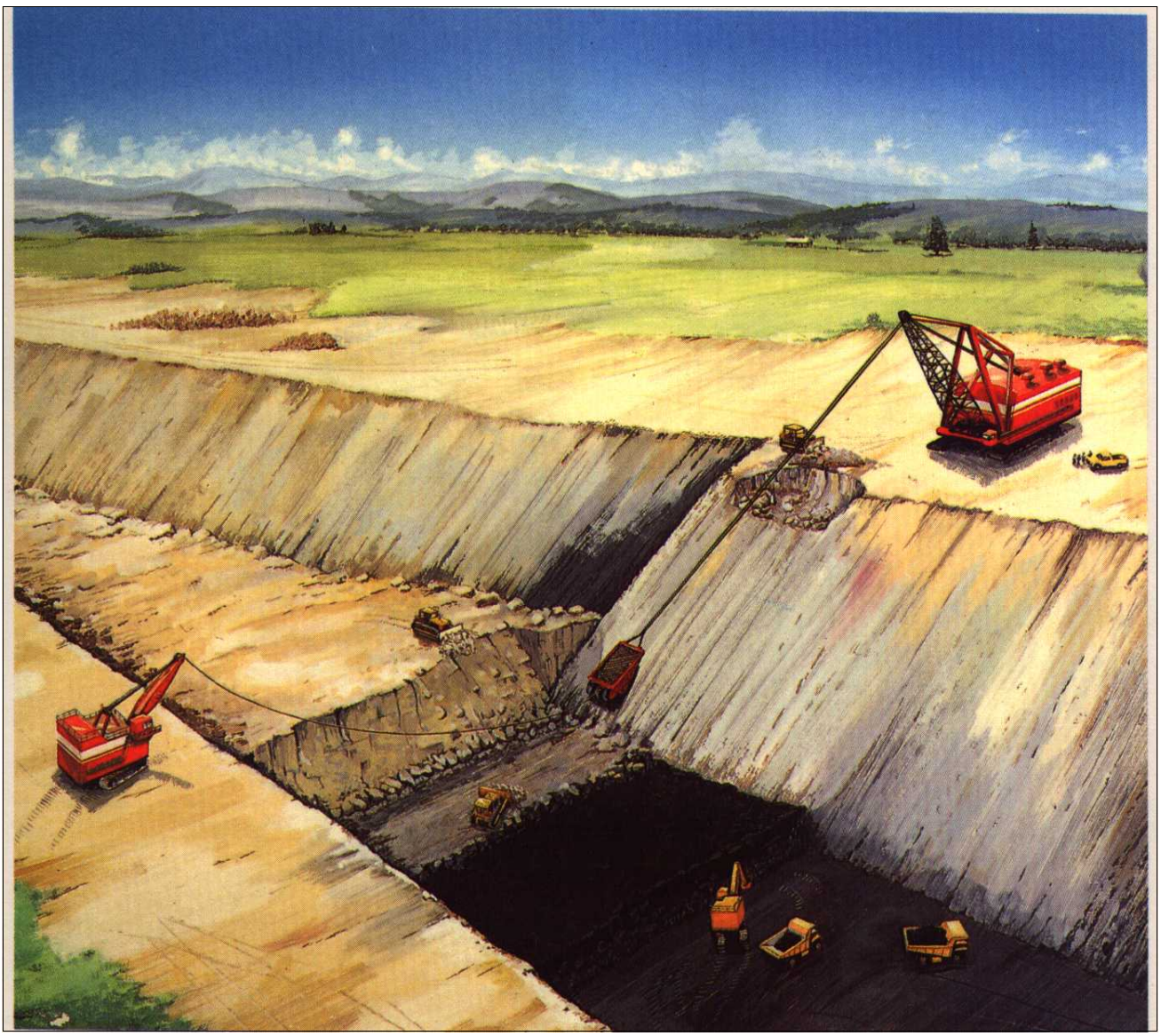
# BOSMIN® OVERBURDEN SLUSHERS

# *THE FUTURE IN OPEN CUT MINING*

**This document explains the operating principles behind the proposed BOSMIN® OS method of strip mining and how OVERBURDEN SLUSHERS translate into better productivity.**



# OS - WHAT is it?

The BOSMIN® OVERBURDEN SLUSHER (OS) system of stripping is most suited to waste removal, and lowers stripping cost relative to a large dragline by $2,000,000pa, or 23%. It involves a high-powered mobile winch on the spoil-side of the pit called a Low Wall Winch (LW). This drags a suitable HOE across the pit and up the side of the spoil pile. The HOE empties by pulling back in the opposite direction using a much smaller winch - the High Wall Winch (HW), sited on the advancing high wall. The process has emerged from several studies as the most cost-effective way of removing waste, but the BOSMIN® OS has emerged with good potential for large construction and mineral extraction projects as well.

