Full Fuel Cycle Analysis of Biomass to Ethanol: Wastewater Treatment System Performance

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Appendix A

Wastewater Characterization

Environmental Analysis For The Utility Systems in The Biomass – To – Ethanol Process
Material Balance For The Waste Water Treatment System

** NOTE : NREL PROTECTED INFORMATION **

05-Dec-91 CDW, DEN32922.A0
SERITABL.WK1

Calculations: 1. See notes by CDW dated 10-21-91 for conversion factor notes as shown here –

Componen	TSS	COD	BOD	SO4	TDS
		Conversion Factor (mg/mg)			
S. SOLIDS		2.47	1.12		
ASH					1
LIGNIN	1				
PROTEIN		1.7	0.4		
XYLOSE		1.07			
HMF		1.67	0.77		

Compone	TSS	COD	BOD	SO4	TDS
		Conversion Factor (mg/mg)			
FURFURAL		1.67	0.77		
GYPSUM(S)				0.56	1
GYPSUM	1			0.56	
CELLULASE		1.7	0.4		
GLYCEROL		1.22			
CELL MASS		1.42			

2. Flow, gpm = Water Loading (lb/hr) * (1.998 E-3)
3. Component concentration, mg/l = Loading (lb/hr) * Conversion Factor (mg/mg) * 7575.76 ((mg/min)/(lb/hr))/ Flow (gpm)/ 3.785 (l/gal)
   note : for eqn. #3, 7575.76/3.785 = 2001.52 was used in the spreadsheet.
4. TDS and TSS are fixed solids which are not biodegradable
5. TDS only includes inorganic solids

ETHANOL TO BIOMASS WASTEWATER CHARACTERIZATION

** NOTE : NREL PROTECTED INFORMATION **

CASE 1: GREAT PLAINS, 2010		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	33534	1149	474	28	275	153	0	23	74	8	15	7.82	5	365.50	67
PROCESS WATER TO	TSS,mg/l				836						239				10.75	
WASTE TREATMENT	COD,mg/l		84781			13966	4891	0	1147			762	277.71	212	1335.29	
	BOD,mg/l		38443			3286		0	529			179			424.37	
	SO4,mg/l									1238	134				13.72	
	TDS,mg/l			14160						2211					163.70	
STRM.NO.2	LB/HR	42514	0	0	0	0	0	0	3720	0	0	0	0	0	462.34	85
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	146383			0	0	0	1463.33	
	BOD,mg/l		0			0		0	67494			0			674.94	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	3.20	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	76368	1149	474	28	275	153	23	3720	74	8	15	7.82	5	830.54	153
STREAM TO	TSS,mg/l				367						105				4.72	
ANAEROBIC DIGESTION	COD,mg/l		37228			6132	2147	504	81492			334	121.85	93	1401.26	
	BOD,mg/l		16861			1443		232	37574			79			562.59	
	SO4,mg/l									544	59				6.02	
	TDS,mg/l			6218						971					71.38	

CASE 2: NORTHEAST, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	33943	1025	227	32	223	128	25	0	75	7	14	793	5	36497	68
PROCESS WATER TO	TSS,mg/l				944						207				1151	
WASTE TREATMENT	COD,mg/l		74720			11188	4042	1232	0			702	28553	210	120647	
	BOD,mg/l		33881			2633		568	0			165			37247	
	SO4,mg/l									1240	116				1355	
	TDS,mg/l			6699						2213					8913	
STRM.NO.2	LB/HR	42775	0	0	0	0	0	0	3469	0	0	0	0	0	46244	85
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	135674			0	0	0	135674	
	BOD,mg/l		0			0		0	62556			0			62556	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	77038	1028	227	32	223	128	25	3469	75	7	14	793	5	83062	154
STREAM TO	TSS,mg/l				416						91				507	
ANAEROBIC DIGESTION	COD,mg/l		32954			4930	1781	543	75332			309	12580	92	128521	
	BOD,mg/l		14943			1160		250	34734			73			51160	
	SO4,mg/l									546	51				597	
	TDS,mg/l			2952						975					3927	

CASE 3: SOUTHEAST, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	36507	759	191	38	162	139	25	0	81	7	15	847	5	38776	73
PROCESS WATER TO	TSS,mg/l				1043						192				1235	
WASTE TREATMENT	COD,mg/l		51443			7557	4081	1146	0			700	28355	195	93477	
	BOD,mg/l		23326			1778		528	0			165			25797	
	SO4,mg/l									1245	108				1352	
	TDS,mg/l			5241						2223					7464	
STRM.NO.2	LB/HR	43054	0	0	0	0	0	0	3627	0	0	0	0	0	46681	86
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	140934			0	0	0	140934	
	BOD,mg/l		0			0		0	64981			0			64981	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	79981	759	181	38	162	139	25	3627	81	7	15	847	5	85867	160
STREAM TO	TSS,mg/l				476						88				564	
ANAEROBIC DIGESTION	COD,mg/l		23481			3449	1863	523	75865			319	12943	89	118532	
	BOD,mg/l		10647			812		241	34980			75			46755	
	SO4,mg/l									568	49				617	
	TDS,mg/l			2267						1015					3282	

