APPENDIX A

CUSHION MATERIAL THICKNESS CALCULATION

Golder Associates	Subject Piñon Ridge Project	Made by KFM	Job No 073-81694
	Ore Stockpile Pad Design	Checked by	Date 4/02/08
	Cushion Material Thickness	Approved by KFM	Sheet No 1 of 1

OBJECTIVES:

Design the minimum thickness of Cushion Material to be placed above the proposed geosynthetic liner for the Ore Stockpile Pad liner system at the Piñon Ridge Project.

GIVEN:

Maximum size of equipment anticipated to travel over the liner system is a Caterpillar Model 988H Wheel Loader with a gross loaded weight of 110,000 pounds with 52 percent of the weight supported by the front axle (i.e., 57,000 lbs). Loader specifications are included in Attachment A.

ASSUMPTIONS:

- Maximum stress allowed on the liner is 8 pounds per square inch (psi); and
- Assume point loading at one of the front tires, with additional stress applied by the second front tire at an assumed distance of 12 feet.

CALCULATIONS:

Stresses imposed on the liner were evaluated using the Boussinesq Method. The attached spreadsheet provides the results of the stress calculation at the first front tire (page 1), and the additional stress imposed from the second front tire (page 2), at the location of the first front tire.

RECOMMENDATIONS:

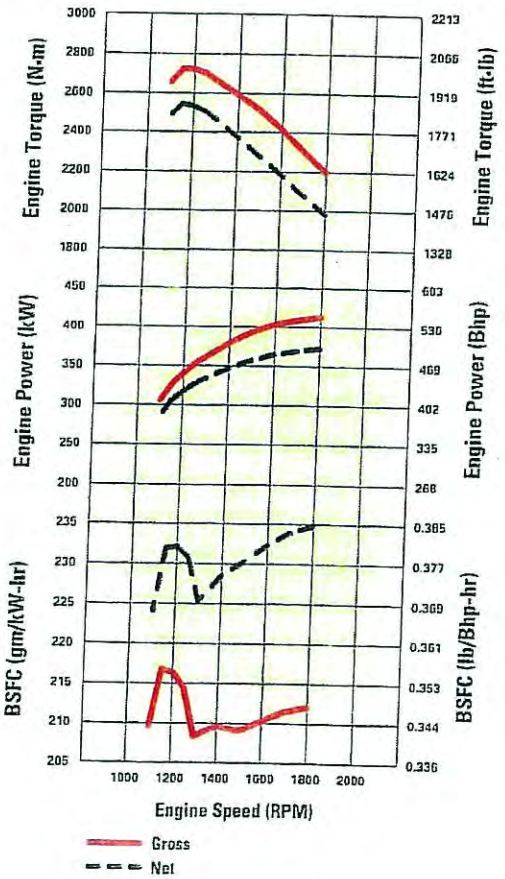
A stress equivalent to, or less than, the recommended design stress of 8 psi is achieved by placement of a cushion material with a minimum thickness of 3.5 feet. To limit erosion and increase the longevity of the ore pad, Golder recommends the lower 2.5 feet be constructed of compacted, on-site soils, with the upper 1.0 feet constructed of roadbase.

ATTACHMENT A
EQUIPMENT SPECIFICATIONS

Engine

Engine Model	Cat C18 ACERT®	
Gross Power	414 kW	555 hp
Flywheel Power	373 kW	501 hp
Net Power – EEC 80/1269	373 kW	501 hp
Net Power – ISO 9249	373 kW	501 hp
Gross Power – ISO 3046-2	388 kW	520 hp
Bore	145 mm	5.7 in
Stroke	183 mm	7.2 in
Displacement	18.1 L	1,104.5 in³

- These ratings apply at 1,800 rpm when tested under the specific standard conditions for the specified standard.
- Power rating conditions based on standard air conditions of 25° C (77° F) and 99 kPa (29.32 in Hg) dry barometer, using 35° API gravity fuel having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 30° C (86° F) [reference a fuel density of 838.9 g/L (7.001 lb/gal)].
- Net power advertised is the power available when the engine is equipped with alternator, air cleaner, muffler and hydraulic fan drive.
- No derating required up to 3048 m (10,000 ft) altitude.
- Direct-electric, 24-volt starting system with 100 amp alternator and four high performance maintenance-free batteries with 1,000 cold cranking amps.



