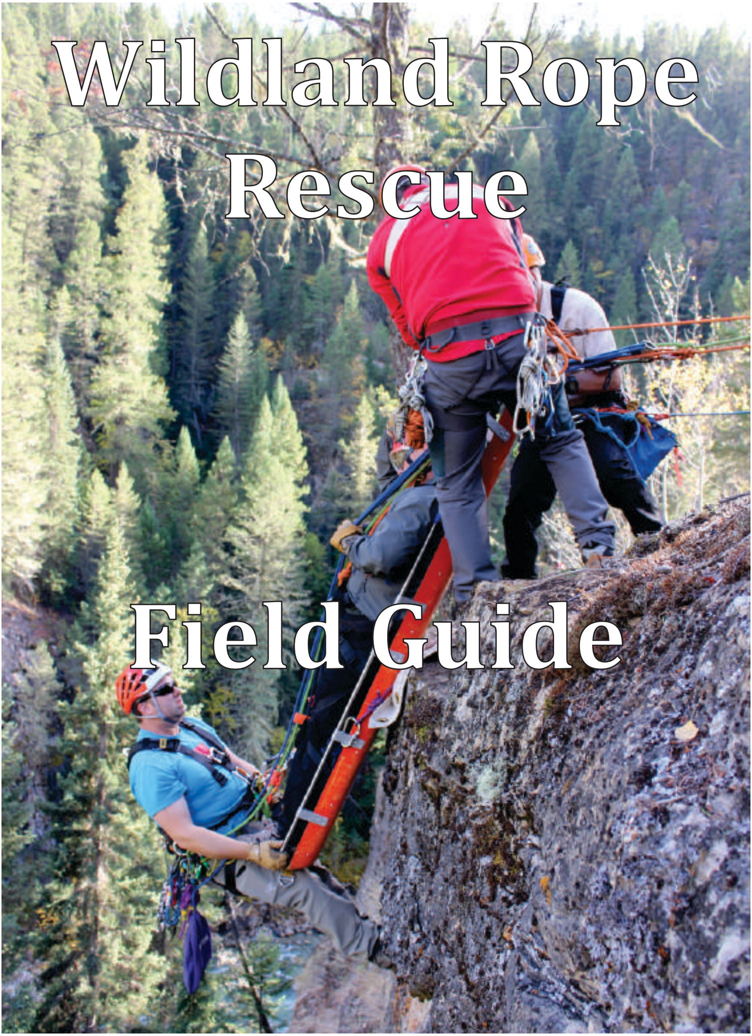
Wildland Rope Rescue

Field Guide



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History of this Guide

EMBC, funded by a NIF grant, collaborated with rope rescue experts to modernize the SAR protocols and procedures in British Columbia.

Over the course of months of work, the Rope Rescue program has developed to use innovative techniques and equipment, based on evidence-based testing procedures.

Thanks to all who contributed and to those who seek to lend care to those in need.

Usage of this Guide

The skills and protocols contained within this guide are to be used by trained experts only. This guide is to be used as an aid only and does not replace appropriate training and experience.

Emergency Management BC accepts no responsibility for any loss, damage, injury or death resulting from information contained in, or omitted from, this guide and strongly suggests that anyone using this guide maintain a high level of readiness and training.

Table of Contents

This BC SAR Rope Rescue Field Guide is based on the 2017 EMBC SAR Rope Rescue Manual, which presents the mandatory governing principles of BC SAR rope rescue and recommends techniques and equipment that conform to these principles. Within this set of principles, rescuers have the flexibility to choose the most efficient, safe and effective tools to solve rescue problems. Rote learning, which focuses simply on "what to do", requires little thought or understanding on the part of the practitioner. It may be a legitimate way to ease into a complex field of study, but ultimately, situations will arise where a precisely prescribed solution does not fit the problem. At that point, an understanding of "why to do" becomes crucial to solving the problem successfully and safely.

Core principles:

1. Top Down Approach - this means that the rope rescue system accesses the subject from above.
2. DCTTRS - Dual capability two tensioned rope system, (i.e. both ropes sharing the load and lowering or hauling simultaneously) either one of them can serve the role of supporting the entire rescue load independently while backed up by the other, or arresting a fall of the rescue load if one of the systems fails.
3. Force Limiting-The systems will apply *force limiting* principles with slippage occurring within a prescribed range of 6-12 kN.
4. Equipment-Use *equipment designed for the purpose, within the manufacturer's specifications,*
5. System Strength-The strength of the rope rescue system must be at least 1.7 times the maximum force that could be applied to the system in a worst case scenario.

Dual Capability Two Tensioned Rope Systems (DCTTRS)

The 2016 EMBC – NIF research and testing results, combined with other prior independent work, demonstrate higher levels of inherent safety with DCTTRS. As a result, EMBC has made a fundamental shift away from *Dedicated Mainline, Dedicated Belay* systems (DMDB) to using *Dual Capability, Two Tensioned Rope Systems* (DCTTRS).

There are many forms and variations of two rope systems, but the key distinction of a *Dual Capability Two Tensioned Rope System* is that DCTTR systems are typically operated with roughly equal tension on each rope system and equipment that enables each rope system to be *capable and competent* both as a main system and as a belay (back-up). For purposes of describing a rope rescue system, *capable* means that system components must be capable of managing a full load including a jolt (1-4 kN) *and* have a strength of at least 20 kN. *Competent* means that system components must function effectively as intended and must remain functional after a worst-case event.

- **Dual capability** - This means that while both ropes are normally used to perform the same function, (i.e. both ropes sharing the load and lowering or hauling simultaneously), either one of them can serve the role of supporting the entire rescue load independently while backed up by the other, or arresting a fall of the rescue load if one of the systems fails.
- **Competence** - In the event of a failure of one rope system, the second system must perform as intended, remaining fully functional and structurally uncompromised. The standard to which these systems are tested is the *BC Council on Technical Rescue Belay Competency Drop Test*.
- **Self-Braking ability** - Both rope systems will be constructed in a way that will automatically stop the rope from moving if the operator lets go or loses control of the rope.
- **Redundancy** - The two rope systems back each other up. If individual anchor points for one rope system are deemed not to be strong enough to use alone, then more anchor points must be added until the strength requirements of the system are met. Anchor points may be shared between both rope systems, but the failure of one anchor point, or one rope system, must not result in a complete failure of the entire system or a fall by anyone connected to that system.

Force Limiting

The systems will apply *force limiting* principles with slippage occurring within a prescribed **range** of 6-12 kN. This is done so that forces that are high enough to damage or cause failure to the system are engineered out.

The rescue system:

- Is designed around a working load of 1-4 kN (the force exerted on the system by 1-4 suspended people and equipment, depending on system configuration).
- Will not have any slippage below 6 kN.
- Will, through the choice of equipment, controlled slippage, and proper system management prevent any forces in excess of 12 kN being transferred to the system.

Equipment

Equipment used in BC SAR Rope Rescue must:

- Be designed for the purpose and used according to the manufacturer's specifications, unless a variation has been rigorously tested to demonstrate safety and suitability.
- Meet applicable standards of manufacture and testing.

System Strength

The strength of the rope rescue system must be at least 1.7 times the maximum force that could be applied to the system in a worst case scenario:

Anchors and rescue systems must be built to ensure a minimum breaking strength of 20 kN

Additional Principles and Guidelines

The BC system of wildland rope rescue works on the foundation of the principles stated above. The flexibility to use different tools to achieve desired goals exists within this foundation. For example, a descent control device or a load release hitch can be used to transfer the load when passing a knot through the system. Beyond the core principles, there are other principles and guidelines that help ensure safety and efficiency on the rescue site.

The key to safety lies in applying a continuous risk assessment process to each aspect of an activity. In simple terms, risk assessment is a process of considering:

- What could go wrong and what would be the consequence if it did?
- What is the probability that an identified factor could go wrong and what would be the severity of the outcome?
- Would it be best to -
  avoid the risk because the frequency/severity factors are unacceptable;
  accept the risk because the frequency/severity factors are of low consequence; or
  reduce the risk by acting to mitigate the probability or severity of something negative occurring?
- How might changing conditions affect risk levels? (terrain, conditions, people)

The Hierarchy of safety on the rescue site is the same as on any SAR task:

1.Self
2.Team
3.Bystanders
4.Subject

Balancing Safety, Efficiency and Simplicity

Achieving a perfect balance of safety, efficiency and simplicity in a rope rescue is highly desirable but is not necessarily an easy challenge to meet.

- Safety is critical. However, a system that is made very safe by many layers of redundancy may be complicated and inefficient, thus introducing new risk factors and delaying a successful outcome when time is of the essence.
- A system that is too simple, such as a haul system without a high directional to reduce friction and ease edge transition, may be relatively safe but very inefficient, resulting in delays and wasted energy.

- A system that is highly efficient, simple and safe in most circumstances might not be advisable for use under special circumstances that could compromise safety (low likelihood but high severity), e.g., **a temporarily un-tensioned** knot pass with a full rope length out on a cliff face having many ledges and irregularities on which a long stopping distance due to rope stretch under sudden loading could injure attendant and subject. In such a case, the safety risk might be mitigated by a minor change in technique that would be only slightly less efficient and simple, e.g, a two tensioned knot pass technique.

Rope rescuers should build and use systems that are recognizable, efficient, easy to check, and which do not exceed the skill level of those operating and overseeing them. In general, the simpler the system, the fewer things that can go wrong, the less gear that is required, and the easier it is to operate. These are all factors that contribute to safety. Every effort must be made to streamline the system while ensuring the safety of rescuers and subjects.

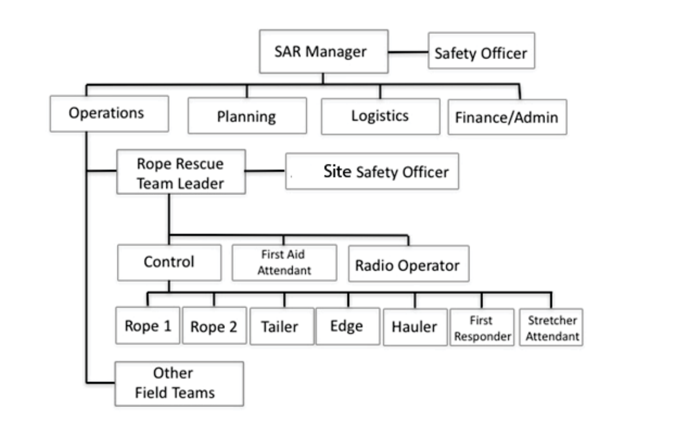
Rescue Mode vs. Recovery Mode

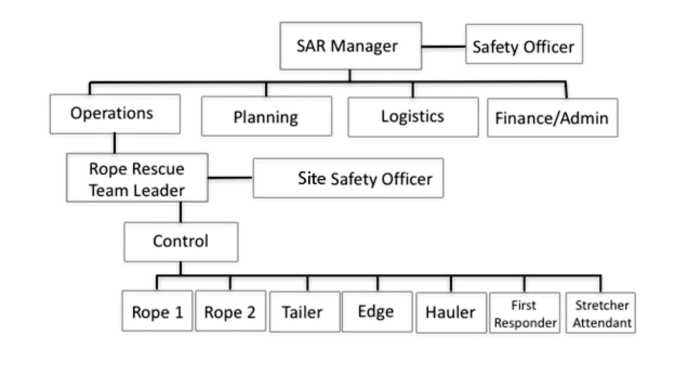
It should be noted that an operation that is in **rescue mode**, where a subject may be rescued alive, has a high degree of urgency. If at some point it is determined that the operation has entered a **recovery mode**, where the subject is known to be deceased or the operation is to recover equipment or evidence, then the level of urgency drops significantly along with the level of acceptable risk.

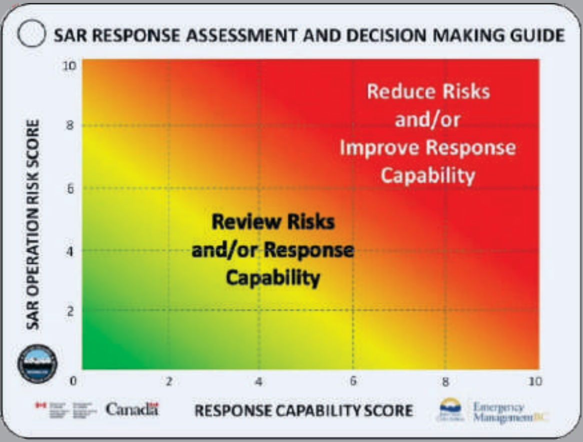
System Redundancy and Critical Point

The idea of system redundancy is a general rule applies to all rope rescues. This means that each system has a back-up system. Therefore, there should be no situation where failure of one component of a system results in failure of the entire system. Such a component is known as a critical point or critical link. The one exception, which needs no backup, is the unquestionably strong steel O-ring or large rescue rigging plate, when used as the stretcher master attachment point.

Incident Command Structure







SAR Operation Risk Score

SAR Operational Complexity How complex & complicated is the task? LOW 0 – MODERATE 1 – HIGH 2	
Activity Hazards How high are the hazards in the activities? LOW 0 – MODERATE 1 – HIGH 2	
Environmental Conditions How high are the environmental hazards? LOW 0 – MODERATE 1 – HIGH 2	
Vulnerability How exposed and vulnerable are the team members? LOW 0 – MODERATE 1 – HIGH 2	
External Influence What is the level of pressure due to survivability, media, family and/or other? LOW 0 – MODERATE 1 – HIGH 2	
Total Score:	

Response Capability Score

Personnel Training What level of training do personnel have? HIGH 0 – MODERATE 1 – LOW 2	
Personnel Experience What level of experience do personnel have? HIGH 0 – MODERATE 1 – LOW 2	
Personnel Mental & Physical Preparedness How mentally & physically prepared are personnel? HIGH 0 – MODERATE 1 – LOW 2	
Planning How much planning has there been? HIGH 0 – MODERATE 1 – LOW 2	
Resources What is the level of resources available? HIGH 0 – MODERATE 1 – LOW 2	
Total Score:	

See rating guide for more thorough interpretation of scores on specific SAR scenarios.

SAR Operation Risk Score			
Operational Complexity	0	Low	Simple operation, 4th class terrain, Trail approach, Top-down access, requires only rappelling in, Simple lower <50 meters in length, Straight forward evacuation, One subject, Minor subject injuries
	1	Moderate	More complex operation, 5th class terrain, Knot pass raise and/or lower <100 meters in length, 2 or more subjects, Significant non-life-threatening injuries
	2	High	Very complex operation, Multiple teams, Convergent volunteers, Difficult access and egress, Multi-pitch raise and/or lower >100 meters in length, Complex evacuation, Life-threatening injuries
Activity Hazards	0	Low	Low hazard rope rescue activities, Low angle site, Simple terrain, Hazards are low probability and low severity
	1	Moderate	Moderate hazard rope rescue activities, Site hazards manageable, Challenging terrain, Hazard probability high but severity manageable
	2	High	High hazard rope rescue, Site hazards not easily managed, Complex terrain, Hazards are high probability and high severity
Environmental Conditions	0	Low	Minimal hazards, Good weather, stable forecast, daylight, warm temperatures and/or good visibility, Low elevation
	1	Moderate	Moderate hazards, Uncertain forecast, low light, freezing temperature, moderate precipitation and/or broken visibility
	2	High	Extreme hazards, High elevation Impending forecast, drastic weather system, darkness, cold temperatures, heavy precipitation, high wind and/or obscured visibility
Vulnerability	0	Low	Minimal exposure to personnel, Good terrain to work in, No overhead hazards, <1 hour exposure, 1-2 rescuers exposed
	1	Moderate	Moderate exposure to personnel due to terrain/activity/environmental hazards and/or weather, 2-4 rescuers exposed Manageable overhead hazards, Safe zones exist to protect rescuers, Short-term exposure to hazards, 1-4 hours exposure
	2	High	High exposure due to extreme terrain/activity/environmental hazards and/or weather, >4 rescuers exposed High overhead hazards, Rock fall likely, No safe-zones to protect rescuers, Long-term exposure to hazards, >4 hours exposure
External Influence	0	Low	Little or no degree of urgency due to either confirmed survivability or confirmed deceased (recovery) Little or no pressure from family, media or agency
	1	Moderate	Some degree of urgency due to subject survivability factors, Local publicity, Family on scene, Agency and/or press asking questions
	2	High	High degree of urgency due to critical subject survivability factors, High profile subject, Family on scene Agency, national media influence and/or political pressure to resolve

Response capability score			
Personnel Training	0	High	Documented training proficiency appropriate for the activities required, Routinely train on incident site Rope rescue team member training with team leader supervision
	1	Moderate	Some training proficiency related to the activities required, Some training on incident site Rope rescue team member training with team leader supervision
	2	Low	Little training proficiency related to the activities or location required, No training on incident site No training in the terrain features, Low rope rescue certification, New rescue team
Personnel Experience	0	High	Extensive experience appropriate for the activities required, Routinely respond to incident site, >20 similar responses Many years of recreational experience, Professional experience
	1	Moderate	Some experience related to the activities required, Some previous responses to incident site 5-20 similar responses, Significant recreational experience
	2	Low	Little or no experience related to the activities required, Completely unfamiliar with the location <5 similar responses, Little or no recreational experience
Personnel Mental & Physical Preparedness	0	High	Personnel are in good spirits, well-rested and exhibit characteristics of a cohesive team, Excellent personal fitness
	1	Moderate	Personnel are generally positive although some are tiring, Adequate physical condition
	2	Low	Personnel are negative and question decisions, Responders have been involved for multi-operational periods Resources have been on task through several assignments and are showing signs of exhaustion, Unfit/does not exercise on a regular basis
Planning	0	High	Plans (and/or Pre-plans) are in place, including contingencies, all documented
	1	Moderate	Overall plan is in place, with some consultation, Basic notes taken about the site
	2	Low	Basic discussions on overall strategies and tactics, Nothing in writing for this site
Resources	0	High	Appropriate resources are in place to cover all anticipated eventualities, contingencies and technical requirements
	1	Moderate	Basic resources are in place to cover response, Back-up is available, but not on site
	2	Low	Resources are barely adequate, No back-up or contingency available

Initial Planning

SAR Manager is in charge of the initial planning stages of a rescue operation
RRTL leads the Initial Response Team -in charge of all on-site operations.
SAR Manager conducts planning with the help of the RRTL.
Considerations:

- Evaluation of the initial information
- Access routes
- Transportation
- Resources needed
- Terrain
- Weather
- Personnel
- Staging
- Communications
- Contingencies (what could go wrong)
- Long term support (shelter, food, extra equipment, consumables)

Equipment Planning

The RRTL determines equipment needs and transport to the rescue site.
- carry extra gear for contingencies.

Initial Response Team (IRT)

- IRT highly skilled, experienced and carry minimal gear
- Moves quickly-to stabilize the subject to prevent further deterioration of their condition.
- Accurately reports the situation to the SAR Manager

First Aid Response

Early access -provides first aid for the subject and increases the success rate of a rescue.
May require patient access prior to the stretcher.
System set up & check
Lowering or rappelling First Aid responder to the subject may be needed
Must be qualified as a Technician 2.

Elements:
- Stabilize the subject's condition
- Address first aid needs
- Address subject comfort needs
- Communicate the situation to the RRTL

Subject psychology can pay a crucial role in the success or failure of a rescue. As the first person to reach the patient the first aid attendant can do much to set the tone, particularly if the patient is conscious. The patient should be empowered to help in the rescue as a part of the team rather than being isolated as a helpless victim.

- Remain calm and upbeat
- Establish a personal relationship; use first names, never use "victim";
- Involve patient in every move by the team with briefings, checks and invitations to assist in even the slightest way;
- Encourage feedback and support any safe efforts by the patient to contribute to his/her own rescue.

On Site Briefing

Before leaving the base and after working with the SAR Manager on initial planning, the RRTL explains the situation and the plan to the entire team. Once the full team assembles on-site, a second briefing explains the plan, identifying any hazards and including safety precautions. After receiving feedback and confirmation that the plan is understood by all, the RRTL delegates individual jobs to qualified team members.

System Set-Up

Once roles have been delegated the team gets to work setting up the system while the RRTL moves around observing and coaching while keeping the SAR Manager updated. The RRTL or Safety Officer calls for a "fresh eyes, final check of the rescue system, including communications and hands off direction to Control (if available)..

"REDO" Sequence

R – **Role Check** - Control takes charge and conducts a role check to establish focus and rapport.

E – **Edge Transition Briefing** - Control conducts an edge transition briefing explaining and demonstrating in detail the actions each team member will perform to complete the edge transition. (Will also apply to a raising edge transition.)

D – **Dry Run(s)** - The team conducts one or more dry runs of the actions required in the actual edge transition until Control is satisfied that all aspects, including the lowering (or raising) speed, are clearly understood and effective.

O – **Operational** - At this point, the team is ready to go operational. The RRTL informs the SAR Manager that the rescue is underway and may request radio silence. Without undue delay, the load is moved to the edge, rope tensions are adjusted, and the edge transition is executed as practiced in the dry runs.

Stop

At any point in time, anyone can call, “Stop”, and this means that all movement of the load must cease. Team members echo the command to ensure that this command has been understood. If the reason for the stop is not clear to the Control person, he or she may ask, “Stop? Why stop?”, and whoever called for the stop should make the reason clear. Once the load safely makes it to secure ground, the Attendant announces, “Secure!” to make it known to the Control that the support from the rope system is no longer required.

Visual/Tactile check Items:
- Anchors
- Systems
- First Responder
- Stretcher
- Edge lines
- Redirections
- Edge guards

De-rigging

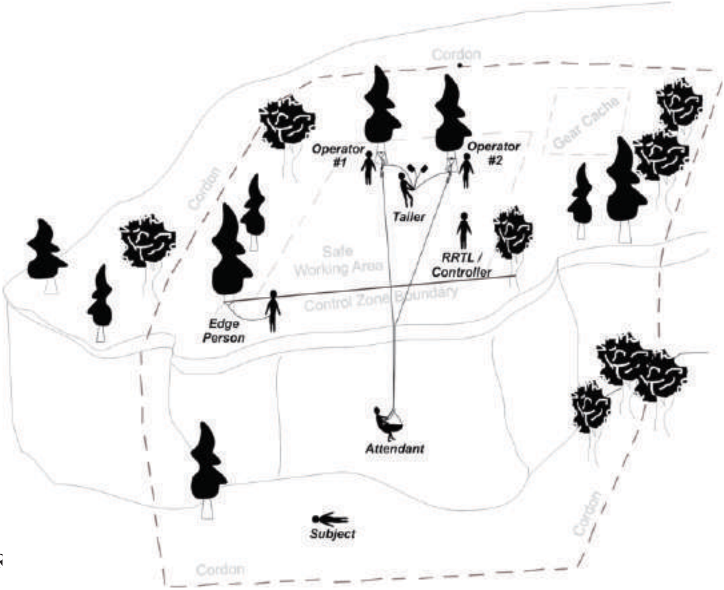
Be aware that hazards may still exist. Before being disconnected from their anchors, all lines must be pulled in to their anchor points to ensure that they are not still in use.

Debriefing/Review

- If a practice, review training objectives
- If a rescue, review the initial information available
- State RRTL's intent
- Review relevant policies, best practices, etc.
- Summarize what happened
- Discuss key events
- Discuss optional issues
- Discuss safety (throughout)
- Summary

Introduction

The basic zones of a high angle rescue site.



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Safe Zone
The Safe Zone is any area where rescuers can move un-roped and without helmets. It will always exclude the Control Zone but may include parts of the Working Zone. Depending on the terrain, it may not be possible to establish a Safe Zone.

Working Zone
The working zone is the area where the rope systems are set up and operated. The area should be big enough to operate from safely. Loose debris, trip hazards and anything that may entangle the ropes should be removed, including branches that may be brought down by high winds or helicopter rotor wash.

