Winching operations in forestry
Tree takedown and vehicle debogging
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Winching operations in forestry often involve large forces due to the nature of the heavy loads involved, for example hung-up trees and bogged vehicles. There is concern that where winches are used the forces involved may not be fully understood by operators. If not carefully controlled, these large forces may threaten the safety of those carrying out the operation. This guide focuses on the principles involved in winching with the aim of improving operators’ appreciation of the forces encountered and ways of implementing safe working practice. The guide also highlights safety issues for current practice when using winches, principally for tree takedown and debogging of vehicles.

A series of basic principles are presented on winch forces and fail-safe systems including a discussion of areas where shortfalls in safety can commonly occur. Guidance is provided on the controlled failure of winch systems. Example winch set-ups are illustrated which demonstrate the forces involved and identify the appropriate equipment rating for a series of hypothetical tree-takedown and debogging situations.

This guide focuses solely on the use of static hand or vehicle mounted mechanised winches and does not cover the use of vehicles used in pulling operators. The use of winches for lifting is a separate subject, especially with regard to the legislation on lifting equipment, and is not covered in this guide.

The guidance contained within this publication serves as a source of information for those involved in winching operations in forestry, and is not a substitute for training. Anyone involved in winching must have first received the appropriate technical and first-aid training.
# 1. Winching safety issues

Table 1.1 summarises the principal safety considerations in the use of winches in forest operations.

## Table 1.1 Principal safety considerations within winching operations.

<table>
<thead>
<tr>
<th>Safety issue</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>Must be appropriate for the task, and therefore rated (see Section 3, Safe working loads and safety factors) to withstand the forces generated in the winch system. Equipment should be maintained and inspected regularly. Damaged equipment should never be used. Equipment should be compatible with regard to safe working load (SWL) (see Section 3, Safe working loads and safety factors). Operators need to ensure winches are inspected and certificated at required intervals.</td>
</tr>
<tr>
<td>Equipment wear</td>
<td>Wear on equipment must be carefully monitored. With some equipment wear is difficult to quantify. Wire rope discard criteria can be accurately judged by measuring rope diameter reduction (see Forestry Commission and Technical Development, 1994).</td>
</tr>
<tr>
<td>Communication</td>
<td>During the operation those involved should establish (prior to the commencement of work) a system of communication, either audible or visible. A clear STOP signal is essential. Visual communication is well suited when machinery noise is loud, however audible communication or the use of a third person to relay the message allows for contact when the line of sight of operators is blocked.</td>
</tr>
<tr>
<td>Control</td>
<td>One person should be placed in control of the winch operation, who shall communicate with any others on site during the progress of the operation. In tree takedown operations this is will usually be the chainsaw operator.</td>
</tr>
<tr>
<td>Training</td>
<td>Winching operations should only be carried out by individuals who have received appropriate training. Required training includes both technical use of winches and appropriate first aid training. In the absence of trained staff, professional winching bodies should be contacted e.g. for the debogging of machinery where forces are likely to be greatest.</td>
</tr>
<tr>
<td>Protective clothing</td>
<td>All individuals should wear appropriate protective clothing when using winches as detailed in Table 7.1. High visibility clothing is also recommended for safe working.</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>Operators must carry out a risk assessment for all winching operations prior to commencement of the operation.</td>
</tr>
<tr>
<td>Site conditions</td>
<td>Slope and traction will vary with site as will the presence of hazards such as overhead power lines, members of the public or dead tops in trees to be winched. If a machine becomes bogged in the middle of a harvesting site there will be produce and brash to climb over to reach the machine. These features should be accounted for at the planning and risk assessment stage.</td>
</tr>
<tr>
<td>Safe working position</td>
<td>If a component in the winch system should fail, operators should be in a working position which minimises the risk of injury. During hand winching a diverted pull can be used. Where mechanised winching is carried out operators should take up a safe position, preferably within the machine’s cab, with appropriate guarding (window guarding). Other people on site should be removed to a safe distance. Operators should also secure a safe escape route.</td>
</tr>
<tr>
<td>Attachment to load</td>
<td>Safe attachment of the load for winching to a point adequate to bear the forces involved is essential. During debogging this may necessitate attachment around the machine’s axle using strops.</td>
</tr>
<tr>
<td>Disassembly</td>
<td>Complacency should be avoided once the winching is completed, care is required during the dismantling of any winch set-up. The winch system should never be left assembled under tension.</td>
</tr>
<tr>
<td>Safety devices</td>
<td>Safety devices should be checked for condition before and after use, and should never be removed or replaced with alternative components to allow loading above the rated capacity of the winch.</td>
</tr>
<tr>
<td>Proper use of equipment</td>
<td>Under no circumstances should operators modify winching equipment in an attempt to exert a greater force. Equipment should only be used for the purpose intended as dictated by the manufacturer’s instructions.</td>
</tr>
<tr>
<td>Legislation</td>
<td>The principle operations of winches discussed within this report are pulling (as opposed to lifting) and therefore their use falls under the Provision and Use of Work Equipment Regulations (PUWER) 1998 and the Health and Safety at Work Act (HASAWA) 1974. Should winching equipment be used for lifting then its use and maintenance falls under the Lifting Operations and Lifting Equipment Regulations (LOLER) 1998. See Health and Safety Executive, 1999 and 2000; Anon, 1974.</td>
</tr>
<tr>
<td>Calculation of force</td>
<td>Prior to the setting up of a winch system operators should calculate the forces required for the operation, enabling appropriate equipment specification selection; see Section 2 (Examples are also given in Appendix 3).</td>
</tr>
<tr>
<td>Information</td>
<td>Consult: AFAG (see References) and PUWER (see Health and Safety Executive, 1999).</td>
</tr>
<tr>
<td>Authority to winch</td>
<td>Check that those involved in winching are authorised to do so with regard to insurance, work policy and training.</td>
</tr>
<tr>
<td>Failure of equipment</td>
<td>Should equipment break/fail during winching with the system under tension, failure must be in a controlled, safe way to minimise the risk to the operator.</td>
</tr>
<tr>
<td>Manual handling</td>
<td>There are implications for the manual handling of equipment used in winching set-ups, especially during debogging operations where the high tonnage rating of equipment may necessitate large bulky components to be carried. In such cases mechanised transport of equipment to site should be considered (see Forestry Commission and Technical Development, 1998).</td>
</tr>
</tbody>
</table>
2. Forces generated in winching systems

Forces generated by winch design

Winches allow large loads or forces to be overcome by using a relatively small effort; as such they are force multipliers. Using a hand winch, the repeated action of a lever converts a small input force over a long distance movement to a large output force over a small distance movement. Similarly, mechanised winches exert magnified forces on an object through a system of gearing.

