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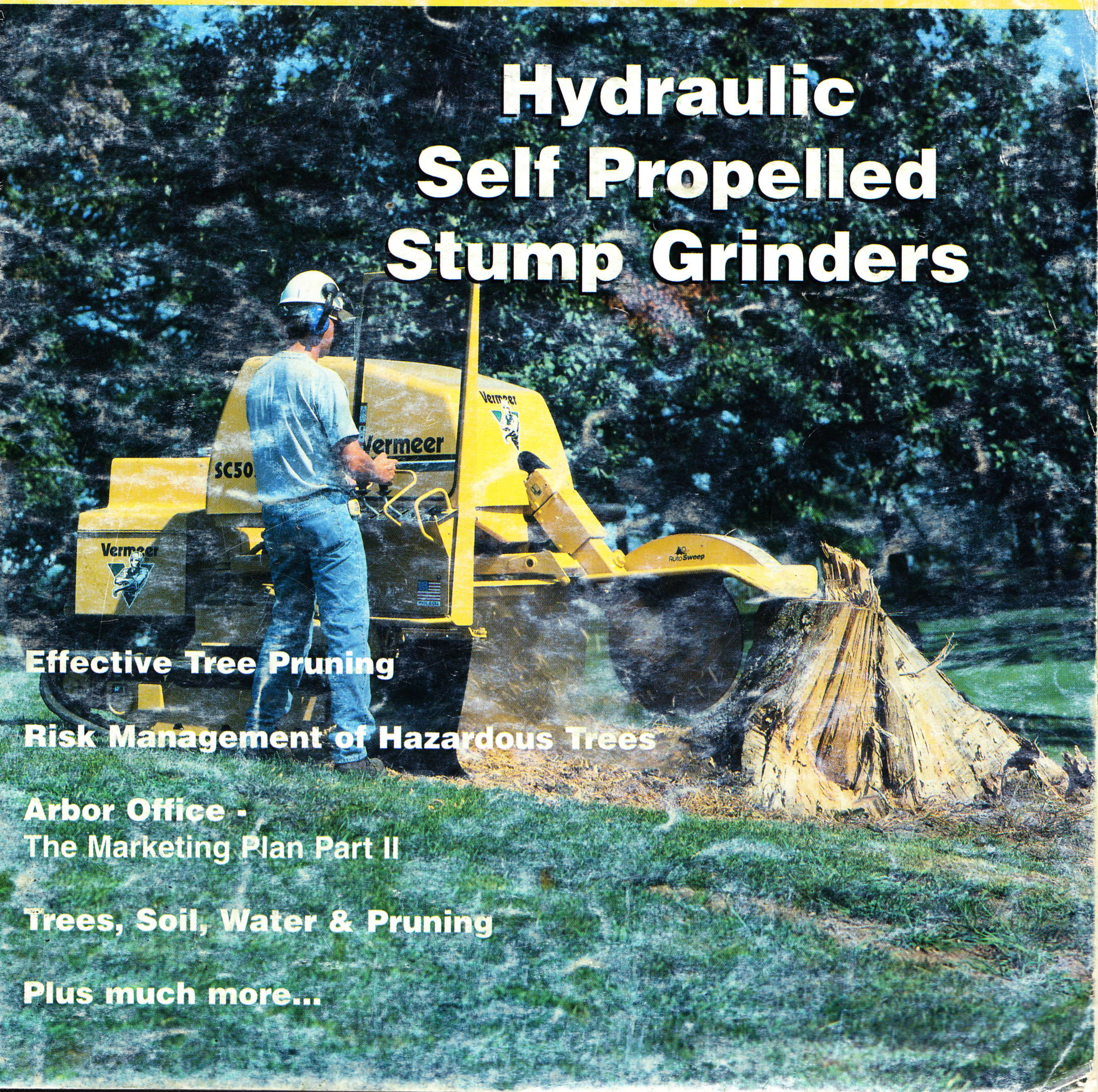

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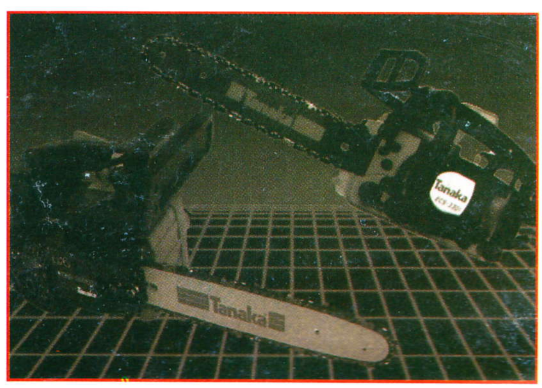


