98-MMP-A5 Mine Management and Systems Analysis

National Exam

December, 2009

Time limit for exam is 3 hours.

Open Book exam any non-communicating calculator is permitted.

Answer any 5 questions so that the total number of marks equals 100. If more than 5 questions are attempted, clearly indicate the 5 questions that are to be graded.

Appendix A with discounted cash flow tables is attached.

Total number of pages is 8.

Front Page

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Question 1 – Mineral Exploration Planning. 20 Marks

You are working for a medium sized mining company involved with exploration in the Canadian Shield. The results of a geophysical prospecting program are described below:

- An airborne VLF survey indicated a tilt angle crossover on a broad flat marshy area.
- Follow up ground based magnetic and gravity surveys were conducted over a 1400 m by 1400 m square area centered approximately at the point of the VLF crossover.
- Both ground surveys were run simultaneously, with measurements conducted at 200 m intervals along North-South lines spaced at 200 m.
- The gravity survey had all the necessary corrections applied and has just been presented to you as a plan of the survey area (Figure 1).

Questions:

a) Contour the provided gravity data in Figure 1 using a 50 mgal contour interval.

b) Knowing that the VLF crossovers indicate subsurface conductors and assuming that positive gravity anomalies indicate higher density, what can you say about the subsurface body regarding its possible mineralogy, shape, and dimensions?

c) Plan an exploration drilling program based on what you conclude from part (b) including the location of the primary, delineation and line boreholes. Include type of drills, borehole collar locations and borehole sequence.

