National Exams December 2016

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 a 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 large neat sketches and drawings to illustrate your answers when possible.
6. Answers to Question 6 must be partially completed on page 15 (or spare page 16). Make sure you hand in Figure 6.1, page 15 (or Spare Copy 6.1.a page 16) with your number/name attached clearly in the space provided if you choose to answer this question.
7. Include any other material you may have written on.

Compulsory Question 1 (40 marks)

You must answer* all *of this question, parts 1.1 to 1.6 inclusive

Question 1.1 (7 marks) *answer compulsory*

In order to determine what is ore and waste, and their respective areas (volumes) in a typical "hard rock" open pit production blast, and provide an input to the estimation of periodic (monthly) mill head grades, grade control measures must be implemented, often under the supervision of the mines' engineering department.

1.1.a Describe a "manual" and an "automatic" method of sampling production blasthole drill cuttings.
1.1.b Discuss the introduction of systemic biases depending on the method of sampling blast hole cuttings and how the sampling method might be improved as a consequence.
1.1.c Discuss how the shapes and areas outlined as ore might lead to erroneous head grade and volume estimates.

(3 marks 1.1.a and 2 marks for 1.1.b and c, total 7 marks)

Question 1.2 (6 marks) *answer compulsory*

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

1.2.a Simple side casting.
1.2.b Advanced bench mining.
1.2.c Extended bench mining.

(1.2.a to 1.2.c, 2 marks each, total 6 marks)

Question 1.3 (7 marks) *answer compulsory*

1.3.a What do you understand by the term "cost index".
1.3.b 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.
1.3.c What are the problems when such indexes are applied to all mine cost sectors.

(3 marks 1.3.b and 2 marks for 1.3.a and c, total 7 marks)

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

From an open pit mine perspective discuss and define the following;

1.4.a Reclamation
1.4.b Sustainability
1.4.c Environmental Challenges

(2 marks each 1.4.a to c, total 6 marks)

Question 1.5 (7 marks) answer compulsory

1.5.a In the context of open pit mine dewatering, what do you understand by the term "water hammer".

1.5.b There are two major effects of water hammer in pipes. What are they.

1.5.c What steps can be taken to minimise water hammer.

(3 marks 1.5.b and 2 marks for 1.5.a and c, total 7 marks)

Question 1.6 (7 marks) *answer compulsory*

1.6.a Clearly define the steps taken (rule base) in the development of the moving (or floating) cone with reference to a simple two dimensional "vertical cut" through the centre of an orebody.

In 1962 Lerchs and Grossmann introduced the first "true" three dimensional algorithm to resolve deficiencies in the moving cone method.

1.6.b What were those deficiencies.

1.6.c Why is the Lerchs and Grossmann algorithm still not "optimal" in the context of an open pit mine with a 10 to 20 year life.

(3 marks 1.6.a and 2 marks for 1.6.b and c, total 7 marks)

Question 2 (20 marks) One of Three Optional Questions

2.1 In the context of "conventional" dragline coal mining operations what do you understand by the term "Range Diagram".

(2 marks)

2.2 The term "dragline positioning" is used to describe the position of the dragline tub with respect to the edge of the high-wall. The term defines the percent of tub diameter from the dragline centerline to the edge of the high-wall.

2.2.1 Draw a neat sketch section showing the dragline tub (20m diameter) and edge of high-wall when the "positioning" is 75%.

2.2.2 What is the distance from the edge of the high-wall to the nearest edge of the tub, and from the high-wall edge to the center line of the dragline.

2.2.3 The dragline reach is the distance from the edge of the highwall to the end of the operating radius. In terms of the operating radius and positioning, what is the dragline reach.

(1 mark each, total 3 marks)

2.3 The term "spoil pile swell factor" is the increase in volume of unbroken overburden when stacked as broken rock (spoil). It is usually stated as a decimal rather than a percentage.

2.3.1 If a spoil pile swell factor is 0.25, what is the volume of 1 m^3 of unbroken overburden after digging and placing on the spoil pile.

