Table 4-05 (a)
Treatment Design Calculations [(1)]

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Wastewater influent flowrates and characteristics -- *Design Inputs*	Flow rate	Q	mgd	1.1	0.4	Project Input	DDR chapter 3.1	1
			m^3 / day	4,164	1,514	Conversion Factor = (1,000,000 gal. / day) x (1 ft.^{3} / 7.48 gal.) x [(0.3048 m / 1 ft.)^3]	Common conversion	2
			gpm	764	278	Conversion Factor = (1,000,000 gal. / day) x (1 day / 24 hrs.) x (1 hr. / 60 min.)	Common conversion	3
	Total 5-day biological oxygen demand	BOD_5	mg / l	350	350	Project Input	DDR chapter 3.1	4
	Total Suspended Solids	TSS	mg / l	350	350	Project Input	DDR chapter 3.1	5
	Ammonia - Nitrogen	NH_3-N	mg / l	30	30	Project Input	DDR chapter 3.1	6
	Total Kjeldahl Nitrogen (Organic N + Ammonia N)	TKN	mg / l	45	45	Project Input	DDR chapter 3.1	7
	Influent Nitrate concentration	NO_3-$N_{influent}$	mg / l	0.0	0.0	Typical value is 0.0 mg/l	M&E Table 3-15	8
	Total Phosphorus	TP	mg / l	10	10	Project Input	DDR chapter 3.1	9
	Alkalinity (as $CaCO_3$)	Alk as $CaCO_3$	mg / l	140	140	Project Input	DDR chapter 3.1 [(3)]	10

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Wastewater influent flowrates and characteristics -- *Typical Inputs*	Ultimate BOD / BOD ratio	UBOD / BOD	---	1.5	1.5	Typical input	M&E Eqn. 8-1	11
	fraction of cell mass remaining as cell debris	f_d	g / g	0.15	0.15	Typical input	M&E Eqn. 8-1	12
	synthesis yield coefficient for heterotrophic bacteria	Y_H	g VSS / g COD	0.4	0.4	Typical input	M&E Eqn. 8-1	13
	bCOD / BOD ratio	bCOD / BOD	---	1.64	1.64	{UBOD / BOD} / {1.0 - [1.42 * f_d * (Y_H)]}}	M&E Eqn. 8-1	14
	Biodegradable chemical oxygen demand	bCOD	mg / l	574	574	BOD x (bCOD / BOD ratio)	calculation	15
	(readily biodegradable soluble chemical oxygen demand) : (total chemical oxygen demand) ratio	rbCOD : COD	---	17.5%	17.5%	Typical input. Recommended conservative range, if unknown, is 15% - 25% (4)	Univ. of Pannonia study (5)	16
	(slowly biodegradable chemical oxygen demand) : (total chemical oxygen demand) ratio	sbCOD : COD	---	57.9%	57.9%	Typical input	Univ. of Pannonia study (5)	17
	(non-biodegradable soluble chemical oxygen demand) : (total chemical oxygen demand) ratio	nbsCOD : COD	---	7.5%	7.5%	Typical input	Univ. of Pannonia study (5)	18
	(non-biodegradable particulate chemical oxygen demand) : (total chemical oxygen demand) ratio	nbpCOD : COD	---	17.1%	17.1%	Typical input	Univ. of Pannonia study (5)	19

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Wastewater influent flowrates and characteristics -- *Fractionate COD*	(biodegradable chemical oxygen demand) : (total chemical oxygen demand) ratio	bCOD : COD	---	75.4%	75.4%	bCOD % = sbCOD % + rbCOD %	interpreted from M&E Eqn. 8-10	20
	(non-biodegradable chemical oxygen demand) : (total chemical oxygen demand) ratio	nbCOD : COD	---	24.6%	24.6%	nbCOD % = nbsCOD % + nbpCOD %	interpreted from M&E Eqn. 8-9	21
	Total chemical oxygen demand	COD	mg / l	761	761	bCOD x (bCOD : COD ratio)	calculation	22
	Non-biodegradable chemical oxygen demand	nbCOD	mg / l	187	187	nbCOD = COD - bCOD	M&E Eqn. 8-7	23
	Readily biodegradable soluble chemical oxygen demand	rbCOD	mg / l	133	133	COD x (rbCOD : COD ratio)	calculation	24
	Slowly biodegradable chemical oxygen demand	sbCOD	mg / l	441	441	COD x (sbCOD : COD ratio)	calculation	25
	Non-biodegradable soluble chemical oxygen demand	nbsCOD	mg / l	57	57	COD x (nbsCOD : COD ratio)	calculation	26
	Non-biodegradable particulate chemical oxygen demand	nbpCOD	mg / l	130	130	COD x (nbpCOD : COD ratio)	calculation	27
	Volatile Suspended Solids : Total Suspended Solids ratio	VSS : TSS	---	80.0%	80.0%	Typical input (range is 76.2% - 79.2%)	M&E Table 3-15; EVOQUA calculations (6)	28
	Volatile Suspended Solids	VSS	mg / l	280.0	280.0	(VSS : TSS Ratio) x TSS	calculation	29
	Soluble BOD : BOD ratio	sBOD : BOD	---	50.0%	50.0%	Created input (range is 48.2% - 50.0%)	M&E Ex. 8-1 & 8-2	30
	Soluble biological oxygen demand	sBOD	mg / l	175.0	175.0	(sBOD : BOD Ratio) x BOD	calculation	31
	Soluble COD : COD ratio	sCOD : COD	---	37.0%	37.0%	Created input (values are 36.6%, 44%, & 33%)	M&E Ex. 8-1, 8-2, & 8-3	32
	Soluble chemical oxygen demand	sCOD	mg / l	281.6	281.6	(sCOD : COD Ratio) x COD	calculation	33
Effluent Requirements (2)	Total 5-day biological oxygen demand	BOD_5	mg / l	5	5	Project Input	DDR chapter 3.2	34
	Total Suspended Solids	TSS	mg / l	20	20	Project Input	DDR chapter 3.2	35
	Ammonia - Nitrogen	NH_3-N	mg / l	1.0	1.0	Project Input	DDR chapter 3.2	36
	Total Nitrogen	TN	mg / l	3.0	3.0	Project Input	EVOQUA calculations (6)	37
	Total Phosphorus	TP	mg / l	1.0	1.0	Project Input	DDR chapter 3.2	38

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrification Design -- *Design Selections*	Minimum Temperature	T_{min}	°C	15	15	Typical input (based on engineering judgment)	South Georgia Winter	39
			°F	59	59	°F = [°C x (9/5)]+ 32	calculation	40
	Nitrification Safety Factor	FS	---	1.5	1.5	Typical input (based on engineering judgment)	M&E Chapter 8-3 (pg. 677-680)	41
	Minimum DO concentration for the aeration basin mixed liquor	DO	mg / l	2.0	2.0	Typical input	M&E Table 8-12 (recommendation #4)	42
Nitrification Design -- *Maximum Growth Rate*	Maximum specific growth rate of nitrifying bacteria	μ_{mn}	g VSS / g VSS * d	0.75	0.75	Typical input (at 20 °C)	M&E Table 8-11	43
	Temperature coefficient	$\theta_{\mu n}$	---	1.07	1.07	Typical input	M&E Table 8-11	44
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	45
	Specific growth rate of nitrifying bacteria	$\mu_{n,m,Tmin}$	g VSS / g VSS * d	0.535	0.535	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	46
Nitrification Design -- *Ammonia Constant*	Half velocity constant for Ammonia	K_n	g NH_4-N / m^3	0.74	0.74	Typical input (at 20 °C)	M&E Table 8-11	47
	Temperature coefficient	θ_{Kn}	---	1.053	1.053	Typical input	M&E Table 8-11	48
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	49
	Half velocity constant for Ammonia at T_{min}	$K_{n,Tmin}$	g NH_4-N / m^3	0.572	0.572	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	50
Nitrification Design -- *Endogenous decay coefficient for nitrifying organisms*	Endogenous decay coefficient for nitrifying organisms	k_{dn}	g VSS / g VSS * d	0.08	0.08	Typical input (at 20 °C)	M&E Table 8-11	51
	Temperature coefficient	θ_{kdn}	---	1.04	1.04	Typical input	M&E Table 8-11	52
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	53
	Endogenous decay coefficient for nitrifying organisms at T_{min}	$k_{dn,Tmin}$	g VSS / g VSS * d	0.066	0.066	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	54

