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The Executive Summary consists of a brief description of the problem followed by a largely equation-free summary of the progress made and the results obtained by the study group.

DIFFUSER TRACER TEST INTERPRETATION

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Executive Summary

The modern method of removing sugar from cane is to use a reverse flow diffuser. Sugar cane is pulped into a fibrous bed which is carried along the length of the diffuser on a conveyor. At the same time water is drained through the bed to flush out the sugar. The water is first introduced at the most downstream end of the diffuser, collected in trays and then reintroduced further upstream using spray jets, collected again and then moved further upstream. The reason for the reverse flow is to maximise the difference between the amount of sugar in the cane and the sugar in the water. In order to determine if the process is working well experiments have been conducted by injecting a pulse of saline solution into the spray jets and collecting it in trays where the concentrations of salt are measured. The study group was asked to interpret the experimental results. The group considered several different models of the flow in the diffuser.

A model was developed in which the diffuser bed was a porous medium. The linearised version of the equations for flow through a porous medium were implemented. The model included an approximate determination of the shape of the water surface within the cane bed. A sinusoidal pressure difference across the top of the cane served to represent the spray jets and permitted an exact solution to the linear equations. Knowing the fluid flow lines the data could be interpreted more clearly.

A model of the diffusion of salt by turbulent mixing was developed and solved. By tuning the model to estimate the rate of diffusion, traces very similar to those in the experimental results were found. The value of the diffusion rate could be used to interpret the results. A further model was developed to investigate the behaviour of a benign tracer added to the diffuser and followed for several cycles through the spray-bed-tray system. A set of delay-differential equations was obtained which were solved numerically to obtain traces of concentration as the tracer travelled through several cycles in the diffuser. The model could be used to interpret future experiments of this kind.

STOCHASTIC BLOCK ECONOMIC VALUE MODELLING FOR GENERATING PROBABILITY STOPES

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Executive Summary

A three dimensional model of the ore body is created from exploration data called a geological block model. Depending on the size of the deposit and the method of mining there may be thousands, hundreds of thousands or millions of blocks in the model. Each block contains specific data, its grade, volume and density. The block economic value (BEV) is the revenue derived from mining, processing and selling the block minus the cost of mining and processing the block. A block is economic to mine if the BEV is positive. The current BEV calculation is deterministic. Fixed values of the parameters for grade, recovery, price and costs are used. In practice these parameters are variable and therefore uncertain. To ensure mine plans incorporate uncertainty in the geological (grade), technical (recovery) and economic (price and costs) parameters, there is a need for a shift from a deterministic to

a stochastic BEV calculation process. The problem posed was to develop a stochastic model that integrates uncertainty in the key parameters used in calculating block economic values.

The Study Group developed a model that accounts for the variability in the parameters used to calculate the BEV. The model has two tools, parameter fitting and stochastic modelling and incorporated the method of interpolation known as kriging in which the interpolated values are modelled by a Gaussian distribution. Each of the parameters has a different probability distribution. The log-normal distribution was found to be the best fit for the gold data. The model was implemented and plots of the BEV against grade quality were obtained.

AN ALGORITHM FOR STOPE BOUNDARY OPTIMIZATION FOR UNDERGROUND MINES

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Executive Summary

A stope is an underground production area where ore is extracted from the surrounding rock mass. A stope comprises of a certain number of individual economic blocks. The Stope Boundary Optimization Problem (SBOP) involves choosing a certain configuration of stopes which maximises the net profit value subject to economical and technical constraints. The problem submitted to the Study Group was to develop a hybrid algorithm for the SBOP which contains components of Dynamic Programming for the applied algorithm to be iterative given the nature of the constraints and Particle Swarm Optimization which can be used to solve optimization problems in three-dimensions. The Particle Swarm Optimization algorithm has not been applied to optimise stope layout in underground mining. In Particle Swarm Optimization, each particle modifies its position according to its current position, its current velocity, the distance between its current position and personal best, and distance between its current position and global best. It

simulates the motion of flocking birds. The results obtained by the Study Group indicate that the hybrid algorithm is able to handle the specified mining constraints associated with the Stope Boundary Optimization Problem and that a Particle Swarm Optimization approach is feasible and warrants further investigation.

MATHEMATICAL MODELLING OF METHANE GAS EXTRACTION FROM LAKE KIVU}

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Executive Summary

Lake Kivu on the Rwanda-Congo border has dangerous accumulations of methane and carbon dioxide within its depths. Methane is extracted to generate electricity. There is concern that gases could be spontaneously released leading to loss of life as occurred in Cameroon in Lake Monoun in 1984 and Lake Nyos in 1986. The problem submitted was to investigate the effect of the extraction of methane on the stability of the lake and also to investigate the gas extraction process.