The BOSMIN® OVERBURDEN SLUSHER is a product from RA Beatty & Associates Pty. Limited, covered under various Australian and International patents. The patents include claims for both the mining process and the mining apparatus, providing an ongoing window of protection for this intellectual property. Development has included research funding under the National Energy Research & Development and Demonstration Council (NERDDC), pit trials, private and public scale model testing using facilities at the University of Queensland Julius Kruttschnitt Mineral Research Centre, and in-depth evaluation studies. Through to the end of 1997, the research effort amounted to over $2.6M.

# WHY is an OVERBURDEN SLUSHER special?

***The BOSMIN® OS uses the physical principle:***

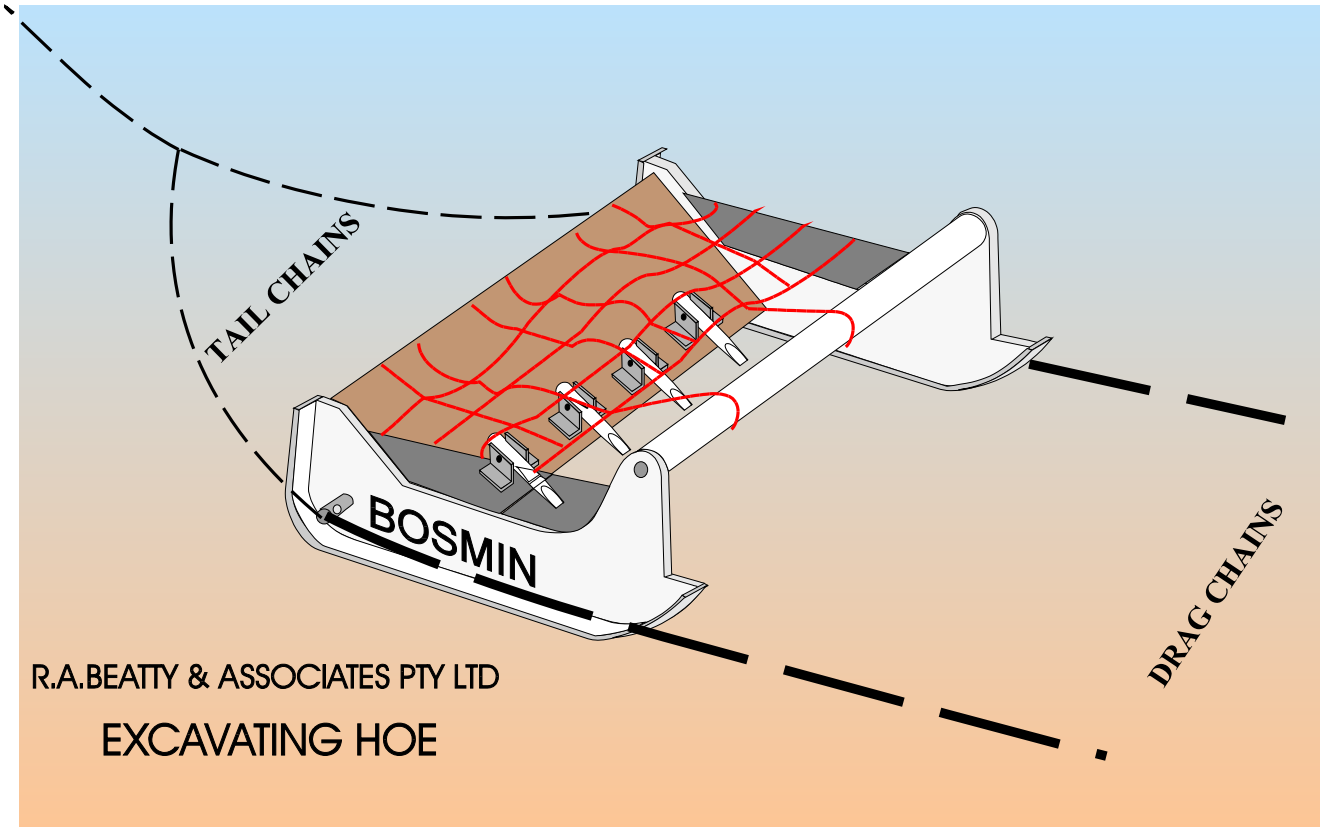
**It is easier to move large loads, for short distances, by sliding them over the ground, than by lifting and carrying them.**

**Sliding force 300g**

**Hoist rope pull 1,200g**

**Tare weight 800g**

- This principle is put to good effect when converting a dragline to OS, because both the hoist and drag winches are used simultaneously in the LW to drag a HOE loaded 2-3 times greater than a dragline payload.
- It is more cost effective to convert an existing dragline than to build a custom-designed LW. Similarly, a shovel is readily convertible to form the HW winch.This makes the OS unique in that a much more productive machine can be largely built, using existing equipment, for reduced capital cost.
- The BOSMIN® HOE is also special because it embodies new earth moving principles. Specifically, the HOE consists of a rear cutting blade, two skid side-plates, and an open front. There is also a lightweight top structure called a TOPNET. This design provides tare weight for the HOE at around a the unit tare weight for a dragline bucket, leading to good volumetric efficiency.