Convention note: The unit of force (F) is the Newton (N) and is a measure of mass (m) x gravity (g) \[ F = mg \]; mass measured in kg and gravity as 9.8 m s\(^{-2}\). A winch rated at 2 tonnes exerts a force of (2000 kg x 9.8) 19.6 kilonewtons (kN). Throughout this guide for the sake of simplicity the forces exerted by winches will refer to their rated tonnage (t), rather than converting the less familiar unit of force, the Newton. For example, a 1 t rated winch exerts a pull of 1 t rather than 9.8 kN.

Increasing winching force by use of blocks

The inclusion of blocks within winch systems allows a multiplication of force to be exerted upon an object, due to the principle of mechanical advantage. When a machine puts out more force than is put in, it has mechanical advantage. The system’s mechanical advantage (MA) acts as a multiplication factor by which we calculate the force on the load from the pull of the winch. Figure 2.1 demonstrates the principle of mechanical advantage.

A simple rule of thumb is that if we count the number of lengths of rope going to and from a movable block, this number is equal to the mechanical advantage gained through the system (see Figure 2.1). This rule holds true so long as the rope lengths are parallel.

Effect of angles of pull on forces in systems

As the angle between the wire rope lengths increases (Figures 2.4 and 2.5), the mechanical advantage is reduced. In order to accurately calculate the forces involved in winching, the following formula must be used:

\[
\text{Pulling force} = 2T \times \cos X
\]

where:
- \( T \) = the force exerted by the winch
- \( \cos X \) = the cosine of the angle \( X \)
- \( X \) = the angle created between the wire rope and the direction through which the load moves during the pull.

Note that where three lengths of wire rope run to and from the block the movement of the load is biased toward the two lengths, as illustrated in Figure 2.6.

Within complex winch set-ups, where multiple blocks are included, the angles created involve calculations so complex that they are of limited use to those involved in winching operations.
Thus the following practice should be adopted. For complex winch set-ups (see Appendix 2, Figures A.11 and A.12) calculate the maximum pulling force which could be generated, ignoring the effects of the angle of wire ropes in reducing the mechanical advantage. This rule can be applied to all winch scenarios. Within this guide the more accurate force calculations are included for the sake of completeness.

A series of diagrams which illustrate the forces involved in winching operations and the direction in which the pull is exerted on the load is shown on page 5. Examples of how the calculation can be simplified for Figures 2.2–2.6 is presented in Table 2.1. By ignoring the effect of the angles of wire rope on reducing the pulling force an additional element of safety is built in. The slight overestimation of the pull results in the equipment rating selection being more than sufficient for the forces involved.

### Table 2.1  Examples of the simple approximation of forces involved in winching operations.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Pull exerted by winch</th>
<th>Pull exerted taking into account effect of angle of rope lengths</th>
<th>Number of rope lengths to and from the block</th>
<th>Pull exerted ignoring effect of angles of wire rope lengths</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>2 t</td>
<td>4.0 t</td>
<td>2</td>
<td>4 t</td>
<td>Rope lengths are perpendicular thus angle does not effect MA.</td>
</tr>
<tr>
<td>2.3</td>
<td>3 t</td>
<td>3.0 t</td>
<td>1</td>
<td>3 t</td>
<td>No movable block in the system therefore 1 to 1 MA.</td>
</tr>
<tr>
<td>2.4</td>
<td>2 t</td>
<td>3.8 t</td>
<td>2</td>
<td>4 t</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>2 t</td>
<td>3.1 t</td>
<td>2</td>
<td>4 t</td>
<td></td>
</tr>
<tr>
<td>2.6</td>
<td>2 t</td>
<td>5.6 t</td>
<td>3</td>
<td>6 t</td>
<td></td>
</tr>
</tbody>
</table>

Note that calculating the pulling force by this simplified method (multiplying the force exerted by the winch by the number of lengths of wire rope running to and from a movable block) slightly overestimates the force when there is a movable block and an angle between the wire rope lengths. If ratings of components in the system (i.e. block, strops and shackles) are selected based on these figures they are likely to be more than adequately rated for the operation.

### Key to equipment represented in Figures 2.2–2.6

<table>
<thead>
<tr>
<th>Strop</th>
<th>Anchor</th>
<th>Hand winch</th>
<th>Trewella</th>
<th>Block</th>
<th>Shackle</th>
<th>Wire rope</th>
</tr>
</thead>
</table>

Note that in Figures 2.2 to 2.6 frictional forces are omitted to simplify force calculations: see Effect of friction on pulling forces (page 6).
Note that Figures 2.4 and 2.5 are essentially the same winch set-up scenario; Figure 2.5, however, has a greater angle between the two anchor points. Consequently as the angle X increases so the MA of the system decreases.
Effect of friction on pulling forces

Frictional forces will act within any winch system, i.e. where the wire rope passes through a sheave in a block. **Commonly a 10% reduction in the pulling force is applied for every sheave in the system with well-maintained equipment.** A reduction in the pulling force exerted will therefore occur within the system. If a complex winching system is set up containing several blocks then an allowance for frictional force reducing the pulling effort should be made in the calculations.

Calculation of forces in systems

Before starting a winching operation an operator should calculate all the forces at work in the system so that the loads placed on various parts of the system are known and equipment ratings selected accordingly. Appendix 2 illustrates typical loads that may be expected within winch systems. By calculating the loading which will occur within a system, operators will be able to select appropriately rated equipment and be able to determine whether the equipment available is adequate for the task.

