Outdoor Access Pty Ltd

Specialist Consultancy & Accreditation

VERTICAL RESCUE OPERATOR – Part 4: HAULING SYSTEMS

Handout

Hauling Systems

Vertical Rescue Operators may encounter situations where they may be required to 'pull' a person back up to the top of a pitch. This may be due to the inability to reach safe ground below the patient or insufficient resources to conduct a rope rescue (eg; pluck off etc).

The movement of a load **vertically up** through pulling via a rope connection is commonly termed 'Hauling'. Hauling can involve simple or complex rope systems involving minimal gear and personnel or specialised hauling frames and multiple interagency personnel. From a Vertical Rescue Operator with a clinical access perspective, hauling systems will reflect the former, with **minimal gear and personnel**.

When conducting hauling operations is it important to consider;

1. Height **safety** of all personnel
2. Hauling is **hard work** (lowering is a better option if suitable).
3. **Type** of system required (2:1, 3:1, 6:1 or 9:1; bolt on vs in-line; simple vs compound etc) – this will be dependant upon the environment, equipment and personnel
4. **Resource** implications of system (personnel, equipment etc)
5. **Communications** & Chain-of-command (always have a person at the edge to act as guide)
6. The amount of **friction** impacting on hauling (Theoretical vs Actual advantage, discussed later)
7. **Contingency** plans (backup system or ability to increase 'mechanical advantage')

CAUTION – BRAKE SYSTEMS

In all circumstances, hauling systems must have 'brakes' installed to prevent uncontrolled descent. In addition, breaks must be **reversible** so that the direction of movement can be changed *deliberately* (but not accidentally) at any stage in the operation.

Some important hauling definitions:

Actual MA – the advantage actually achieved when gravity and friction is taken into account.

Advantage – see MA.

Chock-a-block – when a system has been hauled to the point where there is no more space between moving and standing pulleys.

Deflection – the use of pulleys (or other equipment) to change the direction of a ropes travel.

Diversion – See deflection.

Force – the power exerted by a load or system. Calculated as the 'mass' of an object multiplied by its speed.

Friction – the resistance encountered by ropes on various surfaces (eg; edges, pulley sheaves etc)

Mechanical Advantage (MA) – benefit gained through the use of hauling systems to multiple hauling force.

Major reset – release of all reversible breaks (auto-blocks) to allow the reorganisation of all systems components (moving and standing pulleys) back to pre-haul state. Often required after several 'minor' resets.

Minor reset – release of selected reversible breaks to allow the reorganisation of some systems components (moving and standing pulleys) back to pre-haul state.

Piggy-back hauling system – when a second hauling system is bolted onto an existing system.

Redirection – See diversion. (Usually describes a change of direction greater than 45^{o}.)

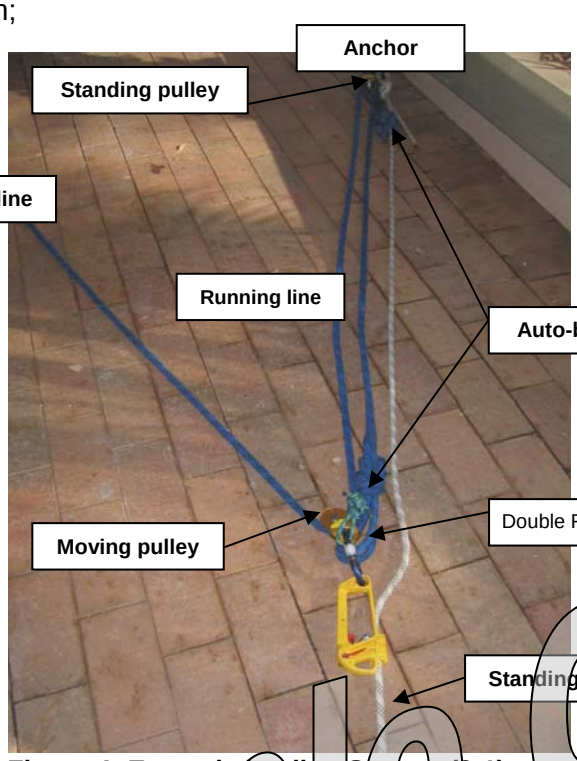
Reset – reorganisation of a hauling system back to its original, pre-haul state (the start).