CASE 4: MIDWEST/LAKE STATES, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	34272	924	207	32	232	116	23	0	76	7	14	784	5	36692	68
PROCESS WATER TO	TSS,mg/l				935						205				1140	
WASTE TREATMENT	COD,mg/l		66710			11528	3628	1123	0			696	27958	208	111850	
	BOD,mg/l		30249			2713		518	0			164			33643	
	SO4,mg/l									1244	115				1359	
	TDS,mg/l			6051						2221					8272	
STRM.NO.2	LB/HR	43027	0	0	0	0	0	0	3274	0	0	0	0	0	46301	86
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	127297			0	0	0	127297	
	BOD,mg/l		0			0		0	58694			0			58694	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	77619	924	207	32	232	116	23	3274	76	7	14	784	5	83313	155
STREAM TO	TSS,mg/l				413						90				503	
ANAEROBIC DIGESTION	COD,mg/l		29455			5090	1602	496	70565			307	12344	92	119952	
	BOD,mg/l		13356			1198		229	32536			72			47391	
	SO4,mg/l									549	51				600	
	TDS,mg/l			2672						981					3652	

CASE 5: PACIFIC NORTHWEST, 2010

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	35044	280	101	49	37	62	24	0	78	5	13	802	4	36499	70
PROCESS WATER TO	TSS,mg/l				1401						143				1544	
WASTE TREATMENT	COD,mg/l		19770			1798	1896	1146	0			632	27970	162	53374	
	BOD,mg/l		8965			423		528	0			149			10064	
	SO4,mg/l									1249	80				1329	
	TDS,mg/l			2887						2230					5117	
STRM.NO.2	LB/HR	43633	0	0	0	0	0	0	2284	0	0	0	0	0	45917	87
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	87571			0	0	0	87571	
	BOD,mg/l		0			0		0	40377			0			40377	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	78997	280	101	49	37	62	24	2284	78	5	13	802	4	82736	158
STREAM TO	TSS,mg/l				621						63				685	
ANAEROBIC DIGESTION	COD,mg/l		8770			798	841	508	48369			280	12408	72	72046	
	BOD,mg/l		3977			188		234	22302			66			26767	
	SO4,mg/l									554	36				589	
	TDS,mg/l			1281						989					2270	

CASE 6: MUN. SOLID WASTE, 2000

		WATER	SOLUBLE SOLIDS	ASH	LIGNIN	CRUDE PROTEIN	XYLOSE	HMF	FURFURAL	GYPSUM (SOL)	GYPSUM (INSOL)	CELLULAS	GLYCEROL	CELL MASS	TOTAL	FLOW gpm
STRM.NO.1	LB/HR	34478	667	166	23	169	33	24	0	77	7	17	835	5	36501	69
PROCESS WATER TO	TSS,mg/l				668						203				872	
WASTE TREATMENT	COD,mg/l		47868			8348	1026	1165	0			840	29598	206	89050	
	BOD,mg/l		21705			1984		537	0			198			24404	
	SO4,mg/l									1253	114				1367	
	TDS,mg/l			4823						2237					7060	
STRM.NO.2	LB/HR	43810	0	0	0	0	0	0	1034	0	0	0	0	0	44844	88
OFFGAS FROM	TSS,mg/l				0						0				0	
BLOWDOWN TANK	COD,mg/l		0			0	0	0	39485			0	0	0	39485	
	BOD,mg/l		0			0		0	18205			0			18205	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.3	LB/HR	320	0	0	0	0	0	0	0	0	0	0	0	0	320	1
WASTE WATER	TSS,mg/l				0						0				0	
FROM CIP/CS	COD,mg/l		0			0	0	0	0			0	0	0	0	
	BOD,mg/l		0			0		0	0			0			0	
	SO4,mg/l									0	0				0	
	TDS,mg/l			0						0					0	
STRM.NO.4	LB/HR	78608	667	166	23	169	33	24	1034	77	7	17	835	5	81665	157
STREAM TO	TSS,mg/l				293						89				382	
ANAEROBIC DIGESTION	COD,mg/l		20995			3661	450	511	22006			368	12982	90	61064	
	BOD,mg/l		9520			861		236	10146			87			20850	
	SO4,mg/l									550	50				599	
	TDS,mg/l			2115						981					3097	

Appendix B

Design Summary

APPENDIX B

DESIGN SUMMARY

CASE 1
GREAT PLAINS, 2010

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 8,300 lb/d urea and 3,300 lb triple super phosphate

Anaerobic Reactor

Number: Six
Type: Above grade, welded steel with cover
Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 366 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 587 gpm

Aeration Tanks

Number: Five
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 18 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 30 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)

Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 150 gpm at 20 ft total head

Sludge Storage Tank

Number: One
Type: Above grade, welded steel
Volume: 850,000 gal
Size: 85 ft diam, 20 ft SWD
Days of Storage: 5
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

Biofilter

Number: One
Type: Composted manure and other organic material
Volume: 38 cu yds (31 tons) (based on 1 cfm/sq ft, 8 ft high)

Effluent Storage Lagoon

Number: One
Type: Lined, open
Criteria: Store Process WW and Utility WW for 3 months
Depth: 10 water depth
Area: 18 acre

Land Application

Area Required: 9,000 ac (based on 9 months of application), 1.1 in/yr over this area
Assumed Required Conductivity: 1.1 mmhos/cm
Assumed Crop Uptake: 200 lbs-N/ac
Blend Water Requirements: 2,500 gpm (7.1 in/yr over above area)
Leach Water: 1.2 in/yr (if applied over the above area)
Application Equipment: provided elsewhere