Control Zone

Extends **at least** two metres back from cliff edge and requires anyone working within that area to be connected to a safety rope. The edge of the control zone should be clearly defined to rescuers. This can be achieved by a team briefing, or by establishing a physical delineation such as flagging tape.

Gear Cache

The site of the gear cache should be picked carefully and early so it is not in the way when the system is set up but remains readily accessible. Personal gear is stored separately from the team gear.

Cordon

May need to be set up to keep bystanders outside of the rescue area for their safety and that of rescuers, may also need to be a cordon below the rescue area to protect bystanders from falling debris.

Hazard Assessment

Prior to rescue, RRTL will conduct a hazard assessment to identify the known hazards.

- **Objective or External Hazards:** Hazards over which we have no control, such as weather, terrain, or rock fall from above

- **Subjective or Internal Hazards**: Hazards such as inadequate equipment or training, fatigue, etc.

Hazard Management Format

The following steps should be followed with regards to hazard management:

- Identify the hazards of the site
- Assess the hazards for probability of occurrence
- Assess the hazards for potential risk to rescuers
- Mitigate the risk through hazard elimination, controls, or protective measures
- Monitor the hazard through the rescue

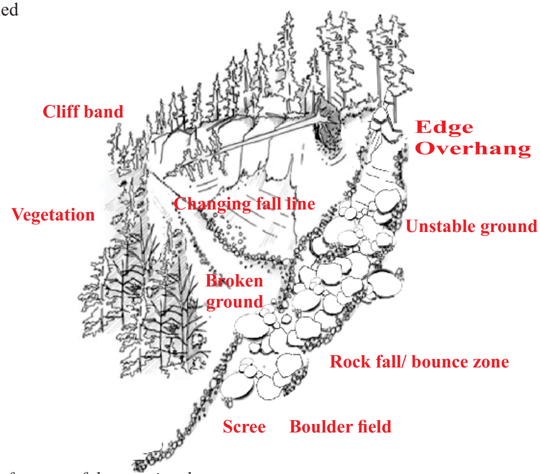
Common Site Hazards

Fall Hazard
The likelihood of a rescuer falling over the cliff or slope. The RRTL will define control zones and cordons.

Rock Fall
May involve picking a site to perform the rescue that is not as convenient to the subject in order to minimize the hazard

Rope Hazards
The hazard presented by the rope moving:
- Knocking loose materials
- Exposure to sharp edges
- Cracks or obstructions which may snag a rope
- Lateral movement of rope system if one rope were to fail for any reason

Terrain Assessment
Terrain assessment is important for the RRTL in order to make appropriate decisions about the techniques to be used and the systems to be built. It is also necessary to address any hazards that may be identified



Some of the features of the terrain where rope rescues occur.

Rescue site zones

Human Factors - Rescuer

Rescuers' ability to perform their jobs should be assessed before they are committed to the rope system. Factors that may affect a rescuer's performance:

- Fear
- Fatigue
- Excitement
- Inexperience
- Lack of training
- Distractions
- Complacency
- Poor communications

Any of these factors may present a hazard to a rescuer or others, especially if individuals are placed in a demanding role.

Human Factors - Subject

Subject hazards include:

- Pulling rescuers over cliff edges
- Belligerent, combative behaviour
- Pulling on loose rope ends, stopping rappelers
- Causing rock fall
- Moving and falling
- Poor communications, i.e. another language, intoxication

Whenever possible, subjects should be approached from a line slightly to the side. Establish voice contact with subjects before getting close enough for them to reach you, brief them on what is going to happen, and assess their mood and situation.

Knots used in rope rescue should be tied neatly, dressed & set.
The knot tails should be at least the length of the knot.

Simple Figure-eight

Figure-eight follow through
Used to tie a rope around an object.

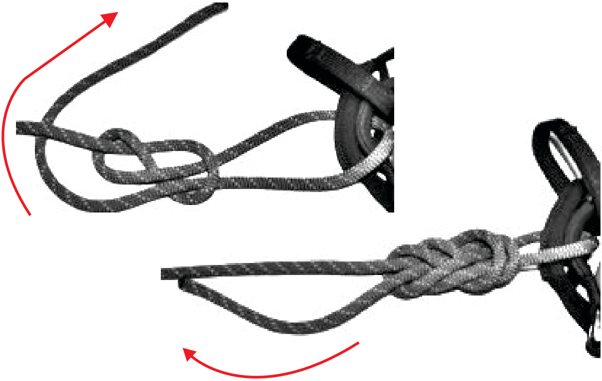
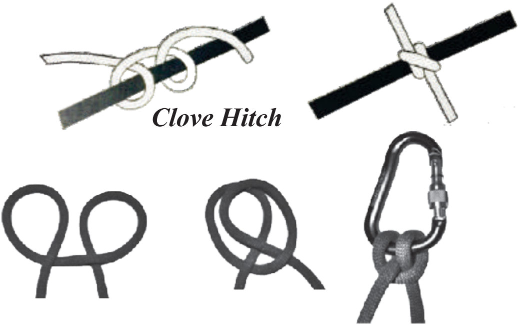


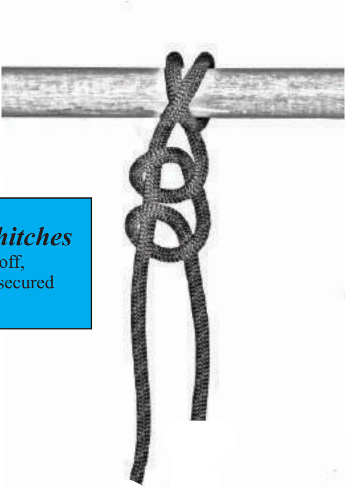
Figure-eight on a bight

Figure-eight follow through bend

This bend is used to tie two rope ends together

Clove Hitch



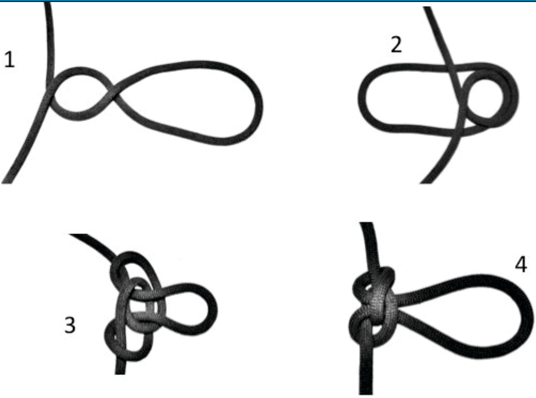


Round Turn with Two Half-hitches

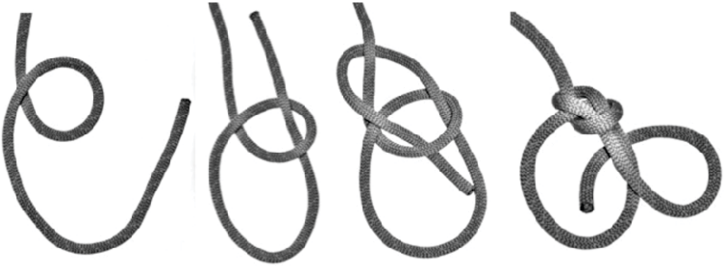
A form of tensionless or high-strength tie-off, rope is wrapped around anchor twice and secured with two half hitches.

Butterfly Knot

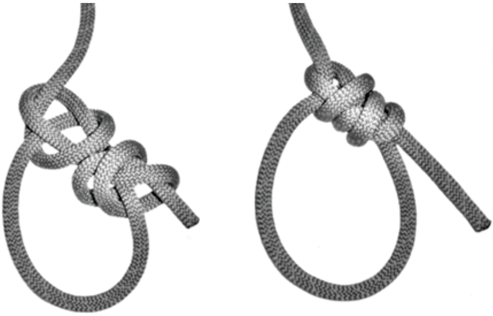
Used as a mid-line knot for 3-way loading.



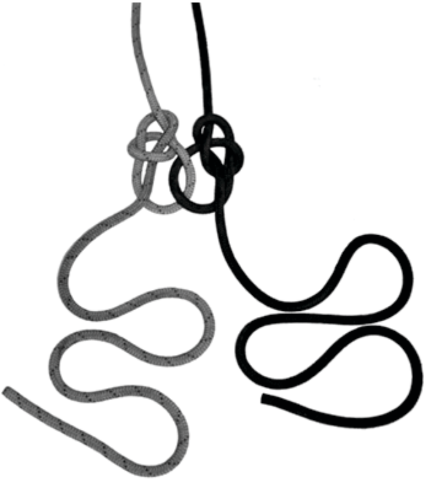
Bowline
Must be backed up with a Double Overhand knot if tails are not otherwise secured.



Finishing (Backup) Knots
Ties that are dressed and set properly with sufficient tail do not need a backup knot.



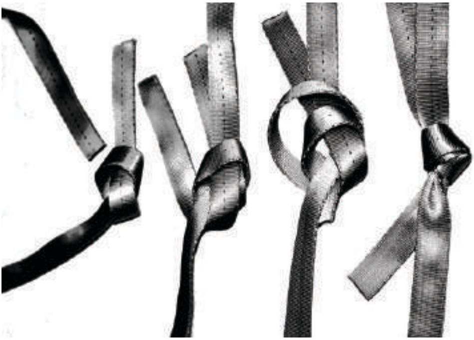
Interlocking long Tail Bowline



long Tail Bowline to an O-Ring MAP

Overhand follow-through bend (ring bend or "water knot")

Tails at least 10cm long retains 50% of webbing strength

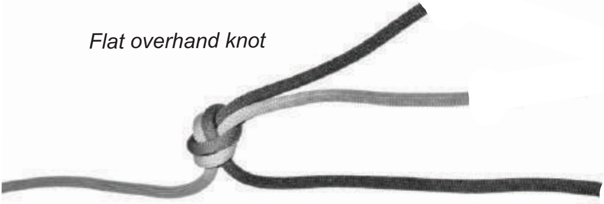


The Water Knot (Bend)

Flat Overhand bend

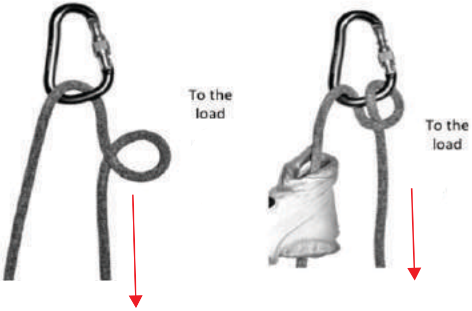
(hand-width tail) use in Wrap 3 Pull 2 or Wrap 2 Pull 2 anchors or joining two rappel ropes together. Do not be use where the full rescue load will be applied to the tie.

Flat overhand knot

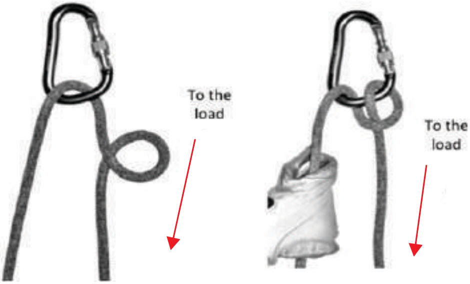


Double Fisherman's bend (Double Overhand bend):

Italian Hitch



Super Italian Hitch:
Two person lower.

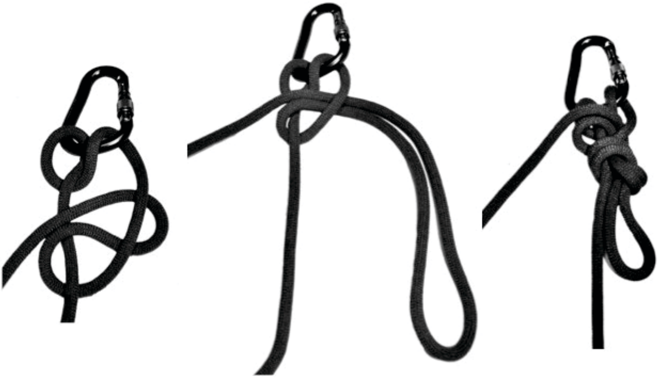


Start with an Italian Hitch

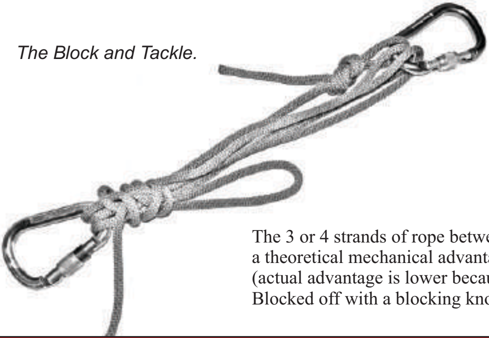
Finish SIH with tail on gate side of carabiner

Blocking Knot

To tie off an Italian hitch. Start with either an overhand slipknot or a half hitch. Finished with a single overhand on a bight as a backup to secure the blocking knot.



The Block and Tackle

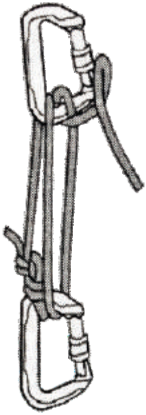


The Block and Tackle.

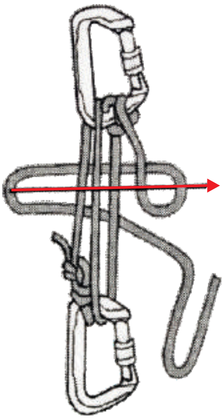
The 3 or 4 strands of rope between carabiners create a theoretical mechanical advantage of from 2:1 to 4:1 (actual advantage is lower because of friction). Blocked off with a blocking knot.

Radium Release Hitch

#1.



#2.



1) Tie a figure eight-on-a-bight in both ends of the cord and clip one end into the load-side carabiner. Clip the standing part of the cord up through the anchor carabiner, wrap back and forth to form a 3:1.

2) Tie an italian hitch with running end on gate side.

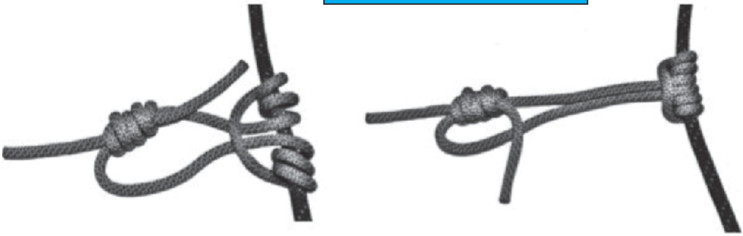
#3. **Radium Release Hitch** #4.

(3) Secure the Radium Release Hitch with a blocking knot, or half hitch on a bight around the entire stem below the Italian hitch, and then back it up with a single overhand-on-a-bight knot, again around the entire stem.

(4) Ensure tail is not trapped in this tie-off. Ensure the blocking knot is tight up against the Italian hitch.

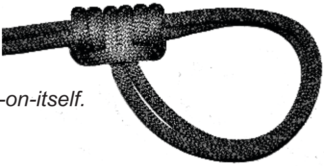
Note: The tail of the RRH should not be daisy chained, as this may impede deployment.

Prusik hitch
Tied with 8mm for rescue



The 3-wrap Prusik.

Prusik-On-Itself
Used in personal ascending and positioning systems



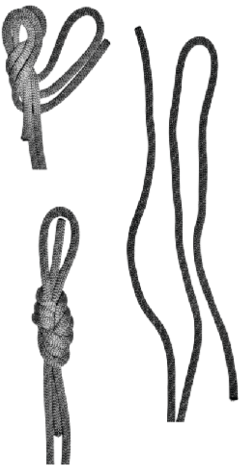
A Prusik-on-itself.

Steps to tie a Prusik-on-itself.

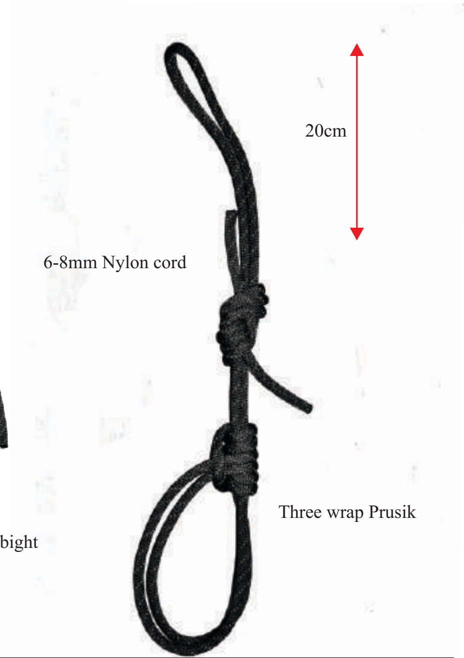
Purcell Prusik
Utilizes Prusik-on-itself to create an adjustable tether

Equipment needs:
10M 6-8mm cord
enough to make
three Purcells

Purcell Prusik



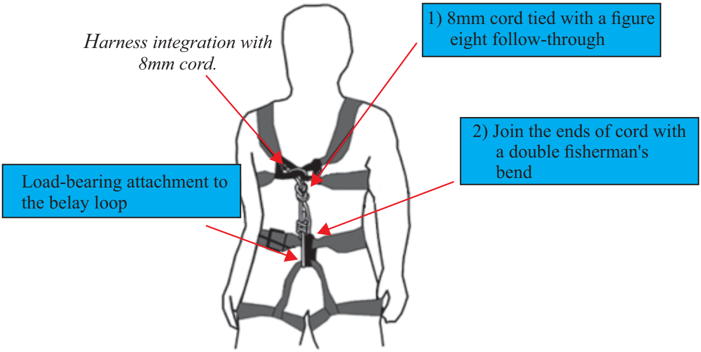
Figurue 8 bend with a double bight



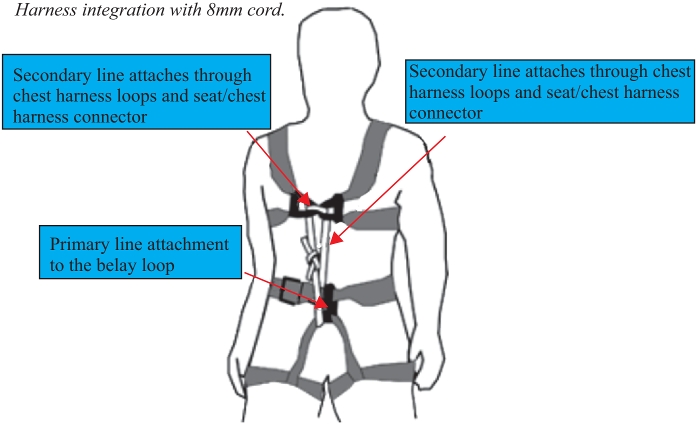
Purcell Prusik
The Purcell Prusik uses the Prusik-on-itself to create a versatile adjustable short tether or an entire Prusiking system with a medium length sling attached to the rope at waist height and a short sling from the harness upper attachment point to a hand-width above the helmet. (Detailed tying diagrams and lengths available in sources such as the Grog Knots app.)

Harness Integration

The following illustrates two methods of integrating separate seat and chest harnesses.



Harness integration with 8mm cord.



Harness integration with 25mm webbing.

Commercial Harnnesses:
With triangular maillon & industrial style connections

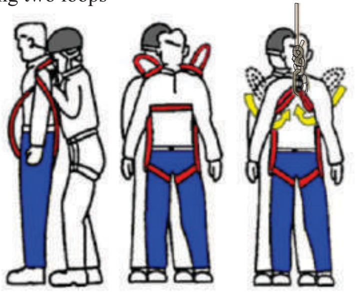
Harness with two tie-in points

Note: a neck-loop chest ascender strap is not acceptable as a harness integration method

Improvised quick-tie Harness using 25 mm Webbing

Step 1. drape webbing over shoulders of Patient
Step 2. bring knotted end of webbing up between legs

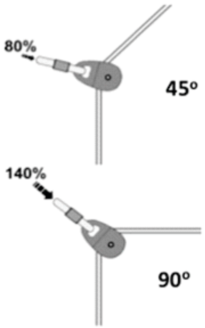
Step 3. split webbing and draw across chest armpit level
Step 4. draw webbing under arms to back at armpit level
Step 5. pull web slack upward under webbing until tight to crotch forming two loops

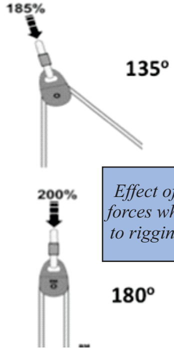


Step 6. bring these two loops around the webbing that was originally placed on shoulders and bring back both loops under armpits to front of chest grab all loops and clip to carabiner. If loop crossing chest is not included, it will provide a more secure initial attachment, particularly if unloaded. However, it may cinch under continuous load.

Force Multipliers:

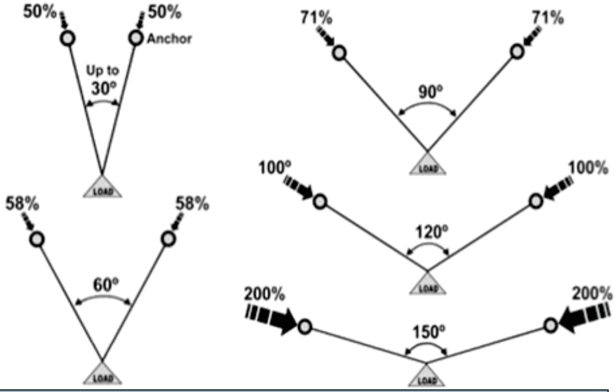
Redirects and High Directional Pulleys/Anchors:





Effect of angle on anchor system forces when the mass is suspended to rigging between anchor points.

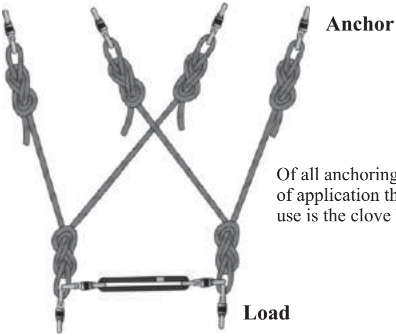
To determine required strength calculate the maximum force to which the component may be subjected. Determine if redirect pulley will be subjected to a 'jolt' or to a 'free-fall' of the load. A jolt increases the system force up to 2.5 times the static force, i.e. rescue load of 2 kN x 2.5=5 kN. a redirect pulley at 90° will add 1.4 times that value, 7 kN, still a relatively low force.



Two-point anchors with internal angles exceeding 90° need to be capable of supporting the entire load (20 kN per anchor); *if warranted,* anchor systems with interior angles greater than 90 degrees can be utilized.

Redundancy

Sharing anchor points between one system and another can often simply and efficiently increase the overall safety of anchor systems used in a rope rescue. This approach prevents either system from failing completely as an independent element. Redundancy also applies to a rescuer tying into an anchor for security. There must be cross linking with other anchors to provide redundancy and ensure that the rescuer would not be dragged over the edge if the anchor to which he is attached should fail.



Of all anchoring knots that can be used for this type of application the most effective and efficient knot to use is the clove hitch as it is the easiest to tie and adjust.

Note if using a clove hitch and it is not under constant load a back up knot may be required.

