FREEPORT-MCMORAN

Freeport-McMoRan Chino Mines Company
P.O. Box 10
Bayard, NM 88023

Sherry Burt-Kested
Manager, Environmental Services
Telephone: 575-912-5927
e-mail: sburtkes@fmi.com

August 30, 2018

Certified Mail #70170660000084655009
Return Receipt Requested

David Ennis
Energy, Minerals and Natural Resources Department
Mining and Minerals Division
Mining Act Reclamation Program
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

Dear Mr. Ennis:

Re: Financial Assurance Cost Estimate for the 9 Waste Rock Stockpile
Revision Application 17-2: Closure Closeout Plan Update, Permit No. GR009RE

Freeport-McMoRan Chino Mines Company (Chino) submitted an application dated April 5, 2017 to revise Permit No. GR009RE to address design limits expansion and update the Chino closure plan to include the construction of the 9 Waste Rock Stockpile. As part of this application, Chino provided a scope of work to develop financial assurance (FA) cost estimate and indicated that a FA cost estimate will be provided to the Mining and Minerals Division (MMD) following the approval of the scope of work.

MMD in a letter dated July 23, 2018 (which Chino received on July 31, 2018) approved the 9 Waste Rock Stockpile closure plan and scope of work with the exception of some aspects of indirect/direct earthwork cost multipliers presented in Appendix A of the application. The MMD requested that Chino provide a cost estimate for reclamation of this stockpile within 30 days after the receipt of the letter. This letter provides the FA cost estimate and supporting documentation for the 9 Waste Rock Stockpile.

Chino is looking forward to participating in the cost estimate workgroup to resolve concerns on cost estimating. Please contact me at (575) 912-5927 or Ms. Rita Lloyd-Mills at (575)-912-5778 if you have additional questions concerning this submittal.

Sincerely,

Sherry Burt-Kested

Sherry Burt-Kested, Manager
Environmental Services

SBK:rlm
Enclosures
20180829-002

c: Brad Reid, NMED

TELESTO
SOLUTIONS INCORPORATED

29 August 2018

Via Electronic Mail

Mrs. Rita Lloyd-Mills
Freeport-McMoRan Chino Mines Company
99 Santa Rita Mine Road
Vanadium, New Mexico 88043

Subject: 9 Waste Rock Stockpile Closure/Closeout Cost Estimate

Dear Rita:

We appreciate once again the opportunity to serve Freeport-McMoRan Chino Mines Company (Chino). The purpose of this letter is to summarize the reclamation cost estimate (RCE) for the 9 Waste Rock Stockpile (9-WRS) and provide an overview of the cost estimating process. The overview and RCE are based on the process that we have developed over time with New Mexico Mining and Minerals Division's (MMD) and the New Mexico Environmental Department, Groundwater Bureau (NMED) as presented in Appendices A, B, and C.

The 2017 9-WRS CCP describes the facilities that are subject to reclamation in the upcoming 5 years. It also provides the cost basis and assumptions utilized in the RCE.

COST ESTIMATE SUMMARY

Table 1 summarizes the total capital and indirect costs associated with the planned reclamation as described in the 2017 9-WRS CCP. Table 2 summarizes the total estimated capital and indirect costs associated with the operations and maintenance (O+M). Chino will provide a memorandum summarizing the net present value of these costs after they are approved by MMD.

Table 1 Earthwork Capital and Indirect Cost Summary

Item	Subtotal, Direct Costs	Subtotal, Indirect Costs	Total Estimated Cost
9 Waste Rock Stockpile	$1,968,877	$442,997	$2,411,874

Table 2 Earthwork O+M Cost Summary

Item	Subtotal, Direct Costs	Subtotal, Indirect Costs	Total Estimated Cost
9 Waste Rock Stockpile	$37,661	$6,591	$44,252

Colorado Office (Corporate)
3801 Automation Way, Suite 201
Fort Collins, Colorado 80525
970-484-7704 / 970-484-7789 (FAX)

Grand Junction
751 Horizon Court, Suite 109
Grand Junction, Colorado 81506
970-697-1550

New Mexico Office
1303 Pope Street
Silver City, New Mexico 88061
575-538-5620 / 575-538-5625 (FAX)

COST ESTIMATING OVERVIEW

Appendix A

For this closure/closeout cost estimate, Appendix A briefly provides a summary of the facility's current condition, the planned reclamation, and the facility's estimated reclamation cost in current dollars. The planned reclamation activities for the 9 Waste Rock Stockpile as summarized in Appendix A are:

- Rough grading
- Dozer assist cover load
- Load cover
- Haul cover
- Place cover and grade
- Scarify and seed/revegetate
- Excavate downdrains
- Excavate bench channels
- Load riprap
- Haul riprap
- Place riprap downdrains
- Place riprap bench channels

Appendix B

Appendix B provides the information utilized to develop the earthwork cost estimate and its structure. The information presented in Appendix B is updated from the information in Appendix A of the 2017 CCP (Golder Associates, 2017) and is in the format which the MMD provides, as follows.

- **Main Text** – the main text describes the specifics of the cost estimating process along with the sub-appendices, which provide back up and support. It describes the reclamation processes utilized to complete the cost estimate
- **Appendix B.1** is a hard copy print out of the excel spreadsheets from which we develop the costs. Electronic versions are provided in Appendix C
- **Appendix B.2** provides the equations and descriptions of data used to populate the variables of the cost estimate and we divide Appendix B.2 into the following sub-appendices:
  - **Appendix B.2.1** provides the production and miscellaneous calculations used to support the earthworks cost estimate
  - **Appendix B.2.2** tabularizes the only the labor rates from the NMDOL

  - **Appendix B.2.3** contains copies of the EquipmentWatch (Penton Media, 2018) sheets from which we obtain unit equipment rates
  - **Appendix B.2.4** provides the curve fits that we use in the production sheets for dozers, and haul trucks
  - **Appendix B.2.5** contains copies of the pertinent pages from the Caterpillar Handbook
  - **Appendix B.2.6** lists referenced miscellaneous unit costs used throughout the cost estimating spreadsheets
  - **Appendix B.2.7** provides bench, channel bench, down drain, top channel, and riprap unit costs
- **Appendix B.3** provides the basis for the quantities utilized in the cost estimating process. We base the quantities upon the 9-WRS CCP (Golder Associates, 2017)
- **Appendix B.4** describes miscellaneous supporting calculations including measures utilized to prevent double counting of certain indirect costs

Overall, the cost estimating process is the typical, standard approach used in the engineering and construction industries (consistent with the RSMeans Construction Cost Estimating Handbook) (RSMeans, 2018). The earthworks cost estimate is an iterative process. We first assume the type of equipment to complete the desired construction steps. Then, we evaluate the number of equipment pieces needed (e.g., number of trucks, loaders, bulldozers) to form a "fleet." We change the number and type of equipment, recalculate the cost and compare to a base cost, which is the lowest of the previous iterations. We repeat this until the most efficient fleet is found and, once found, we utilize the unit costs associated with equipment in the fleet to estimate the total reclamation cost utilizing the spreadsheets which are included as Appendix C. Figure 1 summarizes the costing steps we use for one piece of equipment in developing our fleet.

Appendix C

Appendix C contains the electronic version of the cost estimating spreadsheets from which Appendices A and B are based. Within the spreadsheets, assumptions and other information is provided that reflects the approach described in Appendix B.

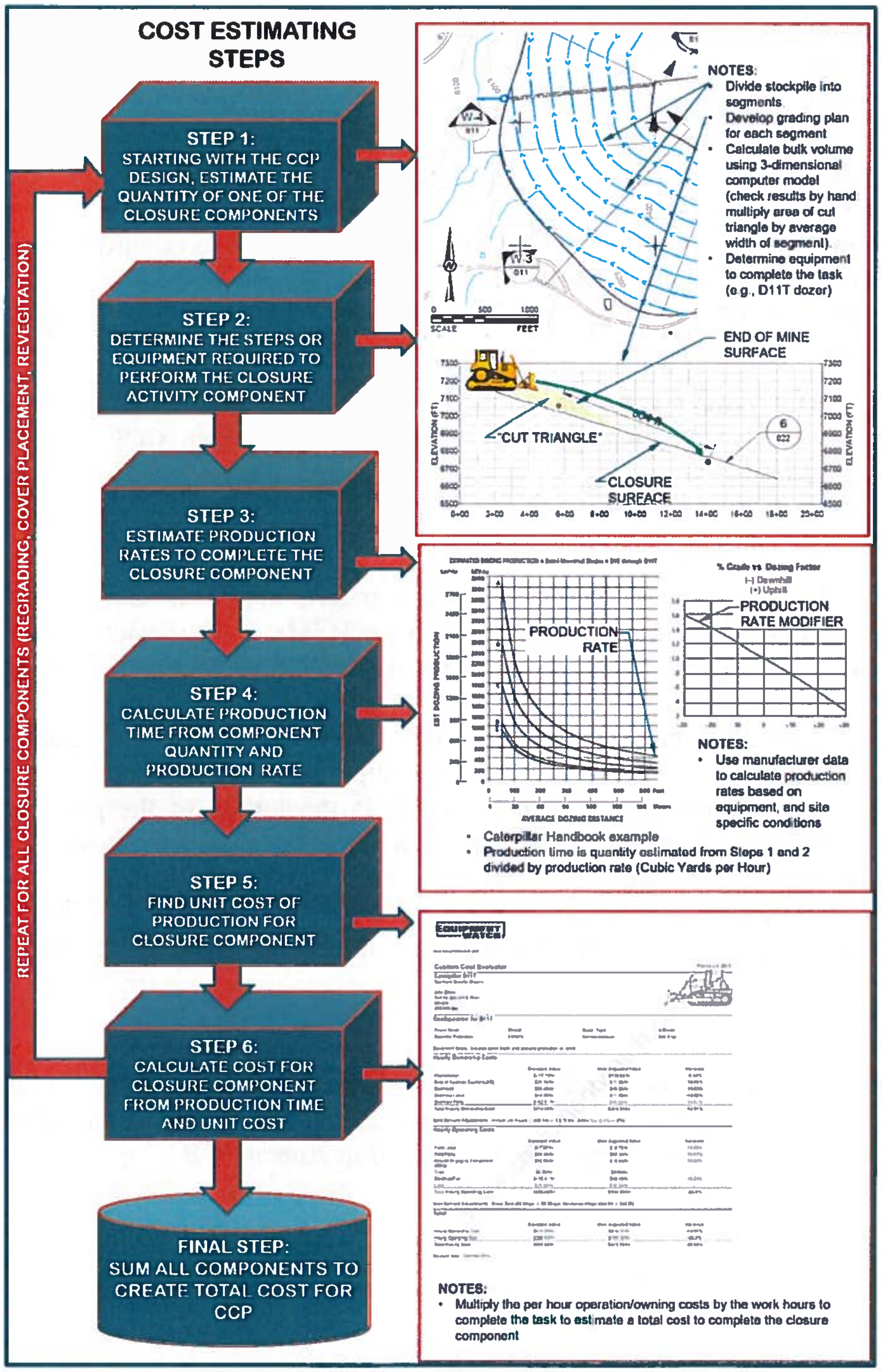


Figure 1 Earthworks Cost Estimating Process

Again, thank you for the opportunity to serve you and your team. Should you have any questions or concerns with this letter or the attached appendices, please do not hesitate to contact me.

Sincerely,
Telesto Solutions, Inc.

Walter L. Niccoli

Walter L. Niccoli, PE
Principal/Senior Engineer

WLN:flc
Enclosure
cc:

REFERENCES

Golder Associates. (2017). *9 Waste Rock Stockpile Closure/Closeout Plan.* Vanadium, New Mexico: Prepared for New Mexico Environment Department and Mining and Minerals Division. Submitted by Freeport-McMoRan Chino Mining Company.

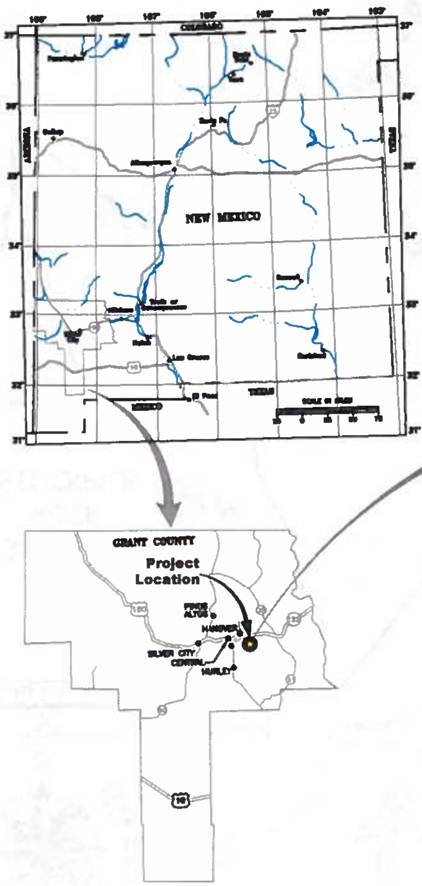
Penton Media. (2018, March 1). *EquipmentWatch Construction Estimator*. Retrieved from EquipmentWatch: https://www3.equipmentwatch.com

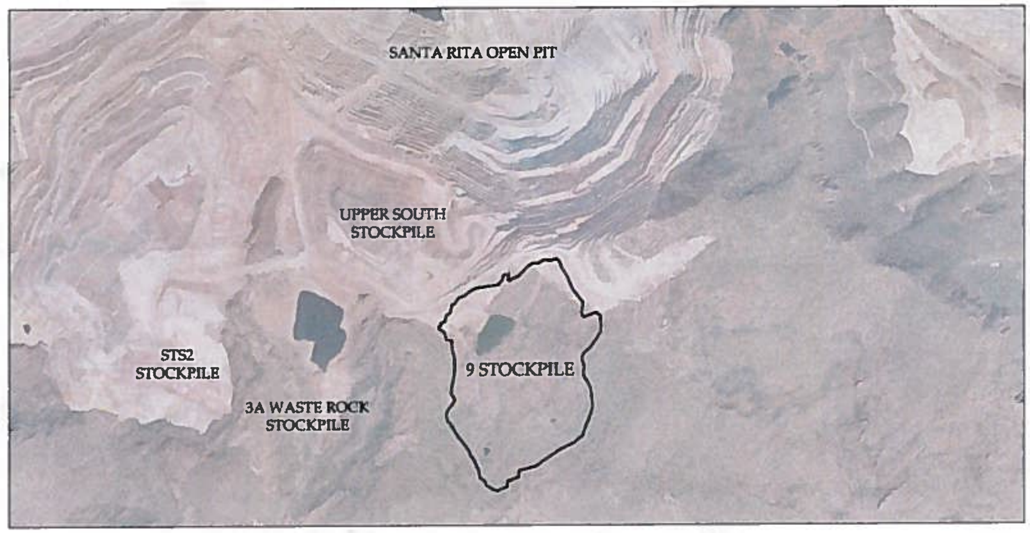
RSMeans. (2018). *Heavy Construction Cost Data. 32nd Edition.* Rockland, MA: RSMeans Construction Publishers & Consultants.

DRAWINGS

PROPOSED RECLAMATION PLAN FOR THE 9 STOCKPILE

ISSUED FOR FINANCIAL ASSURANCE RECLAMATION COST ESTIMATE



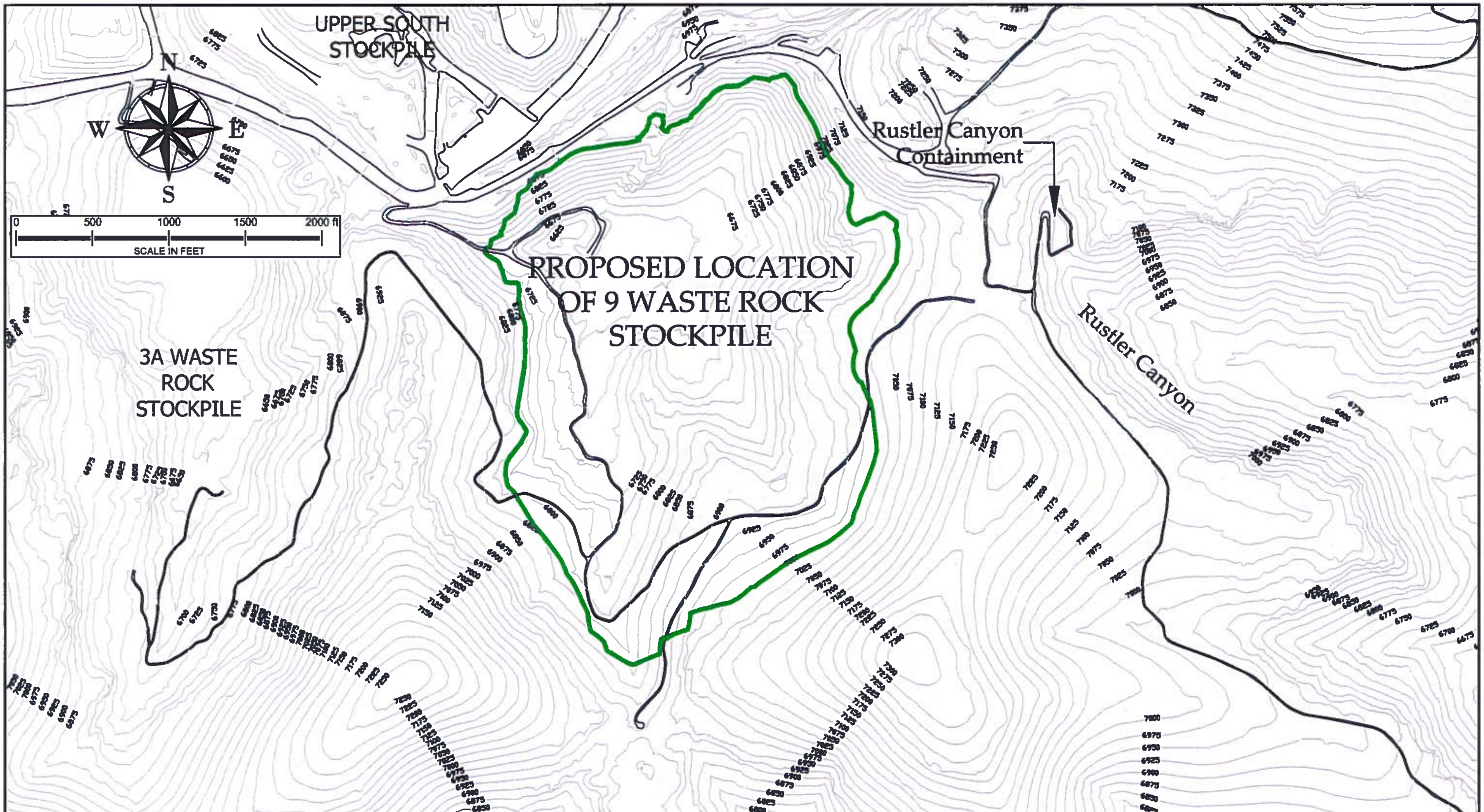


Sheet List Table	
Sheet Number	Sheet Title
1	COVER SHEET
2	EXISTING TOPOGRAPHY
3	CONCEPTUAL PRE-RECLAMATION STOCKPILE
4	CONCEPTUAL RECLAIMED STOCKPILE
5	CROSS SECTIONS
6	DETAILS
7	CONCEPTUAL HAUL PATHS

FREEPORT-McMoRAN
CHINO MINES COMPANY

Sheet: 1 Cover Sheet

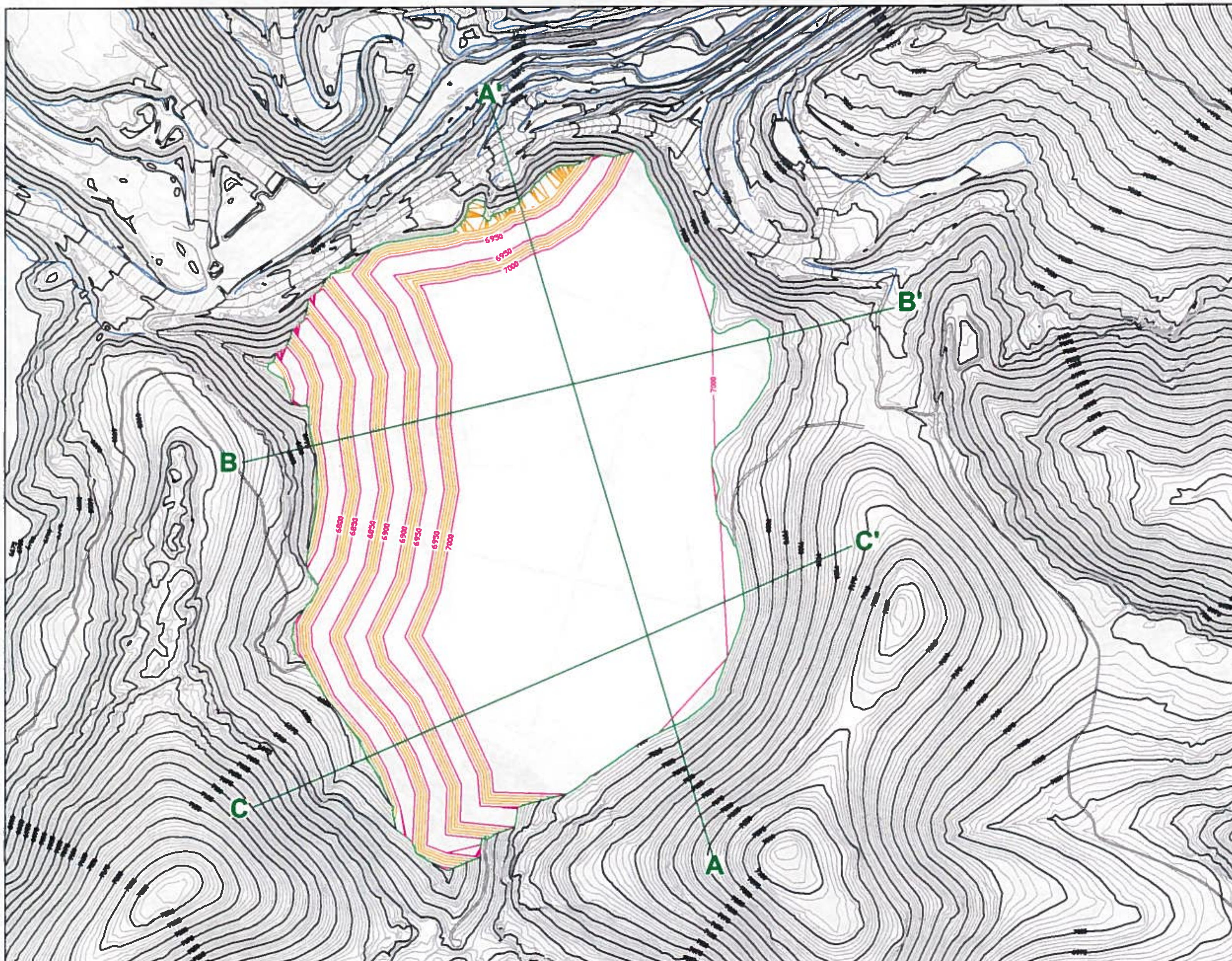
Scale: As Noted | Date: 10/19/2016 | Notes:
Dept. Environmental Services
Drawn By: | Checked By:



FREEPORT-McMoRAN
CHINO MINES COMPANY

Sheet: 2 Existing Topography

Scale: As Noted	Date: 11/17/2016	Notes: Base Map: 2014 Topography
Dept. Environmental Services		
Drawn By:	Checked By:	



Legend

7000	Major Contours (25ft)
	Minor Contours (5ft)
6900	Operational Major Contours (50ft)
	Operational Minor Contours (10ft)
	Stockpile Boundary
A — A'	Cross-Section Lines
	Roads

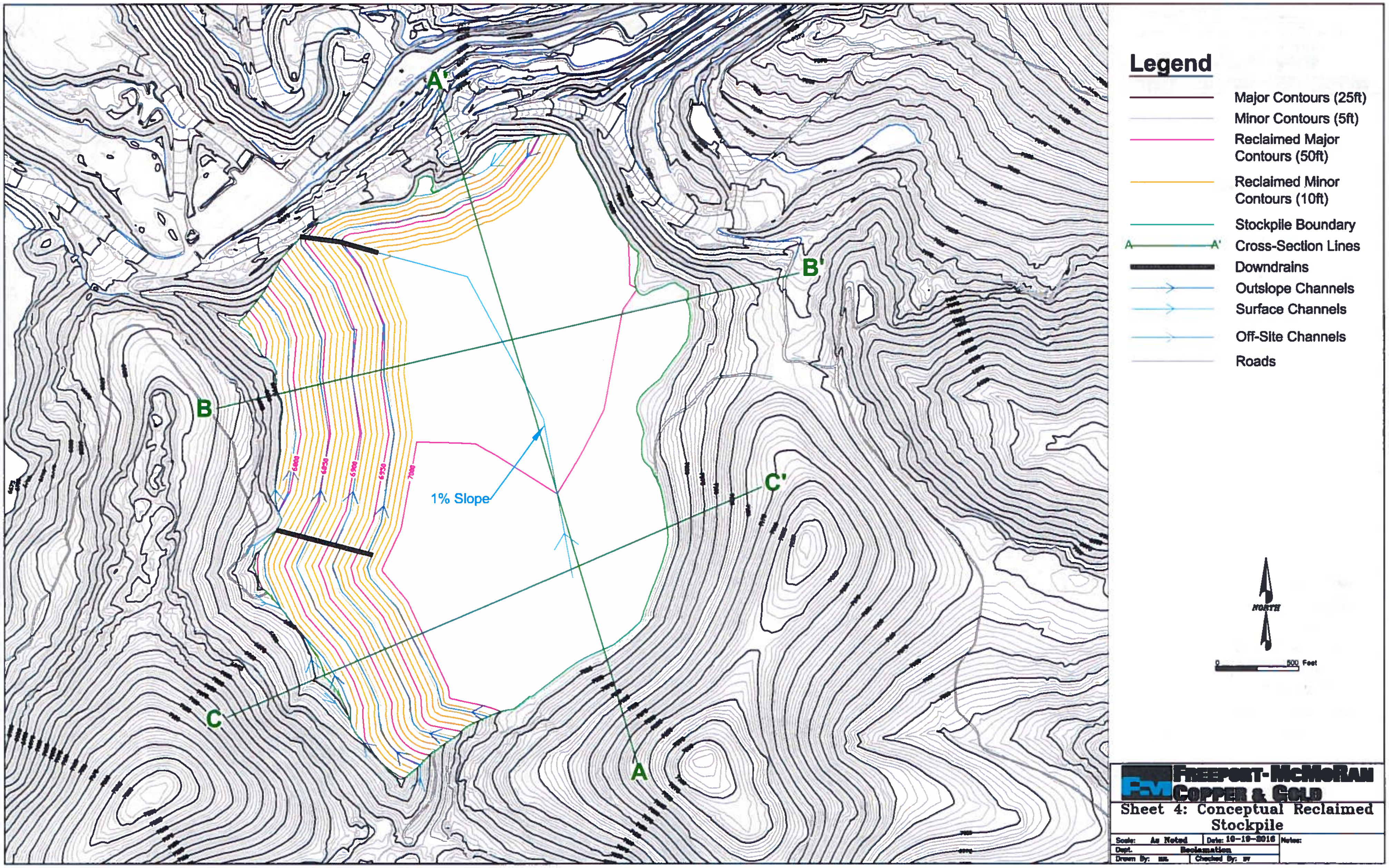
NORTH

0 500 Feet

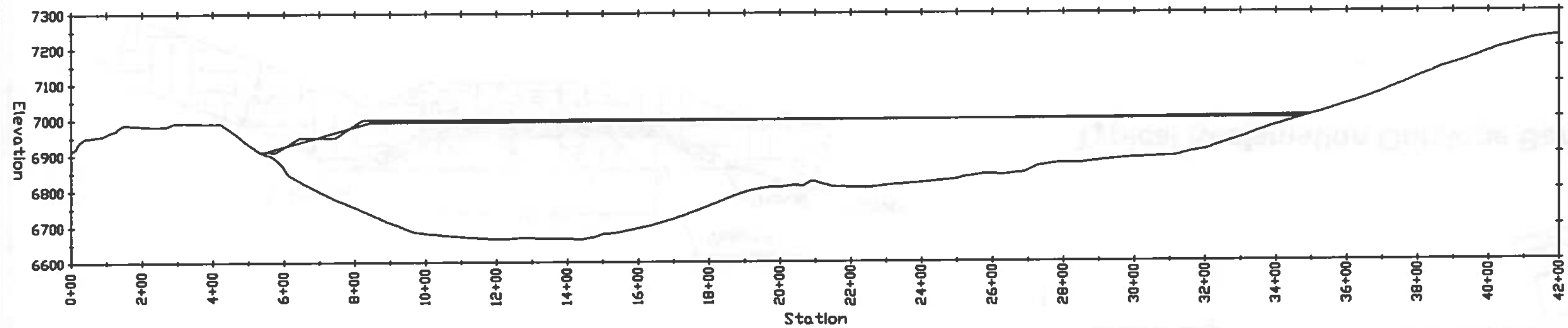
FREEPORT-McMoRAN COPPER & GOLD

Sheet 3: Conceptual Pre-Reclamation Stockpile

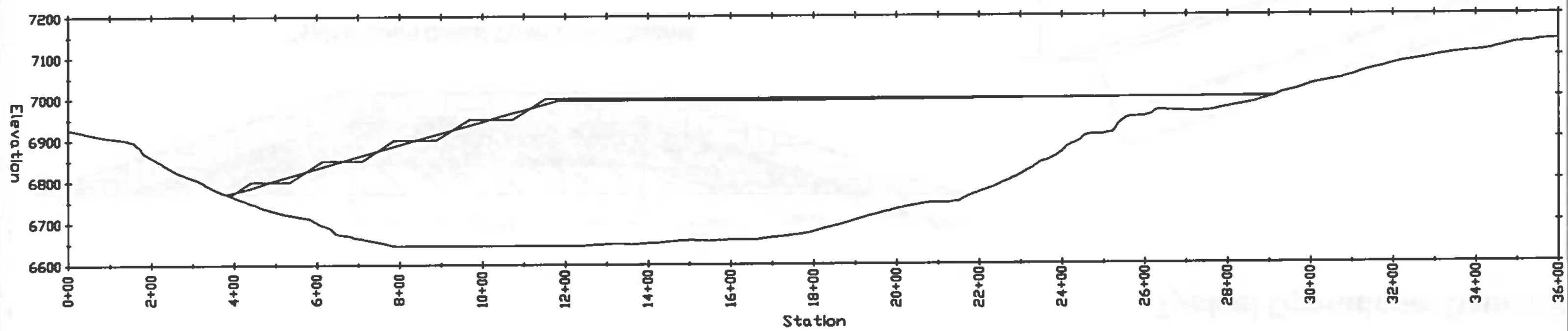
Scale: As Noted	Date: 10-19-2016	Notes:
Dept. Reclamation		
Drawn By: MK	Checked By: MK	


Legend
Major Contours (25ft)
Minor Contours (5ft)
Reclaimed Major Contours (50ft)
Reclaimed Minor Contours (10ft)
Stockpile Boundary
Cross-Section Lines
Downdrains
Outslope Channels
Surface Channels
Off-Site Channels
Roads
A
A'
B
B'
C
C'
1% Slope
6800
6850
6900
6950
7000
NORTH
0
500 Feet
FREEPORT-McMoRAN COPPER & GOLD
Sheet 4: Conceptual Reclaimed Stockpile
Scale: As Noted
Date: 10-19-2016
Notes:
Dept. Reclamation

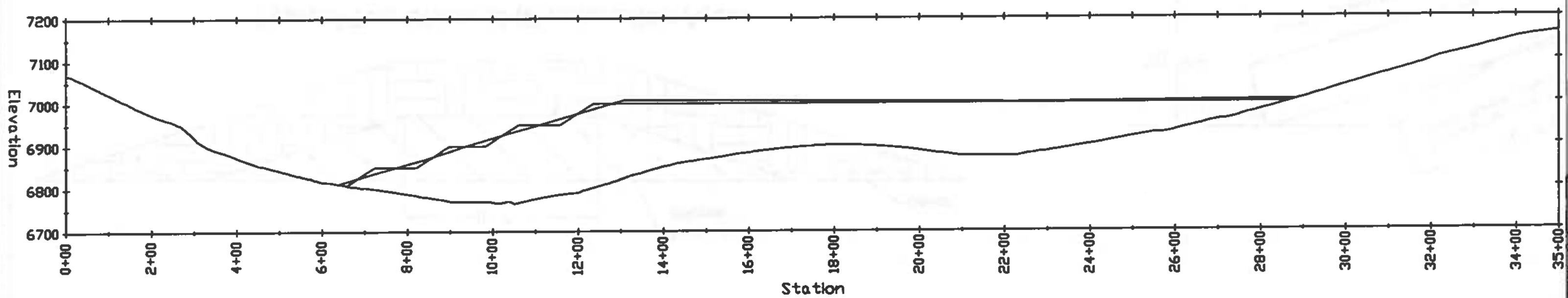
Profile View A-A' (Stations in 200ft)



Profile View B-B' (Stations in 200ft)



Profile View C-C' (Stations in 200ft)



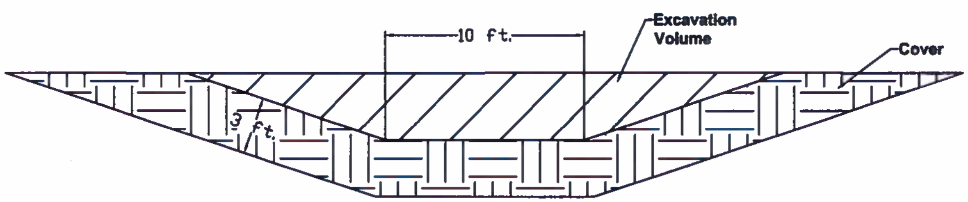
Legend

- Existing Topo
- Operational Stockpile
- Reclaimed Stockpile

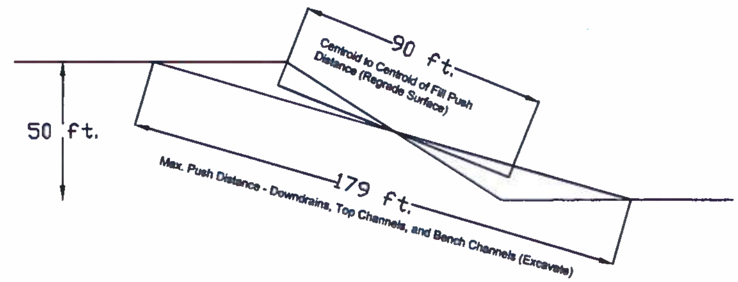
FREEPORT-McMoRAN COPPER & GOLD

Sheet 5: Cross Sections

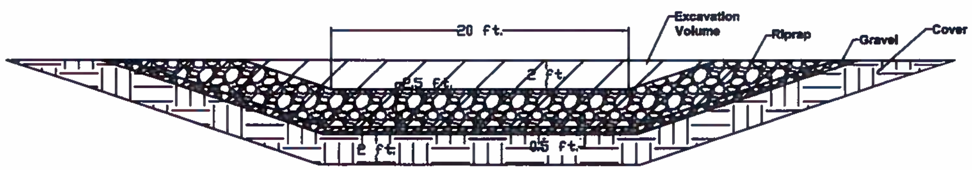
Scale: As Noted	Date: 10-19-2016	Notes:
Dept. Reclamation		
Drawn By:	Checked By:	



