Configuration	
Exercise 5 – Effect of SRT and DO Control on Nitrification	
Exercise 6 – Temperature Effect on Nitrification	
Exercise 7 – Aeration Control	
Exercise 8 – Total Nitrogen Removal: Nitrification and Denitrification	59
Exercise 9 – Exploring Kinetic Parameters	66
Exercise 10 – Secondary Clarifier Performance	73
Exercise 11 – Anaerobic Digestion	
Exercise 12 – Mass Balance	89
Exercise 13 – Dynamic Operations	
Exercise 14 – Aeration Strategy on Plant Performance and Energy	106
Exercise 15 – Model Calibration	115
APPENDIX A: A Brief Discussion of Biotreatment Models in GPS-X TM (Lite)	126
Activated Sludge Model	126
Rate Expressions Hydrolysis Rate Expression Endogenous Decay Nitrogen and Phosphorus Other Minor Differences	126 127 127 127 127
Anaerobic Treatment Model	130
References	

GPS-X Lite Exercises

Refer to the *Quick Start Guide GPS-X Lite* available from the Help selection on the menu bar for supporting information on how to perform specific actions that will be used in the following exercises.

For more detailed content related to the fully-functional version of GPS-X, users can reference the *Technical Reference for GPS-X* and *Complete User Guide for GPS-X*.

Note:

- GPS-X Lite implements a limited version of the International Water Association Activated Sludge Model no. 1 (ASM1).
- The simulation results obtained in GPS-X Lite can differ slightly based on several factors including the model's initial conditions, convergence criteria, and rounding. Therefore, you may observe minor variances between the model results and provided solutions. If you find significant differences (>0.1%) then we recommend that you check your model setting and model inputs.
- Refer Appendix -A for more details of the biological models used in GPS-X Lite.

Exercise 1 – Configuration of the Starting Point Layout

Note: Only make the specified changes outlined in the steps below as this layout will be used at the starting point for all subsequent exercises.

- 1. Open a new model layout in GPS-X Lite. (You will be prompted with "Close current layout"; choose Yes.)
- 2. Navigate to the process table on the left-hand side of the window.
- 3. Within the appropriate process group, left-click and drag the following process objects onto the drawing board.
 - Influent Wastewater Influent
 - Suspended Growth Processes Plug-Flow Tank
 - Secondary Clarifiers Circular Secondary Clarifier
 - Tools Wastewater Outfall

Ω

Note: In GPS-X Lite only specific unit objects are available to the user. All items that are greyed-out are disabled and have only been included to demonstrate what is available in the fully functional version of GPS-X. In addition, users have access to only one instance of each available object.

4. Select the Locator button and zoom-in on the model layout so there is less white space showing on the drawing board and the icons are enlarged.



- 5. Create the following connection paths:
 - a) Wastewater Influent \rightarrow PFR Influent (upper reactor connection point)
 - b) PFR Effluent → Secondary Clarifier Influent
 - c) Secondary Clarifier Effluent \rightarrow Wastewater Outfall
 - d) Secondary Clarifier Underflow (the bottom connection point from the reactor) → PFR Recycle Influent (lower reactor connection point)



Note: The stream connections must be exactly as specified in the image above.

- A 6. Click on the Labels button located on the toolbar to display the stream and object names. Make the following adjustments to the names of the model objects by right-clicking on the object and selecting *Labels*... from the dropdown menu.
 - Wastewater Influent:
 - Label: Influent
 - influent: wwinf



- Plug-Flow Tank:
 - Label: Bioreactor
 - o input: wwinf
 - o recycle: RAS
 - overflow: mlss



- Circular Secondary Clarifier:
 - Label: Secondary Clarifier
 - o influent: mlss
 - o overflow: effluent
 - o pump: WAS
 - o underflow: RAS



- Wastewater Outfall:
 - Label: Outfall
 - input: effluent

Wastewater Outfall	X
Label : Outfall	
offluent	
input	
	-
Accept	Cancel

Note:

- Once you have specified the name of a stream in one location, the name will automatically appear at the other end of the connection.
- After specifying labels, they will not appear in a reloaded layout unless *View > Display Labels > Stream/Objects* has been selected.
- 7. Right-click on the Bioreactor and go to *Input Parameters > Physical* and set **the number of reactors** to **1**. This change allows the PFR model object to be modelled as a complete mixed (CM) reactor.

Physical				×
Dimensions				_
[mlss] number of reactors	1			D
[mlss] tank depth (not editable in GPS-X Lite)	4.0	m	•	
[mlss] volume setup method (not editable in GPS-X Lite)	Volume Fractions		Ŧ	D
Individual Volumes				
[mlss] individual volumes	()	m3	Ŧ	Ľ
Volume Fractions				
[mlss] maximum volume (not editable in GPS-X Lite)	1000.0	m3	•	\Box
[mlss] volume fractions	()	-	•	\Box
More				
		Accept	Can	cel

8. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and change the **specify oxygen transfer by...** to **Entering airflow**, and set the **total air flow into aeration tank** to **30,000 m³/d**.

Aeration Setup				
[mlss] aeration method	Diffused Air		•	
[mlss] specify oxygen transfer by	Entering Airflow		-	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ	
More				
Diffused Aeration				_
[mlss] total air flow into aeration tank	30000.0	m3/d	•	D
[mlss] distribution of air flow to aeration tank	()	-	•	
More				
Mechanical (Surface Aeration)				
[mlss] aeration power	()	kW	Ŧ	
More				
Aeration Control				
[mlss] DO setpoint	()			
More				
Pumped Flow Control				
[4] pumped flow	0.0	m3/d	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				

9. A useful feature in GPS-X Lite is the ability to quickly review the changes the user has made to the default model settings. Right-click on the Bioreactor and navigate to **Summary of changes**. In the form that appears you should see a list of all input changes.

🚱 Summary of Input Changes		\times
Select process: Bioreactor (mlss)		
Bioreactor		5 3
[mlss] number of reactors	1	<u>ئا</u>
[mlss] specify oxygen transfer by	Entering Airflow	2
[mlss] total air flow into aeration tank	30000.0	m3/d 🏹
		Close

H

- 10. Click on the arrow button to the right of the **total air flow into aeration tank** variable in the form. The same form in Step 8 should appear. Close this window.
- 11. Save the model layout under an appropriate name (i.e. startingpoint).



To become familiar with how to navigate to various parts of the interface, recreate and fill out the table below through completion of the following steps. Make note of the units indicated in the table.

(Exercise 1 – Question 1)

	Model Object	Parameter	Unit	Value
Modelling Mode	Wastewater Influent	Influent Flow	m ³ /d	
	Bioreactor	Maximum Volume	m ³	
	Secondary Clarifier	Surface	m ²	
Simulation Mode	Influent	Ammonia	mgN/L	
	Bioreactor	Temperature	С	
	Bioreactor	Hydraulic Residence Time	hr	
	Secondary Clarifier	TSS Removal Efficiency	%	

- 12. Right-click on the Wastewater Influent object and navigate to *Flow* > *Flow Data* and report the value of the **influent flow** rate.
- 13. Right-click on the Bioreactor and navigate to *Input Parameters > Physical* and report the value of the **maximum volume**.
- 14. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Physical* and report the value of the **surface area**.
- 15. Switch into **simulation mode**. The "Model Builder" will activate if this is the first simulation to be conducted with the layout and its parameters. Once the model is built, run the simulation by pressing the Start button located in the bottom-left corner of the interface, on the simulation toolbar.



Note: Values will appear in the locations specified in the images below once the simulation has been run.

Below the Outputs menu ribbon, output tabs have been automatically created for the four model objects on the drawing board: Influent, Bioreactor, Secondary Clarifier, and Outfall.

16. Select the *Influent output tab* and report the **ammonia concentration** under the Simulation Results header.

Influent	Bioreactor	Secondary Clarifi	er Outfall
Influent			
Simulation R	esults		
	244	wwinf	
Flow	m3/d	-	
TSS	mg/L	-	
VSS	mg/L	-	
cBOD5	mg/L	-	
COD	mg/L	-	
Soluble COD	mg/L		-
Ammonia N	mgN/L		
TKN	mgN/L	-	
TN	mgN/L	-	
Soluble PO4-I	P mgP/L	-	
TP	mgP/L		
Alkalinity	mgCaC	03/L -	
Total Alkalinit	y mgCaC	03/L -	
pН	-	-	

17. Select the *Bioreactor output tab* and report the temperature in the top section of the panel.



18. Right-click on the mlss stream of the Bioreactor (ensure that the mouse changes to a connecting arrow before clicking) and navigate to *Output Variables > Hydraulic Variables and* report the **hydraulic residence time** in the table.



19. Right-click on the effluent stream of the Secondary Clarifier (ensure that the mouse changes to a connecting arrow before clicking) and navigate to *Output Variables > Performance Variables and* report the **TSS removal efficiency** in the table.



Select the *Bioreactor output tab*, and in the top-right corner of the panel, choose from the **Display** dropdown, **Ammonia N**. Notice that the values of the streams on the bioreactor image will become updated. Report a screenshot of these results. (Exercise 1 – Question 2)



Exercise 2 – Influent Advisor

This exercise will explore two concepts related to wastewater influent characterization.

- a) Relationship between state and composite variables using the GPS-X influent advisor tool
- b) Effect of influent characterization on plant performance
 - 1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Switch into Modelling Mode.
- 3. Right-click on the Influent Wastewater object and navigate to *Composition > Influent Characterization* to open the **Influent Advisor** tool.

Infl	Influent Advisor - Library: cnlib - Influent Model: codstates - Biological Model: asm 1 🗵													
Γ	Jser I	nputs			_	Stat	e Variables				Compo	site Variables		
1	nflue	nt Composition			4	Inor	ganic Suspended Solids				Volatile Fraction			
0	od	total COD	gCOD/m3	430.0	₽	xii	inert inorganic suspen	ded solids	g/m3	59.7	ivt	VSS/TSS ratio	gVSS/gTSS	0.75
t	kn	total TKN	gN/m3	40.0		Orga	anic Variables				Compo	site Variables		
5	nh	free and ionized ammonia	aN/m3	25.0		si	soluble inert organic n	naterial	gCOD/m3	21.5	x	total suspended solids	g/m3	238.9
	lissol	ved Oxygen				ss	readily biodegradable	substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.2
s	0	dissolved oxygen	g02/m3	0.0		xi	particulate inert organ	ic material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	59.7
	Vitroc	en Compounds				xs	slowly biodegradable	substrate	aCOD/m3	266.6	bod	total carbonaceous BOD5	a02/m3	232.7
s	no	nitrate and nitrite	gN/m3	0.0		xbh	active beterotrophic bi	omass	aCOD/m3	0.0	cod	total COD	aCOD/m3	430.0
s	nn	dinitrogen	gN/m3	0.0		vha	active autotrophic bio	mass	aCOD/m3	0.0	tkn	total TKN	aN/m3	40.0
12	Alkalii	nity				xba	active autotrophic bio		gcob/m3	Additio	nal Composite Variables	greens	40.0	
s	salk alkalinity mole/m3 7.0 xu unbiodegradable particulates from cell decay gCOD/m3 0.0									sbod	filtered carbonaceous BOD5	aO2/m3	56.8	
Į	nflue	nt Fractions				xsto	internal cell storage pr	oduct	gCOD/m3	0.0	wheel	particulate carbonaceour ROD5	a02/m2	176.0
ļ	cv	XCOD/VSS ratio	gCOD/gVSS	1.8		Diss	olved Oxygen		-02/2	0.0	abadu	Elected ultimate and an and a solo	-02/2	05.0
f	bod	BOD5/BODultimate ratio	-	0.66		Nite	dissolved oxygen		g02/ms	0.0	sbodu	Intered utimate carbonaceous BOD	gO2/ms	80.0
i	vt	VSS/TSS ratio	gVSS/gTSS	0.75		snh	free and ionized amm	onia	aN/m3	25.0	xbodu	particulate ultimate carbonaceous BOD	gO2/m3	266.6
	Organ	ic Fractions					and while his designable		nNI/m2	2 70	bodu	total ultimate carbonaceous BOD	gO2/m3	352.6
f	rsi	soluble inert fraction of total COD	-	0.05		snu .	soluble blodegradable	organic nitrogen	giv/ms	2.10	scod	filtered COD	gCOD/m3	107.5
f	rss	readily biodegradable fraction of total COD	-	0.2		xnd	particulate biodegrada	ble organic nitrogen	gN/m3	8.87	xcod	particulate COD	gCOD/m3	322.5
f	rxi	particulate inert fraction of total COD	-	0.13		sno	nitrate and nitrite		gN/m3	0.0	stkn	filtered TKN	gN/m3	27.8
f	rxu	part, cell decay products fraction of total COD		0.0		snn	dinitrogen		gN/m3	0.0	xtkn	particulate TKN	gN/m3	12.2
f	ryhh	heterotrophic biomass fraction of total COD		0.0		Alka	linity				tn	total nitrogen	aN/m3	40.0
	n/ba	autotrophic biomass fraction of total COD		0.0		salk	alkalinity		mole/m3	7.0			3	
Ľ	litror	autonophic biomass naction of total COD	-	0.0							Stoichi	ometric Ratios		
l f	rsnh	ammonium fraction of soluble TKN		0.9							¢ co) / TKN	aCOD/aN	10.8
12	ASM1	Nutrient Fractions										Dhinden / TKN	-COD/-N	0.02
i	xbn	N content of active biomass	gN/gCOD	0.086								Line (marked)	JCOD/giv	0.02
i i	kun	N content of endogenous/inert mass	aN/aCOD	0.06							S NH	1/ IKN		0.625
	-	,,	J								⊈ VSS	/ TSS	gVSS/gTSS	0.75
											¢ xco	DD / VSS	gCOD/gVSS	1.8
											¢ BOI	O / COD	gO2/gCOD	0.541
							Kan Gara Ma Calantina							
						Equa	don for : No selection	NO SELECTION				Change select	on by :	
												Clicking	on variable	
												O moving	over variable	
						_								
1	. 6	Set values to Raw Primary										Ac	cent	Cancel
×		Primary										AC	.epc	cancel

The Influent Advisor is divided into 3 sections: User Inputs, State Variables, and Composite Variables. The following segment provides some background into how these variables are related in the carbon, nitrogen library (cnlib) in GPS-X.

User Inputs – these values are editable by the user (Note: **access is limited to Influent Fractions** in GPS-X Lite)

State Variables – these are the basic variables that are continuously integrated in the model over time. In practical applications the state variables are typically not easily measurable or interpretable.

Composite Variables – these are variables that are calculated (composed of) the state variables. Unlike the state variables, the composite variables can be combined into forms that are typically measured, such as TSS, BOD, COD, and TKN.

The box-and-arrow diagrams below demonstrate the relationships that exist between the user inputs and state and composite variables. The notation is as follows:

- Variables in **BOLD CAPITALS** are the composite variables
- Connection line shows the direction of the calculation
- Multiple lines converging indicate summation
- Stoichiometric parameters above a connection line indicate multiplication of the parameter with the previous boxed variable
- A broken line indicates that the stoichiometric parameters are model dependent

Note: GPS-X uses the usual assumption that 1 mg ultimate BOD equals 1 mg of degradable COD.

The definitions of the state and composite variables used in diagrams are summarized in the table below.

	State Variables		Composite Variables
si	Soluble inert material	BOD ₅	5-day Biological Oxygen Demand
SS	Readily biodegradable soluble substrate	SBOD ₅	Soluble BOD₅
xs	Slowly biodegradable substrate	XBOD ₅	Particulate BOD₅
xbh	Heterotrophic biomass	BODu	Ultimate Biological Oxygen Demand
xba	Autotrophic biomass	SBODu	Soluble BOD _U
xsto	Internal cell storage products	XBOD _U	Particulate BOD _U
xu	Unbiodegradable cell products	COD	Chemical Oxygen Demand
xi	Particulate inert material	SCOD	Soluble COD
xii	Inorganic inert particulate	XCOD	Particulate COD
sno	Nitrite and nitrate	Х	Total Suspended Solids
snh	Ammonia nitrogen	VSS	Volatile Suspended Solids
snd	Soluble organic nitrogen	XISS	Total Inorganic Suspended Solids
xnd	Particulate biodegradable organic	TN	Total Nitrogen
	nitrogen		
		ΤΚΝ	Total Kjeldahl Nitrogen
		STKN	Soluble TKN
		XTKN	Particulate TKN

a) Relationship between the CNLIB state variables and the TSS, BOD, and COD composite variables





b) Relationship between the CNLIB state variables and the TN and TKN composite variables

Visualization of the relationships outlined above can be explored using the GPS-X Influent Advisor tool.

4. Select the **total suspended solids** (**x**) variable within the 3rd panel in the window under the Composite Variables header.

Selection of this variable should highlight the volatile suspended solids variable (vss) under the Composite Variables panel and the VSS/TSS ratio (ivt) under the User Inputs column.

This relationship is also presented at the bottom of the window in the form of an equation:

$$x = \frac{vss}{ivt}$$

Influen	t Advisor - Library: cnlib - Influent Model: cods	tates - Biolog	ical Mode	l: asm1									2
User	Inputs	State Variables								Compo	site Variables		
Influ	ent Composition			4	Inore	ganic Suspended Solids				Volatile Fraction			
cod	total COD	gCOD/m3	430.0		xii	inert inorganic suspend	led solids	g/m3	59.7	ivt	VSS/TSS ratio	gVSS/gTSS	0.75
tkn	total TKN	gN/m3	40.0		Orga	anic Variables				Compo	site Variables		
snh	free and ionized ammonia	aN/m3	25.0		si	soluble inert organic m	aterial	gCOD/m3	21.5	x			238.9
Diss	olved Oxvaen	2.			ss	readily biodegradable s	ubstrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.2
so	dissolved oxygen	g02/m3	0.0		xi	particulate inert organi	c material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	59.7
Nitro	gen Compounds	-			xs	slowly biodegradable s	ubstrate	aCOD/m3	266.6	bod	total carbonaceous BOD5	aO2/m3	232.7
sno	nitrate and nitrite	gN/m3	0.0		xbb	active beterotrophic hi	omass	aCOD/m3	0.0	cod	total COD	aCOD/m3	430.0
snn	dinitrogen	gN/m3	0.0		wha	active autotrophic bio		aCOD/m2	0.0	tke	total COD	abl/m2	40.0
Alka	linity	-			xba	active autotrophic bior	nass	gCOD/ms	0.0	tkn Additio	total IKN nal Composite Variables	giv/ms	40.0
salk	alkalinity	mole/m3	7.0		xu	unbiodegradable partic	culates from cell decay	gCOD/ms	0.0	shod	filtered carbonaceous BOD5	a02/m3	56.8
Influ	ent Fractions				xsto	internal cell storage pro	oduct	gCOD/m3	0.0	wheel	natioulate esthereseaux RODS	g02/m2	176.0
icv	XCOD/VSS ratio	gCOD/gVSS	1.8		Diss	olved Oxygen				xbou	particulate carbonaceous BODS	g02/m5	170.0
fbod	BOD5/BODultimate ratio	-	0.66		so	dissolved oxygen		g02/m3	0.0	sbodu	filtered ultimate carbonaceous BOD	g02/m3	86.0
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		Nitro	ogen Compounds		ALC . 2	25.0	xbodu	particulate ultimate carbonaceous BOD	g02/m3	266.6
Orga	nic Fractions				snn	Tree and Ionized ammo	nia	giv/m3	25.0	bodu	total ultimate carbonaceous BOD	g02/m3	352.6
frsi	soluble inert fraction of total COD	-	0.05		snd	soluble biodegradable	organic nitrogen	gN/m3	2.78	scod	filtered COD	gCOD/m3	107.5
frss	readily biodegradable fraction of total COD		0.2		xnd	particulate biodegrada	ble organic nitrogen	gN/m3	8.87	xcod	particulate COD	gCOD/m3	322.5
frxi	particulate inert fraction of total COD		0.13		sno	nitrate and nitrite		gN/m3	0.0	stkn	filtered TKN	aN/m3	27.8
from	part, cell decay products fraction of total COD		0.0		snn	dinitrogen		gN/m3	0.0	xtkn	particulate TKN	aN/m3	12.2
find the	hatersteachig biogene faction of total COD	-	0.0		Alka	linity				to	total nitrogen	aN/m2	40.0
TIXD	neterotrophic biomass fraction of total COD	-	0.0		salk	alkalinity		mole/m3	7.0	u	totarmitrogen	giv/m5	40.0
trxba	autotrophic biomass fraction of total COD	-	0.0							Ctolchi	amotris Paties		
INIT:	ogen Fractions		0.0							d cor		600 / N	10.0
ACM	1 Nutrient Francisme	-	0.9							G COL	J/ IKN	gCOD/gN	10.8
ixho	N content of active biomass	aN/aCOD	0.086							¢ coi	Dbiodeg / TKN	gCOD/gN	8.82
	N content of endogenous/inert m	aN/aCOD	0.06							¢ NH	1 / TKN		0.625
ixun	in content of endogenous/inert mass	gw/gCOD	0.00							¢ VSS	/ TSS	gVSS/gTSS	0.75
										¢ xcc	DD / VSS	gCOD/gVSS	1.8
										¢ BOE	/ COD	O2/gCOD	0.541
				Г	Four	tion for : x							
					Lquu		x = vss/ivt				Change select	on by:	
									 clicking 	on variable			
										O moving	over variable		
				-	_								_
×	Set values to : Raw Primary										Ac	ept	Cancel

5. Select the volatile suspended solids variable to determine how this composite variable is calculated.

Influent Advisor - Library: cnlib - Influent Model: codstates - Biological Model: asm1 🗵														
User	Inputs				State	e Variables				Compo	site Variables			
Influe	nt Composition				Inore	ganic Suspended Solids				Volatile	Fraction			
cod	total COD	gCOD/m3	430.0		xii	inert inorganic susper	nded solids	g/m3	59.7	ivt	VSS/TSS ratio		gVSS/gTSS	0.75
tkn	total TKN	gN/m3	40.0		Orga	nic Variables				Compo	site Variables			
snh	free and ionized ammonia	gN/m3	25.0		si	soluble inert organic i	material	gCOD/m3	21.5	x	total suspended solids		g/m3	238.9
Disso	ved Oxygen	-			ss	readily biodegradable	substrate	gCOD/m3	86.0	vss				179.2
so	dissolved oxygen	gO2/m3	0.0		xi	particulate inert organ	nic material	gCOD/m3	55.9	xiss	total inorganic suspende	ed solids	g/m3	59.7
Nitro	en Compounds				xs	slowly biodegradable	substrate	gCOD/m3	266.6	bod	total carbonaceous BOD	5	gO2/m3	232.7
sno	nitrate and nitrite	gN/m3	0.0		xbh	active heterotrophic b	iomass	aCOD/m3	0.0	cod	total COD		aCOD/m3	430.0
snn	dinitrogen	gN/m3	0.0		vha	active autotrophic his	mass	aCOD/m3	0.0	tkn	total TKN		aN/m3	40.0
Alkali	nity					unhindenradable part	inulator from cell decau	aCOD/m2	0.0	Additic	nal Composite Variables		gre/mo	40.0
salk	alkalinity	mole/m3	7.0		×u.	unbiodegradable part	iculates from cell decay	gcob/ms	0.0	sbod	filtered carbonaceous BC	DD5	aO2/m3	56.8
Influe	nt Fractions				xsto	internal cell storage p	roduct	gCOD/m3	0.0	xhod	particulate carbonaceou	s BOD5	a02/m3	176.0
icv	XCOD/VSS ratio	gCOD/gVSS	1.8		Diss	dissolved ovvigen		a02/m2	0.0	chodu	filtered ultimate carbona		g02/m2	96.0
fbod	BOD5/BODultimate ratio	-	0.66		Nitre	assorved oxygen		g02/115	0.0	sbouu	nicered dicinate carbona	POD	g02/m3	266.6
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		snh	free and ionized amm	ionia	aN/m3	25.0	xbodu	particulate ultimate carb	onaceous bob	g02/m5	200.0
Organ	ic Fractions				snd	soluble biodegradable	e organic nitrogen	aN/m3	2 78	bodu	total ultimate carbonace	ous BOD	g02/m3	352.6
frsi	soluble inert fraction of total COD	-	0.05		und	particulate biodegrad	able organic nitrogen	aN/m2	0 07	scod	filtered COD		gCOD/m3	107.5
frss	readily biodegradable fraction of total COD	-	0.2		XIIU	particulate biodegrad	able organic microgen		0.07	xcod	particulate COD		gCOD/m3	322.5
frxi	particulate inert fraction of total COD	-	0.13		sno	nitrate and nitrite		giv/ms	0.0	stkn	filtered TKN		gN/m3	27.8
frxu	part. cell decay products fraction of total COD	-	0.0		snn	dinitrogen		gN/m3	0.0	xtkn	particulate TKN		gN/m3	12.2
frxbh	heterotrophic biomass fraction of total COD	-	0.0		Alka	linity			7.0	tn	total nitrogen		gN/m3	40.0
frxba	autotrophic biomass fraction of total COD		0.0		Sdik	aikalinity		mole/ms	7.0					
Nitro	en Fractions									Stoichi	ometric Ratios			
frsnh	ammonium fraction of soluble TKN	-	0.9							¢ co	D / TKN		gCOD/gN	10.8
ASM1	Nutrient Fractions									¢ co	Dbiodea / TKN		aCOD/aN	8.82
ixbn	N content of active biomass	gN/gCOD	0.086							C NH	4 / TKN			0.625
ixun	N content of endogenous/inert mass	gN/gCOD	0.06							e ve	/ TCC		2275/22/05	0.75
										4 V33	7 133			1.0
											JD / VSS		gCOD/gvss	1.8
										¢ BOI	D / COD		g02/gC0D	0.541
					Equa	tion for : vss	ves - xcod/icv					Change coloct	ion huu	
							v33 - xcou/ icv					clicking	on variable	
												© circking	on variable	
												⊖ moving	over variable	
					_								-1	
X I	Set values to : Raw Primary											Ac	cept	Cancel

Substitute the equation for vss into the previous equation for x.

$$x = \frac{vss}{ivt}$$
$$x = \frac{\left(\frac{xcod}{icv}\right)}{ivt}$$

Now find the equation for x in terms of *cod*, *scod*, *icv*, and *ivt* by selecting the appropriate item to reveal the corresponding equation and substituting it into the above equation. In a similar manner determine the equation for x in terms of *cod*, *frss*, *frsi*, *icv*, and *ivt*. (Note: these variables define x solely in terms of user input variables.) (Exercise 2 -Question 1)

6. Select the total carbonaceous BOD₅ (bod) variable within the Composite Variables panel under the Composite Variables header.

Influer	nfluent Advisor - Library: cnlib - Influent Model: codstates - Biological Model: asm 1 🗹												
Use	r Inputs				State	e Variables				Compo	site Variables		
Influ	ent Composition			4	Inore	ganic Suspended Solids				Volatile	Fraction		
cod	total COD	gCOD/m3	430.0		xii	inert inorganic suspend	ded solids	g/m3	59.7	ivt	VSS/TSS ratio	gVSS/gTSS	0.75
tkn	total TKN	gN/m3	40.0		Orga	nic Variables				Compo	site Variables		
snh	free and ionized ammonia	gN/m3	25.0		si	soluble inert organic m	aterial	gCOD/m3	21.5	x	total suspended solids	g/m3	238.9
Diss	olved Oxygen	-			ss	readily biodegradable	substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.2
so	dissolved oxygen	gO2/m3	0.0		xi	particulate inert organi	c material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	59.7
Nitr	ogen Compounds				xs	slowly biodegradable s	ubstrate	gCOD/m3	266.6	bod		g02/m3	232.7
sno	nitrate and nitrite	gN/m3	0.0		xbh	active heterotrophic bi	omass	gCOD/m3	0.0	cod	total COD	gCOD/m3	430.0
snn	dinitrogen	gN/m3	0.0		xba	active autotrophic bior	nass	gCOD/m3	0.0	tkn	total TKN	gN/m3	40.0
Alka	linity	1			xu	unbiodegradable partic	ulates from cell decay	aCOD/m3	0.0	Additio	nal Composite Variables	1	
salk	alkalinity	mole/m3	7.0		vete	internal cell storage pre	duct	aCOD/m2	0.0	sbod	filtered carbonaceous BOD5	g02/m3	56.8
Influ	ent Fractions				Diec	Internal cell storage pro	Juuci	gcob/ms	0.0	xbod	particulate carbonaceous BOD5	g02/m3	176.0
ICV	XCOD/VSS ratio	gCOD/gVSS	1.8		50	dissolved oxygen		aO2/m3	0.0	sbodu	filtered ultimate carbonaceous BOD	aO2/m3	86.0
fbo	BOD5/BODultimate ratio	-	0.66		Nitro	ogen Compounds				xbodu	particulate ultimate carbonaceous BO	n02/m3	266.6
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		snh	free and ionized ammo	nia	gN/m3	25.0	hodu	total ultimate carbonaceous BOD	a02/m3	352.6
Org	inic Fractions				snd	soluble biodegradable	organic nitrogen	qN/m3	2.78	bouu	Chandle COD	-000/2	107.5
trsi	soluble inert fraction of total COD	-	0.05		xnd	particulate biodegrada	ble organic nitrogen	aN/m3	8.87	scoa	filtered COD	gCOD/ms	107.5
frss	readily biodegradable fraction of total COD	-	0.2		cno	pitrate and pitrite	one organice introgen	aN/m2	0.0	xcod	particulate COD	gCOD/m3	322.5
frxi	particulate inert fraction of total COD	-	0.13		SHO	diate and mone		sN/2	0.0	stkn	filtered TKN	gN/m3	27.8
frxu	part. cell decay products fraction of total COD	-	0.0		snn	ainitrogen		giv/ms	0.0	xtkn	particulate TKN	gN/m3	12.2
frxb	h heterotrophic biomass fraction of total COD	-	0.0		Alka	alkalinity		mole/m3	70	tn	total nitrogen	gN/m3	40.0
frxb	a autotrophic biomass fraction of total COD	-	0.0		Jam	ununuy							
Nitr	ogen Fractions									Stoichi	ometric Ratios		
frsn	ammonium fraction of soluble TKN	-	0.9							¢ cor) / TKN	gCOD/gN	10.8
ASN	11 Nutrient Fractions									¢ cor	Dbiodeg / TKN	gCOD/gN	8.82
ixbr	N content of active biomass	gN/gCOD	0.086							¢ NH4	1 / TKN		0.625
ixur	N content of endogenous/inert mass	gN/gCOD	0.06							¢ vss	/ TSS	gVSS/gTSS	0.75
										d xcc	D / VSS	aCOD/aVSS	1.8
										C BOL		a02/aC0D	0.541
										4 000	,, cob	902/9000	0.341
					Equa	tion for : bod	bod = bodu*fbod				Change sele	tion by :	
											clickin	g on variable	
											O movir	- n over variable	
												5	
												1	
×∎	Set values to : Raw Primary											ccept	Cancel

- Repeat the same process as in steps 4-5, to determine the equation relating total BOD₅ (bod) to total COD (cod) using the appropriate Influent Fractions" and Organic Fractions" parameters., (Exercise 2 Question 2). Please note that xsto is not a state variable in ASM1 and it is not included in the calculations.
- 8. Close the Influent Advisor.
- 9. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and change the **total** air flow into aeration tank to 20,000 m³/d.

