APPENDIX E

LEAK COLLECTION AND RECOVERY SYSTEM DESIGN

APPENDIX E

LEAK COLLECTION AND RECOVERY SYSTEM DESIGN

An important feature of the tailings cell liner system is the Leak Collection and Recovery System (LCRS). The purpose of the LCRS is to provide a method to collect potential seepage should leakage develop within the tailings cell through the primary geomembrane liner. The LCRS layer has been designed as a high density polyethylene (HDPE) geonet on the base of the tailings cells, and a drainage geocomposite on the side slopes. The drainage geocomposite is comprised of a geonet laminated on both sides to a nonwoven geotextile filtration media to increase frictional resistance with the overlying and underlying textured geomembrane layers. Per the requirements of 40 CFR 264.221, the transmissivity of the selected drainage layers exceeds the minimum transmissivity requirement of $3x10^{-4}$ square meters per second (m^2/sec), and is designed with a minimum grade of one percent.

LCRS SUMP DESIGN

In the event that leakage were to occur through the upper geomembrane liner, it will be collected in the LCRS layer and routed (via gravity flow) to a LCRS sump located in each tailings cell (or sub-cell in the case of Tailings Cell A). The LCRS sumps were sized for eight (8) hours of maximum flow in the LCRS layer (i.e., geonet or drainage geocomposite) assuming one liner defect per acre for good installation (Giroud & Bonaparte, 1989), an effective porosity of 30 percent in the sump (i.e., available pore space within the gravel backfill materials), and applying a factor of safety of 1.5. The LCRS sump sizing calculations are provided in Appendix E-1. Based on these calculations, a sump with base dimensions of 10 feet by 10 feet with 3H:1V (horizontal:vertical) side slopes and 5-foot depth provides sufficient containment for leak solutions.

PIPE CRUSHING ANALYSES

Two LCRS risers are provided within each sump to add redundancy to the system. The risers consist of two 10-inch diameter, SDR-17 HDPE pipes. The lower ends of the pipes are slotted in the sump area to provide solution access into the risers. Solution is recovered via an automated submersible pump (designed by others) installed in the riser. The LCRS risers will be instrumented and fully-automated to report to the mill control system with an alarm in the mill. Recovered solutions will be

returned to the tailings cells, and then to the mill circuit via tailings return pumps. The HDPE LCRS riser pipes are designed according to the modified Burns & Richard (1964) method (Lupo, 2001) to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. The maximum vertical and horizontal strains calculated for the LCRS riser pipes are 2.5 percent and -2.5 percent, respectively. The design analyses to estimate pipe deformation are presented in Appendix E-2.

REFERENCES

40 CFR Part 264 – "*Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*", Subpart K (Surface Impoundments).

Burns, J.Q. and Richard, R.M. 1964. Attenuation of Stresses for Buried Cylinders. Proceedings, Symposium on Soil-Structure Interaction, University of Arizona. September. 378 p.

Giroud, J.P., and Bonaparte, R. 1989. "Leakage through liners constructed with geomembranes – Part I. Geomembrane Liners." *Geotextiles and Geomembranes*, No. 8, 27-67.

Lupo, J.F. 2001. Stability of HDPE Pipes Under High Heap Loads, SME, Denver.

APPENDIX E-1

LEAK COLLECTION AND RECOVERY SYSTEM SUMP SIZING

Golder Associates	Subject Piñon Ridge Project	Made by EF/KFM	Job No 073-81694
	Tailings Cell Design	Checked by KFM	Date 09/26/08
	LCRS Sump Sizing Calculation	Approved by KFM	Sheet No 1 of 3

OBJECTIVE:

Evaluate the required capacity and dimensions of the Leak Collection and Recovery System (LCRS) sumps for the tailings facilities based on the maximum flow in the LCRS layer for the tailings cells.

GIVEN:

- Tailings cells and sump configuration (Figure 1)
  - Cells A1 and A2: base cell tailings area = 2.6 acres; slope sides cell tailings area = 12.7 acres
  - Cells B and C: base cell tailings area = 6.3 acres; slope sides cell tailings area = 24.2 acres

ASSUMPTIONS:

- The LCRS sump should be sized to accommodate 8 hours of the maximum leakage flow in the LCRS layer (assuming power loss or pump failure of 8 hours);
- The sump will have 3:1(H:V) side slopes;
- Minimum sump dimensions, lower side 10 feet by 10 feet and 5 feet depth;
- Apply a factor of safety (FS) of 1.5;
- Porosity of the gravel within the LCRS sump is assumed as 0.3; and
- Assume 1 liner defect per acre.