Due to the multiplication of forces that can be gained during winching, through the use of blocks, the forces involved may be so large that they are hazardous to operators. While any winching operation carries an inherent element of risk, provided that the operator calculates the forces involved prior to starting work and correctly rated components are used, then the safety factor built into equipment will allow safe working. There is always the possibility that failure may occur if damage to a piece of equipment is overlooked. (For guidance on safe failure of system components see Section 3, page 11.)

**Calculation of the forces required**

When using winches for tree takedown the weight of the load is an unknown, unlike a bogged machine where the force required for debogging can be calculated to a reasonable degree of certainty (see Appendix 2). The operator must estimate the pull required and the rating of a suitable winch. Note that if a machine becomes deeply bogged, beyond the axles, then a greater force than that calculated (as in Appendix 2) may be needed. In such instances the force required to debug the machine is an unknown.
### 3. Selection and maintenance of winches and other equipment

#### Selection of equipment

Tables 3.1 and 3.2 outline factors to take into consideration when selecting winching equipment.

**Table 3.1** Equipment description, advantages, disadvantages and constraints.

<table>
<thead>
<tr>
<th>Equipment type</th>
<th>Description of use</th>
<th>Advantages/disadvantages/constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hand winch</strong> (incorporating wire rope) e.g. Lugall</td>
<td>Allows magnified force application through the actioning of a winching handle. See Section 2.</td>
<td>Self-contained nature of winch reduces manual handling implications of having to carry a reel of wire rope to the site of winching. Limited wire rope length can be a constraint, but see Figure 3.1</td>
</tr>
<tr>
<td><strong>Hand winch</strong> (using separate length of wire rope) e.g. Tirfor</td>
<td>Allows magnified force application through the actioning of a winching handle. See Section 2.</td>
<td>Certain models require specific, non-standard gauge of wire rope (often more expensive): this allows increased purchase to be gained on rope. The Tirfor brand have a reversing lever; should a problem arise mid way through the operation this allows the tension in the system to be released in an efficient and controlled way.</td>
</tr>
<tr>
<td><strong>Shackle</strong></td>
<td>Used for coupling equipment elements, i.e. blocks to strops. Shackle load bearing and dimension will vary depending on their construction material.</td>
<td>The use of alloys in shackle construction allows for equivalently rated components to be of far smaller dimension than conventional galvanised type. D shackles allow coupling of two components, bow shackles are suited to the coupling of three or more components.</td>
</tr>
<tr>
<td><strong>Block</strong></td>
<td>Supporting fixture for winch wire rope, allowing for the rope to change direction, by offsetting the pull in such a way the force applied can be increased (see examples in Appendix 2). Alternatively the direction of the pull can be offset to allow a safe working position.</td>
<td>Some types of block (snatch blocks) allow the side plate to slide open to allow the wire rope to be looped over the sheave, saving time in having to pass the end of the wire rope through the block.</td>
</tr>
<tr>
<td><strong>Wire rope</strong> Fibre core construction</td>
<td>Offers high load bearing means of attachment of a winch to a load.</td>
<td>Fibre core allows for increased flexibility, and acts as a ‘wick’ to hold lubricant for the rope. Fibre core forgoes some strength compared to a solid wire rope.</td>
</tr>
<tr>
<td><strong>Wire rope</strong> Solid wire construction</td>
<td>Offers high load bearing means of attachment of a winch to a load.</td>
<td>Smaller dimension possible than an equally rated fibre core rope.</td>
</tr>
<tr>
<td><strong>Choker chain</strong></td>
<td>May be used for attachment of the load to the wire rope, as an alternative to a strop.</td>
<td>Cheaper than fibre strops but heavier to manhandle, and should failure occur, likely to be rapid and less controlled than strop failure, which pulls apart in a more gradual fashion.</td>
</tr>
<tr>
<td><strong>Strop</strong></td>
<td>Synthetic fibre construction within a durable outer fibre sheath. The construction may be of a loop or a straight length with two looped ends. Allows for attachment of wire rope to the load to be winched.</td>
<td>Lightweight yet extremely strong. Flexibility and ease of use due to low weight allows easy attachment of wire rope around trees and machine axles etc.</td>
</tr>
<tr>
<td><strong>Trewhella</strong></td>
<td>Used to clamp off a suitable length of wire rope for a winching operation from a longer reel of rope.</td>
<td>Has the advantage that one long length of wire rope can be effectively shortened for numerous winching applications. However the drawback is that they are not typically rated to withstand large forces.</td>
</tr>
<tr>
<td><strong>Debogging hook</strong></td>
<td>Often anchorage to stumps is best made with a strop, looped around the stump. Alternatively a debogging hook can provide attachment of the wire to a stump.</td>
<td>Due to the possibility of the hook pulling through the stump the use of debogging hooks should only be a last resort. Additional information can be found in Section 4.</td>
</tr>
</tbody>
</table>
Table 3.2  Considerations leading to equipment selection.

<table>
<thead>
<tr>
<th>System set-up selection</th>
<th>Equipment selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Assess the situation requirements: identify the winching system set-up required.</td>
<td></td>
</tr>
<tr>
<td>• Forces are calculated prior to winching: system designed to adequately produce the pulling force required.</td>
<td></td>
</tr>
<tr>
<td>• Assess site conditions: given constraints of site (re: anchor points, site hazards) select appropriate equipment.</td>
<td></td>
</tr>
<tr>
<td>• Note working distance from load: system designed such that sufficient wire rope is paid out to allow a safe operating position.</td>
<td></td>
</tr>
<tr>
<td>• Planning and risk assessment: essential for every winching operation. Planning prior to setting up equipment will prevent time wasting should, for example, wire rope length be inadequate for proposed set-up.</td>
<td></td>
</tr>
<tr>
<td>• From force calculations: equipment must be adequately rated to develop the forces required for the winching operation.</td>
<td></td>
</tr>
<tr>
<td>• Consider loading within the system from the pre-set-up calculations: equipment must be adequately rated to cope with the forces placed on the components during the pull, preventing equipment failure.</td>
<td></td>
</tr>
<tr>
<td>• Inspect equipment prior to use: ensure all equipment has appropriate safety factors and fail-safe devices (intact and in good working order): see Section 3.</td>
<td></td>
</tr>
<tr>
<td>• Where a choice of equipment allows alternative set-ups: ensure manual effort and manual handling of equipment is minimised.</td>
<td></td>
</tr>
<tr>
<td>• Draw out set-up plan: from plan ensure all items of equipment are available according to system requirements (i.e. numbers of blocks, strops, length of wire rope). This will avoid need for repositioning.</td>
<td></td>
</tr>
</tbody>
</table>

If suitable equipment is not available for the system, contact an approved winching body to carry out the operation.