(1 mark)

2.4 Draw a neat sketch section to scale (this enables you to check your answers later in section 2.5) of a dragline side-casting operation showing;

2.4.1 Dragline operating radius 90m

2.4.2 Dragline tub diameter 20m

2.4.3 Stacking height (maximum) 12m

2.4.4 Cut depth 25m

2.4.5 Positioning factor 75%

Question 2.4 continued

2.4.6 Pit width 20m

2.4.7 Depth of overburden (machine can dig to 35m) 25m

2.4.8 High-wall slope angle 63 degrees

2.4.9 Spoil pile angle of repose 35 degrees

2.4.10 Spoil pile swell factor, 0.25 or 25%

2.4.11 Coal seam thickness 3m

(sketch section to scale, total 4 marks)

2.5 Calculate (not measure from your section) the following for a 1m wide section of the operation

2.5.1 Cut area (an area per meter wide slice)

2.5.2 Spoil pile area

2.5.3 Spoil pile height above coal seam floor

2.5.4 Height of the spoil pile above base of dragline tub

2.5.5 Operational stacking height (not stacking height specified by dragline)

2.5.6 Horizontal reach factor (crest of overburden to vertical line from top of stacked spoil)

(1 mark each 2.5.1 to 6, total 6 marks)

2.6 Will the dragline be capable of mining the overburden and uncovering the coal as planned, i.e. can the dragline complete the operation of the mine without modifications to the mining method or machine.

(2 marks)

2.7 What auxiliary mining methods and/or extra equipment would be required to accomplish the mining if the dragline and its mining configuration were inadequate for purpose.

(2 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 reduce the operating costs of items such as drilling (for blast-holes), trucks (for rock haulage) and shovels (for loading trucks).

(2 marks)

For each of the following three cost centres, list the three major cost items and their percentage of the total of that particular cost sector.

3.1.1 Drilling (for Blast-holes)

3.1.2 Trucking (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 marks each cost centre, total 9 marks)

3.1.4 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)

3.2 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 (US or CDN $) for a potential mining project by the various cost centres.

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, 200 and 0.67 respectively.

3.2.1 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, 520,000 and the power 0.75 respectively.

3.2.2 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

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

3.3 A cost index estimates that a 1997 dollar is now worth 1.33 dollars

What are the costs of buying the drill, shovel and truck today, and are the values realistic. (1 mark)

Question 4 (20 marks) One of Three Optional Questions

4.1 A mining district has operated several very profitable mines for a half century. During this period, specialized mining equipment has been developed, with supporting infrastructure supplying raw materials for fabrication. A skilled workforce has been trained and employed making such equipment and raw materials for worldwide consumption.

The mines eventually close. How would you ensure the continued sustainability of the mine equipment and raw material manufacturing industries which have replaced the mines as the leading employer. The following are a few headings for discussion.

4.1.1 Ownership of manufacturing plants

4.1.2 Training of future manufacturing/design/research employees

4.1.3 In old mining districts, remaining "leading edge" rather than "up-to-date" or conversely, "outdated" with mine equipment, fabrication and raw materials manufacturing is difficult. There are no local mines demanding modern innovative equipment in this case.

4.1.4 Give (discuss) an example where sustainability has been achieved (employing more personnel than the original mines) and an example where it has not (resulting in permanent un-employment rates of over 20% and a sense of hopelessness in the community).

(1 mark each, total 4 marks)

4.2 What are the main elements of a mine closure plan and provide a brief discussion of such a plan. Include the following in your discussion.

4.2.1 Re-vegetation and re-foresting of contoured waste dumps

4.2.2 Acid drainage remediation

4.2.3 Re-vegetation of tailings dams and the selection of vegetation to accomplish this.

4.2.4 Reclamation of the "slimes" area of the tailings pond(s)

4.2.5 Restoring the agricultural capabilities of the disturbed area.

4.2.6 How an abandoned open pit should be developed to provide a lake suitable for fish breeding, and/or alternatives

(1 mark each 4.2.1 to 4.2.6, total 6 marks).

4.3 A mine has been permitted based on a 10 year mine plan and an immediately following "reclamation" period. The cost of reclamation has been estimated as 1 million dollars based on "todays dollar", with no net salvage value.

4.3.1 According to the mining company, inflation averages 6% per year. What will the 1 million dollar reclamation cost be in 10 years.

[interest rate tables are not provided as $(1+r)^n$ can be easily found on the APEO approved calculator allowed in the exam]

4.3.2 Permitting of mines often includes some form of annual "sinking fund installment" to provide the cost of reclamation at a very low government secured bond interest rate. What annual amount (same every year) must the mine deposit in each of the 10 years to provide the required lump sum at the end of mine operations if the government interest rate is 2%.