CALCULATIONS:

Maximum flow in the LCRS layer for the tailings cells (Attachment 1)

- Geonet (base of tailings cells): 1.49×10^{-3} ft^3/sec per defect
- Geocomposite drainage material (slope sides of tailings cells): 6.21×10^{-4} ft^3/sec per defect

Required Size of the LCRS Sump

Tailings A1 and A2

Maximum flow in the LCRS layer:

Base of tailings cells - $Q_{full\text{-}base} = 1.49 \times 10^{-3}$ ft^3/sec = 963.0 gallons per defect per day

Slope of tailings cells - $Q_{full\text{-}slope} = 6.21 \times 10^{-4}$ ft^3/sec = 401.3 gallons per defect per day

Total flow:

$$Q_T = Q_{full-base}(A_{base}) * \left(\frac{1\ defect}{Acre}\right) + Q_{full-slope}(A_{slope}) * \left(\frac{1\ defect}{Acre}\right)$$

Q_T = 963 gpd/acres (2.6 acres) + 401.3 gpd/acres * (12.7 acres) = 7,600 gallons per day

t = 8 hr (time)
n = 0.3 (porosity)
FS = 1.5 (factor of safety)

$$Required\ volume = Q_T * t * \frac{FS}{n}$$

$$Required\ volume = 7{,}600\ \frac{gal}{day} * \frac{1\ day}{24\ hr} * 8\ hr * \frac{1\ ft^3}{7.48\ gal} * \frac{1.5}{0.3} = 1{,}693\ ft^3$$

Tailings Cells B and C:

Maximum flow in the LCRS layer:

Base of tailings cells - $Q_{full\text{-}base} = 1.49 \times 10^{-3}\ ft^3/sec$ = 963.0 gallons per defect per day
Slope of tailings cells - $Q_{full\text{-}slope} = 6.21 \times 10^{-4}\ ft^3/sec$ = 401.3 gallons per defect per day

Total flow:

$$Q_T = Q_{full-base}(A_{base}) * \left(\frac{1\ defect}{Acre}\right) + Q_{full-slope}(A_{slope}) * \left(\frac{1\ defect}{Acre}\right)$$

Q_T = 963 gpd/acres (6.3 acres) + 401.3 gpd/acres * (24.2 acres) = 15,771 gallons per day

t = 8 hr (time)
n = 0.3 (porosity)
FS = 1.5 (factor of safety)

$$Required\ volume = Q_T * t * \frac{FS}{n}$$

$$Required\ volume = 15{,}771\ \frac{gal}{day} * \frac{1\ day}{24\ hr} * 8\ hr * \frac{1\ ft^3}{7.48\ gal} * \frac{1.5}{0.3} = 3{,}514\ ft^3$$

<u>Sump Capacity</u>

The minimum size assumed for construction of the LCRS sump is:

Sump base dimensions: 10 feet x 10 feet
Sump top dimensions: 40 feet x 40 feet
Sump depth: 5 feet
Side slopes: 3H:1V

Calculations of the sump capacity are provided in Attachment 2. A sump with these minimum dimensions has a volume capacity of 4,250 ft^3, which is sufficient for construction in all of the cells. The corresponding available solution volume, based on 30 percent porosity, is 1,275 ft^3 (9,537 gal).

RESULTS:

The maximum required LCRS sump volume based on a gravel porosity of 0.3 is 3,514 ft^3 (i.e., for cells B and C). Using the assumed minimum dimensions for constructability, the minimum volume of the LCRS sump is 4,250 ft^3, which meets this requirement.