DESIGN SUMMARY

CASE 2
NORTHEAST, 2010

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 7,800 lb/d urea and 3,000 lb triple super phosphate

Anaerobic Reactor

Number: Six
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 366 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 587 gpm

Aeration Tanks

Number: Five
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 16 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 30 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 150 gpm at 20 ft total head

Sludge Storage Tank

Number: One
Type: Above grade, welded steel
Volume: 850,000 gal
Size: 85 ft diam, 20 ft SWD
Days of Storage: 5
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

Biofilter

Number: One
Type: Composted manure and other organic material
Volume: 35 cu yds (28 tons) (based on 1 cfm/sq ft, 8 ft high)

Effluent Storage Lagoon

Number: One
Type: Lined, open
Criteria: Store Process WW and Utility WW for 3 months
Depth: 10 water depth
Area: 18 acre

Land Application

Area Required: 8,500 ac (based on 9 months of application), 1.3 in/yr over this area
Assumed Required Conductivity: 1.1 mmhos/cm
Assumed Crop Uptake: 200 lbs-N/ac
Blend Water Requirements: 2,000 gpm (6.0 in/yr over above area)
Leach Water: 1.1 in/yr (if applied over the above area)
Application Equipment: provided elsewhere

DESIGN SUMMARY

CASE 3
SOUTHEAST, 2010

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 7,500 lb/d urea and 3,000 lb triple super phosphate

Anaerobic Reactor

Number: Five
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 366 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 587 gpm

Aeration Tanks

Number: Four
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 15 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 30 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 150 gpm at 20 ft total head

Sludge Storage Tank

Number: One
Type: Above grade, welded steel
Volume: 850,000 gal
Size: 85 ft diam, 20 ft SWD
Days of Storage: 5
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

Biofilter

Number: One
Type: Composted manure and other organic material
Volume: 34 cu yds (27 tons) (based on 1 cfm/sq ft, 8 ft high)

Effluent Storage Lagoon

Number: One
Type: Lined, open
Criteria: Store Process WW and Utility WW for 3 months
Depth: 10 water depth
Area: 18 acre

Land Application

Area Required: 8,300 ac (based on 9 months of application), 1.3 in/yr over this area
Assumed Required Conductivity: 1.1 mmhos/cm
Assumed Crop Uptake: 200 lbs-N/ac
Blend Water Requirements: 1,800 gpm (5.7 in/yr over above area)
Leach Water: 1.0 in/yr (if applied over the above area)
Application Equipment: provided elsewhere

DESIGN SUMMARY

CASE 4
MIDWEST/LAKES STATES, 2010

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 7,300 lb/d urea and 2,800 lb triple super phosphate

Anaerobic Reactor

Number: Five
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 366 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 587 gpm

Aeration Tanks

Number: Four
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 15 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 30 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 150 gpm at 20 ft total head

Sludge Storage Tank

Number: One
Type: Above grade, welded steel
Volume: 850,000 gal
Size: 85 ft diam, 20 ft SWD
Days of Storage: 5
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

Biofilter

Number: One
Type: Composted manure and other organic material
Volume: 33 cu yds (27 tons) (based on 1 cfm/sq ft, 8 ft high)

Effluent Storage Lagoon

Number: One
Type: Lined, open
Criteria: Store Process WW and Utility WW for 3 months
Depth: 10 water depth
Area: 18 acre

Land Application

Area Required: 8,000 ac (based on 9 months of application), 1.3 in/yr over this area
Assumed Required Conductivity: 1.1 mmhos/cm
Assumed Crop Uptake: 200 lbs-N/ac
Blend Water Requirements: 1,900 gpm (6.2 in/yr over above area)
Leach Water: 1.1 in/yr (if applied over the above area)
Application Equipment: provided elsewhere

DESIGN SUMMARY

CASE 5
PACIFIC NORTHWEST, 2010

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 131 sq ft
Temperature Reduction: 142 degrees F to 131 degrees F
Cooling Water Required: 46.5 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 4,500 lb/d urea and 1,700 lb triple super phosphate

Anaerobic Reactor

Number: Three
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 366 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 587 gpm

Aeration Tanks

Number: Three
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 9 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 30 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 150 gpm at 20 ft total head

Sludge Storage Tank

Number: One
Type: Above grade, welded steel
Volume: 850,000 gal
Size: 60 ft diam, 20 ft SWD
Days of Storage: 5
Mixers: Four, side entry, 10 hp (based on 40 hp/mg), supply a small amount of pure oxygen to keep aerobic

Biofilter

Number: One
Type: Composted manure and other organic material
Volume: 20 cu yds (16 tons) (based on 1 cfm/sq ft, 8 ft high)

Effluent Storage Lagoon

Number: One
Type: Lined, open
Criteria: Store Process WW and Utility WW for 3 months
Depth: 10 water depth
Area: 22 acre

Land Application

Area Required: 3,700 ac (based on 9 months of application), 2.8 in/yr over this area
Assumed Required Conductivity: 3 mmhos/cm (for Poplars)
Assumed Crop Uptake: 200 lbs-N/ac
Blend Water Requirements: 427 gpm (2.2 in/yr over above area)
Leach Water: 0.8 in/yr (if applied over the above area)
Application Equipment: provided elsewhere