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrification Design -- *Specific Growth Rate*	Half-saturation coefficient for DO	K_O	g / m^3	0.50	0.50	Typical input	M&E Eqn. 7-93 & Table 8-11	55
	Nitrogen Concentration	N	g / m^3 -or- mg/l	1.0	1.0	Use effluent ammonia-nitrogen as an input for Nitrogen	M&E Eqn. 7-92 & 7-93 (7)	56
	Specific growth rate of nitrifying bacteria	μ_n	g new cells / g cells * d	0.206	0.206	$\mu_n = \{[(\mu_{nm} * N) / (K_n + N)] * [DO / (K_O + DO)]\} - k_{dn}$	M&E Eqn. 7-93	57
Nitrification Design -- *Solids Retention Time*	Theoretical SRT	SRT_{min}	days	4.84	4.84	$SRT = 1 / \mu_n$	M&E Eqn. 7-37 in Table 8-5	58
	Nitrification Safety Factor	FS	---	1.5	1.5	Typical input	See "Design Selections"	59
	Design SRT	SRT_{des}	days	7.27	7.27	$SRT_{des} = FS * SRT_{min}$	M&E Eqn. 7-71 in Table 8-5	60
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Design selection	Engineer selection	61

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Biomass Production -- *Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	62
Biomass Production -- *Heterotrophic biomass component, Part A*	Heterotrophic biomass yield coefficient	Y	g VSS / g bCOD	0.40	0.40	Typical input	M&E Table 8-5 & 8-10	63
	Influent substrate concentration	S_0	mg / l	574	574	S_0 = bCOD	M&E Eqn. 8-14 & Ex. 8-2 (step 11)	64
	Endogenous decay coefficient	k_d	g VSS / g VSS * d	0.12	0.12	Typical input (at 20 °C)	M&E Table 8-10	65
	Temperature coefficient	θ_{kd}	---	1.04	1.04	Typical input	M&E Table 8-10	66
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	67
	Endogenous decay coefficient at T_{min}	$k_{d,Tmin}$	g VSS / g VSS * d	0.099	0.099	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	68
	Half-velocity constant	K_S	g bCOD / m^3	20.0	20.0	Typical input (at 20 °C)	M&E Table 8-10	69
	Temperature coefficient	θ_K	---	1.00	1.00	Typical input	M&E Table 8-10	70
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	71
	Half-velocity constant at T_{min}	$K_{S,Tmin}$	g bCOD / m^3	20.000	20.000	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	72
	Maximum specific growth rate of heterotrophic bacteria	μ_m	g VSS / g VSS * d	6.0	6.0	Typical input (at 20 °C)	M&E Table 8-10	73
	Temperature coefficient	$\theta_{\mu n}$	---	1.07	1.07	Typical input	M&E Table 8-10	74
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	75
	Specific growth rate of heterographic bacteria	$\mu_{m,Tmin}$	g VSS / g VSS * d	4.278	4.278	$k_2 = k_1 * \theta^{(T2 - T1)}$	M&E Eqn. 2-25	76
	Specific growth rate of heterographic bacteria	μ_m = kY	g VSS / g VSS * d	4.278	4.278	μ_m = k * Y	M&E Eqn. 7-13 in Table 8-5	77
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	78
	Concentration of growth-limiting substrate in solution	S	g bCOD / m3	0.90	0.90	S = {K_S * [1 + (k_d * SRT)]} / {[SRT * (μ_m - k_d)] - 1}	Substitute (μ_m) for (kY) within M&E Eqn. 7-40 in Table 8-5	79
	Net wasted activated sludge produced each day *(heterotrophic biomass, Part A)*	$P_{X,VSS\ (heterotrophic\ biomass)}$	kg VSS / d	445.1	161.9	$P_{X,VSS}$ = {Q * Y * (S_0 - S) * (1 kg / 1000 g)} / {1 + [(k_d) * SRT]}	M&E Eqn. 8-15 (Part A)	80

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Biomass Production -- *Cell debris component, Part B*	fraction of cell mass remaining as cell debris	f_d	g / g	0.15	0.15	Use f_d from Wastewater Influent Flowrates and Characteristics -- Typical Inputs	See "Typical Inputs"	81
	Endogenous decay coefficient at T_{min}	$k_{d,Tmin}$	g VSS / g VSS * d	0.099	0.099	Use k_d from Heterotrophic Biomass calculations	See "Part A calculations"	82
	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	83
	Heterotrophic biomass yield coefficient	Y	g VSS / g bCOD	0.40	0.40	Use Y from Heterotrophic Biomass calculations	See "Part A calculations"	84
	Influent substrate concentration	S_0	mg / l	574	574	Use S_0 from Heterotrophic Biomass calculations	See "Part A calculations"	85
	Concentration of growth-limiting substrate in solution	S	g bCOD / m3	0.90	0.90	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	86
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	87
	Net wasted activated sludge produced each day *(cell debris, Part B)*	$P_{X,VSS\ (cell\ debris)}$	kg VSS / d	76.4	27.8	$P_{X,VSS} = \{(f_d) * (k_d) * Q * Y * (S_0 - S) * SRT * (1\ kg / 1000\ g)\} / \{1 + [(k_d) * SRT]\}$	M&E Eqn. 8-15 (Part B)	88
Biomass Production -- *Nitrifying bacteria biomass component, Part C*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	89
	Nitrifying biomass yield coefficient	Y_n	g VSS / g NH_4-N	0.12	0.12	Typical input (at 20 °C)	M&E Table 8-11	90
	Endogenous decay coefficient for nitrifying organisms at T_{min}	$k_{dn,Tmin}$	g VSS / g VSS * d	0.066	0.066	Use $k_{dn,Tmin}$ from Nitrification Design	See "Nitrification Design"	91
	Assumed Nitr(i)(a)te : Total Kjeldahl Nitrogen Ratio	NO_X : TKN	---	64.5%	64.5%	Typical input	M&E Ex. 8-2 (step 11a)	92
	Influent TKN	TKN	mg / l	45	45	Project Input	See "Design Inputs"	93
	Nitr(a)(i)te	NO_X	mg / l	29.0	29.0	NO_X = TKN x (NO_X : TKN Ratio)	calculation	94
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	95
	Net wasted activated sludge produced each day *(nitrifying bacteria biomass, Part C)*	$P_{X,VSS\ (nitrifying\ bacteria)}$	kg VSS / d	8.2	3.0	$P_{X,VSS} = Q * Y_n * (NO_X) * (1\ kg / 1000\ g)\} / \{1 + [(k_{dn}) * SRT]\}$	M&E Eqn. 8-15 (Part C)	96
Biomass Production -- *Biomass components, Parts A, B, & C*	Net wasted activated sludge produced each day *(biomass, Parts A, B, & C)*	$P_{X,Bio}$	kg VSS / d	529.8	192.6	$P_{X,Bio} = P_{X,VSS\ (heterotrophic\ biomass)} + P_{X,VSS\ (cell\ debris)} + P_{X,VSS\ (nitrifying\ bacteria)}$	M&E Ex. 8-2 (step 11) & M&E pg. 682	97