Equipment must be rated in accordance with the loading that it will be placed under, as calculated by the operator. Where the forces are large, i.e. in debugging heavy machines, this may lead to components becoming so bulky as to become impractical to handle manually. The solution to this problem is the use of an equipment trailer, which can be handled by machine, or the use of equipment made of lightweight alloys, alternatively suitable off-road transport. In addition, the winching set-up can be modified, e.g. Appendix 2, Figures A.11 and A.12 show a similar pulling effort; however, by including two points of attachment to the bogged machine in Figure A.11 the block rating is reduced.

Figure 3.1  Set-up to allow a safe working distance to be adopted when winching using a hand winch design with a limited length of self-contained wire rope, and where a diverted pull is desirable when winching downhill.
Where winches have a self-contained length of wire rope in their design (e.g. the Lugall brand) this reduces the manual handling aspect of having to carry long lengths of wire rope. However, the relatively short lengths of rope contained within such models may not allow the operator to adopt a working position at a safe distance from the hung-up tree.

Where a limited length of wire rope is available, takedown may require the tree to be winched down part way to the ground, and then the system to be rehitched to allow lowering to be completed. The practice of rehitching presents a serious compromise to operator safety, therefore it is recommended that every effort is made to complete takedown in one go, eliminating the need for the operator to rehitch the winch set-up. A length of suitable wire rope can be used to extend the working distance of the operator (see Figure 3.1).

Note that hand winches must be CE marked for use within the UK. However, there is no British Standard that covers hand winches, and more specifically shear pins. The shear pins used in Tirfor winches, for example, have no identifying markings. Tirfor are insistent that only their own shear pins should be used in their winches, but since the pins are not marked in any way it is difficult to be sure that a genuine pin, suitable for the purpose, is fitted in the winch. Care must be taken to ensure all items of equipment used in a winching scenario seat correctly and are correctly aligned.

Compatibility of equipment is essential. Winch components, e.g. shackles and blocks of equal rating, vary in size depending on the material used in their construction. Compatibility of equipment includes selecting blocks that are appropriate for the diameter of wire rope in use, with respect to the diameter of the block in use and the depth of the groove. The sheave diameter should be at least eight times the rope diameter and ideally, the sheave diameter should be around the order of 18 times the rope diameter. A smaller sheave forces the wire rope around a tighter curve, increasing the risk of damage to the rope (see Figure 3.2).

Compatibility is also an important consideration with regard to wire rope diameter. Winch brands (e.g. Tirfor) may use a non-standard gauge of wire rope, for use specifically with their brand of winch. The benefit is increased purchase on the rope owing to the slight diameter increase over standard wire rope, by a few millimetres. It is essential that where this is the case only the appropriate rope is used. Otherwise a potentially hazardous situation could arise where the rope could slip through the machine under load. Manufacturer’s own wire rope also has a fused end to aid passing it through the winch. This is not a consideration for winch designs which include a self-contained length of rope, i.e. Lugall. The equipment components in the system must be compatible with the winch in use, as shown in Figure 3.2. Note that wire rope with a fibre core will have a greater diameter than an equivalently rated solid wire rope.

When making up winching tackle for debogging or tree takedown operations, care must be taken to ensure that all components are rated appropriately to cope with the anticipated force under which they will be required to operate. The safe working load of a system is that of the lowest rated component of the system. If any of the components in the system has a feature which will prevent overload of the system or failure, e.g. shear pin in a hand winch, then that element of the system should have the lowest safe working load (SWL) of all components (see page 10). Wire rope should have a SWL that is compatible with that of the blocks, shackles and other components used.

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**Figure 3.2**

Block and wire rope size recommendations.
Manual handling of equipment should be minimised especially over uneven terrain. Machinery may become bogged in areas which represent a significant risk to those involved in debogging, e.g. in the middle of harvesting sites. Provision must be made for the safe working practice over such areas.

Mechanised winches, such as tractor-mounted drum winches, are common in forest operations, i.e. mounted on tractors used for skidding. Commonly, manufacturer’s line pull rating for drum winches are based on half-drum performance, i.e. with half the wire rope paid out, and as such represent an average pulling force. With the drum almost empty there is effectively a lower gearing than when full. This means that the force exerted by the winch varies with the amount of wire rope paid out. Such variations in the force of the winch are unlikely to cause overloading of the system as the safety factor of winching equipment will absorb any such increased loading. Appropriate training of winch operators is essential in order that such factors are appreciated.

When operating a mechanised drum winch the wire should never be fully paid out as the point of attachment of the wire to the drum is not a load-bearing component. The minimum number of turns of rope to be left on the drum should be as per the manufacturer’s guidance.

Safe working loads and safety factors

Equipment used in winching scenarios is rated in terms of the maximum safe loading that should be exerted upon it, referred to as the safe working load (SWL). The SWL is the maximum load (as certified by a competent person) that a piece of equipment may be placed under, taking into account particular service conditions.

The SWL must never be purposely exceeded.

Winching equipment has a safety factor built into each component’s construction. The safety factor is commonly 3–5 times the SWL. If a block has a SWL of 4 t and its construction incorporates a safety factor of 5 times, this indicates that the block is likely to fail should a pull in excess of 20 t be exerted.

Even if a component has a safety factor allowing it to withstand loading above the SWL, the load placed on the component should never knowingly exceed the SWL.