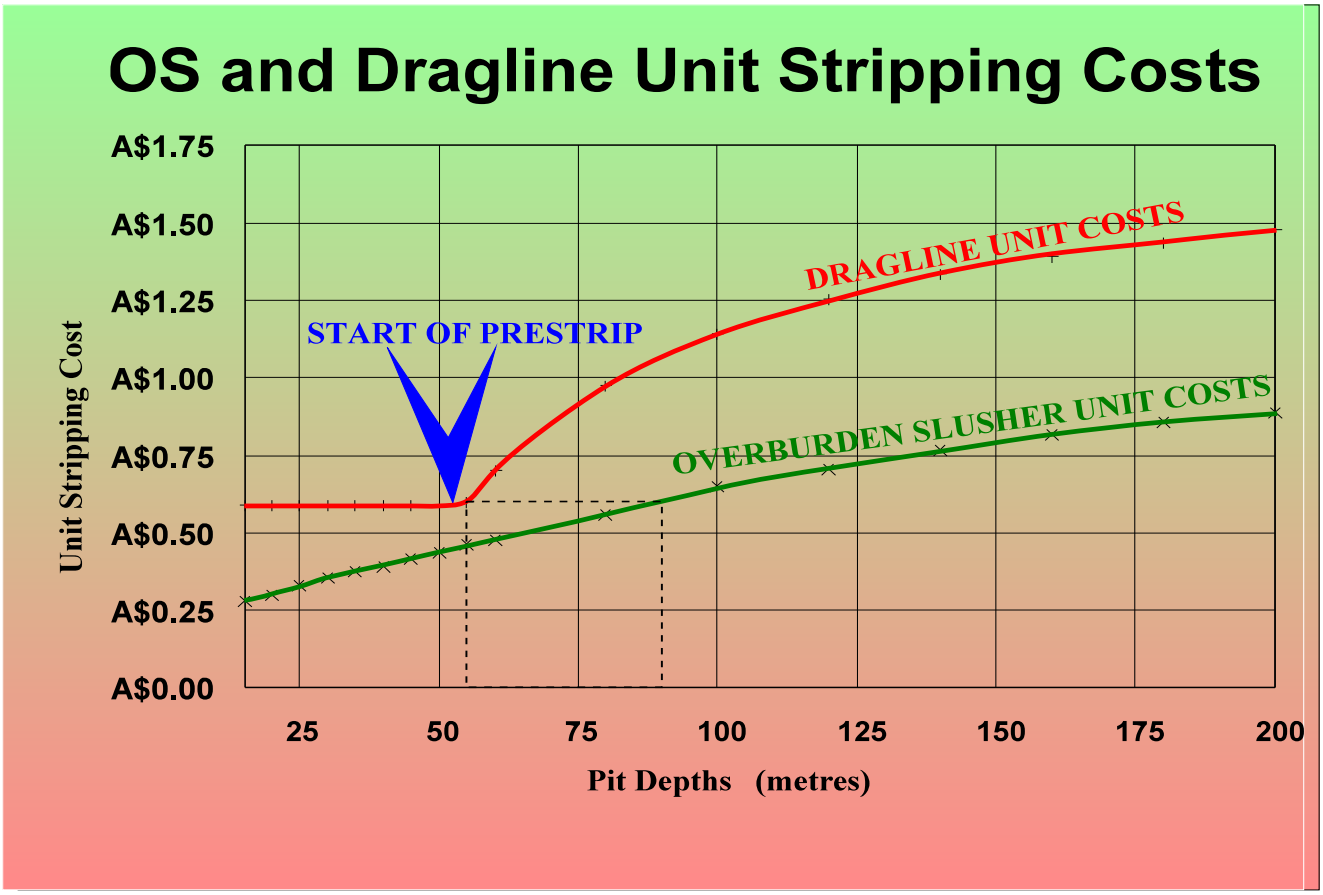

- When the HOE drags forward, material collects in front of the blade, and between the two side plates. The material rises in the HOE until it reaches the TOPNET. Confined under the TOPNET, the load compacts, and the resulting pressure buildup forces the HOE to lift above the digging surface. A shear-plane develops under the loaded HOE and it rides forward at a reduced pulling force.
- This loading action is quite different to existing scraper hoes and bulldozer blades in that the payload stays substantially still, once loaded in the HOE. It reduces internal friction forces, and effectively transports a selected payload across the pit.
- The volume of the HOE can be adjusted, by altering the tension of the TOPNET, to cater for differing soil density conditions. The pulling force then matches the gross HOE load and fully utilises the available machine power for all digging conditions. With a correctly adjusted TOPNET, the BOSMIN® OS achieves close to the perfect payload on every cycle.