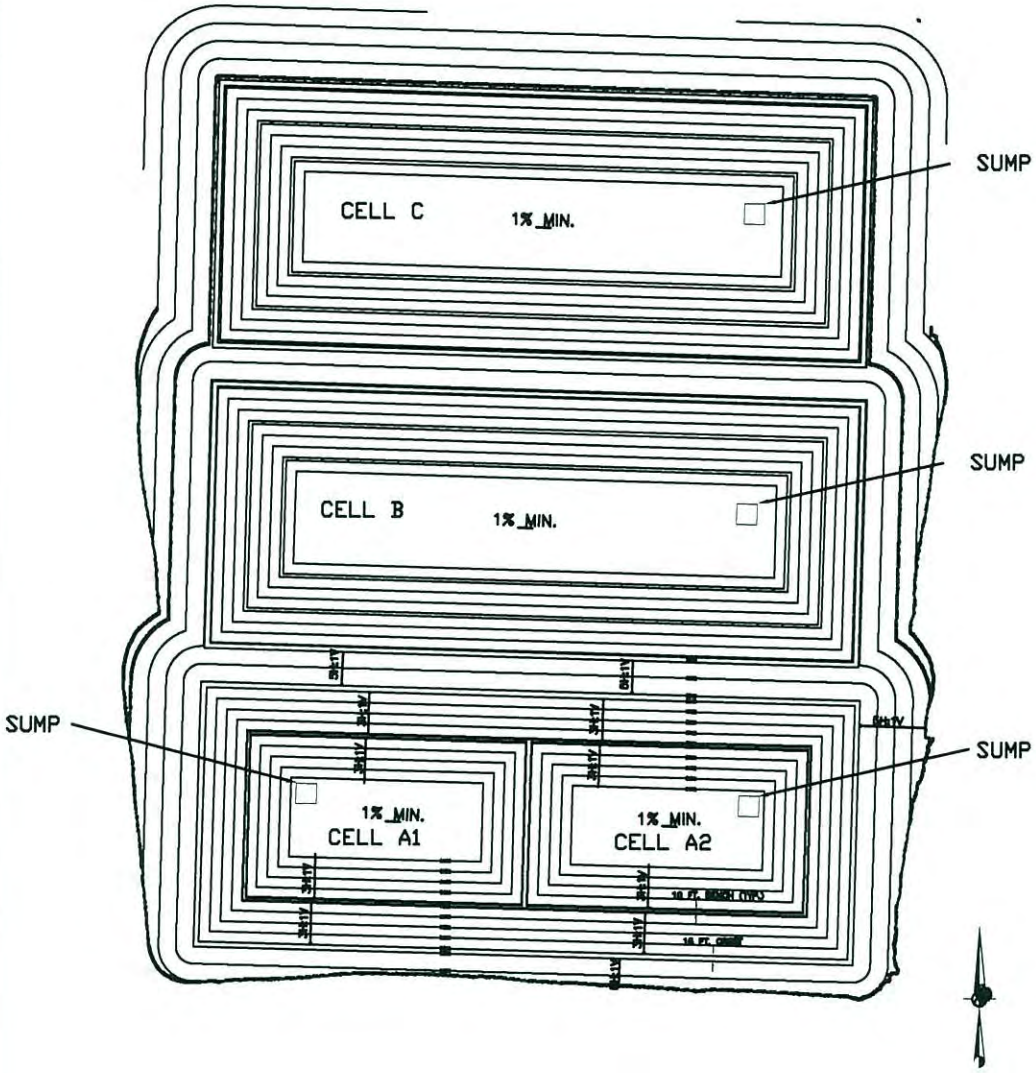
CONCLUSIONS:

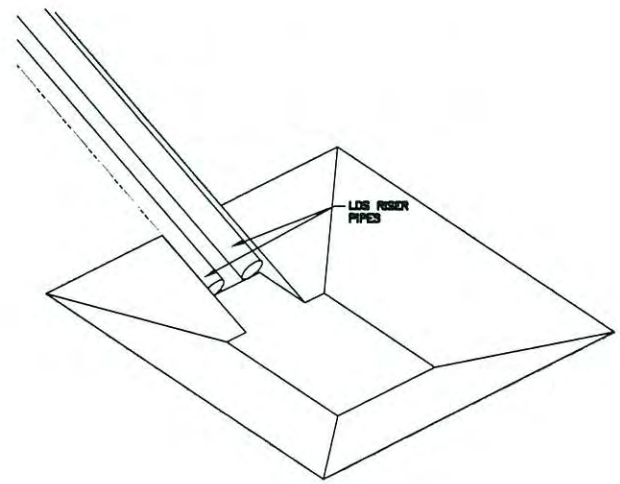
The sump with the minimum assumed dimensions (10 feet by 10 feet at the base, with 3H:1V side slopes and a 5 foot depth) provides sufficient capacity to accommodate 8 hours of a maximum flow in the LCRS layer.