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrogen Balance -- *Amount of Nitrogen Oxidized to Nitrate*	Total Kjeldahl Nitrogen (Organic N + Ammonia N)	TKN	mg / l	45	45	Project Input	See "Design Inputs"	98
	Nitrogen Concentration	N_e	g / m^3 -or- mg/l	1.0	1.0	Use effluent ammonia-nitrogen as an input for Nitrogen	See Row 48: M&E Ex. 8-2 (step 12)	99
	Net wasted activated sludge produced each day *(biomass, Parts A, B, & C)*	$P_{X,Bio}$	kg VSS / d	529.8	192.6	Use $P_{X,Bio}$ from Biomass Production calculations	See "Biomass Production"	100
	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	101
	Nitrogen oxidized	NO_X	mg / l	28.7	28.7	NO_X = TKN - N_e - {[0.12 * $P_{X,Bio}$ * (1,000 g / kg)] / Q}	M&E Eqn. 8-18 & M&E Ex. 8-2 (step 12)	102
	Nitrogen oxidized (assumption vs. calculation)	NO_X	mg / l	100.96%	100.96%	Is assumed NO_X concentration ***(Row 94)*** close to calculated value ***(Row 102)***? If not, adjust NO_X : TKN ratio ***(Row 92)***	assumption check	103
VSS & TSS Mass in Aeration Basin -- *Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	104
	Biodegradable chemical oxygen demand	bCOD	mg / l	574	574	Use bCOD from Typical Inputs	See "Typical Inputs"	105
	Total 5-day biological oxygen demand	BOD	mg / l	350	350	Project Input	See "Design Inputs"	106
	Soluble biological oxygen demand	sBOD	mg / l	175	175	Use sBOD from Typical Inputs	See "Typical Inputs"	107
	Total chemical oxygen demand	COD	mg / l	761	761	Use COD from Typical Inputs	See "Typical Inputs"	108
	Soluble chemical oxygen demand	sCOD	mg / l	282	282	Use sCOD from Typical Inputs	See "Typical Inputs"	109

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
VSS & TSS Mass in Aeration Basin -- *Calculations*	Biodegradable particulate COD : Particulate COD ratio	bpCOD / pCOD	---	0.60	0.60	(bpCOD / pCOD) = {(bCOD / BOD) * (BOD - sBOD)} / {COD - sCOD}	M&E Eqn. 8-4	110
	Volatile Suspended Solids	VSS	mg / l	280.0	280.0	Use VSS from Typical Inputs	See "Typical Inputs"	111
	Non-biodegradable volatile suspended solids	nbVSS	mg / l	112.4	112.4	nbVSS = [1-(bpCOD / pCOD)] * VSS	M&E Eqn. 8-3	112
	Biomass production (non-biodegradable VSS in influent) *Part D*	$P_{X,VSS\ (non\text{-}biodegradable\ influent)}$	kg VSS / d	468.2	170.3	$P_{X,VSS}$ = Q * (nbVSS) * (1 kg / 1000 g)	M&E Eqn. 8-15 (Part D)	113
	Net wasted activated sludge produced each day *(biomass, Parts A, B, & C)*	$P_{X,Bio}$	kg VSS / d	529.8	192.6	Use $P_{X,Bio}$ from Biomass Production calculations	See "Biomass Production"	114
	Net wasted activated sludge produced each day *(biomass & VSS, Parts A, B, C, & D)*	$P_{X,VSS}$	kg VSS / d	998.0	362.9	$P_{X,VSS} = P_{X,Bio} + P_{X,VSS\ (non\text{-}biodegradable\ effluent)}$	M&E Eqn. 8-15 & M&E Ex. 8-2 (step 13.a.i)	115
	Influent TSS concentration	TSS_0	mg / l	350.0	350.0	Project Input	See "Design Inputs"	116
	Influent VSS concentration	VSS_0	mg / l	280.0	280.0	Use VSS from Typical Inputs	See "Typical Inputs"	117
	Inert TSS in influent *(Part E)*	$P_{X,TSS\ (inert\ TSS\ in\ influent)}$	kg / d	291.5	106.0	$P_{X,TSS\ (inert\ TSS\ in\ influent)}$ = Q * (TSS_0 - VSS_0) * (1 kg / 1,000 g)	M&E Eqn. 8-16 (Term E) & M&E Ex. 8-2 (step 13.a.ii)	118
	VSS : Total Biomass ratio	VSS : Total Biomass	---	0.85	0.85	VSS : Total biomass fraction is 0.85 +/-	M&E pg. 682-683	119
	Solids production in terms of TSS	$P_{X,TSS}$	kg / d	1383.0	502.9	$P_{X,TSS}$ = [(A + B + C) / 0.85] + D + E	M&E Eqn. 8-16 (modified)	120
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	121
	Mass of MLVSS (Mass = P_X * SRT)	(X_{VSS}) * (V)	kg	11,577	4,210	(X_{VSS}) * (V) = $P_{X,VSS}$ * SRT	M&E Eqn. 7-54 & M&E Ex. 8-2 (step 13)	122
	Mass of MLSS (Mass = P_X * SRT)	(X_{TSS}) * (V)	kg	16,043	5,834	(X_{TSS}) * (V) = $P_{X,TSS}$ * SRT	M&E Eqn. 7-55 & M&E Ex. 8-2 (step 13)	123

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Aeration Basin Volume *-- Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	124
	Volatile Suspended Solids : Total Suspended Solids ratio	VSS : TSS	---	80.0%	80.0%	Use VSS : TSS ratio from Typical Inputs	See "Typical Inputs"	125
Aeration Basin Volume *-- Select Design MLSS, and Determine Volume & HRT*	Mass of MLSS	(X_{TSS}) * (V)	kg	16,043	5,834	Use Mass of MLSS from VSS & TSS calculations	See "VSS & TSS Calculations"	126
	Mixed Liquor Suspended Solids	MLSS	mg / l	3500	3500	Typical range is 3000 to 4000 mg/l for 5-stage Bardenpho process [8]	Engineer selection	127
	Mixed Liquor Volatile Suspended Solids	MLVSS	mg / l	2800	2800	MLVSS = MLSS * (VSS : TSS ratio)	EVOQUA calculations [6]	128
	Volume	V	m^3	4,584	1,667	V = [(Mass of MLSS) * (1000 g / 1 kg)] / X_{TSS}, with X_{TSS} = MLSS	M&E Ex. 8-2 (step 14)	129
	Volume Selection	$V_{selection}$	m^3	3,960	1,438	Design selection	Engineer selection	130
			Ft^3	139,846	50,782	Conversion Factor = [(1 ft. / 0.3048 m)^3]	Common conversion	131
			Gal	1,046,049	379,853	Conversion Factor = (7.48 gal. / 1 ft.^{3})	Common conversion	132
	Number of Aeration Basins	$\#_{aeration\ basins}$	each	1	1	Design selection	Engineer selection	133
	Share per Aeration Basin	$Share_{aeration\ basin}$	%	100.00%	100.00%	$Share_{aeration\ basin} = 1 / \#_{aeration\ basins}$	calculation	134
	Volume per Aeration Basin	$V_{per\ aeration\ basin}$	m^3	3,960	1,438	$V_{per\ aeration\ basin} = V_{selection} \times Share_{aeration\ basin}$	calculation	135
			Ft^3	139,846	50,782		calculation	136
			Gal	1,046,049	379,853		calculation	137
	Hydraulic Retention Time	τ	days	0.95	0.95	τ = (V / Q)	M&E Ex. 4-1	138
			hours	22.82	22.79	τ = (V / Q) * (24 hours / day)		139