The safety factor allows for the system to tolerate miscalculations, wear and tear on machinery, and dynamic loading. Dynamic loading is a change in the loading on the winch system. For example, dynamic loading may occur if a vehicle should slide over a slope or cliff during the course of a debogging operation. The force then required to pull the vehicle is greater than that initially anticipated. Therefore the system must have flexibility to accommodate some additional loading, and this is accounted for by the safety factor.

In cases where the loads in the system are large or where a failure in the system would be very dangerous (i.e. where the working conditions are confined and necessitate close working to the load), components should be included in the set-up which will act as a safety back-up. Strops should be used in the system to hold the wire rope should a block fail, for example.

In critical situations where the consequences of equipment failure are severe, a second, back-up winch line may be used. During winching the slack in the second line is taken up; should a component fail then this line will take the force of the load, allowing safe completion of the winching or a reversing of the pull to reassess the loading.

Having calculated the forces, if suitably rated equipment is not available and the set-up cannot be redesigned to bring the loads placed upon the equipment components to acceptable levels (see Appendix 2, Figures A.11 and A.12) then a professional operator should be called in to carry out the work. Note that if a winch set-up requires a strop of 10 t rated capacity, it is not safe to use two 5 t rated strops, as the equally distributed load-bearing upon more than one strop cannot be guaranteed.
Fail-safe systems

Owing to the large forces generated within winch set-ups, should an equipment component in the system fail, there is the potential for a serious threat of injury to the operator. If overloading of a component in a winch system occurs the system must be engineered to fail in a controlled manner, minimising the risk to the operator. A controlled failure is one whereby the energy created in the system under tension is released gradually.

Winch fail-safes incorporated into the design of winches are typically shear pins with the Tirfor and Tirfor-like brands of hand winches and the handle design in Lugall and Lugall-type winches. The principle behind shear pins as a winch fail-safe is similar to the one where an electrical fuse will blow should the charge exceed a safe limit. Winch fail-safes will prevent overloading occurring if excessive force is exerted through the actioning of the handle. Should the loading on the winch exceed its rated capacity the pin will break, preventing the operator from continuing to exert a force through the winch and overloading the system. Similarly, some winches use the failure of the handle itself if a force is exerted beyond the capacity of the winch, i.e. if an extension is fitted to attempt to increase the force exerted.

Should the safety device be triggered the winch will continue to support the load in a safe manner, however, further actioning of the handle fails to increase the pulling effort. The shear pins incorporated in Tirfor winches will fail should the load placed on them exceed 50% above the rated capacity of the winch; for example, in a Tirfor winch with rated lifting capacity of 3.2 t the shear pin will fail at 4.8 t. This means that potentially 50% additional loading will be placed on the components (the shackles and blocks) in the system. The safety factor incorporated into the design of these components will accommodate this additional loading and prevent failure of the system. Some mechanised winches incorporate shear pins as a fail-safe measure should loading exceed their rated capacity. Alternatively the winch may incorporate a slip clutch. Should the force exceed the rated pull of the winch the friction plates will simply slide over each other, ceasing the pulling effort.

The operation of a hand winch is a slow, controlled process, during which the winch operator receives feedback through the winch handle, including whether increased effort is required, indicating a possible overloading of the system. Such feedback is not so easily detectable in mechanised winches.

When beginning winching the slack should be taken up gradually, avoiding rapid loading on the system. By taking up slack steadily the operator will be able to judge more accurately if failure within the system is likely, i.e. through the feedback in the winch handle and audible/visible stresses on the equipment components. If winches are used correctly and the safety devices are intact and correctly specified then there should be no possibility of exerting dangerously high forces on the equipment components within the system.

It should be emphasised that safety devices incorporated into winches will not protect against overloading resulting from dynamic loading. The safety factor incorporated into winching equipment will act to ‘absorb’ additional dynamic loading within the system, offering a degree of protection to the operator. The operator should always take up a safe operating position with a clear escape route in order to ensure personal safety if failure does occur (see Section 5).

Care, maintenance and inspection of equipment

As mentioned previously, a winch operator should take up a safe working position during winching, for example, by using a block to offset the line of pull. If, once all safety precautions have been taken, there is an unforeseen failure in the system the operator should then be out of harm’s way. This consideration is most important for tasks involving hand winches, as the operator is exposed, unlike mechanised winching where the operator’s working position is often inside a machine cab which offers protection should equipment failure occur.

During the operation of mechanised winches where the winch is operated from the machine...
The operator should remain in the machine at all times during winching. Guarded cabs will offer optimum protection should a failure occur. The operator should confirm the cab guarding is adequate for the operation undertaken. Winch operators should satisfy themselves that equipment is in safe working order through examination of equipment prior to use. A set of recommended equipment checks prior to the use of winches is shown in Table 3.3.

Currently it is possible that faults with winching equipment may go unreported. A maintenance and inspection log should be kept for winching equipment to provide a record of equipment checks and any faults reported and acted upon as soon as noted.

Through prolonged use of winching equipment natural wear will take place on the components. It is difficult to assess the degree to which such wear affects the safe usage of equipment. Wear can be accurately assessed with regard to diameter reduction of wire rope. Wire ropes used in winching applications should conform to BS 6570:1986 Code of practice for the selection, care and maintenance of steel wire ropes. Wire ropes should be discarded once the diameter measures 90% of their normal new diameter at any point. Wire ropes should be free from kinks, wear and corrosion. Lengths of wire rope should be uncoiled in a straight line between the winch and the load in order to prevent loops which may untwist the wire strands or cause kinks to form once under tension.

The degree to which wear on components such as blocks and shackles affects their safe usage is not so easy to quantify as is the diameter method of wire rope wear assessment, as explained above. Only through the regular maintenance inspection of winch equipment (as specified in PUWER 98: see Table 1.1) can the effect of wear be assessed and it remains the discretion of the inspector to determine when equipment is withdrawn from use.

It is essential that damaged equipment is not used, as weaknesses in the system can result in sudden failure and consequent rapid release of energy, risking operator safety.