Operational										
Aeration Setup										
[mlss] aeration method	Diffused Air		•							
[mlss] specify oxygen transfer by	s] specify oxygen transfer by Entering Airflow									
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	~							
More										
Diffused Aeration				_						
[mlss] total air flow into aeration tank	20000.0	m3/d	•							
[mlss] distribution of air flow to aeration tank	()	-	-							
More										
Mechanical (Surface Aeration)										
[mlss] aeration power	()	kW	~							
More										
Aeration Control										
[mlss] DO setpoint	()									
More										
Pumped Flow Control										
[4] pumped flow	0.0	m3/d	•							
[blank] controller	OFF									
[blank] setpoint for control variable	1.0									
More										
		Accept		Cancel						

10. Right-click on the Secondary Clarifier and navigate to *Input Parameters* > *Operational* and change the **pumped flow** to **100** m^{3}/d .

perational				
Underflow				
[RAS] proportional recycle	OFF			
stream label to which recycle is proportional	blank			D
[RAS] recycle fraction	0.8		~	
[RAS] underflow rate	2000.0	m3/d	•	
[RAS] underflow from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Pumped Flow				
[WAS] pumped flow	100.0	m3/d	•	Ľ
[WAS] pump from layer	()	-	•	C
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Model Parameters				
[effluent] sludge blanket threshold concentration	2000.0	mgTSS/L	•	
[effluent] critical sludge blanket level	0.1	m	•	
State-Point Analysis Model Parameters				
[effluent] use design MLSS in state point analysis	ON			
[effluent] design MLSS concentration	3000.0	mgTSS/L	•	

- 11. Switch into Simulation Mode. Rebuild the model when prompted.
- 12. From the Simulation Toolbar navigate to *Scenario* > *New* and create a new scenario called "Influent."

New Scenario	×
What is a Scenario?	
When organizing simulation runs it is useful to start with a bas then create one or more separate cases, which are modification data set. These cases are referred to a scenarios in GPS-X. GPS create your own scenarios. In each scenario you can specify th model parameter(s), which define the scenario and then save t that it can be restored at some point in the future.	e set of data, and ns to the base -X allows you to e changes to the he scenario so
For more information, refer to the User's Guide.	
New Scenario	
De économic (economic de la conomica	
Name:	
Name : Influent	
Name : Influent	

In the following scenarios you will explore the effect of changes in the influent characterization on the plant performance.

Scenario 1 - XCOD/VSS Ratio

In a word processor, create the table below to record your answers for the following steps.

	Influent	Bioreactor	Secondary Clarifier
XCOD/VSS	TSS (mg/L)	MLSS (mg/L)	RAS TSS (mg/L)
Katio = 1.8	VSS (mg/L)	MLVSS (mg/L)	Effluent TSS (mg/L)
XCOD/VSS	TSS (mg/L)	MLSS (mg/L)	RAS TSS (mg/L)
Kauo = 1.4	VSS (mg/L)	MLVSS (mg/L)	Effluent TSS (mg/L)

- D
- 13. Run the simulation at steady-state. By default, the XCOD/VSS Ratio (icv) is set to 1.8, fbod= 0.66, and ivt = 0.75. Check the Influent Advisor (Step 3 above).
- 14. Through navigation to the various output tabs, record your observations in the table. In addition, report a screenshot of the simulation results on the Outfall output tab. (Exercise 2 Question 3)



Influent Biore	actor Second	lary Clarifier
Outfall		
Simulation Resul	ts	effluent
Flow	m3/d	
TSS	mg/L	
VSS	mg/L	
cBOD5	ma/L	
COD	mg/L	-
Ammonia N	mgN/L	
Nitrite N	mgN/L	
Nitrate N	mgN/L	-
Nitrite/Nitrate N	maN/L	
TIZNI	mgN/L	-
INN		
TN	maN/L	-
TN Soluble PO4-P	mgN/L mgP/L	
TN Soluble PO4-P TP	mgN/L mgP/L mgP/L	
TN Soluble PO4-P TP Alkalinity	mgN/L mgP/L mgP/L mgCaCO3/L	•
TN Soluble PO4-P TP Alkalinity Total Alkalinity	mgN/L mgP/L mgCaCO3/L mgCaCO3/L	- - -

15. Right-click on the Influent Wastewater object and navigate to *Composition* > *Influent Characterization*. In the User Inputs panel, under the Influent Fractions header adjust the XCOD/VSS ratio (icv) to 1.4. (**Note**: In Simulation mode, you can edit the Influent Characterization ONLY in new scenarios, not the Default Scenario.)

User	Immuniter												
	inputs			4	Stat	e Variables				Сотро	site Variables		
Influ	ent Composition			•	Inor	ganic Suspended Solids				Volatile	Fraction		_
cod	total COD	gCOD/m3	430.0		xii	inert inorganic suspen	ded solids	g/m3	76.8	ivt	VSS/TSS ratio	gVSS/gTSS	0.
tkn	total TKN	gN/m3	40.0		Orga	anic Variables				Compo	site Variables		_
snh	free and ionized ammonia	gN/m3	25.0		si	soluble inert organic m	aterial	gCOD/m3	21.5	×	total suspended solids	g/m3	307
Disso	lved Oxygen				ss	readily biodegradable	substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	230
50	dissolved oxygen	gO2/m3	0.0		xi	particulate inert organi	c material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	7
Nitro	qen Compounds				xs	slowly biodegradable s	ubstrate	gCOD/m3	266.6	bod	total carbonaceous BOD5	g02/m3	23
sno	nitrate and nitrite	gN/m3	0.0		xbh	active heterotrophic bi	omass	qCOD/m3	0.0	cod	total COD	gCOD/m3	43
snn	dinitrogen	gN/m3	0.0		xha	active autotrophic bior	nass	aCOD/m3	0.0	tkn	total TKN	aN/m3	4
Alka	inity					under and a second a bill a second		-COD/2	0.0	Additio	nal Composite Variables	9.4,1115	
salk	alkalinity	mole/m3	7.0			unbiodegradable parti	unates from cell decay	gcob/ms	0.0	sbod	filtered carbonaceous BOD5	a02/m3	5
Influ	ent Fractions				xsto	internal cell storage pro	oduct	gCOD/m3	0.0	vhod	particulate carbonaceous BOD5	a02/m3	17
icv	XCOD/VSS ratio	gCOD/gVSS	1.4		Diss	olved Uxygen		-02/2	0.0	-hodu	Ethernel article to an and a second second second	-02/2	
fbod	BOD5/BODultimate ratio	-	0.66		SO	dissolved oxygen		g02/m5	0.0	sbodu	filtered ultimate carbonaceous BOD	g02/ms	
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		coh	free and ionized ammo	nia	aN/m3	25.0	xbodu	particulate ultimate carbonaceous BOD	g02/m3	26
Orga	nic Fractions				3111	Thee and forfized affiline		giv/iiis	2,3.0	bodu	total ultimate carbonaceous BOD	g02/m3	35
frsi	soluble inert fraction of total COD	-	0.05		sna	soluble biodegradable	organic nitrogen	giv/ms	2.78	scod	filtered COD	gCOD/m3	10
frss	readily biodegradable fraction of total COD	-	0.2		xnd	particulate biodegrada	ble organic nitrogen	gN/m3	8.87	xcod	particulate COD	gCOD/m3	32
frxi	particulate inert fraction of total COD		0.13		sno	nitrate and nitrite		gN/m3	0.0	stkn	filtered TKN	gN/m3	2
frxu	nart, cell decay products fraction of total COD		0.0		snn	dinitrogen		gN/m3	0.0	xtkn	particulate TKN	aN/m3	1
£	hataratia his man fastian after I COD		0.0		Alka	linity				to	total nitrogen	aN/m3	4
inx br	neterotrophic biomass fraction of total COD		0.0		salk	alkalinity		mole/m3	7.0		total introgen	groms	-
trxba	autotrophic biomass fraction of total COD	-	0.0							Chalabi	emetric Paties		
Nitro	gen Fractions		0.0							storen	ometric ratios		
ACM	Ammonium fraction of soluble TKIN		0.9							G COI	D/ IKN	gCOD/gN	1
ASIVI	Number to a stick biomass	eN/eCOD	0.026							¢ coi	Obiodeg / TKN	gCOD/gN	8
	N content of active biomass	giv/gcob	0.000							¢ NH	4 / TKN	-	0.6
ixun	N content of endogenous/inert mass	gN/gCOD	0.06							¢ VSS	/ TSS	gVSS/gTSS	0
										¢ xco	DD / VSS	qCOD/qVSS	
										C BOI		a02/aC0D	0.5
										4 000	,,	902/9000	
					Equa	tion for : No Selection					Characteristic	tan buu	
							NO SEECTION				aliabian	ion by :	
												over variable	

16. Rerun the simulation. Complete the table and report a screenshot of the results shown in the Outfall output tab. (Exercise 2 – Question 4)

Scenario 2 – BOD5/BODultimate ratio (Exercise 2 – Question 5)

17. Right-click on the Influent object and navigate to *Composition* > *Influent Characterization*. Set all user inputs to the default values (icv = 1.8, fbod = 0.66, ivt = 0.75).

fluent	t Advisor - Library: cnlib - Influent Model: cods	tates - Biolog	jical Mode	l: asm1								
User	Inputs			4	Stat	te Variables			Comp	site Variables		
Influe	ent Composition				Ino	rganic Suspended Solids			Volatil	Fraction		
cod	total COD	gCOD/m3	430.0		xii	inert inorganic suspended solids	g/m3	59.7	ivt	VSS/TSS ratio	gVSS/gTSS	0.75
tkn	total TKN	gN/m3	40.0		Org	anic Variables			Comp	osite Variables		
snh	free and ionized ammonia	gN/m3	25.0		si	soluble inert organic material	gCOD/m3	21.5	×	total suspended solids	g/m3	238.
Disso	lived Oxygen				SS	readily biodegradable substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.
so	dissolved oxygen	g02/m3	0.0		xi	particulate inert organic material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	59.
Nitro	gen Compounds				xs	slowly biodegradable substrate	gCOD/m3	266.6	bod	total carbonaceous BOD5	gO2/m3	232.
sno	nitrate and nitrite	gN/m3	0.0		xbh	active heterotrophic biomass	gCOD/m3	0.0	cod	total COD	gCOD/m3	430.
snn	dinitrogen	gN/m3	0.0		xba	active autotrophic biomass	aCOD/m3	0.0	tkn	total TKN	aN/m3	40.
Alkal	inity				×11	unbiodegradable particulates from cell deca	aCOD/m3	0.0	Additi	onal Composite Variables	5	
salk	alkalinity	mole/m3	7.0			internal cell starsee meduat	#COD/m2	0.0	sbod	filtered carbonaceous BOD5	g02/m3	56.
Influe	ent Fractions				Dier	internal cell storage product	gcob/ms	0.0	xbod	particulate carbonaceous BOD5	aO2/m3	176.
icv	XCOD/VSS ratio	gCOD/gVSS	1.8		so	dissolved oxygen	a02/m3	0.0	shodu	filtered ultimate carbonaceous BOD	a02/m3	86
fbod	BOD5/BODultimate ratio	-	0.66		Nitr	rogen Compounds	900,000	0.0	vhodu	naticulate ultimate carbonaccous POD	a02/m2	266
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		snh	free and ionized ammonia	gN/m3	25.0		particulate ultimate carbonaceous bob	902/113	200.
Orqa	nic Fractions				snd	soluble biodegradable organic pitrogen	aN/m3	2.78	bodu	total ultimate carbonaceous BOD	gU2/m3	352.
frsi	soluble inert fraction of total COD	-	0.05		v nd	particulate biodegradable organic nitrogen	aN/m2	0.07	scod	filtered COD	gCOD/m3	107.
frss	readily biodegradable fraction of total COD	-	0.2		xnu	particulate biodegradable organic hitrogen	giv/ms	0.07	xcod	particulate COD	gCOD/m3	322.
fnci	particulate inert fraction of total COD	-	0.13		sno	nitrate and nitrite	gN/m3	0.0	stkn	filtered TKN	gN/m3	27.
frxu	part. cell decay products fraction of total COD	-	0.0		snn	dinitrogen	gN/m3	0.0	xtkn	particulate TKN	gN/m3	12.
frxbh	heterotrophic biomass fraction of total COD	-	0.0		Alk	alinity		7.0	tn	total nitrogen	gN/m3	40.
fryba	autotrophic biomass fraction of total COD		0.0		salk	alkalinity	mole/m3	7.0		-	-	
Nitro	gen Fractions		010						Stoich	iometric Ratios		
frsnh	ammonium fraction of soluble TKN	-	0.9						¢ co	D / TKN	aCOD/aN	10.
ASM	1 Nutrient Fractions								0 00	Dhinden (TKN	aCOD/aN	
ixbn	N content of active biomass	gN/gCOD	0.086						4 00		gcob/giv	0.0
ixun	N content of endogenous/inert mass	qN/qCOD	0.06						S INF	4/ IKN		0.02
	,								¢ VS	7 155	gVSS/g1SS	0.7
									¢ xc	DD / VSS	gCOD/gVSS	1.
									¢ BO	D / COD	gO2/gCOD	0.54
					Four	ation for : No Selection No or Forton						
					Lqui	NO SELECTION				Change select	ion by :	
										Clicking	on variable	
										O moving	over variable	
_					_	L						_
la I	Set values to : Raw Primary									Ac	cept	Canc

18. With all user inputs at the default values complete the first row of the table below with values from the Influent Advisor.

	Location	Total Carbonaceous BOD5 (bod)	Filtered Carbonaceous BOD5 (sbod)	Particulate Carbonaceous BOD5 (xbod)
BOD5/BODultimate ratio = 0.66	Influent (wwinf)			
	Bioreactor Effluent (mlss)			
BOD5/BODultimate = 0.4	Influent (wwinf)			
	Bioreactor Effluent (mlss)			

- 19. Close the Influent Advisor and run the simulation.
- 20. Right-click on the mlss steam and navigate to *Output Variables > Composite Variables* and complete the second row within the table. The value for mlss total carbonaceous BOD5 is provided in the first screen. Select the More... button to find another screen with filtered carbonaceous BOD5 and particulate carbonaceous BOD5 values.
- 21. Repeat steps 17-20 after adjusting the **BOD5/BODultimate ratio** in the Influent Advisor to **0.4**. Report the values in final two rows of the above table. Discuss the results.

Influent	t Advisor - Library: cnlib - Influent Model: cods	tates - Biolog	ical Mode	l: asm1								X
User	Inputs				Stat	e Variables			Compo	site Variables		
Influe	ent Composition				Inor	ganic Suspended Solids			Volatile	Fraction		
cod	total COD	gCOD/m3	430.0		xii	inert inorganic suspended solids	g/m3	59.7	ivt	VSS/TSS ratio	gVSS/gTSS	0.75
tkn	total TKN	gN/m3	40.0		Orga	anic Variables			Compo	osite Variables		
snh	free and ionized ammonia	gN/m3	25.0		si	soluble inert organic material	gCOD/m3	21.5	×	total suspended solids	g/m3	238.9
Disso	lved Oxygen				SS	readily biodegradable substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.2
so	dissolved oxygen	g02/m3	0.0		xi	particulate inert organic material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	59.7
Nitro	qen Compounds				xs	slowly biodegradable substrate	gCOD/m3	266.6	bod	total carbonaceous BOD5	gO2/m3	141.0
sno	nitrate and nitrite	gN/m3	0.0		xbh	active heterotrophic biomass	gCOD/m3	0.0	cod	total COD	gCOD/m3	430.0
snn	dinitrogen	gN/m3	0.0		xba	active autotrophic biomass	aCOD/m3	0.0	tkn	total TKN	aN/m3	40.0
Alkali	inity					unbiodegradable particulates from cell decay	aCOD/m3	0.0	Additio	nal Composite Variables	3.4	
salk	alkalinity	mole/m3	7.0			interest cell store as an dust	-COD/2	0.0	sbod	filtered carbonaceous BOD5	gO2/m3	34.4
Influe	ent Fractions		_		XSto	Internal cell storage product	gCOD/ms	0.0	xbod	particulate carbonaceous BOD5	aO2/m3	106.6
icv	XCOD/VSS ratio	gCOD/gVSS	1.8		co	dissolved oxygen	a02/m3	0.0	shodu	filtered ultimate carbonaceous BOD	a02/m3	86.0
fbod	BOD5/BODultimate ratio	-	0.4		Nitro	and compounds	902/115	0.0	wheelu	anticulate ultimate carbonaccous pop	g02/m3	266.6
ivt	VSS/TSS ratio	gVSS/gTSS	0.75		snh	free and ionized ammonia	aN/m3	25.0	xbouu	particulate ultimate carbonaceous BOD	g02/m5	200.0
Orga	nic Fractions				snd	soluble biodegradable organic nitrogen	aN/m3	2 78	bodu	total ultimate carbonaceous BOD	gO2/m3	352.6
frsi	soluble inert fraction of total COD	-	0.05		June	soluble blouegraubble organic mitogen	aNI/as2	0.07	scod	filtered COD	gCOD/m3	107.5
frss	readily biodegradable fraction of total COD	-	0.2		xnu	particulate biodegradable organic hitrogen	giv/ms	0.07	xcod	particulate COD	gCOD/m3	322.5
frxi	particulate inert fraction of total COD	-	0.13		sno	nitrate and nitrite	gN/m3	0.0	stkn	filtered TKN	gN/m3	27.8
frxu	part. cell decay products fraction of total COD	-	0.0		snn	dinitrogen	gN/m3	0.0	xtkn	particulate TKN	gN/m3	12.2
frxbh	heterotrophic biomass fraction of total COD	-	0.0		Alka	linity			tn	total nitrogen	gN/m3	40.0
frxha	autotrophic biomass fraction of total COD		0.0		saik	alkalinity	mole/ms	7.0		-	-	
Nitro	gen Fractions								Stoichi	ometric Ratios		
frsnh	ammonium fraction of soluble TKN	-	0.9						¢ co	D / TKN	aCOD/aN	10.8
ASM	1 Nutrient Fractions								¢	Dhinden / TKN	aCOD/aN	8.82
ixbn	N content of active biomass	gN/gCOD	0.086						4 CO		gcob/gr	0.635
ixun	N content of endogenous/inert mass	gN/gCOD	0.06						4 1917	(700		0.025
	1								4 VSS	/ 155	gv55/g155	0.75
									¢ XC	DD / VSS	gCOD/gVSS	1.8
									¢ BOI	D/COD	gO2/gCOD	0.328
					Equa	tion for : No Selection No STUTCTION				a		
						NO SELECTION				change select	ion by :	
										© clicking	on variable	
										O moving	over variable	
											1	_
X I	Set values to : Raw Primary									Ac	cept	Cancel



Scenario 3 – VSS/TSS Ratio (Exercise 2 – Question 6)

		VSS/TSS Ratio = 0.75	VSS/TSS Ratio = 0.9
	TSS (mg/L)		
Influent	Total Inorganic Suspended Solids (mg/L)		
Rioreactor	MLSS (mg/L)		
Diorcactor	Ammonia (mg/L)		
Secondary	Solids Loading Rate (kg/(m2.d))		
Clarifier	RAS COD (mg/l)		
	TSS (mg/L)		
Outfall	cBOD ₅ (mg/L)		
Outan	COD (mg/L)		
	TN (mg/L)		

In your word processor create the table below to record your responses for the following scenario.

22. Open the Influent Advisor and reset the BOD5/BODultimate ratio to the default value of 0.66. From the Composite Variables column of the Influent Advisor record the influent concentrations of total suspended solids (x) and total inorganic suspended solids (xiss) in the first two rows within the VSS/TSS Ratio = 0.75 column of the table.

11	- Income			Charl	- Madablaa				C	-it- Mariables		
Use	r Inputs		4	Stat	e variables				Velatik	site variables		
cod	total COD	aCOD/m3	430.0	vii	inert inorganic suspended	solids	a/m3	59.7	int	VSS/TSS ratio	aVSS/aTSS	0.7
the	total TVN	aN/m2	40.0	Ora	anic Variables	Solids	9/115	55.1	Compo	osite Variables	g100, g100	0
tKN	total INN	giv/ms	40.0	si	soluble inert organic mate	erial	aCOD/m3	21.5	x	total suspended solids	a/m3	238.
snh	free and ionized ammonia	gN/m3	25.0		readily biodegradable cub	strata	aCOD/m2	86.0		volatile suspended solids	g/m2	170
Diss	olved Oxygen			55	readily biodegradable sub	suate	gcob/ms	00.0	V55	volatile suspended solids	g/ms	179.
50	dissolved oxygen	g02/m3	0.0	×	particulate inert organic n	naterial	gCOD/m3	55.9	XISS	total inorganic suspended solids	g/m3	59.
Nitr	ogen Compounds	N/ 2	0.0	xs	slowly biodegradable sub	strate	gCOD/m3	266.6	bod	total carbonaceous BOD5	g02/m3	232.
sno	nitrate and nitrite	giv/ms	0.0	xbh	active heterotrophic biom	ass	gCOD/m3	0.0	cod	total COD	gCOD/m3	430.
nn	dinitrogen	gN/m3	0.0	xba	active autotrophic biomas	55	gCOD/m3	0.0	tkn	total TKN	gN/m3	40.
Alka	linity			xu	unbiodegradable particula	ates from cell decay	gCOD/m3	0.0	Additio	nal Composite Variables		
alk	alkalinity	mole/m3	7.0	xste	internal cell storage produ	urt -	aCOD/m3	0.0	sbod	filtered carbonaceous BOD5	gO2/m3	56.
ntlu	ent Fractions	600 () /60	10	Diss	olved Oxygen		J		xbod	particulate carbonaceous BOD5	g02/m3	176.
icv	XCOD/VSS ratio	gCOD/gvss	1.8	so	dissolved oxygen		a02/m3	0.0	sbodu	filtered ultimate carbonaceous BOD	a02/m3	86.
fbo	BOD5/BODultimate ratio	-	0.66	Nitr	ogen Compounds		J		vhodu	particulate ultimate carbonaceous POD	a02/m2	266
vt	VSS/TSS ratio	gVSS/gTSS	0.75	snh	free and ionized ammonia	1	aN/m3	25.0		particulate ultimate carbonaceous bob	902/113	200
Drq	anic Fractions			end	coluble biodegradable or	anic nitrogen	aN/m3	2 78	bodu	total ultimate carbonaceous BOD	g02/m3	352
rsi	soluble inert fraction of total COD	-	0.05	3Hu	Soluble blouegradable org	janie nierogen	growing a	2.10	scod	filtered COD	gCOD/m3	107
rss	readily biodegradable fraction of total COD	-	0.2	xna	particulate biodegradable	organic nitrogen	giv/m3	8.87	xcod	particulate COD	gCOD/m3	322.
ixi	particulate inert fraction of total COD	-	0.13	sno	nitrate and nitrite		gN/m3	0.0	stkn	filtered TKN	gN/m3	27.
	nart, cell decay products fraction of total COD	-	0.0	snn	dinitrogen		gN/m3	0.0	xtkn	particulate TKN	aN/m3	12.
	para cen accey produces nacion or total cop		0.0	Alka	linity				to	total pitrogen	aN/m2	40
TXD	n neterotrophic biomass fraction of total COD	-	0.0	salk	alkalinity		mole/m3	7.0	ui	total hittogen	giv/ms	40.
ixb	a autotrophic biomass fraction of total COD	-	0.0									
Vitr	ogen Fractions								Stoichi	ometric Katios		
rsn	ammonium fraction of soluble TKN	-	0.9						¢ coi	D / TKN	gCOD/gN	10.
ASN	11 Nutrient Fractions								¢ COI	Dbiodeg / TKN	gCOD/gN	8.8
xbr	N content of active biomass	gN/gCOD	0.086						¢ NH	4 / TKN	-	0.62
ixur	N content of endogenous/inert mass	gN/gCOD	0.06						¢ vss	/ TSS	aVSS/aTSS	0.7
									e xco		aCOD/aVSS	1
									4 100	0.000	001 000	
									G BOI	5700	g02/gC0D	0.54
				Equa	ation for : No Selection	SELECTION				Change select	ion by :	
										clicking	on variable	
										 cricking moving 	over variable	

- 23. Close the influent advisor and run the simulation. Complete the table by accessing the appropriate output tabs.
- 24. Repeat steps 22-23 for a VSS/TSS Ratio of 0.9 to complete the second column of the table.

nfluent	Advisor - Library: cnlib - Influent Model: cods	tates - Biologic	al Model:	asm1								[
User I	nputs			S	State Variables				Compo	site Variables		
Influe	nt Composition			님 브	norganic Suspended Solids				Volatile	Fraction		
cod	total COD	gCOD/m3	430.0	×	cii inert inorganic susper	ided solids	g/m3	19.9	ivt	VSS/TSS ratio	gVSS/gTSS	0.9
tkn	total TKN	gN/m3	40.0	(Organic Variables				Compo	site Variables		
snh	free and ionized ammonia	gN/m3	25.0	s	i soluble inert organic r	naterial	gCOD/m3	21.5	x	total suspended solids	g/m3	199.1
Dissol	ved Oxygen			s	is readily biodegradable	substrate	gCOD/m3	86.0	vss	volatile suspended solids	g/m3	179.2
so	dissolved oxygen	gO2/m3	0.0	x	i particulate inert organ	ic material	gCOD/m3	55.9	xiss	total inorganic suspended solids	g/m3	19.9
Nitrog	en Compounds			x	s slowly biodegradable	substrate	gCOD/m3	266.6	bod	total carbonaceous BOD5	gO2/m3	232.7
sno	nitrate and nitrite	gN/m3	0.0	x	bh active heterotrophic b	iomass	gCOD/m3	0.0	cod	total COD	gCOD/m3	430.0
snn	dinitrogen	gN/m3	0.0	x	ba active autotrophic bio	mass	qCOD/m3	0.0	tkn	total TKN	qN/m3	40.0
Alkalir	hity			×	unbiodegradable part	iculates from cell decav	aCOD/m3	0.0	Additio	nal Composite Variables		
salk	alkalinity	mole/m3	7.0		rsto internal cell storage p	roduct	aCOD/m3	0.0	sbod	filtered carbonaceous BOD5	gO2/m3	56.8
influe	NCOD 0/SS	-000/>/60	1.0		Dissolved Oxygen		3200,110	010	xbod	particulate carbonaceous BOD5	gO2/m3	176.0
	AC00/ V35 1810	gcob/gvss	1.8	s	o dissolved oxygen		g02/m3	0.0	sbodu	filtered ultimate carbonaceous BO) gO2/m3	86.0
fbod	BOD5/BODultimate ratio	-	0.66	N	Nitrogen Compounds		-		xbodu	particulate ultimate carbonaceous	BOD aO2/m3	266.6
ivt	VSS/TSS ratio	gVSS/gTSS	0.9	s	inh free and ionized amm	onia	gN/m3	25.0	bodu	total ultimate carbonaceous BOD	gO2/m3	352.6
Organ	ic Fractions		0.05	s	nd soluble biodegradable	organic nitrogen	gN/m3	2.78	scod	filtered COD	aCOD/m3	107.5
irsi C	soluble inert fraction of total COD	-	0.05	x	and particulate biodegrada	able organic nitrogen	gN/m3	8.87	vcod	naticulate COD	gCOD/m3	222.5
Trss	readily biodegradable fraction of total COD	-	0.2	s	no nitrate and nitrite		qN/m3	0.0	xcou	Character COD	geob/ins	27.0
frxi	particulate inert fraction of total COD	-	0.13		ann dinitrogen		aN/m3	0.0	stkn	Tiltered IKIN	giv/m3	27.8
frxu	part. cell decay products fraction of total COD	-	0.0		Alkalinity		3		xtkn	particulate IKN	gN/m3	12.2
frxbh	heterotrophic biomass fraction of total COD	-	0.0	s	alk alkalinity		mole/m3	7.0	tn	total nitrogen	gN/m3	40.0
frxba	autotrophic biomass fraction of total COD	-	0.0				1					
Nitrog	en Fractions								Stoichi	ometric Ratios		
frsnh	ammonium fraction of soluble TKN	-	0.9						¢ co) / TKN	gCOD/gN	10.8
ASM1	Nutrient Fractions	N/ COD	0.000						¢ (0	Dbiodeg / TKN	gCOD/gN	8.82
ixbn	N content of active biomass	gN/gCOD	0.086						¢ NH	4 / TKN	-	0.625
ixun	N content of endogenous/inert mass	gN/gCOD	0.06						¢ vss	/ TSS	gVSS/gTSS	0.9
									¢ xco	DD / VSS	qCOD/qVSS	1.8
									¢ BOI	/ COD	qO2/qCOD	0.541
											12 . 2	
				-		r						
				E	quation for : No Selection	NO SELECTION				Change s	election by :	
										• clic	king on variable	
										() mc	ving over variable	
												_
a. 4	Caturitan Dan Driver										A	Const
× I	Set values to : Raw Primary										Ассерт	Cancel

Exercise 3 – Comparing the Performance of Alternative Bioreactor Configurations

The purpose of this exercise is to compare the effluent quality from conventional activated sludge systems with different bioreactor configurations:

- a) Complete mixed, no recycle
- b) Complete mixed, biological solids recycle
- c) Plug flow, biological solids recycle
- d) Plug flow with step-feeding, biological solids recycle
 - 1. Open the Starting Point model layout that was developed in Exercise 1.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Save the layout under a different name.
- 3. In modelling mode, right-click on the Secondary Clarifier and navigate to *Input Parameters* > *Operational*. Change the **underflow rate** to $0 \text{ m}^3/d$; now there is no recycle between the clarifier and the aeration basin.

perational				
Underflow				
[RAS] proportional recycle	OFF			
stream label to which recycle is proportional	blank			
[RAS] recycle fraction	0.8	-	Ŧ	۵
[RAS] underflow rate	0.0	m3/d	•	D
[RAS] underflow from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Pumped Flow				
[WAS] pumped flow	40.0	m3/d	•	
[WAS] pump from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
		Accept	0	ancel

NEW

- 4. Switch into simulation mode. Rebuild the model when prompted.
- 5. Create a new output graph tab. Right-click on the tab and rename to "Operational Performance."
- 6. Right-click on the Outfall object and navigate to *Output Variables > Flow*. From the flow dialog box that appears, drag the **flow** variable to the new graph tab. Right-click on the graph to change its display to **Digital** from the *Output Graph Type* dropdown. Follow the same steps for the subsequent output variables from the Outfall object (drag the variables to the existing digital graph):
 - Composite Variables: total suspended solids, total carbonaceous BOD₅
 - State Variables: dissolved oxygen, free and ionized ammonia

Flow		×
Flow [effluent] flow	1960 m3/d	•
	Accept	Cancel

The screen for total suspended solids and total carbonaceous BOD₅ is as follows.