OPPOSING PENDULUMS
RISK MANAGEMENT OF HAZARDOUS TREES
WILLIAM RICKETTS SANCTUARY

By Graeme McMahon

Removing hazardous Eucalyptus regnans trees from confined sites requires the use of sound rigging techniques implemented by a well-coordinated team. The requirements of such tree removals and hazard reduction becomes compound if the intrusive works are to have maintained the delicate environmental balance of the remaining forest, between the upper-canopy , under-story and surrounding forest. In addition, the late William Ricketts life work of delicate sculptures adorn much of the forest floor. Completing the tree works for public safety whilst maintaining the spiritual atmosphere of the sanctuary, demanded a degree of control not previously justified.

Above: Maneuvering a large load around the delicate sculpture to the landing area.

The use of accurate measurements, special rope and a laptop computer, enabled the calculated control of the blocks of wood, some weighing 1.25 ton, with uncompromised precision.

Background

After many name changes, the now Parks Victoria are custodian of many of the gardens and reserves in the Dandenong ranges, East of Melbourne. None more note worthy than William Ricketts Sanctuary. The late Mr William Ricketts devoted his life to creating the sculptures that are set amongst the trees on the forest floor. The majestic Eucalyptus regnans forest where he lived and worked becomes the living stage, enhancing the spiritual atmosphere of his themes of, Mother Nature, Aboriginal people, being at one with the environment, and white mans influence.

Increasing public visitation to the sanctuary, coupled with many branch and tree failures have raised concerns for public safety and that of the works themselves.

The Centre for Forest Tree Technology (CFTT) was engaged to undertake a study to establish the causes for the general decline in tree health and identify associated hazards in the forest. The detailed document is called, "Ecology, Safety and Silviculture in the Mountain Ash Forests of the Sanctuary and Surrounds". This information contributes to the vegetation management plan, which is focused 50 plus years into the future. The forest trees in the sanctuary were mapped and ten selected for a detailed risk analysis. Of these, seven were identified for prompt removal, the remaining three to have the hazardous dead limbs removed. The reasons for the tree removals were from two main areas:

1. Exhibiting obvious trunk/root ball defects with bias to or directly over high visitation areas.
2. Suppressed or becoming suppressed by the more dominant trees around them. The signs of this are easily seen as the tree is struggling to maintain foliage on a crown that consists mostly of dead wood. Trunk defects are numerous providing easy penetration of ants, grubs and water which further diminish the structural qualities of the trunk. The position of these trees was also considered in relation to areas of high visitation or over a large concentration of works.

The trees to have the dead limbs removed had high concentrations of dead limbs above an area of high visitation and or a large concentration of works.

The contract was tendered and parameters set regarding the end product.

- All to be lowered down onto the narrow path winding through the sanctuary (2'-3' wide).
- Minimal impact on ferns, mosses and remaining trunks as they combine together to give the atmosphere around the works.
- All debris to be removed.

The removal of the limbs and heads went ahead as they had in the past. Rigged, cut off and lowered without causing sudden loading or impacting against itself or the surrounding trees. The dead limbs can range between three and twenty meters (10-66 feet) long. These cannot be treated roughly as they easily break and the sections will fall away leaving the rope tied to a small remaining piece. The consequence of even a small stick falling down sixty meters (200 feet) onto a delicate sculpture could result in irreparable damage. Sudden movements while climbing around in the crown of the tree would cause some large dead wood to wobble dangerously near breaking point.

The fifty to sixty meter (165 -200 feet) high standing trunks presented the difficulties to remove, even when using the more specialised dismantling techniques. Dropping any piece no matter how small was out of the question. Lowering pieces from the trunk being removed, nearby tree or multiple trees, was also discounted as shock loading could result in dead limbs or chunks of bark being dislodged and falling uncontrolled. The basil six to ten meters (20 - 33 feet) of trunk presented its own set of difficulties because of rope elongation (even with pre-load applied), pendulum lengths and pendulum rates with retarders, could not give calculated guaranteed results.