REFERENCES:

Golder (2008). "Comparison of flow through CCL liner and GCL liner for Piñon Ridge Project". Golder project 073-81694

FIGURES





LCRS SUMP ISOMETRIC VIEW

Golder Associates Denver, Colorado

TITLE

SUMP LOCATIONS AND TYPICAL SUMP DETAIL

CLIENT/PROJECT

ENERGY FUELS RESOURCES CORPORATION
PIÑON RIDGE PROJECT - TAILINGS CELL DESIGN
MONTROSE COUNTY, COLORADO

DRAWN EF	DATE FEBRUARY 21, 2008	JOB NO. 073-81694
CHECKED KFM	SCALE N.T.S.	DWG. NO.
REVIEWED KFM	FILE NO.	FIGURE NO. 1

ATTACHMENT 1
MAXIMUM FLOW IN THE LCRS LAYER

Golder Associates	Made by: EF Checked by: KFM Approved by: KFM	Subject: Piñon Ridge Job No.: 073-81694 Date: 9/26/2008 Sheet No. 1 of 1

Maximum Flow in the Leak Collection Layer

Geonet

The permeability of the geonet can be defined by:

$t_{LCL} := 0.023$ ft thickness of the geonet

$\theta := 0.0646$ ft^2 / sec geonet transmissivity

$k := \frac{\theta}{t_{LCL}}$ geonet hydraulic conductivity

$k = 2.81$ ft / sec

The maximum steady-state rate of leachate migration through a defect in the primary liner that the leakage collection layer can accommodate without being filled with leachate (Giroud et al. 1997):

$Q_{full} := k \cdot t_{LCL}^2$

$Q_{full} = 1.49 \times 10^{-3}$ ft^3/ sec

Geocomposite

The permeability of the geonet can be defined by:

$t_{LCL} := 0.023$ ft thickness of the geocomposite

$\theta := 0.027$ ft^2 / sec geocomposite transmissivity

$k := \frac{\theta}{t_{LCL}}$ geocomposite hydraulic conductivity

$k = 1.17$ ft / sec

The maximum steady-state rate of leachate migration through a defect in the primary liner that the leakage collection layer can accommodate without being filled with leachate (Giroud et al. 1997):

$Q_{full} := k \cdot t_{LCL}^2$

$Q_{full} = 6.21 \times 10^{-4}$ ft^3/ sec

References

Giroud, J. P., Gross, B. A., Bonaparte, R., and McKelvey, J. A. (1997). "Leachate flow in leakage collection layers due to defects in geomembrane liners." *Geosynthetics International*, 4(3-4), 215-292.

ATTACHMENT 2
POND SIZING CALCULATION

Attachment 1 - Pond Sizing Worksheet

Project Name: Pinon Mill - Leak Detection Sump
Project Number: 073-81694
Client: Energy Fuels Resources Corp. (EFRC)
By: DLG
Date: 2/8/2008

Pond Depth:	5	ft	1.5	m
Pond Side 1(upper):	40	ft	12.2	m
Pond Side 2 (upper):	40	ft	12.2	m
Pond Side 1(lower):	10	ft	3.0	m
Pond Side 2 (lower):	10	ft	3.0	m
Side Slope:	3	H	1	V
Liner Overlap per Side	0	ft	0.0	m
Dry Freeboard	0	ft	0.0	m
Pond Volume w/o freeboard:	4,250	ft^3	120	m^3
	31,790	gal.	120,441	liters
Liner Area:	1,681	ft^2	156	m^2
Pond Volume w/ freeboard:	4,250	ft^3	120	m^3
	31,790	gal.	120,441	liters

APPENDIX E-2

PIPING CRUSHING CALCULATIONS

Golder Associates	Subject Piñon Ridge Project	Made by JDE	Job No 073-81694
	Tailings Cell Design	Checked by KHM	Date 5/06/08
	LCRS Pipe Crushing Calculation	Approved by KHM	Sheet No 1 of 2

OBJECTIVE:

Evaluate the tailings cell Leak Collection and Recovery System (LCRS) (i.e., LCRS riser pipes) under loading.