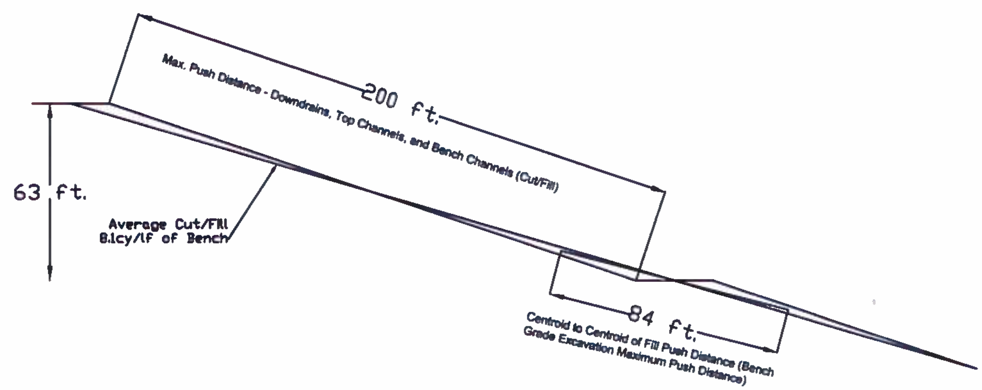
Typical Top Channel (Reclamation Area)

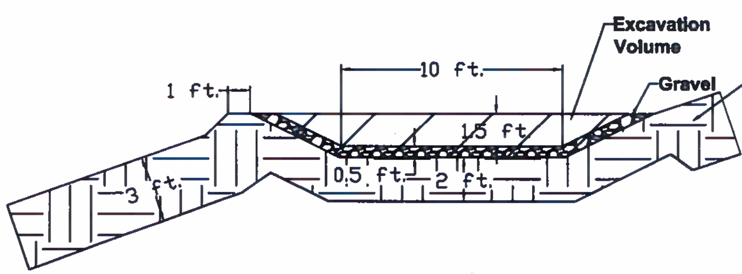


Typical Operational Bench Regrade for 3.5H:1V



Typical Down Chute/ Down Drain Channel





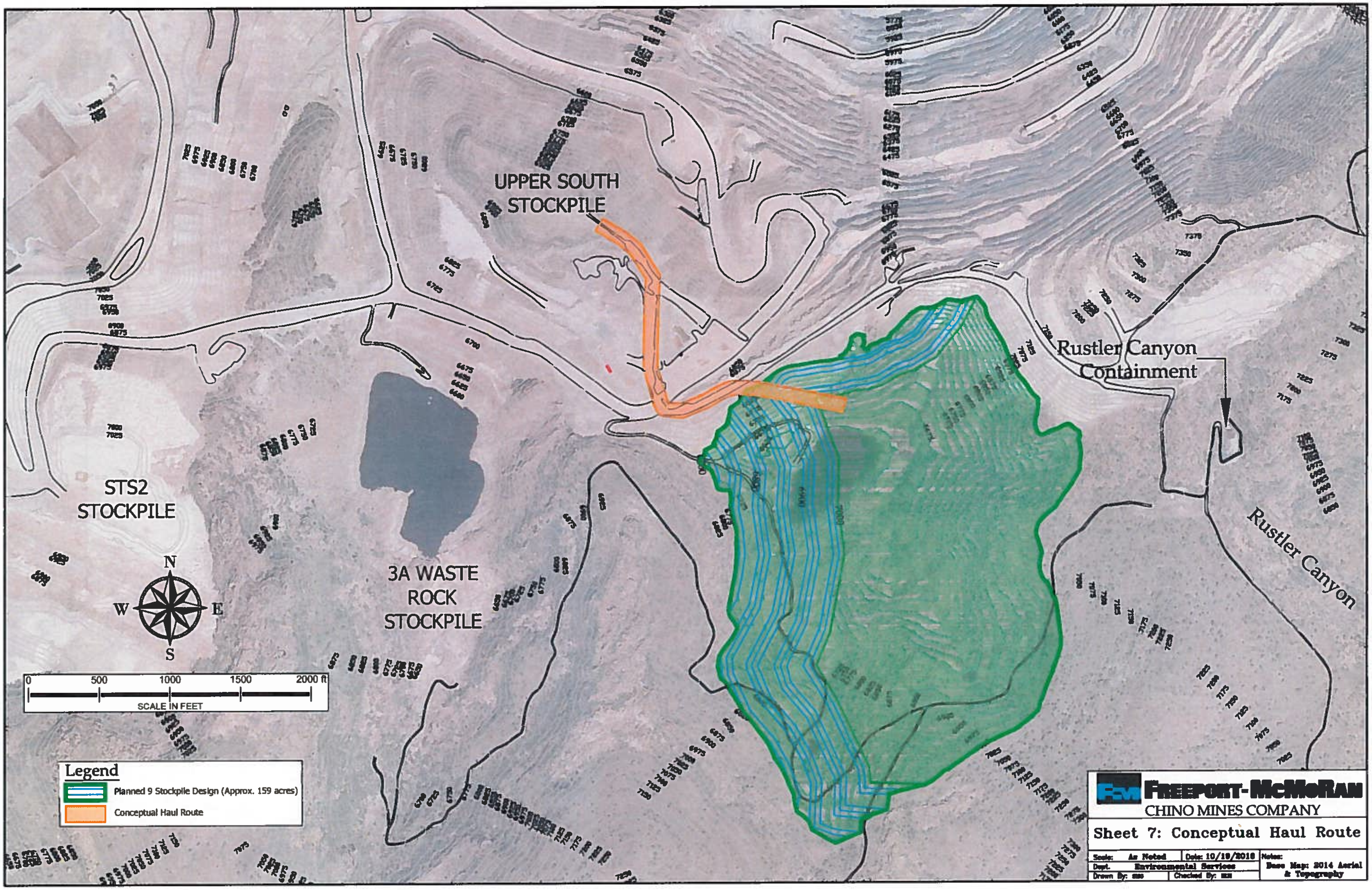
Outslope Terrace Channel

Typical Reclamation Outslope Bench for 3.5H:1V

FREEPORT-McMoRAN COPPER & GOLD

Sheet 6: Details

Scale: As Noted	Date: 10-19-2016	Notes: NTS
Dept. Reclamation		
Drawn By: [illegible]	Checked By: [illegible]	



UPPER SOUTH STOCKPILE
Rustler Canyon Containment
Rustler Canyon
STS2 STOCKPILE
3A WASTE ROCK STOCKPILE
N
W
E
S
0
500
1000
1500
2000 ft
SCALE IN FEET
Legend
Planned 9 Stockpile Design (Approx. 159 acres)
Conceptual Haul Route
FREEPORT-McMoRAN
CHINO MINES COMPANY
Sheet 7: Conceptual Haul Route
Scale: As Noted
Date: 10/19/2018
Dept. Environmental Services
Notes: Base Map: 2014 Aerial & Topography

APPENDIX A

FACILITY CHARACTERISTIC FORMS

List of Tables

NOTE:

1. The costs in these tables include only capital earthwork costs. Operations and maintenance (i.e., revegetation) costs can be found in Appendix B.

2017 9 Waste Rock Stockpile Closure/Closeout Plan
Facility Characteristics Form

9 Waste Rock Stockpile

Function	Stockpile for waste rock removed during mining of Santa Rita Open Pit.
Construction Method	End dumped.
Physical Characteristics	Coarse grained. High saturated hydraulic conductivity.
Existing Engineering Measures	Stormwater management.

Matrix of Costs
Capital Cost/Facility

Reclaimed Area (acres)	161
Item	**Capital Cost**
Cover Material (Load, haul, spread)	$1,364,696
Regrade	$184,429
Seed & Mulch	$144,554
Other[1]	$275,199
Capital Cost Totals	**$2,006,538**
Capital Cost/Acre	**$12,229**

[1] "Other" includes channels and downdrains.

Appendix B
Earthwork Cost Estimate
Summary Report

Prepared for

Freeport-McMoRan Inc.
Chino Mines Company
99 Santa Rita Mine Road
Vanadium, New Mexico 88043

Prepared by

Telesto Solutions, Inc.
3801 Automation Way, Suite 201
Fort Collins, CO 80525

August 2018

TELESTO
SOLUTIONS • INCORPORATED

Signature Page

Appendix B
Earthwork Cost Estimate
Summary Report

August 2018

Report Authors and Contributors

Telesto Solutions, Inc.

Fred Charles, P.E.

Walt Niccoli P.E. – Report Review

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LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Purpose and Summary

As part of the 2017 9 Waste Rock Stockpile (WRS) Closure/Closeout Plan (CCP) (Golder, 2017), Telesto Solutions Inc. (Telesto) prepared an earthwork reclamation cost estimate (RCE) for financial assurance for Freeport-McMoRan Chino Mines Company (Chino). Chino provided the earthwork volumes to Telesto for verification and use in the RCE. The earthwork RCE is based on a template originally created by the New Mexico Energy, Minerals and Natural Resources Department, Mining and Minerals Division (MMD, 1996). This earthwork RCE includes reclamation earthwork and subsequent operations and maintenance (O&M) costs. The earthwork RCE is based on the configuration of the 9 WRS as described in the 9 Waste Rock Stockpile CCP (Golder, 2017). Likewise, the O&M cost estimate is based on revegetation maintenance continuing for 12 years starting the year reclamation is completed (Golder, 2017).

1.2 Reclamation Overview

A summary of the 9 WRS facility is provided in Table B-1. The 9 WRS is the only facility included in this earthwork reclamation and O&M cost estimate.

2.0 COST ESTIMATE

The total current dollar cost for earthwork reclamation is estimated to be **$2,418,465.** A summary of the cost estimate is provided in Table B-2. The costs presented in this estimate are current (2018) dollar costs. Chino will provide a net present value calculation in a separate memorandum. Assumptions used throughout the cost estimate include:

- **Dozer Push Distances:** Dozer push distances represent the distance from the centroid of the cut block to the centroid of the fill block.

- **Cover Placement**: Trucks and loaders with dozer assist perform all cover loading and distribution. The economic optimum number of trucks per loader was used for each haul route.
- **Haul Distances**: Haul distances are calculated along a preferred route and assumed to originate at the approximate centroid of the source and terminate at the approximate centroid of the reclamation area. A maximum of three segments is used for each haul route.
- **Borrow Areas**: The cover source is the Upper South Stockpile. Reclamation of the Upper South Stockpile is not included in this cost estimate but is covered under the main Chino CCP.
- **Dust Suppression and Site Maintenance:** A full time water truck and a motor grader are included as part of the fleet during reclamation (Table B-3). The water truck and grader task time is equal to loader task time.
- **Labor Rates:** All labor rates were developed based on the New Mexico Department of Labor (NMDOL) Type H (Heavy Engineering) labor rates effective January 1, 2018 (NMDOL, 2018). These rates include the base, fringe benefit, and apprenticeship contribution rates (Table B-3).
- **Equipment Rates:** Table B-3 summarizes the earth-moving equipment used in the estimate, which would commonly be available to a contractor. The equipment unit operating costs were taken from EquipmentWatch Custom Cost Evaluator (Penton Media, Inc., 2018) and can be found in Appendix B.2.3.
- **Equipment Production Factors:** Table B-4 summarizes equipment production factors from Caterpillar (2014, 2017) for each type of equipment presented in Table B-3. Productivity curves were also developed from Caterpillar (2014, 2017) and are described in Appendix B.2.4 and B.2.5.
- **Fuel Costs**: Table B-5 lists the off-road diesel fuel cost based on a quote obtained on March 12, 2018 from Griffin Propane for delivery of dyed ultra-low sulfur diesel to the Chino Mine area.
- **Capital Indirect Costs**: Total indirect costs of 22.5% were applied to the capital direct costs per MMD (1996) and OSM (2000) guidance. The indirect costs are comprised of: Mobilization and Demobilization (1.0%), Contingencies (2.0%), Engineering Redesign Fee (2.5%), Contractor Profit and Overhead (15.0%), and Project Management Fee (2.0%). Indirect cost percentages are identical to the percentages presented to MMD and the New Mexico Environment Department (NMED) in meetings with Tyrone on September 20, 2012, and on November 2, 2012.
- **Operations and Maintenance Indirect Costs**: The 9 Reservoir currently has Operations and Maintenance (O&M) costs for Earthwork. No additional Earthwork O&M is included for the 9 WRS. Total indirect costs of 17.5% were applied for long term operations and maintenance per MMD (1996) and OSM (2000) guidance and comprise the same values and factors as the capital indirect costs with exception of Contractor Profit and Overhead. Contractor Profit and Overhead for long term operations and maintenance is 10.0%, to account for the long term contract and repetitive annual work. Indirect cost percentages are identical to the

percentages presented to MMD and the NMED in meetings with Tyrone on September 20, 2012, and on November 2, 2012.

- **Revegetation Unit Costs**: The revegetation unit cost (Table B-5) was based on a quote obtained in April 2018 from Rocky Mountain Reclamation of Laramie, WY. It includes scarifying, discing, rangeland drill seeding, mulching, crimping, and daily per diem (Appendix B.2.6).
- **Revegetation and Scarification:** Scarifying of the final surface is performed at the same time as the revegetation and is included in the revegetation quote.
- **Riprap**: The riprap unit cost was developed based on experience gained producing riprap at the McCain Springs Quarry.
- **Miscellaneous Unit Costs**: Other miscellaneous unit costs shown in Table B-5 were taken from several sources Supporting documentation is included in Appendix B.2.6.

Table B-1 Facility Overview

Feature	Notes
9 Waste Rock Stockpile	The operational stockpile area is 159 acres. Once regraded, cover placement and revegetation will equal 161 acres. Reclamation will be completed in 2 years, with 12 years of O&M (revegetation maintenance) starting the year reclamation is completed.

Table B-2 Earthworks Cost Estimate Summary

Item	Subtotal, Direct Costs	Subtotal, Indirect Costs	Total Estimated Cost
Capital Item		22.5%	
Waste Rock Stockpiles			
9 Waste Rock Stockpile	$1,968,877	$442,997	$2,411,874
O&M		17.5%	
O&M 9 Waste Rock Stockpile	$37,661	$6,591	$44,252
Total Earthwork with O&M	$2,006,538	$449,588	$2,418,465

Table B-3 Labor and Equipment Unit Costs

Parameter	Value	Comment
Labor Rates		
Dozer Operator	$26.29/hr	NMDOL Rate
Haul Truck Operator	$23.84/hr	NMDOL Rate
Truck Driver	$23.84/hr	NMDOL Rate
Loader Operator	$26.56/hr	NMDOL Rate
Motor Grader	$26.29/hr	NMDOL Rate
Equipment for Earthwork[1]		
Caterpillar D11T	$420.39	Standard Crawler Dozer
Caterpillar 785 F	$220.09	Averaged Komatsu HD 1500 and Caterpillar 797
Caterpillar 992K	$300.46	4-WD Articulated Loader
Caterpillar 16M	$136.00	Motor Grader
Off-Highway Water Tanker Truck	$88.11	6,000 Gallon

Table B-4 Earthwork Equipment Production Factors

Parameter	Value	Comment/Reference
Swell Factor Stockpiles and Tailings[2]	0% Pushdown,	No virgin materials are being regraded as part of closure. Thus a swell factor is not applied when regrading material.
	8% load & haul cover	Cover material volumes are calculated based on the reclaimed area and the cover depth. This factor accounts for swell when loading trucks.
Grading (D11T CD, D11T, D9T, 16M, D6T)		
Operator Factor[3]	1.0 Stockpile coarse grading	Due to large job size assume excellent operator (CPH[4] 44, 19-55, excellent)
	0.75 Cover & channel fine grading	(CPH 44, 19-55, average)
Material Factor	1 – Stockpile 1.2 – Cover	CPH 44, 19-55, Loose stockpile
Work Hour	50 min	(CPH 44, 19-55)
Grade Factor – Tops	1.0	(CPH 44, 19-55) 1-5% Slope
Grade Factor - Outslopes[5]	1.6 – 3H:1V Slopes	(CPH 44, 19-55) 1.6 – 3H:1V Slopes
Soil Weight	3,300 lb/cy Stockpile 3,000 lb/cy Cover	Standard Values
Production Method/ Blade Factor	1.2 – Slot 1 – Channels/Down drains/Benches	(CPH 44, 19-55, slot dozing) No correction applied for channels/ downdrains/benches

[1] Equipment Unit Rate Notes: Equipment unit rates from EquipmentWatch Custom Cost Evaluator 2018, first Qtr, adjusted Sales Tax = 0%, Fuel = $2.14/gal (after subtracting indirect costs), mechanic wage $26.39/hr. The Annual Use Hours are adjusted in Equipment Watch to eliminate the EquipmentWatch 50-minute work hour as it is accounted for in the individual Appendix B worksheets.

[2] The swell and operator factors used are consistent with factors presented to MMD and NMED in meetings with Tyrone on June 11, 2012, November 2, 2012, and a letter to MMD and NMED from Tyrone dated September 5, 2012.

[3] Same as footnote 2.

[4] CPH = Caterpillar Performance Handbook Edition 35, 44 (Caterpillar, Inc. 2007, 2014)

[5] Same as footnote 2.

Parameter	Value	Comment/Reference
Effective Blade Width (feet)	22 (D11T Universal Blade) 14.25 (D9T Semi Universal Blade) 16 (16M) 17.5 (D6T XL)	(CPH 44, 19-49) (CPH 44, 19-47) (CPH 44, 11-17) (CPH 44, 19-43)
Speed (miles/hr)	2.5 mph D11T and 16M 1.0 mph D9T and D6T	(CPH 44)
Visibility Factor	1.0	(CPH 44, 19-55) Clear
Elevation Factor	1.0	(CPH 44, 30-5)
Direct Drive Transmission	1.0	-
Loader (992K)		
Net Bucket Capacity (cy)	16.0	(CPH 44, 23-288, Standard, 3000 lb/yd3)
Loader Cycle Time (min)	0.65	(CPH 44, 23-223) Avg 0.6-0.7
Bucket Fill Factor	0.875	(CPH 44, 30-1) Avg 0.85-0.90 Loose Material 1" and over
Work Hour (min/hr)	50	(CPH 44, 19-55)
Trucks (CAT 785F)[6]		
Struck Capacity (cy)	71.0	Equipment Watch Specification Sheet
Heaped Capacity(cy)	102.0	(CPH 41, 9-6)
Rolling Resistance (%)	2.5%	(CPH 44, 30-1) Radial tires, dirt road maintained fairly regularly, watered, flexing slightly
Truck Exchange Time (min)	0.7	(CPH 44, 10-20) Avg. 0.6-0.8
Dump/Maneuver Time (min)	1.1	(CPH 44, 10-20) Avg 1.0-1.2
Work Hour (min/hr)	50	(CPH 44, 19-55)

[6] Equipment Watch did not have recent information for Caterpillar 785F performance. The Komatsu HD1500-5 has the same performance specifications as the Caterpillar 785F. Thus, the Equipment Watch costs for the Komatsu HD1500-5 were used as an equivalent for the Caterpillar 785F.

Table B-5 Miscellaneous Unit Costs

Activity	Base Unit Cost $/unit	Units	Scaled Cost
Fuel	$2.24	gal	Griffin Propane Quote (March 12, 2018). ($2.75/gal with indirect costs, $2.24/gal w/o indirect costs)
Revegetation	$896.73	acre	Rocky Mountain Reclamation Quote (April 2018), ($1,099/acre with indirect costs, $896,73/acre w/o indirect costs)
Bench Grading – 3.5H:1V	$2.53	ft	Finish grade channel benches using D11T and D9T SU. Three passes per bench, 1 MPH operating speed. Soil weight 3,300 lb/cy. Grading benches 15 ft. wide, 8.1 cy cut-to-fill/ft. of bench, 84 foot push distance.
Downdrain Length – 3.5H:1V (Reclaimed Area)	$10.73	ft	Excavate and waste 6.5 cy/lf material on slopes with D11T, 179-foot downslope excavation, 200-foot lateral waste push. Finish grade 2.6 cy/lf with D6T XL SU, 179-foot typical push distance.
Bench Channels – 3.5H:1V	$1.41	feet	Excavate and waste 0.9 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 0.3 cy/lf with D6T XL SU, 179-foot typical push distance.
Top Channels (Reclaimed Area)	$4.40	feet	Excavate and waste 2.7 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 1.1 cy/lf with D6T XL SU, 179-foot typical push distance.
Top Channels (Off-Site Area)	$4.40	feet	Excavate and waste 2.7 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 1.1 cy/lf with D6T XL SU, 179-foot typical push distance.
Bench Channel Filter, Haul	$2.98	cy	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
Downdrain Filter, Haul	$2.98	cy	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
Downdrain Riprap, Haul	$2.98	cy	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
Bench Channel Filter, Backfill	$0.80	cy	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
Downdrain Filter Backfill	$0.80	cy	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
Downdrain Riprap Backfill	$0.80	cy	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
Riprap and Filter production	$14.54	cy	The riprap unit cost was developed based on experience gained producing riprap at the McCain Springs Quarry.

3.0 9 WASTE ROCK STOCKPILE

The proposed 9 WRS will cover approximately 159 acres and will be constructed with waste rock mined from the Santa Rita Open Pit. The stockpile will be constructed by end dumping in lifts approximately 50 feet high. The outslope of the stockpile will be built at angle of repose with between 80- to 100-foot-wide benches on each lift, which will result in an overall slope of approximately 3.5H:1V. This operational outslope design will facilitate reclamation at closure, because it allows attainment of the 3H:1V interbench slopes with minimal regrading (Golder, 2017). The top surface will be nearly level, starting with a 1% grade before reclamation and graded at closure to keep the 1% minimum slope requirement.

Cost calculations are located in the Sheets 1 through 8, in Appendix B.1 in the spreadsheet entitled: 20180829_9Stockpile_CostEst.xlsx. The main activities involved in closing the 9 WRS include:

- Regrading top surfaces and outslope benches
- Hauling and grading cover material
- Completing surface water channels and benches to collect and convey storm water from the stockpile surfaces
- Scarifying and revegetating covered areas

Assumptions for this reclamation cost estimate include (Golder, 2017):

- **Regrading**: 200-foot maximum interbench slope length, maximum 3H:1V interbench slopes, 1% minimum top surface slope, 1% minimum slope for other flat areas.
- **Outslope Channels and Benches:** 15-foot bench width, 1% to 5% crossbench slope, <5.0% longitudinal bench slope; channel 6 inches of gravel underlain by 2 feet of cover.
- **Channels:** maximum 2,500 feet in length, maximum 2% longitudinal slope, 3 feet of cover.
- **Down drains**: 2.5 feet of riprap over 6 inches of gravel bedding underlain by 2 feet of cover material.
- **Cover:** 36-inch cover thickness on top surface and outslopes.

4.0 OPERATIONS AND MAINTENANCE

Operations and maintenance estimated costs relate to revegetation maintenance of the reclaimed 9 WRS. Cost calculations are located in 20180829_9Stockpile_CostEst.xlsx, O&M Sheet 15-18 in Appendix B.1. Operations and maintenance costs are assumed to diminish with time.

Revegetation Maintenance (O&M Sheet 19):

- Reclamation Years 0–11. Based on observations of previously reclaimed areas, the annual vegetation failure is conservatively estimated to be 2% failure every year for a total of 12 years, starting the year reclamation is completed.

5.0 REFERENCES

Caterpillar, Inc. 2014. Caterpillar Performance Handbook, Edition 44. Caterpillar Inc. Peoria, Illinois. January 2014.

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New Mexico Energy and Natural Resources Department, Mining and Minerals Division (MMD). 1996. Closeout Plan Guidelines for Existing Mines, Natural Resources Department. April 30, 1996.

NMDOL. 2018. Prevailing Wage Poster H 2018. Retrieved March 30, 2018, from New Mexico Dept. of Labor:https://www.dws.state.nm.us/Portals/0/DM/Labor Relations/Prevailing_Wage_Poster_H_2018.pdf

OSM. 2000. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement Handbook for Calculation of Reclamation Bond Amounts. April 5, 2000.

Penton Media, Inc. 2018. EquipmentWatch Custom Cost Evaluator 1st Quarter.

R.S. Means. 2018. Heavy Construction Cost Data. 32nd Annual Edition. R.S. Means Company, Inc.

APPENDIX B.1
COST CALCULATIONS

Earthworks Unit Rates

9 Waste Rock Stockpile Reclamation Cost Estimates

EOY 2023

EARTHWORK EQUIPMENT

Equipment Description		Fuel Consumption (gal/hr)	Fuel Cost ($/hr)	Owning and Operating Cost (w/out fuel) ($/hr)	Fuel-Adjusted Own/Op Cost ($/hr)	Reference
HD-1500 5 Truck		28.12	$ 63.13	$ 156.96	$ 220.09	1
Cat 785F Truck		28.12	$ 63.13	$ 156.96	$ 220.09	1
Cat 992K Loader		25.63	$ 57.54	$ 242.92	$ 300.46	1
Cat D11T		29.75	$ 66.79	$ 353.60	$ 420.39	1
Cat D9T		14.35	$ 32.21	$ 148.52	$ 180.73	1
Cat D6T XL		7.80	$ 17.51	$ 74.40	$ 91.91	1
Cat 16M	Motor Grader	9.51	$ 21.34	$ 114.66	$ 136.00	1
Cat 14M	Motor Grader	8.29	$ 18.61	$ 81.82	$ 100.43	1
Off-Hwy Water Tanker Truck,6,000-gal.		11.25	$ 25.26	$ 62.85	$ 88.11	1
2 Deck Screening Plant (5X16, 48X60)		4.85	$ 10.89	$ 36.13	$ 47.02	1
3 Deck Screening Plant (5X16, 48X60)		4.84	$ 10.87	$ 37.89	$ 48.76	1
CAT 769D Truck		9.74	$ 21.87	$ 91.00	$ 112.87	1
CAT 988H Loader		15.20	$ 34.12	$ 124.17	$ 158.29	1
CAT 980H Loader		10.08	$ 22.63	$ 69.79	$ 92.42	1
CAT 966H Loader		8.38	$ 18.82	$ 54.05	$ 72.87	1

O&M EQUIPMENT

Equipment Description	Fuel Consumption (gal/hr)	Fuel Cost ($/hr)	Owning and Operating Cost (w/out fuel) ($/hr)	Fuel-Adjusted Own/Op Cost ($/hr)	Reference

FUEL

Earthwork Oil Broker Quote	$ 2.24	per gallon	2

EARTHWORK AND O&M LABOR

Labor Description		NMDOL Type A Operator Group	NMDOL Type A Operator Classification	Total 2018 Rate ($/hr)	
Cat 785F Truck		Truck Driver III	N/A	$ 23.84	3
Cat 992K Loader		Equipment Operator VI	Loader (over 10 cy)	$ 26.56	3
Cat D11T Bulldozer		Equipment Operator IV	Bulldozer (mult. Units)	$ 26.29	3
Cat D9T		Equipment Operator IV	Bulldozer (mult. Units)	$ 26.29	3
Cat D6T XL		Equipment Operator IV	Bulldozer (mult. Units)	$ 26.29	3
Cat 16M	Motor Grader	Equipment Operator IV	Motor Grader	$ 26.29	3
Cat 14M	Motor Grader	Equipment Operator IV	Motor Grader	$ 26.29	3
Off-Hwy Water Tanker Truck, 6,000-gal.		Truck Driver III	N/A	$ 23.84	3
CAT 769D Truck		Truck Driver III	N/A	$ 23.84	3
CAT 988H Loader		Equipment Operator VI	Loader (over 10 cy)	$ 26.56	3
CAT 980H Loader		Equipment Operator VI	Loader (over 10 cy)	$ 26.56	3
CAT 966H Loader		Equipment Operator VI	Loader (over 10 cy)	$ 26.56	3
Foreman		Laborer II	N/A	$ 23.48	3
Laborer		Laborer I	N/A	$ 22.73	3
Mechanic		Equipment Operator V	N/A	$ 26.39	3

Rocky Mountain Reclamation Quote April, 2018 (before taxes) $1,099 /acre

References
1. Equipment unit rates from EquipmentWatch Custom Cost Evaluator March 2018 (http://www.equipmentwatch.com). See attachments for rate development.
2. Griffin Propane March 12, 2018; Chino receives an all-inclusive quote (direct and indirect costs) for the delivery of fuel to the Chino Mine area (per MMD's requirements).
3. Labor rates based on NM Department of Labor Type H (Heavy Engineering) 2018 labor rates.
https://www.dws.state.nm.us/Portals/0/DM/LaborRelations/Prevailing_Wage_Poster_H_2018.pdf

Table 1: 9 Waste Rock Stockpile - Reclamation Cost Estimate Summary

8/29/2018

Reclamation Summary - 3.5:1 Inter Bench				9 Stockpile
Direct Costs				**Current**
	Earthmoving		$	1,549,124.66
	Vegetation	100%	$	144,553.63
	Other		$	275,198.60
	O&M Revegetation		$	37,661.49
	Subtotal, Earthwork Direct Costs		**$**	**1,968,876.89**
	Subtotal, O&M Direct Costs		**$**	**37,661.49**
	Subtotal, Direct Costs		**$**	**2,006,538.38**
Indirect Costs				
	Mobilization and Demobilization	1.0%	$	19,688.77
	Contingencies	2.0%	$	39,377.54
	Engineering Redesign Fee	2.5%	$	49,221.92
	Contractor Profit and overhead	15.0%	$	295,331.53
	Project Management Fee	2.0%	$	39,377.54
	State Procurement Cost	0%	$	-
	Indirect Percentage Sum =	22.5%		
	Subtotal, Indirect Costs		**$**	**442,997.30**
Earthwork Total			**$**	**2,411,874.19**
O&M Indirect Cost	Mobilization and Demobilization	1.0%	$	376.61
	Contingencies	2.0%	$	753.23
	Engineering Redesign Fee	2.5%	$	941.54
	Contractor Profit and Overhead	10.0%	$	3,766.15
	Project Management Fee	2.0%	$	753.23
	State Procurement Cost	0.0%	$	-
	Indirect Percentage Sum =	17.5%		
	Subtotal, Indirect Costs			**$6,590.76**
O&M Total			**$**	**44,252.25**
Subtotal, Indirect Costs:			**$**	**449,588.06**
Total Costs			**$**	**2,418,464.95**

Data Sources:

MMD. 1996. Closeout Plan Guidelines for Existing Mines, Mining Act Reclamation Bureau Mining and Minerals Division New Mexico Energy, Minerals and Natural Resources Department. April 30, 1996.

OSM. 2000. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement Handbook for Calculation of Reclamation Bond Amounts. April 5, 2000.

Notes:

1) Indirect costs are based on the guidance available from MMD (1996) and OSM (2000).
2) Direct and Indirect Costs are identical to the percentages presented to MMD and the NMED in meetings with Tyrone on September 20, 2012 and November 2, 2012

Table 2: 9 Waste Rock Stockpile - Earthwork Quantities

8/29/2018

Earthwork Quantity Worksheet

Assumptions:

Cover material volumes are calculated based on the reclaimed area and the cover depth. This 8% swell factor accounts for swell when loading trucks.

0% swell factor, no swell factor is applied when regrading material as no virgin materials are being regraded.

Item	Description	Location 1	Location 2	Area (AC)	Cover Depth (in)	Bank/Stockpile Volume (bcy)	Swell Factor (%)	Loose/Stockpile Volume (lcy)
	Grade Surface - Slopes 3.5:1	9 Stockpile	9 Stockpile	-	-	399,767	-	399,767
	Grade Surface - Flat Areas	9 Stockpile	9 Stockpile	96	-	-	-	-
	Grade Cover - Slope 3.5:1	9 Stockpile	9 Stockpile	66	36	317,988	8%	343,427
	Grade Cover - Flat Areas	9 Stockpile	9 Stockpile	96	36	462,220	8%	499,198
	Dozer Assist	Upper South Stockpile		-	-	780,208	-	842,625
	Haul	Upper South Stockpile	9 Stockpile					842,625
	Loading	Upper South Stockpile						842,625

Table 3: 9 Waste Rock Stockpile - Productivity and Hours Required for Dozer Use

Productivity and Hours Required for Dozer Use—Grading

Assumptions:
Grading of top areas by 16M motorgrader

Eff. Blade Width (ft): 16.00 Grading Speed (mph): 2.5

Task Description	Location 1	Equipment	Volume (cy)	Area (acres)	Productivity (acres/hr)	Productivity (cy/hr)	Task Time (hours)	Material	Grade Factor	Soil Weight (lb/cy)	Production Method/ Blade	Effective Blade Width (feet)	Speed (miles/hr)	Work Hour (min/hr)	Visibility	Elevation	Direct Drive Trans.	Grade (%)	Operator	Centroid to Centroid Push Distance (feet)	Normal Production (cy/hr)
Grade Surface - Slopes 3.5:1	9 Stockpile	D11T	399,767			1,983	202	1.0	1.6	3,300	1.2			50	1	1	1	-29	1.00	90	1,810
Grade Surface - Flat Areas	9 Stockpile	16M	-	96	3	-	28	1.0	1.0	3,300	1.2	16.0	2.5	50	1	1	1	-1	1.00	-	-
Grade Cover - Slope 3.5:1	9 Stockpile	D11T	343,427			1,798	191	1.2	1.6	3,000	1.2			50	1	1	1	-29	0.75	100	1,658
Grade Cover - Flat Areas	9 Stockpile	16M	-	96	3	-	28	1.2	1.0	3,000	1.2	16.0	2.5	50	1	1	1	-1	0.75	-	-
Dozer Assist	Borrow Area	D11T	NA	NA	NA	NA	782	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Productivity and Hours Required for Truck Use

Productivity for Front End Loader

Hauling

Trucks

Task Description	Location 1	Location 2	Equipment	Volume	Truck Cycle Time	Optimum No. of Trucks	Productivity	Task Time	Struck Capacity	Heaped Capacity	Loader Cycles per Truck	Total Haul Distance	**Haul Distance Segment 1	**Haul Distance Segment 2	**Haul Grade Segment 1	**Haul Grade Segment 2	Rolling Resistance	Haul Distance Segment 1
				(cy)	(min)		(cy/hr)	(hrs)	(cy)	(cy)		(feet)	(feet)	(feet)	(%)	(%)	(%)	(meters)
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	842,625	12.9	3	1,141	782	71.0	102.0	7	5,132	2,712	2,420	0.8%	8.5%	2.5%	827

Trucks

Task Description	Location 1	Location 2	Equipment	Haul Distance Segment 2	Haul Effective Grade Segment 1	Haul Effective Grade Segment 2	Return Effective Grade Segment 1	Return Effective Grade Segment 2	Haul Time	Return Time	Loading Time	Load/ Maneuver Time	Dump/ Maneuver Time	Work Hour	Travel Time Loaded Segment 1	Travel Time Loaded Segment 2	Travel Time Empty Segment 1	Travel Time Empty Segment 2
				(meters)	(%)	(%)	(%)	(%)	(min)	(min)	(min)	(min)	(min)	(min/hr)	(min/m)	(min/m)	(min/m)	(min/m)
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	738	3%	11%	2%	0%	5.1	1.46	4.6	0.7	1.1	50	0.00160	0.00509	0.00093	0.00093

Loading

Loader

Task Description	Location 1	Location 2	Equipment	Volume	Net Bucket Capacity	Loader Cycle Time	Productivity	Task Time	Heaped Bucket Capacity	Bucket Fill Factor	Haul Distance	Haul Grade	Rolling Resistance	Load Bucket	Swing Loaded	Dump Bucket	Swing Empty	Work Hour
				(cy)	(cy)	(min)	(cy/hr)	(hours)	(cy)		(feet)	(%)	(%)	(min)	(min)	(min)	(min)	(min/hr)
Load Cover Material	Borrow Area	9 Stockpile	Cat 992K Loader	842,625	14.0	0.65	1,077	782	16	0.875	NA	NA	NA	NA	NA	NA	NA	50

Table 5: 9 Waste Rock Stockpile - Summary of Earthmoving Costs

8/29/2018

Equipment Type	Task	Location 1	Location 2	Owning and Operating Cost ($/hr)	Fuel Consumption (gal/hr)	Fuel Consumption (gal)	Labor Cost ($/hr)	Number of Units (Equipment)	Time Req'd (hrs)	Total Cost ($)
Dozers-Earthmoving										
Cat D11T	Grade Surface - Slopes 3.5:1	9 Stockpile	Outslopes	$ 420.39	29.75	5,999	$ 26.29	1	202	$ 90,067
Cat 16M	Grade Surface - Flat Areas	9 Stockpile	Outslopes	$ 136.00	9.51	263	$ 26.29	1	28	$ 4,497
Cat D11T	Grade Cover - Slope 3.5:1	9 Stockpile	Outslopes	$ 420.39	29.75	5,683	$ 26.29	1	191	$ 85,324
Cat 16M	Grade Cover - Flat Areas	9 Stockpile	Outslopes	$ 136.00	9.51	266	$ 26.29	1	28	$ 4,542
Cat D11T	Dozer Assist	9 Stockpile	Outslopes	$ 420.39	29.75	23,279	$ 26.29	1	782	$ 349,499
Loaders										
Cat 992K Loader	Load cover material	Borrow Area	9 Stockpile	$ 300.46	25.63	20,055	$ 26.56	1	782	$ 255,873
Trucks										
Cat 785F Truck	Haul cover material	Borrow Area	Borrow	$ 220.09	28.12	66,010	$ 23.84	3	2347	$ 572,580
Water Truck and Grader										
Off-Hwy Water Tanker Truck,6,000-gal.		9 Stockpile		$ 88.11	11.25	8,804	$ 23.84	1	782	$ 87,594
Cat 14M		9 Stockpile		$ 100.43	8.29	6,486	$ 26.29	1	782	$ 99,150
								9 Stockpile		$ 1,549,125

Data Sources:
1. Equipment unit rates from EquipmentWatch Custom Cost Evaluator 2nd Half of 2018 (http://www.equipmentwatch.com). See attachments for rate development.
2. Fuel quote from Griffin Propane March 12, 2018
3. Labor rates based on 2018 NM Department of Labor Type H (Heavy Engineering) labor rates. See attachments for rate development.