{ a formulae which may be of use as is or inverted $[\ i\ /\ (((1+i)^n)\ -1)\ ]$ }

(1 mark each 4.3.1 to 4.3.2, total 2 marks).

4.4 The permitting process has not allowed for the possibility that the mine might close prematurely (from low product prices, increased costs, reduced mill recovery, slope failure, etc.)

At year 4, the planned 10 year mine closes unexpectedly, declaring bankruptcy. The assets are taken over by the government and all items of salvageable value removed by the government (at no value accrued to the mine) leaving nothing of value. The pit, tailings and waste areas are essentially the same with respect to disturbance as if the mine had operated for its anticipated 10 years. Consequently reclamation costs are those for the 10 year mine plan but lasting only 4 years at 6% annual inflation.

4.4.1 What is the cost of reclamation in today's dollars, i.e. the cost of reclamation in year 4 dollars at 6% expressed in todays' dollars.

4.4.2 At the 2% government rate, how much has the company deposited by year 4 in today's dollars, given that the mine life was expected to be 10 years.

4.4.3 How much must the taxpayer pay in year 4 to complete the reclamation.

(2 marks each 4.4.1 to 4.4.3, total 6 marks).

4.5 Develop a financial plan that will avoid such a taxpayer liability and which is fair to the mine and in a sense "optimal" for both mine and taxpayer.

(2 marks)

Question 5 (20 marks) One of Four Optional Questions

5.1 A mine has chosen to use in-pit pumps in a sinking cut sump to remove water. There are two of the same type of pump available with the characteristic curves shown in Figure 5.1. below. The pumps can be used in high volume (MT) or high head (HT) configuration. The pumps can also be used submersible (with a screen adaptor around the intake) or in series (tandem) with a pipe adaptor at the inlet such that the pump inlet may have a pressure.

The mine has to move water from the sinking cut sump at 1650 meters to the pit crest discharge at 1740 meters, a 90 meter lift. The 15 meter benches from 1695 meters and up are accessible for the laying of high density polyethylene pipe, but are not suitable for pump infrastructure such as power lines, generators or for pump etc. maintenance.

The cost of a pipe line buried in the 10% ramp (900+ meters) is regarded as far too expensive and not easily repaired and therefore ignored.

One pump will be placed in the sump (1650m) and run as a submersible unit and the other placed as far as possible up the ramp at the 1695 meter elevation. At this upper pump, a tandem fitting will be coupled directly to the pipeline coming up from the sump. The upper tandem pump must deliver sufficient pressure to discharge water at the pit crest. You may assume that the friction loss in the large diameter polyethylene pipe used is small over a 127 meter length on a 45^0 pit wall and from the sinking cut.