Operating Specifications

Rated Payload	11.4 tonnes	12.5 tons
Operating Weight	49 546 kg	109,249 lb
Rated Payload – Standard	11.4 tonnes	12.5 tons

Transmission

Converter Drive – Forward 1	6.7 kph	4.2 mph
Converter Drive – Forward 2	11.8 kph	7.3 mph
Converter Drive – Forward 3	20.8 kph	12.9 mph
Converter Drive – Forward 4	36 kph	22.3 mph
Converter Drive – Reverse 1	7.6 kph	4.7 mph
Converter Drive – Reverse 2	13.5 kph	8.4 mph
Converter Drive – Reverse 3	23.7 kph	14.7 mph
Direct Drive – Forward 1	Lock-up disabled	
Direct Drive – Forward 2	12.3 kph	7.7 mph
Direct Drive – Forward 3	21.9 kph	13.6 mph
Direct Drive – Forward 4	38.6 kph	24 mph
Direct Drive – Reverse 1	7.9 kph	4.9 mph
Direct Drive – Reverse 2	14.1 kph	8.8 mph
Direct Drive – Reverse 3	25.1 kph	15.6 mph

- Travel speeds based on two percent rolling resistance and 35/65-33 tires.

Hydraulic Cycle Time

Raise	9.4 Seconds
Dump	2.4 Seconds
Lower Float Down (Empty)	3.8 Seconds
Total Hydraulic Cycle Time	15.6 Seconds

Service Refill Capacities

Fuel Tank	712 L	188 gal
Cooling System	103 L	27.2 gal
Crankcase	60 L	15.9 gal
Transmission	70 L	18.5 gal
Differentials and Final Drives – Front	186 L	49 gal
Differentials and Final Drives – Rear	186 L	49 gal
Hydraulic System (factory fill)	470 L	124.2 gal
Hydraulic System (tank only)	267 L	70.5 gal

Buckets

Bucket Capacities	6.3 m³–7.0 m³	8.2 yd³–9.2 yd³
Max. Bucket Capacity	7 m³	9.2 yd³

Axles

Maximum Single-Wheel Rise and Fall	568 mm	22.4 in
Front	Fixed	
Rear	Oscillating ±13°	

Brakes

Brakes	Meet SAE ISO 3450:1996

Cab

Cab – ROPS/FOPS	Meets SAE and ISO standards

- Cat cab with integrated Rollover Protective Structure (ROPS) and Falling Object Protective Structure (FOPS) is standard.
- ROPS meets SAE J1040 APR99 and ISO 3471:1994 criteria.
- FOPS meets SAE J231 JAN 81 and ISO 3449:1992 Level II criteria.

Sound Performance

Meets ANSI, SAE and ISO standards

- The operator sound exposure Leq (equivalent sound pressure level) measured according to the work cycle procedures specified in ANSI/SAE J1166 OCT 98 is 76 dB(A), for the cab offered by Caterpillar, when properly installed, maintained and tested with the doors and windows closed.
- Hearing protection may be needed when operating with an open operator station and cab (when not properly maintained or doors/windows open) for extended periods or in noisy environment.
- The exterior sound pressure level for the standard machine measured at a distance of 15 m (49.2 ft) according to the test procedures specified in SAE J88 JUN 86 mid-gear-moving operation is 81 dB(A).
- The sound power level is 115 dB(A) measured according to the dynamic test procedure and conditions specified in ISO 6395:1998/AMD. 1:1996 for a standard machine configuration.
- For "CE" marked configurations, the labeled sound power level is 110 dB(A) measured according to the test procedures and conditions specified in 2000/14/EC.
- For "CE" marked configurations, the operator sound pressure level is 73 dB(A) measured according to the test procedures and conditions specified in 2000/14/EC Directive and ISO 6396:1992.