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Sludge Production & Observed Yield -- *Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	140
Sludge Production & Observed Yield -- *Calculations based on TSS*	Solids production in terms of TSS	$P_{X,TSS}$	kg / d	1383.0	502.9	Use $P_{X,TSS}$ from VSS & TSS calculations	See "VSS & TSS Calculations"	141
	Total TSS production rate	$r_{X(T),TSS}$	g / m^3 * d	1383.0	502.9	$r_{X(T),TSS} = P_{X,TSS}$	Exchange TSS for VSS in M&E Eqn. 7-26, per M&E Ex. 8-2 (step 16)	142
	Influent substrate concentration	S_0	mg / l	574	574	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	143
	Concentration of growth-limiting substrate in solution	S	g bCOD / m3	0.90	0.90	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	144
	bCOD removed	$bCOD_{removed}$	kg / d	2,386.1	867.7	$bCOD_{removed} = Q * (S_0 - S) * (1 kg / 1000 g)$	M&E Ex. 8-2 (step 16)	145
	Substrate utilization rate	r_{su}	g / m^3 * d	2,386.1	867.7	$r_{su} = bCOD_{removed}$	Term defined in M&E Eqn. 7-12; see M&E Ex. 8-2 (step 16)	146
	bCOD / BOD ratio	bCOD / BOD	---	1.64	1.64	Use bCOD from Typical Inputs	See "Typical Inputs"	147
	Observed yield	$Y_{obs,TSS}$	g TSS / g bCOD	0.58	0.58	$Y_{obs,TSS} = r_{X(T),TSS} / r_{su}$ (9)	Exchange TSS for VSS in M&E Eqn. 7-29, per M&E Ex. 8-2 (step 16a)	148
			g TSS / g BOD	0.95	0.95	$Y_{obs,TSS}$ = {$Y_{obs,TSS}$ (based on bCOD substrate)} x {bCOD / BOD ratio}	M&E Ex. 8-2 (step 16a)	149
Sludge Production & Observed Yield -- *Calculations based on VSS*	Volatile Suspended Solids : Total Suspended Solids ratio	VSS : TSS	---	80.0%	80.0%	Use VSS : TSS ratio from Typical Inputs	See "Typical Inputs"	150
	Observed yield	$Y_{obs,VSS}$	g VSS / g bCOD	0.46	0.46	$Y_{obs,VSS}$ = {$Y_{obs,TSS}$ (based on bCOD substrate)} x {VSS / TSS ratio}	M&E Ex. 8-2 (step 16b)	151
			g VSS / g BOD	0.76	0.76	$Y_{obs,VSS}$ = {$Y_{obs,TSS}$ (based on BOD substrate)} x {VSS / TSS ratio}	M&E Ex. 8-2 (step 16b)	152

				Lyons WWTP (1.1 mgd Train)	Lyons WWTP (0.4 mgd Train)			
Category	**Characteristic**	**Symbol**	**Unit**	**Value**	**Value**	**(Input) or (Calculation)**	**Reference**	**Row**
Biomass Concentration -- *Calculations based on Nitrification Design calculations*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	153
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	154
	Hydraulic Retention Time	τ	days	0.95	0.95	Use τ from Aeration Basin Volume design	See "Aeration Basin Volume"	155
	Heterotrophic biomass yield coefficient	Y	g VSS / g bCOD	0.40	0.40	Use Y from Heterotrophic Biomass calculations	See "Part A calculations"	156
	Influent substrate concentration	S_0	mg / l	574	574	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	157
	Concentration of growth-limiting substrate in solution	S	g bCOD / m3	0.90	0.90	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	158
	Endogenous decay coefficient at T_{min}	$k_{d,Tmin}$	g VSS / g VSS * d	0.099	0.099	Use k_d from Heterotrophic Biomass calculations	See "Part A calculations"	159
	SRT Selection	$SRT_{selection}$	days	11.6	11.6	Use SRT from Nitrification Design	See "Nitrification Design"	160
	Biomass concentration in the aeration tank	X_b	g / m^3	1,304	1,306	$X_b = \{SRT / \tau\} * \{[Y * (S_0 - S)] / [1+(k_d * SRT)]\}$	M&E Eqn. 7-43 & M&E Ex. 8-5 (step 1)	161
Internal Recycle (IR) Ratio	Nitrate produced in aeration zone as a concentration relative to influent flow	NO_X	mg NO_3-N / L	28.7	28.7	Use NO_X from Nitrogen Balance calculations [10]	See "Nitrogen Balance" calculations	162
	Effluent NO_3-N concentration	N_e	mg / l	6.0	6.0	Recommended input range is 5 to 7 mg/l	M&E pg. 758	163
	RAS recycle ratio (RAS flowrate / influent flowrate)	R	% Q	50.0%	50.0%	R = (RAS flowrate) / (Influent flowrate) [11]	EVOQUA calculations [6]	164
	Internal recycle ratio (internal recycle flowrate / influent flowrate)	IR	---	3.3	3.3	$IR = (NO_X / N_e) - 1.0 - R$	M&E Eqn. 8-48	165