Theoretical MA – the advantage *potentially* achieved, if gravity or friction is not considered.

Tension – is force.

Velocity Ratio (VR) – the relationship between the distance a load is moved and the amount of hauling rope retrieved (pulled). Calculated depending upon the MA used.

Hauling System Anatomy:
To successfully undertake hauling operations is it essential to have a sound working knowledge of the parts of a hauling system;



Note:
- *Pulleys can be exchanged for carabiners, if required.*
- *Prussik knots can be exchanged for mechanical rope grabs*

Figure 4: Example hauling System (3:1)

In general broad two (2) categories of hauling systems exist;

1. **Direct/Basic** – consists of a very simple direct lifting system with rescuers hauling the full weight of the load. These systems are often simple to set up, but require extensive man-power and co-ordination to pull the weight up efficiently.

2. **Advantage/Mechanical** – consists of ropes reeved through pulleys to create a system that multiples the force applied to lifting a load (advantage). Can be built to various designs or increasing advantage.

Hauling systems can be sub-categorised into either;

'Bolt-on': a separate/independent system attached to the victim's line via rope grab.
'Independent': conversion of the victim's or the main line into a hauling line.

Bolt-on	In-line
	

Mechanical Advantage (MA):
Involves the use of **pulleys to redirect ropes and multiply** the amount of force a hauling team can apply when pulling on a load. When ropes are *reeved* (threaded) through pulleys they become similar to simple machines. The way ropes are reeved and the number of pulleys used can either increase or decrease the 'advantage' available to haul (termed; *'Mechanical Advantage'*).

Mechanical advantage hauling systems consist of two (2) classes;

1. **Simple** – have only one moving 'pulley' (see Fig 4).

2. **Compound** – have more than one moving pulley. Compound systems can greatly multiply and magnify the advantage

In many cases, mechanical advantage systems can be altered to either **increase or decrease** the 'advantage' **by adding or removing components** (eg; pulleys etc, discussed later).

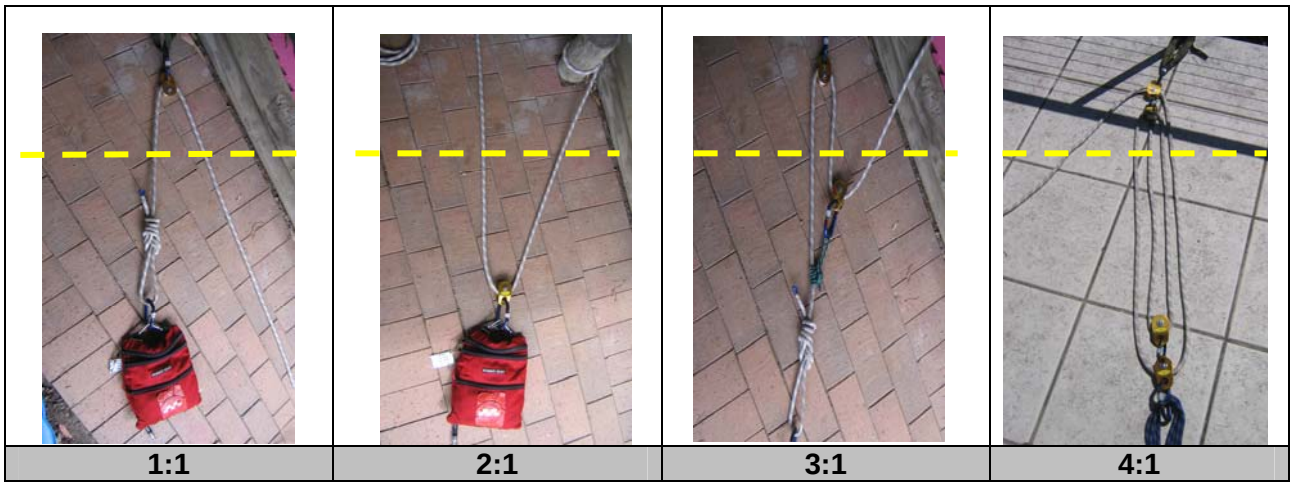
The following section shall describe the methods for calculating MA, adjusting and altering the system to meet operational needs.

