

A study of internal overburden dump design and stability analysis for Hazelwood Power Mine, Latrobe Valley, Victoria, Australia

J. FERNANDO* and D. NAG†

*Hazelwood Power, Morwell, Victoria, Australia

†Monash University, Churchill, Victoria, Australia

Hazelwood Power Mine is one of the largest open pit brown coal mines in Australia. The removal of overburden is the first step in coal winning operation. The primary aim of construction of overburden dump is to provide an effective stable working surface for stacker. The paper discusses site investigation techniques used to determine dump soil properties, stability analysis method using GALENA and GWEDGEM, results of stability analysis. The paper concludes with recommendation for a safe dumping strategy for level 2 stacker dumping.

Introduction

Hazelwood Power owns one of the largest brown coal open pit mines in Australia, situated in Latrobe Valley, Victoria, Australia (Figure 1). Annually the mine produces approximately 19.5 million tonnes of brown coal for its 1600MW coal fired power station. Approximately a 5.8 million cubic metres of overburden is removed per year which includes dredger and truck and shovel operation in Coal winning process. Thickness of overburden in the present field (south-east field) varies between 20 to 40 metres from the ground level. Overburden dumping internally in older part of the mine was commenced in the year 1998 with the help of a stacker and a dedicated conveyor system. In this process first bottom side dump was constructed and then conveyor was shifted to allow top- side dumping. First level of dump was constructed to a height of 28 metres from the bottom of the pit

Background

The removal of overburden is the first step in a coal winning operation, so as to expose underlying coal for excavation. The overburden material being a non-marketable product, it is removed and dumped safely and economically. The primary aim for construction of overburden dump is to provide an effective stable working surface for the stacker. Failure of improperly constructed dump is likely to cause risks for mining equipment and personnel and extensive loss of production. In the present study the design and stability analysis of the overburden dump has been undertaken. Positioning of the internal overburden dump within the mine pit is shown in Figure 2.

The overburden dump material is composed of a mixture of inferior coal, silty clay, sandy clay and baked clay. Water table of the area was closer to the ground surface.

The overburden materials have been categorized into three groups depending on their respective handling properties for the purpose of overburden dumping. The general principle governing dump

Construction involves placement of all wet, soft materials

in the lower parts of the dump, grading to dry, stiff materials at the surface.

Baked clay (Type 1) is a critical material in the dumping operation. It is utilized to construct the dump formation and also used for the construction material for the head and tail end pad formation for the conveyor positioning.

Type 2 (Figure 3) materials are usually utilized to cover the softer, wet material of Type 3. They are restricted for use to below the top 3 metres of the dump formation, and usually behave similarly to Type 1 material depending on the proximity to the water table in the overburden face and inherent levels of saturation. If this material is found in a saturated condition, it behaves closely to that of Type 3 materials.

Type 3 materials are generally saturated in the overburden face, and behave in a plastic or liquid form on the dump. These materials are unsuitable for inclusion into the top 3 metres of the dump due to the low strength properties.

This paper discusses site investigation techniques used to determine internal dump soil parameters, stability analysis methods and results of the stability analysis. Finally the paper summarizes a safe dumping strategy for level 2 stacker dumping and further recommendation.

The foundation for the proposed dump was built using the same type material as during the previous years. Therefore sampling and laboratory testing for soil strength parameters was found to be unsuitable due to the heterogeneity of the foundation material. A field soil investigation technique was deployed to investigate subsurface soil strength parameters (AS1289-1977). Cone penetration testing was carried out at 500 metre intervals across the internal dump foundation area in order to obtain downhole soil strength parameters. Results from the tests were analysed and interpreted (Bowles, J.E. 1998) to define probable representative soil profiles across the dump. Interpretations revealed that the internal overburden dump is mainly comprised of silty clays and silty sands with minor clays, coal and sludge material particularly closer to the northern batters in Sectors 1, 2, and 3. The results were used for

