National Exams May 2014

09-MMP-A5, Surface Mining Methods and Design

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. One only reference sheet, 8.5 x 11 inch, hand written both sides is allowed in the exam. This is Closed book exam, therefore only the approved Sharp or Casio type calculators are permitted.

3. Compulsory Question 1 and THREE (3) other questions constitute a complete exam paper. Only question 1 and the first three optional questions as they appear in the answer book will be marked. You must select three questions from the "optional" Questions 2 to 6.

4. Compulsory Question 1 is worth 40 marks. Each optional question is of equal value (20 marks). Three optional questions plus Question 1 constitute a complete exam paper.

5. Many questions require an answer in essay format. Clarity and organization of the answer are important. Use sketches and drawings to illustrate your answers when possible.

If you answer Questions 4 and/or 6, make sure you hand in figures 4.1.a, 4.1.b and .1.4c, and/or figures 6.1 and 6.2 with your number/name attached clearly in the spaces provided.

Question 1 (40 marks) *You must answer all of this question, parts 1.1 to 1.6 inclusive*

Question 1.1 (6 marks) ***answer compulsory***

What do you understand by the terms "availability" and "utilization" in the context of an 8760 hour year. What other definitions are available to make the mechanical and operating % availability and % utilization look better than they are.

Question 1.2 (7 marks) ***answer compulsory***

With respect to conventional dragline mining, what do you understand by the following. Neat sketch sections and/or plans are expected, 2 marks per 1.2.1 to 1.2.3.

1.2.1 Simple side casting.
1.2.2 Advanced bench mining.
1.2.3 Extended bench mining.

Question 1.3 (7 marks) ***answer compulsory***

What do you understand by the term "cost index". Describe two such indexes which might be used for estimating costs in the context of the capital and operating costs of future open pit mines. What are the problems when such indexes are applied to all mine cost sectors and to the various national situations.

Question 1.4 (6 marks) ***answer compulsory***

Briefly describe the methodology and explain the differences between short term mine planning (days to months) and long term mine planning (years to life-of-mine). Include advantages and disadvantages of routinely employing these planning applications.

Question 1.5 (7 marks) ***answer compulsory***

What do you understand by the terms "spotting", "double back-up" and "drive by" in the context of open pit truck-shovel loading operations and blast layouts. Neat sketches are expected.

(4 marks)

Trucks can be classified by drive type. What are the two types of truck drives in typical use in open pit mines. (3 marks)

Question 1.6 (7 marks) ***answer compulsory***

1.6.1 Describe the development of a block model typically used in studying the feasibility of open pit mines. What single piece of important information (a double precision number) is attached to each block to locate the block in 3D space and give examples of calculations to and from this number. (4 marks)

1.6.2 After applying such as wall slope restrictions, rock types, discontinuities, and recoveries, there are two specific rules governing whether a "parcel of ore" (or ore block which generates a profit)) will be included in the "optimal" open pit or not. What are these two rules. (3 marks)

Question 2 (20 marks) **One of Three Optional Questions**

2.1 The following are the specifications of a walking dragline mining the overburden covering a 5m thick coal seam by simple side casting. The machine is operating about half way along the cut. Positioning is the distance from crest to tub centre as a % of tub diameter.

Dragline Specifications

• Tub Diameter	18m
• Operating Radius	95m
• Positioning Factor	75%
• Stacking Height	12m
• Digging Depth	35m

Mined Material Specifications

• High-wall angle (from horizontal)	63 degrees
• Coal face angle (from horizontal)	90 degrees (to make calculations simpler)
• Spoil Pile slope (from horizontal)	35 degrees
• Spoil Pile Swell Factor	0.25
• Depth of Overburden	30m
• Pit Width	45m

(The following questions 2.1.1 to 2.1.6 are worth 2 marks each and 2.1.7, 3 marks, total 15 marks)

2.1.1 Draw a neat (preferably to scale) section of the spoil pile and cut, i.e. a range diagram.

Calculate the following on a section 1 m thick along the pit cut (i.e. one lineal meter). This represents the volumes per lineal meter of cut length,