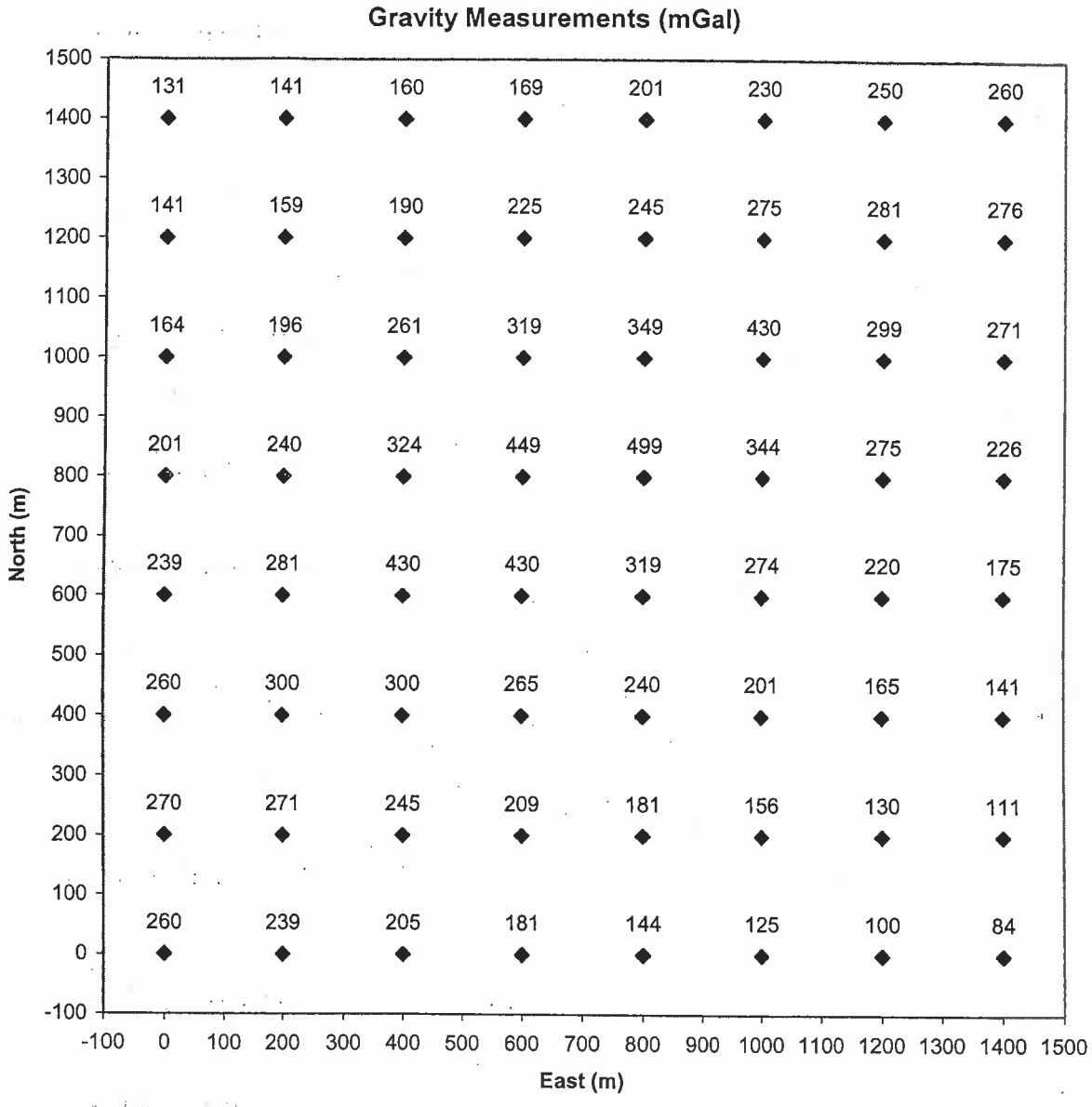


Figure 1. Plan of gravity data measurements for ground geophysical survey.

Question 2 - Project Scheduling. 20 Marks

Analyze the following mining development schedule using the CPM method. What sequence of tasks defines the Critical Path and what is its total duration. What four tasks have the greatest amount of slack or float time. Report all task durations in months.

Task #	Description	Duration (Months)	Dependent on Task #
1	10 km access road to minesite	4	none
2	15 km rail link to main CN line	6	none
3	Hoist and headframe installation	3	1
4	Collaring of shaft	1	3
5	Shaft sinking to Phase 1 depth	9	4
6	Ramp development to initial development levels	12	4
7	Construction of surface buildings (offices, warehouses, workshops, permanent dry rooms)	8	3
8	Shaft lining/guides, installation of cage and skip	5	5
9	Construction of surface crusher, ball mill	24	2
10	Construction of concentrator	24	2
11	Construction of flotation mill	30	2
12	Construction of underground crusher station	3	8
13	Excavation of initial 2 development levels	12	8
14	Excavation of initial ore passes	3	12
15	Construction of level 2 refuge station & garage	4	6,13
16	First production excavation (final step)	N/A	9,10,11,14,15

Question 3 - Feasibility Study and Financial Analysis. 20 Marks

This question is based on economic analysis of the mining project described in the press release below as published in the Northern Miner newsletter:

> ***Falconbridge OKs Nickel Rim South**: Falconbridge (FL-T) has approved a US$368-million program of definition drilling underground at its Nickel Rim South deposit in Sudbury, Ont. The program is expected to last five years and will begin immediately. Expenditures for 2004 are pegged at US$75 million.*
>
> *Inferred resources at Nickel Rim South stand at 13.2 million tonnes grading 1.7% nickel, 3.5% copper and 0.04% cobalt, plus 0.8 gram gold per tonne and platinum group element credits. The resource boundaries remain open, and surface drilling is expected to wrap up by the fall.*
>
> *Falco says the cost of bringing a mine into production following underground drilling would be US$185 million. Initial production is expected in 2008. Net of US$141 million worth of projected preproduction revenues, the overall net capital cost is pegged at US$413 million.*
>
> *The pretax internal rate of return is expected to be 40%, based on a nickel price of US$3.25 per lb. and a copper price of US$0.90 per lb. Operating cash costs are estimated at minus US$0.66 per lb. of nickel, owing to byproduct credits.*
>
> *"The addition of a large, high-grade inferred resource such as Nickel Rim South has dramatically changed our resource profile in Sudbury," says President Aaron Regent. "Combined with our recent discovery of the Fraser Morgan deposit, we now have a resource base that will allow us to operate in Sudbury for at least the next twenty years"*