### Table 3.3  Winch equipment checks.

- Check that the SWL of all components is adequate for the load.
- Examine load pins/hooks and hook seatings for wear, distortion or cracking.
- Where hooks are a component part of equipment, i.e. winches and blocks, check the operation of safety catches and ensure hooks are free to swivel.
- Check blocks for wear and distortion on sheaves swivel head, shackles/eye and side plates.
- Ensure there are no sharp edges or burrs in the side plates that could damage the wire rope.
- Check operation of winch forward and reverse operating levers and ensure shear pins are intact.
- Check operation of the winch release lever/handle.
- Check that the stroke of both forward and reversing levers of the winch are as detailed in the manufacturer’s instructions (stroke length will vary with model in use). A longer stroke length may indicate internal wear. A shorter stroke may be due to internal contamination or damage.
- Check the gauge of rope is correct for the winch in question.
- Mechanised winches: ensure all guarding is securely in place and not damaged so as to risk abrading rope.
- Check strops for tears and chafing.
- Check ropes for damage, kinks, wear and corrosion.
- Check strops for burst stitching, chemical damage and foreign bodies in fibres.
- Ensure all split pins are in place where in use.

Note: Appropriate equipment checks will vary with the nature of the set-up in place. If additional equipment components are included in a scenario that is not mentioned in this table, these should be checked in accordance with the manufacturer’s recommendations.

### Figure 3.3

**Measuring wire rope diameter.**

Correct measuring position  Incorrect measuring position

- Correct measuring position
- Incorrect measuring position
**Communications**

During winching more than one operator may be involved. It is essential that a system of communication is established between operators to allow contact while winching is carried out. In some circumstances radios will be used for communication. Alternatively a system of hand signals exists which has been adopted for winching operations. Hand signals for general winching communication are shown in Figure 3.4.

**Figure 3.4** Hand signals for general winch operator communication. (Reproduced from Forestry Commission, Forestry Training Service Debogging Course Notes.)

- **Heave in**
- **Pay out**
- **Steer left**
- **Steer right**
- **Travel to me**
- **Slow down**
- **Stop**
- **Emergency stop**

Signalling with both hands
4. Selection and use of anchor and fixing points

Trees

Table 4.1 shows a guide to the maximum pull at stump height (in kN) that should be exerted upon green trees and the upper limit of winch rating appropriate.

Table 4.1

Guide to bearing capacity of standing trees
(Reproduced from Samset, I., Winch and cable systems).

<table>
<thead>
<tr>
<th>DBH (cm)</th>
<th>Max. pulling force (kN)</th>
<th>Max. straight line pull related to winch tonnage rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>13</td>
<td>1.3 t</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td>3.0 t</td>
</tr>
<tr>
<td>40</td>
<td>53</td>
<td>5.3 t</td>
</tr>
<tr>
<td>50</td>
<td>83</td>
<td>8.3 t</td>
</tr>
<tr>
<td>60</td>
<td>120</td>
<td>12.0 t</td>
</tr>
</tbody>
</table>

When using trees as anchor points the bearing strength of the tree is unknown, and will vary with rooting, soil type, soil moisture and presence of decay. Trees growing on shallow soil or boggy ground should be avoided if possible (likely to be a difficult criterion to meet in areas where machinery is likely to become bogged). Dry or rotten stumps should be avoided as anchor points. If there is doubt about the load-bearing capacity of an anchor tree it should be further anchored back to adjacent tree(s). If the tree selected for anchoring is not to be subsequently felled, care must be taken not to damage the standing tree.

Stumps

When using stumps for anchor points in winching operations secure attachment is essential. Attachment of the wire rope to the stump may be through the use of a strop and shackle, requiring a notch to be cut in the stump to prevent the strop pulling over the top of the stump.

Vehicles or machinery

Anchorage should be as far away from the load as the length of the wire rope allows to ensure a safe working position. Attachment of wire rope to vehicles must be to a structurally sound load-bearing point. The tow-hitch should be avoided as its capacity is generally unknown. Ensure that the wire rope is properly attached to the pulling machine in the case of debogging, i.e. to a tow bar and not just a tow hitch. The latter is not designed to cope with large pulling forces; attachment around the machine axle is a more secure method.

Debogging hooks

Debogging hooks may be used for the purpose of anchoring but only as a ‘last resort’ should alternative anchorage be unavailable and only where appropriate training has been received. Debogging hooks may pull through the stump under large forces and therefore the quality of the stump and its anchoring in the ground should be checked. The use of a terminal pin inserted at the point of attachment of the hook to the stump will help to prevent the hook pulling through the stump.

Using strops for load attachment

The configuration of strops will influence their safe working load. Figure 4.1 illustrates the change in strop SWL with different strop configurations. As shown, using a strop in a chokered fashion will reduce the force that should be exerted to 80% of the stated SWL.

Figure 4.1 Influence of strop configuration on SWL (the multiplication factor of SWL is shown below).
5. Identification of safe working positions

As far as tree takedown is concerned, during the operation there is no guarantee of the exact direction in which the hung-up tree will move or fall. This is an especially important consideration when takedown takes place on sloping ground and there is potential for the tree to slide down slope during the pull. Owing to the nature of tree crowns, where trees are likely to be hung up, precise directional control of the stem during winching is difficult. If the tree deviates from the intended direction of takedown mid pull, there could be significant danger to the operator. This reinforces the need for the operator to take up a safe working position with a clearly identified ‘escape route’ in case the direction of the tree deviates from that intended (see examples marked in green in Appendix 2).

The potential for equipment to be thrown through the air should a breakage occur increases with the elasticity of the system. Trees used in a system may impart some elasticity, especially if support strops are placed high up the stem. Wire rope stretches very little when used in pulling applications. As such, it is probable that if equipment failure occurs during normal winch takedown/debogging, the rope will simply slump to the ground, in a reasonably safe manner. The main danger in such cases is that the load being winched ceases to be supported and may move uncontrollably. The working distance from the load should be as great as the wire rope will allow, and the pull should be offset through the use of a block to allow a winching position for the operator out of the direct line of pull.

Owing to the exposed operating position of those involved in manual winching, the operator has little protection should failure occur. It is therefore essential that these aspects are fully covered during the planning, organising and risk assessment of the operation.