## BOSMIN® OVERBURDEN SLUSHERS (OS) - WHY use one?

***The BOSMIN® OS is all about machine productivity.***

- For many open cut strip operations, a BOSMIN® OS will significantly increase the output of the existing dragline equipment by improving the use of the available power.
- Using an OVERBURDEN SLUSHER reduces, or eliminates, pre-stripping requirements.
- Reclamation and other environmental impacts of existing open cut stripping operations are significantly reduced when using the BOSMIN® OS system of stripping.
- OS stripping conserves natural resources with the coal recovery greater than 85%.

## What are the Costs ?




Dragline unit costs at 55m depth (60.3¢/bcm) match the OS at 90m. Put another way, a large dragline stripping 14,430,000bcmpa at 55m pit depth, costs $8,700,000pa to operate. An OS system, shifting the same overburden, has operating costs of $6,700,000pa. **The lower OS stripping cost amounts to a saving of $2,000,000pa, or 23%.** However, there are also productivity improvement opportunities.

Similarly, prestrip and dragline costs for a 70m deep pit coincide with OS operating costs at 150m pit depth. Reduced unit-costs permit the economic removal of a much higher strip-ratio product.

***Ground preparation***

Drill and blasting typically adds $0.28/bcm to the stripping costs. An OS can dig harder unblasted material than a similar powered dragline, because more force is applied to the rippers on the HOE. This is a significant cost advantage to the OS over the dragline, in some applications. An OS can also cycle along a strip removing soft upper layers before the drills prepare the remaining horizon. This can simplify the drilling task at some mines.

## What about productivity improvement ?

On a 40m deep pit, the dragline uses about 1.7kWh of electricity for every cubic metre of overburden removed from the coal seam. In contrast, an OS uses, around 0.6kWh for a similar task. When converting a dragline to LW duty, the resulting OS can shift up to 3 times more overburden. This delivers "***economies of scale***" benefits, and opportunities for low capital expansion.

# How does an OS affect open cut coal reserves?

OS deep stripping results in the optimal recovery of all available seams with a corresponding increase in mineable coal-reserve. For example, a seam dipping at 5° to 100m depth may contain 85,000,000 tonnes of dragline coal reserves, below the oxidation line. The OS fresh coal reserve at 150m depth expands to 135,000,000 tonnes, for the same stripping cost. Usually, additional coal seams appear with increasing pit depth, further enhancing the economics of deep OVERBURDEN SLUSHER stripping. The OS is an ideal mining method where multiple coal horizons appear in the high wall.

# BOSMIN® OS - HOW does it work?

***The stripping sequence***

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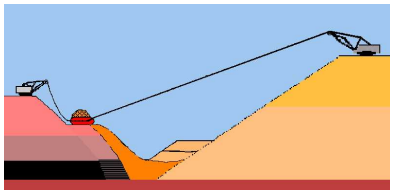

An OVERBURDEN SLUSHER starts strip-mining following the ground preparation. Where this involves drill and blast, the HOE starts stripping directly on top of the shot rock, without the need for pre-levelling. The LW pulls the HOE forward to fill and then transport the load through to the spoil bank, on an underlying shear-plane. Drag ropes then slacken, stopping the HOE. The payload develops passive resistance across the underlying shear-plane. The HW then pulls the HOE backwards, and the payload remains in a discrete pile. As the HOE returns, it is supported on skids attached to the side plates. Ripper teeth, fitted to the blade, swing up reducing the drag effects.

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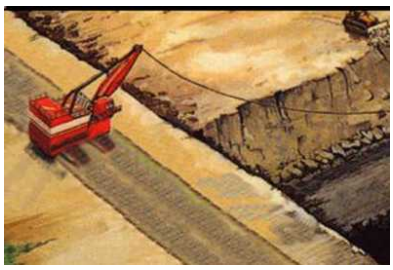

While the HOE is travelling forward, the HW may tram along the high wall to pull the HOE back to a slightly different pit starting position. In this way, the muck pile lowers in a series of layers, comprising the stripping block. Similarly, while the HOE returns to the loading point, the LW boom can be swung through a slight angle. This moves the drag-rope sheaves across the pit and allows the spoil bank to build over a block area. In this way, the HOE operation can proceed uninterrupted while the digging and unloading points alter.