DESIGN SUMMARY

CASE 6
MSW, YEAR 2000

Bar Screens

Number: Two
Type: Mechanically Cleaned
Bar Spacing: 1/2 inch

Equalization Tank

Number: One
Type: Above grade, welded steel
Volume: 225,000 gal
Size: 45 ft diam, 20 ft SWD
Hydraulic Retention Time: 24 hours
Mixers: 3, side entry, 4 hp (based on 30 hp/mg)

Primary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Primary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 221 sq ft
Temperature Reduction: 182 degrees F to 131 degrees F
Cooling Water Required: 136 gpm

Nutrient Feed System

Number: One
Type: Dry or liquid
Capacity: 3,800 lb/d urea and 1,500 lb triple super phosphate

Anaerobic Reactor

Number: Three
Type: Above grade, welded steel with cover

Volume: 2.0 mill gal
Size: 130 ft diam, 20 ft SWD
Organic Loading Rate: 2.5 kg/d/cu m
Mixers: Four, side entry, 20 hp (based on 40 hp/mg)

Secondary Heat Exchanger Influent Pump

Number: Two (one redundant)
Type: Centrifugal, variable speed drive
Capacity: 400 gpm at 15 ft total head

Secondary Heat Exchanger

Number: One
Type: Shell and tube type, process water in tube
Surface Area: 336 sq ft
Temperature Reduction: 131 degrees F to 86 degrees F
Cooling Water Required: 338 gpm

Aeration Tanks

Number: Two
Type: Above grade, concrete, covered
Volume: 0.675 mill gal
Size: 40 ft wide by 150 ft long, 15 ft SWD
Solids Retention Time: 20 days
Mixers: Four per tank, surface, 15 hp (based on 4 lb O2/hp-hr transfer)

Pressure Swing Adsorbtion Oxygen Generator

Number: One
Capacity: 8 tons per day

Clarifier

Number: Two
Type: Flocculating center well with positive sludge drawoff
Size: 20 ft diam, 15 ft SWD
Solids Loading Rate: 20 lb/d/sq ft

Return Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 400 gpm at 20 ft total head

Waste Activated Sludge Pumps

Number: Two (one redundant)
Type: Centrifugal, solids handling, variable speed
Capacity: 100 gpm at 20 ft total head

Belt Filter Press

Number: One
Size: One meter press
Filtrate/Wash Recycle Pump: 200 gpm, centrifugal at 20 ft head
Polymer Feed System: Liquid feed, 32 lbs/d
Off-gas: 6460 cfm (based on 100 ft/m face velocity in a 2 m by 3 m hood)

Off-Gas Srubber System

Type: Two stage
First Stage: Caustic and hyochlorite mist scrubber
Size: 21 ft high, 10 ft diam.
Chemical Usage: 2 gal/hr of 12% NaOCl and 0.1 gal/hr NaOH
Second Stage: Granular Activated Carbon
Size: 10 ft diameter

Appendix C

Mass Balance

MASS BALANCE SPREADSHEET – SERI BIOMASS TO ETHANOL WWTP
CDW, DEN32922.A0, MASSBAL.WK1 10-25-91

FOLLOWING IS A MASS BALANCE FOR THE WWT PROCESS IN TERMS OF COD, TSS, AND WATER FLOW

STREAM 1: PROCESS WASTEWATER

	FLOW	TSS IN		COD IN	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	153	868	472	257,476	140,126
CASE 2	154	938	507	237,698	128,521
CASE 3	160	1,083	564	227,764	118,532
CASE 4	155	937	503	223,289	119,952
CASE 5	158	1,299	685	136,709	72,046
CASE 6	157	721	382	115,136	61,064

STREAM 2: RECYCLES

	FLOW	TSS IN		COD IN	
	gpm	lb/d	mg/l	lb/d	mg/l
CASE 1	199	1,194	500	1,433	600
CASE 2	169	1,017	500	1,221	600
CASE 3	160	961	500	1,153	600
CASE 4	155	931	500	1,117	600
CASE 5	32	190	500	228	600
CASE 6	180	432	200	1,297	600

STREAM 3: ANAEROBIC REACTOR INFLUENT

	FLOW	TSS IN		COD IN		
	gpm	lb/d	mg/l	lb/d	mg/l	
CASE 1	352	2,062	488	258,910	61,261	15.22
CASE 2	323	1,955	503	238,918	61,513	15.79
CASE 3	320	2,044	532	228,917	59,564	15.33
CASE 4	310	1,868	502	224,406	60,274	[illegible]
CASE 5	190	1,489	654	136,936	60,136	16.15
CASE 6	337	1,153	285	116,433	28,768	15.23

STREAM 4: AEROBIC REACTOR INFLUENT

	FLOW	TSS OUT		COD OUT		
	gpm	lb/d	mg/l	lb/d	mg/l	
CASE 1	352	18,373	4,347	40,571	9,600	2.17%
CASE 2	323	17,007	4,379	37,438	9,639	2.19%
CASE 3	320	16,466	4,284	35,871	9,334	2.17%
CASE 4	310	16,005	4,299	35,164	9,445	2.17%
CASE 5	190	10,116	4,443	21,458	9,423	2.17%
CASE 6	337	8,488	2,097	18,245	4,508	2.17%