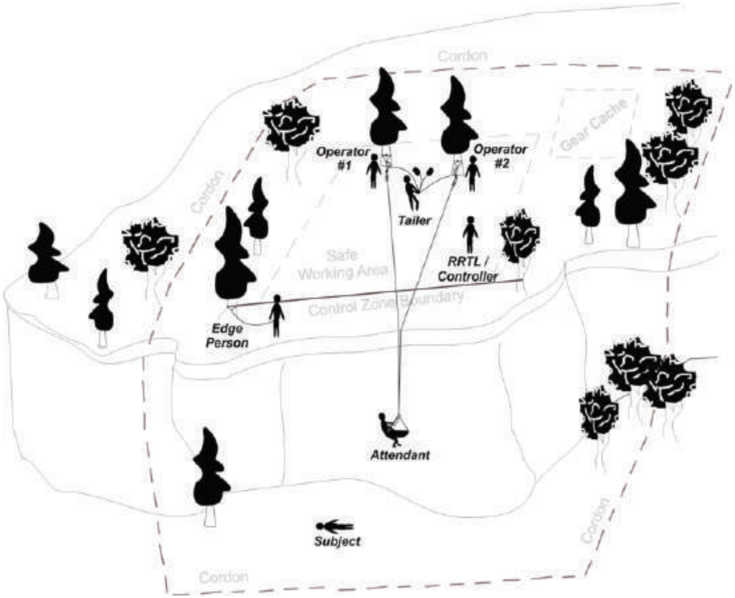
Direction and Distribution of Loading

Anchor systems need to be oriented with the anticipated direction of loading.
In a system with multiple anchor points, load stronger points more heavily.
Locate the progress capture device on the anchor side of any redirects.

Carabiner Orientation

There are several considerations around D-shaped screwgate carabiner gate orientation:

- When hanging vertically against a wall or in contact with the ground, gates should face away from the wall or ground with collars screwing downward (i.e., gates opening downward). This configuration will minimize chances that the screwgates can be opened by moving against a surface.
- When suspended above the ground horizontally, carabiners will tend to hang with gates down. This configuration should be used in suspended setups, as loading will be maintained along the spine. If loaded suddenly in a gates-up configuration, a carabiner may load diagonally toward the gate side, resulting in damage to the carabiner.



Layout & Location

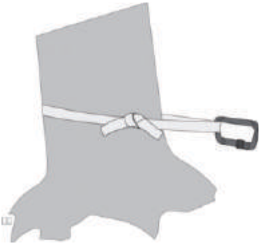
For DC TTRS try to place the control focal points with sufficient room to work side by side and far enough back from the edge to allow effective operation of a haul system and greater force limiting (by rope elongation) in the event of any peak loading during an edge transition.

Comparison of Webbing Anchor Attachments		
	Pros	*Cons*
Simple Slung	- Easy to rig. - Minimal material required.	- Weakest (~17-18 kN). - Difficult to untie after loading.
Wrap-2-Pull-1	- Relatively easy to rig - Cinches to anchor - Knot easier to untie than simple slung.	- Marginal strength for rescue loads
Wrap-2-Pull-2	- Strong (~36 kN) - Relatively easy to rig	Requires twice length for a simple slung (but no more than for others listed below)
Wrap-3-Pull-2	- Cinches to anchor - Strong ~36 kN). - Easy to untie knot after loading.	- Slow to rig wraps - Flat overhand bend is faster to tie than an overhand bend.
Basket Hitch	- Quicker than field-tied slings. - Strong (~36 kN).	- Does not accommodate change of vector well. - Risk of tri-loading on carabiner.
Tied-off Basket Hitch	- Solves basket hitch tri-loading problem - Strong (~36 kN)	- Still does not accommodate change of direction well. - Knot takes time to tie and may be difficult to untie after loading.
Simple Wrapped Sling	- Quick to rig. - Strong (~36 kN). - No risk of tri-loading. - Accommodates change of vector.	- Requires 2nd carabiner.
Cinching Wrapped Sling	- Relatively quick to rig - Strong (~36 kN) - Multidirectional	- Requires 2nd carabiner - Sling length critical for efficient cinching.

Comparison of webbing anchor attachments

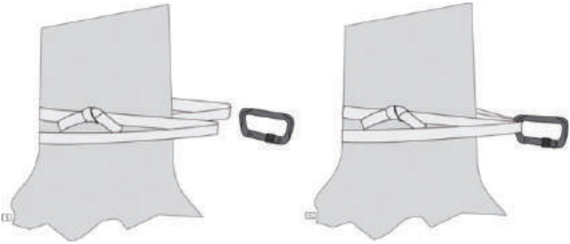
Comparison of Rope Anchor Attachments		
	Pros	*Cons*
Simple Slung	- Easy to rig. - Adequate strength (20 kN or better, assuming 30 kN rope rating and 1/3 strength reduction for ties). - Offers a multidirectional attachment loop for the anchor point (remainder of the rope can be isolated).	- Uses more rope than an end knot.
Bowline	- Compared with the Figure-8-follow-through, - is easier to adjust for length; - is easier to untie after loading.	Is more complex than Figure 8 to tie correctly and safely
Figue-8-follow-through	- Figure-8-follow-through is easier to tie safely and to inspect than a Bowline.	- Compared with the Bowline, - is more difficult to adjust for length; - is more difficult to untie after loading.

Most suitable only for “low load” applications.



Simple sling anchor

- •strength of around 18 kN
- •Edge line rigging
- •First responder anchors
- •A single point for a multi-point anchor
- •Difficult to untie once loaded.



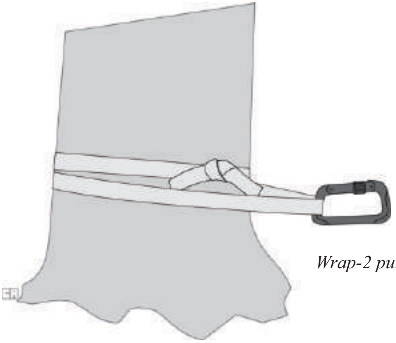
Carabiner clipped into both bights

Basket Hitch

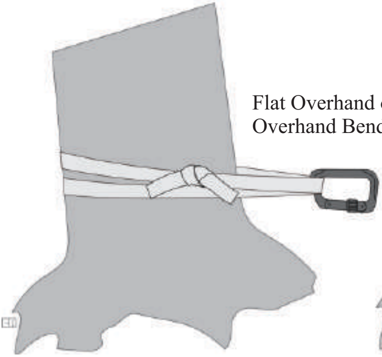
Essential internal angle is less than 45°. Greater angles will load carabiner in three directions, a poor choice for situations in which the direction of pull changes, such as with edge lines. Has a breaking strength of approximately 36 kN when properly rigged.

Girth Hitch

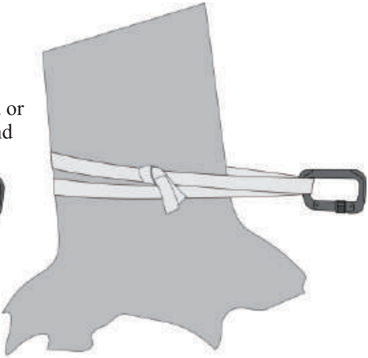
A tremendous amount of the strength of the material used can be lost in a girth hitch and it can create an anchor attachment that will fail below 20 kN



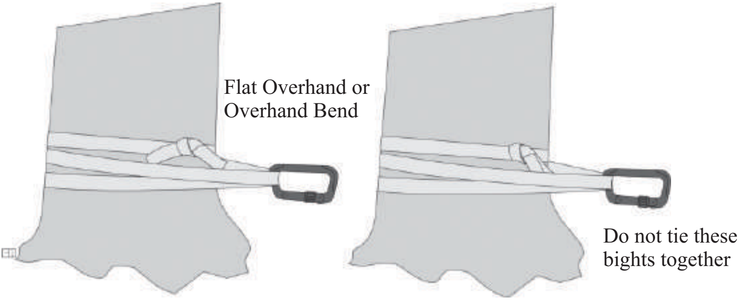
Wrap-2 pull-1 anchor sling



Wrap-2-Pull-2

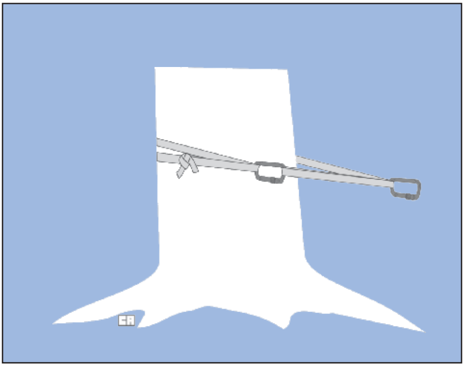


Wrap-2-Pull-2 flat overhand



Wrap-3-Pull-2

- Can accommodate change of direction as allows carabiners to slide around, will cinch onto a tree when high point is needed
- Normally maintain an angle between legs lower than 90 but if you need to cinch a high point position on a tree, an angle greater than 90 up to 120 is preferred without compromising the minimum 20 kN strength principle



Simple Wrapped Sling

With pre-tied or sewn slings, it is the quickest anchor attachment to set up, producing a strong, multi-directional anchor. Adding an extra wrap creates a cinching anchor for high points.

Anchor attachments with rope

Figure-8 follow through

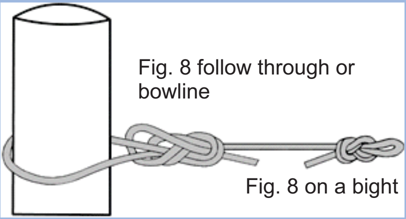
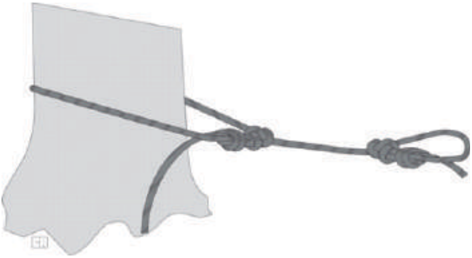


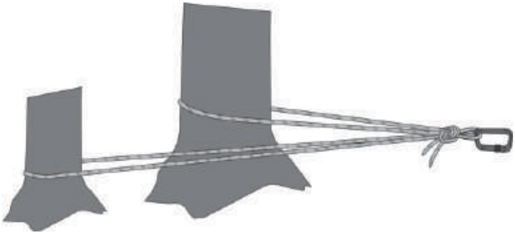
Fig.-8 follow through or bowline finish with a fig. 8 on a bight (11mm rope). Internal angle of legs up to 120°will still maintain full strength of knotted rope (20kN).

Bowline is easier to adjust and untie after loading than the fig.-8 follow through. Note, must always be backed up with a double overhand knot.



Bowline rope to anchor attachment

Tied-Off Multi-Point

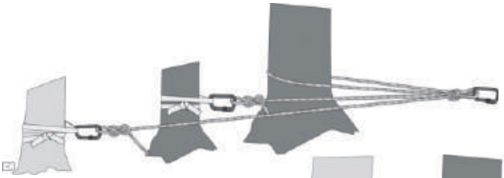


Tied-off equalization for a “doubled all around” two-point anchor system.

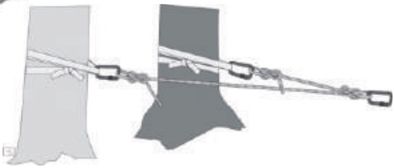
Joined Anchor System

Compensate for differences in stretch from different lengths and angles to ensure the anchors are equally loaded.

Three-point anchor system showing “one doubled leg” configuration to favour the strongest anchor. Note use of overhand knot on the four strands

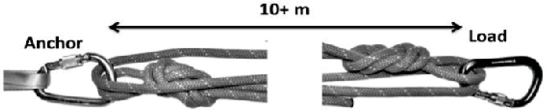


Joined anchor systems.



Two point anchor system

Anchor Extensions



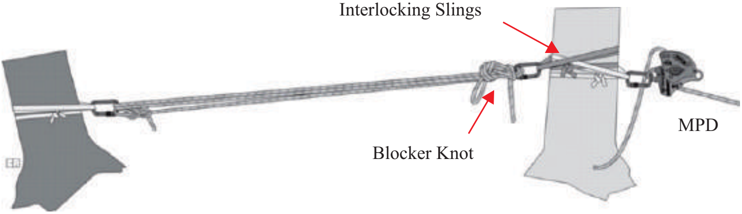
Extension Setup for over 10 m

- Tie a fig.-8 bight in one end of the rope
- Clip the bight into the anchor end carabiner
- Place a load end carabiner on the rope a meter from the anchor
- Loop the rope back through the anchor end carabiner
- Extend the load end carabiner out to the desired location
- Tie a fig.-8 bight and clip it into the load end carabiner

Distances less than 10 m, can use single strand of 11mm rope, loop of webbing, or equivalent (stretch <40 cm). For distances 10 m or more, anchors are extended with three strands to the attachment point, reducing stretch to ~2%.

Pre-tensioned Back-Ties

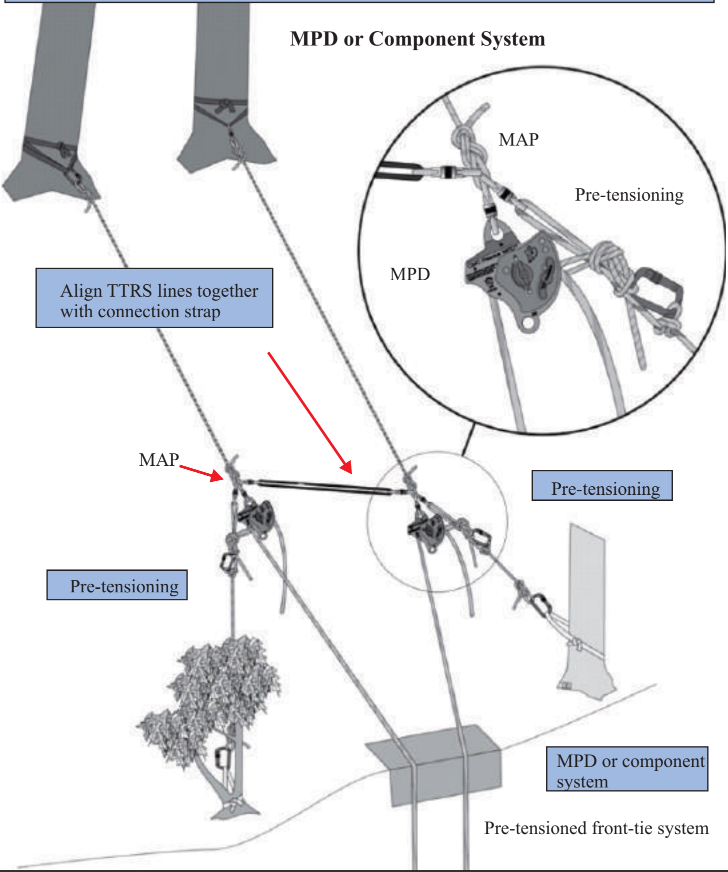
The pre-tensioned back-tie webbing should be interlocked with system attachment point to provide redundancy if primary anchor point failed.



A pre-tensioned back-tie creating a strong two-point anchor.

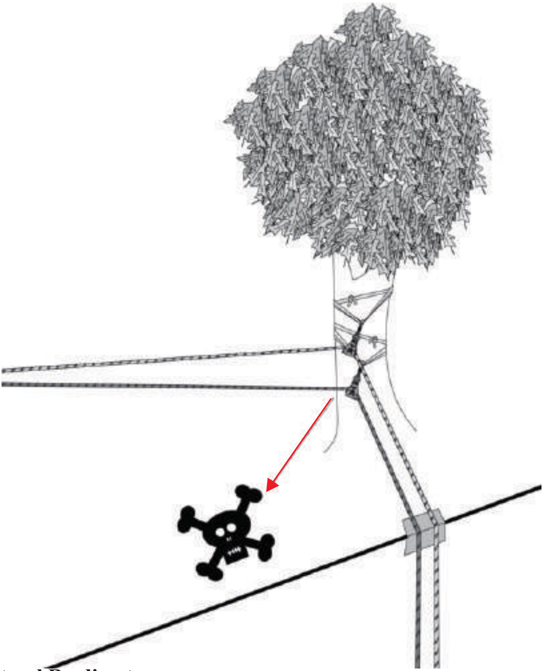
- Use a 3:1 mechanical advantage with 11mm rescue rope.
- If 8mm cord is used, 5:1.
- Very tight (ideally, 4kN of tension) secured with a Prusik or a blocker knot
- Add pre-tensioned back-ties as needed to create required system strength (20kN).

Pre-tensioned Front Ties
If stretch 20+cm can result in stumble by the attendant apply a pre-tensioned front tie



In general, the method of building a pre-tensioned front-tie is:

1. Build a primary anchor system with 20kN capacity. Consider that the direction of pull may change as the anchor system is forward tensioned.
2. Extend the anchor system forward and create a focal point at the desired working area.
3. From the focal point, towards the direction of loading, tension the anchor system using an appropriate method. This may be a jigger, a block and tackle, or a vector pull, amongst other methods. The objective is to tension to approximately the same as the static load that you will put on the system.
4. The focal point may also be shifted from side to side, either by tensioning to lateral anchor points, or by pulling the two focal points together.



Lateral Re-directs

Used to redirect the load rope onto the appropriate angle perpendicular to the cliff edge. Also used to operate a haul system parallel to the edge, where there is insufficient room.

Caution:
1.The force will be increased on the redirect anchor and pulley proportionally based on the change in angle.
2.Do not operate in the bight of rope created by the pulley. Sweep fall hazard to exposed cliff edge.

Anchoring

Trees

Trees are commonly used as anchor points by rescuers but their actual strength may be far less certain than that of manufactured components of the rescue system. Inspect prospective anchor trees carefully up and down, as even a large tree may not have the strength required if it is diseased or shallowly rooted. Risk assessment is particularly important with tree anchors to ensure potential failure and the consequences of any failure are clearly understood.

Trees used for anchors should:

- Be alive, healthy and free of overhead hazards (always look up carefully);
- Have no signs of rot or fungus, particularly around the base;
- Be well anchored (cannot be rocked from their roots);
- Have a diameter >25 cm for a single point anchor;
- Not have their roots undercut or damaged or the soil disturbed;
- Not have nails, wire, etc. imbedded in their surface where attachments will be made;
- Have anchor attachment slings placed at the tree's strongest point, usually close to the ground if possible to reduce the effect of leverage.

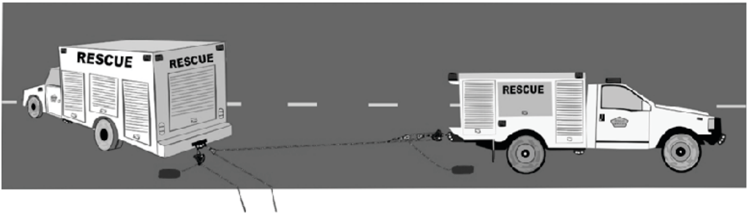
Boulders/Rock Outcrops

Ensure they are not fractured and are stable.
Note: even a large boulder can be moved with little force if on a slope or sitting on a bed of small pebbles.

Boulders or rock outcrops used for anchor points should:

- Be large and well grounded,
- Have undercut surfaces to prevent the anchor slings from slipping up and off,
- Have sharp edges padded to protect anchor slings,
- Not be sitting on an incline that slopes toward the direction of pull.

Road-side rescues often require the use of vehicles to be used as anchors. Because vehicles are not 'fixed' to the terrain, they must be of sufficient mass and properly chocked to prevent being dragged and anchorage focal points on the vehicle must be of sufficient strength (i.e. 20+ kN).



Vehicles

Considerations may include:

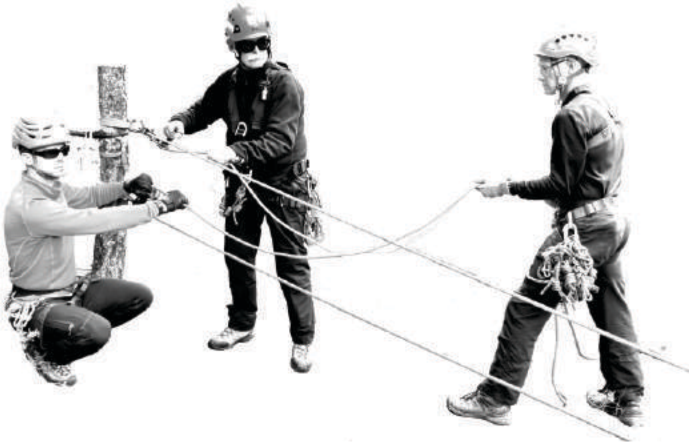
- Vehicle weight and stability
- Road surface – Friction is the only thing keeping the vehicle in place; a concern on wet, icy, muddy or gravel surfaces.
- Slope direction relative to the edge
- Direction of loading – Park at 90 degrees to the load direction, or park with wheels chocked facing direction of load and aligned with vehicle tow hooks.
- Placing anchor attachments around a structural part of the vehicle such as the frame
- Padding dirty, oily, sharp or abrasive areas to protect the rope or webbing
- Not exposing rope or webbing to hot surfaces
- Locking-out ignition and securing keys (e.g., with the Team Leader)

Lowering (Descent Control & Belay) Operations:

Focal Point Selection
The focal point locations should be far enough back to allow dry runs as well as building of a pulley system to raise the load if needed.

Rope Tailing

For effective rope tailing, the person tailing the ropes must assume a strong stance position, grip and feed both ropes concurrently



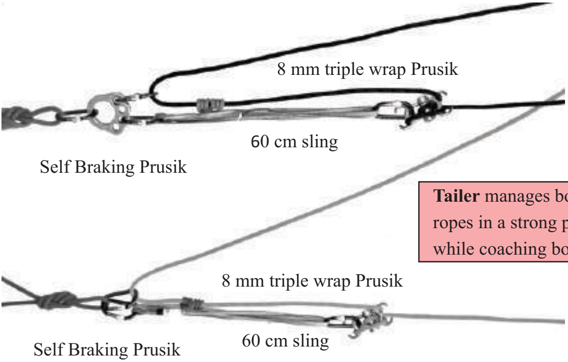
Two MPD's, side by side, with ropes being tailed

Component Descent Control & Self-braking Systems

In all *Component Systems* it is imperative that the system have a self-braking component.
Set up:

Use a 8 mm, triple-wrapped Prusik positioned *behind* the descent control device.

- Clip the 8 mm Prusik and the 60 cm 20 kN sling extension to the same carabiner at the anchor focal point.
- Attach the Descent Control Device to the load side of the sling extension. Load the rope into the DCD (use 3 horns for the Scarab; 4-bars plus one Hyperbar for brake-racks).
- Redirect the rope through a separate carabiner at the anchor system focal point.
- If it will be unsupervised, tie a half hitch on a bight around the redirect carabiner followed with an overhand on a bight.
- Ensure the ropes are being tailed prior to any lowering.
- Whenever 'Stop" is called, set the Prusik.



Tailer manages both tail ropes in a strong position while coaching both operators

Purpose-designed Devices

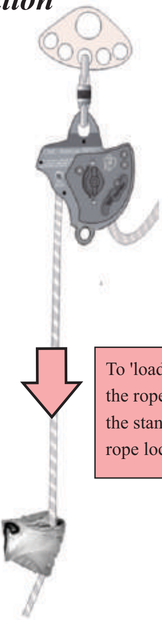
Must be capable and competent to serve equally as a main and as a belay. The current EMBC devices for lowering are: MPD, or *component systems* comprised of a 8 mm triple-wrapped Prusik rigged behind a suitable DCD (e.g. Scarab or 4-bar brake rack with hyperbars.

CMC Rescue MPD

- Ensure that the rope is correctly loaded into the device.
- Connect to the anchor, and 'load check'.
- Put the parking brake on whenever doing a change-over from lower to raise.
- If MPD is left unsupervised 'close the system' by tying an overhand on a bight around the standing part.
- Ensure ropes are tailed from a position that will keep the running end in the secondary friction post.
- To lower, disengage parking brake, with the running end hooked into the secondary friction post. One hand grips the running end and the other hand grips the release handle.
- If there is no load on the standing part, pull out on the handle and then rotate counter-clockwise to disengage the movable brake off the rope.
- If rope is in tension, first rotate the handle clockwise 90-degrees before pulling out on handle. This produces a more comfortable and ergonomic hand position for lowering.
- To adjust friction change angle of feed past friction post. Always maintain grip on rope while feeding into the MPD during lowering.
- If "Stop" is called, allow the movable brake to re-engage and lock the rope; only engage the Parking Brake if the running end rope must be let go.