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When the block is complete, the OVERBURDEN SLUSHER moves down the pit to the next block, which is about 30m along the strike. Stripping proceeds until the current strip horizon of coal is uncovered. Coal is then extracted, and the OVERBURDEN SLUSHER returns to remove another layer of waste - either as parting down to the next coal seam, or overburden in the next strip.

❹. After the current strip is complete, the OS moves to the next strip. This allows surface revegetation to proceed behind the LW, as no further recontouring should be needed on the spoil bank.

***Minimising the OS cycle time***

The OS cycle time depends on the speed the HOE travels to and fro across the pit, and the time it takes to change the direction of winch pull. The HOE forward velocity is a function of the available LW power with the drag force multiplied by the rope speed being a constant.

Larger HOE loads moving slowly are more productive than small loads moving quickly. It lessens the cycles required, and reduces deadheading time. Large loads call for massive pulling ropes and a big HOE, leading to practical compromises between payload size and fewer cycles.

The speed of the returning HOE can be increased to reduce cycle times. This requires that the HW can operate at a higher winch speed and that the LW can unwind the drag ropes sufficiently quickly. The drag rope unwinding speed can be increased by 50% through field-weakening the DC winch motors.

***Operating factors***

- The HOE starts loading as soon as the forward motion begins. It fills, and then stops digging automatically. This eliminates operator judgment variations and makes for a fast efficient work cycle.
- The OS system of stripping maximises the use of throw blasting. This happens because the HOE starts digging from the top of the blasted muck pile, and there is no need to maintain the pile at any particular height or to any limiting profile (as is the case with dragline operations).
- OVERBURDEN SLUSHERS can be scaled up to very large capacities. Installed LW power up to 35,000kW are possible using standard dragline hoist winches. These units can theoretically shift 55,000 bank cubic meters per hour (330 Mbcmpa) from 45m deep pits, and could also find application at large earth moving projects. This OS digging to 300m depth will open 73,000$m^2$ of pit area per year (21.8Mbcmpa), and has the potential to move traditional economic open cut pit limits further down dip.
- OS productivity can be incremented up or down by varying the width of the strip. Extra capacity can also be added by including slot dozing machines, to move some of the overburden into a windrow along the low wall side. The OS then elevates this material out of the pit, benefiting from a shorter cycle time, than if the OS loaded the material from the HW side of the pit.

***Equipment maintenance***

The HOE, the LW and HW machines must operate concurrently. The mechanical availability (MA) for the system is therefore the product of each unit's availability. However, the mobile winches are expected to have high MA, because there is less movement required from each machine than say a shovel or a dragline. This should be particularly true if the LW and HW machines are electrically powered. The HOE is supported by a standby unit in the pit which can be quickly changed over when the HOE needs repairing. Under these circumstances, a system MA above 90% is anticipated.

The drag and tail ropes will result in high maintenance cost if they have short working lives. However, the OVERBURDEN SLUSHER is designed so these ropes operate above the ground when under tension. This ensures that premature rope failure will not be a common occurrence, and that rope changes can be scheduled to meet normal working rope lives.

***Reducing HOE wear***

With a BOSMIN® TOPNET fitted, a full HOE rises out of the spoil bank with the payload in the HOE staying still. Material cannot flow through the HOE resulting in less abrasion. A shear-plane develops in front and under the HOE, forming the main working surface. This lessens wear in the HOE.

On the return trip, the HOE rides on skids under the two side plates. Wear pads mounted under these skids are replaced as a routine field maintenance task, and a spare HOE is available in the pit to enable wear pads to be replaced without interrupting the stripping cycle - other than to change the HOE.

***Helping your operators to boost productivity***

Installing an OVERBURDEN SLUSHER is the perfect time to promote upgrade training involving the machine operators, as one facet of a continuous improvement program (CIP). Operator inputs are instrumental to making the most out of the extra stripping flexibility provided by the OS.

***Adding it all together***

The BOSMIN® OS is a new energy efficient equipment design to ensure open cut strip-mining stays competitive in the future. The bottom line is machine productivity, and the challenge is to move as much dirt as possible, without over straining the equipment. That means achieving the highest utilisation of the available machine power. The OVERBURDEN SLUSHER goes a long way to achieving that goal.

***Cleaning the coal surface***

The BOSMIN® OS is designed to efficiently elevate large loads. This is not conducive to delicately cleaning a coal surface. A pit dozer is included with the OS operating fleet for the final coal surface cleanup. The overburden depth left for the final cleanup depends on the size of the ripper teeth employed in the HOE. Large ripper teeth penetrate deeper and require that a thicker layer be left to protect the coal surface. Alternatively, a HOE operating without teeth may be able to clean right down to the coal surface - particularly if the coal surface is hard, and resists blade penetration.