GIVEN:

- LCRS riser piping consists of two 10-inch SDR17 HDPE pipes (eg., DriscoPlex™), non-corrugated, Series 1500 IPS. Pipe data included in Attachment 1, and summarized below:
  - Pipe outside diameter = 10.75 inches;
  - Pipe inside diameter = 9.41 inches;
  - Pipe wall thickness = 0.632 inches; and
  - Weight of pipe = 8.78 lb/ft.

ASSUMPTIONS:

- LCRS Riser Pipe envelope (tailings) properties assumed as follows:
  - Fine-grained soils with less than 25 percent sand, at about 85 percent relative compaction;
  - Modulus of soil reaction assumed as 500 pounds per square inch (psi);
  - Poisson's ratio = 0.30;
  - Soil friction angle = 20 degrees; and
  - Constrained modulus = 1,540 psi.
- Modulus of elasticity of pipe = 172 MPa (25,000 psi) (long term value for HDPE);
- Unit weight of tailings assumed as 100 pounds per cubic foot (pcf); and
- Pipe calculations conducted assuming depth of burial of 80 feet.
- Others, as stated

CALCULATIONS:

LCRS Riser Piping:

- Deformation characteristics calculated using modified Burns & Richard (1964) method (see Attachment 2), as follows:
  - Expected vertical deflections range from 2.4 percent (no slippage, positive strain denotes flattening) to 2.5 percent (full slippage).
  - Expected horizontal deflections range from -2.2 percent (no slippage, negative denotes outward deformation) to -2.5 percent (full slippage).

CONCLUSIONS:

The maximum LCRS riser pipe vertical strain was estimated at 2.5 percent. The acceptable maximum deflection for HDPE pipe is on the order of 20 percent, and the estimated deflections are considerably less than 20 percent. Therefore, pipe crushing of the LCRS riser piping is not considered a concern.

REFERENCES:

Performance Pipe website, http://www.cpchem.com/enu/performance_pipe.asp

Burns, J.Q. & Richard, R.M. (1964). Attenuation of Stresses for Buried Cylinders. Proceedings, Symposium on Soil-Structure Interaction, University of Arizona. September. 378 p.

Lupo, J.F. (2001). Stability of HDPE Pipes Under High Heap Loads, SME, Denver.

ATTACHMENT 1

MANUFACTURER PIPE DATA

PERFORMANCE PIPE
A DIVISION OF CHEVRON PHILLIPS CHEMICAL COMPANY LP

PERFORMANCE PIPE Municipal & Industrial Series/IPS Pipe Data

Pipe weights are calculated in accordance with PPI TR-7. Average inside diameter calculated using nominal OD and minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary. When designing components to fit the pipe ID, refer to pipe dimensions and tolerances in applicable pipe specifications.

Pressure Ratings are for water at 73.4 °F. For other fluid and service temperature, ratings may differ. Refer to Engineering Manual for Chemical and Environmental Considerations.