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrate Fed to Anoxic Tank -- *Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	166
Nitrate Fed to Anoxic Tank -- *Nitrate Feed*	Internal recycle ratio (internal recycle flowrate / influent flowrate)	IR	---	3.3	3.3	Use IR from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	167
	RAS recycle ratio (RAS flowrate / influent flowrate)	R	% Q	50.0%	50.0%	Use R from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	168
	Flowrate to anoxic basin	Q_{anoxic}	m^3 / day	15,789	5,741	Flowrate to anoxic tank = (IR * Q) + (R * Q)	M&E Ex. 8-5 (step 3)	169
	Effluent NO_3-N concentration	N_e	mg / l	6.0	6.0	Use NO_3-N from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	170
	Nitrate feed to anoxic basin	NO_X feed	g / d	94,733	34,449	NO_X = (Flowrate to anoxic tank) x N_e	M&E Ex. 8-5 (step 3)	171
Nitrate Fed to Anoxic Tank -- *Anoxic Basin Volume*	Hydraulic Retention Time (Target)	τ	hours	4	4	Typical range is 1 to 3 hours for 5-stage Bardenpho process [8]	Engineer selection	172
			days	0.167	0.167	# Days = # Hours / (24 hours / day)	calculation	173
	Anoxic Volume (Target)	V_{nox}	m^3	694	252	$V_{nox} = \tau \times Q$	M&E Ex. 8-5 (step 4) [12]	174
	Anoxic Volume (Selection)	$V_{nox\ (selection)}$	m^3	690	250	Design selection	Engineer selection	175
			Ft^3	24,367	8,829	Conversion Factor = $[(1\ ft. / 0.3048\ m)^3]$	Common conversion	176
			Gal	182,266	66,038	Conversion Factor = (7.48 gal. / 1 $ft.^3$)	Common conversion	177
	Hydraulic Retention Time (Selection)	τ	hours	3.98	3.96	τ = (V / Q) * (24 hours / day)	M&E Ex. 4-1	178
			days	0.166	0.165	τ = (V / Q)		179
	Number of Anoxic Basins	$\#_{anoxic\ basins}$	each	2	2	Design selection	Engineer selection	180
	Share per Anoxic Basin	$Share_{anoxic\ basin}$	%	50.00%	50.00%	$Share_{anoxic\ basin} = 1 / \#_{anoxic\ basins}$	calculation	181
	Volume per Anoxic Basin	$V_{per\ anoxic\ basin}$	m^3	345	125	$V_{per\ anoxic\ basin} = V_{selection} \times Share_{anoxic\ basin}$	calculation	182
			Ft^3	12,184	4,414		calculation	183
			Gal	91,133	33,019		calculation	184
Nitrate Fed to Anoxic Tank -- *F/M$_b$ Ratio*	Influent BOD concentration	S_0	mg / l	350	350	S_0 = influent BOD	M&E Eqn. 8-43	185
	Anoxic Volume	V_{nox}	m^3	690	250	Use V_{nox} from above	See "Anoxic Basin Volume"	186
	Anoxic zone biomass concentration	X_b	mg / l	1,304	1,306	Use X_b from Biomass Concentration calculations	See "Biomass Concentration"	187
	BOD Food : Mass ratio based on active biomass concentration	F/M_b	g BOD / g biomass * d	1.62	1.62	$F/M_b = [Q * S_0] / [(V_{nox}) * X_b]$	M&E Eqn. 8-43	188

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrate Fed to Anoxic Tank -- *SDNR*	Readily biodegradable soluble chemical oxygen demand	rbCOD	mg / l	133	133	Input rbCOD from Typical Inputs	See "Typical Inputs"	189
	Biodegradable chemical oxygen demand	bCOD	mg / l	574	574	Input bCOD from Typical Inputs	See "Typical Inputs"	190
	Fraction of rbCOD : bCOD	rbCOD : bCOD	%	23.21%	23.21%	rbCOD : bCOD = rbCOD / bCOD	calculation	191
	Specific denitrification rate (at 20° C)	$SDNR_{20}$	g NO_3-N / g MLVSS * d	0.26	0.26	Input SDNR from Figure 8-23	M&E Figure 8-23 (13)	192
	Temperature coefficient	θ_{SDNR}	---	1.026	1.026	Constant	M&E Eqn. 8-44	193
	Minimum Temperature	T_{min}	°C	15	15	Use T_{min} from Nitrification Design calculations	See "Design Selections"	194
	Specific denitrification rate (at T_{min}° C)	$SDNR_{Tmin}$	g NO_3-N / g MLVSS * d	0.229	0.229	$SDNR_T = SDNR_{20} * \theta^{(T - 20)}$	M&E Eqn. 8-44 (13)	195
	Internal recycle ratio (internal recycle flowrate / influent flowrate)	IR	---	3.3	3.3	Use IR from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	196
	BOD Food : Mass ratio based on active biomass concentration	F/M_b	g BOD / g biomass * d	1.62	1.62	Use F/M_b from above	See "F/M_b Ratio" calculations	197
	SDNR adjustment required	Adj_{req}	Yes -or- No	Yes	Yes	If F/M_b >1.0, SDNR adjustment is required. Is adjustment required?	Requirement Check	198
	$SDNR_{adj}$ coefficient for F/M	$Coef_{SDNR}$	---	0.0000	0.0000	Coefficient at IR = 1.0	M&E Eqn. 8-45 & 8-46	199
				0.0166	0.0166	Coefficient at IR = 2.0		200
				0.0290	0.0290	Coefficient at IR = 3.0		201
				0.0290	0.0290	Coefficient at IR = 4.0		202
				0.0290	0.0290	Pro-rate Coefficient for Project IR		203
	$SDNR_{adj}$ constant	C_{SDNR}	---	0.0000	0.0000	Constant at IR = 1.0	M&E Eqn. 8-45 & 8-46	204
				0.0078	0.0078	Constant at IR = 2.0		205
				0.0120	0.0120	Constant at IR = 3.0		206
				0.0120	0.0120	Constant at IR = 4.0		207
				0.0120	0.0120	Pro-rate Constant for Project IR		208
	Specific denitrification rate (at T_{min}° C), adjusted for IR rate	$SDNR_{Tmin,adj}$	g NO_3-N / g MLVSS * d	0.203	0.203	$SDNR_{adj} = SDNR_{IR1} - [Coef_{SDNR} * \ln(F/M_b)] - C_{SDNR}$ (14) (15)	M&E Eqn. 8-45 & 8-46	209
Nitrate Fed to Anoxic Tank -- *Nitrate Removed*	Anoxic Volume	V_{nox}	m^3	690	250	Use V_{nox} from above	See "Anoxic Basin Volume"	210
	Specific denitrification rate	$SDNR_{Tmin,adj}$	g NO_3-N / g MLVSS * d	0.203	0.203	Use SDNR from above	See "Nitrate Feed" calculations	211
	Anoxic zone MLVSS biomass concentration	X_b	mg / l	1,304	1,306	Use X_b from Biomass Concentration calculations	See "Biomass Concentration"	212
	Nitrate removed	NO_r	g / d	182,369	66,146	$NO_r = V_{nox}$ * SDNR * MLVSS	M&E Eqn. 8-41	213

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Nitrate Fed to Anoxic Tank -- *Checks & Feeback Loop*	Specific denitrification rate	$SDNR_{Tmin,adj}$	g NO_3-N / g MLVSS * d	0.203	0.203	Use $SDNR_{Tmin,adj}$ from SDNR calculations	See "SDNR" calculations	214
	Specific denitrification rate (at T_{min}° C)	$SDNR_{Tmin}$	g NO_3-N / g MLVSS * d	0.229	0.229	Use $SDNR_{Tmin}$ from SDNR calculations	See "SDNR" calculations	215
	Anoxic zone biomass concentration	X_b	mg / l	1,304	1,306	Use X_b from Biomass Concentration calculations	See "Biomass Concentration"	216
	Mixed Liquor Suspended Solids	X_T	mg / l	3500	3500	Use design MLSS concentration from Aerobic Basin Volume calculations	See "Aerobic Basin Volume"	217
	Specific denitrification rate (based on MLSS)	$SDNR_{MLSS}$	g / g * d	0.085	0.085	$SDNR_{MLSS} = SDNR_{Tmin} * (X_b / X_T)$	M&E Ex. 8-5 (step 7c)	218
	Nitrate feed to anoxic basin	NO_X feed	g / d	94,733	34,449	Use NO_x from Nitrate Feed calculations	See "Nitrate Feed" calculations	219
	Nitrate removed	NO_r	g / d	182,369	66,146	Use NO_r from Nitrate Removed calculations	See "Nitrate Removed" calculations	220
	Project SDNR value is within typical range	$SDNR_{project\ within\ range}$	g / g * d	Acceptable	Acceptable	Base range check on ***Row 218*** instead of ***Row 214***: SDNR values range between 0.04 to 0.42 g / g * d [16]	range check (per Ex. 8-5, step 7c)	221
	Nitrate Removed : Nitrate Fed ratio	NO_r / (NO_x feed)	%	192.51%	192.02%	Is there enough nitrate removal capacity to treat the nitrate feed amount (i.e., ratio must exceed 100%)? If there is sufficient capacity, the τ ***(Row 172)*** and V_{nox} ***(Row 175)*** can be reduced.	assumption check	222
	Effluent Nitrate concentration	NO_3-N $_{effluent}$	mg / l	0.3	0.3	Typical range is 0.1 to 0.3 mg/l	M&E Table 8-19 (note 5)	223