STREAM 5: WASTE SLUDGE

		FLOW gpm	TSS OUT lb/d	TSS OUT mg/l	SOLUBLE COD OUT lb/d	SOLUBLE COD OUT mg/l
GP	CASE 1	119	14,231	10,000	854	600
NE	CASE 2	110	13,151	10,000	789	600
SE	CASE 3	106	12,730	10,000	764	600
MWLS	CASE 4	104	12,430	10,000	746	600
PNW	CASE 5	63	7,566	10,000	454	600
MSW	CASE 6	53	6,365	10,000	382	600

STREAM 6: EFFLUENT
(INCLUDING UTILITY WATER)

FLOW gpm	TSS OUT lb/d	TSS OUT mg/l	COD OUT lb/d	COD OUT mg/l
475	2,855	500	3,426	600
503	3,020	500	3,624	600
503	3,021	500	3,625	600
483	2,897	500	3,477	600
491	2,946	500	3,535	600
500	3,870	600	3,603	600

Appendix D

Cost Estimates

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

SUMMARY OF COSTS

CASE	TOTAL COST
CASE 1	$22,832,422
CASE 2	$22,019,922
CASE 3	$19,999,834
CASE 4	$19,999,833
CASE 5	$14,671,925
CASE 6	$11,389,682

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 6					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$8,761,294	$525,678	
SITEWORK:					
Clear & Grub	8	ACRES	$2,000.00	$16,000	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	2	EA			
Concrete:					
12" Slab on Grade	444	CY	$200.00	$88,889	
12" Walls	551	CY	$400.00	$220,296	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 x 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	
Primary Heat Exchanger	1	EA	$12,181.00	$12,181	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	3	EA	$624,000.00	$1,872,000	91 MEANS 132-051-1500 x 1.2

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Biogas System	1	EA	$144,000.00	$144,000	
Anerobic Mixers (20 HP)	12	EA	$22,555.00	$270,660	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$18,948.80	$18,949	
O2 Generation & Mixing System	1	LS	$1,600,000	$1,600,000	← + surface mixer
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
WAS Blower (400 cfm)	2	EA	$13,960.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Belt Filter Press	1	EA	$192,000.00	$192,000	
Carbon Scrubber System	1	EA	$36,400.00	$36,400	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$8,761,294	$438,065	
MECHANICAL					
Allowance for Mechanical	15.00%		$8,761,294	$1,314,194	
ELECTRICAL					
Allowance for Electrical	10.00%		$8,761,294	$876,129	
SUBTOTAL				$8,761,294	
CONTINGENCY	30.00%		$8,761,294	$2,628,388	
TOTAL - *CASE 6*				$11,389,682	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 1					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$17,563,401	$1,053,804	
SITEWORK:					
Clear & Grub	9	ACRES	$2,000.00	$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,987	CY	$10.00	$669,867	91 MEANS 022-282-0100
HPDE Liner (20 mil)	104,564	SY	$2.50	$261,411	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	5	EA			
Concrete:					
12" Slab on Grade	1,111	CY	$200.00	$222,222	
12" Walls	1,152	CY	$400.00	$460,741	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	$9,046.70	$9,047	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	6	EA	$624,000.00	$3,744,000	91 MEANS 132-051-1300 * 1.2
Biogas System	1	EA	$144,000.00	$144,000	
Anerobic Mixers (20 HP)	24	EA	$22,555.00	$541,320	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$27,820.00	$27,820	
O2 Generation & Mixing System	1	LS	$3,600,000	$3,600,000	
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
RAS Pumps (400 gpm)	2	EA	$13,840.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
Biofilter	1	EA	$6,500.00	$6,500	
Sludge Storage Tank (Steel,85'D,20'SWD, 850,000 gal)	1	EA	$217,796.25	$217,796	BASED ON PEABODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	$36,400.00	$145,600	
Effluent Pump Station	1	EA	$36,400.00	$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$17,563,401	$878,170	
MECHANICAL					
Allowance for Mechanical	15.00%		$17,563,401	$2,634,510	
ELECTRICAL					
Allowance for Electrical	10.00%		$17,563,401	$1,756,340	
SUBTOTAL				$17,563,401	
CONTINGENCY	30.00%		$17,563,401	$5,269,020	
TOTAL - *CASE 1*				$22,832,422	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 2					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$16,938,401	$1,016,304	
SITEWORK:					
Clear & Grub	9	ACRES	$2,000.00	$18,000	
Effluent Storage Lagoon (15 Acres):					
Embankment	66,987	CY	$10.00	$669,867	91 MEANS 022-282-0100
HPDE Liner (20 mil)	104,564	SY	$2.50	$261,411	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	5	EA			
Concrete:					
12" Slab on Grade	1,111	CY	$200.00	$222,222	
12" Walls	1,152	CY	$400.00	$460,741	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	$9,046.70	$9,047	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	6	EA	$624,000.00	$3,744,000	91 MEANS 132-051-1500 * 1.2
Biogas System	1	EA	$144,000.00	$144,000	
Anaerobic Mixers (20 HP)	24	EA	$22,555.00	$541,320	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$27,820.00	$27,820	
O2 Generation & Mixing System	1	LS	$3,200,000	$3,200,000	
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
RAS Pumps (400 gpm)	2	EA	$13,850.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
Biofilter	1	EA	$6,500.00	$6,500	
Sludge Storage Tank (Steel,85'D,20'SWD, 850,000 gal)	1	EA	$217,796.25	$217,796	BASED ON PEABODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	$36,400.00	$145,600	
Effluent Pump Station	1	EA	$36,400.00	$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$16,938,401	$846,920	
MECHANICAL					
Allowance for Mechanical	15.00%		$16,938,401	$2,540,760	
ELECTRICAL					
Allowance for Electrical	10.00%		$16,938,401	$1,693,840	
SUBTOTAL				$16,938,401	
CONTINGENCY	30.00%		$16,938,401	$5,081,520	
TOTAL - *CASE 2*				$22,019,922	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: BERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 3					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$15,315,257	$918,915	
SITEWORK:					
Clear & Grub	9	ACRES	$2,000.00	$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,987	CY	$10.00	$669,867	91 MEANS 022-282-0100
HPDE Liner (20 mil)	104,364	SY	$2.50	$261,411	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,632	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	4	EA			
Concrete:					
12" Slab on Grade	889	CY	$200.00	$177,778	
12" Walls	951	CY	$400.00	$380,393	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