Steering

Steering	Meets SAE and ISO standards
Total Steering Angle	86°

- Full hydraulic, load-sensing steering system meets SAE J1511 FEB94 and ISO 5010:1992 specified standards.
- Center point frame articulation.
- Front and rear wheels track.

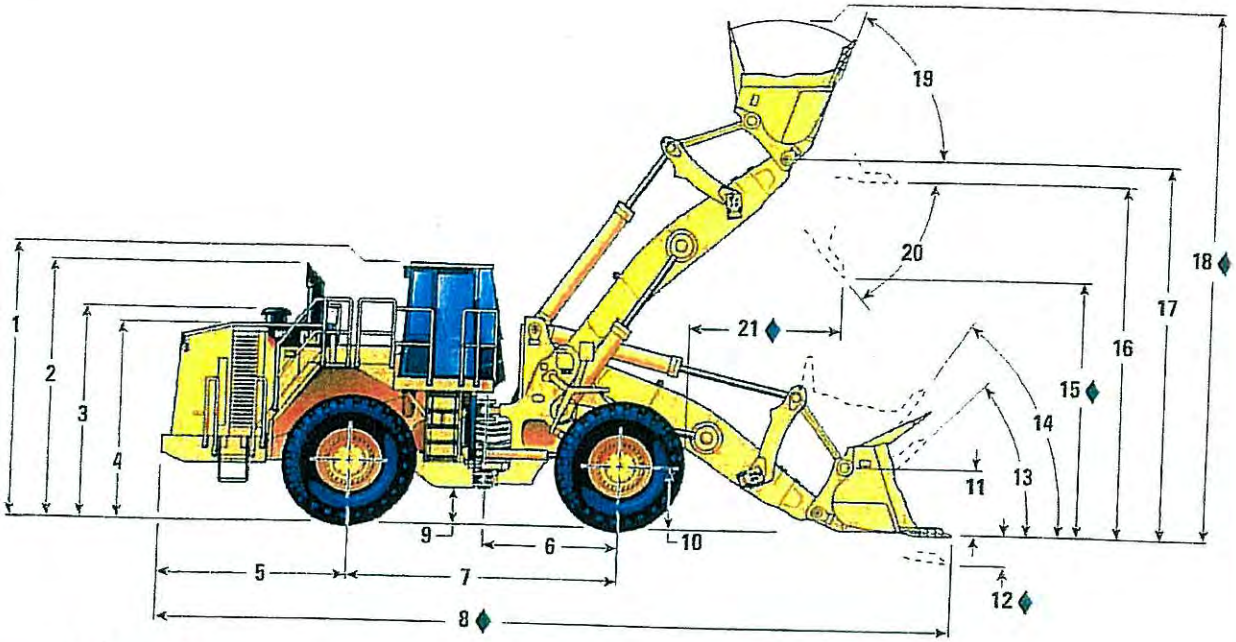
Loader Hydraulic System

Main Hydraulic System Output at 2,010 rpm and 6900 kPa (1,000 psi)	492 L/min	130 gal/min
Relief Valve Setting	31 000 kPa	4,500 psi
Cylinders, Double Acting: Lift, Bore and Stroke	220 × 911 mm	8.7 × 35.9 in
Cylinder, Double Acting: Tilt, Bore and Stroke	220 × 1770 mm	8.7 × 69.7 in
Pilot System, Gear-Type Pump Output at 2,010 rpm and 2500 kPa (363 psi)	76 L/min	20.1 gal/min
Relief Valve Setting (low idle)	2400 kPa	348.1 psi

- With SAE 10W oil at 66° C (150° F).

Dimensions

All dimensions are approximate.



4.25 Meter Linkage

◆ Dimensions vary with bucket. Refer to Operation/Bucket Specifications.