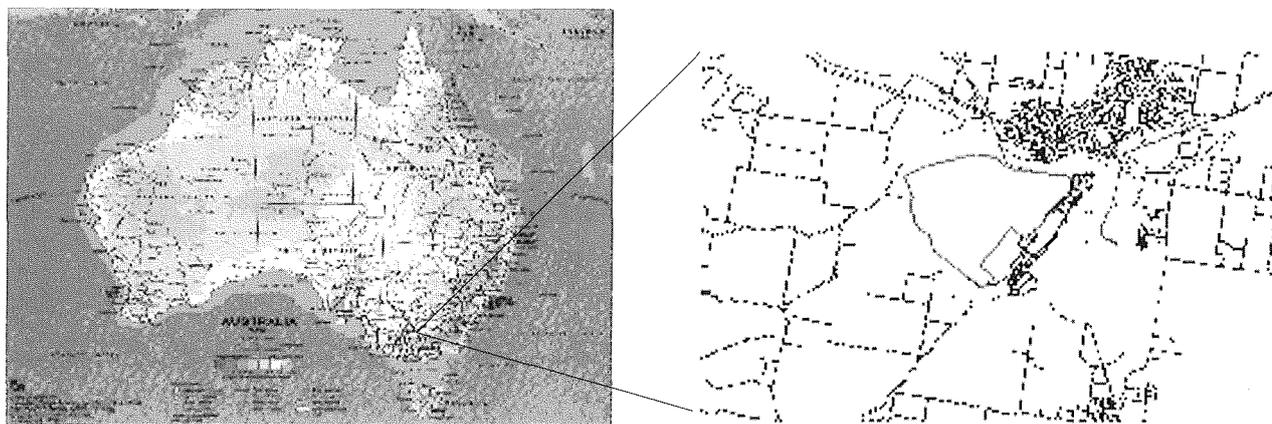


Figure 1

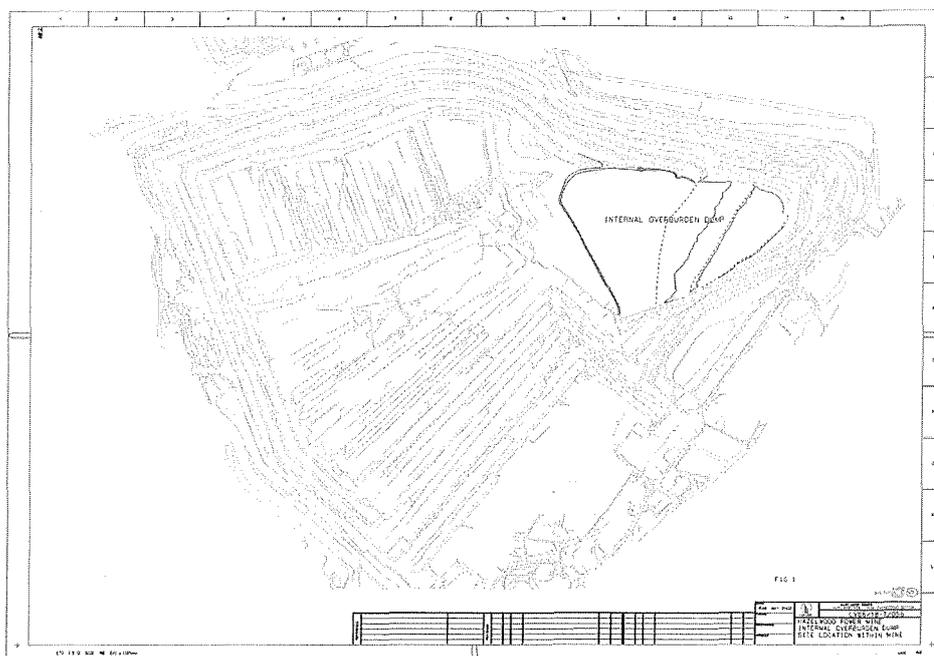


Figure 2. General layout of the internal overburden dump in October 2002

slope stability analysis. In addition water table was measured in the holes left over after cone penetration tests.