Rope hooked into secondary friction post on MPD

MPD operation

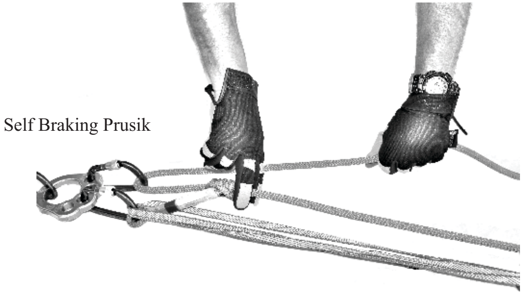


To 'load check 'Parking Brake is in off position and the rope is not around the hook, pull quickly on the standing part (load side rope). Confirm that the rope locks from this action;

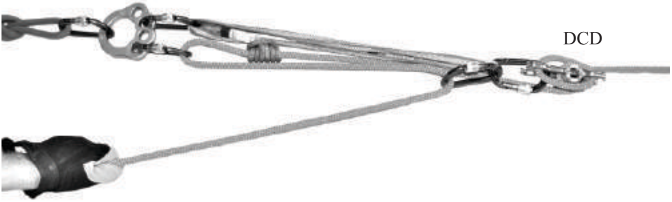
Prior to lowering, ensure the ropes are being tailed

If the MPD station is unsupervised tie an overhand on a bight around the standing part of rope. To lower, one hand grips the running end the other the release handle. If no load yet on the standing part, pull out on the handle to engage the internal gear and then rotate counter-clockwise to disengage the brake. If under tension first rotate the handle clockwise about 90-degrees before pulling out on handle this provides a more natural hand position for lowering..

Hitchhiker grip for rope deployment when tension is low



Scissor grip for rope deployment when load under tension



Improvised 3:1 to break stuck Prusik

Simple 2:1 Pulley System:

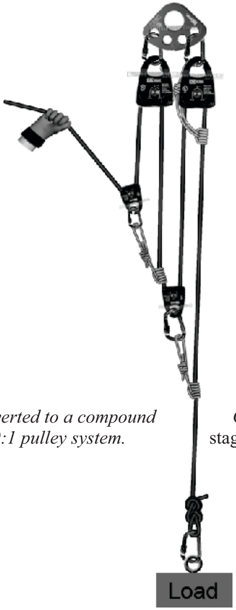
Simple 3:1 Pulley System:

Most common mechanical advantage system used in rope rescue. Versatility in that it can be easily converted to a Simple 5:1 , Compound 9:1 or a complex 5:1 by adding some additional gear without having to dismantle

Simple 5:1 Pulley System

Simple 5:1 pulley system with two traveling pulleys at the haul Prusik.

Unclip the travelling pulley closest to the haulers. Use a 2nd haul Prusik to attach this traveling pulley to the rope exiting the other traveling pulley.



Converted to a compound 9:1 pulley system.

Compound 9:1 pulley system with staggered anchors to increase efficiency.

Complex 5:1

Easy conversion from a 3:1 – 5:1 complex

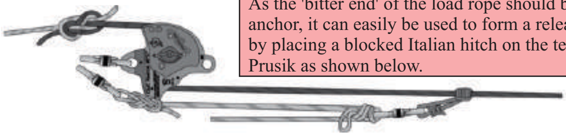
Redirected Simple 3:1 to build a 5:1 complex

1. Disconnect change of direction from anchor

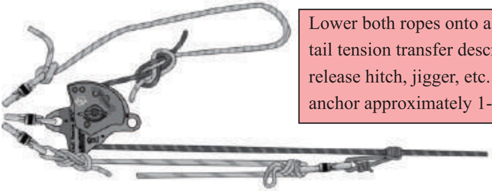
2. Add haul Prusik and reconnect pulley

Simultaneous (Two Tensioned) Knot Pass Lower

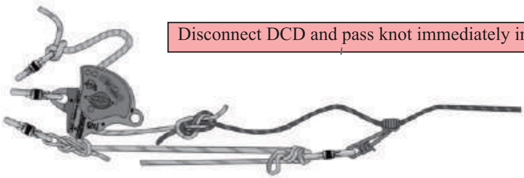
As the 'bitter end' of the load rope should be secured to the anchor, it can easily be used to form a releasable attachment by placing a blocked Italian hitch on the tension-transfer Prusik as shown below.



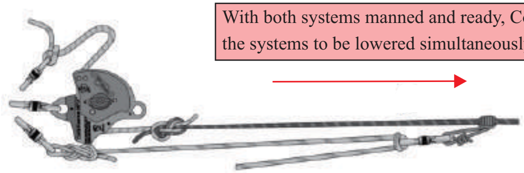
Lower both ropes onto a releasable system - the rope tail tension transfer described above, a Radium release hitch, jigger, etc. Clove hitch each rope to its anchor approximately 1-1.5m behind the knot.



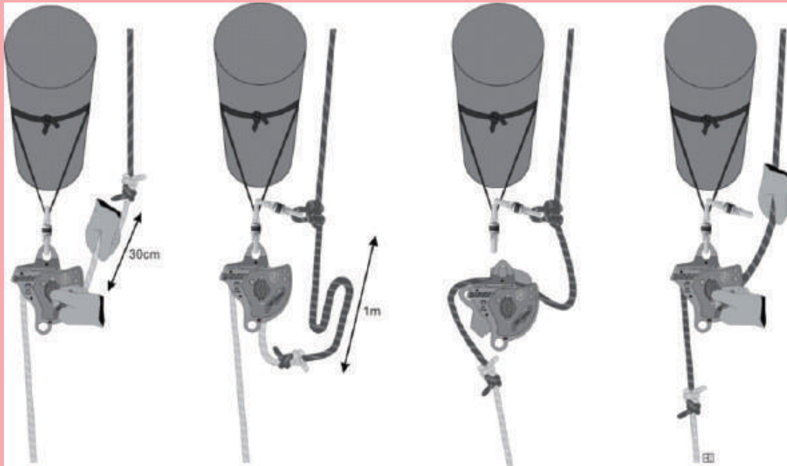
Disconnect DCD and pass knot immediately in front of both DCDs.



With both systems manned and ready, Control directs the systems to be lowered simultaneously back onto the DCDs.



Offset Knot Pass lowering sequence

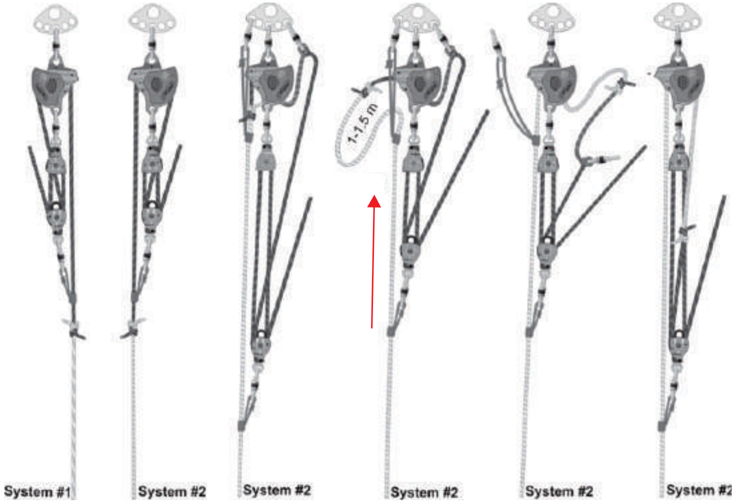


- Transfer tension onto the rope without the knot. Allow for 5% static rope stretch under load by stopping the lower on the unknotted rope with 5% of the length of rope in service (e.g., 3-4m with 60m in service) in order to completely un-tension the knotted rope pass.
- Once the knot is about 30-40 cm from the DCD, stop; secure the rope to the anchor about 1-1.5 m behind the knot.
- Pass the knot. Note that some slack will develop. Do not allow this slack to get pulled over the edge; have someone hold this slack on top.
- Do a load check to ensure the rope has been properly loaded back into the DCD.
- Continue lowering on the tensioned rope until half of the load has been transferred back to the other rope, and then lower on both together.

Simultaneous (Two Tensioned) Knot Pass Raise

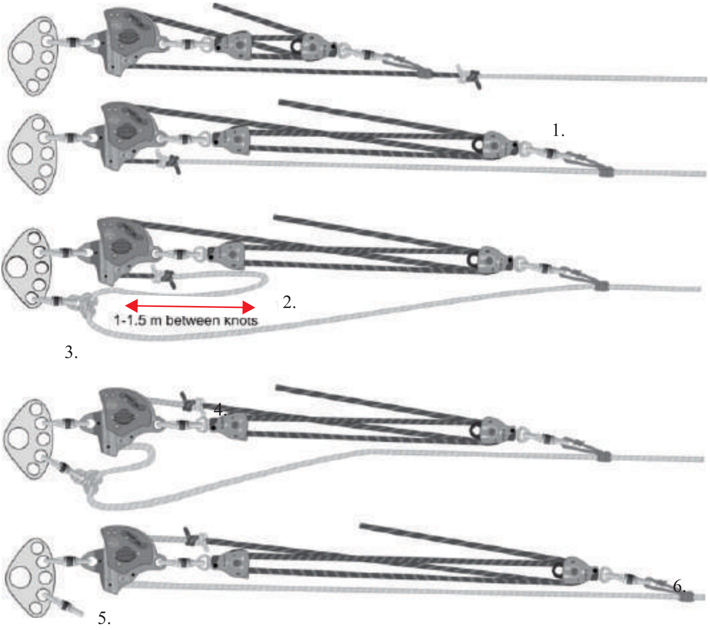
Sequence:

1) Bring both knots up to the point where they are about to enter the respective progress capture devices.
2) Note that this knot pass can be done concurrently on both ropes for efficiency. On each rope system, isolate the progress capture by securing the rope exiting the other side of the progress capture to the anchor with a clove hitch or suitable knot. This will effectively 'dead-leg' the portion of rope entering the progress capture and prevent the knot from entering it when that haul system is pulled on. This also temporarily reduces the MA by1.
3) A temporary progress capture Prusik can now be attached to each haul rope and clipped into the anchor
4) Take in on both haul ropes until the load has been raised far enough to allow the knots in the both systems to be positioned on the 'other side' of there progress capture devices.
5) Reposition both knots on the opposite sides of the progress capture devices and reset the devices ready for a raise.
6) Unclip the security hitches (Step 2) and reset the haul Prusiks.
7) After careful inspection, raise on both ropes to release and remove the temporary progress capture Prusiks, and then continue raising.



Offset (Alternately Tensioned) Knot Pass Raise

1) Raise the load with both raising systems until the knot is about to enter the progress capture
2) Keep raising on the system which does not require a knot pass until sufficient rope on the other system has been brought up to allow the knot to be positioned on the 'other side' of the progress capture.
3) Back up the slackened system to the anchor with a clove hitch or suitable knot before removing the rope from the progress capture system.
4) Position the knot on the 'other side' of the progress capture
5) Conduct a 'Load Check' on the load line once the knot has been passed and the progress capture re-established.
6) Confirm correct rigging by 'fresh eyes' inspection.
5) Remove the security tie-off knot.
6) Continue hauling.



Component system - A typical process for performing a two tensioned (***simultaneous) knot pass*** while lowering with a component system is as follows:

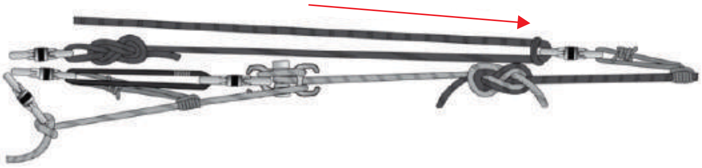
1. Keep lowering on both ropes until the knots are approximately 30-40 cm away from entering the self-braking Prusik of the component system.

2. Position and set a releasable Prusik onto each rope immediately below the DCD and attach it to the anchor with a separate carabiner and (if required) an extension of suitable length. The releasable components must be capable of extending slightly more than the distance between the stopped knots and the originally set position of the releasable Prusiks.

3. Lower both ropes enough to transfer tension to the releasable Prusik systems.
4. Using a clove hitch or other suitable knot, secure each rope to its anchor approximately 1-1.5 m behind the knot.

Component system -Simultaneous (Two Tensioned) knot pass

5. Remove each unloaded rope from the DCD and self-braking Prusik to pass the knot and then replace the them on the rope, placing the knot immediately in front of the DCD with no excess rope in order to minimize release distance.



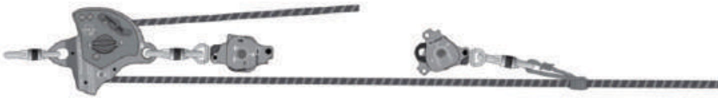
6. Both stations must be ready to transfer the tension back to the DCD by lowering their releasable Prusiks at the same time. Inform 'Control' when ready. Control will need to confirm that the attendant is ready for this action. Transfer tension when commanded by Control.

7. Following transfer of tension back to the DCD, a "fresh eyes" inspection and a load check, remove the releasable Prusik from the load rope, remove the security knot from the anchor, and resume the lower.

Sequence to convert from a lower to a raise with an MPD:

1. Release the handle.
2. Allow the rope to settle-in and lock in the MPD.
3. Remove the running end from the secondary friction post.
4. Set the Parking Brake.

5. Move the rope bag to the farthest end of where the haul team will work.



6. Attach a haul Prusik only a short distance (e.g. 1 m) down rope of the MPD (i.e. build the pulley system within a short distance so it is easy to spot any rope twists and keep rigging clean).

7.Connect the pulleys to build the desired MA.

8.Have 'fresh eyes' inspect the system.
9.Communicate readiness to the RRTL.
10.Fully reset the system.
11.Ensure the haul team has hands on rope
12.Unlock the Parking Brake.
13.Wait for Control to issue commands.

Component alternately tensioned lower to raise conversion

1.Stop lowering on Rope 2 and continue lowering on Rope 1 until there is enough slack in Rope 1 to allow securement of Rope 1 to the anchor and removal of the DCD and replacement with a haul system (1-1.5 m).

2.Secure Rope 1 to the anchor behind the self-braking Prusik using a clove hitch or a figure-8 on a bight.

3.Remove the DCD from Rope 1, place a Prusik minding pulley (PMP) onto the rope behind the self-braking Prusik and clip the PMP into the rope tailing redirect carabiner already on the anchor.

Component alternately tensioned lower to raise conversion

4. With the self-braking Prusik and PMP now serving as the raising system progress capture device, add a haul Prusik and build the desired MA pulley system.

5. After a "fresh eyes" inspection of the haul system on Rope 1, remove the security clove hitch and raise on Rope 1 until there is enough slack in Rope 2 to repeat steps 2-4 above.

6. Once the pulley system is on Rope 2, do a "fresh eyes" inspection of both systems and commence the raise.

Component two tensioned lower to raise conversion

1. Remove each rope from the tailing carabiner and clove hitch the tail into a carabiner on the anchor 1-1.5 m from the self-braking Prusik.

2. Clip a tension transfer Prusik into the extension sling into which the DCD is clipped and transfer the load. (This Prusik does not need to be 'releasable' since by default it will become un-tensioned once raising commences, at which point it can easily be removed.)

3. Unclip the DCD from the extension sling, place a Prusik minding pulley (PMP) onto the rope behind the self-braking Prusik, and clip the PMP into the anchor.

Component two tensioned lower to raise conversion

4. With the self-braking Prusik and PMP now serving as the raising system progress capture device and the transfer Prusik as the haul Prusik, build the desired MA pulley system.

5. Take up on the pulley system enough to unclip the extension sling carabiner from the haul Prusik and reset the pulley system. After a “fresh eyes” inspection and load check of both rope systems, the security clove hitch can be removed and hauling can begin.

Component two tensioned raise to lower conversion

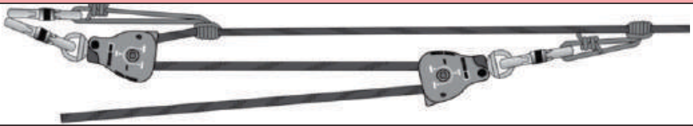
Using Dual Capability Two Tensioned Rope Systems with component systems, conversions from lower to raise can occur with both ropes continuously tensioned or with one rope temporarily un-tensioned.

Two tensioned conversion (both ropes continuously tensioned)

This technique is for "hot transfers" when the system must be converted from raise to lower while under tension without changing vertical positioning of the subject and attendant.
In a component DCTTRS, both ropes remain continuously tensioned by transferring the tension on each rope temporarily to a releasable component (rope end tension transfer recommended) to the haul Prusik while the progress capture is converted to a descent control device.

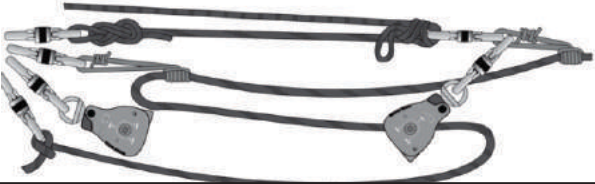
Sequence to convert from a raise to a lower on each rope with a component system:

1.Set the haul Prusik on each DCTTRS rope about 1m from each ratchet Prusik.



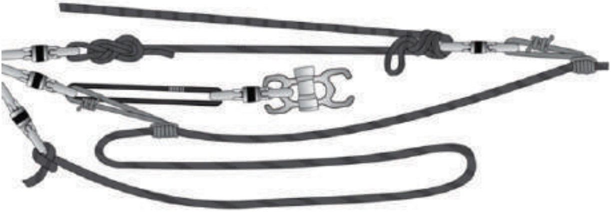
2. Clip a rope end tension transfer system or a Radium release hitch into the haul Prusik on each DCTTRS rope and attach the release component to each rope's anchor with an extension if necessary, leaving no slack.

3. Haul on both ropes enough to release both progress capture Prusiks and then lower on both ropes to transfer the load tension to the releasable components clipped to the haul Prusiks.

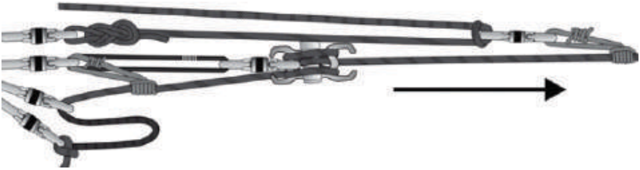


Component two tensioned raise to lower conversion

4. With each load rope now slack behind the haul Prusik, remove each PMP from the anchor, leaving the progress capture Prusik in place to serve as the self-braking Prusik in the descent control system.



5. On each rope, clip a 60 cm extension sling into self-braking Prusik (former ratchet) carabiner at the anchor, clip the descent control device (DCD) into the other end of the sling, and install the DCD on the load rope. (If the carabiner is to be opened, temporarily secure the rope to the anchor with a clove hitch or Figure 8 on a bight before opening up the carabiner to attach the sling.)



6. Pass each rope through a tailing carabiner on the anchor and position the rope bags at a convenient location for the rope tailer.

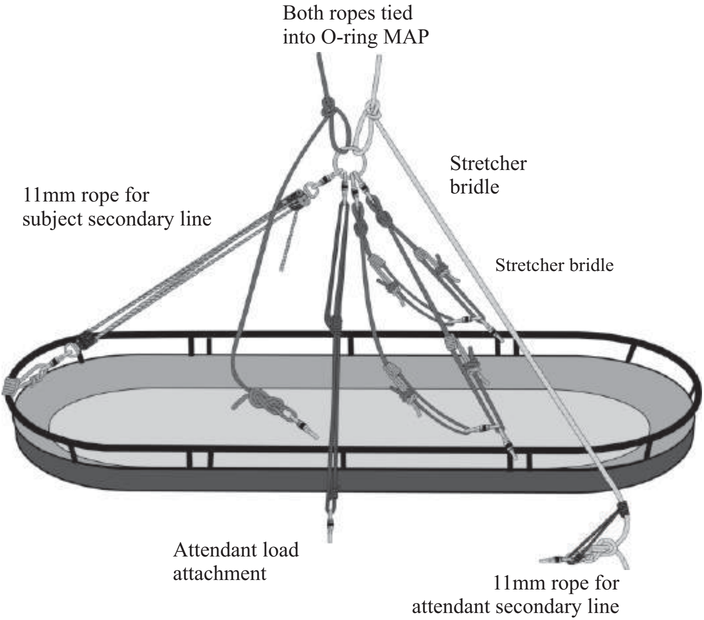
7. After completing a “fresh eyes” inspection of both systems, transfer the load evenly onto both lowering systems and remove the former haul/load transfer Prusiks from the ropes.

8. Commence a DCTTRS lower.

Notes

Preferred Stretcher Attachment

Master Attachment Point (MAP)
The preferred method for stretcher rigging uses long-tailed bowlines with the loops through an O-ring MAP and the tails serving as the subject and attendant secondary lines. The O-ring provides for more convenient attachments.



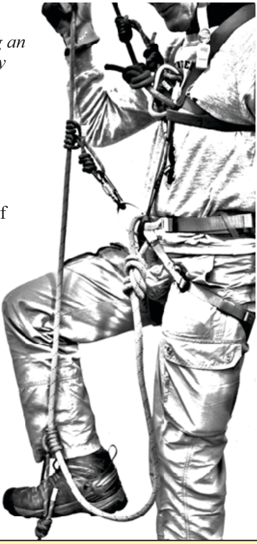
The attendant attachment and secondary line as well as the subject secondary line should be attached to the O-ring MAP between the stretcher bridle legs so that these lines can hang vertically and avoid cross loading of the carabiners.

Horizontal stretcher MAP with O-ring & end-knots

Preferred Attendant Attachment

The attendant requires an adjustable load attachment at the waist. One option is to use a short Prusik on a piece of 11mm rope long enough to allow free movement around the stretcher. Attendants should also have a second Prusik as a foot loop attached to the load lanyard or an etrier attached to the MAP to assist in positioning themselves in relation to the stretcher.

Basic stretcher attendant rigging using an adjustable primary line & secondary



Load attachment from MAP tied or clipped to seat harness. Prusik gives adjustability. A pick-off strap or Prusik-on-itself can be used for this attachment.

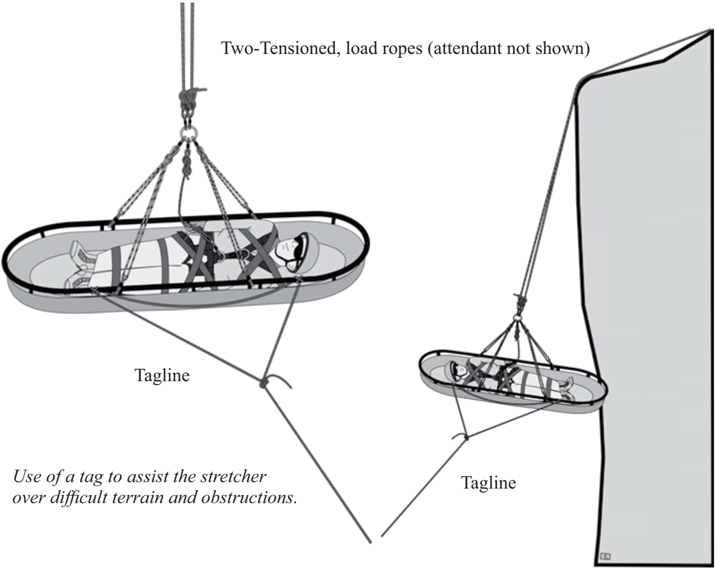
Foot loop Prusik for adjusting height

Stretcher Attendants

- Need to be qualified as a Rope Rescue Technician 2
- Strong and fit
- Knowledgeable and proficient in rope rescue systems
- First aid trained
- Able to self-evacuate (ascend the rope) and position themselves above and below the stretcher
- Be comfortable functioning on-rope
- Stretcher attendant should always wear safety glasses.

Taglines

- Divert the stretcher from the fall line or to redirect around obstacles.
- Tied to the stretcher rail at two points or to the MAP



Use of a tag to assist the stretcher over difficult terrain and obstructions.