Table 6: 9 Waste Rock Stockpile - Vegetation Cost

8/29/2018

Description:

Includes scarifying, discing, rangeland drill seeding, mulching, crimping, and daily per diem

Stockpile Areas

Unit or Disturbance	Area (acres)	Unit Cost ($/acre)	Subtotal Cost ($)
9 Stockpile	161	$ 896.73	$ 144,554

9 Stockpile	$	144,554
Direct Cost Total	$	144,554

Rocky Mountain Reclemation Quote (April 2018) from Continent CCP, Rate $1099/acres Pre-tax

Other Reclamation Activity Costs

Item	Activity	Quantity	Unit	Unit Cost ($/unit)	Direct Item Cost ($)	Reference
Downdrains						
Bench Grading						
9 Stockpile	Bench Grading - 3.5H:1V	14,085	ft	$2.53	$35,566	Finish grade channel benches using D11T and D9T SU. Three passes per bench, 1 MPH operating speed. Soil weight 3,300 lb/cy. Grading benches 15 ft. wide, 8.1 cy cut-to-fill/ft. of bench, 84 foot push distance. See attachment Bench Grading Appendix B.
Channel Excavation						
9 Stockpile	Downdrain Length - 3.5H:1V (Reclaimed Area)	1,067	ft	$10.73	$11,445	Excavate and waste 6.5 cy/lf material on slopes with D11T, 179-foot downslope excavation, 200-foot lateral waste push. Finish grade 2.6 cy/lf with D6T XL SU, 179-foot typical push distance.
9 Stockpile	Bench Channels - 3.5H:1V	14,085	feet	$1.41	$19,856	Excavate and waste 0.9 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 0.3 cy/lf with D6T XL SU, 179-foot typical push distance.
9 Stockpile	Top Channels (Reclaimed Area)	3,069	feet	$4.40	$13,497	Excavate and waste 2.7 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 1.1 cy/lf with D6T XL SU, 179-foot typical push distance.
9 Stockpile	Top Channels (Off-Site Area)	3,698	feet	$4.40	$16,262	Excavate and waste 2.7 cy/lf material with D11T, 179-foot excavation, 200-foot lateral waste push. Finish grade 1.1 cy/lf with D6T XL SU, 179-foot typical push distance.
Riprap						
9 Stockpile	Bench Channel Filter, Haul	4,695	cy	$2.98	$13,985	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
9 Stockpile	Downdrain Filter, Haul	1,000	cy	$2.98	$2,978	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
9 Stockpile	Downdrain Riprap, Haul	4,051	cy	$2.98	$12,066	Load and haul rock, max load 71 cy, 1 mile average one way trip, 785F haul trucks, 1 992K loader, 1,077 cy/hr.
9 Stockpile	Bench Channel Filter, Backfill	4,695	cy	$0.8	$3,756	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
9 Stockpile	Downdrain Filter Backfill	1,000	cy	$0.8	$800	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
9 Stockpile	Downdrain Riprap Backfill	4,051	cy	$0.8	$3,241	300hp 980H Loader, Net 6.4CY, 23 loads/hr at 50 min/hr
9 Stockpile	Riprap and Filter production	9,746	cy	$14.54	$141,746	The rip rap unit cost was developed based on erience gained producing rip rap at the McCain Springs Quarry. Supporting documentation is included in Appendix B.

Channels and Benches Total Direct Cost $ 275,199

References
See Appendix B.7 for Channel, Bench, and Downdrain unit rate development.

Table 8: NE Stockpile Expansion - NPV Calculation

Net Present Value

8/29/2018

	Escalation Rate	Yr 1-12 Discount Rate
Earth	3.64%	5.00%

Component	Current Cost	NPV
Earthwork	$2,418,465	$2,253,404
Total	**$2,418,465**	**$2,253,404**

Year	Earthwork Current Cost	Earthwork NPV
1	201,539	201,539
2	201,539	198,928
3	201,539	196,352
4	201,539	193,809
5	201,539	191,298
6	201,539	188,820
7	201,539	186,375
8	201,539	183,961
9	201,539	181,578
10	201,539	179,226
11	201,539	176,905
12	201,539	174,613
Total	2,418,465	2,253,404

$201,539 equals $1,150,270 ÷ 12

$2,418,465 9 Stockpile Stockpile FA

Chino Mine

9WRP
Total Cost
8/29/2018

Trucks Productivity (cy/hr)

Assumptions:

Productivity (cy/hr) = work hour (min/hr) x loader cycles per truck x net bucket capacity (cy) x no. of trucks / truck cycle time (min)

Example: 50 min/hr x 6 buckets x 11.9 cy/bucket x 8 trucks / 50 min = 571 cy/hr

Task Description	Location 1	Location 2	Equipment	No. of Trucks 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	761	1,141	1,521	1,902	2,282	2,663	3,043	3,423	3,804	4,184	4,564	4,945	5,325	5,706	6,086	6,466	6,847	7,227	7,607	7,988	8,368	8,748	9,129	9,509

Chino Mine

9WRP
Total Cost
8/29/2018

Truck Time (hours)

Truck Time (hr) = If vol./prod. (cy/cy per hr)<loader task time (hr), then use loader task time (hr); if not, use vol./ prod. (cy/cy per hr)

Example: 1,000,000 cy / 571 cy/hr = 1,751 hr < 2,000 hr =====> 2,000 hr

Task Description	Location 1	Location 2	Equipment	No. of Trucks 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	1,108	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782	782

Chino Mine

Truck Cost

Truck Cost ($) = Truck time (hr) x [owning/operating cost ($/hr) + labor cost ($/hr)] x no. of trucks

Example: 5,000 hr x ($187.01/hr + $20.00/hr) x 8 trucks = $8,280,400

				No. of Trucks								
	Location 1	Location 2	Equipment	2	3	4	5	6	7	8	9	10
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	$540,374	$572,580	$763,440	$954,299	$1,145,159	$1,336,019	$1,526,879	$1,717,739	$1,908,599

	11	12	13	14	15	16	17	18
Haul Cover Material	$2,099,459	$2,290,319	$2,481,179	$2,672,039	$2,862,898	$3,053,758	$3,244,618	$3,435,478

	19	20	21	22	23	24	25
Haul Cover Material	$3,626,338	$3,817,198	$4,008,058	$4,198,918	$4,389,778	$4,580,638	$4,771,497

Chino Mine

Loader Cost

Loader Cost ($) = Loader time (hr) x [owning/operating cost ($/hr) + labor cost ($/hr)]

Example: 5,000 hr x ($206.13/hr + $20.00/hr) = $1,130,650

	Location 1	Location 2	Equipment	No. of Trucks 2	3	4	5	6	7	8	9	10	11	12	13
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	$362,221	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873

	14	15	16	17	18	19	20	21	22	23	24	25
Haul Cover Material	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873	$255,873

Chino Mine

Trucks & Loader Total Cost

Total Cost ($) = Truck Cost ($) + Loader Cost ($)

Example: $8,280,400 + $1,130,650 = $9,411,050

Task Description	Location 1	Location 2	Equipment	No. of Trucks 2	3	4	5	6	7	8	9	10	11	12
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	$902,595	$828,452	$1,019,312	$1,210,172	$1,401,032	$1,591,892	$1,782,752	$1,973,612	$2,164,472	$2,355,331	$2,546,191

Task Description	13	14	15	16	17	18	19	20	21	22	23	24	25	Minimum Cost
Haul Cover Material	$2,737,051	$2,927,911	$3,118,771	$3,309,631	$3,500,491	$3,691,351	$3,882,211	$4,073,071	$4,263,930	$4,454,790	$4,645,650	$4,836,510	$5,027,370	$828,452

Chino Mine

9WRS
Optimum
8/29/2018

Trucks Optimum

Optimum = If minimum total cost >or = total cost for this no. of trucks, then enter this no. of trucks; if not, enter zero

Example: $4,478,191 < $6,060,707 =====> enter zero

Task Description	Location 1	Location 2	Equipment	No. of Trucks 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Optimum No. of Trucks
Haul Cover Material	Borrow Area	9 Stockpile	Cat 785F Truck	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Operations & Maintenance Reclamation Cost Estimate

O&M Vegetation Maintenance
8/29/2018

Vegetation Maintenance Costs

Location	Total Area (acres)	Reclamation Complete	Veg Maintenance Complete	# yrs veg Maint.	Percent loss per year	Quantity	Unit	Unit Cost* ($/unit)	Item Cost ($)	Description
Stockpiles	161	0	11	12	2%	3.2	acres	$935	$36,124	2% of veg fails every year for 12 years.

Vegetation Maintenance Total Direct Cost: $36,124
Vegetation Maintenance Total Cost (with indirects): $44,252

Notes:
Reclamation Start Date: Dec-19

0
$ 934.89 $/acre O&M Vegetation Unit Cost

9 Waste Rock Stockpile

O&M Table
8/29/2018

Total Earthwork O&M Cost: Direct/Indirect by time period			
	Direct	Indirect	Total
Overall Site			
0 to 12	$36,124	$6,322	$42,446
Totals	**$36,124**	**$6,322**	**$42,446**

O&M Worksheet
8/29/2018

Operations and Maintenance Summary

Cobre Mining Company

Operations and Maintenance
Based on Projected EOY 2019 Mine Plan

				Current Value
DIRECT COSTS	Facility and Structure Removal			$0
	Earthmoving			$0
	Revegetation			$37,661
		Subtotal, Direct Costs		**$37,661**
INDIRECT COSTS[1]	Mobilization and Demobilization		1.0%	$377
	Contingencies		2.0%	$753
	Engineering Redesign Fee		2.5%	$942
	Contractor Profit and Overhead		10.0%	$3,766
	Project Management Fee		2.0%	$753
	State Procurement Cost		0.0%	$0
		Indirect Percentage Sum =	17.5%	
		Subtotal, Indirect Costs		**$6,591**
TOTAL COST				**$44,252**

Data Sources:

MMD. 1996. Closeout Plan Guidelines for Existing Mines, Mining Act Reclamation Bureau Mining and Minerals Division New Mexico Energy, Minerals and Natural Resources Department. April 30, 1996.

OSM. 2000. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement Handbook for Calculation of Reclamation Bond Amounts. April 5, 2000.

Notes:

1) Indirect costs are based on the guidance available from MMD (1996) and OSM (2000).

APPENDIX B.2
SUPPORTING DOCUMENTATION

Appendix B.2.1

Production and Misc. Calculation Documentation

EQUATIONS USED IN CAPITAL COST SPREADSHEET

Sheet #2 Earthwork:

Bank Volume (bcy) = $Area\ (acre) * Cover\ Depth\ (in) * \frac{43{,}560\left(\frac{ft^2}{acre}\right)}{\left(12\left(\frac{in}{ft}\right)\right)} * \frac{1}{27\left(\frac{ft^3}{cy}\right)}$

Loose or Stockpile Volume (lcy) = Bank or stockpile Volume (cy) * [1 + Swell Factor]

Sheet #3 Grading:

Normal Production (lcy/hr) = 76845* Maximum Push Distance (ft)$^{-0.833}$
(Caterpillar Performance Handbook Edition 47 D11T 1-52)

Productivity (cy/hr) =

$$Normal\ Production\left(\frac{lcy}{hr}\right) * Operator * Material * Work\ Hour\left(\frac{min}{hr}\right) * Grade\ Factor * \frac{2{,}300\left(\frac{lbs}{cy}\right)}{SoilWeight\left(\frac{lbs}{cy}\right)} * Prod.Method * Visibility * Elev. * Drive\ Trans.$$

Total Task Time (hr) = $\frac{Loose\ or\ Stockpile\ Volume(cy)}{Productivity\left(\frac{cy}{hr}\right)}$

Grade (Dozing Factor) = -0.02 * Grade (%) + 1
(Curve Fit Cat Handbook Ed 44 19 - 55)

Sheet #4 Loader&Truck:

Total Haul Distance (ft) = ∑ Segment Haul Distance (ft)

Haul Distance Segment (m) = Haul Distance (ft) * 0.3048 (m / ft)

Haul Effective Grade (%) = (Haul Grade (%) + Rolling Resistance (%))(unless < 0 then 0)

Return Effective Grade (%) = (Rolling Resistance (%) - Haul Grade (%))(unless < 0 then 0)

Truck Segment Travel Time Loaded (min/ m) =
-1.6825 * Haul Effective Grade Segment (%)^3 + 0.4592 * Haul Effective Grade Segment (%)^2
* 0.0079* Haul Effective Grade Segment (%) + 0.0009

Truck Segment Travel Time Empty (min/ m) =

-6.2135 * Return Effective Grade Segment (%)^4 + 1.0448 * Return Effective Grade Segment (%)^3 + 0.1016 * Return Effective Grade Segment - 0.0035* Return Effective Grade Segment (%) + 0.0009

(Curve Fit Cat Handbook Ed 41 9 - 42)

Loader (cycles / truck) = $Maximum[\frac{Struck\ Capacity(cy)}{Loader\ Net\ Bucket\ Capacity(cy)}, \frac{Heaped\ Capacity(cy)}{Loader\ Net\ Bucket\ Capacity(cy)}]$

Haul Time (min) = ∑(Segment Travel Time Loaded (min/ m) * Segment Haul Dist (m))

Return Time (min) = ∑(Segment Travel Time Empty (min/ m) * Segment Haul Dist (m))

Loading Time (min) = Loader Cycle Time (min) * Loader (cycles / truck)

Task Time (hr) = $Maximum[\frac{Volume(cy)}{Productivity(\frac{cy}{hr})}, Loader\ Task\ Time\ (Hr)]$

Truck Cycle Time (min) =

Haul Time (min) + Return Time (min) + Loading Time (min) + Load / Maneuver Time (min) + Dump Maneuver Time (min)

Productivity (cy / hr) =

$$Work\ Hour\left(\frac{min}{hr}\right) * Loader\left(\frac{cycles}{truck}\right) * Loader\ Net\ Bucket\ Capacity(cy) * \left(\frac{Optimum\ Number\ of\ Trucks}{Truck\ Cycle\ Time(\mathrm{min})}\right)$$

Net Bucket Capacity (cy) = Heaped Bucket Capacity (cy) * Bucket Fill Factor

Productivity (cy / hr) = $\left(\frac{\text{Net Bucket Capacity(cy)} * \text{Work Hour}\left(\frac{\text{min}}{\text{hr}}\right)}{\text{Loader Cycle Time}(min)}\right)$

Task Time (hr) = $\frac{Volume(cy)}{Productivity(\frac{cy}{hr})}$

Sheet #5 Earth Sum:

Direct Cost ($) = [Owning & Operating Cost ($ / hr) + Labor Cost ($ / hr)] * Time Required (hr)
* Number of Units of Equipment

Unit Cost ($ / unit) = $\frac{Direct\ Cost(\$)}{Total\ Production(unit)}$

Earthwork Total Direct Cost ($) = ∑(Total Cost ($))

Sheet #6 Veg:

Direct Cost ($) = Area (acres) * Unit Cost ($ / acre)

Veg Total Direct Cost ($) = ∑(Direct Costs ($))

Sheet #7 Other:

Direct Cost ($) = Quantity (units) * Unit Cost ($ / unit)

Other Total Direct Cost ($) = ∑(Direct Cost ($))

Sheet #1 General:

Subtotal Direct Cost ($) = Earthmoving Total Direct Cost ($)
+ Vegetation Total Direct Cost ($) + Other Total Direct Cost ($)

Subtotal Indirect Costs ($) = $Subtotal\ Direct\ Cost(\$) * \frac{Various\ Indirect\ Costs(\%)}{100}$

Total Cost ($) = Subtotal Direct Cost ($) + Subtotal Indirect Cost ($)

OPTIMIZATION EQUATIONS:

Each Equation for number of trucks (n) from 2 to 25.

Productivity Sheet:

Productivity (cy / hr) =

$$Work\ Hour\left(\frac{min}{hr}\right) * Loader\left(\frac{cycle}{truck}\right) * Loader\ Net\ Bucket\ Cap\ (cy) * \frac{Number\ Of\ Trucks(n)}{Truck\ Cycle\ Time\ (min)}$$

Time Sheet:

Time (hr) = $Maximum[\frac{Volume\ (cy)}{Productivity\left(\frac{cy}{hr}\right)}, Loader\ Task\ Time\ (hr)$

Truck Cost Sheet:

Truck Cost ($) =

Time (hr) * Number of Trucks[n] * (Owning & Operating Cost ($ / hr) + Labor Cost ($ / hr).

Loader Cost Sheet:

Loader Cost for Number of Trucks[n] ($) =

Time (hr) * (Owning & Operating Cost ($ / hr) + Labor Cost ($ / hr))

Total Cost Sheet:

Total Cost Number of Trucks[n] ($) = Truck Cost ($) + Loader Cost ($)

Minimum Cost = Minimum (Total Cost for Number of Trucks[n]($))

Optimum Number of Trucks:

Number of Trucks[n] =

when (Minimum Cost ($) > or = Total Cost for Number of Trucks[n].

then use Number of Trucks[n]; if not, use 0

Optimum Number of Trucks = $\sum_{n=2}^{25} \text{Number of Trucks } [n]$

Appendix B.2.2

NMDOL
Labor Rates

LABOR RATES

Labor	Equipment	Group	Base rate[1]	Fringes[1]	Apprentice Rate[1]	Subtotal
Power Equipment Operator	Front End Loaders	VI	$20.15	$5.74	$0.67	$26.56
Power Equipment Operator	Dozer	IV	$19.88	$5.74	$0.67	$26.29
Power Equipment Operator	Motor Grader (Rough)	IV	$19.88	$5.74	$0.67	$26.29
Power Equipment Operator	Mechanic	V	$19.98	$5.74	$0.67	$26.39
Truck Drivers	Haul Trucks	III	$16.00	$7.17	$0.67	$23.84
Laborers	Forman	II	$17.51	$5.30	$0.67	$23.48
Laborers	Laborer	I	$16.76	$5.30	$0.67	$22.73

1. Base Rate, Fringes, Apprentice Rate https://www.dws.state.nm.us/Portals/0/DM/LaborRelations/Prevailing_Wage_Poster_H_2018.pdf

Appendix B.2.3

EquipmentWatch Sheets

EquipmentWatch.

www.equipmentwatch.com

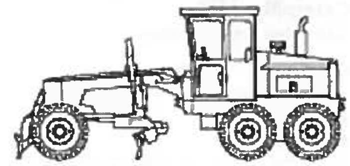
All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 14M (disc. 2015)
Articulated Frame Graders

Size Class:
250 HP & Over
Weight:
46,796 lbs.



Configuration for 14M (disc. 2015)

Power Mode	**Diesel**	Net Horsepower	**259 hp**
Operator Protection	**EROPS**	Moldboard Size	**14 ft**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$30.16/hr	$28.25/hr	-6.3%
Cost of Facilities Capital (CFC)	$7.33/hr	$6.05/hr	-17.5%
Overhead	$21.11/hr	$0.00/hr	-100%
Overhaul Labor	$7.49/hr	$2.76/hr	-63.2%
Overhaul Parts	$17.36/hr	$14.15/hr	-18.5%
Total Hourly Ownership Cost:	**$83.45/hr**	**$51.21/hr**	**-38.6%**

User Defined Adjustments: Annual Overhead ($29,550.57 -> $1.00) Annual Use Hours (1,400hrs -> 1,718hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$6.25/hr	$2.30/hr	-63.2%
Field Parts	$16.84/hr	$13.72/hr	-18.5%
Ground Engaging Component (GEC)	$1.38/hr	$1.13/hr	-18.1%
Tire	$7.11/hr	-	-
Electrical/Fuel	$24.95/hr	$18.61/hr	-25.4%
Lube	$6.35/hr	-	-
Total Operating Ownership Cost:	**$62.88/hr**	**$49.22/hr**	**-21.7%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$83.45/hr	$51.21/hr	-38.6%
Hourly Operating Costs	$62.88/hr	$49.22/hr	-21.7%
Total Hourly Cost	**$146.33**	**$100.43/hr**	**-31.4%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$58.60/hr	$34.30/hr	-41.5%
Idle	$108.40/hr	$69.82/hr	-35.6%

Revised Date: 2nd Half 2018

The equipment represented in this report has been exclusively prepared for MANDY LILLA (mlilla@fmi.com)

EquipmentWatch

www.equipmentwatch.com

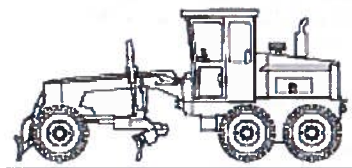
All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 16M
Articulated Frame Graders

Size Class:
250 HP & Over
Weight:
59,435 lbs.



Configuration for 16M

Power Mode	**Diesel**	Net Horsepower	**297 hp**
Operator Protection	**EROPS**	Moldboard Size	**16 ft**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$43.66/hr	$40.89/hr	-6.3%
Cost of Facilities Capital (CFC)	$10.61/hr	$8.75/hr	-17.5%
Overhead	$13.10/hr	$0.00/hr	-100%
Overhaul Labor	$7.49/hr	$2.76/hr	-63.2%
Overhaul Parts	$24.76/hr	$20.18/hr	-18.5%
Total Hourly Ownership Cost:	**$99.62/hr**	**$72.58/hr**	**-27.1%**

User Defined Adjustments: Annual Overhead ($18,343.62 -> $1.00) Annual Use Hours (1,400hrs -> 1,718hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$6.25/hr	$2.30/hr	-63.2%
Field Parts	$24.01/hr	$19.57/hr	-18.5%
Ground Engaging Component (GEC)	$2.00/hr	$1.63/hr	-18.5%
Tire	$10.13/hr	-	-
Electrical/Fuel	$28.61/hr	$21.34/hr	-25.4%
Lube	$8.45/hr	-	-
Total Operating Ownership Cost:	**$79.45/hr**	**$63.42/hr**	**-20.2%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$99.62/hr	$72.58/hr	-27.1%
Hourly Operating Costs	$79.45/hr	$63.42/hr	-20.2%
Total Hourly Cost	**$179.07**	**$136.00/hr**	**-24.1%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$67.37/hr	$49.64/hr	-26.3%
Idle	$128.23/hr	$93.92/hr	-26.8%

Revised Date: 2nd Half 2018

The equipment represented in this report has been exclusively prepared for MANDY LILLA (mlilla@fmi.com)

EquipmentWatch

www.equipmentwatch.com

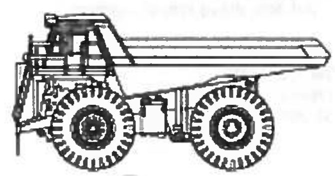
All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 769D (disc. 2007)
Mechanical Drive Rear Dumps

Size Class:
30 - 39 MTons
Weight:
66,800 lbs.



Configuration for 769D (disc. 2007)

Body Capacity (Struck–Heaped)	**22.2 cu yd - 31.7 cu yd**	Power Mode	**Diesel**
Net Horsepower	**487 hp**	Rated Payload	**36.4 mt**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$33.52/hr	$31.57/hr	-5.8%
Cost of Facilities Capital (CFC)	$6.03/hr	$5.11/hr	-15.3%
Overhead	$5.20/hr	$0.00/hr	-100%
Overhaul Labor	$15.75/hr	$5.94/hr	-62.3%
Overhaul Parts	$16.24/hr	$13.53/hr	-16.7%
Total Hourly Ownership Cost:	**$76.74/hr**	**$56.15/hr**	**-26.8%**

User Defined Adjustments: Annual Overhead ($9,623.89 -> $1.00) Annual Use Hours (1,850hrs -> 2,220hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.45/hr	$4.70/hr	-62.2%
Field Parts	$9.90/hr	$8.25/hr	-16.7%
Ground Engaging Component (GEC)	$0.00/hr	-	-
Tire	$13.38/hr		-
Electrical/Fuel	$29.32/hr	$21.87/hr	-25.4%
Lube	$8.52/hr	-	-
Total Operating Ownership Cost:	**$73.57/hr**	**$56.72/hr**	**-22.9%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$76.74/hr	$56.15/hr	-26.8%
Hourly Operating Costs	$73.57/hr	$56.72/hr	-22.9%
Total Hourly Cost	**$150.31**	**$112.87/hr**	**-24.9%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$44.75/hr	$36.68/hr	-18%
Idle	$106.06/hr	$78.02/hr	-26.4%

Revised Date: 2nd Half 2018

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EquipmentWatch

www.equipmentwatch.com

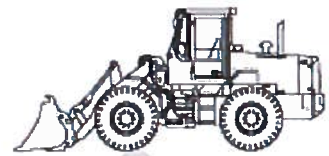
All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 966H
4-Wd Articulated Wheel Loaders

Size Class:
250 - 274 HP
Weight:
52,254 lbs.



Configuration for 966H

Power Mode	**Diesel**	Net Horsepower	**262 hp**
Operator Protection	**EROPS**	Bucket Capacity - Heaped	**5.5 cu yd**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$20.82/hr	$19.42/hr	-6.7%
Cost of Facilities Capital (CFC)	$4.91/hr	$4.14/hr	-15.7%
Overhead	$7.45/hr	$0.00/hr	-100%
Overhaul Labor	$10.08/hr	$3.80/hr	-62.3%
Overhaul Parts	$6.05/hr	$5.04/hr	-16.7%
Total Hourly Ownership Cost:	**$49.31/hr**	**$32.40/hr**	**-34.3%**

User Defined Adjustments: Annual Overhead ($10,761.44 -> $1.00) Annual Use Hours (1,445hrs -> 1,734hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.30/hr	$4.64/hr	-62.3%
Field Parts	$6.68/hr	$5.57/hr	-16.6%
Ground Engaging Component (GEC)	$0.91/hr	$0.76/hr	-16.5%
Tire	$5.57/hr	-	-
Electrical/Fuel	$25.24/hr	$18.82/hr	-25.4%
Lube	$5.11/hr	-	-
Total Operating Ownership Cost:	**$55.81/hr**	**$40.47/hr**	**-27.5%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$49.31/hr	$32.40/hr	-34.3%
Hourly Operating Costs	$55.81/hr	$40.47/hr	-27.5%
Total Hourly Cost	**$105.12**	**$72.87/hr**	**-30.7%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$33.18/hr	$23.56/hr	-29%
Idle	$74.55/hr	$51.22/hr	-31.3%

Revised Date: 2nd Half 2018

The equipment represented in this report has been exclusively prepared for MANDY LILLA (mlilla@fmi.com)

EquipmentWatch

www.equipmentwatch.com

All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 980H (disc. 2013)
4-Wd Articulated Wheel Loaders

Size Class:
275 - 349 HP
Weight:
67,294 lbs.

Configuration for 980H (disc. 2013)

Power Mode	**Diesel**	Net Horsepower	**315 hp**
Operator Protection	**EROPS**	Bucket Capacity - Heaped	**7.5 cu yd**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$27.41/hr	$25.55/hr	-6.8%
Cost of Facilities Capital (CFC)	$6.46/hr	$5.45/hr	-15.6%
Overhead	$6.50/hr	$0.00/hr	-100%
Overhaul Labor	$10.08/hr	$3.80/hr	-62.3%
Overhaul Parts	$8.57/hr	$7.14/hr	-16.7%
Total Hourly Ownership Cost:	**$59.02/hr**	**$41.94/hr**	**-28.9%**

User Defined Adjustments: Annual Overhead ($9,389.41 -> $1.00) Annual Use Hours (1,445hrs -> 1,734hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.30/hr	$4.64/hr	-62.3%
Field Parts	$9.46/hr	$7.88/hr	-16.7%
Ground Engaging Component (GEC)	$1.20/hr	$1.00/hr	-16.7%
Tire	$7.89/hr	-	-
Electrical/Fuel	$30.34/hr	$22.63/hr	-25.4%
Lube	$6.44/hr	-	-
Total Operating Ownership Cost:	**$67.63/hr**	**$50.48/hr**	**-25.4%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$59.02/hr	$41.94/hr	-28.9%
Hourly Operating Costs	$67.63/hr	$50.48/hr	-25.4%
Total Hourly Cost	**$126.65**	**$92.42/hr**	**-27%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$40.37/hr	$31.00/hr	-23.2%
Idle	$89.36/hr	$64.57/hr	-27.7%

Revised Date: 2nd Half 2018

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EquipmentWatch

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All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 988H (disc. 2014)
4-Wd Articulated Wheel Loaders

Size Class:
350 - 499 HP
Weight:
109,230 lbs.

Configuration for 988H (disc. 2014)

Power Mode	**Diesel**	Net Horsepower	**475 hp**
Operator Protection	**EROPS**	Bucket Capacity - Heaped	**8.33 cu yd**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$51.99/hr	$48.49/hr	-6.7%
Cost of Facilities Capital (CFC)	$12.20/hr	$10.30/hr	-15.6%
Overhead	$18.39/hr	$0.00/hr	-100%
Overhaul Labor	$10.08/hr	$3.80/hr	-62.3%
Overhaul Parts	$15.53/hr	$12.95/hr	-16.6%
Total Hourly Ownership Cost:	**$108.19/hr**	**$75.54/hr**	**-30.2%**

User Defined Adjustments: Annual Overhead ($26,571.40 -> $1.00) Annual Use Hours (1,445hrs -> 1,734hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.30/hr	$4.64/hr	-62.3%
Field Parts	$17.14/hr	$14.28/hr	-16.7%
Ground Engaging Component (GEC)	$2.26/hr	$1.88/hr	-16.8%
Tire	$16.82/hr	-	-
Electrical/Fuel	$45.75/hr	$34.12/hr	-25.4%
Lube	$11.01/hr	-	-
Total Operating Ownership Cost:	**$105.28/hr**	**$82.75/hr**	**-21.4%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$108.19/hr	$75.54/hr	-30.2%
Hourly Operating Costs	$105.28/hr	$82.75/hr	-21.4%
Total Hourly Cost	**$213.47**	**$158.29/hr**	**-25.8%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$82.58/hr	$58.79/hr	-28.8%
Idle	$153.94/hr	$109.66/hr	-28.8%

Revised Date: 2nd Half 2018

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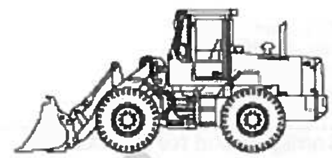
All prices shown in US$

Custom Cost Evaluator

August 29, 2018

Caterpillar 992K
4-Wd Articulated Wheel Loaders

Size Class:
500 - 999 HP
Weight:
214,948 lbs.



Configuration for 992K

Power Mode	**Diesel**	Net Horsepower	**801 hp**
Operator Protection	**EROPS**	Bucket Capacity - Heaped	**14 cu yd**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$111.16/hr	$103.81/hr	-6.6%
Cost of Facilities Capital (CFC)	$24.47/hr	$20.66/hr	-15.6%
Overhead	$33.64/hr	$0.00/hr	-100%
Overhaul Labor	$10.08/hr	$3.80/hr	-62.3%
Overhaul Parts	$30.19/hr	$25.16/hr	-16.7%
Total Hourly Ownership Cost:	**$209.54/hr**	**$153.43/hr**	**-26.8%**

User Defined Adjustments: Annual Overhead ($48,603.89 -> $1.00) Annual Use Hours (1,445hrs -> 1,734hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.30/hr	$4.64/hr	-62.3%
Field Parts	$33.31/hr	$27.76/hr	-16.7%
Ground Engaging Component (GEC)	$4.54/hr	$3.78/hr	-16.7%
Tire	$32.69/hr	-	-
Electrical/Fuel	$77.15/hr	$57.54/hr	-25.4%
Lube	$20.62/hr	-	-
Total Operating Ownership Cost:	**$180.61/hr**	**$147.03/hr**	**-18.6%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$209.54/hr	$153.43/hr	-26.8%
Hourly Operating Costs	$180.61/hr	$147.03/hr	-18.6%
Total Hourly Cost	**$390.15**	**$300.46/hr**	**-23%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$169.27/hr	$124.47/hr	-26.5%
Idle	$286.69/hr	$210.97/hr	-26.4%

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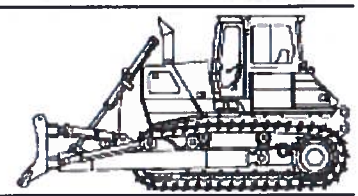
Custom Cost Evaluator

August 29, 2018

Caterpillar D6T XL
Standard Crawler Dozers

Size Class:
190 - 259 HP
Weight:
44,420 lbs.



Configuration for D6T XL

Dozer Type	**Semi-U**	Power Mode	**Diesel**
Net Horsepower	**200 hp**	Operator Protection	**EROPS**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$26.11/hr	$24.43/hr	-6.4%
Cost of Facilities Capital (CFC)	$5.83/hr	$4.92/hr	-15.6%
Overhead	$16.61/hr	$0.00/hr	-100%
Overhaul Labor	$9.75/hr	$3.68/hr	-62.3%
Overhaul Parts	$17.88/hr	$14.90/hr	-16.7%
Total Hourly Ownership Cost:	$76.18/hr	$47.93/hr	-37.1%

User Defined Adjustments: Annual Overhead ($21,347.45 -> $1.00) Annual Use Hours (1,285hrs -> 1,542hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$12.02/hr	$4.54/hr	-62.2%
Field Parts	$17.33/hr	$14.44/hr	-16.7%
Ground Engaging Component (GEC)	$2.89/hr	$2.41/hr	-16.6%
Tire	$0.00/hr	-	-
Electrical/Fuel	$23.48/hr	$17.51/hr	-25.4%
Lube	$5.08/hr	-	-
Total Operating Ownership Cost:	$60.80/hr	$43.98/hr	-27.7%

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$76.18/hr	$47.93/hr	-37.1%
Hourly Operating Costs	$60.80/hr	$43.98/hr	-27.7%
Total Hourly Cost	$136.98	$91.91/hr	-32.9%

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$48.55/hr	$29.35/hr	-39.5%
Idle	$99.66/hr	$65.44/hr	-34.3%

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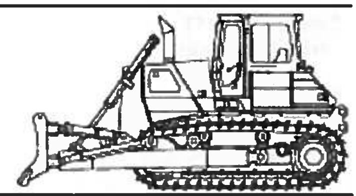
Custom Cost Evaluator

August 29, 2018

Caterpillar D9T
Standard Crawler Dozers

Size Class:
360 - 519 HP
Weight:
105,600 lbs.