Regarding mechanised winching there is little advice regarding safety guarding suitable for machine cabs. Due to the varying nature and size of equipment components current machine cab guarding may be insufficient for the purpose. There is currently no standard for assessing the suitability of such guarding for winching operations.

During the winching operation anyone who is not directly involved should move to a safe distance of at least twice the distance of the wire rope in use under tension. The operator should remain in the cab or in the designated safe operating position until tension has been released from the winch cable; and the winch system should never be left assembled and under tension.

6. Training requirements

Information and courses relating to the appropriate training of winch operators in forest operations can be obtained from Forestry Training Services (see References and useful sources of information for contact details). Information about the use of winches in forestry can be obtained from the AFAG Guides listed in the References. It is essential that anyone involved in winching in forest operations must have first received the appropriate training both in the technical use of winches and in appropriate first aid.

Training will address safety issues connected with winching which fall outside the scope of this guide. These include such factors as the weather conditions, e.g. strong winds, at the time of winching.
7. Personal protective equipment (PPE)

The appropriate PPE for winching operations is set out in Table 7.1. It is accepted practice that gloves are worn by those involved, however, there is no designated specification for gloves suitable for winching operations. Suitable gloves should afford the operator adequate protection from injury, principally in the handling of wire rope. Commonly during takedown operations those involved will have chainsaw gloves and these should provide acceptable protection during winching. AFAG Guide 310 states that for all winching operations suitable work gloves should be used.

Table 7.1  Safety clothing requirements for winch operations  (Reproduced from AFAG Guide 310: Use of winches in directional felling and takedown. EN: European Norm: European-wide safety standard).

- Protective helmet (Complying with EN 397)
- Suitable eye protection (mesh visor complying with EN 1731 or safety glasses to EN 166)
- Ear protection if working near or with a tractor (complying with EN 352)
- Gloves
- Protective boots with good grip (complying with EN 345-1)
- Non-snag outer clothing
- First aid kit including large wound dressing
- High visibility clothing when working on or near the public highway or when working with other machinery
Appendix 1
Definition of terms

Equipment failure
The point at which an element of equipment breaks (loses structural integrity) due to loading beyond its capacity.

Force
Force (F) = Mass (M) x Acceleration (A);
F=MA

Lifting equipment
As defined by PUWER 98: How the Regulations apply to agriculture and forestry: ‘Any equipment that lifts or lowers loads, including: processing machines that lift as part of their function, such as tree harvesters, bed processors; extraction machines that lift as part of their function, such as cable cranes; machines fitted with log loaders, such as forwarders and clam bunk skidders’.

Lug-all
Brand of hand winch with length of wire rope self-contained within the unit.

Mechanical advantage (MA)
Exists in a machine where a machine puts out more force than is put in.

Movable block
A block included in a winch system that moves with the load as winching progresses.

Safe working load (SWL)
The SWL is the maximum load (as certified by a competent person) that a piece of equipment may be placed under, taking into account particular service conditions.

Safety factor
A factor above the SWL above which failure of an equipment component will occur.

Sheave
A ‘wheel’ with a groove over which the rope passes in a pulley block.

Straight line pull
Pulling effort whereby the input force directly acts upon the load, without a diversion in the angle of pull, i.e. through the use of a block.

Tirfor
Brand of hand winch.

Trehwella
A clamping device, commonly used within skyline operations, which allows a secure fastening point for a length of wire rope at a given point along the rope’s length; see key equipment, Figures 2.2–2.6.

Diverted pull
Use of a block which allows for a change in direction of the winch rope, i.e. allowing the operator to take up a safe working position, offset from the line of pull.
Appendix 2
Winch set-up scenarios and debugging

Winch set-up scenarios: tree takedown (forces of friction are not included for the purposes of simplification).

Figure A.1
Angle $X = 50^\circ$. 1 t rated hand winch (T): Force on hung-up tree = 1 t. Advantage of setup: change in direction of pull: allows operator to take up a safe working position. NB Force on anchor tree $2T\cos X = 2 \times 0.6 = 1.3$ t

Figure A.2
Angle $X = 40^\circ$. 1 t rated hand winch (T): Force on anchor tree = 1 t. Advantage of setup: Multiplication of takedown force on hung-up tree = $2T\cos X = 2 \times 0.8 = 1.5$ t

Figure A.3
Angle $X = 25^\circ$. 1 t rated hand winch (T): Advantage of setup: Multiplication of takedown force on hung-up tree = $(T\cos 2X) + (2T\cos X) = 0.6 + 1.8 = 2.4$ t

Figure A.4
Angle $X = 20^\circ$. 1 t rated hand winch (T): Advantage of setup: Multiplication of takedown force on hung-up tree = $(T\cos 3X) + (3T\cos X) = 0.5 + 2.8 = 3.3$ t
Winch set-up scenarios: debogging (forces of friction are not included for the purposes of simplification).

**Figure A.5**
Similar set-up to Figure A.2: mechanised winch replaces hand winch. Angle $X = 40^\circ$. 4 t rated mechanised winch ($T$). Force on anchor tree = 4 t. 
Advantage of Setup: Multiplication of takedown force on hung-up tree $= 2T\cos X = 8 \times 0.8 = 6.4$ t

**Figure A.6**
Similar set-up to Figure A.1: mechanised winch replaces hand winch. Angle $X = 50^\circ$. 4 t rated mechanised winch ($T$). Force on anchor tree = 4 t. 
Advantage of Setup: change in direction of pull: allows operator to take up a safe working position. NB force on anchor tree $= 2T\cos X = 8 \times 0.6 = 4.8$ t

**Figure A.7**
Angle $X = 20^\circ$. Pull required to debog machine: 4.5 t. 
Winch rated at 3 t. Force exerted on anchor tree 3 t. 
Force exerted on vehicle through winch set-up $= 2T\cos X = 6 \times 0.9 = 5.4$ t

**Figure A.8**
Angle $X = 21^\circ$. Pull required to debog machine: 10.4 t. 
Winch rated at 4 t. Force exerted on anchor tree 8 t. 
Force exerted on bogged vehicle through winch set-up $= (T\cos 2X) + (2T\cos X) = 3 + 7.5 = 10.5$ t
Figure A.9
Angle $\alpha = 18^\circ$. Pull required to debog machine: 10.4 t. Winch rated at 3 t. Force exerted on anchor tree 9 t.
Force exerted on bogged vehicle through winch set-up = $(T \cos 3\alpha) + (3T\cos\alpha) = 1.8 t + 8.6 = 10.4$ t.