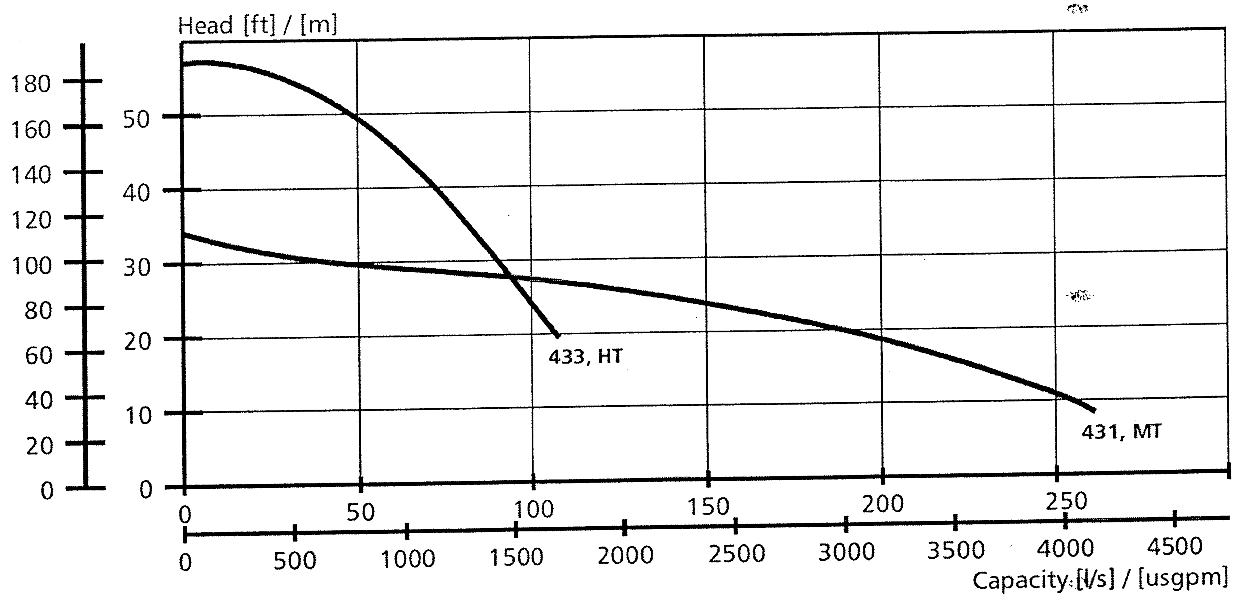

Figure 5.1 Pump characteristics (head and flow rate) for high head (433, HT) and high volume (431, MT) versions.

Assume the water is "clean" and temperature/pressure has no effect on density.

Some conversion factors that may or may not be of use,

1 m water at 8^{0}C is 1.41 psi, 1 ft water at 62^{0}F is 0.43 psi,
1 psi = 6.9 kPa, 1 ft water = 3 kPa

Do not forget to use neat diagrams to explain your answers to this question.

5.1.1 From the graph, Fig. 5.1, will the high volume pump configuration (431, MT) be used for both pumps.

5.1.2 What will be the maximum volume of water (liters per second) discharged at the pit crest based on the best pump configurations (HT and/or MT).

5.1.3 What will be the inlet and outlet pressures at each of the pumps in meters of water.

5.1.4 What schedule of pipe will be required at the outlets of the two pumps

5.1.5 If a check (gate) valve is fitted at the outlet of the top pump to stop water returning to the sump, what modifications will be required.

(2 marks each for 5.1.1 to 5.1.5, total 10 marks)

Question 5.2

Do not forget to use neat diagrams to explain your answers to this question.

An alternative to the pumping system described in 5.1 is a series of deep well pumps around the pit perimeter and possibly on the ramp inside the pit.

From this perspective and described by Jacob, Theis and others, discuss;

5.2.1 What do you understand by the terms "transmissibility" and "storage". How are the transmissibility and storage constants of the pit wall rocks are found using a graphical solution and experimental wells.

(4 marks)

5.2.2 How the pumps might be laid out in plan and the pump depth determined.

(2 marks)

5.2.3 How the feasibility and cost of such a system might be estimated.

(2 marks)

5.2.4 The operational advantages quantified from a pit operations perspective.

(2 marks)

(Total mark for 5.2 is (4+2+2+2) or 10 marks)

Question 6 One of Three Optional Questions

This question and all calculations and answers relate to the 3D Lerchs-Grossman (L-G) algorithm as applied to a simplified 2D example. It does not involve the "moving cone" algorithm of Question 1.6. Answers which in total or in part apply the moving cone method will receive no marks.

Figure 6.1 below shows a simple 2 dimensional section of an open pit being mined with $15m^3$ blocks (15 x 15 meter square blocks in single section 2D drawing) and a 45 degree wall slope.

The cash flow per block is indicated showing ore and waste as positive and negative values respectively. A potential expansion is outlined and shaded on the right hand pit wall. The example is "contrived" to demonstrate the problem. A spare copy (Fig 6.1.a) is included as part of your written exam.

The lower part of the Figure 6.1 is available for calculations and a spare copy of the figure (6.1.a) is attached. Make sure you hand in your Figure 6.1 and/or Figure 6.1.a with your name/number shown clearly.