Composite Variables			
Volatile Fraction			
[effluent] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[effluent] total suspended solids	10.0	mg/L	•
[effluent] volatile suspended solids	5.488	mg/L	•
[effluent] total inorganic suspended solids	4.512	mg/L	•
[effluent] total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] total COD	43.12	mgCOD/L	•
[effluent] total TKN	2.535	mgN/L	•
More			
۳.	Acc	ept Can	cel



tate Variables			
[effluent] internal cell storage product	0.0	mgCOD/L	•
Dissolved Oxygen			
[effluent] dissolved oxygen	2.0	mgO2/L	Ŧ
Nitrogen Compounds			
[effluent] free and ionized ammonia	2.0	mgN/L	•
[effluent] soluble biodegradable organic nitrogen	0.0	mgN/L	•
[effluent] particulate biodegradable organic nitrogen	0.004512	mgN/L	•
[effluent] nitrate and nitrite	20.0	mgN/L	•
[effluent] dinitrogen	0.0	mgN/L	•
Alkalinity			
[effluent] alkalinity	350.0	mgCaCO3/L	•
			T

- 7. Right-click on the Bioreactor and navigate to *Output Variables > Composite Variables in Individual Reactors*. Left-click on the **mixed liquor suspended solids in individual reactors** variable name and drag it to the Operational Performance output tab to create a new graph in this tab. After dragging the mlss, press Accept in the dialog box. Follow the same steps to create individual graphs for the following output variables from the Bioreactor object:
 - Composite Variables: total carbonaceous BOD5 in individual reactors
 - State Variables: dissolved oxygen in reactor, free and ionized ammonia in reactor

Composite Variables in Individual Reactors			×
Volatile Fraction			
[mlss] VSS/TSS ratio in individual reactors	()	gVSS/gTSS	•
Composite Variables			
[mlss] mixed liquor suspended solids in individual reac	()	mg/L	•
[mlss] mixed liquor volatile suspended solids in individ	()	mg/L	•
[mlss] total inorganic suspended solids in individual re	()	mg/L	•
[mlss] total carbonaceous BOD5 in individual reactors	()	mgO2/L	•
[mlss] total COD in individual reactors	()	mgCOD/L	•
[mlss] total TKN in individual reactors	()	mgN/L	•
More			
	Ac	cept Can	cel

State Variables in Individual Reactors			×
[mlss] active heterotrophic biomass in reactor	()	mg(COD/L 👻 📥
[mlss] active autotrophic biomass in reactor	()	mg(COD/L -
[mlss] unbiodegradable particulates from cell decay in	()	mg(COD/L 👻
[mlss] internal cell storage product in reactor	()	mg(COD/L 👻
Dissolved Oxygen			
[mlss] dissolved oxygen in reactor	()	mg(02/L 🔫
Nitrogen Compounds			
[mlss] free and ionized ammonia in reactor	()	mgl	√L 🔫
[mlss] soluble biodegradable organic nitrogen in reactor	()	mgl	√/L ▼
[mlss] particulate biodegradable organic nitrogen in re	()	mgt	√/L ~
[mlss] nitrate and nitrite in reactor	()	mgl	√/L ▼
[mlss] dinitrogen in reactor	()	mgl	v/L
		Accept	Cancel

8. Auto arrange the graphs to fit them into the output window.

F

Ö

9. Access the properties button for each graph and rename appropriately. Alternatively, right-click on a graph and select **Rename Output Graph...** to name a graph.

Outputs 🔛 🐭 🦪 📻 💠 鹶 🍇 🖶 🤿	- 🕉 💼 -
Influent Bioreactor Secondary Clarifier Outfall Operational Perform	ance
Output: 1	
[effluent] flow m3/d	
[effluent] total suspended solids mg/L [effluent] total carbonaceous BOD5 mgO2/L	
[effluent] dissolved oxygen mg02/L	
[effluent] free and ionized ammonia mgN/L	
Bioreactor MLSS	Z [™] Bioreactor cBOD5 Z [™]
Bioreactor MLSS	Bioreactor cB0D5
S. C.	ER,
	5 8
40.04	
	50 50
2200	
	arbo
1 index	2 1 2 Index
Bioreactor DO	Bioreactor NH3 Image: Constraint of the second
Bioreactor DO	Bioreactor NH3
I I I I I I I I I I I I I I I I I I I	
	5
5	eact
5	
50 G	
Index	- Index

10. Run the simulation at steady-state. Take a screenshot of the results in the Operational Performance output tab. (Exercise 3 – Question 1)

- 11. Open the Sankey Diagram and take a screenshot to record the flow profile of the continuous mixed, no recycle configuration. Select the OK button in the bottom-right corner of the window to close the Sankey diagram. (Exercise 3 Question 2)
 - 12. You will now explore the effect of adding in the recycle stream from the secondary clarifier. Add a new scenario by navigating to *Scenario* > *New* from the simulation toolbar. Call the simulation "CM-recycle." Accept the form.

New Scenario	2
What is a Scenario?	
When organizing simulation runs it is useful to start with a base s then create one or more separate cases, which are modifications data set. These cases are referred to as scenarios in GPS-X. GPS-X create your own scenarios. In each scenario you can specify the c model parameter(s), which define the scenario and then save the that it can be restored at some point in the future.	et of data, and to the base allows you to changes to the escenario so
For more information, refer to the User's Guide.	
New Scenario	
Derive new scenario from :	
Name :	
CM-Recycle	
Accept	Cancel

5

13. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Operational* and drag the **underflow rate** variable from the Underflow header to the input controller area. Right-click on the tab and rename this new input control tab to "RAS."

OperationalSIMULATION IS LOADED				×
Underflow				-
[RAS] proportional recycle	OFF			D.
stream label to which recycle is proportional	blank			D
[RAS] recycle fraction	0.8	-	Ŧ	
[RAS] underflow rate	0.0	m3/d	•	Ľ
[RAS] underflow from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
	_	Accept	Car	ncel

14. Select the RAS input controls property button and set the **maximum limit** to **4000 m³/d**. Ensure to Accept the form to save the changes. Set the value of the slider to **2000 m³/d** and rerun the simulation.

Controls 📑 🛲 与 🔅 🏂 🏣			-	-
RAS				
[RAS] underflow rate	2000.0 m3/d	0.0	 4000.0)

15. Take screenshots of the results on the operational performance tab, and the Sankey diagram. (Exercise 3 – Question 3)

Now explore the effect of modelling the bioreactor as a PFR rather than a CM reactor.

5

- 16. In the existing model layout go to Save As... and save a copy of the model layout under a different name.
- 17. Switch back into modelling mode. Right-click on the Bioreactor and go to *Input Parameters* > *Physical*. Change the **number of reactors** to **4**. Accept this change. By default, the volume of the reactor (1000 m³) will be divided into 4 equal sized basins (250 m³).

Physical				×
Dimensions				_
[mlss] number of reactors	4			
[mlss] tank depth (not editable in GPS-X Lite)	4.0	m	•	
[mlss] volume setup method (not editable in GPS-X Lite)	Volume Fractions		Ŧ	
Individual Volumes				
[mlss] individual volumes	()	m3	~	
Volume Fractions				
[mlss] maximum volume (not editable in GPS-X Lite)	1000.0	m3	•	
[mlss] volume fractions	()	-	•	
More				
		Accept	Cano	cel

- 18. Switch into Simulation Mode. Rebuild the model when prompted.
- 19. Ensure you are working in the Default Scenario. Verify that the underflow rate variable on the RAS input control tab is set to 2000 m³/d and run the simulation. You should now see that the output graphs have 4 indexes representing the individual compartments within the bioreactors.
- 20. Take a screenshot of the results on the Operational Performance tab. (Exercise 3 Question 4)

The final reactor configuration involves the addition of step feeding to the PFR.

21. You will now delete the old CM recycle scenario and create a new scenario for the PFR step feeding. In Simulation mode navigate to *Scenario* > *Configuration* from the Simulation Toolbar. Select the CM – Recycle scenario and click on the Delete button. Close this form.

31

cenario Configuration	×
How to Configure Scenarios	
You can view and organize various details with the features in this wi	ndow.
"Data Files" allows you to easily browse, manage, and edit the files th input and display data for the selected scenario. "Compare" allows you to view the differences between scenarios. Us 'Alt-Click' to select multiple scenarios. "Delete" allows you to remove unwanted scenarios. "Up/Down" allows you to reorder the scenarios.	nat are used to se 'Ctrl+Click' or
For more information, refer to the User's Guide.	
Configuration	
Default Scenario	Data Files
CM-Recycle	
	Compare
	DVete
	🔺 Up
	Down

22. From the simulation toolbar select *Scenario* > *New*. Select the button next to Default Scenario then name the new scenario to "PFR-Step Feeding." Accept this form.

New Scenario	×
What is a Scenario?	_
When organizing simulation runs it is useful to start with a base set of data, ar then create one or more separate cases, which are modifications to the base data set. These cases are referred to as scenarios in GPS-X. GPS-X allows you t create your own scenarios. In each scenario you can specify the changes to th model parameter(s), which define the scenario and then save the scenario so that it can be restored at some point in the future.	nd o ne
For more information, refer to the User's Guide.	
New Scenario	
Derive new scenario from :	
Default Scenario	
Name :	
PFR-Step Feeding	
Accept Cancel	

Note: The input control tab that was created earlier will still be present, do not delete it.

23. In this new scenario, right-click on the Bioreactor and navigate to *Input Parameters > Operational* and scroll down to the *Internal Flow Distribution Menu*. Select the **influent fractions** ellipse button and set all entries to **0.25**. Make the same change to the **recycle fractions**. The effect of these adjustments is that all the incoming flow to the Bioreactor will be split evenly between each of the four basins.

fluent fractions ()SIMULATION IS LOADED		
[mlss(1)] influent fractions	0.25 -	
[mlss(2)] influent fractions	0.25 -	
[mlss(3)] influent fractions	0.25 -	
[mlss(4)] influent fractions	0.25 -	
	Accept	Cancel
cycle fractions ()SIMULATION IS LOADED		
cycle fractions ()SIMULATION IS LOADED [mlss(1)] recycle fractions	0.25 -	
cycle fractions ()SIMULATION IS LOADED [mlss(1)] recycle fractions [mlss(2)] recycle fractions	0.25 -	
cycle fractions ()SIMULATION IS LOADED [mlss(1)] recycle fractions [mlss(2)] recycle fractions [mlss(3)] recycle fractions	0.25 - 0.25 - 0.25 -	
cycle fractions ()SIMULATION IS LOADED [mlss(1)] recycle fractions [mlss(2)] recycle fractions [mlss(3)] recycle fractions [mlss(4)] recycle fractions	0.25 - 0.25 - 0.25 - 0.25 - 0.25 -	

- 24. Set the underflow rate (recycle) to 2000 m³/d from the input control slider variables tab and run the simulation. Record a screenshot of the effluent from the Operational Performance tab. (Exercise 3 Question 5)
- 25. Save the model layout.

Completion of the previous steps should have yielded snapshots of the operational performance of each bioreactor configuration:

- a) Complete mixed, no recycle
- b) Complete mixed, biological solids recycle
- c) Plug flow, biological solids recycle
- d) Plug flow with step-feeding, biological solids recycle

Prepare a discussion regarding the similarities and differences of each of these configurations and suggest reasons for the observations. (Exercise 3 -Question 6)

Exercise 4 – Plug-Flow Configuration

This exercise will explore the effect of the number of tanks in the plug-flow configuration.

1. Open the Starting Point model layout developed in Exercise 1.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Save the Layout under a different name.
- 3. Switch into Simulation Mode in not already in this mode.
- 4. Select the New Table Tab button in the Outputs section of the window. In the Table Properties window that appears uncheck the include mass flows selection and the deselect all buttons under the stream choices and variable choices menus.



🕼 Table Properties	×
Table Type : Stream Variables ✓ include concentrations ○ include mass flows Stream Choices	Variable Choices
Include: 	
	Accept Cancel

- 5. Select the following stream variables:
 - Stream Choices:
 - i. Influent > wwinf
 - ii. Bioreactor > Internal Streams, mlss
 - iii. Secondary Clarifier > effluent, RAS
 - Variable Choices:
 - i. Solids > TSS
 - ii. Organic Variables > cBOD5
 - iii. Nitrogen Variables > Ammonia Nitrogen, Nitrite and Nitrate
 - iv. Other Variables > Dissolved Oxygen

 ✓ include concentrations ☐ include mass flows 	
tream Choices	Variable Choices
Include: Winffuent (wwinf) Giver actor (mls) Conternal Stream(s) Conternal Stream(s) Con	Include: Flow Rate Flow Flow Galaxy Flow F

6. Acceptance of this form will create a table on a new output tab.



Note: If you make a mistake or desire to enter another item into the table, select the table and then the **Properties** button to access the properties menu.

Outputs 🔛 🛲 🚛 📰 💠 鹶 🍇 🖶 🔫 🖄 🌑							
Influent Bioreactor Secondary Clarifier Outfall Table: 5							
wwinf mlss(1) mlss effluent RAS							
TSS mg/L 🛍							
cBOD5 mgO2/L 🛍							
Ammonia Nitrogen	mgN/L	-	-	-	-	-	
Nitrite and Nitrate	mgN/L		-	-	-	-	
Dissolved Oxygen	mgO2/L	l -	-	-	-	-	



H

- Run the simulation at steady-state. Record a screenshot of the results in the output table. (Exercise 4 Question 1)
- 8. Beside each of the output variable names is a **Create Bar Chart** button. Select the button for the cBOD5 variable. Record a screenshot of the bar chart that appears. (**Exercise 4 Question 2**)
- 9. Switch back into modelling mode.
- Right-click on the Bioreactor and navigate to *Input Parameters > Physical* and change the number of reactors to 3. Accept this form and switch back into Simulation Mode. Rebuild the model when prompted.

Physical				×
Dimensions				
[mlss] number of reactors	3			D
[mlss] tank depth (not editable in GPS-X Lite)	4.0	m	•	\Box
[mlss] volume setup method (not editable in GPS-X Lite)	Volume Fractions		Ŧ	
Individual Volumes				
[mlss] individual volumes	()	m3	~	Ľ
Volume Fractions				
[mlss] maximum volume (not editable in GPS-X Lite)	1000.0	m3	•	D
[mlss] volume fractions	()	-	•	
More				
		Accept	Cano	cel



- 11. Run the simulation at steady-state and record a screenshot of the results in the output table. (Exercise 4 Question 3)
- 12. Switch back into modelling mode.
- Right-click on the Bioreactor and navigate to *Input Parameters > Physical* and change the number of reactors to 5. Accept this form and switch back into Simulation Mode. Rebuild the model when prompted.
| Physical | | | | × |
|---|------------------|--------|------|--------|
| Dimensions | | | | |
| [mlss] number of reactors | | | | |
| [mlss] tank depth (not editable in GPS-X Lite) | 4.0 | m | • | |
| [mlss] volume setup method (not editable in GPS-X Lite) | Volume Fractions | | * | |
| Individual Volumes | | | | |
| [mlss] individual volumes | () | m3 | ~ | |
| Volume Fractions | | | | |
| [mlss] maximum volume (not editable in GPS-X Lite) | 1000.0 | m3 | • | D |
| [mlss] volume fractions | () | - | • | \Box |
| More | | | | |
| | | Accept | Cano | cel |

- 14. Run the simulation at steady-state and record a screenshot of the results in the output table. (Exercise 4 Question 4)
- 15. Save the model layout.
- 16. Compare the bioreactor profiles from steps 7, 11, and 14. Suggest reasoning for your observations. Create bar charts as needed to support your reasoning. Is each bioreactor configuration able to achieve the same level of nutrient removal?

Exercise 5 – Effect of SRT and DO Control on Nitrification

The purpose of this scenario is to explore the effect of the solids retention time (SRT) and bioreactor dissolved oxygen (DO) concentration on the extent of nitrification.

1. Open the Starting Point layout that was created in Exercise 1.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Save the layout under a different name.
- 3. In modelling mode right-click on the Bioreactor and navigate to *Input Parameters > Physical* and change the **number of reactors** to **3**.

Physical				×
Dimensions				_
[mlss] number of reactors	3			
[mlss] tank depth (not editable in GPS-X Lite)	4.0	m	•	
[mlss] volume setup method (not editable in GPS-X Lite)	Volume Fractions		Ŧ	
Individual Volumes				
[mlss] individual volumes	()	m3	Ŧ	Ľ
Volume Fractions				
[mlss] maximum volume (not editable in GPS-X Lite)	1000.0	m3	•	
[mlss] volume fractions	()	-	•	
More				
		Accept	Cano	cel

f(x) 4. Select the Define button from the main toolbar and choose the Solids Retention Time option from the bottom of the list.



Select the green + button to create a new SRT variable and name it "CAS."

- This creates a new formula: Mass()/Mass Flow().
- The numerator will represent the mass of solids in the bioreactor, while the denominator will represent the mass flow of solids out of the system. To add to the numerator, simply left-click on the Bioreactor (the cursor changes to a hand). In the dialog box the selection for Reactors 1, 2, and 3 should be checked. Add to the denominator by hovering the mouse on the WAS stream connection point from the secondary clarifier until the cursor changes to an arrow, then left-click it. The equation should appear as: Mass(mlss)/Mass Flow(WAS). Now, hover the mouse over the clarified effluent from the secondary clarifier connection point until it changes to an arrow, then left-click to also add this to the denominator of the SRT equation.

Note: If you make a mistake, use the red x button next to the green plus button to delete the selected srtCAS; then redo creating the SRT variable.

- The final equation should appear as: Mass(mlss)/Mass Flow(effluent, WAS). Keep the window open.
- Select the "Estimate WAS using set SRT" button. Close this window.

crining orti					
lick "+" to create a r	new SRT variable.				
Define the SRT by clic connection points for can be used to "Estim	king on the unit pro total mass flowing ate WAS using set S	cesses for total mass in the selected units in the selected streams. Note: Only the fir RT".	and pump st SRT varia	ed/overflow ble in the list	t
RT=(solids in the sys	tem)/(solids in the s	stream flowing out of the system)			
or more information	, refer to the User's (Guide.			
SRT Variables					
510010		nasi(mas), mass now (emach, mas)			
	[Estimate WAS using set SRT Controlled Flow	WAS 🔻		
	[Estimate WAS using set SRT Controlled Flow SRT set point	WAS -	days	
	[Estimate WAS using set SRT Controlled Flow SRT set point minimum SRT controller pump flow 	WAS - 10.0 0.0	days m3/d	•

Note: If you require further information on setting up a new SRT variable, access the *Quick Start Guide GPS-X Lite* from the Help Menu.



- 5. Switch into Simulation Mode. Rebuild the model when prompted.
- 6. Create a new output graph and rename the graph tab to "Nitrification."
- 7. Right-click on the Bioreactor and navigate to *Output Variables > Composite Variables in Individual Reactors*. Left-click on the **mixed liquor suspended solids in individual reactors** variable name and drag to create a new graph on the Nitrification output tab.

Composite Variables in Individual Reactors			X
Volatile Fraction			
[mlss] VSS/TSS ratio in individual reactors	()	gVSS/gTSS	•
Composite Variables			
[mlss] mixed liquor suspended solids in individual reac	()	mg/L	•
[mlss] mixed liquor volatile suspended solids in individ	()	mg/L	•
[mlss] total inorganic suspended solids in individual re	()	mg/L	•
[mlss] total carbonaceous BOD5 in individual reactors	()	mgO2/L	•
[mlss] total COD in individual reactors	()	mgCOD/L	•
[mlss] total TKN in individual reactors	()	mgN/L	•
More			
¥	A	ccept Cano	el

- 8. Right-click on the Bioreactor and navigate to *Output Variables > State Variables in Individual Reactors.* Drag the following output variables to the new graph tab.
 - Dissolved Oxygen dissolved oxygen in reactor
 - Nitrogen Compounds free and ionized ammonia in reactor
 - Nitrogen Compounds nitrate and nitrite in reactor



Rename each graph by accessing the property button for each graph.



State Variables in Individual Reactors			×
[mlss] internal cell storage product in reactor	()	mgCOD/L	•
Dissolved Oxygen			
[mlss] dissolved oxygen in reactor	()	mgO2/L	•
Nitrogen Compounds			
[mlss] free and ionized ammonia in reactor	()	mgN/L	•
[mlss] soluble biodegradable organic nitrogen in reactor	()	mgN/L	•
[mlss] particulate biodegradable organic nitrogen in re	()	mgN/L	-
[mlss] nitrate and nitrite in reactor	()	mgN/L	•
[mlss] dinitrogen in reactor	()	mgN/L	-
Alkalinity			_
[mlss] alkalinity in reactor	()	mgCaCO3/L	-
	Ac	cept Cano	el

9. From the main toolbar go to *Define > Solids Retention* Time and drag the **srtCAS** variable to the Nitrification output graph tab. Right-click on this new graph and select **Digital** from the *Output Graph Type* menu.

he set point is used, you	can drag the label to a control tab to create a controller.	
tCAS	Mass(miss)/Mass Flow(effluent,WAS)	
	Estimate WAS using set SRT Controlled Flow WAS	
	SRT set point 10.0 days	
	minimum SRT controller pump flow 0.0 m3/d	•
	maximum SRT controller pump flow 1000000 m3/d	•

- 10. Right-click on the effluent stream and go to *Output Variables* > *State Variables*. Drag the following variables to the same digital graph on the Nitrification tab.
 - Nitrogen Compounds free and ionized ammonia
 - Nitrogen Compounds nitrate and nitrite

State Variables]
[effluent] internal cell storage product	0.0	mgCOD/L	•
Dissolved Oxygen			
[effluent] dissolved oxygen	2.0	mgO2/L	•
Nitrogen Compounds			
[effluent] free and ionized ammonia	2.0	mgN/L	•
[effluent] soluble biodegradable organic nitrogen	0.0	mgN/L	•
[effluent] particulate biodegradable organic nitrogen	0.004512	mgN/L	•
[effluent] nitrate and nitrite	20.0	mgN/L	•
[effluent] dinitrogen	0.0	mgN/L	•
Alkalinity			
[effluent] alkalinity	350.0	mgCaCO3/L	•
•			►
¥∎ 1	Ac	cept Canco	el

11. Right-click on the mlss stream at the connection point on the top-left of the reactor, hover until the cursor changes to an arrow, then go to *Output Variables* > *Composite Variables* and drag the **mixed liquor suspended solids** to the digital graph.

Composite Variables			×
Volatile Fraction			
[mlss] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[mlss] mixed liquor suspended solids	2216	mg/L	-
[mlss] mixed liquor volatile suspended solids	1216	mg/L	•
[mlss] total inorganic suspended solids	1000	mg/L	•
[mlss] total carbonaceous BOD5	465.3	mgO2/L	•
[mlss] total COD	1835	mgCOD/L	•
[mlss] total TKN	121.6	mgN/L	•
More			
	Acc	cept Can	cel

12. Auto arrange the graphs in the output tab.

F



Scenario 1 – Effect of SRT on Nitrification

- 13. Create a new input control tab and rename it to "SRT."
- 14. From the Main Toolbar select *Define* > *Solids Retention Time* and drag onto the new input controls tab the **SRT set point**.

Controls 📑 🚛 与 🔅 🗮 📆			•
SRT			
SRT set point	10.0 d	0.0 50.0	5



NEW

f(x)

15. Run the simulation at **SRT set points** of **2**, **6**, **10**, **and 14 days** and record the values of the following from the Nitrification output tab:

- a. Mixed liquor suspended solids
- b. Free and ionized ammonia
- c. Nitrate and nitrite

Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different SRT set points with the SRT setpoint presented on the x-axis rather than time.

16. In Excel, create a graph with SRT on the x-axis, and the recorded variables from Step 15 on the y-axis. Discuss the results. (Exercise 5 – Question 1)

Scenario 2 – Effect of Dissolved Oxygen on Nitrification

 \square

- 17. Create a new input controls tab and rename it to "DO Control."
- 18. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and drag onto the input controls area the following variables:
 - Aeration Setup specify oxygen transfer by...
 - Diffused Aeration **distribution of air flow to aeration tank** (will create 3 controls due to the specification of 3 tanks in the physical menu of this object)

OperationalSIMULATION IS LOADED					×
Aeration Setup					-
[mlss] aeration method	Diffused Air		-	D	
[mlss] specify oxygen transfer by	Entering Airflow		-	Ľ	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	~	Ľ	
More					
Diffused Aeration					
[mlss] total air flow into aeration tank	30000.0	m3/d	•		
[mlss] distribution of air flow to aeration tank	()	-	•	Ľ	
More					
Mechanical (Surface Aeration)					
[mlss] aeration power	()	kW	~	\Box	
More					
Aeration Control					
[mlss] DO setpoint	()			Ľ	
More					Ļ
		Accept		Cancel	

ł	D
1.6666667	D
1.6666667	C
1.6666667	C
-	1.0000007 *

- 19. Set the SRT set point to 5 days in the SRT input controls tab.
- Run the simulation at the default DO control settings and record a screenshot of the results on the Nitrification output tab. (Exercise 5 – Question 2)
- 21. In the input controls section set the **distribution of air flow to aeration tank** to **0.6**, **0.25**, **and 0.15** for tanks 1, 2, and 3 respectively.

Controls 🚠 🧫 🏷 🌣 玩 🏹				•
SKI DO Control				
[mlss] specify oxygen transfer by		Entering Airfl 🔻		5
[mlss(1)] distribution of air flow to aeration tank	0.6 -	00	1.6666667	5
[mlss(2)] distribution of air flow to aeration tank	0.25 -	00	1.6666667	5
[mlss(3)] distribution of air flow to aeration tank	0.15 -	00	1.6666667	5

- Rerun the simulation and record a screenshot of the results on the Nitrification output tab. (Exercise 5 Question 3)
- 23. In the input controls section set the distribution of air flow to aeration tank to 0.15, 0.25, and 0.6 for tanks 1, 2, and 3 respectively. Keep the SRT Setpoint at 5 days.

Controls 🚉 📰 🏷 🔅 🎘 🎼			•
[mlss] specify oxygen transfer by		Entering Airfl 👻	Q
[mlss(1)] distribution of air flow to aeration tank	0.15 -	0.0 1.66666	,)
[mlss(2)] distribution of air flow to aeration tank	0.25 -	0.0 1.66666	57 5
[mlss(3)] distribution of air flow to aeration tank	0.6 -	0.0 1.66666	,)

- 24. Rerun the simulation and record a screenshot of the results on the Nitrification output tab. (Exercise 5 Question 4)
- 25. In the input controls area set the specify oxygen transfer by ... to Using a DO Controller. By default, this will set the *DO concentration in each tank to 2 mg/L*. Rerun the simulation and record a screenshot of the results in the Nitrification output tab. Compare and contrast the results from steps 20, 22, and 24. (Exercise 5 Question 5)

45

Exercise 6 – Temperature Effect on Nitrification

Biological nitrogen removal is highly dependent on temperature; therefore, nitrogen removal is an important consideration in the determination of summer versus winter operating conditions.

The objective of this exercise is to explore the effect of temperature on nitrification.

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. In modelling mode, define the SRT calculation. From the main toolbar select *Define* > *Solids Retention Time*.

Follow the steps in Step 4 of Exercise 5. In this case, the pop-up box for the numerator will only have Reactor 1 specified as opposed to three reactors above.

Also, for this exercise, make sure that the "Estimate WAS using set SRT" box is unchecked.



G Solids Retention Time Manag	er
Defining SRT Click "+" to create a new SRT var Define the SRT by clicking on the connection points for total mass can be used to "Estimate WAS us	iable. : unit processes for total mass in the selected units and pumped/overflow flowing in the selected streams. Note: Only the first SRT variable in the list ing set SRT.
SRT=(solids in the system)/(solid	Is in the stream flowing out of the system)
For more information, refer to the SRT Variables	e User's Guide.
srtCAS	Mass(mlss)/Mass Flow(WAS,effluent)
	Estimate WAS using set SRT Controlled Flow WAS SRT set point 10.0 days minimum SRT controller pump flow 0.0 m3/d
⊡ ×	maximum SRT controller pump flow 1000000 m3/d Close
Quick Help Shift-F1	n f(x) - 📿 - 🐭 - 🔍
Manuals 🔹 🕨	GPS-X Lite Exercises
About	Quick Start Guide GPS-X Lite
	Technical Reference for GPS-X

 Right-click on the Bioreactor and navigate to *Input Parameters > Physical > Volume Fractions* More... > Local Environment Selection and set the use local settings for O2 solubility and biological activity to ON. This allows for access to the liquid temperature which sets the temperature within the Bioreactor basins.

[mlss] use local settings for O2 solubility and biological	ON ON			Г
[mlss] liquid temperature	20.0	С	•	
Dxygen Solubility (if individual settings are used)				
[mlss] blower inlet air temperature	20.0	С	•	
[mlss] elevation above sea level	0.0	m	•	
[mlss] standard air conditions	U.S. (air temp 20C,	36% humidity)	-	
Properties of User-Defined Air				
[mlss] mole fraction of oxygen in user-defined air	1.0	mole/mole	Ŧ	
[mlss] density of user-defined air	1429.0	mg/L	Ŧ	
[mlss] molecular weight of user-defined air	32.0	g/mol	~	
[mlss] exponent in blower power equation	0.284	-	~	

- 4. Switch into Simulation Mode. Rebuild the model when prompted.
- 5. Create a new graph tab and call it "SRT."

NEW

6. From the main toolbar navigate to *Define > Solids Retention Time* and drag the srtCAS variable to the new output tab. Right-click on the created graph and navigate to *Output Graph Type > Digital*.