2.1.2 Cut Area (Volume/m)

2.1.3 Spoil Pile Area (Volume/m)

2.1.4 Spoil Pile Height

2.1.5 Stacking Height (Calculated, not as per dragline specifications)

2.1.6 Horizontal Reach Factor

2.1.7 Operating Radius (Calculated, not as per dragline specifications)

2.2 In the event that the dragline will not complete the removal of overburden with the use of simple side casting, auxiliary mining methods using extra equipment will be required to accomplish the removal. Explain such other methods with neat sketch plans/sections.` (5 marks)

Question 3 (20 marks) One of Three Optional Questions

3.1 "Pareto's Law" can be used to find the major cost components of the operating cost of drills, trucks or shovels in a typical truck/shovel hard rock open pit mine. Given that you have access to all accounting information for such a mine, how would you apply Pareto's Law to quickly isolate the major operating costs of items such as drilling (for blast-holes), trucks (for rock haulage) and shovels (for loading trucks). (4 marks)

For each of the following three cost centres, list the three major cost items and their approximate percentage of the total cost of that particular cost sector. (2 mark each, total 6 marks)

3.1.1 Drilling (for Blast-holes)
3.1.2 Truck (Haulage)
3.1.3 Shovel (Loading)

(an example answer for the blasting cost centre might be 30% ANFO, 25% Slurried Explosive, 20% Wages and Benefits, 10% Blast Hole Dewatering, 10% Detonators and Accessories and 5% "Other").

3.2 Discuss how inflation cost indexes could improve cost estimates of future operations based on your answers to questions 3.1.1, 3.1.2 and 3.1.3. (2 marks)

3.3 A publication has produced capital cost indexes for a variety of mining purchases based on the equipment size for the year 1997. Such information allows the mining engineer to estimate capital costs (CDN $) for potential mining projects by the various cost centres in 1997 dollars.

For drills the relationship is

$P=a X^{b}$ where P is the capital cost of a drill, X is the pull-down force in pounds (lbs.), and a and b are constants, 400 and 0.67 respectively.

3.3.1 What is the 1997 cost of a 55,000 kg pull-down force rotary drill. (2 marks)

For shovels the relationship is

$P = a X^{b}$ where P is the capital cost of a shovel, X is the shovel bucket capacity in cubic yards and a and b are constants, 540,000 and the power 0.75 respectively.

3.3.2 What is the 1997 cost of a 53 cubic meter bucket size shovel. (2 marks)

For trucks the relationship is

$P = a X^{b}$ where P is the cost of a truck, X the truck capacity in short tons and a and b are constants, 20,000 and the power 0.90 respectively

3.3.3 What is the 1997 cost of a 300 tonne truck. (2 marks)

3.4 A cost index estimates that a 1997 dollar is now worth 2.00 dollars

What are the costs of buying the drill, shovel and truck today, and are the values realistic.

(2 mark)

Question 4 (20 marks) **One of Three Optional Questions**

SPARE COPIES of Figures 4.1.a, 4.1.b and 4.1.c are Appended

4.1 Figure 4.1.a shows a tabulation of ore and waste to be mined from the first open pit without considering any pushbacks, and operates for almost 6 years. The far left hand side of the tabulation has the bench elevation shown with the highest elevation mined at the top and the lowest elevation mined near the bottom. On the left of the tabulation, the totals for ore and waste for each bench, and overall total (bottom line), are shown in million tonnes. Extra copies of Figures 4.1.a, 4.1.b and 4.1.c are attached at the end of the exam paper in case you need to repeat your calculations.

Because the shovels require time to be constructed in the first year, a total of 15 million tonnes can be mined. The mill ***must process10 million tonnes of ore in year one*** and the pit mine 15 million tonnes, 10 ore and ***5mt of waste***. After year one, the mine has the capacity to move a maximum of 20 million tonnes/year. The mill ***must*** process 10 million tonnes per year and the mine dig the 10mt ore and ***up to 10 million tonnes of waste***. The mine cannot mine waste below, and on the bottom, of the ore mining elevation.