Configuration for D9T

Power Mode	**Diesel**	Net Horsepower	**410 hp**
Operator Protection	**ROPS/FOPS**	Dozer Type	**Semi-U**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$45.49/hr	$42.80/hr	-5.9%
Cost of Facilities Capital (CFC)	$10.25/hr	$8.64/hr	-15.7%
Overhead	$40.08/hr	$0.00/hr	-100%
Overhaul Labor	$17.07/hr	$6.44/hr	-62.3%
Overhaul Parts	$40.59/hr	$33.82/hr	-16.7%
Total Hourly Ownership Cost:	**$153.48/hr**	**$91.70/hr**	**-40.3%**

User Defined Adjustments: Annual Overhead ($56,109.35 -> $1.00) Annual Use Hours (1,400hrs -> 1,680hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$19.99/hr	$7.54/hr	-62.3%
Field Parts	$39.53/hr	$32.94/hr	-16.7%
Ground Engaging Component (GEC)	$6.59/hr	$5.49/hr	-16.7%
Tire	$0.00/hr	-	-
Electrical/Fuel	$43.19/hr	$32.21/hr	-25.4%
Lube	$10.85/hr	-	-
Total Operating Ownership Cost:	**$120.15/hr**	**$89.03/hr**	**-25.9%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$153.48/hr	$91.70/hr	-40.3%
Hourly Operating Costs	$120.15/hr	$89.03/hr	-25.9%
Total Hourly Cost	**$273.63**	**$180.73/hr**	**-34%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$95.82/hr	$51.44/hr	-46.3%
Idle	$196.67/hr	$123.91/hr	-37%

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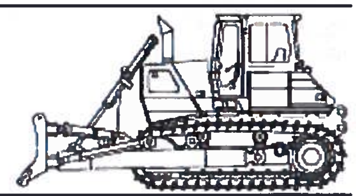
Custom Cost Evaluator

August 29, 2018

Caterpillar D11T
Standard Crawler Dozers

Size Class:
520 HP & Over
Weight:
208,885 lbs.



Configuration for D11T

Dozer Type	**U Blade**	Power Mode	**Diesel**
Net Horsepower	**850 hp**	Operator Protection	**EROPS**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$116.51/hr	$109.64/hr	-5.9%
Cost of Facilities Capital (CFC)	$25.91/hr	$21.84/hr	-15.7%
Overhead	$56.69/hr	$0.00/hr	-100%
Overhaul Labor	$17.07/hr	$6.44/hr	-62.3%
Overhaul Parts	$102.61/hr	$85.51/hr	-16.7%
Total Hourly Ownership Cost:	**$318.79/hr**	**$223.43/hr**	**-29.9%**

User Defined Adjustments: Annual Overhead ($79,359.31 -> $1.00) Annual Use Hours (1,400hrs -> 1,680hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$19.99/hr	$7.54/hr	-62.3%
Field Parts	$99.94/hr	$83.29/hr	-16.7%
Ground Engaging Component (GEC)	$16.66/hr	$13.88/hr	-16.7%
Tire	$0.00/hr	-	-
Electrical/Fuel	$89.55/hr	$66.79/hr	-25.4%
Lube	$25.46/hr	-	-
Total Operating Ownership Cost:	**$251.60/hr**	**$196.96/hr**	**-21.7%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$318.79/hr	$223.43/hr	-29.9%
Hourly Operating Costs	$251.60/hr	$196.96/hr	-21.7%
Total Hourly Cost	**$570.39**	**$420.39/hr**	**-26.3%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$199.11/hr	$131.48/hr	-34%
Idle	$408.34/hr	$290.22/hr	-28.9%

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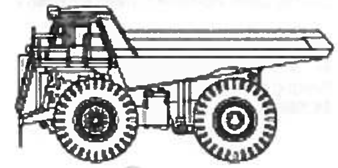
Custom Cost Evaluator

August 29, 2018

Komatsu HD1500-5 (disc. 2008)
Mechanical Drive Rear Dumps

Size Class:
105 - 139 MTons
Weight:
221,481 lbs.



Configuration for HD1500-5 (disc. 2008)

Net Horsepower	**1406 hp**	Power Mode	**Diesel**
Body Capacity (Struck–Heaped)	**71 cu yd - 102 cu yd**	Rated Payload	**136 mt**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$53.84/hr	$50.71/hr	-5.8%
Cost of Facilities Capital (CFC)	$11.40/hr	$9.64/hr	-15.4%
Overhead	$24.81/hr	$0.00/hr	-100%
Overhaul Labor	$35.45/hr	$13.37/hr	-62.3%
Overhaul Parts	$26.78/hr	$22.31/hr	-16.7%
Total Hourly Ownership Cost:	**$152.28/hr**	**$96.03/hr**	**-36.9%**

User Defined Adjustments: Annual Overhead ($45,902.04 -> $1.00) Annual Use Hours (1,850hrs -> 2,220hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$20.48/hr	$7.73/hr	-62.3%
Field Parts	$11.35/hr	$9.46/hr	-16.7%
Ground Engaging Component (GEC)	$0.00/hr	-	-
Tire	$24.57/hr	-	-
Electrical/Fuel	$84.64/hr	$63.13/hr	-25.4%
Lube	$19.17/hr	-	-
Total Operating Ownership Cost:	**$160.21/hr**	**$124.06/hr**	**-22.6%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$152.28/hr	$96.03/hr	-36.9%
Hourly Operating Costs	$160.21/hr	$124.06/hr	-22.6%
Total Hourly Cost	**$312.49**	**$220.09/hr**	**-29.6%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$90.05/hr	$60.35/hr	-33%
Idle	$236.92/hr	$159.16/hr	-32.8%

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August 29, 2018

Miscellaneous 48" X 60' - 516
Double Deck Portable Screening Plants

Size Class:
37" & Over
Weight:
24,800 lbs.

Configuration for 48" X 60' - 516

Screen Size	5' X 16'	Power Mode	Diesel
Horsepower	110	Conveyor Size	48" X 60'

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$10.28/hr	$9.72/hr	-5.4%
Cost of Facilities Capital (CFC)	$1.60/hr	$1.36/hr	-15%
Overhead	$3.56/hr	$0.00/hr	-100%
Overhaul Labor	$12.59/hr	$4.75/hr	-62.3%
Overhaul Parts	$7.71/hr	$6.42/hr	-16.7%
Total Hourly Ownership Cost:	**$35.74/hr**	**$22.25/hr**	**-37.7%**

User Defined Adjustments: Annual Overhead ($4,443.86 -> $1.00) Annual Use Hours (1,250hrs -> 1,500hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$13.99/hr	$5.28/hr	-62.3%
Field Parts	$7.12/hr	$5.94/hr	-16.6%
Ground Engaging Component (GEC)	$0.00/hr	-	-
Tire	$0.40/hr	-	-
Electrical/Fuel	$14.60/hr	$10.89/hr	-25.4%
Lube	$2.26/hr	-	-
Total Operating Ownership Cost:	**$38.37/hr**	**$24.77/hr**	**-35.4%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$35.74/hr	$22.25/hr	-37.7%
Hourly Operating Costs	$38.37/hr	$24.77/hr	-35.4%
Total Hourly Cost	**$74.11**	**$47.02/hr**	**-36.6%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$15.44/hr	$11.08/hr	-28.2%
Idle	$50.34/hr	$33.14/hr	-34.2%

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August 29, 2018

Miscellaneous 6000 330
Off-Highway Water Tanker Trucks

Size Class:
300 - 399 HP
Weight:
54,400 lbs.

Model Image

Configuration for 6000 330

Power Mode	**Diesel**	Horsepower	**330**
Tank Capacity	**6000 gal**		

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$22.90/hr	$21.43/hr	-6.4%
Cost of Facilities Capital (CFC)	$4.37/hr	$3.70/hr	-15.3%
Overhead	$7.31/hr	$0.00/hr	-100%
Overhaul Labor	$8.94/hr	$3.37/hr	-62.3%
Overhaul Parts	$5.85/hr	$4.88/hr	-16.6%
Total Hourly Ownership Cost:	**$49.37/hr**	**$33.38/hr**	**-32.4%**

User Defined Adjustments: Annual Overhead ($10,969.00 -> $1.00) Annual Use Hours (1,500hrs -> 1,800hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$21.96/hr	$8.28/hr	-62.3%
Field Parts	$10.69/hr	$8.91/hr	-16.7%
Ground Engaging Component (GEC)	$0.00/hr	-	-
Tire	$6.42/hr	-	-
Electrical/Fuel	$33.87/hr	$25.26/hr	-25.4%
Lube	$5.86/hr	-	-
Total Operating Ownership Cost:	**$78.80/hr**	**$54.73/hr**	**-30.5%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.2449) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$49.37/hr	$33.38/hr	-32.4%
Hourly Operating Costs	$78.80/hr	$54.73/hr	-30.5%
Total Hourly Cost	**$128.17**	**$88.11/hr**	**-31.3%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$34.58/hr	$25.13/hr	-27.3%
Idle	$83.24/hr	$58.64/hr	-29.6%

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August 29, 2018

Miscellaneous 48" X 60' - 516
Triple Deck Portable Screening Plants

Size Class:
37" & Over
Weight:
27,400 lbs.

Configuration for 48" X 60' - 516

Screen Size	**5' X 16'**	Power Mode	**Diesel**
Horsepower	**110**	Conveyor Size	**48" X 60'**

Hourly Ownership Costs

	Standard Value	User Adjusted Value	Variance
Depreciation	$10.88/hr	$10.28/hr	-5.5%
Cost of Facilities Capital (CFC)	$1.69/hr	$1.43/hr	-15.4%
Overhead	$3.76/hr	$0.00/hr	-100%
Overhaul Labor	$12.92/hr	$4.87/hr	-62.3%
Overhaul Parts	$8.08/hr	$6.73/hr	-16.7%
Total Hourly Ownership Cost:	**$37.33/hr**	**$23.31/hr**	**-37.6%**

User Defined Adjustments: Annual Overhead ($4,698.79 -> $1.00) Annual Use Hours (1,250hrs -> 1,500hrs) Sales Tax (5.1% -> 0%)

Hourly Operating Costs

	Standard Value	User Adjusted Value	Variance
Field Labor	$14.46/hr	$5.45/hr	-62.3%
Field Parts	$7.72/hr	$6.43/hr	-16.7%
Ground Engaging Component (GEC)	$0.00/hr	-	-
Tire	$0.39/hr	-	-
Electrical/Fuel	$14.60/hr	$10.87/hr	-25.5%
Lube	$2.31/hr	-	-
Total Operating Ownership Cost:	**$39.48/hr**	**$25.45/hr**	**-35.5%**

User Defined Adjustments: Diesel Cost (3.01 -> 2.24) Mechanics Wage ($58.29 -> $26.39)

Total

	Standard Value	User Adjusted Value	Variance
Hourly Ownership Costs	$37.33/hr	$23.31/hr	-37.6%
Hourly Operating Costs	$39.48/hr	$25.45/hr	-35.5%
Total Hourly Cost	**$76.81**	**$48.76/hr**	**-36.5%**

Non-active use rates

	Standard Value	User Adjusted Value	Variance
Standby	$16.33/hr	$11.71/hr	-28.3%
Idle	$51.93/hr	$34.18/hr	-34.2%

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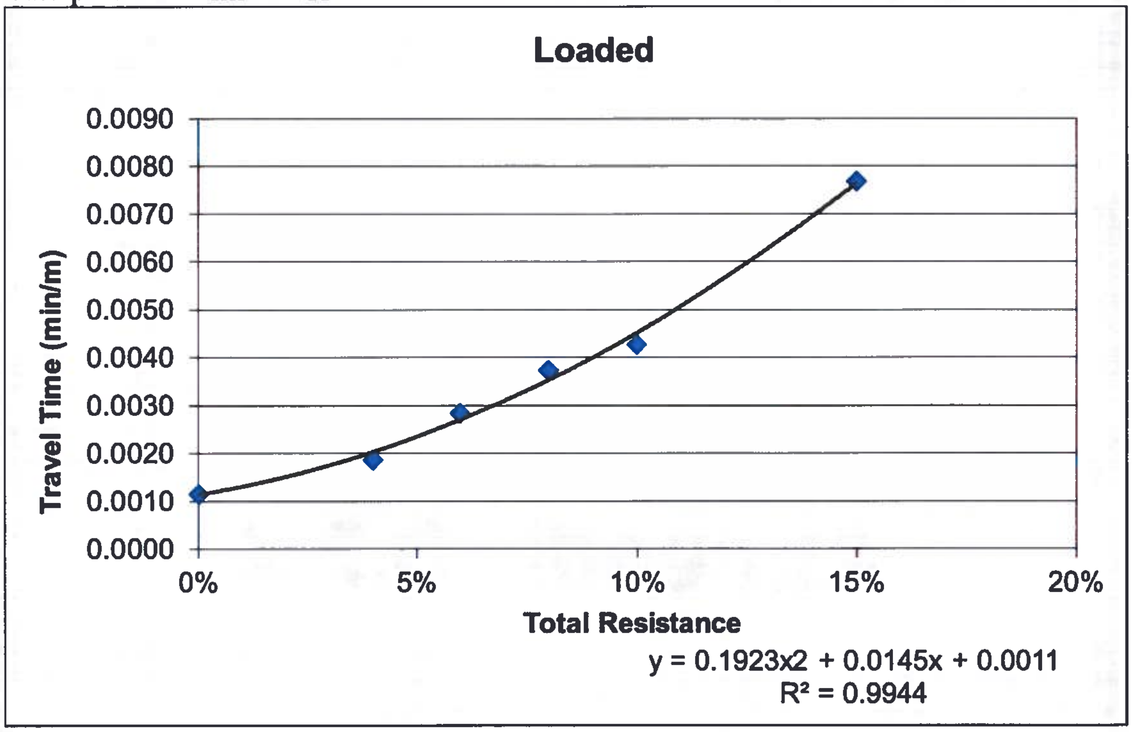
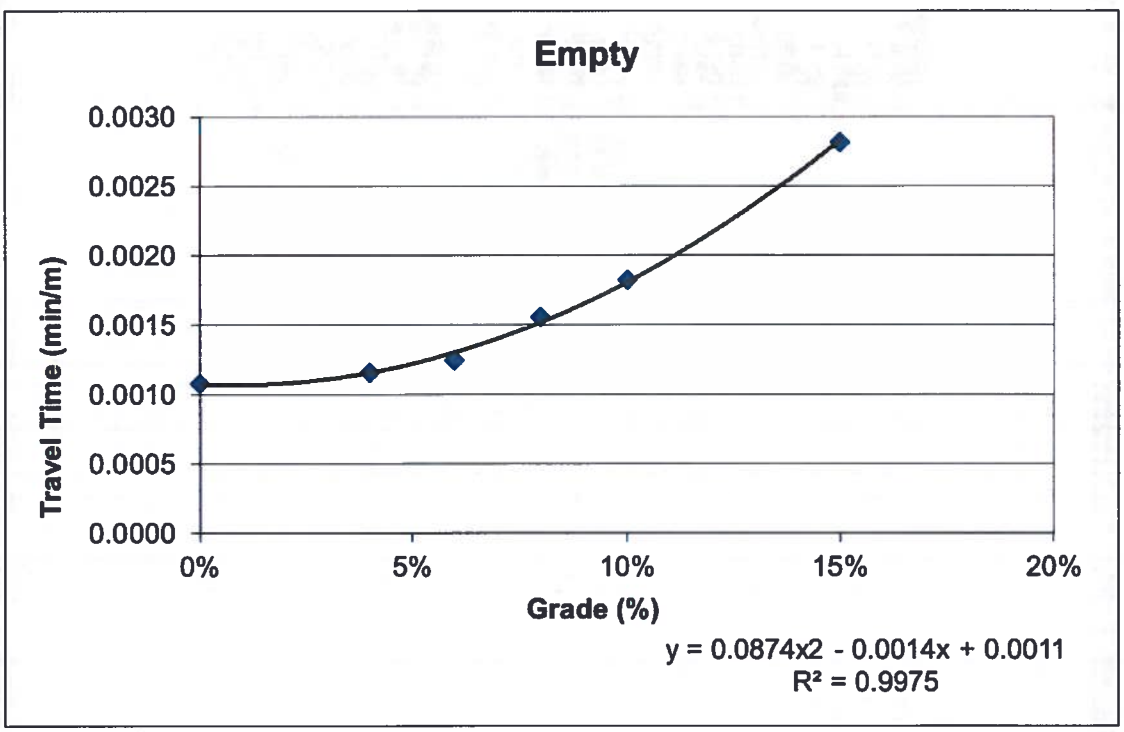
Appendix B.2.4

Equipment Curve Fits

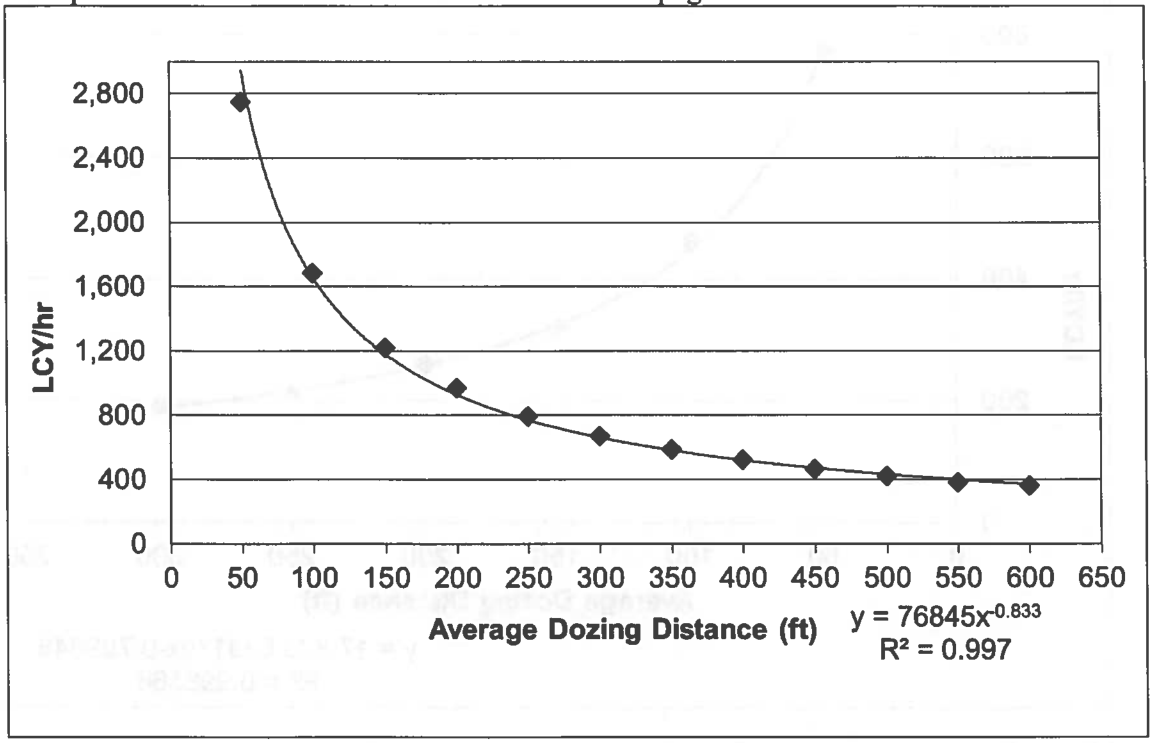
785
Caterpillar Performance Handbook Edition 41 9-42





D11T

Caterpillar Performance Handbook Edition 47 D11T page1-52



D9T

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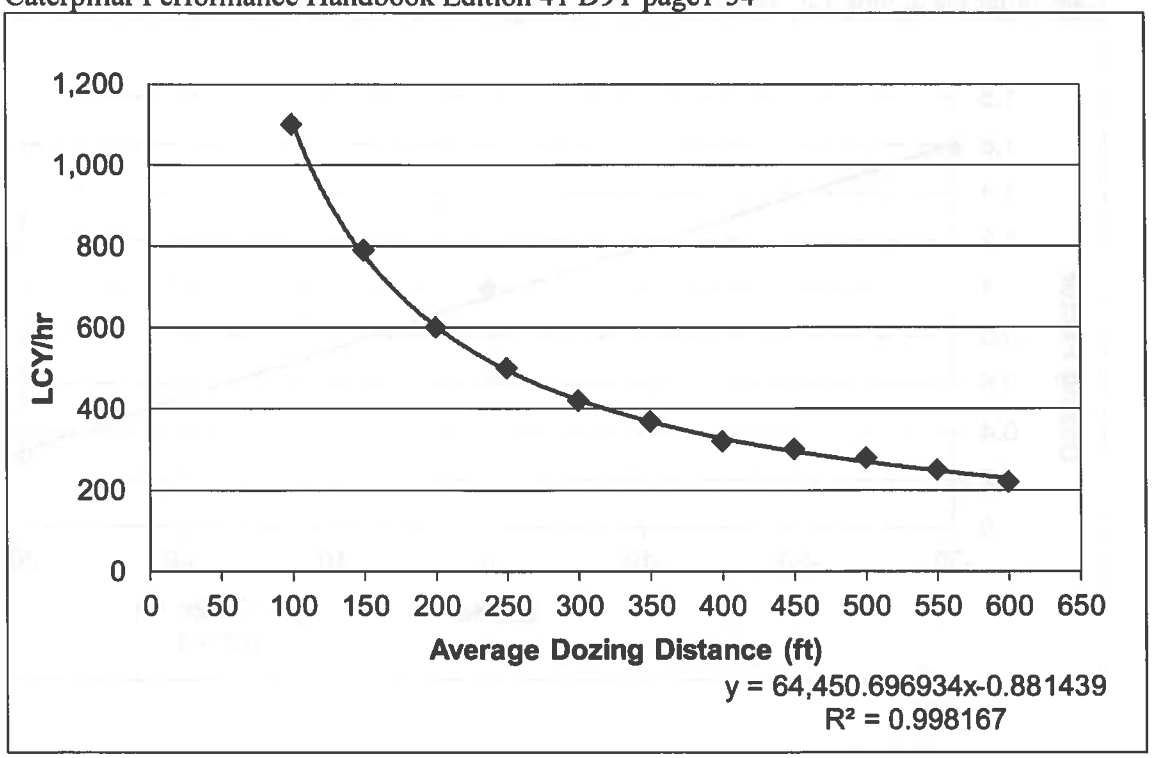

D6T

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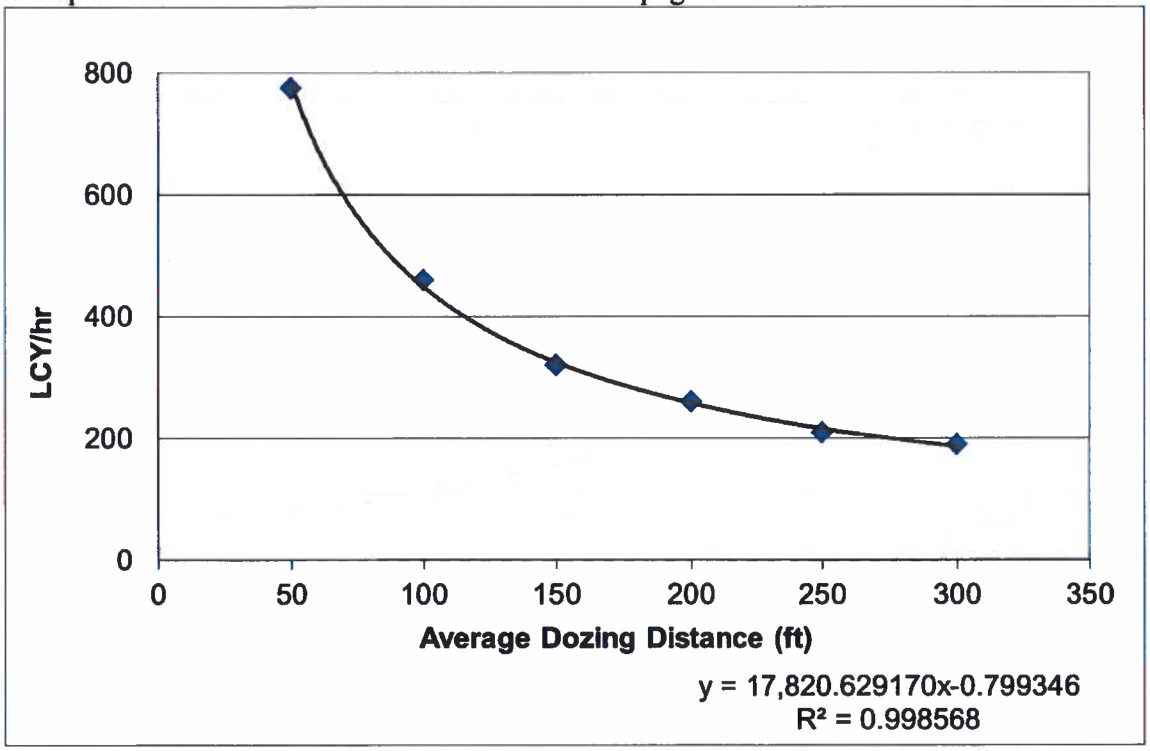

Dozing Factor
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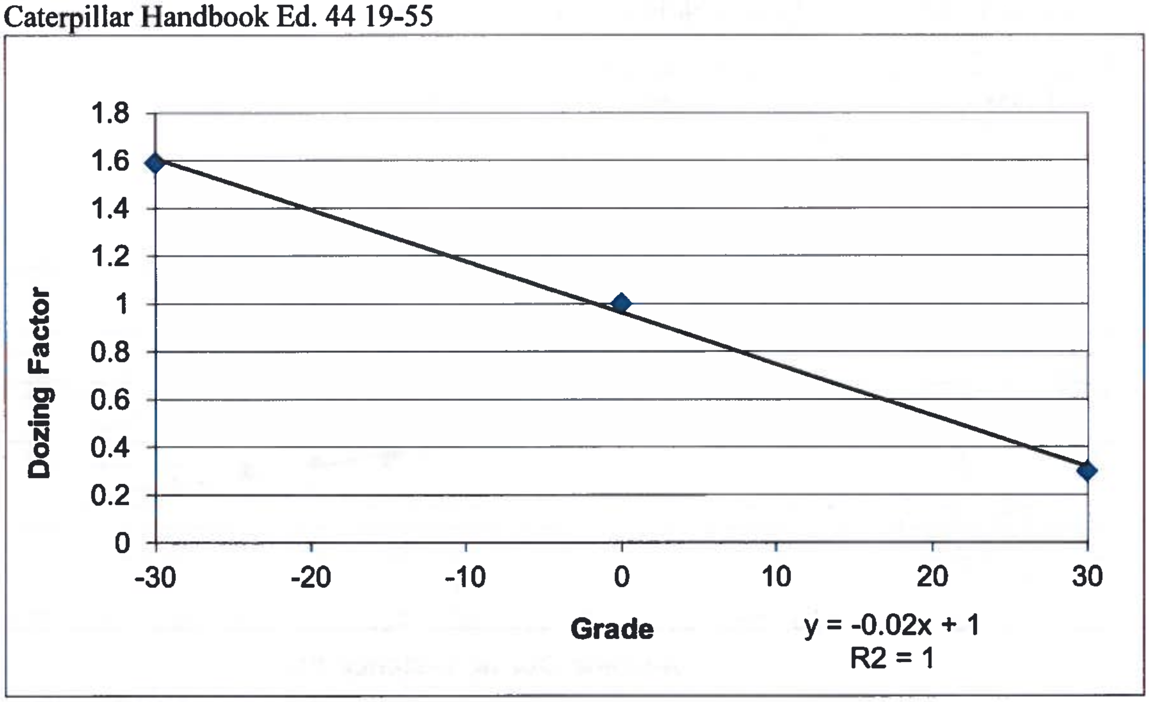

Appendix B.2.5

Misc. Caterpillar Handbook Sheets

CATERPILLAR PERFORMANCE HANDBOOK

a publication by Caterpillar, Peoria, Illinois, U.S.A.

JANUARY 2017

Performance information in this booklet is intended for estimating purposes only. Because of the many variables peculiar to individual jobs (including material characteristics, operator efficiency, underfoot conditions, altitude, etc.), neither Caterpillar nor its dealers warrant that the machines described will perform as estimated.

NOTE: Always refer to the appropriate Operation and Maintenance Manual for specific product information.

Materials and specifications are subject to change without notice.

SEBD0351-47

CATERPILLAR PERFORMANCE HANDBOOK

a publication by Caterpillar Inc., Peoria, Illinois, U.S.A.

JANUARY 2011

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Printed in U.S.A. SEBD0351-41

GENERAL

MINING AND EARTHMOVING

CONTENTS

INTRODUCTION

This section explains the earthmoving principles used to determine machine productivity. It shows how to calculate production on-the-job or estimate production off-the-job.

ELEMENTS OF PRODUCTION

Production is the hourly rate at which material is moved. Production can be expressed in various units:

Metric

Bank Cubic Meters — BCM — bank m³
Loose Cubic Meters — LCM — loose m³
Compacted Cubic Meters — CCM — compacted m³
Tonnes

English

Bank Cubic Yards — BCY — bank yd³
Loose Cubic Yards — LCY — loose yd³
Compacted Cubic Yards — CCY — compacted yd³
Tons

For most earthmoving and material handling applications, production is calculated by multiplying the quantity of material (load) moved per cycle by the number of cycles per hour.

Production = Load/cycle × cycles/hour

The load can be determined by
1) load weighing with scales
2) load estimating based on machine rating
3) surveyed volume divided by load count
4) machine payload measurement system

Generally, earthmoving and overburden removal for coal mines are calculated by volume (bank cubic meters or bank cubic yards). Metal mines and aggregate producers usually work in weight (tons or tonnes).

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Elements of Production
• Volume Measure • Swell • Load Factor • Material Density

Volume Measure — Material volume is defined according to its state in the earthmoving process. The three measures of volume are:

BCM (BCY) — one cubic meter (yard) of material as it lies in the natural bank state.

LCM (LCY) — one cubic meter (yard) of material which has been disturbed and has swelled as a result of movement.

CCM (CCY) — one cubic meter (yard) of material which has been compacted and has become more dense as a result of compaction.

In order to estimate production, the relationships between bank measure, loose measure, and compacted measure must be known.

Swell — Swell is the percentage of original volume (cubic meters or cubic yards) that a material increases when it is removed from the natural state. When excavated, the material breaks up into different size particles that do not fit together, causing air pockets or voids to reduce the weight per volume. For example to hold the same weight of one cubic unit of bank material it takes 30% more volume (1.3 times) after excavation. (Swell is 30%.)

$$1 + \text{Swell} = \frac{\text{Loose cubic volume for a given weight}}{\text{Bank cubic volume for the same given weight}}$$

$$\text{Bank} = \frac{\text{Loose}}{(1 + \text{Swell})}$$

$$\text{Loose} = \text{Bank} \times (1 + \text{Swell})$$

Example Problem:

If a material swells 20%, how many loose cubic meters (loose cubic yards) will it take to move 1000 bank cubic meters (1308 bank cubic yards)?

$$\text{Loose} = \text{Bank} \times (1 + \text{Swell}) =$$
$$1000 \text{ BCM} \times (1 + 0.2) = 1200 \text{ LCM}$$
$$1308 \text{ BCY} \times (1 + 0.2) = 1570 \text{ LCY}$$

How many bank cubic meters (yards) were moved if a total of 1000 loose cubic meters (1308 yards) have been moved? Swell is 25%.

$$\text{Bank} = \text{Loose} \div (1 + \text{Swell}) =$$
$$1000 \text{ LCM} \div (1 + 0.25) = 800 \text{ BCM}$$
$$1308 \text{ LCY} \div (1 + 0.25) = 1046 \text{ BCY}$$

Load Factor — Assume one bank cubic yard of material weighs 3000 lb. Because of material characteristics, this bank cubic yard swells 30% to 1.3 loose cubic yards when loaded, with no change in weight. If this 1.0 bank cubic yard or 1.3 loose cubic yards is compacted, its volume may be reduced to 0.8 compacted cubic yard, and the weight is still 3000 lb.

Instead of dividing by 1 + Swell to determine bank volume, the loose volume can be multiplied by the load factor.

If the percent of material swell is known, the load factor (L.F.) may be obtained by using the following relationship:

$$\text{L.F.} = \frac{100\%}{100\% + \%\text{ swell}}$$

Load factors for various materials are listed in the Tables Section of this handbook.

To estimate the machine payload in bank cubic yards, the volume in loose cubic yards is multiplied by the load factor:

$$\text{Load (BCY)} = \text{Load (LCY)} \times \text{L.F.}$$

The ratio between compacted measure and bank measure is called shrinkage factor (S.F.):

$$\text{S.F.} = \frac{\text{Compacted cubic yards (CCY)}}{\text{Bank cubic yards (BCY)}}$$

Shrinkage factor is either estimated or obtained from job plans or specifications which show the conversion from compacted measure to bank measure. Shrinkage factor should not be confused with percentage compaction (used for specifying embankment density, such as Modified Proctor or California Bearing Ratio [CBR]).

Material Density — Density is the weight per unit volume of a material. Materials have various densities depending on particle size, moisture content and variations in the material. The denser the material the more weight there is per unit of equal volume. Density estimates are provided in the Tables Section of this handbook.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}} = \frac{\text{kg (lb)}}{\text{m}^3\,(\text{yd}^3)}$$

$$\text{Weight} = \text{Volume} \times \text{Density}$$

A given material's density changes between bank and loose. One cubic unit of loose material has less weight than one cubic unit of bank material due to air pockets and voids. To correct between bank and loose use the following equations.

$$1 + \text{Swell} = \frac{\text{kg/BCM}}{\text{kg/LCM}} \text{ or } \frac{\text{lb/BCY}}{\text{lb/LCY}}$$

$$\text{lb/LCY} = \frac{\text{lb/BCY}}{(1 + \text{Swell})}$$

$$\text{lb/BCY} = \text{lb/LCY} \times (1 + \text{Swell})$$

Fill Factor — The percentage of an available volume in a body, bucket, or bowl that is actually used is expressed as the fill factor. A fill factor of 87% for a hauler body means that 13% of the rated volume is not being used to carry material. Buckets often have fill factors over 100%.

Example Problem:

A 14 cubic yard (heaped 2:1) bucket has a 105% fill factor when operating in a shot sandstone (4125 lb/BCY and a 35% swell).

a) What is the loose density of the material?
b) What is the usable volume of the bucket?
c) What is the bucket payload per pass in BCY?
d) What is the bucket payload per pass in tons?

a) lb/LCY = lb/BCY ÷ (1 + Swell) = 4125 ÷ (1.35) = 3056 lb/LCY
b) LCY = rated LCY × fill factor = 14 × 1.05 = 14.7 LCY
c) lb/pass = volume × density lb/LCY = 14.7 × 3056 = 44,923 lb
BCY/pass = weight ÷ density lb/BCY = 44,923 ÷ 4125 = 10.9 BCY
or bucket LCY from part b ÷ (1 + Swell) = 14.7 ÷ 1.35 = 10.9 BCY
d) tons/pass = lb ÷ 2000 lb/ton = 44,923 ÷ 2000 = 22.5 tons

Example Problem:

Construct a 10,000 compacted cubic yard (CCY) bridge approach of dry clay with a shrinkage factor (S.F.) of 0.80. Haul unit is rated 14 loose cubic yards struck and 20 loose cubic yards heaped.

a) How many bank yards are needed?
b) How many loads are required?

a) $\text{BCY} = \frac{\text{CCY}}{\text{S.F.}} = \frac{10{,}000}{0.80} = 12{,}500 \text{ BCY}$

b) Load (BCY) = Capacity (LCY) × Load factor (L.F.) = 20 × 0.81 = 16.2 BCY/Load
(L.F. of 0.81 from Tables)

$$\text{Number of loads required} = \frac{12{,}500 \text{ BCY}}{16.2 \text{ BCY/Load}} = 772 \text{ Loads}$$

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Soil Density Tests — There are a number of acceptable methods that can be used to determine soil density. Some that are currently in use are:

Nuclear density moisture gauge
Sand cone method
Oil method
Balloon method
Cylinder method

All these except the nuclear method use the following procedure:

1. Remove a soil sample from bank state.
2. Determine the volume of the hole.
3. Weigh the soil sample.
4. Calculate the bank density kg/BCM (lb/BCY).

The nuclear density moisture gauge is one of the most modern instruments for measuring soil density and moisture. A common radiation channel emits either neutrons or gamma rays into the soil. In determining soil density, the number of gamma rays absorbed and back scattered by soil particles is *indirectly* proportional to the soil density. When measuring moisture content, the number of moderated neutrons reflected back to the detector after colliding with hydrogen particles in the soil is *directly* proportional to the soil's moisture content.