The test case to either side of any pre-load pendulum technique is,

a) **Not enough pre-load applied:**

The block would fall onto the rope past the desired pre-load, causing an increased loading on the rope as its fall was arrested. This momentary increased loading (shock) would be transferred to the high point by the rope. The sudden changes in tension of the rope could cause the crown of the tree supporting the high point to be given a violent shake. This reaction could cause dead limbs to break off and fall uncontrolled to the ground. The possible results could be, damage to sculptures, injury to persons or pass safe working load of the system.

b) **Too much pre-load applied:**

The block may be pulled back sharply by the rope causing a sharp reduction in line tension. The block would continue to rise up passed the desired pre-load until the force of gravity prevented its continuous rise and causes it to fall back onto the rope as previously described. The initial direction of movement of the high point would be in the opposite direction as example a), however the possible results would be the same.

Using any of the conventional lowering devices with the lowering point at the point of cut created the obvious problems. At elevated positions the impact of the block of wood could pulverise a chunk of bark off and it fall uncontrolled. The smooth parallel sides of the Mountain ash would require extra precautions to ensure the block cannot escape the rope. Close to the ground would mean that the pendulum down could be too close to the objects to be avoided. In addition to this the ratio of log diameter to the length of section being removed (given the limitations of the safe working load of the system), created more difficulties of the rope grasping the section during the dynamic movement of being transferred to a hanging position below its lowering point.

THE METHOD DEVISED

For the method of dismantling of the trunks to be suitable it was required to be reliable and cost effective. Gravity is constant in this context and, costs nothing to use. The 12,000 kg (26,400 lb) lift of the "sky-crane" helicopter was considered as it is rigged for helicopter logging, however a cheaper method was devised.

Essentially the technique uses two opposing pendulums. The two lowering (high) points are above, either side of and in line with the load to be supported. If we consider the two ropes rising from either side of the load as vectors, the sum of the vertical components equal the load to be held. The two horizontal components sum to zero. The result of preloading each rope accurately is that the load stays exactly where it was released. When the angle of each vector is the same the solution to the required magnitude is straightforward trigonometry.

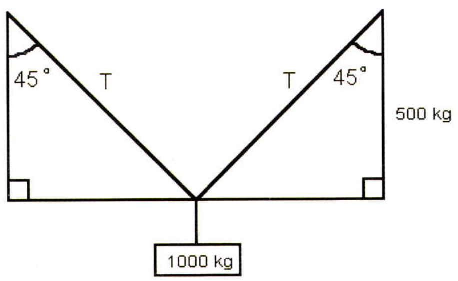
E.g. If we require to hold a 1000 kg (2200 lb) load. Each rope needs to support 500kg (1100 lb). If each rope rises at an angle of 45 degrees, the required tension (T) for each rope can be calculated. (See Fig.1)

The horizontal components of the two vectors are 500kg (1100 lb) each and in opposite directions, hence cancel out while holding the opposing rope and preventing its pendulum.

For this concept to work practically we needed to be able to calculate the line tensions for any combination with a variable load, i.e. 0 degree to 90 degrees with any combination of the same. This required building a relationship between the two vectors, and deriving the formula.

With the above formula (derived in Appendix 1) it was now possible to calculate both the line tensions required, given any angles of the supporting pendulum or load to be held. Pulleys set at the high points; either side of the trunk being dismantled enabled the friction

Fig.1 Ropes with equal angles



$$\text{Cos } 0 = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\text{Therefore Cos } 45 = \frac{500}{T_1}$$

$$\text{Therefore } T_1 = \frac{500}{\text{Cos } 45}$$

$$\text{Therefore } T_1 = \frac{500}{0.707}$$

$$= 707.1 \text{ kg}$$

at that point to be considered zero. Where possible the rope continued in the same vertical plane to reduce the side loading on the lowering point. (See Fig. 2).

The rope continued down to the ground where another pulley was used to give the final change in direction. The rope would now present in a horizontal fashion to the anchor point, thus making it easier for the ground crew to perform the necessary tasks. (See Fig. 3 below)

The two functions at the anchor point were to,

1. Accurately pretension the rope.

A dynamometer (crane scales) was attached to the anchor point. The other side to a 1500 kg (3300 lb) winch, the winch hook onto a prussic loop which grasped the main lowering line. The winch could now be used to give the exact preload required.

2. Control the lowering of the loads.

A single "Goldtail" (large friction device) was used to control the loads less than 750kg (1650 lb). Lines required to control blocks of up to 1250 kg (2750 lb) had large steel friction device used in series with the "Goldtail". The steel device, which was a similar design to the "goldtail" and crudely fashioned by myself, this was attached to the anchor point and the "goldtail" attached in series to it. Friction could be added and reduced during the lowering operation. Because of the changes in load share it was essential to have this flexibility. At times a rope may be controlling 1.25ton of load when the block is released, and toward the end of the lowering of the same block be disconnected entirely from its friction point.