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Oxygen Demand -- *Input Data*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	224
Oxygen Demand -- *Total Oxygen Required (without denitrification)*	Influent substrate concentration	S_0	mg / l	574	574	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	225
	Concentration of growth-limiting substrate in solution	S	g bCOD / m3	0.90	0.90	Use S from Heterotrophic Biomass calculations	See "Part A calculations"	226
	Net wasted activated sludge produced each day *(biomass, Parts A, B, & C)*	$P_{X,Bio}$	kg VSS / d	529.8	192.6	Use $P_{X,Bio}$ from Biomass Production calculations	See "Biomass Production"	227
	Concentration of influent NH_4-N that is nitrified	NO_X	mg / l	28.7	28.7	Use NO_X from Nitrogen Balance calculations (10)	See "Nitrogen Balance" calculations	228
	Total Oxygen Required (without nitrification)	$R_{O\ (without\ nitrification)}$	kg / d	2152.2	782.6	R_O = [Q * (S_0 - S) * (1 kg / 1000 g)] - [1.42 * $P_{X,bio}$] + [4.33 * Q * (NO_X) * (1 kg / 1000 g)]	M&E Eqn. 8-17 & Ex. 8-2 (step 17)	229
			kg / hour	89.7	32.6	Conversion Factor = (24 hours / 1 day)	calculation	230
			# / hour	197.7	71.9	Conversion Factor = (2.205 lbs / 1 kg)	calculation	231
Oxygen Demand -- *Denitrification Oxygen Credit*	(Oxygen utilization rate, g/m^3*d) / (Nitrate reduction rate, g/m^3*d) ratio	r_O / r_{NOx}	---	2.86	2.86	Ratio = 2.86	M&E Eqn. 8-51	232
	Concentration of influent NH_4-N that is nitrified	NO_X	mg / l	28.7	28.7	Use NO_X from Nitrogen Balance calculations (10)	See "Nitrogen Balance" calculations	233
	Effluent NO_3-N concentration	N_e	mg / l	6.0	6.0	Use NO_3-N from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	234
	Oxygen Credit	$O_{2\ credit}$	kg / d	270.9	98.5	$O_{2\ credit}$ = 2.86 * [NO_X - N_e] * Q * (1 kg / 1000 g)	M&E Eqn. 8-5 (step 8)	235
			kg / hour	11.3	4.1	Conversion Factor = (24 hours / 1 day)	calculation	236
			# / hour	24.9	9.1	Conversion Factor = (2.205 lbs / 1 kg)	calculation	237
Oxygen Demand -- *Net O_2 Required*	Net oxygen required	Net $O_{2\ required}$	kg / d	1881.3	684.1	Net $O_{2\ required}$ = $R_{O\ (without\ nitrification)}$ - $O_{2\ credit}$	M&E Eqn. 8-5 (step 8)	238
			kg / hour	78.4	28.5			239
			# / hour	172.8	62.9			240
	Oxygen Reduction from denitrification credit	$O_{2\ reduction}$	%	12.59%	12.59%	$O_{2\ reduction}$ = 100% - {[Net $O_{2\ required}$] / [$R_{O\ (without\ nitrification)}$]}	M&E Eqn. 8-5 (step 8)	241

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train)	Lyons WWTP (0.4 mgd Train)	(Input) or (Calculation)	Reference	Row
				Value	Value			
Alkalinity Addition	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	242
	Influent Alakalinity	Alk_{inf} (as $CaCO_3$)	mg / l	140	140	Use Alk as $CaCO_3$ from Design Inputs	See "Design Inputs"	243
	Concentration of influent NH_4-N that is nitrified	NO_X	mg / l	28.7	28.7	Use NO_X from Nitrogen Balance calculations (10)	See "Nitrogen Balance" calculations	244
	Effluent NO_3-N concentration	N_e	mg / l	6.0	6.0	Use NO_3-N from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	245
	Alakalinity consumed per ammonia nitrogen converted to nitrate	$Alk\ ratio_{consumed}$	g Alkalinity (as $CaCO_3$) / g NH_4-N converted	7.14	7.14	$Alk\ ratio_{consumed} = 7.14$	M&E Eqn. 7-89 & Ex. 8-5 (step 9)	246
	Alakalinity produced (recovered) per nitrate reduced (denitrified)	$Alk\ ratio_{recovered}$	g Alkalinity (as $CaCO_3$) / g NO_3-N reduced	3.57	3.57	$Alk\ ratio_{recovered} = 3.57$	M&E Eqn. 7-97 & Ex. 8-5 (step 9)	247
	Residual Alkalinity required to remain neutral pH (+/- 7)	$Alk_{residual}$ as ($CaCO_3$)	mg / l	80	80	Range is 70 - 80 mg / l (as $CaCO_3$)	M&E (pg. 684)	248
	Alkalinity used during nitrification	Alk_{used} (as $CaCO_3$)	mg / l	205.27	205.27	$Alk_{used} = Alk\ ratio_{consumed} * NO_X$	M&E Eqn. 8-5 (step 9)	249
	Alkalinity produced during denitrification	$Alk_{produced}$ (as $CaCO_3$)	mg / l	81.21	81.21	$Alk_{produced} = Alk\ ratio_{recovered} * [NO_X - N_e]$	M&E Eqn. 8-5 (step 9)	250
	Alkalinity to be added (to maintain neutral pH)	Alk_{added} (as $CaCO_3$)	mg / l	64.05	64.05	$Alk_{added} = Alk_{residual} - Alk_{inf} + Alk_{used} - Alk_{produced}$	M&E Eqn. 8-5 (step 9)	251
	Mass of alkalinity to be added (to maintain neutral pH)	Alk_{mass}	kg / d	267	97	$Alk_{mass} = Alk_{added}$ * Q * (1 kg / 1000 g)	M&E Eqn. 8-5 (step 9)	252
			# / d	588	214	Conversion Factor = (2.205 lbs / 1 kg)	calculation	253
Anoxic Zone -- *Mixing System*	Anoxic Volume	V_{nox}	m^3	690	250	Use V_{nox} from Nitrate calculations	See "Anoxic Basin Volume"	254
	Required mixing energy	$Mix\ Energy_{required}$	kW / 1,000 m^3	10	10	Typical input: $Mix\ Energy_{required}$ = 10 kW / 1,000 m^3	M&E Eqn. 8-5 (step 10)	255
	Anoxic Power	$Power_{anoxic}$	kW	6.90	2.50	$Power_{anoxic} = (V_{nox} / 1,000\ m^3) * (Mix\ Energy_{required})$	M&E Eqn. 8-5 (step 10)	256
	Anoxic Power (selection)	$Power_{anoxic\ (selection)}$	kW	7	2.5	Design selection	Engineer selection	257