All these methods are satisfactory and will provide accurate densities when performed correctly. Several repetitions are necessary to obtain an average.

NOTE: Several newer methods have been successfully applied, along with weigh scales to determine volume and loose density of material moved in hauler bodies. These measurements include photogrammatic and laser scanning technologies.

FIGURING PRODUCTION ON-THE-JOB

Load Weighing — The most accurate method of determining the actual load carried is by weighing. This is normally done by weighing the haul unit one wheel or axle at a time with portable scales. Any scales of adequate capacity and accuracy can be used. While weighing, the machine must be level to reduce error caused by weight transfer. Enough loads must be weighed to provide a good average. Machine weight is the sum of the individual wheel or axle weights.

The weight of the load can be determined using the empty and loaded weight of the unit.

Weight of load = gross machine weight – empty weight

To determine the bank cubic measure carried by a machine, the load weight is divided by the bankstate density of the material being hauled.

$$\text{BCY} = \frac{\text{Weight of load}}{\text{Bank density}}$$

Times Studies — To estimate production, the number of complete trips a unit makes per hour must be determined. First obtain the unit's cycle time with the help of a stop watch. Time several complete cycles to arrive at an average cycle time. By allowing the watch to run continuously, different segments such as load time, wait time, etc. can be recorded for each cycle. Knowing the individual time segments affords a good opportunity to evaluate the balance of the spread and job efficiency. The following is an example of a scraper load time study form. Numbers in the white columns are stop watch readings; numbers in the shaded columns are calculated:

Total Cycle Times (less delays)	Arrive Cut	Wait Time	Begin Load	Load Time	End Load	Begin Delay	Delay Time	End Delay
	0.00	0.30	0.30	0.60	0.90			
3.50	3.50	0.30	3.80	0.65	4.45			
4.00	7.50	0.35	7.85	0.70	8.55	9.95	1.00	10.95
4.00	12.50	0.42	12.92	0.68	13.60			

NOTE: All numbers are in minutes

This may be easily extended to include other segments of the cycle such as haul time, dump time, etc. Haul roads may be further segmented to more accurately define performance, including measured speed traps. Similar forms can be made for pushers, loaders, dozers, etc. *Wait Time* is the time a unit must wait for another unit so that the two can function together (haul unit waiting for pusher). *Delay Time* is any time, other than wait time, when a machine is not performing in the work cycle (scraper waiting to cross railroad track).

To determine trips-per-hour at 100% efficiency, divide 60 minutes by the average cycle time less all wait and delay time. Cycle time may or may not include wait and/or delay time. Therefore, it is possible to figure different kinds of production: measured production, production without wait or delay, maximum production, etc. For example:

Actual Production: includes all wait and delay time.

Normal Production (without delays): includes wait time that is considered normal, but no delay time.

Maximum Production: to figure maximum (or optimum) production, both wait time and delay time are eliminated. The cycle time may be further altered by using an optimum load time.

Example (English)

A job study of a Wheel Tractor-Scraper might yield the following information:

Average wait time	= 0.28 minute
Average load time	= 0.65
Average delay time	= 0.25
Average haul time	= 4.26
Average dump time	= 0.50
Average return time	= 2.09
Average total cycle	= 8.03 minutes
Less wait & delay time	= 0.53
Average cycle 100% eff.	= 7.50 minutes

Weight of haul unit empty — 48,650 lb

Weights of haul unit loaded —

Weighing unit #1 — 93,420 lb
Weighing unit #2 — 89,770 lb
Weighing unit #3 — 88,760 lb

271,950 lb;
average = 90,650 lb

1. Average load weight = 90,650 lb – 48,650 lb = 42,000 lb
2. Bank density = 3125 lb/BCY
3. $\text{Load} = \frac{\text{Weight of load}}{\text{Bank density}}$

   $= \frac{42{,}000 \text{ lb}}{3125 \text{ lb/BCY}} = 13.4 \text{ BCY}$
4. Cycles/hr =

   $\frac{60 \text{ min/hr}}{\text{Cycle time}} = \frac{60 \text{ min/hr}}{7.50 \text{ min/cycle}} = 80 \text{ cycles/hr}$
5. Production = Load/cycle × cycles/hr
   (less delays) = 13.4 BCY/cycle × 8.0 cycles/hr
   = 107.2 BCY/hr

Example (Metric)

A job study of a Wheel Tractor-Scraper might yield the following information:

Average wait time	= 0.28 minute
Average load time	= 0.65
Average delay time	= 0.25
Average haul time	= 4.26
Average dump time	= 0.50
Average return time	= 2.09
Average total cycle	= 8.03 minutes
Less wait & delay time	= 0.53
Average cycle 100% eff.	= 7.50 minutes

Weight of haul unit empty — 22 070 kg
Weights of haul unit loaded —
Weighing unit #1 — 42 375 kg
Weighing unit #2 — 40 720 kg
Weighing unit #3 — 40 260 kg
123 355 kg;
average = 41 120 kg

1. Average load weight = 41 120 kg – 22 070 kg = 19 050 kg
2. Bank density = 1854 kg/BCM
3. Load = $\frac{\text{Weight of load}}{\text{Bank density}}$

   $= \frac{19\,050 \text{ kg}}{1854 \text{ kg/BCM}} = 10.3 \text{ BCM}$
4. Cycles/hr =

   $\frac{60 \text{ min/hr}}{\text{Cycle time}} = \frac{60 \text{ min/hr}}{7.50 \text{ min/cycle}} = 80 \text{ cycles/hr}$
5. Production = Load/cycle × cycles/hr
   (less delays) = 10.3 BCM/cycle × 8.0 cycles/hr
   = 82 BCM/hrr

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ESTIMATING PRODUCTION OFF-THE-JOB

It is often necessary to estimate production of earthmoving machines which will be selected for a job. As a guide, the remainder of the section is devoted to discussions of various factors that may affect production. Some of the figures have been rounded for easier calculation.

Rolling Resistance (RR) is a measure of the force that must be overcome to roll or pull a wheel over the ground. It is affected by ground conditions and load — the deeper a wheel sinks into the ground, the higher the rolling resistance. Internal friction and tire flexing also contribute to rolling resistance. Experience has shown that minimum resistance is 1%-1.5% (see Typical Rolling Resistance Factors in Tables section) of the gross machine weight (on tires). A 2% base resistance is quite often used for estimating. Resistance due to tire penetration is approximately 1.5% of the gross machine weight for each inch of tire penetration (0.6% for each cm of tire penetration). Thus rolling resistance can be calculated using these relationships in the following manner:

RR = 2% of GMW + 0.6% of GMW per cm tire penetration

RR = 2% of GMW + 1.5% of GMW per inch tire penetration

It's *not* necessary for the tires to actually penetrate the road surface for rolling resistance to increase above the minimum. If the road surface flexes under load, the effect is nearly the same — the tire is always running "uphill." Only on very hard, smooth surfaces with a well compacted base will the rolling resistance approach the minimum.

When actual penetration takes place, some variation in rolling resistance can be noted with various inflation pressures and tread patterns.

NOTE: When figuring "pull" requirements for track-type tractors, rolling resistance applies only to the trailed unit's *weight on wheels.* Since track-type tractors utilize steel wheels moving on steel "roads," a tractor's rolling resistance is relatively constant and is accounted for in the Drawbar Pull rating.

Estimating Production Off-the-Job
• Grade Resistance
• Total Resistance
• Traction

Grade Resistance is a measure of the force that must be overcome to move a machine over unfavorable grades (uphill). Grade assistance is a measure of the force that assists machine movement on favorable grades (downhill).

Grades are generally measured in percent slope, which is the ratio between vertical rise or fall and the horizontal distance in which the rise or fall occurs. For example, a 1% grade is equivalent to a 1 m (ft) rise or fall for every 100 m (ft) of horizontal distance; a rise of 4.6 m (15 ft) in 53.3 m (175 ft) equals an 8.6% grade.

$$\frac{4.6 \text{ m (rise)}}{53.3 \text{ m (horizontal distance)}} = 8.6\% \text{ grade}$$

$$\frac{15 \text{ ft (rise)}}{175 \text{ ft (horizontal distance)}} = 8.6\% \text{ grade}$$

Uphill grades are normally referred to as adverse grades and downhill grades as favorable grades. Grade resistance is usually expressed as a positive (+) percentage and grade assistance is expressed as a negative (–) percentage.

It has been found that for each 1% increment of adverse grade an additional 10 kg (20 lb) of resistance must be overcome for each metric (U.S.) ton of machine weight. This relationship is the basis for determining the Grade Resistance Factor which is expressed in kg/metric ton (lb/U.S. ton):

Grade Resistance Factor = 10 kg/m ton × % grade
= 20 lb/U.S. ton × % grade

Grade resistance (assistance) is then obtained by multiplying the Grade Resistance Factor by the machine weight (GMW) in metric (U.S.) tons.

Grade Resistance = GR Factor × GMW in metric (U.S.) tons

Grade resistance may also be calculated using percentage of gross weight. This method is based on the relationship that grade resistance is approximately equal to 1% of the gross machine weight for 1% of grade.

Grade Resistance = 1% of GMW × % grade

Grade resistance (assistance) affects both wheel and track-type machines.

Total Resistance is the combined effect of rolling resistance (wheel vehicles) and grade resistance. It can be computed by summing the values of rolling resistance and grade resistance to give a resistance in kilogram (pounds) force.

Total Resistance = Rolling Resistance + Grade Resistance

Total resistance can also be represented as consisting completely of grade resistance expressed in percent grade. In other words, the rolling resistance component is viewed as a corresponding quantity of additional adverse grade resistance. Using this approach, total resistance can then be considered in terms of percent grade.

This can be done by converting the contribution of rolling resistance into a corresponding percentage of grade resistance. Since 1% of adverse grade offers a resistance of 10 kg (20 lb) for each metric or (U.S.) ton of machine weight, then each 10 kg (20 lb) of resistance per ton of machine weight can be represented as an additional 1% of adverse grade. Rolling resistance in percent grade and grade resistance in percent grade can then be summed to give Total Resistance in percent or Effective Grade. The following formulas are useful in arriving at Effective Grade.

Rolling Resistance (%) = 2% + 0.6% per cm tire penetration
= 2% + 1.5% per inch tire penetration
Grade Resistance (%) = % grade
Effective Grade (%) = RR (%) + GR (%)

Effective grade is a useful concept when working with Rimpull-Speed-Gradeability curves, Retarder curves, Brake Performance curves, and Travel Time curves.

Traction — is the driving force developed by a wheel or track as it acts upon a surface. It is expressed as usable Drawbar Pull or Rimpull. The following factors affect traction: weight on the driving wheel or tracks, gripping action of the wheel or track, and ground conditions. The coefficient of traction (for any roadway) is the ratio of the maximum pull developed by the machine to the total weight on the drivers.

$$\text{Coeff. of traction} = \frac{\text{Pull}}{\text{weight on drivers}}$$

Therefore, to find the usable pull for a given machine:
Usable pull = Coeff. of traction × weight on drivers

Example: Track-Type Tractor

What usable drawbar pull (DBP) can a 26 800 kg (59,100 lb) Track-type Tractor exert while working on firm earth? on loose earth? (See table section for coefficient of traction.)

Answer:
Firm earth — Usable DBP =
0.90 × 26 800 kg = 24 120 kg
(0.90 × 59,100 lb = 53,190 lb)
Loose earth — Usable DBP =
0.60 × 26 800 kg = 16 080 kg
(0.60 × 59,100 lb = 35,460 lb)

If a load required 21 800 kg (48,000 lb) pull to move it, this tractor could move the load on firm earth. However, if the earth were loose, the tracks would spin.

NOTE: D8R through D11R Tractors may attain higher coefficients of traction due to their suspended undercarriage.

Example: Wheel Tractor-Scraper

What usable rimpull can a 621F size machine exert while working on firm earth? on loose earth? The total loaded weight distribution of this unit is:

Drive unit	Scraper unit
wheels: 23 600 kg (52,000 lb)	wheels: 21 800 kg (48,000 lb)

Remember, use weight on drivers only.
Answer:
Firm earth — 0.55 × 23 600 kg = 12 980 kg
(0.55 × 52,000 lb = 28,600 lb)
Loose earth — 0.45 × 23 600 kg = 10 620 kg
(0.45 × 52,000 lb = 23,400 lb)

On firm earth this unit can exert up to 12 980 kg (28,600 lb) rimpull without excessive slipping. However, on loose earth the drivers would slip if more than 10 620 kg (23,400 lb) rimpull were developed.

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Altitude — Specification sheets show how much pull a machine can produce for a given gear and speed when the engine is operating at rated horsepower. When a standard machine is operated in high altitudes, the engine may require derating to maintain normal engine life. This engine deration will produce less drawbar pull or rimpull.

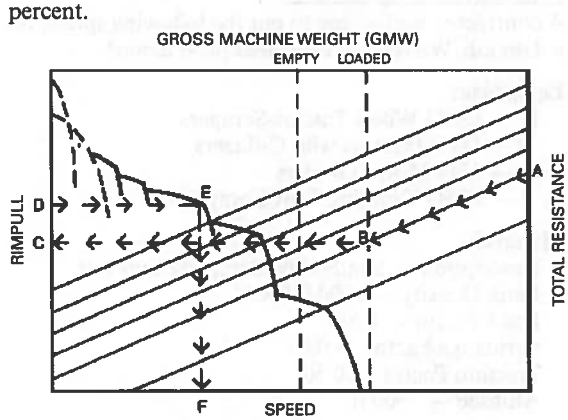
The Tables Section gives the altitude deration in percent of flywheel horsepower for current machines. It should be noted that some turbocharged engines can operate up to 4570 m (15,000 ft) before they require derating. Most machines are engineered to operate up to 1500-2290 m (5000-7500 ft) before they require deration.

The horsepower deration due to altitude must be considered in any job estimating. The amount of power deration will be reflected in the machine's gradeability and in the load, travel, and dump and load times (unless loading is independent of the machine itself). Altitude may also reduce retarding performance. Consult a Cat representative to determine if deration is applicable. Fuel grade (heat content) can have a similar effect of derating engine performance.

The example job problem that follows indicates one method of accounting for altitude deration: by increasing the appropriate components of the total cycle time by a percentage equal to the percent of horsepower deration due to altitude. (i.e., if the travel time of a hauling unit is determined to be 1.00 minute at full HP, the time for the same machine derated to 90% of full HP will be 1.10 min.) This is an approximate method that yields reasonably accurate estimates up to 3000 m (10,000 feet) elevation.

Travel time for hauling units derated more than 10% should be calculated as follows using Rimpull-Speed-Gradeability charts.

1) Determine total resistance (grade plus rolling) in percent.



2) Beginning at point A on the chart follow the total resistance line diagonally to its intersection, B, with the vertical line corresponding to the appropriate gross machine weight. (Rated loaded and empty GMW lines are shown dotted.)

3) Using a straight-edge, establish a horizontal line to the left from point B to point C on the rim-pull scale.

4) Divide the value of point C as read on the rim-pull scale by the percent of total horsepower available after altitude deration from the Tables Section. This yields rimpull value D higher than point C.

Estimating Production Off-the-Job
• Job Efficiency
• Example Problem (English)

5) Establish a horizontal line right from point D. The farthest right intersection of this line with a curved speed range line is point E.

6) A vertical line down from point E determines point F on the speed scale.

7) Multiply speed in kmh by 16.7 (mph by 88) to obtain speed in m/min (ft/min). Travel time in minutes for a given distance in feet is determined by the formula:

$$\text{Time (min)} = \frac{\text{Distance in m (ft)}}{\text{Speed in m/min (ft/min)}}$$

The Travel Time Graphs in sections on Wheel Tractor-Scrapers and Construction & Mining Trucks can be used as an alternative method of calculating haul and/or return times.

Job Efficiency is one of the most complex elements of estimating production since it is influenced by factors such as operator skill, minor repairs and adjustments, personnel delays, and delays caused by job layout. An approximation of efficiency, if no job data is available, is given below.

Operation	Working Hour	Efficiency Factor
Day	50 min/hr	0.83
Night	45 min/hr	0.75

These factors do not account for delays due to weather or machine downtime for maintenance and repairs. You must account for such factors based on experience and local conditions.

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The following example provides a method to manually estimate production and cost. Today, computer programs, such as Caterpillar's Fleet Production and Cost Analysis (FPC), provide a much faster and more accurate means to obtain those application results.

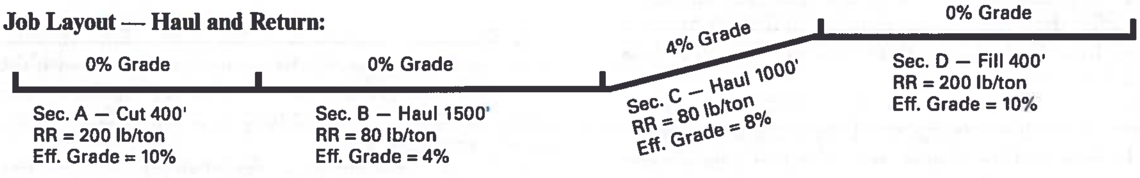
Example problem (English)

A contractor is planning to put the following spread on a dam job. What is the estimated production?

Equipment:
- 11 — 631G Wheel Tractor-Scrapers
- 2 — D9T Tractors with C-dozers
- 2 — 12H Motor Graders
- 1 — 825G Tamping Foot Compactor

Material:
- Description — Sandy clay; damp, natural bed
- Bank Density — 3000 lb/BCY
- Load Factor — 0.80
- Shrinkage Factor — 0.85
- Traction Factor — 0.50
- Altitude — 7500 ft

Job Layout — Haul and Return:



Total Effective Grade = RR (%) ± GR (%)

Sec. A: Total Effective Grade = 10% + 0% = 10%
Sec. B: Total Effective Grade = 4% + 0% = 4%
Sec. C: Total Effective Grade = 4% + 4% = 8%
Sec. D: Total Effective Grade = 10% + 0% = 10%

1. Estimate Payload:
Est. load (LCY) × L.F. × Bank Density = payload
31 LCY × 0.80 × 3000 lb/BCY = 74,400 lb payload

2. Establish Machine Weight:
Empty Wt. — 102,460 lb or 51.27 tons
Wt. of Load — 74,400 lb or 37.2 tons
Total (GMW) — 176,860 lb or 88.4 tons

3. Calculate Usable Pull (traction limitation):
Loaded: (weight on driving wheels = 54%) (GMW)
Traction Factor × Wt. on driving wheels =
0.50 × 176,860 lb × 54% = 47,628 lb
Empty: (weight on driving wheels = 69%) (GMW)
Traction Factor × Wt. on driving wheels =
0.50 × 102,460 lb × 69% = 35,394 lb

4. Derate for Altitude:
Check power available at 7500 ft from altitude deration table in the Tables Section.

631G — 100%	12H — 83%
D9T — 100%	825G — 100%

Then adjust if necessary:
Load Time — controlled by D9T, at 100% power, no change.
Travel, Maneuver and Spread time — 631G, no change.

5. Compare Total Resistance to Tractive Effort on haul:

Grade Resistance —
GR = lb/ton × tons × adverse grade in percent
Sec. C: = 20 lb/ton × 88.4 tons × 4% grade = 7072 lb

Rolling Resistance —
RR = RR Factor (lb/ton) × GMW (tons)
Sec. A: = 200 lb/ton × 88.4 tons = 17,686 lb
Sec. B: = 80 lb/ton × 88.4 tons = 7072 lb
Sec. C: = 80 lb/ton × 88.4 tons = 7072 lb
Sec. D: = 200 lb/ton × 88.4 tons = 17,686 lb

Total Resistance —
TR = RR + GR
Sec. A: = 17,686 lb + 0 = 17,686 lb
Sec. B: = 7072 lb + 0 = 7072 lb
Sec. C: = 7072 lb + 6496 lb = 14,144 lb
Sec. D: = 17,686 lb + 0 = 17,686 lb

Check usable pounds pull against maximum pounds pull required to move the 631G.
Pull usable … 47,628 lb loaded
Pull required … 17,686 lb maximum total resistance
Estimate travel time for haul from 631G (loaded) travel time curve; read travel time from distance and effective grade.
Travel time (from curves):
Sec. A: 0.60 min
Sec. B: 1.00
Sec. C: 1.20
Sec. D: 0.60
3.40 min

NOTE: This is an estimate only; it *does not account for all the acceleration and deceleration time*, therefore it is not as accurate as the information obtained from a computer program.

6. Compare Total Resistance to Tractive Effort on return:

Grade Assistance —
GA = 20 lb/ton × tons × negative grade in percent
Sec. C: = 20 lb/ton × 51.2 tons × 4% grade = 4096 lb

Rolling Resistance —
RR = RR Factor × Empty Wt (tons)
Sec. D: = 200 lb/ton × 51.2 tons = 10,240 lb
Sec. C: = 80 lb/ton × 51.2 tons = 4091 lb
Sec. B: = 80 lb/ton × 51.2 tons = 4091 lb
Sec. A: = 200 lb/ton × 51.2 tons = 10,240 lb

Total Resistance —
TR = RR – GA
Sec. D: = 10,240 lb – 0 = 10,240 lb
Sec. C: = 4096 lb – 4096 lb = 0
Sec. B: = 4096 lb – 0 = 4096 lb
Sec. A: = 10,240 lb – 0 = 10,240 lb

Check usable pounds pull against maximum pounds pull required to move the 631G.
Pounds pull usable … 35,349 lb empty
Pounds pull required … 10,240 lb
Estimate travel time for return from 631G empty travel time curve.
Travel time (from curves):
Sec. A: 0.40 min
Sec. B: 0.55
Sec. C: 0.80
Sec. D: 0.40
2.15 min

7. Estimate Cycle Time:

Total Travel Time (Haul plus Return)	= 5.55 min
Adjusted for altitude: 100% × 5.55 min	= 5.55 min
Load Time	0.7 min
Maneuver and Spread Time	0.7 min
Total Cycle Time	6.95 min

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8. Check pusher-scraper combinations:

Pusher cycle time consists of load, boost, return and maneuver time. Where actual job data is not available, the following may be used.

Boost time = 0.10 minute
Return time = 40% of load time
Maneuver time = 0.15 minute
Pusher cycle time = 140% of load time + 0.25 minute
Pusher cycle time = 140% of 0.7 min + 0.25 minute
= 0.98 + 0.25 = 1.23 minute

Scraper cycle time divided by pusher cycle time indicates the number of scrapers which can be handled by each pusher.

$$\frac{6.95 \text{ min}}{1.23 \text{ min}} = 5.65$$

Each push tractor is capable of handling five plus scrapers. Therefore the two pushers can adequately serve the eleven scrapers.

9. Estimate Production:

Cycles/hour = 60 min ÷ Total cycle time
= 60 min/hr ÷ 6.95 min/cycle
= 8.6 cycles/hr

Estimated load = Heaped capacity × L.F.
= 31 LCY × 0.80
= 24.8 BCY

Hourly unit production = Est. load × cycles/hr
= 24.8 BCY × 8.6 cycles/hr
= 213 BCY/hr

Adjusted production = Efficiency factor × hourly production
= 0.83 (50 min hour) × 213 BCY
= 177 BCY/hr

Hourly fleet production = Unit production × No. of units
= 177 BCY/hr × 11
= 1947 BCY/hr

10. Estimate Compaction:

Compaction requirement = S.F. × hourly fleet production
= 0.85 × 1947 BCY/hr
= 1655 CCY/hr

Compaction capability (given the following):

Compacting width, 7.4 ft (W)
Average compacting speed, 6 mph (S)
Compacted lift thickness, 7 in (L)
No. of passes required, 3 (P)

825G production =

$$\text{CCY/hr} = \frac{W \times S \times L \times 16.3}{P} \text{ (conversion constant)}$$

$$= \frac{7.4 \times 6 \times 7 \times 16.3}{3}$$

= 1688 CCY/hr

Given the compaction requirement of 1655 CCY/hr, the 825G is an adequate compactor match-up for the rest of the fleet. However, any change to job layout that would increase fleet production would upset this balance.

● ● ●

Example problem (Metric)

A contractor is planning to put the following spread on a dam job. What is the estimated production?

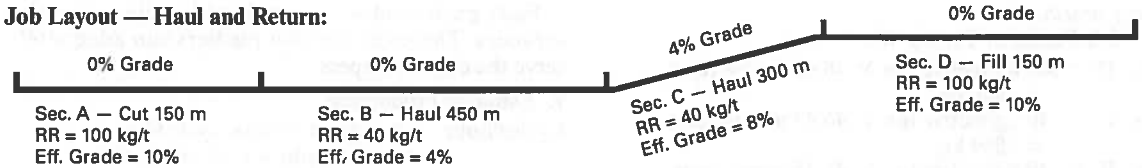
Equipment:

11 — 631G Wheel Tractor-Scrapers
2 — D9T Tractors with C-dozers
2 — 12H Motor Graders
1 — 825G Tamping Foot Compactor

Material:

Description — Sandy clay; damp, natural bed
Bank Density — 1770 kg/BCM
Load Factor — 0.80
Shrinkage Factor — 0.85
Traction Factor — 0.50
Altitude — 2300 meters

Job Layout — Haul and Return:



Total Effective Grade = RR (%) ± GR (%)
Sec. A: Total Effective Grade = 10% + 0% = 10%
Sec. B: Total Effective Grade = 4% + 0% = 4%
Sec. C: Total Effective Grade = 4% + 4% = 8%
Sec. D: Total Effective Grade = 10% + 0% = 10%

1. Estimate Payload:
Est. load (LCM) × L.F. × Bank Density = payload
24 LCM × 0.80 × 1770 kg/BCM = 34 000 kg payload

2. Machine Weight:
Empty Wt. — 46 475 kg or 46.48 metric tons
Wt. of Load — 34 000 kg or 34 metric tons
Total (GMW) — 80 475 kg or 80.48 metric tons

3. Calculate Usable Pull (traction limitation):
Loaded: (weight on driving wheels = 54%) (GMW)
Traction Factor × Wt. on driving wheels =
0.50 × 80 475 kg × 54% = 21 728 kg
Empty: (weight on driving wheels = 69%) (GMW)
Traction Factor × Wt. on driving wheels =
0.50 × 46 475 kg × 69% = 16 034 kg

4. Derate for Altitude:
Check power available at 2300 m from altitude deration table in the Tables Section.

631G — 100%	12H — 83%
D9T — 100%	825G — 100%

Then adjust if necessary:
Load Time — controlled by D9T, at 100% power, no change.
Travel, Maneuver and Spread time — 631G, no change.

5. Compare Total Resistance to Tractive Effort on haul:
Grade Resistance —
GR = 10 kg/metric ton × tons × adverse grade in percent
Sec. C: = 10 kg/metric ton × 80.48 metric tons × 4% grade = 3219 kg

Rolling Resistance —
RR = RR Factor (kg/mton) × GMW (metric tons)
Sec. A: = 100 kg/metric ton × 80.48 metric tons = 8048 kg
Sec. B: = 40 kg/metric ton × 80.48 metric tons = 3219 kg
Sec. C: = 40 kg/metric ton × 80.48 metric tons = 3219 kg
Sec. D: = 100 kg/metric ton × 80.48 metric tons = 8048 kg

Total Resistance —
TR = RR + GR
Sec. A: = 8048 kg + 0 = 8048 kg
Sec. B: = 3219 kg + 0 = 3219 kg
Sec. C: = 3219 kg + 3219 kg = 6438 kg
Sec. D: = 8048 kg + 0 = 8048 kg

Check usable kilogram force against maximum kilogram force required to move the 631G.
Force usable … 21 728 kg loaded
Force required … 8048 kg maximum total resistance

Estimate travel time for haul from 631G (loaded) travel time curve; read travel time from distance and effective grade.
Travel time (from curves):
Sec. A: 0.60 min
Sec. B: 1.00
Sec. C: 1.20
Sec. D: 0.60
3.40 min

NOTE: This is an estimate only; it *does not account for all the acceleration and deceleration time*, therefore it is not as accurate as the information obtained from a computer program.

6. Compare Total Resistance to Tractive Effort on return:
Grade Assistance —
GA = 10 kg/mton × metric tons × negative grade in percent
Sec. C: = 10 kg/metric ton × 46.48 metric tons × 4% grade = 1859 kg

Rolling Resistance —
RR = RR Factor × Empty Wt.

Sec. D: = 100 kg/metric ton × 46.48 metric tons
= 4648 kg
Sec. C: = 40 kg/metric ton × 46.48 metric tons
= 1859 kg
Sec. B: = 40 kg/metric ton × 46.48 metric tons
= 1859 kg
Sec. A: = 100 kg/metric ton × 46.48 metric tons
= 4648 kg

Total Resistance —
TR = RR – GA

Sec. D: = 4648 kg – 0 = 4648 kg
Sec. C: = 1859 kg – 1859 kg = 0
Sec. B: = 1859 kg – 0 = 1859 kg
Sec. A: = 4648 kg – 0 = 4648 kg

Check usable kilogram force against maximum force required to move the 631G.

Kilogram force usable ... 16 034 kg empty
Kilogram force required ... 4645 kg

Estimate travel time for return from 631G empty travel time curve.

Travel time (from curves):

Sec. A: 0.40 min
Sec. B: 0.55
Sec. C: 0.80
Sec. D: 0.40
2.15 min

7. Estimate Cycle Time:

Total Travel Time (Haul plus Return)	= 5.55 min
Adjusted for altitude: 100% × 5.55 min	= 5.55 min
Load Time	0.7 min
Maneuver and Spread Time	0.7 min
Total Cycle Time	6.95 min

8. Check pusher-scraper combinations:

Pusher cycle time consists of load, boost, return and maneuver time. Where actual job data is not available, the following may be used.

Boost time = 0.10 minute
Return time = 40% of load time
Maneuver time = 0.15 minute
Pusher cycle time = 140% of load time + 0.25 minute
Pusher cycle time = 140% of 0.7 min + 0.25 minute
= 0.98 + 0.25 = 1.23 minute

Scraper cycle time divided by pusher cycle time indicates the number of scrapers which can be handled by each pusher.

$$\frac{6.95 \text{ min}}{1.23 \text{ min}} = 5.65$$

Each push tractor is capable of handling five plus scrapers. Therefore the two pushers can adequately serve the eleven scrapers.

9. Estimate Production:

Cycles/hour = 60 min ÷ Total cycle time
= 60 min/hr ÷ 6.95 min/cycle
= 8.6 cycles/hr

Estimated load = Heaped capacity × L.F.
= 24 LCM × 0.80
= 19.2 BCM

Hourly unit production = Est. load × cycles/hr
= 19.2 BCM × 8.6 cycles/hr
= 165 BCM

Adjusted production = Efficiency factor × hourly production
= 0.83 (50 min hour) × 165 BCM
= 137 BCM/hour

Hourly fleet production = Unit production × No. of units
= 137 BCM/hr × 11 units
= 1507 BCM/hr

10. Estimate Compaction:

Compaction requirement = S.F. × hourly fleet production
= 0.85 × 1507 BCM/hr
= 1280 CCM/hr

Compaction capability (given the following):

Compacting width, 2.26 m	(W)
Average compacting speed, 9.6 km/h	(S)
Compacted lift thickness, 18 cm	(L)
No. of passes required, 3	(P)

825G production =

$$\text{CCY/hr} = \frac{W \times S \times L \times 10}{P} \text{ (conversion factor)}$$

$$= \frac{2.26 \times 9.6 \times 18 \times 10}{3}$$

= 1302

Given the compaction requirement of 1280 CCM/h, the 825G is an adequate compactor match-up for the rest of the fleet. However, any change to job layout that would increase fleet production would upset this balance.

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SYSTEMS

Caterpillar offers a variety of machines for different applications and jobs. Many of these separate machines function together in mining and earthmoving systems.

- Bulldozing with track-type tractors
- Load-and-Carry with wheel loaders
- Scrapers self-loading, elevator, auger, or push-pull configurations, or push-loaded by track-type tractors
- Articulated trucks loaded by excavators, track loaders or wheel loaders
- Off-highway trucks loaded by shovels, excavators or wheel loaders

Haul System Selection: In selecting a hauling system for a project, there may seem to be more than one "right" choice. Many systems may meet the distance, ground conditions, grade, material type, and production rate requirements. After considering all of the different factors, one hauling system usually provides better performance. This makes it critical for the dealer and customer to work together to get accurate information for their operation or project. Caterpillar is committed to providing the correct earthmoving system to match the customer's specific needs.

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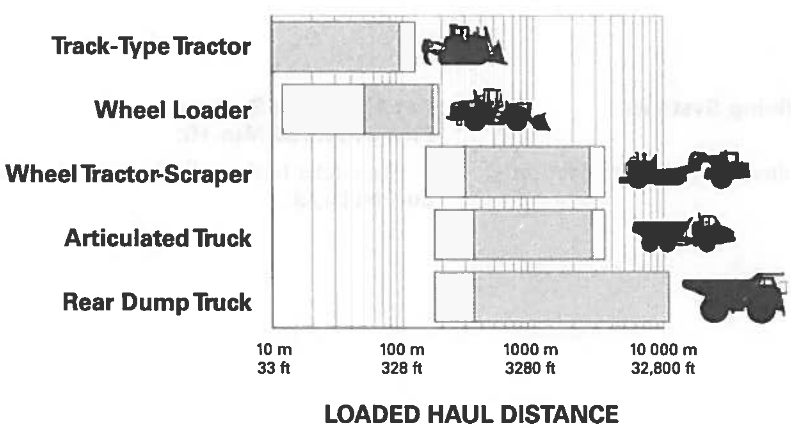
GENERAL LOADED HAUL DISTANCES FOR MOBILE SYSTEMS



PRODUCTION ESTIMATING

Loading Match — Loading tools have a production range that varies with material, bucket configuration, target size, operator skill and load area conditions. The loader/truck matches given in the following table are with the typical number of passes and production range.

Your Cat® dealer can provide advice and estimates based on your specific conditions.

FUEL CONSUMPTION AND PRODUCTIVITY

Fuel efficiency is the term used to relate fuel consumption and machine productivity. It is expressed in units of material moved per volume of fuel consumed. Common units are cubic meters or tonnes per liter of fuel (cubic yards or tons/gal). Determining fuel efficiency requires measuring both fuel consumption and production.

Measuring fuel consumption involves tapping into the vehicle's fuel supply system — without contaminating the fuel. The amount of fuel consumed during operation is then measured on a weight or volumetric basis and correlated with the amount of work the machine has done. Cat machines equipped with VIMS™ system can record fuel consumed with relative accuracy, given the engine is performing close to specifications.

Cat Earthmoving and Mining Systems Production/50 Min. Hr.

Please refer to the individual machine section for production targets.

Cat Aggregate Systems Production/50 Min. Hr.

Please refer to the individual machine section for production targets.

FORMULAS AND RULES OF THUMB

Production, hourly = Load (BCM)/cycle × cycles/hr
= Load (BCY)/cycle × cycles/hr

Load Factor (L.F.) $= \dfrac{100\%}{100\% + \%\ \text{swell}}$

Load (bank measure) = Loose cubic meters (LCM) × L.F.
= Loose cubic yards (LCY) × L.F.

Shrinkage Factor (S.F.) $= \dfrac{\text{Compacted cubic meters (or yards)}}{\text{Bank cubic meters (or yards)}}$

Density = Weight/Unit Volume

Load (bank measure) $= \dfrac{\text{Weight of load}}{\text{Bank density}}$

Rolling Resistance Factor
= 20 kg/t + (6 kg/t/cm × cm)
= 40 lb/ton + (30 lb/ton/inch × inches)

Rolling Resistance
= RR Factor (kg/t) × GMW (tons)
= RR Factor (lb/ton) × GMW (tons)

Rolling Resistance (general estimation)
= 2% of GMW + 0.6% of GMW per cm tire penetration
= 2% of GMW + 1.5% of GMW per inch tire penetration

$\%\ \text{Grade} = \dfrac{\text{vertical change in elevation (rise)}}{\text{corresponding horizontal distance (run)}}$

Grade Resistance Factor = 10 kg/m ton × % grade
= 20 lb/ton × % grade

Grade Resistance = GR Factor (kg/t) × GMW (tons)
= GR Factor (lb/ton) × GMW (tons)

Grade Resistance = 1% of GMW × % grade

Total Resistance
= Rolling Resistance (kg or lb) + Grade Resistance (kg or lb)

Total Effective Grade (%) = RR (%) + GR (%)

Usable pull (traction limitation)
= Coeff. of traction × weight on drivers
= Coeff. of traction × (Total weight × % on drivers)

Pull required = Rolling Resistance + Grade Resistance
= Total Resistance

Total Cycle Time = Fixed time + Variable time

Fixed time: See respective machine production section.