🚱 Solids Retention Time Manager			\times			
Creating SRT Outputs Drag the variable to the graph area to If the set point is used, you can drag th	create an output display for the SRT variable. he label to a control tab to create a controlle:	r.				
SRT Variables						
ertCAS	Mass(mlss)/Mass Flow(effluent, WAS)					
	Estimate WAS using set SRT Controlled Flow SRT set point minimum SRT controller pump flow maximum SRT controller pump flow	WAS - 10.0 days 0.0 m3/d 1000000 m3/d	•			
			Close			
Outputs				Ş	S	
Influent Bioreactor	Secondary Clarifier Outf	all SKI				
Output: 1				Ø		
Solids Retention Time (srt Dynamic Solids Retention	CAS) Time (srtdynCAS)		d d			

7. Right-click on the Bioreactor and go to *Input Parameters > Physical > Volume Fractions More...* menu and drag the **liquid temperature** variable to the input controls section. Rename the tab that is created to "Input Settings."

Volume Fractions More SIMULATION IS LOADED				×
Local Environment Selection				
[mlss] use local settings for O2 solubility and biological	ON			
[mlss] liquid temperature	20.0	С	•	D
Oxygen Solubility (if individual settings are used)				
[mlss] blower inlet air temperature	20.0	С	•	
[mlss] elevation above sea level	0.0	m	•	
[mlss] standard air conditions	U.S. (air temp 20C,	36% humidity)	~	
Properties of User-Defined Air				
[mlss] mole fraction of oxygen in user-defined air	1.0	mole/mole	Ŧ	
[mlss] density of user-defined air	1429.0	mg/L	~	
[mlss] molecular weight of user-defined air	32.0	g/mol	Ŧ	
[mlss] exponent in blower power equation	0.284	-	Ŧ	
		Accept	Can	cel

8. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Operational* and drag the **pumped flow** variable to the input control Input Settings tab.

			_	44
Operational SIMULATION IS LOADED				×
Underflow	OFF			D
[roco] proportional recycle	U. I			
stream label to which recycle is proportional	blank			
[RAS] recycle fraction	0.8	-	Ŧ	
[RAS] underflow rate	2000.0	m3/d	•	D
[RAS] underflow from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Pumped Flow				_
[WAS] pumped flow	40.0	m3/d	•	
[WAS] pump from layer	()	-	•	D
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Model Parameters				
[effluent] sludge blanket threshold concentration	2000.0	mgTSS/L	-	
[effluent] critical sludge blanket level	0.1	m	•	
State-Point Analysis Model Parameters				
[effluent] use design MLSS in state point analysis	ON			
[effluent] design MLSS concentration	3000.0	mgTSS/L	-	
		-		
	_	Accept	Car	cel
controls 🛲 🤐 🍑 🐺 😼				
Input Settings				
[mlss] liquid temperature	20.0 C		0.0	
OperationalSIMULATION IS LOADED- [RAS] proportional recycle [RAS] proportional recycle is proportional [Bas] recycle fraction [RAS] underflow rate [RAS] underflow rate [RAS] underflow for control variable [Bank] controller [Bank] stepoint for control variable [VAS] pumped flow [UMSS] pumpet flow [UMSS] pumpet flow [Bank] stepoint for control variable [VAS] pumpet flow [Bank] stepoint for control variable [IM Re				
			0.0	

D

9. It has been stated that "The minimum SRT used to ensure nitrification at average conditions is 7 d at 10°C" [1]. Simulate these settings by adjusting the liquid temperature and the pumped flow to 10°C and 70 m³/d, respectively, in the input controls area. Run the simulation and observe the results. Take a screenshot of the results on the Outfall tab under the Simulation Results header. (Exercise 6 – Question 1)

Controls 🚉 處 ಶ 🔅 📆 🎼				•
[mlss] liquid temperature	10.0 C	00	100.0	5
[WAS] pumped flow	70.0 m3/d	00	200.0	5

Influent I	Bioreactor Se	condary Clarifier
Outfall		
Simulation F	Results	
		effluent
Flow	m3/d	-
TSS	mg/L	-
VSS	mg/L	-
cBOD5	mg/L	-
COD	mg/L	-
Ammonia N	mgN/L	
Nitrite N	mgN/L	-
Nitrate N	mgN/L	
Nitrite/Nitrat	e N mgN/L	-
TKN	mgN/L	-
TN	mgN/L	
Soluble PO4-	P mgP/L	-
TP	mgP/L	-
Alkalinity	mgCaCO3	3/L -
Total Alkalini	ity mgCaCO3	3/L -
рH	-	

10. In this exercise the SRT will be held constant to observe the effect of temperature on nitrification. Set the **pumped flow** variable to **100 m³/d** (this will result in an SRT of approximately 5 days), and run the simulation at **liquid temperatures** of **20**, **16**, **12**, **8**, **and 4** °C. Create a plot in Excel of effluent ammonia vs. liquid temperature. Ensure appropriate axis labels and title are given.

Controls 📑 💼 🏷 🔅				•
Input Settings				
[mlss] liquid temperature	Adjust 10.0 c	0.0	100.0	5
[WAS] pumped flow	100.0 m3/d	0.0	200.0	5



Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different bioreactor temperatures with the bioreactor temperature presented on the x-axis rather than time.

- For temperatures 16 and 4°C, determine the minimum SRT required to obtain an *effluent ammonia concentration below 2 mgN/L*. Adjust the SRT by changing the WAS **pumped flow**. (Exercise 6 Question 3)
- 12. Save the model layout.

(Exercise 6 – Question 2)

Exercise 7 – Aeration Control

In a conventional activated sludge process, good aeration control is arguably one of the most important factors for the removal of ammonia and organics. This exercise will explore several factors that affect oxygen transfer including:

- 1. Equipment:
 - a) Diffuser type
 - b) Diffuser Density
 - c) Diffuser Submergence
- 2. Operations:
 - a) Solids Retention Time
 - b) Airflow Rate per Diffuser
 - c) Diffuser Fouling
- 3. Wastewater Characteristics:
 - a) Temperature

Create the following table to record answers to the questions presented in this exercise. (Exercise 7 – Question 1)

	Factor	Factor Setting	Total Actual Oxygen Transfer Rate (OTR) (kg/d)	Effluent cBOD5	Effluent Free and Ionized Ammonia	Observation
Equipment	Diffuser Type	Fine Bubble	651	5.53	0.359	
		Coarse Bubble				
	Diffuser Density	0.2	651	5.53	0.359	
		0.8				
	Diffuser Submergence	0.3	651	5.53	0.359	
	(height of diffuser from floor)	1.2				
Operations	Solids Retention Time	10 d	651	5.53	0.359	
		3 d				
	Total Air Flow into aeration tank	20,000 m ³ /d	651	5.53	0.359	
		50,000 m³/d				
	Diffuser Fouling	1.0	651	5.53	0.359	
		0.5				
Wastewater	Temperature	20 °C	651	5.53	0.359	
Characteristics		10 °C				

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



Define the SRT calculation.

Follow the steps in Step 4 of Exercise 5. In this case, the pop-up box for the numerator will only have Reactor 1 specified as opposed to three reactors above.

• Select the "Estimate WAS using set SRT" button. Close this window.

criting orti	
lick "+" to create a new SRT variabl	e.
lefine the SRT by clicking on the un onnection points for total mass flo an be used to "Estimate WAS using	it processes for total mass in the selected units and pumped/overflow wing in the selected streams. Note: Only the first SRT variable in the list set SRT [®] .
RT=(solids in the system)/(solids in	the stream flowing out of the system)
or more information, refer to the U	ser's Guide.
RT Variables	
	Estimate WAS using set SRT
	Controlled Flow WAS
	SKI SET DOIDT IUUI DAVS
	minimum SRT controller pump flow 0.0 m3/d

In modelling mode right-click on the Bioreactor and navigate to *Input Parameters > Physical > Volume Fractions More... > Local Environment Selection* and set the use local settings for O2 solubility and biological activity to ON. This allows access to the liquid temperature which sets the temperature within the Bioreactor basins.

/olume FractionsMore				2
Local Environment Selection				
[mlss] use local settings for O2 solubility and biological	ON			
[mlss] liquid temperature	20.0	С	•	D
Oxygen Solubility (if individual settings are used)				
[mlss] blower inlet air temperature	20.0	С	•	\square
[mlss] elevation above sea level	0.0	m	•	
[mlss] standard air conditions	U.S. (air temp 20C,	36% humidity)	•	D
Properties of User-Defined Air				
[mlss] mole fraction of oxygen in user-defined air	1.0	mole/mole	Ŧ	D
[mlss] density of user-defined air	1429.0	mg/L	Ŧ	\square
[mlss] molecular weight of user-defined air	32.0	g/mol	Ŧ	
[mlss] exponent in blower power equation	0.284	-	Ŧ	
		1		
		Accept	Can	cel

3. Right-click on the Bioreactor and navigate to *Input Parameters > Operational > Diffused Aeration header* and change the **total air flow into aeration tank variable** setting to **20,000 m³/d**.

Operational					[
Aeration Setup					
[mlss] aeration method	Diffused Air		-	D	
[mlss] specify oxygen transfer by	Entering Airflow		•		
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ		
More					
Diffused Aeration				_	
[mlss] total air flow into aeration tank	20000.0	m3/d	•		
[mlss] distribution of air flow to aeration tank	()	-	•		
More					
Mechanical (Surface Aeration)					
[mlss] aeration power	()	kW	~		
More					
Aeration Control					
[mlss] DO setpoint	()			Ľ	
More					
Pumped Flow Control					
		Accept	1	Cancel	

4. Right-click on the Bioreactor and navigate to *Input Parameters > Operational > Diffused Aeration More... > Standard Oxygen Transfer Efficiency (SOTE)* and set the **SOTE type** to **correlation**.

Diffused AerationMore					×
Aeration Limits					•
[mlss] minimum airflow per diffuser	0.0	m3/d	~		
[mlss] maximum airflow per diffuser (fine bubble)	120.0	m3/d	~		
[mlss] maximum airflow per diffuser (coarse bubble)	1392.0	m3/d	Ŧ		
[mlss] maximum airflow per diffuser (jet)	3360.0	m3/d	~		
[mlss] maximum airflow per diffuser (user-defined)	120.0	m3/d	Ŧ		
Diffused Air					
[mlss] input air flow at	Standard Condition	15	•		
[mlss] diffuser type	Fine Bubble		•		-
[mlss] alpha factor (fine bubble)	()	-	•		
[mlss] alpha factor (coarse bubble)	()	-	~		
[mlss] alpha factor (jet)	()	-	Ŧ		
[mlss] alpha factor (user-defined)	()	-	Ŧ		
[mlss] fouling constant	1.0	-	•		
[mlss] depth correction factor for user-defined diffuser	Fine Bubble		~		Н
Standard Oxygen Transfer Efficiency (SOTE)					
[mlss] SOTE type	Correlation		•	D	
[mlss] standard oxygen transfer efficiency	()	-	Ŧ		
[mlss] height of diffuser from floor	0.3	m	•		
[mlss] method of specifying diffuser setup	Enter Diffuser Dens	ity	•		
[mlss] diffuser density (diffuser area/tank area)	()	-	•		
[mlss] number of diffusers or jets	()				•
		Accept		Cancel	

- 5. Switch into Simulation Mode. Rebuild the model when prompted.
- 6. Create a new scenario to explore the effect of the various factors on aeration control. Navigate to *Scenario* > *New* and call the new scenario "Aeration Control."

lew S	Scenario		
Wha	it is a Scenario?		
Whe then data creat mod that	n organizing simulation runs it is useful to st create one or more separate cases, which ar set. These cases are referred to as scenarios i te your own scenarios. In each scenario you (el parameter(s), which define the scenario ar it can be restored at some point in the future	art with a base se e modifications t n GPS-X. GPS-X a can specify the cl nd then save the e.	et of data, and to the base allows you to hanges to the scenario so
For r	nore information, refer to the User's Guide.		
New	/ Scenario		
Deri	ve new scenario from :		
	Default Scenario		
Nan	ne :		
	Aeration Control		

- NEW
- 7. Create 3 input control tabs and relabel for each factor grouping: "Equipment Factors," "Operational Factors", "Wastewater Characteristics."
- 8. Select the Equipment Factors input control tab and add the following variables to the tab.
 - a. Bioreactor Input Parameters > Operational > Diffused Aeration More... > Diffused Air
 diffuser type

- b. Bioreactor Input Parameters > Operational > Diffused Aeration More... > Standard Oxygen Transfer Efficiency (SOTE) - diffuser density (diffuser area/tank area)
- c. Bioreactor Input Parameters > Operational > Diffused Aeration More... > Standard Oxygen Transfer Efficiency (SOTE) – height of diffuser from floor

eration Limits	-				×	
[mlss] minimum airflow per diffuser	0.0	m3/d	~			
[mlss] maximum airflow per diffuser (fine bubble)	120.0	m3/d	~			
[mlss] maximum airflow per diffuser (coarse bubble)	1392.0	m3/d	~			
[mlss] maximum airflow per diffuser (jet)	3360.0	m3/d	~			
[mlss] maximum airflow per diffuser (user-defined)	120.0	m3/d	~			
)iffused Air						
[mlss] input air flow at	Standard Condition	ns	•			
[mlss] diffuser type	Fine Bubble		•		8	
[mlss] alpha factor (fine bubble)	()	-	•			
[mlss] alpha factor (coarse bubble)	()		~			
[mlss] alpha factor (jet)	()		~			
[mlss] alpha factor (user-defined)	()		~			
[mlss] fouling constant	1.0		•			
[mlss] depth correction factor for user-defined diffuse	Fine Bubble		Ŧ			
tandard Oxygen Transfer Efficiency (SOTE)						
[mlss] SOTE type	Correlation		•			
[mlss] standard oxygen transfer efficiency	()	-	~			
[mlss] height of diffuser from floor	0.3	m	•			
[mlss] method of specifying diffuser setup	Enter Diffuser Dens	iity	•	D		
[mlss] diffuser density (diffuser area/tank area)	()	-	÷			
[mlss] number of diffusers or jets	(L)			D	Ļ	
			1.		1	
		Accept		ancei		

9. Select the Operational Factors input control tab and add to it the following variables:
 d. Define > Solids Retention Time > SRT set point

🖁 Solids Retention Time Manage	r			>
Creating SRT Outputs Drag the variable to the graph are f the set point is used, you can d	a to create an output display for the SRT variable. ag the label to a control tab to create a controller.			
RT Variables				
srtCAS	Mass(miss)/Mass Flow(effluent,WAS)			
	Estimate WAS using set SRT			
	Controlled Flow	WAS 👻		
	SRT set point	10.0	days	
	minimum SRT controller pump flow	0.0	m3/d	•
	maximum SRT controller pump flow	1000000	m3/d	•
				Close

e. Bioreactor – Input Parameters > Operational > Diffused Aeration – total air into aeration tank

Aeration Setup				_
[mlss] aeration method	Diffused Air		-	
[mlss] specify oxygen transfer by	Entering Airflow		-	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	~	
More				
Diffused Aeration				_
[mlss] total air flow into aeration tank	20000.0	m3/d	•	
[mlss] distribution of air flow to aeration tank	()	-	•	D
More				
Nechanical (Surface Aeration)				
[mlss] aeration power	()	kW	~	
More	,			
Aeration Control				
[mlss] DO setpoint	()			
More				
Pumped Flow Control				
[4] pumped flow	0.0	m3/d	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
		Accent	1	

f. Bioreactor – *Input Parameters > Operational > Diffused Aeration More... > Diffused Air –* fouling constant

ffused AerationMore				
Aeration Limits				
[mlss] minimum airflow per diffuser	0.0	m3/d	~	
[mlss] maximum airflow per diffuser (fine bubble)	120.0	m3/d	~	
[mlss] maximum airflow per diffuser (coarse bubble)	1392.0	m3/d	Ŧ	
[mlss] maximum airflow per diffuser (jet)	3360.0	m3/d	~	
[mlss] maximum airflow per diffuser (user-defined)	120.0	m3/d	Ŧ	
Diffused Air				
[mlss] input air flow at	Standard Condition	ns	-	Ď
[mlss] diffuser type	Fine Bubble		•	
[mlss] alpha factor (fine bubble)	()	-	•	
[mlss] alpha factor (coarse bubble)	()	-	Ŧ	
[mlss] alpha factor (jet)	()	-	Ŧ	
[mlss] alpha factor (user-defined)	()	-	~	
[mlss] fouling constant	1.0	-	•	D
[mlss] depth correction factor for user-defined diffuser	Fine Bubble		Ŧ	
Standard Oxygen Transfer Efficiency (SOTE)				
[mlss] SOTE type	Correlation		-	
[mlss] standard oxygen transfer efficiency	()	-	~	
[mlss] height of diffuser from floor	0.3	m	•	
[mlss] method of specifying diffuser setup	Enter Diffuser Dens	iity	•	
[mlss] diffuser density (diffuser area/tank area)	()	-	•	
[mlss] number of diffusers or jets	()			
		Accept	1	Cancel

ົ

Controls 🚠 🐨 🏷 🏷 🐜 🐄			•
Equipment Factors Operational Factors Wastewater Char	acteristics		
SRT set point	10.0 d	00 500	5
[mlss] total air flow into aeration tank	20000.0 m3/d	0.00000	5
[mlss] fouling constant	1.0 -	00 50	5

- 10. Select the Wastewater Characteristics input controls tab and add to it the following variable:
 - g. Bioreactor Input Parameters > Physical > Volume Fractions More... > Local Environment Selection – liquid temperature

ocal Environment Selection				
[mlss] use local settings for O2 solubility and biological	ON			
[mlss] liquid temperature	20.0	С	•	D
Oxygen Solubility (if individual settings are used)				
[mlss] blower inlet air temperature	20.0	С	•	
[mlss] elevation above sea level	0.0	m	•	
[mlss] standard air conditions	U.S. (air temp 20C,	36% humidity)	•	
Properties of User-Defined Air				
[mlss] mole fraction of oxygen in user-defined air	1.0	mole/mole	Ŧ	
[mlss] density of user-defined air	1429.0	mg/L	Ŧ	
[mlss] molecular weight of user-defined air	32.0	g/mol	Ŧ	
[mlss] exponent in blower power equation	0.284	-	Ŧ	
		Accept	Can	cel
				_
ntrols 煮 🛲 🍎 🗱 🏗				
uipment Factors Operational Factors Wastewater Characteristics	s			

11. Run the simulation and complete the previous table to explore the effect of each factor. **Ensure all** variable settings are at the default values except for the factor of interest.

Output results for entry into the table can be found in the following locations:

a) Total Actual Oxygen Transfer Rate (OTR) (kg/d)

Note: Hover on the mlss stream connection point of the Bioreactor and when the cursor becomes an arrow right-click and select *Output Variables* > *Total Oxygen Transfer*.



b) Effluent cBOD₅ and Effluent Free and Ionized Ammonia are found within the Outfall tab in the **Outputs** area.

initiacité biorea	ictor Seconda	ry Clarifier	Outfall	
Outfall				
				effluent
Simulation Result	ts			
		effluent		
Flow	m3/d	-		
TSS	mg/L	-		
VSS	mg/L	-		
cBOD5	mg/L	-		
COD	mg/L	-		
Ammonia N	mgN/L	-		
Nitrite N	mgN/L	-		
Nitrate N	mgN/L	-		
Nitrite/Nitrate N	mgN/L	-		
TKN	mgN/L	-		
TN	mgN/L	-		
Soluble PO4-P	mgP/L	-		
TP	mgP/L	-		
Alkalinity	mgCaCO3/L	-		
Total Alkalinity	mgCaCO3/L	-		
pН	-	-		

Exercise 8 – Total Nitrogen Removal: Nitrification and Denitrification

The objective of this exercise is to demonstrate how a PFR can be configured to allow for total nitrogen removal.

1. Open the Starting Point layout developed in Exercise 1 and rename appropriately.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. In modelling mode, right-click on the Bioreactor and navigate to *Input Parameters > Physical* and change **the number of tanks** to **3**. This change allows the bioreactor to be modelled as a PFR with 3 equally distributed tanks.

Physical				×
Dimensions				
[mlss] number of reactors	3			
[mlss] tank depth (not editable in GPS-X Lite)	4.0	m	•	
[mlss] volume setup method (not editable in GPS-X Lite)	Volume Fractions		*	
Individual Volumes				
[mlss] individual volumes	()	m3	Ŧ	
Volume Fractions				
[mlss] maximum volume (not editable in GPS-X Lite)	1000.0	m3	•	
[mlss] volume fractions	()	-	•	
More				
		Accept	Cano	:el

3. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and under the Aeration Setup header set the **specify oxygen transfer by...** to **Using a DO Controller**. This change will set the DO concentration to 2 mg/L in each of the aeration tanks.

perational				
Aeration Setup				
[mlss] aeration method	Diffused Air		-	
[mlss] specify oxygen transfer by	Using a DO Control	ler	•	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ	D
More				
Diffused Aeration				
[mlss] total air flow into aeration tank	30000.0	m3/d	~	
[mlss] distribution of air flow to aeration tank	()		•	
More				
Mechanical (Surface Aeration)				
[mlss] aeration power	()	kW	*	Ľ
More				
Aeration Control				
[mlss] DO setpoint	()			
More				
Pumped Flow Control				
[4] pumped flow	0.0	m3/d	•	
[blank] controller	OFF			Ď
[blank] setpoint for control variable	1.0			
More				
		Accept	1	Cancel

 In this same form scroll to the bottom of the window to see the Internal Flow Distribution section. Select the internal recycle ellipse button and set the From, To, and Flow values to 3, 1, and 0 m³/d, respectively.

In GPS-X Lite you	are only able to define a single internal recycle
	From To Flow
[mlss] internal recycle1	3 1 0.0 m3/d -
[mlss] internal recycle2	m3/d 🔻
[mlss] internal recycle3	m3/d -
[mlss] internal recycle4	m3/d 🔻
[mlss] internal recycle5	m3/d 🔻
[mlss] internal recycle6	m3/d -
[mlss] internal recycle7	m3/d -
[mlss] internal recycle8	m3/d -
[mlss] internal recycle9	m3/d -
[mlss] internal recycle10	m3/d 🔻
	Accept Cancel

- 5. Switch into Simulation Mode. Rebuild the model when prompted.
- Run the simulation at steady-state and observe the simulation outputs in the Outfall tab. Record a screenshot of the results under the Simulation Results header within this tab. (Exercise 8 Question 1)

Influent	Bioreactor	Secondary Clarifier	Outfall	
Outfall				effluent
Simulation I	Results			
		effluent		
Flow	m3/d	100 A		
TSS	mg/L	-		
VSS	mg/L	-		
cBOD5	mg/L	-		
COD	mg/L	-		
Ammonia N	mgN/	L -		
Nitrite/Nitrat	te N mgN/	Ъ –		
TKN	mgN/	Ъ –		
TN	mgN/	Ъ –		
Alkalinity	mgCa	CO3/L -		

Observe the nitrogen variables and make the following observations:

- Low ammonia concentration indicates complete nitrification
- High nitrite and nitrate concentrations indicates incomplete denitrification

The nitrification process converts ammonia to nitrite and nitrate in an oxygen-rich environment, while the denitrification process converts nitrate to nitrogen gas (N_2) in the absence of oxygen.

Select the Bioreactor output tab. Notice that the DO concentration in all three tanks is 2 mg/L, as a DO controller is being used to maintain this oxygen-rich environment. With no oxygen-limited conditions present, denitrification is constrained.

7. Create a new scenario to explore the changes needed to allow for complete nitrogen removal. Navigate to *Scenario* > *New* from the simulation toolbar and call the new scenario "MLE."

New S	cenario
What	t is a Scenario?
When then data create mode that i	n organizing simulation runs it is useful to start with a base set of data, and create one or more separate cases, which are modifications to the base set. These cases are referred to as scenarios in $06^{5}\times$, $06^{5}\times$, allows you to e your own scenarios. In each scenarios in $06^{5}\times$, $06^{5}\times$, allows you to be parameter(s), which define the scenario and then save the scenario so t can be restored at some point in the future.
Form	nore information, refer to the User's Guide.
New	Scenario
Deriv	ve new scenario from : Default Scenario
Nam	ie:
	MLE
	Accept Cancel

MLE stands for Modified Ludzack-Ettinger. In this configuration, there are two zones, anoxic and aerobic, and two recycles, one being the RAS stream from the Secondary Clarifier and the other an internal recycle stream. The internal recycle allows for more nitrate to be fed into the anoxic zone directly from the aerobic zone.



Configure the PFR as an MLE system by creating an anoxic zone and specify an internal recycle rate. Right-click on the Bioreactor and navigate to *Input Parameters > Operational >Aeration Control header*. Select the **DO setpoint** ellipse button and change the **DO setpoint** in the **first tank** to **0 mg/L**.

DO setpoint ()SIMULATION IS LOAD	ED
[mlss(1)] DO setpoint	0.0
[mlss(2)] DO setpoint	2.0
[mlss(3)] DO setpoint	2.0
	Accept Cancel

9. Within the same window, scroll to the *Internal Flow Distribution header* menu. Select the internal recycle ellipse button and drag the **internal recycle1** variable to the input controls area.

In GPS-X Lite, you	are only able to define a single internal recycle.	
	From To Flow	
[mlss] internal recycle1	3 1 0.0 m3/d	•
[mlss] internal recycle2	m3/d	•
[mlss] internal recycle3	m3/d	•
[mlss] internal recycle4	m3/d	•
[mlss] internal recycle5	m3/d	•
mlss] internal recycle6	m3/d	•
[mlss] internal recycle7	m3/d	•
[mlss] internal recycle8	m3/d	
[mlss] internal recycle9	m3/d	•
[mlss] internal recycle10	m3/d	

Ö

10. Rename the new input controls tab to "Internal Recycle", then select the input controls property button and set the **max** value to **10,000 m³/d**.

Controls 💒 🛲 🏷 🗱 📆 💏				•
[mlss(3,1)] internal recycle	0.0 m3/d	00 10	0.0000	5

NEW

11. Create a new graph output tab and rename it to "Nitrogen Variables." Right-click on the bioreactor and navigate to *Output Variables > State Variables in Individual Reactors*. Drag the following **Nitrogen Compound** variables to the new output tab to create three new graphs:

- Free and ionized ammonia in reactor
- Nitrate and nitrite in reactor
- Dinitrogen in reactor

Inorganic Suspended Solids [mlss] inert inorganic suspended solids in reactor () mg/L Organic Variables () mgCOD/ [mlss] soluble inert organic material in reactor () mgCOD/ [mlss] readily biodegradable substrate in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] slowly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen [mlss] mgCOD/ [mlss] dissolved oxygen in reactor () mgOZ/L Nitrogen Compounds [mlss] mgN/L [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] nitrate and nitrite in reactor ()	
[mlss] inert inorganic suspended solids in reactor () mg/L Organic Variables [mlss] soluble inert organic material in reactor () mgCOD/ [mlss] readily biodegradable substrate in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] solwly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen [mlss] dissolved oxygen in reactor () mgO2/L Nitrogen Compounds [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] par	
Organic Variables [mlss] soluble inert organic material in reactor () mgCOD/ [mlss] readily biodegradable substrate in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] solwly biodegradable substrate in reactor () mgCOD/ [mlss] solwly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen [mlss] mgCOD/ [mlss] dissolved oxygen in reactor () mgO2/L Nitrogen Compounds [mlss] mgN/L [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] alubie biodegradable organic nitrogen in re () mgN/L [mlss] dinitrogen in reactor () mgN	•
[mlss] soluble inert organic material in reactor () mgCOD/ [mlss] readily biodegradable substrate in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] slowly biodegradable substrate in reactor () mgCOD/ [mlss] slowly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen meactor () mgO2/L Nitrogen Compounds	
[mlss] readily biodegradable substrate in reactor () mgCOD/ [mlss] particulate inert organic material in reactor () mgCOD/ [mlss] slowly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] unbiodegradable particulates from cell decay in () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen	L •
[mlss] particulate inert organic material in reactor () mgCOD/ [mlss] slowly biodegradable substrate in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] unbiodegradable particulates from cell decay in () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ [mlss] dissolved oxygen () mgO2/L Nitrogen Compounds () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L	ι.
[miss] slowly biodegradable substrate in reactor () mgCOD/ [miss] active heterotrophic biomass in reactor () mgCOD/ [miss] active autotrophic biomass in reactor () mgCOD/ [miss] active autotrophic biomass in reactor () mgCOD/ [miss] active autotrophic biomass in reactor () mgCOD/ [miss] internal cell storage product in reactor () mgCOD/ [miss] dissolved Oxygen () mgOZ/L [miss] dissolved oxygen in reactor () mgOZ/L [miss] free and ionized ammonia in reactor () mgN/L [miss] soluble biodegradable organic nitrogen in reactor () mgN/L [miss] particulate biodegradable organic nitrogen in reactor () mgN/L [miss] nitrate and nitrite in reactor () mgN/L [miss] nitrate and nitrite in reactor () mgN/L	. •
[mlss] active heterotrophic biomass in reactor () mgCOD/ [mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] unbiodegradable particulates from cell decay in () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ Dissolved Oxygen () mgCOZ/L Witrogen Compounds () mgN/L [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] initrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] olinitrogen in reactor () mgN/L	ι •
[mlss] active autotrophic biomass in reactor () mgCOD/ [mlss] unbiodegradable particulates from cell decay in () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ Dissolved Oxygen () mgO2/L Witrogen Compounds () mgN/L [mlss] oluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L	L •
[mlss] unbiodegradable particulates from cell decay in () mgCOD/ [mlss] internal cell storage product in reactor () mgCOD/ Dissolved Oxygen () mgOD/ [mlss] dissolved oxygen in reactor () mgOD/ Vitrogen Compounds () mgN/L [mlss] particulate biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] dinitrogen in reactor () mgN/L	ι.
internal cell storage product in reactor () mgCOD/ Dissolved Oxygen mgOD/ imlss] dissolved oxygen in reactor () mgO2/L Nitrogen Compounds mgN/L imlss] free and ionized ammonia in reactor () mgN/L imlss] soluble biodegradable organic nitrogen in reactor () mgN/L imlss] particulate biodegradable organic nitrogen in re () mgN/L imlss] nitrate and nitrite in reactor () mgN/L imlss] onitrogen in reactor () mgN/L	ι.
Dissolved Oxygen (mlss) dissolved oxygen in reactor () mgO2/L Nitrogen Compounds (mlss) free and ionized ammonia in reactor () mgN/L (mlss) soluble biodegradable organic nitrogen in reactor () mgN/L (mlss) particulate biodegradable organic nitrogen in re () mgN/L (mlss) nitrate and nitrite in reactor () mgN/L (mlss) dinitrogen in reactor () mgN/L	ι.
imiss] dissolved oxygen in reactor () mgO2/L Vitrogen Compounds mgN/L [miss] free and ionized ammonia in reactor () mgN/L [miss] soluble biodegradable organic nitrogen in reactor () mgN/L [miss] particulate biodegradable organic nitrogen in re () mgN/L [miss] nitrate and nitrite in reactor () mgN/L [miss] dinitrogen in reactor () mgN/L	
Nitrogen Compounds [mlss] free and ionized ammonia in reactor () mgN/L [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] dinitrogen in reactor () mgN/L	•
[mlss] free and ionized ammonia in reactor () mgN/L [mlss] soluble biodegradable organic nitrogen in reactor () mgN/L [mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] dinitrogen in reactor () mgN/L	
Imiss] soluble biodegradable organic nitrogen in reactor () mgN/L [miss] particulate biodegradable organic nitrogen in re () mgN/L [miss] nitrate and nitrite in reactor () mgN/L [miss] dinitrogen in reactor () mgN/L	•
[mlss] particulate biodegradable organic nitrogen in re () mgN/L [mlss] nitrate and nitrite in reactor () mgN/L [mlss] dinitrogen in reactor () mgN/L	•
mlss] nitrate and nitrite in reactor () mgN/L mlss] dinitrogen in reactor () mgN/L	•
[mlss] dinitrogen in reactor() mgN/L	•
	•
Alkalinity	
[mlss] alkalinity in reactor () mgCaCC	3/L 🔻



Rename each graph appropriately and auto arrange the graphs.