***The HW winch duty***

The HW mainly serves to retrieve the empty HOE from the unloading position and to position it at the start of digging. This generally requires comparatively little power and the installed HW power is about 10% of the LW power.

The HW can tram along the high wall to alter the digging start position for the HOE. Tramming occurs while the HOE operates on the forward cycle with the tail rope slack. HW tracks face at right angles to the boom direction, with the boom point overhanging the high wall. The HW operates in a shallow trench formed parallel to the high wall brow, to stop the tracks sliding sideways. This provides a definitive pathway for the HW operation.

Some options for forming the high wall include running the empty HOE up and down the wall to remove loose material, or to cut the slope. This procedure requires the drag ropes and chains be left slack while the HW moves the HOE over the wall. Higher HW rope-forces than normal are needed, and a gearing-down device operates in the winch drive.

***Power supplies***

- A large OS stripping unit requires both a low wall and high wall power supply. High voltage lines to the winches will reduce the size of the trailing cables needed for the large power use.
- Smaller LW units of less than 1,000kW may operate using diesel engines.

***Linking the HW and LW machines***

The two winches operate together, alternately pulling the HOE across the pit. The distance between the winches requires a remote control, and radio telemetry is a suitable option. This system will interlock the two winches to prevent simultaneous pulling of the HOE. A further safety device in the form of a shear-pin will detach the tail rope should the interlocks fail.

***OS stability considerations***

The LW and HW units are vulnerable to both sliding and overturning moments. These effects are catered for by counter-balancing the winches to provide the usual safety factors associated with these potential movements. Additionally, the HW operates in a shallow trench along the high wall to provide a further safety protection against sliding or mis-tramming near the crest.

***Pit Access***

The range of the BOSMIN® OS can be increased by operating with longer ropes. This permits the unit to dig inclined ramp faces parallel to the high wall. These are established every strip and include more than one ramp, giving continued access to the pit. This arrangement permits the usual low wall ramps to be closed off and the ramp voids to be filled, providing much needed spoil room.

***Stabilising the spoil bank***

The spoil bank progressively builds from the base to the top, and the potential energy input is minimised by not elevating spoil any higher than is required to form the spoil bank. This contrasts strongly with dragline spoiling method, where much potential energy is lost. OS spoil banks rise, one layer at a time. The HOE travels over each successive layer, compacting the underlying material, which ensures a stable surface for the LW to work on.

***Major Geotechnical factors***

Low wall spoil banks associated with OS stripping are inherently stable, because they can be set at a designed angle of repose. This feature ensures that any failures are caused by unanticipated ground conditions rather than any inherent limitation of the OS mining method. However, the BOSMIN® OS moves along the pit with the LW and HW positioned on fixed benches. This feature allows the OS to return to pits where slumped material has covered the exposed coal to easily retrieve the situation.

Slumps may occur through high wall failure, or spoil bank slippage. Both these geotechnical events can be remedied by returning the OS to the site of the failure and cutting the failed material back to a stable bank angle. Floor failures can be corrected by removing soft or wet floor material with pit pumps or the OS before starting the next strip.

***Crossing ramps***

The BOSMIN® OS is capable of cutting ramps in the high wall. However, converting an existing dragline to an OS operation may involve a period when the LW has to cross over low wall ramp voids. There are two suitable ways to do this:

- The LW can walk back to the brow of the ramp and reconnect the ropes to the HW when repositioned across the void.
- The OS can bridge across the void by moving the HW 45° ahead of the LW, and then pulling bridge material into the mouth of the ramp. After the LW crosses the bridge, the HW moves back along the strip to trail the LW by 45°. The bridge material is then pulled onto the leading ramp spoil face, completing the crossing. Extra spoil room can be gained by ramping the LW to a higher level, if needed.

***Forming the high wall***

The high wall can be formed by the BOSMIN® OS in several ways, depending on site-specific conditions. Methods for forming the high walls include:

- Employ the associated pit dozer to cut the wall as the OS lowers the block.
- Use the HW unit only to cut and dress the wall by raising and lowering the HOE in a series of near vertical traverses.
- Pre-split the high wall and use the HOE to dress the wall.

- Form the wall at a low angle using the LW to contour the slope at the cut-in angle for the HOE.

***Automating the OS operation***
The OS is suited to substantial automation, because the operation essentially occurs in two dimensions. As initial stripping sequence can be set manually and the following cycles set automatically using Logic Control Programing, until reaching a pre determined cutoff point.