Conduct a discounted cash flow analysis of this project, **clearly stating and justifying all of the economic factors that you interpreted from the press release.** Note that DCF tables are provided in the attached Appendix A. From the press release and your justified assumptions, determine:

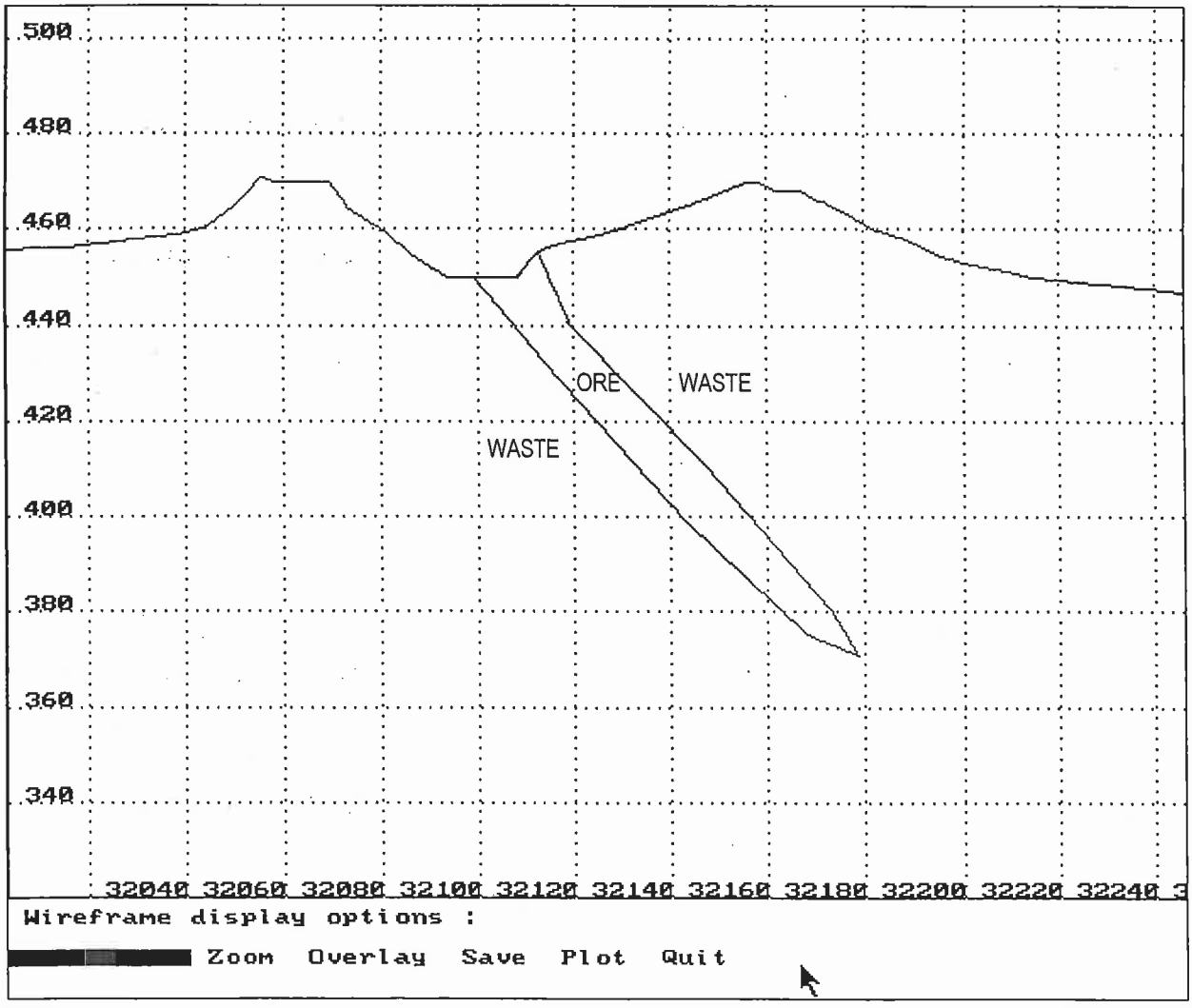
i. The gross value of ore per tonne and operating costs per tonne.
ii. NPV and PVR at a discount rate of 10% and payback period on a before-tax basis.
iii. Conduct a sensitivity analysis of NPV and PVR using discount rates of 10%, 20%, 30% and 40% on a before-tax basis and plot your results using standard practices. What is the significance of these results?