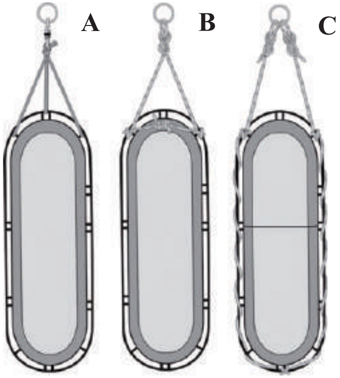
Using the tagline

- Maintain good communication
- Pull just enough to clear obstacles with minimal impact if the tag were lost.
- Not be used when there is significant chance of injury to the rescuer or subject in the case of tag line failure.

Horizontally (Transverse) Oriented Stretcher/Moderate, Steep and High Angle terrain,

- Horizontal arrangement may be preferable (for injuries which do not readily allow for vertically stretcher configurations)
- Terrain must be suitable for this type of technique/'footprint' of stretcher much wider than when vertically oriented.

Transverse stretcher carry.



Slope Rescue Rigging

A. Uses 6 m of 25 mm webbing. Tie end around the upright and rail on one side stretcher, pass it around the rail at the head end, then tie off the same as previously done on other side. This creates two bights of webbing. Equalize loops and tie together with an overhand knot.

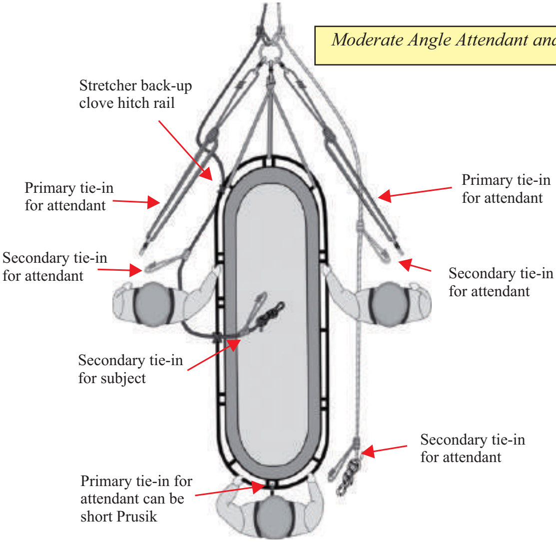
B Use 5 m length of 11 mm rope. Tie a figure-8 on a bight at midpoint (include MAP ring in bight if desired). Tie a clove hitch onto the rail at each head-end corner. Tie the two ends together

C Full-wrap bridle for older model two-piece stretchers Incorporates the entire rail, spreads the load around the stretcher and firmly holds the two pieces together. Use 10 m of 11 mm rope, find midpoint and tie a clove hitch to middle of the foot end of the stretcher. Wrap the two halves of the rope around the side rails of the stretcher to head-end. Finish off by tying a clove onto rail and then a figure-8 follow through to the MAP.

Stretcher Rigging:

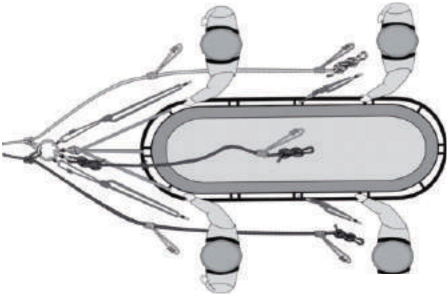
- Head-end attendants are supported from MAP using an adjustable attachment-Prusik-on-itself, pick-off strap, or Prusik onto a short length of 11mm rope.
- Foot-end attendant uses a 8 mm Prusik-on-itself to the MAP, or an adjustable or direct attachment to the stretcher foot rail.
- Caution: Foot Bearer's primary attachment connected to the MAP may result in that attachment running directly over the patient's face; a stretcher head shield is required.
- Two short lengths of 11mm rope are attached to the MAP or the tails of long-tailed bowlines are used as secondary lines.
- Each of the head-end attendants attaches a short Prusik to one of the strands and clips that into his/her harness as the secondary attachment. The end of one of the secondary lines is initially attached to the stretcher head rail (clove hitch or butterfly knot & carabiner), and becomes the belay tie-in for the subject, while the end of the other becomes the belay tie-in for the foot-end attendant.

Moderate Angle Attendant and Stretcher Rigging.



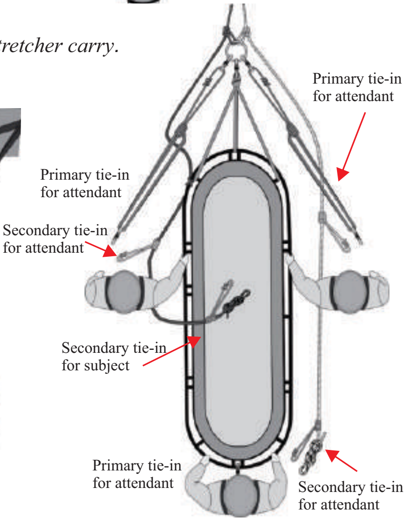
Attachments for 3 attendants

Variation of rigging possibilities



Four attendant stretcher carry.

Variety of preferred options for
lowering devices on low angle slope:



Medical Considerations

Proper first aid treatment must be rendered to the subject before the rescue proceeds in order to stabilize condition and prevent aggravation of injuries. Packaging must always consider the extent and nature of the subject's injuries. However, in some cases, particularly where time is crucial, “life over limb” considerations apply.

Rescue one
First in Rescue Attendant minimum response kit:

Initial Response Minimum First Aid Kit:

A means of securement for subject e,g, tubular webbing or harness

Personal Protective Equipment:
Gloves x 5 pairs
Safety Glasses
EMT Shears

Nu Mask or CPR Mask
Oropharyngeal Airway

Tourniquet
Israeli-bandages -with-pressure-bar x6
Pressure Dressing x 2

Adjustable c-spine collar
(Adult and possibly Paediatric)

SAM Splint
Triangular bandages x 3
Tensor Bandages 3" - x 2

Foil blanket x 2 (Thermoregulation)
Thermal Pack (e.g. “Ready heat blanket)

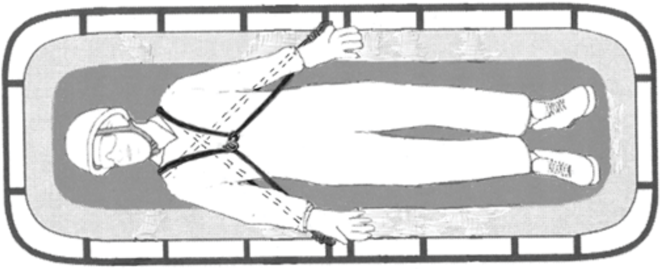
Pages from first aid field guide to cover:
1 - Patient assessment
2 - Bleeding control
3 - Respiratory emergencies
4 - Nervous system emergencies
5 - Musculoskeletal injuries

Packaging

Note:
A vacuum mattress is preferred method of packaging.
- Otherwise, use blankets, pre-glued closed-cell pad, or a Thermarest (partially inflated under the subject)
- Objects in subject's pockets or on harness should be removed.
- Pad between legs and the natural hollows, & along the sides of the subject
- Strap the subject onto spine board, vacuum mattress, etc., and then into the stretcher
- Protect from the elements and make comfortable for a long-duration rescue.
- Have a face shield or helmet/safety glasses.
- Have a means of removing the subject from stretcher to prevent aggravating injuries.
- Re-assess the subject's condition periodically.

Subject Securement

Backup subject attachment to gaurd against the risk of failure in the stretcher or its securement.



Head End Securement

Tie- 3 m of 25 mm webbing within 30 cm of the mid-point of the stretcher, mirror on opposite side with the other webbing. Do not allow to slide along the stretcher rail. Lay diagonally across upper part of the stretcher, cross behind the subject's back before the placement in the stretcher.

Once subject is placed in the stretcher, take one strap from behind shoulder, lay it across the chest, and tie an overhand-on-a-bight with a 5 cm bight at a point just below the solar plexus.

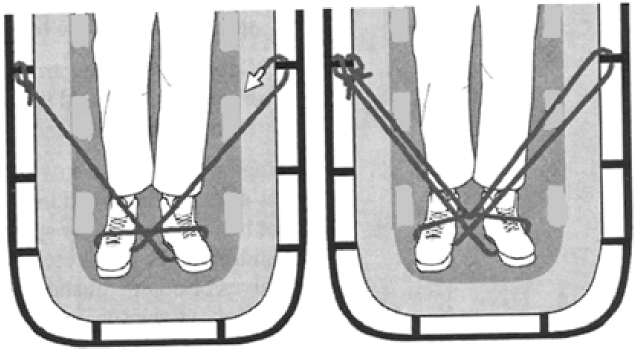
Pass the other shoulder strap through the bight of the knot in the first strap and with light and equal tension on both straps, secure their ends to anchor points at or near the original tie-down points. **Do not over tighten these straps.**

Foot End Securement

Tie a 5m length of 25mm webbing within 30 cm of the mid-point of the stretcher, weave as shown in diagram and tie off at starting point.

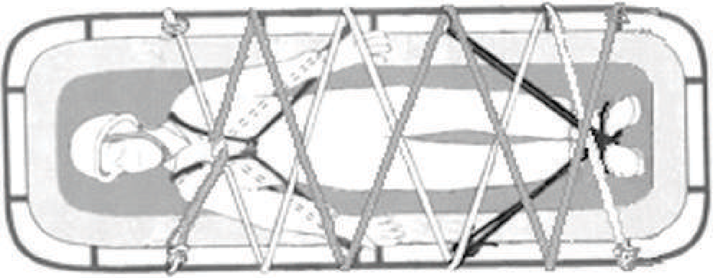
Once the subject is comfortably snug between the head and foot supports, tie off the end of the foot webbing.

If an injury precludes capturing both feet with this system, a similar wrapping pattern can still be used to support the uninjured foot.



A round turn & two half-hitches is preferred for stretcher webbing securement as it is easy to set tension and quick to tie.

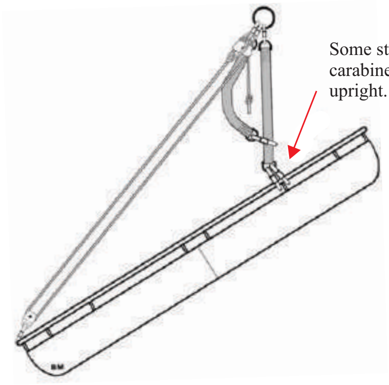
Diamond lashing



Full subject securement, showing head end, foot end and final diamond lashing tie down system. Note the optional twist of the two webbing strands below the patient's neck.

- Using two 5 m lengths of 25 mm webbing attach end of each piece of webbing to tie-points or the stretcher rails on opposite sides below the subject's feet.
- Bring the free ends of each length of webbing diagonally forward toward the head of the stretcher, alternately wrapping from side to side around the opposite side rail or tie-down point so that the webbings cross in a diamond pattern toward the head of the stretcher.
- Ensure crossing points avoid pressure on sensitive areas such as the knees or points of injury that are not well protected or padded.
- Final crossover point should be located high enough on the subject's chest to hold it securely but not so high that it may pressure the neck should subject shift toward the foot end of stretcher.
- Secured both arms inside lashing. However, depending on the medical circumstances, subject's preferences and other factors, one or both arms may be left free.
- Tighten lashing from foot toward head, moving any slack upward to the final head-end tie-points.
- If the top crossover point is close to neck, it should be lowered by wrapping the two sections of webbing two or three turns before continuing them to the rails or tie-down points for anchoring.
- Once the diamond lashing has been tensioned, tie off to an upright post below the stretcher rail.

Stretcher bridle rigging for the stretcher tilt-lift



Some stretchers require doubled carabiners, one on either side of upright.

Some special considerations must be made when rigging the stretcher for the tilt-lift:

1. If the stretcher has only single uprights connecting the rail to the body of the stretcher, then the head-end stretcher bridle must be connected with two carabiners, one on either side of the upright to prevent the bridle from shifting as the orientation is changed.

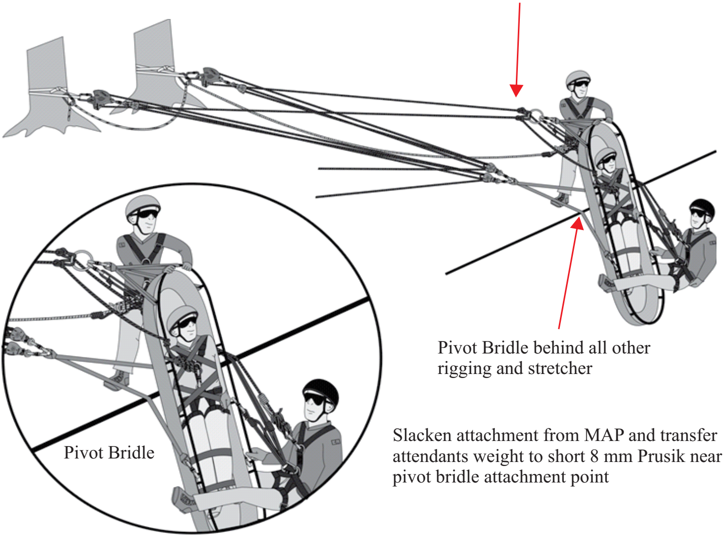
2. The attendant attachments, both load lines, must be longer than normal as the attendant will be required to move up and down in relation to the stretcher during the packaging of the subject in the stretcher.

3. A means must be made to support the subject in the stretcher as soon as he/she is placed in it to keep him/her from sliding down. A Purcell Prusik or other adjustable attachment extending from one stretcher rail, through the subject's harness and back up to the stretcher rail can help facilitate this.

Pike and Pivot Lowering

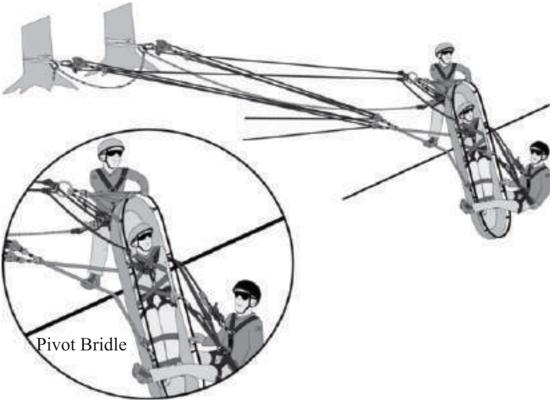
Lowering procedure

1. Role call and edge transition briefing should be complete.
2. Approach edge with the stretcher at 90 degrees, feet end first, until the centre of gravity is almost at the edge. Attendant straddles the stretcher, and loads the system.
3. Continue lowering while the edge people vector the lines.
4. Just before the stretcher reaches a vertical position, insure that the edge protection is in place, and ready to receive the lines. Be cautious of the pinch point.
6. Once stretcher is vertical it is best to position attendant at the foot of the stretcher to guide it over terrain features.
7. If rigged to do so, the stretcher may be raised to a horizontal position at this point also



Pike and Pivot
Requires a long pivot bridle.This can be made from a 10m section of rope or 8mm cord.

Tie a figure-eight on a bight at the ends, and one in the middle. The knot in the middle is the "head" of the bridle. If needed, rig the stretcher with a tilt lift rig to be able to move it into a horizontal position below the edge. Note: not all rescues may require this.



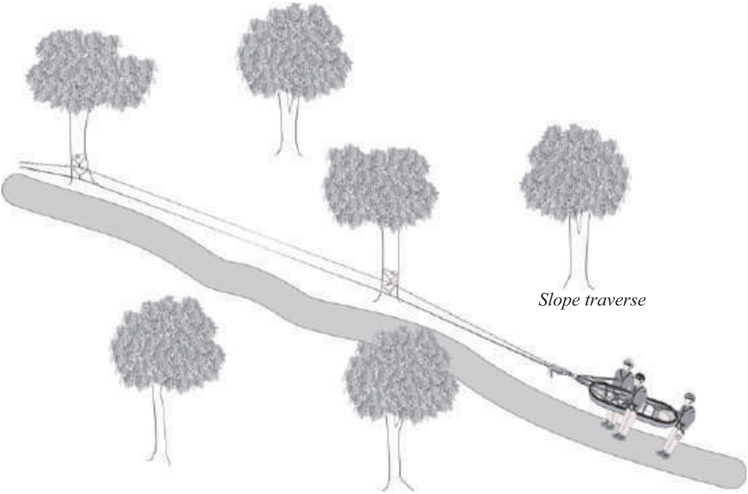
Raising procedure
Pivot bridle is rigged to the outside of the stretcher stanchions or uprights at about knee height (below centre of gravity) on the subject, it must be underneath all other rigging, and may require its own edge protection.

1. Raise until the MAP is nearing the edge.
2. Do an edge transition briefing.
3. Continue raise until the MAP is at the edge.
4. Attendant can now climb over the edge, but if the attendant will continue to manage the stretcher, then he/she must instead transfer off of their attachment (i.e. jigger) and attach to the rail of the stretcher at a similar location as the pivot bridle. A simple girth hitch with a short 8mm Prusik to the stretcher rail works well, attachment to the MAP must be slackened.
5. Raise stretcher with a haul system attached to the pivot bridle (see diagram above)while attendant pushes in on the bottom of the stretcher and the edge people push out on the head of the stretcher to keep it vertical until such it makes sense to pivot it into the terrain on top.

Note: The TTRS lines must be tended to remain tight through the whole raise.

Movement on Slopes

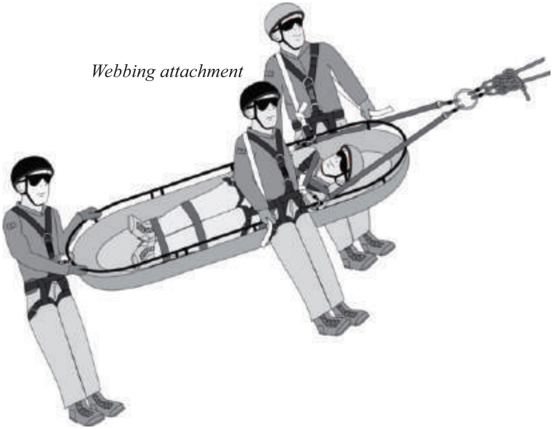
To minimize the fall and pendulum hazard if crossing a slope (e.g., following a trail rather than the fall line), consider clipping both ropes through carabiners on sling extensions from anchors, adjusted to the correct length to keep the load in the correct path.



Vertically Oriented Stretcher
For most moderate angle slopes it is common to use a vertically oriented stretcher with three attendants, one on each side at the head end and one at the foot end of the stretcher

Movement on Slopes

To minimize the fall and pendulum hazard if crossing a slope (e.g., following a trail rather than the fall line), consider clipping both ropes through carabiners on sling extensions from anchors, adjusted to the correct length to keep the load in the correct path.



To assist the side attendants to support the stretcher, the following technique is recommended:

- Attach a length of webbing to the rail just behind the attendant's position.
- Pass the webbing up the back and over the outside shoulder.
- Hold it with the outside hand.
- Lean backwards and slightly outwards.

In three attendant configurations, the back attendant can girth-hitch a short cord loop to the back rail of the stretcher, or clip in with one or more carabiners. (This suspension assist can also serve as the attendant's primary load attachment.) Leaning back on this attachment with hands on the side rails supports most of the stretcher weight on the harness and offers good control.

Low Slope Rope Assist Stretcher Descent - MPD, Scarab/ Brake Rack-Hyper Bar extended on sling with single self-braking Prusik behind DCD, or Italian hitch on anchor with self-braking Prusik to the anchor.

Counterbalance Rope Assist.

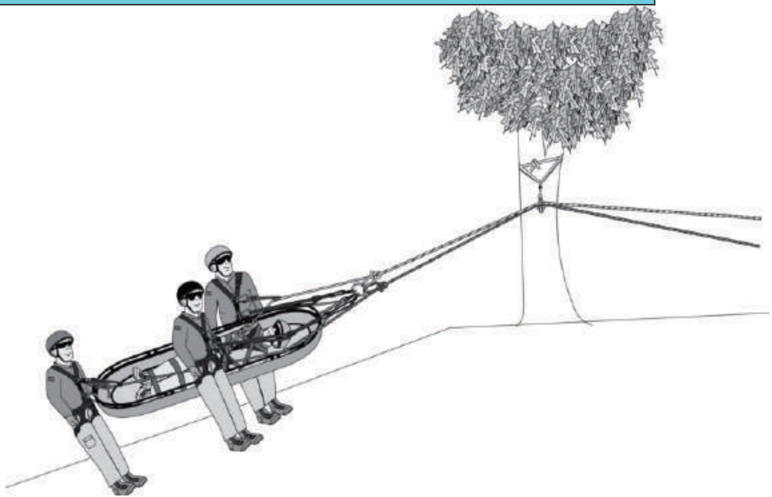
Raising

While raising loads, incorporate a progress capture. This also applies to counterbalance systems. Counterbalance techniques are reserved for Low Slope Terrain (i.e. less than 20 degrees

Slope Rescue

Moderate and Steep Angle Slope Rescue

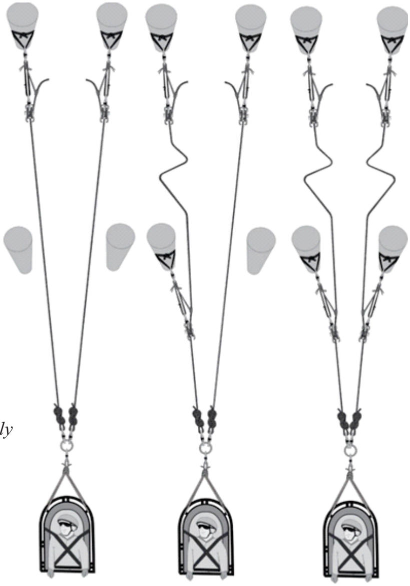
Whenever possible, high directional pulleys at the top of the slope should be used to mitigate the hazard of rope-induced rock fall. It also allows for easier edge transitions for the attendants.



Multi-pitch Rigging

A separate “Station Leader” as well as Control Person manage each 'station'.

- One overall Rope Team Leader
- Station Leader at the respective stations
- Good communication back to the RRTL is essential.
- Early in operation, designate & distinguish rescuer access route and rescue path.
- Designate location of each station early on.
- Watch out for overhead hazard. If a raise, start at the top and work your way down to the subject.
- Inventory gear and people.
- Plan ahead
- Pick the route carefully
- Anticipate fatigue



The process for moving to successively lower multi-pitch stations with a two tensioned rope system:

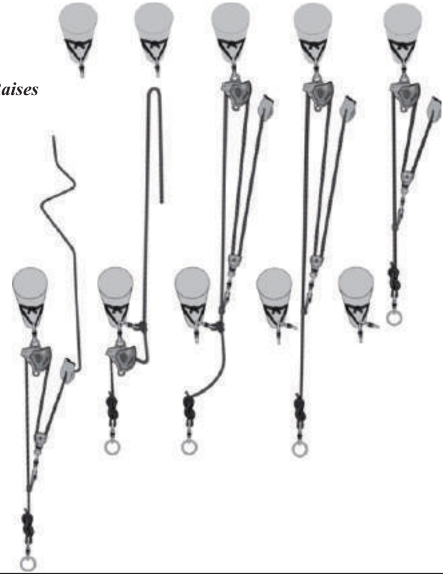
Multi-pitch lowers with DCTTRS:

Typical sequence is as follows:

- Lower and manoeuvre the load past and directly under the next station; stop.
- Call for “slack' on one of the ropes; anticipate settling-in of the load. The rope must not be removed from the device at the upper station.
- Load the slackened rope into the new station; conduct a load check then lock off the device.
- Call for a transfer of tension and slacken the remaining rope; again, this rope must not yet be removed from the upper station.
- Load the second rope into its new respective station; conduct a load check, (fresh eyes) then lock off the device.
- Release the ropes from the upper station; flake the ropes into where they need to be for effective rope tailing. Secure the ends of the ropes to the anchors.
- Control at the new station takes over and commences operation for that station.