The tabulation has to be converted into an annual open pit mining schedule within all the constraints of open pit mining, e.g. The mill must operate at its rated annual capacity of 10mt/yr for nearly 6 years.

Other constraints include;

4.a In any year, the lower benches cannot be mined and "undercut" the benches above. This is achieved by mining the upper benches first to depletion.

4.b On any particular bench ore is mined ahead of waste where possible. Thus the ore schedule must be run first. That is required by the mining company.

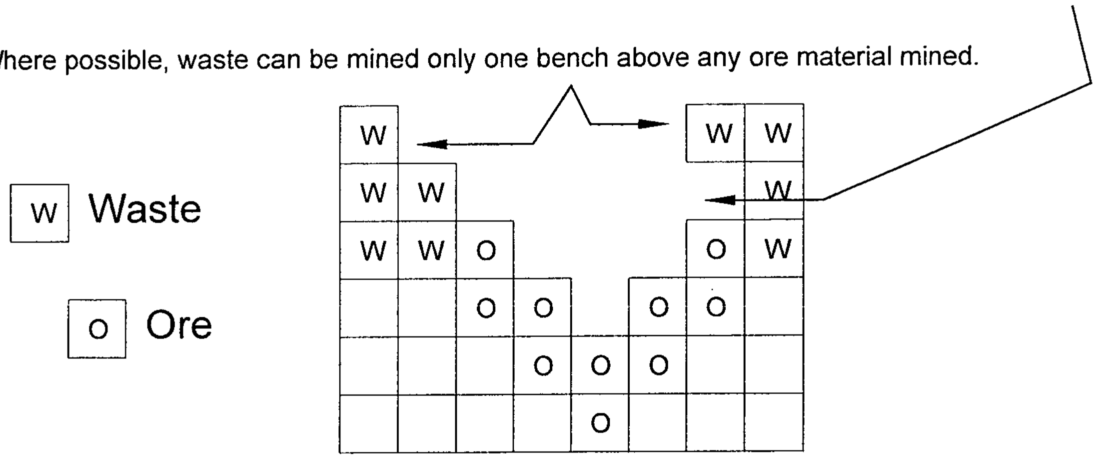
4.c Where possible waste can be mined only one bench or more above any ore material mined. This keeps the mined "area" compact, avoids moving drills and shovels long distances on ramps and avoids mining waste ahead of ore (except the very bottom bench).

Figure 4.1 shows a "contrived" example section to help understand the above rules.

The matrix template Figure 4.1.a or both Figures 4.1.b and 4.1.c is to be used to show the ore and waste schedule. The year of mining is shown on the top of the matrix starting with year 1 on the left. The production by bench is shown in the left side of the matrix, and annual totals on the bottom.

4.a In any year, the lower benches cannot be mined and "undercut" the benches above.

4.c Where possible, waste can be mined only one bench above any ore material mined.



4.b On any particular bench ore is mined ahead of waste where possible.

Figure 4.1 Mining Rules on "Contrived" Section

4.1.1 For ore mining, calculate and insert the values within the matrix 4.1.b and c showing the time and elevation of mining ore. Show the ore totals by year of mining. (2 marks)

4.1.2 Calculate and insert the values within the matrix 4.1.a or 4.1.b and c showing the time and elevation of mining waste. Show the waste totals by year of mining. (5 marks)

You can use matrix 4.1.a and complete tasks 4.1.1.and 4.1.2 in one step.

4.2.1 Place the annual production of ore, waste and total per year at the bottom of the matrix (The resulting matrices will have values roughly from the top left to bottom right diagonal).