The range that the blocks of wood could be lowered into, using gravity only was between the two high points. By allowing the block to pendulum entirely onto one rope it could be pulled/pushed around the base of the tree and layed over. Because of the 60 meter (200 ft) plus pendulum length the work required to do this was minimal. For

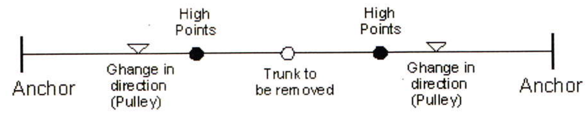


Fig.2. Birds eye view of path of lowering ropes.

Below: Equation A

$$T_2 = \frac{W \text{ Sin } 0_1}{\text{Sin } 0_2 \text{ Cos } 0_1 + \text{Cos } 0_1 \text{ Sin } 0_1}$$

Below: Equation B

$$T_1 = \frac{W \text{ Sin } 0_2}{\text{Sin } 0_2 \text{ Cos } 0_1 + \text{Cos } 0_2 \text{ Sin } 0_1}$$

one of the trunks the wood was bought to the ground 10 meters (33 ft) outside the above range. A tag line was attached to the section, prior to it reaching the ground a horizontal force was applied to the tag line in the intended direction. This enabled the load to be displaced the required distance.

Prior to the lower end of the block of wood touching the ground, it was found that applying a force in the opposite direction to the direction you wished to lie the section down made the task of laying it in a precise direction, easier. When the block touched the ground this displacement ensured its base of support was well outside its centre of gravity. Thus the section would, due to gravity, tend to lay down exactly in the intended position. By controlled lowering between the two ropes successful placement was ensured.

One of the trunks was displaced horizontally in sections, 35 metres (115 ft) using the controlled pendulum, this was only possible because of the height of the lowering points. Using these rope pendulums only for the descent, meant that sometimes the section was too low to clear some sculptures, buildings, plants etc. With the winch in place, it was lit tle fuss to raise the section up the small amount. For higher lifts, there are many other winches more suited to that task.

ROPE SELECTION

Over 300 meters (1000 ft) of the main lowering lines had to be handled off the ground at any one time. There were many other ropes and slings used during the operation for a range of other tasks. The lowering lines needed to have specific characteristics if the system was to be cost effective and efficient, they were:

a) High breaking strain for a low weight of rope (kg/m or lb/ft).

b) Good "knotability", retention of knot characteristics and braking strains).

c) Very low elongation throughout the loading spectrum of the fibre type.

d) Minimum length of 180 meters (590 ft).

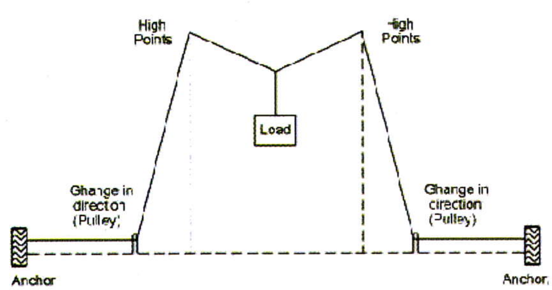


Fig. 3. Side view of path of lowering ropes

Left: Using the log volume tables to estimate the load and point of cut.

One fibre type stood out from the rest, "Vectran". It is a polyester derivative, produced by Kinnears ropes and used in the core of ropes in the Challenge Braid range. Challenge Braid was developed for the "America's cup" yachts and available through Kinnears ropes in Melbourne. With vectran core and polyester multifiliment sheath, in 14mm has an average breaking strain of 10,200 kg (22440 lb). This meant that I could stay under the 1:8 safety factor and still lower the volume of wood needed to maintain a productive rate. Much higher breaking strains are possible if the vectran is used in constructing the sheath. They didn't carry the vectran fibre here in Australia, let alone the lengths required, so they were sourced and flown out from their New Zealand branch.

The rope had good knotability and didn't fall outside the normal strength reductions experienced in normal rigging. Unlike some of the other low elongation fibre types that experience lower strength retentions when applying knots to them.

The elongation on break is 1 % which ensures direct control while lowering and reduced work to be done when winching in the pretension.

A 250m (825 ft) coil of red colour sheath, and another of blue, reduced confusion when calculating the pre-load for each rope and enabled the fine control required between the sculptures even when it was out of sight of both anchor points.