1. Halt the raise as it reaches the first station. Station 1 Leader communicates initiation of transition to overall Rope Rescue Team Leader.
2. If only one set of load ropes is being used hold the load position with Rope 2. Leaving the progress capture device in place on Rope 1, remove the haul system pulleys from this rope and secure the rope to its Station 1 anchor with a clove hitch or figure-8 on a bight above the progress capture device.
3. Remove Rope 1 from its progress capture device and convey the ends of the rope(s) accumulated at Station 1 to the prepared anchors at the next station up the slope (Station 2). If gear is in short supply, the Rope 1 progress capture device and haul pulleys can be used at Station 2.

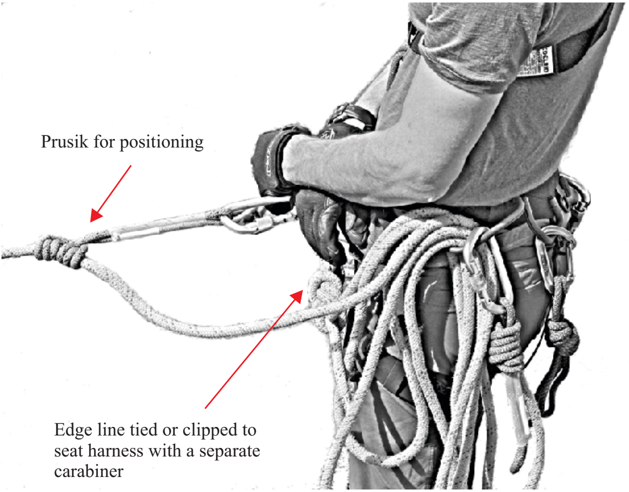
Multi-pitch Raises



4. Set Rope 1 into its progress capture device at Station 2, build a haul system with the desired mechanical advantage and take up slack to the Station 1 security attachment.
5. Conduct a load check at Station 2 and have the Rope 1 haul team stand by.
6. Remove the Station 1 security attachment and raise Rope 1 until it transfers any load tension from Rope 2.
7. With Rope 1 now holding the load position, repeat Steps 2 to 5 on Rope 2
8. At Station 2, Control conducts a final load check and Station Leader communicates readiness to raise to overall Rope Rescue Team Leader.

Edge Lines

(Edge line)s) should be set-up right away may require two or more edge persons.
Edge person preparation, showing positioning Prusik engaged and excess rope tucked into harness loop for trip-free deployment while moving to the edge.



Edge lines

1. Select separate anchor perpendicular to edge & close to rescue lines.
2. Attach a sling anchor capable of accommodating changes in load direction. Sewn or pre-tied webbing simple wrapped sling attachments are quickest to set up.
3. Tie fig.-8 to one end of a suitable length of the rope, toss knot from outside control zone to the edge, trace back to anchor and secure to anchor sling.
4. Place a positioning Prusik on the edge line and clip it into a locking carabiner on the edge person's harness lower attachment point
5. Retrieve knot and clip rope end to harness, with separate carabiner to seat harness, (this can be tied in but takes longer).

Edge Lines

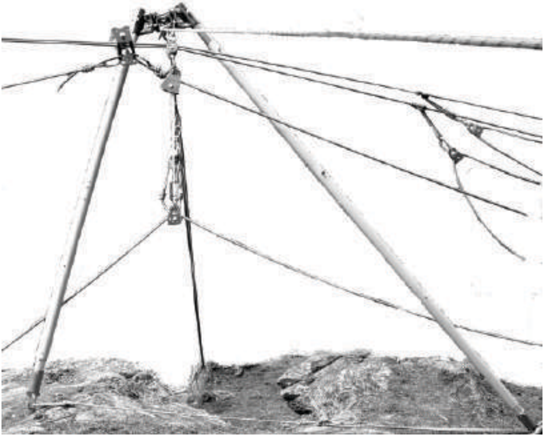
To Ensure Safety,

- All ropes should be pulled in to their anchors before disconnecting.
- The precaution that all ropes must be pulled up to their anchors before being disconnected is particularly important to ensure that the edge person is not disconnected while still working at the edge during operations and tear-down.

The use of a single rope is acceptable for edge lines if the system will prevent a rescuer from falling over the edge (Fall Restraint). **If for some reason the edge person must go over the edge and be supported by the rope he/she must have a second rope.** This is the same system that a first responder would use for descending down the cliff with capacity to ascend back up to the top.

Sideways A-frame

- High directionals should be used wherever possible at high angle and slope edge transitions to ease the job of the stretcher attendants, reduce potential shock forces, and prevent the stretcher from being pulled into the ground by the rope as it goes over the edge at the top of the slope.
- Position high directional pulleys at equal heights when using DCTTRS.
- Conveniently located trees are commonly used but another option is to span multiple ropes between substantial trees at the edge to suspend high directional pulleys.
- Alternatively, side-ways A-frame or a tripod with a long back-leg can be used these can be either field constructed or commercially made devices.
- These artificial high redirects do not need to be in place before rescuers are lowered over the edge, as the first aider, stretcher attendant can be sent down to the subject using other methods.
- High directional pulleys can be rigged while assessment and packaging take place Caution - high directional pulley failure could expose rescuers in the area under the lines to impact from the tensioned ropes.

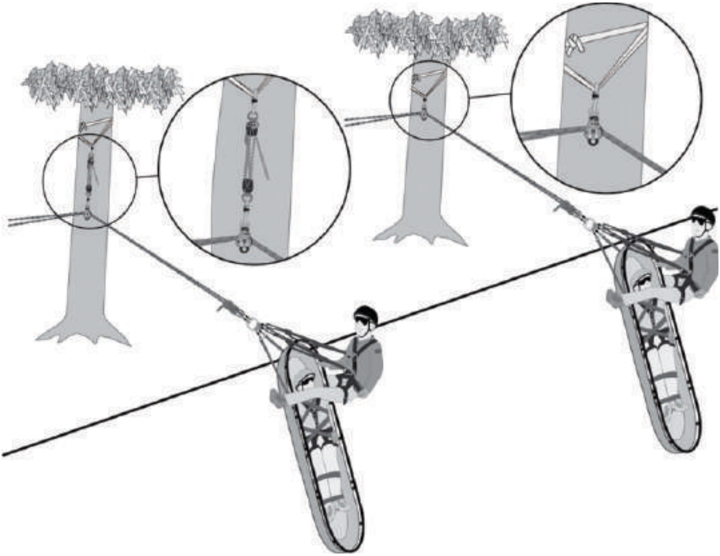


Artificial High Directional (AHD)

If the vectors are allowed to act outside of the footprint of the AHD,
then toppling may occur, unless specifically designed (and appropriately guyed)
to resist these forces.

High Directional Edge Transition

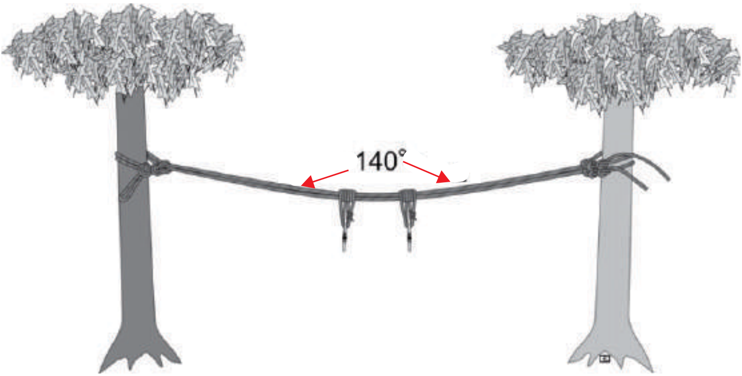
When high directionals are close to the leading edge you will need to use a jigger or a side opening pulley to facilitate movement past this high point during edge transition.



A high directional aids stretcher movement over the crest of the drop. Left: Rigged with a jigger to facilitate raising into position under load. Right: Rigged with a side-opening pulley.

Spanned Anchor

An option to consider is to suspend high directional pulleys from multiple ropes spanned between substantial trees at the edge. Subject to the availability of sufficient rope, such *spanned anchor systems* can be a very effective and efficient means of creating a high directional at the desired location. This practice can work equally well when spanning a small gulley, with the multiple ropes spanning between solid rock outcrops, for example.



Using a spanned anchor system for a high directional. Because of force multiplication on anchors, prudent angle should not exceed 140° and span ropes must be anchored separately for complete redundancy

High Directionals

Operation Sequence

Installing or removing ropes under load into a high redirect can be done while lowering with the following sequence:

1. The load is moved on the TTRS beyond the redirect point.
2. Rope system 1 is stopped in order to take the entire load.
3. Rope system 2 continues to lower until the entire load is on the stopped system.
4. Enough slack is introduced into system 2 to place it into the pulley of the redirect.
5. Excess slack is removed from system 2, and system 1 is lowered in order to transfer the load to system 2.
6. Slack is fed in system 1 to allow the line to be placed into the redirect.
7. The loaded line of system 2 is lowered until both lines are sharing the load again, and the system is now usable.

To remove the lines from the redirect, the sequence is reversed.

Key points for rigging redirects:

1. Use cinching types of anchors”W3P2”preferable, with interior angle greater than 90 degrees; up to 120 degrees.
2. Both lines of the TTRS should be redirected equally and in parallel.
3. Using two single pulleys allows the lines to be connected and disconnected independently, can use same anchor. A double Omni Block type pulley can be used.
4. Positioning can be adjusted by using a small pulley system, or jigger.
5. HD pulleys positioned too high increases risk should the HD fail.
6. If there is any 'real' possibility of the HD failing, the lines may be moved to a lower position once the rescue load is below the lip of the edge.

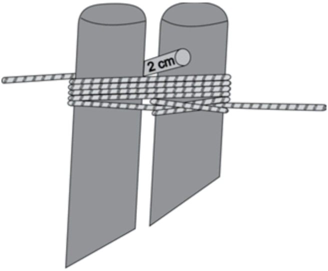
Setting up and tensioning the Sideways A-frame

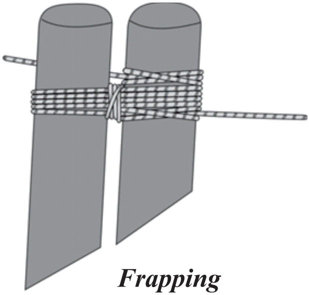
Field built Sideways A-frame

The sideways A-frame is the default setup

- 2 log poles, 1-2-2.5 m long and approx. 3-4 m long; log diameters about 12-15 cm diameter.
- 10 m of 8 mm cord used to Wrap and Frap the two poles together,
- 10 m length of 8 mm cord to 'hobble' the two pole legs together.
- Webbing-W3P2 around the vertical front pole to support the HDPs,
- Rope may be used for guy lines.

2 cm spacer





Frapping

Wrapping

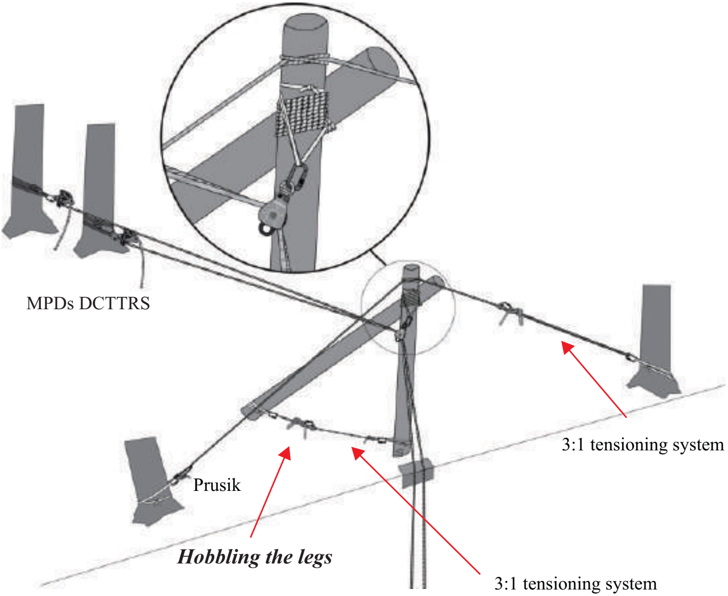
Split the posts to form the A-frame shape on the ground.

Wrapping and Frapping

1. Place the logs side-by-side with a stick between them to act as a 2 cm spacer. Use 10 m of 8 mm cord,
2. Clove hitch one end to a log, then wrap two thirds of its length around the two logs.
3. Use the remaining cord around the wraps clove hitch the remaining end to the same log as you started with and tie the ends together with a flat overhand bend to secure them.

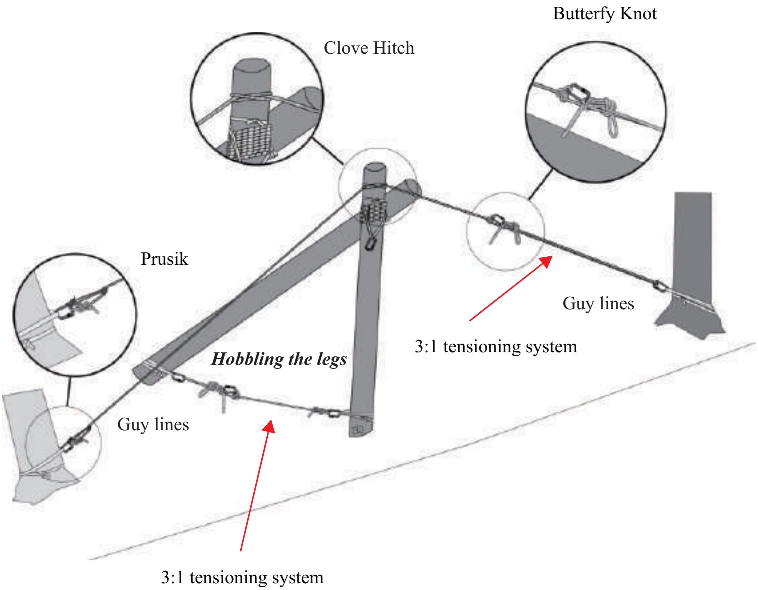
Guy Lines

1. Using rescue rope, secure one end of the rope to an anchor on the same side of the A-frame as the high directional pulleys, located at least as far away as the A-frame is tall, and positioned ideally perpendicular to the parallel footprint of the A-frame.
2. Place an adjusting Prusik to this rope and clip it into the anchor.
3. The rope is then secured to the vertical pole of the sideways A-frame with a clove hitch and the rest of the rope is used to create an improvised 3:1 tensioning system connected to the opposite anchor. When fully tensioned, the sideways A-frame front pole should be essentially vertical; however, be sure to hobble the legs before fully tensioning the A-frame



Hanging the Pulleys

A W3P2 webbing anchor can be placed onto the vertical pole above the wraps and fraps; the pulleys should be located on the vertical pole side opposite the back leg pole side.



Attach an improvised block-and-tackle to the anchor attachments at the bottom of the legs and loosely tie-off. Once erected, tension and tie off the block-and-tackle in order to keep the feet from skating out.

Securing Sideways A-frame

Setting up and tensioning the Sideways A-frame

- Secure the A-frame before moving it towards the edge.
- Lock the feet of the A-frame by either locating them in natural terrain features, or by securing them to anchors.
- Raise the A-frame, tipped slightly towards the Prusik side-anchor and, tension the opposite side with 3:1 made from guy line.
- Set up with the legs close to parallel with the system ropes, back leg should be considerably further back than vertical front leg.
- Anchor side guy lines close to perpendicular to the plane of the frame for the best stability.
- Anchors farther from the A-frame increase stability and make it more convenient to bring the stretcher under lines during edge transitions,
- Stretch of the guy lines should be fully removed, especially if lengths exceed 10m.

Key points for sideways A-frames:

1. The guy line tensioning system opposite the side where the pulley is located may bear some of the load. Consider this when choosing the anchor point.
2. Essential that the foot ends of the A-frame are secure; either by hobbling them together, or sitting in pockets on the ground to prevent them shifting. May be lashed to anchor points to stabilize them.
3. The vector direction of the guy lines should be close to perpendicular to the plane of the A-frame
4. Both lines of the TTRS should be redirected through the pulleys on the A-frame

Setup and use of Tripods

Key points

1. It is essential that the foot ends of the tripod be secured from spreading. This can be achieved with hobbling and/or lashing the feet to secure anchors.
2. Insure that the vector of any forces acting on the tripod is directed inside of the footprint. Ideally it will be within the central third of the footprint
3. Both lines of a TTRS should be redirected through the pulleys on the A-frame

Panorama Pick-Off

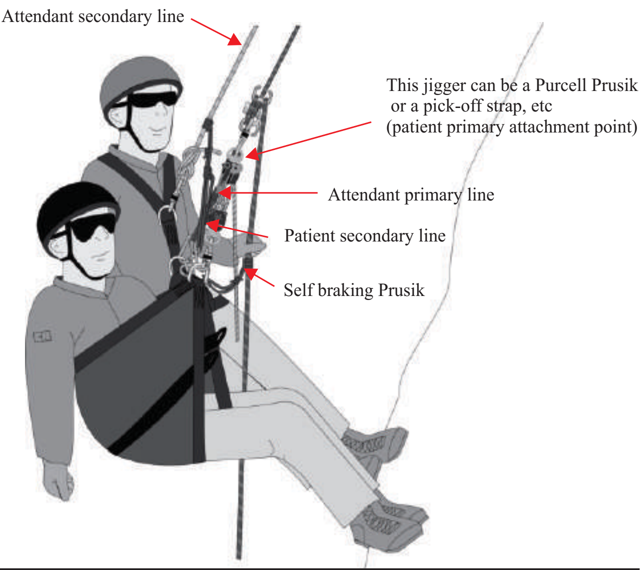
- A 5:1 MA is built at the end of the fixed line to be used as rappel line.
- The rope is bagged and attached to the attendant's harness.
- The rescuer attaches to the pre-rigged haul system line and rappels to subject.
- The second line is rigged in DCTTRS configuration, and managed by the rescuer at the top.

Panorama Pick-off

1. Attendant attaches subject to the system.
2. Rescuer at the top uses the pre-built haul system to raise the attendant and subject, transferring the subject's weight onto the rescue system.
3. Slack in the backup line can be managed with a haul system and short raises alternating between the two lines if there are only two rescuers. Use of a purpose-designed device (e.g., MPD) vastly simplifies this process.)
4. Attendant disconnects subject from his/her lines(s) and rappels with subject to bottom of drop.

Rappel pick-off

Rappel pick-off rigging with the subject positioned to the side.



Attendant-performed load transfer using a jigger, pick-off strap, etc.

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- Systems are rigged as before, with attendant rappelling to the subject, and a backup line managed by the team at the top. The attendant's load transfer system (pick-off strap, jigger, etc) is attached to the DCD directly, and not to their harness.
- Once the subject is reached and secured to the system, the attendant performs the load transfer, and then continues rappelling to the bottom of the drop with the subject.

Resultant angles and forces applied to anchors

Rescuers must 'visualize' if this 'triangle' fits into the terrain without interference; use an inclinometer, or similar tool (e.g. App)

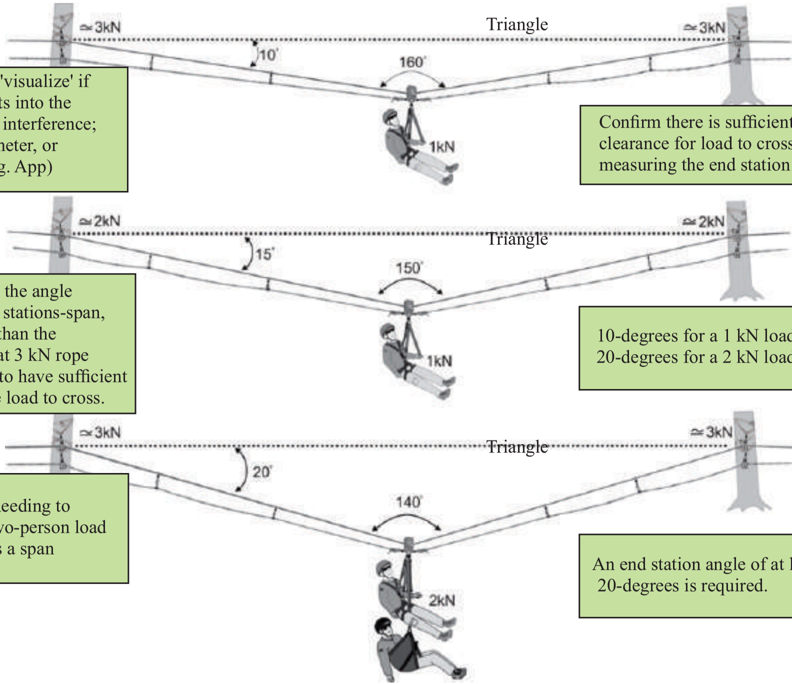
Confirm there is sufficient clearance for load to cross by measuring the end station angle.

Single trackline: the angle between the end stations-span, must be greater than the reference angle at 3 kN rope tension in order to have sufficient clearance for the load to cross.

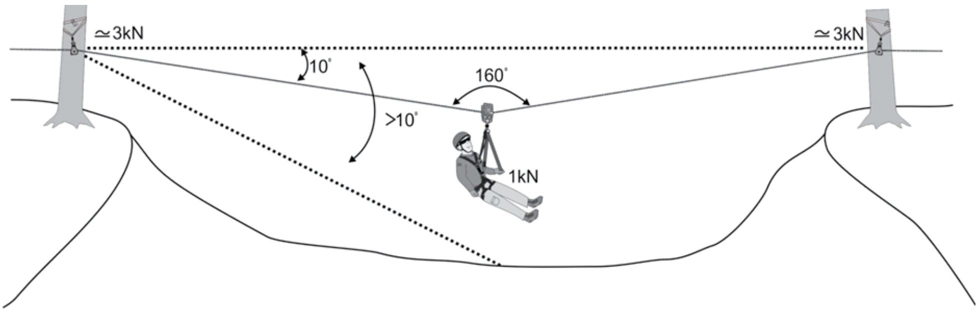
10-degrees for a 1 kN load
20-degrees for a 2 kN load

For rescues needing to transport a two-person load (2 kN) across a span

An end station angle of at least 20-degrees is required.



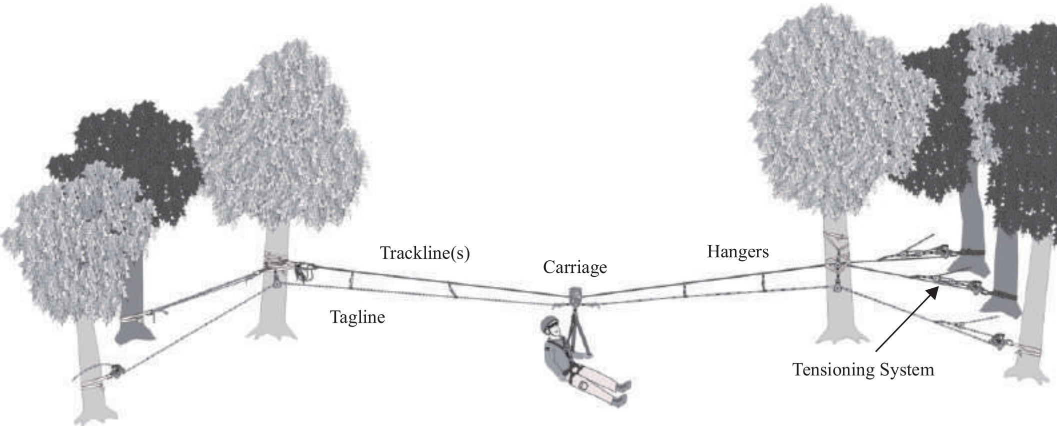
Clearance Requirements Above Ground



Single trackline highline failure could fall 1/5th the span during fall arrest (mid-span).