Stability analysis was carried out on five representative profiles across the proposed internal dump Level 2 foundation area to determine safe slopes and operational bench widths. Analysis was conducted using two slope stability software packages incorporating a combination of different stacker operating scenarios, slope angles and saturated and unsaturated conditions.

Two different stability analysis computer software package GALENA (Clover Technology, 1999) and GWEDGEM (Donald, I.B. and Zavo, T. 1995) was used in stability analysis computations and results were compared.

Factor of safety determined from two slope stability analysis packages for five profiles were compared and a minimum average Factor of Safety of 1.40 was adopted for safe overburden dumping profile design. The design included the following slope geometry and piezometric conditions:

- 30 degree bottom and top side slope

- maximum slope heights of 20 metres for bottom side and 8 metres for top side slopes
- stacker positioned 30 metres from the crest of the bottom side crest
- operational bench width (from crest of bottom side slope to toe of top side slope) of 90 metres
- saturated and unsaturated conditions.

It was recommended that this operating scenario be adhered to minimize the risk of failure while keeping productivity at a maximum level. However, under extremely dry conditions, the stacker could be moved forward to 20 metres from the bottom side slope crest, in turn reducing the operational bench width to 80 metres.

Geology

Latrobe valley is a part of the Gippsland Basin situated in South-east part of Victoria. Brown coal was formed in the Latrobe valley depression during Tertiary period. There were three distinct brown coal seams found in Hazelwood

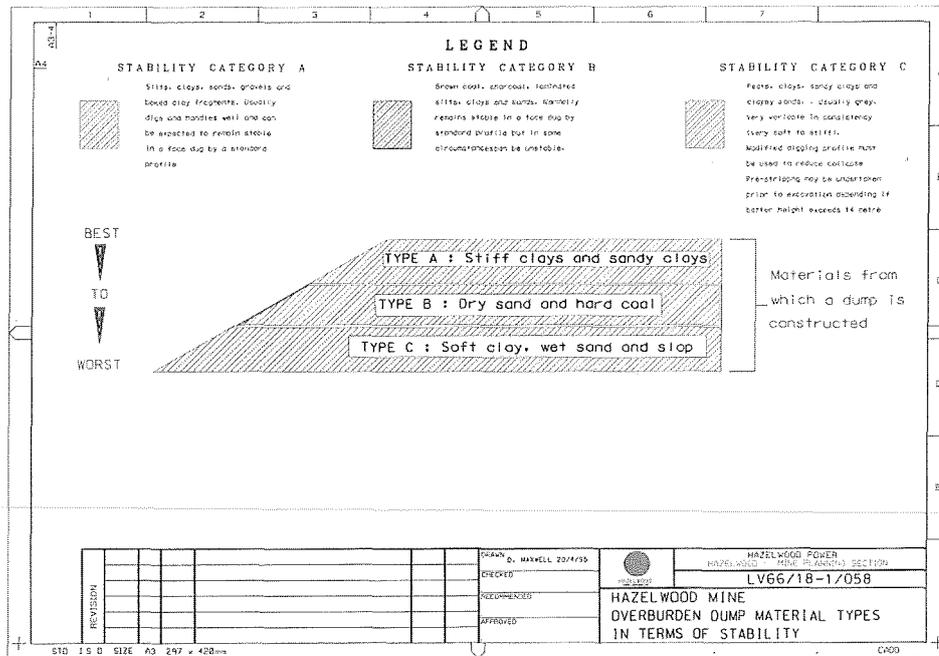


Figure 3. Material types in the overburden dump

Mine area such as Yallourn, Morwell 1 (Morwell 1 seam splits into 1A and 1B) and Morwell 2 seams. Morwell 1 coal seam is mined in Hazelwood Mine. These coal seams are variable in thickness. Thickness of Morwell 1 seam varies from 70 to 100 whereas Morwell 2 seam is generally 40 metres and Yallourn seam is 5 to 25 metres within the Hazelwood Mine area.