Calculating Mechanical Advantage:
There are numerous methods used to calculate mechanical advantage. The value of knowing how to calculate mechanical advantage is seen in the ability to determine the best system suited to a given situation (ie; how heavy is the load? what resources do I have? and how much safe work area do I have? to name a few).

Two common systems are; the 'counting the lines' method and the 'adding the tensions' method, with the former often being considered the easier to remember.

Counting the lines;
To calculate the mechanical advantage of a hauling system you simply need to **count the number of lines supporting the load** (either directly or via pulley).

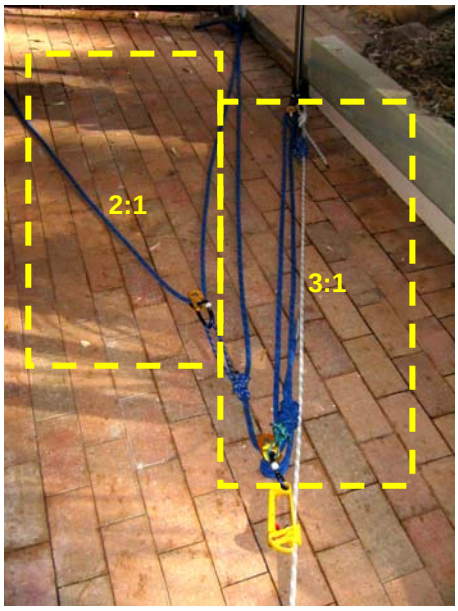
For example;



Tip: cover the top half of the system & only view the bottom half to give you the correct number of support lines.

This method slightly changes when you have **'Piggy-back'** hauling systems. In this case you need to count the lines in each system separately and then multiply the advantage by each other.

For example;



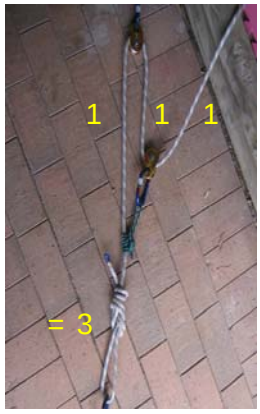
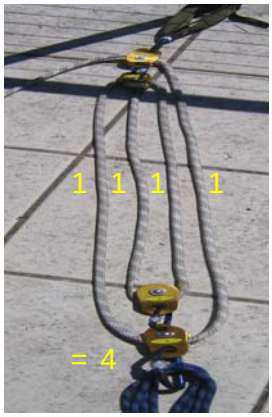
Multiply the original 3:1 systems with the 2:1 system (3 x 2 = 6) and this gives you a **6:1 MA** system.

Adding the tension;

To calculate the mechanical advantage of a hauling system using this method, you need to count the number of lines supporting a given section of the system (eg; supporting the load or hanging from the anchor pulley etc) and **apply a unit of tension to each rope** in that section.

Remember that in simple terms, if there is 100kg of load on one side of the pulley, then there must be 100kg of load on the other side of the pulley – this means that there must be a 200kg load on the end of the pulley. (This is the same whether the pulley is moving or stationary.)

For example;

			
1:1	**2:1**	**3:1**	**4:1**

Tip: Stop calculating when you reach a prussik knot.

Reeved to Advantage vs Disadvantage:
From a purely technical perspective, pulley systems can be threaded to 'advantage' or 'disadvantage'. Reeved to **'disadvantage'** simply means that the hauling line is going through a pulley that does not add to mechanical advantage, only adds friction. (This is usually the last pulley in the system & typically a 're-directional' pulley)

'Disadvantage' simply means extra friction. There can be times when reeving to 'disadvantage' can actually be an advantage.