The equipment operator can work outside the LW and HW units, and control the equipment by radio telemetry from a base in a four-wheel drive vehicle, or from a bulldozer cabin in the pit. An OS operator will preferentially locate near to the HOE loading point, where the most need for direction exists.

***Keeping the work area tidy***
A BOSMIN® OS carries the whole load to the spoil bank. No material spills out the back or front of the HOE. The spoil bank face angle is set at less than the rill angle for the material. Rocks rolling back down the spoil bank to re-cover exposed coal will not be a frequent occurrence. The area around the LW remains unaltered during the majority of the digging cycle and only needs smoothing over after the final spoil bank lift is in place. Once the LW moves off the immediate area, it is ready for replanting. The HW works on an advancing high wall face. Carefully prepared drainage layouts and roads will ensure the area is always conducive to efficient machine operations.

## Is the OS a safe system?

**The OVERBURDEN SLUSHER is inherently safe, because:**

- The payload never leaves the ground and cannot move in an uncontrolled way if the moving mechanisms fail.
- Catenary pulling rope profiles provide an inherent shock absorbing feature in the connection between the working winch and the HOE. The drag force also has a vertical component allowing the HOE to ride over any immovable objects.
- The spoil bank angle is less than the rill angle for the material thereby insuring bank surface, spoil, and pit floor stability. This removes the risk of rocks cascading into the mining pit, and possibly disrupting the coal winning operations.

**Fail-safe mechanisms are included in all key components consisting of:**

- Radio telemetry interlocks between the HW and LW machines.
- Electrical interlocks between multiple winches in the LW unit.
- Mechanical safety shears to protect against excessive rope pulls.
- Sliding and overturning stability protectors on the LW and HW machines.

## What are the key OS environmental factors?

The BOSMIN® OS system of stripping is significantly ahead of traditional open cut coal mining methods. The key factors include:

- ***Less power and diesel fuel used in deep strip mining.***
  The OS moves overburden using two to three times less energy than other methods. There is an operating cost benefit, but there is also a significant environmental cost benefit in that using fewer kilowatts, results in smaller generating impacts. With approximately 850 million cubic meters of overburden stripped in Queensland each year, significant energy savings can be made in electricity and imported diesel fuel consumption. Lower power requirements mean a decrease in domestic power station stack emissions, waste storage, water use, and an increase in overall

efficiency. This releases, about 270,000t of coal per annum, for the export market, rather than burning it at local power stations. Much of the diesel truck fuel used for overburden removal can be replaced by locally generated electric power.

- ***Low noise emission due to ground-contact operation.***
  Focusing on the noise aspect, the OS is a significantly less noisy operation. There is no occasion when large chains and bucket can freely clang together, particularly during the hours of darkness, where some mines are close to residential districts. The hauling gear attached to the OS rests quietly on the ground during to and fro, transfer cycles. The operating machinery is electrically powered, and it only emits a low hum from the cooling fans, while operating. Large overburden trucks can be a source of noise impact which is also avoidable where truck and shovel mining can be replaced by the BOSMIN® OS.
- ***Low dust emissions.***
  BOSMIN® OS greatly reduces dust release. Always moving along the ground, whether engaged to strip or moving into position to release its load. This transporting operation minimises the incidence of air catching in the load to cause dust. The OS is also designed with a TOPNET which controls the dust while filling. When full it disengages, and any dust immediately decreases because soil is no longer being churned up.
- ***Spoil rehabilitation with recontouring integral to stripping.***
  The illustrated process shows a BOSMIN® OS providing immediate contouring - eliminating an unsightly development and a prime cost aspect of mine rehabilitation. It therefore speeds up the rate of top soiling and mine re-vegetation. The mining industry is committed to responsible rehabilitation. However, time and uncommitted future stripping plans are the main issues which postpone rehabilitation to relevant mining progress. Theoretically the two should be concurrent. BOSMIN® OS ensures simultaneous progress is practiced because the most costly and time-consuming aspect of mine rehabilitation, that being: re-contouring and shaping the overburden heaps, is complete. From this point on, the rest is less time, machinery and personnel.
- ***Topsoil spoiling makes for better rehabilitation.***
  Topsoil can be discreetly loaded from the high wall and deposited on the spoil surface by the HOE. Also, a fertile stratum of overburden found near a coal seam can be moved selectively to the surface. This simplifies the reclamation process. Conversely, some mines report the existence of unsuitable spoil material which should be completely buried. The BOSMIN® OS can unload this material into a lower part of the spoil bank and out of harm's way.

## Is the BOSMIN OS a wise use of human resources?

Introducing some new mining equipment can result in severe HR problems due to the need for very specialised skills or the need for people prepared to work in unfamiliar surroundings. The OS requires few operators and much of the work can be automated. This eliminates many potential HR difficulties and makes for short operator induction periods.