Haunted Hill Formation overlies the M1 coal seams in Hazelwood Mine area. It generally consists of peat, alluvial sands and gravel, silts and clays. This has been subdivided into five units according to their depositional environment and characteristics. They are as follows:

- Peat unit, baked clay unit, grey clay unit, silty clay unit, sandy silt unit
- Peat unit
- Generally soft clays with significant wood and grass debris
- Baked clay unit.

Large indurate clay fragments, generally in a sandy or clayey matrix, mottled, predominant colours, orange, red, yellowish grey. Consistency of indurate fragments is stiff to hard and matrix is firm to stiff or loose. The baked clay group consists a wide range of material types, varying from soft clay to large, extremely hard (rock) lumps. This material usually digs well, as it is generally loose. However, the large hard lumps may cause jarring at transfer points and their angular shape may tend to cause abrasion during transport.

- *Grey clay unit*—Grey, blue, green, organic clays. Soft to very soft laminated silts, clayey sands as lenses. Consistency varies from firm to soft. This material can be very soft and unstable in the digging face when being excavated. It can either flow out of the face or collapses in large blocks. When wet it is very sticky.
- *Silty clay unit*—Silt and soft clays with sand and gravel, generally leached and occasionally consists of weathered baked clay fragments, lightly mottled in parts, yellow, grey, white, orange predominant colours.

- *Sandy silt unit*—Consisted of grey, yellow, brown laminated silts, clays and thin sand layers, fine gravel lenses, minor ironstone boulders. When, dry fracturing develops perpendicular to laminations. Consistency ranges from firm to stiff and loose.

Internal overburden dump design consideration

Background theory

The overburden material found in the Hazelwood Power Mine mainly consists of baked clays, stiff silty clays, grey clays, sandy silts and inferior coal. A typical profile along the overburden face is shown in Figure 2 which clearly highlights these various overburden materials. The overburden materials have been categorized into three groups depending on their respective handling properties for the purpose of overburden dumping. The general principle governing dump construction involves placement of all wet, soft materials in the lower parts of the dump, grading to dry, stiff materials at the surface. These material categories and an ideal dump material profile is shown in Figure 4.

Handling properties of material types

Baked clay (Type 1) is a critical material in the dumping operation. It is utilized to construct the dump formation and also used for the construction material for the head and tail end pad formation for the conveyor positioning.

Type 2 (Figure 3) materials are usually utilized to cover the softer, wet material of Type 3. They are restricted for use to below the top 3 metres of the dump formation, and usually behave similarly to Type 1 material depending on the proximity to the water table in the overburden face and inherent levels of saturation. If this material is found in a saturated condition, it behaves closely to that of Type 3 materials.

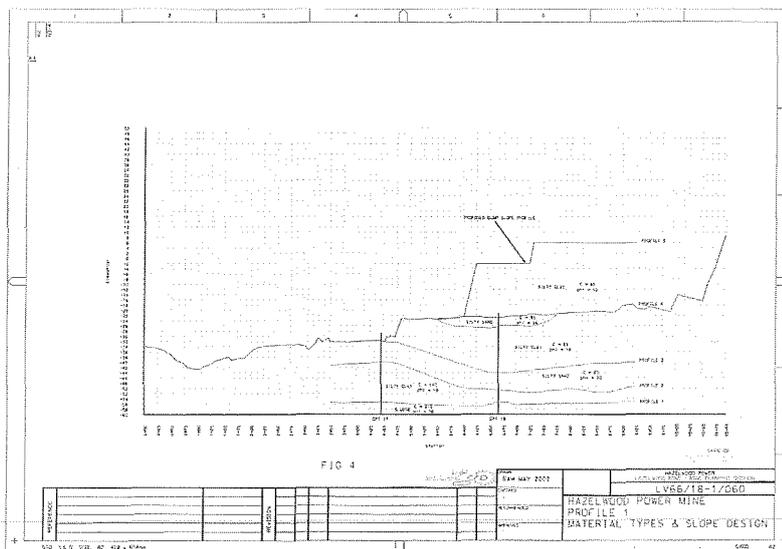


Figure 4. Typical material profile found in the internal overburden dump

Type 3 materials are generally saturated in the overburden face, and behave in a plastic or liquid form on the dump. These materials are unsuitable for inclusion into the top 3 metres of the dump due to the low strength properties.