1	Height to Top of Cab	4128 mm	13.54 ft
2	Height to Top of Exhaust Stacks	4112 mm	13.49 ft
3	Height to Top of Air Cleaner	3382 mm	11.1 ft
4	Height to Top of Hood	3156 mm	10.35 ft
5	Center Line of Rear Axle to Edge of Rear Bumper	3132 mm	10.28 ft
6	Center Line of Front Axle to Hitch	2275 mm	7.46 ft
7	Wheel Base Length	4550 mm	14.93 ft
8	Length with Bucket on Ground	◆	◆
9	Ground Clearance	549 mm	1.8 ft
10	Height to Center of Wheel	978 mm	3.21 ft
11	C-Pin Height	1009 mm 899 mm*	3.31 ft 2.95 ft*
12	Dig Depth	226 mm 195 mm*	0.74 ft 0.64 ft*

*3.88 Meter Linkage

13	Rack Back Angle at Ground	47.8° 45.7°*	
14	Rack Back Angle at Carry	56.5° 54°*	
15	Clearance at Maximum Lift/Dump	3879 mm 3466 mm*	12.73 ft 11.37 ft*
16	Height to Spillguard	5432 mm 5019 mm*	17.82 ft 16.47 ft*
17	B-Pin Height	5853 mm 5440 mm*	19.2 ft 17.85 ft*
18	Overall Height with Bucket Raised	◆ ◆*	◆ ◆*
19	Rack Back Angle at Maximum Lift	65° 73°*	
20	Dump Angle at Maximum Lift	45° 45°*	
21	Reach	◆	◆

Operation/Bucket Specifications

		3.88 Meter Linkage		
Bucket Type		Spade Rock (Standard Bucket)	Wide Spade Rock	Spade Rock
GET		Teeth & Segments	Teeth & Segments	BOCE
Rated Capacity	m^3 (yd^3)	6.4 (8.33)	6.9 (9.0)	6.9 (9.0)
Struck Capacity	m^3 (yd^3)	5.3 (6.9)	5.7 (7.5)	5.7 (7.5)
Heaped Capacity	m^3 (yd^3)	6.4 (8.33)	6.9 (9.0)	6.9 (9.0)
Bucket Width	mm (ft/in)	3810 (12'6")	3980 (13'1")	3964 (13'0")
Overall Height	mm (ft/in)	7699 (25'3")	7772 (25'6")	7772 (25'6")
Dump Clearance at 45° dump				
Bare	mm (ft/in)	3742 (12'3")	3682 (12'1")	3638 (11'11")
Teeth	mm (ft/in)	3466 (11'4")	3410 (11'2")	—
Reach at 45° dump				
Bare	mm (ft/in)	1494 (4'11")	1554 (5'1")	1881 (6'2")
Teeth	mm (ft/in)	2028 (6'8")	2084 (6'10")	—
Overall Length				
Bare	mm (ft/in)	11 877 (39'0")	11 962 (39'3")	11 982 (39'4")
Teeth	mm (ft/in)	12 215 (40'1")	12 294 (40'4")	—
Turning Radius at SAE Carry				
Bare	mm (ft/in)	8543 (28'0")	8641 (28'4")	8644 (28'4")
Teeth	mm (ft/in)	8597 (28'2")	8689 (28'6")	—
Reach at 45° dump and 2.13 m (7'0") HGT				
Bare	mm (ft/in)	2389 (7'10")	2427 (8'0")	2840 (9'4")
Teeth	mm (ft/in)	2924 (9'7")	2957 (9'8")	—
Reach with level boom level bucket				
Bare	mm (ft/in)	3435 (11'3")	3520 (11'7")	3972 (13'0")
Teeth	mm (ft/in)	4198 (13'9")	4277 (14'0")	—
Digging Depth – Bucket Level	mm (in)	195 (7.7")	195 (7.7")	185 (7.3")
Full Dump at Maximum Lift	degrees	51.4	51.4	51.4
Tipping Load				
Straight	kg (lb)	34 825 (76,776)	34 355 (75,740)	34 635 (76,357)
Articulated 43°	kg (lb)	29 368 (64,745)	28 923 (63,764)	29 182 (64,335)
Breakout Force	kN (lb-f)	378.4 (85,068)	360.6 (81,066)	383.9 (86,304)
Operating Weight	kg (lb)	49 546 (109,230)	49 816 (109,825)	49 716 (109,605)
Weight Distribution at SAE Carry				
Front	kg (lb)	25 265 (55,700)	25 746 (56,760)	25 540 (56,306)
Rear	kg (lb)	24 281 (53,530)	24 070 (53,065)	24 176 (53,299)