The Study Group found that lake stability can be maintained by careful management of the process of extraction of methane and the re-injection of water into the lake. Improper management of the extraction process or lack of intervention could result in lake stability not being maintained. The lake has four layers of slightly different density. The effect on gas release of an

internal wave due to a seismic event propagating on the picnocline, which is the interface between the two lowest layers, was studied. It was found that two internal waves can propagate on the picnocline, a fast wave and a slow wave. Although the pressure change due to the slow wave is slightly less than that due to the fast wave the slow wave is much more important in the formation of bubbles. The period of the slow wave is about sixty times greater than that of the fast wave which gives much more time for bubble formation. However, the pressure changes due to the internal waves are very small and will only be important if the water is supersaturated. The fast and slow waves on the picnocline generate fast and slow waves with the same speed and frequency on the surface of the lake. The amplitude of the slow wave on the surface is proportional to the density difference
across the picnocline and is very small but the amplitude of the fast wave is more than twice the amplitude of the fast wave on the interface and could cause damage around the shores of the lake. Bubble formation and movement on the picnocline were also examined. It was found that there is an approximate linear growth in bubble radius with time. The associated drift in velocity from the background flow field is quadratic in bubble radius. Once the bubble escapes the picnocline zone there will be a further large change in bubble radius due to hydrostatic pressure changes and this will induce much accelerated motion.

ALGORITHM TO COUNT MODERN HOUSES FROM LiDAR DATA SETS OVER RURAL AREAS IN MPUMALANGA

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Executive Summary

Light image detection and ranging (LiDAR) aerial surveys provide a high resolution, three-dimensional picture of any landscape. The picture is generated by tracking the time-to-return of individual laser pulses that bounce off objects on the ground. This generates a three-dimensional point cloud with up to 20 points per square meter. Extensive LiDAR data sets have been collected over rural areas in Mpumalanga. The Study Group was asked to develop an algorithm to count modern houses. A modern house means a house with several planes in its roof, as opposed to thatched rondavels and flat roofed dwellings.

The study group developed a simple way of clustering LiDAR data points so that each cluster contains a particular object, for example, the roof of a house

or a tree. One method of categorising clusters is by fitting planes to the LiDAR points which can be done using the Hough transform. The strength of fit of the planes in the cluster will determine if it is a modern house with at least two planes strongly fitted at the roof, an informal house which is assumed to have only one strongly fitted plane, or trees or other vegetation with a large number of weakly fitted planes in a cluster. The application of the Hough transform and the counting of bounding boxes that contain clusters corresponding to modern houses can commence but due to time constraints is future work. By counting the change in the number of modern houses a measure of the economic welfare of the rural area can be developed.

SPONTANEOUS COMBUSTION OF STOCK-PILED COAL

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Executive Summary

Spontaneous combustion of stock-piled coal is a well-known problem in the coal industry. It occurs when a temperature dependent process occurs which acts to heat up a material. With increasing heat the process speeds up until it runs out of control and the material reaches its ignition point. In most cases the reaction is modelled by an Arrhenius term. For small temperatures the reaction heat tends to zero but for large temperatures the heat increases driving the temperature up even further. The Study Group was asked to investigate the effect of height and shape of the stockpile, the variation in grain size, the degree of compaction, oxygen availability, moisture content and the chemical composition of coal on the spontaneous combustion of coal.

The Study Group considered various forms of model. First a simple one-dimensional heat equation with a constant heat source was analysed. The base was insulated while the top was set to air temperature. The results demonstrated how heating evolved but led to the highest temperature at the base which is not observed in practice. An Arrhenius source term was then included. The maximum

height of the pile for spontaneous combustion to be avoided was calculated but found to be too low using typical values for coal. The group next analysed a coupled model for temperature and oxygen evolution. The results for this model were more realistic showing a maximum temperature near the upper surface. The model also showed how crucial it is to take oxygen dynamics into account for modelling coal pile self-heating. One conclusion is that to prevent a coal pile from combustion it should be deprived of oxygen by keeping it well sheltered, although high wind flow also acts to cool down the coal pile. The simple models considered show that the height of a coal pile has a huge effect on the likelihood of combustion. Also, due to faster reactions at high temperature there is the possibility of unstoppable runaway reactions. To understand the optimal pile shape requires a numerical solution for the airflow over a porous pile which was beyond the scope of the Study Group.