Dump design performance criteria

In order for the stacker to efficiently spread overburden materials, the dump must provide a suitable working surface for the stacker to operate. A well designed and constructed dump will generally support the stacker and other plant located on the dump without significant deformation of the material below the crawler tracks. To provide this working surface, the bearing resistance of the dump formation must be sufficient at all times to support plant parked on the surface. TS2 stacker crawler pads exert 80 kPa of pressure onto the dump surface, therefore the minimum shear strength of the underlying material must be approximately 26 kPa which refers to a soil with a firm consistency (Hazelwood Power Mine, 1995).

Failure of the advancing dump slope is also a significant factor in the dump construction. Suitable slope gradients and stacker positioning must be constantly adhered to minimise the risk of failure. Past studies have shown that a minimum stacker position of 20 metres from the bottom side crest and a maximum slope height of 20 metres is sufficient in order to minimize this risk. Along with these criteria, a minimum bench width between the bottom side crest and top side toe has been set at 90 metres (Hazelwood Power Mine, 1995).

Site investigations

Internal overburden dump Level 1 material is comprised of a mixture of inferior coal, brown silty clay, grey clay, sandy clay, sandy silt and silty sands. A field soil investigation—Cone penetration testing (CPT) was carried out.

CPT results were analysed and interpreted to define probable representative soil profiles across the dump. This method determined soil strength characteristics such as cohesion and angle of internal friction, and representative soil types through Level 1 of the dump.

Five representative profiles across the existing Level 1 of

the overburden dump were selected for stability assessment for Level 2. Then different soil horizons were identified in each profile using their soil strength parameters. Location of profiles are shown in Figure 4. A typical geotechnical section along most representative material profiles is shown in Figure 4.

Input data for stability analysis

A summary of the generalized soil types and strength characteristics is shown in Table I.

When constructing the slope profiles, Level 2 dumping was not present on some of the cross sections. Level 1 dumping guidelines were used to predict the most likely slope profile.

Stacker dimensions and exerted pressures obtained to determine the influence of the machinery on slope stability is given in Figure 5.

Table I
Generalized soil types and soil characteristics for each profile

Profile	Layer	C, kPa	PHI, deg.	Material
1	1	215	38	Coal
	2	140	10	Silty clay
	3	85	30	Silty sand
	4	85	10	Silty clay
	5	91	26	Silty sand
2	1	131	8	Silty clay
	2	108	21	Silty sand
	3	46	14	Silty clay
3	1	112	10	Silty clay
	2	50	29	Silty sand
4	3	142	12	Silty clay
	1	29	14	Silty clay
	2	56	21	Silty sand
5	3	29	14	Silty clay
	1	226	22	Silty sand
	2	58	13	Silty clay
	3	24	32	Silty sand
	4	58	13	Silty clay

Stability analysis method

Mechanism of slope failure

There are two major types of slope failure that could occur within the internal overburden dump. These are:

- Rotational failure
- Failure along an irregular surface.

Methods of stability analysis

The geology, ground condition and the nature of the material is the major influencing factors in stability analyses. Stability analysis were carried out on the five representative profiles across the Level 1 dump to determine safe slopes and bench widths for stacker and other heavy machinery to operate on the dump without risking infrastructure or human life. Two different stability analysis computer software packages GALENA and GWEDGEM were used in this analysis. GALENA evaluated profiles using the Bishop simplified circular failure method where as GWEDGEM utilized the Sharma slices for non-circular failure method for stability analysis. Both of these programs allowed analysis of slope failure under both saturated and unsaturated conditions and also under different stacker positioning scenarios. The different operating conditions used for stability analysis were:

- 30 degree bottom side slope with stacker at 20 metres from the crest of the bottom side slope
- 30 degree bottom side slope with stacker at 30 metres from the crest of bottom side slope
- Final dump profile with no stacker
- Unsaturated and fully saturated conditions.