6.1.1 How are the "cash flows per block" estimated for both the negative and positive values

(2 marks)

Figure 6.1 Proposed Pit Expansion Your Name/Number ____________________

-1	-1	-1														-1	-1	-1	-2	-2	-2
-2	-2	-2	-2												-2	0	-1	-2	-2	-2	-2
-2	-2	-2	-2	-2										-2	4	4	2	-2	-2	-2	-2
-3	-3	-3	-3	-3	-3								-3	-3	-1	3	4	2	-3	-3	-3
-3	-3	-3	-3	-3	-3	-3						2	-3	-3	-3	-3	-1	3	3	-1	-3
-4	-4	-4	-4	-4	-4	-4	-4				3	2	-1	-4	-4	-4	-1	-1	-1	-3	-4
-4	-4	-4	-4	-4	-4	-4	-4	-4		4	2	2	2	1	-4	-4	-4	-4	-2	-2	-4
-5	-5	-5	-5	-5	-5	-5	-5	-5	-4	-1	2	2	2	-1	-4	-5	-5	-5	-5	-5	-5
-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6

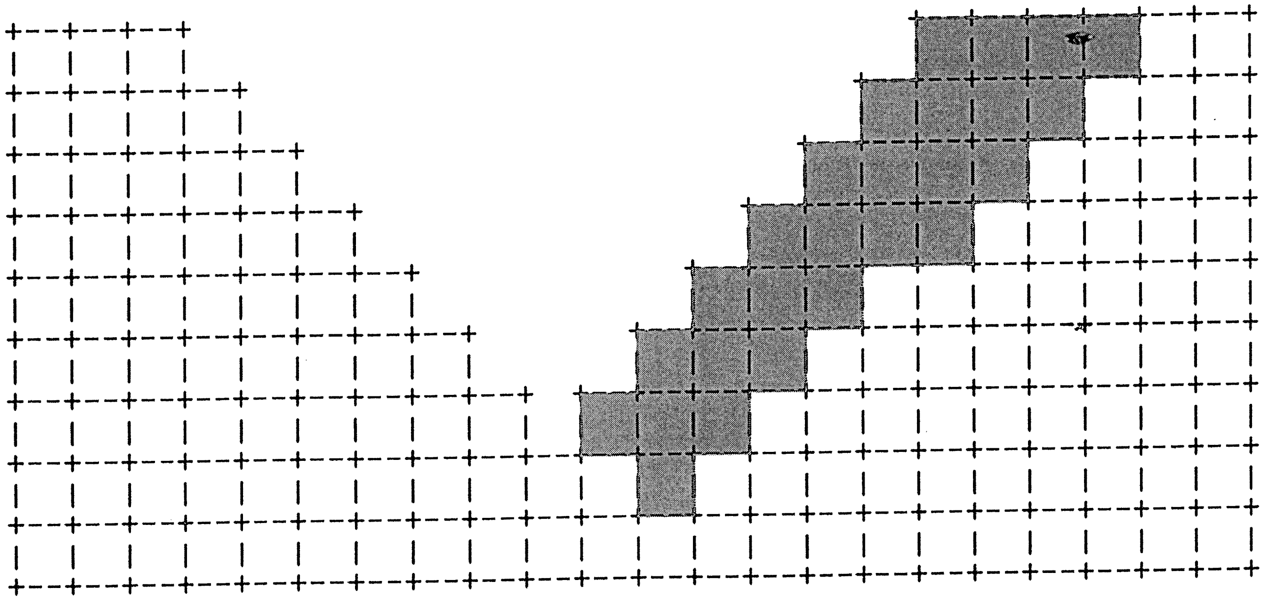

Figure 6.1. Top part shows the cash flow for each block on a single two dimensional section for a typical pit expansion. The middle and lower parts of the figure are spaces to calculate the Lerchs-Grossman "optimal" pit expansion. Blocks are 15x15m and wall slope 45 degrees.

Figure 6.1.a Proposed Pit Expansion ***SPARE COPY*** **Your Name/Number**________________

-1	-1	-1														-1	-1	-1	-2	-2	-2
-2	-2	-2	-2												-2	0	-1	-2	-2	-2	-2
-2	-2	-2	-2	-2										-2	4	4	2	-2	-2	-2	-2
-3	-3	-3	-3	-3	-3								-3	-3	-1	3	4	2	-3	-3	-3
-3	-3	-3	-3	-3	-3	-3						2	-3	-3	-3	-3	-1	3	3	-1	-3
-4	-4	-4	-4	-4	-4	-4	-4				3	2	-1	-4	-4	-4	-1	-1	-1	-3	-4
-4	-4	-4	-4	-4	-4	-4	-4	-4		4	2	2	2	1	-4	-4	-4	-4	-2	-2	-4
-5	-5	-5	-5	-5	-5	-5	-5	-5	-4	-1	2	2	2	-1	-4	-5	-5	-5	-5	-5	-5
-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6