Outp	nts 🔛 🧟 🚛 📰 🔅 鹶 🌆 🚔 📼	3		•
Amm	onia	17	Nitrite and Nitrate	p"
gNA.] 20.0	Ammonia		Nitrite and Nitrate	
nonia in reactor [m 12.0 16.0			e hr societ of instance of the societ of instance of the societ of instance of the societ of the soc	
ee and ionized amr 4.0 8.0			a) microsoft and microsoft and microsoft and a	
JJ [SS]W] Dinit	1 2 3 Index	a N	1 2 3 index	
	Dinimana			
[mgMA] 50.0	Unitrogen			
dinitrogen in reactor 20.0 30.0				
[miss] 0.0 10.0	1 2 3 Index			

12. Run the simulation with the **internal recycle** set to **2000 m³/d**. Record a screenshot of the Nitrogen Variables graphs. Discuss the results. (**Exercise 8 – Question 2**)

Controls 🚠 🛲 🏷 🔅 📆 😽			•
Internal Recycle			
[mlss(3,1)] internal recycle	2000.0 m3/d	0.0	10000.0

13. From the input controls area select the **Transfer controls to scenario** button. Within this window select the internal recycle variable and click Accept. This change allows the internal recycle rate to be held at 0 m³/d and 2000 m³/d in the Default and MLE scenarios respectively.

Transfer to Scenario	×
Select the items to transfer to the scenario	:
Control Items	
✓ [mlss(3,1)] internal recycle	2000.0 m3/d
	Accept Cancel

5

14. From the simulation toolbar navigate to *Scenario* > *Show*. This will provide a summary of the changes that have been made within a specific scenario. Close this window.

Scenario Show : MLE	X
🛃 🛛 🗱 🖓 🖶	
Bioreactor(mlss)	
[mlss(1)] DO setpoint	0.0
[mlss(3,1)] internal recycle	2000.0 m3/d
	Accept Cancel

- 15. In Excel, create a graph of the effluent ammonia, nitrite/nitrate, TKN and TN, for internal recycle rates of 0, 2000, 4000, 6000, and 8000 m³/d (ie. y-axis = nitrogen variables, x-axis = internal recycle rates). (Exercise 8 Question 3)
- Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different internal recycle rates with the internal recycle rates presented on the x-axis rather than time.

16. Save the model layout.

P

Exercise 9 – Exploring Kinetic Parameters

This exercise will explore the various factors that affect the growth of heterotrophs and autotrophs, including review of several key kinetic parameters.

1. Open the Starting Point model layout developed in Exercise 1.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Save the Layout under a different name.
- 3. Select the Define button from the main toolbar and choose the Solids Retention Time option from the bottom of the list.



Follow the steps in Step 4 of Exercise 5. In this case, the pop-up box for the numerator will only have Reactor 1 specified as opposed to three reactors in Exercise 5.

• Select the "Estimate WAS using set SRT" button. Close this window.

🚱 Solids Retention Time Manager	×
Defining SRT Click "+" to create a new SRT variable.	
Define the SRT by clicking on the unit processes for total mass in the selected units and pumped/overflo connection points for total mass flowing in the selected streams. Note: Only the first SRT variable in the can be used to "Estimate WAS using set SRT".	w list
SRT=(solids in the system)/(solids in the stream flowing out of the system)	
For more information, refer to the User's Guide.	
SRT Variables	
Miccas Messimiss) Mess Rowjetrident, VAS)	
Estimate WAS using set SRT	
Controlled Flow WAS 👻	
SRT set point 10.0 days	
minimum SRT controller pump flow 0.0 m3/d	•
maximum SRT controller pump flow 1000000 m3/d	•

Note: If you require further support with setting up a new SRT variable, access the *Quick Start Guide GPS-X Lite* from the Help Menu.

<u>H</u> elp			
k ?	Quick Help	Shift-F1	n f(x) - / - 🐖 - 🔍
	Manuals	•	GPS-X Lite Exercises
	<u>A</u> bout		Quick Start Guide GPS-X Lite
			Technical Reference for GPS-X
			Complete User Guide for GPS-X

NEW

- 4. Switch into Simulation Mode. Rebuild the model when prompted.
- 5. Create two new input control tabs, one called "SRT" and the other "Kinetics."
- 6. To the SRT input control tab, add the following by dragging them to the tab:
 - Main toolbar Define > Solids Retention Time > Estimate WAS using set SRT
 - Main toolbar Define > Solids Retention Time > SRT set point

rag the variable to the	raph area to create an output display for the SRT variable.
the set point is used, y	ou can drag the label to a control tab to create a controller.
rtCAS	Mass(mlss)/Mass Flow(effluent,WAS)
	Estimate WAS using set SRT Controlled Flow WAS
	SRT set point 10.0 days
	minimum SRT controller pump flow 0.0 m3/d
	maximum SRT controller pump flow 1000000 m3/d

- Secondary Clarifier > Input Parameters > Operational > Underflow header > Underflow Rate
- Secondary Clarifier > Input Parameters > Operational > Pumped Flow header > Pumped Flow

Operational SIMULATION IS LOADE	D		×	
Underflow			-	
[RAS] proportional recycle		OFF		
stream label to which recycle is prop	ortional blank			
[RAS] recycle fraction		0.8 -	· D	
[RAS] underflow rate		2000.0 m3/d	- C	
[RAS] underflow from layer	()	-	• D	
[blank] controller		OFF		
[blank] setpoint for control variable		1.0		
More				
C Pumped Flow				
[WAS] pumped flow		40.0 m3/d	• 🗅	
[WAS] pump from layer	()	-	• D	
[blank] controller		OFF		
	333333			
		Accept	Cancel	
Controls 🚠 🛲 🏷 🔅 🧮 🏹				-
SRT Kinetics				
use set point SRT to estimate waste flow		ON		5
SRT set point	10.0 d	0.0		 50.0 5
[RAS] underflow rate	2000.0 m3/d			 <u> </u>
IWASI numbed flow	40.0 m3/d			
TARA Printer new	40.0 113/4	0.0		200.0

- 7. To the Kinetics input control tab add the following by dragging:
 - Bioreactor > Input Parameters > Kinetic > Active Heterotrophic Biomass header > Heterotrophic Maximum Specific Growth Rate
 - Bioreactor > Input Parameters > Kinetic > Active Autotrophic Biomass header > Autotrophic Maximum Specific Growth Rate

Active Heterotrophic Biomass [mlss] heterotrophic maximum specific growth rate 6.0 1/d • [mlss] needily biodegradable substrate half saturation c 20.0 mgCOD/L • [mlss] oxygen half saturation coefficient 0.2 mgO2/L • [mlss] nitrate half saturation coefficient 0.5 mgN/L • [mlss] anoxic growth factor 0.8 - • [mlss] heterotrophic Biomass 0.62 1/d • [mlss] autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d • [mlss] autotrophic decay rate 0.04 1/d • • • [mlss] autotrophic decay rate 0.04 1/d • • • [mlss] autotrophic decay rate 0.04 1/d • • • [mlss] autotrophic decay rate 0.04 1/d • • • • [mlss] autotrophic decay rate 0.04 1/d • • • • metics • • • • • • • • <	KineticSIMULATION IS LOADED					×
[mlss] heterotrophic maximum specific growth rate 6.0 1/d • [mlss] readily biodegradable substrate half saturation c 20.0 mgCOD/L • [mlss] oxygen half saturation coefficient 0.2 mgO2/L • [mlss] nitrate half saturation coefficient 0.5 mgN/L • [mlss] anoxic growth factor 0.8 - • [mlss] heterotrophic decay rate 0.62 1/d • [mlss] autotrophic Biomass [mlss] autotrophic decay rate 0.04 1/d Prophic maximum specific growth rate [mlss] autotrophic decay rate 0.04	Active Heterotrophic Biomass				_	•
[mlss] readily biodegradable substrate half saturation c 20.0 mgCOD/L - [mlss] oxygen half saturation coefficient 0.2 mgO2/L - [mlss] nitrate half saturation coefficient 0.5 mgN/L - [mlss] anoxic growth factor 0.8 - - [mlss] heterotrophic decay rate 0.62 1/d - Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d - [mlss] autotrophic decay rate 0.04 1/d - - - [mlss] autotrophic decay rate 0.04 1/d - - - [mlss] autotrophic decay rate 0.04 1/d - - - - [mlss] autotrophic decay rate 0.04 1/d - - - - - [mlss] autotrophic decay rate 0.04 1/d -	[mlss] heterotrophic maximum specific growth rate	6.0	1/d	•	Ľ	
[mlss] oxygen half saturation coefficient 0.2 mg02/L - [mlss] nitrate half saturation coefficient 0.5 mgN/L - [mlss] anoxic growth factor 0.8 - - [mlss] heterotrophic decay rate 0.62 1/d - Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d - [mlss] autotrophic decay rate 0.04 1/d - - [mtss] autotrophic decay rate 0.01 1/d - - [mtss] autotrophic maximum specific growth rate 0.8 1/d - - [mtss] 0.8 1/d 00	[mlss] readily biodegradable substrate half saturation c	20.0	mgCOD/L	•	D	
[mlss] nitrate half saturation coefficient 0.5 mgN/L • [mlss] anoxic growth factor 0.8 - • [mlss] heterotrophic decay rate 0.62 1/d • Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d • [mlss] autotrophic decay rate 0.0 1/d • [mlss] autotrophic decay rate 0.04 1/d •	[mlss] oxygen half saturation coefficient	0.2	mgO2/L	•	D	
[mlss] anoxic growth factor 0.8 [mlss] heterotrophic decay rate 0.62 1/d 0 Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d 0 [mlss] autotrophic decay rate 0.04 1/d [mlss] autotrophic decay rate 0.04 1/d 0.04 1/d 1/d 1/d 0.04 1/d 0.05	[mlss] nitrate half saturation coefficient	0.5	mgN/L	•		
[mlss] heterotrophic decay rate Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d [mlss] autotrophic decay rate 0.04 1/d [mlss] autotrophic decay rate 0.04 1/d 1/d <td>[mlss] anoxic growth factor</td> <td>0.8</td> <td>-</td> <td>•</td> <td>D</td> <td>П</td>	[mlss] anoxic growth factor	0.8	-	•	D	П
Active Autotrophic Biomass [mlss] autotrophic maximum specific growth rate 0.8 1/d • 0 [mlss] ammonia half saturation coefficient for autotrop 1.0 mgN/L • 0 [mlss] autotrophic decay rate 0.04 1/d • 0 Accept Cancel	[mlss] heterotrophic decay rate	0.62	1/d	•	D	
Image: Accept Cancel Image:	Active Autotrophic Biomass					
[mlss] ammonia half saturation coefficient for autotrop 1.0 mgN/L • [mlss] autotrophic decay rate 0.04 1/d • [mlss] autotrophic decay rate 0.04 1/d • Accept Cancel	[mlss] autotrophic maximum specific growth rate	0.8	1/d	•	D	
[mlss] autotrophic decay rate 0.04 1/d 0.04 0.0	[mlss] ammonia half saturation coefficient for autotrop	1.0	mgN/L	•	D	
Accept Cancel	[mlss] autotrophic decay rate	0.04	1/d	•		
Accept Cancel			02/1		R	-
Image:			Accept		Cancel	
Image: Second						
etics otrophic maximum specific growth rate 0.8 1/d 0.0 rophic maximum specific growth rate 0.8 1/d 0.0	😹 🛲 🎝 🔅 ! 📆 📆					
otrophic maximum specific growth rate 6.0 1/d 00 rophic maximum specific growth rate 0.8 1/d 00	etics					
rophic maximum specific growth rate 0.8 1/d 00	otrophic maximum specific growth rate 6.0 1/d					
	rophic maximum specific growth rate 0.8 1/d 00					
	ropnic maximum specific growth rate 0.8 1/d 0.0					

8. Create a new graph output tab and rename it "Kinetics."

NEW

f(x)

F

- 9. Select the Define button from the main toolbar and navigate to Solids Retention Time. Add the **srtCAS** variable to the new graph tab. Change the graph type to **Digital** by right-clicking on the graph and navigating to *Output Graph Type*.
- 10. Right-click on the mlss stream and navigate to *Output variables > State Variables > Organic Variables header* and drag the **active heterotrophic biomass** variable to the new digital graph.
- 11. To this digital graph also add the **active autotrophic biomass** variable from the same output menu. Auto Arrange the digital graph.

State Variables			X	
r Inorganic Suspended Solids				
[mlss] inert inorganic suspended solids	1000	mg/L	-	
Organic Variables				
[mlss] soluble inert organic material	30.0	mgCOD/L	- 33	
[mlss] readily biodegradable substrate	5.0	mgCOD/L	-	
[mlss] particulate inert organic material	1000	mgCOD/L	-	
[mlss] slowly biodegradable substrate	100.0	mgCOD/L	-	
[mlss] active heterotrophic biomass	500.0	mgCOD/L	-	
[mlss] active autotrophic biomass	100.0	mgCOD/L	-	
[mlss] unbiodegradable particulates from cell decay	100.0	mgCOD/L	-	
[mlss] internal cell storage product	0.0	mgCOD/L	•	
¥e 🌓	Ac	cept Car	ncel	
Outputs Rev cut	arifier Outf	all Kine	tics	
Output: 1				മ്
Solids Retention Time (srtCAS) Dynamic Solids Retention Time (srtdynC/ [mlss] active heterotrophic biomass [mlss] active autotrophic biomass	AS)		d d mg	JCOD/L JCOD/L

- Run the simulation at steady-state for SRT set points of 2, 8, 14, and 20 days. Create a plot in Excel of the heterotrophic and autotrophic biomass vs. SRT and discuss the results. (Exercise 9 Question 1)
- Note: In the fully-functional version of GPS-X, an analyze feature is available. This feature would allow the user to automatically run the simulation at the different SRT set points with the SRT set point presented on the x-axis rather than time.
 - 13. Hover over the mlss stream connection point on the bioreactor until the cursor changes to an arrow; then right-click on the mlss stream and navigate to *Output Variables* > *Other Operational Variables* and drag the **RAS recycle ratio** to the digital graph.

Other Operational Variables		×
Other Operational Variables		
[mlss] food-to-microorganism ratio	0.2094	kgBOD5/(kg ▼
[mlss] volumetric organic loading	0.4654	kgBOD5/(m ▼
[mlss] RAS recycle ratio	1.0	. •
₩∎ ₽	Acce	ept Cancel

 \square

Outputs 🛛 👫 📠 🚛 🕽	🔅 鹶 🍇 🖶 🗟 🖄
Influent Bioreactor Secondary Clarifier	r Outfall Kinetics
Output: 1	⊠ ⁿ
Solids Retention Time (srtCAS)	d
Dynamic Solids Retention Time (srtdynCAS)	d
[mlss] active heterotrophic biomass	mgCOD/L
[mlss] active autotrophic biomass	mgCOD/L
[mlss] RAS recycle ratio	

14. In the SRT input control tab set the **use set point SRT to estimate waste flow** to **OFF** and set the **pumped flow** variable to **100 m³/d**. This sets an SRT of approximately 5 days when the underflow rate is set to 2000 m³/d.

Controls 💼 🥌 🏷 🏷 🧒 🏹				•
use set point SRT to estimate waste flow		OFF		5
SRT set point	10.0 d	00	50.0	5
[RAS] underflow rate	2000.0 m3/d	00	10000.0	5
[WAS] pumped flow	100.0 m3/d	00	200.0	5

- 15. Run the simulation as underflow rates of 1000, 2000, 4000, and 8000 m³/d and record the results for the heterotrophic biomass, autotrophic biomass, and RAS recycle ratio. Prepare a plot in Excel of the heterotrophic and autotrophic biomass vs. RAS recycle ratio and discuss the results. How does the plot compare to the one created in Step 12? (Exercise 9 Question 2)
- Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different RAS recycle ratios with the RAS recycle ratio presented on the x-axis rather than time.
 - 16. Reset all of the variables in the SRT input controls tab and switch to the Kinetics input controls tab.
 - 17. Run the simulation with heterotrophic maximum specific growth rates of 4.8, 5.6, 6.4 and 7.2
 1/d. Prepare a plot in Excel of the effluent cBOD₅ and effluent ammonia vs. the heterotrophic growth rate. Discuss the results. (Exercise 9 Question 3)

Influent Biore	actor Sec	ondary Clarifier	Outfall	Kinetics	
Outfall					
				eff	iluent
					-
Simulation Resu	lts				
		effluent			
Flow	m3/d	-			
TSS	mg/L	-			
VSS	mg/L				
cBOD5	mg/L	-			
COD	ma/L				
Ammonia N	mgN/L	-			
Nitrite/Nitrate N	mgN/L	-			
Nitrite/Nitrate N TKN	mgN/L mgN/L	-			
Nitrite/Nitrate N TKN TN	mgN/L mgN/L mgN/L				

 \square

Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different heterotrophic growth rates with the heterotrophic growth rates presented on the x-axis rather than time.

18. In the Kinetics input control reset the heterotrophic maximum specific growth rate to 6.0 1/d and run the simulation with **autotrophic maximum specific growth rates** of **0.64**, **0.76**, **0.88** 1/d. Prepare a plot in Excel of the effluent cBOD₅ and effluent ammonia vs. the autotrophic growth rate. Discuss the results and compare to those in Step 17. (Exercise 9 – Question 4)

Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different autotrophic growth rates with the autotrophic growth rates presented on the x-axis rather than time.
Exercise 10 – Secondary Clarifier Performance

Having a good secondary clarifier design is critical for ensuring low effluent solids and preventing operational upsets such as poor sludge settling. This exercise will explore several properties of clarifiers.

1. Open the Starting Point layout that was created in Exercise 1

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



- 2. Save the layout under a different name.
- 3. Switch into simulation mode.

NEW

- 4. Create a new graph output tab and call it "Clarifier Performance."
 Add the following output variables to a *single graph* on the new output tab. Right-click on the graph and change to **Digital** from the *Output Graph Type* dropdown.
 MLSS stream:
 - Output Variables > Composite Variables → mixed liquor suspended solids

73

Composite Variables			×
Volatile Fraction [mlss] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[mlss] mixed liquor suspended solids	2216	mg/L	•
[mlss] mixed liquor volatile suspended solids	1216	mg/L	•
[mlss] total inorganic suspended solids	1000	mg/L	•
[mlss] total carbonaceous BOD5	465.3	mgO2/L	•
[mlss] total COD	1835	mgCOD/L	•
[mlss] total TKN	121.6	mgN/L	•
More			
	Acc	ept Can	cel

Effluent Stream:

• *Output Variables > Composite Variables →* total suspended solids

Composite Variables			X
Volatile Fraction			
[effluent] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[effluent] total suspended solids	10.0	mg/L	•
[effluent] volatile suspended solids	5.488	mg/L	•
[effluent] total inorganic suspended solids	4.512	mg/L	•
[effluent] total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] total COD	43.12	mgCOD/L	•
[effluent] total TKN	2.535	mgN/L	•
More			
Ve D	Acc	cept Car	icel

• Output Variables > Performance Variables → TSS removal efficiency

Performance Variables			X
Performance Variables			
[effluent] TSS removal efficiency	0.9967	-	•
[effluent] BOD5 removal efficiency	0.995	-	-
[effluent] TN removal efficiency	0.9163	-	•
¥a 💕	Ac	cept	Cancel

- *Output Variables* > *Clarifier Variables* \rightarrow **sludge blanket height**
- *Output Variables* > *Clarifier Variables* → **solids loading rate**

Clarifier Variables			×
Physical			
[effluent] height (water level)	3.0	m	•
[effluent] sludge blanket height	0.3651	m	•
[effluent] maximum volume	300.0	m3	•
[effluent] volume change (derivative)	0.0	m3/d	•
[effluent] maximum layer thickness	0.3	m	•
[effluent] number of feed layer	7.0	-	•
[effluent] sludge mass	295.0	kg	-
Operational			
[effluent] surface overflow rate	19.6	m/d	-
[effluent] solids loading rate	157.3	kg/(m2.d)	•
Settling			
[effluent] maximum Vesilind settling velocity	410.0	m/d	•
[effluent] hindered zone settling parameter	0.0004	m3/gTSS	•
[effluent] flocculant zone settling parameter	0.0025	m3/gTSS	•
[effluent] minimum attainable suspended solids	3.931	mg/L	•
Ve 🗈	Acc	cept Ca	ncel

RAS Stream:

[effluent] TSS removal efficiency [RAS] total suspended solids

Output Variables > Composite Variables \rightarrow total suspended solids •

Composite Variables			×
Volatile Fraction			
[RAS] VSS/TSS ratio	0.6415	gVSS/gTSS	-
Composite Variables			
[RAS] total suspended solids	7696	mg/L	•
[RAS] volatile suspended solids	4937	mg/L	•
[RAS] total inorganic suspended solids	2759	mg/L	-
[RAS] total carbonaceous BOD5	2026	mgO2/L	-
[RAS] total COD	7331	mgCOD/L	-
[RAS] total TKN	518.4	mgN/L	-
More			
	Acce	ept Can	cel
tput: 1			
ss] mixed liquor suspended solids		ma	/L
uent] total suspended solids		mg	/L
uent] sludge blanket height		m	
uent] solids loading rate		kg/	(m2.d)

5. Create a graph for the clarifier suspended solids in layers by right-clicking on the Secondary Clarifier, navigating to Output Variables > Suspended Solids, and drag the suspended solids variable to the Clarifier Performance output tab.

mg/L

Suspended Solids	X
Suspended Solids [effluent] suspended solids	() mg/L 🗸
	Accept Cancel



Right-click on the graph and change the *Output Graph Type* to **Bar Chart (Horizontal)**. Rename the graph to "Clarifier Suspended Solids." Auto arrange the graphs.

Outpu	uts	REN REN		🗘 🗳	🏚 📄		ø 🖒 🗌				•
Influe	ent E	lioreactor	Secondary Clarifie	er Outfall	Clarifier Per	ormance	State Point Analy	/sis: 6		 	
Outpu	ut: 1				R	7					
[mlss] [efflue [efflue [efflue [RAS] f	mixed ent] tota ent] slud ent] solic ent] TSS total sue	iquor suspe l suspended ge blanket ds loading r removal eff spended so	ended solids d solids height ate iciency lids		mg/L mg/L m kg/(m2.d) - mg/L						
Clarifi	ier Susp	ended Sol	ids								N
					С	arifier S	uspended Soli	ds			
	/										
-											
2											
е											
4											
idex 5											
-9											
7											
8											
6											
10								<u> </u>		 $ \longrightarrow $	
	0.0		2.0		4.0 [effluent] sus	pended so	6.0 lids [mg/L] *10* 3		8.0	10.0	



- 6. Create a new input controls tab called "Clarifier Settling."
- 7. To this new input control tab, add the following:
 - Secondary Clarifier > Input Parameters > Physical > Input Required for All Types of Clarifiers header > Feed Point from Bottom

Flat Bottom		-	
1.0	m	•	
100.0	m2 m	•	
	Accent	Can	el
	Flat Bottom 1.0 100.0 3.0	Flat Bottom 1.0 m 100.0 m2 3.0 m	Flat Bottom ▼ 1.0 m ▼ 100.0 m2 ▼ 3.0 m ▼

- Secondary Clarifier > Input Parameters > Settling > Use SVI to Estimate Settling Parameters
- Secondary Clarifier > Input Parameters > Settling > Sludge Volume Index (SVI)

SettlingSIMULATION IS LOADED				×
Double Exponential Parameters				
[effluent] use SVI to estimate settling parameters	OFF			
[effluent] sludge volume index (SVI)	150.0	mL/g	Ŧ	
[effluent] clarification (0 - bad, 1 - good)	0.5	-	Ŧ	D
[effluent] maximum settling velocity	274.0	m/d	•	
[effluent] maximum Vesilind settling velocity	410.0	m/d	•	
[effluent] hindered zone settling parameter	0.0004	m3/gTSS	•	
[effluent] flocculant zone settling parameter	0.0025	m3/gTSS	•	
[effluent] non-settleable fraction	0.001	-	•	
[effluent] maximum non-settleable solids	20.0	mgTSS/L	•	
More				
		Accept	Can	cel

- Secondary Clarifier > Input Parameters > Operational > Underflow Rate
- Secondary Clarifier > Input Parameters > Operational > Pumped Flow

perationalSIMULATION IS LOADED		X
Underflow		^
[RAS] proportional recycle	OFF	D
stream label to which recycle is proportional	blank	
[RAS] recycle fraction	0.8 -	- D
[RAS] underflow rate	2000.0 m3/d	• D
[RAS] underflow from layer	() -	• 🗅
[blank] controller	OFF	D
[blank] setpoint for control variable	1.0	D
More		
Dumment Flaur		
[WAS] pumped flow	40.0 m3/d	- D
[WAS] numn from laver	() -	• D
[black] controller	OFF	
[black] setucitefor control variable	10	
	1.0	
More		
	Accept	Cancel
Settling		
eed point from bottom	1.0 m 0.0	•

rifier Settling			
uent] feed point from bottom	1.0 m	00 50	>
uent] use SVI to estimate settling parameters		OFF	>
uent] sludge volume index (SVI)	150.0 mL/g	0.0 7500	>
] underflow rate	2000.0 m3/d	0.0 10000.0)
S] pumped flow	40.0 m3/d	00 2000	>

The secondary clarifier object has a water depth of 3 m, and a default feed point from the bottom of 1 m. The feed point is an important design consideration and its effect on clarifier performance will be explored in the following section.

- 8. Run the simulation with all input control variables at their default values. Record a screenshot of the table and plot on the Clarifier Performance tab. (Exercise 10 Question 1)
- 9. Change the **feed point from bottom** variable to **0.25 m**, rerun the simulation and take a screenshot of the results. Discuss the effect of a lower clarifier feed point. (**Exercise 10 Question 2**)

Controls	🗄 🗘 🎝 🗱 📆			•
Clarifier Settling				
[effluent] feed point from	m bottom	0.25 m	00 50	5
[effluent] use SVI to esti	mate settling parameters		OFF	5
[effluent] sludge volume	e index (SVI)	150.0 mL/g	0.0 750.0	3
[RAS] underflow rate		2000.0 m3/d	0.0 10000.0	5
[WAS] pumped flow		40.0 m3/d	0.0 200.0	3

Con

The next section will explore the sludge volume index (SVI) parameter. This is not a physical design parameter but is rather a measurement of the 'goodness' of sludge settleability.

- 10. Click on the Reset button beside the slider of the **feed point from bottom** variable to reset it to **1.0 m**. Set the **use SVI to estimate settling parameters** to **ON**.
- 11. Run the simulation at **sludge volume index (SVI)** values of **50, 150, 250 mL/g,** recording the sludge blanket height and effluent total suspended solids. (Exercise 10 Question 3)

ontrols 煮 🚛 🏷 👯 🏂 🕫				•
Clarifier Settling				
effluent] feed point from bottom	1.0 m	0.0	5.0	5
effluent] use SVI to estimate settling parameters		ON		5
effluent] sludge volume index (SVI) Adjus	150.0 mL/g	0.0	750.0	5
[RAS] underflow rate	2000.0 m3/d	0.0	10000.0	5
[WAS] pumped flow	40.0 m3/d	0.0	200.0	5

Is a lower or higher SVI more desirable in secondary clarifier treatment? Explain your answer.

Using state point analysis curves can be a convenient method of observing the impact of different MLSS operating conditions on the clarifier performance. This is made easy in GPS-X as the software contains a built-in state point analysis tool.

12. Switch into modelling mode. Right-click on the secondary clarifier and navigate to *Input Parameters* > *Operational* > *State Point Analysis Model Parameters header* and switch the **use design MLSS in state point analysis** to **OFF**.