Variable time = Total haul time + Total return time

Travel Time $= \dfrac{\text{Distance (m)}}{\text{Speed (m/min)}}$
$= \dfrac{\text{Distance (ft)}}{\text{Speed (fpm)}}$

Cycles per hour $= \dfrac{\text{60 min/hr}}{\text{Total cycle time (min/cycle)}}$

Adjusted production = Hourly production × Efficiency factor

No. of units required $= \dfrac{\text{Hourly production required}}{\text{Unit hourly production}}$

No. of scrapers a pusher will load $= \dfrac{\text{Scraper cycle time}}{\text{Pusher cycle time}}$

Pusher cycle time (min) = 1.40 Load time (min) + 0.25 min

Grade Horsepower $= \dfrac{\text{GMW (kg)} \times \text{Total Effective Grade} \times \text{Speed (km/h)}}{273.75}$
$= \dfrac{\text{GMW (lb)} \times \text{Total Effective Grade} \times \text{Speed (mph)}}{375}$

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Notes —

BUCKET FILL FACTORS

Loose Material	Fill Factor
Mixed Moist Aggregates	95-100%
Uniform Aggregates up to 3 mm (1/8")	95-100
3 mm-9 mm (1/8"-3/8")	90-95
12 mm-20 mm (1/2"-3/4")	85-90
24 mm (1") and over	85-90
Blasted Rock	
Well Blasted	80-95%
Average Blasted	75-90
Poorly Blasted	60-75
Other	
Rock Dirt Mixtures	100-120%
Moist Loam	100-110
Soil, Boulders, Roots	80-100
Cemented Materials	85-95

NOTE: Loader bucket fill factors are affected by bucket penetration, breakout force, rack back angle, bucket profile and ground engaging tools such as bucket teeth or bolt-on replaceable cutting edges.

NOTE: For bucket fill factors for hydraulic excavators, see bucket payloads in the hydraulic excavator section.

NOTE: Above values are not valid for Hydraulic Mining Shovels.

ANGLE OF REPOSE OF VARIOUS MATERIALS

MATERIAL	ANGLE BETWEEN HORIZONTAL AND SLOPE OF HEAPED PILE	
	Ratio	Degrees
Coal, industrial	1.4:1—1.3:1	35-38
Common earth, Dry	2.8:1—1.0:1	20-45
Moist	2.1:1—1.0:1	25-45
Wet	2.1:1—1.7:1	25-30
Gravel, Round to angular	1.7:1—0.9:1	30-50
Sand & clay	2.8:1—1.4:1	20-35
Sand, Dry	2.8:1—1.7:1	20-30
Moist	1.8:1—1.0:1	30-45
Wet	2.8:1—1.0:1	20-45

TYPICAL ROLLING RESISTANCE FACTORS

Various tire sizes and inflation pressures will greatly reduce or increase the rolling resistance. The values in this table are approximate, particularly for the track and track + tire machines. These values can be used for estimating purposes when specific performance information on particular equipment and given soil conditions is not available. See Mining and Earthmoving Section for more detail.

UNDERFOOTING	ROLLING RESISTANCE, PERCENT*			
	Tires		Track	Track
	Bias	Radial	**	+Tires
A very hard, smooth roadway, concrete, cold asphalt or dirt surface, no penetration or flexing	1.5%*	1.2%	0%	1.0%
A hard, smooth, stabilized surfaced roadway without penetration under load, watered, maintained	2.0%	1.7%	0%	1.2%
A firm, smooth, rolling roadway with dirt or light surfacing, flexing slightly under load or undulating, maintained fairly regularly, watered	3.0%	2.5%	0%	1.8%
A dirt roadway, rutted or flexing under load, little maintenance, no water, 25 mm (1") tire penetration or flexing	4.0%	4.0%	0%	2.4%
A dirt roadway, rutted or flexing under load, little maintenance, no water, 50 mm (2") tire penetration or flexing	5.0%	5.0%	0%	3.0%
Rutted dirt roadway, soft under travel, no maintenance, no stabilization, 100 mm (4") tire penetration or flexing	8.0%	8.0%	0%	4.8%
Loose sand or gravel	10.0%	10.0%	2%	7.0%
Rutted dirt roadway, soft under travel, no maintenance, no stabilization, 200 mm (8") tire penetration and flexing	14.0%	14.0%	5%	10.0%
Very soft, muddy, rutted roadway, 300 mm (12") tire penetration, no flexing	20.0%	20.0%	8%	15.0%

*Percent of combined machine weight.

**Assumes drag load has been subtracted to give Drawbar Pull for good to moderate conditions. Some resistance added for very soft conditions.

MOTO GRADERS

MODEL	14M3		16M3	
Base Power — Net	178 kW	238 hp	216 kW	290 hp
VHP Range — Net	178-213 kW	238-285 hp	216-259 kW	290-348 hp
VHP Plus Range — Net	180-215 kW	241-289 hp	—	
Operating Weight*	25 968 kg	57,250 lb	32 411 kg	71,454 lb
Engine Model	C13 ACERT		C13 ACERT	
Rated Engine RPM	1850		2000	
No. of Cylinders	6		6	
Displacement	12.5 L	763 in³	12.5 L	763 in³
Max. Torque:				
Tier 4 Final[1]	1542 N·m	1137 lb-ft	1771 N·m	1306 lb-ft
Tier 2 and Tier 3 Equivalent[2]	1542 N·m	1137 lb-ft	1721 N·m	1270 lb-ft
No. of Speeds Forward/Reverse	8/6		8/6	
Top Speed: Forward	50.5 km/h	31.4 mph	51.7 km/h	32.1 mph
Reverse	39.9 km/h	24.8 mph	40.8 km/h	25.3 mph
Std. Tires — Front and Rear	20.5R25		23.5R25	
Front Axle/Steering:				
Oscillation Angle	32°		35°	
Wheel Lean Angle — Left/Right	17.1°/17.1°		18°/17°	
Steering Angle	50°		47.5°	
Articulation Angle	20°		20°	
Minimum Turning Radius**	7.9 m	25'11"	9.3 m	30'6"
No. Circle Support Shoes	6		6	
Hydraulics:				
Pump Type	Variable Piston		Variable Piston	
Max. Pump Flow	257 L/min	68 gpm	280 L/min	74 gpm
Tank Capacity	64 L	16.9 U.S. gal	70 L	18.5 U.S. gal
Implement Pressure: Max.	24 100 kPa	3495 psi	24 750 kPa	3590 psi
Min.	3400 kPa	493 psi	3400 kPa	493 psi
Interior Sound Level/SAE J919:				
Tier 4 Final/EU Certified[1]	73 dB(A)		71 dB(A)	
Tier 2 and Tier 3 Equivalent[2]	73 dB(A)		72 dB(A)	
Electrical:				
System Size	24V		24V	
Std. Battery CCA @ 0° F	1125		1400	
Std. Alternator	150		150	
GENERAL DIMENSIONS:				
Height (to top of ROPS)	3566 mm	140.4"	3719 mm	146.4"
Overall Length	9677 mm	381"	10 593 mm	417"
With Ripper and Pushplate	10 899 mm	429.1"	12 051 mm	474.4"
Wheelbase	6616 mm	260.5"	7365 mm	290"
Blade Base	2880 mm	113.4"	3066 mm	120.7"
Overall Width (at top of front tires)	3050 mm	120.1"	3411 mm	134.3"
Standard Blade: Length	4267 mm	14'0"	4877 mm	16'0"
Height	585 mm	23.0"	787 mm	31.0"
Thickness	25.4 mm	1.0"	25 mm	1.0"
Lift Above Ground	438 mm	17.2"	400 mm	15.7"
Max. Shoulder Reach:***				
Frame Straight — Left	3460 mm	136.2"	2311 mm	91"
Frame Straight — Right	3350 mm	131.9"	2311 mm	91"
Fuel Tank Capacity	416 L	109.9 U.S. gal	496 L	131 U.S. gal

***Operating Weight** — based on standard machine configuration with full fuel tank, coolant, lubricants and operator.
****Minimum Turning Radius** — combining the use of articulated frame steering, front wheel steer and unlocked differential.
***Applicable for the standard blade with hydraulic sideshift and tip control. Maximum shoulder reach is obtainable to the right.
[1] Meets Tier 4 Final/Stage IV/Japan 2014 (Tier 4 Final) emission standards.
[2] Meets Tier 2/Stage II/Japan 2001 (Tier 2) equivalent and Tier 3/Stage IIIA/Japan 2006 (Tier 3) equivalent emission standards.

PRODUCTION

The motor grader is used in a variety of applications in a variety of industries. Therefore, there are many ways to measure its operating capacity, or production. One method expresses a motor grader's production in relation to the area covered by the moldboard.

Formula:

$$A = S \times (L_e - L_o) \times 1000 \times E \quad \text{(Metric)}$$
$$A = S \times (L_e - L_o) \times 5280 \times E \quad \text{(English)}$$

where
- A: Hourly operating area (m^2/h or ft^2/h)
- S: Operating speed (km/h or mph)
- L_e: Effective blade length (m or ft)
- L_o: Width of overlap (m or ft)
- E: Job efficiency

Operating Speeds:

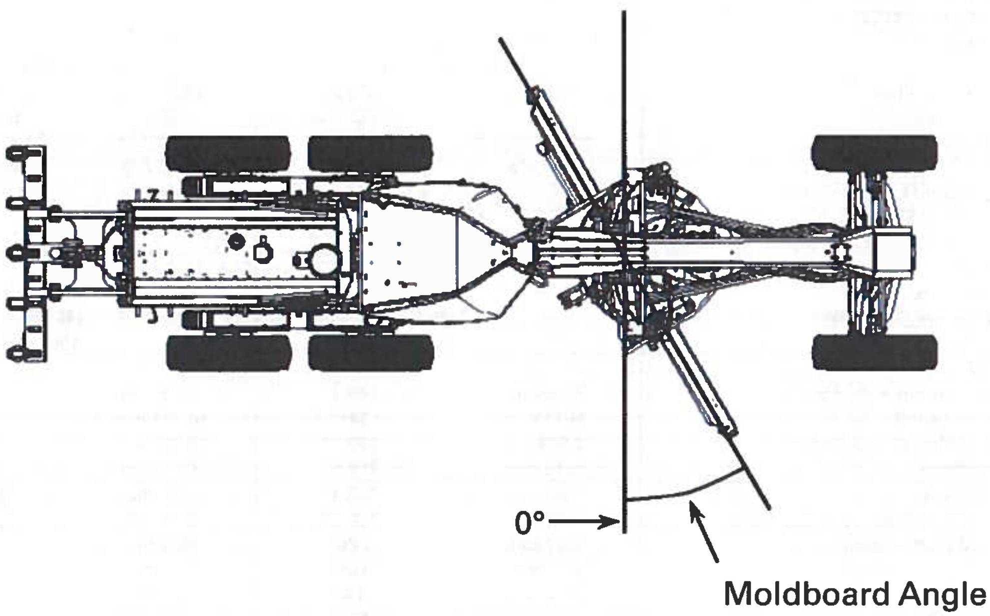
Typical operating speeds by application

Finish Grading:	0-4 km/h	(0-2.5 mph)
Heavy Blading:	0-9 km/h	(0-6 mph)
Ditch Repair:	0-5 km/h	(0-3 mph)
Ripping:	0-5 km/h	(0-3 mph)
Road Maintenance:	5-16 km/h	(3-9.5 mph)
Haul Road Maintenance:	5-16 km/h	(3-9.5 mph)
Snow Plowing:	7-21 km/h	(4-13 mph)
Snow Winging:	15-28 km/h	(9-17 mph)

Effective Blade Length:

Since the moldboard is usually angled when moving material, an effective blade length must be computed to account for this angle. This is the actual width of material swept by the moldboard.

NOTE: Angles are measured as shown below. The effective length becomes shorter as the angle increases.



Moldboard Length, m (ft)	Effective Length, m (ft) 30 degree blade angle	Effective Length, m (ft) 45 degree blade angle
3.658 (12)	3.17 (10.4)	2.59 (8.5)
4.267 (14)	3.70 (12.1)	3.02 (9.9)
4.877 (16)	4.22 (13.9)	3.45 (11.3)
7.315 (24)	6.33 (20.8)	5.17 (17.0)

For other blade lengths and carry angles:
Effective length = COS [Radians (Blade L)] 3 Blade Length

Width of Overlap:

The width of overlap is generally 0.6 m (2.0 ft). This overlap accounts for the need to keep the tires out of the windrow on the return pass.

Job Efficiency:

Job efficiencies vary based on job conditions, operator skill, etc.

A good estimation for efficiency is approximately 0.70 to 0.85, but actual operating conditions should be used to determine the best value.

Example problem:

A Cat motor grader with a 3.66 m (12 ft) moldboard is performing road maintenance on a township road. The machine is working at an average speed of 13 km/h (8 mph) with a moldboard carry angle of 30 degrees. What is the motor grader's production based on coverage area?

Note: Due to the long passes involved in road maintenance — fewer turnarounds — a higher job efficiency of 0.90 is chosen.

Solution:

From the table, the effective blade length is 3.17 m (10.4 ft).

Metric

Production, A = 13 km/h × (3.17 m – 0.6 m) × 1000 × 0.90
= **30 069 m^2/hr (3.07 hectares/hr)**

English

Production, A = 8 mph × (10.4 ft – 2.0 ft) × 5280 × 0.90
= **319,334 ft^2/hr (7.33 acres/hr)**

To pinpoint the theoretical number of motor graders required to properly maintain your haul roads, based on your specific mining applications, please download the haul road maintenance calculator on *https://catminer.cat.com.*

Haul road maintenance impacts cycle time, tire, frame and drive train components, safety and ultimately your cost per ton. To achieve optimal truck productivity, your haul roads must be properly maintained.

Moderate:
- Road Maintenance
- Pad Cleaning
- Rock Clearing
- Shoulder Sweeping

Difficult:
- Ripping
- Spreading Dump Material
- Road Profiling/Reshaping

BLADE PULL

This specification is also known as drawbar pull. This spec can be calculated as follows:

Variables:

Rear weight of machine = Wr

Tire traction coefficient = T (Look up the table entitled "Coefficient of Traction Factors")

Wr × T = Blade Pull

Example problem:

Calculate the blade pull for a 140M Global Version version machine operating in a quarry pit...

Metric

RW = 10 501 kg

T = 0.65

10 501 × 0.65 = 6825.65

English

RW = 23,151 lb

T = 0.65

23,151 × 0.65 = 15,048.15

BLADE DOWN PRESSURE

This spec can be calculated as follows:

Variables:

Blade to front axle length = BA

Wheel base length = WB

Weight on front wheels = FW

Blade down pressure = BD

$$\frac{WB}{(WB - BA)} \times FW = BD$$

Example problem:

Calculate the blade down pressure for a 140M Global Version version machine...

Metric

BA = 2565 mm FW = 4223 kg

WB = 6086 mm BD = ?

$$\frac{6086}{(6086 - 2565)} \times 4223 = 7299 \text{ kg}$$

English

BA = 101 in FW = 9310 lb

WB = 240 in BD = ?

$$\frac{240}{(240 - 101)} \times 9310 = 16{,}075 \text{ lb}$$

This specification is only a minor indicator of a motor grader's productivity. It alone gives no measure of overall machine productivity. When considering motor grader production you need an optimum balance between the machine's front and rear weights. If a machine has too much weight on the front axle, it might have a high blade down pressure spec. It will, however, lack the essential rear weight and traction needed to push through the load. Too much weight in the rear and it will not have the necessary weight in the front during heavy cuts to maintain proper steering control.

Cat machines are built with this optimum balance in mind. A Cat motor grader is engineered with the proper weight distribution necessary for maximum productivity.

Effective Blade Length*

	Moldboard							
	3.66 m (12')		4.27 m (14')		4.88 m (16')		7.32 m (24')	
Angle°	m	ft	m	ft	m	ft	m	ft
0°	3.66	**12.00**	4.27	**14.00**	4.88	**16.00**	7.32	**24.00**
5°	3.64	**11.95**	4.25	**13.95**	4.86	**15.94**	7.29	**23.91**
10°	3.60	**11.82**	4.20	**13.79**	4.80	**15.76**	7.21	**23.64**
15°	3.53	**11.59**	4.12	**13.52**	4.71	**15.45**	7.07	**23.18**
20°	3.44	**11.28**	4.01	**13.16**	4.58	**15.04**	6.87	**22.55**
25°	3.32	**10.88**	3.87	**12.69**	4.42	**14.50**	6.63	**21.75**
30°	3.17	**10.39**	3.69	**12.12**	4.22	**13.86**	6.33	**20.78**
35°	3.00	**9.83**	3.50	**11.47**	4.00	**13.11**	5.99	**19.66**
40°	2.80	**9.19**	3.27	**10.72**	3.74	**12.26**	5.61	**18.39**
45°	2.59	**8.49**	3.02	**9.90**	3.45	**11.31**	5.17	**16.97**

*Effective blade length is the amount of blade coverage the machine is capable of when the blade is at a given angle.

11

EXTREME SLOPE OPERATION

There are two ways of defining slope work. The slope perpendicular to the machine's direction of travel is commonly referred to as "Side Sloping." The slope parallel to the machine's direction of travel — the machines ability to travel up or down terrain, is commonly referred to as "Gradeability."

Side Sloping capability for our Cat graders is somewhat subjective, but general agreement among professional operators is that working on a slope ratio of 2.5:1 (21.8 degrees) is the safe limit … an experienced operator may be able to operate on a 2:1 (28 degrees) slope. Many factors influence this limit such as operator experience, machine configuration, tires and soil conditions, but a 2.5:1 is achievable. Further, a 3:1 slope is the approximate maximum side slope a grader can work on in straight frame configuration. The steeper side slopes all require the machine be articulated to safely navigate the slope.

Gradeability is approximately 22 degrees. This is established by the grader's ability to stop without skidding the tires while moving downhill. The motor grader can, however, *climb* grades steeper than 22 degrees. The traction coefficient is the critical factor in determining whether a grader can safely navigate the slope. Caterpillar recommends that you never climb a slope steeper than you can safely descend.

Maximum lubrication angle: We have measured the graders on a tilt table and pump cavitation occurs around 30 degrees (58% or 1.7:1). This is beyond the grade or slope a motor grader can operate on.

When working side hills and slopes, consideration should be given to the following important points.

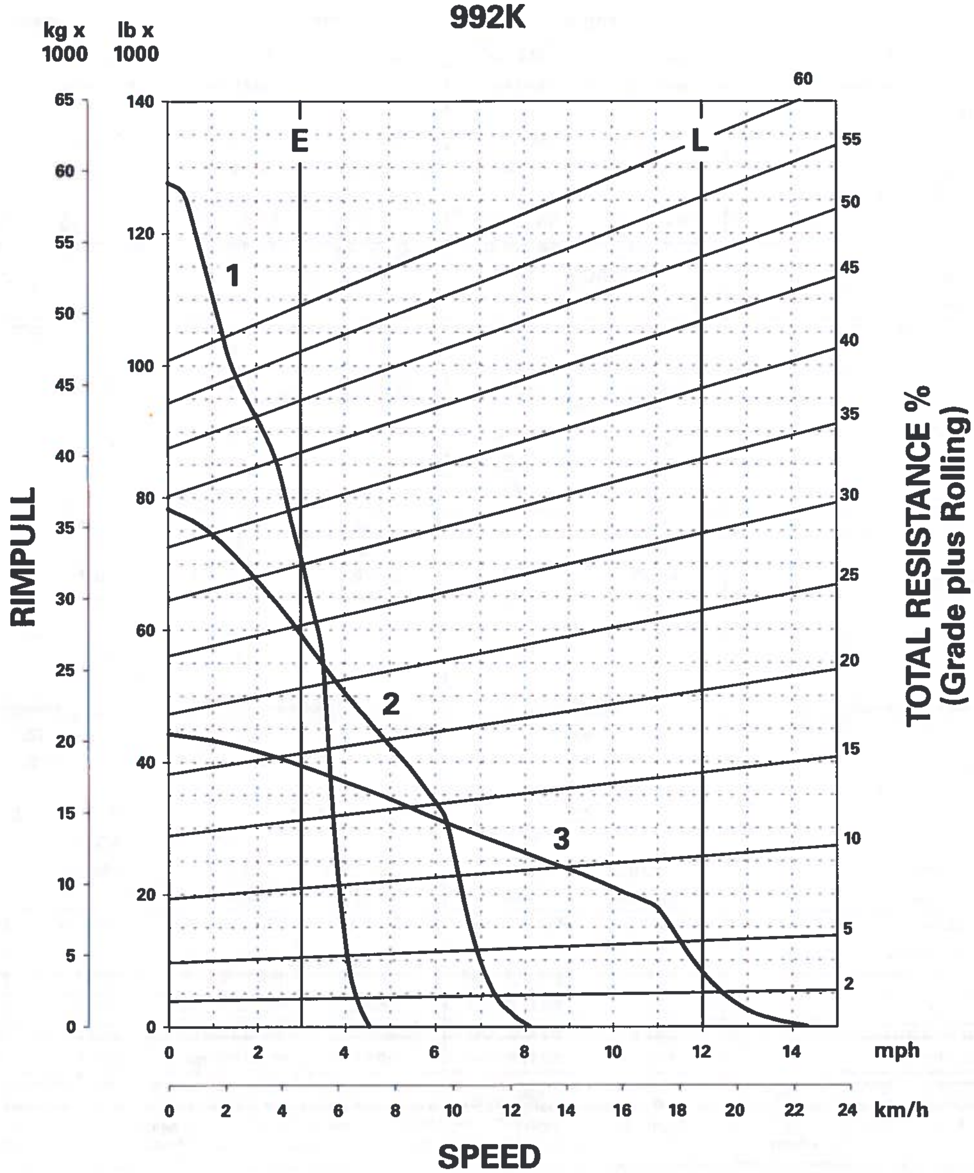
- **Speed of Travel** — At higher speeds, inertia forces tend to make the grader less stable.
- **Roughness of Terrain or Surface** — Ample allowance should be made where the terrain or surface is uneven.
- **Mounted Equipment** — Mounted attachments such as front plows, snow wings, rippers and other mounted equipment cause the tractor to balance differently.
- **Nature of Surface** — New earthen fills may give way with the weight of the grader. Rocky surfaces may promote side slipping of grader.
- **Excessive Loads or Side Draft** — This may cause wheel slippage, where the downhill tires "dig in," increasing the angle of grader.
- **Tire Selection and Maintenance** — Consideration should be given to proper tire selection and air pressure. For more information, consult Caterpillar publications — Motor Grader Tire Selection Guide and Operation and Maintenance Manual.
- **Drawbar, Circle and Blade Position** — The position of the blade can affect the stability of the machine.
- **Articulation Angle** — Articulation angle can affect the stability of the machine.
- **Wheel Lean Angle** — Wheel lean angle can affect the stability of the machine.

NOTE: Safe operation on steep slopes may require special machine maintenance as well as excellent operator skill and proper equipment setup for the specific application. Consult Caterpillar publications for further operating tips — Operation & Maintenance Manual, Motor Grader Application Guide, and the Grade Comparison Chart in the Tables section of this Performance Handbook.

WHEELED LOADERS

MODEL	992K		993K		994K	
Maximum Engine: Net	607 kW	814 hp	764 kW	1024 hp	1297 kW	1739 hp
Gross	671 kW	900 hp	773 kW	1036 hp	1377 kW	1847 hp
Rated Payload:*						
STD	21.8 tonnes	24 tons	22.7 tonnes	30 tons	40.8 tonnes	45 tons
HL, EHL, SHL	19 tonnes	21 tons	24.9 tonnes	27.5 tons	38.1 tonnes	42 tons
Gross Rated Bucket Payload:*						
STD	33 687 kg	74,265 lb	42 912 kg	94,603 lb	64 791 kg	142,838 lb
HL	30 138 kg	66,441 lb	40 459 kg	89,195 lb	61 458 kg	135,489 lb
Engine Model	C32 ACERT**		C32 ACERT**		3516E	
Emission Level						
Rated Engine RPM	1750		1900		1600	
Bore	145 mm	5.7"	145 mm	5.7"	170 mm	6.7"
Stroke	162 mm	6.4"	162 mm	6.4"	215 mm	8.5"
No. Cylinders	12		12		16	
Displacement	32.1 L	1959 in³	32.1 L	1959 in³	78 L	4766 in³
Speeds Forward:	km/h	mph	km/h	mph	km/h	mph
1st	7.1	4.4	6.8	4.2	7.4	4.6
2nd	12.2	7.6	11.9	7.4	12.9	8.0
3rd	20.6	12.8	20.5	12.7	24.0	14.9
Speeds Reverse:	km/h	mph	km/h	mph	km/h	mph
1st	7.4	4.6	7.5	4.7	8.1	5.0
2nd	13.0	8.1	13.1	8.1	14.1	8.8
3rd	22.4	13.9	22.5	13.9	24.0	14.9
Hydraulic Cycle Time, Rated Load in Bucket:	Seconds		Seconds		Seconds	
Raise	9.4		9.2		12.6	
Dump	1.8		1.8		3.1	
Lower (Empty, Float Down)	3.7		3.1		4.2	
Total	14.9		14.1		19.9	
Tread Width	3.3 m	10'10"	3.54 m	11'6"	4.3 m	14'1"
Width Over Tires	4.5 m	14'9"	4.93 m	16'2"	5.49 m	18'10"
Ground Clearance	682 mm	26.8"	721 mm	2'5"	898 mm	33"
Fuel Tank Capacity	1610 L	425 U.S. gal	2170 L	573 U.S. gal	3445 L	910 U.S. gal
Hydraulic Systems:						
Lift, Tilt	646 L	171 U.S. gal	755 L	199 U.S. gal	1022 L	270 U.S. gal
Tank Only	326 L	86 U.S. gal	553 L	146 U.S. gal	756 L	200 U.S. gal
Steering and Brakes	231 L	61 U.S. gal	227 L	60 U.S. gal	379 L	100 U.S. gal
Tank Only	159 L	42 U.S. gal	185 L	48.9 U.S. gal	340 L	90 U.S. gal

*Changes in bucket weight, including field installed wear iron, can impact rated payload. Consult your Cat dealer for assistance in selecting and configuring the proper bucket for the application. The Cat Large Wheel Loader Payload Policy is a guideline intended to maximize wheel loader structural and component life. The Cat Payload Policy is that the "Gross Bucket plus Payload Capacity" is the MAXIMUM weight that should be carried on the end of the Lift Arm/Boom.
**Products available to meet Tier 2/Stage II/Japan 2001 (Tier 2) equivalent OR Tier 4 Final/Stage IV/Japan 2014 (Tier 4 Final) emission standards.
NOTE: The 994K meets Tier 1 equivalent emission standards.



KEY

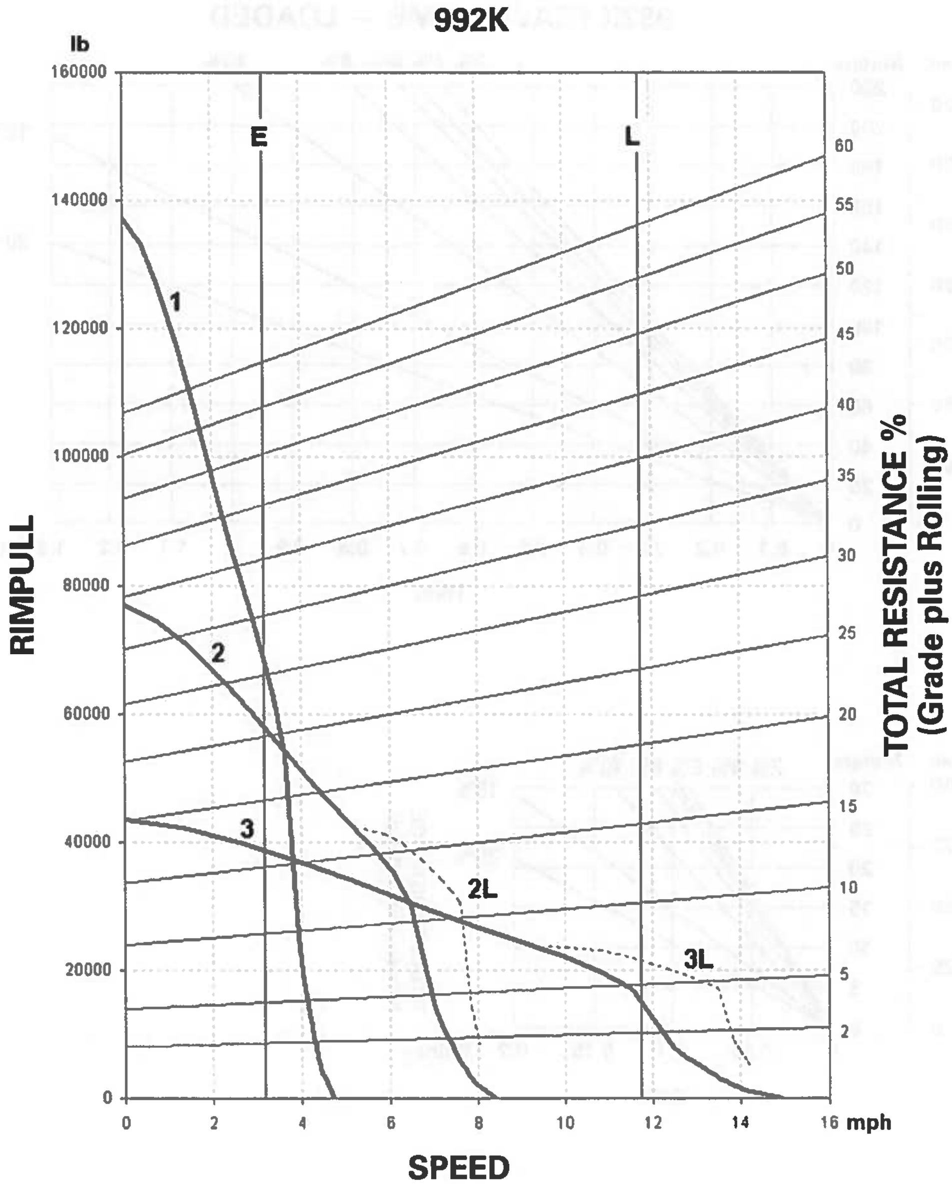
1 — 1st Gear
2 — 2nd Gear
3 — 3rd Gear

KEY

E — Empty 92 797 kg (204,580 lb)
L — Loaded 114 570 kg (252,580 lb)

Calculated Pull: Idle Hydraulics
Curves Assume NO SLIP Conditions

992K Rimpull-Speed-Gradeability
- Lock-Up Clutch



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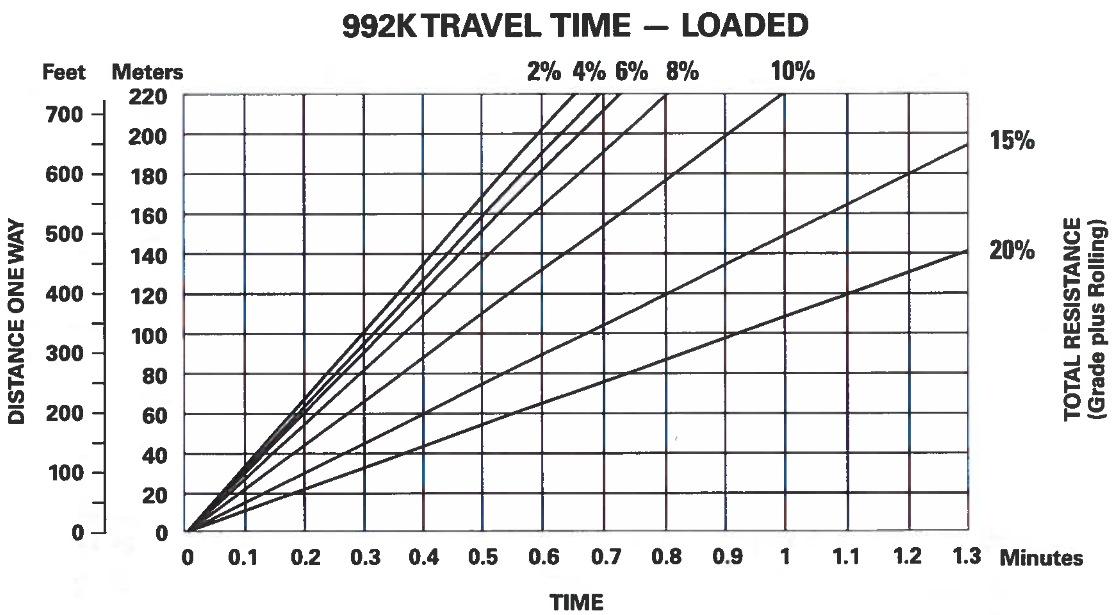
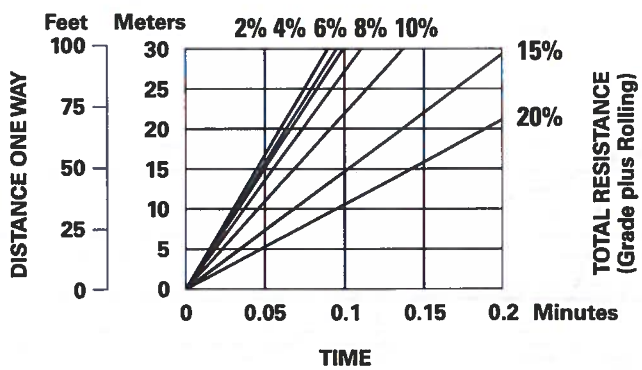
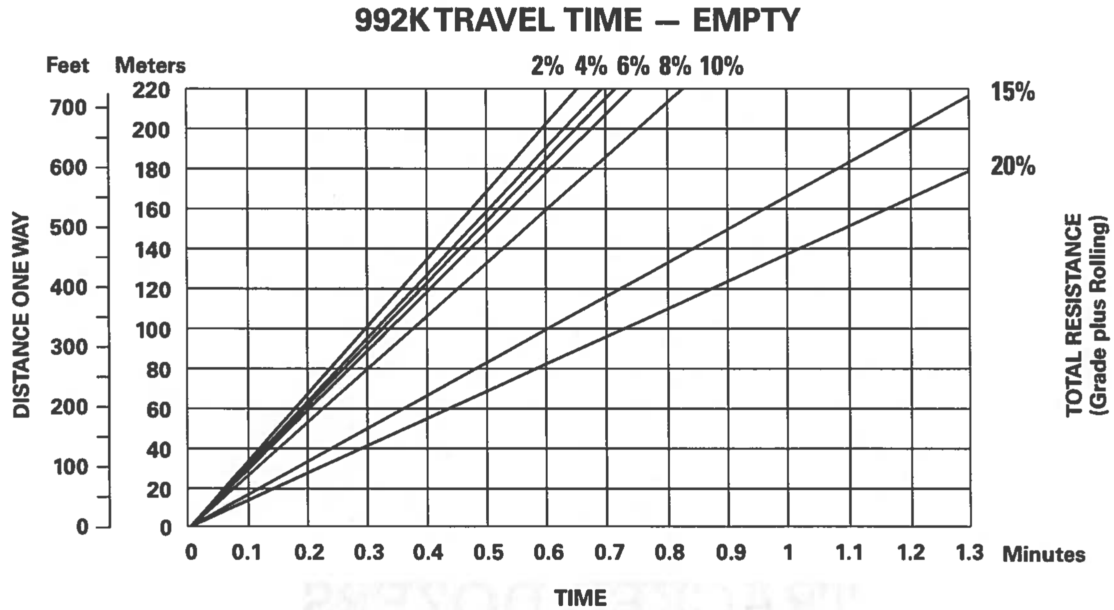


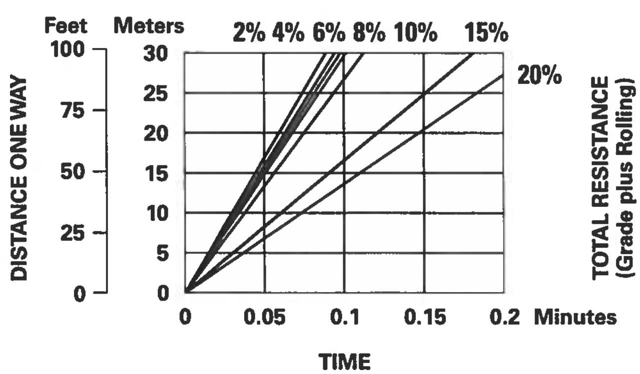


NOTE: Curves assume use of highest operating speed attainable: 3rd gear for 2%-10% TR, 2nd gear for 15% and 20% TR.