(2 marks)

4.2.2 What is the overall stripping ratio of this pit. (1 mark)

4.3 If the rules in Figure 4.1 (4.a to 4.c) could not be achieved, what action would you recommend.

(2 marks)

4.4 The mine has 3 shovels, each capable of producing 7 million tonnes per year.

From your schedule, in what year(s) would it be possible to permanently release shovels from this Pit to mine (strip) later pushbacks. (2 marks)

4.5 In Figures 4.1.a to c, no ore grade information is available. If grade values were included, it would be recognized that this initial pit has been operated with a higher than economic cut-off grade, i.e. "high graded". Here lower grade economic material has been placed in stockpiles (selective "waste" dumps) closer to the mill for mill feed later in the life of the operation. Stockpile mining can occur when ore is sometimes unavailable because of scheduling problems, wall slope instabilities or when variations in commodity prices occur during the mining of pushbacks.

The initial pit could have been mined with a lower but economic cut-off grade. This would have reduced the number of shovels and trucks in the early years.

Explain how you would justify the;

4.5.1 Purchase of sufficient equipment to mine at full capacity immediately and produce better grade ore in the early years of mining (used in the example of Figure 4.1). (3 marks)

4.5.2 Purchasing shovels and trucks in stages as required and accepting the mining of lower grade as mill feed in the early years of mining. (3 marks)

Figure 4.1.a

Matrix for Mine Schedule **Year One 15mt total, 5mt ore.** **Remainder ~20mt total, 10mt ore, ~10mt waste**

bench elev-ation	Totals for Pit			Year 1			Year 2			Year 3			Year 4			Year 5			Year 6		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25																		
1585	0.83	0.00	0.83																		
1570	1.67	0.67	1.00																		
1555	4.13	1.70	2.43																		
1540	7.70	3.85	3.85																		
1525	9.80	5.42	4.38																		
1510	10.79	6.95	3.84																		
1495	10.67	6.63	4.04																		
1480	9.38	6.46	2.92																		
1465	8.08	5.76	2.32																		
1450	6.87	5.26	1.61																		
1435	5.67	4.65	1.02																		
1420	4.50	3.97	0.53																		
1405	3.58	3.27	0.31																		
1390	2.63	2.46	0.17																		
1375	1.87	1.78	0.09																		
1360	1.17	1.15	0.02																		
total	89.59	59.98	29.61																		

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Figure 4.1.b *Matrix for Mine Schedule* *Year One 15mt total, 5mt ore,10mt waste* *Years Two and Three ~20mt total, 10mt ore, ~10 mt waste*

bench elev-ation	Totals for Pit			Year 1			Year 2			Year 3		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25									
1585	0.83	0.00	0.83									
1570	1.67	0.67	1.00									
1555	4.13	1.70	2.43									
1540	7.70	3.85	3.85									
1525	9.80	5.42	4.38									
1510	10.79	6.95	3.84									
1495	10.67	6.63	4.04									
1480	9.38	6.46	2.92									
1465	8.08	5.76	2.32									
1450	6.87	5.26	1.61									
1435	5.67	4.65	1.02									
1420	4.50	3.97	0.53									
1405	3.58	3.27	0.31									
1390	2.63	2.46	0.17									
1375	1.87	1.78	0.09									
1360	1.17	1.15	0.02									
total	89.59	59.98	29.61									

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Figure 4.1.c *Matrix for Mine Schedule* *Years Four to Six* *~20mt total, 10mt ore, ~10mt waste*

bench elevation	Totals for Pit			Year 4			Year 5			Year 6		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25									
1585	0.83	0.00	0.83									
1570	1.67	0.67	1.00									
1555	4.13	1.70	2.43									
1540	7.70	3.85	3.85									
1525	9.80	5.42	4.38									
1510	10.79	6.95	3.84									
1495	10.67	6.63	4.04									
1480	9.38	6.46	2.92									
1465	8.08	5.76	2.32									
1450	6.87	5.26	1.61									
1435	5.67	4.65	1.02									
1420	4.50	3.97	0.53									
1405	3.58	3.27	0.31									
1390	2.63	2.46	0.17									
1375	1.87	1.78	0.09									
1360	1.17	1.15	0.02									
total	89.59	59.98	29.61									

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Question 5 **(20 marks)** **One of Three Optional Questions**

This question involves truck-shovel mining system productivity in open pit mines.