- Ensure sufficient clearance exists to mitigate the hazard of the load striking an obstruction during fall.
- Two independently managed tracklines, result in less than half the fall distance than single trackline highlines.
- Where possible, two independent trackline systems are preferred. If insufficient clearance exists, then the load must be transported close to the ground, as is done with guiding lines.

Horizontal Highline

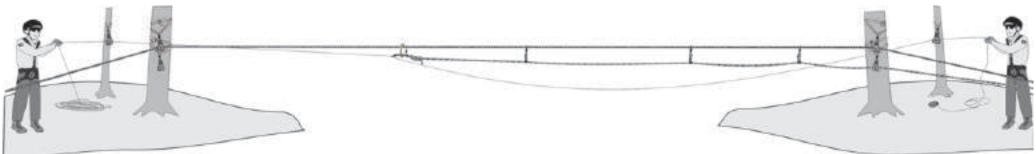


Basic Setup Requirements

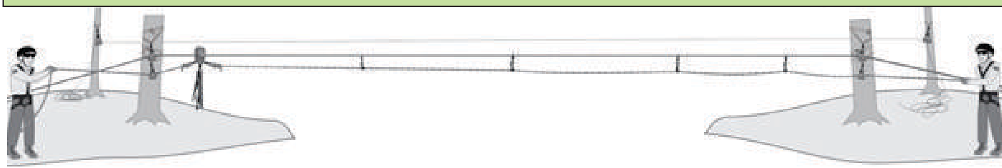
- Pilot Line is used when needed to pull a heavier cord called a messenger cord across a span.
- Messenger cord can quite often be hand thrown with a small mass, or catapulted with a specialised slingshot and is used to ferry ropes back and forth from control side to far side.
- Messenger cord length must be at least twice as long as the span.
- Must be anchored several metres away from where the highline will be rigged.
- The messenger cord will stay in place – off to the side – in case it is needed.
- Handle the messenger cord with care (e.g. onto rope tarps or into buckets) as these light lines are easy to get tangled resulting in significant delays in progress.
- High directional must be at least as high from the ground as it is back in distance from the edge, in order for the ropes to not contact terrain.(45° rule)

Once the messenger cord is across the span to the far side, tie a butterfly on the control side and pull over to the far side with the trackline(s) attached.

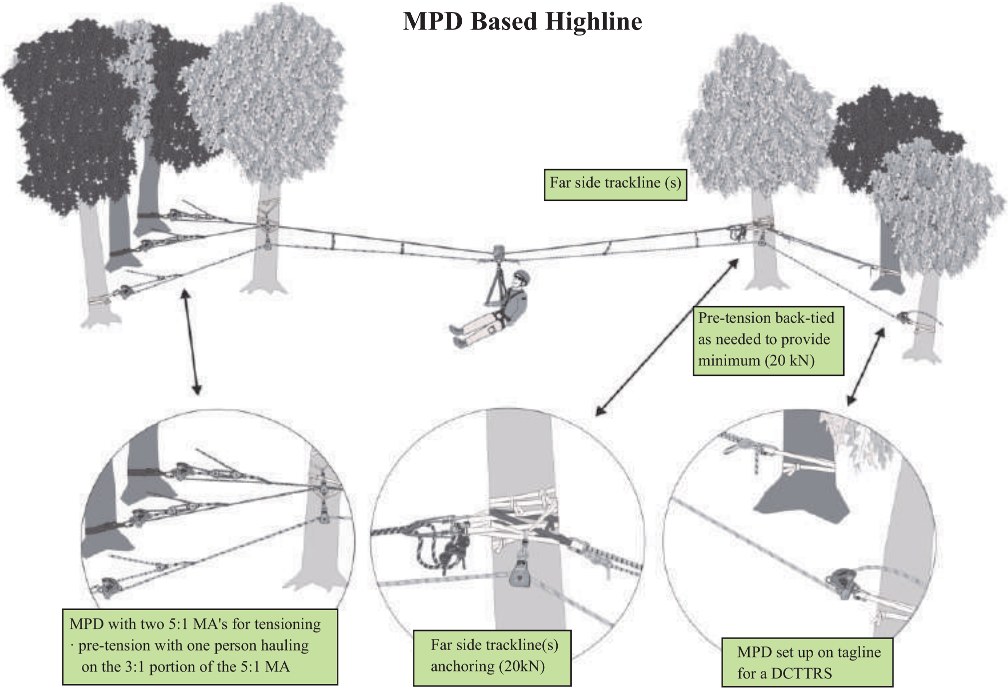
Anchor the trackline(s) and pull the far side tagline back to the control side (Far side riggers attach hangers every 10 m as you bring the tagline over to the control side.

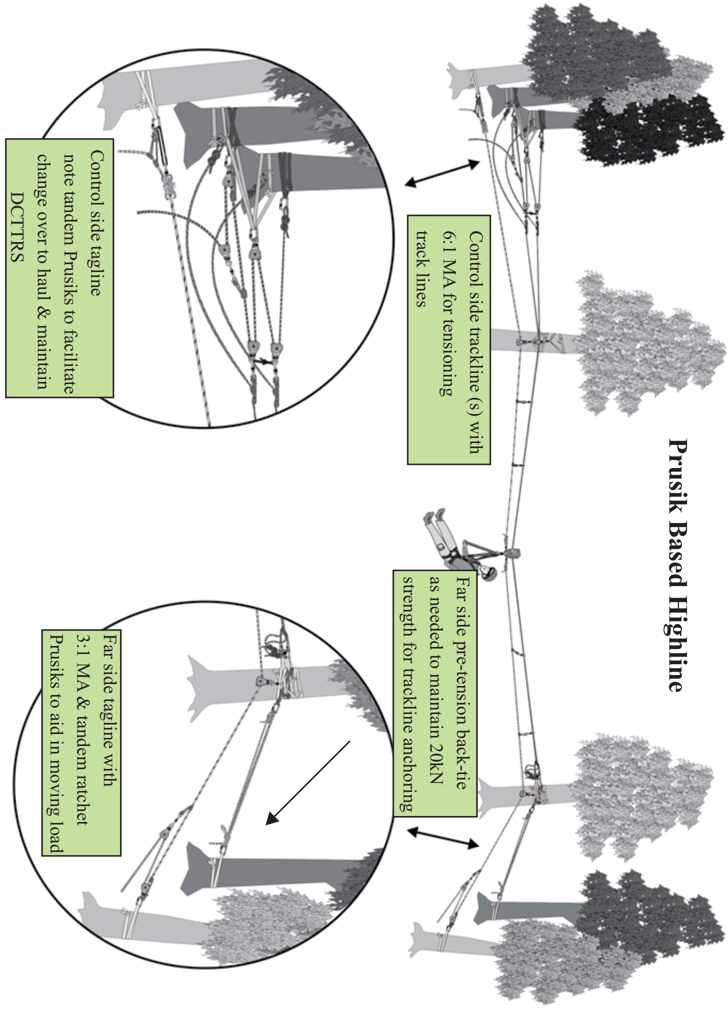


While the far side tagline is being pulled across, the control side team can hang the carriage on the trackline with the control side tagline already attached to it. When the far side tagline reaches the control side end station, it can be clipped directly to this carriage.



MPD Based Highline



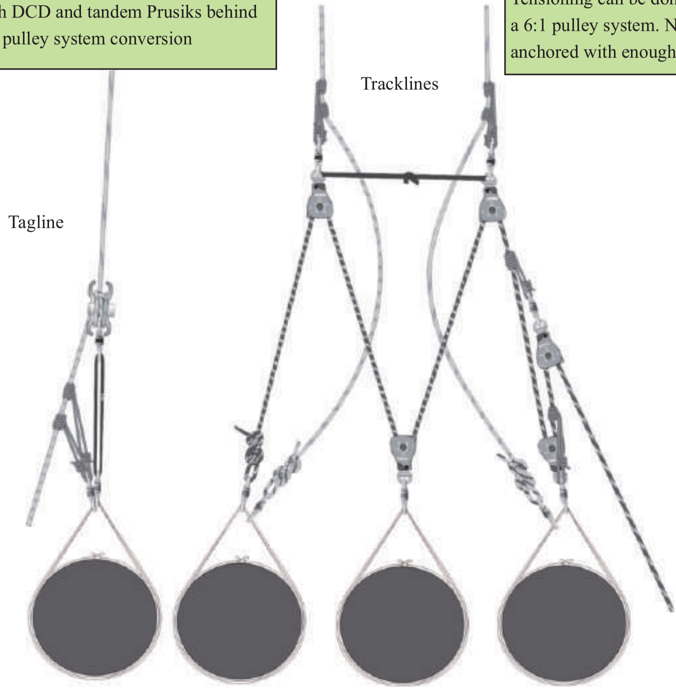


Prusik Based Highline

Trackline tensioning

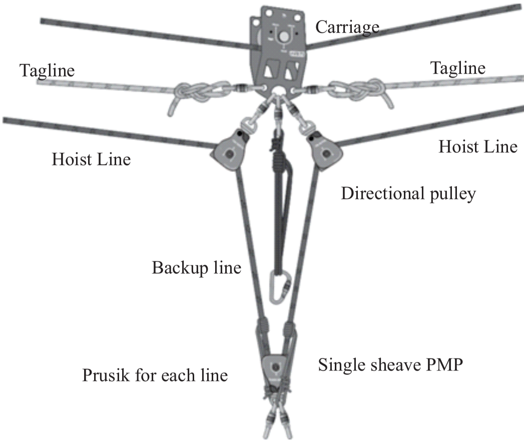
Tagline with DCD and tandem Prusiks behind to facilitate pulley system conversion

Tensioning can be done with separate rope with a 6:1 pulley system. Note tracklines are anchored with enough slack to allow for slippage

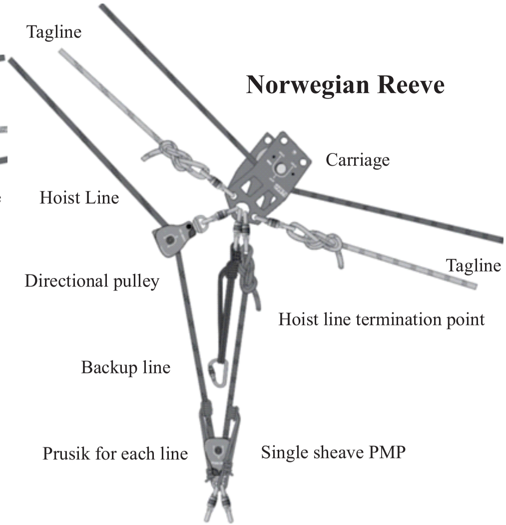


Note the English reeve is preferable to the Norwegian unless used on a sloping highline due to the unequal pull on system when raising (the Norwegian will travel towards the haul side when raising the hoist line)

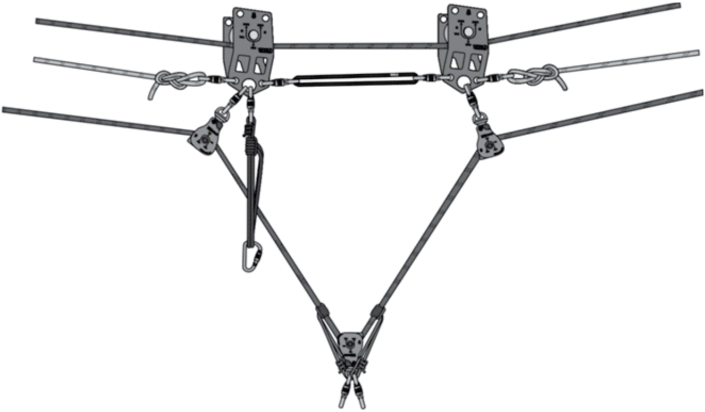
English Reeve



Norwegian Reeve

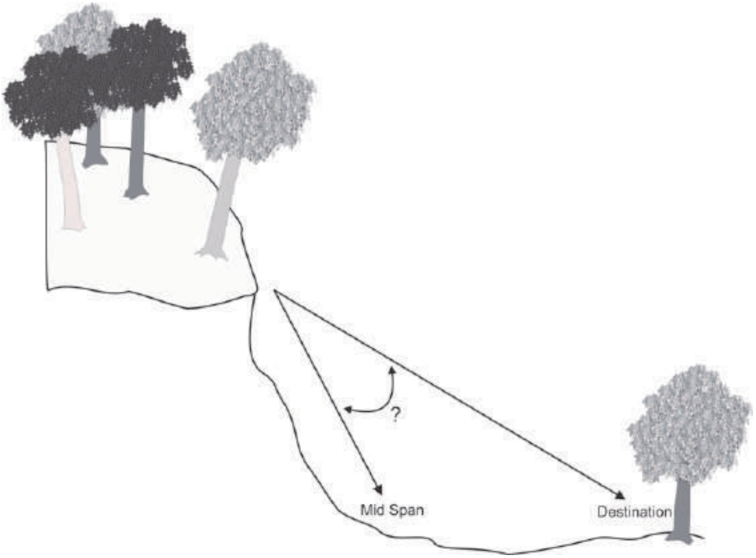


To prevent load spin, it's important to maintain hoist rope separation at the carriage of 30 cm for every 30 m of distance below the carriage. For long lowers, this will require two carriages running on the tracklines, connected with an appropriate length 20 kN sling between them. The connector strap should always be connected to the pulley on the side of the receiving station.



Two-carriage highline with 60cm (20+ kN) sling separation to avoid spinning of the load. (In this diagram, the receiving station is assumed to be to the left.

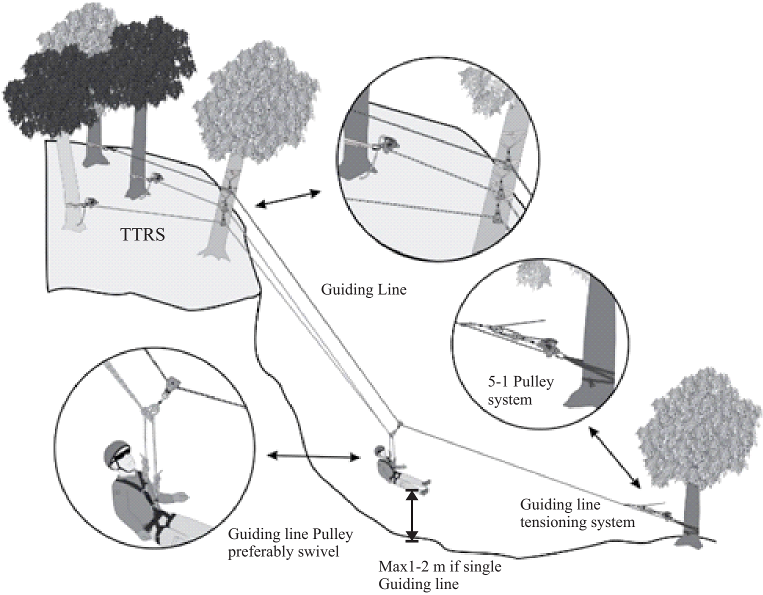
Guiding Line Angle



- Must be adequate height between the end stations to clear the load across the terrain.
- Best angle is > 20 degrees, can be done at angles as shallow as 10 degrees; if so ensure bridle profile is as small as possible, preferably use a swivel pulley to connect, stretcher to guiding line.

Guiding line setup

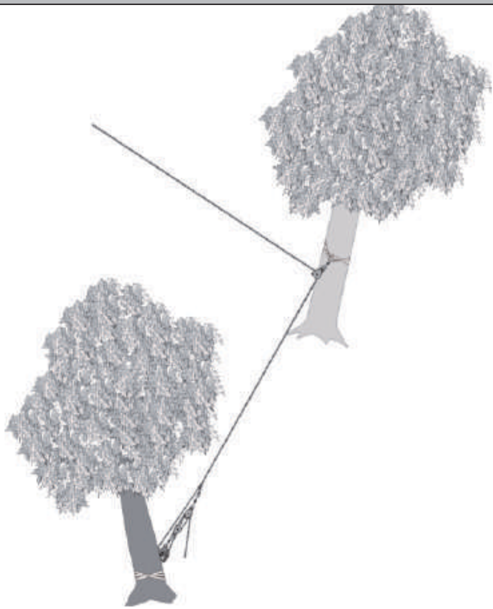
- Preferable to tension system from bottom station as it is easier to see from that location.
- The Control person manages the rate of lower, guiding line team manages the taking-in and letting-out of the guiding line to minimize/eliminate extraneous communication.
- If the guiding line team cannot see the load, then the Control person retains command and control of the guiding Line until such time that the guiding line team attains a 'good visual of the load'.
- As soon as guiding line team has a good visual of the load, confirm this to the Control who then transfers control of the guiding line back.



Caution; guiding line will rise behind the load as it descends.

This makes these lines prone to hanging up on branches or other terrain as the load passes by. If this happens when the rope springs free, it will introduce sudden slack into the system resulting in the potential of slamming the load into the ground. To managed this hazard, guiding lines should be deflected sideways around these obstacles as needed.

These lines are tensioned stationary ropes so must be well protected from exposure to sharp edges and pendulums.



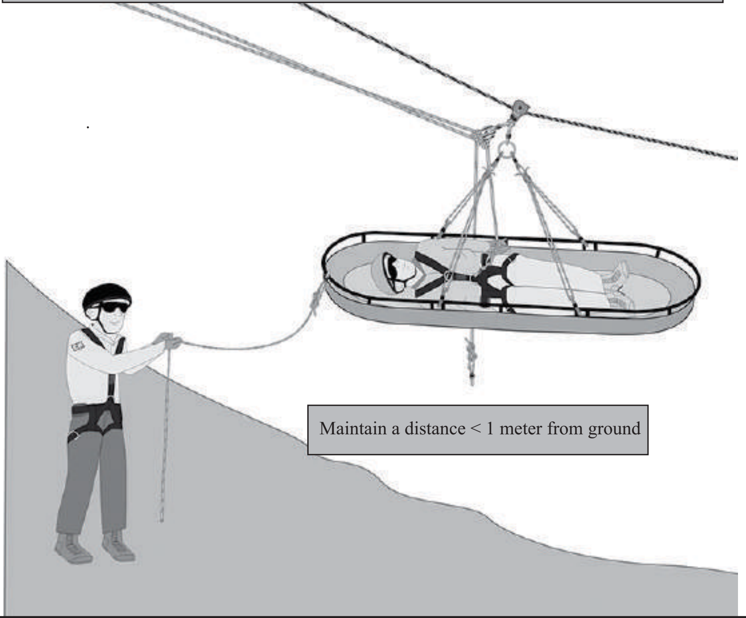
5:1 MA guiding line tensioning systems haul Prusik must be in of reach of guiding line team so that tension can be reduced as needed in order to keep patient close to ground.

Attendant

Walks alongside subject. If vertical or of high consequence, the attendant clips in, with two attachments. For safety, the attendant(s) are best positioned beside or behind stretcher not below, if walking with the stretcher.

Attendant should:

- Manage stretcher with a leash attached to the head end.
- Continually use hand signals to indicate to guiding line team if the load should be raised, lowered, or kept the same height.
- If Guiding line is too steep, redirect all components of the tensioning system so that they are within easy reach.



Briefing
Once the TL has determined a plan, brief the whole team together so all members know what the entire plan is. Control then initiates the "R E D O" sequence:.

Role Check
Role check can start with any role, but needs to end with the attendant.

Control will ask each person if they are ready. Reply should include who they are and “Ready!” or “Standby

Edge transition briefing is performed."This is the edge transition briefing. I will say...."

Dry runs are performed until all team members are comfortable with procedure and pace.

Lowering Communication
Note: You need two different coloured ropes.

“Blue Rope ready?”	**Control:** questions if DCD operator on the “Blue” rope is ready.
“Red Rope ready?”	**Control:** questions if DCD operator on the “Red” rope is ready
“Standby!”	**DCD Operator:** indicates they are not yet ready
“Advise when ready”	**Control:** requests notification when they are ready
“Blue Rope or (Red) ready!”	**DCD Operator:** confirms DCD readiness
“Edge ready!”	**Control:** questions if edge person is ready
“Rope Tailer ready!”	**Rope Tailer:** confirms readiness
“Edge ready!”	**Edge person:** confirms readiness
“Attendant Ready?”	Control: questions if the stretcher attendant is ready
“Attendant Ready!”	**Attendant:** confirms readiness
“Edge Transition Briefing”	**Control:** Explains edge transition.
“Dry Run(s)”	**Control:** Runs team through dry runs until satisfactory
“Going Operational”	**Control:** Advises team to prepare for operational movements.
“Edge, vector both ropes”	Control: Continuation of process practiced in dry run.
“Blue & Red ropes, down.”	**Control:** Signals the DCD operators to lower at the speed rehearsed in the dry run. This can be followed by slow or fast speed, as necessary. The DCD operators should mirror each other's movements.

Lowering Communication con’td

“Stop!”	**Control:** Calls stop to allow the attendant to broaden his/her view and exchange information before continuing the lower.
“Attendant, report on your situation”	**Control**: Encourages attendant to report on transition, assess next moves and identify any needed adjustments
“All stations ready?”	**Control**: Optional check, depending on circumstances, to ensure that all stations remain ready after the stop.
“[Position] Ready!”	**Each Station:** Each station confirms readiness.
“Down, Down!”	**Control**: Signals the DCD operators to lower at a relatively faster speed.
Monitoring Rope Tension	**Control:** Asks Edge or other available team member to check for equal tension between ropes and advise. Control may instruct one rope or the other to adjust speed accordingly.
“Stop!”	**Anyone/All:** Indicates all movement on the rope system must stop immediately. All team members echo this command to ensure that all operations stop.
“Stop? Why stop?”	**Control:** If the reason for the call to stop is unclear, Control requests information from the person who called for the stop. This information is provided to the Team Leader.
“Secure.	*”***Stretcher attendant or rappeller**: Secure ground has been reached and this person is in an area where support from the lines is longer needed.

Raising communication

"Haul Team Blue ready?"	**Control:** Questions the haul team on the Blue rope - ready?
"Haul Team Red ready?"	**Control:** Questions the haul team on the Red rope - ready?
"Haul Team Blue or Red ready!"	**Haul Team:** Confirms they are ready to haul
"Edge ready?"	**Control:** Questions that the edge is ready
"Edge ready!"	**Edge:** Confirms readiness
"Attendant Ready?"	**Control:** Questions that the attendants readiness
"Attendant Ready!	**Attendant:** Confirms readiness
"Haul teams, up"	**Control:** Signals team to pull, may be slow or fast
"Monitoring Rope Tension"	**Control:** Asks Edge or other available team member to check for equal tension between ropes and advise. Control may instruct one rope or the other to adjust speed accordingly.
"Set"	**Ratchet attendant:** The Ratchet Prusik is set to hold load while the system is reset.
"Reset"	**Ratchet attendant:** Signals the haul team to stretch out the haul system and reset the haul Prusik

Raising Communication Con’td

“Approaching edge”	**Edge:** Advises that the load is nearing the edge (~2 m).
“Stop”	**Control:** Stops the raise to prepare for edge transition. (Haul Prusiks are reset, Edge Transition Briefing is given.
Dry Run(s)	**Control:** Depending on circumstances, a dry run may be done immediately prior to the edge transition.
“Haul Team up.”	**Control:** Signals team to pull, may be slow or fast according to Edge Transition Briefing directions.
“Secure.”	**Stretcher attendant**: Secure ground has been reached and this person is in an area where support from the lines is longer needed.