Question 4 – Open Pit Limits and Development Planning. 20 Marks

On the provided geological section, determine the open pit boundaries which satisfy an overall stripping ratio of 2.0 ± 0.1 tonnes waste to tonnes ore and maximize the amount of ore mined. Note that the floor of the final pit must be horizontal and have a minimum width of 20 m. Use this info in your calculations:

$\rho_{ore} = 4000$ kg/m^3
$\rho_{waste} = 2700$ kg/m^3
max slope angle = 60°

Propose separate phased mine development plans that i) maintain and approximately constant stripping ratio, and ii) involve alternating mining and stripping phases.



Question 5 – Equipment Selection. 20 Marks

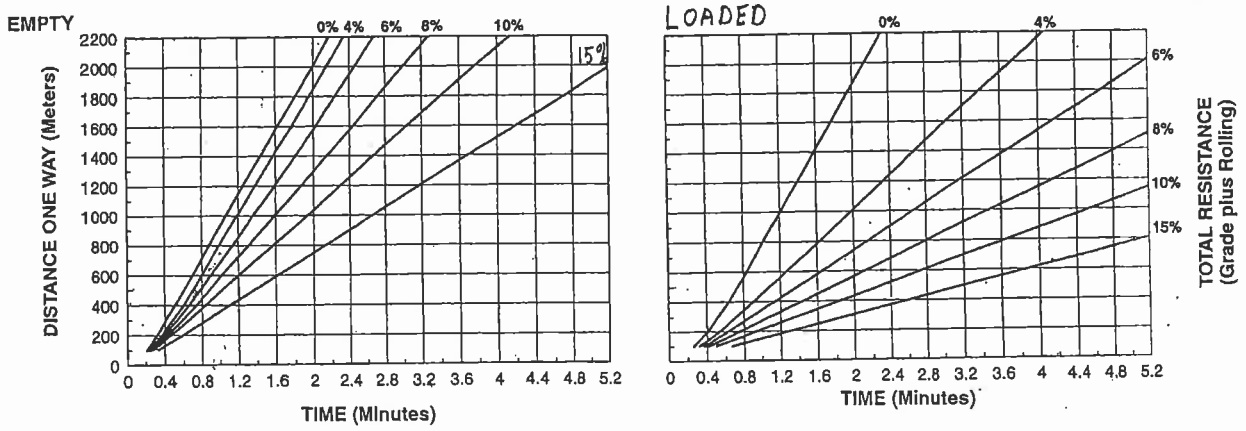
Designers for a new surface mine are considering two potential production fleet options: Fleet Option A consisting of two 20 m^3 hydraulic shovels and 12 200 tonne trucks, while Fleet Option B consisting of one 40 m^3 shovel and 16 150 tonne trucks. FPC analysis indicates comparable production rates for both options. The expected mine life is 12 years with 350 working days per year, and the salvage value for any piece of equipment at the end of the mine life is 75% of the remaining fraction of useable life times the initial capital cost.

a) Determine the Net Present Value and the Equivalent Annual Cost for each of these options using a 10% cost of capital. Note that DCF tables are provided in the attached Appendix A.
b) Which option is the most attractive from an economic point of view?
c) Which option is the most attractive from an operational point of view and why?

Equipment	Capital Cost	Operating Cost	Lifespan
20 m^3 shovel	$2,000,000	$2,000 / day	8 years
40 m^3 shovel	$3,500,000	$3,000 /day	12 years
150 tonne truck	$1,500,000	$1,500 / day	7 years
200 tonne truck	$2,000,000	$2,000 / day	6 years

Question 6. Shovel-Truck Fleet Analysis. 20 Marks

For a particular working area of the mine, the haul route from the shovel to the crusher is i) 300 m of level in-pit haulage, ii) climbing through 100 m of elevation change up a 10% ramp, and iii) traveling a horizontal distance of 650 m to the crusher. The rolling resistance of all road surfaces is 5%, downhill speed limits of 30 km/h are imposed, and average loading and dumping times are each 2 minutes. Using the truck performance charts below, determine (a) the expected truck cycle time, and (b) the optimum number of trucks to assign to a single shovel.