In load-and-carry applications it is important to consult the tire manufacturer on Ton-MPH ratings and pressure recommendations.

Travel Time — Empty
- 992K
- 45/65-45 Tires





NOTE: Curves assume use of highest operating speed attainable: 3rd gear for 2%-10%TR, 2nd gear for 15% and 20%TR.

In load-and-carry applications it is important to consult the tire manufacturer on Ton-MPH ratings and pressure recommendations.

TRACKED DOZERS

MODEL	D6T		D6T XL	
Emission Standards	Tier 3/Stage IIIA/ Japan 2006 (Tier 3) equivalent		Tier 3/Stage IIIA/ Japan 2006 (Tier 3) equivalent	
Flywheel Power	149 kW	200 hp	149 kW	200 hp
Operating Weight:[1]				
Power Shift Differential Steer				
SU Blade	20 580 kg	45,370 lb	21 600 kg	47,620 lb
Engine Model	C9 ACERT		C9 ACERT	
Rated Engine RPM: Power Shift	1850		1850	
No. of Cylinders	6		6	
Bore	112 mm	4.4"	112 mm	4.4"
Stroke	149 mm	5.9"	149 mm	5.9"
Displacement	8.8 L	537 in³	8.8 L	537 in³
Track Rollers (Each Side)	6		7	
Width of Standard Track Shoe	560 mm	22"	560 mm	22"
Length of Track on Ground	2.61 m	8'7"	2.81 m	9'3"
Ground Contact Area (w/Std. Shoe)	2.92 m²	4531 in²	3.15 m²	4878 in²
Track Gauge	1.88 m	74"	1.88 m	74"
GENERAL DIMENSIONS:				
Height[2] (Stripped Top)[3]	2.40 m	7'11"	2.40 m	7'11"
Height[2] (To Top of ROPS Canopy)	3.11 m	10'2"	3.11 m	10'2"
Height[2] (To Top of ROPS Cab)	3.11 m	10'2"	3.11 m	10'2"
Overall Length (without Blade)	3.85 m	12'7"	3.85 m	12'7"
with SU Blade	5.08 m	16'8"	5.33 m	17'6"
with Angle Blade	5.00 m	16'5"	5.21 m	17'1"
Width (over Trunnion)	2.64 m	8'8"	2.64 m	8'8"
Width (w/o Trunnion — Std. Track)	2.44 m	8'0"	2.44 m	8'0"
Ground Clearance[2]	384 mm	1'3"	384 mm	1'3"
Blade Types and Widths:				
Angle Straight	4.16 m	13'8"	4.16 m	13'8"
Full 25° Angle	3.77 m	12'5"	3.77 m	12'5"
Semi-U	3.26 m	10'8"	3.26 m	10'8"
Fuel Tank Refill Capacity	425 L	112 U.S. gal	425 L	112 U.S. gal

[1] Operating weight includes cab, operator, lubricants, coolant, full fuel tank, standard track, hydraulic controls and fluid, SU blade, drawbar and counterweight.
[2] Dimensions measured from ground line. Add grouser height for total dimension on hard surfaces.
[3] Height (Stripped Top) — without ROPS canopy, exhaust, seat back or other easily removed encumbrances.

Track-Type Tractor Sustainability

Well matched engine and power train systems enhance productivity and fuel efficiency.

MODEL	D9R		D9T		D9T	
Emission Standards	—		Tier 3/Stage IIIA/ Japan 2006 (Tier 3) equivalent[1]		Tier 4 Final/Stage IV/ Japan 2014 (Tier 4 Final)	
Flywheel Power	302 kW	**405 hp**	306 kW	**410 hp**	325 kW	**436 hp**
Operating Weight:[2]						
Power Shift Clutch Brake	48 784 kg	**107,548 lb**	—		—	
Power Shift Differential Steer	—		47 872 kg	**105,539 lb**	48 361 kg	**106,618 lb**
Engine Model	**3408C SCAC**		**C18 ACERT**		**C18 ACERT**	
Rated Engine RPM	**1900**		**1833**		**1800**	
No. of Cylinders	**8**		**6**		**6**	
Bore	137 mm	**5.4"**	145 mm	**5.7"**	145 mm	**5.7"**
Stroke	152 mm	**6"**	183 mm	**7.2"**	183 mm	**7.2"**
Displacement	18 L	**1099 in³**	18.1 L	**1106 in³**	18.1 L	**1106 in³**
Track Rollers (Each Side)	**8**		**8**		**8**	
Width of Standard Track Shoe	610 mm	**24"**	610 mm	**24"**	610 mm	**24"**
Length of Track on Ground	3.47 m	**11'5"**	3.47 m	**11'5"**	3.47 m	**11'5"**
Ground Contact Area (w/Std. Shoe)	4.24 m²	**6569 in²**	4.24 m²	**6569 in²**	4.24 m²	**6569 in²**
Track Gauge	2.25 m	**7'5"**	2.25 m	**7'5"**	2.25 m	**7'5"**
GENERAL DIMENSIONS:						
Height[3] (Stripped Top)[4]	3.69 m	**12'1"**	3.69 m	**12'1"**	3.69 m	**12'1"**
Height[3] (To Top of ROPS Canopy)	4.00 m	**13'1"**	4.00 m	**13'1"**	4.00 m	**13'1"**
Height[3] (To Top of FOPS Cab)	3.82 m	**12'6"**	3.82 m	**12'6"**	3.82 m	**12'6"**
Overall Length (with SU Blade)[5]	6.88 m	**22'6"**	6.88 m	**22'6"**	6.88 m	**22'6"**
(without Blade)	5.18 m	**17'0"**	5.18 m	**17'0"**	5.18 m	**17'0"**
(with SU Blade and Ripper)[5]	8.23 m	**27'0"**	8.23 m	**27'0"**	8.23 m	**27'0"**
(without Blade and Ripper)	4.91 m	**16'1"**	4.91 m	**16'1"**	4.91 m	**16'1"**
Width (over Trunnion)	3.30 m	**10'8"**	3.30 m	**10'8"**	3.30 m	**10'8"**
Width (w/o Trunnion — Std. Shoe)	2.88 m	**9'5"**	2.88 m	**9'5"**	2.88 m	**9'5"**
Ground Clearance[6]	496 mm	**1'7"**	496 mm	**1'7"**	496 mm	**1'7"**
Blade Types and Widths:						
Universal	4.65 m	**15'3"**	4.65 m	**15'3"**	4.65 m	**15'3"**
Semi-U	4.31 m	**14'2"**	4.31 m	**14'2"**	4.31 m	**14'2"**
Fuel Tank Refill Capacity	818 L	**216 U.S. gal**	889 L	**235 U.S. gal**	821 L	**217 U.S. gal**
DEF Tank Refill Capacity	—		—		36 L	**9.5 U.S. gal**

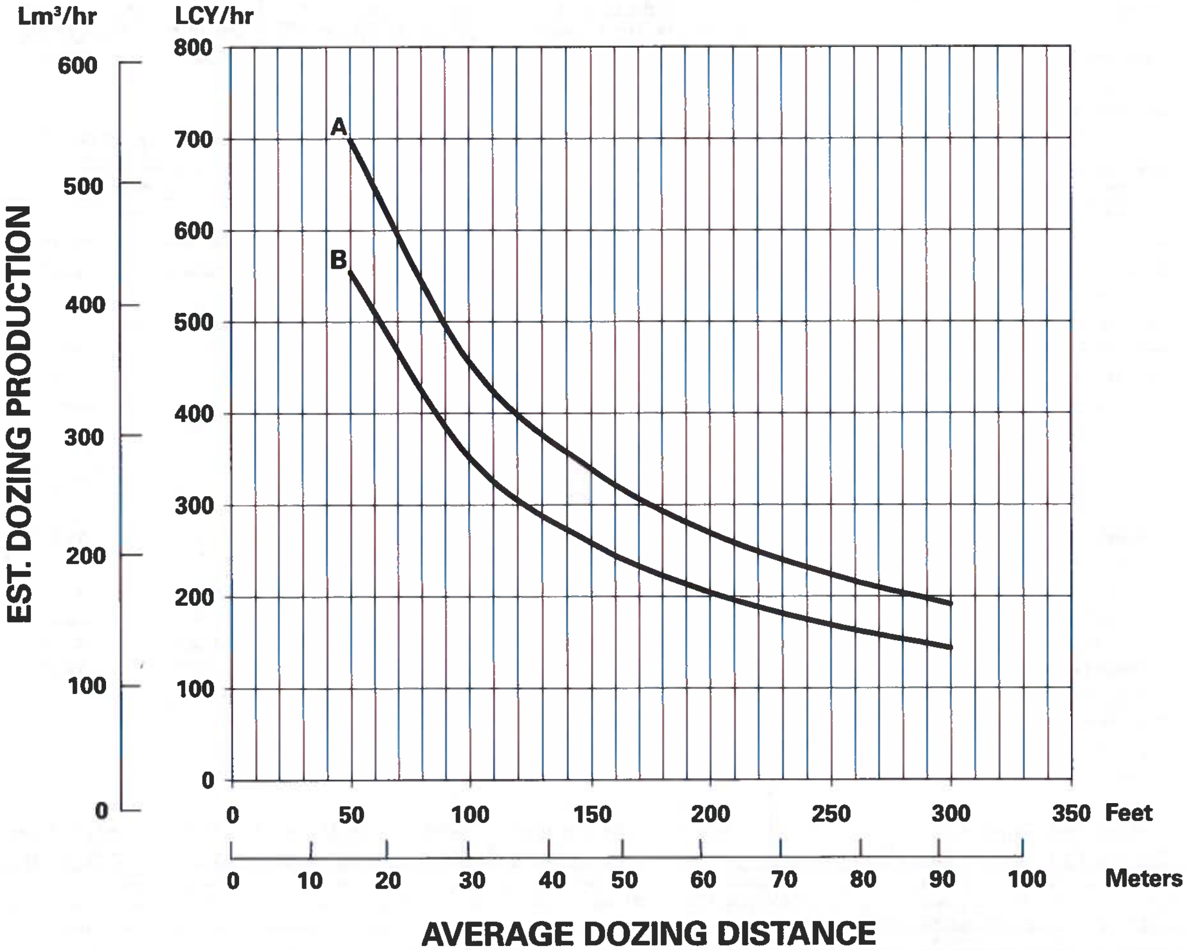
[1] Product available to meet Tier 2/Stage II/Japan 2001 (Tier 2) equivalent OR Tier 3/Stage IIIA/Japan 2006 (Tier 3) equivalent emission standards.
[2] Operating weight includes ROPS canopy, operator, lubricants, coolant, full fuel tank, hydraulic controls and fluids, semi universal blade with tilt, back-up alarm, seat belts, lights, and single shank ripper.
— D9R equipped with track guides, ROPS/FOPS cab, single shank ripper and SU blade.
[3] Dimensions measured from ground line. Add grouser height for total dimension on hard surfaces.
[4] Height (Stripped Top) — without ROPS canopy, exhaust, seat back or other easily removed encumbrances.
[5] Includes drawbar.
[6] Per ISO 6746 — Must add grouser height for total dimension on hard surfaces.

MODEL	D10T2		D11T		D11T CD	
Emission Standards	Tier 4 Final/Stage IV/ Japan 2014 (Tier 4 Final)[1]		Tier 4 Final/Stage IV/ Japan 2014 (Tier 4 Final)[1]		Tier 4 Final/Stage IV/ Japan 2014 (Tier 4 Final)[1]	
Flywheel Power	447 kW	**600 hp**	634 kW	**850 hp**	634 kW	**850 hp**
Reverse Gears	538 kW	**722 hp**	—		—	
Operating Weight:[2]						
Power Shift Clutch Brake	70 171 kg	**154,700 lb**	104 236 kg	**229,800 lb**	112 718 kg	**248,500 lb**
Engine Model	C27 ACERT		C32 ACERT		C32 ACERT	
Rated Engine RPM	1800		1800		1800	
No. of Cylinders	12		12		12	
Bore	137 mm	**5.4"**	145 mm	**5.71"**	145 mm	**5.71"**
Stroke	152 mm	**6"**	162 mm	**6.38"**	162 mm	**6.38"**
Displacement	27 L	**1648 in³**	32.1 L	**1959 in³**	32.1 L	**1959 in³**
Track Rollers (Each Side)	8		8		8	
Width of Standard Track Shoe	610 mm	**24"**	710 mm	**28"**	915 mm	**36"**
Length of Track on Ground (Idler to Idler)	3.88 m	**12'9"**	4.44 m	**14'7"**	4.44 m	**14'7"**
Ground Contact Area (w/Std. Shoe)	4.74 m²	**7347 in²**	6.31 m²	**9781 in²**	8.13 m²	**12,605 in²**
Track Gauge	2.55 m	**8'4"**	2.89 m	**9'6"**	2.89 m	**9'6"**
GENERAL DIMENSIONS:						
Height (Stripped Top)[3]	3.222 m	**10'7"**	3.64 m	**11'11"**	3.64 m	**11'11"**
Height (To Top of ROPS Canopy)	4.41 m	**14'5"**	4.70 m	**15'5"**	4.70 m	**15'5"**
Height (To Top of FOPS Cab)	4.10 m	**13'5"**	4.39 m	**14'5"**	4.39 m	**14'5"**
Overall Length:						
(with SU Blade and SS Ripper)[4]	9.16 m	**30'1"**	10.59 m	**34'9"**	10.70 m	**35'1"**
(without Blade and Ripper)[5]	5.32 m	**17'5"**	6.16 m	**20'3"**	6.16 m	**20'3"**
Width (over Trunnion)	3.74 m	**12'3"**	4.38 m	**14'4"**	4.38 m	**14'4"**
Width (w/o Trunnion — Std. Shoe)	3.30 m	**10'10"**	3.78 m	**12'5"**	3.81 m	**12'6"**
Ground Clearance[6]	632 mm	**2'1"**	675 mm	**2'3"**	675 mm	**2'3"**
Blade Types and Widths:						
CarryDozer	—		—		6.71 m	**22'0"**
Universal	5.26 m	**17'3"**	6.36 m	**20'10"**	—	
Semi-U	4.94 m	**16'3"**	5.60 m	**18'4"**	—	
Fuel Tank Refill Capacity	1204 L	**314 U.S. gal**	1609 L	**425 U.S. gal**	1609 L	**425 U.S. gal**
Fuel Tank Refill Capacity (Extra Capacity)	—		1987 L	**505 U.S. gal**	1987 L	**505 U.S. gal**

[1] Product available to meet Tier 2/Stage II/Japan 2001 (Tier 2) equivalent OR Tier 4 Final/Stage IV/Japan 2014 (Tier 4 Final) emission standards.
[2] Operating weight includes coolant, lubricants, full fuel tank, ROPS, FOPS cab, SU ABR bulldozer (D10T2) or U ABR bulldozer (D11T), dual tilt, single-shank ripper with pin-puller, fast fuel, standard ES shoes, and operator.
D11T CD has 11 Carrydozer and single-shank Carrydozer ripper.
[3] Height (Stripped Top) — without ROPS canopy, cab, exhaust, lift cylinders, seat back or other easily removed encumbrances.
[4] Overall length of D11T CD includes Straight (CarryDozer) Blade and SS Ripper.
[5] Overall length of machine from front tag link trunnion to rigid drawbar and excludes track grouser height.
[6] Per ISO 6746 — Must add grouser height for total dimension on hard surfaces.

All dimensions are approximate.

ESTIMATED DOZING PRODUCTION ● Straight Blades ● D6T through D7E

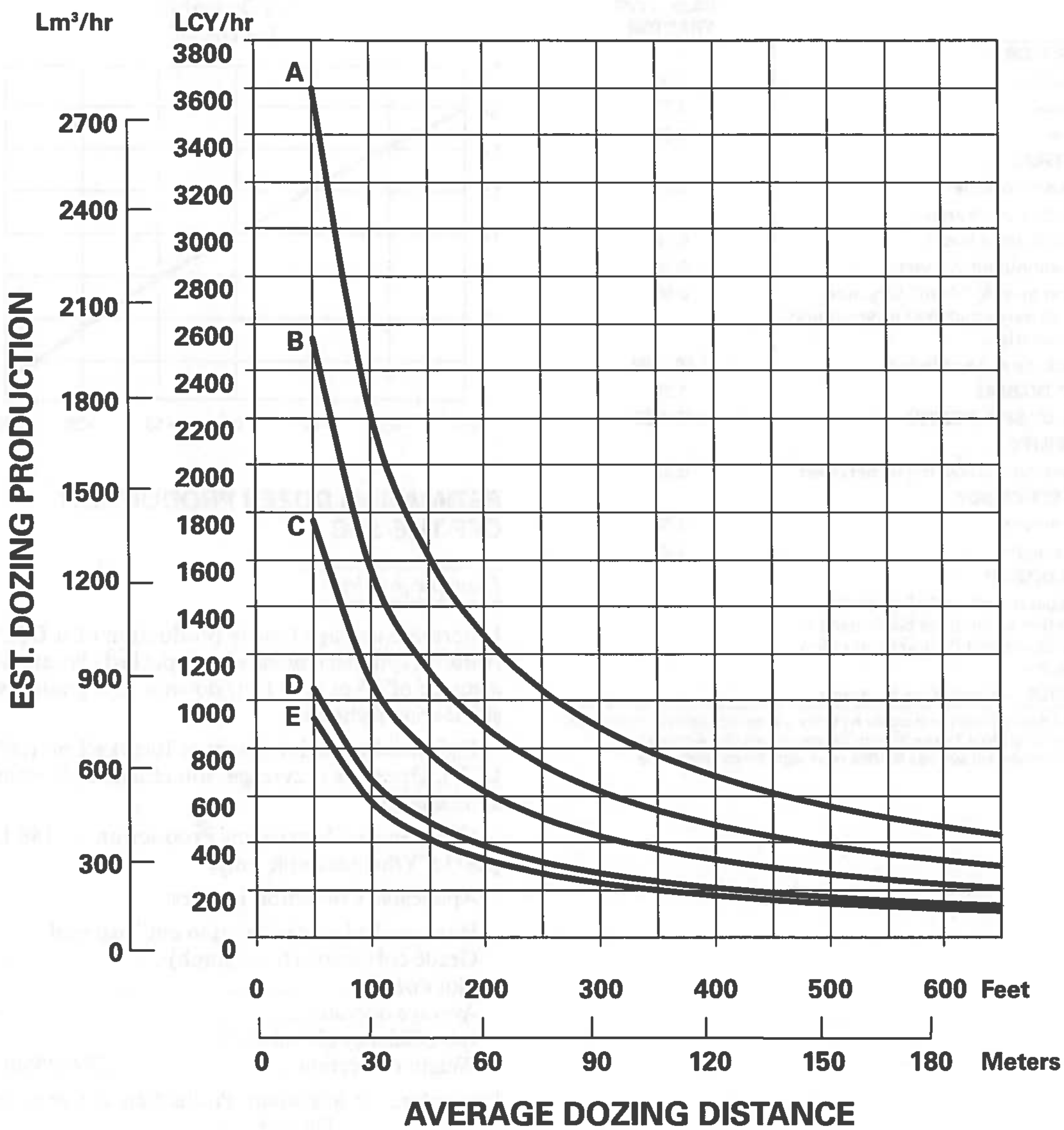


KEY

A — D7E
B — D6T

NOTE: This chart is based on numerous field studies made under varying job conditions. Refer to correction factors following these charts.

ESTIMATED DOZING PRODUCTION ● Semi-Universal Blades ● D7E through D11T



KEY

A — D11T
B — D10T2
C — D9T
D — D8T
E — D7E

NOTE: This chart is based on numerous field studies made under varying job conditions. Refer to correction factors following these charts.

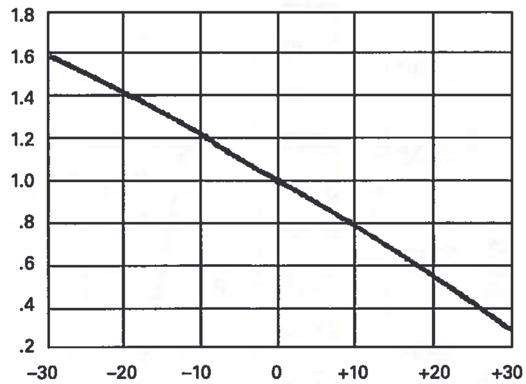
JOB CONDITION CORRECTION FACTORS

	TRACK-TYPE TRACTOR
OPERATOR –	
Excellent	1.00
Average	0.75
Poor	0.60
MATERIAL –	
Loose stockpile	1.20
Hard to cut; frozen –	
with tilt cylinder	0.80
without tilt cylinder	0.70
Hard to drift; "dead" (dry, non-cohesive material) or very sticky material	0.80
Rock, ripped or blasted	0.60-0.80
SLOT DOZING	1.20
SIDE BY SIDE DOZING	1.15-1.25
VISIBILITY –	
Dust, rain, snow, fog or darkness	0.80
JOB EFFICIENCY –	
50 min/hr	0.83
40 min/hr	0.67
BULLDOZER*	
Adjust based on SAE capacity relative to the base blade used in the Estimated Dozing Production graphs.	
GRADES – See following graph.	

***NOTE:** Angling blades and cushion blades are not considered production dozing tools. Depending on job conditions, the A-blade and C-blade will average 50-75% of straight blade production.

% Grade vs. Dozing Factor

(–) Downhill
(+) Uphill



ESTIMATING DOZER PRODUCTION OFF-THE-JOB

Example problem:

Determine average hourly production of a D8T/8SU (with tilt cylinder) moving hard-packed clay an average distance of 45 m (150 feet) down a 15% grade, using a slot dozing technique.

Estimated material weight is 1600 kg/Lm³ (2650 lb/LCY). Operator is average. Job efficiency is estimated at 50 min/hr.

Uncorrected Maximum Production — 458 Lm³/h (600 LCY/hr) (example only)

Applicable Correction Factors:

Hard-packed clay is "hard to cut" material . . .–0.80
Grade correction (from graph) . . . .–1.30
Slot dozing . . . .–1.20
Average operator . . . .–0.75
Job efficiency (50 min/hr) . . . .–0.83
Weight correction. . . . . (2300/2650)–0.87

Production = Maximum Production × Correction Factors
= (600 LCY/hr) (0.80) (1.30) (1.20) (0.75) (0.83) (0.87)
= 405.5 LCY/hr

To obtain production in metric units, the same procedure is used substituting maximum uncorrected production in Lm³.

= 458 Lm³/h × Factors
= 309.6 Lm³/h

OFF-HIGHWAY TRUCKS

MODEL	785C		785D		789C	
Body Type	Dual Slope		Dual Slope		Dual Slope	
Target Gross Machine Weight §	249 476 kg	**550,000 lb**	249 476 kg	**550,000 lb**	317 515 kg	**700,000 lb**
Basic Machine Weight*	59 669 kg	**131,548 lb**	53 265 kg	**117,429 lb**	67 344 kg	**148,425 lb**
Attachments**	23 267 kg	**51,295 lb**	30 786 kg	**67,871 lb**	30 668 kg	**67,592 lb**
Body Weight without Liners***	22 153 kg	**48,839 lb**	22 293 kg	**49,148 lb**	27 094 kg	**59,715 lb**
Full Liner	7739 kg	**17,062 lb**	7876 kg	**17,364 lb**	9392 kg	**20,701 lb**
Standard Sideboard	1263 kg	**2785 lb**	1263 kg	**2785 lb**	1292 kg	**2848 lb**
Operating Machine Weight	112 828 kg	**248,744 lb**	114 220 kg	**251,812 lb**	135 790 kg	**299,281 lb**
Debris (2% of Operating Machine Weight)	2257 kg	**4975 lb**	2284 kg	**5035 lb**	1905 kg	**4198 lb**
Empty Operating Weight	115 085 kg	**253,718 lb**	116 505 kg	**256,849 lb**	137 695 kg	**303,479 lb**
Target Payload §	134 m tons	**148 tons**	133 m tons	**147 tons**	177 m tons	**195 tons**
Capacity:						
Heaped (2:1) (SAE) Base Body	78 m³	**102 yd³**	78 m³	**102 yd³**	105 m³	**137 yd³**
Heaped (2:1) (SAE) with Std. Sideboards	91 m³	**119 yd³**	91 m³	**119 yd³**	120 m³	**157 yd³**
Distribution Empty:						
Front	**43.5%**		**46%**		**46.9%**	
Rear	**56.5%**		**54%**		**53.1%**	
Distribution Loaded:						
Front	**33%**		**33%**		**33.6%**	
Rear	**67%**		**67%**		**66.4%**	
Engine Model	**3512B EUI**		**3512C HD-EUI**		**3516B EUI**	
Number of Cylinders	**12**		**12**		**16**	
Bore	170 mm	**6.7"**	170 mm	**6.7"**	170 mm	**6.7"**
Stroke	190 mm	**7.5"**	215 mm	**8.46"**	190 mm	**7.5"**
Displacement	51.8 L	**3158 in³**	58.56 L	**3574 in³**	69 L	**4210 in³**
Net Power	1005 kW	**1348 hp**	1005 kW	**1348 hp**	1320 kW	**1771 hp**
Gross Power	1082 kW	**1450 hp**	1082 kW	**1450 hp**	1417 kW	**1900 hp**
Standard Tires	**33.00R51**		**33.00R51**		**37.00R57**	
Machine Clearance Turning Circle	30.6 m	**100'5"**	33.2 m	**108'11"**	30.2 m	**99'2"**
Fuel Tank Refill Capacity	1893 L	**500 U.S. gal**	1893 L	**500 U.S. gal**	3222 L	**850 U.S. gal**
Top Speed (Loaded)	56.5 km/h	**35.1 mph**	56.5 km/h	**35.1 mph**	57.2 km/h	**35.5 mph**
GENERAL DIMENSIONS (Empty):						
Height to Canopy Rock Guard Rail	5.77 m	**18'11"**	5.68 m	**18'7"**	6.15 m	**20'2"**
Wheelbase	5.18 m	**17'0"**	5.18 m	**17'0"**	5.70 m	**18'8"**
Overall Length (Base Body)	10.62 m	**34'10"**	11.55 m	**37'9"**	12.18 m	**39'11"**
Loading Height (Base Body)	4.97 m	**16'4"**	4.97 m	**16'4"**	5.21 m	**17'1"**
Height at Full Dump	11.21 m	**36'9"**	11.81 m	**38'9"**	11.90 m	**39'1"**
Body Length (Target Length)	7.65 m	**25'1"**	7.65 m	**25'2"**	8.15 m	**26'9"**
Width (Operating)	6.64 m	**21'4"**	7.06 m	**23'2"**	7.67 m	**25'2"**
Width (Shipping)***	3.91 m	**12'10"**	3.91 m	**12'10"**	3.84 m	**12'7"**
Front Tire Tread	4.85 m	**15'11"**	4.85 m	**15'11"**	5.43 m	**17'10"**

*See Weight Definitions and Relations on 9-11. Note: No mandatory or optional attachments or fuel.
**Typical selection of mandatory and optional attachments.
***Data provided is for a representative body and liner package. Several dual slope, flat floor, and mine specific design (MSD) bodies and liner packages are available. All weights, capacities, and dimensions are dependent on the machine configuration (body type, attachments, tires, and optional equipment selected).
§Reference Caterpillar's latest 10/10/20 Payload Policy for information on gross machine operating weight and target payload.

USE OF BRAKE PERFORMANCE CURVES

The speed that can be maintained when the machine is descending a grade with retarder applied can be determined from the retarder curves in this section when gross machine weight and total effective grade are known.

Select appropriate grade distance chart that covers total downhill haul; don't break haul into individual segments.

To determine brake performance: Read from gross weight down to the percent effective grade. (Effective grade equals actual % grade *minus* 1% for each 10 kg/metric ton (20 lb/U.S. ton) of rolling resistance.) From this weight-effective grade point, read horizontally to the curve with the highest obtainable speed range, then down to maximum descent speed brakes can safely handle without exceeding cooling capacity. When braking, engine RPM should be maintained at the highest possible level without overspeeding. If cooling oil overheats, reduce ground speed to allow transmission to shift to next lower speed range.

Brake Performance Curves are made in compliance with ISO 10268 and applicable to Sea Level and 32° C (90° F) temperature. Contact Factory for Application Specific Performance.

USE OF RIMPULL-SPEED-GRADEABILITY CURVES

For best results, use Caterpillar Fleet Production and Cost Analysis (FPC) to simulate cycle time, fuel burn, and production for Application Specific Performance inquiries. Contact Factory Representative or visit catminer.cat.com/stb for more information.

(See Wheel Tractor Scraper Section)

Total Effective Grade (or Total Resistance) is grade assistance *minus* rolling resistance.

10 kg/metric ton (20 lb/U.S. ton) = 1% adverse grade.

Example —

With a favorable grade of 20% and rolling resistance of 50 kg/metric ton (100 lb/U.S. ton), find Total Effective Grade.

(50 kg/metric ton) = 50 ÷ 10 = 5% Effective Grade
(from Rolling Resistance)
100 lb/ton = 100 ÷ 20 = 5% Effective Grade
20% (grade) – 5% (resistance) =
15% Total Effective Grade

TYPICAL FIXED TIMES FOR HAULING UNITS

Wait time, delays and operator efficiency all impact cycle time. Minimizing truck exchange time can have a significant effect on productivity.

Fixed time for hauling units include:

1. Truck load time (various with loading tool)
2. Truck maneuver in load area (Truck exchange) (Typically 0.6-0.8 min.)
3. Maneuver and dump time at dump point (Typically 1.0-1.2 min.)

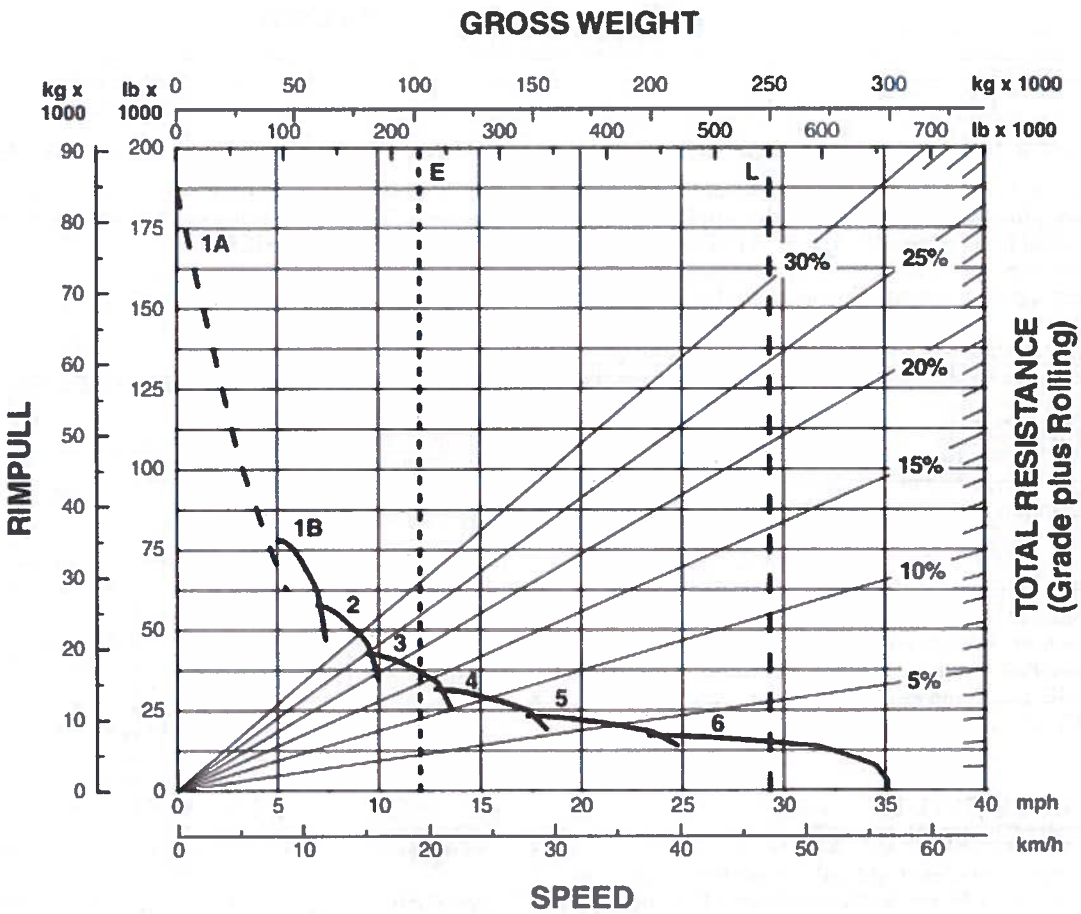
Total cycle time is the combination of:

1. The above fixed time
2. Hauling time (Loaded)
3. Return time (Empty)

Example — assume load tool spots hauler with full bucket

		988F	5130B
cycle times		.60	.45
First pass	(dump time)	.10 min.	.05 min.
2 passes	(full cycle)	.70	.50
3 passes	"	1.30	.95
4 passes	"	1.90	1.40
5 passes	"	2.50	1.85
6 passes	"	3.10	2.30
7 passes	"	3.70	2.75
8 passes	"	4.30	3.20
9 passes	"	4.90	3.65
10 passes	"	5.40	4.10

NOTE: Other sizes of loading tools will have different cycle times. See Wheel Loader section for **average** cycle times for truck loading.