3.88 Meter Linkage			
Straight Rock	Heavy Duty Quarry	High Abrasion	General Purpose
Teeth & Segments	Teeth & Segments	Teeth & Segments	BOCE
6.3 (8.2)	6.4 (8.33)	6.4 (8.33)	7.0 (9.2)
5.2 (6.8)	5.3 (6.9)	5.3 (6.9)	5.88 (7.7)
6.3 (8.2)	6.4 (8.33)	6.4 (8.33)	7.0 (9.2)
3800 (12'6")	3862 (12'8")	3926 (12'11")	3695 (11'2")
7699 (25'3")	7698 (25'3")	7699 (25'3")	7698 (25'3")
4011 (13'2")	3728 (12'3")	3811 (12'6")	3790 (12'5")
3735 (12'3")	3376 (11'1")	3447 (11'4")	—
1526 (5'0")	1543 (5'1")	1577 (5'2")	1720 (5'8")
1765 (5'9")	2076 (6'10")	2047 (6'9")	—
11 497 (37'9")	11 917 (39'1")	11 779 (38'8")	11 765 (38'7")
11 839 (38'10")	12 333 (40'6")	12 242 (40'2")	—
8550 (28'0")	8605 (28'3")	8625 (28'4")	8573 (28'2")
8634 (28'4")	8678 (28'6")	8682 (28'6")	—
2518 (8'3")	2401 (7'11")	2464 (8'1")	2729 (8'11")
2757 (9'1")	2934 (9'8")	2935 (9'8")	—
3480 (11'5")	3535 (11'7")	3552 (11'8")	3751 (12'0")
3822 (12'6")	4295 (14'1")	4225 (13'10")	—
195 (7.7")	225 (8.9")	195 (7.7")	191 (7.5")
51.4	51.4	51.4	51.4
35 257 (77,728)	32 650 (71,981)	33 833 (74,589)	35 026 (77,219)
29 816 (65,733)	27 239 (60.052)	28 383 (62,574)	29 568 (65,186)
467.4 (105,076)	360.7 (81,089)	389.2 (87,496)	433.1 (97,365)
49 261 (108,602)	51 181 (112,835)	51 016 (112,471)	49 401 (108,910)
24 616 (54,269)	28 161 (62,084)	27 367 (60,334)	24 988 (55,089)
24 645 (54,333)	23 020 (50,750)	23 649 (52,137)	24 413 (53,821)