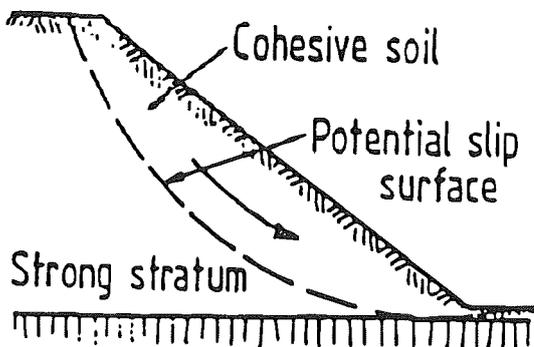
Stability analysis results

GALENA results

GALENA was utilized to analyse failure of the bottom side slope of the Level 2 dump. Favourable Factors of Safety were determined under current unsaturated condition and when analysed under saturated conditions the Factors of safety were reduced (Table II). Positioning of the stacker was found to be most safe at 30 metres from the crest of the bottom side slope however, placement of the stacker 20 metres from the crest is feasible with favourable Factors of Safety under both saturated and unsaturated conditions. Factors of Safety derived from GALENA trials are shown in Table Iii. A typical stability analysis result using GALENA is given in Figure 5.

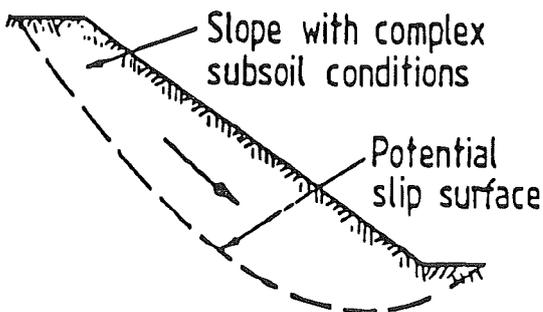
GWEDGEM results

GWEDGEM was also used to evaluate the stability of the Level 2 bottom side slope of the internal overburden dump. The results obtained from the GWEDGEM trials were used to verify the GALENA results. Similar results to that of GALENA were achieved using GWEDGEM. Factors of Safety were closer but lower than those obtained from GALENA with the exception of Profile 3 where higher Factors of Safety were found with GWEDGEM. Those lower Factors of Safety derived from GWEDGEM were still favourable for different (20 or 30 metres from bottom side slope crest) stacker positions under unsaturated conditions. Profile 4 is an exception, where unfavourable Factors of Safety (Table II) were resulted under both stacker positions and therefore failure is highly possible when the stacker was positioned 20 metres from the crest of



ROTATIONAL FAILURE

The most common form of failure in cohesive soils is deep rotational slip. The deepest surfaces which can form within the weak material are almost invariably the most critical. Thus, the base of the critical slip surface is usually controlled by an underlying strong stratum.



FAILURE ALONG AN IRREGULAR SURFACE

In a slope with complex soil and groundwater conditions, and perhaps an irregular face, failure or potential failure surfaces may not follow any of the standard patterns shown above

Typical slope Failures in a poorly designed Overburden Dump (Carter, 1983)

Table II
Factors of Safety evaluated for each pProfile using GALENA and GWEDGEM

Profile (across the dump east to west)	Slope parameters		GWEDGEM		GALENA	
			Factor of Safety		Factor of Safety	
	Slope angle degrees	Stacker position from the crest of bottom side slope	Unsaturated condition	Saturated condition	Unsaturated condition	Saturated condition
1	30	20m from crest	1.7	1.6	2.4	2.1
	30	30m from crest	2.8	2.4		
	30	No stacker	2.6	2.4	2.5	2.1
2	30	20m from crest	1.3	1	1.9	1.7
	30	30m from crest	1.4	1.1	2.1	1.8
	30	No Stacker	1.9	1.5	2	1.8
3	30	20m from crest	5.8	4.4	3.7	3.3
	30	30m from crest	5.9	3.8		
	30	No stacker	3.9	3.8	3.9	3.5
4	30	20m from crest	1.1	0.9	1.9	1.8
	30	30m from crest	1.2	1.4	2.3	1.9
	30	No stacker	1.5	1.4	2.1	1.9
5	30	20m from crest	1.6	1.2	2.2	2.1
	30	30m from crest	1.6	1.5	2.3	2.2
	30	No stacker	2.2	1.8	2.3	2.2
	Current (8)	20m from crest	2.3	1.9	5.1	3.8

Note: Current(8) means present bottom side slope at 8 degrees.