Pressure Rating		100 psi DR 17.0			80 psi DR 21.0			65 psi DR 26.0			50 psi DR 32.5			
IPS Pipe Size	Nominal OD (in)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	Minimum Wall (in)	Average ID (in)	Weight (lbs/ft)	IPS Pipe Size
1 1/4"	1.660													1 1/4"
1 1/2"	1.900													1 1/2"
2"	2.375	0.140	2.078	0.43										2"
3"	3.500	0.206	3.063	0.93										3"
4"	4.500	0.265	3.938	1.54	0.214	4.046	1.26							4"
5 3/8"	5.375	0.316	4.705	2.20	0.256	4.832	1.80	0.207	4.936	1.47				5 3/8"
5"	5.563	0.327	4.870	2.35	0.265	5.001	1.93	0.214	5.109	1.57				5"
6"	6.625	0.390	5.798	3.34	0.315	5.957	2.73	0.255	6.084	2.23	0.204	6.193	1.80	6"
7 1/8"	7.125	0.419	6.237	3.86	0.339	6.406	3.16	0.274	6.544	2.58	0.219	6.661	2.08	7 1/8"
8"	8.625	0.507	7.550	5.65	0.411	7.754	4.64	0.332	7.921	3.79	0.265	8.063	3.05	8"
10"	10.750	0.632	9.410	8.78	0.512	9.665	7.21	0.413	9.874	5.87	0.331	10.048	4.75	10"
12"	12.750	0.750	11.160	12.36	0.607	11.463	10.13	0.490	11.711	8.26	0.392	11.919	6.67	12"
13 3/8"	13.375	0.787	11.707	13.61	0.637	12.025	11.15	0.514	12.285	9.09	0.412	12.502	7.35	13 3/8"
14"	14.000	0.824	12.253	14.91	0.667	12.586	12.22	0.538	12.859	9.96	0.431	13.086	8.05	14"
16"	16.000	0.941	14.005	19.46	0.762	14.385	15.96	0.615	14.696	13.01	0.492	14.957	10.50	16"
18"	18.000	1.059	15.755	24.64	0.857	16.183	20.19	0.692	16.533	16.47	0.554	16.826	13.30	18"
20"	20.000	1.176	17.507	30.41	0.952	17.982	24.93	0.769	18.370	20.34	0.615	18.696	16.41	20"
22"	22.000	1.294	19.257	36.80	1.048	19.778	30.18	0.846	20.206	24.61	0.677	20.565	19.86	22"
24"	24.000	1.412	21.007	43.81	1.143	21.577	35.91	0.923	22.043	29.30	0.738	22.435	23.62	24"
26"	26.000	1.529	22.759	51.39	1.238	23.375	42.14	1.000	23.880	34.39	0.800	24.304	27.74	26"
28"	28.000	1.647	24.508	59.62	1.333	25.174	48.86	1.077	25.717	39.88	0.862	26.173	32.19	28"
30"	30.000	1.765	26.258	68.45	1.429	26.971	56.12	1.154	27.554	45.78	0.923	28.043	36.93	30"
32"	32.000	1.882	28.010	77.86	1.524	28.769	63.84	1.231	29.390	52.10	0.985	29.912	42.04	32"
34"	34.000	2.000	29.760	87.91	1.619	30.568	72.06	1.308	31.227	58.81	1.046	31.782	47.43	34"
36"	36.000	2.118	31.510	98.57	1.714	32.366	80.78	1.385	33.064	65.94	1.108	33.651	53.20	36"
42"	42.000	2.471	36.761	134.16	2.000	37.760	109.97	1.615	38.576	89.71	1.292	39.261	72.37	42"
48"	48.000	2.824	42.013	175.23	2.286	43.154	143.65	1.846	44.086	117.18	1.477	44.869	94.56	48"
54"	54.000				2.571	48.549	181.75	2.077	49.597	148.33	1.662	50.477	119.70	54"

Performance Pipe can produce to specialized pipe dimensions. Check with your Performance Pipe contact for availability of dimensions not listed.

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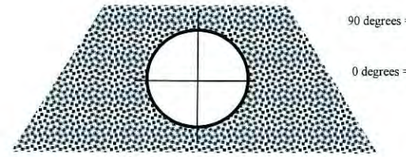
ATTACHMENT 2

LCRS RISER PIPE
DEFORMATION CALCULATIONS

BURIED PLASTIC PIPE LOADING WORKSHEET V2.0

[With Incremental Stress Analysis (non-linear)]



Model Geometry

Golder Associates

Project: Pinon Ridge Project - Tailings Cell Design

By: JDE

Date: 5/06/08

Note: Compression is positive, tension is negative.