Operation/Bucket Specifications

		4.25 Meter Linkage		
Bucket Type		Spade Rock (Standard Bucket)	Wide Spade Rock	Spade Rock
GET		Teeth & Segments	Teeth & Segments	BOCE
Rated Capacity	m^3 (yd^3)	6.4 (8.33)	6.9 (9.0)	6.9 (9.0)
Struck Capacity	m^3 (yd^3)	5.3 (6.9)	5.7 (7.5)	5.7 (7.5)
Heaped Capacity	m^3 (yd^3)	6.4 (8.33)	6.9 (9.0)	6.9 (9.0)
Bucket Width	mm (ft/in)	3810 (12'6")	3980 (13'1")	3964 (13'0")
Overall Height	mm (ft/in)	8112 (26'7")	8186 (26'10")	8186 (26'10")
Dump Clearance at 45° dump				
Bare	mm (ft/in)	4155 (13'8")	4095 (13'5")	4051 (13'3")
Teeth	mm (ft/in)	3879 (12'9")	3823 (12'7")	—
Reach at 45° dump				
Bare	mm (ft/in)	1591 (5'3")	1652 (5'5")	1699 (5'7")
Teeth	mm (ft/in)	2126 (7'0")	2182 (7'2")	—
Overall Length				
Bare	mm (ft/in)	12 321 (40'5")	12 406 (40'8")	12 426 (40'9")
Teeth	mm (ft/in)	12 658 (41'6")	12 738 (41'9")	—
Turning Radius at SAE Carry				
Bare	mm (ft/in)	8731 (28'8")	8828 (29'0")	8803 (28'11")
Teeth	mm (ft/in)	8787 (28'10")	8879 (29'2")	—
Reach at 45° dump and 2.13 m (7'0") HGT				
Bare	mm (ft/in)	2785 (9'2")	2825 (9'3")	2951 (9'8")
Teeth	mm (ft/in)	3320 (10'11")	3355 (11'0")	—
Reach with level boom level bucket				
Bare	mm (ft/in)	3805 (12'6")	3890 (12'9")	3947 (12'11")
Teeth	mm (ft/in)	4568 (15'0")	4647 (15'3")	—
Digging Depth – Bucket Level	mm (in)	226 (8.9")	226 (8.9")	216 (8.5")
Full Dump at Maximum Lift	degrees	48.5	48.5	48.5
Tipping Load				
Straight	kg (lb)	32 445 (71,529)	32 014 (70,579)	32 264 (71,130)
Articulated 43°	kg (lb)	27 191 (59,946)	26 780 (59,040)	27 012 (59,551)
Breakout Force	kN (lb-f)	409.2 (91,992)	390.1 (87,698)	415.3 (93,363)
Operating Weight	kg (lb)	50 574 (111,497)	50 844 (112,092)	50 744 (111,871)
Weight Distribution at SAE Carry				
Front	kg (lb)	25 583 (56,401)	26 088 (57,514)	25 874 (57,042)
Rear	kg (lb)	24 991 (55,096)	24 756 (54,578)	24 870 (54,829)

4.25 Meter Linkage			
Straight Rock	Heavy Duty Quarry	High Abrasion	General Purpose
Teeth & Segments	Teeth & Segments	Teeth & Segments	BOCE
6.3 (8.2)	6.4 (8.33)	6.4 (8.33)	7.0 (9.2)
5.2 (6.8)	5.3 (6.9)	5.3 (6.9)	5.88 (7.7)
6.3 (8.2)	6.4 (8.33)	6.4 (8.33)	7.0 (9.2)
3800 (12'6")	3862 (12'8")	3926 (12'11")	3695 (11'2")
8112 (26'7")	8112 (26'7")	8112 (26'7")	8111 (26'7")
4424 (14'6")	4141 (13'7")	4225 (13'10")	4203 (13'9")
4148 (13'7")	3790 (12'5")	3860 (12'8")	—
1623 (5'4")	1641 (5'5")	1674 (5'6")	1818 (6'0")
1863 (6'1")	2173 (7'2")	2145 (7'0")	—
11 941 (39'2")	12 358 (40'7")	12 223 (40'1")	12 209 (40'1")
12 283 (40'4")	12 774 (41'11")	12 686 (41'7")	—
8738 (28'8")	8795 (28'10")	8812 (28'11")	8763 (28'9")
8824 (28'11")	8871 (29'1")	8873 (29'1")	—
2904 (9'6")	2801 (9'2")	2861 (9'5")	3114 (10'3")
3144 (10'4")	3334 (10'11")	3332 (10'11")	—
3850 (12'8")	3905 (12'10")	3922 (12'10")	4121 (13'6")
4192 (13'9")	4665 (15'4")	4595 (15'1")	—
226 (8.9")	256 (10.1")	226 (8.9")	222 (8.7")
48.5	48.5	48.5	48.5
32 867 (72,459)	30 346 (66,901)	31 421 (69,271)	32 650 (71,981)
27 628 (60,909)	25 130 (55,402)	26 172 (57,699)	27 394 (60,393)
505.1 (113,551)	390.5 (87,788)	421.6 (94,779)	468.3 (105,278)
50 289 (110,868)	52 209 (115,101)	52 044 (114,737)	50 429 (111,177)
24 907 (54,910)	28 634 (63,127)	27 811 (61,313)	25 293 (55,761)
25 382 (55,958)	23 575 (51,974)	24 233 (53,425)	25 136 (55,415)