## Who is responsible for developing new mining machines?

Long term equipment owners (contractors or mine operators) will benefit most by initiating the development of new equipment designs. They own the machine for the longest time and therefore have the best opportunity to depreciate the development cost over an acceptably long period. Contractors or mine operators also benefit most from the introduction of more efficient machines. While their short term focus remains on profitable operations, they should also employ Outside Equipment Manufacturers (OEMs) to build machines which meet their specifications.

# Where to from here?

1. A desk study will quantify the site specific benefits of using a BOSMIN® OS. Significant benefits must be defined before making the extraordinary effort required to build a large new mining machine. BOSMIN® has software to evaluate all combinations of pit layout and winching power options, and can quantify the above benefits for any property.
2. Quantify the strategic advantages of developing a cheaper open cut stripping method.
3. Conduct field trials to evaluate productivity sensitive factors at a nominated site.
4. Select suitable equipment for conversion to OS use.

***References***


- A simulated BOSMIN® OS operation can be viewed by downloading the Win95/NT executable file (1.2Mb) **BOSMIN1.EXE** from the WWW home page, listed below. A more detailed sequence, **BOSMIN2.EXE** (6.6Mb), is available on floppy discs where a 100m deep box cut is excavated together with a subsequent strip.
- Bob Beatty supervised the prestigious ***Nimmo Medal for Engineering Excellence*** award winning thesis, **Increasing the Economic Depth of Open Cut Coal Mining using the Overburden Slusher** by Graham Lumley, at the University of Queensland, Department of Mining and Metallurgy, 1985.
- **Back to Basics in Open Cut Mining**, R.A. Beatty, ***University of Queensland Rock Excavation Seminar***, July 1986.
- **Overburden Stripping Using Large Slushers**, R.A. Beatty, G.I. Lumley, Prof.D. Rowlands, ***AusIMM Proc.*** Dec. 1986.
- **Overburden Slusher (OS) Study. #1217 NERDDC Project.** Final Report Sept.89. R.A. Beatty & R.J Frost (BHPE).
- **Conceptual Mine Stripping Comparison**. R.A. Beatty, presentation, ***ACIRL 1989 Annual Surface Mining Seminar***, Moranbah, Central Qld, 26 Oct 1989 and Singleton, Hunter Valley NSW, 30 Nov 1989
- **BOSMIN Scoop.** Co-author, **ICs INTERNATIONAL**, ***Submission for the Inaugural Premier's Award for Environmental Excellence of Coal Innovative Technology in the Queensland Mining Industry*** 7/93
- **R&D From Rhetoric to Reality**. R.A. Beatty, ***AusIMM Bulletin*** Feb.1994.
- **Large Dozer Stripping Case Studies**. R.A. Beatty, discussion, ***Society for Mining, Metallurgy and Exploration Inc. Mining Engineering***, April 1994.
- **BOSMIN® TOP NETS- Technical Bulletin #1**, ***R.A Beatty & Associates Pty Limited,*** 1996.
- **New Equipment Designs for Deep Open Cut Mines**. ***COSMET Meeting #84***, Montreal, R.A. Beatty, presentation, 25th Oct.97.

# What can a BOSMIN® OS do for your operation?

***The BOSMIN® OVERBURDEN SLUSHER offers significant advantages including:***

- ➔ Operating cost benefits realised through lower unit costs.
- ➔ A better utilisation of deep-strip multi-seam coal resources.
- ➔ Major geotechnical benefits due to low angle spoil banks and the ability to remove unstable floor materials, or pick up collapsed slopes.
- ➔ Improved energy efficiency, 2-3 times better than with dragline stripping.
- ➔ Concurrent land reclamation, while stripping ore, ie it is "***environmentally friendly***".
- ➔ Replacing the low wall ramp spoil voids with high wall haul ramps.
- ➔ Deep stripping ability without the need for companion equipment.
- ➔ Reduced stripping-in-advance inventories.

***An opportunity exists to retrofit existing draglines and shovels to give:-***

- ☞ Increased stripping capacity, at reduced capital costs, due to better power efficiency with less gear.
- ☞ Increased use of cast blasting.
- ☞ Simplified pit layout for multi seam mining, and deeper open cut strip-mines.

***Improved mine operating flexibility exists because:-***

- ☺ Partial strip lengths give better access-scheduling, limit wet-weather restrictions, and improve coal quality planning.
- ☺ Strip width variations give options for changing in-pit inventory levels and stripping capacities.
- ☺ Incrementing stripping capacity is possible with an OS, through varying the strip width, or by adding pit dozers.

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