5.1 What could happen if the number of trucks assigned to a shovel was (say) twice the number theoretically required based on productivity observations. (1 mark)

5.2 In the context of truck-shovel open pit mining what do you understand by the term "match factor" as defined by; (2 marks)

5.2.1 Equipment manufacturers. Give an example calculation.

5.2.2 Feasibility engineers responsible for numbers of trucks per shovel over the life of an open pit.

5.3 The average loading time for a truck, including truck positioning, is 3.0 minutes. The time taken for the loaded trucks to reach the crusher is 12.0 minutes. Backup and dumping take 1.0 minute in total, and the empty truck return is 8.0 minutes.

What is the total "theoretical" truck cycle time (1 mark)

What is the total cycle time divided by the loading time. What is the name of this value. (2 marks)

5.4 Figure 5 shows a sketch with two shovels operating. One shovel is digging waste which must be trucked to the waste dump and the other shovel is loading ore which must be trucked to the crusher. With respect to truck routings in a truck-shovel mining operation, what do you understand by the terms "closed out" and "dispatched". Referencing Figure 5 showing all possible routings, draw neat diagrams showing the respective closed out and dispatched routes. (1 mark)

5.5 The times taken by the trucks to travel to and from the shovels and dumps are shown below, as are the load and dump times. All times are in minutes and refer to figure 5.

- Shovel 1 to Crusher 12 minutes
- Crusher to Shovel 1 8
- Shovel 2 to Waste Dump 12
- Waste Dump to Shovel 2 8

- Crusher to Shovel 2 — 4 minutes
- Waste Dump to Shovel 1 — 3
- Loading at Shovel 1 — 3
- Dumping Ore at Crusher — 1
- Loading Waste at Shovel 2 — 3
- Dumping at Waste Dump — 1

5.5.1 What are the theoretical numbers of trucks required for "closed out" and for "dispatched" operation in Figure 5 to obtain theoretical maximum production. (2 marks)