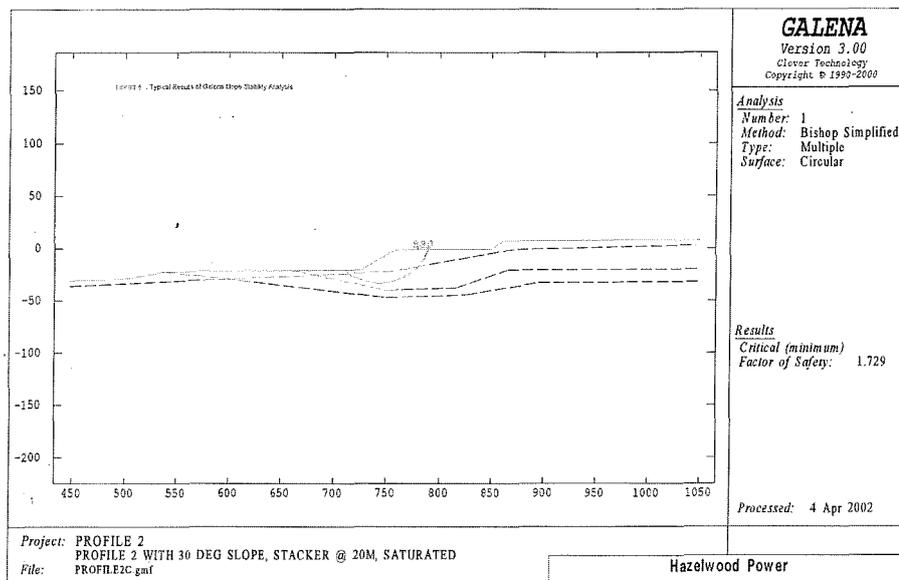


Figure 5. A typical stability analysis result using GALENA

the Level 2 bottom side slope. Factors of Safety derived from GWEDGEM trials are shown in Table II. A typical stability analysis result using GWEDGEM is given in Figure 6.

Figure 7 shows the comparison between the two stability analysis methods used in this report, and also shows change in Factors of Safety throughout the overburden dump. This comparison has assumed that the stacker is positioned 30 metres from the bottom side crest and the slope is maintained at 30°. From this comparison, an average minimum Factor of Safety of 1.40 was adopted for safe overburden dumping profile design.

Conclusions

A number of general conclusions can be made from the

results produced from the various models. For mining environments a Factor of Safety of 1.4 is considered to be sufficient.

- GALENA analysis results showed favourable Factors of Safety (1.90 to 3.90) under current unsaturated condition. Factors of Safety reduce under saturated though remain favourable slope stability conditions.
- GWEDGEM analysis results showed favourable Factors of Safety (1.30 to 2.80) under currently unsaturated condition. However, profile 4 shows unusually low Factors of Safety (1.10 to 1.50) under unsaturated condition whereas profile 3 results unusually high Factors of Safety (3.90 to 5.80). When compared with GALENA computations, Factors of Safety are significantly reduced with saturation, though

JOB TITLE -	INTERNAL OB DUMP STABILITY PROFILE 1					
a	1	2	3	4	5	6
(kPa)	85.00	81.00	85.00	85.00	140.00	215.00
PHI (degree)	10.00	26.00	10.00	30.00	10.00	30.00
DEN (kN/m ³)	14.64	15.88	14.64	15.53	14.64	10.87
SAFETY FACTOR ---	2.6250					