12/09/91

FILE: SER1

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: 9EN32922.A0
PREPARED BY: S.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	$9,046.70	$9,047	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	5	EA	$624,000.00	$3,120,000	91 MEANS 132-051-1500 X 1.2
Biogas System	1	EA	$144,000.00	$144,000	
Anerobic Mixers (20 HP)	20	EA	$22,555.00	$451,100	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$27,820.00	$27,820	
O2 Generation & Mixing System	1	LS	$3,000,000	$3,000,000	
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
RAS Pumps (400 gpm)	2	EA	$13,840.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
Biofilter	1	EA	$6,500.00	$6,500	
Sludge Storage Tank (Steel,85'D,20'SWD, 850,000 gal)	1	EA	$217,796.25	$217,796	BASED ON PEABODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	$36,400.00	$145,600	
Effluent Pump Station	1	EA	$36,400.00	$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$15,315,257	$765,763	
MECHANICAL					
Allowance for Mechanical	15.00%		$15,315,257	$2,297,288	
ELECTRICAL					
Allowance for Electrical	10.00%		$15,315,257	$1,531,526	
SUBTOTAL				$15,315,257	
CONTINGENCY	30.00%		$15,315,257	$4,594,577	
TOTAL - *CASE 3*				$19,909,834	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 4					
GENERAL REQUIREMENTS:					
General Requirements	6.00%		$15,315,256	$918,915	
SITEWORK:					
Clear & Brush	9	ACRES	$2,000.00	$18,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	66,957	CY	$10.00	$669,867	91 MEANS 022-282-0100
HPDE Liner (20 mil)	104,564	SY	$2.50	$261,411	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	807	CY	$2.00	$1,613	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	4	EA			
Concrete:					
12" Slab on Grade	889	CY	$200.00	$177,778	
12" Walls	951	CY	$400.00	$380,593	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-051-1000 * 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

12/09/91

FILE: SERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN02922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	$9,046.70	$9,047	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	5	EA	$624,000.00	$3,120,000	P1 MEANS 132-051-1500 X 1.2
Biogas System	1	EA	$144,000.00	$144,000	
Anerobic Mixers (20 HP)	20	EA	$22,555.00	$451,100	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$27,820.00	$27,820	
O2 Generation & Mixing System	1	LS	$3,000,000	$3,000,000	
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
RAS Pumps (400 gpm)	2	EA	$13,840.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
Biofilter	1	EA	$6,500.00	$6,500	
Sludge Storage Tank (Steel,85'D,20'SWD, 850,000 gal)	1	EA	$217,796.25	$217,796	BASED ON PEABODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	$36,400.00	$145,600	
Effluent Pump Station	1	EA	$36,400.00	$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$15,315,236	$765,763	
MECHANICAL					
Allowance for Mechanical	15.00%		$15,315,236	$2,297,286	
ELECTRICAL					
Allowance for Electrical	10.00%		$15,315,236	$1,531,526	
SUBTOTAL				$15,315,236	
CONTINGENCY	30.00%		$15,315,236	$4,594,577	
TOTAL - *CASE 4*				$19,909,833	

NOTE: Unit costs include the cost of installation.

12/09/91

FILE: SERI

CHEM HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DENJ2922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
CASE 5					
GENERAL REQUIREMENTS:					
General Requirements	5.00%		$11,266,077	$677,165	
SITEWORK:					
Clear & Grub	8	ACRES	$2,000.00	$16,000	
Effluent Storage Lagoon (18 Acres):					
Embankment	73,963	CY	$10.00	$739,627	91 MEANS 022-292-0100
HPDE Liner (20 mil)	125,741	SY	$2.50	$314,353	
CLARIFIER STRUCTURE (20'D, 15' SWD):					
Earthwork:					
Excavation	1,068	CY	$3.00	$3,203	
Structural Backfill	23	CY	$10.00	$233	
Backfill	507	CY	$2.00	$1,013	
Concrete:					
12" Slab on Grade	23	CY	$200.00	$4,652	
12" Walls	79	CY	$400.00	$31,633	
Metals:	1	LS	$5,000.00	$5,000	
AERATION TANKS (40'X150'X17'H, ABOVE GRADE):	3	EA			
Concrete:					
12" Slab on Grade	667	CY	$200.00	$133,333	
12" Walls	751	CY	$400.00	$300,444	
Metals:	1	LS	$5,000.00	$5,000	
BUILDINGS:					
Office/Lab	2,100	SF	$100.00	$210,000	
Preliminary Treatment Building	900	SF	$75.00	$67,500	
Pump Building	1,200	SF	$75.00	$90,000	
Belt Filter Press Building	2,000	SF	$75.00	$150,000	
EQUIPMENT					
Bar Screens	1	EA	$55,900.00	$55,900	
Equalization Tank (Steel,45'D, 20' SWD, 225,000 gal)	1	EA	$126,000.00	$126,000	91 MEANS 132-031-1000 X 1.2
Equalization Tank Mixers (3.2 HP)	3	EA	$9,360.00	$28,080	
Primary Heat Exchanger Influent Pump (400 gpm)	2	EA	$5,590.00	$11,180	