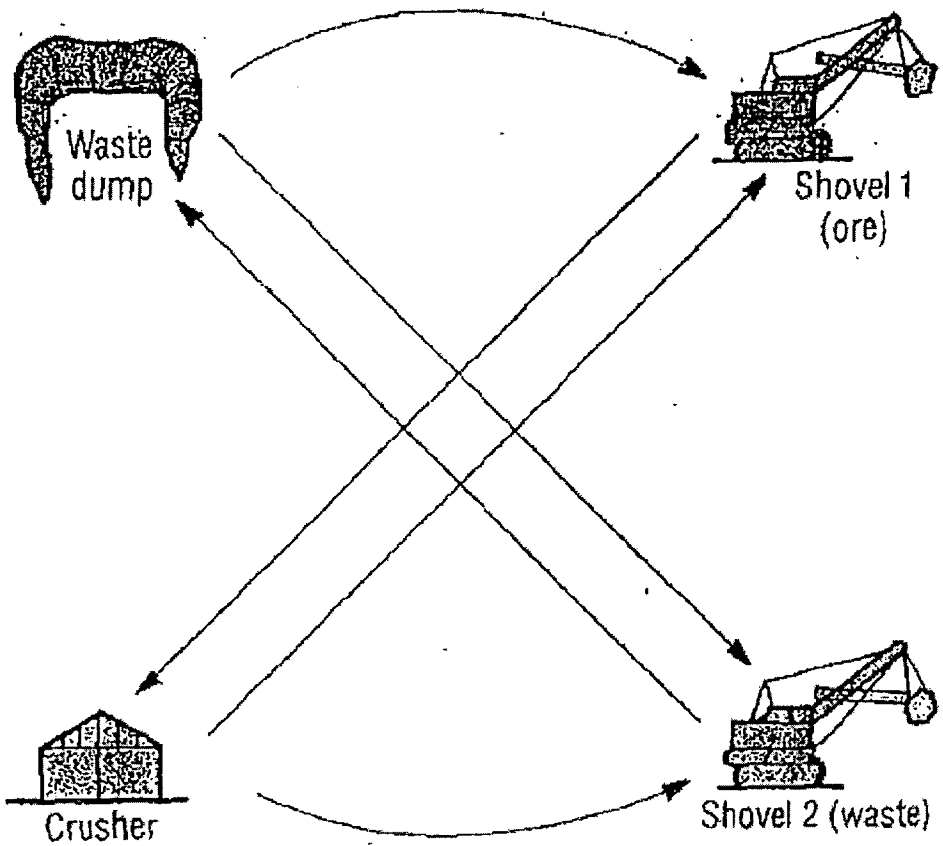

Figure 5 **All Possible Truck Routings**

5.5.2 Which trucking configuration is the most efficient, closed out or dispatched and how many trucks are "theoretically" required in each case. (1 mark).

5.5.3 Using the most efficient configuration, how many truckloads are theoretically delivered to the crusher and dump in an 8 hour shift and is this value realistic (1 mark)

5.6 All large open pits use the principles shown in figure 5 as part of their "dispatch" systems. The truck dispatch system can be described in three terms, BP (best path), LP (linear programming) and DP (dynamic programming).

Explain the following as applied to truck shovel systems. Include examples in your explanation.

(3 marks)

5.6.1 BP
5.6.2 LP
5.6.3 DP

5.7 With respect to electronic truck dispatch systems;

5.7.1 Briefly describe the computer hardware employed on the shovels and trucks to achieve maximum trucking efficiency with dispatch in large open pits. (2 marks)

5.7.2 Discuss how and where grade control and stripping ratio constraints can be included in such a system. (2 marks)

5.7.3 Practically, the LP setup does not precisely achieve its goals and is inefficient because some shovels may be grossly underutilized during a 24 hour period when grade control and stripping ratio constraints are met. How is the underuse managed while still maintaining the 24 hour goals. (2 marks)

Question 6 (20 marks) **One of Three Optional Questions**

Spare Copies of Figure 6.1 and 6.2 are Appended

6.1 An open pit copper mine has developed a revenue model for material in the pit. The model provides revenue in CDN $ based on grade as follows

Revenue per tonne mined = 60.0 * % Copper − 8.0

The mining cost is $2.0 / tonne mined and the mill and other (smelting, refining, plant, administration and general but **not** including mining) costs total $6.0 / tonne milled.

Note that the terms "cash flow" and "profit" are taken to be the same for questions 6.

6.1.1 What is the revenue / tonne produced by a block grade of 0.4% copper.

What is the cash flow / tonne for the block in the block model. (2 marks)

6.1.2 What is the revenue / tonne produced by a block grade of 0.15% copper.

What is the cash flow / tonne for the block in the block model. (2 marks)

6.1.3 What is the revenue / tonne produced by a waste block with 0% copper grade.

What is the cash flow / tonne for the block in the block model. (2 marks)

The ore-body section shown in figures 6.1 and 6.2 consists of square blocks 15m X 15m and the wall slope is 45 degrees. Effects of ramps are not part of the answer. The pit is a typical tabular copper deposit, and the "profit" or "cash flow" for the block is given for each block in the matrix. Negative blocks are waste or sub-marginal ore which are placed on waste or low grade dumps and do not provide revenue.

6.2 The "Moving Cone" (or "Floating Cone") (MC) algorithm can be applied to provide a close approximation to a true "optimal" pit limit.

6.2.1 Explain each of the five steps involved in the moving cone (MC) procedure. The steps are continually repeated from the top to the bottom of the block model until no ore blocks can be profitably mined. (2 marks)

6.2.2 Complete the extraction of the pit on section in figure 6.1 using the "Moving Cone" (MC) rules of 6.4.1. Do not use the "combine adjacent blocks into parcels" as you develop your answer as this procedure is extremely difficult to program in three dimensions on a computer. (2 marks)

6.2.3 What is the maximum cash flow and how many blocks of ore and waste are removed. In 6.4.2. Include the respective number of ore blocks and waste blocks in your answer. (2marks)

6.3 In 1965, Lerchs and Grossman published a paper explaining how to solve the optimal pit problem in three dimensions using operations research techniques including graph theory. The solution to the application of the Lerchs Grossman (LG) algorithm to the problem (fig 6.1) is shown in Figure 6.2. Figure 6.2 shows a simple section through the same ore-body as in part 6.2.