Figure A.10
A. Angle $\alpha = 15^\circ$. Pull required to debog machine: 10.4 t. Winch rated at 4 t. Force exerted on anchor tree 8 t.
Force exerted on bogged vehicle through winch set-up = $(T \cos 2\alpha) + (2T\cos\alpha) = 3.1 t + 7.5 t = 10.6$ t.
B. Angles between wire rope sections so small so as to be considered negligible. Thus: Winch rated 4 t.
Force exerted on bogged vehicle through winch set-up = $4 t \times 3 = 12$ t.

Figure A.11
In these examples the multiple blocks used in the set-ups introduce multiple angles of force exerted upon the load. Owing to the complexity of these set-ups, the calculations involved are so lengthy that an operator is best to apply the general rule of thumb: calculating the maximum forces that could be at work within the system. Hence:
Figure A.11: Force exerted on bogged vehicle = $4 \times 4$ t = 16 t
Figure A.12: Force exerted on bogged vehicle = $4 \times 4$ t = 16 t
**Table A.1**  Factors to be used in calculations

<table>
<thead>
<tr>
<th>Rolling resistance : ground factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth road</td>
<td>25</td>
</tr>
<tr>
<td>Grass</td>
<td>7</td>
</tr>
<tr>
<td>Gravel and wet sand</td>
<td>5</td>
</tr>
<tr>
<td>Soft clay/Peat/Mud</td>
<td>2</td>
</tr>
</tbody>
</table>

**Gradient**
Divisor 60 is a constant

**Damage resistance**
Multiplication factor (R)
No wheels locked    0
1/2 wheels locked   1
All wheels locked   2
Divisor 3 is a constant

---

**Table A.2**  Examples of the calculation of forces required

**Calculation for determining the force required to debog machine (Figure A.7).**

A. Rolling resistance = \( \frac{\text{Weight of vehicle}}{\text{Ground factor}} \) = \( \frac{4 \text{ t}}{2 \text{ (soft clay peat)}} \) = 2 t
B. Gradient resistance = \( \frac{\text{Weight of vehicle} \times \text{Degree of slope}}{60} \) = \( \frac{4 \text{ t} \times 0 \text{ (level ground)}}{60} \) = 0 t
C. Damage resistance = \( \frac{R \times \text{Weight of vehicle (assume 1/2 wheels locked)}}{3} \) = \( \frac{4 \text{ t}}{3} \) = 1.3 t
D. Safety factor = \( (A. + B. + C.) \times 25\% \) = \( 3.3 \times 0.25 \) = 0.825 t

Force required = (A. + B. + C. + D.) = 4.125 t

---

**Calculation for determining the force required to debog machine (Figures A.8–A.10).**

A. Rolling resistance = \( \frac{\text{Weight of vehicle}}{\text{Ground factor}} \) = \( \frac{10 \text{ t}}{2 \text{ (soft clay peat)}} \) = 5 t
B. Gradient resistance = \( \frac{\text{Weight of vehicle} \times \text{Degree of slope}}{60} \) = \( \frac{10 \text{ t} \times 0 \text{ (level ground)}}{60} \) = 0 t
C. Damage resistance = \( \frac{R \times \text{Weight of vehicle (assume 1/2 wheels locked)}}{3} \) = \( \frac{10 \text{ t}}{3} \) = 3.3 t
D. Safety factor = \( (A. + B. + C.) \times 25\% \) = \( 8.3 \times 0.25 \) = 2.1 t

Force required = (A. + B. + C. + D.) = 10.4 t

---

**Calculation for determining the force required to debog machine (Figures A.11 and A.12).**

A. Rolling resistance = \( \frac{\text{Weight of vehicle}}{\text{Ground factor}} \) = \( \frac{10 \text{ t}}{2 \text{ (soft clay peat)}} \) = 5 t
B. Gradient resistance = \( \frac{\text{Weight of vehicle} \times \text{Degree of slope}}{60} \) = \( \frac{10 \text{ t} \times 0 \text{ (level ground)}}{60} \) = 0 t
C. Damage resistance = \( \frac{R \times \text{Weight of vehicle (assume 1/2 wheels locked)}}{3} \) = \( \frac{20 \text{ t}}{3} \) = 6.7 t
D. Safety factor = \( (A. + B. + C.) \times 25\% \) = \( 11.6 \times 0.25 \) = 2.9 t

Force required = (A. + B. + C. + D.) = 14.6 t
Appendix 3
References and useful sources of information

Publications

AFAG Guides
The following Arboriculture and Forestry Advisory Group (AFAG) safety guides are relevant to winching operations and should be read in conjunction with this report:

310: Uses of winches in directional felling and takedown
501: Tractors in tree work
502: Extraction by skidder
504: Extraction by cable crane
502 and 504: Cover wider operational safety aspects regarding the use of components common to winch systems.

AFAG guides are printed and published by the Health and Safety Executive.

Forestry Commission

ANON (1974).
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HMSO, London.

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Technical Note 8/94.
Technical Development, Ae, Dumfries.

The Grizedale debogging equipment trailer.
Information Note 4/98.
Technical Development, Ae, Dumfries.

Other

HEALTH AND SAFETY EXECUTIVE (1999).
PUWER 98: How the Regulations apply to agriculture and forestry. AIS 27
Health and Safety Executive Books, Sudbury, Suffolk.

HEALTH AND SAFETY EXECUTIVE (2000).
LOLER: How the Regulations apply to forestry. AIS 29
Health and Safety Executive Books, Sudbury, Suffolk.

Winch and cable systems.
Martinus Nijhoff, Dordrecht, Netherlands.

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