12/09/91

FILE: GERI

CH2M HILL
WASTEWATER TREATMENT FOR ETHANOL FACILITY
PROJECT NO: DEN32922.A0
PREPARED BY: E.R.MEYER

WASTEWATER TREATMENT FOR ETHANOL FACILITY

DESCRIPTION	QUANT	UNIT	$/UNIT	TOTAL COST	REFERENCE
Primary Heat Exchanger	1	EA	$9,046.70	$9,047	
Nutrient Feed System	1	EA	$23,400.00	$23,400	
Anaerobic Reactor (2 Million Gallon)	3	EA	$624,000.00	$1,872,000	91 MEANS 132-051-1500 * 1.2
Biogas System	1	EA	$144,000.00	$144,000	
Anerobic Mixers (20 HP)	12	EA	$22,555.00	$270,660	
Secondary Heat Exchanger Influent Pump	2	EA	$5,590.00	$11,180	
Secondary Heat Exchanger	1	EA	$27,820.00	$27,820	
O2 Generation & Mixing System	1	LB	$1,800,000	$1,800,000	
Clarifier Mechanism	2	EA	$50,000.00	$100,000	
RAS Pumps (400 gpm)	2	EA	$13,840.00	$27,680	
WAS Pumps	2	EA	$7,800.00	$15,600	
Mist System & Backup Carbon	1	EA	$168,000.00	$168,000	
Biofilter	1	EA	$6,500.00	$6,500	
Sludge Storage Tank (Steel,85'D,20'SWD, 850,000 gal)	1	EA	$217,796.23	$217,796	BASED ON PEABODY TECH TANK
Storage Tank Mixers (10 HP)	4	EA	$36,400.00	$145,600	
Effluent Pump Station	1	EA	$36,400.00	$36,400	
INSTRUMENTATION					
Allowance for Instrumentation	5.00%		$11,286,097	$564,305	
MECHANICAL					
Allowance for Mechanical	15.00%		$11,286,097	$1,692,914	
ELECTRICAL					
Allowance for Electrical	10.00%		$11,286,097	$1,128,610	
SUBTOTAL				$11,286,097	
CONTINGENCY	30.00%		$11,286,097	$3,385,829	
TOTAL - *CASE 5*				$14,671,925	

NOTE: Unit costs include the cost of installation.

SERI O&M COST TABLE
FILE SERI_O&M.WK1
CDW, 12-3-91, DEN32922.A0

THE FOLLOWING TABULATED O&M COSTS PROJECTED FOR THE SERI WWTP ESTIMATES ARE CONSERVATIVE. NUMBERS ARE BASED ON VENDOR SUPPLIED POWER REQUIREMENTS PROVIDED FOR CONCEPTUAL DESIGN EQUIPMENT. THESE ARE 1991 DOLLARS.

POWER COSTS

CALC : _ HP*24 HR/DAY * .7457 KWHR/HPHR * P$/KWHR = $/DAY
(note : Albuquerque, NM power costs used for this application)
ASSUME P = $0.04 PER KWHR

CASE

EQUIPMENT ITEM	1		2		3		4		5		6	
	hp	$/day	hp	$/day	hp	$/day	hp	$/day	hp	$/day	hp	$/day
Bar Screens	0.5	$0.36	0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6	0.5	0.6
Equalization mixer	12.0	$8.59	12.0	15.0	12.0	15.0	12.0	15.0	12.0	15.0	12.0	15.0
Primary Pump	5.0	$3.58	5.0	6.2	5.0	6.2	5.0	6.2	5.0	6.2	5.0	6.2
Nutrient Mixing	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36
Nutrient pumping	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36	0.5	$0.36
Anaerobic mixer	480.0	$343.62	480.0	$343.62	400.0	$286.35	400.0	$286.35	240.0	$171.81	240.0	$171.81
Secondary Pump	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58
O2 Mixing	300.0	$214.76	300.0	$214.76	240.0	$171.81	240.0	$171.81	180.0	$128.86	120.0	$85.90
O2 Generation	540.0	$386.57	480.0	$343.62	450.0	$322.14	450.0	$322.14	270.0	$193.29	240.0	$171.81
RAS Pumping	3.0	$2.15	3.0	$2.15	3.0	$2.15	3.0	$2.15	3.0	$2.15	3.0	$2.15
WAS Pumping	2.0	$1.43	2.0	$1.43	2.0	$1.43	2.0	$1.43	2.0	$1.43	2.0	$1.43
Sludge Mixing	40.0	$28.63	40.0	$28.63	40.0	$28.63	40.0	$28.63	40.0	$28.63	0.0	$0.00
Belt Filter Press	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	10.0	$7.16
Filtrate Pumping	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	5.0	$3.58
Eff. Recycle Pump	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	0.0	$0.00
Scrubber Supply Fan	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58
Scrubber Exhaust Fan	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	16.0	$11.45
Polymer Pumping	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.0	$0.00	0.5	$0.36
Effluent Pumping	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	5.0	$3.58	0.0	$0.00
total :	1403.5	$1,004.73	1343.5	$971.08	1173.5	$849.38	1173.5	$849.38	773.5	$563.03	665.0	$485.36
Lights & HVAC @ %10:	140.4	$100.47	134.4	$97.11	117.4	$84.94	117.4	$84.94	77.4	$56.30	66.5	$48.54