SOIL and PIPE Input Data

Material	Cohesion	Friction Angle	Contrained Modulus (psi)	Lateral Stress Ratio	Lateral Pressure Parameters B	Lateral Pressure Parameters C
Pipe	n/a	n/a				
Soil (Tailings)	0	20	1540.0	0.70	0.849	0.15

Pipe Diameter (in):	10.75		
Pipe ID (in):	9.41		
Weight of Pipe (lb/ft):	8.78	DR=	16.04
Pipe Corrugated (y/n):	n		55.00
Prescribed Constrained Modulus (y/n):	y		0.49
Prescribed Constrained Modulus (psi):	1540		
Pipe Wall Thickness (in):	0.67		
Pipe Area (in^2/in):	21.220		
Flexural Modulus (psi), E_f =	25,000		
Ring Compression Modulus (psi), E_{rc} =	25,000		
C value (in)	0.335		
Moment of Inertia (in^4/in) non-corrugated:	0.0251		
Moment of Inertia (in^4/in) corrugated (input from manufacturer data):	0.0000	selected I:	0.0251
Stiffness Coefficients			
Flexural Stiffness	29.4		
Ring Compression Stiffness	105257.9	Ring Stiffness Factor:	4.9 Pipe Stiffness Less Than Soil

Shell-Medium Parameters		
UF	0.02	Extensional Flexibility ratio = Compressibility ratio = relative flexibility of pipe and soil under uniform loading.
VF	15.9	Bending Felxibility ratio = Flexibility ratio = relative flexibility of pipe and soil under varying radial and tangential loads.
		If both UF and VF are zero then a perfectly rigid embedded pipe.

Pipe Mean Radius (in):	5.04	
Depth of Burial (ft):	80	
Applied Surface Stress (psf):	0	
Soil Density (pcf):	100	
Total Vertical Stress Component (psf):	8000	Free Field Stress Values
Total Vertical Stress Component (psi):	55.6	

NO INTERFACE SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	55.5	52.4	0.0	-0.110	0.00E+00	290.6	15.4	432.7	0.0173	0.0152	206	-206	638	227
10	55.1	52.0	5.7	-0.099	3.75E-02	287.9	14.6	428.6	0.0171	0.0151	195	-195	623	234
20	53.9	50.8	10.8	-0.067	7.05E-02	280.1	12.2	417.0	0.0167	0.0147	163	-163	580	254
30	52.1	49.0	14.5	-0.018	9.50E-02	268.1	8.6	399.2	0.0160	0.0140	115	-115	514	284
40	49.9	46.8	16.5	0.042	1.08E-01	253.5	4.2	377.4	0.0151	0.0133	56	-56	433	322
50	47.6	44.4	16.5	0.106	1.08E-01	237.8	-0.5	354.1	0.0142	0.0125	-7	7	347	361
60	45.3	42.1	14.5	0.165	9.50E-02	223.2	-5.0	332.3	0.0133	0.0117	-66	66	266	399
70	43.5	40.3	10.8	0.214	7.05E-02	211.2	-8.6	314.4	0.0126	0.0111	-115	115	200	429
80	42.4	39.1	5.7	0.246	3.75E-02	203.4	-10.9	302.8	0.0121	0.0107	-146	146	157	449
90	42.0	38.7	0.0	0.257	1.34E-17	200.7	-11.8	298.8	0.0120	0.0105	-157	157	142	456

Vertical Deflection (%):	2.39
Horizontal Deflection (%):	-2.18
Radial Soil Pressure at Crown (psi):	42.0
Circumferential Shortening (in):	0.51
Arc length of each sector (in) =	0.88