				Lyons WWTP (1.1 mgd Train)	Lyons WWTP (0.4 mgd Train)			
Category	**Characteristic**	**Symbol**	**Unit**	**Value**	**Value**	**(Input) or (Calculation)**	**Reference**	**Row**
Anaerobic Zone -- *Data Inputs*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	258
	RAS recycle ratio (RAS flowrate / influent flowrate)	R	% Q	50.0%	50.0%	Use R from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	259
	RAS Flow Rate	Q_{RAS}	m^3 / day	2,082	757	$Q_{RAS} = Q * R$	calculation	260
	Influent Phosphorus concentration	TP	mg / l	10	10	Project Input	See "Design Inputs"	261
	Influent Nitrate concentration	$(NO_3\text{-}N)_{influent}$	mg / l	0.0	0.0	Project Input	See "Design Inputs"	262
	Readily biodegradable soluble chemical oxygen demand	rbCOD	mg / l	133	133	Input rbCOD from Typical Inputs	See "Typical Inputs"	263
	Effluent NO_3-N concentration	$(NO_3\text{-}N)_{RAS}$	mg / l	6.0	6.0	Use NO_3-N from Internal Recycle Ratio calculations	See "Internal Recycle Ratio"	264
Anaerobic Zone -- *Ratios*	Enhanced phosporus removal conversion ratio	rbCOD : P	g rbCOD / g P	10.0	10.0	Recommended input range is 7 to 10 mg/l	M&E pg. 801	265
	rbCOD : nitrate ratio	rbCOD : NO_3-N	g rbCOD / g NO_3-N	6.6	6.6	Stoichiometric input	M&E Eqn. 8-60	266
	Phosphorus content of heterotrophic biomass	$P_{biomass\ \%}$	g P / g biomass	1.5%	1.5%	Recommended input range is 1.5 - 2.0%	M&E pg. 626	267
Anaerobic Zone -- *Biological Phosphorus Removal*	Nitrate feed into anaerobic reactor	$(NO_3\text{-}N)_{React}$	g $(NO_3\text{-}N)$ / m^3	2.00	2.00	***Mass balance equation:*** $[Q_{RAS} * (NO_3\text{-}N)_{influent}] + [Q_{RAS} * (NO_3\text{-}N)_{RAS}] = [(Q + Q_{RAS}) * (NO_3\text{-}N)_{React}]$	M&E Ex. 8-10 (step 1a)	268
	rbCOD equivalent	$rbCOD_{equiv}$	g / m^3	13.2	13.2	$rbCOD_{equiv} = (NO_3\text{-}N)_{React} * (rbCOD : NO_3\text{-}N)$	M&E Ex. 8-10 (step 1b)	269
	rbCOD available for P removal	$rbCOD_{avail\ for\ Prem}$	g / m^3	120.0	120.0	$rbCOD_{avail\ for\ Prem} = rbCOD - rbCOD_{equiv}$	M&E Ex. 8-10 (step 1b)	270
	Biological Phosphorus removal	$P_{Bio(removed)}$	g P / m^3	12.0	12.0	$P_{Bio(removed)} = (rbCOD_{avail\ for\ Prem}) / (rbCOD : P)$	M&E Ex. 8-10 (step 2)	271
	Biomass Production	$P_{X,VSS\ (heterotrophic\ biomass)}$	kg VSS / d	445.1	161.9	Use $P_{X,VSS}$ from Heterotrophic Biomass calculations	See "Part A calculations"	272
			g / d	445,139	161,869	$P_{X,VSS} * (1000\ g / 1\ kg)$	calculation	273
		$P_{X,VSS\ (nitrifying\ bacteria)}$	kg VSS / d	8.2	3.0	Use $P_{X,VSS}$ from Nitrifying Bacteria calculations	See "Part C calculations"	274
			g / d	8,228	2,992	$P_{X,VSS} * (1000\ g / 1\ kg)$	calculation	275
		$P_{X,Biomass\ Production}$	g / d	453,367	164,861	$P_{X,Biomass\ Production} = P_{X,VSS\ (heterotrophic\ biomass)} + P_{X,VSS\ (nitrifying\ bacteria)}$	M&E Ex. 8-10 (step 3)	276
	P utilized for biomass growth	P_{used}	g / d	6,801	2,473	$P_{used} = (P_{biomass\ \%}) * (P_{X,Biomass\ Production})$	M&E Ex. 8-10 (step 3)	277
			g / m^3	1.6	1.6	$P_{used}\ (g/m^3) = P_{used}\ (g/d) / P_{used}\ (m^3/d)$	M&E Ex. 8-10 (step 3)	278
	P removed	$P_{removed}$	g / m^3	9.7	9.7	$P_{removed} = P_{Bio(removed)} + P_{used}$ (17)	M&E Ex. 8-10 (step 4)	279
	Effluent soluble P	$P_{effluent}$	g / m^3	0.3	0.3	$P_{effluent} = TP - P_{removed}$ (18)	M&E Ex. 8-10 (step 4)	280

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Anaerobic Zone -- *Basin Geometry*	Hydraulic Retention Time (Target)	τ	hours	3.1	3.1	Typical range is 0.5 to 1.5 hours for 5-stage Bardenpho process [8]	Engineer selection	281
			days	0.129	0.129	# Days = # Hours / (24 hours / day)	calculation	282
	Anaerobic Volume (Target)	$V_{Anaerobic}$	m^3	538	196	$V_{Anaerobic} = τ \times Q$	calculation	283
	Anaerobic Volume (Selection)	$V_{Anaerobic\ (selection)}$	m^3	545	198	Design selection	Engineer selection	284
			Ft^3	19,246	6,992	Conversion Factor = $[(1\ ft. / 0.3048\ m)^3]$	Common conversion	285
			Gal	143,964	52,302	Conversion Factor = $(7.48\ gal. / 1\ ft.^3)$	Common conversion	286
	Hydraulic Retention Time (Selection)	τ	hours	3.14	3.14	τ = (V / Q) * (24 hours / day)	M&E Ex. 4-1	287
			days	0.131	0.131	τ = (V / Q)		288
	Number of Anaerobic Basins	$\#_{anaerobic\ basins}$	each	3	3	Design selection	Engineer selection	289
	Share per Anaerobic Basin	$Share_{anaerobic\ basin}$	%	33.33%	33.33%	$Share_{anaerobic\ basin} = 1 / \#_{anaerobic\ basins}$	calculation	290
	Volume per Anaerobic Basin	$V_{per\ anaerobic\ basin}$	m^3	182	66	$V_{per\ anaerobic\ basin} = V_{selection} \times Share_{anaerobic\ basin}$	calculation	291
			Ft^3	6,415	2,331		calculation	292
			Gal	47,988	17,434		calculation	293
2nd Anoxic Basin -- *Post-Anoxic Basin Volume*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	294
	Hydraulic Retention Time (Target)	τ	hours	6.96	6.96	Typical range is 2 to 4 hours for 5-stage Bardenpho process [8]	Engineer selection	295
			days	0.290	0.290	# Days = # Hours / (24 hours / day)	calculation	296
	Anoxic Volume (Target)	$V_{2nd\ nox}$	m^3	1,208	439	$V_{2nd\ nox} = τ \times Q$	calculation	297
	Anoxic Volume (Selection)	$V_{2nd\ nox\ (selection)}$	m^3	1,208	439	Design selection	Engineer selection	298
			Ft^3	42,660	15,503	Conversion Factor = $[(1\ ft. / 0.3048\ m)^3]$	Common conversion	299
			Gal	319,098	115,963	Conversion Factor = $(7.48\ gal. / 1\ ft.^3)$	Common conversion	300
	Hydraulic Retention Time (Selection)	τ	hours	6.96	6.96	τ = (V / Q) * (24 hours / day)	M&E Ex. 4-1	301
			days	0.290	0.290	τ = (V / Q)		302
	Number of Anoxic Basins	$\#_{2nd\ anoxic\ basins}$	each	1	1	Design selection	Engineer selection	303
	Share per Anoxic Basin	$Share_{2nd\ anoxic\ basin}$	%	100.00%	100.00%	$Share_{2nd\ anoxic\ basin} = 1 / \#_{2nd\ anoxic\ basins}$	calculation	304
	Volume per Anoxic Basin	$V_{per\ 2nd\ anoxic\ basin}$	m^3	1,208	439	$V_{per\ 2nd\ anoxic\ basin} = V_{2nd\ nox\ (selections)} \times Share_{2nd\ anoxic\ basin}$	calculation	305
			Ft^3	42,660	15,503		calculation	306
			Gal	319,098	115,963		calculation	307