Total per day:		1543.85	$1,105.20	1477.85	$1,068.18	1290.85	$934.32	1290.85	$934.32	850.85	$619.33	731.5	$533.89
Total per year :		563505.25	$403,397.63	539415.25	$389,886.97	471160.25	$341,025.13	471160.25	$341,025.13	310560.25	$226,056.08	266997.5	$194,870.73

INPUT COSTS

CASE

		1		2		3		4		5		6	
UNIT CO	UNIT INPUT	AMOUNT	$/DAY	AMOUNT	$/DAY	AMOUNT	$/DAY	AMOUNT	$/DAY	AMOUNT	$/DAY	AMOUNT	$/DAY
$0.14	UREA, lb/d	8400	$1,142.40	7800	$1,060.80	7450	$1,013.20	7300	$992.80	4400	$598.40	3700	$503.20
$0.38	TRIPLE S PHOS., lb/d	3300	$1,267.20	3000	$1,152.00	2900	$1,113.60	2800	$1,075.20	1700	$652.80	1500	$576.00
$12.00	POTABLE H2O, M lb/d	7.6	$91.37	7.6	$91.37	7.6	$91.37	7.6	$91.37	5.7	$68.57	5.7	$68.57
$0.01	MANURE, lb/d	83.8	$0.84	77.8	$0.78	74.5	$0.75	72.8	$0.73	44.3	$0.44	0	$0.00
$1.00	%50 CAUSTIC, gal/d	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1.2	$1.20
$4.30	GAC REPL., lb/d	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	3.21	$13.80
$1.40	POLYMER, lb/d	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	31.8	$44.52
	SLUDGE APPL., lb/d	14200	$0.00	13200	$0.00	12700	$0.00	12400	$0.00	7580	$0.00	0	$0.00
$900.00	POTW DISCHARGE, M	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0.6	$540.00
	TOTAL PER DAY :		$2,501.81		$2,304.95		$2,218.92		$2,160.10		$1,320.22		$1,747.30
	TOTAL PER YEAR :		$913,161.02		$841,307.12		$809,905.07		$788,436.87		$481,878.84		$637,763.04

LABOR COSTS

UNIT COST

$43,210	LABOR	3	$129,630.00	3	$129,630.00	3	$129,630.00	3	$129,630.00	3	$129,630.00	3	$129,630.00
$49,300	FOREMAN	1	$49,300.00	1	$49,300.00	1	$49,300.00	1	$49,300.00	1	$49,300.00	1	$49,300.00
$58,000	SUPERVISOR	1	$58,000.00	1	$58,000.00	1	$58,000.00	1	$58,000.00	1	$58,000.00	1	$58,000.00
	TOTAL PER YEAR:		$236,930.00		$236,930.00		$236,930.00		$236,930.00		$236,930.00		$236,930.00

MAINTENANCE COST

3.00% OF CAPITAL	$22,832,000	$684,960	$22,020,000	$660,600	$19,910,000	$597,300	$19,910,000	$597,300	$14,672,000	$440,160	$11,390,000	$341,700

GENERAL PLANT OVERHEAD

65% OF LABOR AND MAINT	$921,890	$599,229	$897,530	$583,395	$834,230	$542,250	$834,230	$542,250	$677,090	$440,109	$578,630	$376,110

CASE

	1		2		3		4		5		6	
SUBTOTAL		$2,837,677		$2,712,119		$2,527,410		$2,505,941		$1,825,133		$1,787,373
SCOPE CONTINGENCY	10%	$283,768	10%	$271,212	10%	$252,741	10%	$250,594	10%	$182,513	10%	$178,737
TOTAL ANNUAL O&M COST		$3,121,445		$2,983,330		$2,780,151		$2,756,536		$2,007,647		$1,966,111

COST ESTIMATE ASSUMPTIONS

CAPITAL COST ESTIMATES

- Land application equipment will be provided as part of the crop production system.
- Cost of land is not included.
- The wastewater system is in the vicinity of the production facility and the point of discharge, so that extreme piping lengths are not required to get the wastewater to the plant and to get the effluent to the point of discharge.
- Special materials of construction are not required.
- A relatively inexpensive liner may be used for the effluent storage lagoons since the effluent is relatively benign.

OPERATIONS AND MAINTENANCE COST ESTIMATES

- Maximum power consumptions were used for each piece of equipment, so that the power costs are conservative.
- The operations costs include a "general plant overhead" allowance, as described by NREL.
- The cost of disposal of ash from the sludge burned in the boiler in Case 6 is not significant.
- No credit is taken for the methane burned in the boiler.
- Five operators are required to operate the facility and to perform laboratory analysis.
- The cost of sludge and effluent land application is covered in the cost of crop production.
- The oxygen used in the sludge storage tank is insignificant.