6.3.1 Indicate (circle) the total cash flow determined from the LG algorithm on Figure 6.2. (2 marks)

6.3.2 In Figure 6.2, show the pit outline on section as a thick or coloured line. (2 marks)

6.3.3 Find the number of blocks of ore, waste and total from the "LG" method (2 mark)

6.3.4 Explain the differences between the "MC" and "LG" solutions. (2 marks)

Figure 6.1 Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	**3**	**29**	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	**24**	**3**	**24**	**4**	**5**	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

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Figure 6.2 **Final Matrix of "P" Values from Lerchs-Grossman Algorithm** **Wall Slope 45 degrees** **Blocks 15x15x15 m**

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	6	5	5	4	3	2	1	0	-1	-1	-1	10	9
-2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	7	6	6	4	3	2	1	0	-1	-2	-3	11	9	8
-3	-5	-6	-6	-6	-6	-6	-6	-6	-6	-6	9	8	8	5	3	1	0	-1	-2	-3	-4	13	10	8	6
-4	-7	-9	-10	-10	-10	-10	-10	-5	-7	12	11	11	7	4	1	-1	-3	-4	-5	-6	16	12	9	6	4
-5	-9	-12	-14	-15	-15	-15	-1	-3	16	15	15	10	6	2	-1	-4	-6	-8	-5	20	15	11	7	4	1
-7	-12	-16	-19	-21	-22	4	2	21	20	20	14	8	3	-1	-5	-8	-11	-13	-11	18	13	8	4	0	-3
-9	-16	-21	-25	-28	-30	-5	0	19	18	18	12	5	-1	-6	-10	-14	-17	-20	-18	10	9	4	-1	-5	-9
-11	-20	-27	-32	-36	-39	-15	-11	15	14	14	8	1	-6	-12	-17	-21	-25	-28	-27	1	-1	-2	-7	-12	-16

6.3.1 Indicate (circle) the total cash flow determined from the LG algorithm on Figure 6.2. (2 marks)

6.3.2 In Figure 6.2, show the pit outline on section as a thick or coloured line. (2 marks)

6.3.3 Find the number of blocks of ore, waste and total from the "LG" method (2 mark)

6.3.4 Explain the differences between the "MC" and "LG" solutions. (2 marks)

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Be sure to hand in your Figures 4.a, 4.b and 4.c and Figures 6.1 and 6.2 and include your number/name in the spaces provided on the figures where applicable.

End of Exam

Figure 4.1.a Matrix for Mine Schedule Year One 15mt total, 5mt ore, Remainder ~20mt total, ~10mt ore

bench elev-ation	Totals for Pit			Year 1			Year 2			Year 3			Year 4			Year 5			Year 6		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25																		
1585	0.83	0.00	0.83																		
1570	1.67	0.67	1.00																		
1555	4.13	1.70	2.43																		
1540	7.70	3.85	3.85																		
1525	9.80	5.42	4.38																		
1510	10.79	6.95	3.84																		
1495	10.67	6.63	4.04																		
1480	9.38	6.46	2.92																		
1465	8.08	5.76	2.32																		
1450	6.87	5.26	1.61																		
1435	5.67	4.65	1.02																		
1420	4.50	3.97	0.53																		
1405	3.58	3.27	0.31																		
1390	2.63	2.46	0.17																		
1375	1.87	1.78	0.09																		
1360	1.17	1.15	0.02																		
total	89.59	59.98	29.61																		