Operational				×
Underflow				
[RAS] proportional recycle	OFF			Ľ
stream label to which recycle is proportional	blank			
[RAS] recycle fraction	0.8	-	Ŧ	\square
[RAS] underflow rate	2000.0	m3/d	•	
[RAS] underflow from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
More				
Pumped Flow				
[WAS] pumped flow	40.0	m3/d	•	
[WAS] pump from layer	()	-	•	\square
[blank] controller	OFF			\square
[blank] setpoint for control variable	1.0			
More				
Model Parameters				
[effluent] sludge blanket threshold concentration	2000.0	mgTSS/L	•	\square
[effluent] critical sludge blanket level	0.1	m	•	
State-Point Analysis Model Parameters				
[effluent] use design MLSS in state point analysis	OFF			
[effluent] design MLSS concentration	3000.0	mgTSS/L	•	
		Accept	Can	cel



- 13. Accept the form and switch back into simulation mode. Rebuild the model when prompted.
- 14. With all the input control variables at their default values, run the simulation at steady-state. (Default values: feed point- 1.0; use SVI- OFF ; sludge volume- 150; RAS underflow- 2000; WAS pumped- 40).
- 15. Right-click on the Secondary Clarifier and navigate to *Output Variables > State Point Analysis*. This will open a new output tab with a graph for the state point analysis for the secondary clarifier. Record a screenshot of this graph. (Exercise 10 – Question 4)
- Within the input controls tab, set the **pumped flow** to **150 m³/d**. Rerun the simulation and observe the effect on the state point analysis graph. Discuss the results of this adjustment to operations. (Exercise 10 Question 5)

Controls 📑 👼 🎝 🏟 🖏 🏹			•
[effluent] feed point from bottom	1.0 m	00 50	5
[effluent] use SVI to estimate settling parameters		OFF	5
[effluent] sludge volume index (SVI)	150.0 mL/g	0.0 750.0	5
[RAS] underflow rate	2000.0 m3/d	0.0 10000.0	5
[WAS] pumped flow	150.0 m3/d	0.0 200.0	5

17. Reset the **pumped flow** back to **40 m³/d** and adjust the **underflow rate** to **4000 m³/d**. Rerun the simulation and observe the effect of this change. Discuss the results. (Exercise 10 – Question 6)

Controls 📑 🔤 🕽 🛱 🗮 🏹 🛛			•
Clarifier Settling			
[effluent] feed point from bottom	1.0 m	00 50	5
[effluent] use SVI to estimate settling parameters		OFF	5
[effluent] sludge volume index (SVI)	150.0 mL/g	0.0 750.0	5
[RAS] underflow rate	4000.0 m3/d	0.0 10000.0	5
[WAS] pumped flow	40.0 m3/d	0.0 2000	5

5

26. Reset the underflow rate back to 2000 m³/d. Set the use SVI to estimate settling parameters to ON and the sludge volume index (SVI) to 200 mL/g. Run the simulation and observe the impact of this change. Discuss the results. (Exercise 10 – Question 7)





Exercise 11 – Anaerobic Digestion

The objective of this exercise is to explore the effect of various factors on the anaerobic digester performance including:

- a) Relationship between SRT and operating temperature
- b) Relationship between operating temperature and gas production
- 1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



In modelling mode use the locator window to make more room at the bottom-right of the drawing board.



3. Locate the process table on the left-hand side of the Modelling window. Click on the Biosolids Treatment Tab, then drag an **Anaerobic Digestion** object and **Dewatering** object onto the drawing board.



4. Click on Tools tab and drag a **Sludge Disposal** object onto the drawing board. Then click on the Flow Combiners and Splitters tab and drag a **2-Flow Combiner** object onto the drawing board.





5. Arrange the objects as displayed in the image above. Use the Mirror and Rotate buttons on the main toolbar to help arrange the process objects, if necessary.



- 6. Delete the following connection by right-clicking on the connection line and selecting **Delete Connection**:
 - Secondary Clarifier Underflow \rightarrow PFR Recycle Influent
- 7. Create the following connections between the process objects (an explanatory screenshot follows):
 - a) Secondary Clarifier Pump \rightarrow Dewatering Input
 - b) Dewatering Filtrate \rightarrow 2-Flow Combiner Input #2
 - c) Secondary Clarifier Underflow \rightarrow 2-Flow Combiner Input #1
 - d) 2-Flow Combiner Output \rightarrow PFR Recycle Influent
 - e) Dewatering Cake \rightarrow Anaerobic Digestion Input
 - f) Anaerobic Digestion Overflow \rightarrow Sludge Disposal Input



Note: Ensure the connections are exactly as specified as in the image above.

8. Add appropriate labels to the process objects and their respective streams so the final model layout appears as the image below.





Note: Depending on the sequence of placing the objects onto the drawing board, the default connection numbers may differ from the images above. This is not an issue; it is only important to ensure that your connections are between the appropriate objects as indicated below.



9. Right-click on the Thickener object and navigate to *Input Parameters > Operational* and change the **specify solids removal by setting...** to **underflow and solids**.

Operational				×
Operational Parameters				
[filtrate] specify solids removal by setting	underflow and sol	ids	-	
[cake] pumped flow	1.5	m3/d	•	Ľ
[cake] underflow solids	200000.0	mg/L	•	Ľ
[filtrate] removal efficiency (concentration basis)	0.95	-	~	
		Accept	Can	cel

10. Switch into simulation mode.

O

Scenario 1 – Relationship Between Digester Operating Temperature and SRT (Exercise 11 – Question 1)

- 11. Create a new input controls tab and rename it "Anaerobic Digestion."
- 12. Right-click on the Thickener object and navigate to *Input Parameters > Operational* and drag the **pumped flow** variable to the window under the new input controls tab. This variable will be used to control the SRT within the anaerobic digester.
- Use the properties button to set the maximum flow to 90 m^3/d .

0	perationalSIMULATION IS LOADED				2	<
	Operational Parameters					
	[filtrate] specify solids removal by setting	underflow and sol	lids			
	[cake] pumped flow	1.5	m3/d	•	D	
	[cake] underflow solids	200000.0	mg/L	•	D	
	[filtrate] removal efficiency (concentration basis)	0.95	-	~	Ľ	
			Accept	Ca	ncel	

13. Right-click on the Anaerobic Digester and navigate to *Input Parameters > Physical* and drag the **digester temperature** to the input controls area.

PhysicalSIMULATION IS LOADED				×
Real Dimension				
[sludge] maximum volume (not editable in GPS-X Lite)	400.0	m3	•	Ľ
[gas] volume of the gas phase	20.0	m3	•	
[gas] total pressure of dry gas @35C	0.934	atm	•	
[sludge] digester temperature	35.0	с	•	D
		Accept	Can	cel

To maintain the same amount of solids removal while changing the digester operating temperature, the HRT needs to be adjusted [1]. Complete the following table through completion of the steps below. (Exercise 11 - Question 1)

Note: The digester HRT is the same as the digester SRT in this scenario.

Temperature (°C)	HRT (d)	Pumped Flow (m ³ /d)	Sludge TSS (kg/d)	VSS Destruction (%)
18	28			
24	20			
30	14			
35	10			

14. In input controls tab set the **digester temperature** to **18** °C and the **pumped flow** to **14 m³/d** and run the simulation.

Controls 📑 🛲 👌 🏟 🐜 🐂				•
Anderobic Digestion				
[cake] pumped flow	14.0 m3/d	0.0	50.0	5
[sludge] digester temperature	18.0 C	0.0	175.0	5

15. Select the Anaerobic Digestion output tab and observe the HRT value under the Operational Variables header. Notice that it is at approximately 28 days due to the adjustment of the pumped flow variable. Record the VSS destruction and sludge TSS values in the table.

Outputs			K 👔 👔		f 发 🖥					•
Influent E	Bioreactor Sec	ondary Clarifier	Outfall Thick	ener Anaero	bic Digestion	Sludge Disposal	Plot: 8			
Anaerobic D	igestion						Display	Flow	▼ m3/d	•
						— gas : 44.73 m3/d				
				e		-				
			cake : 14.	0 m3/d —		— sludge : 14.0 m3/d				
					_	14:0.0 m3/d				
					Ť					
Simulation R	lesults									
Fla		cake 14.0	sludge	14						
TCC	ms/d	21080	17000	17700						
221	mg/L mg/l	14110	10120	9921						
COD	mg/L	20900	15350	15350						
Ammonia N	mgN/I	0.2251	270.2	270.2						
Alkalinity	mgCaCO3/I	182.5	831.2	831.2						
nH		-	6.6	-						
Operational	Variables									
operational	variables		dudae	036						
нрт		d	28.57							
VSS Loading	Rate	ka\/\$\$/(m3.d)	0.4938	-						
VSS Destructi	on	%	28.28	-						
Gas Prod. per	Mass VSS Dest.	m3/kgVSS	0.8008	-						
Total Gas Flov	w Rate	m3/d		44.73						
CH4 Content		%	-	69.74						
CO2 Content		%		30.26						
Mass Flows										
		cake sludg	e 14	gas	Total In	Total Out				
TSS k	kg/d	307.7	51.8 0.0	-	307.7	251.8				
COD k	cg/d	292.7 2	15.0 0.0	64.53	292.7	279.5				
TN k	(g/d	21.03 2	0.72 0.0	-	21.03	20.72				

16. Complete the remainder of the table through adjustment of the digester temperature and pumped flow rate in the Anaerobic Digestion input controls tab. You should notice that the digester performance remains relatively consistent, indicating that a lower operating temperature necessitates a higher operating HRT.

Scenario 2 – Relationship Between Digester Operating Temperature and Gas Production (Exercise 11 – Question 2)

The next section will explore the effect of the digester operating temperature on the quantity of methane gas production.

17. In the Anaerobic Digestion input controls tab set the **pumped flow** to **20 m³/d**. Run the simulation at **digester temperatures** of **15 °C**, **25 °C**, **and 35 °C** and record the gas flow rate of methane. This can be approximated by simply multiplying the CH₄ Content by the Total Gas Flow Rate in the Operational Variables section on the Anaerobic Digestion output tab.

Anaerobic L	Discustions.							Disale	Elen.	_	e
	Digestion							Displa	ay: riow		m5/d
							— gas : 44.53 m3/o	ł			
					6		i				
				cake : 20	0.0 m3/d —		— sludge : 20.0 m3	3/d			
					L		9:0.0 m3/a				
Simulation	Results										
		cake		sludge	9						
Flow	m3/d		20.0	20.0	0.0						
rss	mg/L	1	5380	13570	13320						
VSS	mg/L		9870	8064	7810						
COD	mg/L	1	4630	12240	12240						
Ammonia N	l mgN/L	0.	2249	117.3	117.3						
Alkalinity	mgCaCO3/L	1	82.4	277.7	277.7						
pН	-	-		6.2	-						
Operational	l Variables										
Operational	l Variables			sludge	gas						
Operational HRT	I Variables	d		sludge 20.0	gas						
Operational HRT VSS Loading	l Variables Rate	d kgVSS/(m3.	d)	sludge 20.0 0.4935	gas - -						
Operational HRT VSS Loading VSS Destruct	I Variables Rate tion	d kgVSS/(m3. %	d)	sludge 20.0 0.4935 18.3 1.222	gas - -						
Operational HRT VSS Loading VSS Destruct Gas Prod. pe	I Variables Rate tion er Mass VSS Dest.	d kgVSS/(m3. % m3/kgVSS m2/d	d)	sludge 20.0 0.4935 18.3 1.232	gas - - - -						
Operational HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo	I Variables Rate tion er Mass VSS Dest. ow Rate	d kgVSS/(m3. % m3/kgVSS m3/d %	d)	sludge 20.0 0.4935 18.3 1.232	gas - - - 44,53 43,28						
Operational HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten	I Variables Rate tion er Mass VSS Dest. ow Rate t	d kgVSS/(m3. % m3/kgVSS m3/d %	d)	sludge 20.0 0.4935 18.3 1.232 - -	gas - - - 44.53 43.28 56.72						
Operational HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten	I Variables Rate tion rr Mass VSS Dest. ow Rate tt	d kgVSS/(m3. % m3/kgVSS m3/d % %	d)	sludge 20.0 0.4935 18.3 1.232 - - -	gas - - - 44.55 43.28 56.72						
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten Mass Flows	I Variables Rate tion er Mass VSS Dest. ww Rate it	d kgVSS/(m3. % m3/kgVSS m3/d % %	d)	sludge 20.0 0.4935 18.3 1.232 - -	gas - - - 44,53 43.28 56.72						
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten Mass Flows	I Variables Rate trion tr Mass VSS Dest. w Rate t t	d kgVSS/(m3. % m3/kgVSS m3/d % %	d)	sludge 20.0 0.4935 18.3 1.232 - - - - 9 9	gas - - - 44,53 43,28 56.72	Total In	Total Out				
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten Mass Flows TSS	I Variables Rate Trion Tri Mass VSS Dest. W Rate tt t kg/d	d kgVSS/(m3. % m3/kgVSS m3/d % % %	d) sludge 271.4	sludge 20.0 0.4935 18.3 1.232 - - - - - 9 0	gas - - 44.53 56.72 gas .0 -	Total In 307.6	Total Out 2714				
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Flo CH4 Conten CO2 Conten Mass Flows TSS COD	I Variables Rate tion TMass VSS Dest. w Rate tt kg/d kg/d kg/d	d kgVSS/(m3. % m3/kgVSS m3/d % % %	d) sludge 271.4 244.9	sludge 20.0 0.4935 18.3 1.232 - - - - 9 0 0 0 0 0 0 0 0 0 0 0 0 0	gas - - - - - - - - - - - - - - - - - - -	Total In 307.6	Total Out 271.4 317.0				
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas FIC CH4 Conten CO2 Conten Mass Flows TSS COD TN	I Variables Rate tion rr Mass VSS Dest. www.Rate t t kg/d kg/d kg/d kg/d kg/d	d kgVSS/(m3, % m3/kgVSS m3/kgVSS % %	d) iludge 271.4 244.9 20.72	sludge 20.0 0.4935 18.3 1.232 - - - 9 0 0 0 0 0 0 0 0 0	gas - - 44,53 43,23 56,72 gas .0 - .0 - 2,1! .0 - .0 .0 - .0 .0 - .0 .0 .72,1! .0 .0 .72,1!	Total In 307.6 5 292.6 21.16	Total Out 271.4 317.0 20.72				
Operationa HRT VSS Loading VSS Destruct Gas Prod. pe Total Gas Fic Total Gas Fic CO14 Conten CO2 Conten Mass Flows TSS COD TN	I Variables	d kgVSS/(m3, % m3/kgVSS m3/d % % %	d) sludge 271.4 244.9 20.72	sludge 20.0 0.4935 18.3 1.232 - - - - - 9 0 0 0 0 0	gas - - - 44.53 43.28 56.72 - - - - - - - - - - - - - - - - - - -	Total In 307.6 5 292.6 21.16	Total Out 271.4 317.0 20.72				

18. Create a graph in Excel of the Methane Gas Flow Rate vs. Digester Temperature. Discuss the effect that digester temperature has on the rate of methane production.

 \square

Note: In the fully-functional version of GPS-X an analyze feature is available. This feature would allow the user to automatically run the simulation at the different digester temperatures with the digester temperature presented on the x-axis rather than time.

Exercise 12 – Mass Balance

GPS-X contains a useful feature that allows users to create a Sankey Diagram for flow, solids, and nutrient components throughout the plant. This exercise will explore this feature to aid in understanding how the fate of nutrients is affected by different operational settings.

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. Follow Steps 2-9 for Exercise 11. (DO NOT change the operational parameters in the Thickener.)



- f(x)
- Select the Define button from the main toolbar and choose the Solids Retention Time option from the bottom of the list.

Follow the steps in Step 4 of Exercise 5. In this case, the pop-up box for the numerator will only have Reactor 1 specified as opposed to three reactors above.

- Note: Since this layout contains a Thickener, the loss of solids from the system are from the cake stream, rather than the WAS stream. Therefore, the equation should appear as Mass(mlss)/Mass Flow(effluent,cake) NOT Mass(mlss)/Mass Flow(effluent,WAS) .
- Ensure that the "Estimate WAS using set SRT" box in the Define window is unchecked.

🕁 Solids Retention Time Manager		
Defining SRT		
Click "+" to create a new SRI variable.		
Define the SRT by clicking on the unit connection points for total mass flow can be used to "Estimate WAS using s	processes for total mass in the selected units and pumped/overflow ing in the selected streams. Note: Only the first SRT variable in the list set SRT".	
RT=(solids in the system)/(solids in t	he stream flowing out of the system)	
or more information, refer to the Use	er's Guide.	
SRT Variables		
prtCAS	Mass(mlss)/Mass Flow(effluent,cake)	
	Estimate WAS using set SRT	
	Controlled Flow	
	Estimate WAS using set SRT Controlled Flow SRT set point 10.0	
	Estimate WAS using set SRT Controlled Flow SRT set point 10.0 days minimum SRT controller pump flow	Ŧ

Note: If you require further support with setting up a new SRT variable, access the *Quick Start Guide GPS-X Lite* from the Help Menu.

<u>H</u> elp			_
k ?	Quick Help	Shift-F1	🖛 f(x) - 🖉 - 🔗 .
	Manuals		GPS-X Lite Exercises
	<u>A</u> bout		Quick Start Guide GPS-X Lite
			Technical Reference for GPS-X
			Complete User Guide for GPS-X

3. Switch into Simulation Mode.

NEW

5

- 4. Create a new graph output tab and rename it "SRT." From the main toolbar go to *Define > Solids Retention* Time and drag the **srtCAS** variable to the SRT output graph tab. Right-click on this new graph and select **Digital** from the *Output Graph Type* menu.
- 5. Run the simulation at steady-state and open the Sankey diagram.
- 6. Under the Sankey heading at the top of the window select the **color box** and change the stream color to one of your choice.

Sankey		
Color:		
Width :	-	
Effect (> width):	◎ 📃 🔳	Ø

7. Observe the flow rate and mass flow of TSS, COD, and TN across the plant by selecting the appropriate variable from the dropdown list that appears under the Variable header. Ensure that the values that you observe when running the simulation at the default setting are nearly the same as

those presented in the table below. (Numerical simulations can produce slightly variable results even for the same starting information.)

Variabl	e
Flow 🔻	m3/d
Flow	
TSS	
COD	
TN	

Variable	wwinf	mlss	effluent	WAS	RAS	filtrate	recycle	cake	sludge
Flow (m ³ /d)	2000	4039	1999	40	2000	38.5	2039	1.5	1.5
TSS (kg/d)	477.8	16350	26.63	320.1	16010	15.4	16020	304.7	124.8
COD (kg/d)	860	15580	73.58	304	15200	15.51	15220	288.5	24.53
TN (kg/d)	80	1187	48.15	22.33	1117	1.923	1119	20.41	20.38

- Perform a mass balance on the total nitrogen (TN). Does the mass of TN into the plant (wwinf) equal the mass of solids out of the plant (effluent, sludge)? If not, describe the location, quantity, and form of nitrogen, that makes up the difference. Use simulation results to support your answer. (Exercise 12 Question 1)
- Show that the masses of TSS and COD balance (in equals out) across the Thickener. (Exercise 12 Question 2)
- 10. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Operational* and drag the **pumped flow** variable to the input controls area. Rename the new input controls tab to "Operational Settings."
- 11. Set the **pumped flow** variable to $173 \text{ m}^3/\text{d}$ (SRT = 3 days) and run the steady-state simulation.
- 12. Open the Sankey diagram and report the TN values in the table below. Discuss how the results compare to the default values. (Exercise 12 Question 3)

Variable	wwinf	mlss	effluent	WAS	RAS	filtrate	recycle	cake	sludge
Default - TN (kg/d)	80	1187	48.15	22.33	1117	1.923	1119	20.41	20.38
TN (kg/d)									

13. Close the Sankey window and reset the pumped flow variable.

14. Right-click on the Bioreactor and navigate to *Input Parameters > Operational*. Under the Diffused Aeration header drag the **total air flow into aeration tank** variable to the input control tab and set the value to **15,000 m³/d**.

OperationalSIMULATION IS LOADED					×
Aeration Setup					-
[mlss] aeration method	Diffused Air		*	D	-
[mlss] specify oxygen transfer by	Entering Airflow		-	Ľ	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ	D	
More					
Diffused Aeration					
[mlss] total air flow into aeration tank	30000.0	m3/d	•	D	
[mlss] distribution of air flow to aeration tank	()	-	•	Ľ	
More					-
		Accept		Cancel	

Rerun the steady-state simulation and open the Sankey diagram window. Report the COD values in the table below and discuss how the results compare to the default values. (Exercise 12 – Question 4)

Variable	wwinf	mlss	effluent	WAS	RAS	filtrate	recycle	cake	sludge
Default - COD (kg/d)	860	15580	73.58	304	15200	15.51	15220	288.5	24.53
COD (kg/d)									

- 5
- 16. Close the Sankey window and reset the total air flow into aeration tank back to $30,000 \text{ m}^3/\text{d}$.
- 17. Right-click on the Thickener object and navigate to *Input Parameters > Operational* and drag the **removal efficiency (concentration basis)** variable to the input controls section.
- Set the removal efficiency to 0.8, rerun the simulation and open the Sankey diagram. Report the TSS values in the table below and discuss how the results compare to the default values. (Exercise 12 Question 5)

Variable	wwinf	mlss	effluent	WAS	RAS	filtrate	recycle	cake	sludge
Default - TSS (kg/d)	477.8	16350	26.63	320.1	16000	15.4	16020	304.7	124.8
TSS (kg/d)									

Exercise 13 – Dynamic Operations

The purpose of this exercise is to explore the effect of the influent flow profile on operations.

Recreate the table below to record your answers for the following steps. (Exercise 13 – Question 1)

Daily Avera	ge		Signal Integrati	on
Flow Type	Total Suspended Solids (mg/L)	Total Carbonaceous BOD (mg/L)	Free and Ionized Ammonia (mg/L)	Mass Flow Total Suspended Solids (kg)
Data				
Sinusoidal				
Diurnal Flow				

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. In modelling mode right-click on the Influent Wastewater object and navigate to Flow > Flow Data and change the **influent flow** to **3000 m³/d**.

Flow Data		×
Flow Type [wwinf] flow type	Data	• D
Data [wwinf] influent flow	3000.0 m3/d	• 🗅
Other Flow Options		
	Accept	Cancel

3. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and change the total air flow into aeration tank to 35,000 m³/d.

perational				
Aeration Setup				
[mlss] aeration method	Diffused Air		-	\Box
[mlss] specify oxygen transfer by	Entering Airflow		•	
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ	
More				
Diffused Aeration				
				_
[mlss] total air flow into aeration tank	35000.0	m3/d	•	D
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank	35000.0	m3/d -	•	
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank More	35000.0	m3/d -	•	<u>[</u>]
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank More	35000.0	m3/d -	•	
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank More Mechanical (Surface Aeration)	()	m3/d -	•	
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank More Mechanical (Surface Aeration) [mlss] aeration power	35000.0 ()	m3/d - kW	•	
[mlss] total air flow into aeration tank [mlss] distribution of air flow to aeration tank More Mechanical (Surface Aeration) [mlss] aeration power More	35000.0 ()	m3/d - kW	•	

4. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Operational* and set the **pumped flow** to **100 m³/d**.

Operational		
Underflow		
[RAS] proportional recycle	OFF	
stream label to which recycle is proportional	blank	
[RAS] recycle fraction	0.8 -	- D
[RAS] underflow rate	2000.0 m3/d	• 🗋
[RAS] underflow from layer	() -	• 🗋
[blank] controller	OFF	
[blank] setpoint for control variable	1.0	
More		
Pumped Flow		
[WAS] pumped flow	100.0 m3/d	•
[WAS] pump from layer	() -	• 🗋
[blank] controller	OFF	
[blank] setpoint for control variable	1.0	
More		
		•
	Accept	Cancel

- 5. Select the Define button from the main toolbar and choose the Solids Retention Time option from the bottom of the list. Follow the steps in Step 4 of Exercise 5. In this case, the pop-up box for the numerator will only have Reactor 1 specified as opposed to three reactors above.
 - Ensure that the "Estimate WAS using set SRT" button is unchecked.

🚱 Solids Retention Time Manager	×
Defining SRT Click "+" to create a new SRT variable.	
Define the SRT by clicking on the unit processes for total mass in the selected units and pumped/overflow connection points for total mass flowing in the selected streams. Note: Only the first SRT variable in the list can be used to "Estimate WAS using set SRT". SRT=(solids in the system)/(solids in the stream flowing out of the system) For more information after the local Guide.	
For more information, refer to the User's Guide.	
sttCAS Mass(miss)/Mass Flow(WAS,effluent)	
Estimate WAS using set SRT Controlled Flow WAS SRT set point 10.0 days minimum SRT controller pump flow 0.0 m3/d maximum SRT controller pump flow 1000000 m3/d	*
C	ose

Note: If you require further support with setting up a new SRT variable, access the *Quick Start Guide GPS-X Lite* from the Help Menu.

<u>H</u> elp		_
k ?	Quick Help Shift-F1	🖬 🛛 f(x) - 🛛 🖉 - 🛛 🧟
	Manuals 🔹 🕨	GPS-X Lite Exercises
	<u>A</u> bout	Quick Start Guide GPS-X Lite
		Technical Reference for GPS-X
		Complete User Guide for GPS-X

- 6. From the main toolbar select *Define* > *Daily Average*. Keeping the Variable Type as Stream Variables select the following:
 - Stream Choices:
 - i. Secondary Clarifier (effluent) > effluent
 - Variable Choices:
 - i. Nitrogen Compounds (click on the +) > free and ionized ammonia
 - ii. Composite Variables (click on the +) > total suspended solids, total carbonaceous BOD5

Accept the form to save the changes.

tream Choices	Variable Choices
Include: - Influent (wwinf) - Wioreactor (mlss) - Miss - 4 - WAS - RAS	Include: - Flow - Flow - Organic Variables - Organic Variables

- 7. From the main toolbar select *Define > Mass Flow*. Keeping the Variable Type as Stream Variables select the following:
 - Stream Choices:
 - i. Secondary Clarifier (effluent) > effluent and WAS
 - Variable Choices:
 - i. Composite Variables > total suspended solids

🚱 Define Mode: Mass Flow	×
Variable Type : Stream Variables 🔻	
Stream Choices	Variable Choices
Include: 	Include:
	Accept Cancel

Accept the form to save the changes.

- 8. From the main toolbar select *Define* > *Totalizer*. Change the Variable Type to Define Variables and select the following:
 - i. Secondary Clarifier (effluent) > WAS > Mass Flow > Mass Flow.total suspended solids

Accept the form to save the changes.

NEW

Ω

🚱 Define Mode: Totalizer	×
Variable Type : Define Variables 🔻	
Secondary Clarifier(effluent) effluent Daily Average	
A	Accept Cancel

- 9. Switch into Simulation Mode. Rebuild the model if prompted.
- 10. Create a new output graph tab and rename the tab to "WWTP Performance." Right-click on the WAS stream (after the cursor changes to an arrow) and navigate to *Output Variables* > *Defined Variables* > *Totalizer* and drag the **Signal Integration.Mass Flow.total suspended solids** variable to the new graph tab. Right-click on the graph that is created and go to *Output Graph Type* > *Digital*. Click on the *Output Properties*... button and change the unit of this variable to kg.

Defined Variables : Signal Integration			×
Defined Variables [WAS] Signal Integration.Mass Flow.total suspended so	0.0	(g/d)d	•
		Accept	Cancel

- 11. To this same digital output graph add the following:
 - Effluent Stream Output Variables > Defined Variables > Daily Average: Daily Average.total suspended solids, Daily Average.total carbonaceous BOD5, Daily Average.free and ionized ammonia

Defined Variables : Daily Average			×
Defined Variables			
[effluent] Daily Average.total suspended solids	10.0	mg/L	•
[effluent] Daily Average.total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] Daily Average.free and ionized ammonia	2.0	mgN/L	•
			-
	Accept	Cano	el

Output: 5	Z
[effluent] Daily Average.total suspended solids	mg/L
[effluent] Daily Average.total carbonaceous BOD5	mgO2/L
[effluent] Daily Average.free and ionized ammonia	mgN/L
[WAS] Signal Integration.Mass Flow.total suspended solids	kg

- 12. Create 4 new X-Y output graphs in the WWTP Performance output tab. All variables are accessed by hovering the cursor over the appropriate connection point then right-clicking and choosing the designated item(s).
 - Graph 1: Bioreactor
 - i. MLSS Stream *Output Variables > State Variables >* active heterotrophic biomass, active autotrophic biomass, dissolved oxygen. Place all three variables on the same graph.

S	tate Variables				×
	Inorganic Suspended Solids				-
	[mlss] inert inorganic suspended solids	1000	mg/L	•	
	Organic Variables				-
	[mlss] soluble inert organic material	30.0	mgCOD/	'L -	
	[mlss] readily biodegradable substrate	5.0	mgCOD/	'L -	100010
	[mlss] particulate inert organic material	1000	mgCOD/	۲L –	595
	[mlss] slowly biodegradable substrate	100.0	mgCOD/	ʻL -	
	[mlss] active heterotrophic biomass	500.0	mgCOD/	Έ τ	
	[mlss] active autotrophic biomass	100.0	mgCOD/	ʻL 🔻	
	[mlss] unbiodegradable particulates from cell decay	100.0	mgCOD/	1L -	
	[mlss] internal cell storage product	0.0	mgCOD/	۲L –	
	Dissolved Oxygen				
	[mlss] dissolved oxygen	2.0	mgO2/L	-]_
4				•	
	¥= 1	Ac	cept	Cancel	

• Graph 2: SRT

i	Define >	Solids	Retention	Time >	srtCAS
ι.	Define >	Sonas	Releniion	1 une >	SICAS

Creating SRT Outputs	aranh area to create an output display for the SRT variable	
f the set point is used,	ou can drag the label to a control tab to create a controller.	
RT Variables srtCAS	Mass(mlss)/Mass Flow(WAS,effluent)	
	Estimate WAS using set SRT	
	Controlled Flow WAS 💌	
	SRT set point 10.0 days	
	minimum SRT controller pump flow 0.0 m3/d	Ŧ

- Graph 3: Effluent Quality
 - i. Effluent Stream *Output Variables > Composite Variables >* total suspended solids, total carbonaceous BOD5. Place both variables on the graph.
 - ii. Effluent Stream *Output Variables* > *State Variables* > **free and ionized ammonia**. Drag this variable to the plot area.

Composite Variables			×
Volatile Fraction			
[effluent] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[effluent] total suspended solids	10.0	mg/L	•
[effluent] volatile suspended solids	5.488	mg/L	•
[effluent] total inorganic suspended solids	4.512	mg/L	•
[effluent] total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] total COD	43.12	mgCOD/L	•
[effluent] total TKN	2.535	mgN/L	•
More			
¥e 💕	Acc	ept Can	cel

State Variables			×
Inorganic Suspended Solids			-
[effluent] inert inorganic suspended solids	4.512	mg/L	-
Organic Variables			
[effluent] soluble inert organic material	30.0	mgCOD/L	-
[effluent] readily biodegradable substrate	5.0	mgCOD/L	-
[effluent] particulate inert organic material	4.512	mgCOD/L	-
[effluent] slowly biodegradable substrate	0.4512	mgCOD/L	-
[effluent] active heterotrophic biomass	2.256	mgCOD/L	- 33
[effluent] active autotrophic biomass	0.4512	mgCOD/L	- *
[effluent] unbiodegradable particulates from cell decay	0.4512	mgCOD/L	-
[effluent] internal cell storage product	0.0	mgCOD/L	-
Dissolved Oxygen			
[effluent] dissolved oxygen	2.0	mgO2/L	•
Nitrogen Compounds			
[effluent] free and ionized ammonia	2.0	mgN/L	•
[effluent] soluble biodegradable organic nitrogen	0.0	mgN/L	•
[effluent] particulate biodegradable organic nitrogen	0.004512	mgN/L	•
[effluent] nitrate and nitrite	20.0	mgN/L	•
•			
	Ac	cept Car	ncel

- Graph 4: Influent Flow
 - i. wwinf steam Output Variables > Flow > flow

Flow	×
Flow [wwinf] flow	3000 m3/d •
¥e 💕	Accept Cancel

¢

Auto arrange the graphs and rename them appropriately.