Question 7 - Mineral Resource Block Modelling and Pit Limits. 20 Marks

The 2-D geological block model shown below gives ore grades for a disseminated mineral deposit in percent. For this deposit, a grade cutoff of 1.5% is used to differentiate between ore and waste. Use the criteria listed below to determine the equivalent 2-D economic block model where the mineral grade for the block is replaced by either i) the cost to mine waste blocks or ii) the net revenue generated by the mining and processing of ore blocks. Then conduct a 2-D Lerchs-Grossman or Floating Cone analysis to determine the most profitable open pit outline:

- Block dimensions are 10 m by 10 m by 10 m;
- Ore and waste densities are both 2500 kg/m^3;
- Net processed mineral value (including NSR and transportation charges) is $2632/tonne;
- Mine recovery is 100%;
- Mill recovery is 95%;
- Combined mining costs are $20/tonne;
- Combined milling costs are $15/tonne;
- Combined overhead costs are $15/tonne.

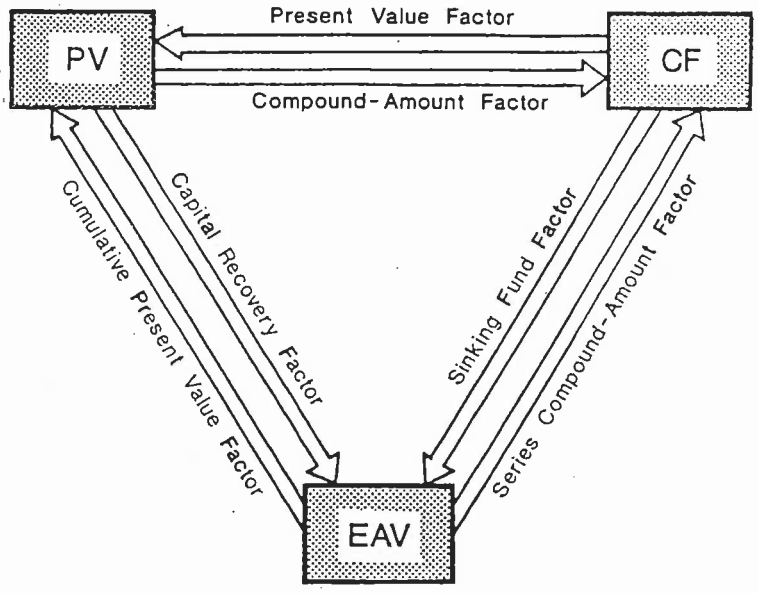
Geological Block Model (% grade):

0	0	2	3	4	3	1	1
0	0	1	4	4	0	1	0
0	0	1	4	2	3	0	0
1	1	1	2	3	1	0	0
0	1	1	2	2	1	0	0

Economic Block Model ($):

Optimum Pit Outline:

Appendix A – Discounted Cash Flow Analysis Tables and Charts



	PVF				CPVF				SFF			
years	10%	20%	30%	40%	10%	20%	30%	40%	10%	20%	30%	40%
1	0.9091	0.8333	0.7692	0.7143	0.9091	0.8333	0.7692	0.7143	1.0000	1.0000	1.0000	1.0000
2	0.8264	0.6944	0.5917	0.5102	1.7355	1.5278	1.3609	1.2245	0.4762	0.4545	0.4348	0.4167
3	0.7513	0.5787	0.4552	0.3644	2.4869	2.1065	1.8161	1.5889	0.3021	0.2747	0.2506	0.2294
4	0.6830	0.4823	0.3501	0.2603	3.1699	2.5887	2.1662	1.8492	0.2155	0.1863	0.1616	0.1408
5	0.6209	0.4019	0.2693	0.1859	3.7908	2.9906	2.4356	2.0352	0.1638	0.1344	0.1106	0.0914
6	0.5645	0.3349	0.2072	0.1328	4.3553	3.3255	2.6427	2.1680	0.1296	0.1007	0.0784	0.0613
7	0.5132	0.2791	0.1594	0.0949	4.8684	3.6046	2.8021	2.2628	0.1054	0.0774	0.0569	0.0419
8	0.4665	0.2326	0.1226	0.0678	5.3349	3.8372	2.9247	2.3306	0.0874	0.0606	0.0419	0.0291
9	0.4241	0.1938	0.0943	0.0484	5.7590	4.0310	3.0190	2.3790	0.0736	0.0481	0.0312	0.0203
10	0.3855	0.1615	0.0725	0.0346	6.1446	4.1925	3.0915	2.4136	0.0627	0.0385	0.0235	0.0143
11	0.3505	0.1346	0.0558	0.0247	6.4951	4.3271	3.1473	2.4383	0.0540	0.0311	0.0177	0.0101
12	0.3186	0.1122	0.0429	0.0176	6.8137	4.4392	3.1903	2.4559	0.0468	0.0253	0.0135	0.0072
13	0.2897	0.0935	0.0330	0.0126	7.1034	4.5327	3.2233	2.4685	0.0408	0.0206	0.0102	0.0051
14	0.2633	0.0779	0.0254	0.0090	7.3667	4.6106	3.2487	2.4775	0.0357	0.0169	0.0078	0.0036
15	0.2394	0.0649	0.0195	0.0064	7.6061	4.6755	3.2682	2.4839	0.0315	0.0139	0.0060	0.0026
16	0.2176	0.0541	0.0150	0.0046	7.8237	4.7296	3.2832	2.4885	0.0278	0.0114	0.0046	0.0018
17	0.1978	0.0451	0.0116	0.0033	8.0216	4.7746	3.2948	2.4918	0.0247	0.0094	0.0035	0.0013
18	0.1799	0.0376	0.0089	0.0023	8.2014	4.8122	3.3037	2.4941	0.0219	0.0078	0.0027	0.0009
19	0.1635	0.0313	0.0068	0.0017	8.3649	4.8435	3.3105	2.4958	0.0195	0.0065	0.0021	0.0007
20	0.1486	0.0261	0.0053	0.0012	8.5136	4.8696	3.3158	2.4970	0.0175	0.0054	0.0016	0.0005
21	0.1351	0.0217	0.0040	0.0009	8.6487	4.8913	3.3198	2.4979	0.0156	0.0044	0.0012	0.0003
22	0.1228	0.0181	0.0031	0.0006	8.7715	4.9094	3.3230	2.4985	0.0140	0.0037	0.0009	0.0002
23	0.1117	0.0151	0.0024	0.0004	8.8832	4.9245	3.3254	2.4989	0.0126	0.0031	0.0007	0.0002
24	0.1015	0.0126	0.0018	0.0003	8.9847	4.9371	3.3272	2.4992	0.0113	0.0025	0.0006	0.0001
25	0.0923	0.0105	0.0014	0.0002	9.0770	4.9476	3.3286	2.4994	0.0102	0.0021	0.0004	0.0001
26	0.0839	0.0087	0.0011	0.0002	9.1609	4.9563	3.3297	2.4996	0.0092	0.0018	0.0003	0.0001
27	0.0763	0.0073	0.0008	0.0001	9.2372	4.9636	3.3305	2.4997	0.0083	0.0015	0.0003	0.0000
28	0.0693	0.0061	0.0006	0.0001	9.3066	4.9697	3.3312	2.4998	0.0075	0.0012	0.0002	0.0000
29	0.0630	0.0051	0.0005	0.0001	9.3696	4.9747	3.3317	2.4999	0.0067	0.0010	0.0001	0.0000
30	0.0573	0.0042	0.0004	0.0000	9.4269	4.9789	3.3321	2.4999	0.0061	0.0008	0.0001	0.0000