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row
Re-Aeration Basin -- *Re-Aeration Basin Volume*	Flow Rate	Q	m^3 / day	4,164	1,514	Project Input	See "Design Inputs"	308
	Hydraulic Retention Time (Target)	τ	hours	0.7852582	0.7852582	Typical range is 0.5 to 1 hours for 5-stage Bardenpho process [8]	Engineer selection	309
			days	0.033	0.033	# Days = # Hours / (24 hours / day)	calculation	310
	Re-Aeration Volume (Target)	$V_{Re\text{-}Aeration}$	m^3	136	50	$V_{re\text{-}Aeration} = \tau \times Q$	calculation	311
	Re-Aeration Volume (Selection)	$V_{Re\text{-}Aeration\ (selection)}$	m^3	136	50	Design selection	Engineer selection	312
			Ft^3	4,803	1,766	Conversion Factor = [(1 ft. / 0.3048 m)^3]	Common conversion	313
			Gal	35,925	13,208	Conversion Factor = (7.48 gal. / 1 ft.^{3})	Common conversion	314
	Hydraulic Retention Time (Selection)	τ	hours	0.78	0.79	τ = (V / Q) * (24 hours / day)	M&E Ex. 4-1	315
			days	0.033	0.033	τ = (V / Q)		316
	Number of Re-Aeration Basins	$\#_{Re\text{-}Aeration\ basins}$	each	1	1	Design selection	Engineer selection	317
	Share per Re-Aeration Basin	$Share_{Re\text{-}Aeration\ basin}$	%	100.00%	100.00%	$Share_{Re\text{-}Aeration\ basin} = 1 / \#_{Re\text{-}Aeration\ basins}$	calculation	318
	Volume per Re-Aeration Basin	$V_{per\ Re\text{-}Aeration\ basin}$	m^3	136	50	$V_{per\ Re\text{-}Aeration\ basin} = V_{re\text{-}Aeration\ (selections)} \times Share_{Re\text{-}Aeration\ basin}$	calculation	319
			Ft^3	4,803	1,766		calculation	320
			Gal	35,925	13,208		calculation	321
Process Analysis -- *Effluent Characteristics*	Effluent soluble BOD	$sBOD_e$	mg / l	3.0	3.0	Typical range is 2 to 4 mg/l for well-operated activated sludge process with SRT > 4 days [19]	M&E pg. 689	322
	Effluent Volatile Suspended Solids : Total Suspended Solids ratio	VSS : $TSS_{effluent}$	---	0.85	0.85	Typical assumption is 0.85 [19]	M&E pg. 689	323
	Effluent Total Suspended Solids	TSS_e	mg / l	10	10	Typical range is 5 to 15 mg/l for well-operated activated sludge process with SRT > 4 days [19]	M&E pg. 689	324
	Effluent BOD	BOD_e	mg / l	9.0	9.0	BOD_e = sBOD + [(1 g BOD / 1.42 g VSS) * (VSS : $TSS_{effluent}$) * (TSS, mg/l)]	M&E Eqn. 8-25	325
	Effluent Total Nitrogen	TN_e	mg / l	3.0	3.0	Typical range is 3 to 5 mg/l for 5-Stage Bardenpho Process	M&E Table 8-27	326

Category	Characteristic	Symbol	Unit	Lyons WWTP (1.1 mgd Train) Value	Lyons WWTP (0.4 mgd Train) Value	(Input) or (Calculation)	Reference	Row

General NOTE: ***M&E*** refers to ***"Wastewater Engineering Treatment and Reuse"*** (Fourth Edition) by Metcalf & Eddy

General NOTE: (g / m^3) = (mg / l)

General NOTE: The following shading cells are used in the spreadsheet:

6.96	Design target value (used to aid in design selection)
1	Project design input or design selection
80	Typical input value
0.26	Typical input value, based upon project variables
0.79	Value calculated, or transferred from previous inputs and/or calculations

NOTE 1: Computation approach is based upon Tables 8-12 & 8-19 from ***M&E***

NOTE 2: Effluent requirements are measured at secondary clarifier effluent for the treatment design calculations. Further treatment occurs at downstream components and is calculated in the respective DDR sections..

NOTE 3: Term Alk as $CaCO_3$ is defined in Equation 2-36 (***M&E***)

NOTE 4: See recommended range for rbCOD on page 757 of ***M&E***

NOTE 5: Univ. of Pannonia study refers to ***"Chemical Oxygen Demand Fractions of Municipal Wastewater for Modeling of Wastewater Treatment"*** (Winter 2009) by Dept. of Env. Eng. And Chemical Technology, Univ. of Pannonia, Veszprem, Hungary

NOTE 6: Refer to EVOQUA process calculations in DDR Appendix

NOTE 7: Example 8-2 (***M&E***) uses the required effluent NH_4-N concentration interchangeably with the N item in Equation 7-93

NOTE 8: Refer to Table 8-26 (***M&E***) for typical range

NOTE 9: Although the rate of change is negative, as described in Equation 7-12 and following (***M&E***), the sign will be dropped, per Example 8-2 (step 16)

NOTE 10: Term NO_X is defined in Equations 8-15 and/or 8-48 (***M&E***)

NOTE 11: RAS flowrate (as %Q) is assigned by designer

NOTE 12: Term V_{nox} is defined in Equation 8-43 (***M&E***)

NOTE 13: Units for SDNR are defined in Equation 8-41 (***M&E***)

NOTE 14: Per description on page 756 (***M&E***): ***1)*** If $F/M_b \leq 1.0$, no correction necssary; ***2)*** If $F/M_b > 1.0$, correction factor is based on Equation 8-45 or 8-46

NOTE 15: Per description on page 756 (***M&E***), if no correction is necessary, use $SDNR_{Tmin}$

NOTE 16: Per description on page 754 (***M&E***), SDNR values are typically between 0.04 and 0.42 g NO_3-N / g MLVSS * d; per Ex. 8-5 (step 7c), SDNR values are based on g / g * d. (0.04 - 0.42)

NOTE 17: Phosphorus removed cannot exceed influent phosphorus concentration. Per description on page 803 (***M&E***), effluent P concentration can be in the 0.2 - 0.3 mg/l range

NOTE 18: Provisions for chemical addition can be made to remove phosphorus by chemical precipitation in addition to biological removal, per description on page 803 (***M&E***)

NOTE 19: See discussion on page 689 (***M&E***)