KEY

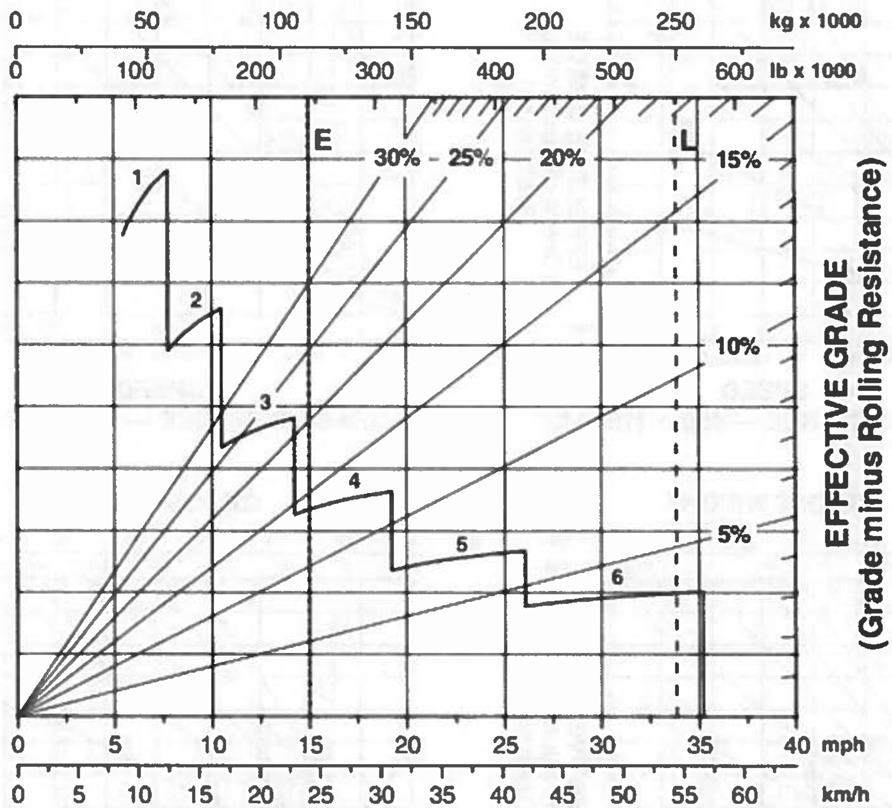
1A— 1st Gear (Torque Converter)
1B— 1st Gear
2 — 2nd Gear
3 — 3rd Gear
4 — 4th Gear
5 — 5th Gear
6 — 6th Gear

KEY

E — Est. Max Field Empty Weight 116 505 kg (256,849 lb)
L — Max GMW 249 475 kg (550,000 lb)

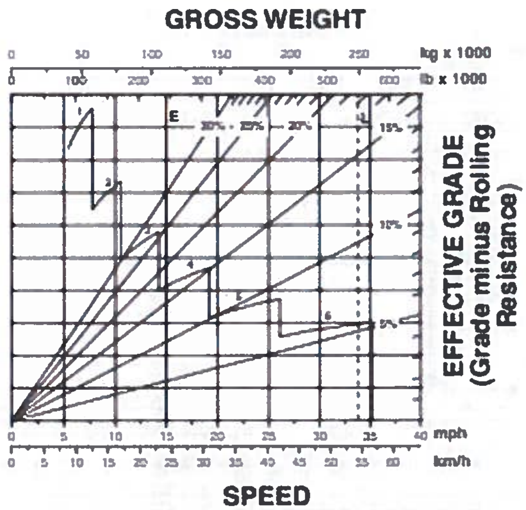
*At Sea Level

GROSS WEIGHT

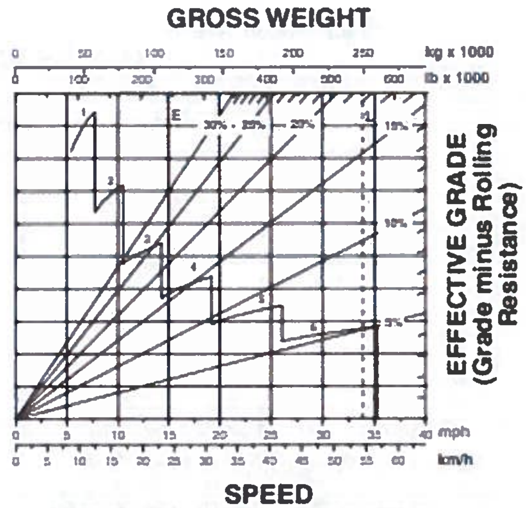


CONTINUOUS GRADE LENGTH

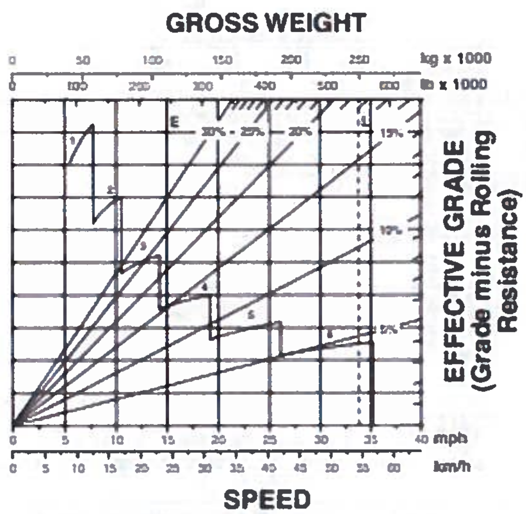
KEY	KEY
1 — 1st Gear	E — Est. Field Empty Weight 108 481 kg (239,160 lb)
2 — 2nd Gear	L — Max GMW 249 433 kg (550,000 lb)
3 — 3rd Gear	*At Sea Level
4 — 4th Gear	
5 — 5th Gear	
6 — 6th Gear	



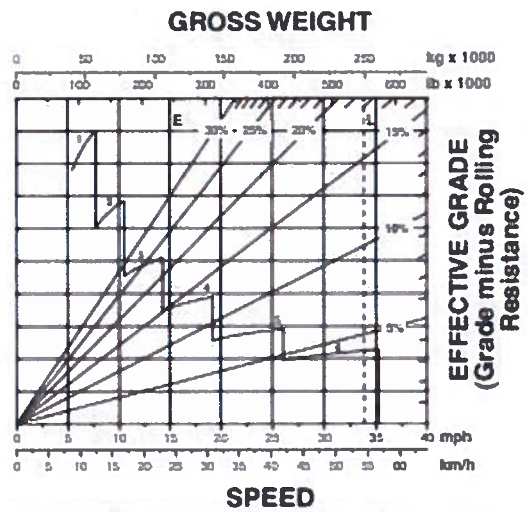
GRADE DISTANCE — 450 m (1500 ft)*



GRADE DISTANCE — 600 m (2000 ft)*



GRADE DISTANCE — 900 m (3000 ft)*



GRADE DISTANCE — 1500 m (5000 ft)*

KEY

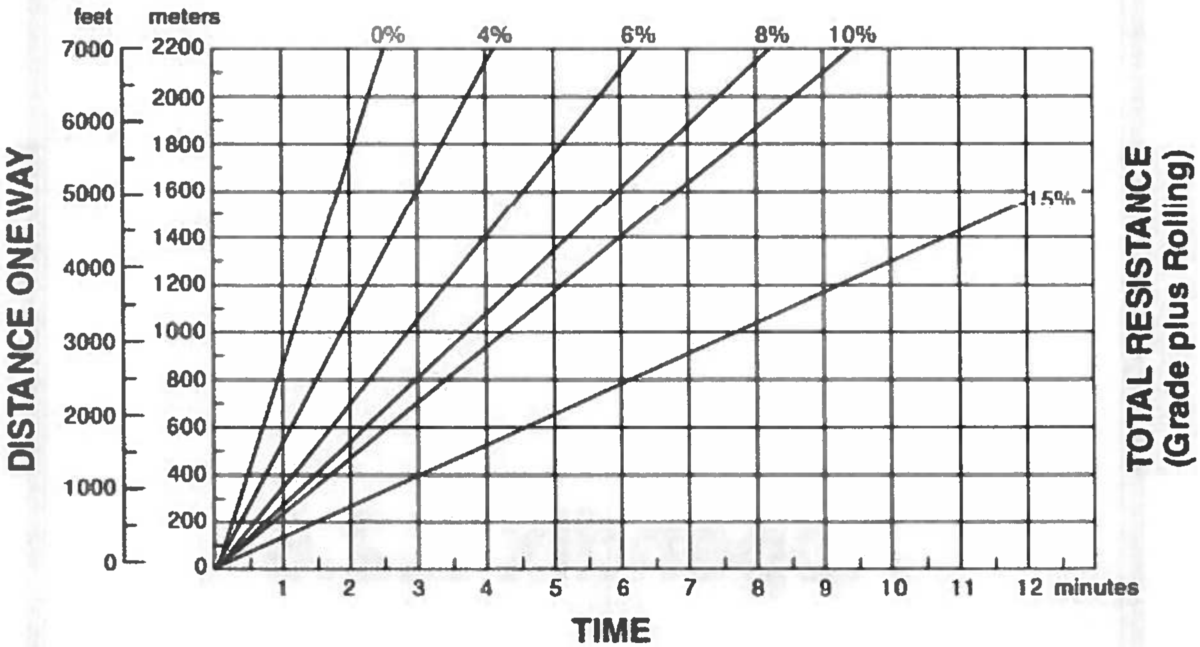
1 — 1st Gear
2 — 2nd Gear
3 — 3rd Gear
4 — 4th Gear
5 — 5th Gear
6 — 6th Gear

KEY

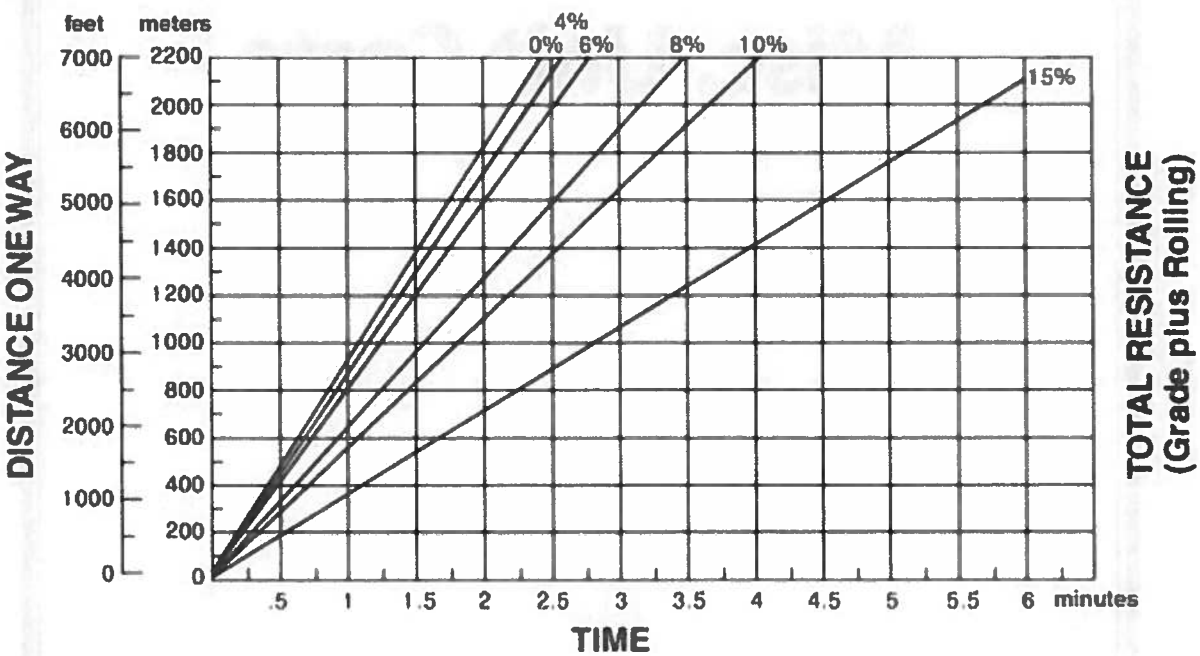
E — Est. Field Empty Weight 108 481 kg (239,160 lb)
L — Max GMW 249 433 kg (550,000 lb)

*At Sea Level.

LOADED



EMPTY



Appendix B.2.6

Misc. Unit Costs

Revegetation/Reclamation
Rangeland Rehabilitation
Landscaping / Fencing
Hydroseeding
Environmental Consulting

ROCKY MOUNTAIN RECLAMATION

Phone (307) 745-5235
(307) 745-5230

ron@reveg.us
www.reveg.us

P.O. Box 1695
Laramie, WY 82073

FREEPORT MCMORAN – NEW MEXICO MINING OPERATIONS

PRICE ESTIMATES FOR REVEGETATION SERVICES FOR BUDGETING ESTIMATES

Table 1 –Freeport McMoRan, New Mexico Mining Operations – Price Estimates for Revegetation Services for Budgeting Estimates, prepared April, 2018.

	REVEGETATION OPERATION	ESTIMATED QUANTITY	UNITS	COST/UNIT ($)	TOTAL COST
I.	**OPERATIONS:**				
1	**SCARIFYING**	500	Acres	$30.00	$15,000.00
2	**DISCING**	500	Acres	$20.00	$10,000.00
3	**DRILL SEEDING (special Rangeland Drill)**	500	Acres	$80.00	$40,000.00
4	**MULCHING**	500	Acres	$148.00	$74,000.00
5	**CRIMPING**	500	Acres	$55.00	$27,500.00
6	**DAILY PER DIEM, ETC.**	50	Days	$385.00	$19,250.00
7	**MOBILIZATION**	1	Each	$13,500.00	$13,500.00
	Subtotal				**$199,250.00**
II.	**MATERIALS:**				
1	**SEED** at 8.9 PLS/acre	500	Acres	$210.00	$105,000.00
2	**HAY MULCH** - nox. weed free, native	1000	Tons	$245.00	$245,000.00
	Subtotal				**$350,000.00**
	TOTAL ESTIMATED REVEGETATION COST BEFORE TAX				**$549,250.00**
	Add New Mexico Gross Receipts Tax	5.9375	%		**$32,611.72**
	ESTIMATED REVEGETATION COST PER ACRE:			**$1,163.72**	
	TOTAL ESTIMATED REVEGETATION COST				**$581,861.72**

Estimate prepared by Ron Schreibeis, Rocky Mountain Reclamation, for use for Budgeting Estimates.

Appendix B.2.7

Down Drain
Channel Bench
Top Channel
Unit Costs

Benches
Channels
Berms
and Down Drains
Unit Costs

Channel/Bench Grading and Excavation Costs

Bench Grading - 3.5H:1V

Task Description	Equipment	Productivity (cy/hr)	Productivity (hrs/lf)	Material	Grade Factor	Soil Weight (lb/cy)	Production Method/ Blade	Work Hour (min/hr)	Visibility	Elevation	Direct Drive Trans.	Grade (%)	Operator	Maximum Push Distance (feet)	Normal Production (cy/hr)
Excavate	Cat D11T	1,575	-	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	84	1917
Finish Grade	Cat D9T	-	0.0011	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	0	0

Task Description	Equipment	# Passes	Width (feet)	Speed (mi/hr)	Volume[1] (cy/lf)	Productivity (hrs/lf)	Operator Cost (IV) ($/hr)	Dozer Costs ($/hr)	Bench Cost ($/lf)
Excavate	Cat D11T	-	-	-	8.1	0.0051	$ 26.29	$ 420.39	$ 2.30
Finish Grade	Cat D9T	3	14.25	1.0	-	0.0011	$ 26.29	$ 180.73	$ 0.23
Total									$ 2.53

[1]Bench width: Stockpiles 15 ft.

Outslope Bench Channels - 3.5H:1V

Task Description	Equipment	Productivity (cy/hr)	Material	Grade Factor	Soil Weight (lb/cy)	Production Method/ Blade	Work Hour (min/hr)	Visibility	Elevation	Direct Drive Trans.	Grade (%)	Operator	Maximum Push Distance (feet)	Normal Production (cy/hr)
Excavate	D11T	839	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	1021
Cut/Fill	D11T	487	1.2	1.00	3300	1	50	1	1	1	0.0	0.75	200	931
Finish Grade	D6T XL	232	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	282

Task Description	Equipment	Volume[1] (cy/lf)	Productivity (hrs/lf)	Operator Cost (IV) ($/hr)	Dozer Costs ($/hr)	Bench Cost ($/lf)
Excavate	D11T	0.9	0.0010	$ 26.29	$ 420.39	$ 0.45
Cut/Fill	D11T	0.9	0.0018	$ 26.29	$ 420.39	$ 0.78
Finish Grade	D6T XL	0.3	0.0015	$ 26.29	$ 91.91	$ 0.17
Total						$ 1.41

[1]Volumes based on cross-section area for excavation and waste, unit volume/linear foot of downdrain (23 ft^2 * 1 ft/27)

Channel/Bench Grading and Excavation Costs

Top Channels

Task Description	Equipment	Productivity (cy/hr)	Material	Grade Factor	Soil Weight (lb/cy)	Production Method/ Blade	Work Hour (min/hr)	Visibility	Elevation	Direct Drive Trans.	Grade (%)	Operator	Maximum Push Distance (feet)	Normal Production (cy/hr)
Excavate	D11T	839	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	1021
Cut/Fill	D11T	487	1.2	1.00	3300	1	50	1	1	1	0.0	0.75	200	931
Finish Grade	D6T XL	232	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	282

Task Description	Equipment	Volume[1] (cy/lf)	Productivity (hrs/lf)	Operator Cost (IV) ($/hr)	Dozer Costs ($/hr)	Bench Cost ($/lf)	
Excavate	D11T	2.7	0.0032	$ 26.29	$ 420.39	$ 1.42	
Cut/Fill	D11T	2.7	0.0055	$ 26.29	$ 420.39	$ 2.44	
Finish Grade	D6T XL	1.1	0.0046	$ 26.29	$ 91.91	$ 0.54	
Total						$ 4.40	2.46

[1]Volumes based on cross-section area for excavation and waste, unit volume/linear foot of downdrain (73 ft^2 * 1 ft/27)

Downdrains - 3.5H:1V

Task Description	Equipment	Productivity (cy/hr)	Material	Grade Factor	Soil Weight (lb/cy)	Production Method/ Blade	Work Hour (min/hr)	Visibility	Elevation	Direct Drive Trans.	Grade (%)	Operator	Maximum Push Distance (feet)	Normal Production (cy/hr)
Excavate	D11T	839	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	1021
Cut/Fill	D11T	487	1.2	1.00	3300	1	50	1	1	1	0.0	0.75	200	931
Finish Grade	D6T XL	232	1.2	1.57	3300	1	50	1	1	1	-28.6	0.75	179	282

Task Description	Equipment	Volume[1] (cy/lf)	Productivity (hrs/lf)	Operator Cost (IV) ($/hr)	Dozer Costs ($/hr)	Bench Cost ($/lf)	
Excavate	D11T	6.5	0.0077	$ 26.29	$ 420.39	$ 3.45	
Cut/Fill	D11T	6.5	0.0133	$ 26.29	$ 420.39	$ 5.95	
Finish Grade	D6T XL	2.6	0.0112	$ 26.29	$ 91.91	$ 1.32	
Total						$ 10.73	6.01

[1]Volumes based on cross-section area for excavation and waste, unit volume/linear foot of downdrain (175.5 ft^2 * 1 ft/27)

Rip Rap Load and Haul Unit Cost

Table 3: 9AX Borrow Material Stockpile - Summary of Earthmoving Costs

RipRap Haul and Load

August 29, 2018

Equipment Type	Task	Location 1	Location 2	Owning and Operating Cost ($/hr)	Fuel Consumption (gal/hr)	Fuel Consumption (gal)	Labor Cost ($/hr)	Number of Units (Equipment)	Time Req'd (hrs)	Total Cost ($)
Dozers-Earthmoving										
Cat D11T	Dozer Assist	Borrow Area		$ 420.39	29.8	23,279	$ 26.29	1	782	$ 349,499.03
Off-Hwy Water Tanker Truck,6,000-gal.		9 Stockpile		$ 88.11	11.3	8,804	$ 23.84	1	782	$ 87,593.84
Cat 14M		9 Stockpile		$ 100.43	8.3	6,486	$ 26.29	1	782	$ 99,150.44
Loaders										
Cat 992K Loader	Load cover material	Borrow Area	Borrow Area	$ 300.46	25.6	20,055	$ 26.56	1	782	$ 255,872.60
Trucks										
Cat 785F Truck	Haul cover material	Borrow Area	9 Stockpile	$ 220.09	28.1	66,010	$ 23.84	3	2347	$ 1,717,739.08
									NE Stockpile StockpileExp	$ 2,509,854.99
									$/yd^3	$ 2.98

Data Sources:
1. EquipmentWatch(http://www.equipmentwatch.com). Revised Date: 2nd Half 2018
2. Griffin Propane March 12, 2018
3. Labor rates based on NM Department of Labor Type H (Heavy Engineering) labor rates 2018.

Rip Rap Placement
Unit Cost

Gravel Placement

<u>Assumptions:</u>

300hp 980H Front Loader				
7.5 CY Bucket (heaped)				
85% bucket fill[1]				
Net 6.4 CY				
Load Time[1]				0.65 min
Delivery Travel Time[1]	150 ft at	4 mph =	5.87 ft/sec	0.43 min
Unload and Maneuver Time[1]	20 sec +	20 sec		0.67 min
Return Travel Time[1]				0.43 min
				2.17 min

300 hp 980H Front End Loader Operating, Ownership, Fuel, and Labor Cost (per hour)

	Fuel Use Gal per Hour[2]	Fuel Total $/hr[2,4]	Owner/Operate $/hr	Owner/Operate $/hr w/Fuel[2]	Owner/Operate $/hr w/Fuel & Labor
Cat 980H Loader	10.1	$ 22.63	$ 69.79	$ 92.42	$ 118.98

[3] Cost per cubic yard at 2.17 minutes per load, 50 minute work hour

23 loads per hour

Loader costs $118.98 per hour, $5.13 per load

Cost per CY $0.8

<u>**NOTES:**</u>

1 - Load, dump, travel, maneuver times from Cat Handbook Edition 46
2 - Owner/Operating costs, fuel use collected from Equipment Watch 8/29/18
3 - 50 minutes actual work hour recommended in Cat Handbook Edition 46
4 - Earthwork Oil Broker Quote from Conitental Mine CCP (May 2018) is $2.24

Rip Rap Production Unit Cost

Riprap Production Costs

Rip Rap Producation Cost

Equipment	Equipment ($/hr)	# Equipment	Operator ($/hr)	# Operator	Total ($/hr)
988H Loader	$ 158.29	1	$ 26.56	1	$ 184.85
769D Haul Truck	$ 112.87	2	$ 23.84	2	$ 273.42
2 Deck (5X16, 48X60)	$ 47.02	1	$ 22.73	1	$ 69.75
3 Deck (5X16, 48X60)	$ 48.76	1	$ 22.73	1	$ 71.49
980H Loader	$ 92.42	1	$ 26.56	1	$ 118.98
966H Loader	$ 72.87	1	$ 26.56	1	$ 99.43
769D Haul Truck	$ 112.87	1	$ 23.84	1	$ 136.71
Water Truck	$ 88.11	1	$ 23.84	1	$ 111.95
Supervisor	$ -	-	$ 23.48	1	$ 23.48

Direct Costs			
	$	1,090.06	$/hr
		8	hrs/day
	$	8,720.48	$/day
Production			
		200	tons input/hr (total)
		30%	% waste
		70%	% rip rap and gravel/filter
		140	tons produced/hr (net)
		280,000	lbs/hr
		3000	lb/cy
		93	cy/hr
		6.7	hr/day
		622	cy/day
Total	$	14.02	$/cy average for gravel and riprap produced together for a ratio of 2.6 cy of riprap per 1 cy of gravel for use in reclamation

APPENDIX B.3
ENGINEERING QUANTITIES

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TECHNICAL MEMORANDUM

DATE:	August 30, 2018	Telesto #	200371c
TO:	Chino Mining Company		
FROM:	Taryn Tigges/Fred Charles		
SUBJECT:	Earthwork Cost Estimate Takeoff Summary Quantity Definitions		

This technical memorandum presents a summary discussion of the engineering quantities used in developing the reclamation earthwork cost estimate for the 9 Waste Rock Stockpile (WRS) for the anticipated reclamation/closure topography, based on the 9 Waste Rock Stockpile Closure/Closeout Plan (CCP) by Golder Associates (2017). The reclamation quantities are summarized in Tables 1 and 2. Table 1 lists the quantities associated with the earthwork and Table 2 provides the riprap and gravel volume per foot for each channel type. The quantities were separated into sections of uniform slope, and matching reclamation criteria. A summary description of each item shown in Table 1 is presented below which includes the basis for determining each particular quantity.

Item 1.1 Outslope Cut/Fill Pushdown Distance

This item is the average sloped distance between the approximate centroids of the cut and fill blocks for regrading the stockpile and tailings outslopes.

Item 1.2 Outslope Surface Grade

This item is the final overall grade of the regraded outslope, prior to cutting in any benches. For locations where benches are not required it is equal to the final slope.

Item 2.1 Top Surface Grade %

This item is the final overall grade of the regraded top surface. Where no quantities are indicated in Items 2.2 and 2.3, the grading is done by area, Item 4.1, to obtain a smooth finish at the grade specified.

Item 3.1 Outslope Surface Approximate Sloped Area

This item includes the outslope area that will receive cover, and revegetation. Revegetation costs include chiseling or ripping, scarifying, discing, rangeland drill seeding, mulching, crimping, and mobilization. The planer (horizontal) area was multiplied by a slope correction factor to approximate the true sloped surface area.

Item 3.2 Outslope Surface Cover Push Distance

This item is the estimated average push distance to spread cover material over tailings or stockpile outslopes. It assumes the truck haul and dumping can be coordinated to minimize push distance.

Item 3.3 Outslope Surface Cover Depth

This item is the depth of cover, measured normal to the slope, to be placed over the stockpile outslopes.

Item 3.4 Outslope Surface Cover Fill

This item is the quantity of cover fill to cover the stockpile outslopes at the depth specified in Item 3.3, over the area specified in Item 3.1. Cover fill volumes were obtained by multiplying the area specified in Item 3.1 by Item 3.3 and converting to cubic yards.

Item 4.1 Top Surface Area

This item includes the top surface area of the stockpile. The stockpile will receive grading, cover, and revegetation where indicated. Grading involves making one pass with a blade over the surface to obtain a smooth finished grade. Revegetation costs include chiseling or ripping, scarifying, discing, rangeland drill seeding, mulching, crimping, and mobilization.

Item 4.2 Top Surface Cover Depth

This item is the depth of cover to be placed over the stockpile.

Item 4.3 Top Surface Cover Fill

This item is the quantity of cover fill to cover the stockpile at the depth specified in Item 4.3 over the area specified in Item 4.1. Cover fill volumes were obtained by multiplying the area specified in Item 4.1 by Item 4.3 and converting to cubic yards.

Item 5.1 Cover Source

Borrow locations are used to determine haul distance and grades in Items 5.2 through 5.6.

Item 5.2 - 5.4 Cover Haul Distance

These items describe the two-dimensional haul distance between the approximate centroid of the borrow source and cover areas. Depending on the terrain, the haul route has been divided into two segments. If the grades along the haul route are generally uniform, the haul route was described using two haul segments. The Drawings in the CCP show the main haul routes.

Item 5.5 - 5.6 Cover Haul Grades

These items represent the grades of the haul segments described in Items 5.2-5.4

Item 6.1 Outslope Bench Length

This item represents the length of benches to be cut into the stockpile outslopes. The length of benches is equal to the length of the outslope channels. Bench cross sections are shown in the CCP Drawings.

Item 6.2 Outslope Channel Length

This item represents the length of surface water channels to be constructed on benches of the stockpile outslopes. It was assumed that channels will be located on each outslope bench. The conceptual channel locations and channel cross sections are shown on the CCP Drawings.

Item 6.3 Outslope Channel Gravel

This item includes the volume of gravel material required for the outslope channels described in Item 6.2. The gravel quantity calculations are summarized in Table 2.

Item 7.1 Channel Length

This item represents the length of surface water channels to be constructed on the stockpile top surface. The conceptual channel locations and channel cross-sections are shown on the CCP Drawings.

Item 8.1 Downdrain Length

This item represents the length of the downdrains to be constructed on the stockpiles and tailings. The conceptual downdrain locations, and channel cross-sections are shown on the Drawings in the CCP.

Item 8.2 Downdrain Riprap

This item includes the volume of riprap material required for the downdrains described in Item 8.1. The downdrain riprap calculations are summarized in Table 2.

Item 8.3 Downdrain Gravel

This item includes the volume of gravel required for the downdrains described in Item 8.1. The gravel quantity calculations are summarized in Table 2.

TELESTO SOLUTIONS	9 Waste Rock Stockpile Closure/Closeout Plan	Made By: TMT	Date: 30-Aug-18
	Quantity Summary Sheet		

TABLE 1 - STOCKPILE QUANTITY SUMMARY[1]

Facility Type	Item	Outslope Cut/Fill Pushdown Distance (ft)	Outslope Surface Grade %	Top Grade %	Outslope Surface Area (Acres)	Outslope Surface Cover Push Distance (FT)	Outslope Surface Cover depth Depth (inches)	Outslope Surface Cover Cover Fill (CY)	Top Surface Surface Area (Acres)	Top Surface Cover depth Depth (inches)	Top Surface Cover Fill (CY)	Cover Source	Cover Fill Haul Dist. Distance Total (ft)	Cover Fill Haul Dist. Distance Leg 1 (ft)	Cover Fill Haul Dist. Distance Leg 2 (ft)	Cover Fill Haul Grade Grade Leg 1 (%)	Cover Fill Haul Grade Grade Leg 2 (%)
		Item 1.1	Item 1.2	Item 2.1	Item 3.1	Item 3.2	Item 3.3	Item 3.4	Item 4.1	Item 4.2	Item 4.3	Item 5.1	Item 5.2	Item 5.3	Item 5.4	Item 5.5	Item 5.6
Stockpiles	9 Waste Rock Stockpile	90	-0.29%	-1%	66	100	36	317,998	96	36	462,220	Upper South Stockpile	5,132	2,712	2,420	0.8%	8.5%
Borrow Areas	Upper South Stockpile	-	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-

Facility Type	Item	Bench	Outslope Channel		Channel Reclaimed Area	Channel Off-Site Area	Downdrain		
		Length (ft)	Length (ft)	Gravel (CY)	Length (ft)	Length (ft)	Length (ft)	Riprap (CY)	Gravel (CY)
		Item 6.1	Item 6.2	Item 6.3	Item 7.1a	Item 7.1b	Item 8.1	Item 8.2	Item 8.3
Stockpiles	9 Waste Rock Stockpile	14,085	14,085	4,695	3,069	3,698	1,067	4,051	1,000

[1]Quantities were developed by Chino Mining Company in accordance with standard engineering practice

Table 2 Channel Quantities

Item	Material	Units	Amount[2]	Description[1]
Outslope/Bench Channel	Gravel	cy/ft	0.33	Bench width 15 ft, 1% to 5% crossbench slope, <5% longitudinal bench slope and 30-feet of cover, channel 0.5' thick gravel and 2' of cover
Downdrain	Riprap	cy/ft	3.80	2.5' thick riprap, 0.5' thick gravel
	Gravel	cy/ft	0.94	

[1]Cross Sections are shown in the CCP Drawings.
[2]Quantities were developed by Chino Mining Company in accordance with standard engineering practice

APPENDIX B.4
MISCELLANEOUS SUPPORTING CALCULATIONS

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TECHNICAL MEMORANDUM

DATE: August 29, 2018 **Telesto #** 200414

TO: Chino Mining Company

FROM: Fred Charles

SUBJECT: Documentation of Miscellaneous Supporting Calculations

This technical memorandum presents information on miscellaneous supporting calculations for preparation of the reclamation cost estimate for the 9 Waste Rock Stockpile. Information is provided for development of indirect costs, the grading sequence/process, the hourly adjustment, and unit costs.

Indirect costs

Direct costs are cost for specific activities or services and include items such as stockpile regrading, hauling of cover material, channel construction, etc. Indirect costs are applied to the reclamation cost estimates as part of capital costs and operation and maintenance (O&M) costs and are estimated based on the guidance available from MMD (1996) and OSM (2000). Indirect costs are fees and charges that benefit the entire project but cannot be assigned to any one particular task and include items such as management and moving equipment to and from the site. Indirect costs occur above and beyond the direct cost of reclamation (see Table B.4.1 for breakdown of indirect costs).

Indirect costs are expressed as a percentage of the direct cost and are added to the direct cost to determine the project total cost:

Total Cost = Direct Cost + Indirect Cost

Where:

Indirect Costs = Direct Costs × Indirect Percentages

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Table B.4.1. Indirect cost percentage summary

Direct Cost ($)	MMD (1996)	OSM (2000)	Capital	Earthwork O&M	Water Treatment O&M	Notes
Mobilization & Demobilization	1%-5%	<10%	1%	1%	0%	Mobilization and Demobilization not needed for water management operations and maintenance
Contingencies	-	3% - 5%	-	-	-	
0 - 500,000	10%		-	-	-	
500,000 - 5 million	7%		-	-	-	
5 million - 50 million	4%		-	-	-	
Greater than 50 million	2%		2%	2%	2%	
Engineering Redesign	-	2.5% - 6%	2.5%	2.5%	0%	Engineering Redesign not needed for water management operations and maintenance
Profit & Overhead (OSM)	-	10% - 30%	-	-	-	
0 - 100,000	-	30%	-	-	-	Contractor Profit and overhead decreased by 5% for operations and maintenance since not new construction
100,000 - 500,000	-	25%	-	-	-	
500,000 - 2,000,000	-	20%	-	-	-	
>10,000,000	-	15%	15%	10%	10%	
Reclamation or Closeout Plan Management	-	-	-	-	-	
10,000	-	7%	-	-	-	
500,000		5%	-	-	-	
1,000,000	-	4.5%	-	-	-	
10,000,000	-	3.25%	-	-	-	
100,000,000	-	2%	2%	2%	2%	
State Procurement Cost	-	-	-	-	-	Included in Engineering Redesign and Reclamation Management Fee
Contract Administration	-	-	-	-	-	Included in Reclamation Management Fee, Procurement Cost, and Engineering Redesign
			22.5%	17.5%	14.0%	

Notes: Chino overall earthwork reclamation costs ~$300,000,000. Indirect cost percentage breakdown is based on information presented to NMED and MMD in September 2012.

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Some unit costs obtained from outside sources already include indirect costs, which we remove for the base cost estimating calculation, and then include as part of the total based on percentages of the direct cost after the direct cost is calculated. Unit cost information from the following sources were adjusted to remove indirect costs:

- EquipmentWatch (Penton Media, 2018) notes that certain costs (e.g., equipment depreciation, profit, overhead) included in their standard values are typical indirect costs, and adjustments to the standard values may be needed if the estimator plans to later add indirect costs (which is our approach). We have removed most of the indirect costs from the EquipmentWatch direct costs and apply them to the total direct costs with the exception of equipment depreciation. Indirect costs removed from the EquipmentWatch data include sales tax and annual overhead.

- Fuel cost quote obtained for delivery of fuel to the Chino Mine area is all-inclusive (covers direct and indirect costs). Therefore, indirect costs are removed from the all-inclusive fuel quote at the same percentage as later added back when the total is calculated (described below).

- Revegetation quote includes the indirect cost of sales tax, which is removed from the quote along with all other indirect costs at the same percentage as later added back when the total is calculated (described below).

- Labor rates are based on 2018 NM Department of Labor Type H (Heavy Engineering) labor rates which include indirect costs (i.e., overhead) which are removed.

After removing indirect costs as discussed above, unit costs based on the direct rates are used to calculate direct costs for the project. Then, based on the direct costs, indirect rates are added to the reclamation cost estimate based on the percentages shown in Table B.4.1.

Grading sequence/process

The grading sequence/process for the 9 Waste Rock Stockpile is summarized in this subsection. The top surface will be nearly level, starting with a 1% grade before reclamation and graded at closure to keep the 1% minimum slope requirement. The stockpile, constructed by end dumping in lifts approximately 50 feet high, will have an outslope at the angle of repose between 80- to 100-foot-wide benches on each lift, which will result in an overall slope of approximately 3.5H:1V (Golder, 2017). At closure, the outslope of the stockpile first will be rough graded to achieve a slope of 3.5H:1V. Then, benches will be cut in the slope at intervals of approximately 200 feet, with a 3H:1V slope graded between the benches, and downdrains excavated from the top to bottom of the stockpile. Finally, bench channels will be cut in the benches at a 2% longitudinal slope, maximum of 2,500 feet in length, to the downdrains. These steps of the grading sequence/process are accounted for in the development of the reclamation cost estimate, as shown in the calculation spreadsheets.

Hourly adjustment

The Chino RCE is based on 50 minutes of work per hour. Cost information presented in EquipmentWatch is also typically based on 50 minutes of work per hour. Because the hourly adjustment is made in the RCE calculations, an hourly adjustment to a 60-minute work hour is applied to the EquipmentWatch source data with a multiplication factor of 60/50 (=1.2).

References

Golder Associates (Golder). 2017. 9 Waste Rock Stockpile Closure/Closeout Plan. Prepared for New Mexico Environment Department and Mining and Minerals Division. Submitted by Freeport-McMoRan Chino Mining Company, Vanadium, New Mexico. March 30.

New Mexico Energy and Natural Resources Department, Mining and Minerals Division (MMD). 1996. Closeout Plan Guidelines for Existing Mines, Natural Resources Department. April 30, 1996.

OSM. 2000. U.S. Department of the Interior, Office of Surface Mining Reclamation and Enforcement Handbook for Calculation of Reclamation Bond Amounts. April 5, 2000.

Penton Media, Inc. 2018. EquipmentWatch Custom Cost Evaluator 1st Quarter.