PULLEYS

Six were "Tailor made" by Crux Rescue Australia. The pulley wheels were turned so as to allow for a slight flattening of the 14mm rope. This maximised the load share capabilities of the low stretch Vectran fibre. The stainless steel cheek plates although snug fitting to the edge of the pulley wheels, allowed clear access for the haul line knots to pull the lowering rope through unobstructed. These were tested and rated to 10 kn. The pulleys were pinned directly into a double 14mm vectran sling, so there would be no link in the system under a 10,000 kg (22,000lb) rating.

Above: The winch set with the dynamometer 'in line'. The blue rope on the other end of the winch is the prussick loop grasping the red load bearing rope.

COMPUTER

The formula was derived, and subsequently programmed it into his laptop computer in a spreadsheet format. The computer was run on battery power for some of the trees, but for most we had a power source in William Ricketts old residence. The building was central to a number of trees, of which we passed two right over to the other side to reduce the work of extraction. The building also provided a conducive environment to operate the computer, away from, dirt, moisture and the continual shower of sawdust.

MEASUREMENTS

Measurements that were necessary up the tree required the use of an inclination meter, tape measure and log volume tables. The inclination meter sat on the rope and because of the internal pendulum gives an accurate angle measure from the vertical. Log volume is easily calculated with the tape and tables. Timber densities increased due to increased amounts of water retained as we progressed down the trunk. This meant juggling (guess work) the densities from under 1000 kg (2200 lb) to the cubic meter to over 1,250 kg (2750 lb) to the cubic meter. One good indicator that the density was going to increase was when the preceding section being lowered started to run water out, after being cut off. This indicated that the next section to be removed would be contain more water than the previous, and an increase in density would follow. Working down the trunk the increasing density soon became constant when the section could retain no more water for its volume.

CONCLUSION

The result of this system was that even with minor deviations in measurements and estimates, an extremely high level of control was maintained. The main reason for this is the extremely low stretch rope selected for the task. It gave direct control of the sections being lowered, to the anchor point, where the rope was being fed through the friction device. The positive control achieved meant that 10 cm (4 inch) of rope allowed through the friction device, gave exactly 10 cm (4 inches) of "down" at the other end without any bouncing. With around 140 meters (460 ft) of rope between the friction device and load, this control enabled confident lowering of over 1000 kg (2200 lb) of wood at a time between the sculptures.

The only uncontrolled movement possible was that initiated by the head of the tree used as the high point. Small air currents passing through the crown could result in the high point oscillating one to two meters. Stronger winds can result in excessive displacements of the high point.

Most of the blocks being cut off lifted 6 mm (1/4 inch) or just sat gently where they were. By rigging the high points slightly out of line of the trunk being removed the sections didn't have to be pushed manually off the stump. The cutting was started from the compression side of the section until it started to close, then from the tension side just below the previous cut. When the cuts overlapped the block would slowly drag off to the side away from me. The high points seemed unaffected by this refinement, as the pre-load was precise.

Left: Pushing a block of wood so gravity can tak effect again.

Below: Cutting up is started while the ropes are being sent back up to the climber.

When lowering mid trunk sections the limiting factor was the length that would fit onto the narrow winding path under the fern canopy. That section would then have to be extracted to create enough space for the next one. Whilst I had difficulties keeping up with the efficient extraction team, the system over all is productive enough to be worthwhile in this case. There is room for improvements on the raising and lowering equipment that was used. The concept of opposing pendulums may be transferable into other work applications, like tree transplanting, extracting material from a confined site or extend the system to three high points.

Above: The Precise preload enables quite large sections to be pushed off.

Above: The section now in 'space' is now being directed over the under story to the landing area just visible at the bottom of the plate.

Acknowledgments

I wish to thank Alan McMahon for his assistance in deriving the formula, placing it in a useable format on his laptop computer and its subsequent use. Bill Rouse for the use of one dynamometer and as a tireless source of information regarding ropes and their applications. Paul Maroney from Kinnears Ropes for sourcing the ropes and backing my endeavour with advice from the technical and research sections. Mick Herrick from Crux Rescue Australia, for designing and making the pulleys to fit the rope. My crew on the ground who functioned as a team, overcoming any problems created by the new procedure. Peter Roweth from Enth Degree Photographics for continuing to pursue a high standard of plates under very difficult conditions.

Appendix 1

For those interested, the following is a full derivation of the Formula A and Formula B shown in this article. Contact The Australian Arbor Age on (02) 9972 4688 and we can fax it to you. Members only. ■