6041

Max. Compressive Stress (psi): 638

Max. Tensile Stress (psi): No Tensile Stress

FULL SLIPPAGE

Angle	Soil Stresses (psi)			Pipe Displacements (in)		Circumferential Thrust	Moment Thrust	Ring Compression Stress (psi)	Ring Compression Strain (in/in)	Ring Shortening (in)	Inner Bending Stress (psi)	Outer Bending Stress (psi)	Total Inner Stress (psi)	Total Outer Stress (psi)
	Radial	Hoop	Shear	Radial	Hoop									
0	47.0	30.5	0.0	-0.125	0.00E+00	248.6	16.5	370.1	0.0148	0.0130	221	-221	591	150
10	47.1	31.4	16.1	-0.113	7.00E-02	248.4	15.6	369.8	0.0148	0.0130	209	-209	579	161
20	47.4	34.0	30.2	-0.078	1.32E-01	247.9	13.1	369.1	0.0148	0.0130	175	-175	544	194
30	47.9	38.0	40.7	-0.025	1.77E-01	247.1	9.2	367.9	0.0147	0.0129	122	-122	490	245
40	48.4	42.9	46.2	0.039	2.02E-01	246.2	4.4	366.5	0.0147	0.0129	58	-58	425	308
50	49.0	48.2	46.2	0.108	2.02E-01	245.1	-0.7	365.0	0.0146	0.0128	-10	10	355	375
60	49.6	53.1	40.7	0.173	1.77E-01	244.2	-5.5	363.6	0.0145	0.0128	-74	74	290	437
70	50.1	57.1	30.2	0.226	1.32E-01	243.4	-9.4	362.4	0.0145	0.0128	-126	126	236	488
80	50.4	59.7	16.1	0.260	7.00E-02	242.9	-12.0	361.7	0.0145	0.0127	-160	160	202	522
90	50.5	60.6	0.0	0.272	2.51E-17	242.7	-12.9	361.4	0.0145	0.0127	-172	172	189	533

Vertical Deflection (%):	2.53
Horizontal Deflection (%):	-2.47
Radial Soil Pressure at Crown (psi):	50.5
Circumferential Shortening (in):	0.51
Arc length of each sector (in) =	0.88

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Max. Compressive Stress (psi): 591

Max. Tensile Stress (psi): No Tensile Stress

Free Field Stress: 55.6 psi

Free Field Stress Times Pipe Radius: 881 psi

Radius (in)	CROWN				SPRINGLINE			
	Circumferential Thrust (full slip)	Circumferential Thrust (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)	Circumferential Thrust (full slip)	Circumferential Thrust (no slip)	Hoop Stress, psi (full slip)	Hoop Stress, psi (no slip)
5.04	242.7	200.7	60.6	38.7	248.6	290.6	30.5	52.4
5.54	266.8	220.6	53.5	38.5	273.2	319.4	38.2	53.2
6.04	290.9	240.5	49.0	38.4	297.9	348.3	43.1	53.7
6.54	315.0	260.4	46.1	38.4	322.5	377.1	46.3	54.1
7.04	339.1	280.3	44.1	38.3	347.2	405.9	48.6	54.3
7.54	363.1	300.2	42.7	38.3	371.9	434.8	50.2	54.5
8.04	387.2	320.1	41.7	38.4	396.5	463.6	51.3	54.7
8.54	411.3	340.0	41.0	38.4	421.2	492.4	52.2	54.8
9.04	435.4	360.0	40.5	38.4	445.8	521.3	52.8	54.9
9.54	459.5	379.9	40.1	38.4	470.5	550.1	53.3	55.0
10.04	483.5	399.8	39.8	38.4	495.1	578.9	53.7	55.1
10.54	507.6	419.7	39.6	38.5	519.8	607.8	54.0	55.1
11.04	531.7	439.6	39.4	38.5	544.5	636.6	54.2	55.2
11.54	555.8	459.5	39.3	38.5	569.1	665.4	54.4	55.2
12.04	579.9	479.4	39.2	38.5	593.8	694.2	54.6	55.2
12.54	603.9	499.3	39.1	38.5	618.4	723.1	54.7	55.3
13.04	628.0	519.2	39.0	38.5	643.1	751.9	54.8	55.3
13.54	652.1	539.1	39.0	38.6	667.8	780.7	54.9	55.3
14.04	676.2	559.0	38.9	38.6	692.4	809.6	55.0	55.3
14.54	700.3	578.9	38.9	38.6	717.1	838.4	55.0	55.3
15.04	724.4	598.9	38.9	38.6	741.7	867.2	55.1	55.4
15.54	748.4	618.8	38.8	38.6	766.4	896.1	55.1	55.4
16.04	772.5	638.7	38.8	38.6	791.1	924.9	55.2	55.4
16.54	796.6	658.6	38.8	38.6	815.7	953.7	55.2	55.4
17.04	820.7	678.5	38.8	38.6	840.4	982.6	55.2	55.4
Check Values:	531.7	439.6	48.3	38.4	544.5	636.6	44.0	53.8
Soil Arching:	Positive Arch	Positive Arch	Negative Arch	Negative Arch	Positive Arch	Negative Arch	Positive Arch	Positive Arch