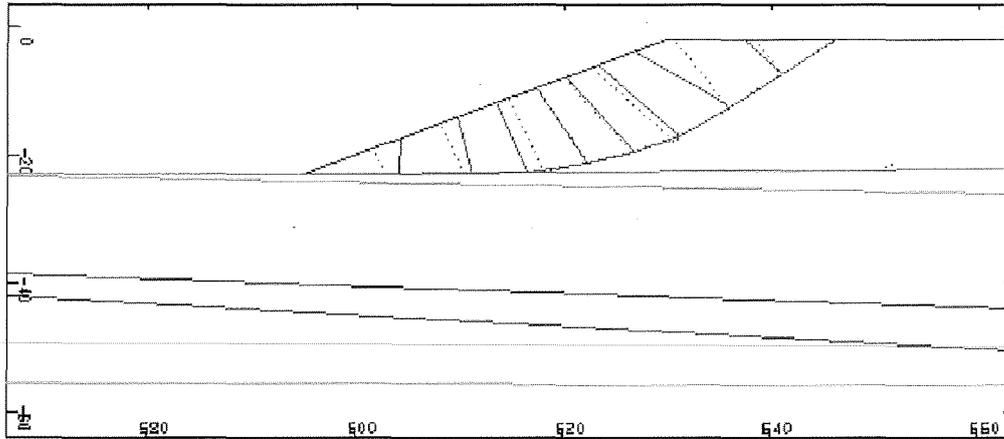


Figure 6. A typical stability analysis result using GWEDGEM

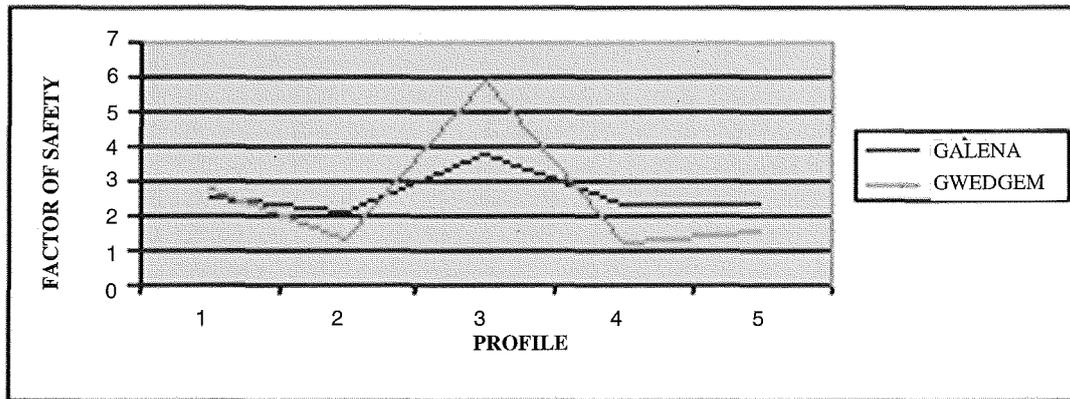


Figure 7. Comparison of Factors of Safety derived from GALENA and GWEDGEM stability analysis software packages for five profiles across the internal overburden dump (stacker positioned 30 metres from the crest of 30 deg.

rest of the profiles remain favourable under both saturated and unsaturated conditions.

- After a comparison of safety factors between profiles and between analysis methods, a probable safe dumping profile was adopted with minimum average Factor of Safety of 1.40.
- A safe overburden dumping profile determined from the analysis was a 30° bottom and top side slopes (ratio of 2:1), 90 metre bench between top and bottom side slopes and stacker positioning of a minimum of 30 meters from the bottom side crest.
- Suitable drainage similar to that implemented in Level 1 of the internal dump should be utilized in Level 2 so as to reduce the risk of saturation and in turn reducing the risk of failure.
- Under normal operating conditions, the stacker should be kept at a maximum of 30 metres from the bottom side slope crest. This would allow for a minimum operating bench width (from the crest of the bottom side slope to the toe of the top side slope) of 90 metres
- In dry conditions, the stacker could be operated from a

maximum of 20 metres from the crest of the bottom side slope, reducing the operational bench width to 80 metres.

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