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Figure 4.1.b *Matrix for Mine Schedule* *Year One 15mt total, 5mt ore,10mt waste* *Years Two and Three ~20mt total, 10mt ore,~ 10mt waste*

bench elev-ation	Totals for Pit			Year 1			Year 2			Year 3		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25									
1585	0.83	0.00	0.83									
1570	1.67	0.67	1.00									
1555	4.13	1.70	2.43									
1540	7.70	3.85	3.85									
1525	9.80	5.42	4.38									
1510	10.79	6.95	3.84									
1495	10.67	6.63	4.04									
1480	9.38	6.46	2.92									
1465	8.08	5.76	2.32									
1450	6.87	5.26	1.61									
1435	5.67	4.65	1.02									
1420	4.50	3.97	0.53									
1405	3.58	3.27	0.31									
1390	2.63	2.46	0.17									
1375	1.87	1.78	0.09									
1360	1.17	1.15	0.02									
total	89.59	59.98	29.61									

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Figure 4.1.c *Matrix for Mine Schedule* *Years Three to Six* *~20mt total, 10mt ore,~ 10mt waste*

bench elev-ation	Totals for Pit			Year 4			Year 5			Year 6		
	total	ore	waste	total	ore	waste	total	ore	waste	total	ore	waste
1600	0.25	0.00	0.25									
1585	0.83	0.00	0.83									
1570	1.67	0.67	1.00									
1555	4.13	1.70	2.43									
1540	7.70	3.85	3.85									
1525	9.80	5.42	4.38									
1510	10.79	6.95	3.84									
1495	10.67	6.63	4.04									
1480	9.38	6.46	2.92									
1465	8.08	5.76	2.32									
1450	6.87	5.26	1.61									
1435	5.67	4.65	1.02									
1420	4.50	3.97	0.53									
1405	3.58	3.27	0.31									
1390	2.63	2.46	0.17									
1375	1.87	1.78	0.09									
1360	1.17	1.15	0.02									
total	89.59	59.98	29.61									

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Figure 6.1 Block Profit (Cash Flow) Matrix Section Wall Slope 45 degrees Blocks 15x15x15 m

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	**3**	**29**	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	**24**	**3**	**24**	**4**	**5**	-1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

6.2.2 Complete the "Moving (Floating) Cone" solution to the "optimum pit" without combining ore blocks into parcels. *(2 marks)*

6.2.3 Find the total cash flow and number of blocks of ore, waste and total using the "MC" method. *(2 marks)*

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Figure 6.2 Final Matrix of "P" Values from Lerchs-Grossman Algorithm Wall Slope 45 degrees Blocks 15x15x15 m

-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	6	5	5	4	3	2	1	0	-1	-1	-1	10	9
-2	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	7	6	6	4	3	2	1	0	-1	-2	-3	11	9	8
-3	-5	-6	-6	-6	-6	-6	-6	-6	-6	-6	9	8	8	5	3	1	0	-1	-2	-3	-4	13	10	8	6
-4	-7	-9	-10	-10	-10	-10	-10	-5	-7	12	11	11	7	4	1	-1	-3	-4	-5	-6	16	12	9	6	4
-5	-9	-12	-14	-15	-15	-15	-1	-3	16	15	15	10	6	2	-1	-4	-6	-8	-5	20	15	11	7	4	1
-7	-12	-16	-19	-21	-22	4	2	21	20	20	14	8	3	-1	-5	-8	-11	-13	-11	18	13	8	4	0	-3
-9	-16	-21	-25	-28	-30	-5	0	19	18	18	12	5	-1	-6	-10	-14	-17	-20	-18	10	9	4	-1	-5	-9
-11	-20	-27	-32	-36	-39	-15	-11	15	14	14	8	1	-6	-12	-17	-21	-25	-28	-27	1	-1	-2	-7	-12	-16

6.3.1 Indicate (circle) the total cash flow determined from the LG algorithm on Figure 6.2. (2 marks)

6.3.2 Show the pit outline on section as a thick or coloured line. (2 marks)

6.3.3 Find the total cash flow and number of blocks of ore, waste and total using the "LG" method (2 marks)

6.3.4 Explain the differences between the "MC" and "LG" solutions (2 marks)

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Be sure to hand in your Figures 4.a, 4.b and 4.c and Figures 6.1 and 6.2 and include your number/name in the spaces provided on the figures where applicable.