- 13. Create a new input controls tab and rename it to "Operational Settings."
- 14. Right-click on the Influent Wastewater object and navigate to *Flow* > *Flow Data*. Drag the **flow type** variable to the input controls tab.

Flow Data SIMULATION IS LOADED		×
Flow Type		
[wwinf] flow type	Data	- D
r Data		
[wwinf] influent flow	3000.0 m3/	d 🕶 🗋
Other Flow Options		
More		
		1 1
	Accep	ot Cancel

Ö.

15. Within this same form select the *Other Flow Options More*... form and under the Sinusoidal header drag the **sine wave frequency** and the **amplitude scaling factor** to the input controls tab.

ther How OptionsMoreSIMULATION IS LOA	DED			X
Sinusoidal				_
[wwinf] amplitude scaling factor	0.2	-	Ŧ	
[wwinf] time shift	0.35	d	~	D
[wwinf] sine wave frequency	1.0	1/d	Ŧ	Ľ
Diurnal Flow				_
[wwinf] diurnal flow data	()	m3/d	~	Ľ
Diurnal Flow Factor (to average)				
[wwinf] diurnal flow factor	()	-	~	Ľ
Runoff				
[wwinf] rainfall depths	0.0	mm/h	~	D
[wwinf] catchment area	1.16e+08	m2	Ŧ	
[wwinf] direct runoff coefficient	0.15			Ľ
[wwinf] indirect runoff coefficient	0.2			Ľ
[wwinf] direct decay	0.9	1/d	Ŧ	
[wwinf] indirect decay	0.5	1/d	Ŧ	D
[wwinf] initial direct volume	0.0	m3	~	Ľ
A CONTRACTOR OF	0.0	m3	-	Γ

Controls 📑 🚾 🕨 🏷 🤴 🦡 🦮			•
[wwinf] flow type		Data 🗸	5
[wwinf] sine wave frequency	1.0 1/d	00 5	ູ່ອ
[wwinf] amplitude scaling factor	0.2 -	0.0 1.	ູ່ງ

In the following steps you will record screenshots of the outputs graphs. Select the Bioreactor graph under the WWTP Performance tab. Open the graph's properties window to adjust the autoscale and axes as shown in the screenshot below.

	Uncheck the autoscale box		U	nlock th	ne axis		
Outpu	ıt Graph Properties					×	
Disp Title Out	e B oreactor put Graph Type X-Y Autoscale						
Varia	able Properties			- +			
	Display Item	Unit	Min 🔒	Max 🚡	Color Save Data Points		
×	[mlss] active heterotrophic biomass	mgCOD/L 👻	0.0	2000.0	None -		
×	[mlss] active autotrophic biomass	mgCOD/L 🔻	0.0	200		Set the	axis
×	[mlss] dissolved oxygen	mg02/L 👻	0.0	10	None	Tunge	
					Accept Cancel	1	

- 16. In the Simulation Toolbar set the Stop Time to 1-day. With the input controls at the default settings, run the simulation at steady state. Report the results in the first row of the table. Record a screenshot of the output graphs. (Exercise 13 Question 1)
- 17. In the Operational Settings tab, change the **flow type** to **Sinusoidal**, the **sine wave frequency** to **2.0 1/d** and the **amplitude scaling factor** to **0.5**.

Controls 📑 👼 🏷 🔅 🦮			•
			-
[wwinf] flow type		Sinusoidal	ື
[wwinf] sine wave frequency	2.0 1/d	00 50	5
[wwinf] amplitude scaling factor	0.5 -	0.0 1.0	5

- Run the simulation for 1-day at steady-state and report the values in the 2nd row of the table. Record a screenshot of the output graphs. (Exercise 13 Question 2)
- In the Operational Settings tab change the flow type to Diurnal Flow Factor and run the simulation for 1-day at steady-state and report the values in the table. Record a screenshot of the output graphs. (Exercise 13 – Question 3)
- 20. Prepare a discussion regarding the following questions (Exercise 13 Question 4):
 - How are the daily average TSS, total cBOD₅, NH₃, and mass flow of solids affected by the flow type?
 - Compare the dynamic vs. instantaneous solids retention time between each flow type.

• How is the concentration of heterotrophic and autotrophic biomass affected by the flow type?

Exercise 14 – Aeration Strategy on Plant Performance and Energy

As observed in Exercise 7, aeration control has a strong impact on the plant performance. The objective of this exercise is to better understand the effect of the dissolved oxygen concentration in the aeration basin on plant performance.

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. In modelling mode right-click on the Secondary Clarifier and navigate to *Input Parameters* > *Operational* and change the **pumped flow** to $100 \text{ m}^3/\text{d}$.

perational					2
Underflow					I
[RAS] proportional recycle	OFF				
stream label to which recycle is proportional	blank				
[RAS] recycle fraction	0.8		~	۵	
[RAS] underflow rate	2000.0	m3/d	•		
[RAS] underflow from layer	()	-	•		
[blank] controller	OFF				
[blank] setpoint for control variable	1.0				
More					
Pumped Flow					
[WAS] pumped flow	100.0	m3/d	-	D	
[WAS] pump from layer	()	-	•	Ľ	
[blank] controller	OFF				
[blank] setpoint for control variable	1.0				
More					
Model Parameters					
[effluent] sludge blanket threshold concentration	2000.0	maTSS/I	-	Π	1
		Accept	0	Cancel	

3. Right-click on the Bioreactor and navigate to *Input Parameters > Operational* and under the heading "Aeration Setup" change the **specify oxygen transfer by...** to **Using a DO Controller**.

perational				
[mlss] aeration method	Diffused Air		•	
[mlss] specify oxygen transfer by	Using a DO Control	er	•	Ľ
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	~	D
More				
Diffused Aeration				
[mlss] total air flow into aeration tank	30000.0	m3/d	Ŧ	Ľ
[mlss] distribution of air flow to aeration tank	()	-	•	Ľ
More				
Mechanical (Surface Aeration)				
		Accept		Cancel

f(x) 4. From the Define menu on the main toolbar select Daily Average.



- 5. With the Variable Type set at Stream Variables make the following selections:
- Stream Choices:
 - i. Secondary Clarifier (effluent) > effluent
- Variable Choices:
 - i. Nitrogen Compounds > free and ionized ammonia
 - ii. Composite Variables > total carbonaceous BOD5

🚱 Define Mode: Daily Average	×
Variable Type : Stream Variables 💌	
Stream Choices	Variable Choices
Include: 	How Inorganic Suspended Solids Organic Variables Dissolved Oxygen Vitrogen Compounds If ree and ionized ammonia soluble biodegradable organic nitrogen particulate biodegradable organic nitrogen initrate and nitrite dinitrogen Alkalinity Volatile Fraction Composite Variables total suspended solids volatile suspended solids volatile CoD total TKN
	Accept Cancel

- 6. Accept this form and switch into simulation mode. Rebuild the model if prompted.
- 7. Create a new input controls tab and rename it to "DO Control."
- 8. Right-click on the Bioreactor and navigate to *Input Parameters > Operational > Aeration Control header* and drag the **DO setpoint** variable to the input controls area.

				×			
Diffused Air		Ŧ					
Using a DO Contro	ller	Ŧ					
()	1/d	Ŧ					
30000.0	m3/d	~					
()	-	•					
()	kW	Ŧ					
()			D				
		1		-			
	Accept	(Cancel				
2.0	00	-					
	3.5						101
	Diffused Air Using a DO Contro () 30000.0 () () ()	Diffused Air Using a DO Controller () 1/d 30000.0 m3/d () - () kW () Accept 2.0 00	Diffused Air Using a DO Controller () 1/d 30000.0 m3/d () () () () kW () Accept 00	Diffused Air Using a DO Controller () 1/d))	Diffused Air Diffused Air Using a DO Controller () 1/d C <lic< li=""> <lic< li=""> <lic< li=""> C</lic<></lic<></lic<>	Diffused Air Image: Controller Using a DO Controller Image: Controller () 1/d Image: Controller () kW Image: Controller () Image: Controller Image: Controller Image: Controller Image: Controller Image: Controller Image: Controller Image: Controller Image: Controller <t< td=""><td>Diffused Air Image: Controller Using a DO Controller Image: Controller () 1/d Image: Controller () MW Image: Controller () kW Image: Controller () Image: Controller Image: Controller</td></t<>	Diffused Air Image: Controller Using a DO Controller Image: Controller () 1/d Image: Controller () MW Image: Controller () kW Image: Controller () Image: Controller Image: Controller
- 9. Create a new output graph tab called "Performance Variables" and add to it 3 new graphs. To access the designated variables, go to the connection point, hover until the cursor become an arrow, then right-click to access the menu.
 - Effluent Stream Output Variables > State Variables > Free and Ionized Ammonia

NEW

State Variables	0.01	mqcob/L	3
Directived Onumer			
[effluent] dissolved oxygen	2.0	mgO2/L	•
Nitrogen Compounds			_
[effluent] free and ionized ammonia	2.0	mgN/L	•
[effluent] soluble biodegradable organic nitrogen	0.0	mgN/L	•
[effluent] particulate biodegradable organic nitrogen	0.004512	mgN/L	•
[effluent] nitrate and nitrite	20.0	mgN/L	•
[effluent] dinitrogen	0.0	mgN/L	•
Alkalinity			
[effluent] alkalinity	350.0	mgCaCO3/L	•
			•
	Ac	cept Can	cel

• Effluent Stream – Output Variables > Composite Variables > Total Carbonaceous BOD5

Composite Variables			×
Volatile Fraction			
[effluent] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[effluent] total suspended solids	10.0	mg/L	•
[effluent] volatile suspended solids	5.488	mg/L	•
[effluent] total inorganic suspended solids	4.512	mg/L	•
[effluent] total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] total COD	43.12	mgCOD/L	•
[effluent] total TKN	2.535	mgN/L	•
More			
¥∎ 💕	Ac	cept Can	cel

• MLSS Stream – Output Variables > State Variables > Dissolved Oxygen

State Variables		
[mlss] internal cell storage product	0.0	mgCOD/L 🔻
Dissolved Oxygen		
[mlss] dissolved oxygen	2.0	mgO2/L 🔻
Nitrogen Compounds		
[mlss] free and ionized ammonia	2.0	mgN/L 🔻
[mlss] soluble biodegradable organic nitrogen	1.0	mgN/L 🔻
[mlss] particulate biodegradable organic nitrogen	1.0	mgN/L 👻
[mlss] nitrate and nitrite	20.0	mgN/L 🔻
[mlss] dinitrogen	0.0	mgN/L 🔻
Alkalinity		
[mlss] alkalinity	350.0	mgCaCO3/L 🔻
L		•
¥∎ ₽	Ac	cept Cancel



T

Rename the graphs appropriately.

- 10. Additionally, within this tab, add the Daily Average values as follows. Right-click on the effluent stream when the cursor changes to an arrow and navigate to *Output Variables > Defined Variables > Daily Average* and drag the **Daily Average.total carbonaceous BOD5** to the Performance Variables tab. Drag the **Daily Average.free and ionized ammonia** variable to this same graph. Change the graph type to **Digital** by right-clicking on the graph and navigating to *Output Graph Type*.
- 11. Right-click on the mlss stream and navigate to *Output Variables > Operating Cost* and drag the **cumulative blower energy cost** variable to the existing digital output graph.
- 12. Auto arrange the graphs.

Outp	uts 🛛 🖳	A MEN		🌣 📫) 📑	S						•
Outo	ent Bior	eactor Si	econdary Clarifi	er Outfall	Performan	ce Variables	p?						
(miss) [efflue [efflue	cumulativ ent] Daily A ent] Daily A	e blower en verage.total verage.free	ergy cost I carbonaceous and ionized am	BOD5 monia		\$ mgO2/L mgN/L							
Plant	Effluent -	cBOD5				12	Plant	Effluen	t - Ammonia				d.
		1	Plant Effluer	nt - cBOD5					P	lant Efflue	nt - Ammon	ia	
17 °							3						
20gm							16m] 9						
] SODS							nonta						
a no							dam 12						
onace							onize						
dan 4.0							and 0.8						
1 tota							t] free						
Inem C							Then 1						
B 8.							B 8						
	0.0	0.2	0.4 Time [d	0.6 ays]	0.8	1.0		0.0	0.2	0.4 Time	0.6 [days]	0.8	1.0
Biore	actor Efflu	ient - Disso	lved Oxygen			2 ⁷							
		Bioreacte	or Effluent -	Dissolved	Oxygen								
-													
54													
<u>n</u>													
orgen 0.6						_							
ed o													
lossi 4.0													
lss] d													
E													
80	0.0	0.2	0.4 Time [d	0.6 ays]	0.8	1.0							

The following sections will explore the effect of 2 scenarios on DO control and plant performance.

Scenario 1 – Continuous vs. Intermittent Aeration

To simulate the effect of intermittent aeration an input file can be created.

13. Right-click on the DO setpoint variable in the input controls section and select Data File... from the dropdown menu. This will open a window where you can set the value of the DO setpoint at user-specified time steps.

🚱 Data File		\times
File :new data file		
🔊 🔓 🚥 🚥		
t [d]	setpsolmlss(1)
		▲
		•
	Accept	Cancel

14. Create the following input in the data file. The value specified at t = -1 days is the steady-state DO setpoint.

🔊 🔓 🗆				
t [c	1]	set	psolmlss(1)	
-1	2			-
0	2			3
0.1	0			
0.2	2			-
0.3	2			
0.4	0			
0.5	2			
0.6	2			
0.7	0			
0.8	2			
0.9	2			
1.0	0			

- 15. Accept this form and save the data file in an appropriate location.
- 16. Adjust the DO Setpoint controller settings. Right-click on the Bioreactor and navigate to *Input Parameters* > *Operational* > *Aeration Control* > *More* ... and drag the **proportional gain** and **integral time** variables to the input controller tab.

Aeration ControlMoreSIMULATION IS LOADED				×
Controller Setup				
[mlss] controller form	Velocity		~	
[mlss] controller type	PID		~	
[mlss] controller sampling time	0.00347222	d	•	
[mlss] proportional gain	10.0			D
[mlss] integral time	0.01	d	•	D
[mlss] derivative time	0.0	d	•	
[mlss] control cell (0 to control all)	0			
[mlss] air distribution method in single cell control	air distribution frac	tion	Ŧ	
[mlss] derivative kick protection	OFF			
[mlss] derivative filtering	OFF			D
[mlss] cutoff frequency	99999.0	1/d	•	
Aeration Control Tuning				
[mlss] tuning	OFF			
[mlss] fractional step size	0.1	-	~	
[mlss] time of step	0.5	d	~	D
[mlss] maximum possible dead time	100.0	d	~	
		Accept	Can	cel

Controls 🚠 🦽 🏷 🗱 📆 🦮			•
[mlss(1)] DO setpoint	2.0		
	10.0		° •
[miss] proportional gain	10.0	00 9	
[mlss] integral time	0.01 d	0.0 0) ₅

17. Set the proportional gain and integral time to 25.0 and 0.001 d, respectively.

Controls 📑 🛲 🏷 🔅 📆 💏			•
[mlss(1)] DO setpoint	0.0	00	10.0
[mlss] proportional gain	25.0	00	50.0 5
[mlss] integral time	0.001 d	0.0	0.05 🔊

- 18. In the simulation toolbar increase the stop time to 1 day and run the simulation. Record a screenshot of the results on the Performance Variables output tab. (Exercise 14 Question 1)
- 19. Select the *Input Control Properties*... button and change the DO setpoint controller *type* from File Input to **Slider**. Accept the form. In the Input control window set the **DO setpoint** to **2.0 mg/L**.

Controls 📩 🛲 🕽 🏟 🖏 🐄				•
[mlss(1)] DO setpoint	2.0	0.0	10.	, ว
[mlss] proportional gain	10.0	0.0	50.	, ว
[mlss] integral time	0.01 d	0.0		, D

20. With the **Stop Time** at **1 day** run the simulation. Report the values for the daily average effluent cBOD₅ and ammonia concentrations, and the cumulative blower energy cost. Compare the results with those obtained from intermittent aeration. In your opinion is the extra cost of constant aeration worth it? (Exercise 14 – Question 2)

Scenario 2 – Effect of DO Setpoint on Aeration Energy Usage

21. In the input control, set the **DO setpoint** to **5 mg/L** and run the simulation with a stop time of 0days. (No values will appear in the X-Y graphs.)

Ö

Controls 📩 🚾 🏷 🔅 🧮						•
[mlss(1)] DO setpoint	5.0	0.0		-	10.0	5
[mlss] proportional gain	10.0	0.0	-		50.0	5
[mlss] integral time	0.01 d	0.0	-		0.05	5

- S
- 22. Open the Energy Usage Summary window. Record a screenshot of the Layout View with the Aeration Power variable selected from the banner at the top of the window. (Exercise 14 Question 3)
- Switch to the Table/Pie View tab at the top of the Energy Usage Summary window and select the Layout Total row. Record a screenshot of the resulting Layout Total Pie Chart. (Exercise 14 Question 4)
- 24. Close the Energy Usage Summary window by clicking "OK" and select the Outfall output tab and report the value for the plant effluent $cBOD_5$ and ammonia. (Exercise 14 Question 5)
- 25. Repeat steps 21 24 for a **DO setpoint** of **0.5 mg/L**. Compare the results with use of a DO setpoint of 5.0 mg/L and 0.5 mg/L. (Exercise 14 Question 6)

Exercise 15 – Model Calibration

Modelling can provide a valuable tool for the exploration of a plant's performance and how it is affected by various operational settings. Although the default parameter settings in the GPS-X models are based on highly reviewed literature values, it is always necessary to perform a calibration to improve the fit of actual and model-predicted values as parameters can differ between plants.

1. Open the Starting Point model layout developed in Exercise 1 and save it under a different name.

Note: If you ran into any trouble with configuring the layout in Exercise 1, it can be accessed from the main toolbar by going to *File > Sample Layouts*...



2. In modelling mode, right-click on the Bioreactor and navigate to *Input Parameters > Operational* and under the Diffused Aeration heading adjust the **total air flow into aeration tank** to **35,000** m³/d.

Operational				×
Aeration Setup				
[mlss] aeration method	Diffused Air		-	D .
[mlss] specify oxygen transfer by	Entering Airflow		•	D
[mlss] oxygen mass transfer coefficient (clean water)	()	1/d	Ŧ	D
More				
Unitused Aeration	25000.0	m3/d	•	
[mlss] distribution of air flow to aeration tank	()	-	•	
		Accept		Cancel

3. Right-click on the Secondary Clarifier and navigate to *Input Parameters > Settling* and switch the **use SVI to estimate settling parameters** to **ON**.

Settling				×
Double Exponential Parameters				_
[effluent] use SVI to estimate settling parameters	ON			
[effluent] sludge volume index (SVI)	150.0	mL/g	•	D
[effluent] clarification (0 - bad, 1 - good)	0.5	-	•	D
[effluent] maximum settling velocity	274.0	m/d	•	D
[effluent] maximum Vesilind settling velocity	410.0	m/d	Ŧ	D
[effluent] hindered zone settling parameter	0.0004	m3/gTSS	Ŧ	D
[effluent] flocculant zone settling parameter	0.0025	m3/gTSS	Ŧ	Ľ
[effluent] non-settleable fraction	0.001	-	•	D
[effluent] maximum non-settleable solids	20.0	mgTSS/L	•	D
More				
		1		
	_	Accept	Can	cel

- 4. Switch into Simulation Mode. Rebuild the model if prompted.
- 5. Create a new output graph tab and rename it to "Calibration." To this tab, you will add four new graphs.
- 6. Hover on the connection point for the wwinf stream and when the cursor changes to an arrow rightclick. Navigate to *Output Variables* > *Flow* and drag the **flow** variable to the output tab.

Flow Data SIMULATION IS LOADED					×
Flow Type [wwinf] flow type	Data			v	D
Data [wwinf] influent flow		2000.0	m3/d	•	D
Other Flow Options					
More				1	
			Accept	Ca	ncel

7. Right-click on the cursor changed to an arrow at the connection point for the mlss stream and navigate to *Output Variables* > *Composite Variables* and drag the **mixed liquor suspended solids** variable to the Calibration output tab.



Composite Variables			×
Volatile Fraction			
[mlss] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[mlss] mixed liquor suspended solids	2216	mg/L	•
[mlss] mixed liquor volatile suspended solids	1216	mg/L	•
[mlss] total inorganic suspended solids	1000	mg/L	•
[mlss] total carbonaceous BOD5	465.3	mgO2/L	•
[mlss] total COD	1835	mgCOD/L	•
[mlss] total TKN	121.6	mgN/L	•
More			
Ve D	Acc	cept Can	cel

8. Right-click on cursor arrow shape on the mlss stream and navigate to *Output Variables* > *State Variables* and drag the **dissolved oxygen** variable to the same output tab.

State Variables			×
[mlss] unbiodegradable particulates from cell decay	100.0	- mgCOD/L	-
[mlss] internal cell storage product	0.0	mgCOD/L	-
Dissolved Oxygen			
[mlss] dissolved oxygen	2.0	mgO2/L	•
Nitrogen Compounds			
[mlss] free and ionized ammonia	2.0	mgN/L	-
[mlss] soluble biodegradable organic nitrogen	1.0	mgN/L	- 333
[mlss] particulate biodegradable organic nitrogen	1.0	mgN/L	
[mlss] nitrate and nitrite	20.0	mgN/L	-
[mlss] dinitrogen	0.0	mgN/L	-
Alles E-tas			-
¥e 🗈	Aco	cept C	ancel

9. Right-click on the cursor arrow shape at the connection point for the effluent stream and navigate to *Output Variables* > *Composite Variables* and drag the **total suspended solids** variable to the same output tab.

Composite Variables			X
Volatile Fraction			
[effluent] VSS/TSS ratio	0.5488	gVSS/gTSS	•
Composite Variables			
[effluent] total suspended solids	10.0	mg/L	•
[effluent] volatile suspended solids	5.488	mg/L	•
[effluent] total inorganic suspended solids	4.512	mg/L	•
[effluent] total carbonaceous BOD5	5.385	mgO2/L	•
[effluent] total COD	43.12	mgCOD/L	•
[effluent] total TKN	2.535	mgN/L	•
More			
	Ac	cept Can	cel



10. Rename the graphs appropriately and auto arrange in the output tab.



The next section of this exercise involves the creation of a data file.

11. Open a new excel file and enter the following information:

	А	В	С	D	E	F
1	t	qconwwinf	xmlss	somIss	xeffluent	
2	d	m3/d	mg/L	mg/L	mg/L	
3	-1	2000	3500	2.5	10	
4	0	2000	3500	2.5	10	
5	0.2	2500	3500	2.5	10	
6	0.4	2000	3500	1.5	12	
7	0.6	1500	3500	2.2	10	
8	0.8	2500	3500	3.2	8	
9	1	3000	3500	1.8	12	
10						

- Row 1 contains the cryptic variable name of each parameter
 - qconwwinf is the influent flow variable (input)
 - xmlss is the mixed liquor suspended solids concentration (output)
 - somlss is the dissolved oxygen concentration in the mlss stream (output)
 - xeffluent is the total suspended solids concentration in the effluent stream (output)

Note: You can verify these cryptic variable names by hovering your mouse over the variable name in GPS-X. Below is an example of this for the influent flow variable.

Flow Data			×
Flow Type [wwinf] flow type	Data	•	
Data [wwinf] influent flt	2000.0 m3/d	•	
Other Flow Options Influent flow gconwwinf			
	Accept	Cano	el

- Row 2 contains the measurement unit for each variable
- Row 3 contains the steady-state value of each variable
- Rows 4 9 contain the dynamic value of each variable
- 12. Save this excel file in an appropriate location.

Since the influent flow to the WWTP is an input in the data file, it needs to be added to the input controls area, so it can be automatically adjusted over the 1-day simulation window.

13. Right-click on the Influent Wastewater object and navigate to *Flow* > *Flow Data* and drag the **influent flow** variable to the input controls area. Rename the input tab to "Calibration Settings."

Data	- D		
2000.0 m3/d	• 🗅		
Accept	Cancel		
			·
	-		
2000.0 m3/d 0.0			10000.0
	Data 2000.0 m3/d Accept 2000.0 m3/d 00	Data Data Data Data Data Dot Data Dot Data Dot Data Dot Data Dot D	Data

14. In GPS-X Lite from the Simulation Toolbar navigate to *Scenario* > *Configuration* and select the Data Files button.

cenario Configuration	×
How to Configure Scenarios	
You can view and organize various details with the features in this	window.
"Data Files" allows you to easily browse, manage, and edit the files input and display data for the selected scenario. "Compare" allows you to view the differences between scenarios. 'Alt-Ciick' to select multiple scenarios. "Delete" allows you to remove unwanted scenarios. "Up/Down" allows you to reorder the scenarios.	that are used to Use 'Ctrl+Click' or
For more information, refer to the User's Guide.	
Configuration	
Default Scenario	Data Files
	Compare
	Delete
	Delete
	_
	L≜ Up
	Down

15. Select the Add... button and add the excel file that you previously created in Step 11. Once you accept this form you should notice that the influent flow variable in the input controls section changes from a slider-type to a file input-type controller.



16. Set the **Stop Time** to **1-day** and run the simulation at steady-state. Record a screenshot of the graphs on the Calibration output tab. (**Exercise 15 – Question 1**)

You should notice that the actual values (points on the graph) and the simulation results (line) do not align. You will now explore the process of manually making changes to plant operations to improve the fit between the actual and simulation values.