Other Voice signals

"Rock!"	Indicates a loose rock or other object that is falling down the slope. You should not look up but take shelter if available.
"Standby"	**Control:** Asks that the person stops what they are doing but stay ready.
"Stop!"	**Anyone:** This means everyone stops movement on the rope system. The rest of the team should echo this command to ensure that all members stop.
"Stop? Why Stop?"	**Control:** If the reason for the call to stop was unclear, this question should be asked and whoever called for stop should make the reason clear to the Team Leader.
"Secure"	**Stretcher attendant or rappeller**: Secure ground has been reached and this person may be taken off the system. They are in an area where they no longer need support from the lines.
Fresh Eyes	Safety check is done by another rigger to confirm correct rigging

Whistle Signals

1 short blast	**Stop**
2 short blasts	**Up/Ascending:** letting team know to continue hauling
3 short blasts	**Down/Rappelling:** letting team know to continue raising
4 short blasts	**Off rope**: rescuer is secure and off the rope system
Long blast	For difficult or emergency situations: **'Help!'**

Rappelling communication

For DCTTRS two separate coloured ropes need to be utilized.

"On red (colour) rope"	**Rappeller:** He/she has tied into the red (colour) rope.
"Ready on red rope?"	**Rappeller:** Asking red tensioned line if they are ready to lower them
"Red rope ready"	**Red Rope attendant:** Indicates to the rappeler that he/she is ready to lower and the rappeller can begin the rappel.
"Rappelling"	**Rappeller:** He/she has attached the rappel device and safety Prusik to the blue rope and is ready to begin rappelling.
"Rappel"	**Red Rope attendant:** It is OK to begin rappelling.
"Slow on red"	**Rappeller:** Indicates line is too slack and requests that red rope attendant reduce speed of lower. This command may also be issued by Control who should be feeling for equal tension between the two ropes.
"Down on red"	**Rappeller:** The red rope attendant's line is too taut and he/she should quicken the lower. This command may also be issued by Control who should be feeling for equal tension between the two tensioned ropes.
"Secure"	**Rappeller:** He/she is in a secure position and no longer requires the red rope.
"Off Red Rope "	**Red Rope attendant:** Replies that he/she is no longer lowering and may be de-rigging.
"Off rope"	**Rappeller:** Has detached the rappel device and safety Prusik from the rappel rope as well as disconnecting from the red rope.

Ascending Communication

Communication for ascending is between the climber and their belay, same as for rappelling.

"On red (colour) rope"	**Climber:** He/she has tied into the red (colour) rope.
"Ready on red rope?"	**Climber:** Asking the red line attendant if he/she is ready to tension line. The red line attendant prepares to tension rope.
"Tensioning red rope!"	**Red line attendant:** Indicates to the climber that he/she is tensioning the red rope and the climber can begin climbing.
"Climbing"	**Climber:** He/she has attached Prusiks or ascenders and is ready to begin climbing on blue rope.
"Climb on"	**Red line attendant:** It is OK to begin climbing.
"Up Rope"	**Climber:** Red rope is too slack and the red line attendant should increase tension on red rope.
"Slack"	**Climber:** The red line is too taut and the attendant should reduce tension by decreasing speed.
"Secure"	**Climber:** He/she is in a secure position and no longer requires red line to be further tensioned.
"Off Red line"	**Red line attendant:** Replies that he/she is no longer providing the red tensioned line.
"Off rope"	**Climber:** He/she has detached ascending gear from the fixed rope and has disconnected the red rope.

During any lowering or raising operations, anyone on-site may use the following commands:

"Rock"	Warns of falling rock or debris
"Stop"	A hazard or perceived hazard has been noticed and needs to be addressed.

Radio Communication

When direct voice communication alone is not practical, the use of radios is warranted. Radio communication and protocol should be practiced as laid out in the GSAR manual.

In rope rescue, radios should be checked prior to going over the edge. The rescuer may want to carry extra batteries, and possibly a spare radio.

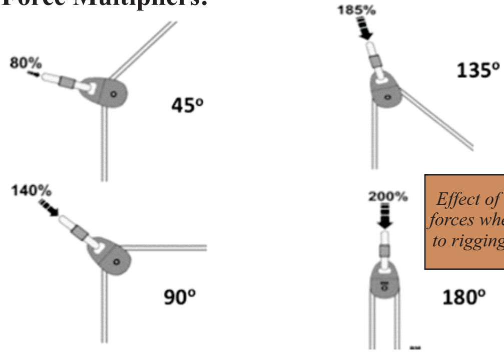
When radios are used, everyone on the rescue site should listen in on the communications with the stretcher attendant so they can anticipate what will be needed. This is especially useful on rescue sites where the stations are spread out.

When the RRTL broadcasts, “Going operational” to the SAR Manager, this is a request for radio silence to dedicate the channel to the rescue.

Rope teams may use FRS/GMRS radios for short distance internal communications. This will reserve the use of the VHF or UHF units for communication between the rope teams and other SAR units.

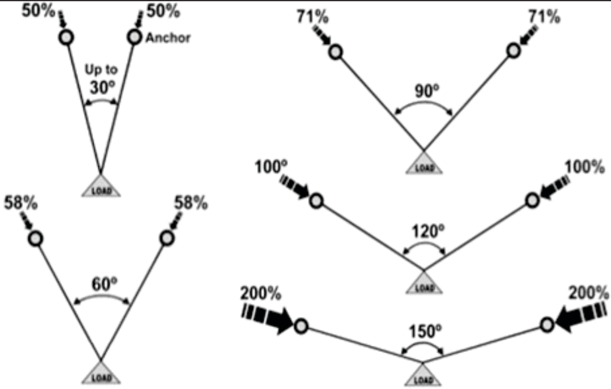
Force Multipliers:

Redirects and High Directional Pulleys/Anchors:



Effect of angle on anchor system forces when the mass is suspended to rigging between anchor points.

To determine required strength, calculate the maximum force to which the component may be subjected. Determine if the redirect pulley will be subjected to a 'jolt' or to a 'free-fall' of the load. A jolt' increases the system force up to 2.5 times the static force, i.e., rescue load of 2 kN x 2.5=5 kN. A redirect pulley at 90° will add 1.4 times that value, i.e., 7 kN, still a relatively low force.

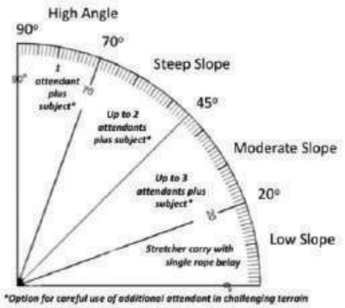


Two-point anchors with internal angles exceeding 90° need to be capable of supporting the entire load (20 kN per anchor); *if warranted,* anchor systems with interior angles greater than 90 degrees can be utilized.

DCTTRS limit forces between 6-12 kN and require component minimum strengths of 20 kN. Any combination of angle and number of attendants can be used as long as the combined static tension to the ropes supporting the load is less than 3-3.5 kN. This keeps any jolt force to the system to the lower end of the slip force threshold, which prevents inadvertent 'inertial runaway' loads.

Static Loads and Potential Peak Forces: The following are approximate combined rope tensions for given sized loads (number of attendants plus patient) and slope angle:

- 0-20 Degrees: **Low Angle**;
- 20-45 Degrees: **Moderate Angle**
- 45-70 Degrees: **Steep Angle**
- 70-90 Degrees: **High Angle**



Angle	Attendants	Subject	Static Load (kN)
0-20	4-6	1	≤2.1
20-45	3	1	2.5
20-45*	4*	1*	3.1*
45-70	2	1	2.6
70-90	1	1	2
70-90*	2*	1*	2.8*

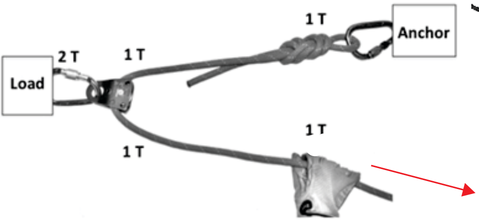
- In general the worst-case force, which can occur in Slope Rescue is a jolt to the system.
- Even if one of the ropes in a TTRS is temporarily bearing the entire load and it fails, this would only result in peak force less than 2.5 times the static load.
- If both ropes in a TTRS are roughly equally tensioned, and one fails, then the peak force is only about 1.5 times the static load

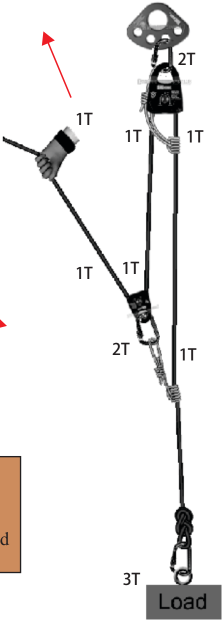
For this reason, on slopes below 45 degrees, the primary consideration should be to select the appropriate number of attendants to minimize risk to them of stumbling, straining backs or knees due to awkward terrain or a heavy patient.

T-Method of Calculating Mechanical Advantage

The T-method can be used to determine the MA of any pulley system. If one unit of tension is inputted to the pulley system by the haul team, this tension / force, equals 1T. We can follow the rope to the load to calculate the final output tension reaching the load. It is this ratio of the output to the input that describes the MA for that system. Tension on the rope entering one side of a pulley must equal the tension on the rope exiting on the other side. Therefore any single moving pulley will double input tension. The following diagram illustrates a single unit of tension (1T) is balanced on both sides of the pulley creating two units of tension (2T) as the output of this MA pulley, a 2:1 MA.

T method of MA calculation (2:1)





Note that the T-method can also be used to calculate what proportion of tension is applied to the anchors. In some cases, i.e. when pulling down hill, the tension applied to the anchors is greater than the tension applied to the load

T-method to calculate 3:1 MA

Personal recommended minimum gear list

Individual Items	*Team Items*	*Individual*	*Collective Team Minimum*
Helmet	Subject helmet	1	Team +1
Harness	Subject harness	1	Team +1
	Cradle for subject (advisable to have both options available).		1
	Animal attachment harness		1
Headlamp with spare batteries		1	
EMT shears (or knife)		1	
(Leather) gloves		1	
Safety glasses	Spare safety glasses	1	Team +1
Whistle		1	
Flagging tape		1	5
Personal pack		1	
	MPDs		5
DCD (Scarab recommended)		1	4
60 cm sewn Dyneema slings		1	5
120 cm sewn Dyneema slings		1	5
Locking D carabiners		4	20
Locking pear carabiner		1	4
5 m of 8mm cord		1	
10 m of 8mm cord		1	4
1.4m 8mm Prusik		1	6
1.7m 8mm Prusik		1	6
	3m of 25mm webbing		8
5 m 25mm webbing		2	8
	10 m of 25mm webbing		5
	Edge carpet		1
	Plastic edge protection		1
	Edge protection: pads, plates & tubes.	?	6
	4x6 gear tarp	?	2
Short Purcell Prusik		1	4
Long Purcell Prusik		1	4
PMP (side locking, swivel 2.0" preferred)		1	10
	Knot-passing pulleys		2
	Rigging plates		2
	Steel O-ring		1
	60 m 11mm ropes, two colours		4
	20 m 11mm ropes, two colours (edge)		2
	10 m 11mm ropes (anchors, etc.)		2
	3 m 11mm ropes, (anchors, etc.)		4
	Accessory cord for edge protection		~15m
Personal 1st Aid kit ((BLS, AR mask, exam gloves etc.).		1	
	Team first aid kit.		1
	Subject (over-the-edge) first aid kit		1
	Vacuum splint (or other spinal immobilization) with straps & C-collars		1
	Stretcher with face shield, blankets, tarp, padding, tie-in straps, etc.		1
	Stretcher bridle kit (horizontal orientation)		1
	Primary & secondary attachments for attendant and subject.		2
	Large locking D carabiners (bridle rig)		4
	Duct Tape		1
	Pliers.	?	1
	Radios/communication equipment	?	4
	Rope Log.	?	1
	Incident Logbook.	?	1
	Pen and Notebook.	?	1

Team recommended minimum gear list

Individual Items	*Team Items*	*Individual*	*Collective Team Minimum*
Helmet	Subject helmet	1	Team +1
Harness	Subject harness	1	Team +1
	Cradle for subject (advisable to have both options available).		1
	Animal attachment harness		1
Headlamp with spare batteries		1	
EMT shears (or knife)		1	
(Leather) gloves		1	
Safety glasses	Spare safety glasses	1	Team +1
Whistle		1	
Flagging tape		1	5
Personal pack		1	
	MPDs		5
DCD (Scarab recommended)		1	4
60 cm sewn Dyneema slings		1	5
120 cm sewn Dyneema slings		1	5
Locking D carabiners		4	20
Locking pear carabiner		1	4
5 m of 8mm cord		1	
10 m of 8mm cord		1	4
1.4m 8mm Prusik		1	6
1.7m 8mm Prusik		1	6
	3m of 25mm webbing		8
5 m 25mm webbing		2	8
	10 m of 25mm webbing		5
	Edge carpet		1
	Plastic edge protection		1
	Edge protection: pads, plates & tubes.	?	6
	4x6 gear tarp	?	2
Short Purcell Prusik		1	4
Long Purcell Prusik		1	4
PMP (side locking, swivel 2.0" preferred)		1	10
	Knot-passing pulleys		2
	Rigging plates		2
	Steel O-ring		1
	60 m 11mm ropes, two colours		4
	20 m 11mm ropes, two colours (edge)		2
	10 m 11mm ropes (anchors, etc.)		2
	3 m 11mm ropes, (anchors, etc.)		4
	Accessory cord for edge protection		~15m
Personal 1st Aid kit ((BLS, AR mask, exam gloves etc.).		1	
	Team first aid kit.		1
	Subject (over-the-edge) first aid kit		1
	Vacuum splint (or other spinal immobilization) with straps & C-collars		1
	Stretcher with face shield, blankets, tarp, padding, tie-in straps, etc.		1
	Stretcher bridle kit (horizontal orientation)		1
	Primary & secondary attachments for attendant and subject.		2
	Large locking D carabiners (bridle rig)		4
	Duct Tape		1
	Pliers.	?	1
	Radios/communication equipment	?	4
	Rope Log.	?	1
	Incident Logbook.	?	1
	Pen and Notebook.	?	1

- Length in metres (m).
- Mass in kilograms (kg).
- Force in kiloNewtons (kN).
- ***Mass***

- *Mass is simply the amount of matter, unaffected by gravity. It is measured in kilograms (kg) and is not to be confused with weight. (Technically, weight is the combination of mass being affected by gravity and is commonly measured in pounds of force). In lay language, weight might refer to either mass or force but in physics, 'weight' is an ambiguous term and should therefore be avoided. The following are commonly accepted values of mass for rope rescue loads:*

- 1 Person + gear = 80 kg person + 20 kg gear = 100 kg
- 2 People + gear = 80 kg + 80 kg + 40 kg = 200 kg
- 3 People + gear = 80 kg + 80 kg + 80 kg + 40 kg = 280 kg
- 4 People + gear = 80 kg + 80 kg + 80 kg + 80 kg + 40 kg = 360 kg

- (Note: no additional gear is added after 2 person loads, only more people)

- ***Force***

- ***Force is either a push or a pull.*** For example, a *mass* hanging on a rope will have the *acceleration* due to gravity acting on it, which will result in a 'pull' of that mass towards earth with a given amount of tension, or force on the rope and anchor system.

Acceleration is acting on that mass even though the load is not physically moving (i.e. it is statically hanging there). As such, static force is calculated by multiplying the mass (kg) times acceleration (metres per second squared or m/s^2), the latter being defined as the rate of change of speed over time.

The unit for force is the Newton (N) and is comprised of units of mass and acceleration (i.e. kg x m/s^2). Consistent with other forms of the modernized metric system, 1000 units of something becomes a kilo, and therefore 1000 N becomes 1 kN (lower case 'k', upper case 'N'). For simplicity and ease of math, it is a commonly accepted practice in rope rescue to assume that gravity has a value of 10 m/s^2 instead of the more accurate 9.81 m/s^2.

Dual Capability Devices

Devices used for lowering and raising operations must meet the EMBC criteria for dual capability. They must be capable and competent to serve the functions of both a force-limiting main and a force-limiting belay simultaneously:

Capable and Competent Belay

To qualify as a *capable and competent* belay (back-up), that meets EMBC requirements, devices must pass the EMBC 2016 Belay Competence Drop Test Method criteria, as follows:

- 1m drop on 3m of rope (Fall Factor 0.33) and rope tailing using a 200 kg mass and rope tailing tension of 0.1 kN.
- Maximum arrest force must be no more than 12 kN.
- Stopping distance (pre-rebound) must not exceed 1 m.
- The system must remain competent to function after a worst-case event.
- Residual rope strength must be greater than 80%.
- For a Fall Factor 0.5 drop test (i.e. 1.5 m drop onto 3 m rope with 200 kg mass), the system must not fail. This test ensures there is sufficient strength margin above and beyond the minimum FF 0.33 drop test criteria.

Force calculation for worst case event

The worst-case event described above is for a 1 m drop onto 3 m of rope with a 200 kg mass, resulting in a peak force potential of 12 kN. The process of calculation for arriving at this figure is as follows:

Anything that causes a vertical displacement without resistance is a freefall *– adds energy to the system.*

Energy = *force* in Newtons (i.e., mass x gravity) x *distance* in metres (*N x m*)

Energy potential in an edge transition drop = *mass* x *gravity* x *height* (kg x m/s2 x m) or N x m The stopping distance for a 200 kg load free-falling 1m in an edge transition drop with 3m of rope in service is assumed to be less than 1m, or 0.5 m for purposes of calculation. As the height includes the freefall plus the stopping distance, the height in the above equation will be 1.0 m + 0.5 m. or 1.5 m.

Average is defined as the *arithmetic* 50^{th} *percentile* (halfway point between extremes), so the calculation for the average dynamic force resulting from an edge transition drop would be: $\frac{\text{Nm}}{\text{m}}$ $\text{Average dynamic force (ADF)} = \frac{\text{mass x gravity x height}}{\text{stop distance (assume 0.5 m)}}$

$$\text{ADF} = \frac{\text{N (200 kg x 10 m/s2) x m (1 m + 0.5 m)}}{\text{m (0.5 m)}} = \frac{\text{2000 N x 1.5 m}}{\text{0.5 m}} = \frac{\text{3000 N}}{0.5} = \text{6000 N}$$

Average dynamic force is therefore 6000 N or 6 kN

And peak force will be twice the average: ADF x 2 = 6 kN x 2 = 12 kN

Note that actual mass per person is likely to be only 80kg, but we use 12kN as maximum arrest force (MAF or peak force) for a human body for consistency with Worksafe BC regulations.

Energy

Energy is *force* (N) *times distance in metres* (m) described as a Newton-metre N.-m. The relationship between mass, force and energy must be understood. In rope rescue, assuming acceleration due to gravity is constant, energy increases with mass and fall distance. In a static state, this is often referred to as the 'potential energy' in a system (the potential fall distance). This energy remains only a potential as long as the system remains static. The potential energy is released (becomes "kinetic" energy) only if a fall, or some other movement that creates a jolt in the system, occurs.

When a fall or jolt is arrested or stopped, the kinetic energy must be dissipated as the system returns to a static state. The energy dissipation process adds force to the components of the system supporting the load. The maximum (peak) force generated during the dissipation phase depends on how quickly the movement is arrested. Simply put, if the falling mass is stopped quickly, energy will be dissipated quickly and therefore peak force will be higher than if the falling load is stopped more slowly over a greater distance.

Energy

The components of a system must be able to withstand peak force—if not they will break. And the human body can tolerate only a limited amount of force without injury. As long as peak force does not exceed system strength and the upper limits of tolerance to what humans can 'comfortably' withstand, then *stopping distance* in rope rescue should occur as quickly as possible so as to reduce the chance of the rescue load striking an obstruction during fall arrest, risking injury, or worse.

Fall Factors
The relative severity of a fall is related to the length of the fall and the amount of rope available to absorb and dissipate the forces generated.

FF example 1: 1 m fall / 3 m rope = FF *0.33 (one third)*

The same length of fall with six metres of rope in service produces a lower FF:
FF example 2: *1 m fall / 6 m rope = FF 0.17*

A two metre fall on six metres of rope in service once again produces:
FF example 3: *2 m fall / 6 m rope = FF 0.33*

At an awareness level, rescuers must know that the basic minimum strength requirement of rigging systems is 20 kN. This is consistent with common industry requirements that the strength of materials be sufficient to withstand at least 1.7 times the controlled peak forces to which they may be subjected. In SAR rope rescue, with highest peak forces at 12 kN (worst-case situation of an edge transition going wrong), the minimum strength requirement would be 18-24 kN, which we round off to 20 kN for convenience.

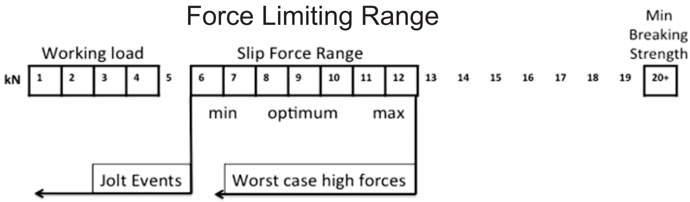
Working Load	Mass	Static Force
1 Person plus gear	100 kg	1.0 kN
2 People plus gear	200 kg	2.0 kN
3 People plus gear	280 kg	2.8 kN
4 People plus gear	360 kg	3.6 kN

Force Limiting Systems

EMBC has adopted ***Force Limiting Systems*** as the fundamental principle for effective control of peak force and to minimize the stopping distance of falls. The premise of *Force Limiting Systems* is simple. It allows rope rescue systems to 'slip' and allow movement of rope through devices gripping the rope(s) within a prescribed 'bandwidth' or range of force, and it must occur in a manner that maintains the functionality of the rope system. Devices gripping a rope, whether they are rope grabs, belay systems or descent control systems, must slip within an 'ideal range.' Stated differently, slippage must occur somewhere between the minimum and maximum allowable values. If the slip force of a device is too low, then stopping distances during fall arrest may be excessive or not even possible—this is called "inertial runaway." If the slip force is too high the forces generated may be too high for humans to tolerate.

Force limiting bandwidth has been determined through detailed testing and failure analysis of rope rescue systems (EMBC – NIF, 2016). The acceptable range of force is a minimum of 6 kN and a maximum of 12 kN. Essentially this means is rope grabs, auto-locking descent control devices and rescue back-up systems (i.e. belays) must slip somewhere between 6 and 12 kN if high forces are inadvertently applied. The minimum slip force value will prevent inertial runaway whereas the maximum allowable slip force value keeps forces within tolerable levels for human safety. The upper slip force value (i.e. no more than 12 kN) also makes determining system strength requirements a fairly straightforward process.

The more rope in service between the load to be arrested and the arrest system, the lower the peak force will be. This is because more rope allows greater stretch resulting in dissipation of energy fall over a greater distance. In many cases, force limiting by arrest devices may not even occur if there is rope stretch to keep peak forces low.



Static loads chart for slope rescue

Angle	Attendants	Subject	Static Load (kN)
0-20	4-6	1	$\leq$2.1
20-45	3	1	2.5
20-45*	4*	1*	3.1*
45-70	2	1	2.6
70-90	1	1	2
70-90*	2*	1*	2.8*

Fall forces on rope systems

Type of Event	Worst-Case 1m drop on 3m rope; 200 kg	Jolt 200 kg Free-hang	Jolt 360 kg 45-degree slope	Jolt 360 kg Free-hang[1]
Condition	Edge Transition	Top Rope	Top Rope	Top Rope
Static Force	2 kN	2 kN	2.5 kN[2]	3.6 kN
Peak Force	< 12 kN	< 5 kN	< 6 kN	< 9 kN

1. 360 kg in a free-hanging condition represents a highly unlikely accidental lowering of a multi-attendant load from a sloped environment into a vertical, free-hanging environment.

2. Three attendants and a patient (360 kg) being supported by a rope on a 45°slope will result in an approximate rope tension of 2.5 kN.

The table above shows that the highest potential forces, which require Force Limiting, occur in edge transitions gone wrong. Under all other 'normal' top rope conditions, peak forces will be 6 kN or less, so Force Limiting (i.e. slipping of the rope grabs or rescue belay) is not required and will not come into play. The required rope rescue system strength of 20kN is adequate no matter what the scenario.

Notes

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Important Contacts