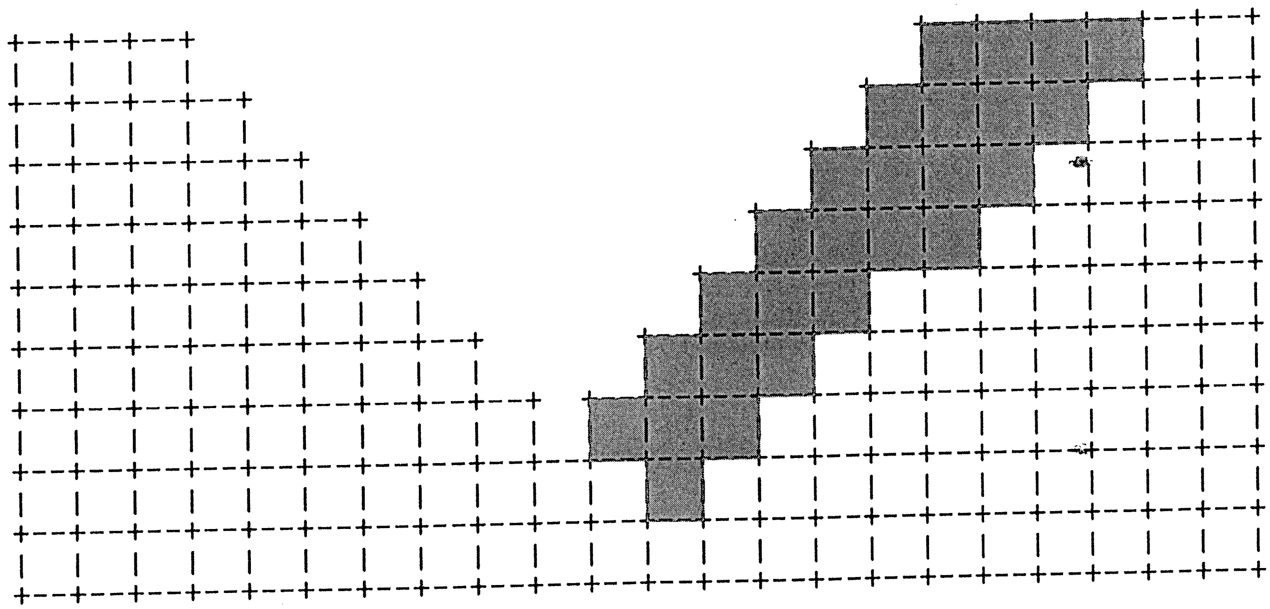

Figure 6.1.a (Spare figure 6.1) Top part shows the cash flow for each block on a single two dimensional section for a typical pit expansion. The middle and lower parts of the figure are spaces to calculate the Lerchs-Grossman "optimal" pit expansion. Blocks are 15x15m and wall slope 45 degrees

6.1.2 On the section Figure 6.1 (or 6.1.a), a pit expansion to the right is indicated as a shaded outline. Using a true L-G method, develop the optimal pit outline and explain each of the steps you have taken to arrive at your solution at each stage.

(10 marks)

6.1.3 In which of the squares is the value of the optimal pit given as part of your L-G solution.

(2 marks)

For the optimal pit outline;

6.2.1 Develop the "optimal" pit based on your answer to the Lerchs-Grossman method (NOT the moving cone description of question 1.6.1)

6.2.2 How many waste and ore blocks are mined

6.2.3 What is the total "cash flow"

6.2.4 Is this the "optimal" pit expansion, and if not, what is.

(1 mark each for 6.2.1 to 6.2.4, total 4 marks)

6.3 Neatly show your "optimal" pit outline on your Figure 6.1 (or 6.1.a). Do not forget to place your name/number on the Figure 6.1 and/or 6.1.a, and hand it in with your answer booklet. An extra copy of Figure 6.1 is provided as 6.1.a in case you need to revise your "optimally" mined out area.

(2 marks)

Space has been allocated on the figure(s) for calculations and a spare duplicate copy is included in case you need to revise your answer.

You **must detach the figure(s) 6.1 and /or 6.1.a which form part of your answer** and place them in your exam answer book with your name printed in the space provided on **all the figures you have written on.**

END OF EXAM