We will look at adjusting 3 parameters to improve the calibration:

- a) WAS pumped flow rate \rightarrow A higher wastage rate decreases the MLSS concentration in the bioreactor
- b) Sludge Volume Index (SVI) \rightarrow A lower SVI reflects improved clarifier settling allowing for lower effluent suspended solids
- c) Diffuser Fouling Constant → Increased fouling decreases the concentration of dissolved oxygen in the bioreactor
- 17. To the input controls area add the following:
- Secondary Clarifier *Input Parameters > Operational >* **pumped flow**

OperationalSIMULATION IS LOADED				×
Underflow				-
[RAS] proportional recycle	OFF			D
stream label to which recycle is proportional	blank			D
[RAS] recycle fraction	0.8	-	Ŧ	D
[RAS] underflow rate	2000.0	m3/d	•	D
[RAS] underflow from layer	()	-	•	D
[blank] controller	OFF			۵
[blank] setpoint for control variable	1.0			D
More				
Pumped Flow				
[WAS] pumped flow	40.0	m3/d	•	
[WAS] pump from layer	()	-	•	
[blank] controller	OFF			
[blank] setpoint for control variable	1.0			
•				•
		Accept	Cano	el

• Secondary Clarifier – *Input Parameters > Settling >* sludge volume index (SVI)

SettlingSIMULATION IS LOADED				X
Double Exponential Parameters				
[effluent] use SVI to estimate settling parameters	ON			Ľ
[effluent] sludge volume index (SVI)	150.0	mL/g	•	D
[effluent] clarification (0 - bad, 1 - good)	0.5	-	•	Ľ
[effluent] maximum settling velocity	274.0	m/d	•	Ľ
[effluent] maximum Vesilind settling velocity	410.0	m/d	Ŧ	Ľ
[effluent] hindered zone settling parameter	0.0004	m3/gTSS	~	D
[effluent] flocculant zone settling parameter	0.0025	m3/gTSS	Ŧ	D
[effluent] non-settleable fraction	0.001	-	•	Ľ
[effluent] maximum non-settleable solids	20.0	mgTSS/L	•	Ľ
More				
		1		
	_	Accept	Can	cel

Bioreactor – Input Parameters > Operational > Diffused Aeration More... > fouling constant •

eration Limits mlss] minimum airflow per diffuser (fine bubble) mlss] maximum airflow per diffuser (coarse bubble) mlss] maximum airflow per diffuser (coarse bubble) mlss] maximum airflow per diffuser (get) mlss] maximum airflow per diffuser (user-defined) mlss] maximum airflow per diffuser (user-defined) mlss] input air flow at mlss] diffuser type mlss] alpha factor (fine bubble) mlss] alpha factor (coarse bubble) mlss] alpha factor (coarse bubble) mlss] alpha factor (get) mlss] alpha factor (get) mlss] alpha factor (get) mlss] alpha factor (user-defined) mlss] alpha factor (ser-defined) mlss] alpha factor (ser-defined) mlss] alpha factor (ser-defined) mlss] alpha factor (for user-defined diffuser mlss] alpha factor for user-defined diffuser mlss] dufing constant mlss] dufing constant mlss] dufth correction factor for user-defined diffuser fine Bubble mlss] fouling constant mlss] dufth correction factor for user-defined diffuser fine Bubble mlss] dufth correction factor for user-defined diffuser fine Bubble mlss] funct flow 2000.0 m3/d mlss]	d AerationMoreSIMULATION IS LOADED					×
[mlss] minimum airflow per diffuser 0.0 m3/d * [mlss] maximum airflow per diffuser (fine bubble) 120.0 m3/d * [mlss] maximum airflow per diffuser (coarse bubble) 1392.0 m3/d * [mlss] maximum airflow per diffuser (iet) 3360.0 m3/d * [mlss] maximum airflow per diffuser (iet) 3360.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] maximum airflow at Standard Conditions * [mlss] alpha factor (fine bubble) () - * [mlss] alpha factor (coarse bubble) () - * [mlss] alpha factor (secondefined) () - * [mlss] dupth correction factor for user-defined diffuser Fine Bubble _ [mlss] depth correction factor for user-defined diffuser Fine Bubble _ [mlss] diptartion Settings	on Limits					-
[mlss] maximum airflow per diffuser (coarse bubble) 120.0 m3/d * [mlss] maximum airflow per diffuser (coarse bubble) 1392.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] input air flow at Standard Conditions * [mlss] alpha factor (fine bubble) () - * [mlss] alpha factor (coarse bubble) () - * [mlss] dupta factor (coarse bubble) () - * [mlss] dupta factor for user-defined () - * [mlss] dupta factor for user-defined diffuser Fine Bubble * * [mlss] dupta factor for user-defined diffuser * * * [mlss] dupta factor for user-defined diffuser * * * [mlss] dupta factrings * * * *	;] minimum airflow per diffuser	0.0	m3/d	~		
[mlss] maximum airflow per diffuser (coarse bubble) 1392.0 m3/d * [mlss] maximum airflow per diffuser (iet) 3360.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * [mlss] input air flow at Standard Conditions * [mlss] diffuser type Fine Bubble * [mlss] alpha factor (fine bubble) * [mlss] alpha factor (coarse bubble) * [mlss] alpha factor (iet) * [mlss] alpha factor (iet) * [mlss] alpha factor (or (or user-defined) * [mlss] fouling constant 1.0 - * [mlss] depth correction factor for user-defined diffuser Fine Bubble Imtrols Accept Cancel	i] maximum airflow per diffuser (fine bubble)	120.0	m3/d	~		
[mlss] maximum airflow per diffuser (jet) 3360.0 m3/d * [mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d * Diffused Air [mlss] input air flow at Standard Conditions * [mlss] diffuser type Fine Bubble * [mlss] alpha factor (fine bubble) () - * [mlss] alpha factor (coarse bubble) () - * [mlss] alpha factor (iet) () - * [mlss] alpha factor (iet) () - * [mlss] fouling constant 1.0 - * [mlss] fouling constant 0 * *] maximum airflow per diffuser (coarse bubble)	1392.0	m3/d	~		
[mlss] maximum airflow per diffuser (user-defined) 120.0 m3/d • Diffused Air [mlss] input air flow at Standard Conditions • [mlss] diffuser type Fine Bubble • [mlss] alpha factor (fine bubble) () - • [mlss] alpha factor (coarse bubble) () - • [mlss] alpha factor (ifine bubble) () - • [mlss] alpha factor (coarse bubble) () - • [mlss] alpha factor (ifine bubble) () - • [mlss] alpha factor (coarse bubble) () - • [mlss] alpha factor (coarse bubble) () - • [mlss] dipta factor (secondefined) () - • [mlss] fouling constant 1.0 - • [mlss] depth correction factor for user-defined diffuser Fine Bubble • [mlss] depth correction factor for user-defined diffuser • • [mlss] dibtration Settings • • •] maximum airflow per diffuser (jet)	3360.0	m3/d	Ŧ		88
Diffused Air [mlss] input air flow at Standard Conditions [mlss] diffuser type Fine Bubble [mlss] alpha factor (fine bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (iet) [mlss] alpha factor (iet) [mlss] alpha factor (user-defined) [mlss] alpha factor (user-defined diffuser Fine Bubble [mlss] depth correction factor for user-defined diffuser Fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser fine Bubble [mlss] depth correction factor for user-defined diffuser [mlss] [mlss] depth correction factor for user-defined diffuser [mlss] [mlss] depth correction factor for user-defined diffuser [mlss] [mlss] [mlss] depth correction factor for user-defined diffuser [mlss] [ml] maximum airflow per diffuser (user-defined)	120.0	m3/d	Ŧ		
[mlss] input air flow at Standard Conditions [mlss] diffuser type Fine Bubble [mlss] alpha factor (fine bubble) () [mlss] alpha factor (coarse bubble) () [mlss] alpha factor (jet) () [mlss] alpha factor (user-defined) () [mlss] fouling constant 1.0 [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser	ed Air					
[mlss] diffuser type Fine Bubble [mlss] alpha factor (fine bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (jet) [mlss] alpha factor (user-defined) [mlss] fouling constant 1.0 [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser	;] input air flow at	Standard Condition	S	Ŧ	D	П
[mlss] alpha factor (fine bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (coarse bubble) [mlss] alpha factor (get) [mlss] alpha factor (user-defined) [mlss] fouling constant [mlss] fouling constant [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser Imlss] depth correction factor for user-defined diffuser	i] diffuser type	Fine Bubble		~		
[mlss] alpha factor (coarse bubble) [mlss] alpha factor (jet) [mlss] alpha factor (user-defined) [mlss] fouling constant [mlss] fouling constant [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser [mlss] depth correction factor for user-defined diffuser	i] alpha factor (fine bubble)	()	-	•		
[mlss] alpha factor (jet) [mlss] alpha factor (user-defined) [mlss] fouling constant 1.0 [mlss] depth correction factor for user-defined diffuser	;] alpha factor (coarse bubble)	()	-	Ŧ		
[mlss] alpha factor (user-defined) [mlss] fouling constant 1.0 [mlss] depth correction factor for user-defined diffuser Accept Cancel winf] influent flow 2000.0	i] alpha factor (jet)	()	-	~		
[mlss] fouling constant 1.0 - Imlss] [mlss] depth correction factor for user-defined diffuser Fine Bubble Imlss] Introls Imlss] Imlss] Imlss] Introls Imlss] Imlss] Imlss] Introls Imlss] Imlss] Imlss]	:] alpha factor (user-defined)	()	-	~		
[mlss] depth correction factor for user-defined diffuser Fine Bubble D Accept Cancel ntrols Image: Second Sec	:] fouling constant	1.0	-	•	D	
Accept Cancel] depth correction factor for user-defined diffuser	Fine Bubble		~		-
ntrols 🚉 🚛 🔊 🌾 📆 🌾 alibration Settings winf] influent flow 2000.0 m3/d			Accept	: (Cancel	
ntrols and a strings and a string and a stri						
ntrols and a second sec						
winf] influent flow 2000.0 m3/d						
vinf] influent flow 2000.0 m3/d	tion Settings					
	nfluent flow	2000.0 m3/d	0.0			
AS] pumped flow 40.0 m3/d	mped flow	40.0 m3/d	0.0		-	_
fluent] sludge volume index (SVI)	sludge volume index (SVI)	150.0 mL/g			-	
Issi fouling constant	uling constant	1.0 -	0.0		-	

18. Start by adjusting the **pumped flow** variable to **60 m³/d** and run the simulation for 1-day.

0.0

•

5

5.0

10000.0 5 200.0 5 750.0

Controls 🚠 🧫 🏷 🔅 📆 🏂			•
[wwinf] influent flow	3000.0 m3/d	0.0 10000.0)
[WAS] pumped flow	60.0 m3/d	0.0 2004	, 🤊
[effluent] sludge volume index (SVI)	150.0 mL/g	0.0 750/	5
[mlss] fouling constant	1.0 -	00 54	5

You should notice that this pumped flow value causes the simulated MLSS concentration to decrease below the actual values on the output graph.

- 19. Continue to adjust the pumped flow variable to approximately match the actual bioreactor mlss concentration. Record the value of the pumped flow. (Exercise 15 Question 2)
- 20. Next, adjust the **sludge volume index** (**SVI**) variable to **100 mL/g** and rerun the simulation. Keep the pumped flow value at the appropriate setting that you determined in Step 19.

You should notice that this change helps to decrease the effluent TSS value.

- 21. Continue to adjust the sludge volume index (SVI) variable to approximately match the effluent TSS concentration. Record the value of the SVI. (Exercise 15 Question 3)
- 22. Lastly, adjust the **fouling constant** to **0.95** and rerun the simulation. Keep the pumped flow value and sludge volume index value at the settings you determined in steps 19 and 21 respectively.

You should notice that this helps to align the actual and model-predicted dissolved oxygen concentration in the bioreactor.

23. Continue to adjust the fouling constant to approximately match the bioreactor dissolved oxygen concentration. Record the value of the fouling constant (**Exercise 15 – Question 4**)

Adjustment of some of these parameters impacts more than one output parameter. For example, improving the secondary clarifier settling by lowering the SVI not only decreases the solids in the effluent but also increases the bioreactor mlss concentration.

Make further changes to the 3 calibration parameters until you are satisfied with the fit between the actual and model-predicted results. Record the values of each parameter setting and the results of the output graphs. (Exercise 15 – Question 5)

Once you have calibrated the parameter settings you can add them to the model layout, so they will appear in modelling mode, and as the base values in the Default Scenario in simulation mode. This will be done as follows.

25. Select the Transfer Values to Layout button in the Input Controls section. In the form that appears click on the checkmark button to select all items to be transferred to the layout.

Once accepting this form, you will have to confirm that you want to transfer the values to the layout as this will result in a rebuild of the model.

Transfer to Layout	X						
Select the items to transfer to the layout:							
Control Items							
☑ [wwinf] influent flow	3000.0 m3/d						
☑ [WAS] pumped flow	47.0 m3/d						
✓ [effluent] sludge volume index (SVI)	60.0 mL/g						
[mlss] fouling constant	0.85 -						
Accept	Cancel						
Transfer to layout	×						
Transferring variables to the layout will cause the layout to be saved and rebuilt. Continue with the transfer?							

A useful tool in GPS-X is the ability to conduct statistical analysis on graphical outputs.

26. Run the simulation for 1-day. Right-click on the dissolved oxygen graph and select *Statistics* > *dissolved oxygen* from the available menu.



27. From the window that appears, under "Model Fit Evaluation" select the **plot of simulation vs measured** and under "Residual Analysis" select **residuals**. Accept this form.

Statistics: [mlss] dissolved oxygen somlss	×
Model Fit Evaluation	
plot of simulated vs measured	
☐ table of goodness-of-fit statistics	
histogram of standardized residuals	
Residual Analysis	
plot against measured values	plot against time
✓ residuals	residuals
absolute residuals	absolute residuals
square residuals	square residuals
relative residuals	relative residuals
absolute relative residuals	absolute relative residuals
square relative residuals	square relative residuals
standardized residuals	standardized residuals
Measured Data Type	
sample type grab sample	•
composite period 24.0 h	composite period 24.0 h
sample time interval 1.0 h	sample flow interval 1000.0 m3/d
	Accent
	Accept

28. Two graphs appear. Separate them by clicking on one and moving it. Record screenshots of the two statistics graphs. (Exercise 15 – Question 6)

APPENDIX A: A Brief Discussion of Biotreatment Models in GPS-XTM (Lite)

This section provides additional information regarding the activated sludge and digestion model provided in GPS-X Lite. *Theory and Practice of Water and Wastewater Treatment*, 2nd ed. by Droste and Gehr is a complimentary text book to GPS-X Lite. The textbook which is geared to present the fundamentals of biotreatment (and other processes) at an undergraduate or first graduate course level uses some simplifications leading to some differences when compared to more advanced models with various refinements available in GPS-X Lite. This section will also describe the major differences between the biological models used in GPS-X Lite and the textbook models.

The commercial version of GPS-X offers the user a choice from many advanced and custom models for various wastewater treatment processes as well as a host of analytical tools. The discussion here will be confined to the two models supporting the textbook.

Consult the Technical Reference for GPS-X under the Help-Manual tab for further information.

Activated Sludge Model

As noted in the GPS-X manual for the application related to the textbook, GPS-X Lite implements the International Water Association (IWA) activated sludge model 1 (ASM1) which was the first of the more principled models developed under the aegis of the IWA. This model made significant improvements over historical approaches in describing aerobic suspended growth processes.

The ASM1 matrix is presented in Table 1. Compare it to Table 17.9 in the textbook. The advanced C-N model in the text, as noted in the text, has some simplifications to make the model algebraically manageable; of course, GPS-X with its numerical engine does not suffer any limitations of this nature. The most significant differences in the two models are as follows.

RATE EXPRESSIONS

In ASM1, the specific growth rate of heterotrophs includes a term for oxygen dependence.

$$\mu_{\rm H} = \mu_{\rm Hm} \frac{S_{\rm S}}{K_{\rm S} + S_{\rm S}} \frac{S_{\rm O}}{K_{\rm OH} + S_{\rm O}}$$

A typical value for K_{OH} is 0.2 mg/L At the minimum dissolved oxygen (DO) concentration of 2 mg/L recommended for an aerobic treatment process, the value of the oxygen hyperbolic expression is 0.91 and it approaches 1 at higher DO concentrations.

The anoxic heterotrophic growth expression contains the term, $\frac{K_{\rm OH}}{K_{\rm OH} + S_{\rm O}}$, which is known as a "switching

function" to turn it off and off in aerobic and anoxic conditions, respectively. Ideally, anoxic conditions should have zero DO (there is no aeration supplied in an anoxic tank, only incidental oxygen transfer at the water surface). For $S_0 = 0$, the value of the switching function is 1.0.

Growth rate of autotrophs is also mediated by a hyperbolic DO expression.

HYDROLYSIS RATE EXPRESSION

See the note below Table 17.6 in the text. The ASM1 expression is more versatile and will yield better results.

ENDOGENOUS DECAY

ASM1 uses a death-regeneration approach to endogenous decay. In fact, the endogenous decay rate coefficient is a die-off coefficient. The degradable part of decayed microorganisms are simply rendered as X_S (degradable particulate matter). Concomitantly, degradable particulate organic nitrogen (in X_{ND}) is generated. The degradable particulates are hydrolysed to soluble degradable organics (S_S) and then metabolized to complete the death-regeneration cycle. Hydrolysis of degradable particulates also results in release of soluble organic nitrogen discussed below.

The text uses a net decay approach for endogenous decay (this approach was adopted in a later IWA model, ASM3). Endogenous decay simply results in the oxidation of the degradable portion of microorganisms. The endogenous decay incorporates metabolism kinetics resulting in the net loss of the degradable portion of microorganisms.

NITROGEN AND PHOSPHORUS

In ASM1, additional nitrogen processes are necessitated by the endogenous decay-regeneration approach. In ASM1, the particulate organic nitrogen (Kjeldahl N, X_{ND}) generated from endogenous decay is converted to soluble organic nitrogen (S_{ND}) at the rate of hydrolysis of degradable particulates according to process 8. The rate of X_{ND} transformation depends on the ratio of X_{ND} to X_S . Hydrolysis of soluble degradable organic nitrogen produced from endogenous decay to ammonia is another process.

In the text, nitrogen yielded from endogenous decay of biomass is assumed to be released as ammonia.

ASM1 is not concerned with phosphorus; it is considered an inert entity in ASM1.

OTHER MINOR DIFFERENCES

ASM1 tracks nondegradable particulates in the influent (X_1) separately from those produced by endogenous decay (X_p).

ASM1 includes alkalinity transformations (S_{Alk}) for aerobic and anoxic growth.

Co	$mponent \rightarrow i$	1	2	3	4	5	6	7	8	9	10	11	12	13	Process Rate, ρ_j [ML ⁻³ T ⁻¹]
j	Process \downarrow	Si	Ss	$X_{\rm I}$	Xs	$X_{ m H}$	XA	X_{P}	So	SNOX	S _{NH}	$S_{\rm ND}$	X _{ND}	S _{Alk}	
1	Aerobic growth of heterotrophs		$-\frac{1}{Y_{\rm H}}$			1			$-\frac{1-Y_{\rm H}}{Y_{\rm H}}$		-i _{NBM}			$-\frac{\dot{i}_{\text{XB}}}{14}$	$\mu_{\rm Hm} \left(\frac{S_{\rm S}}{K_{\rm S} + S_{\rm S}} \right) \left(\frac{S_{\rm O}}{K_{\rm OH} + S_{\rm O}} \right) X_{\rm H}$
2	Anoxic growth of heterotrophs		$-\frac{1}{Y_{\rm H}}$			1				$-\frac{1-Y_{\rm H}}{2.86Y_{\rm H}}$	-i _{NBM}			$\frac{1-Y_{\rm H}}{14\cdot 2.86Y_{\rm H}}$	$\mu_{\rm Hm} \left(\frac{S_{\rm S}}{K_{\rm S} + S_{\rm S}} \right) \left(\frac{K_{\rm OH}}{K_{\rm OH} + S_{\rm O}} \right)$
	•													$-i_{\rm XB}/14$	$\times \left(\frac{S_{\rm NOX}}{K_{\rm NOX} + S_{\rm NOX}}\right) \eta X_{\rm H}$
3	Aerobic growth of autotrophs						1		$-\frac{4.57-Y_{\rm A}}{Y_{\rm A}}$	$\frac{1}{Y_{\rm A}}$	$-i_{\rm NBM} - \frac{1}{Y_{\rm A}}$			$-\frac{i_{\rm XB}}{14}-\frac{1}{7Y_{\rm A}}$	$\mu_{\rm Am}\left(\frac{S_{\rm NH}}{K_{\rm NH}+S_{\rm NH}}\right)\left(\frac{S_{\rm O}}{K_{\rm OA}+S_{\rm O}}\right)X_{\rm A}$
4	Decay of heterotrophs				1–f _{XI}	-1		fхı					<i>і</i> хвм— <i>f</i> хі <i>і</i> _{ХР}		b _H X _H
5	Decay of autotrophs				1–f _{XI}		-1	fхı					іхвм—fxi іхр		$b_{\mathrm{A}}X_{\mathrm{A}}$
6	Ammonifica- tion of soluble organic nitrogen										1	-1		$\frac{1}{14}$	k _a S _{ND} X _H
7	Hydrolysis of entrapped organics		1		-1										$\frac{k_{\rm h} \left(\frac{X_{\rm S}/X_{\rm H}}{K_{\rm X} + (X_{\rm S}/X_{\rm H})}\right) \left[\left(\frac{S_{\rm O}}{K_{\rm OH} + S_{\rm O}}\right) + \eta \left(\frac{K_{\rm OH}}{K_{\rm out} + S_{\rm o}}\right) \left(\frac{S_{\rm NOX}}{K_{\rm NOX} + S_{\rm NOX}}\right) \right] X_{\rm H}$
8	Hydrolysis of entrapped organic nitrogen											1	-1		$\rho_7(X_{\rm ND}/X_{\rm S})$

Table 1. IWA ASM1: Process kinetics and stoichiometry for carbon oxidation, nitrification, and denitrification

Anaerobic Treatment Model

The anaerobic digestion model, MantisAD, provided in GPS-X Lite is a simpler version of anaerobic digestion model no. 1 (ADM1) which is the most advanced anaerobic digestion model (requiring a plethora of data for calibration and implementation and beyond the scope of the textbook). The degradation scheme of organic material and N- transformations are as shown in Figures 1 and 2. The model (22 state variables, 13 processes plus chemical and gas exchange) assumes that the disintegration of composite particulate organic material results in the production of both slowly and readily biodegradable particulate material. This particulate material then undergoes hydrolysis resulting in the production of soluble material that is also slowly and readily biodegradable. This soluble material is then fermented to acetate and hydrogen which is subsequently converted to methane gas. Four biomass types (slowly and readily biodegradable substrate degraders, acetate utilizing methanogens, and hydrogen utilizing methanogens) mediate the steps and are subject to various pH, ammonia, and hydrogen inhibitions.



Figure 1 Anaerobic Transformation of Organic Material in Digester

The matrix describing the major metabolic phenomena in the anaerobic digestion model (MantisAD) in GPS-X Lite is given in Table 2 (see Copp et al. 2005) for comparison to the advanced anaerobic digestion model in Table 19.3. It is readily observed that the GPS-X Lite model uses concepts developed in the text but implements them differently from the model in Table 19.3. The model implemented in GPS-X Lite is

geared for anaerobic digestion of solids produced in primary clarifiers and aerobic biotreatment processes and it easily integrates with these processes in an overall treatment plant model.

Definitions of parameters in the MantisAD model are given in Tables 3-5. In the model, particulate matter is separated into slowly (X_{Ss}) and rapidly (X_{Sr}) degradable particulate matter. Soluble products of hydrolysis are slowly (S_{Ss}) and rapidly (S_{Sr}) degradable substrate which are each metabolized into acetate and hydrogen. Acetoclastic and hydrogenotrophic methanogens then metabolize these products into methane. Endogenous decay renders the decayed groups of bacteria as composite particulate matter. MantisAD also provides a more detailed approach to modelling nitrogen as shown in Figure 2 and the matrix.



Figure 2 Anaerobic Transformation of Nitrogen in Digester

Table 2 MantisAD anaerobic digester model

	Component \rightarrow i	1	2	3	4	5	6	7	8	9	10	11	12	13	14
j	Process ↓	X _I	S _I	X _{bs}	X_{br}	X _{Ac}	X_{H2}	X _C	X _{sb}	X _{rb}	S _{sb}	S _{rb}	S _{Ac}	S _{H2}	S_{CH4}
1	Disintegration	Y_{X_I}	Y_{S_I}					-1	Y_{sb}	$1-Y_{X_I}-Y_{S_I}-Y_{Sb}$					
2	Hydrolysis of readily hydrolysable material									-1		1			
3	Hydrolysis of slowly hydrolysable material								-1		1				
4	Uptake of readily biodegradable substrate				Y _{br}							-1	$Y_{Acrb}(1-Y_{br})$	$(1-Y_{Acrb})(1-Y_{br})$	
5	Uptake of slowly biodegradable substrate			Y _{bs}							-1		$Y_{Acsb}(1-Y_{bs})$	$(1-Y_{Acsb})(1-Y_{bs})$	
6	Uptake of acetate					Y_{Ac}							-1		$1 - Y_{Ac}$
7	Uptake of Hydrogen						Y_{H2}							-1	$1 - Y_{H2}$
8	Organic nitrogen hydrolysis														
9	Ammonification														
10	Endogenous decay of slow degraders			-1				1							
11	Endogenous decay of rapid degraders				-1			1							
12	Endogenous decay of hydrogenotrophic methanogens					-1		1							
13	Endogenous decay of acetoclastic methanogens						-1	1							

Table2 continued.

	Component \rightarrow i	15	16	17	18	19	20	21	Process Rate
j	Process \downarrow	S _{IC}	S _{IN}	X _{Nb}	X _{NI}	adS _{NI}	adS _{Nd}	adX_{Nd}	$ ho_{1} [\mathrm{ML}^{-3}\mathrm{T}^{-1}]$
1	Disintegration	$\frac{C_{XC} - Y_{S_{I}}C_{S_{I}} - Y_{X_{I}}C_{X_{I}} - Y_{Sb}C_{XSb} - (1 - Y_{X_{I}} - Y_{S_{I}} - Y_{Sb})C_{Xrb}}{(1 - Y_{X_{I}} - Y_{S_{I}} - Y_{Sb})C_{Xrb}}$			$Y_{X_I}Y_{X_{NI}}$	$Y_{S_I}Y_{S_{NI}}$	$-Y_{X_I}Y_{X_{NI}}-Y_{S_I}Y_{S_{NI}}$		K _{dis} X _C
2	Hydrolysis of readily hydrolysable organics	$C_{Xrb} - C_{Srb}$							$K_{hydrh}X_{rb}$
3	Hydrolysis of slowly hydrolysable organics	$C_{Xsb} - C_{Ssb}$							K _{hydsh} X _{sb}
4	Uptake of readily biodegradable substrate	$C_{Srb} - Y_{br}C_{bio} - Y_{Acrb}(1) - Y_{br}C_{SAc}$	$-Y_{br}Y_{NXB}$	$Y_{br}Y_{NXB}$					$\frac{\mu_{Xbr}S_{rb}}{K_{Srb}+S_{rb}}X_{br}\nu_4$
5	Uptake of slowly biodegradable substrate	$C_{Ssb} - Y_{bs}C_{bio} - Y_{Acsb}(1) - Y_{bs}C_{SAc}$	$-Y_{bs}Y_{NXB}$	$Y_{bs}Y_{NXB}$					$\frac{\mu_{Xbs}S_{sb}}{K_{ssb}+S_{sb}}X_{bs}\nu_5$
6	Uptake of acetate	$C_{SAc} - Y_{Ac}C_{bio} - (1 - Y_{Ac})C_{SCH4}$	$-Y_{AC}Y_{NXB}$	$Y_{Ac}Y_{NXB}$					$\frac{\mu_{XAC}S_{AC}}{K_{SAC}+S_{AC}}X_{AC}\nu_6$
7	Uptake of Hydrogen	$-Y_{H2}C_{bio} - (1 - Y_{H2})C_{SCH4}$	$-Y_{H2}Y_{NXB}$	$Y_{H2}Y_{NXB}$					$\frac{\mu_{XH2}S_{H2}}{K_{SH2} + S_{H2}} X_{H2} \nu_7$
8	Organic nitrogen hydrolysis						1	-1	K _{dis} adX _{Nd}
9	Ammonification		1				-1		$(K_{hydrb}X_{rb} + K_{hydsb}X_{sb})\frac{adS_{Nd}}{X_{rb} + X_{sb}}$
10	Endogenous de-cay of slow degraders	$C_{bio} - C_{Xc}$		$-Y_{NXB}$				Y _{NXB}	b _h X _{bs}
11	Endogenous decay of rapid degraders	$C_{bio} - C_{Xc}$		$-Y_{NXB}$				Y _{NXB}	$b_h X_{br}$
12	Endogenous decay of hydrogenotrophic methanogens	$C_{bio} - C_{Xc}$		$-Y_{NXB}$				Y _{NXB}	$b_h X_{Ac}$
13	Endogenous decay of acetoclastic methanogens	$C_{bio} - C_{Xc}$		$-Y_{NXB}$				Y _{NXB}	$b_h X_{H2}$

Notes on Table 2.

Soluble CO_2 and inert inorganic solids are also state variables tracked by MantisAD but they are not listed in the table due to space limitations.

Rates 4-7 include inhibition terms (μ) that are function of pH, unionized ammonia, and hydrogen; see Copp et al. (2005) for details.

The model calculates pH and gas transfer from the liquid phase to the gaseous phase. Thus, the initially soluble methane (S_{CH4}) produced leaves in both the gas exiting the reactor as well as the liquid effluent. Carbon dioxide and hydrogen also exit by both routes.

Table 3 State Variables in MantisAD							
Variable	Symbol	Units					
Inert inorganic suspended solids	X _{II}	mg/L					
Inert organic suspended solids	X _I	mg COD/L					
Inert soluble COD	S_I	mg COD/L					
Biomass growing on slowly biodegradable material	X_{bs}	mg COD/L					
Biomass growing on readily biodegradable material	X_{br}	mg COD/L					
Acetate degraders	X _{Ac}	mg COD/L					
Hydrogen degraders	X_{H2}	mg COD/L					
Composite material	X _C	mg COD/L					
Slowly hydrolysable particulate material	X_{sb}	mg COD/L					
Readily hydrolysable particulate material	X_{rb}	mg COD/L					
Slowly biodegradable soluble material	S _{sb}	mg COD/L					
Readily biodegradable soluble material	S _{rb}	mg COD/L					
Acetate	S _{Ac}	mg COD/L					
Hydrogen	S_{H2}	mg COD/L					
Methane	S _{CH4}	mg COD/L					
Ammonia	S _{IN}	mg N/L					
Biomass associated nitrogen	X_{Nb}	mg N/L					
Inert organic particulate nitrogen	X_{NI}	mg N/L					
Inert organic soluble nitrogen	adS_{NI}	mg N/L					
Organically bound soluble nitrogen	adS_{Nd}	mg N/L					
Organically bound particulate nitrogen	adX_{Nd}	mg N/L					
Inorganic carbon	S _{IC}	mole/L					

When using the MantisAD model together with ASM1 model, the phosphorus is considered an inert entity in MantisAD and its reactions are disabled.

Table 4 Stoichiometry Constants in MantisAD							
Parameter	Symbol	Unit					
Readily biodegradable biomass yield	Y_{br}	g COD/g COD					
Slowly biodegradable biomass yield	Y_{bs}	g COD/g COD					
Acetate degraders biomass yield	Y_{Ac}	g COD/g COD					
Hydrogen degraders biomass yield	Y_{H2}	g COD/g COD					
Yield of particulate inert material from composite material	Y_{X_I}	g COD/g COD					
Yield of soluble inert material from composite material	Y_{S_I}	g COD/g COD					
Yield of slowly biodegradable material from composite material	Y_{sb}	g COD/g COD					
Acetate yield from readily biodegradable substrate	Y _{Acrb}	g COD/g COD					
Acetate yield from slowly biodegradable substrate	Y_{Acsb}	g COD/g COD					
Fraction of hydrolysed nitrogen becoming particulate inert nitrogen	$Y_{X_{NI}}$	g N/g N					
Fraction of hydrolysed nitrogen becoming soluble inert nitrogen	$Y_{S_{NI}}$	g N/g N					
Fraction of ammonia becoming associated with the biomass	Y_{NXB}	g N/g N					
Composites carbon content	C_{Xc}	mole C/g COD					
Soluble inerts carbon content	C_{S_I}	mole C/g COD					
Particulate inerts carbon content	C_{X_I}	mole C/g COD					
Readily hydrolysable particulate material carbon content	C_{Xrb}	mole C/g COD					
Slowly hydrolysable particulate material carbon content	C_{Xsb}	mole C/g COD					
Soluble readily biodegradable carbon content	C_{Srb}	mole C/g COD					
Particulate slowly biodegradable carbon content	C_{SSD}	mole C/g COD					
Acetate carbon content	C_{SAC}	mole C/g COD					
Methane carbon content	C _{SCH4}	mole C/g COD					
Biomass carbon content	C_{bio}	mole C/g COD					

Table 5 Kinetic Constant in MantisAD								
Parameter	Symbol	Unit						
Rate of disintegration	K _{dis}	1/d						
Hydrolysis rate of readily biodegradable particulate material	K _{hydrb}	1/d						
Hydrolysis rate of readily biodegradable soluble material	K _{hydsb}	1/d						
Readily biodegradable substrate uptake rate	μ_{Xbr}	1/d						
Slowly biodegradable substrate uptake rate	μ_{Xbs}	1/d						
Acetate degraders growth rate	μ_{XAc}	1/d						
Hydrogen degraders growth rate	μ_{XH2}	1/d						
Biomass decay rate	b_h	1/d						
Half saturation coefficient for readily biodegradable substrate uptake	K _{Srb}	mg COD/L						
Half saturation coefficient for slowly biodegradable substrate uptake	K _{Ssb}	mg COD/L						
Half saturation coefficient for acetate uptake	K _{SAc}	mg COD/L						
Half saturation coefficient for hydrogen uptake	K _{SH2}	mg COD/L						

References

Copp, JB, E Belia, S Snowling, and O Schraa (2005), "Anaerobic digestion: a new model for plat-wide wastewater treatment process modeling," *Water Sci Technol*, 52, 10-11, 1-11.

Droste RL and RL Gehr (2018), *Theory and Practice of Water and Wastewater Treatment*, 2nd ed., John Wiley & Sons, New York.

Henze, M, CPL Grady, Jr, W Gujer, GvR Marais, and T Matsuo (1987), *Activated Sludge Model No.1*. *IAWQ Scientific and Technical Report No. 1*, IWA Publishing, London, England.