Tire Dimensions/Specifications

	Width over tires		Ground clearance		Change in vertical dimensions		Change in operating weight		Change in full turn static tipping load	
	mm	inches	mm	inches	mm	inches	kg	lb	kg	lb
35/65R33 (L-4) Michelin XLDD1	3579	140.9	445	17.5	—	—	—	—	—	—
35/65-33 42 PR (L-5) Bridgestone D-Lug	3541	139.4	544	21.4	–99	–3.9	2259	4980	1310	2888
35/65R33 (L-4) Bridgestone V-Steel N Traction VSNT	3566	140.4	483	19.0	–38	–1.5	664	1464	385	849
35/65R33 (L-5) Bridgestone V-Steel D-Lug VSDL	3566	140.4	498	19.6	–53	–2.1	1257	2772	729	1608
35/65-33 42PR (L-5) General LD 250 Belted	3487	137.3	506	19.9	–61	–2.4	1510	3328	876	1930
875/65R33 (L-4) Goodyear RL-4K Hi Stability	3487	137.3	506	19.9	–61	–2.4	552	1217	320	705
35/65R33 (L-5) Goodyear RL-5K 20 20 6S	3574	140.7	508	20.0	–64	–2.5	974	2148	565	1246
35/65-33 42PR (L-5) Goodyear NRL D/L 5A	3574	140.7	508	20.0	–64	–2.5	1646	3628	954	2104
875/65R33 (L-5) Goodyear RL-5K Hi Stability	3574	140.7	508	20.0	–64	–2.5	1486	3276	862	1900
35/65R33 (L-5) Michelin XLDD2	3579	140.9	463	18.2	–18	–0.7	648	1428	376	828
35/65R33 (L-5) Michelin XMINED2	3579	140.9	478	18.8	–33	–1.3	1404	3096	815	1796

NOTE: In certain applications (such as load-and-carry work), the loader's productive capabilities might exceed the tires tonnes-km/f (ton-mph) capabilities. Caterpillar recommends that you consult a tire supplier to evaluate all conditions before selecting a tire model. Other special tires are available on request.

ATTACHMENT B
CALCULATION SPREADSHEETS

Vertical Pressure Equations

Project # 073-81694
Date: 1/22/08
By: KFM

Project Description: Evaluate the depth of overliner required to protect geomembrane liner from stress inflicted by a Caterpillar Model 988H Wheel Loader. From the published specifications, the gross loaded weight is 110,000 lb, with 52% of the weight supported by the front axle (57,000 lb). Assume a maximum allowable vertical stress of up to 8 psi on the liner is acceptable

Add stress caused by second front wheel
Use of 3.5 feet of cushion material cover is recommended.

Boussinesq Method

Input Parameters

Point Load(lbs):	28500	28500	28500	28500	28500	28500	28500	28500	28500	28500
Distance from Load(ft):	0	0	0	0	0	0	0	0	0	0
Depth of Interest (ft):	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Calc. Values										
Vertical Stress due to Load (psf):	3401.9	2177.2	1512.0	1110.8	850.5	672.0	544.3	449.8	378.0	322.1
(psi)	23.6	15.1	10.5	7.7	5.9	4.7	3.8	3.1	2.6	2.2
Horizontal Stress due to Load (psf): (radially from load pt)	-283.5	-181.4	-126.0	-92.6	-70.9	-56.0	-45.4	-37.5	-31.5	-26.8
(psi)	-2.0	-1.3	-0.9	-0.6	-0.5	-0.4	-0.3	-0.3	-0.2	-0.2
Horizontal Stress due to Load (psf): (tangential from load pt)	-283.5	-181.4	-126.0	-92.6	-70.9	-56.0	-45.4	-37.5	-31.5	-26.8
(psi)	-2.0	-1.3	-0.9	-0.6	-0.5	-0.4	-0.3	-0.3	-0.2	-0.2
Shear Stress due to Load (psf):	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(psi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vertical Soil Stress (psf)	210.0	262.5	315.0	367.5	420.0	472.5	525.0	577.5	630.0	682.5
(psi)	1.5	1.8	2.2	2.6	2.9	3.3	3.6	4.0	4.4	4.7
Horizontal Soil Stress (psf):	105.0	131.3	157.5	183.8	210.0	236.3	262.5	288.8	315.0	341.3
(psi)	0.7	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.4
Total Major Principal Stress (psf):	3611.9	2439.7	1827.0	1478.3	1270.5	1144.5	1069.3	1027.3	1008.0	1004.6
(psi)	25.1	16.9	12.7	10.3	8.8	7.9	7.4	7.1	7.0	7.0
Total Minor Principal Stress (psf):	-178.5	-50.2	31.5	91.2	139.1	180.3	217.1	251.3	283.5	314.4
(psi)	-1.2	-0.3	0.2	0.6	1.0	1.3	1.5	1.7	2.0	2.2
P Parameter (psi)	11.9	8.3	6.5	5.4	4.9	4.6	4.5	4.4	4.5	4.6
Q Parameter (psi)	13.2	8.6	6.2	4.8	3.9	3.3	3.0	2.7	2.5	2.4

Vertical Pressure Equations

Project # 073-81694
Date: 1/22/08
By: KFM

Project Description: Evaluate the depth of overliner required to protect geomembrane liner from stress inflicted by a Caterpillar Model 988H Wheel Loader. From the published specifications, the gross loaded weight is 110,000 lb, with 52% of the weight supported by the front axle (57,000 lb). Assume a maximum allowable vertical stress of up to 8 psi on the liner is acceptable

Boussinesq Method

Stress caused by second front wheel.

Input Parameters

Point Load(lbs):	28,500	28500	28500	28500	28500	28500	28500	28500	28500	28500
Distance from Load(ft):	12	12	12	12	12	12	12	12	12	12
Depth of Interest (ft):	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5
Calc. Values										
Vertical Stress due to Load (psf):	0.4	0.8	1.3	1.9	2.7	3.6	4.6	5.6	6.8	7.9
(psi)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Horizontal Stress due to Load (psf): (radially from load pt)	1.5	5.2	8.4	11.1	13.4	15.3	16.7	17.7	18.3	18.7
(psi)	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Horizontal Stress due to Load (psf): (tangential from load pt)	10.6	9.5	8.3	7.3	6.3	5.4	4.5	3.8	3.1	2.4
(psi)	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Shear Stress due to Load (psf):	2.5	3.7	5.1	6.6	8.1	9.6	11.0	12.3	13.5	14.6
(psi)	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Vertical Soil Stress (psf)	210.0	262.5	315.0	367.5	420.0	472.5	525.0	577.5	630.0	682.5
(psi)	1.5	1.8	2.2	2.6	2.9	3.3	3.6	4.0	4.4	4.7
Horizontal Soil Stress (psf):	105.0	131.3	157.5	183.8	210.0	236.3	262.5	288.8	315.0	341.3
(psi)	0.7	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.4
Total Major Principal Stress (psf):	210.4	263.3	316.3	369.4	422.7	476.1	529.6	583.1	636.8	690.4
(psi)	1.5	1.8	2.2	2.6	2.9	3.3	3.7	4.0	4.4	4.8
Total Minor Principal Stress (psf):	106.5	136.4	165.9	194.9	223.4	251.5	279.2	306.5	333.3	359.9
(psi)	0.7	0.9	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5
P Parameter (psi)	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.1	3.4	3.6
Q Parameter (psi)	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.1